THE DEVELOPMENT AND USE OF A GAIT ANALYSIS FORCE PLATE WALKWAY INTENDED FOR USE IN THE ROUTINE CLINICAL CONTEXT

Volume 1

Jane Barrance, MEng, MSc

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SUMMARY

It has been suggested that a long force plate walkway measuring vertical force only might be useful as a stand-alone tool for gait analysis in the routine clinical context. This project addressed the design and validation of such a walkway.

The project achieved its objectives of developing a gait analysis walkway system from an incomplete prototype, calibrating it and testing it using volunteers in order to assess its usefulness in the routine clinical context.

A pair of walkway plates were designed and built. Commercial transducers and signal conditioning equipment were chosen and installed. Fixings to attach the walkway to the floor were designed, built and installed. Software was written enabling the user to record, recall and output data, incorporating algorithms which calculate various parameters of gait automatically for each walk.

The walkway was calibrated under static and dynamic loads and tested with normal subjects.

It was subsequently assessed using volunteers with gait pathology: 16 amputees, 6 elderly joint replacement subjects and 4 others.

The walkway was shown to be capable of producing reliable, repeatable data in which the intended gait parameters were clearly displayed. Some aspects of the data quality remained to be improved before the system would be fully ready for clinical application. No serious practical problems were shown except that, in common with other methods of gait analysis, the system could only produce statistically significant results with subjects who can complete an adequate number of traverses at an adequate speed range.

Useful information was obtained on how to improve the hardware and software and protocol so that the technique could be optimised so that it could have the best possible chance of being clinically useful.

It will be necessary to try out these improvements and to show whether the users can interpret the output to form useful conclusions. Recommendations for further work are given.
ACKNOWLEDGMENTS

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NOTE

This thesis is divided into two volumes. Volume 1 is expected to be sufficient for most readers' needs. Volume 2 contains further details which are expected to be of interest only to those continuing the work.
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Chapter 1: Introduction

1.1 Hypothesis

The motivation for the work described in this thesis derives from a hypothesis first suggested by Mr Graham Deane, Consultant Orthopaedic Surgeon, Heatherwood and Wexham Park Hospital Trust in 1979 that A LONG FORCE PLATE WALKWAY MEASURING VERTICAL FORCE AND THE POSITION OF THE POINT OF APPLICATION OF THE FORCE MIGHT BE USEFUL AS A STAND-ALONE TOOL FOR GAIT ANALYSIS IN THE ROUTINE CLINICAL CONTEXT. A long walkway offers study of more than one footfall during each walking traverse. This suggestion is also based on the concern that patients 'target' small force platforms and this may introduce artefacts. Both these imply improved clinical usefulness of a long force platform.

In order to perform complete gait analyses as described below, a large amount of time, expertise and complex, expensive equipment is required (review, Yack, 1984). The cost and complexity of gait analysis equipment available to date has contributed to restriction of its availability for routine clinical measurement of gait (Miyazaki and Kubota, 1984; Miyazaki et al, 1983). Few laboratories in the United Kingdom are involved in the routine clinical assessment of patients (Messenger and Bowker, 1987). A long force plate walkway alone would be likely to be cheaper than a comprehensive system. It would not produce so much data but this might make it more widely applicable by making the interpretation of results easier. It would produce data on vertical ground reaction forces, and the position of the force vector would be manipulated to estimate the temporal-distance factors of gait such as step length and velocity. It was believed by Mr Deane that this would be a clinically useful combination of variables, i.e. it would provide information which would improve the quality and/or reduce the cost of treatment. Previous work using these variables is discussed in chapter 4, as are possible clinical uses of the data.
The small area of commercial force plates and the requirement that the subject's foot should fall completely on the plate can mean that the subject needs to take several trial walks which may be tiring and can mean that the subject's gait is disrupted in order to place the foot on the platform (Hirokawa, 1989). Robinson et al (1987), using a Kistler Z4852c force plate to study patients with sacroiliac dyskinesia, required 10 practice trials for each patient before getting results, because of the small size of the force plate. Kistler force plates are in clinical use in a small number of centres in the UK, often in conjunction with other equipment (Messenger and Bowker, 1987).

The specified area of the force plate walkway in this study was to be much greater so as to increase the amount of data gained for the same number of walks, allowing simultaneous measurement of spatio-temporal data. Potentially it would disturb the subjects' gait less.

Commercial force plates measure force in three directions: vertical, antero-posterior and medio-lateral. The decision was made for this study to measure only in the vertical direction. This makes the equipment cheaper to fabricate and enabled the walkway to be evaluated and later modified to include horizontal forces. An M.Sc. project is in progress (Jackson, 1993) attempting to produce a design for a 3-D force measuring version of the walkway.

1.2 Project Objectives

The project's objectives were to develop a gait analysis walkway system from an incomplete prototype, calibrate it with static and dynamic loads and test it using volunteers with and without gait pathology, in order to assess its usefulness in the routine clinical context.

For the walkway to be clinically useful, it was considered necessary that the data would be of an appropriate quality (i.e. that it would be

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repeatable and that measured differences between for instance pre- and post-operative states would be statistically significant), that the users could interpret it to form useful conclusions, that there were no other practical problems which made it unfeasible and that the benefits justified the resources. This project's assessment of the system concentrated on the quality of the data but also assessed the resources needed and the practical problems encountered and considered the potential usefulness of the data.

The system was to consist of a pair of plates forming the walking surface attached through force transducers to the floor. The device was to be surrounded by a raised floor, providing a level walking surface. The transducers were to be connected to a signal conditioner which was to supply power to the transducers and amplify and low-pass filter the output. The signals were then to enter an analogue-to-digital conversion card in a computer. Software was to be written enabling the user to record, recall and output data. It was to incorporate algorithms designed by the author to calculate various parameters of gait automatically for each walk.

The accuracy of position data depends on the instantaneous total force measured by the platform (Barrance, 1989) and the accuracy of the transducers, i.e. the heavier the subject and the more expensive the transducers, the more accurate the measurements. It was decided on the grounds of cost to design this system for use with adults only.

It was decided to perform measurements using the walkway for subjects with various pathologies in order to give an indication of the suitability of the walkway for use in the routine clinical context with different groups of patients.
Messenger and Bowker (1987) broke down the clinical gait analysis work done in the UK by pathology:

<table>
<thead>
<tr>
<th>Pathology type</th>
<th>Total number of centres who undertake clinical work using/seeing each pathology (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General foot problems</td>
<td>60</td>
</tr>
<tr>
<td>Cerebral palsy</td>
<td>40</td>
</tr>
<tr>
<td>General or non-specific</td>
<td>30</td>
</tr>
<tr>
<td>Polio/Multiple Sclerosis/Muscular Dystrophy</td>
<td>30</td>
</tr>
<tr>
<td>Amputees above/below knee</td>
<td>30</td>
</tr>
<tr>
<td>General Orthotics</td>
<td>30</td>
</tr>
<tr>
<td>Rheumatoid arthritis/Osteoarthritis</td>
<td>20</td>
</tr>
<tr>
<td>Geriatric</td>
<td>10</td>
</tr>
<tr>
<td>Joint Arthroplasty</td>
<td>0</td>
</tr>
</tbody>
</table>

The aim was, therefore, to invite volunteer subjects so that as many as possible of these pathologies would be represented.

1.3 Background studies completed at the University of Surrey

A project to develop a long force-plate walkway at the University of Surrey was initiated over 20 years ago, in conjunction with Mr Deane. Tully (1973) used a platform at Nuffield Orthopaedic Centre in Oxford, whose construction was mild steel latticed, approximately 2.5m long and 0.6m wide, supported at the corners on four strain gauged cantilever arms. It weighed approx 100lb (45kg). This walkway was neither adequately high in stiffness nor adequately low in mass and measured only vertical force. Tully does not give constructional details or design calculations so it is not clear whether he built the platform, but he does not refer to anyone else having designed or built it.
Adams (1974) modified Tully's force plates, by joining them end to end and repositioning the cantilevers, and tested them. The errors in determination of a static force were large; greater than 13%. No tests of frequency response were performed. Adams concluded that the walkway could not be used for clinical research because of its poor static response and expected poor dynamic response.

Grew (1975) modified Tully's force plates, whose dimensions were now given as 7 feet long, 1 foot 6 inches wide. He changed the wiring of the strain gauge bridges, redesigned the supports and changed their positions. This improved the static accuracy to approximately +/-5% and the resonance frequency to 29Hz.

Kitchen (1979) reviewed clinical gait analysis and suggested the use of Grew's walkway for vertical forces with manual measurement of inked footprints for the spatial data.

Khodadadeh et al (1979) did a study on the ground-reaction forces of 42 patients before and after total hip replacement. The study used two 400mm x 600mm Kistler force plates, and two 540mm (21 inch) x 2175mm (7' 2'') Grew's Surrey force plates, which were of lower accuracy than the Kistler force plate and provided the vertical component of force and its position. The error in the positional data from the Surrey walkway was around 150mm for the centre of each footfall, with oscillations of peak-to-peak amplitude of around 200mm. The walkway's data was not used in the remainder of the study.

Other developments at Surrey occurred more recently via several MSc projects (Lewis, 1985; Michael, 1986; Hart, 1987; Jones, 1988; Barrance, 1989) under the supervision of Mr Hughes, the supervisor of this study. These resulted in an incomplete but promising prototype.

Lewis (1985) was given the task of assessing the walkway's potential for performing as a system for simultaneous measurement of force and
spatio-temporal information. In consultation with Mr Deane, he arrived at a list of gait parameters to be measured using the walkway, and suggested renovating Grew's walkway, recording the output from each support separately and applying software in order to calculate the spatio-temporal gait parameters.

Consideration of the inertial behaviour of the platforms led to the basis of a subsequent project by Michael, who was required to focus on a design with low weight and high stiffness. The specification was defined by Hughes (personal communication) and Deane. Michael (1986) therefore abandoned Grew's walkway and produced a wooden plate 2m x 0.46m x 72mm consisting of softwood battens and birch plywood sheets. Wood was chosen because it was cheap, light and easy to construct and preliminary analysis suggested it could meet the specification. She chose the transducers and reduced the number of supports from 4 to 3. Using finite element analysis, she predicted the structure's fundamental resonant frequency as 49Hz. She modified the design and later determined the frequency experimentally as 92Hz. She amplified the data without low-pass filtering it and collected it using a BBC microcomputer.

Hart (1987) evaluated Grew's and Michael's walkways. He rejected Grew's walkway because its resonant frequency was too low (22Hz for 3-point support). He rejected Michael's walkway despite finding its resonant frequency to be 51Hz for 3-point support, on the grounds that he thought there were too many internal vibrations and that the dynamic behaviour depended on whether the subject stepped above one of the struts or between them. Hughes (personal communication, 1993) suggested that it may have been poor manufacture rather than poor design that caused its rejection. Hart designed, and Jones (1988) built and began to instrument a pair of aluminium prototype plates. Barrance (1989) continued with instrumentation and began calibration of Jones's plates.
1.4 Previous work in gait analysis

'Gait analysis' was defined by Davis (1988) as 'the systematic measurement, description and assessment of those quantities thought to characterise human locomotion'. ('Gait evaluation' was defined by Cappozzo (1984) as 'the assessment of the ability of the subject to move through space by ambulation'.)

There are many forms of gait analysis available. These include measurement of the movement of the body (kinematics), and measurements of forces exerted by the body and estimation of forces across the joints (kinetics). Kinematics includes the measurement of stride dimensions and timing. In walking (or running) without walking aids or assistance, the only external forces acting on the body are ground reactions, gravity and air resistance. The body can be modelled as an assembly of linked segments, each rigid, and all linked by joints having fixed axes of rotation. Anthropometric data estimating the mass and position of the centre of mass of each segment is available. Using these three types of data and neglecting air resistance, it is possible to estimate the forces and moments acting across the joints between the segments. By placing electrodes on the skin over muscles or inserting them into muscles, it is possible to measure the electrical activity of muscles, which is related to the force generated. This is called electromyography (E.M.G.).

Data on the geometry of the bones and soft tissue and joints has been obtained from cadavers. Using the forces and moments across the joints, and the anatomical data from the cadavers, it is possible to set up equations relating forces in individual bones and muscles. These equations are not statically determinate, so in order that they can be solved, assumptions must be made. The E.M.G. data is useful for this; e.g. if at a certain point in the gait cycle the E.M.G. activity from a particular muscle is negligible, the force in that muscle can be assumed to be zero. (e.g. Winter, 1990)
Motion analysis is used for research (Isakov et al, 1992), teaching biomechanics (Messenger and Bowker, 1987), in sport (Cook et al, 1989) and clinically (Rose et al, 1991). In research, the purpose is to improve understanding of biomechanics in healthy individuals (human (Laassel et al, 1992) and non-human (Johnston et al, 1991) e.g., horses), sporting activities (Cook et al, 1989) and pathology (Menard et al, 1992). In sport, the purpose is to improve an individual's performance and minimise the risk of injury.

1.5 Gait analysis in the routine clinical context

Uses of gait analysis in the routine clinical context are:


5. Adjustment of orthotics/prosthetics (Kljajic and Krajnik (1987), Lin (1985), Ranu (1986)).

1.6 Advantages of introducing instruments to clinical gait assessment

Little (1981) and Baumann (1984) state that the two advantages of introducing instruments are:

- Increased assimilation of detail which the eye misses. (Miyazaki and Kubota (1984) compared the ratings of four observers with measurements of vertical foot forces and found that visual rating had several problems; scattering of grades among raters, bias, dependence on judgement, and confusion of the meaning of the evaluation item. Saleh and Murdoch (1985) argued that visual observation was an unreliable clinical skill. Messenger and Bowker (1987) quote a number of studies demonstrating that visual assessment of a patient's gait is markedly inferior to quantitative assessment using 'gait analysis' techniques.)

-A permanent record is obtained of performance at a particular time.

Despite the claimed advantages of gait analysis, it has not much been used in the clinical context in the UK. Messenger and Bowker carried out a survey (1987), in view of the contradiction between the sustained claims for the clinical potential of gait analysis and assessment techniques on the one hand, and the increasing concern expressed by a number of respected workers in the field on the other hand. They aimed to determine what routine clinical use was being made of the gait analysis facilities in the UK, and to assess the value of these facilities as perceived by clinicians in the field. Eight of their respondents believed gait analysis was a useful routine clinical tool, seven believed it wasn't, and one made no comment. Of those who believed that it was not a useful routine clinical tool, six believed that it had future potential to become so.
1.7 Clinical gait analysis methodologies

Several authors [Porter and Roberts (1989), Collins and Whittle (1989), Begg et al (1989), Davis (1988), Lord et al (1986), Yack (1984)] have reviewed the application of gait analysis in the clinical context. The various methodologies are described below. Details of commercial suppliers are given in Appendix 1.1.

1.7.1 Temporal measurements

Footswitches

Footswitches are one or more contact switches placed on the subject’s feet to determine when the feet are in contact with the ground (review, Davis, 1988). This data can be used to calculate the durations of the phases of gait shown in figure 1.3.

1.7.2 Kinematic measurements

These measurements describe the way the positions of the parts of the body change with time. Examples of the measurements are step lengths, stride time, speed, joint angles and joint velocities.

Video/cine cameras/sequential photography

Yack (review, 1984) discusses imaging techniques. These vary greatly in cost and sophistication, ranging from sequential photography, through TV and cinematography to video/film marker systems. Interrupted light photography and video recordings have advantages over cinematography: immediate feedback, darkened room not needed to view results. However, cinematography can be used to provide a complete kinematic analysis of movement, but if the data is reduced manually, this is extremely time-consuming and therefore not clinically viable.

Video is not strictly a measurement technique; the walking is merely videoed and then viewed in slow motion. It is possible to then apply a visual
rating scale to the gait, but Eastlack et al (1991) found Videotaped Observational Gait Analysis to be only slightly to moderately reliable. Physiotherapists were asked to rate various kinematic parameters as inadequate, normal or excessive, and their ratings (-1, 0, 1) were statistically analysed. When different raters rated the same parameter, their ratings were found to be in only slight to moderate agreement with each other.

Optical tracking systems

These sophisticated (and expensive) data collection techniques (review, Davis, 1988) employ optical systems to track the displacement of markers placed at particular anatomical sites on the limb segments. Three-dimensional limb segment rotation angles are calculated from the embedded coordinate system information. Commercial systems include Vicon, Selspot II, CODA 3, ExpertVision and the Salford College of Technology Biomechanics Workstation version 1, which offers video tracking in 2 dimensions. M.I.E. Medical Research Limited sell the Kinemetrix 2-D and 3-D Motion Analysis Systems. Suntech Medical (U.K.) Ltd sell the Elite system, including tracking of passive markers, force plate data acquisition and E.M.G. data acquisition.

Non-automatic footprint methods

Some quantities are measurable with a stop-watch and a dimensioned walkway. These include walking speed, step frequency (cadence), length of one step (step length) and distance between two successive steps (stride length) (review, Davis, 1988).
Temporal-distance mats/walkways

Yack (review, 1984) notes that electronic temporal mats can be used to document the timing aspects of the gait cycle and in some cases, divide the stance phase of the gait cycle into component parts (heel contact, forefoot contact, and toe contact). More expensive walkway systems are available and are used in conjunction with a computer to produce a temporal and spatial profile averaged over several strides.

Accelerometers

Yack (review, 1984) discusses the use of accelerometers for clinical assessment of human movement. From Newton’s 2nd law (F=ma), measuring the acceleration of a body or body segment by an accelerometer would seem to be a straightforward way of gauging the forces acting on the body segments, given that the mass of the body segments can be estimated based on anthropometric measurements. It is common practice to use three accelerometers placed on orthogonal axes to measure the acceleration in the three planes of motion (vertical, anterior-posterior, and medial-lateral). Systems which correct for rotations are too complex to be of practical use in the clinic.

Anemometers

Hot wire anemometry was used by Sun et al (1992) to measure limb velocity. In hot wire anemometry, the hot wire sensor is heated by passing current through it. When it is placed in a moving fluid, part of the heat generated is convected away by the passing fluid. The higher the fluid velocity, the higher is the heat transfer rate. The electrical resistance of the sensor (or the current required to maintain the sensor at constant temperature) is used to measure the velocity of the fluid. Anemometers measure velocity directly rather than integrating from acceleration or
differentiating from position so that kinetic energy of limb segments can be estimated more directly.

**Electrogoniometers**

Electrogoniometers are multi-axis potentiometers strapped to the limb segments at a joint, used to measure relative joint angles. The consistent alignment of goniometers may be difficult, if at all possible, on patients with significant joint deformities. (review, Davis, 1988).

**Optical switches**

Optical switches can be used to time how long a subject takes to cover the distance between two infra-red beams (e.g. West London Institute of Higher Education, 1992).

**1.7.3 Kinetic measurements**

**Harris and Beath mat**

West (review, 1987) mentions the Harris and Beath mat. This is a rubber mat with its upper surface covered by fine ridges at different levels. The ridges alternate in a regular pattern to produce a grid. The whole upper surface of the mat is coated with printer's ink, and is then covered with paper on which the subject walks or stands. The result is a qualitative assessment of time-averaged distribution of foot pressure.

**Monolithic force plates**

A monolithic force plate is a flat surface with force transducers attached. Force platforms can be used to define the magnitude and direction of the resultant ground reaction force applied by the foot to the ground (review, Collins and Whittle, 1989).
Commercial monolithic force plates are considered below in section 1.8.

**Real Time Video Vector System**

A vector representing the measured ground reaction force can be superimposed on the video of the subject (Tait and Rose, 1979). Application of the system to the assessment of clinical orthotic problems is illustrated by examples at all levels of lower limb bracing (Stallard, 1987). The presentation of the data appears to make it accessible to clinical staff. However, it is not widely used.

**Plates/mats measuring force distribution**

West (1987) mentions the pedobarograph developed by Chodera. This consists of an optically clear plate with light conducted across the surface by internal reflection. This is covered by a thin sheet which contacts the glass plate when a subject stands on it, thus allowing light to escape. It gives a black-and-white intensity-modulated footprint representing force distribution.

Arcan and Brull (1976) introduced an instrument consisting of a rigid, transparent plate of plastic or glass, and layers of reflective, polarising and optically sensitive material. The loading device, which could be either a topsheet or a sole of a special sandal, consisted of a material with a matrix of rigid protrusions. When viewed from beneath, the local force of each protrusion created a circular pattern the diameter of which was a direct function of local force.

The Musgrave Pressure Plate (Musgrave Research Group) measures foot pressure distribution.

The Dynamic Pedobarograph is sold by Biokinetics.

**Force transducers carried by the subject**

These include force transducers attached to the feet, force-measuring shoes/insoles, and force transducers incorporated in assistive devices (canes and crutches).

West (1987) mentions Baumann and Brand's capacitative pressure pads adhered to the sole of the foot to record peak pressures in predetermined areas during gait. Pollard et al (1983), Barcroft (1984) and Birke et al (1985) also describe systems involving transducers stuck to the sole of the bare foot. Hargreaves and Scales (1975), Miyazaki and Iwakura (1978), Hermens et al (1986), Miyazaki et al (1986), Ranu (1986), Kljajic and Krajnik (1987) and Toyoshima et al (1987) used transducers attached to the sole of the shoe/dedicated transduced shoes to record floor reaction. West (1987) mentions an insole for recording plantar pressures developed by Lereim and Serek-Hanssen in which miniature transducers were positioned into a PVC insole to be worn in the shoe. The advantage of these devices is that many successive steps can be recorded. The disadvantages are the presence of the load cells beneath the feet, the associated wiring, and the coordinate system which moves with the foot which makes it difficult to combine the data with kinematic data.

Cunningham and Brown (1952) and Symington et al (1979) built load-measuring pylons to be substituted for the shank of a prosthesis.

Yack (review, 1984) states that no systems incorporating force transducers within the shoe of the subject had proven to be practical enough to receive wide clinical application, and that no system
incorporating force transducers within assistive devices had been developed for clinical application.

1.7.4 Electromyography

Yack (review, 1984) discusses the use of electromyography for clinical assessment of human movement. The results give insight into the neural control of the movement. The information can be invaluable when attempting to determine which muscles are functioning and in gauging the level of contraction of the muscle.

1.7.5 Expert systems

Dzierzanowski et al (1985) describe GAITSPERT, an expert system for use in stroke. It requires E.M.G. patterns, bilateral foot contact patterns indicating heel, ball and the contact sequences of both feet and angular motions. They claim that the system has shown clinical usefulness.

1.8 Commercial force plates

The commercial force plates found all measured force in three-directions.

Additional details are given in Appendix 1.2.

Advanced Mechanical Technology Inc. In July 1991, their largest force plate available was 4 feet (1.22m) long and cost $18 000.

Anima company A pair of large force plates manufactured by this company were used by Takegami (1992). He gives the dimensions of the plates as 2.5m long, 0.4m wide. Morita (1988) in Japan used four force plates each 2m long, 0.4m wide.
Bertec Force Platforms, sold by M.I.E. Medical Research Limited These are available in a range of sizes and specifications. The prices for the force plates, amplifier and cable (February 1992) are shown below.

<table>
<thead>
<tr>
<th>Size</th>
<th>Type</th>
<th>Frequency</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4m x 0.6m</td>
<td>Solid aluminium type 4060A (500Hz)</td>
<td>£7 345</td>
<td></td>
</tr>
<tr>
<td>0.4m x 0.6m</td>
<td>Honeycomb top type 4060H (1500Hz)</td>
<td>£9 557</td>
<td></td>
</tr>
<tr>
<td>0.4m x 0.6m</td>
<td>Honeycomb top type 4060S (1500Hz)</td>
<td>£11 800</td>
<td></td>
</tr>
<tr>
<td>0.4m x 0.8m</td>
<td>Honeycomb top type 4080H</td>
<td>£11 800</td>
<td></td>
</tr>
<tr>
<td>0.4m x 0.8m</td>
<td>Honeycomb top type 4080S</td>
<td>£12 800</td>
<td></td>
</tr>
<tr>
<td>0.6m x 0.9m</td>
<td>Honeycomb top type 6090S</td>
<td>£15 800</td>
<td></td>
</tr>
<tr>
<td>0.6m x 1.2m</td>
<td>Honeycomb top type 6012S</td>
<td>£18 800</td>
<td></td>
</tr>
<tr>
<td>0.9m x 0.9m</td>
<td>Honeycomb top type 9090S</td>
<td>£18 800</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amplifier AM6-2 six channel pre-amplifier and amplifier</td>
<td>£4 380</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cable for up to 15 metres</td>
<td>£220</td>
<td></td>
</tr>
</tbody>
</table>

Kistler Instruments Limited A choice of top plates is available, including a glass one, enabling the walking to be videoed from below.

Sample prices (June 1993) are:

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 force platform, type 9281B11 (0.4m x 0.6m)</td>
<td>£10 500</td>
</tr>
<tr>
<td>mounting frame, type 9423</td>
<td>£422</td>
</tr>
<tr>
<td>eight-channel charge amplifier, type 9865B1Y28</td>
<td>£4300</td>
</tr>
<tr>
<td>cable, type 1681B10</td>
<td>£1210</td>
</tr>
<tr>
<td>Bioware software package including set of connecting cables to eight channel amplifier and A/D card</td>
<td>£4350</td>
</tr>
<tr>
<td></td>
<td>£20 782</td>
</tr>
<tr>
<td>plus 17.5% V.A.T.</td>
<td>£24 419</td>
</tr>
</tbody>
</table>
1.9 Previous work with long force plates

Skorecki gait machine

Skorecki (1966) describes the Skorecki gait machine which was a pair of large force plates. It replaced an earlier prototype which had been in clinical use for 4 years. It was installed in a hospital and intended as a clinical, diagnostic and research tool. Each platform was 11 feet long. The forces were transduced by reflecting ultraviolet light from steel diaphragms onto sensitive paper. The damping was provided by oil dashpots (necessitating temperature control). The accuracy of the system, static and dynamic, was within 1%. Only vertical force for each foot (not position) was measured, from several successive steps. Possibly this was because suitable computer technology was not available, or possibly the idea had not occurred to the researchers. A retractable dividing wall was used to keep each foot on one platform. The platforms were mounted 1.5" above floor level so that the subjects could not accidentally partially support their feet external to the platforms. A ramp was provided at each end.

Charnley and Pusso (1968) used the Skorecki gait machine in relationship to surgery of the hip joint. 'This arrangement was considered to be more suitable for clinical practice than any design necessitating apparatus being attached to the shoes, since the adjustment would take too much time in a busy outpatient clinic.' Vertical force only was used, because they thought that was the most informative element. They also wanted to be able to measure several successive steps rather than just one. They wished to be able to dissociate gait improvement from pain reduction. The vertical force traces were superimposed on the same baseline, as I have done. They believed that this was a good method of display for clinical practice. The method of step length measurement was to count the number of steps recorded in the 11 feet length of the platform, clearly only an approximate method.
The paper gives these examples in clinical practice:

1. Helps to separate pain from load-carrying ability, so helps to plan operations.

2. Retrospective research.

3. Which hip to replace first. They believed that the hip with the shorter single support time should be replaced first.

4. How much is stick taking weight, i.e. is it just for balance.

A tentative attempt was made to express the result of the assessment as a single number.

Jacobs et al (1972) measured the vertical component of force in normal and pathological gait using the Skorecki gait machine. They used Fourier analysis and other factors to classify different kinds of waveforms of gait. They found some correlation between the factors describing the waveform and the diagnostic state of the hip joint.

The walkway was used for research and clinical use by Sir John Charnley for several years but has not been used for at least 10 years. It fell out of use when Charnley left and because other diagnostic methods such as X-rays had improved. It was still there in 1990 and may or may not still exist (Lambert, 1993).

Rydell walkway

Rydell (1966) describes a two-track walkway in Gothenburg in Sweden. The walkway consisted of two parallel platforms, each 5m long, 200mm wide and 20mm apart, one per foot. Fore and aft shear and the vertical component of the floor reaction were measured from several consecutive steps. The vertical dimension of the walkway appears to be much greater than that of the University of Surrey walkway. Each walking-plate consists of two U-beams, joined by flat bars, force transducers and stabilizing equipment. The U-beams, with their hollow
faces together form, with the flat bars, a framework which gives good stability and reduces the risk of deflection under load. Each force-plate weighed about 30kg. Details of the transducers and mounting arrangements are given. The force transducers recording vertical force were connected in series so no position measurement was available. As for the Skorecki gait machine, possibly this was because suitable computer technology was not available, or possibly the idea had not occurred to the researchers. The output was recorded on a chart recorder.

Hirsch and Goldie (1969) used the walkway described by Rydell (1966) in a study on the forces acting on the hip joint after intertrochanteric osteotomy for osteoarthritis of the hip. They believed that after the operation, some patients made less use of the operated leg and wished to verify this. The results confirmed the assumption that that patients osteotomised for osteoarthritis did not use the operated limb to the same extent as the non-operated side.

Olsson (1984) also used the walkway described by Rydell (1966). Gait, hip muscular function and clinical features were analysed in 5 patients with chondrosarcoma of the pelvis operated with removal of the tumour, including the acetabular ring. Single limb support time, maximum vertical load and cadence were measured using the walkway. Step length and velocity were only measured using a stop-watch, measured distance and inked footprints.

Yamashita and Katoh, 1976

This paper describes a force platform in the shape of right isosceles triangles, side length = 1.57m, which was long enough to measure one step for each leg. Figure 1.1 shows the platform.
A commercial vertical force strain gauge transducer was attached to each vertex of each force plate. The plate was a steel frame topped with laminated wood. The coordinates of the centre of pressure were calculated as in the Surrey system. Both feet walked on the same force plate, so during double stance, only the total force and average centre of pressure were available. Double-support time was measured using footswitches.

Elisabeth Olsson's group in Sweden

Olsson et al (1986) describes a system which is based on the Rydell (1966) walkway. The method was still intended for clinical use. The system also included photocells and hip and knee goniometers. The walkway was fixed down to the concrete floor and a raised surround was built round it. Walking speed was measured using the photocells. Step length was measured using the ratio of vertical forces from each end of the platform. The system was connected up to a computer which calculated the gait parameters automatically using a program called Kl-step.

The walkway was calibrated quickly and efficiently using a weight on wheels.
The walkway's vertical natural frequency was 45-50Hz and its anterior-posterior natural frequency was 20-25Hz. Third-order low-pass filters were used for all of the force signals. This walkway cannot study the highest frequencies of gait i.e. initial foot contact.

The system measured vertical force adequately but the same could not be said for horizontal force.

The walkway measured mean step length to within 1%.

KI-step analysed body weight, average velocity, mean step length, right and left step length, stride length, stride time, right and left single stance times, right and left stance times, right and left double stance phase, maximum vertical force (right and left), vertical force integral (right and left) and time from heel strike to maximal vertical force as a percentage of the stance phase (right and left). Where possible the mean value for all the complete steps in a traverse was used. 12 traverses were used per assessment, to record the full range of walking speeds. The maximum sampling time was 10-12s per traverse.

The system was suitable for subjects who could walk unassisted along a straight line with one foot on each plate, without toe scuffs and without placing the walking aids on the platform.

Olsson et al (1985) used the walkway described above as one method to compare cemented and non-cemented hip implants 6 and 12 months postoperatively. They found that it was valuable in the assessment of locomotor function.

Olsson and Barck (1986) correlated clinical examination and quantitative gait analysis using the walkway and goniometers for patients who had been operated with the Gunston-Hult knee prosthesis 10 years previously. Of the 72 patients only 22 fulfilled the criteria required for the test on the force plate walkway. The criteria were that the patients could walk 40m without a rest and 200m with a rest. Attempts were made to record
over each subject's entire range of walking speed. The gait analysis confirms the results from a clinical examination and provides additional objective information impossible to measure by clinical observation.

Olsson (1986) reviews gait analysis in hip and knee disabilities, reviews papers mentioned above plus one from 1982 which used the Rydell walkway and one which analysed gait variables in relation to hip motion after total hip replacement and compared cemented and non-cemented prostheses using the walkway. The subjects were a subset of those used by Olsson et al (1985) but particular emphasis was put on the joint angles.

It was found that of those which their system could measure, the gait variables most sensitive in giving evidence of a change in a patient's ambulatory status were maximal vertical force and average velocity followed by step rate, single limb support and weight acceptance.

Selin et al (1988) describe the development of a new walkway. The walkway consists of two 5m long and 0.25m wide force measuring platforms. Each platform weighs 19kg and consists of two U-beams with their hollow faces joined together by thin angled bars. The upper beam is a sandwich of 23mm thick foam plastic between thin aluminium sheets. Each platform rests on strain gauge force transducers installed to record forces in all 3 directions. The transducers are connected through amplifiers, filters and an analogue to digital converter to a computer.

The walkway proved to be linear with coefficient of correlation $r^2 = 0.99$ in all directions and a maximum hysteresis of 1% in the horizontal plane. Regarding the point of application, an error in the range -2mm to +8mm was found. The natural frequency in the vertical direction was found to be 48Hz. In the fore and aft direction the platforms were found to contain a natural frequency of 30Hz. The natural frequency seemed to disturb the registered force curve since a slight augmentation of the signal energy at about 30Hz could be seen. In the medio-lateral direction the impulse
response contained signals with a frequency of 15Hz and 56Hz. The frequency response was thus acceptable for vertical force measurement, borderline for anterior-posterior and unacceptable for medio-lateral forces. The authors suggested applying a sixth order Butterworth filter and a digital band-reject filter to the horizontal signals. They thought that further development of the software would allow the walkway to become a more widely used clinical tool.

Olsson (1989) reviews gait analysis in orthopaedics and discusses the 1966 and 1986 walkway systems and their use. The 1966 walkway was also used in three theses: by J. Kenwright in 1972 to evaluate the result after arthrodesis of the knee and ankle joint, S. Collert in 1974 to evaluate the results after intertrochanteric osteotomy of the hip and L. Baon in 1976 to evaluate the results after total hip replacement.

Walheim et al (1990) used the 1986 walkway to perform analyses on patients with trochanteric hip fracture, 3 and 6 months post-operatively. They found no statistically significant differences in maximum vertical force between the occasions, but there were statistically significant differences for single limb support phase.

Mattsson et al (1990) compared different methods of assessment of walking 1 day before and 1 year after unicompartmental knee arthroplasty. They used the British Orthopaedic Association knee function chart, self-selected and maximal speed of walking and several variables from the 1986 walkway. These were self-selected walking speed, step frequency, stride length/lower extremity length, maximal vertical force for each leg, maximal vertical force ratio and vertical force impulse for each leg. They used 12 traverses per subject, at a range of speeds. Oxygen cost was also measured. When controlled for speed, step frequency and stride length/lower extremity length did not change significantly. They concluded that 'for clinical routine purpose clinical assessment, especially
of pain, supplemented with measurement of self-selected walking speed were found to be sufficient for assessing effects of treatment such as unicompartamental prosthetic knee replacement.

Wykman et al (1991) used the 1986 walkway as one method to compare cemented and press-fit non-cemented fixation in total hip arthroplasty. They used average free walking speed, single stance phase of each leg (% gait cycle), weight acceptance phase of each leg (% gait cycle) and maximum vertical force.

Engardt and Olsson (1992) used the 1986 walkway to examine the weight distribution between the two legs during rising and sitting down in patients with stroke.

Wykman and Olsson (1992) compared gait analysis in unilateral and bilateral total hip replacement, using the 1986 walkway. Free walking speed, step frequency, stride length related to lower extremity length and the single-stance duration of each leg as a percentage of the gait cycle were recorded.

**Anima commercial force plates**

Anima large force plates were used by Ito (1984) and Takegami (1992).

Ito used one plate to measure the serial floor reaction force of several steps for a hemiparesis patient. The x, y and z force components were transformed to resultant force, velocity, acceleration and paths of centre of pressure. He wrote an analysis program for the force plate data, intended for use in rehabilitation. He concentrated on graphical information, believing this to be the most suitable for clinical use.

Takegami used two force plates each 2.5m long x 0.4m wide to study the wave pattern of ground reaction force for 241 normal children, aged 4-10 years. He believed this would be useful control data in evaluating
pathological gaits. The force plates were placed inconspicuously at the same level as the surrounding ground. No directions were given, in order to ensure normal walking. Cadence, velocity, step lengths, step widths and the ratio of stance time to one walking cycle were measured from the graphs of the coordinates of the mean centre of pressure (averaged between the 2 feet) against time. This is a different algorithm from the one which I have used. It is not clear whether the analysis was done automatically or manually.

University of Salford balance platform

Edwards et al (1990) designed a pair of large force plates for balance measurement, but they appeared to be designed with a view to gait. They used Maywood U3030 transducers. They found it was very important how they were mounted. The behaviour of the device was non-linear, so they planned to calibrate it and use look-up tables. This would get labour-intensive if one were mass-producing the walkways. They planned to make another platform of honeycomb and welded duralumin channel.

1.10 Comments in the light of these designs

It was hoped that our new walkway design, using a new structure, could improve on the Olsson walkway, by being less deep and shorter, therefore less cumbersome to install. It was hoped to produce a portable, low cost system.

1.11 Explanation of normal walking

In normal walking, the walking pattern for each leg consists of a 35% swing phase (off the ground) and a 65% stance phase (on the ground). There is always at least one foot touching the ground. After swing phase, the heel touches the ground. Through mid-stance and push-off, the centre
of pressure moves from a point that is slightly lateral to the principal longitudinal axis of the foot to a position slightly medial to it. The final propulsion is given by the distal heads of the first and second metatarsals. As the body weight comes forward over the foot, the ankle dorsiflexes and the hip and knee flex. These movements help absorb the shock of body weight coming down on the lower extremity. As soon as the line of gravity passes forward of midstance, the anterior-posterior ground reaction force can provide an accelerating rather than a decelerating force to the body. The hip and knee joints begin to extend sequentially. The ankle continues to dorsiflex until the heel is lifted of the ground. (Kreighbaum and Barthels, 1990)

Whittle (1991) contains a chapter on normal gait. Figures 1.2 to 1.12 are taken from it. Figure 1.2 shows the gait cycle.

![Diagram of gait cycle](image)

Fig. 1.2. Positions of the legs during a single gait cycle from right heel contact to right heel contact.
Figure 1.3 shows the phases of gait.

Fig. 1.3 Timing of single and double support during a single gait cycle from right heel contact to right heel contact.

Figure 1.4 shows the terms used to describe foot placement on the ground.

Fig. 1.4 Terms used to describe foot placement on the ground.
Figure 1.5 shows a 'butterfly diagram' for a normal subject.

Figures 1.6, 1.7, 1.8, 1.9, 1.10 and 1.11 show the force vector during the heelstrike transient, just after the heelstrike transient, at foot flat, at mid stance (when the swing phase leg passes the stance phase leg), at heel off and at toe off.
Fig. 1.7  Position of limb and ground reaction force vector 20 ms after heel contact.

Fig. 1.8  Position of limb and ground reaction force vector at foot flat.
Fig. 4.9 Position of limb and ground reaction force vector at mid stance.

Fig. 4.10 Position of limb and ground reaction force vector at heel off.
Figure 1.12 shows the force vectors superimposed on the outline of the foot of a normal male walking in shoes.
1.12 Introduction to subjects studied

The subjects tested were from two sources. Most of them were recruited by Dr Denis May of Queen Mary's University Hospital, London and the University of Surrey. His main interest is in amputees so most of the subjects were amputees. The rest were recruited by Mr Graham Deane and Sister Maureen Harris of Wexham Park Hospital, Slough.

The subjects were:

16 adult amputees (of varying levels of amputation),
2 miscellaneous adult subjects and
2 child subjects recruited by Dr May, and
6 adults with joint disease prior to joint replacement recruited by Mr Deane.

Each pathology is considered in more detail below.

1.12.1 Amputees

Amputees' limbs can be absent due to congenital deformity, disease or trauma. In 1979, a total of 5599 patients who had amputations were referred to the Artificial Limb and Appliance Centres of the Department of Health and Social Security. 8% were due to trauma, 61% to vascular disease and 5% to tumours, leaving 26% unaccounted for. There was 1 arm amputation for every 23 leg amputations (Thomson, 1984).

The amputees studied here were biased toward the young, active end of the lower limb amputee population.

An amputee's treatment consists of surgery, prosthetics and rehabilitation training. The rehabilitation of amputees aims towards a safe, symmetrical gait at good speed. Symmetrical forces are desirable because lower forces can lead to osteoporosis and higher forces can lead to osteoarthritis (Lewallen et al, 1986). The walkway might be used in assessment of the suitability of different components (to improve prescription) or adjustments of prostheses (to reduce the need for the
patients to come back for readjustments) or to measure rehabilitation progress over time (to improve rehabilitation methods, and to be shown to the patient so that they can see what they are doing wrong/ how they are improving) or used in biofeedback gait training (to improve rehabilitation training). No gait measurement is currently used for amputees at Queen Mary's Hospital, Roehampton (Dr May, personal communication).

Gait analysis in amputees has been reviewed by Skinner and Effeney (1985) and Porter and Roberts (1989).

Gait analysis has been used to determine the effects of prosthetic components on amputee gait (Wirta et al, 1990 and 1991; Gitter et al, 1991; and Hale, 1990). Torburn et al (1990) found minimal differences in BK amputee gait with different dynamic response prosthetic feet during free or fast-paced walking on level ground.

Seliktar and Mizrahi (1986) measured all three force components in below-knee amputees, and they decided that 'the conclusions suggest that some of these variables are suitable for evaluation of gait and some, such as small perturbations superimposed on the curve, may serve as indications of specific malfunction of the prosthetic system'.

Symington et al (1979) used a device involving strain gauges applied to the pylon of a modular prosthesis to measure axial load, which is nearly equal to the resultant force which would be measured by a force plate under the prosthetic foot. They state that preliminary experience with the described equipment has shown that it is of value in monitoring and regulating weight bearing in patients with healing or maturing stumps or impairment of stump sensation.

Dewar and Judge (1980) used temporal components of the walking cycle (measured using insole footswitches designed for clinical assessment) to derive a temporal asymmetry index, intended for monitoring gait in the routine clinical context. The system was tested on lower limb amputees (and
on a hemiplegic stroke patient). The system was shown to be capable of highlighting features of pathological gait which would have been less likely to have been observed without such measurements. The authors believed that the potential had been demonstrated, but that the only real test of the value of such an approach was whether it was found to be useful in the routine clinical situation.

Wall (1985) studied the duration of double limb support and speed of walking in lower-limb amputees. He considered that asymmetry indices based on these should prove useful in monitoring progress during the gait retraining period of the rehabilitation process.

According to Seliktar and Mizrahi (1986), fluctuations of the vertical force were believed to represent a stability problem, or rather, a stabilising activity of the foot, but this was difficult to quantify. They did not think this was of much value without an indication of what was wrong. I have not attempted to quantify fluctuations, but modelled the force curve as the 'm' shape typical in normals and performed analysis on the greatest force value in the first half of the step, the greatest force value in the second half of the step and its timing in percentage of the stance phase, and the smallest force value between the two peaks.

Particularly during early rehabilitation, patients routinely use walking aids (Baker and Hewison, 1990) so it might be useful to make the walkway usable by these patients (see section 5.2.1.8).

1.12.2 Joint replacements

This patient group was chosen for study because it is important to the work of Mr Deane. The individual patients were patients of Mr Deane who volunteered and were available for travel to the University of Surrey on a particular date.

In the U.K, many joint replacements are carried out due to osteoarthritis. Osteoarthrosis or osteoarthritis is a term applied to a chronic inflammation of the bones composing a joint, and leading to deformity (Thomson, 1984). This tends to affect elderly people. Of the order of half of joint replacement patients are so disabled that they would not be able to walk along the walkway even once, let alone 10 times (personal communication, Mr Deane). The subjects studied here are therefore biased towards the more active part of the elderly pre-operative joint replacement population. However, no form of gait analysis would be useful for subjects who could not walk along the walkway even once. At first after their operation, the subjects have to use walking aids so their gait cannot be measured using the walkway in its present form. According to Mr Deane, a patient's recovery is complete after 6 months. Also, Wall et al (1981) studying hip replacement patients found that that there was little improvement in gait between 6 and 12 months post-operatively. An envisaged use of the walkway would be to assess the effect of a subject's operation and rehabilitation, so it would have been desirable to have measured the subjects' gait again 6 months after their operations in order to find out whether the walkway could detect changes and in what variables. However, time did not permit this. It was decided to try to retest the subjects approximately 3 months after their operations. The subjects' recovery was expected to have been substantial and they were expected to have progressed to a stage where they could walk without walking aids (Deane, 1992).
1.12.3 Cerebral palsy

'Cerebral palsy is the term used to describe a group of conditions characterized by varying degrees of paralysis and occurring in infancy or early childhood.' In 80% of cases it takes the form of spastic paralysis. In the majority of cases the abnormality occurs before or during birth. The most important single factor is considered to be oxygen starvation during birth. 'The victim may be spastic or flaccid, or the slow, writhing involuntary movements known as athetosis may be the predominant feature.' (Thomson, 1984)

Gait analysis has been used to plan operations on patients with cerebral palsy. De Luca (1991) reviews gait analysis in the treatment of the ambulatory child with cerebral palsy: 'Surgical treatment of children with cerebral palsy has changed from staged, single joint procedures to comprehensive simultaneous bony and soft tissue corrections. It is subject to error when based solely on the clinical examination.’. Perry et al (1974) performed gait analysis of the triceps surae, using E.M.G. to decide what operation to do. Baumann (1984) believes that the pathophysiology of cerebral palsy is so complex that a more detailed analysis than that obtainable by standard methods of examination is required for treatment planning. He states that experience in a busy cerebral palsy clinic has demonstrated that the long term management of these patients is greatly facilitated by gait analysis.

Because the walkway does not give enough information to allow detailed analysis of the gait and localisation of problems it is not expected that the walkway could give enough data to plan operations on patients with cerebral palsy. It is however envisaged that it could be used to monitor the effects of treatment such as surgery, sports therapy rehabilitation and cerebellar stimulation. Frobose (1989) studied the results of treatment in a 6-month movement and sports therapy rehabilitation program of children.
with cerebral palsy using just a force plate. Clear modifications after the therapy were found. Vaughan et al (1988) performed kinematic gait analysis of 14 patients with spastic cerebral palsy before and after selective posterior rhizotomy. Improvement was found including in temporal-distance factors. It corroborated clinical findings of improvement.

1.12.4 Orthoses

It was envisaged that the walkway could be used to determine which orthotic treatment would be most suitable for a particular child. It would not be useful in its present form for use with orthoses which can only be used with crutches, e.g. the Hip Guidance Orthosis.

McPoil et al (1989) studied the effects of foot orthoses on centre-of-pressure paths in women with forefoot deformities during walking. A force platform was used.

Brodke et al (1989) performed gait analysis on five normal children with two types of orthoses. They found that the metal-and-leather A.F.O.s impaired normal walking more than the plastic orthoses. They thought that in clinical practice this information may be useful in selection of orthotic materials for some patients.

Balmeseda et al (1988) analysed the effects of an ankle-foot orthosis (A.F.O.) on the ground reaction forces, the position of the centre of pressure, and the timing of stance phase events during walking in 18 healthy volunteers using a Kistler force plate.

Hamill et al (1988) studied exercise moderation of foot function during walking with a re-usable semi-rigid ankle orthosis using an Advanced Mechanical Technology Incorporated force platform and a high-speed camera. The analysis consisted of the evaluation of selected ground reaction force parameters and kinematic parameters describing rearfoot motion.
Nene and Major (1987) measured the dynamics of reciprocal gait of adult paraplegics using the Parawalker (Hip Guidance Orthosis). They used video recording and measured foot forces (using a Kistler force plate) and crutch forces in all three directions. Using their Real Time Video Vector system, they combined real time force vectors with the video information. Stallard (1987) uses the system with a subject with an ankle-foot orthosis, one with a knee orthosis, and one with a swivel walker.

Middleton et al (1988) carried out a case study of the role of rigid and hinged polypropylene ankle-foot orthoses in the management of cerebral palsy. They used a 4.5 year old female, a WATSMART video system and a Kistler force plate. They found the hinged ankle-foot orthosis to be more effective than the rigid one.

Kljajic and Krajnik (1987) used measuring shoes to measure vertical force component and its distribution under the foot. They report having found the device useful, especially in the adjustment procedures for orthotic and prosthetic devices, and claim simple application to a broad population of patients with different pathologies and extents of impairment, and immediate results in a clear, easily understood form.
Chapter 2: Development of the system

2.1 Introduction

The walkway was to consist of a pair of plates forming the walking surface, attached through force transducers to the floor. The device was to be surrounded by a raised floor, providing a level walking surface. The transducers were to be connected to a signal conditioner which was to supply power to the transducers and amplify and low-pass filter the output. The signals were then to enter an analogue-to-digital conversion card in a computer. Software was to be written enabling the user to record, recall and output data. It was to incorporate algorithms designed by the author to calculate various parameters of gait automatically for each walk.

A schematic diagram of the system is shown in Appendix 2.1. Figure 2.1 shows the system.
A list of suppliers forms Appendix 2.2.

2.2 Overall specification

It was decided on the grounds of cost to design the system for use with adults only (see Appendix 2.3).

The walkway was to be long enough to capture a complete stride.

The system was for use indoors at room temperature.

The designed safe loads were 210kgf in the vertical direction and 47kgf horizontally (see below). The minimum design factor was 3.
Accuracy in the determination of position of a 35kgf (half of a typical body weight) force of +/-10mm was desired (Barrance, 1989). This seemed an appropriate level to give accurate enough positional data to allow calculation of the stride dimensions for adults.

Electrically, the system was to be single fault protected. It was to work safely from a 240V, 50Hz mains supply. The levels of electrical safety were to be commensurate with relevant sections in BS 5724.

It was to be used for approximately 2 afternoons per week over a working life of five years.

It was of necessity to be fixed down to a suspended concrete floor.

The raised surround was to be long enough for the subject to be walking at steady speed while they were on the platform. A 1 in 12 ramp was to be provided.

2.3 Plates

2.3.1 Existing plates

Each of the plates existing at the beginning of this project was a sandwich structure, consisting of a honeycomb top sheet and an aluminium bottom sheet, joined by aluminium channel sections. They are described by Jones (1988): 'The top plate consists of a nominally 8 feet by 2 feet half inch aluminium honeycomb upper surface edged with aluminium channel, stiffened by a SWG 18 NS4 grade aluminium sheet spaced 37mm below the honeycomb. The two are separated by triangular cross-sectioned channel made from SWG 22 NS4 grade aluminium.' The structure was glued together using Araldite 2005 adhesive (Ciba-Geigy, 1986).

2.3.2 Evaluation of the existing plates

The plates were designed (Hart, 1987) to have a fundamental resonant frequency of 50Hz. It had been found (Barrance, 1989) that their
fundamental resonant frequency was 32Hz. It was then calculated (Parkhouse, 1989) as 28Hz. Checking of Hart's calculation showed that he took the ratio of \((EI/m)\) where \(E\) is the Young's modulus of the material, \(I\) is the second moment of area of the section, and \(m\) is the mass per unit area of the platform to be \((44939\text{Nm}^2 \times 2.4384\text{m})/6.43\text{kg} = 17042\text{m}^4\text{s}^{-2}\). This makes \((EI/m)^{0.5} = 130.54 \text{m}^2\text{s}^{-1}\). This value has been re-calculated and found to be \(85.558\text{m}^2\text{s}^{-1}\). The fact that he neglected the mass and stiffness of the channel section may account for the discrepancy. This difference would make the resonance frequency \(85.558/130.54 = 66\%\) of his design value, i.e. 33Hz for 4-point support, so it appears to have been a major cause of inaccuracy.

The 32Hz resonant frequency was insufficiently high. Baumann et al (1985), studying the pathological gait of two subjects with knee instability, identified components up to 22Hz. Antonsson and Mann (1985) demonstrated that 98 percent of the power is contained below 10Hz and 99 percent below 15Hz in normal walking, with the highest frequency occurring during heelstrike. Olsson et al (1986) state that this is in accordance with the findings of Rydell (1966).

The results of Folman et al (1986) showed that the impact loads at heel strike during normal human walking last about 5ms and consist of frequency spectra up to and above 100Hz.

Simon et al (1981) found that the frequency content of the high frequency impulsive load at heel strike varied from 10 to 75Hz.

Olsson et al (1986) have produced usable data from a walkway whose natural frequency is 45-50Hz.

It was decided to design new plates to have a resonant frequency greater than 50Hz in order that a low pass filter of, say, 30Hz cutoff frequency could be used to filter out the resonant frequency of the plates while causing minimal distortion to the gait signals. The heelstrike
transient was to be lost or diminished but this was considered as representing only a small fraction of the information and greatly reduces the resonant frequency required. It has been suggested that the heelstrike transient tends to cause degenerative joint disease (Folman et al, 1986), so the measurement of heelstrike may be required in future designs.

Also, the existing plates were found to be too weak. The bonding on one of them failed when jumped on, and transducer attachment discs became detached. These problems were attributed to the brittleness and failure of adhesion of the glue, the small area of glue contact between the channel sections and the bottom sheet, and insufficient size of the transducer attachment discs. The problem of the small area of glue contact was caused by the geometry of the parts to be joined, and the fact that the glue (Araldite 2005) had low viscosity in the uncured state and had tended to run out of the joints during curing (Jones, 1988).

The plates were also insufficiently rigid, deflecting by approximately 3.5mm at the midpoint when subjected to a vertical static load of 70kgf, which meant that subjects' gait was affected.

It was therefore decided to design and build new plates.

2.3.3 Design of new plates
2.3.3.1 Introduction

In designing a plate, if one keeps the same plate structure (same flexural rigidity per unit width and same mass per unit area) and support geometry but scales up all the horizontal dimensions, the fundamental resonance frequency will decrease, the mass of the plate will increase and the deflections due to an applied weight will increase. If one wishes to keep the fundamental resonant frequency constant, one must increase the stiffness to mass ratio of the section. If the same materials are used, this means that the material needs to be further from the neutral axis of the
section, i.e. the depth of the plate must increase. If one wishes to keep the
deflections constant, one must increase the stiffness of the section.

In order to achieve appropriate values for the mass and depth of the
plate it was thus important to set specifications for fundamental resonance
frequency and deflections which were realistic.

It was decided to keep the number of transducers as 3 rather than
increasing it to 4. Using an extra transducer gives no more information
(because with 3 transducers the walkway is kinematically mounted) and
tends to lower the fundamental resonance frequency (Hart, 1987). It also
increases the amount of amplification and filtering equipment needed (and
therefore its cost).

2.3.3.2 Drawings

The drawings for the plates, fixings, connection box plates, stops for
walkway corners and protective earth connections form Appendix 2.4.

<table>
<thead>
<tr>
<th>Drawing number</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Walkway plate assembly</td>
</tr>
<tr>
<td>1a</td>
<td>Cross section through walkway on A-A (see drawing number 1)</td>
</tr>
<tr>
<td>2</td>
<td>Walkway bottom sheet</td>
</tr>
<tr>
<td>3</td>
<td>Walkway channel section</td>
</tr>
<tr>
<td>4</td>
<td>Edging for honeycomb</td>
</tr>
<tr>
<td>5</td>
<td>Edging to hide structure of walkway</td>
</tr>
<tr>
<td>6</td>
<td>Joining plates for channel sections for walkway</td>
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<tr>
<td>7</td>
<td>Aluminium sandwich panels for walkway</td>
</tr>
<tr>
<td>9</td>
<td>Transducer mounting discs for gait analysis walkway</td>
</tr>
<tr>
<td>10</td>
<td>Attachments to fix gait analysis walkway to floor</td>
</tr>
<tr>
<td>11</td>
<td>Attachments to fix gait analysis walkway to floor: base</td>
</tr>
<tr>
<td>12</td>
<td>Attachments to fix gait analysis walkway to floor: bolt</td>
</tr>
</tbody>
</table>
2.3.3.3 Choice of length

It was necessary to decide the required length for the walkway, using literature data on step/stride lengths.

Finley and Cody (1970) studied the locomotive characteristics of urban pedestrians; 534 men and 572 women. They found the following results for step length:

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>29.172&quot; = 0.741m</td>
<td>3.492&quot; = 0.0887m</td>
</tr>
<tr>
<td>Women</td>
<td>24.972&quot; = 0.634m</td>
<td>2.604&quot; = 0.0661m</td>
</tr>
</tbody>
</table>

The minimum length of walkway needed always to capture a complete stride (i.e. 3 consecutive footfalls completely on the platform) is 3 step lengths plus one foot length. Estimating the average foot length as 0.30m, this length is $3 \times 0.741m + 0.30m = 2.5m$ for men and $2.2m$ for women.

The minimum length of walkway needed to capture a complete stride at all is 2 step lengths plus one foot length. Estimating the average foot length as 0.30m, this length is $2 \times 0.741m + 0.30m = 1.8m$ for men and $1.6m$ for women.

The length of the existing prototype was 8 feet = 2.44m. It was therefore thought long enough always to capture a full stride for nearly
half of normal men and over half of normal women. Disabled adults were expected to have shorter step lengths.

It would have been desirable to make the new version longer. However, this would have added to the cost, and in order to maintain the resonant frequency in a longer structure, it would have been necessary to increase the depth. This would have made it harder for disabled people to have climbed onto it and made it less safe and less neat in appearance. Also, the top sheet and bottom sheet materials used were not supplied in lengths greater than 8 feet. Also, the available space was only 8.41m long, which even with an 8 feet (2.44m) long walkway, left only 2.98m available space at each end of the walkway. With, say, a 5m long walkway, only 1.71m would have been left at each end, which would have meant that the subjects were accelerating and decelerating while on the walkway. (See section 2.10, installation, below.) This would have meant that those steps would have had to have been discarded, so it would not have been possible to assess the walkway properly.

The length was chosen as $2.438m + 2(3.2mm) = 2.444m$, the size of the honeycomb plus the edging.

### 2.3.3.4 Choice of width

The width of the platforms was kept at nominally $0.610m + 2(3.2mm) = 0.616m$, the width of the honeycomb top sheet plus the edging, with the idea that the old and new plates would be interchangeable. This idea was later abandoned. The next version of the walkway has been designed to be narrower (see section 5.2.1.6).

### 2.3.3.5 Top sheet

The top sheet contributes to the stiffness of the structure, but is also exposed to localised loading (such as sharp heels) and to increased loading...
at the transducer attachment points where it is unsupported. It is therefore not permissible to use an aluminium sheet alone.

It was decided to explore whether it was desirable to replace the whole structure by a single honeycomb sandwich. It was thought that this might make the walkway cheaper in terms of materials, and easier to construct.

From the calculations of Parkhouse (1991) and the eigenvalue method of Hart (1987), for two isotropic platforms of the same length and width, supported in the same places, the fundamental resonant frequency $F$ is directly proportional to $(EI/m)^{0.5}$, where $E$ is the Young's modulus of the material, $I$ is the second moment of area of the section, and $m$ is the mass per unit area of the platform.

i.e. $F = K(EI/m)^{0.5}$ where $K$ is a constant.

For the existing walkway, $(EI/m)^{0.5} = 85.558m^2s^{-1}$ (calculated using the geometry and the fact that the structure was aluminium) and by experiment, $F = 32Hz$.

so substituting these values into the equation,

$32Hz = K(85.558m^2s^{-1})$, so $K = 32Hz/(85.558m^2s^{-1})$

and the new version was to have a fundamental resonance frequency of at least 50Hz, so it was decided to use a design value of 60Hz.

So using $F$ and $K$, the required value of $EI/m$ can be calculated.

$60Hz = (32Hz/(85.558m^2s^{-1})) x (EI/m)^{0.5}$

$EI/m = 25735 \text{ m}^4 \text{s}^{-2}$

The use of carbon fibre sandwich was considered. Two specifications were sent to Technical Resin Bonders of Huntingdonshire: option 1, where a 1/2" thick honeycomb sandwich was to form the top sheet, and option 2, where it was to form the whole plate. According to their information, 1/2" carbon fibre honeycomb compared with 1/2" aluminium honeycomb was 2.8 times as stiff and 1.4 times as heavy, therefore $E/m$ was twice as much.
The thickest honeycomb sandwich they quoted had an EI/m value only 1/17 of that required for the whole plate, so option 2 did not appear to be feasible. We were quoted an order of magnitude figure of £600 for a piece 8 feet by 4 feet by any thickness they could supply (compared with £165 for 8 feet x 4 feet x 0.5" aluminium honeycomb). It was decided, however, to proceed using the aluminium honeycomb.

A piece of 3 inch core, 0.55mm aluminium skinned honeycomb would have had an adequate stiffness-to-mass ratio, but was not available as standard, so it was prohibitively expensive and there was a large minimum order. The sheet used by Jones (2438.mm x 610mm x 13.8mm Ciba Geigy M-board (Ciba Geigy, 1986)) was therefore retained. It consists of a 12.7mm honeycomb core sandwiched between two 0.55mm aluminium skins.

The structure was to be all aluminium, so E = 69GN/m² (because E is not sensitive to the small amounts of impurities used in aluminium alloy), so it was required that l/m > 372.97 x 10⁻⁹m⁵/kg.

2.3.3.6 Bottom sheet

In order to make the structure most efficient in terms of stiffness to weight, the neutral axis should be halfway up the depth of the walkway, so the stiffness of the top sheet and bottom sheet in longitudinal tension should be equal. The stiffness of the core in this direction is negligible, so the stiffness is that of 2(0.55mm)=1.1mm thick aluminium.

It was decided to use 1.2mm thick (SWG 18) NS4 grade aluminium alloy as used by Jones (1988).

The bottom sheet could have been made from the same honeycomb as the top sheet. This would have been more expensive but more resistant to buckling than the simple metal sheet used. With this choice, the pitch of the V-shaped channels could have been increased, so fewer of them and less glue would have been needed. This option should be considered if
another version of the walkway is produced. It would have made the design more different from the existing prototype, thus possibly creating new problems, e.g. failure of the glue due to the reduced total joint area. It was decided that it was more important to the aims of the project to produce a prototype which could be tested with subjects with pathological gait for its clinical usefulness. It was therefore decided to use an aluminium alloy sheet.

2.3.3.7 Channel section

Since the minimum fundamental resonance frequency of the walkway had been set as 50Hz, it was decided to use a design value of 60Hz. The design criteria for the channel section are that it should provide the necessary value of EI/m and resist buckling. The design method used was to guess the height of the channel, calculate the dimensions of channel needed to resist buckling, calculate the stiffness-to-weight ratio of the resulting section and thus the fundamental resonance frequency of the structure, and use this value to iterate to the required height of channel.

The height calculated from the iteration was 114mm.

Jones (1988) orientated the channels across the walkway rather than along it, to make the channels easier to manufacture. Their second moment of area did not contribute much to the stiffness of the section, so it was less important which way they were aligned. The walkway is four times as long as it is wide, so its vibrational frequency is mainly governed by its length rather than its width. The new channels contribute more to the stiffness of the section because their greater thickness and depth gives them a higher second moment of area, so it was decided to align them along the walkway to provide extra stiffness where it was most needed.
Hart (1987) stated that the determining factor was stability of the bottom sheet in compression, i.e. there must be no buckling of the skin. This gives the maximum permissible channel pitch:

Hart chose a maximum load of 1.4kN. I decided to design for a maximum load of 2.06kN. This was subsequently decided to have been insufficiently high. Following Hart's calculations, a pitch of 69.3mm was chosen. However, the calculations were over-conservative due to the change in the directions of the channels. Amended calculations for a safe load of 3 x 70kgf and a design factor of 3 are shown below. See figure 2.2.
Assume the moment arm of this force is 0.610m (the width of the platform), and as an extreme case it is assumed that this bending moment tends to bend the structure along its length.

The peak stress in the bottom extreme fibre is given by:
Peak stress = \( \frac{M \times E \times y}{E \times I} \), but the structure is entirely aluminium, so:

Peak stress = \( \frac{M \times y}{I} \), where:

\( M \) = bending moment = \( (70 \times 9.81 \times 3) \times 3 \times 0.610 \times 3.7700 \times 10^3 G\text{Nm} \),
\( y \) = distance of extreme fibre from neutral axis
  = \( \frac{(2 \times 114 \times 10^{-3}) + 12.7}{4} \times 10^{-3} = 0.0602 \times 10^{-3} \) m and
\( I \) = second moment of area of the section = \( 7.8212 \times 10^{-6} \times 2.438 \times 10^{-3} \times m^4 \).

Therefore:
Peak stress = \( \frac{3.7700 \times 10^3 \times 0.0602 \times 10^{-3}}{19.068 \times 10^{-6}} \times 2.438 \times 10^{-3} \) = 11.902 MN/m².

The buckling load in the rectangle of bottom sheet between two successive sections is thus:

\[ \text{Buckling load} = \text{peak stress} \times \text{breadth} \times \text{depth} \]

= \( 11.902 \times 10^3 \times 1.1 \times 2.438 \times 10^{-3} \times 10^3 \) = 31.924 kN.

From Euler, taking the rectangle as a pinned beam,

Critical load = \( \pi^2 \times E \times I \times \text{column} \).\( l^2 \).

Rearranging: \( l = \left( \frac{\pi^2 \times E \times I \times \text{column} \times \text{critical load}}{0.5} \right) \).

E=69 G\text{N/m}²

\( I \times \text{column} = b \times d^3 / 12 = 2.438 \times 10^{-3} \times (1.1 \times 10^{-3})^3 / 12 = 2.7046 \times 10^{-10} \times m^4 \)

Critical load = 31.924 kN.

So \( l = \left( \frac{\pi^2 \times 69 \times 10^9 \times 2.7046 \times 10^{-10} \times m^4}{31.924 \times 10^3} \right) \)

= 0.0760 m, so 76 mm is the new calculated minimum pitch, while 69 mm was the value used, so fortuitously, this aspect of the platform is neither unsafe nor grossly over-designed.
It was decided to retain the truncated isosceles triangle design used by Jones (1988), (see figure 2.3) but the calculated values for the lips were so small that it was impossible to manufacture them, so the channels were made as simple V-shapes.

![figure 2.3](image)

In calculating the required thickness of the channel section, it was assumed, following Hart's calculations, that the worst case of loading is when a patient (taken as a 2.06kN vertical load) steps on an unsupported corner, and that the shear force is resisted only by a length of the channel equal to the depth of the section, i.e. 69.3mm. This gave a required thickness of 1.98mm. The nearest available size was 2.03mm (SWG 14). According to Parkhouse (1991) it would have been more appropriate to use the length of one arm of the V, i.e.

\[
((69.3/2)^2 + (114)^2)^{0.5} = 119\text{mm}.
\]

The new calculation, for a safe load of 3 x 70kgf, a design factor of 3 and a buckling length of 119mm, is shown below. See figure 2.4.
angle to horizontal of sloping part of section
= \tan^{-1}\left(\frac{114}{(69.3/2)}\right) = \tan^{-1}(3.29) = 73.1\ degrees.

Vertical component of buckling force = 3 \times 3 \times 70 \times 9.81 = 6.1803\ kN.
So buckling force = \frac{6.1803\ kN}{\sin\ (73.1\ degrees)} = 6.4593\ kN.
Column length = \frac{114\ mm}{\sin\ 73.1\ degrees} = 119\ mm = 0.119\ m.
From Euler, taking the rectangle as a pinned beam,
Critical load = (\pi)^2 \frac{E I_{\text{column}}}{l^2}.
Rearranging: \quad I_{\text{column}} = \frac{(\text{critical load} \times l^2)}{(\pi)^2 \ E)}\ where:
E=69\ GN/m^2
I_{\text{column}} = bd^3/12 = 0.119\ m \times (d)^3 / 12
\text{critical load} = 6.4593\ kN.
l = 0.119\ mm
So $I_{\text{column}} = 6.4593 \times 10^3 \, \text{N} \times (0.119\, \text{m})^2 / (\pi)^2 \times 69 \times 10^9 \, \text{N/m}^2$

$$= 1.3432 \times 10^{-10} \, \text{m}^4.$$ 

So $0.119\, \text{m} \times (d)^3 / 12 = 1.3432 \times 10^{-10} \, \text{m}^4$.

$$d = (1.3432 \times 10^{-10} \, \text{m}^4 \times 12 / 0.119 \, \text{m})^{1/3} = 2.38\, \text{mm}.$$

The channel section was made using material of thickness 2.03mm, so the walkway is slightly under-built in this respect; the design factor is less than 3.

The pitch of the channel was 69.3mm and the height 114mm. On the department's bending machine this meant that the width of metal needed was 236mm and it needed to be bent to an angle of 31.7 degrees. SWG 14 S1-C bending grade aluminium was used because it was necessary to use very soft material in order to bend such an acute angle. It was only just possible to bend such an acute angle without the bending machine hitting its stops.

When the sections were removed from the bending machine they were of narrower pitch at the ends than in the middle. They were corrected by hand and ruler.

It was not possible in the department to bend channels of the required length, so they were bent in sections and welded together. The joints were staggered to avoid creating weak points (see drawing 1). If more walkways were to be built, it would be worth considering contracting out the channel fabrication to a firm with an 8 feet long bending machine.

The calculated mass per unit area of the section (assumed in the height iteration to be 12.5kg/m$^2$) is 17.7 kg/m$^3$. This was not expected to lower the fundamental resonant frequency to below 50Hz.

2.3.3.8 Adhesive

It was necessary to use a thixotropic (enabling it to stay in the joint while curing). It also need to be less brittle adhesive than the Araldite 2005
and to have improved adhesion properties. On the recommendation of an adhesives expert (Richardson, 1991) and the manufacturers, Permabond Vox 501 was used. The glue was a two part toughened vinyl oxirane adhesive. This glue is very flexible. It has a six month shelf life. It was kept in the refrigerator to increase shelf life and working time. It was supplied in 825ml canisters. The canisters fitted into a pneumatic glue gun. The two components were pumped through a disposable nozzle in which they mixed, directly onto the workpiece.

The manufacturers recommended a 3mm diameter bead. The total length of bead required for each platform is approximately 17 x 1.20m x 2 = 40.6m, so the volume of glue estimated to be needed for both platforms was 2 x 40.63m x pi x (3e-3)^2 / 4 = 5.7e-4m^3

= 5.7e-4 x (1e3) litres

=0.57l

When the previous prototype plates were repaired, it was found that 3 times the calculated amount of adhesive was used. The glue was sold in multiples of 1650ml. Four 825ml canisters were ordered, and all of it (5.8 times the calculated amount) was used. If several platforms were to be built, the overuse of glue could be reduced.

The manufacturers recommended that surfaces to be glued were prepared by abrasion, cleaning with solvent and re-abrading.

Permabond were unable to give a precise figure for the operational lifespan of Vox 501, but said that it is long; there are some structures which date from 8 years ago when it was developed and some 20-year-old ones using similar chemistry (Kemp, 1993).
2.3.3.9 Edging

It was decided to edge the honeycomb top sheet in order to protect its edges during use and to cover rough edges for safety during manufacture and installation. See 'Assembly', section 2.3.3.14 below.

End plates were stuck to the channel sections in order to cover sharp edges for safety during installation. These were to be light and the loads were to be small, so they were made from SWG 20 (0.5mm thick) NS4 grade aluminium sheet.

2.3.3.10 Positions of Transducers

It was found (Barrance, 1989) that the positions of the transducers on the prototype built by Jones (1988) were of the order of 10mm different from those described by him. It was decided to design the new top plates to have the distances between the transducer positions described by Jones. These were appropriate and allowed the fundamental resonance frequency of the new top plates to be estimated using the experimental value for Jones' top plates.

2.3.3.11 Transducer housings

An unsupported 120mm x 150mm corner of the same honeycomb material was acceptable according to Gareth Jones's calculations, and has proved acceptable in use, so it has been decided that this will be used, and that there is no need to reinforce the transducer housings further.

The previous design had the defect that there was inadequate clearance for rotating the transducers. A 60mm radius is required for this, so was used. The unsupported area of honeycomb top sheet was not to be significantly greater than before.
Each transducer had an M10 female thread at the top and the bottom, through which the load was to be applied. Transducer mounting discs which could be stuck onto the undersurface of the top sheet and onto which the transducers could be screwed were to be made. The discs can be seen in figure 2.6 and drawing 9. There were three anticipated failure modes for these: failure of the screw thread in tension, failure of the glue and failure of the lower skin of the honeycomb in shear.

Failure of the screw thread in tension:

Yield strength for mild steel = 220MNm^{-2} (Tennent, 1979)

Cross-sectional area of M10 thread = \pi x (8mm)^2/4 = 5.0 \times 10^{-5} m^2

So the yield strength is stress x area = 220MNm^{-2} \times 5.0 \times 10^{-5} m^2

= 11 kN

= 1.1 \times 10^3 kgf, and the maximum force expected due to walking is around 70kgf x 2 x 1.5 = 0.21 \times 10^3 kgf, so the safety factor is 1.1/0.21 = 5.2 which is acceptable.

Failure of the glue depends on the area of the glue, the strength and adhesive qualities of the glue and the presence of stress concentrations. The area of the glue was set to be at least that of the discs used by Jones (1988). The next size of material available in the department was 75mm diameter so this was used. The strength and adhesive qualities of the glue were improved by using Vox 501 rather than Araldite 2005: Permabond give a typical shear strength for the glue of 20-25MPa. Over an area of \pi x (75mm)^2/4 = 4.42 \times 10^{-3} m^2, this gives a shear strength of 20MPa x 4.42 \times 10^{-3} m^2 = 88.4 kN = 9011 kgf. From the fixings section, for a 70kgf male running, the estimated maximum resultant force is 47kgf, so the safety factor for shear failure for a 70kgf male running is 9011 kgf/47kgf = 192 which is more than adequate.
The circular shape was retained because it minimised stress concentrations.

For failure of the lower skin of the honeycomb in shear, assume that the honeycomb core takes none of the load.

The failure area is $0.55\text{mm} \times \pi \times (75\text{mm}) = 130 \times 10^{-6}\text{m}^2$.

Yield strength = $200\text{MNm}^{-2}$ (Ciba Geigy, 1986) and shear strength = $\frac{\text{yield strength}}{3^{0.5}}$ (Cambridge University Engineering Department, 1984, from the Von Mises criterion) = $115\text{MNm}^{-2}$.

So the yield force = $130 \times 10^{-6}\text{m}^2 \times 115\text{MNm}^{-2} = 14.9\text{kN} = 1520\text{kgf}$, so the design factor for a 300kgf load is $1520\text{kgf}/300\text{kgf} = 5.0$ which is acceptable.

The discs were machined from solid material for strength.

2.3.3.13 Damping

No mechanical damping was added to the plates. Because of this, signals at the resonance frequency had to be removed by electronic low-pass filtering, and the walkway emits a slight metallic ringing sound when walked on. The possibility of damping the walkway by filling it with foam could be explored. Possibly this would not add greatly to the weight, and thus not greatly decrease the fundamental resonant frequency of the structure, but reduce the complexity and hence cost of electrical filtering needed and reduce the amount of sound emitted, thus making the subject less aware of the change in surface as they walked over the platform.

2.3.3.14 Assembly

The edging was applied to the edges of the honeycomb. At first, aluminium U-shaped channel $5/8'' \times 5/8'' \times 1/16''$ (15.9mm x 15.9mm x 1.6mm) was used, as described by Jones (1988). It was then decided that the
lip thus created was unacceptable, so this edging was removed and replaced with 5/8" x 5/8" x 1/8" aluminium angle. See figure 2.5.

![honeycomb honeycomb u-shaped channel angle](image)

figure 2.5

This was glued in place. Low loading was expected so Araldite 2005 which was much cheaper than Permabond 501 was used. Less than one 0.5kg pack was needed.

The positions for the transducer mounting plates were marked out. Surfaces to be glued were degreased with Inhibisol solvent, abraded and degreased again as recommended by Permabond. Degreasing first means that impurities are not rubbed into the surface. Permabond Vox 501 was mixed by hand because only a small quantity was required. The plates were glued into position.

The V-shaped channels were joined together end-to-end to the correct lengths. Glueing the channels together proved impractical because the working time of the glue is short and many clamps are needed, so they were welded together. The technician had feared that welding such thin aluminium would distort its shape but a trial attempt showed that there was no problem. Now the walkway was ready for the bulk of the glueing.

The technicians familiarised themselves with the assembly and marked out the glue lines. Surfaces to be glued were degreased, abraded and degreased again. The glue gun was connected to the compressed air supply
and loaded with a glue cartridge and nozzle. The end two rings were cut off the nozzle to set the correct hole size.

The glue was applied to the glue lines on the honeycomb top sheet (figure 2.6).

A close eye was kept on the time since the glue had been applied and on the glue remaining in the gun. Each pause of five minutes meant that glue
would cure in the nozzle and be wasted. The channel sections were positioned (figures 2.7 and 2.8).
figure 2.8
They were then weighted and left to cure (figure 2.9).

Figure 2.10 shows the assembly after curing of the glue.
The lines for the glue were marked out onto the bottom sheet. Glue was then applied to the bottom sheet. It was then lowered onto the assembly and checked for position (figure 2.11).

The assembly was weighted and left to cure.

Using adhesive mixed by hand, end plates were attached to the exposed ends of the channel sections (figures 2.12 and 2.13).
Permabond recommended that the walkway should not be used for a week because the open nature of the joints would make curing slow.

The upper surface was primed, then painted with grey non-slip Courtaulds International's Garage Floor Paint.

2.3.3.15 Evaluation

The plates were weighed (Pourbiazar, 1991). The weight was 35kgf each.

For Jones's walkway, \((EI/m)_1 = 7320.2m^4s^{-2}\) (calculated) and the deflection was 3.5mm per 70kgf (from section 2.3.2 above). For the new walkway, \((EI/m)_2 = 25735m^4s^{-2}\) (calculated). The mass ratio \(m_2/m_1 = 35/10 = 3.5\) (measured). Therefore the stiffness ratio \((EI)_2/(EI)_1 = (25735/7320.2) \times 3.5 = 12\). This means that the expected deflection for the new walkway for
the 70kgf static load at the midpoint is $3.5\text{mm}/12 = 0.28\text{mm}$. The deflection of the plate was visible to the naked eye but it felt firm to walk on.

It rings slightly when walked on, so one can hear that it is a metal surface.

The assembled system was subjected to an impulsive load on the top surface. By Fourier analysis of the output of an accelerometer (see Barrance, 1989, for method) the fundamental resonant frequency was found to be 68-70Hz, which is better than the required minimum value of 50Hz and better than the value for the Olsson walkway (Olsson et al, 1986).

2.4 Transducers
2.4.1 Introduction

Ideally, all three force components should be measured, but a device measuring only the vertical force was expected to be cheaper and therefore possibly more widely applicable than one which measured all 3 components.

Each transducer was to be suitable for use in both tension and compression, and to be mechanically safe between 3000N (300kgf) compression and 3000N (300kgf) tension. Usage was to be indoors at room temperature.

As stated above, accuracy in the determination of position of a 35kgf (half of a typical body weight) force of +/-10mm was desired (Barrance, 1989). Because of the way the position of the force is calculated, this implies a required accuracy in the determination of the force on each transducer of $((10\text{mm}/2202\text{mm})/5) \times $ applied load = 0.1% of the applied load when the load $=35\text{kgf}$. 
2.4.2 Choice of Transducers

Different transducers were surveyed and tested. The details are given in Appendix 2.5. The +/-300kgf range Novatech F241 was retained. Three further transducers were purchased.

2.5 Amplification and filtering

2.5.1 Evaluation of the existing signal conditioner

A signal conditioner had been built (Barrance, 1989), around a basic amplification and filtering circuit (Jones, 1988). It energised the transducers, amplified the voltages to the range -5 to +5 V and low-pass filtered them with 100Hz cutoff frequency. It had only 3 channels, when 6 were needed, and a cut-off frequency of 100Hz, when 30Hz was needed, so it was necessary to replace it. Thirty Hz was chosen in order to attenuate the noise due to the vibration of the top plates (fundamental frequency 68-70Hz) while causing minimal distortion to the signals of walking gait.

2.5.2 Specification for new gait analysis signal conditioner

2.5.2.1 Introduction

The signal conditioner was required to supply power to the six transducers and amplify and low-pass filter the six output voltages prior to digitisation.

It was to work safely from a 240V, 50Hz mains supply. The device was to be used for approximately 2 afternoons per week. It was to have a working life of five years. It was to be in a conducting, earthed, metal case in order to shield out noise. The device was to be for indoor use at room temperature.

The warm-up time was to be not more than five minutes.
2.5.2.2 Power Supply to Transducers

The power supply to the transducers was to be 10V DC, capable of supplying at least 156mA (26mA per transducer).

2.5.2.3 Gain and offset

There were to be six nominally identical channels.

The DC gain was to be 200 and the output voltage was to be able to be set to be -2.5V when the walkway was unloaded (to give 3 times as much range in compression as in tension) because this was the approximate expected loading.

The force error generated by each channel of the signal conditioner (including error due to the power supply to the transducers) was to be less than 0.03kgf. The range of the output was to be -5 to +5V, representing a range of around -75kgf to +225kgf, so 0.03kgf was to be represented by \((0.03 \times 10 / 300)\)V = 1mV at the output.

The equipment was to be recalibrated for zero reading before every experimental run, so long term zero drift was not expected to be important.

2.5.2.4 Frequency response

The filter was to have a cutoff frequency of 30Hz. The gain at 68-70Hz (the experimentally determined fundamental resonant frequency) was to be less than 0.01 (determined by preliminary work investigating the amount of vibration noise caused by walking) of the gain at DC. A six-pole Butterworth filter was the expected solution. The Butterworth type was chosen for its high passband flatness and compromise properties between Chebyshev which gives good passband-to-stopband transition but poor phase shift characteristics and Bessel which has virtually constant time delay but poor passband to stopband transition.
The gain, $H(jw)$, at frequency $w$ of a Butterworth filter whose cutoff frequency is $W$, is

$$
H(jw) = \frac{1}{(1+(w/W)^2n)^{0.5}}
$$

Let $W = 30$Hz and $n = 6$. Then at 25Hz, the maximum frequency component of pathological gait,

$$
H(jw) = \frac{1}{(1+(25/30)^{12})^{0.5}} = 0.95 \text{ i.e. close to 1 as required.}
$$

Also, tan(phase lag(jw)) = $\frac{(w)^n}{(W)^n}$ $\frac{(25)^6}{(30)^6}$ = 0.33 so phase lag = 19 degrees.

while at 70Hz,

$$
H(jw) = \frac{1}{(1+(70/30)^{12})^{0.5}} = 0.0062 \text{ which is less than 0.01 as required.}
$$

2.5.2.5 Noise

Noise on the outputs was to be less than 1mV peak-to-peak per channel = 0.03kgf peak-to-peak/channel = 0.1kgf peak-to-peak/walkway.
2.5.3 Sourcing of signal conditioner

It was decided to purchase a commercial signal conditioner. Various companies were surveyed.

Only two companies, CIL Ltd and Fylde Electronic Laboratories Ltd, had anything suitable. CIL's system was cheaper so it was purchased.

The unit consisted of a 19" Eurorack containing a power supply and six instrumentation units. The power supply block was an 'Alpha-P' block (trade name). Three of the instrumentation units were standard 'Alpha-B' blocks (trade name), each with two channel amplification and filtering and voltage supply for two transducers. The amplification incorporated variable gain. The filtering was 2-pole low-pass with variable cutoff frequency. The voltage supply for the transducers was adjustable. Their temperature coefficient of gain was less than 0.015%/degree C (manufacturers' specification). The other three units were custom 2 channel 4-pole 30Hz cutoff Butterworth low-pass filter units with a gain of 2. No information was available as to their temperature coefficient of gain.

The unit's adjustable gain would perhaps be useful for child subjects. Only the gain setting of 200 has been calibrated at present. The prices are shown in the costing section below. VAT, carriage and packaging were extra. The device was warranted for a year.

2.5.4 Commissioning of signal conditioner

For reasons of safety and tidiness it would have been preferable to situate the signal conditioner in the security cabinet with the computer. However, this would have meant that the small signals from the transducers would have been transmitted along a 25-foot cable before being amplified, which was undesirable from the point of view of noise. It was therefore decided that the signal conditioner should be situated on the floor next to the platforms (see figure 2.1 above).
The cabling is sketched in figure 2.14.

Each transducer was supplied by the manufacturer with 2m four-core screened cable. This length was sufficient to connect to the signal...
conditioner when placed next to the platforms. The six Lemo connectors supplied were connected to the transducer leads.

Six short BNC-BNC cables were made and used to connect the output of each Alpha-B block channel to the input of the corresponding filter unit channel (see figure 2.15 below). The bridge voltage supply on each Alpha-B block channel was set up to be 10V when not loaded. The gain of each Alpha-B block channel was set to be 200. The unit was installed in a case. Six seven-metre BNC-BNC cables were made to connect the signal conditioner which was next to the walkway to the junction box which was next to the computer. A junction box was made, incorporating the termination panel bought with the data acquisition card (Burr-Brown PCI 20024T-1) (see below). The signals entered the junction box through 6 BNC connectors and left through the cable supplied with the data acquisition card. The holes made in the junction box are shown in drawings 15 and 16 in Appendix 2.4.

A 25 feet long mains cable was made up so that the signal conditioner could be powered from the security cabinet housing the computer.

Figure 2.15 shows the signal conditioner.
2.6 Signal capture hardware

2.6.1 Introduction

In previous work (Barrance, 1989), analogue signals had been fed through a CED1401 intelligent interface (Cambridge Electronic Design, 1987), where they were digitised, into the computer.

The CED1401 intelligent interface was replaced with a data acquisition card which was cheaper, if less versatile, so that the CED1401 could be released for other projects.

2.6.2 Specification for data acquisition card and accompanying software

The equipment was to be IBM compatible, to digitise six analogue voltage channels in the range +/-5V, simultaneously or virtually simultaneously, at at least 100 samples per second, with at least 12-bit
accuracy. One hundred Hz is a suitable sampling rate because it is more than twice the maximum signal frequency (2 x 30Hz = 60Hz), thus preventing aliasing. The gain of each channel is approximately 30kgf/V, so the 10V range and 12-bit accuracy means that 1 bit was to represent

\[ \frac{10V \times 30\text{kgf/V}}{2^{12}} = 0.073\text{kgf}. \]

Quantisation errors are up to +/- 0.5 bit = 0.036kgf. For a 35kgf mass, this is +/- (0.036/35) x 100% = 0.10%. Maximum errors in the x-direction due to quantisation error will therefore be +/- 5 x 0.10% x 2202mm = +/-12mm which is acceptable. Higher accuracy A-D cards are more expensive.

It was to be possible to store at least 20 seconds' worth of data in each experimental run (enough time to record a pathological subject walking the length of the platforms). (2.44m in 20s is 0.40km/hour, compared with normal walking speed which is of the order of 5km/hour.)

2.6.3 Choice of data capture hardware

A number of companies were surveyed in order to select the cheapest suitable hardware and accompanying software. Two systems seemed suitable. They are detailed in Appendix 2.6. The second system was fast enough to allow for anticipated expansion of the system. This hardware and accompanying software was purchased.

2.7 Software

2.7.1 Introduction

Software was needed for calibration of the assembled system and for use with human subjects. The existing program (Barrance, 1989) was crude and was not compatible with the new data acquisition card.
2.7.2 Literature review

Features mentioned in the literature as desirable are:

1. ease of use (Betts et al., 1980)
2. testing time minimised (Davis, 1988)
3. data reduction processes efficient so as to allow the verification of data before the patient leaves the laboratory (Davis, 1988)
4. the 'information' presented to the clinician must be in a form that is useful; more emphasis must be placed on the form and method of data presentation, assisting the clinicians to make subjective decisions about a particular patient's gait (Davis, 1988; Messenger and Bowker, 1987; Betts et al., 1980)

Possible ways of processing the data (Seliktar and Mizrahi, 1984) include selection of specific quantitative values, e.g. peak forces, processing of data by integration and comparison of data: symmetry measurements, with respect to normal gait, with other patients classified in the same way, or with self at different times.

Grieve (1980) comments that 'it seems fairly ridiculous that a clinician should replace the subjective assessment of the patient after direct observation with the subjective assessment of a record of that individual.' There is some truth in this, but the display of the measurement may mean that the clinician can assess a quantity which he could not visually observe adequately, so that it does actually give valuable information to aid decisions. This can be considered as an argument for the application of artificial intelligence techniques, such as that described by Tracy et al (1979). They developed a computer program to help diagnose orthopaedic gait disorders. Results of the project indicated that gait analysis does lend itself to diagnosis by computer.
2.7.3 Choice of approach

It was decided to write software rather than buying a commercial package, since a commercial package was not found which would calculate the desired parameters of gait. Funds available were very limited, so it was not possible to use a high level data acquisition and analysis program such as Lab Windows or Lab View.

The calibration software was written in such a way that it could form the basis of the clinical software.

2.7.4 Algorithms

The vertical force and coordinates and centre of pressure are computed by resolving vertically and taking moments, neglecting the inertia of the platform. Figure 2.16 shows the symbols used.

\[a = \text{half distance between transducers 1 and 2 (}=1.101\text{m})\]

\[b = \text{half lateral distance between transducers 1 and 3 (}=0.230\text{m})\]

\[d = \text{lateral distance between transducer and edge of platform (}=0.078\text{m})\]

\[e = \text{anteroposterior distance between transducer and edge of platform (}=0.121\text{m})\]

\[g = \text{gap between platforms (}=0.003\text{m})\]

figure 2.16
The equations (used in the procedure 'calculate Fxy') are listed below.

\[ \text{platform1 force} = F1 + F2 + F3 \]
\[ \text{platform2 force} = F4 + F5 + F6 \]

If the force on a platform does not exceed a threshold value, the coordinates of the centre of pressure are not calculated but set to -1. Otherwise,

\[ x_{\text{platform1}} = a \frac{(2F2 + F3)}{\text{platform1 force}} \]
\[ y_{\text{platform1}} = 2b x \frac{F3}{\text{platform1 force}} \]
\[ x_{\text{platform2}} = a \frac{(2F6 + F4)}{\text{platform2 force}} \]
\[ y_{\text{platform1}} = -(d + g + b) - 2b x \frac{F4}{\text{platform2 force}}. \]

2.7.5 Software for calibration

This software was to be used only by the author, so user-friendliness was not emphasised. Three versions were written: 'force' for force calibration, 'posit' for positional calibration and 'dyn' for dynamic calibration. A program 'convert2' was written to convert data from the force plate at the West London Institute of Higher Education.

2.7.6 Software for use with human subjects

This software was aiming towards use by people other than the author so an attempt was made to make it more user-friendly. 'uosgws5' (University of Surrey Gait Walkway System, program version 5) was written.

The program was written to display parameters of gait which appeared appropriate to assessment in the routine clinical context. These were force versus time curves, x-y plots of the centre of pressure, a graph combining these two graphs, temporal-distance factors, vertical force peaks and their timings, and vertical impulses (see section 2.7.12.2 below
for details). This was chosen as a mixture of graphical information for subjective comparison, and numerical data for objective comparison.

2.7.7 Commercial software used

2.7.7.1 Turbo Pascal Version 5.0B (Borland International)

This was the programming environment used, which was available in the department and with which the author was familiar and which offered a user-friendly programming environment. According to the Borland Turbo Pascal 5.0 manual, compiled programs containing code may be sold without paying royalties, but one must not sell programs containing any of the source code. This is relevant with respect to possible future commercial exploitation of the system.

2.7.7.2 Turbo Pascal Graphix Toolbox version 4.0 (Borland International)

This enabled graphics to be produced using Turbo Pascal.

2.7.7.3 Turbo Pascal Database Toolbox version 4.0 (Borland International)

This enabled a database to be produced using Turbo Pascal.

2.7.7.4 PCI-20026S-3 Modular Software Drivers for Turbo Pascal, version 1.1 (Industrial Data Processing Ltd)

This enabled the data acquisition card to be run from Turbo Pascal.
2.7.7.5 PCI-20074S-1 SYSCHK System Assurance Utilities
Software Package Version 2.10 (Industrial Data Processing Ltd)

This is a menu-driven system verification software package for the PCI-20000 product line. It tests the functioning of the data acquisition card.

2.7.8 Force calibration program 'Force'

2.7.8.1 Introduction

This program was for use during calibration of the walkway with static loads. Weights were applied to the walkway in various positions. For each loading condition, a key was pressed and the indicated values of force and position were read from the screen and written down.

2.7.8.2 Flowchart

Appendix 2.7 contains the flowchart for programs 'force', 'posit' and 'dyn'.

2.7.8.3 Program structure

Forcetyp.typ: contains the definitions of the data record and key by which they are indexed.

Forcea.pas: contains the definitions of the global variables, and levels 6, 5 and 4 of the program.

Forceb.pas: contains levels 3, 2 and 1 of the program.

2.7.9 Position calibration program 'Posit'

2.7.9.1 Introduction

This program was for use during calibration of the walkway with static loads at different positions. The accuracy of position data depends on the instantaneous total force measured by the platform (Barrance, 1989).
Loads were applied to the walkway in various positions through the end of a wooden pole, in order to determine the accuracy of the determination of position for loads just above 20kgf. For each loading condition, the sampling proceeded at a constant rate until the loading exceeded 25kgf on one platform. At this point the computer emitted a beep and the load was removed. Several points were loaded during each experimental run. The beeping delayed the sampling so that only approximately 1-5 readings were recorded for each position. After the experimental run, the readings for loads greater than 20kgf were displayed on the screen and written down.

The flowchart of this program is the same as that for the program 'force'.

2.7.9.2 Program structure
Posityp.typ: contains the definitions of the data record and key by which they are indexed.
Posita.pas: contains the definitions of the global variables, and levels 6, 5 and 4 of the program.
Positb.pas: contains levels 3, 2 and 1 of the program.

2.7.10 Dynamic calibration program 'Dyn'
2.7.10.1 Introduction

This program was for use during calibration of the walkway with dynamic loads at different positions. Loads were applied to the walkway in various positions by dropping an object onto it, and the response was measured. One position was used during each experimental run. After the experimental run, the readings for loads greater than 20kgf were displayed on the screen and written down, as were various parameters of each impact.
The flowchart of this program is the same as that for the program 'force'.

2.7.10.2 Program structure
Dyn.typ: contains the definitions of the data record and key by which they are indexed.
Dyna.pas: contains the definitions of the global variables, and levels 6, 5 and 4 of the program.
Dynb.pas: contains levels 3, 2 and 1 of the program.

2.7.11 Conversion programs 'Convert2' and 'UOSGWS4'.
2.7.11.1 Introduction
These programs were written to convert data from the Kistler force plate at the West London Institute of Higher Education into a form suitable for comparison with data gathered at the University of Surrey (used in section 3.3.4). Convert2 converted the raw data points from the West London Institute of Higher Education into F, x and y values. UOSGWS4 processed these values into gait variables.

2.7.11.2 Program 'Convert2'
Flowchart
See Appendix 2.8.

Program structure
Convert2.pas contains the entire program (levels 3, 2 and 1).

2.7.11.3 Program UOSGWS4
This was an adapted earlier version of UOSGWS5.
2.7.12 Program for use with volunteers

2.7.12.1 Introduction

A program, 'uosgws5', was written. This program aims towards use for gait assessment in the routine clinical context.

The program is structured, the variable names and procedure names are explicit and the program is written in a modern, user-friendly language. These factors will facilitate further development of the software.

When the program is invoked, the user is presented with a menu screen (Jeffery, 1992) from which he may choose one of several options concerned with accessing MS-DOS functions, recalling existing walkway data, recording new data and outputting the data. The options are:

'DOS command' (Jeffery, 1992),
'find extant record',
'record new data abbreviated display', 'record new data detailed display'
'display on screen', 'make excel file', 'print data', 'make print file'.

2.7.12.2 Description of menu options

'DOS command'

This option allows the user to execute MS-DOS commands without leaving the menu program (Jeffery, 1992).

'find extant record'

This option offers the user the option of seeing a list of the existing records, then enables him to choose a record for display. The user is then returned to the menu screen where the selected record name is now displayed.
It was decided not to store patient details such as height, age, dominance in the computer because this was not found convenient for research purposes. It would perhaps be appropriate to store this data in the computer in the routine clinical context.

The operator inputs the number of trials to be performed with the same sampling rate. He is then given the option of increasing the sampling time from 5s (sampling at 400Hz per channel) to 20s (sampling at 100Hz per channel). This is appropriate for slower walking. For each trial, the voltage of each channel when the walkway is unloaded is then recorded. If any of the voltages are outside the expected range, an error message is displayed. The subject's weight and distribution of the weight between right and left feet in standing are measured. The operator asks the subject to walk. As the subject is about to step onto the platform, the operator presses a key to start the test. Sampling takes place. The sampling time is measured, and if it falls outside a threshold band (+/-5%) an error message is displayed. Next, the data is processed and displayed on the screen in an abbreviated form: the forces are displayed versus time, the x-y plots of the centre of pressure are displayed and the error codes are displayed. This allows obviously anomalous trials to be identified.

The error codes are:

'anyerrormessages', assigned as true if there are any errors,

'lowforcesteps', assigned as true if any of the steps do not exceed a certain force threshold (20kgf). This is usually because the subject's foot was partially off one end of the walkway.

'toomanysteps', assigned as true if there are too many steps for the program to analyse.
'stepsnearend', assigned as true if any of the points are within a threshold distance (120mm) of the ends of the walkway. This implies that the foot may have been partially off the end of the walkway.

'negativedoublestancetimes' is assigned as true if any of the calculated double stance times (when both feet are in contact with the floor) are negative. These times should always be positive in walking.

'highlyunequalnumbersofsteps' is assigned as true if after the elimination of any invalid steps (first or last steps on each platform which do not exceed the force threshold or are too close to the ends of the walkway), the numbers of steps on each platform differ by more than one. This implies that the steps cannot have been alternate.

'crossover' is assigned as true if the distance travelled on one foot exceeds a threshold (0.5m). Long apparent distances travelled on one foot are characteristic of results corrupted by the subject's foot crossing over onto the opposite platform.

'outoftime' is assigned as true if the load exceeds a threshold at the beginning or end of the trial. This usually means that the subject was on the walkway at the beginning or end of the trial.

The operator then chooses whether to store or reject the trial. If he chooses to store it he gives the trial a name/number, it is stored and the program proceeds to the next trial. Otherwise the program restarts the trial. After each trial, a message 'Number of trials recorded so far = ... of ...' is displayed. When all trials are complete, the user is returned to the menu screen.

'record new data detailed display'

This option is the same as the previous option except that a full display is offered. It is expected that this will be helpful to inexperienced users.
It is possible for the user to step forwards and backwards within the display by pressing 'n' for next or 'p' for previous. When he has finished looking at the display, he presses 'q' for quit and proceeds.

The full display consists of:
1 heading
2 name of record
3 graph of vertical force on each platform versus time
4 x-y plot of centre of pressure on each platform.
5 isometric plot combining the information of the two previous graphs, showing, for each reading in which the force exceeded a certain threshold (20kgf), a vector showing the magnitude of the force plotted at its correct position on the walkway. Khodadadeh (1988) describes 'a simple three-dimensional vector diagram display combining all the force components of gait in one diagram'. It illustrates the locus of the centre of pressure on a diagram of the force plate. From each point on the locus, the corresponding three-dimensional force vector was drawn. It was stated that in the case of some pathological gaits, the lateral displacement can be substantial. The traditional two-dimensional diagram does not show all these effects. Unfortunately, it is not possible unambiguously to show all the three dimensional data on one diagram. However, the Surrey walkway records only vertical force and centre of pressure, so this method of display could be used.
6 error messages
7 the subject's weight
8 the test date and time
9 force plate data:
the number of channels (at present, 6),
the nominal and measured sampling rate per channel,
the sampling time,
the number of readings per channel (at present, 2000),
the output of each channel for zero load.

10 the average vertical load on each of the subject's feet in standing
11 the temporal-distance factors of gait:
   • which platform the first step was on,
   • total stance times (duration of each footfall; time during which the
     force exceeds the lower force threshold (4kgf). It was necessary to set the
     force threshold as high as this because subject 28, one of the amputees,
     scuffed his feet with maximum forces of up to 3.3kgf. In future it might be
     more appropriate to reject scuffs according to a time threshold.),
   • double stance times (time during which both feet were in contact
     with the ground; time during which the force exceeds the lower force
     threshold for both feet)
   • stride times (time from beginning of one step to beginning of next
     step of the same foot)
   • which platform the left foot was on,
   • the first and last calculated positions of the centre of pressure for
     each footfall,
   • the average calculated position of the centre of pressure for each
     footfall (x and y are only calculated when the force exceeds the upper
     threshold),
   • step lengths: the absolute value of (the average calculated x co-
     ordinate of the centre of pressure for the footfall, minus that for the
     previous footfall on the opposite platform),
   • step widths: the absolute value of (the average calculated y co-
     ordinate of the centre of pressure for the footfall, minus that for the
     previous footfall on the opposite platform),
• stride lengths (the average calculated x co-ordinate of the centre of pressure for the footfall, minus that for the previous footfall on the same platform),
  • velocities according to each platform (the sum of the stride lengths divided by the sum of the stride times)
  • velocity (velocity calculated from platform 1 if only this could be calculated, velocity calculated from platform 2 if only this could be calculated, average of the two if both could be calculated)

12 the peak vertical forces of each footfall and their timings as a percentage of the stance phase:
  • greatest vertical force in the first half of the footfall and its timing,
  • greatest vertical force in the second half of the footfall and its timing,
  • smallest force between these maxima and its timing.

13 the vertical impulse (integral of force with respect to time) of each footfall.

'display on screen'

The user is offered a full display as described above. It is possible for the user to step forwards and backwards within the display by pressing 'n' for next or 'p' for previous. He presses 'q' for quit in order to return to the menu screen.

'make excel file'

This option is used to output data from a previously selected record to a file suitable for importing to a spreadsheet program for further processing. When the user invokes the option, the data is recalled and processed. So that all trials are comparable, trials in which the subject
walked in the direction of decreasing \( x \) are rotated 180 degrees and reprocessed. A file for the data is opened if it exists or created if it does not exist. The data is output, separated by commas. The file is closed and the user is returned to the menu screen.

'\texttt{print data}''

This option is used to print out a full display of a trial. A sample display is shown in Appendix 2.9.

'make print file''

This option is used to create a file of the output of a trial which can be printed out later from DOS.

2.7.12.3 \textbf{Flowchart}

See Appendix 2.10.

2.7.12.4 \textbf{Program structure}

'uosgws.typ': contains the definitions of the data record and key by which they are indexed.

'uosgws5a.pas': contains the definitions of the global variables, and levels 6, 5 and part of level 4 of the program.

uosgws5b.pas: contains part of level 4 of the program.

uosgws5c.pas: contains part of level 4 of the program.

uosgws5d.pas: contains level 3 of the program.

uosgws5e.pas: contains levels 2, 1 and 0 of the program.

batch file 'go': invokes the data acquisition card software pci26s_t, invokes the menu program 'gws' (Jeffery, 1992) and when 'gws' terminates, terminates the data acquisition card software pci26s_t.
batch file init.bat': invokes the program 'uosgws5' with the command line parameter 'INIT'. Invoked by 'gws' when 'gws' initialises.

'dos.pro' (Jeffery, 1992): enables the user to execute DOS commands. Invoked by 'gws' when the user selects 'DOS command'.

batch file 'fer.bat': invokes the program 'uosgws5' with the command line parameter 'FER'. Invoked by 'gws' when the user selects 'find extant record'.

batch file 'rndad.bat': invokes the program 'uosgws5' with the command line parameter 'RNDAD'. Invoked by 'gws' when the user selects 'record new data abbreviated display'.

batch file 'rnddd.bat': invokes the program 'uosgws5' with the command line parameter 'RNDDD'. Invoked by 'gws' when the user selects 'record new data detailed display'.

batch file 'dos.bat': invokes the program 'uosgws5' with the command line parameter 'DOS'. Invoked by 'gws' when the user selects 'display data on screen'.

batch file 'mef.bat': invokes the program 'uosgws5' with the command line parameter 'MEF'. Invoked by 'gws' when the user selects 'make excel file'.

batch file 'pd.bat': invokes the program 'uosgws5' with the command line parameter 'PD'. Invoked by 'gws' when the user selects 'print data'.

batch file 'mpf.bat': invokes the program 'uosgws5' with the command line parameter 'MPF'. Invoked by 'gws' when the user selects 'make print file'.

2.8 Computer

The computer used initially was a Tandon Model TM70C2 IBM compatible 286. During the later stages of the project it became possible to upgrade to an IBM-compatible MESH mini-tower 486-33 giving much increased speed, thus increasing efficiency and decreasing subject fatigue.
2.9 Printer

The printer initially used was an Epson FX-80 (dot matrix). This wore out and during the later stages of the project it became possible to replace it with a Starscript Laser 8 III laser printer. This is much faster and quieter and produces better quality output. At present it is being used in Epson emulation mode with the graphics written for the Epson printer, but the printer has Postscript capability which will allow upgrading of the graphics.

2.10 Installation

2.10.1 Introduction

In order to obtain meaningful results, it was necessary that the gait analysis platforms should be fixed down to the floor.

The floor was a suspended concrete floor, so it was not possible to set the walkway level with it. Instead, the walkway was to be bolted down and a raised wooden surround was to be built around it so that subjects would be walking on a flat horizontal surface.

The raised wooden surround had by this stage already been built, and the site chosen was adjacent to a wall, so access was limited to one side, and the distance between the lower surface of the walkway and the floor was fixed.

The fixings were to be rigid and accurate in dimensions. Accuracy of dimensions was necessary to ensure that the walkway was continuous with the wooden surround so as not to affect gait. Rigidity was necessary so that vibration, particularly low frequency modes, was not encouraged. It was desired to introduce as little as possible prestress into the transducers because it was expected that this would corrupt the readings and/or damage the transducers.
The strength of the supports was to be such as to be safe for normal and pathological walking.

2.10.2 Specification of fixings

Six fixings were required.

The spatial constraints on the fixings are shown in drawing 10 in Appendix 2.4. Each fixing was to be attached to the transducer using an M10, 10mm deep tapped hole in the bottom of the transducer and anchored rigidly to a suspended concrete floor. Sufficient clearance around the fixing was to be allowed for the transducer cables.

The fixings were for indoor use at room temperature.

It was considered unacceptable to make holes in the top surface of the walkway.

The walkway and the floor were flat enough that the fixings did not need to compensate for angular misalignment.

Gait forces are generally smaller along the lateral axis than the antero-posterior axis. In practice the equipment will be subjected to forces due to causes other than normal gait so it is acceptable to design the supports for the same conditions along both axes.

2.10.3 Design

2.10.3.1 Conceptual design

It was decided that there were to be as few loose parts as possible because of the limited access during fixing.

One idea was a collar over opposed screw threads. This would not have been rigid enough.

The use of hydraulics was considered. This would have allowed height adjustment while in place and could then have been locked rigid. I
did not have the expertise to do this and it seemed over-complicated for this prototype.

Because of the need to drill down into the floor, the requirement not to make holes in the top surface and the access restrictions, it was necessary to make each support in two parts, one of which would be bolted down.

It was not possible to obtain adequate accuracy in the manufacture of the platforms and surrounds, and the floor was significantly uneven, so it was necessary to put the walkway in position and measure the final adjustments needed, then complete the installation.

It was not possible to find a feasible way to adjust the heights other than machining the parts down to the correct size as measured in situ.

2.10.3.2 Detail design

The components of one fixing are shown in figure 2.17 and shown assembled in figure 2.18.
The drawings of the fixings are in Appendix 2.4 (drawings 10 - 14).

The fixings were made from mild steel. This is cheap, strong and
tough and has adequate corrosion properties.

**Vertical strength**

The weakest part of the design is the M10 steel screw thread. It is safe
(see calculations for transducer mounting disc in section 2.3.3.12).

**Horizontal strength**

Along the antero-posterior (x) axis and medio-lateral (y) axis, the
fixings need to withstand the forces due to gait. In Nilsson and
Thorstensson (1989), twelve healthy male subjects were studied in walking
and running. x peak forces were up to 0.55 bodyweight in running and y
peak forces were up to 0.38 bodyweight in running. So for a 70kgf person,
the estimated maximum resultant force would be 
\[ 70((0.55)^2+(0.38)^2)^{0.5} \text{kgf} = 47 \text{kgf}. \]
The weakest part of the design is the M10 stud.

Area over which the shear is taken = root area of M10 = 52.3mm\(^2\).

The shear strength is given approximately by the yield
strength/(3\(^{1/2}\) (Cambridge University Engineering Department, 1984,
from the Von Mises criterion) and the yield strength is 220MN/m\(^2\)
(Tennent, 1979).

So the shear strength of the M10 stud is 
\[ 52.3 \text{mm}^2 \times 220 \text{MN/m}^2/(3)^{1/2} \]
\[ = 6.6 \times 10^3 \text{ N} = 6.6 \times 10^3 \text{N/9.81kgf} = 677 \text{kgf}, \]
so the estimated design factor for a 70kgf male running is 
\[ 677 \text{kgf}/47 \text{kgf} = 14. \]
The subjects may weigh more than this but they will not be running. This design factor is
acceptable.
Vertical stiffness

For vertical stiffness, it was necessary to estimate the frequency of the rigid body vertical vibration mode and the static deflection due to the expected loads. The walkway was treated as a mass supported on three vertical springs. To estimate the stiffness of the spring, the stiffnesses of the disc, transducer stem, transducer body and fixing were estimated. The stiffness of the modelled support was estimated as $1.4 \times 10^8 \text{Nm}^{-1}$. Therefore the vertical deflection of the support under a static weight would be $9.81 \text{N}/(1.4 \times 10^8 \text{Nm}^{-1}) = 7 \times 10^{-8} \text{m/kgf}$ which is negligible. For the rigid body mode of vibration, the frequency $f$ is given by

$$f = (3k/m)^{0.5}/(2\pi)$$

where $k = 1.4 \times 10^8 \text{Nm}^{-1}$, $m = 35 \text{kgf}$ (measured),

$$f = 560\text{Hz} >> 71\text{Hz}$$

so this is acceptable.

Horizontal stiffness

Finding the spring constant for shear using the same model as before, the static shear displacement per unit force can be found and the frequency of the vibrational mode in which the top plate behaves as a rigid body and the supports are in shear can be estimated:

For crystalline solids, as a guide, $G$ (the shear modulus) is approximately $3E/8$, where $E$ is the Young's modulus (Cambridge University Engineering Department, 1984). So, adding up the shear displacement per unit force for each component, the shear spring constant $= 6.4 \times 10^8 \text{Nm}^{-1}$. For horizontal force on the walkway, the estimated shear displacement would thus be $(9.81 \text{N/kgf})/6.4 \times 10^8 \text{Nm}^{-1} = 15 \times 10^{-9} \text{m/kgf}$, i.e. negligible.

For the frequency of the vibrational mode in which the top plate behaves as a rigid body and the supports are in shear,

$$f = (3k/m)^{0.5}/(2\pi)$$

as before, where $k = 6.4 \times 10^8 \text{Nm}^{-1}$, $m = 35 \text{kgf}$ (measured),

$$f = 1.2\text{kHz} >> 71\text{Hz}$$

so this is acceptable.
Bending strength

The estimated load in the stud due to a 300kgf force 4 feet from the support is 0.97kN, and the calculated yield load of the stud is 12kN, so there is a design factor of 12kN/0.97kN = 12 which is acceptable. In the thread of the transducer disc the estimated load due to a 300kgf force 4 feet from the support is 4.4kN and the calculated yield load of the thread is 12kN, so there is a design factor of 12kN/4.4kN = 2.7 which is just about acceptable, but is not as much as the 3 which was set as the specification. The transducer mounting discs have been acceptable in use, but it might be wise if duplicating the walkway to make them out of a stronger material (ensuring that it would be suitable for the glue).

Bending stiffness

Estimated maximum bending of the fixing due to a 300kgf force 4 feet from the support is 0.1 degrees which is fine.

The two horizontal bolts

For the horizontal bolts, M8 were the largest that could be used due to the space needed for the box spanner. Stress calculations showed that one was insufficient so two were used.

The Rawlbolts

The floor was a suspended concrete floor, consisting of 1.5-2 inches of screed (weak sand and cement layer) over Bison slabs (prestressed concrete slabs consisting of concrete, steel reinforcing rods and air cavities) (Barret, 1991).

According to Rawlplug Company Limited's Technical Department, it was necessary to bolt 1" into the structural concrete. They recommended using T1040P bolts and drilling a 10mm diameter hole 95mm deep below the
screed layer. T1040L bolts were used instead, due to availability. This made no real difference because it was a floor fixing.

I was unable to find out where the cavities and reinforcing rods were in the Bison slabs, so it was decided to design the fixings with more than enough bolts in case some would not hold.

The concrete was continuous under the wall so there were no problems of edge distance restrictions (distance between bolts and edge of concrete). It was however necessary to allow room for drill access.

2.11 Wooden surround

A space 5.97m (19' 7") was available in which to build the wooden surround. The walkway was 8 feet long. For reasons of ease of construction, it was decided to build an 8 feet long level wooden platform at one end and an 11' 7" level wooden platform at the other end.

Hirokawa (1989) concluded that the two steps from starting and the three steps before stopping should be excluded from ordinary data due to their acceleration and deceleration properties. Mann et al (1979) studied the initiation of gait. It was found that the transition from standing still to steady walking took approximately three steps. For normal subjects, experience has suggested the runup is a little too short, particularly at the 8 feet end. The problem is less severe for more disabled subjects.

A 1 in 12 ramp was built at one end. (Amputees have preferred to step straight up and orthopaedic patients have preferred to use the ramp.)

The height of the wooden surround was to be the depth of the walkway plus enough extra to allow for installation of the walkway. It was to suit standard material sizes. It was 162mm tall. The width of the ramp was the width of the space between the pillar and the wall. The width of the main section of the walkway was that of the walkway (4 feet) plus a margin
along side away from wall of 2 feet for safety reasons and so as not to disturb the subjects' gait.

The basic construction was a sheet of 22mm medium density fibreboard supported by 5.5" x 1" timbers.

It was not to be unduly flexible so that the subjects would be walking normally. For this reason it was reinforced with wooden struts. Polyurethane foam was placed inside it in order to deaden noise.

Ensuring the top surface was flat, sections were bolted together to form two large sections, one for each end of metal walkways, leaving one loose section eight feet by two feet to fit next to the metal walkways.

The linoleum floor was de-waxed where the wooden platforms were to be glued down. The two end sections were glued in place, packed where necessary to achieve levelness.

The top surface was covered with mid-grey linoleum, approximately the same colour as the walkway. Linoleum was chosen rather than paint for its superior appearance and wear properties.

2.12 Installation procedure

The procedure is essentially the same for both platforms. The procedure for the second platform (further from the wall) is described.

The first platform was put in place so that the second platform could be positioned relative to it.

The linoleum where the fixings were to be positioned was sanded down level.

The transducer fixings were attached to platform 2 and Blu-tac was applied to the undersurface of each fixing (figure 2.19).
Two of the transducers had to be transposed because the technician could not tighten one of them with the spanner. The transducer stems were made with only one pair of flats. In the future, one could ask the manufacturers to make the stems with more flats.

Ties were attached to platform 2 (figure 2.20).
Platform 2 was lowered into position (figure 2.21).
Platform 1 was removed (figure 2.22).

The positions of the fixings were marked (figure 2.23).
Platform 2 was removed (figure 2.24).

The Blu-tac was removed, the surfaces were degreased with Inhibisol solvent and the fixings were stuck down with cyano-acrylate adhesive (9 grammes used in total) (figures 2.25 - 2.29).
The positions of all the fixing bases having been established, the two upper components of each fixing were marked, then detached (figures 2.30...
and 2.31) so that the holes could be made for the three bolts to fix them together in the correct orientation.

figure 2.30

figure 2.31
The platforms were now prepared for putting in place so that each fixing could be machined down to the appropriate height. The two upper components were attached by means of the three bolts, and the assembly was attached to the transducer. Earthing plates as described in the electrical safety section below were fitted. Rubber O-rings were placed over the ends of the bolts to hold them in the holes. See figure 2.32.

The platforms were put in position, the height measurements were taken, the fixings were removed and dismantled and the lower end of each upper component was reduced by the required amount.

The base of the fixings for platform 2 now had to be bolted down. The horizontal holes were covered with masking tape against dust (figure 2.33).
Holes were drilled (figure 2.34).
The Rawlbolts were hammered into position (figure 2.35) and tightened to the manufacturers' recommended torque (10Nm = 8.4" x 11lb) (figure 2.36).
The platforms were now prepared for final installation. The fixings were reassembled using the cut down components (figure 2.37).
The connections were made to the earth plates (figure 2.38).
The two safety stops nearest the wall were fixed down with Blu-tac (figure 2.39).

Figure 2.39

The platforms were positioned and bolted down (figures 2.40 - 2.44).
The wooden side platform was packed to height and length and put in place (figure 2.45).
Holes were made for the leads (figure 2.46).

The assembled system is shown in figure 2.47.
2.13 Safety precautions

2.13.1 Safety stops

As a safety precaution, triangular wooden and rubber stops (shown in figure 2.48 and in drawing 17 in Appendix 2.4) were installed under the unsupported corners of the platforms to reduce the amount by which the walkway would tip should one of the support points fail in tension, the most expected mode of failure.

![figure 2.48](image)

(The walkway was of course tested before volunteers were allowed to walk on it.) 25mm thick plywood was used and the thickness was made up to an appropriate value using 6mm thick rubber.

2.13.2 Electrical safety

The equipment was designed to be single fault protected.

The sliding shelves in the computer workstation were earthed.
The manufacturers of the transducers (Novatech, 1991) were asked what protection there was to prevent the transducer casing from becoming live, should any or all of the supply positive, supply negative, output high or output low or screen connections become accidentally connected to the mains 240V AC. They would not guarantee that if one of the transducer bridge supplies became connected to mains voltage, the insulation would not break down, resulting in the body of the transducer becoming live at mains voltage. There is a conductive path from each transducer to the walkway top surface which in turn is in contact with the subject. This means that a single fault situation could result in a hazard, so it was necessary to provide protection. This was done by double-earthing the top panels of the walkway.

Two aluminium earth plates were pop-riveted onto each platform, to the undersurface of the honeycomb (as shown in drawings 19 and 20 in Appendix 2.4). This avoided disrupting the upper surface of the walkway. Sticking them with conducting glue was not feasible. Cables were attached from these to the earth rail of the mains supply. The earth connection cables were protected by trunking; we didn’t want to be relying on the strength of the cable or of soldered connections. This is recommended by the manufacturers of the cable. The cable used was conduit cable 6491B (LSF), 17A rating, catalogue number 363-250 (RS Components). The earth cable was connected directly to the mains earth, not through the earth leakage circuit breaker.

An earth-leakage circuit breaker was used (as shown in the schematic diagram of the system, Appendix 2.1). The circuit breaker is 30ms, 30mA, catalogue number 415-749 (RS Components).

The leads are protected from mechanical damage and the subjects are protected from tripping over them by means of self-adhesive plastic trunking.
Warning notices were installed saying not to touch the system without prior consultation with the operator, only one person at a time on the walkway, no running or jumping, and giving operator details for the referral of any questions.

The equipment was labelled underneath with the following information: Gait Analysis Walkway, designed by Jane Barrance, contact details. Questions should be referred to Jane Barrance. Built by Mechanical Engineering Workshop, University of Surrey.

2.14 Costing

The total materials cost of the system excluding VAT is:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plates</td>
<td>£646.18</td>
</tr>
<tr>
<td>Transducers</td>
<td>£1974.00</td>
</tr>
<tr>
<td>Amplification/filtering</td>
<td>£2397.96</td>
</tr>
<tr>
<td>Signal capture hardware</td>
<td>£840.00</td>
</tr>
<tr>
<td>Software</td>
<td>£175.00</td>
</tr>
<tr>
<td>Fixings</td>
<td>£89.72</td>
</tr>
<tr>
<td>Electrical safety</td>
<td>£115.89</td>
</tr>
<tr>
<td>Safety stops</td>
<td>£20.08</td>
</tr>
<tr>
<td>Wooden surround</td>
<td>£540.00</td>
</tr>
<tr>
<td>Electrical connections</td>
<td>£295.01</td>
</tr>
<tr>
<td>Computer workstation</td>
<td>£499.00</td>
</tr>
<tr>
<td>Computer</td>
<td>£1729.00</td>
</tr>
<tr>
<td>Printer</td>
<td>£1299.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>£10620.84</strong></td>
</tr>
</tbody>
</table>
The time needed for prototype manufacturing and installation is estimated as:

- Plates: 2 man-weeks
- Fixings: 2 man-weeks
- Safety stops: 0.5 man-weeks
- Wooden surround: 1 man-week
- Electrical connections: 0.5 man-week
- Installation: 3 man-weeks
- TOTAL: 9 man-weeks

Counting a man-week as £500, this gives estimated labour costs of 9 x £500 = £4500, so the estimated total of manufacturing plus labour costs is £10620.84 + £4500 = 15120.84, i.e. £15000.

The development cost for the principal researcher was £7000/year for 3 years, i.e. £21 000. A typical overhead is 80%, giving a total of £21 000 x 1.80 = £37 800. Amortised over 10 years, this means = £3780 per year is to be recovered against potential sales. This is not relevant for the prototype which is aimed at fundamental research.

Kistler Instruments Limited's June 1993 price for 1 force platform, type 9281B11 (0.4m x 0.6m) was £10 500. The estimated cost of the Surrey system (plates, transducers, fixings and electrical safety) is £2412.90 per plate (£1412.90 for materials plus £1000 for labour). The cost of producing the Surrey platform is thus reasonable compared with the price of the Kistler platform.
3.1 Calibration with inanimate loads

3.1.1 Testing of signal conditioner

3.1.1.1 Introduction

It was desired to quantify the variation of the gain of the signal conditioner with frequency so as to verify its general behaviour and quantify the variations between the channels.

For each module of each channel in turn, the input was connected to a function generator (HM 8030-3) output and the output was connected to the input of a storage oscilloscope (Hameg 20MHz oscilloscope HM 20S). A sinusoidal signal of known amplitude and known varying frequency was applied (the performance of the signal generator having been checked) and the corresponding output voltage amplitude was recorded.

3.1.1.2 Results and discussion

Gains of Alpha-B block channels

![Graph of gains](image)

**figure 3.1**
The above graph (figure 3.1) shows the general behaviour of the Alpha-B blocks: gain of 200 at DC, 30Hz low-pass cutoff and gain of approximately 20 at 71Hz, i.e. approximately 0.1 of the DC value.

![Relative gains of Alpha-B block channels](image)

The above graph (figure 3.2) clarifies the relative behaviour of the Alpha-B blocks: close agreement of gains at DC, variation of approximately 5% between gains at 10Hz, variation of approximately 25% between gains at 30Hz, and variation of approximately 40% between gains at 100Hz. The estimated error in the determination of the gain values at 10Hz is 0.1%. The agreement of gains in the 0 - 25Hz band, particularly the lower end of it, is most important to the accurate recording of walking signals. This is due to their frequency spectrum (Schneider and Chao, 1983, figure 4). For accurate recording of the x-co-ordinate of the centre of pressure, the agreement of channels 1 and 2 on platform 1 and channels 5 and 6 on platform 2 is most important; transducers 3 and 4 take little of the load due to their positions. From the graph, at 10Hz, channels 1 and 2 are much
better matched than channels 5 and 6. This is consistent with the observed pattern of poorer determination of the x coordinate of the centre of pressure during gait of platform 2 compared with platform 1 (found in preliminary work).

It was decided to check that the origin of the poorer determination of the x coordinate of the centre of pressure during gait of platform 2 compared with platform 1 was electrical rather than mechanical. A normal subject walked along the walkway 10 times at fast speed, then the electronics from the two walkways was swapped over, then she walked along 10 more times at fast speed. The positional results were visually inspected and confirmed that it was the electronics that were to blame. The experiment is described more fully in Appendix 3.1.

Because the determination of position by platform 2 was found to be as poor as it was, it was decided to calculate the step and stride dimensions using the mean position of the footfall rather than the first position. The error was observed to be of one sign at the beginning of the footfall and the opposite sign at the end of the footfall so using the mean value was expected to largely cancel it out. The inaccuracy is such that care must be taken during interpretation of the shape of the x-y trace during an individual footfall. Users of the data must be aware of this characteristic of the prototype so that they do not misinterpret the data.
The above graph (figure 3.3) shows the general behaviour of the filter blocks: gain of 2 at DC, 30Hz low-pass cutoff and gain of approximately 0.05 at 71Hz, i.e. approximately 0.25 of the DC value. This gives a combined response for the two modules of each channel of a gain at DC of $200 \times 2 = 400$, 30Hz low-pass cutoff and gain at 71Hz of approximately $0.1 \times 0.025 = 0.0025$ of the DC value, which meets the specification.
The above graph (figure 3.4) shows the relative behaviour of the filter blocks: close agreement of gains at DC and 10Hz, variation of approximately 70% between gains at 30Hz, and variation of approximately 3% between gains at 100Hz. The estimated error in the determination of the gain values at 10Hz is 0.1%. It appears that the agreement of gains at 10Hz for the filter blocks is better than that for the Alpha-B blocks, so it seems likely that the Alpha-B blocks are predominantly responsible for the poor performance of platform 2 as described above.

If one wished to improve the performance of the system to give a positional error of less than 10mm at 35kgf for gait (as in the desired specification in section 2.2), then as a worst case, one could assume that the gait signals had equal amplitude at all frequencies up to 25Hz and zero amplitude at frequencies above 25Hz. For the static error to be less than 10mm at 35kgf, this implies a required accuracy in the determination of the force on each transducer of 0.1% of 35kgf when the load is 35kgf (from
section 2.4.1). This means that the gains of the electronics of each channel, each normalised by the static gain of the channel, must be within 0.1% of each other at all frequencies up to 25Hz. This is an overestimate because the signal content tails off towards 25Hz so the filter matching need not be as accurate at the upper end of the band. (In order to achieve this level of performance, other improvements would probably be necessary, since this level of accuracy has not been achieved under static conditions.)

3.1.2 Testing of individual channels

3.1.2.1 Introduction

Each channel (transducer plus signal conditioner channel plus junction box plus data acquisition card plus program) was calibrated to find its static gain (change in volts recorded by the computer per change in applied force) so that these values could be used in the computer program. The loads were applied using an Instron model 1250 mechanical testing machine. Although the main loading in use was to be compressive, it was decided to apply the load in tension since there were not mountings available for compressive testing and it was expected that the transducers' behaviour would be linear (terminal nonlinearity = 0.05% rated load according to the manufacturers' data). Two pieces of M10 studding were each tapered at one end to fit the clamps. The length was chosen so that the extensibility of the assembly would be sufficient to allow adequate control of the load. Tapering the studding to 6mm thick at the clamps allowed a safety factor of 3 at 3kN. The other ends were screwed into the transducer. See figure 3.5.
Loads of 0 to 3kN were applied. The test was performed three times per transducer, removing the transducer and reclamping it each time. The force was written down from the Instron screen and the corresponding load was written down from the walkway computer screen, at approximately 0.1kN intervals.
### Results and discussion

#### Summary of data from channel calibration

The above graph (figure 3.6) shows the main features of the data: the channel behaviour is linear with a slope of approximately -3V/kN.

For each channel, a graph was plotted and a least-squares best fit line was fitted to each test. The measured gain values for all the trials are summarised below.

<table>
<thead>
<tr>
<th>Transducer</th>
<th>trial 1 gain (V/kN)</th>
<th>trial 2 gain (V/kN)</th>
<th>trial 3 gain (V/kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-3.3441</td>
<td>-3.3393</td>
<td>-3.3376</td>
</tr>
<tr>
<td>2</td>
<td>-3.4609</td>
<td>-3.4391</td>
<td>-3.4397</td>
</tr>
<tr>
<td>3</td>
<td>-3.4572</td>
<td>-3.4424</td>
<td>-3.4456</td>
</tr>
<tr>
<td>4</td>
<td>-3.5807</td>
<td>-3.5701</td>
<td>-3.5681</td>
</tr>
<tr>
<td>5</td>
<td>-3.4771</td>
<td>-3.4628</td>
<td>-3.4623</td>
</tr>
<tr>
<td>6</td>
<td>-3.5270</td>
<td>-3.4916</td>
<td>-3.4919</td>
</tr>
</tbody>
</table>
This information is illustrated in figure 3.7. Note the false zero.

**Results of calibration of individual channels**

The worst variation between trials was around 1%, for channel 2. This exceeded the specified errors for both the Novatech transducers and the Instron load cell (Novatech, 1989; Instron, 1981). However, when Novatech test their transducers they precondition them first by running them up to full load and back three times. This has the effect of preconditioning the stainless steel of the load cell. Otherwise the errors can be up to 3% (Taylor, 1993). The last value for each channel was converted into kgf/V and used in the software.

### 3.1.3 Testing of the assembled system with static weights
#### 3.1.3.1 Introduction
The walkway was proof-loaded in various positions for safety. Static weights were applied at different positions in order to determine the accuracy of determination of force and position.
3.1.3.2 Method

The walkway was proof loaded up to 220kgf at ten positions, approximately at the four corners and middle of each platform: (0,40), (220, 40), (100, 20), (0,4), (220,4), (0,-20), (220,-20), (100,-40), (0,-58), (220,-58) (points 1 to 10).

The walkway was tested with static weights (25kgf, 50kgf, 75kgf, 100kgf, 125kgf, 150kgf, 125kgf, 100kgf, 75kgf, 50kgf, 25kgf) placed at the positions mentioned above. Each weight was within 0.01% of 25kgf (2.5g) according to the manufacturers, had been used only once previously and appeared undamaged. See figure 3.8.
Nominal weight, nominal position, measured weight and measured position were recorded. For each loading condition, a key was pressed and the indicated values of force and position were read from the screen and written down.

This was done on two successive days, to make sure that the behaviour was consistent with time.
The graph above (figure 3.9) shows the variation of percentage force error with position number. The worst percentage force error is -1.2%. The mean error is -0.2%. The root mean square error is 0.4%.

The main source of error is not known. The maximum quantisation error is +/-3(0.5) bits/platform. 1 bit = 0.073kgf from section 2.6.2, so quantisation error is up to +/-0.11kgf per platform. This is 0.4% of 25kgf, so this source of error is enough to account for around 1/3 of the error seen.

The percentage error seen was greater than hoped for, but was still considered adequate to justify continuing with the walkway. It compares reasonably with Kistler's quoted data for a 9821 force plate: sensitivity variation with force application inside the top plate, under +/-1% and with the values found by Olsson et al (1986): 1% stability, less than 1% deviation from linearity for weights between 5 and 98kgf and less than 1% hysteresis over the same weight range. However, the sensitivity variation for gait forces is unfortunately likely to be greater than this because of the divergence between the gains of the signal conditioner channels for dynamic signals.
Comparison of the two trials' results showed that the behaviour of the system appeared to be acceptably consistent with time.

It was suggested that some of the error might have been due to using the wrong values from the calibration of the separate channels above. If the first value for each channel had been used, the mean channel gain would have changed from 

\[ -(\frac{1000}{9.81})\left(\frac{1}{-3.3376} + \frac{1}{-3.4397} + \frac{1}{-3.4456} + \frac{1}{-3.5681} + \frac{1}{-3.4623} + \frac{1}{-3.4919}\right) / 6 = 29.494 \text{kgf/V} \]

to 

\[ -(\frac{1000}{9.81})\left(\frac{1}{-3.3441} + \frac{1}{-3.4609} + \frac{1}{-3.4572} + \frac{1}{-3.5807} + \frac{1}{-3.4771} + \frac{1}{-3.5270}\right) / 6 = 29.352 \text{kgf/V}. \]

This would have caused the mean error to have been -0.7% instead of -0.2% so it would not have been helpful.

\[ x \text{ error/cm at different applied loads.} \]

![Graph showing x error/cm at different applied loads.](image)

\[ \text{Applied load/kgf} \]

\[ \text{figure 3.10} \]

The above graph (figure 3.10) shows the variation in \( x \) error with applied load. If there is any significant variation of error with position over this range, it is masked by the error in placing the weights, which is estimated as around +/-10mm. The worst recorded apparent error in \( x \) was
-18mm. This indicates that the maximum error in the walkway’s position measurement was between 8mm and 28mm.

\[ y \text{ error/cm at different applied loads.} \]

![Graph showing y error/cm at different applied loads.](image)

**Applied load/kgf**

**figure 3.11**

The above graph (figure 3.11) shows the variation in y error with applied load. If there is any significant variation over this range, it is masked by the error in placing the weights, which is estimated as around +/-10mm. The worst recorded error in y was +22mm. The estimated maximum error in the walkway’s measurement of y is therefore between 12mm and 32mm.

The positional accuracy of the walkway over this range of static load (25kgf - 150kgf) is therefore around +/-8mm to +/-32mm which is close to the specification and was considered acceptable. (However, errors for dynamic loading are higher, as described below).
3.1.4 Testing of the assembled system with point loads applied at known positions

3.1.4.1 Introduction

It would have been difficult to determine accurately the centres of gravity of the weights available. It was therefore decided to use a rigid pole held by an experimenter to exert an approximately vertical force on the walkway. This is the method used by researchers at the Orthotics Research and Locomotor Assessment Unit (ORLAU) at Oswestry, Shropshire to apply forces in the calibration of their Vector Generator equipment (Major, 1989). This was done at each of the points on the 200mm grid. See figure 3.12.

Software described in section 2.7.9 was used. It was intended to use a threshold of 20kgf for positional calculation during gait, i.e. not to
calculate the positions of forces less than 20kgf. This value was expected to be low enough to be less than the minimum force value for the 'dip' in the vertical force curve for most adult gait. This was a compromise between achieving the best positional accuracy and having positional data for as large a percentage as possible of the stance phase. Positional accuracy was expected to improve with increasing magnitude of applied load so it was necessary to determine the accuracy of the determination of position for loads just above 20kgf. For each loading condition, the sampling proceeded at a constant rate until the loading exceeded 25kgf on one platform. At this point the computer emitted a beep and the load was removed. Several points were loaded during each experimental run. The beeping delayed the sampling so that only approximately 1-5 readings were recorded for each position. After the experimental run, the readings for loads greater than 20kgf were displayed on the screen and written down.

This was done on two successive days, to make sure that the behaviour was consistent with time, and also on several subsequent dates to make sure it was stable over a longer period of time.
3.1.4.2 Results and discussion

When initially calibrated in January 1992, the above results (figure 3.13) were obtained. The maximum error in x was -18mm and in y was +11mm. The maximum error due to the positioning of the pole is estimated as 5mm so the positional errors for loads just above 20kgf are up to around 13mm to 23mm in x and 6mm to 16mm in y. These values were considered acceptable.

The skewedness of the data from the origin may have been due to inaccuracies in the gain values used in the program, irregularity in the end of the pole, poor positioning of the transducers (an incorrect value of 'e' (defined in figure 2.16) used in the program) and/or non-vertical loads applied.
The tests were repeated and the following results were obtained.

<table>
<thead>
<tr>
<th>Date</th>
<th>Maximum Error in x</th>
<th>Maximum Error in y</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 1992</td>
<td>between 13mm and 23mm</td>
<td>between 6 and 16mm</td>
</tr>
<tr>
<td>March 1992</td>
<td>between 11mm and 21mm</td>
<td>between 4 and 14mm</td>
</tr>
<tr>
<td>June 1992</td>
<td>between 11mm and 21mm</td>
<td>between 3 and 13mm</td>
</tr>
<tr>
<td>September 1992</td>
<td>between 12mm and 22mm</td>
<td>between 7 and 17mm</td>
</tr>
</tbody>
</table>

The behaviour of the platforms therefore appears stable.

3.1.5 Testing of the assembled system with dynamic loads applied at known positions

3.1.5.1 Introduction

It is important that the measured effect of a footfall should not depend significantly on the position of the footfall. It was therefore decided to test the system's response to a dynamic load produced by dropping an object onto the walkway from a constant, known height.

The applied load did not have the same frequency spectrum as gait but it was possible to see some qualitative effects.

3.1.5.2 Method

It was convenient to use a basketball as the object. It created a maximum force of over 20kgf so that the measurement of position could be assessed. This force was dispersed enough not to damage the walkway. The ball's spherical geometry allowed assumption of its centre of mass to be at its geometrical centre. The height to which the ball rebounded was estimated visually. The ball was dropped onto aluminium foil taped to the walkway. The bottom of the ball was held at the nominal height it was to be dropped from, i.e. deformation of the ball was neglected in estimating the distance it had fallen. The edges of the indentation in the foil were marked.
and the centre of the indentation was taken as the point of action of the applied impulse.

This was done twice each for several positions on each walkway, approximately at the four corners and the middle of the walkway.

3.1.5.3 Results and discussion

The height from which the ball was dropped was 0.99m, +/-0.02m. The height to which it rebounded was 0.60m +/- 0.2m. No variation with position of the height to which it rebounded was thus detected by this crude experiment.

The above graph (figure 3.14) shows the impact positions measured from the foil.
The above graph (figure 3.15) shows the positions as measured by the walkway, for all points for which the force exceeded 20kgf. The accuracy is worst furthest from the transducers (at the corners of the diagram).

The above graph (figure 3.16) shows the differences between the positions measured from the foil and by the walkway. The errors are up to
The error of determination of the position on the foil is estimated as +/-2mm, so is negligible.) These errors are large, but this is a more impulsive load than walking, so proportionately more of the energy is at higher frequencies. In section 3.1.1.2 it was shown that the gains of the channels of the signal conditioner diverge at high frequencies, so one would expect the positional errors for a load containing proportionately more of the energy at higher frequencies to be greater than for a load containing proportionately less of the energy at higher frequencies. Therefore the positional errors in gait were expected to be smaller than those found in this experiment. Next the error in the time-averaged position of each impact was found (figure 3.17):

This shows errors up to -90mm +80mm in x and -20mm +20mm in y.

The maximum force measured at the different positions was found. If the poor response were due to the top plates, I would expect to see that the response would be 'sharper' near to the transducers and more 'flattened out' between the transducers. The variation of recorded maximum force with position was therefore examined. The results showed random
variation, presumably because the sampling rate was not fast enough to record the maximum force. The force peaks in gait are less sharp. The range of maximum recorded $F$ was from 24.6kgf to 28.7kgf, i.e. around 26.6kgf +/- 8%.

Looking at impulses, the calculated impulse is:

$$\text{Impulse} = m((2gh_1)^{0.5} + (2gh_2)^{0.5})$$
from conservation of energy, where

- $m = \text{mass of ball} = 0.5826\text{kg}$
- $g = 9.81\text{ms}^{-2}$
- $h_1 = \text{initial height} = 0.99\text{m} +/- 0.02\text{m}$
- $h_2 = \text{final height} = 0.6\text{m} +/- 0.2\text{m}$, so

upper estimate of $(2gh_1)^{0.5} = (2 \times 9.81 \times 1.01)^{0.5} = 4.45\text{ms}^{-1}$
lower estimate of $(2gh_1)^{0.5} = (2 \times 9.81 \times 0.97)^{0.5} = 4.36\text{ms}^{-1}$
upper estimate of $(2gh_2)^{0.5} = (2 \times 9.81 \times 0.8)^{0.5} = 3.96\text{ms}^{-1}$
lower estimate of $(2gh_2)^{0.5} = (2 \times 9.81 \times 0.4)^{0.5} = 2.80\text{ms}^{-1}$

so upper estimate of impulse = 0.5826 $(4.45 + 3.96) = 4.90\text{Ns} = 4.90/9.81 = 0.50\text{kgf.s}$

and lower estimate of impulse = 0.5826 $(4.36 + 2.80) = 4.17\text{Ns} = 4.17/9.81 = 0.43\text{kgf.s}$
The above graph (figure 3.18) above shows the measured impulses in kgf.s for each impact. They vary from 0.45 kgf.s to 0.52kgf.s, i.e. approximately 0.48kgf.s +/-8%, compared with the estimated true value of between 0.43kgf.s and 0.50kgf.s, so the measured values are reasonably in agreement with the estimated true value. This experiment does not show noticeable non-random variation of measured impulse with position; any variation due to the walkway is masked by that due to the experimental technique.

3.1.6 Summary of conclusions from experiments with inanimate loads

The behaviour of the signal conditioner is adequate but closer matching of the channels would improve the system's performance. If one wished to improve the performance of the system to give a positional error of less than 10mm at 35kgf for gait (as in the desired specification in section 2.2), then as a worst case, the gains of the electronics of each channel, each normalised by the static gain of the channel, must be within 0.1% of each other at all frequencies up to 25Hz. This is an overestimate.
because the signal content tails off towards 25Hz so the filter matching need not be as accurate at the upper end of the band. (In order to achieve this level of performance, other improvements would be necessary, since this level of accuracy has not been achieved under static conditions.)

Tests on the individual channels gave values which were put into the computer programme. The results showed preconditioning effects. They could be perhaps have been slightly improved upon by preloading the transducers up to full load and back a few times before testing, giving a slight improvement in the system's accuracy of determination of force and position.

The worst percentage error in the determination of a static force of magnitude 25kgf - 150kgf was 1.2%, which was considered adequate.

Tests with the weights estimated the maximum error in the determination of position of a static force of magnitude 25kgf - 150kgf as between 8mm and 28mm in x and between 12mm and 32mm in y. Tests with the point load of magnitudes just above 20kgf estimated the maximum error in the determination of its position as between 13mm and 23mm in x and between 6mm and 16mm in y. These values were considered acceptable. This is slightly poorer than the values found by Olsson et al (1986) and for a Kistler 9821 force plate.

Tests using a basketball to apply a dynamic load were somewhat inconclusive due to the crudity of the experiment. No variation was detectable with position of the height to which the object rebounded. The accuracy of position measurement was found to be better closer to the transducers. The errors in positional measurement for all points for which the force exceeded 20kgf were up to -160mm + 130mm in x, and up to -50mm +40mm in y.

The load had a proportionately higher frequency content than gait so the accuracies of force and position data for gait were expected to be
better than the above values so the results were accepted at this stage in the study.

The impulse recorded varied over a range of 0.48kgf.s +/-8%, so it was reasonably in agreement with the estimated true value. Any variation in measured impulse with position due to the walkway is masked by that due to the experimental technique.

The experiments with inanimate loads indicated that the walkway was of sufficient accuracy to be worth testing with normal subjects.

3.2 Estimation of time and space required

3.2.1 Introduction

It is recognised that the system is only a prototype, so the values are likely to change during further development of the system, but it was felt that it was valuable to assess it at this point.

The Surrey walkway system has been in place for over a year with no breakdowns.

3.2.2 Space required

The space used at Surrey is 8 feet (walkway) plus 8 feet (run-up at one end) plus 11 feet 7 inches (run-up at other end) plus 8 feet ramp = 35 feet 7 inches long, by 4 feet (walkway) plus 2 feet (side platform for safety) = 6 feet wide. The overall space needed is somewhat greater than that for a small force plate mounted in the floor.

3.2.3 Time for set-up and shut-down

Half an hour to an hour is needed at the beginning of a session for the transducers to warm up (Taylor, 1993). During this time the system can be initialised (45s) and the signal conditioner can warm up (5 minutes). To shut the system down after use takes 10s.
3.2.4 Subject preparation time

It is estimated that it takes 5 minutes to give the subject instructions and let them do a few practice traverses.

3.2.5 Printout

To produce a printout of the results from one traverse takes around a minute (less if several are done in succession, because the next one can be queued up while the previous one is being printed).

3.2.6 Data collection

To go round one data-recording cycle for 5s sampling time takes a minimum of around 20 - 25s. In chapter 4, the time taken to collect the data from the subjects with pathological gait is presented.

3.3 Calibration and tests of walkway with normal volunteers

3.3.1 Introduction

Several sets of tests were carried out in order to characterise the walkway's performance with normal volunteers and to answer some questions as to how the tests with the subjects with pathological gait should be carried out.

The tests were:
1. Positional calibration. This was intended to estimate the accuracy of determination of position of a footfall in normal gait. (The positions are subtracted to calculate e.g. step length.)
2. Consistency tests. The purpose of these experiments was to check that the results from the walkway were consistent for the same normal subject on different days.
3 Kistler comparison experiments. The purpose of these experiments was to compare the results obtained from a typical commercial small force plate with the results from the Surrey walkway for the same subject. Only one footfall per traverse could be recorded by the Kistler plate, so only parameters relating to single footfalls could be compared.

4 Instructions experiments. It was necessary to determine the effects of the instructions given on the gait measurements obtained. It had been suggested that the subjects would naturally walk with one foot on each side of the centre line and that to draw their attention to the requirement to do this would affect their gait. It was decided to test this so that appropriate instructions could be given to the subjects in the clinical study.

3.3.2 Positional calibration

3.3.2.1 Introduction

The purpose of this experiment was to assess the walkway's positional accuracy for 4 normal subjects at self-selected slow, normal and fast speeds, i.e. to compare the walkway-calculated average position for each footfall with the value measured directly from the footprint.

3.3.2.2 Method

Four normal subjects were recruited. Each subject's date of birth, height, hand dominance, footwear and sex were recorded. Their weight was measured on the walkway.

The walkway was covered with aluminium foil in order to allow footprint images to be formed.

Each subject walked over the pair of platforms, twice in each direction at self-selected slow, normal and fast speeds, i.e. 4 subjects x 3 speeds x 2 directions x 2 trials = 48 traverses. Visual observation of the gait suggested that it was normal. The subjects wore shoes. I expected that the
subjects would not tend to adjust their foot positions as much as if they were barefoot and that it would be more comfortable and convenient for them. The signals from the walkway were recorded. After each trial, the extreme x and y values of each footprint were recorded.

Each subject's weight and distribution of weight between right and left feet in standing was measured. The subject stood still with one foot on each platform, four times, for around 5s per time, stepping off the walkway between the measurements. The subjects were not told that weight distribution was being measured. It was hoped that the distribution would be repeatable so that it could be used for assessment. It might for instance relate to how painful the legs were in relation to each other.

3.3.2.3 Results and discussion

A typical graphical output is shown in figure 3.19. It shows the variation of the vertical force with time, the path of the centre of pressure and a three-dimensional plot of the data. It shows three footfalls, i.e. a complete stride.

The subjects' details are shown below:

<table>
<thead>
<tr>
<th>Subject</th>
<th>sex</th>
<th>stature</th>
<th>hand dominance</th>
<th>age</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>male</td>
<td>1.80m</td>
<td>right</td>
<td>23</td>
</tr>
<tr>
<td>12</td>
<td>male</td>
<td>1.88m</td>
<td>right</td>
<td>21</td>
</tr>
<tr>
<td>13</td>
<td>female</td>
<td>1.57m</td>
<td>right</td>
<td>29</td>
</tr>
<tr>
<td>14</td>
<td>female</td>
<td>1.57m</td>
<td>right</td>
<td>25</td>
</tr>
</tbody>
</table>

In summary, there were 2 male and 2 female subjects, height 1.57m - 1.88m (mean 1.70m), all right-handed, aged 21-29 (mean 24).
length of vector represents magnitude of vertical force

time interval between vectors = 0.0025 seconds

platform 1

platform 2

right foot                    right foot

left foot

Direction of travel: ←
The subjects' weight and distribution of weight are shown below: Symmetry ratios are calculated as \((W_R - W_L)/0.5(W_R + W_L)\) where \(W_R\) is the quantity measured for the right foot and \(W_L\) is the quantity measured for the left foot (Robinson et al, 1987).

<table>
<thead>
<tr>
<th>Subject</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>weight</td>
<td>80.4kgf</td>
<td>87.2kgf</td>
<td>51.4kgf</td>
<td>59.0kgf</td>
</tr>
</tbody>
</table>

The symmetry ratios are shown in the graph (figure 3.20):

Symmetry of weight distribution for basic calibration

![Graph showing symmetry ratios for subjects 11 to 14]
Calculating the mean and confidence limits for each subject:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Mean</th>
<th>95% Confidence Limits</th>
<th>95% Confidence Limits as a Percentage of the Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>0.03</td>
<td>+/-0.12</td>
<td>+/-488%</td>
</tr>
<tr>
<td>12</td>
<td>-0.10</td>
<td>+/-0.18</td>
<td>+/-173%</td>
</tr>
<tr>
<td>13</td>
<td>-0.17</td>
<td>+/-0.23</td>
<td>+/-137%</td>
</tr>
<tr>
<td>14</td>
<td>-0.03</td>
<td>+/-0.18</td>
<td>+/-695%</td>
</tr>
</tbody>
</table>

So this variable is unlikely to be useful for assessment unless the percentage confidence limits are much lower than this in pathological subjects. It appears that the subjects' weight distribution varies substantially between measurements and a longer sampling period would be necessary to obtain more repeatable results.

The mean position of each footfall registered by the walkway is calculated by taking the calculated positions of the force for which the force exceeded 20kgf, adding them up and dividing by the number of measurements. The mean position of each footfall transcribed from the foil is calculated by taking the extreme x values (furthest backward and furthest forward) for the footfall and averaging them, and doing the same for the y values.

The graph below (figure 3.21) shows the difference between the mean position of each footfall registered by the walkway and transcribed from the foil.

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Assuming the two outlying values are due to experimental error in transcription, this leaves errors of up to +/-60mm in x and +20mm-30mm in y. However, the mean position of the force is not necessarily at the mean position of the foot. Possibly if the results were reflected and rotated to correct for right and left feet and the two directions of walking, they would collapse down more.

Finley and Cody (1970) studied the locomotive characteristics of urban pedestrians; 534 men and 572 women. They found the following results for mean step length: men: 0.741m, women 0.634m. An error of twice +/-0.06m on a step length of 0.741m is +/-16% and on a step length of 0.634m is +/-19%, so the expected maximum error in step length for normals with the mean step length walking at free speed is around 18%, and for stride length, around 18%/2 = 9%. This was less good than hoped. However, it was an upper limit: it would have been useful to have compared step lengths and stride lengths from the foil with those from the walkway. Also, the limits on accuracy required for clinical usefulness had not been defined. Therefore, it was considered worth continuing with the walkway.
3.3.3 Consistency tests

3.3.3.1 Introduction

The purpose of these experiments was to check that the results from the walkway were consistent for the same normal subject on different days.

3.3.3.2 Method

Four normal subjects were recruited. Volunteers were asked to take no strenuous exercise before testing. The subjects were asked to walk along the walkway at Surrey, on two different days, 30 times each occasion, wearing the same footwear each time, at self-selected normal speed.

Each subject was asked their height, age, sex, hand dominance and leg dominance. Each subject's weight was measured on each occasion using the walkway.

Any subject comments were noted.

3.3.3.3 Results and discussion

The subjects' details are shown below.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Height</th>
<th>Age</th>
<th>Sex</th>
<th>Hand dominance</th>
<th>Leg dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>1.88m</td>
<td>22</td>
<td>m</td>
<td>right</td>
<td>right</td>
</tr>
<tr>
<td>17</td>
<td>1.68m</td>
<td>44</td>
<td>m</td>
<td>right</td>
<td>right</td>
</tr>
<tr>
<td>25</td>
<td>1.63m</td>
<td>21</td>
<td>f</td>
<td>right</td>
<td>'probably right'</td>
</tr>
<tr>
<td>27</td>
<td>1.78m</td>
<td>23</td>
<td>m</td>
<td>right</td>
<td>right</td>
</tr>
</tbody>
</table>

In summary, there were 3 males and 1 female, with heights ranging between 1.63m and 1.88m (mean 1.74m), aged 21-44 (mean 28), all right-handed, three right leg dominant and one probably right leg dominant.
Subject weight on first occasion weight on second occasion

16 88.0kgf 87.9kgf (negligible change)
17 62.4kgf 63.9kgf (an increase of 2.4%)
25 52.8kgf 53.0kgf (negligible change)
27 62.0kgf 62.7kgf (an increase of 1.1%)

So the maximum weight change between assessments was 2.4%.

The numbers of days between assessments were as follows:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Number of days</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>27</td>
<td>6</td>
</tr>
</tbody>
</table>

Trials lost due to operator error in order to record the $4 \times 30 \times 2 = 240$ valid trials

<table>
<thead>
<tr>
<th>Subject</th>
<th>First occasion</th>
<th>Second occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>25</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>27</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

There were $6/240 = 2.5\%$ trials lost due to operator error, so this is not a great problem.

Subject comments

The subjects occasionally commented that they had to concentrate to keep one foot each side of the centre line.

Subject 27 after his first test said that he had slightly aching calf muscles. He said he felt that looking down was making him sway. He
thought it was disturbing his gait slightly. Some of the time he was trying to look up more at the marks on the wall. After his second test he said that his shoulders ached now and his calves were fine.

The error messages for all the traverses were considered. Trial 134 from the first set of subject 25's results suffered from crossover. It was therefore omitted from the analysis. Trial 7 from subject 16's first set registered 'negativedoublestancetimes'. On inspection this proved to be due to a double registration of a foot contact, showing the need for further work on the algorithms (see section 5.2.2). This trial was also omitted from the analysis. Trial 141 in subject 25's second set was registering 'toomanysteps'. This also proved to be due to double registration of a foot contact. This trial was also omitted from the analysis. Trials 116, 123 and 129 from subject 25's first set, and trial 149 from subject 25's second set were omitted after inspection of the data prompted by notes made during the experiments.

Graphs of the selected gait variables were produced. Two tailed t-tests assuming equal variance (p<0.05) were performed to find whether there were statistical differences between the data from the two occasions for each subject. The results and comments are summarised in figure 3.22 and described below. Where there was more than one value per traverse only the first one was analysed, for simplicity. It was expected that generally there would not be statistically significant differences, or if there were, their magnitude would not be large.

Figure 3.23 shows the speed readings obtained. This was surprising, showing that the changes in speed were statistically significant and in some cases of large magnitude (16.7% in the case of subject 16). These changes in speed would be expected to produce changes in many of the other variables and by comparison of the graphs it can be seen that this is so. The first conclusion of this experiment is that in order
Summary of results of consistency tests

<table>
<thead>
<tr>
<th>subject</th>
<th>velocity/(m/s)</th>
<th>step width/m</th>
<th>stance time symmetry ratio</th>
<th>left step length/m</th>
<th>right step length/m</th>
<th>first peak force symmetry ratio</th>
<th>second peak force symmetry ratio</th>
<th>minimum force symmetry ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean, first occasion</td>
<td>mean, second occasion</td>
<td>variance, first occasion</td>
<td>variance, second occasion</td>
<td>% change</td>
<td>signif. at p&lt;0.05</td>
<td>comment</td>
<td>mean, first occasion</td>
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<tr>
<td>17</td>
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<td>0.00</td>
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<tr>
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<tr>
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<td></td>
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</tr>
<tr>
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<td></td>
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<td>0.065</td>
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<tr>
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Figure 3.22 page 1
### Summary of results of consistency tests

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</tr>
<tr>
<td></td>
<td>appears stable when speed</td>
<td>stays constant</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>second peak force, left leg/kgf</strong></td>
<td></td>
<td></td>
<td></td>
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<td>yes</td>
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<tr>
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<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>appears stable when speed</td>
<td>stays constant</td>
<td></td>
<td></td>
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<tr>
<td><strong>left second peak force timing/%</strong></td>
<td></td>
<td></td>
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<tr>
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<td>no</td>
</tr>
<tr>
<td></td>
<td>appears stable</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.22 page 2
Figure 3.23: velocity measurements from consistency experiment
to compare different treatments etc., it is necessary to conduct assessments with subjects with pathological gait in such a way as to compensate for the effect of speed. Subject 17's first set also exhibit a marked learning curve. This shows the importance of ensuring that the subject is used to the test before one begins to record results. Unfortunately this tends to be less practical with disabled subjects due to their tendencies to fatigue more quickly and to have pain in walking. When the other variables were examined it was found that the changes tended to be least in the subjects whose speed had changed least, i.e. subjects 25 and 27.

Figure 3.24 shows the changes in step width. Subjects 17, 25 and 27 show consistent values but subject 16's values are larger and show a large, statistically significant difference between the occasions. Many subjects must be instructed to place one foot on each platform, so this aspect of their gait is affected by conscious control. In the case of subject 16 it appears to me that the subject has made an exaggerated effort to widen his steps. This shows that this variable must be interpreted with care and may not be clinically useful except for a limited group of subjects who normally walk with a wide gait.

For stance time symmetry ratio, none of the subjects showed a statistically significant difference between the occasions, so this appears to be a stable variable in normals.

Left step length increases statistically significantly for subjects 16, 17 and 27. However, for subjects 25 and 27 whose speed only changed by 3%, the changes in left step length are below 2% so this appears to be a fairly stable variable in normals provided that speed stays constant. Right step length increases statistically significantly in subjects 16, 17 and 25. However, for subjects 25 and 27 whose speed only changed by 3%, the changes in right step length are below 4% so this appears to be a fairly stable variable in normals provided that speed stays constant.
Figure 3.24: Step width measurements from consistency experiment
For first peak force symmetry ratio, there were statistically significant changes for subjects 17 and 27. The percentage changes are large because the mean values are close to zero because the subjects are normals, but the magnitudes of the larger of the two changes is only 0.02, equivalent to the difference between the peak forces changing by 2% of the average. This also appears to be a fairly stable variable in normals.

For second peak force symmetry ratio, there are statistically significant changes for subjects 25 and 27. The percentage changes are large because the mean values are close to zero because the subjects are normals, but the magnitude of the larger of the two changes is only 0.03, equivalent to the difference between the peak forces changing by 3% of the average. This also appears to be a fairly stable variable in normals.

For minimum force symmetry ratio, there is a statistically significant change for subject 25. The percentage change is large because the mean value is close to zero because the subjects are normals, but the magnitude of the change is only 0.03, equivalent to the difference between the minimum forces changing by 3% of the average. This also appears to be a fairly stable variable in normals.

The forces have not been normalised to take account of the small changes in weight that occurred.

Figure 3.25 shows first peak forces on the left leg. There are statistically significant changes for subjects 16, 17 and 25, but for subject 25 where the speed only varied by 3%, the change in first peak force was only 2.5%. Figure 3.26 shows similar behaviour in the right leg.

For second peak forces on the left leg, there are statistically significant changes for all of the subjects, but for subjects 25 and 27 where the speed only varied by 3%, the changes in second peak force were only 3.2% and 1.7%.
Figure 3.25: Left first peak force measurements from consistency experiment.
Figure 3.26: Right first peak force measurements from consistency experiment.
For minimum forces on the left leg, all subjects show statistically significant changes. However, for subjects 25 and 27 where the speed only varied by 3%, the changes in minimum force were only 4.0% and 2.3%.

For the left second peak force timing in percentage of the stance phase, subjects 16 and 17 show significant changes but their magnitudes are only 0.9% and 0.5% of the stance phase respectively. Subjects 25 and 27 where the speed only varied by 3% show no significant changes. This variable thus seems to be quite stable in normals.

For the impulse symmetry ratio, none of the subjects show statistically significant changes. The scatter is large compared with the mean values because the mean values are close to zero because the subjects are normals. This variable seems quite stable in normals but the large scatter may make it difficult to detect changes in subjects with pathological gait.

3.3.3.4 Conclusions

A few trials had to be omitted due to error messages. There is need for further development of the algorithms (see section 5.2.2).

According to two-tailed t-tests (p<0.05) there were significant changes in some variables even in subjects 25 and 27 where the average speed had only changed by 3%. Fifty-two t-tests were performed and the test has a 1 in 20 probability of producing a false positive result, so there are likely to be 2-3 false positive results. The other changes were presumably due to the slight changes in speed, other changes in the subjects and possibly the measuring system. However, these were of small magnitude: below 2% in left step length, 4% in right step length, 0.02 in first peak force symmetry ratio, 0.03 in second peak force symmetry ratio, 0.03 in minimum force symmetry ratio 3% in first peak force on the left
leg, 4% in second peak force on the left leg, 4% in minimum force on the left leg and 1% of the stance phase in left second peak force timing.

The results for normals varied between occasions when the above analysis, which does not compensate for speed changes between occasions, was used. The average speed for a given normal changed substantially between occasions and this changed the other gait variables. It is reasonable to expect this also to happen for subjects with gait pathology. If one tried to apply the above analysis by measuring the difference between pre- and post-operative gait and using this to assess the effects of the operation, one would not to be able to distinguish how much of the measured changes were spontaneous occasion-to-occasion variation, and might therefore reach an erroneous conclusion. It is therefore necessary to use an analysis which accounts for the effect of speed.

It is important, if possible, to ensure that the subject is used to the test before recording begins, in order to eliminate learning curve effects. Novatech recommend preconditioning the load cells by applying a few load cycles before beginning measurements (Taylor, 1993) so this is another reason to walk people up and down a few times before beginning recording.

Subject comments plus the anomalous results for subject 16 indicate that in normals, step width is an unreliable variable. It is affected too much by the measurement technique. It is expected that it could only be clinically useful for subjects whose normal gait is wide enough to clear the walkway centre line.

In order to compensate for the effect of speed it was decided to re-analyse the data making a simple correction: to assume that each variable varied linearly with speed. The assumptions used in the choice of this analysis and evidence from the literature to support them are explained below.
3.3.3.4.1 The assumptions used in the choice of the new statistical analysis and evidence from the literature to support them

The choice of the statistics used, which treat each gait variable as a linear function of walking speed, makes several assumptions:

- For healthy subjects and subjects with gait pathology, each of the gait variables used varies with speed in a repeatable way.
- This variation is linear.
- For healthy subjects and subjects with gait pathology, a subject's freely selected average 'normal', 'slow' or 'fast' speed will vary substantially from occasion to occasion for reasons not attributable to gait pathology.

When combined with assumption 1, this means that the values of the other gait variables obtained at freely selected 'normal', 'slow' or 'fast' speed will also vary from occasion to occasion for reasons not attributable to gait pathology.

The evidence from the literature to support each assumption is considered below.

- For healthy subjects and subjects with gait pathology, each of the gait variables used varies with speed in a repeatable way.

Grieve and Gear (1966) retested 13 adult subjects over their entire speed range with cine photography three months after testing them with inked footprints and a photocell beam. Within experimental error, they found the same relationship between step frequency and speed.

Grieve (1969) says that in daily life our gait is constantly changing in speed but unless we are very young or are 'play-acting' (as in a drum majorette's walk) we do not choose new combinations of stride length, step frequency, speed and time of swing, i.e. our gait varies with speed in a
repeatable manner. She also points out that if a normal person did not do very similar things on different occasions, then gait analysis would have little clinical importance.

Figure 3.27

An illustration of the steplength–velocity relationships for a normal subject and a patient treated with a total knee replacement.

Figure 3.28

An illustration of the time of swing–velocity relationships for a normal subject and patient treated for a total joint disability.
Andriacchi et al. (1977) measured temporal-distance and foot-ground reaction force measurements for seventeen normal subjects on two occasions each. When plotted against speed, the curves for the two occasions coincided, showing that the gait variables varied with speed in a repeatable way (see figures 3.27, 3.28 and 3.29).

The literature thus shows that temporal-distance and foot-ground reaction force measurements for normals vary with speed in a repeatable way. It is reasonable to expect this to be the case for other gait parameters and for subjects with gait pathology provided that their pathology was stable.

- This variation is linear.

Ten variables (from the list in section 4.1) were used. For stance time symmetry ratio, first and second peak force and minimum force symmetry ratios and impulse symmetry ratio, no data on their variation with speed could be found. The other 5 variables are considered below.
An illustration of the step length–velocity relationships for a normal subject and a patient treated with a total knee replacement.

Figure 3.30
Step length

Figure 3.30, (Andriacchi et al, 1977) shows the variation of stride length with speed for a normal subject. Figure 3.31 (Grieve, 1969) shows normalised stride length against normalised speed for 6 normal young males. The relationships shown in both cases are approximately linear. For
normals, the step lengths are approximately equal to half the stride length so one would expect them also to vary linearly with speed.

first and second peak force and minimum force

Figure 3.32
Andriacchi et al (1977) plotted these parameters of the vertical force, which he called Z1, Z3 and Z2 respectively, normalised by body weight, against speed for 17 normal subjects for slow, normal and fast walking speeds. The results obtained for all the subjects are shown in figure 3.32. A least squares regression analysis was used to fit linear, quadratic and cubic polynomials to each data set. An analysis of the multiple correlation coefficients for the polynomials indicated that the linear polynomial was adequate to describe each relationship. However, this does not show how linear the relationships for the individual subjects were.

Figure 3.33. Mean values (plus or minus one standard deviation) for selected amplitudes in ground reaction forces expressed in multiples of body weight (b.w.) for walking (open symbols) and running (filled symbols).

Figure 3.33 (Nilsson and Thorstensson, 1989) shows the variation of first and second peak force and minimum force with speed for twelve healthy male subjects. These relationships appear less linear than those found by Andriacchi et al (1977).
second peak force timing

Figure 3.34 (Nilsson and Thorstensson, 1989) shows the variation of second peak force timing (Fz3) with speed for twelve healthy male subjects. It appears to increase at low speeds and then stay constant. A linear relationship does not fit the data particularly well.

The literature supporting the linearity with speed in normals of the gait parameters used is poor and there is even less to support it in subjects with gait pathology. However, there was not sufficient information to
establish a more complex model so linearity was assumed, as a necessary simplification.

- For healthy subjects and subjects with gait pathology, a subject's freely selected average 'normal', 'slow' or 'fast' speed will vary substantially from occasion to occasion for reasons not attributable to gait pathology.

Grieve (1969) and Andriacchi et al (1977) said that people continually change their walking speed in daily life, so it is plausible that both normals and subjects with gait pathology would select slightly different speeds when subjected to gait analysis on different occasions.

![Figure 3.35: Mean and standard deviation of velocity within each test day as well as between three test days for a representative subject.](image)

Kadaba et al (1989) measured the gait of 40 normal subjects. Each subject's gait was recorded on 3 separate days, at their preferred or normal speed. Figure 3.35 shows mean and standard deviation of spatiotemporal parameters for a representative subject over the 3 days of testing. The walking speed has clearly varied substantially from occasion to occasion.

It is therefore reasonable to use this assumption.
3.3.3.4.2 Further explanation of the new statistical analysis used, application of it to the results of the consistency experiments, discussion and new conclusions

Ten variables were chosen (see section 4.1 for the explanation of the choice of variables). Each variable for each occasion was plotted against speed and least squares best fit lines were fitted, using the LINEST function in Microsoft Excel version 4. Figures 3.36 and 3.37 show sample results for subject 16. Certain parameters of each line were calculated, also using the LINEST function in Microsoft Excel. These described the quality of the lines. T-tests were performed as advised by Crowder (1993), between the lines in order to determine whether there were statistically significant differences between the variables between the occasions when speed was compensated for.

Coefficients of determination were calculated (using Microsoft Excel version 4's LINEST function) for all of the 40 best fit lines. This quantity describes how well a straight-line relationship describes the data, and ranges from 0 if it is of no use to 1 if it is a perfect straight line (Microsoft Excel version 4 Function Reference). The overall mean value is 0.15, i.e. not very close to a straight line. The highest value is 0.76, for subject 17's right step length on the second occasion. The lowest value is 0.00, e.g. for subject 16's first peak force symmetry ratio on the first occasion. It can be seen in figure 3.37 that this set of values shows large scatter and no visually discernible trend of first peak force symmetry ratio with speed. It is expected that wider speed ranges (e.g. 'slow', 'normal' and 'fast') would have given larger values of coefficients of determination, i.e. a better description of how gait behaviour varied with speed. The mean value of coefficient of determination for each variable was calculated. The highest value was for right step length, showing that it varied relatively strongly
Figure 3.36: right step length for subject 16
Figure 3.37: first peak force symmetry ratio for subject 16
with speed, and the lowest value was for minimum force symmetry ratio, showing that it varied relatively weakly with speed.

The observed F-statistics (variance ratios) for each subject, variable and occasion were calculated (using the LINEST function in Microsoft Excel version 4). As before, there was wide variation between the values for different variables. The highest mean value is for right step length, indicating that it is relatively unlikely that the observed trend with speed occurred by chance. The lowest mean value is for minimum force symmetry ratio, indicating that it is relatively likely that the observed trend with speed occurred by chance.

The critical F-statistics were found by looking them up in a standard statistical table for a given probability value and given values of V1 and V2, the degrees of freedom for the variance estimates. The chosen probability value was 5%. This means that if the observed F-statistic is greater than the critical F-statistic, there is only a 5% chance of obtaining the observed relationship (here, between the gait variable and speed) by chance. Applied to a plot of a gait variable against speed, a positive F-test means that the variation of the gait parameter with speed is statistically significant. For the 80 F-tests done here, using a 5% significance threshold, one would expect 5% x 80 = 4 of them to give a positive result even if the variables showed no real changes with speed. V1 was 1 because there was only 1 independent variable (speed) used in each best fit line. V2 was the number of points minus the number of independent variables minus 1, i.e. the number of traverses for which a whole stride was obtained, minus 2. V1 and V2 were calculated using the instructions for Microsoft Excel version 4's LINEST function.

The results of the F-tests showed that the total percentage of the tests which show statistically significant results is 23.75%, i.e. far more than the 5% which one would expect by chance alone. The percentages for each
subject are 20%, 30%, 20% and 25%, i.e. much the same as each other. However the percentages for each variable vary widely, from 87.5% for right step length to 0%, e.g. for first peak force symmetry ratio. This indicates that some variables are much more likely than others to show statistically significant trends with speed.

The slopes (rate of change of each variable with speed) and their standard errors were calculated. The slopes and the F-tests can be used together to show whether the quantities statistically significantly increase or decrease with speed. The slopes and their standard errors can be used to determine the confidence limits on the slope value, e.g. one could say with 95% confidence that the value of a slope was between value a and value b. They are also used below in t-tests to determine whether the slopes changed significantly between the two occasions.

The values on the best fit lines at v=1.291m/s were calculated, (together with their standard errors). This value is the mean walking speed for street pedestrians (Finley and Cody, 1970). It was chosen as a suitable arbitrary speed within the physiological range at which comparisons could be made. The values and standard errors can be used to determine the confidence limits on a value as for the slopes. They are also used below in t-tests to determine whether the values on the best fit line at v=1.291m/s changed significantly between the two occasions.

The observed t-values for the slope comparisons were calculated. The t-tests compare the differences in the means of each variable on the two occasions and compare it with the variability in the variable. The formula to used to calculate t is:

\[ t = \frac{\text{mean}_2 - \text{mean}_1}{\left(\frac{\text{se}_1^2 + \text{se}_2^2}{2}\right)^{0.5}} \]  
(Crowder, 1993).

The critical t-values with which the observed t-values were compared were calculated. They depended on N, the number of points for
each subject for each occasion, i.e. the number of traverses for which a complete stride was obtained. They also depended on the number of degrees of freedom for each subject, calculated by adding the number of trials for the two occasions together and subtracting 4 (Crowder, 1993). The significance level was chosen as 5%, so one would expect 5% of the tests to be positive by chance alone. The critical t values were looked up in a standard statistical table for 5% significance and the four numbers of degrees of freedom.

The t-tests were performed, i.e. the magnitudes of the observed t-values were compared with the critical t-values. If the former was greater than the latter, the t-test was significant and 'yes' was recorded. The overall percentage yeses was 7.5% (3/40) compared with 5% (2/40) which one would expect through chance alone. The differences are thus hardly more than one would expect by chance so the slope values are reproducible in normals so they can be used for assessment of changes in pathological gait.

T-tests were also performed for the intercepts at $v = 1.291 \text{m/s}$. The analysis was the same as for the slopes. The overall percentage of positive t-tests is 25% (10/40), i.e. much more than the 5% (2/40) that one would expect from chance alone. The intercepts are thus much less repeatable than the slopes. Subject 16 has 6/10 yeses, subject 17 has 4/10 yeses and subject 25 and 27 have none. Subject 16's average speed changed by 16.7%, subject 17's by 7.9%, subject 25's by 3.1% and subject 27's by -2.9%. It thus appears that the intercept values become less repeatable when the average speed changes more between the occasions. This may be due to changes in the walkway's behaviour, changes in the subject's behaviour, and/or inadequacy of the analysis technique. It can be seen from subject 16's results that $1.291 \text{m/s}$ falls within the observed range of speed for occasion 1 but not for occasion 2. The further one has to extrapolate, the more inaccurate the values become. It would give a better comparison if one
widened the speed range and ideally controlled the speed range to be the same on both occasions. The latter approach may be impractical for clinical use. Changes in the subjects' behaviour might be reducible by concealing the walkway and allowing test trials before recording commences. However, it is not always practical to allow many practice trials when testing disabled subjects. Changes in the walkway's behaviour would lead to changed results even if the subject did not walk differently. Variations in the walkway's behaviour with position could lead to non-linearity in behaviour as changes in speed caused the subject to strike different areas of the platform. However, the behaviour of the variables with speed is not in all cases linear anyway: this was only an assumption made for simplicity.

The percentage of yeses differs between the variables as well as between the subjects. Stance time symmetry ratio intercept, first peak force symmetry ratio and first peak force on the right leg all change significantly for subjects 16 and 17. Right step length, second peak force on the right leg, minimum force on the right leg and impulse symmetry ratio each show significant changes in 1 of the 4 cases. The remaining 3 variables show no significant changes. Looking at the t-values for the significant changes:

Subject 16: -2.56, -2.09, -2.13, -4.88, 2.66, -2.37 (t_{1%} = 2.76, t_{0.1%} = 3.66)
Subject 17: -2.40, -2.45, -4.59, -2.35 (t_{1%} = 2.70, t_{0.1%} = 3.55)

So for p=1% or 0.1%, 2 tests are still significant: those for subject 16 and 17, intercept, first peak force 1, right leg. So if one uses a probability value of 1% and does not use intercept, first peak force 1, right leg, one gets no significant differences for normals. This analysis will thus be used for the subjects with pathological gait. It is not ideal; it would have been better to have taken a larger range of speed and modelled the relationships of each variable with speed using more suitable-shaped curves such as parabolas.
3.3.4 Kistler comparison tests

Subjects walked on the Surrey walkway and then on a Kistler force plate. However, it was not possible to compare the results because the speed of walking on the Kistler force plate had not been measured. This experiment should be repeated.

3.3.5 Instructions experiments

3.3.5.1 Introduction

It was necessary to determine the effects of the instructions given on the gait measurements obtained. It had been suggested that the subjects would naturally walk with one foot on each side of the centre line and that to draw their attention to the requirement to do this would affect their gait. It was decided to test this so that appropriate instructions could be given to the subjects in the clinical study.

It was thought that some quantities might be relatively sensitive to the instructions being given and some might be relatively insensitive. It was expected that there would be some effect due to the second instructions even if the subject had previously been clearing the line.

3.3.5.2 Method

Marks were set up on the wall and floor at each end of the walkway, in line with the mid-line of the walkway.

Normal subjects were recruited who were unfamiliar with the walkway.

Each subject was given tightly defined instructions: 'Start from the mark on the floor, and keeping your eyes on the mark on the wall, walk to the end'

The walking was repeated 30 times. The subject was given no feedback as to his performance.
The subject was then given the second set of instructions: 'Now do the same thing, but make sure that you keep one foot on each platform. It doesn't matter if your feet cross the ends of the platform'.

The subject was then asked to walk 30 more times.

Each subject's sex, stature, hand dominance, leg dominance and age was recorded.

Each subject's weight was recorded three times using the walkway.

<table>
<thead>
<tr>
<th>Subject</th>
<th>sex</th>
<th>height</th>
<th>age</th>
<th>weight</th>
<th>hand, leg dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>f</td>
<td>1.62m</td>
<td>24</td>
<td>56.2kgf</td>
<td>right, right</td>
</tr>
<tr>
<td>20</td>
<td>f</td>
<td>1.52m</td>
<td>28</td>
<td>51.1kgf</td>
<td>right, 'maybe right'</td>
</tr>
<tr>
<td>21</td>
<td>m</td>
<td>1.82m</td>
<td>19</td>
<td>62.0kgf</td>
<td>right, right</td>
</tr>
<tr>
<td>22</td>
<td>m</td>
<td>1.84m</td>
<td>18</td>
<td>69.4kgf</td>
<td>right, right</td>
</tr>
</tbody>
</table>

In summary, there were 2 male and 2 female subjects, heights 1.52m - 1.84m (mean 1.70m), aged 18 - 28 (mean 22), weights 51.1kgf - 69.4kgf, mean 59.7kgf, all right handed, 3 right footed and 1 maybe right-footed.

4 trials were lost due to operator error in order to record the 240 valid trials. This is only 2% so it is not an important problem.

Subject comments (from consistency experiments)

Subject 20 commented during the first set of tests that she could not see the mark on the wall until she was halfway across the walkway because her glasses were an old prescription. After the second set of tests, she said the tests had tired her because she had a cold. She thought she had slightly flat feet. She did not think she consciously avoided stepping on the ends of the platforms.

Subject 21, second test, he said he had slight hay fever and no known gait pathology. He said that the test made him a bit tired. It was a hot day. He
said it was more the standing up than the walking that was tiring. He said he wasn't consciously avoiding stepping on the ends of the platforms.

Subject 22, second test, he said he had no known gait pathology. He wasn't really tired after the tests and didn't consciously avoid stepping on the ends.

These subject comments suggest that the subjects did not consciously avoid stepping on the ends of the platforms. This means that any apparent avoidance of stepping on the ends was likely to have been caused subconsciously, which would be likely to make it more difficult to prevent in future assessments.

The comments also suggest that the subjects' gaits may have been affected by minor respiratory complaints and fatigue. This suggests possible factors which may perturb the dependence of a subject's gait on the specific pathology which is of interest in a particular clinical context, so may adversely affect the information which can be obtained from the gait assessment in the clinical context.

The error messages for the traverses were examined. Many traverses in the first set of results from each subject are corrupted by crossover error, showing immediately that it is necessary to ask normal subjects to keep their feet on each side of the centre line in order to obtain a reasonable proportion of usable trials. In fact there are even more trials which are actually corrupted by crossover error which the algorithms cannot detect. The results in the first set from each subject were visually inspected for crossover and the crossover ones were eliminated from further analysis.
The number of trials lost to crossover:

<table>
<thead>
<tr>
<th>Subject</th>
<th>First set</th>
<th>Second set</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>30 (all)</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>21</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>22</td>
<td>22</td>
<td>0</td>
</tr>
</tbody>
</table>

Uetake (1992) found that 20 healthy Japanese men asked to walk as straight as possible towards a target 60m away at normal speed all walked in a sinuous rather than straight line. Typical traces show the subjects crossing over the centre line.

In order to be able to compare the results before and after the second set of instructions for each subject, it was necessary to eliminate some other trials which were also unsuitable. Trial 101 in the second set from subject 20 was registering 'negativedoublestancetimes' because it was registering a contact twice due to the need for further work on the algorithms (see section 5.2.2). Trial 85 in subject 20's first set was eliminated because I had made a note during the experiment that the subject had stumbled.

The results were analysed to find what differences could be detected between the valid trials in the first and second series for each subject, i.e. what were the effects on the variables when the subject was consciously trying to put one foot on each platform. It was not possible to make any comparison for subject 19 since there were no valid trials in subject 19's first set. The results were analysed by two-tailed t-test, p<0.05. They were not corrected for speed. Where more than one value of a variable was obtained during a traverse, for simplicity only the first was analysed. The results are shown in figure 3.38.

Figure 3.39 shows the results for speed. Subject 20 slowed down significantly, subject 21 speeded up significantly and subject 22's speed did
## Differences between the results for each set of instructions

<table>
<thead>
<tr>
<th>Subject</th>
<th>Velocity (m/s) mean, 1st trial</th>
<th>Standard deviation, 1st trial</th>
<th>Velocity (m/s) mean, 2nd trial</th>
<th>Standard deviation, 2nd trial</th>
<th>% Change</th>
<th>Significant at p&lt;0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1.45</td>
<td>0.03</td>
<td>1.34</td>
<td>0.07</td>
<td>-7.7</td>
<td>yes</td>
</tr>
<tr>
<td>21</td>
<td>1.60</td>
<td>0.05</td>
<td>1.66</td>
<td>0.01</td>
<td>3.9</td>
<td>yes</td>
</tr>
<tr>
<td>22</td>
<td>1.44</td>
<td>0.06</td>
<td>1.42</td>
<td>0.04</td>
<td>-1.0</td>
<td>no</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step width (m)</th>
<th>20</th>
<th>0.144</th>
<th>0.027</th>
<th>0.167</th>
<th>0.020</th>
<th>16.3</th>
<th>yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21</td>
<td>0.164</td>
<td>0.011</td>
<td>0.232</td>
<td>0.016</td>
<td>41.6</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>0.113</td>
<td>0.017</td>
<td>0.169</td>
<td>0.011</td>
<td>49.9</td>
<td>yes</td>
</tr>
</tbody>
</table>

| Symmetry ratio | 20 | -0.012 | 0.034 | 0.016 | 0.029 | -231.6 | yes |
|                | 21 | 0.009  | 0.013 | 0.000 | 0.035 | -102.5 | no |
|                | 22 | -0.006 | 0.018 | -0.005 | 0.020 | -23.6 | no |

<table>
<thead>
<tr>
<th>Length (m)</th>
<th>20</th>
<th>0.695</th>
<th>0.011</th>
<th>0.672</th>
<th>0.029</th>
<th>-3.3</th>
<th>yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21</td>
<td>0.773</td>
<td>0.015</td>
<td>0.809</td>
<td>0.022</td>
<td>4.6</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>0.790</td>
<td>0.029</td>
<td>0.767</td>
<td>0.033</td>
<td>-2.9</td>
<td>no</td>
</tr>
</tbody>
</table>

| Symmetry ratio | 20 | 0.037 | 0.045 | 0.042 | 0.054 | 11.7 | no |
|                | 21 | 0.058 | 0.037 | 0.050 | 0.070 | -13.4 | no |
|                | 22 | 0.009 | 0.045 | 0.014 | 0.038 | -43.7 | no |

| Ratio | 20 | -0.019 | 0.051 | 0.009 | 0.050 | -145.0 | no |
|       | 21 | 0.022  | 0.018 | 0.029 | 0.074 | 30.7  | no  |
|       | 22 | -0.026 | 0.028 | -0.010 | 0.037 | -49.9 | no  |

| Symmetry ratio | 20 | -0.013 | 0.051 | -0.033 | 0.055 | 154.9 | no |
|                | 21 | -0.030 | 0.065 | -0.025 | 0.070 | -15.7 | no  |
|                | 22 | -0.021 | 0.041 | -0.010 | 0.055 | -50.6 | no  |

| Left leg (kgf) | 20 | 63.5  | 2.0  | 61.0  | 2.6  | -3.9 | yes |
|                | 21 | 72.7  | 2.0  | 77.9  | 5.3  | 7.2  | yes |
|                | 22 | 81.7  | 5.0  | 83.1  | 1.9  | 1.7  | no  |

| Leg (kgf) | 20 | 57.7  | 1.5  | 56.4  | 1.8  | -2.2 | no  |
|           | 21 | 68.6  | 1.3  | 69.7  | 3.4  | 1.7  | no  |
|           | 22 | 85.2  | 2.1  | 83.2  | 2.2  | -2.4 | no  |

| Left leg (kgf) | 20 | 32.6  | 1.5  | 35.6  | 2.8  | 9.3  | yes |
|                | 21 | 41.7  | 1.3  | 39.6  | 1.8  | -4.7 | yes |
|                | 22 | 47.9  | 3.7  | 47.5  | 1.9  | 0.6  | no  |

| Timing (%) | 20 | 79.0  | 0.9  | 77.8  | 1.3  | -1.5 | yes |
|            | 21 | 78.8  | 0.5  | 79.1  | 1.0  | 0.6  | no  |
|            | 22 | 80.6  | 0.5  | 80.5  | 0.9  | -0.2 | no  |

| Timing (%) | 20 | 77.1  | 1.6  | 76.1  | 1.7  | -1.3 | no  |
|            | 21 | 77.3  | 1.1  | 79.0  | 1.0  | 2.2  | yes |
### Differences between steps in the same traverse of the second set of results

<table>
<thead>
<tr>
<th>Subject</th>
<th>Step Width/m</th>
<th>Mean, 1st Trial</th>
<th>Mean, 2nd Trial</th>
<th>% Change</th>
<th>Significant at p&lt;0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>0.167</td>
<td>0.191</td>
<td>14.4</td>
<td>observations</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.167</td>
<td>0.178</td>
<td>6.5</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>0.232</td>
<td>observations</td>
<td>-</td>
<td>observations</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>0.169</td>
<td>observations</td>
<td>-</td>
<td>observations</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Symmetry Ratio</th>
<th>Mean, 1st Trial</th>
<th>Mean, 2nd Trial</th>
<th>% Change</th>
<th>Significant at p&lt;0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>0.009</td>
<td>0.025</td>
<td>170.5</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.016</td>
<td>0.021</td>
<td>27.5</td>
<td>no</td>
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</tr>
<tr>
<td>21</td>
<td>0.000</td>
<td>observations</td>
<td>-</td>
<td>observations</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>-0.005</td>
<td>observations</td>
<td>-</td>
<td>observations</td>
<td></td>
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<table>
<thead>
<tr>
<th>Subject</th>
<th>Length/m</th>
<th>Mean, 1st Trial</th>
<th>Mean, 2nd Trial</th>
<th>% Change</th>
<th>Significant at p&lt;0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>0.696</td>
<td>0.673</td>
<td>-3.2</td>
<td>observations</td>
<td></td>
</tr>
<tr>
<td>20</td>
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Figure 3.39: velocity measurements from instructions experiment
not change significantly. As is shown in the previous section, changes in speed between occasions can occur without changes in instructions, and these changes affect other gait parameters. There is no consistent effect of instructions on speed. Changes in other variables were in some cases attributed to changes in speed rather than changes in instructions.

Figure 3.40 shows the results for step width. All three subjects show a significant increase. In subject 22's case the magnitude of the change is 49.9%. These results show, as did the consistency tests, that step width is an unreliable variable because it is strongly affected by the measurement technique. It was therefore decided not to use it in the analysis for the subjects with pathological gait.

For stance time symmetry ratio, only subject 20 showed a significant change. This is the subject whose speed changed by the greatest percentage. The magnitude of the change is 0.028, i.e. the difference between the stance times changes by 2.8% of the average. None of the subjects in the consistency experiments showed a significant change so there is some indication that this variable has been affected by the change in instructions. The magnitude of the change is small.

Figure 3.41 shows the results for left step length. (The results for subject 20's second trial are further considered below.) Subject 20's left step length showed a significant decrease, subject 21's showed a significant increase and subject 22's did not show a significant change. These results are consistent with the speed changes and it is not possible to show that the left step length has been significantly affected by the instructions.

Figure 3.42 shows the results for first peak force symmetry ratio. None of the subjects showed significant changes so this variable does not appear sensitive to the instructions. Similar results were found for second peak and minimum force ratios.
Figure 3.40: step width measurements from instructions experiment
Figure 3.41: step length measurements from instructions experiment
Figure 3.42: first peak force symmetry ratio measurements from instructions experiment
Figure 3.43 shows the results for first peak force, left leg. Subject 20 shows a decrease, subject 21 shows an increase and subject 22 shows no significant change. These results are consistent with the speed changes and it is not possible to show that the first peak force, left leg has been significantly affected by the instructions.

Figure 3.44 shows the results for second peak force, left leg. None of the subjects show a statistically significant change. This contrasts with the non-speed-corrected results from the consistency experiments, where all four subjects showed significant changes between the occasions. No significant change of second peak force on the left leg with instructions is shown.

For minimum force, left leg, subject 20 shows an increase, subject 21 shows a decrease and subject 22 shows no significant change. As for the first peak force, these results are consistent with the speed changes and it is not possible to show that the minimum force, left leg has been significantly affected by the instructions.

For left second peak force timing in percent of the stance phase, subject 20 exhibits a significant decrease. This is the subject whose speed changed by the greatest percentage. The magnitude of the change is 1.2% of the stance phase. The two subjects in the consistency experiments whose speed changed by the greatest percentages showed significant changes so this variable may well have been affected by the speed change. The magnitude of the change is small. It is not possible to show that there is a significant change due to the change in instructions for this variable. For the right leg, only subject 21 shows a significant change. The magnitude of the change is 1.7% of the stance phase. Neither of the subjects in the consistency experiments whose speeds changed by a similar percentage showed significant results so there is some indication that this variable is affected by the instructions.
Figure 3.44: second peak force measurements from instructions experiment
For impulse symmetry ratio, only subject 20 showed a significant change. This is the subject whose speed changed by the greatest percentage so it appears likely that this variable is affected by speed so it is not possible to show that there is a significant effect on this variable due to the change in instructions.

The results so far show some significant changes between the two sets of results for each subject. Changes due to speed appear to predominate. The exception is step width, which increases significantly in all 3 subjects. Other changes due to the instructions of which there is some indication are changes in stance time symmetry ratio and right second peak force timing. The subjects' gait when they are asked to place one foot on each platform thus appears to be reasonably natural (i.e. similar to that when they are not asked to do this) apart from the increased step width. A predicted problem however was that the subjects would 'target' the platform, subconsciously adjusting their gait because they could see the ends of the platform because they were looking down to place their feet on either side of the centre line. To investigate this, it was decided to perform a second series of t-tests to compare successive steps from each traverse. Ideally the successive steps in a traverse would differ only by random step-to-step variation so no significant difference would be detected. The t-tests were two-tailed, p<0.05 as before.

A problem with these tests was that there were often so few observations as to make it impossible to perform the statistical test. This is because the walkway is not long enough to accommodate many steps. In increasing order of average step lengths the subjects were: 20, 19, 22, 21. The problem was therefore worst for subject 21 and least bad for subject 20.

There were no significant differences for step width or stance time symmetry ratio.
For left step length, subject 20 shows a statistically significant decrease of 14.2%. For the graph, refer back to figure 3.41. Unfortunately there are no results in the first set from this subject which show whether this effect was present before the instructions were given, perhaps due to the raised wooden platform being insufficiently long or the walkway's behaviour varying with position. There were no statistically significant differences in right step length.

There were no significant differences for first peak force symmetry ratio, second peak force symmetry ratio, minimum force symmetry ratio or first peak force, left leg.

Second peak force, left leg shows statistically significant differences for subjects 21 and 22 (surprisingly, the two with the longest step lengths). From the graph (figure 3.44) the effect appears to have existed before the instructions. On visual inspection of the results for second peak force force, right leg, the effect was not apparent.

Minimum force, left leg shows a statistically significant increase for subject 21 (surprisingly, the subject with the longest average step length). From visual inspection of the results it was difficult to tell whether the effect existed before the instructions. From visual inspection of the results for minimum force, right leg it was difficult to tell whether the effect existed.

Left second peak force timing shows no significant differences.

Right second peak force timing shows a significant difference for subject 21. There are not enough results from before the instructions to be able to tell whether the effect existed before the instructions.

Impulse symmetry ratio shows no significant differences.

In summary of this second part of this analysis, statistical differences from step to step were found after the second set of experiments for left step length (14.2%), second peak force, left leg (-4.8%, 200
-5.3%), minimum force, left leg (6.8%) and right second peak force timing (-1.2%). Some of these changes are large enough to cause concern (arbitrarily taken as >5%). However inspection of the graphs illustrating the results of the first set of walks of each subject suggests that they existed before the instructions were given. There is not enough data to justify statistical analysis. I recommend that further work is done to determine what modifications to the system are most necessary. These are expected to include camouflaging the walkway, improving the matching of the signal conditioner channels, increasing the rigidity of the plate and/or making the raised wooden platforms longer.

3.3.5.4 Conclusions

Ideally, the walkway should eventually be camouflaged in order that subjects should not change their gait due to knowing that they are being assessed. This may not be practicable. Apart from the fact that it would be difficult to draw conclusions from only one traverse, from the instructions experiments, it transpired that the subjects did not put their feet on each side of the centre line. Therefore for work with normal subjects it is necessary to instruct the subjects to place each foot on one side of the centre line. It was decided that this had to be done with the disabled subjects also. Some of them had wide gaits and would perhaps have been able to clear the line anyway.

3.3.6 Summary of conclusions from tests with normal volunteers

There is a need for further development of the algorithms. At present, the algorithms necessitate the omission of a small number of trials. The code executes the algorithms correctly but the algorithms should
be improved so that they can deal correctly with these trials too. See section 5.2.2.

The comparison with the commercial force plate was inconclusive and should be repeated.

It is important if possible to ensure that the subject is used to the test before recording begins, in order to eliminate learning curve effects. This is not always practical with subjects with pathological gaits. Novatech recommend preconditioning the load cells by applying a few load cycles before beginning measurements (Taylor, 1993) so this is another reason to walk people up and down a few times before beginning recording.

In the consistency experiments, it was found that the subjects changed speeds between the occasions, causing changes in other gait parameters. It was therefore decided to re-analyse the data applying a linear correction for speed. T-tests (p<0.05) between the slopes showed hardly more changes than one would expect by chance, so the slope values appear to be reproducible in normals so they are to be used for assessment of changes in pathological gait. T-tests (p<0.01) for the intercepts at v=1.291 m/s, excluding that for the first peak force on the right leg showed no significant differences for the normals so it was decided to use this analysis for the subjects with pathological gait.

It was decided not to analyse step width for the subjects with pathological gaits as it was found to be inconsistent in normals and affected by the instructions.

For work with normal subjects it is necessary to instruct the subjects to place each foot on one side of the centre line. It was decided that this had to be done with the disabled subjects also.
Chapter 4: Experiments with subjects with pathological gait

4.1 Introduction

The subjects were:
16 adult amputees (of varying levels of amputation),
2 miscellaneous adult subjects and
2 child subjects recruited by Dr May, and
6 adults with joint disease prior to joint replacement recruited by Mr Deane.

Dr May was present during virtually all of the tests with the subjects whom he recruited. He obtained access to their medical records and extracted the relevant data. He and I determined the protocol together.

Mr Deane and Sister Harris or a physiotherapist from Wexham Park Hospital were present during the tests with the subjects whom Mr Deane and Sister Harris recruited. Sister Harris extracted certain information from the subject's medical files for me and gave me copies of the forms which she used to assess the urgency with which the operations were needed. Mr Deane commented on the protocol.

The subjects were able to walk along the walkway unassisted and with no walking aids.

The subjects generally wore their own footwear. This was most convenient and gives results most typical of their gait. It was suspected that subjects would adjust their steps to the ends of the walkway more if they were barefoot. It was desired not to spread foot infections and not to have to disinfect the floor.

Certain personal details of the subject were recorded: date of birth, sex, hand dominance, leg dominance and stature. It was expected for taller, less disabled subjects that fewer of the traverses would record a complete stride (but that the percentage error of step lengths would be smaller).
The test was explained to the subject. From experiments with normals, it was found that by no means everyone put their feet each side of a line when not asked to. Also it was difficult and not always possible reliably to eliminate those trials where a subject crossed over the centre line; if the corruption was slight one could not always see it. Also it was desired to minimise the number of trials required because it was felt that this would be desirable in a clinical setting in order to save time and thus money and to limit fatigue. It was therefore decided to instruct the subjects to walk as naturally as possible but to keep one foot each side of the centre line. Takegami (1992) using a similar walkway claims to have given no instructions and Olsson et al (1986) does not give information regarding instructions.

Where practicable, the subject was allowed to become accustomed to the test by walking along the walkway several times.

The numbers of trials for each speed varied from subject to subject. For the early subjects, my inexperience meant that insufficient numbers of trials were recorded. Some subjects' performance began to deteriorate during the trial so the trial was curtailed. Not all the subjects were capable of all the speeds. With the joint replacement patients, only normal speed was studied as these subjects suffer pain in walking and also Mr Deane felt that the assessments should be kept short. (These limitations would also have applied to a small force plate.)

For the amputees, the general pattern was:

3 measurements of weight and static weight distribution between the feet to enable forces to be normalised to the weight and to find out whether the static weight distribution between the feet was repeatable enough to be useful. During measurement of weight and distribution of weight between subject's feet, the subject was asked to stand on both of the platforms, facing in the direction of decreasing x, for approximately three seconds.
This was repeated three times, with the subject stepping on and off the walkway each time. The subject was not told that distribution of weight between the feet was being measured.

10 trials at self-selected normal speed.
4 trials at self-selected slow speed.
4 trials at self-selected fast speed.
(4 trials at self-selected very fast speed where the subject felt capable of this)

It was decided to perform 10 trials at normal speed as this is the most functionally important speed, but also to perform a smaller number of trials at the other speeds. $10 + 4 + 4 = 18$ trials seemed to be what could be achieved in an acceptable amount of time. This number of trials is quite time-consuming and is quite tiring for the more disabled of the group so it did not seem appropriate to increase the number of trials above this.

For the adult joint replacement patients, the general pattern was:

3 measurements of weight and static weight distribution between the feet

10 trials at self-selected normal speed

The two miscellaneous adult subjects performed different numbers of trials. One of them followed the pattern for the amputees. The child subjects performed different numbers of trials.

The subjects' relevant medical histories and the technical details of the prostheses were obtained from the subject's medical records.

One of the main objectives of the project was to assess the walkway's likely performance in the routine clinical context. As part of this, it was necessary to choose a rational method of assessing the data gained. The statistics used below were chosen as a way of doing this.

It was necessary to choose a group of variables to be analysed. These variables were chosen to be a cross-section of the walkway's capabilities
(i.e. forces, lengths and times) and because they were expected to have some significance in assessment of function. The number of variables was set as 12 in order to keep the volume of data within reasonable limits whilst giving a good indication of the features of the walkway's data. Also the occurrence of error messages (particularly crossover, highlyunequalnumbersofsteps, negativedoublestancetimes, outoftime and toomanysteps) was examined so that unsuitable data could be eliminated and modifications to software could be suggested.

The variables chosen were:

1. **Velocity.** This is a basic index of walking function, used by Baker and Hewison (1990) to study the gait recovery pattern of unilateral amputees during rehabilitation, by Andriacchi et al (1977) to measure the recovery of knee patients after joint replacements, by Wall et al (1981) to measure the effect of hip replacement and by Gifford and Hughes (1983) to monitor total hip replacement and juvenile chronic arthritis patients. It was decided to compare speed but it was regarded with care because it was unrepeatable in normals. Also, if a subject walks too fast their stride lengthens so that the walkway does not capture a whole stride. This means that the trials at higher speed tend to be eliminated so the assessment is biased.

2. **Stance time symmetry ratio.** Values close to zero indicate good symmetry: that the stance time on the 'damaged' leg is equal to that on the 'undamaged' leg. This variable was used by Baker and Hewison (1990) to study the gait recovery pattern of unilateral amputees during rehabilitation and by Wall et al (1981) to measure the effect of hip replacement.

3. **One of the step lengths.** For unilateral amputees, the data from the prosthetic leg was used. Only one was analysed, in order to keep the amount of data manageable. During rehabilitation, the prosthetist attempts to
equalise step length (Hurley et al, 1990). Step lengths were used by Wall et al (1981) to measure the effect of hip replacement and by Gifford and Hughes (1983) to monitor total hip replacement and juvenile chronic arthritis patients. Stride length was found by Vaughan et al (1988, 1991) to improve in patients with spastic cerebral palsy who underwent selective posterior rhizotomy. Brodke et al (1989) found no significant difference in stride length when children's barefoot walking was compared with their walking with ankle-foot orthoses.

4. 5 and 6 First and second peak force and minimum force symmetry ratios. Values close to zero indicate good loading of the damaged leg in walking. If the joint forces in the contralateral limb exceed natural limits, the individual may be predisposed to premature degenerative arthritis (Lewallen et al, 1986). Seliktar and Mizrahi (1986), using amputees, found that 'Peak vertical forces and their ratios were not found meaningful in representing locomotor problems.'

7. 8 and 9 First and second peak force and minimum force, one leg. For unilateral amputees, the data from the prosthetic leg was used. Prostheses sometimes break during use. Possibly walkway assessment of subjects could be used in order to prescribe stronger prostheses for particular patients. Andriacchi et al (1977), with knee replacement patients, found that the foot ground reaction force amplitudes were not as sensitive an indicator of gait abnormalities as temporal measurements. Khodadadeh (1987) found that an accurate assessment of pre- and post-operative hip osteoarthritic gait could be made, but only by reference to the horizontal as well as vertical force curves. There is an association between stance phase flexion of the knee and a dip at mid stance in the vertical component of force (Whittle, 1991).
Second peak force timing, one leg. It was desired to include another time parameter. For the unilateral amputees, the data from the prosthetic leg was used.

Impulse symmetry ratio. The prosthetist strives to achieve a symmetrical gait pattern (Hurley et al, 1990). According to Seliktar and Mizrahi (1986), working with amputees, vertical impulse ratio is sensitive to the quality of performance and can only serve as an overall performance index.

Standing forces symmetry ratio. A value close to zero indicates good loading of the damaged leg in standing.

Step width was not analysed because it was found in chapter 3 to be unsuitable.

According to Davis (1988), techniques and technologies that work well to measure and assess normal gait patterns, often fail when applied to pathological gait. The analysis was expected to show whether the parameters were useful in the context of the different pathologies.

Analysis:

1 For one subject in each of the four subject groups (for reasons of space), graphs of speed and the variation of the other 10 gait variables listed above with speed were plotted, as in section 3.3.3.4. Least-squares best fit lines were superimposed on the data. Only the first value of a variable in a traverse was plotted and analysed (i.e. subsequent steps were ignored). Otherwise the graphs would have been very cluttered and the analysis would have been more complicated.

Typical individual traverse printouts were also included as appropriate.

2 The tests assessed the robustness of the algorithms. Some subjects' gaits gave corrupted results due to peculiar features of the gait and the
need for further development of the algorithms. This was commented on for each group of subjects (and suggested improvements are described in section 5.2.2).

3 For each subject and each treatment, statistical tests (coefficient of determination and F-tests) were performed on the best fit lines for the 10 variables as in chapter 3 in order to assess the quality of the description of the gait. (The statistics used are described in section 3.3.3.4.)

From section 3.3.3.4, the coefficient of determination varies between 1 when the data falls on a perfect straight line and 0 when a straight line relationship is of no use in describing the data. Applied to a plot of a gait variable against speed, a high value of coefficient of determination means that the data falls close to a straight line. This means that the pattern of the measurements of the gait variable with speed is close to linear and that the amount of scatter is small, so the data is likely to have given an accurate indication of the underlying trend. A low coefficient of determination indicates that the data is very scattered and/or non-linear so the data is likely to have given a less accurate indication of the underlying trend. Since the gait analyses aim to find the underlying trend of each variable with speed, the coefficient of determination is an indicator of the effectiveness of the assessment for different subjects/treatments and gait parameters.

From section 3.3.3.4, if an F-test using $p<0.05$ is positive, this means that there is only a 5% chance of obtaining the observed relationship by chance. Applied to a plot of a gait variable against speed, a positive F-test means that the variation of the gait parameter with speed is statistically significant. Since the gait assessments aim to provide statistically significant information on the underlying trend of each variable with speed, then when one considers a collection of F-tests corresponding to say one subject and one treatment, the proportion of the F-tests which are
positive gives an indication of the effectiveness of the assessment for that subject and treatment.

An arbitrary cut-off point of 50% was used, i.e. if more than 50% of F-tests were positive it was concluded that the amount of information from the walkway was enough to be clinically useful.

4 Where the subject was tested with more than one treatment (e.g. subject 6 with 3 different prostheses) statistical tests on the behaviour of the 10 variables with speed were performed. The tests were as decided from the consistency tests (see section 3.3.3.4): each of the 10 gait variables listed above was plotted against speed and t-tests (p<0.05) for all the slope values and t-tests (p<0.01) for the intercepts at speed = 1.29m/s, excluding the intercept for first peak force were performed. Since the comparison of assessments aims to show statistically significant differences between the underlying trends of each gait variable with speed for the different treatments, the proportion of positive t-tests is an indication of how successful the system was in detecting differences between conditions.

Arbitrarily I have taken a cut-off point of 50%, i.e. if more than 50% of t-tests were positive I concluded that the amount of information from the walkway was enough to be clinically useful.

5 The percentage of times a complete stride (3 valid footfalls) was registered in a traverse was found at each speed for a few key subjects. For the length of the platform to be adequate it must capture the information from a complete stride during a traverse for most traverses for all subjects and all speeds.

6 The time taken by each assessment and the number of trials in the assessment were tabulated and the statistics were commented on in order to put the quality of information obtained into the context of how long it took to obtain.
7 Statistical tests (t-tests for 2 treatments and analyses of variance for more than 2 treatments) were performed for standing force symmetry ratio to determine whether this variable could show differences between conditions (e.g. different prostheses).

4.2 Adult amputees

4.2.1 Adult amputees: method

Each subject was tested wearing their own prosthesis/prostheses. If they could bring a spare prosthesis or prostheses they were also tested in these. The subjects wore their normal footwear. They wore the same footwear with each prosthesis. The footwear affects the biomechanics: for example heel height affects knee stability.

It was hoped to show that the walkway could detect differences between different prostheses of the same subject. If the walkway could not detect these differences in a reasonable number of trials it seemed unlikely that it would be useful for prescription of a more appropriate prosthesis for a particular patient. The prostheses each subject brought were generally of varying design so the differences between them were expected to be greater than between different adjustment settings of the same prosthesis. If the walkway could not detect the changes in this experiment, it seemed unlikely that it would be useful in adjustment of prostheses.

No experiments to explore the effectiveness of the walkway in assessing rehabilitation were performed. It seems plausible, provided the results of the planned experiments are encouraging, that the walkway could be useful in measuring these changes.

Figure 4.1 shows an above-knee amputee undergoing assessment.
The subjects studied were 13 unilateral amputees: 3 below knees, 2 through knees, 6 above knees and 2 hip disarticulations; and 3 bilateral amputees: one bilateral absent feet, one right above knee, left below knee and one bilateral above knee. The detailed list is in Appendix 4.1.

4.2.2 Adult amputees: results and discussion

The subjects' personal data and the technical details of their prostheses are shown in Appendix 4.1. There were 14 males and 2 females. The subjects' ages ranged from 26 to 61 years (mean 43). The subjects' statures ranged from 1.55m to 1.91m (mean 1.76m). The subjects' weights ranged from 40.2kgf to 116.6kgf (mean 77.2kgf).

Subject 24 (right hip disarticulation) was tested using a stick in his left hand. Subject 42 (right above knee, left below knee) was tested carrying his 2 sticks for confidence. He had a very wide gait naturally, so he looked at the marks on the wall rather than needing to look down.
The numbers of treatments and numbers of trials per treatment for each subject are shown in Appendix 4.2.

Two subjects commented that they felt that they were walking abnormally or with their feet abnormally wide apart. Some of the subjects commented that they had to concentrate in order to clear the centre line or that the built-up area was not long enough, especially to go fast.

Of the causes of unusable traverses, the worst appeared to be failing to clear the centre line of the walkway. Subject 18 (bilateral absent feet) had the worst percentage (9/32 = 28%) of extra trials needed due to this. The other amputees all needed 8% or fewer. Some subjects lost one or two trials due to atypical gait. A few percent of trials were lost due to operator error. None of these problems were serious enough to cast doubt on the walkway's clinical potential.

4.2.2.1 Graphs

Some of the data for subject 6 (right above knee) are shown as examples.

Figure 4.2 shows the speeds for subject 6, prosthetic legs a, b and c. This shows that for example 'slow' speed was not the same speed for all three prostheses, and that faster trials tend to be lost because the stride length increases with speed, so there is less chance of the walkway capturing a complete stride. Figures 4.3, 4.4, 4.5, 4.6 and 4.7 show examples from the other 10 gait parameters plotted against speed. Figure 4.3 shows data relatively poorly represented by straight lines. Figure 4.4 shows data relatively well represented by straight lines. Figure 4.5, the first peak force graph and figure 4.6, the minimum force graph look as though they might be better modelled by parabolas. 2nd peak force timing for leg c (figure 4.7) varies discontinuously; many of the results are just above 50%. This is because the largest force in the second half of the stance was not
Figure 4.2: velocities for subject 6
Figure 4.3: stance time symmetry ratio for subject 6 (right above knee amputee)
Figure 4.4: right step length for subject 6 (right above knee amputee)
Figure 4.5: first peak force, right (prosthetic) leg for subject 6 (right above knee amputee)
Figure 4.6: minimum force, right (prosthetic) leg for subject 6 (right above knee amputee)
Figure 4.7: second peak force timing, right (prosthetic) leg for subject 6 (right above knee amputee)
always a peak, i.e. the parameter extracted from the data by the algorithms did not vary continuously.

To illustrate the range of the data, figure 4.8 shows subject 28 (right below knee) walking fast, figure 4.9 shows subject 40 (bilateral above knee) walking slowly and figure 4.10 shows subject 18 (bilateral absent feet) walking at his normal speed.

4.2.2.2 Assessment of the robustness of the algorithms

Trials lost due to the need for further development of the algorithms:

Unilateral amputees

Subject 4 (left above knee): trial 155 was lost due to error code 'negativedoublestancetimes'. A footfall of which the toe was only just on the walkway was registered twice.

Bilateral amputees

Subject 18 (bilateral absent feet): trial 43 was lost due to double registration of one step because this subject's minimum force peak is so low, particularly at 'very fast' speed which this trial is.

Only two trials were lost due to problems with the algorithms while testing the 16 subjects. However, it is troublesome to have to check for this so it is recommended that the problem should be addressed (see section 5.2.2).

4.2.2.3 Statistical tests for gait

The coefficients of determination for the amputees were calculated. The values vary widely with subject, treatment and gait variable, from 0.00 to 0.99. The overall mean is 0.42. A two-way analysis of variance (p<0.05) using Microsoft Excel version 4 was performed in order to determine the effects of subject, treatment and gait variable. This showed that there was
Figure 4.8: sample results: subject 28 (right below knee amputee), walking at his 'fast' speed

--- Data from University of Surrey gait assessment walkway ---
--- record name=250 ---

--- top of screen: platform 1 ---
--- bottom of screen: platform 2 ---

Direction of travel: →
length of vector represents magnitude of vertical force

time interval between vectors = 0.0025 seconds

platform 1

platform 2

Direction of travel: -->
Figure 4.9: sample results: subject 40 (bilateral above knee amputee), walking at her 'slow' speed

--- Data from University of Surrey gait assessment walkway ---

--- Record name ---

--- Right of vertical metres versus time for each platform ---

solid line: platform 1 (left foot)
broken line: platform 2 (right foot)

centre of pressure on each platform

direction of travel:

--- top of screen: platform 1 ---

direction of travel:

--- bottom of screen: platform 2 ---

--- Record name ---
length of vector represents magnitude of vertical force

time interval between vectors = 0.8188 seconds

platform 1

platform 2

Direction of travel: -->
Figure 4.10: sample results: subject 18 (bilateral absent feet), walking at his 'normal' speed

solid line: platform 1 (right foot)
broken line: platform 2 (left foot)

top of screen: platform 1
bottom of screen: platform 2

Direction of travel: <—
length of vector represents magnitude of vertical force
time interval between vectors = 0.8825 seconds

Direction of travel:<—
significant variation in coefficient of determination with both subject/treatment and gait variable.

The table below shows how mean coefficient of determination varied with amputation level:

<table>
<thead>
<tr>
<th>Amputation Type</th>
<th>Mean coefficient of determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral below knee</td>
<td>0.52</td>
</tr>
<tr>
<td>Unilateral through knee</td>
<td>0.36</td>
</tr>
<tr>
<td>Unilateral above knee</td>
<td>0.45</td>
</tr>
<tr>
<td>Unilateral hip disarticulation</td>
<td>0.32</td>
</tr>
<tr>
<td>Bilateral absent feet</td>
<td>0.44</td>
</tr>
<tr>
<td>Above knee, below knee</td>
<td>0.30</td>
</tr>
<tr>
<td>Bilateral above knee</td>
<td>0.10</td>
</tr>
</tbody>
</table>

This shows that increasingly high amputation level tends to lead to lower coefficient of determination. It can be shown that narrower speed range leads to lower coefficient of variation. The higher level amputees would be expected not to be able to achieve such a wide speed range, so this may account for their lower coefficients of determination.
The table below shows how mean coefficient of determination varied with gait parameter:

<table>
<thead>
<tr>
<th>Gait parameter</th>
<th>Mean coefficient of determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>step length</td>
<td>0.77</td>
</tr>
<tr>
<td>minimum force</td>
<td>0.69</td>
</tr>
<tr>
<td>second peak force symmetry ratio</td>
<td>0.45</td>
</tr>
<tr>
<td>first peak force</td>
<td>0.42</td>
</tr>
<tr>
<td>second peak force timing</td>
<td>0.40</td>
</tr>
<tr>
<td>minimum force symmetry ratio</td>
<td>0.39</td>
</tr>
<tr>
<td>first peak force symmetry ratio</td>
<td>0.33</td>
</tr>
<tr>
<td>second peak force</td>
<td>0.30</td>
</tr>
<tr>
<td>impulse symmetry ratio</td>
<td>0.25</td>
</tr>
<tr>
<td>stance time symmetry ratio</td>
<td>0.21</td>
</tr>
</tbody>
</table>

This means that the quality of description of the behaviour of the gait variable with speed by a straight line varied widely with gait variable.

The observed F-statistics for the amputees were calculated. The values vary widely with subject, treatment and gait variable, from 0.00 to 877.79. The critical F-statistics for the amputees were also calculated. They range between 4.49 and 7.71. When the F-tests were performed, the mean number of significant tests was 5.4, i.e. the walkway gave a statistically significant straight line 54% of the time, which is much greater than the 5% which one would expect through chance alone and exceeds the 50% arbitrarily set by the author to mean that the data contained enough information to be clinically useful.
The table below shows how the percentage of positive F-tests varied with amputation level:

<table>
<thead>
<tr>
<th>Amputation Level</th>
<th>Percentage of positive F-tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral below knee</td>
<td>56%</td>
</tr>
<tr>
<td>Unilateral through knee</td>
<td>53%</td>
</tr>
<tr>
<td>Unilateral above knee</td>
<td>53%</td>
</tr>
<tr>
<td>Unilateral hip disarticulation</td>
<td>50%</td>
</tr>
<tr>
<td>Bilateral absent feet</td>
<td>45%</td>
</tr>
<tr>
<td>Above knee, below knee</td>
<td>30%</td>
</tr>
<tr>
<td>Bilateral above knee</td>
<td>20%</td>
</tr>
</tbody>
</table>

There is a trend of decreasing number of significant results for increasingly high amputation level. This is also consistent with a decreasing speed range at high amputation level.

The F-test significances for each gait parameter are shown below.

<table>
<thead>
<tr>
<th>Gait parameter</th>
<th>Number of significant tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>step length</td>
<td>28/29 = 97%</td>
</tr>
<tr>
<td>minimum force</td>
<td>25/29 = 86%</td>
</tr>
<tr>
<td>second peak force symmetry ratio</td>
<td>15/29 = 52%</td>
</tr>
<tr>
<td>first peak force</td>
<td>15/29 = 52%</td>
</tr>
<tr>
<td>minimum force symmetry ratio</td>
<td>14/29 = 48%</td>
</tr>
<tr>
<td>second peak force timing</td>
<td>14/29 = 48%</td>
</tr>
<tr>
<td>first peak force symmetry ratio</td>
<td>12/29 = 41%</td>
</tr>
<tr>
<td>second peak force</td>
<td>9/29 = 31%</td>
</tr>
<tr>
<td>impulse symmetry ratio</td>
<td>8/29 = 28%</td>
</tr>
<tr>
<td>stance time symmetry ratio</td>
<td>7/29 = 24%</td>
</tr>
</tbody>
</table>
The proportion of significant tests varies very widely with gait parameter. Step length and minimum force give over 85% significant values. This is analogous to the results for coefficient of determination, where these two parameters gave significantly more linear values than the others. The other variables only gave significant results a quarter to half of the time. All of the variables gave far more than the 5% significant results which one would expect by chance. First and second peak force gave 52% and 31% respectively. As mentioned above, 'second peak force' from the algorithms corresponds less often than 'first peak force' with an actual peak, i.e. varies less continuously. This would explain the poorer statistical significance. First, second and minimum peak force symmetry ratio gave positive results 41%, 52% and 48% of the time respectively. The poor reliability of the second peak force values seems to be less obvious when the two sides of the body are compared but the values but some of the values must still not correspond to actual peaks. Impulse symmetry ratio and stance time symmetry ratio gave significant results only 28% and 24% of the time respectively. This means that the scatter/nonlinearity of values is large compared with the trend with velocity. Figures 4.3 to 4.7 show that scatter is more apparent than nonlinearity.

The slope values, the standard errors of the slopes for the amputees, the intercepts at speed = 1.29m/s and their corresponding standard errors were calculated. From these, the observed t-tests were calculated. The critical t-values were found from tables. The mean number of significant results was 2.2, i.e. 22%, and for 4 (i.e. 25%) of the comparisons there are no statistically significant results. This is far more than the 5% that one would expect by chance alone but less than the 50% arbitrarily set by the author to mean that the data from the walkway contained enough information to be clinically useful.
Tabulating the results by amputation level as for the F-tests:

<table>
<thead>
<tr>
<th>Unilateral amputees:</th>
<th>Percentage of positive t-tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral below knee</td>
<td>27%</td>
</tr>
<tr>
<td>Unilateral through knee</td>
<td>30%</td>
</tr>
<tr>
<td>Unilateral above knee</td>
<td>25%</td>
</tr>
<tr>
<td>Unilateral hip disarticulation</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Bilateral amputees:**

| Bilateral absent feet                        | 0%                            |
| Above knee, below knee                       | -                             |
| Bilateral above knee                         | -                             |

The results show no trend with amputation level.

The slope t-test results are tabulated by gait parameter below.

<table>
<thead>
<tr>
<th>Gait parameter</th>
<th>Number of significant tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>first peak force symmetry ratio</td>
<td>6/16 = 38%</td>
</tr>
<tr>
<td>minimum force</td>
<td>5/16 = 31%</td>
</tr>
<tr>
<td>second peak force</td>
<td>5/16 = 31%</td>
</tr>
<tr>
<td>step length</td>
<td>4/16 = 25%</td>
</tr>
<tr>
<td>minimum force symmetry ratio</td>
<td>4/16 = 25%</td>
</tr>
<tr>
<td>second peak force timing</td>
<td>4/16 = 25%</td>
</tr>
<tr>
<td>stance time symmetry ratio</td>
<td>3/16 = 19%</td>
</tr>
<tr>
<td>second peak force symmetry ratio</td>
<td>2/16 = 12%</td>
</tr>
<tr>
<td>impulse symmetry ratio</td>
<td>2/16 = 12%</td>
</tr>
<tr>
<td>first peak force</td>
<td>1/16 = 6%</td>
</tr>
</tbody>
</table>

The best variable (first peak force symmetry ratio) gave significant differences 38% of the time, which is less than the arbitrary 50% cutoff set by the author to mean that the walkway data is useful, so even by selecting a subset of these variables, one cannot achieve the 50% target. The worst
variable, first peak force, gave significant differences only 6% of the time, which is virtually the same as the 5% one would expect from chance alone.

The observed values of t to be used in the t-tests for intercepts at speed = 1.29m/s were calculated, as were the corresponding critical values of t. The mean proportion of significant results in these tests was 24%. This is far more than the 1% that one would expect by chance alone but does not reach the arbitrary 50% target set by the author to mean that the data from the walkway contains enough information to be clinically useful.

Tabulating the results by amputation level as for the slope t-tests:

**Unilateral amputees:**
- Unilateral below knee: 33%
- Unilateral through knee: 33%
- Unilateral above knee: 22%
- Unilateral hip disarticulation: 11%

**Bilateral amputees:**
- Bilateral absent feet: 22%
- Above knee, below knee: -
- Bilateral above knee: -

The results show a trend with amputation level: the walkway can show more significant differences between the intercepts at speed = 1.29m/s for different prostheses for lower amputation levels. For the higher level amputees the intercept at 1.29m/s was extrapolated while for the lower level amputees it was interpolated. This could explain the results seen.
Looking at the intercept t-test results by gait parameter:

<table>
<thead>
<tr>
<th>Gait parameter</th>
<th>Number of significant tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>second peak force timing</td>
<td>6/16 = 38%</td>
</tr>
<tr>
<td>first peak force symmetry ratio</td>
<td>5/16 = 31%</td>
</tr>
<tr>
<td>minimum force</td>
<td>5/16 = 31%</td>
</tr>
<tr>
<td>second peak force</td>
<td>5/16 = 31%</td>
</tr>
<tr>
<td>step length</td>
<td>5/16 = 31%</td>
</tr>
<tr>
<td>impulse symmetry ratio</td>
<td>4/16 = 25%</td>
</tr>
<tr>
<td>minimum force symmetry ratio</td>
<td>3/16 = 19%</td>
</tr>
<tr>
<td>stance time symmetry ratio</td>
<td>1/16 = 6%</td>
</tr>
<tr>
<td>second peak force symmetry ratio</td>
<td>1/16 = 6%</td>
</tr>
</tbody>
</table>

The best variable, second peak force timing (not the same variable as in the slope t-tests) gives significant differences 38% of the time, which did not reach the arbitrary 50% cutoff point mentioned above. Stance time symmetry ratio and second peak force symmetry ratio gave results virtually the same as one would expect by chance.

4.2.2.4 Percentage of times a complete stride was registered in a traverse

From observation of the subjects the percentage of times a complete stride was registered in a traverse was expected to be greatest for short, high-level amputees walking at their 'slow' speed. Three subjects were chosen in order to estimate the range of variation.

Tallest subject

This was subject 28 (right below knee) who was 1.91m (6' 3") tall.

Below-knee subject closest to the mean height for all the amputees

The mean height was 1.76m. The below-knee amputee closest to this was subject 33 (1.79m).
Shortest subject, who was also the highest level amputee

This was subject 40 who was 1.55m (5'1") tall.

The results are tabulated below.

<table>
<thead>
<tr>
<th></th>
<th>'slow'</th>
<th>'normal'</th>
<th>'fast'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tallest subject</td>
<td>100</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>below-knee subject closest to mean height</td>
<td>100</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>shortest subject, highest level amputee</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

The walkway is not long enough to record a complete stride during a traverse for most traverses for all subjects and speeds, so for routine clinical use with amputees it must be redesigned to be longer.

4.2.2.5 Time taken

The number of trials, time taken and time taken per trial are in Appendix 4.3. The minutes per trial range from 0.79 to 4.56. The longer times probably included more chatting, plus waiting for the video to be set up (which is not due to the walkway). The average time taken per trial was 1.61 minutes, so for one prosthesis and 21 trials (3 weight, 10 normal, 4 slow, 4 fast) the estimated average time necessary is 21 x 1.61 minutes = 34 minutes. Arbitrarily taking 30 minutes as a maximum allowable duration for an assessment using the walkway in the clinical context, it would not be possible to increase the quality of the data by increasing the number of trials unless the time taken per trial could be reduced.

4.2.2.6 Statistical tests for standing force symmetry ratio

As stated above (in section 4.1), statistical tests (t-tests for 2 treatments and analyses of variance for more than 2 treatments) were
performed for standing force symmetry ratio to determine whether this variable could show differences between conditions (e.g. different prostheses).

For one subject (29) the result of the t-test was significant. For 9 subjects (23, 41, 3, 4, 5, 6, 7, 8, 18) it was insignificant. For the other 6 subjects it was not applicable. One would expect $5\% \times 10 = 0.5$ i.e. 0 or 1 significant differences by chance alone, so this variable does not vary statistically significantly between prostheses, so it appears that it would not be useful for clinical assessment in amputees.

4.2.3 Adult amputees: conclusions

The walkway requires modifications if it is to be used routinely with amputees who use walking aids.

Some subjects felt that they were walking abnormally but all of those tested could complete the test, with less than 8% extra trials in all but one case. A few extra trials were needed due to operator error and atypical gait. None of these problems were serious enough to cast doubt on the walkway's clinical potential.

The algorithms for second and minimum force peaks do not always identify peak values. This means that the results often vary discontinuously with speed which is undesirable in the analysis used, which fits straight lines to the data. Two trials were lost due to other imperfections in the algorithms. These problems should be addressed (see section 5.2.2).

The analysis assuming all gait variables vary linearly with speed should be improved upon, by fitting non-linear curves where appropriate.

The mean coefficient of determination was 0.42. It varied statistically significantly with subject/prosthesis (0.66 down to 0.10, lower at higher
amputation level, probably due to narrower speed range) and with gait
cParameter (0.77 down to 0.21).

The F-tests showed that the walkway gave a statistically significantly
straight line 54% of the time (range 20% to 80% for different
subjects/prostheses, apparently slightly higher at lower amputation
levels). This exceeded the arbitrary 50% cutoff set by the author, so the
amount of information from the walkway was concluded to be enough to be
clinically useful. By gait parameter, step length gave significant F-tests
97% of the time, and at the other end of the range, stance time symmetry
ratio only 24% of the time.

The mean number of significant t-tests for slope was 22%, which was
less than the 50% minimum arbitrarily set, so it indicated that the walkway
is not useful in the clinical context. It did not depend on amputation level
but varied from 38% to 6% with gait parameter, so even the best parameter
gave significant results less than 50% of the time.

The mean number of significant t-tests for intercept was 24%, which
was less than the 50% minimum arbitrarily set, so it indicates that the
walkway is not useful in the clinical context. There were more significant
differences at lower amputation level. For the higher level amputees the
intercept at 1.29m/s was extrapolated while for the lower level amputees it
was interpolated. This could explain the results seen. It also varied from
38% to 6% by gait parameter, so even the best parameter gave significant
results less than half of the time.

If this analysis is to be used in the future, it will be important to use
the maximum practical speed range and number of traverses for each
subject in order to improve the data's statistical significance.

The walkway was not long enough to record a complete stride during
a traverse for most traverses for all subjects and speeds, so for routine
clinical use with amputees it must be redesigned to be longer (see section 5.2.1.5).

Arbitrarily taking 30 minutes as a maximum allowable duration for an assessment using the walkway in the clinical context, it would be unfeasible to increase the quality of the data by increasing the number of trials unless the time taken per trial could be reduced.

Standing force symmetry ratio as measured was not found to be useful for comparing prostheses.

The statistical results for the t-tests did not pass the arbitrary threshold for clinical usefulness, so this suggests that the system is not likely to be clinically useful for these subjects. However, it must be remembered that this conclusion was reached for the current prototype of the system, the speed range and number of trials used, the gait variables chosen and the statistical analysis used, so if any of these parameters were changed, a different conclusion might be reached. In chapter 5, it is recommended that modifications to these parameters are made and that the system is re-assessed.

4.3 Joint replacement adults
4.3.1 Joint replacement adults: method

The operations studied were 3 right total knee replacements, 2 right total hip replacements and one left total hip replacement.

The personal data of the subject were recorded. The subject's weight and distribution of weight between their feet was measured three times. The subject's gait was measured as they walked along the walkway 10 times at normal speed (or as many times as possible if 10 was not possible). Practice trials were not used in an effort to minimise pain and fatigue.

A brief questionnaire was administered. It asked whether the subjects found the testing environment intimidating, because a non-
intimidating environment for the subjects was considered by Davis (1988) to be necessary for successful gait analysis. It was also designed to assess whether the amount of standing and walking involved in the test (10 traverses) was fatiguing the subjects and to ascertain whether they felt that they were walking with their typical gait without walking aids.

4.3.2 Joint replacement adults: results and discussion

The subjects' personal data are shown in Appendix 4.4 and summarised below.

<table>
<thead>
<tr>
<th>Females</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>1</td>
</tr>
<tr>
<td>Stature range</td>
<td>1.49m-1.74m (mean 1.58m)</td>
</tr>
<tr>
<td>Age range</td>
<td>62 to 80 years (mean 72)</td>
</tr>
<tr>
<td>Time between first test and operation</td>
<td>3 - 21 days (mean 16 days)</td>
</tr>
<tr>
<td>Time between operation and second test</td>
<td>87 - 109 days (2.9 - 3.6 months) (mean 96 days)</td>
</tr>
</tbody>
</table>

One subject could not be tested after her operation because it had been delayed too much. Of the five subjects who were retested, 4 wore the same shoes on the two occasions and the other wore shoes of the same height.

The subjects' medical data are shown in Appendix 4.5. This information was gathered by Sister Harris from the patients' medical records.

Information from the check-list which Sister Harris uses to prioritise the patients for operations is shown in Appendix 4.6. Five patients had constant pain and one did not. All patients had limited mobility. Four could climb stairs, one could not and for one the information was not available. The distance one subject could walk was not available.
The others could walk between 100yds (90m) and 1/2 mile (800m). For one subject, the information as to mobility aids was not available. Three subjects normally walked with a stick and two did not use a walking aid.

The results of the subject questionnaire are shown in Appendix 4.7. One subject on the second occasion, found the set-up intimidating. Around half of the subjects found the test fatiguing. The final question did not yield useful information because it had been phrased poorly.

Appendix 4.8 shows the numbers of treatments and trials for each subject. One subject could only manage 4 trials on the first occasion and 3 trials on the second occasion. After this she was unable to maintain a straight line.

The mean percentage of extra trials needed due to the subjects failing to clear the centre line was 22%. The range was from 10% to 100%.

### 4.3.2.1 Graphs

Figures 4.11 to 4.13 show some results for subject 34 (right total knee replacement) as examples. To illustrate the range of the data, figure 4.14 shows one traverse for subject 34, post-operatively and figure 4.15 shows one traverse from subject 37, pre-operatively.

### 4.3.2.2 Assessment of the robustness of the algorithms

For subject 38, trial 828 was lost due to double registration of a low force step at the beginning. As for the amputees, this was only a minor, although troublesome, cause of unusable traverses.

### 4.3.2.3 Statistical tests for gait

The coefficients of determination for the joint replacement subjects were calculated. The values vary widely with subject, pre- and post-op, and gait variable, from 0.0 to 0.75. The overall mean is 0.26, i.e. a straight line
Figure 4.11: velocity for subject 34 (elderly right total knee replacement patient)
Figure 4.12: stance time symmetry ratio for subject 34 (elderly right total knee replacement patient)
Figure 4.13: right step length for subject 34 (elderly right total knee replacement patient)
Figure 4.14: Sample results: subject 34 (elderly right total knee replacement patient), walking at his 'normal' speed, post-operatively.

--- Data from University of Surrey gait assessment walkway ---

Record name = 878

--- Record name = 878 ---

* Solid line: platform 1 (right foot)
* Broken line: platform 2 (left foot)

--- Direction of travel: <<--- ---
length of vector represents magnitude of vertical force

Time interval between vectors = 0.0025 seconds

Platform 1

Platform 2

Direction of travel: <-
Figure 4.15: Sample results: subject 37 (elderly right total hip replacement patient), walking at her 'normal' speed, pre-operatively

*-- Data from University of Surrey gait assessment walkway --*

record name=626

---

solid line: platform 1 (left foot)
broken line: platform 2 (right foot)

Direction of travel: -->

top of screen: platform 1
bottom of screen: platform 2
length of vector represents magnitude of vertical force

time interval between vectors=0.0188 seconds

platform 1

platform 2

Direction of travel:-->
describes the data more poorly than for the amputees. This is probably
because of the narrow speed range used. A two-way analysis of variance
(p<0.05) using Microsoft Excel version 4 in order to determine the effects of
subject, treatment and gait variable, showed that there was significant
variation in coefficient of determination with both factors.

The table below shows how mean coefficient of determination varied
with gait parameter:

<table>
<thead>
<tr>
<th>Gait parameter</th>
<th>Mean coefficient of determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>step length</td>
<td>0.47</td>
</tr>
<tr>
<td>first peak force</td>
<td>0.37</td>
</tr>
<tr>
<td>minimum force</td>
<td>0.31</td>
</tr>
<tr>
<td>second peak force timing</td>
<td>0.26</td>
</tr>
<tr>
<td>minimum force symmetry ratio</td>
<td>0.23</td>
</tr>
<tr>
<td>first peak force symmetry ratio</td>
<td>0.22</td>
</tr>
<tr>
<td>second peak force symmetry ratio</td>
<td>0.20</td>
</tr>
<tr>
<td>second peak force</td>
<td>0.19</td>
</tr>
<tr>
<td>impulse symmetry ratio</td>
<td>0.16</td>
</tr>
<tr>
<td>stance time symmetry ratio</td>
<td>0.16</td>
</tr>
</tbody>
</table>

This means that the quality of description of the behaviour of the
gait variable with speed by a straight line varied widely with gait variable.

The observed F-statistics for the joint replacement subjects, and the
critical F-statistics were found. The results of the F-tests showed that the
mean proportion of significant tests is 15%, which is greater than the 5%
which one would expect through chance alone. This is a much smaller
proportion than for the amputees and falls below the arbitrary 50%
required for clinical usefulness. With wider speed range and more
traverses per subject it would be expected to improve.
The F-test significances are shown by gait parameter below.

<table>
<thead>
<tr>
<th>Gait parameter</th>
<th>Number of significant tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>step length</td>
<td>6/11 = 55%</td>
</tr>
<tr>
<td>first peak force</td>
<td>3/11 = 27%</td>
</tr>
<tr>
<td>minimum force</td>
<td>2/11 = 18%</td>
</tr>
<tr>
<td>second peak force timing</td>
<td>2/11 = 18%</td>
</tr>
<tr>
<td>second peak force symmetry ratio</td>
<td>1/11 = 9%</td>
</tr>
<tr>
<td>first peak force symmetry ratio</td>
<td>1/11 = 9%</td>
</tr>
<tr>
<td>second peak force</td>
<td>1/11 = 9%</td>
</tr>
<tr>
<td>minimum force symmetry ratio</td>
<td>0/11 = 0%</td>
</tr>
<tr>
<td>impulse symmetry ratio</td>
<td>0/11 = 0%</td>
</tr>
<tr>
<td>stance time symmetry ratio</td>
<td>0/11 = 0%</td>
</tr>
</tbody>
</table>

These are much lower proportions than for the amputees, probably due to the narrower speed range and smaller number of trials. Only one variable (step length) gave a significant result over half of the time. 3 of the gait parameters gave no significant results. As before, second peak force gave poorer statistical significance than first peak force, probably due to discontinuous variation due to the algorithms as mentioned above.

The slope values and intercepts at speed = 1.29m/s and their corresponding standard errors for the joint replacement subjects were calculated. These values were used in the t-tests. The observed values of t and the critical values of t were found and compared. The numbers of significant results were 0 each for subjects 34, 35 and 37; and 2 each for subjects 38 and 39. These results do not reach the arbitrary 50% cutoff, so the amount of data is not considered enough to be clinically useful. The mean proportion significant results is 8%. By chance alone, one would expect 5% x 50 = 2.5 positive tests. 4 were obtained. The results are thus hardly better than one would expect by chance.
The slope t-test results are tabulated by gait parameter below.

<table>
<thead>
<tr>
<th>Gait parameter</th>
<th>Number of significant tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>first peak force symmetry ratio</td>
<td>1/5 = 20%</td>
</tr>
<tr>
<td>minimum force</td>
<td>1/5 = 20%</td>
</tr>
<tr>
<td>step length</td>
<td>1/5 = 20%</td>
</tr>
<tr>
<td>second peak force symmetry ratio</td>
<td>1/5 = 20%</td>
</tr>
<tr>
<td>second peak force</td>
<td>0/5 = 0%</td>
</tr>
<tr>
<td>minimum force symmetry ratio</td>
<td>0/5 = 0%</td>
</tr>
<tr>
<td>second peak force timing</td>
<td>0/5 = 0%</td>
</tr>
<tr>
<td>stance time symmetry ratio</td>
<td>0/5 = 0%</td>
</tr>
<tr>
<td>impulse symmetry ratio</td>
<td>0/5 = 0%</td>
</tr>
<tr>
<td>first peak force</td>
<td>0/5 = 0%</td>
</tr>
</tbody>
</table>

None of the variables reached the arbitrary 50% cutoff.

The observed and critical values of t to be used in the t-tests for intercepts at speed = 1.29m/s were calculated. The numbers of significant results were 0 each for subjects 34, 35, 37 and 39; and 2 for subject 38. The mean proportion of significant results is 4%. By chance alone, one would expect 1% x 45 = 0.45, i.e. 0 or 1 positive t-tests, so the results obtained are hardly better than this.

T-tests between the pre- and post-operative velocities show that all 5 subjects showed a statistically significant increase in velocity (see figures 4.16 and 4.17). The results obtained, plus Olsson et al (1985)'s comment that 'the main indication for total hip replacement is pain', suggest that the benefit of the operations has been in reduced pain and increased gait speed rather than changed gait behaviour with speed.
Figure 4.16: pre-operative and post-operative velocities for the joint replacement subjects
### Figure 4.17: Post-operative changes in velocity for the joint replacement subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Mean velocity pre-op (m/s)</th>
<th>Mean velocity post-op (m/s)</th>
<th>Percentage change</th>
<th>Statistically significant (p&lt;0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>1.04</td>
<td>1.18</td>
<td></td>
<td>14 yes</td>
</tr>
<tr>
<td>35</td>
<td>0.62</td>
<td>N/A</td>
<td></td>
<td>16 yes</td>
</tr>
<tr>
<td>36</td>
<td>0.57</td>
<td>N/A</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>37</td>
<td>0.71</td>
<td>0.89</td>
<td></td>
<td>26 yes</td>
</tr>
<tr>
<td>38</td>
<td>0.78</td>
<td>1.06</td>
<td></td>
<td>37 yes</td>
</tr>
<tr>
<td>39</td>
<td>0.72</td>
<td>0.83</td>
<td></td>
<td>15 yes</td>
</tr>
</tbody>
</table>
4.3.2.4 Percentage of times a complete stride was registered in a traverse

From observation of the subjects it appeared that the step length increased with stature. Two subjects were chosen in order to give an estimate of the range of this effect.

Tallest subject

This was subject 34 who was 1.74m (5'9") tall.

Shortest subject

This was subject 38 who was 1.50m (4'11") tall.

The results are tabulated below.

<table>
<thead>
<tr>
<th></th>
<th>'slow'</th>
<th>'normal'</th>
<th>'fast'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tallest subject</td>
<td>-</td>
<td>95%</td>
<td>-</td>
</tr>
<tr>
<td>Shortest subject</td>
<td>-</td>
<td>100%</td>
<td>-</td>
</tr>
</tbody>
</table>

The walkway is long enough to record a complete stride during a traverse for most traverses for these subjects at their normal speeds. However I have recommended using a wider range of speed so the walkway length is not necessarily adequate.

4.3.2.5 Time taken

The number of trials, time taken and time taken per trial are in Appendix 4.9. The average time taken per trial is 0.93 minutes, so each assessment of 13 trials takes an average of 12 minutes. If each assessment were expanded to contain 18 trials as for the amputees then it would take an estimated time of 17 minutes which would be within the half hour arbitrarily taken as acceptable for routine clinical use.
4.3.2.6 Statistical tests for standing force symmetry ratio

The results of the standing force symmetry ratio t-tests for joint replacement subjects were not significant for 5 subjects. For the other subject the test was not applicable. None of the results were significant, so this variable is not useful for clinical assessment in joint replacement subjects.

4.3.3 Joint replacement adults: conclusions

The subjects studied were biassed toward the more active part of the elderly pre-operative joint replacement population, and it was necessary to wait until 3 months after the operations until they could walk without walking aids before they could be re-assessed using the walkway. One of the subjects could not complete 10 trials and around half of the subjects found the tests fatiguing so it seems that the walking ability of the subjects would limit the number of traverses which could be done in an assessment and the proportion of the population who could be assessed, especially if the walkway were not made suitable for those walking with walking aids.

These subjects needed a mean of 22% extra trials due to not clearing the centre line, so this is a more significant problem than for the amputees.

As for the amputees, loss of trials due to the need for further development of the algorithms was only a minor, although troublesome, cause of unusable traverses.

The results were poorer straight lines (lower coefficients of determination) than for the amputees. The coefficients of determination ranged from 0.05 to 0.63 for different assessments and from 0.16 to 0.47 for different gait parameters. The walkway gave statistically significant straight lines (F-tests) only 15% of the time, which was much less than for the amputees. This does not reach the arbitrary 50% cutoff.
The results showed negligible significant differences between pre-operative and post-operative states, so this assessment protocol is useless for comparison between these states in the clinical context. If the speed range and number of trials were increased, the statistics would be expected to improve and the assessments might yield useful information.

All subjects showed a statistically significant increase in velocity. This could be used as an approximate indication of gait improvement due to the operations (but a walkway is not required in order to measure it). It could only be approximate because the average speed of a normal subject can change spontaneously from assessment to assessment (see Appendix 3.2), so presumably it also can for these subjects. A useful piece of further work would be to test the spontaneous variation of the subjects’ speed between assessments. If it is small, the method of analysis which has been used in this study may not be the most suitable.

The walkway is long enough for these subjects at their normal speeds, but not necessarily at the wider range of speed which I have recommended.

An assessment of 18 trials would take an estimated time of 17 minutes which is inside the arbitrary half hour limit set for routine clinical use.

Standing force symmetry ratio as measured was not found to be useful.

The statistical results for the F-tests and t-tests did not pass the arbitrary thresholds for clinical usefulness, so this suggests that the system is not likely to be clinically useful for these subjects. However, it must be remembered that this conclusion was reached for the current prototype of the system, the speed range and number of trials used, the gait variables chosen and the statistical analysis used, so if any of these parameters were changed, a different conclusion might be reached. In
chapter 5, it is recommended that modifications to these parameters are made and that the system is re-assessed.

4.4 Miscellaneous adult subjects

4.4.1 Miscellaneous adult subjects: introduction

Two miscellaneous adult subjects were studied. One had cerebral palsy and the other had a specialised hip implant.

The subjects' personal data are shown in Appendix 4.10. The numbers of treatments and trials per subject are shown in Appendix 4.11.

4.4.2 Cerebral palsy

4.4.2.1 Method for cerebral palsy adult

The gait of a cerebral palsy adult who walked with crutches was studied.

The subject was asked for her medical details.

The subject walked with elbow crutches with custom handgrips. Planks on bricks were placed over the edges of the walkway and her crutches were reduced in length so that she could walk along the walkway resting her crutches on the planks so that only her feet transmitted forces to the walkway. I recommend that this technique should not be used again. It is not sufficiently safe.

She walked along the walkway 4 times at self-selected normal speed. Then the planks were moved out as far as possible and her crutches were adjusted 1 notch shorter. Then she walked along 4 times at self-selected fast speed.

The leg lengths were measured using a tape measure.
4.4.2.2 Results and discussion for subject with cerebral palsy

The subject had cerebral palsy due to premature birth.

She had had a right hip operation approx 10 years before (when approximately 12 years old). The hip had been about to dislocate so a part of the ileum had been used in an acetabular reconstruction. A rotation osteotomy had been done at the same time. Five years later, because the muscles were weak, a muscle was moved on the right leg. A tendon release and Achilles lengthening were done on the left leg. A plate was put into the right leg for a year and there was a screw that had been in there for 7 years.

The subject had an obvious leg length discrepancy. She walked on her left foot and right forefoot. Her leg length measurements were measured with a tape measure through jeans. Her right leg was 6cm shorter and the difference was above the knee.

4.4.2.2.1 Graphs

Figure 4.18 shows the data from one traverse at 'normal' speed. As explained below, there are no graphs of the combined data of all the trials. The traces show the irregularity of the force profile, less loading on the right foot and the fact that the load on each leg never reaches body weight.

4.4.2.2.2 Assessment of the robustness of the algorithms

With this subject's gait, my algorithms were of no use. There was double registration of many stances, due to the irregular nature of her gait, i.e. not loading feet smoothly and alternately. Because of this, 6/8 trials suffered from 'negativedoublestancetimes' and 6/8 trials suffered from 'highlyunequalnumbersofsteps'. All of the trials suffered from at least one of these fatal error messages so that no gait parameters could be calculated.
Figure 4.18: sample results: adult subject with cerebral palsy, walking at her 'normal' speed

--- Data from University of Surrey gait assessment walkway ---
--- Record name: planksi ---

Record name: planksi

--- Stresses of vertical force due to upper body on both platforms ---

solid line: platform 1 (right foot)
broken line: platform 2 (left foot)

top of screen: platform 1
bottom of screen: platform 2

Direction of travel: <---

257
length of vector represents magnitude of vertical force

time interval between vectors=0.0100 seconds

--- Error Messages ---
THE RAW DATA HAS PROPERTIES WHICH MAY CAUSE THE CALCULATION ALGORITHMS TO GIVE MISLEADING RESULTS. THE CALCULATED PARAMETERS SHOULD THEREFORE BE TREATED WITH CAUTION

More than 4 steps were found on at least one of the platforms. The program can only deal with up to 4 steps on each platform, so data beyond this has not been analysed.

Some of the points are within 0.12 metres of the ends of the platforms. It may be that these steps are partially off the ends of the platform and should therefore be interpreted with care.

--- Date and time ---
test date=Tuesday 25 February 1992
test time=10:36

--- Force plate data ---
numberofchannels=6
nominalsamplingrateperchannel=100Hz
actuallsamplingrateperchannel=100.0Hz
samplingtime=20s
readingsperchannel=2000
zero1=1024.470
zero2=1019.010
zero3=1026.080
zero4=1070.470
zero5=1024.300
zero6=1040.080

--- Weight on each foot in standing ---
Average weight on left foot in standing= 33.0kgf
Average weight on right foot in standing= 27.2kgf

--- Temporal factors ---

--- Directions of travel: ---

Direction of travel: ←
first step was on platform 1
Total stance time of step 1 on platform 1=1.9600 seconds
Total stance time of step 2 on platform 1=1.9000 seconds
Total stance time of step 3 on platform 1=1.9300 seconds
Total stance time of step 4 on platform 1=2.1800 seconds
Total stance time of step 1 on platform 2=1.9200 seconds
Total stance time of step 2 on platform 2=2.1500 seconds
Total stance time of step 3 on platform 2=1.9900 seconds

double stance time [1]=0.7500 seconds
double stance time [2]=0.6900 seconds
double stance time [3]=0.7200 seconds
double stance time [4]=0.7000 seconds
double stance time [5]=0.6300 seconds
double stance time [6]=0.6800 seconds

platform 1 stride time [1]=2.4400 seconds
platform 1 stride time [2]=2.6300 seconds
platform 1 stride time [3]=2.6100 seconds
platform 2 stride time [1]=2.4100 seconds
platform 2 stride time [2]=2.7500 seconds

--- Distance factors ---

left foot was on platform 2
platform 1, step 1
position where force first exceeds force upper threshold is (x,y)=(1.961 metres, 0.039 metres)
position where force last exceeds force upper threshold is (x,y)=(1.862 metres, 0.026 metres)
platform 1, step 2
position where force first exceeds force upper threshold is (x,y)=(1.458 metres, 0.006 metres)
position where force last exceeds force upper threshold is (x,y)=(1.390 metres, -0.001 metres)
platform 1, step 3
position where force first exceeds force upper threshold is (x,y)=(0.941 metres, -0.005 metres)
position where force last exceeds force upper threshold is (x,y)=(0.851 metres, -0.014 metres)
platform 1, step 4
position where force first exceeds force upper threshold is (x,y)=(0.407 metres, 0.025 metres)
position where force last exceeds force upper threshold is (x,y)=(0.285 metres, 0.039 metres)
platform 2, step 1
position where force first exceeds force upper threshold is (x,y)=(1.714 metres, -0.133 metres)
position where force last exceeds force upper threshold is (x,y)=(1.621 metres, -0.206 metres)
platform 2, step 2
position where force first exceeds force upper threshold is (x,y)=(1.143 metres, -0.151 metres)
position where force last exceeds force upper threshold is (x,y)=(1.084 metres, -0.211 metres)
platform 2, step 3
position where force first exceeds force upper threshold is (x,y)=(0.527 metres, -0.152 metres)
position where force last exceeds force upper threshold is...
(x,y) = (0.503 metres, -0.202 metres)

Platform 1, step 1 time averaged (x,y) = (1.950 metres, 0.043 metres)
Platform 1, step 2 time averaged (x,y) = (1.430 metres, 0.007 metres)
Platform 1, step 3 time averaged (x,y) = (0.920 metres, 0.009 metres)
Platform 1, step 4 time averaged (x,y) = (0.346 metres, 0.021 metres)
Platform 2, step 1 time averaged (x,y) = (1.668 metres, -0.207 metres)
Platform 2, step 2 time averaged (x,y) = (1.122 metres, -0.211 metres)
Platform 2, step 3 time averaged (x,y) = (0.559 metres, -0.197 metres)

Platform 1 step length [1] = -0.238 metres
Platform 1 step length [2] = -0.202 metres
Platform 1 step length [3] = -0.214 metres
Platform 2 step length [1] = -0.283 metres
Platform 2 step length [2] = -0.308 metres
Platform 2 step length [3] = -0.361 metres

Platform 1 step width [1] = 0.213 metres
Platform 1 step width [2] = 0.221 metres
Platform 1 step width [3] = 0.217 metres
Platform 2 step width [1] = 0.250 metres
Platform 2 step width [2] = 0.218 metres
Platform 2 step width [3] = 0.206 metres

Platform 1 stride length [1] = -0.520 metres
Platform 1 stride length [2] = -0.510 metres
Platform 1 stride length [3] = -0.575 metres
Platform 2 stride length [1] = -0.546 metres
Platform 2 stride length [2] = -0.563 metres

Velocity factors

Velocity based on platform 1 = -0.21 metres per second
Velocity based on platform 2 = -0.21 metres per second
Velocity = -0.21 metres per second

Measured peak forces

*** Platform 1, step 1 ***
Beginning of step is at time= 1.640 seconds
End of step is at time= 3.600 seconds
Maximum force in first half of step= 32.8kgf after 22.4% of the step
Minimum force between these two peaks 25.7kgf after 41.8% of the step

*** Platform 1, step 2 ***
Beginning of step is at time= 4.080 seconds
End of step is at time= 5.980 seconds
Maximum force in first half of step= 37.0kgf after 23.7% of the step
Minimum force between these two peaks 29.9kgf after 47.4% of the step

*** Platform 1, step 3 ***
Beginning of step is at time= 6.710 seconds
end of step is at time= 8.640 seconds
maximum force in first half of step= 35.4kgf after 24.9% of the step
maximum force in second half of step= 31.6kgf after 52.8% of the step
minimum force between these two peaks 23.4kgf after 36.8% of the step

*** platform 1, step 4 ***
beginning of step is at time= 9.320 seconds
end of step is at time=11.500 seconds
maximum force in first half of step= 35.7kgf after 20.6% of the step
maximum force in second half of step= 32.4kgf after 56.4% of the step
minimum force between these two peaks 24.7kgf after 38.1% of the step

* platform 1, step 4 *
beginning of step is at time= 2.850 seconds
end of step is at time= 4.770 seconds
maximum force in first half of step= 48.0kgf after 24.0% of the step
maximum force in second half of step= 44.6kgf after 67.7% of the step
minimum force between these two peaks 27.2kgf after 50.5% of the step

*** platform 2, step 1 ***
beginning of step is at time= 5.260 seconds
end of step is at time= 7.410 seconds
maximum force in first half of step= 45.1kgf after 22.8% of the step
maximum force in second half of step= 40.6kgf after 73.0% of the step
minimum force between these two peaks 23.4kgf after 53.5% of the step

*** platform 2, step 2 ***
beginning of step is at time= 8.010 seconds
end of step is at time=10.000 seconds
maximum force in first half of step= 52.7kgf after 25.6% of the step
maximum force in second half of step= 45.1kgf after 71.9% of the step
minimum force between these two peaks 24.7kgf after 53.3% of the step

**---** Measured vertical impulses ---**

impulse of step 1 on platform 1= 41.1kgf*seconds
impulse of step 2 on platform 1= 44.8kgf*seconds
impulse of step 3 on platform 1= 38.4kgf*seconds
impulse of step 4 on platform 1= 42.1kgf*seconds
impulse of step 1 on platform 2= 57.6kgf*seconds
impulse of step 2 on platform 2= 63.4kgf*seconds
impulse of step 3 on platform 2= 64.1kgf*seconds

**---**
4.4.2.2.3 Statistical tests for gait

Because my algorithms were of no use with this subject, no statistical tests on gait were possible.

4.4.2.2.4 Percentage of times a complete stride was registered in a traverse

No statistics on this are available, but from figure 4.18 it appears that even at fast speed a complete stride would always be captured, so the walkway is long enough for this subject.

4.4.2.2.5 Time taken

This has not been considered for this subject, since no statistical information was obtained from the analysis.

4.4.2.2.6 Statistical tests for standing force symmetry ratio

This could not be done since only one condition was studied.

4.4.3 Specialised hip implant

4.4.3.1 Introduction to the specialised hip implant

The subject had been fitted with a specialised hip implant, so this case is related to the joint replacement section above. The medical details are those told to us by the subject. 31 years before testing, at age 21, the subject was in a motor cycle accident which caused complicated and complex fracture dislocation of the right hip. He was treated by manipulation and refused to have the hip fixed. It apparently remained permanently dislocated and a pseudarthrosis developed. He had 2 inches of leg shortening. The subject was active and was then given a special hip replacement 8 months prior to testing. Two weeks later he had had two revisions: the acetabular component was revised and the implant was
revised due to it having dislocated. He had no leg length difference. By 5 months before testing he was weight-bearing on the leg. He did not yet consider himself fully recovered; he still had muscle problems.

4.4.3.2 Results and discussion for subject with specialised hip implant

4.4.3.2.1 Graphs

Figures 4.19 to 4.23 show examples from this subject's graphs of the 11 gait parameters. His gait pattern is illustrated in figures 4.24 and 4.25 which show one traverse at slow speed and one traverse at fast speed respectively.

4.4.3.2.2 Assessment of the robustness of the algorithms

The minimum peak force on the right foot and the timing of the second peak force on the right foot each appear to vary discontinuously. This is because the second peak force of the right foot is small: see figures 4.26 and 4.27. This means that sometimes the largest force value in the second half of the stance is not at the peak. In figure 4.26 the 'second peak force' is at a peak, while in figure 4.27 it is not. This shows the need for further development of the algorithms (see section 5.2.2).

4.4.3.2.3 Statistical tests for gait

The coefficients of determination were calculated for the subject. The mean value is 0.38, i.e. higher than for the other joint replacement subjects. This is consistent with the wider speed range investigated. 7 of the 10 F-tests gave positive results, while the highest number for the joint replacement subjects was 3. This is consistent with the wider speed range and larger number of trials used. This value exceeds the arbitrary 50% cutoff so the walkway data is considered to contain enough data to be useful.
Figure 4.19: velocity for subject 32 (right specialised total hip replacement patient)
Figure 4.20: stance time symmetry ratio for subject 32 (right specialised total hip replacement patient)
Figure 4.21: Right step length for subject 32 (right specialised total hip replacement patient)
Figure 4.22: second peak force timing for subject 32
(right specialised total hip replacement patient)
Figure 4.23: impulse symmetry ratio for subject 32 (right specialised total hip replacement patient)
Figure 4.24: sample results: subject 32 (right specialised total hip replacement patient), walking at his 'slow' speed

--- Data from University of Surrey gait assessment walkway ---

--- Record name ---

Record name=460

solid line: platform 1 (left foot)
broken line: platform 2 (right foot)

top of screen: platform 1
bottom of screen: platform 2

Direction of travel:---→

---
length of vector represents magnitude of vertical force
time interval between vectors = 0.0100 seconds

platform 1
platform 2

Direction of travel: ——>
Figure 4.25: sample results: subject 32 (right specialised total hip replacement patient), walking at his 'fast' speed

--- Data from University of Surrey gait assessment walkway ---

record name=464

--- solid line: platform 1 (left foot) ---
--- broken line: platform 2 (right foot) ---

top of screen: platform 1
bottom of screen: platform 2

Direction of travel: →
length of vector represents magnitude of vertical force

time interval between vectors = 0.0025 seconds

platform 1

platform 2

Direction of travel: -->
Figure 4.26: sample results: subject 32 (right specialised total hip replacement patient)
length of vector represents magnitude of vertical force

time interval between vectors=0.0025 seconds

platform 1

platform 2

Direction of travel: \[\rightarrow\]

Error Messages

THE RAW DATA HAS PROPERTIES WHICH MAY CAUSE THE CALCULATION ALGORITHMS TO GIVE MISLEADING RESULTS. THE CALCULATED PARAMETERS SHOULD THEREFORE BE TREATED WITH CAUTION

Some of the points are within 0.12 metres of the ends of the platforms. It may be that these steps are partially off the ends of the platform and should therefore be interpreted with care.

Date and time

test date=Tuesday 17 November 1992
test time=11:58

Force plate data

number of channels=6
nominal sampling rate per channel=400Hz
actual sampling rate per channel=400.3Hz
sampling time=5s
readings per channel=2000
zero1=1019.280
zero2=1020.780
zero3=1036.960
zero4=1043.330
zero5=1004.130
zero6=1033.370

Weight on each foot in standing

Average weight on left foot in standing= 0.0kgf
Average weight on right foot in standing= 0.0kgf

Temporal factors

first step was on platform 1
Total stance time of step 1 on platform 1=0.7744 seconds
Total stance time of step 2 on platform 1=0.7569 seconds
Total stance time of step 1 on platform 2 = 0.6370 seconds
double stance time [1]= 0.1599 seconds
double stance time [2]= 0.1749 seconds
platform 1 stride time [1]= 1.0767 seconds

** Distance factors **

left foot was on platform 1

platform 1, step 1
position where force first exceeds force upper threshold is (x,y)= (0.609 metres, 0.038 metres)
position where force last exceeds force upper threshold is (x,y)= (0.865 metres, 0.055 metres)

platform 1, step 2
position where force first exceeds force upper threshold is (x,y)= (1.803 metres, 0.015 metres)
position where force last exceeds force upper threshold is (x,y)= (2.052 metres, 0.034 metres)

platform 2, step 1
position where force first exceeds force upper threshold is (x,y)= (1.120 metres, -0.115 metres)
position where force last exceeds force upper threshold is (x,y)= (1.431 metres, -0.175 metres)

platform 1, step 1 time averaged (x,y)= (0.752 metres, 0.062 metres)
platform 1, step 2 time averaged (x,y)= (1.956 metres, 0.029 metres)
platform 2, step 1 time averaged (x,y)= (1.344 metres, -0.155 metres)

platform 1 step length [1]= 0.612 metres
platform 2 step length [1]= 0.592 metres
platform 1 step width [1]= 0.184 metres
platform 2 step width [1]= 0.217 metres
platform 1 stride length [1]= 1.204 metres

** Velocity factors **

velocity based on platform 1 = 1.12 metres per second
velocity= 1.12 metres per second

** Measured peak forces **

*** platform 1, step 1 ***
beginning of step is at time= 1.153 seconds
end of step is at time= 1.928 seconds
maximum force in first half of step= 74.4kgf after 24.8% of the step
maximum force in second half of step= 101.5kgf after 81.0% of the step
minimum force between these two peaks 58.3kgf after 55.8% of the step

*** platform 1, step 2 ***
beginning of step is at time= 2.230 seconds
end of step is at time= 2.988 seconds
maximum force in first half of step= 81.1kgf after 27.4% of the step
maximum force in second half of step= 95.8kgf after 82.2% of the step
minimum force between these two peaks 56.9kgf after 54.8% of the step

*** platform 2, step 1 ***
beginning of step is at time= 1.768 seconds
end of step is at time= 2.405 seconds

maximum force in first half of step= 70.3kgf after 32.5% of the step
maximum force in second half of step= 69.9kgf after 74.5% of the step
minimum force between these two peaks 64.9kgf after 60.0% of the step

Measured vertical impulses

impulse of step 1 on platform 1= 49.4kgf*seconds
impulse of step 2 on platform 1= 47.7kgf*seconds
impulse of step 1 on platform 2= 32.9kgf*seconds
Figure 4.27: sample results: subject 32 (right specialised total hip replacement patient)

--- Data from University of Surrey gait assessment walkway ---
--- Record name ---
record name=457

--- solid line: platform 1 (right foot) ---
--- broken line: platform 2 (left foot) ---

Direction of travel:←
length of vector represents magnitude of vertical force

time interval between vectors=0.8825 seconds

Direction of travel:<—

--- Error Messages ---
THE RAW DATA HAS PROPERTIES WHICH MAY CAUSE THE CALCULATION ALGORITHMS TO GIVE MISLEADING RESULTS. THE CALCULATED PARAMETERS SHOULD THEREFORE BE TREATED WITH CAUTION

Some of the points are within 0.12 metres of the ends of the platforms. It may be that these steps are partially off the ends of the platform and should therefore be interpreted with care.

--- Date and time ---
test date=Tuesday 17 November 1992
test time=11:59

--- Force plate data ---
numberofchannels=6
nominalsamplingrateperchannel=400Hz
actualsamplingrateperchannel=400.3Hz
samplingtime=5s
readingsperchannel=2000
zero1=1019.110
zer02=1021.070
zer03=1037.300
zer04=1043.360
zer05=1094.270
zer06=1033.580

--- Weight on each foot in standing ---
Average weight on left foot in standing= -0.0kgf
Average weight on right foot in standing= -0.0kgf

--- Temporal factors ---
first step was on platform 2
Total stance time of step 1 on platform 1=0.5821 seconds
Total stance time of step 1 on platform 2=0.6945 seconds
Total stance time of step 2 on platform 2 = 0.6970 seconds

double stance time [1] = 0.1299 seconds

double stance time [2] = 0.1249 seconds

platform 2 stride time [1] = 1.0217 seconds

--- Distance factors ---

left foot was on platform 2.

platform 1, step 1
position where force first exceeds force upper threshold is
(x,y) = (1.428 metres, -0.008 metres)
position where force last exceeds force upper threshold is
(x,y) = (1.185 metres, 0.034 metres)

platform 2, step 1
position where force first exceeds force upper threshold is
(x,y) = (1.802 metres, -0.181 metres)
position where force last exceeds force upper threshold is
(x,y) = (1.640 metres, -0.162 metres)

platform 2, step 2
position where force first exceeds force upper threshold is
(x,y) = (0.640 metres, -0.162 metres)
position where force last exceeds force upper threshold is
(x,y) = (0.560 metres, -0.186 metres)

platform 1, step 1 time averaged
(x,y) = (1.259 metres, 0.020 metres)
platform 2, step 1 time averaged
(x,y) = (1.872 metres, -0.164 metres)
platform 2, step 2 time averaged
(x,y) = (0.604 metres, -0.184 metres)

platform 1 step length [1] = 0.613 metres
platform 2 step length [1] = 0.655 metres
platform 1 step width [1] = 0.184 metres
platform 2 step width [1] = 0.205 metres
platform 2 stride length [1] = 1.268 metres

--- Velocity factors ---

velocity based on platform 2 = -1.24 metres per second
velocity = -1.24 metres per second

--- Measured peak forces ---

*** platform 1, step 1 ***
begning of step is at time = 1.540 seconds
end of step is at time = 2.123 seconds
maximum force in first half of step = 79.2kgf after 28.8% of the step
maximum force in second half of step = 67.7kgf after 50.2% of the step
minimum force between these two peaks 77.7kgf after 50.1% of the step

*** platform 2, step 1 ***
begning of step is at time = 0.975 seconds
end of step is at time = 1.670 seconds
maximum force in first half of step = 78.9kgf after 26.6% of the step
maximum force in second half of step = 92.8kgf after 80.6% of the step

---
minimum force between these two peaks 55.4kgf after 50.4% of the step

*** platform 2, step 2 ***
begining of step is at time= 1.998 seconds
end of step is at time= 2.695 seconds

maximum force in first half of step= 86.5kgf after 21.1% of the step
maximum force in second half of step= 92.2kgf after 81.0% of the step
minimum force between these two peaks 53.3kgf after 44.4% of the step

*--------------* Measured vertical impulses *--------------*

impulse of step 1 on platform 1= 32.0kgf*seconds
impulse of step 1 on platform 2= 43.3kgf*seconds
impulse of step 2 on platform 2= 45.6kgf*seconds

*----------------------*--------------------*----------------------*
in the routine clinical context. Only one condition was studied in this subject so no t-tests could be performed.

4.4.3.2.4 Percentage of times a complete stride was registered in a traverse
'slow speed': 100
'normal speed': 100
'fast speed': 100

The walkway is long enough for this subject.

4.4.3.2.5 Time taken
The time taken was 23 min for 18 trials, i.e. 1.28 minutes per trial. This was within the arbitrary half hour limit.

4.4.3.2.6 Statistical tests for standing force symmetry ratio
Only one condition was studied so no test could be performed.

4.4.4 Miscellaneous adult subjects: conclusions
The cerebral palsy subject's data are not suitable for the existing algorithms. For the walkway to be useful with all subject groups, further work on the algorithms is necessary (see section 5.2.2). The walkway was long enough for her.

For the subject with the special hip replacement, the algorithms did not always identify the second peak force due to the small second peak of the right foot. Further work on the algorithms is necessary (see section 5.2.2). The mean coefficient of determination was higher than for the other joint replacement subjects, which is consistent with the wider speed range investigated. Far more of the F-tests (70% c.f. 15%) gave positive results than for the other joint replacement subjects. This is consistent with the
wider speed range and larger number of trials used and exceeds the arbitrary 50% target. The walkway was long enough for this subject. The time taken was 23 min for 18 trials, i.e. 1.28 minutes per trial. This was within the arbitrary half hour limit.

4.5 Child subjects

4.5.1 Child subjects: introduction

The walkway was not designed for use with children. It was expected that the data would be of low accuracy due to the subjects' low weight and short steps. However the opportunity for testing it with children arose so it was decided to do this.

Because of the lesser weight of the children, it was decided to analyse the data using a 'forceupperthreshold' of 5kgf.

The subjects studied were:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Down's syndrome</td>
</tr>
<tr>
<td>31</td>
<td>cerebral palsy, spastic diplegia</td>
</tr>
</tbody>
</table>

No children under 4 years old were investigated. According to Lewallen et al (1986), if a child is too young, it cannot cooperate in the gait analysis. 'The gait of children of 4 years old or above is well developed and consistent and approaches the final gait pattern for that individual.'

Down's syndrome is a variety of mental subnormality in which the patient has certain characteristic facial features, a small round skull and short, thick hands and feet. In 95% of cases the cause is the presence of an extra chromosome in the ovum. In the remaining cases the cause is a fault in the division of the germ cells known as translocation. (Thomson, 1984)

Subject 30 had recurvation of left knee, absence of plantar / dorsiflexion of the left ankle and increased pelvic retraction on the left side resulting in left hemiplegia.
A one stage distal hamstring release was performed on subject 31 3 years before testing. He would normally walk with elbow crutches. He was tested barefoot, with socks and shoes with insoles, then with socks and shoes without the insoles, then with removable inhibitory plasters. If the walkway was to be used to determine which orthotic treatment was most suitable for a particular child, it would be necessary for it to be able to show the difference between the gaits associated with the different treatments.

4.5.2 Child subjects: method

Subject 30 was weighed three times, then at normal speed two traverses were recorded in shoes and two were recorded barefoot.

Subject 31 was weighed 3 times, then 4 traverses each were recorded at normal speed in bare feet, socks and shoes with insoles in, socks and shoes with the insoles taken out. He then took his shoes and socks off and put on special stockings and removable inhibitory plasters (R.I.P.s). These were intended to restrict the ankles so that he had to stand with his knees straight. He was weighed and then performed 4 traverses at normal speed.

4.5.3 Child subjects: results and discussion

The subjects' personal data are shown in Appendix 4.12.

4.5.3.1 Graphs

Figure 4.28 illustrates subject 30's gait for one traverse at normal speed. Figure 4.29 shows subject 31's gait for one traverse with bare feet, while figures 4.30, 4.31 and 4.32 do the same for shoes, socks and insoles; shoes, socks, no insoles and removable inhibitory plasters respectively. The results show the poorer quality of positional data due to
Figure 4.28: Sample results: subject 30 (child with Down's syndrome) walking at his normal speed.
length of vector represents magnitude of vertical force

time interval between vectors = 0.0100 seconds

platform 1

platform 2

Direction of travel: →
Figure 4.29: sample results: subject 31 (child with spastic diplegia) walking at his normal speed with bare feet

Data from University of Surrey gait assessment walkway

Record name: 421

---

Solid line: platform 1 (left foot)

Broken line: platform 2 (right foot)

Top of screen: platform 1

Bottom of screen: platform 2

Direction of travel: →
length of vector represents magnitude of vertical force

time interval between vectors = 0.0180 seconds

platform 1

platform 2

Direction of travel: --->
Figure 4.30: sample results: subject 31 (child with spastic diplegia) walking at his normal speed with shoes, socks and insoles
length of vector represents magnitude of vertical force

time interval between vectors = 0.0188 seconds

Direction of travel: →
Figure 4.31: Sample results: subject 31 (child with spastic diplegia) walking at his normal speed with shoes, socks and no insoles.

Data from University of Surrey gait assessment walkway.

---

---

Record name = 432

---

---

------

---

---

Direction of travel: <——
length of vector represents magnitude of vertical force

time interval between vectors = 8.0100 seconds

Direction of travel: <—
'forceupperthreshold' being set as 5kgf instead of 20kgf. Figure 4.32 shows shortened stride length and decreased speed.

Figures 4.33 to 4.35 show examples from the 11 gait variables for subject 31. It is difficult to see the underlying gait behaviour with only 3 or 4 points, especially for shoes, sock and insoles, where the speed range was so narrow.

4.5.3.2 Assessment of the robustness of the algorithms

For subject 30, no trials were lost due to the need for further development of the algorithms.

For subject 31, 5/16 trials suffered from 'negativedoublestancetimes' and 'highlyunequalnumbersofsteps' errors: runs 427, 441-444. This was due to double registration of stances, particularly of the right foot, due to the shape of the force-time curve. Further work on the algorithms is needed (see section 5.2.2).

4.5.3.3 Statistical tests for gait

The coefficients of determination for the children were calculated. The overall mean is 0.56, i.e. higher than for the other groups. Performing a two-way analysis of variance (p<0.05) using Microsoft Excel version 4 in order to determine the effects of subject, treatment and gait variable, it was found that there was significant variation in coefficient of determination with gait parameter but not with subject and treatment.
Figure 4.32: sample results: subject 31 (child with spastic diplegia) walking at his normal speed with removable inhibitory plasters

Data from University of Surrey gait assessment walkway

Record name record name=443

solid line: platform 1 (left foot)
broken line: platform 2 (right foot)

top of screen: platform 1
bottom of screen: platform 2

Direction of travel: →
length of vector represents magnitude of vertical force

time interval between vectors=0.0100 seconds

platform 1

platform 2

Direction of travel: ——>
Figure 4.33: velocity for subject 31 (child with spastic diplegia)
Figure 4.34: stance time symmetry ratio for subject 31 (child with spastic diplegia)
Figure 4.35: right step length for subject 31 (child with spastic diplegia)
The table below shows how mean coefficient of determination varied with gait parameter:

<table>
<thead>
<tr>
<th>Gait parameter</th>
<th>Mean coefficient of determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>second peak force timing</td>
<td>0.75</td>
</tr>
<tr>
<td>first peak force</td>
<td>0.71</td>
</tr>
<tr>
<td>stance time symmetry ratio</td>
<td>0.69</td>
</tr>
<tr>
<td>first peak force symmetry ratio</td>
<td>0.68</td>
</tr>
<tr>
<td>impulse symmetry ratio</td>
<td>0.65</td>
</tr>
<tr>
<td>step length</td>
<td>0.53</td>
</tr>
<tr>
<td>minimum force</td>
<td>0.46</td>
</tr>
<tr>
<td>second peak force symmetry ratio</td>
<td>0.46</td>
</tr>
<tr>
<td>minimum force symmetry ratio</td>
<td>0.44</td>
</tr>
<tr>
<td>second peak force</td>
<td>0.26</td>
</tr>
</tbody>
</table>

This means that quality of description of the behaviour of the gait variable with speed by a straight line varies widely with gait variable.

The observed and critical F-statistics for the children were obtained and compared. The numbers of significant results are tabulated below:

- subject 30: 1
- subject 31, bare feet: 2
- subject 31, shoes, socks, insoles: 1
- subject 31, shoes, socks, no insoles: 2
- (subject 31, removable inhibitory plasters: All data lost due to algorithms)

The walkway gave a statistically significant straight line 15% of the time, which is greater than the 5% which one would expect through chance alone. This is the same proportion as for the joint replacement subjects. It does not reach the arbitrary 50% target.
The F-test significances are tabulated by gait parameter below.

<table>
<thead>
<tr>
<th>Gait parameter</th>
<th>Number of significant tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>second peak force timing</td>
<td>2/4 = 50%</td>
</tr>
<tr>
<td>first peak force</td>
<td>1/4 = 25%</td>
</tr>
<tr>
<td>minimum force</td>
<td>1/4 = 25%</td>
</tr>
<tr>
<td>first peak force symmetry ratio</td>
<td>1/4 = 25%</td>
</tr>
<tr>
<td>minimum force symmetry ratio</td>
<td>1/4 = 25%</td>
</tr>
<tr>
<td>step length</td>
<td>0/4 = 0%</td>
</tr>
<tr>
<td>second peak force symmetry ratio</td>
<td>0/4 = 0%</td>
</tr>
<tr>
<td>second peak force</td>
<td>0/4 = 0%</td>
</tr>
<tr>
<td>impulse symmetry ratio</td>
<td>0/4 = 0%</td>
</tr>
<tr>
<td>stance time symmetry ratio</td>
<td>0/4 = 0%</td>
</tr>
</tbody>
</table>

Only second peak force timing reached the arbitrary 50% target. This variable also gave the highest coefficient of determination. Half of the gait parameters gave no significant results.

The slope values and intercepts at speed = 1.29m/s and their corresponding standard errors for the children were obtained. These values were used in the t-tests below.

The observed and critical values of t to be used in the t-tests for slope were obtained and compared. The numbers of significant results are tabulated below:

- subject 31, bare feet vs shoes, socks, insoles: 2
- subject 31, shoes, socks, insoles vs shoes, socks, no insoles: 3
- subject 31, bare feet vs shoes, socks, no insoles: 4

The mean proportion of significant results is 30%. By chance alone, one would expect 5% x 30 = 1.5 positive tests. 9 were obtained. The results are thus better than one would expect by chance but do not reach the arbitrary 50% target.
The slope t-test results by gait parameter are tabulated below.

<table>
<thead>
<tr>
<th>Gait parameter</th>
<th>Number of significant tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>second peak force timing</td>
<td>3/3 = 100%</td>
</tr>
<tr>
<td>first peak force symmetry ratio</td>
<td>2/3 = 66%</td>
</tr>
<tr>
<td>first peak force</td>
<td>2/3 = 66%</td>
</tr>
<tr>
<td>minimum force</td>
<td>1/3 = 33%</td>
</tr>
<tr>
<td>minimum force symmetry ratio</td>
<td>1/3 = 33%</td>
</tr>
<tr>
<td>step length</td>
<td>0/3 = 0%</td>
</tr>
<tr>
<td>second peak force symmetry ratio</td>
<td>0/3 = 0%</td>
</tr>
<tr>
<td>second peak force</td>
<td>0/3 = 0%</td>
</tr>
<tr>
<td>stance time symmetry ratio</td>
<td>0/3 = 0%</td>
</tr>
<tr>
<td>impulse symmetry ratio</td>
<td>0/3 = 0%</td>
</tr>
</tbody>
</table>

Three of the variables reach the arbitrary 50% cutoff.

The observed and critical values of t to be used in the t-tests for intercepts at speed = 1.29m/s were obtained and compared. The numbers of significant results are tabulated below:

subject 31, bare feet vs shoes, socks, insoles 1
subject 31, shoes, socks, insoles vs shoes, socks, no insoles 1
subject 31, bare feet vs shoes, socks, no insoles 3

The mean proportion of significant results is 19%. By chance alone, one would expect 1% x 27 = 0.27, i.e. 0 or 1 positive t-tests, so the results obtained are better than this but do not reach the arbitrary 50% cutoff. 3 of the positive results are for right second peak force timing, 1 is for minimum force symmetry ratio and 1 is for minimum force. However the values of right second peak force timing are 7.47%, 726.97% and 86.57%, which is because of discontinuous variation of the second peak force timing due to the algorithms not always finding peaks and also shows the problems when one extrapolates from a few points at similar speeds. The
minimum force and minimum force symmetry ratio intercepts are also unrealistic values.

4.5.3.4 Percentage of times a complete stride was registered in a traverse

'slow' 'normal' 'fast'

subject 30 - 100% -
subject 31 - 100% -

The walkway is long enough for these subjects. This is not surprising since they were fairly small children.

4.5.3.5 Time taken

The mean time taken per trial was 1.67 minutes. This value is comparable with the average for the amputees. An assessment of 18 traverses would take 30 minutes, i.e. it would be within the arbitrary maximum allowed time for clinical usefulness.

4.5.3.6 Statistical tests for standing force symmetry ratio

The standing force test (for subject 31) is significant. However, it is not possible to draw any generalisations for this subject group from only one subject.

4.5.4 Child subjects: conclusions

For subject 31, many trials were lost due to double registration of stances. This was caused by irregularity of gait as for subject 15 but also possibly by an inappropriately high 'force lower threshold' (see section 5.2.2).

The speed range and number of traverses must be increased in future analyses so that the statistical quality of the results is improved. For
children, where a relatively large number of steps are registered per traverse, it would be particularly advantageous to analyse all the strides rather than concentrating on the first one of each traverse.

The walkway is long enough for these subjects.

The time taken per trial was comparable with the average for the amputees.

It was not possible to draw any conclusions as to the usefulness of standing force symmetry ratio.

The statistical results for the F-tests and t-tests did not pass the arbitrary thresholds for clinical usefulness, so this suggests that the system is not likely to be clinically useful for these subjects. However, it must be remembered that this conclusion was reached for the current prototype of the system, the speed range and number of trials used, the gait variables chosen and the statistical analysis used, so if any of these parameters were changed, a different conclusion might be reached. In chapter 5, it is recommended that modifications to these parameters are made and that the system is re-assessed.

4.6 Conclusions of chapter

The coefficient of determination varied significantly with subject/treatment and with gait parameter. It appeared to be higher for wider speed ranges, as one would expect.

The F-tests and t-tests appeared to give a higher percentage of significant tests for wider speed ranges and larger numbers of tests as one would expect so it will be important to try to maximise these in the future. It will also be important to modify the analysis to include all steps in a traverse so that better statistics can be obtained from the same data.

The time taken for 18 trials was around 18-30 minutes so taking an arbitrary upper limit of 30 minutes on the allowable time for an assessment
in routine clinical use, it did not seem that it would be feasible to increase
the quality of the data by increasing the number of traverses much above
18 unless the time taken per trial could be reduced. 5 of the 6 joint
replacement subjects could perform 10 trials per occasion. Around half of
the joint replacement subjects found the tests fatiguing so it seemed that
the walking ability of the subjects would limit the number of traverses
which could be done in an assessment. However, this would be true with
any gait analysis technique.

The amputees and joint replacement patients were biassed towards
the more active ends of the amputee and elderly pre-operative joint
replacement populations respectively. If the walkway could be made usable
by subjects who could not walk without walking aids, this would broaden its
potential usefulness (see section 5.2.1.8).

Some subjects felt that they were walking abnormally. However the
requirement that the subjects place one foot on each side of the centre line
is fundamental to the system. Small force plates also constrain the subject's
foot placement and even the fact that they are being watched will make
some people walk awkwardly.

The amputees tested required less than 8% extra trials due to crossing
the centre line in all but one case. A few extra trials were needed due to
operator error and atypical gait. The joint replacement subjects needed a
mean of 22% extra trials due to not clearing the centre line, so this was a
more significant problem than for the amputees. None of these problems
are serious enough to cast doubt on the walkway's clinical potential.

The code executes the algorithms correctly but the algorithms
require further work (see section 5.2.2). The algorithms for second and
minimum force peaks did not always register actual peak values. A few
trials were lost due to other problems with the algorithms. The existing
algorithms are not suitable for the cerebral palsy subject's data. For subject
31 (child, cerebral palsy, spastic diplegia), 5/16 trials were lost due to double registration of stances. This was caused by irregularity of gait as for subject 15 (adult with cerebral palsy) but also possibly by an inappropriately high 'forcelowerthreshold'.

The analysis assuming all gait variables vary linearly with speed should be improved upon, by fitting non-linear curves where appropriate.

The walkway was too short for some of the amputees although long enough for the joint replacement subjects and children at their 'normal' speeds, the special hip replacement subject at 'slow', 'normal' and 'fast' and the cerebral palsy adult at 'normal' and 'fast' speeds. For general clinical use it should be made longer (see section 5.2.1.5).

Standing force symmetry ratio as measured was not found to be useful. Possibly it would give statistically significant results if the measurement time were increased.

Only for the amputees did the proportion of positive F-tests exceed the arbitrary 50% target required for clinical usefulness.

The t-tests for the amputees gave significant results 22% of the time for slopes and 24% of the time for intercepts (c.f. 5% and 1% respectively to be expected by chance alone). These results showed that the data did contain information about the differences between prostheses. The t-tests for the joint replacement subjects showed negligible significant differences between pre-operative and post-operative states. The t-tests for the cerebral palsy child gave positive results 30% of the time for slopes and 19% of the time for intercepts but showed the perils of extrapolating from a few trials at similar speeds. For none of the subjects groups did the proportion of positive tests reach the arbitrary 50% threshold required for clinical usefulness.

The statistical results for the F-tests (except for the amputees and the subject with the specialised hip implant) and t-tests did not pass the
arbitrary thresholds for clinical usefulness, so this suggests that the system is not likely to be clinically useful for these subjects. However, it must be remembered that this conclusion was reached for the current prototype of the system, the speed range and number of trials used, the gait variables chosen and the statistical analysis used, so if any of these parameters were changed, different conclusions might be reached. In chapter 5, it is recommended that modifications to these parameters are made and that the system is re-assessed.
Chapter 5: Conclusions and suggestions for further work

5.1 Conclusions

This project had the aim of testing the hypothesis that a long force plate walkway measuring vertical force and the position of the force might be useful as a stand-alone tool for gait analysis in the routine clinical context. Its objectives were to develop a gait analysis walkway system from an existing incomplete prototype, calibrate it with static and dynamic loads and test it using volunteers with and without gait pathology, in order to assess its usefulness in the routine clinical context.

The objectives have been achieved and progress has been made towards the aim;

- a walkway system has been built which has better frequency response that that of Olsson et al (1986), but for various reasons is not yet suitable for clinical use,

- useful information has been obtained regarding the clinical usefulness of this version of the device,

- useful information has been obtained on how to improve the hardware and software so that the technique can be optimised so that it can have the best chance of being clinically useful (see section 5.2),

- the results with the subjects with pathological gait showed that the system was not yet ready for clinical use, but useful information has been obtained on how to improve the testing protocol so that the technique can be optimised so that it can have the best possible chance of being clinically useful (see section 5.2),

- the hypothesis has not been proved or disproved. In section 1.2 it was stated that in order for the walkway to be clinically useful, it was necessary that the data was of an appropriate quality, that the users could interpret it to form useful conclusions, that there were no other practical problems which made it unfeasible and that the benefits justified the
resources. This project has shown that the quality of the data is not yet adequate, assessed the resources needed, shown no serious practical problems except that in common with other methods of gait analysis, the system can only produce statistically significant results with subjects who can complete an adequate number of traverses at an adequate speed range and reviewed the usefulness of similar data but not shown whether the users could interpret it to form useful conclusions.

If the walkway is to be of routine clinical use, substantial further research will be required.

5.2 Suggestions for further work
5.2.1 Improvements to hardware
5.2.1.1 Improvements to accuracy

The accuracy of the determination of position was insufficient to allow real interpretation of the movement of the centre of pressure during the footfall, but was adequate for the calculation of step and stride lengths. It is desirable to improve the accuracy of determination of position by improving the transducers, signal conditioner and/or data acquisition card until interpretation of the movement of the centre of pressure during the footfall could be achieved. As described in section 3.1.1.2, the filters are the main cause of inaccuracy at present. Improvement of the positional accuracy to the desired specification in section 2.2 is recommended.

5.2.1.2 Mechanical damping

It is possible that mechanical damping by filling the hollow walkway sections with foam could damp out the ringing of the plates sufficiently to decrease the complexity of electrical filtering required. If the existing walkways are no longer required, they should be used to experiment with this, using short removable prisms of polyurethane foam.
The foam would be expected to bring down the natural frequency slightly because it would probably decrease the stiffness to weight ratio slightly. However, it would be expected to bring down the resonance frequency more significantly due to the increased damping factor. Hopefully, though, it would reduce its amplitude so much that it became insignificant.

5.2.1.3 Addition of horizontal force measurement

Work aiming to modify the walkway for 3D force measurement is underway (Jackson, 1993).

5.2.1.4 Modifications to the wooden surround

The signal conditioner was intrusive in its position next to the walkway and should ideally be hidden underneath the wooden surround. Also some subjects, when asked to go to the opposite end of the walkway before a trial, stepped over the signal conditioner which was dangerous. This would necessitate raising the wooden surround slightly, which would be undesirable in terms of disabled access, safety and aesthetics, but would make it easier to see and reach under the walkway during installation. The new walkway design (Jackson, 1993), if used, will necessitate a higher wooden surround.

There is some evidence from section 3.5.3.3 that the length of the wooden surround will require increase.

5.2.1.5 Increase in plate length

The present length of the walkway was found to be inadequate for some of the amputees. The walkway was therefore not long enough for general clinical use.

Jackson (1993) is designing a new platform 12 feet long, after discussion with me. The length needed in order to always capture a
complete stride is 1.5 step lengths plus one foot length plus whatever length must be excluded at each end, i.e. approximately 1.75 stride lengths. The maximum stride lengths for different platform lengths are shown below.

<table>
<thead>
<tr>
<th>Platform length</th>
<th>Maximum stride length</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 feet (4.88m)</td>
<td>2.79m</td>
</tr>
<tr>
<td>14 feet (4.27m)</td>
<td>2.44m</td>
</tr>
<tr>
<td>12 feet (3.66m)</td>
<td>2.09m</td>
</tr>
<tr>
<td>10 feet (3.05m)</td>
<td>1.74m</td>
</tr>
<tr>
<td>8 feet (2.44m)</td>
<td>1.39m</td>
</tr>
</tbody>
</table>

The maximum stride length will be for tall, minimally disabled subjects walking fast. The stride length I recorded for the 1.91m tall unilateral below knee amputee walking fast was 1.915m. The largest stride length recorded by Finley and Cody (1970) for pedestrians walking in the street was 1.93m. Rosenrot et al (1980), investigating 10 normal males of whom the tallest was 1.88m tall, and including 'fast' walking recorded a maximum stride length of 2.1m. 12 feet was chosen as the most appropriate value.

5.2.1.6 Reduction in plate width

Jackson (1993) is working on the design of a pair of new plates each 30cm wide, which aim to allow the subject's walking aids to rest on the surrounding floor.

5.2.1.7 Concealment of walkway ends

There was some suggestion in section 3.3.5.3 that the subjects might walk more naturally if they could not see the ends of the platform. Possibly one could paint a squared pattern to camouflage them. One would need to
retain a visible centre line so that the subjects would place one foot on each platform.

A suggestion from one of the subjects was that one could paint one platform and the corresponding side of the surround in one colour and the other platform and side of the surround in a contrasting colour so that the subject could keep one foot on each platform using their peripheral vision so they would not have to look down so they would notice the ends of the platforms less.

5.2.1.8 Modification for use with subjects using walking aids

The system cannot be used to measure the gait of subjects who can only walk with walking aids. Two possible solutions are the modification of the force plates to reduce their width so that the subject can rest sticks/crutches on the surrounding floor (as used by Olsson et al, 1986) and mentioned above, and the installation of parallel bars. Electrically adjustable parallel bars are available and are used at Queen Mary's Hospital, Roehampton (Dr May, personal communication, 1993). These could be perhaps be instrumented in order to investigate forces transmitted through the subject's arms. Alternatively the walking aids could be supported by additional instrumented platforms parallel to those for the feet.

5.2.1.9 Fixings

The fixings could be modified to make them less overbuilt and easier to install. (The walkway would be easier to install if in future sites it were not adjacent to a wall.)
5.2.1.10 Position of operator

The operator should be able to look along the walkway and see whether the subject is crossing over the centre line.

5.2.1.11 Portable gait laboratory

It has been suggested (Mr Hughes, personal communication, 1992) that a system could be mounted in a lorry and shared between several hospitals.

5.2.2 Improvements to software

It will be necessary to improve the algorithms further. They are extracting certain parameters from the data. However, the parameters 'firstpeakforce', 'minimumforce', 'secondpeakforce' and 'secondpeakforce.timing' do not always identify true peaks, so the values found do not always vary continuously. Also, particularly for pathological gait, the force-time curves are often multipeaked. In this case one must decide which peaks are to be used, or it may be more meaningful to use other techniques such as Fourier analysis.

To prevent the registration of scuffs as steps, and the consequent generation of false values for gait parameters, ‘forcelowerthreshold’ was raised from 1kgf to 4kgf. Clearly this distorts the data (e.g. shortens stance times) and increases double registration of steps when the force falls to a low value during a stance. It should be made possible to identify scuffs and eliminate them from the analysis. This could be done by checking whether the force in a scuff ever exceeded ‘forceupperthreshold’. This would mean that ‘forcelowerthreshold’ could be lowered. So that the information that the scuff occurred is not suppressed, scuffs could be counted separately.

Occasionally, only the toe of a subject’s footfall is on the walkway and the force rises above ‘forcelowerthreshold’, dips below it then rises
above it again. This means that the footfall is registered as two footfalls. The first one is eliminated because it does not reach 'forceupperthreshold' but the second one is taken as valid, causing the program to generate false gait values. If 'forcelowerthreshold' were lowered and the scuff detection suggested above were implemented, the occurrence of double registration would be reduced and the second 'footfall' would be treated as a scuff. The program cannot be made to distinguish it from a scuff.

The weight measurement should not be in the same control loop as the walking measurement.

Grieve (1980) comments that if routine clinical measurements are contemplated 'it is probably false economy to consider methods that do not instantly produce records suitable for the patient's file'. At present, data collation has to be done by sending the data to a spreadsheet program and then manipulating it. The author considers that it is not necessary that the output should be instant, but that the amount of human input required to process the data at present would have to be greatly reduced before the method would be clinically useful, i.e. the post-processing of the data must be virtually automated. The analysis should include all the data, not just the data from the first stride per traverse. The assumption that the gait parameters all vary linearly with velocity is an over-simplification, so different forms of curve should be used as appropriate. It would be useful to be able to compare automatically a patient's results with their earlier results.

It will be necessary to decide on the form in which the data is to be output for the clinicians. Mr Deane (1992) thought the visual information and maybe a simple number would be appropriate. Dr May (1992) suggested that a 6-line summary sheet might be appropriate.
Clinicians appear to want to be able to make judgements from graphical information but there is a lot of variation between individual traces. Therefore perhaps average shapes should be produced.

If the system is modified to measure horizontal as well as vertical forces, this will require modifications to the software.

The scaling of the data could also be improved, so that the data filled more of the screen. It would be desirable to make the graphics clearer and more attractive by modifying the program to use a more up-to-date graphics package. There is a graphics language called 'Postscript' which appears suitable (Jeffery, 1992). (The printer attached to the system has Postscript capability.)

It has been suggested that in future the software should be an expert system in order to assist interpretation of the data. It could contain normals data with which the subjects' data could be compared. It might be appropriate to introduce pattern recognition to the system.

5.2.3 Improvements to protocol

It is important if possible to ensure that the subject is used to the test before recording begins, in order to eliminate learning curve effects. This is not always practical with subjects with pathological gaits. It is also desirable to walk subjects along the walkway a few times in order to precondition the load cells before beginning measurements.

It is important that subjects start and finish far enough away from the platform in order that steady state gait is achieved.

It is important to maximise the speed range and number of traverses in any assessment. Ideally one would use the same speed range in assessments to be compared but this may not be practical.

For certain patient groups, it may be that their spontaneous occasion-to-occasion speed variation is very low so that the analysis used
above, which was designed to be insensitive to it, would not be the most suitable. The degree of spontaneous occasion-to-occasion speed variation would be a suitable subject for further work.

Alternatively one might control the speed to within a narrow range so that all the traverses from all the assessments were at virtually the same speed. This would facilitate comparison, but it might be difficult or impossible for the subjects to achieve the given speed and it might make their gait unrepresentative.

5.2.4 Use with other equipment

Richard Major at the Orthotics Research and Locomotor Assessment Unit at Oswestry in Shropshire indicated (1989) that if the walkway measured horizontal forces as well as vertical he could be considered for linking it with their force vector visualisation system.

5.2.5 Suggested programme for further work

It is suggested that the work should be continued by producing a new pair of force plates of the recommended dimensions, and instrumenting them to measure horizontal as well as vertical forces. This is likely to necessitate redesign of the fixings. The system's accuracy should be improved. It should be positioned to make best use of the available space. The software should be modified. If possible, the use of mechanical damping should be investigated.

If possible, the walkway should be concealed and the effect on subjects' gait of concealing it should be assessed.

The new system should be tested in conjunction with potential users (bearing in mind the recommended improvements to the protocol) with the aims of determining the most appropriate presentation of the data and validating specific clinical applications.
Appendix 1.1:

Commercial suppliers of gait analysis equipment

Advanced Mechanical Technology Inc., 141 California Street, Newton, Mass 02158, USA.

Anima company, 3-65-1 Shimoishihara, Choufu-shi, Tokyo, Japan. Tel 0424-87-6111, Fax 0424-87-6116

Biokinetics, Unit 103, 5413 West Cedar Lane, Bethesda, Maryland 20814

Kistler Instruments Limited, Whiteoaks, The Grove, Hartley Wintney, Hants RG27 8RN

M.I.E. Medical Research Limited, 6 Wortley Moor Road, Leeds LS12 4JF, Tel (0532) 793710, Fax (0532) 310820

Musgrave Research Group, 23 Castle Street, Llangollen (North Wales), LL20 8TF, telephone 0978 861480, fax 0978 861814 / 861334

Suntech Medical (U.K.) Ltd, 3, Banbury Street, Kineton, Nr. Warwick, CV35 0JW, Tel: (0926) 641718, Fax: (0926) 641695
Appendix 1.2: Commercial force plates

Advanced Mechanical Technology Inc. In July 1991, their largest force plate available was 4 feet (1.22m) long and cost $18 000. They offer several mounting options and can provide custom mounting. The surface has to be flat to within 0.05mm (to avoid damaging the platform) and stiff (to provide maximum frequency response). The most popular option is an aluminium plate epoxy-bonded to a concrete foundation. This system is very difficult to remove once installed. There is a version in which the platform is mounted on a large aluminium plate and can be moved, and another version in which the platform can be moved around on an air bearing.

Anima company A pair of large force plates manufactured by this company were used by Takegami (1992). He gives the dimensions of the plates as 2.5m long, 0.4m wide. The system is not being exported because it needs instrumentation and maintenance of high quality (Imaoka, 1992).

Bertec Force Platforms, sold by M.I.E. Medical Research Limited These are available in a range of sizes and specifications. The transducers are strain gauge type rather than piezo-electric so they suffer less from zero drift. The base of the platform is made of cast aluminium, on which four precision load transducers are mounted. A pre-amplifier is mounted inside the platform to improve the signal-to-noise ratio so that long cables can be used. The main amplifier incorporates a low-pass, second order, active 3 pole, 1000Hz cutoff frequency filter. The prices for the force plates, amplifier and cable (February 1992) are shown below.
M.I.E. sell PRO-VEC software to accompany the force platforms. They also sell Modular Biokinetic Measurement software permitting data from different gait analysis equipment to be collected, analysed and displayed together.

Kistler Instruments Limited Kistler force platforms use piezo-electric transducers. The measurement elements are crystals whose surfaces become charged when they are mechanically stressed. The force plate consists of a base frame and an interchangeable force plate, with 4 3-component force transducer fitted between them under high prestress. The force plate is fixed down to a stiff metal frame which is installed by embedding it in concrete. It can be unscrewed and lifted off. The output signals are input to an 8-channel charge amplifier. A choice of top plates is available, including a glass one, enabling the walking to be videoed from below.
Sample prices (June 1993) are:

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 force platform, type 9281B11 (0.4m x 0.6m)</td>
<td>£10 500.00</td>
</tr>
<tr>
<td>mounting frame, type 9423</td>
<td>£422.00</td>
</tr>
<tr>
<td>eight-channel charge amplifier, type 9865B1Y28</td>
<td>£4300.00</td>
</tr>
<tr>
<td>cable, type 1681B10</td>
<td>£1210.00</td>
</tr>
<tr>
<td>Bioware software package including set of connecting cables to</td>
<td>£4350.00</td>
</tr>
<tr>
<td>eight channel amplifier and A/D card</td>
<td></td>
</tr>
<tr>
<td>plus 17.5% V.A.T.</td>
<td>£24 418.85</td>
</tr>
</tbody>
</table>
Schematic diagram of system

Appendix 2.1
**Appendix 2.2: list of suppliers**

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Address</th>
<th>Telephone</th>
</tr>
</thead>
<tbody>
<tr>
<td>BATS Nationwide</td>
<td>267 Findon Road, Findon Valley, Worthing, West Sussex BN14 0HA</td>
<td>0903 877224</td>
</tr>
<tr>
<td>Borland International</td>
<td>1800 Green Hills Road, P.O. Box 660001, Scotts Valley, California 95066-0001</td>
<td>0101 408 438 5300</td>
</tr>
<tr>
<td>Courtaulds International</td>
<td>International Paint Retail Division, The Special Paint People, Southampton SO9 3AS</td>
<td>0703 226722</td>
</tr>
<tr>
<td>CBA Metals</td>
<td>Daux Road, Billingshurst, RH14 9SN</td>
<td>0403 783944</td>
</tr>
<tr>
<td>CIL Electronics Ltd</td>
<td>4 Wayside, Commerce Way, Lancing, West Sussex BN15 8TA</td>
<td>0903 765225</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fax 0903 765547</td>
</tr>
<tr>
<td>Clba Geigy</td>
<td>Duxford, Cambridge CB2 4QD</td>
<td>0223 832121</td>
</tr>
<tr>
<td>Farnell Electronic Components Ltd</td>
<td>Canal Road, Leeds LS12 2TU</td>
<td>0532 636311</td>
</tr>
<tr>
<td>Harcros Timber Merchants</td>
<td>Walnut Tree Close, Guildford</td>
<td>0483 60066</td>
</tr>
<tr>
<td>F.P. Hartings</td>
<td>Units 3 and 4, 427 Long Drive, Greenford, London</td>
<td>081-575-9600</td>
</tr>
<tr>
<td>Industrial Data Processing Ltd</td>
<td>Melbourne Science Park, Cambridge Road, Melbourne, Herts SG8 6TB</td>
<td>0763 262662</td>
</tr>
<tr>
<td>Inmac Ltd</td>
<td>79-80 Buckingham Avenue, Slough, Berks SL1 4PN</td>
<td>0753 825311</td>
</tr>
<tr>
<td>Margnor (Fasteners) Ltd</td>
<td>36 Stringers Avenue, Jacobs Well, Guildford</td>
<td>0483 302705</td>
</tr>
<tr>
<td>Mesh Computers and Electronics</td>
<td>Mesh House, Apsley Court, Apsley Way, London NW2 7HF</td>
<td>081 452 1111</td>
</tr>
<tr>
<td>Novatech Ltd</td>
<td>83 Castleham Road, St Leonards-on-sea, Sussex TN38 9NT</td>
<td>0424 52744</td>
</tr>
<tr>
<td>Payne Products</td>
<td>Hewitts Industrial Estate, Elmbridge Road, Cranleigh, Surrey</td>
<td>0483 276000</td>
</tr>
<tr>
<td>Permabond Adhesives Limited</td>
<td>Woodside Road, Eastleigh, Hants SO5 4EX</td>
<td>0703 629628</td>
</tr>
<tr>
<td>RS Components Ltd</td>
<td>PO Box 99, Corby, Northants NN17 9RS</td>
<td>081 360 8600</td>
</tr>
</tbody>
</table>
Appendix 2.3: Some implications of making the walkway suitable for use with children

Children are lighter than adults. To achieve the same percentage errors in force measurements the absolute force errors must therefore be smaller than those for adults. The children also have shorter step lengths than adults so to achieve the same percentage errors in step length the absolute errors in distance measurements must be reduced. If the walkway had been designed to be used with adults as well as children, it would have meant that it would have needed to have measured more accurately, which would have made it more expensive. Calculations are performed below to estimate how more accurate it would have had to have been.

According to Lewallen et al (1986), if a child is too young, it cannot cooperate in the gait analysis. 'The gait of children of 4 years old or above is well developed and consistent and approaches the final gait pattern for that individual.' The calculations are therefore performed using a 4 year old child as the basis.

The median weight for 4 year old boys is 16.6kgf and for 4 year old girls is 16.0kgf (Lebow, 1991). This gives an estimated mean weight for 4 year old children of (16.6 + 16.0)/2 = 16.3kgf. The corresponding figures for 18 year olds are 69.2kgf and 56.8kgf. This means that adults are (69.2 + 56.8)/16.3 = 3.87 times as heavy as 4 year old children. Assuming that the foot forces vary in proportion to the weight, this means that the walkway's errors would have needed to have been reduced by a factor of 3.87 to keep the percentage errors constant.

Takegami (1992) found that the mean step length/height for twenty 4 year old children was 0.37. The median height for 4 year old boys is 1.035m and that for girls is 1.020m, so the mean step length for 4 year old children can be estimated as 0.37 x (1.035 + 1.020)/2 = 0.38m. The mean step lengths for men is 0.741m and for women is 0.634m (Finley and Cody, 1970).
Therefore it can be estimated that the children's step lengths are shorter than the adults' by a factor of \((0.741 + 0.634) / (0.38 \times 2) = 1.8\).

The effect of a given absolute force error on a positional measurement is inversely proportional to the force being measured. Above, it was estimated that the forces produced by the children would be 3.87 times less than those produced by the adults, so to maintain the same absolute positional errors, the absolute force errors would have to reduce by a factor of 3.87. However, the children also have shorter step lengths so in order to keep the percentage errors in step lengths constant, the absolute force errors would have had to reduce by a further factor of 1.8.

In conclusion, in order for the walkway to have given results of similar percentage accuracy for children to those given for adults, the absolute errors in force measurement would have had to have been reduced by a factor of \(3.87 \times 1.8 = 7.0\), which would have increased its cost significantly.
Appendix 2.4: Drawings

See pocket at back of volume 1 of thesis.
### Appendix 2.5: choice of transducers

Prices quoted for transducers which would fulfil the given criteria were:

<table>
<thead>
<tr>
<th>Company</th>
<th>Price per transducer/£</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandhurst Scientific Instrument Co. Ltd., 68A High Street, Camberley, Surrey, GU17 8ED</td>
<td>825¹</td>
</tr>
<tr>
<td>Kistler Instruments Ltd, Whiteoaks, The Grove, Hartley Wintney, Hants RG27 8RN</td>
<td>514¹</td>
</tr>
<tr>
<td>RDP Electronics Ltd, Grove Street, Heath Town, Wolverhampton WV10 0PY</td>
<td>503¹</td>
</tr>
<tr>
<td>Techni Measure, Alexandra Buildings, 59 Alcester Road, Studley, Warwickshire B80 7NJ</td>
<td>342.20¹</td>
</tr>
<tr>
<td>Novatech Measurements Limited, Castleham Road, Castleham Industrial Estate, St. Leonards on Sea, East Sussex TN38 9NT</td>
<td>329²</td>
</tr>
<tr>
<td>Entran Ltd, 5 Albert Road, Crowthorne, Berks, RG11 7LT</td>
<td>284³</td>
</tr>
<tr>
<td>Maywood Instruments Limited, Rankine Road, Daneshill Industrial Estate, Basingstoke, Hampshire RG24 OPP</td>
<td>269³</td>
</tr>
</tbody>
</table>
1 More expensive than type presently in use, so not considered further.
2 The type already in use at Surrey.
3 Not considered sufficiently cheaper to justify buying 6 of them rather than 3 more of the ones we had, so not considered further.
4 Considered significantly cheaper and therefore worthy of further investigation.

The manufacturer's specification for the Novatech F241 transducer appeared adequate.

The Variohm transducer could cope with a safe side load of 50% full scale. Its height was 2.50 inches (or 2.40 inches if made of stainless steel). The height of the transducers already in use was 50mm, so the Variohm transducers would not have added significantly to the depth of the assembled force plate. The manufacturers were unable to supply adequate data as to how the device would cope with off-axis loads, off-centre loads and dynamic loads. It was not considered to be worth the expense and time to purchase a transducer and test it, so it was decided not to use this transducer.

The response of one of the Novatech F241s was tested under off-axis loading. It was tested by using an Instron mechanical testing machine to apply a known load perpendicular to the axis of the transducer (see sketch below).
The load was applied at various angles within the plane perpendicular to the axis of the transducer. Ideally the transducer should have been free to move axially, to ensure that no axial force was applied. In practice, axial force was minimised by ensuring that the transducer was rigidly held horizontal and that the geometry of the equipment was such that the force would be applied accurately vertically. The force was displaced from the end of the transducer case by a distance equivalent to the expected distance to the top surface of the walkway, to simulate the bending effect on the transducer due to the horizontal forces exerted by a subject walking on the force platform.

The transducer was tested up to 500N (i.e. 51.0kgf i.e. 500N/3000N = 17 percent of full scale). The angle between the transducer power lead and a reference direction was set to 0, 30, 60, 90, 120, 150, 180, 210 and 330 degrees. Values between 210 and 330 degrees could not be used due to an oversight when designing the test rig. It was thought likely that the design of the transducer would have symmetry, so it was not thought worthwhile to modify the attachment in order to measure the remaining angles.
The voltage results were converted into equivalent force readings. The worst registered load was approximately -0.7kgf at an applied side load of 51.0kgf, i.e. 1.4% of the applied load. At 10kgf applied side load, the worst registered vertical load was approximately -0.15kgf, i.e. 1.5% horizontal applied load.

Since the horizontal load exerted in walking is less than the vertical load and the transducer was not unconstrained axially, it was judged that the performance of the transducers was sufficient to justify buying 3 more of them.
Appendix 2.6: data capture hardware

1 Strawberry Tree Incorporated, Computer Instrumentation and Controls, 160 South Wolfe Road, Sunnyvale, California 94086. Strawberry Tree ACJR-12-8 card with software (£495) and a T31 termination board with cable (£125), i.e. a total of £620. It seemed that that the maximum rate using the ACJR-12-8 was 333Hz each for 6 channels. Samples were equally spaced in time, because of the slowness of the ADC. It was preferable for all channels to be sampled virtually simultaneously. Also, in the long term it was hoped to expand the equipment to sample a greater number of voltage channels at the same sampling rate (in order to measure horizontal as well as vertical force). This would not have been possible with this equipment. It was decided not to buy equipment that would not allow this.

2 Burr-Brown (sold by Test Data Systems Limited, St. John's Innovation Centre, Cowley Road, Cambridge CB4 4WS):

<table>
<thead>
<tr>
<th>Equipment Description</th>
<th>Price (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI 20098C Multi-function carrier card</td>
<td>840</td>
</tr>
<tr>
<td>PCI-20024T-1 termination panel</td>
<td>140</td>
</tr>
<tr>
<td>PCI-20008A-1B analogue cable</td>
<td>65</td>
</tr>
<tr>
<td>PCI-20026S-3 modular software drivers for Turbo Pascal</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>1220</td>
</tr>
</tbody>
</table>
Appendix 2.7

Flowchart for programmes 'force, 'posit' and 'dyn'
Flowchart for programme 'Convert2'
Appendix 2.9: sample printout

--- Data from University of Surrey gait assessment walkway ---

--- Record name ---
record name=106

--- Graphs ---

**Top graph:**
- **Solid line:** platform 1 (right foot)
- **Broken line:** platform 2 (left foot)

**Bottom graph:**
- **Top of screen:** platform 1
- **Bottom of screen:** platform 2

Direction of travel: <——
length of vector represents magnitude of vertical force
time interval between vectors=0.0025 seconds

platform 1
platform 2

Direction of travel:<—

Error Messages
No error messages

Date and time
test date=Wednesday 7 October 1992
test time=13:44

Force plate data
numberofchannels=6
nominalsamplingrateperchannel=400Hz
actualsamplingrateperchannel=400.3Hz
samplingtime=5s
readingsperchannel=2000
zero1=1018.550
zero2=1022.610
zero3=1035.600
zero4=1043.600
zero5=1009.670
zero6=1035.400

Weight on each foot in standing
Average weight on left foot in standing= 0.0kgf
Average weight on right foot in standing= -0.0kgf

Temporal factors
first step was on platform 1
Total stance time of step 1 on platform 1=0.6695 seconds
Total stance time of step 2 on platform 1=0.7020 seconds
Total stance time of step 1 on platform 2=0.6395 seconds
double stance time [1]=0.0999 seconds
double stance time [2]=0.1124 seconds
platform 1 stride time [1]=1.0967 seconds
left foot was on platform 2

platform 1, step 1
position where force first exceeds force upper threshold is
\((x,y)=(1.954 \text{ metres},-0.038 \text{ metres})\)
position where force last exceeds force upper threshold is
\((x,y)=(1.761 \text{ metres},-0.001 \text{ metres})\)

platform 1, step 2
position where force first exceeds force upper threshold is
\((x,y)=(0.600 \text{ metres},-0.011 \text{ metres})\)
position where force last exceeds force upper threshold is
\((x,y)=(0.404 \text{ metres}, 0.005 \text{ metres})\)

platform 2, step 1
position where force first exceeds force upper threshold is
\((x,y)=(1.226 \text{ metres},-0.143 \text{ metres})\)
position where force last exceeds force upper threshold is
\((x,y)=(1.132 \text{ metres},-0.155 \text{ metres})\)

platform 1, step 1 time averaged \((x,y)=(1.841 \text{ metres},-0.004 \text{ metres})\)
platform 1, step 2 time averaged \((x,y)=(0.489 \text{ metres},-0.002 \text{ metres})\)
platform 2, step 1 time averaged \((x,y)=(1.159 \text{ metres},-0.151 \text{ metres})\)

platform 1 step length \([l]=-0.670 \text{ metres}\)
platform 2 step length \([l]=-0.682 \text{ metres}\)
platform 1 step width \([l]= 0.149 \text{ metres}\)
platform 2 step width \([l]= 0.148 \text{ metres}\)
platform 1 stride length \([l]=-1.351 \text{ metres}\)

velocity based on platform 1 = -1.23 metres per second

velocity = -1.23 metres per second

*** Measured peak forces ***

*** platform 1, step 1 ***
beginning of step is at time= 0.933 seconds
end of step is at time= 1.603 seconds
maximum force in first half of step= 56.8kgf after 23.1% of the step
maximum force in second half of step= 62.5kgf after 77.2% of the step
minimum force between these two peaks = 40.1kgf after 47.0% of the step

*** platform 1, step 2 ***
beginning of step is at time= 2.030 seconds
end of step is at time= 2.733 seconds
maximum force in first half of step= 55.4kgf after 20.6% of the step
maximum force in second half of step= 60.7kgf after 79.0% of the step
minimum force between these two peaks = 41.5kgf after 43.8% of the step

*** platform 2, step 1 ***
beginning of step is at time= 1.503 seconds
end of step is at time= 2.143 seconds
maximum force in first half of step= 59.5kgf after 18.0% of the step
maximum force in second half of step = 60.9kgf after 76.6% of the step
minimum force between these two peaks = 39.0kgf after 44.9% of the step

*---------* Measured vertical impulses *---------*

impulse of step 1 on platform 1 = 28.6kgf*seconds
impulse of step 2 on platform 1 = 31.0kgf*seconds
impulse of step 1 on platform 2 = 28.2kgf*seconds

*---------*
Flowchart for programme 'uosgws5'

Appendix 2.10
Appendix 3.1: Determination of source of poor dynamic behaviour of platform 2

Introduction

It was decided to check that the origin of the poor dynamic behaviour of platform 2 was electrical rather than mechanical.

Method

An approximate static calibration of the walkway was performed. This established a set of 6 static gain values for the channels ('unswapped' position). The electronics from platform 1 were swapped with those from platform 2 (channel 1 with 6, 2 with 5, 3 with 4, 'swapped' position). Another approximate static calibration of the walkway was performed, establishing a second set of 6 static gain values.

A normal subject (22 years old, 1.65m tall, right handed, right footed, wearing trainers, weighing 68kg) walked along the walkway 10 times at fast speed with the electronics in the 'unswapped' position and using the 'unswapped' gain values. The electronics from the two walkways were swapped over and the gains changed to the 'swapped' values. She then walked along 10 more times at fast speed. The positional results were visually inspected to see whether the poor dynamic behaviour moved to platform 1 when the electronics were swapped over.

Results

The errors from the static calibration were satisfactory.

The positional data shown in runs 1122 and 1123 show the 'unswapped' behaviour. When the subject walks in the direction of increasing x, the footfall data on platform 2 is 'stretched'. When the subject walks in the direction of decreasing x, the footfall data on platform 2 is 'curled'.

336
Data from University of Surrey gait assessment walkway

---

Record name = 1122

---

solid line: platform 1
broken line: platform 2

---

top of screen: platform 1
bottom of screen: platform 2

---

Direction of travel: →

---

'Unswapped' behaviour

337
Data from University of Surrey gait assessment walkway

Record name = 1123

solid line: platform 1
broken line: platform 2

unswapped' behaviour

338
Data from University of Surrey gait assessment walkway

Record name = llll

---

solid line: platform 1
broken line: platform 2

top of screen: platform 1
bottom of screen: platform 2
Direction of travel: →

'Swapped' behaviour

339
Data from University of Surrey gait assessment walkway

Record name = record name=1112

solid line: platform 1
broken line: platform 2

Direction of travel:

'Swapped' behaviour
The positional data shown in runs 1111 and 1112 show the 'swapped' behaviour. When the subject walks in the direction of increasing \( x \), the footfall data on platform 1 is 'curled'. When the subject walks in the direction of decreasing \( x \), the footfall data on platform 1 is 'stretched'.

The poor dynamic behaviour thus moved to platform 1 when the electronics were swapped over, showing that it was due to the electronics.
<table>
<thead>
<tr>
<th>Subject</th>
<th>Pathology</th>
<th>sex</th>
<th>age</th>
<th>stature</th>
<th>weight inc. prosthesis a</th>
<th>hand dominance</th>
<th>leg dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>right BK amputee</td>
<td>m</td>
<td>36</td>
<td>1.68m</td>
<td>80.5kgf</td>
<td>not available</td>
<td>not available</td>
</tr>
<tr>
<td>28</td>
<td>right BK amputee</td>
<td>m</td>
<td>45</td>
<td>1.91m</td>
<td>116.6kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>33</td>
<td>left BK amputee</td>
<td>m</td>
<td>58</td>
<td>1.79m</td>
<td>81.3kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>26</td>
<td>right through knee</td>
<td>m</td>
<td>61</td>
<td>1.73m</td>
<td>75.6kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>41</td>
<td>right through knee</td>
<td>f</td>
<td>47</td>
<td>1.57m</td>
<td>49.9kgf</td>
<td>r</td>
<td>didn't know</td>
</tr>
<tr>
<td>3</td>
<td>right AK amputee</td>
<td>m</td>
<td>53</td>
<td>1.75m</td>
<td>89.7kgf</td>
<td>not available</td>
<td>not available</td>
</tr>
<tr>
<td>4</td>
<td>left AK amputee</td>
<td>m</td>
<td>39</td>
<td>1.80m</td>
<td>71.6kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>5</td>
<td>right AK amputee</td>
<td>m</td>
<td>45</td>
<td>1.85m</td>
<td>84.3kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>6</td>
<td>right AK amputee</td>
<td>m</td>
<td>45</td>
<td>1.82m</td>
<td>73.7kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>7</td>
<td>right AK amputee</td>
<td>m</td>
<td>45</td>
<td>1.83m</td>
<td>84.2kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>8</td>
<td>left AK amputee</td>
<td>m</td>
<td>26</td>
<td>1.71m</td>
<td>55.2kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>24</td>
<td>right hip disarticulation</td>
<td>m</td>
<td>54</td>
<td>1.83m</td>
<td>107.0kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>29</td>
<td>left hip disarticulation (effectively)</td>
<td>m</td>
<td>26</td>
<td>1.85m</td>
<td>90.0kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>18</td>
<td>bilateral absent feet</td>
<td>m</td>
<td>33</td>
<td>1.69m</td>
<td>58.8kgf</td>
<td>l</td>
<td>r</td>
</tr>
<tr>
<td>42</td>
<td>right above knee, left below knee amputee</td>
<td>m</td>
<td>32</td>
<td>1.83m</td>
<td>77.1kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>40</td>
<td>bilateral AK amputee</td>
<td>f</td>
<td>38</td>
<td>1.55m</td>
<td>40.2kgf</td>
<td>r</td>
<td>r</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Reason for amputation</th>
<th>years since amputation</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>road accident</td>
<td>11</td>
</tr>
<tr>
<td>28</td>
<td>osteomyelitis after trauma</td>
<td>21</td>
</tr>
<tr>
<td>33</td>
<td>osteomyelitis and non-union after road accident</td>
<td>34</td>
</tr>
<tr>
<td>26</td>
<td>vascular ischaemia and Buerger's Disease</td>
<td>23</td>
</tr>
<tr>
<td>41</td>
<td>congenital deformity</td>
<td>42</td>
</tr>
<tr>
<td>3</td>
<td>road accident</td>
<td>39</td>
</tr>
<tr>
<td>4</td>
<td>congenital absence of the tibia</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>road accident</td>
<td>27</td>
</tr>
<tr>
<td>6</td>
<td>road accident</td>
<td>35</td>
</tr>
<tr>
<td>7</td>
<td>road accident</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>road accident</td>
<td>11</td>
</tr>
<tr>
<td>24</td>
<td>malignant fibrosarcoma of the fibula</td>
<td>15</td>
</tr>
<tr>
<td>29</td>
<td>fibrous sarcoma of proximal femur</td>
<td>18</td>
</tr>
<tr>
<td>18</td>
<td>congenital absence of both feet due to arthrogryphosis</td>
<td>absent at birth</td>
</tr>
<tr>
<td>42</td>
<td>road accident</td>
<td>2</td>
</tr>
<tr>
<td>40</td>
<td>Meningococcus Septicaemia (gangrene due to infection)</td>
<td>27</td>
</tr>
</tbody>
</table>
### Technical Details of Leg B

<table>
<thead>
<tr>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTB and coret, 11/90, Blatchford Endolite no. 8 GRP PTB socket, reinforced with carbon fibre, side steels and thigh corset. Seattle light foot</td>
</tr>
<tr>
<td>N/A</td>
</tr>
<tr>
<td>N/A</td>
</tr>
<tr>
<td>N/A</td>
</tr>
<tr>
<td>Conventional no. 3 metal limb dated 5/2/70 fitted with WTKC control and conventional wood foot</td>
</tr>
<tr>
<td>Vessa no. 3 Roelite 6/80, metal socket, 4-bar linkage knee, quantum foot</td>
</tr>
<tr>
<td>No. 3 Endolite, Endolite stabilised knee and pneumatic swing phase control with a multiflex ankle</td>
</tr>
<tr>
<td>No. 3 Endolite, dated 1/1/90. Fitted with a Malch S and S unit, multiflex ankle and foot</td>
</tr>
<tr>
<td>Experimental 4-bar knee with a Seattle light foot</td>
</tr>
<tr>
<td>No. 3 Endolite dated 24/2/88 with an Endolite Stabilised Knee, Pneumatic Swing Phase Control, multiflex ankle. Socket at fitting stage, probably poor.</td>
</tr>
<tr>
<td>No. 3 Endolite fitted with an Isney Socket, Endolite Stabilised Knee and Pneumatic Swing Phase Control, Quantum foot. Dated 26/3/90</td>
</tr>
<tr>
<td>N/A</td>
</tr>
<tr>
<td>Quantum no. 1 limb, block leather socket with GRP shell, modular hip joint, 4-bar knee, quantum foot</td>
</tr>
<tr>
<td>slippers: double Symes leather slippers</td>
</tr>
<tr>
<td>N/A</td>
</tr>
<tr>
<td>N/A</td>
</tr>
</tbody>
</table>

### Technical Details of Leg A

<table>
<thead>
<tr>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old conventional limb, no. 8, Vessa 9/83, required major overhaul including new foot</td>
</tr>
<tr>
<td>PTB prosthesis with sleeve suspension and fitted with a multiflex ankle joint.</td>
</tr>
<tr>
<td>Vessa conventional no. 8 metal leg dated 1/10/81</td>
</tr>
<tr>
<td>Endolite no. 6. Block leather socket, GRP cells, short knee chassis, Swing Phase Control, multiflex ankle</td>
</tr>
<tr>
<td>Hanger no. 3 metal limb dated 3/3/71 fitted with WTKC control and conventional wood foot</td>
</tr>
<tr>
<td>Quantum stabilised knee, 1/11/89, Vessa Ultra roelite no. 3, quantum foot</td>
</tr>
<tr>
<td>No. 2 Endolite, fitted with Malch S and S unit, dated 18/1988</td>
</tr>
<tr>
<td>No. 3 Endolite, dated 2/3/88. Fitted with an Endolite Stabilised Knee and a Pneumatic Swing Phase Control Unit.</td>
</tr>
<tr>
<td>Vessa Endolite no. 3 fitted with a Malch S and S unit and a Quantum foot</td>
</tr>
<tr>
<td>No. 3 Endolite dated 2/12/92 fitted with a metal socket, Malch S and S unit with a Multiflex foot</td>
</tr>
<tr>
<td>No. 3 Endolite fitted with an Isney Socket, Malch Knee S and S unit, Quanum foot. Dated 8/7/87</td>
</tr>
<tr>
<td>No. 1 Endolite with Polypropylene Embracing Socket, 4-bar linkage hip joint and Endolite Stabilised Knee with an ICS, multiflex ankle and foot</td>
</tr>
<tr>
<td>Vessa Ultra Roelite no. 1 limb 4/9/86 with block leather socket, GRP shell, modular hip limiter, 4 bar linkage knee, Quantum foot</td>
</tr>
<tr>
<td>shoes: double Symes elephant peg rocker ends</td>
</tr>
<tr>
<td>set a: left: PTB Endolite, polypropylene socket, petite liner, cuff suspension, multiflex ankle, Seattle light foot</td>
</tr>
<tr>
<td>set a: limbs dated 2/11/87: fitted with Quantum Stabilised Knee and Quantum Foot</td>
</tr>
</tbody>
</table>

Appendix 4.1: details of amputees and their prostheses page 2
### Technical Details of Leg C

<table>
<thead>
<tr>
<th>11/89 Blatchfords P.T. bearing supracondylar GRP socket, Seattle light foot</th>
<th>N/A</th>
<th>N/A</th>
<th>N/A</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>conventional, 4/89. Vessa metal no. 3, metal suction socket, free knee with WTKC (friction knee), quantum foot</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>No. 3 Metal Conventional limb with wheel type knee control and Hanger moulded unaxial foot</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Other Details of Leg A</th>
<th>Other Details of Leg B</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>very creaky, couldn’t get shoe on fully</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>subject felt he had to work harder and alignment was worse</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>subject said fit was slightly different, thought it swung through t</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>subject said the slippers were more comfortable</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Appendix 4.1: details of amputees and their prostheses page 3
<table>
<thead>
<tr>
<th>Other Details of Leg</th>
<th>Occupation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Computer programmer</td>
</tr>
<tr>
<td></td>
<td>Professor</td>
</tr>
<tr>
<td></td>
<td>Unemployed engineering technician</td>
</tr>
<tr>
<td></td>
<td>Retired police officer</td>
</tr>
<tr>
<td></td>
<td>Housewife</td>
</tr>
<tr>
<td>Subject thought</td>
<td>Taxi driver</td>
</tr>
<tr>
<td>Socket more</td>
<td>Business consultant</td>
</tr>
<tr>
<td>Comfortable</td>
<td>Policeman; Road Traffic Officer</td>
</tr>
<tr>
<td>Letter.</td>
<td>Prosthetic Manager</td>
</tr>
<tr>
<td></td>
<td>Unemployed Decorator</td>
</tr>
<tr>
<td></td>
<td>Unemployed Clerk</td>
</tr>
<tr>
<td></td>
<td>Lecturer</td>
</tr>
<tr>
<td></td>
<td>Unemployed Butcher</td>
</tr>
<tr>
<td></td>
<td>Trainee Prosthetist</td>
</tr>
<tr>
<td></td>
<td>Accountant</td>
</tr>
<tr>
<td></td>
<td>Secretary</td>
</tr>
<tr>
<td>Subject</td>
<td>Pathology</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>23</td>
<td>right BK amputee</td>
</tr>
<tr>
<td>28</td>
<td>right BK amputee</td>
</tr>
<tr>
<td>33</td>
<td>left BK amputee</td>
</tr>
<tr>
<td>26</td>
<td>right through knee</td>
</tr>
<tr>
<td>41</td>
<td>right through knee</td>
</tr>
<tr>
<td>3</td>
<td>right AK amputee</td>
</tr>
<tr>
<td>4</td>
<td>left AK amputee</td>
</tr>
<tr>
<td>5</td>
<td>right AK amputee</td>
</tr>
<tr>
<td>6</td>
<td>right AK amputee</td>
</tr>
<tr>
<td>7</td>
<td>right AK amputee</td>
</tr>
<tr>
<td>8</td>
<td>left AK amputee</td>
</tr>
<tr>
<td>24</td>
<td>right hip disarticulation</td>
</tr>
<tr>
<td>29</td>
<td>left hip disarticulation</td>
</tr>
<tr>
<td>18</td>
<td>bilateral absent feet</td>
</tr>
<tr>
<td>42</td>
<td>right AK, left BK amputee</td>
</tr>
<tr>
<td>40</td>
<td>bilateral AK amputee</td>
</tr>
</tbody>
</table>

Appendix 4.2: numbers of trials for amputee subjects
<table>
<thead>
<tr>
<th>Subject</th>
<th>No. of trials</th>
<th>Time taken (min)</th>
<th>Time taken (min per trial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>57</td>
<td>45</td>
<td>0.8</td>
</tr>
<tr>
<td>28</td>
<td>25</td>
<td>38</td>
<td>1.5</td>
</tr>
<tr>
<td>33</td>
<td>25</td>
<td>29</td>
<td>1.2</td>
</tr>
<tr>
<td>26</td>
<td>29</td>
<td>49</td>
<td>1.7</td>
</tr>
<tr>
<td>41</td>
<td>50</td>
<td>62</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>82</td>
<td>4.6</td>
</tr>
<tr>
<td>4</td>
<td>37</td>
<td>75</td>
<td>2.0</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
<td>71</td>
<td>2.2</td>
</tr>
<tr>
<td>6</td>
<td>69</td>
<td>103</td>
<td>1.5</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>46</td>
<td>0.9</td>
</tr>
<tr>
<td>8</td>
<td>49</td>
<td>55</td>
<td>1.1</td>
</tr>
<tr>
<td>24</td>
<td>19</td>
<td>33</td>
<td>1.7</td>
</tr>
<tr>
<td>29</td>
<td>50</td>
<td>49</td>
<td>1.0</td>
</tr>
<tr>
<td>18</td>
<td>32</td>
<td>46</td>
<td>1.4</td>
</tr>
<tr>
<td>42</td>
<td>25</td>
<td>37</td>
<td>1.5</td>
</tr>
<tr>
<td>40</td>
<td>21</td>
<td>29</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Appendix 4.3: time taken for testing of amputee subjects
### Appendix 4.4: joint replacement subjects' personal data

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pathology</th>
<th>sex</th>
<th>stature</th>
<th>weight</th>
<th>hand dominance</th>
<th>leg dominance</th>
<th>footwear, first occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>right total knee replacement</td>
<td>m</td>
<td>1.74m</td>
<td>87.9kgf</td>
<td>r</td>
<td>r</td>
<td>1&quot; heel</td>
</tr>
<tr>
<td>35</td>
<td>right total knee replacement</td>
<td>f</td>
<td>1.53m</td>
<td>53.0kgf</td>
<td>r</td>
<td>r</td>
<td>1&quot; rubber sole</td>
</tr>
<tr>
<td>36</td>
<td>right total hip replacement</td>
<td>f</td>
<td>1.57m</td>
<td>73.2kgf</td>
<td>r</td>
<td>r</td>
<td>1.5&quot; solid heel</td>
</tr>
<tr>
<td>37</td>
<td>right total hip replacement</td>
<td>f</td>
<td>1.49m</td>
<td>43.2kgf</td>
<td>l</td>
<td>r</td>
<td>1.5&quot; solid wedge heel</td>
</tr>
<tr>
<td>38</td>
<td>left total hip replacement</td>
<td>f</td>
<td>1.50m</td>
<td>62.9kgf</td>
<td>r</td>
<td>r</td>
<td>cushioned shoes</td>
</tr>
<tr>
<td>39</td>
<td>right total knee replacement</td>
<td>f</td>
<td>1.63m</td>
<td>55.7kgf</td>
<td>r</td>
<td>r</td>
<td>1.5&quot; solid heel</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>footwear, second occasion</th>
<th>age</th>
<th>first test date to operation</th>
<th>operation to second test date</th>
</tr>
</thead>
<tbody>
<tr>
<td>same</td>
<td>73</td>
<td>14 days</td>
<td>98 days</td>
</tr>
<tr>
<td>different shoes, same heel height</td>
<td>80</td>
<td>3 days</td>
<td>109 days</td>
</tr>
<tr>
<td>N/A</td>
<td>70</td>
<td>not known</td>
<td>N/A</td>
</tr>
<tr>
<td>same</td>
<td>78</td>
<td>19 days</td>
<td>93 days</td>
</tr>
<tr>
<td>same</td>
<td>62</td>
<td>25 days</td>
<td>87 days</td>
</tr>
<tr>
<td>same</td>
<td>72</td>
<td>21 days</td>
<td>91 days</td>
</tr>
</tbody>
</table>

### Appendix 4.5: joint replacement subjects' medical details

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pathology</th>
<th>other orthopaedic problems</th>
<th>other pathologies affecting gait</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>right total knee replacement</td>
<td>o/a left knee, both hips, Titanium plate in left knee for 3 years</td>
<td>none</td>
</tr>
<tr>
<td>35</td>
<td>right total knee replacement</td>
<td>o/a shoulder, cervical spine, lumbar spine</td>
<td>angina, suspected heart attack, hypertensiv</td>
</tr>
<tr>
<td>36</td>
<td>right total hip replacement</td>
<td>o/a shoulder, neck, spine</td>
<td>none</td>
</tr>
<tr>
<td>37</td>
<td>right total hip replacement</td>
<td>o/a lumbar spine, cervical spine</td>
<td>none</td>
</tr>
<tr>
<td>38</td>
<td>left total hip replacement</td>
<td>none</td>
<td>asthama</td>
</tr>
<tr>
<td>39</td>
<td>right total knee replacement</td>
<td>o/a hands, spine, Left total knee replacement a year before</td>
<td>asthama</td>
</tr>
</tbody>
</table>
### Appendix 4.6: Joint Replacement Subjects' Details from Sister Harris's Checklist

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pathology</th>
<th>Constant Pain</th>
<th>Mobility Limited</th>
<th>Climb Stairs</th>
<th>Distance Able to Walk</th>
<th>Aids to Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>Prospective Right Total Knee Replacement</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>300yds</td>
<td>None</td>
</tr>
<tr>
<td>35</td>
<td>Prospective Right Total Knee Replacement</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>500yds</td>
<td>Stick</td>
</tr>
<tr>
<td>36</td>
<td>Prospective Right Total Hip Replacement</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Not Available</td>
<td>Not Available</td>
</tr>
<tr>
<td>37</td>
<td>Prospective Right Total Hip Replacement</td>
<td>Yes</td>
<td>Yes</td>
<td>Not Applicable</td>
<td>1/2 mile</td>
<td>Stick</td>
</tr>
<tr>
<td>38</td>
<td>Prospective Left Total Hip Replacement</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>500yds</td>
<td>None</td>
</tr>
<tr>
<td>39</td>
<td>Prospective Right Total Knee Replacement</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>100yds</td>
<td>Stick</td>
</tr>
</tbody>
</table>

### Appendix 4.7: Joint Replacement Subjects' Questionnaire Results

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pathology</th>
<th>Intimidating?</th>
<th>Tired at Beginning?</th>
<th>Tired at End?</th>
<th>Their Normal Gait?</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Occasion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Prospective Right Total Knee Replacement</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>35</td>
<td>Prospective Right Total Knee Replacement</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>36</td>
<td>Prospective Right Total Hip Replacement</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>37</td>
<td>Prospective Right Total Hip Replacement</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>38</td>
<td>Prospective Left Total Hip Replacement</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>39</td>
<td>Prospective Right Total Knee Replacement</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
</tr>
<tr>
<td>35</td>
</tr>
<tr>
<td>36</td>
</tr>
<tr>
<td>37</td>
</tr>
<tr>
<td>38</td>
</tr>
<tr>
<td>39</td>
</tr>
<tr>
<td>Subject</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>34</td>
</tr>
<tr>
<td>35</td>
</tr>
<tr>
<td>36</td>
</tr>
<tr>
<td>37</td>
</tr>
<tr>
<td>38</td>
</tr>
<tr>
<td>39</td>
</tr>
</tbody>
</table>

Appendix 4.8: joint replacement subjects' numbers of treatments and trials
### Appendix 4.9: time taken for testing of joint replacement subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>No. of trials</th>
<th>Time taken (min)</th>
<th>Time taken/(min per trial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>26</td>
<td>23</td>
<td>0.9</td>
</tr>
<tr>
<td>35</td>
<td>26</td>
<td>24</td>
<td>0.9</td>
</tr>
<tr>
<td>36</td>
<td>13</td>
<td>13</td>
<td>1.0</td>
</tr>
<tr>
<td>37</td>
<td>14</td>
<td>10</td>
<td>0.7</td>
</tr>
<tr>
<td>38</td>
<td>26</td>
<td>29</td>
<td>1.1</td>
</tr>
<tr>
<td>39</td>
<td>26</td>
<td>25</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Appendix 4.10: miscellaneous adults' personal data

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pathology</th>
<th>sex</th>
<th>stature</th>
<th>weight</th>
<th>hand dominance</th>
<th>leg dominance</th>
<th>age</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>cerebral palsy</td>
<td>f</td>
<td>1.59m</td>
<td>60.3kgf</td>
<td>not available</td>
<td>not available</td>
<td>22</td>
</tr>
<tr>
<td>32</td>
<td>specialised hip implant</td>
<td>m</td>
<td>1.79m</td>
<td>76.3kgf</td>
<td>r</td>
<td>'probably right'</td>
<td>52</td>
</tr>
</tbody>
</table>

### Appendix 4.11: miscellaneous adults' trials data

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pathology</th>
<th>treatments</th>
<th>weight</th>
<th>measurements</th>
<th>normal speed</th>
<th>slow</th>
<th>fast</th>
<th>very fast</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>cerebral palsy</td>
<td>1</td>
<td>1</td>
<td></td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>32</td>
<td>specialised hip implant</td>
<td>1</td>
<td>3</td>
<td></td>
<td>10</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

### Appendix 4.12: children's personal data

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pathology</th>
<th>sex</th>
<th>stature</th>
<th>weight</th>
<th>hand dominance</th>
<th>leg dominance</th>
<th>age</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Down's syndrome</td>
<td>m</td>
<td>1.00m</td>
<td>16.6kgf</td>
<td>r</td>
<td>r</td>
<td>8</td>
</tr>
<tr>
<td>31</td>
<td>Cerebral palsy, spastic diplegia</td>
<td>m</td>
<td>1.16m</td>
<td>20.9kgf</td>
<td>r</td>
<td>r</td>
<td>9</td>
</tr>
</tbody>
</table>
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360


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4. OFF 609.6 (2') (CHECK SIZE OF HONEYCOMB)
4. OFF 2438.4 (8') AND MAKE EDGING TO FIT

All dimensions in mm

Material: 5/16" x 6/8" x 1/6" L-shaped aluminium channel

University of Surrey
Guildford
Gu2 5XH

Scale: 2:1
Date: 15/7/31
Revision No.: 2
Checked By: 

General tolerance: Unless stated otherwise

Treatment processes

Surface processes

For internal use only

Title: Edging for Honeycomb
EDGING FOR HONEYCOMB (5/8" x 5/8" x 1/8" NOMINAL). DECREASE, ABRIDE AND DECREASE AGAIN ALL SURFACES TO BE JOINED. GLUE TOGETHER WITH ARADITE 2005 FOLLOWING MANUFACTURERS' INSTRUCTIONS. 0.25 KG (HALF PACK) MAXIMUM ALLOWED PER PLATFORM. WHEN GLUE IS CURED, REMOVE ANY EDGES OF ANGLE PROTRUDING ABOVE TOP SURFACE OF HONEYCOMB.

BOTTOM SHEET

CHANNEL SECTIONS

JOINING PLATES FOR CHANNEL SECTIONS

ALUMINIUM HONEYCOMB

2.03MM (14 GAUGE)

1.2MM (SWG 18)

EDGING TO HIDE STRUCTURE OF WALKWAY

1/4
2 OFF (TO BE CUT FROM 8" x 4" PANEL)
SECTION ON B-B

REMOVE SHARP EDGES

6 OFF
END POINTED TO ACT AS LOCATOR PIN

12 OFF
REMOVE SHARP EDGES
6 OFF

M10 TAPPED HOLE

2 HOLES Ø9

3 HOLES CLEARANCE M8

3 HOLES TAPPED M8
6 HOLES, 12.9 Ø, 12.0 ACROSS FLATS

1 OFF REMOVE SHARP EDGES
5 CLEARANCE HOLES FOR 6-32 SCREWS
4 OFF (2 LEFT-HANDED, 2 RIGHT-HANDED)
HOLE 06:6

-5 HOLES FOR 3MM OR 1/4" POP RIVETS

SECTION ON A-A

VIEW...FROM...UNDERNEATH

4 OFF
REMOVE SHARP EDGES

UNIVERSITY OF SURREY
GUILDFORD
GU2 5XH

SCALE 1:1

DATE 15/11/11

REVISION NO.

CHECKED BY

DRAWN BY

DRAWING NO.

ALL DIMENSIONS IN 1/16

MATERIAL 3MM THICK ALUMINIUM SHEET

TREATMENT PROCESSES

SURFACE PROCESSES

FOR INTERNAL USE ONLY

EARTHING PLATES FOR WALKWAY
THE DEVELOPMENT AND USE OF A GAIT ANALYSIS FORCE PLATE WALKWAY INTENDED FOR USE IN THE ROUTINE CLINICAL CONTEXT

Volume 2

Jane Barrance, MEng, MSc  Copyright ©

presented as part of the requirements for the degree of Doctor of Philosophy in Biomedical Engineering at the University of Surrey, Guildford

1993
Chapter 6:

Supplement to chapter 2, which described the development of the system

Appendix 6.1 contains a list of companies contacted during the design of the system, from which nothing was bought. It is hoped that this may be useful to those continuing the work.

Appendix 6.2 contains an expanded version of Appendix 2.5, the explanation of the choice of transducers.

Appendix 6.3 contains the software listings.

Appendix 6.4 contains a breakdown of the materials costs of the system.
Chapter 7:
Supplement to chapter 3, which described the calibration and tests with normal subjects

7.1 Documentation of data

The data from chapter 3 are documented in Appendix 7.1, so they are available for further work such as validation of future algorithms if required.

7.2 Consistency experiments (see section 3.3.3)

Figures 7.1 to 7.8 show the error messages (explained in section 2.7.12.2) from the consistency experiments. These may be of use to workers needing to understand the details of the error coding system used in order to improve the software. Figure 7.1 showed that trial 134 from the first set of subject 25's results suffered from crossover. It was therefore omitted from the analysis. Figure 7.5 showed that trial 7 from subject 16's first set registered 'negativedoublestancetimes'. On inspection this proved to be due to a double registration of a foot contact, showing the need for further work on the algorithms (see section 5.2.2). This trial was also omitted from the analysis. Figure 7.8 showed that trial 141 in subject 25's second set was registering 'toomanysteps'. This also proved to be due to double registration of a foot contact. This trial was also omitted from the analysis.

Trials 116, 123 and 129 from subject 25's first set, and trial 149 from subject 25's second set were omitted after inspection of the data prompted by notes made during the experiments. These notes indicated that the gait was atypical.

Figures 7.9 to 7.20 show the remaining results from the first analysis of the consistency experiments, i.e. those for which there was not space in volume 1. These may be of use to workers wishing to examine the results in greater detail in order to help them to make a new choice of gait.
Figure 7.1
Figure 7.2

crossover

error

1st occ.
subject 16

2nd occ.
subject 17

1st occ.
subject 25

2nd occ.
subject 27

no error
Figure 7.3

highly unequal numbers of steps

error

no error

1st occ. subject 16

2nd occ. subject 17

1st occ. subject 25

2nd occ. subject 27
Figure 7.4
Figure 7.6
Figure 7.9
Figure 7.12

subject 25

subject 17

subject 16

subject 27
Figure 7.14:
Figure 7.15
Figure 7.16
Figure 7.20

Impulse symmetry ratio 1

1st occ. 2nd occ. subject 16
1st occ. 2nd occ. subject 17
1st occ. 2nd occ. subject 25
1st occ. 2nd occ. subject 27
parameters and/or statistical analysis. Figure 7.9 shows the changes in stance time symmetry ratio. Figure 7.10 shows step length. Figure 7.11 shows first peak force symmetry ratio. Figure 7.12 shows second peak force symmetry ratio. Figure 7.13 shows minimum force symmetry ratio. Figure 7.14 shows second peak forces on the left leg. Figure 7.15 shows similar behaviour in the right leg. Figure 7.16 shows minimum forces on the left leg. Figure 7.17 shows similar behaviour in the right leg. Figure 7.18 shows the left second peak force timing in percentage of the stance phase. Figure 7.19 shows similar behaviour in the right leg. Figure 7.20 shows the impulse symmetry ratio.

Figures 7.21 to 7.28 show additional results of the plotting of gait variables against speed for subject 16, for which there was not space in section 3.3.3.4.2. These may also be of use to workers wishing to examine the results in greater detail in order to help them to make a new choice of gait parameters and/or statistical analysis.

Figures 7.29 to 7.42 show detailed results from the statistical analysis. Figure 7.29 shows all of the coefficients of determination (calculated using the LINEST function in Microsoft Excel version 4) for the best fit lines for the different subject, gait parameters and occasion. Figure 7.29 also shows the mean value of coefficient of determination for each variable. Figure 7.30 shows the observed F-statistics (variance ratios) for each subject, variable and occasion (calculated using the LINEST function in Microsoft Excel version 4). Figure 7.31 shows the critical F-statistics. Figure 7.32 shows the results of the F-tests. Figures 7.33 and 7.34 show the slopes (rate of change of each variable with speed) and their standard errors. Figure 7.35 shows the values on the best fit lines at v=1.29m/s. Figure 7.36 shows the standard errors of the values. Figure 7.37 shows the observed t-values for the slope comparisons. Figure 7.38 shows the critical t-values with which the observed t-values were compared. Figure 7.39 shows the results
Figure 7.21: stance time symmetry ratio for subject 16
Figure 7.22: second peak force symmetry ratio for subject 16
Figure 7.23: minimum force symmetry ratio for subject 16
Figure 7.24: first peak force, right leg, for subject 16
Figure 7.25: second peak force, right leg, for subject 16
Figure 7.26: minimum force, right leg, for subject 16
Figure 7.27: right second peak force timing for subject 16
Figure 7.28: impulse symmetry ratio for subject 16
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Figure 7.36
### Observed t-values for slope comparisons

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of the t-tests, i.e. the comparison of the magnitudes of the observed t-values with the critical t-values. Figure 7.40 shows the observed values of t for the intercepts at \( v = 1.29 \text{m/s} \). Figure 7.41 shows the critical values for the t-tests of the intercepts at \( v = 1.29 \text{m/s} \). Figure 7.42 shows the results of the t-tests between the intercepts at \( v = 1.29 \text{m/s} \). These values may be of use if a future worker wishes to perform further analysis.

7.3 Instructions experiments (see section 3.3.5)

Figures 7.43 to 7.50 show the error messages (explained in section 2.7.12.2) from the instructions experiments. These may be of use to workers needing to understand the details of the error coding system used in order to improve the software.

Figures 7.51 to 7.61 show the remaining results from the instructions experiments, i.e. those for which there was not space in volume 1. These may be of use to workers wishing to examine the results in greater detail in order to help them to make a new choice of gait parameters and/or statistical analysis. Figure 7.51 shows the results for stance time symmetry ratio. Figure 7.52 shows results for the right step length, which are similar to those for the left step length (figure 3.41). Figures 7.53 and 7.54 show the results for second peak and minimum force ratios respectively. Figures 7.55, 7.56 and 7.58 shows results for the first peak force, second peak force and minimum force on the right leg which are similar to those for the left leg (figures 3.43, 3.44 and 7.57 respectively). Figure 7.59 shows the results for left second peak force timing in percent of the stance phase. Figure 7.60 shows the corresponding results for the right leg. Figure 7.61 shows the results for impulse symmetry ratio.
Figure 7.43
Figure 7.45
Figure 7.54
Figure 7.55
Figure 7.58
Chapter 8: supplement to chapter 4, which dealt with the experiments with subjects with pathological gait

8.1 Statistics used (see section 4.1)

Appendix 8.1 describes the variation of coefficient of determination, F-test significance and t-test significance with number of traverses and breadth of speed range.

8.2 Experiments with amputees (see section 4.2)

Appendix 8.2 shows the details of amputees and their prostheses.

Figures 4.3 to 4.7 in section 4.2.2.1 showed data for subject 6 plotted against gait speed. Figures 8.1 to 8.5 show the remaining gait parameters plotted against speed.

Figures 8.6 to 8.19 show detailed results from the statistical analysis for the amputees. Figure 8.6 shows all of the coefficients of determination (calculated using the LINEST function in Microsoft Excel version 4) for the best fit lines for the different subject, gait parameters and occasion. Figure 8.6 also shows the mean value of coefficient of determination for each variable. Figure 8.7 shows the observed F-statistics (variance ratios) for each subject, variable and occasion (calculated using the LINEST function in Microsoft Excel version 4). Figure 8.8 shows the critical F-statistics. Figure 8.9 shows the results of the F-tests. Figures 8.10 and 8.11 show the slopes (rate of change of each variable with speed) and their standard errors. Figure 8.12 shows the values on the best fit lines at v=1.29m/s. Figure 8.13 shows the standard errors of the values. Figure 8.14 shows the observed t-values for the slope comparisons. Figure 8.15 shows the critical t-values with which the observed t-values were compared. Figure 8.16 shows the results of the t-tests, i.e. the comparison of the magnitudes of the observed t-values with the critical t-values. Figure 8.17 shows the observed values of t for the intercepts at v = 1.29m/s. Figure 8.18 shows the critical
values for the t-tests of the intercepts at $v = 1.29\text{m/s}$. Figure 8.19 shows the results of the t-tests between the intercepts at $v = 1.29\text{m/s}$. These values may be of use if a future worker wishes to perform further analysis.
Figure 8.1: first peak force symmetry ratio for subject 6
Figure 8.2: second peak force symmetry ratio for subject 6
Figure 8.3: minimum force symmetry ratio for subject 6
Figure 8.4: second peak force, right (prosthetic) leg, for subject 6
Figure 8.5: impulse symmetry ratio for subject 6
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<tr>
<th>Prosthesis</th>
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<th>Subject 28 (right below knee)</th>
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Figure 8.6 page 1
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Subject 24 (right hip disarticulation)

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Subject 29 (left hip disarticulation)

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Subject 18 (bilateral absent feet)

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Figure 8.7 page 4
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subject 24 (right hip disarticulation)

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subject 20 (left hip disarticulation)

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subject 18 (bilateral absent feet)

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Figure 8.8 page 5
### SIGNIFICANCE OF FISHER TESTS

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**Subject 1**

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**Subject 2**

No statistics available

**Subject 3 (right above knee)**

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Figure 8.11 page 5
### B-VALUES (INTERCEPTS AT SPEED = 1.291M/S)

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**Subject 2**

No statistics available

**Subject 3 (Right Above Knee)**

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Figure 8.12 page 5
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Subject 42 (Right Above Knee, Left Above Knee)

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Subject 40 (Bilateral Above Knee)

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### Observed Values of t for Slopes

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**Figure 8.14 page 1**
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<th>Prosthesis Dynamic</th>
<th>Prosthesis Trajectory</th>
<th>Prosthesis Stability</th>
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**Figure 8.14 page 2**
<table>
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<tr>
<th>Subject 4 (left above knee)</th>
<th>t2slope, stance time symmetry ratio 1</th>
<th>t2slope, left step length 1/m</th>
<th>t2slope, first peak force symmetry ratio 1</th>
<th>t2slope, second peak force symmetry ratio 1</th>
<th>t2slope, minimum force ratio 1</th>
<th>t2slope, first peak force 1, left leg[kg]</th>
<th>t2slope, second peak force 1, left leg[kg]</th>
<th>t2slope, minimum force 1, left leg[kg]</th>
<th>t2slope, first peak force timing 12%</th>
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<th>t2slope, impulse symmetry ratio 1</th>
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<td>Prosthesis A vs B</td>
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<th>t2slope, second peak force symmetry ratio 1</th>
<th>t2slope, minimum force ratio 1</th>
<th>t2slope, first peak force 1, right leg[kg]</th>
<th>t2slope, second peak force 1, right leg[kg]</th>
<th>t2slope, minimum force 1, right leg[kg]</th>
<th>t2slope, first peak force timing 12%</th>
<th>t2slope, second peak force timing 12%</th>
<th>t2slope, impulse symmetry ratio 1</th>
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<th>t2slope, stance time symmetry ratio 1</th>
<th>t2slope, right step length 1/m</th>
<th>t2slope, first peak force symmetry ratio 1</th>
<th>t2slope, second peak force symmetry ratio 1</th>
<th>t2slope, minimum force ratio 1</th>
<th>t2slope, first peak force 1, right leg[kg]</th>
<th>t2slope, second peak force 1, right leg[kg]</th>
<th>t2slope, minimum force 1, right leg[kg]</th>
<th>t2slope, first peak force timing 12%</th>
<th>t2slope, second peak force timing 12%</th>
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<td>Prosthesis A vs B</td>
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<td>0.24</td>
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<td>Prosthesis B vs C</td>
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<td>-0.27</td>
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<td>Prosthesis A vs C</td>
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Figure 8.14 page 3
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<th>Subject 7 (right above knee)</th>
<th>tSlope, stance time symmetry ratio</th>
<th>tSlope, right step length</th>
<th>tSlope, first peak force symmetry ratio</th>
<th>tSlope, second peak force symmetry ratio</th>
<th>tSlope, minimum force ratio</th>
<th>tSlope, first peak force 1, right leg/kgf</th>
<th>tSlope, second peak force 1, right leg/kgf</th>
<th>tSlope, minimum force 1, right leg/kgf</th>
<th>tSlope, right second peak force timing %</th>
<th>tSlope, impulse symmetry ratio</th>
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<th>tSlope, left step length</th>
<th>tSlope, first peak force symmetry ratio</th>
<th>tSlope, second peak force symmetry ratio</th>
<th>tSlope, minimum force ratio</th>
<th>tSlope, first peak force 1, left leg/kgf</th>
<th>tSlope, second peak force 1, left leg/kgf</th>
<th>tSlope, minimum force 1, left leg/kgf</th>
<th>tSlope, left second peak force timing %</th>
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<th>tSlope, first peak force symmetry ratio</th>
<th>tSlope, second peak force symmetry ratio</th>
<th>tSlope, minimum force ratio</th>
<th>tSlope, first peak force 1, left leg/kgf</th>
<th>tSlope, second peak force 1, left leg/kgf</th>
<th>tSlope, minimum force 1, left leg/kgf</th>
<th>tSlope, left second peak force timing %</th>
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<th>tSlope, minimum force ratio</th>
<th>tSlope, first peak force 1, left leg/kgf</th>
<th>tSlope, second peak force 1, left leg/kgf</th>
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<th>tSlope, left second peak force timing %</th>
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Figure 8.14 page 4
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<th>Tslope, right step length 1.0m</th>
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<th>Tslope, minimum force 1, right leg kgf</th>
<th>Tslope, first peak force 1, right leg kgf</th>
<th>Tslope, second peak force 1, right leg kgf</th>
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<tr>
<td>Subject 40 (bilateral above knee)</td>
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<td>$t_{pcrit}$</td>
<td>Degrees of Freedom</td>
<td>$t_{slope, crit}$</td>
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<td>C</td>
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<th>p_value</th>
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| subject 1                       | no statistics available                                   |         |                   |              |
| subject 2                       | no statistics available                                   |         |                   |              |
| subject 3 (right above knee)    | no statistics available                                   |         |                   |              |

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Figure 8.15 page 2
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<th>Degrees of Freedom</th>
<th>Tslope,crit</th>
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<th>Prosthesis A vs B</th>
<th>PCrit</th>
<th>Degrees of Freedom</th>
<th>Tslope,crit</th>
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<td></td>
<td>b</td>
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<th>Number of Traverses in Which a Complete Step Was Captured</th>
<th>Prosthesis A vs B</th>
<th>PCrit</th>
<th>Degrees of Freedom</th>
<th>Tslope,crit</th>
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<td>footwear</td>
<td>p</td>
<td>t</td>
<td>df</td>
<td>degrees of freedom</td>
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</table>

| subject 42 (right above knee, left above knee) | number of traverses in which a complete stride was only one pair of protheses captured | studied | 14 |

| subject 40 (bilateral above knee) | number of traverses in which a complete stride was only one pair of protheses captured | 17 |

Figure 8.15 page 5
<table>
<thead>
<tr>
<th>SIGNIFICANCE OF T-TESTS ON SLOPES</th>
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<td><strong>Subject 23 (right below knee)</strong></td>
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Figure 8.16 page 4
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*Figure 8.17 page 1*
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Figure 8.17 page 2
| Subject 4 (left above knee) |  |  |  |  |  |  |  |  |
|-----------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
|                             | Tb, stance time  | Tb, first peak   | Tb, second peak  | Tb, minimum force| Tb, minimum force| Tb, left second   | Tb, impulse      |
|                             | symmetry ratio 1 | force symmetry   | force symmetry   | 1, left leg/kgf | 1, right leg/kgf | peak force timing| symmetry ratio 1 |
| Prosthesis a vs b           | -1.03            | -0.96            | 0.54             | -0.12            | 0.77             | 0.17             | -0.41            |
|                             |                  |                  |                  |                  |                  |                  |                  |
| Subject 5 (right above knee)|  |  |  |  |  |  |  |  |
|                             | Tb, stance time  | Tb, right step   | Tb, first peak   | Tb, second peak  | Tb, minimum force| Tb, minimum force| Tb, right second  |
|                             | symmetry ratio 1 | length 1/m       | force symmetry   | force symmetry   | 1, right leg/kgf | 1, right leg/kgf | peak force timing|
|                             |                  |                  |                  |                  |                  |                  |                  |
| Prosthesis a vs b           | -1.50            | -2.78            | -4.06            | -1.61            | 0.78             | -4.24            | 1.64             |
|                             |                  |                  |                  |                  |                  |                  |                  |
| Subject 6 (right above knee)|  |  |  |  |  |  |  |  |
|                             | Tb, stance time  | Tb, right step   | Tb, first peak   | Tb, second peak  | Tb, minimum force| Tb, minimum force| Tb, right second  |
|                             | symmetry ratio 1 | length 1/m       | force symmetry   | force symmetry   | 1, right leg/kgf | 1, right leg/kgf | peak force timing|
|                             |                  |                  |                  |                  |                  |                  |                  |
| Prosthesis a vs b           | 2.92             | 0.06             | 1.78             | 2.04             | -1.10            | -0.66            | 4.61             |
| Prosthesis b vs c           | 0.39             | -2.89            | -4.42            | 0.24             | 0.03             | 1.67             | -4.31            |
| Prosthesis a vs c           | 4.30             | -3.48            | -1.04            | 2.82             | -1.13            | 1.40             | -0.99            |
|                             |                  |                  |                  |                  |                  |                  |                  |

Figure 8.17 page 3
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Note: Flow and Length values are not explicitly provided, but they can be inferred from the context of the table.

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Figure 8.19 page 2
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Figure 8.19 page 4
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Figure 8.19 page 5
Appendix 8.3 shows the questionnaire used with the joint replacement subjects (see section 4.3.1).

Appendix 8.4 shows the numbers of extra trials required by each of the joint replacement subjects due to failing to clear the centre line (see section 4.3.2).

Figures 4.11 to 4.13 in section 4.3.2.1 showed data for subject 34 (right total knee replacement) plotted against gait speed. Figures 8.20 to 8.27 show the remaining gait parameters plotted against speed.

Figures 8.28 to 8.41 show detailed results from the statistical analysis for the joint replacement subjects. Figure 8.28 shows all of the coefficients of determination (calculated using the LINEST function in Microsoft Excel version 4) for the best fit lines for the different subject, gait parameters and occasion. Figure 8.28 also shows the mean value of coefficient of determination for each variable. Figure 8.29 shows the observed F-statistics (variance ratios) for each subject, variable and occasion (calculated using the LINEST function in Microsoft Excel version 4). Figure 8.30 shows the critical F-statistics. Figure 8.31 shows the results of the F-tests. Figures 8.32 and 8.33 show the slopes (rate of change of each variable with speed) and their standard errors. Figure 8.34 shows the values on the best fit lines at v=1.29m/s. Figure 8.35 shows the standard errors of the values. Figure 8.36 shows the observed t-values for the slope comparisons. Figure 8.37 shows the critical t-values with which the observed t-values were compared. Figure 8.38 shows the results of the t-tests, i.e. the comparison of the magnitudes of the observed t-values with the critical t-values. Figure 8.39 shows the observed values of t for the intercepts at v = 1.29m/s. Figure 8.40 shows the critical values for the t-tests of the intercepts at v = 1.29m/s. Figure 8.41 shows the results of the t-tests between the intercepts at v =
1.29 m/s. These values may be of use if a future worker wishes to perform further analysis.
Figure 8.20: first peak force symmetry ratio for subject 34
Figure 8.21: second peak force symmetry ratio for subject 34
Figure 8.22: minimum force symmetry ratio for subject 34
Figure 8.23: first peak force on right foot for subject 34
Figure 8.24: second peak force on right foot for subject 34
Figure 8.25: minimum force on right foot for subject 34
Figure 8.26: second peak force timing on right foot for subject 34
Figure 8.27: impulse symmetry ratio for subject 34
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Figure 8.33 page 1
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Figure 8.33 page 2
## Figure 8.34

### B-VALUES (INTERCEPTS AT SPEED = 1.291 M/S)

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Figure 8.39 page 2
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<th>Post-op</th>
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*Note: Only Pre-op studied*
| Subject 37 (right total hip replacement) | | | | |
|---|---|---|---|
| Number of traverses in which a complete stride was captured | Pre-op | 4 | Pre-op vs Post-op | 0.01 | Degrees of freedom | 9 | Tb crit | 6.84 |
| Post-op | 3 | | | | | | |

| Subject 38 (left total hip replacement) | | | | |
|---|---|---|---|
| Number of traverses in which a complete stride was captured | Pre-op | 10 | Pre-op vs Post-op | 0.01 | Degrees of freedom | 15 | Tb crit | 2.96 |
| Post-op | 9 | | | | | | |

| Subject 39 (right total knee replacement) | | | | |
|---|---|---|---|
| Number of traverses in which a complete stride was captured | Pre-op | 10 | Pre-op vs Post-op | 0.01 | Degrees of freedom | 16 | Tb crit | 2.92 |
| Post-op | 10 | | | | | | |

Figure 8.40 page 2
### SIGNIFICANCE OF T-TESTS ON INTERCEPTS AT SPEED = 1.201 MS

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Figure 8.41 page 1
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Figure 8.41 page 2
8.4 Experiments with miscellaneous adult subjects (see section 4.4)

Figures 4.19 to 4.23 in section 4.4.3.2.1 showed data for subject 32 (specialised hip implant) plotted against gait speed. Figures 8.42 to 8.47 show the remaining gait parameters plotted against speed.

Figures 8.48 to 8.55 show detailed results from the statistical analysis for the joint replacement subjects. Figure 8.48 shows all of the coefficients of determination (calculated using the LINEST function in Microsoft Excel version 4) for the best fit line. Figure 8.49 shows the observed F-statistics (variance ratios) (calculated using the LINEST function in Microsoft Excel version 4). Figure 8.50 shows the critical F-statistics. Figure 8.51 shows the results of the F-tests. Figures 8.52 and 8.53 show the slopes (rate of change of each variable with speed) and their standard errors. Figure 8.54 shows the values on the best fit lines at v=1.29m/s. Figure 8.55 shows the standard errors of the values. These values may be of use if a future worker wishes to perform further analysis.
Figure 8.42: first peak force symmetry ratio for subject 32
Figure 8.43: second peak force symmetry ratio for subject 32
Figure 8.44: Minimum force symmetry ratio for subject 32

- leg a, minimum force symmetry ratio 1
- best fit, leg a, minimum force symmetry ratio 1

Velocity (m/s)

Minimum force symmetry ratio

0.5 0.45 0.4 0.35 0.3 0.25 0.2 0.15 0.1 0.05 0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5
Figure 8.45: first peak force on the right foot for subject 32
Figure 8.46: second peak force on the right foot for subject 32
Figure 8.47: minimum force on the right foot for subject 32
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<th>seab. second peak force symmetry ratio 1</th>
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<th>seab. second peak force 1, right leg/kgf</th>
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8.5 Experiments with child subjects (see section 4.5)

Figures 4.33 to 4.35 in section 4.5.3.1 showed data for subject 31 (spastic diplegia) plotted against gait speed. Figures 8.56 to 8.63 show the remaining gait parameters plotted against speed.

Figures 8.64 to 8.77 show detailed results from the statistical analysis for the joint replacement subjects. Figure 8.64 shows all of the coefficients of determination (calculated using the LINEST function in Microsoft Excel version 4) for the best fit lines for the different subjects, gait parameters and occasion. Figure 8.65 shows the observed F-statistics (variance ratios) for each subject, variable and occasion (calculated using the LINEST function in Microsoft Excel version 4). Figure 8.66 shows the critical F-statistics. Figure 8.67 shows the results of the F-tests. Figures 8.68 and 8.69 show the slopes (rate of change of each variable with speed) and their standard errors. Figure 8.70 shows the values on the best fit lines at \( v = 1.29 \text{m/s} \). Figure 8.71 shows the standard errors of the values. Figure 8.72 shows the observed t-values for the slope comparisons. Figure 8.73 shows the critical t-values with which the observed t-values were compared. Figure 8.74 shows the results of the t-tests, i.e. the comparison of the magnitudes of the observed t-values with the critical t-values. Figure 8.75 shows the observed values of t for the intercepts at \( v = 1.29 \text{m/s} \). Figure 8.76 shows the critical values for the t-tests of the intercepts at \( v = 1.29 \text{m/s} \). Figure 8.77 shows the results of the t-tests between the intercepts at \( v = 1.29 \text{m/s} \). These values may be of use if a future worker wishes to perform further analysis.
Figure 8.56: first peak force symmetry ratio for subject 31
Figure 8.57: second peak force symmetry ratio for subject 31
Figure 8.58: minimum force symmetry ratio for subject 31
Figure 8.59: first peak force on the right foot for subject 31
Figure 8.60: second peak force on the right foot for subject 31
Figure 8.61: minimum force on the right foot for subject 31
Figure 8.62: second peak force timing on the right foot for subject 31
Figure 8.63: Impulse symmetry ratio for subject 31
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Figure 8.66
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bare feet | -2.28 | 0.24 | -1.69 | -0.89 | 13.70 | -39.65 | -5.44 | 108.63 | -73.64 | -2.84 |  |
shoes, socks, insoles | -11.79 | -1.00 | -22.58 | -21.76 | 6.83 | -420.00 | -185.00 | 350.00 | 1170.00 | -22.81 |  |
shoes, socks, no insoles | -1.23 | 0.23 | 1.35 | -0.01 | -2.64 | 13.58 | 1.62 | 1.78 | 63.72 | -1.05 |  |

Figure 8.68
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Figure 8.69
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<td>37.96</td>
<td>22.56</td>
<td>9.36</td>
<td>86.57</td>
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Figure 8.70
|                | children (Down's syndrome) |                |                |                |                |                |                |                |
|----------------|-----------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                | seb, stance time            | seb, stance    | seb, first peak| seb, minimum   | seb, first peak| seb, second peak| seb, second peak|
|                | symmetry ratio 1            | step length    | force symmetry | force symmetry | force 1, right | force 1, right | force 1, right  |
|                | 0.07                        | 1.00           | 0.23           | 0.13           | 0.43           | 1.91           | 1.48           |
|                | seb, right step             | seb, first peak| seb, minimum   | seb, first peak| seb, second peak| seb, minimum   | seb, right second|
|                | symmetry ratio 1            | force symmetry | force 1, right | force 1, right | force 1, right | force 1, right | legkgf          |
|                | 0.06                        | 0.13           | 0.43           | 1.91           | 1.48           | 2.06           | 12.08          |

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Figure 8.71
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<td>slope, first peak force symmetry ratio</td>
<td>slope, second peak force symmetry ratio</td>
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<td>slope, first peak force 1, right leg kgf</td>
<td>slope, second peak force 1, right leg kgf</td>
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Figure 8.72
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Figure 8.73
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<td><em>Significance, slope, first peak force 1, right leg kgf</em></td>
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<td>no</td>
<td>no</td>
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<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
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<tr>
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<td>no</td>
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<td>no</td>
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Figure 8.74
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<th>bare feet vs shoes, socks, no insoles</th>
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<td>6.07</td>
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<td>ti, right second peak force timing 1/4%</td>
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<td>16.00</td>
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### Critical Values of T for Intercepts at Speed = 1.281 m/s

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<th>Number of Traverses in Which a Complete stride was Captured</th>
<th>Only One Condition Studied</th>
<th>Degrees of Freedom</th>
<th>F Statistic</th>
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<th>Condition</th>
<th>Number of Traverses in Which a Complete stride was Captured</th>
<th>Only One Condition Studied</th>
<th>Degrees of Freedom</th>
<th>F Statistic</th>
</tr>
</thead>
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<td>0.01</td>
<td>9</td>
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<td>3</td>
<td>shoes, socks, insoles vs shoes, socks, no insoles</td>
<td>0.01</td>
<td>9</td>
</tr>
<tr>
<td>shoes, socks, no insoles</td>
<td>4</td>
<td>bare feet vs shoes, socks, no insoles</td>
<td>0.01</td>
<td>4</td>
</tr>
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</table>

Figure 8.76
| SIGNIFICANCE OF T-TESTS ON INTERCEPTS AT SPEED=1.20 M/S |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| children                        |                 |                 |                 |
| subject 30 (Down's syndrome)    |                 |                 |                 |
| only one condition studied      |                 |                 |                 |
| subject 31 (cerebral palsy diplegia) |                 |                 |                 |
|                                                 | significance b. | significance b. | significance b. | significance b. |
|                                                 | stance time     | right step length | second peak     | second peak    |
|                                                 | symmetry ratio 1| ratio 1          | force symmetry  | force 1, right |
|                                                 |                 |                  | ratio 1         | minimum force   |
|                                                 |                 |                  |                 | 1, right logkgf |
|                                                 |                 |                  |                 | right logkgf   |
|                                                 |                 |                  |                 | force timing 1% |
|                                                 |                 |                  |                 | ratio 1        |
| bare feet vs shoes no            | no              | no              | no              | no             |
| shoes, socks,                    |                 |                 |                 |
| insoles vs shoes, no socks, no   |                 |                 |                 |
| insoles                          | no              | no              | no              | yes            |
| bare feet vs shoes, socks, no    | no              | no              | no              | yes            |
| insoles                          | no              | no              | yes             | yes            |

Figure 8.77
8.6 Data documentation

The data are documented in Appendix 8.5 and are thus available for future work such as validation of future algorithms.
Appendix 6.1: list of other companies contacted

**Carbon fibre honeycomb**
Technical Resin Bonders, Huntingdonshire

tel 0480 52381,
fax 0480 414992

**Signal conditioner**
CED Electronics, Science Park, Milton Road, Cambridge
0223 316186

STC Electronic Services
0279 626777

Farnell Electronic Components
0532 636311

**RS Components (Technical Helpline)**
0536 402888

Waugh Instruments Ltd, Carnhelyg Isaf, Glyn Ceirog, Llangollen, Clwyd LL20 7PB.
0691 72597

Sartec Analytical Systems Ltd., Sevenoaks Business Centre, Cramptons Road, Sevenoaks, Kent TN14 5DQ.
0732 460505

Lee-Integer Ltd, 31 Commercial Road, Kettering, Northants NN16 8DQ.
0536 511010

Fylde Electronic Laboratories Ltd, 49-51 Fylde Road, Preston, Lancs PR1 2XQ.

CIL Electronics Ltd, 4 Wayside, Commerce Way, Commerce Way, Lancing, West Sussex BN15 8TA.
0903 765225

**Fixings**
Rawlplug Company Limited, Langley, Slough
0753 581212

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Appendix 6.2:

Expanded explanation of choice of transducers

Prices quoted for transducers which would fulfil the given criteria were:

<table>
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<th>Company</th>
<th>Price per transducer/£</th>
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<tr>
<td>Sandhurst Scientific Instrument Co. Ltd.,</td>
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</tr>
<tr>
<td>68A High Street, Camberley, Surrey,</td>
<td></td>
</tr>
<tr>
<td>GU17 8ED</td>
<td>825</td>
</tr>
<tr>
<td>Kistler Instruments Ltd, Whiteoaks,</td>
<td></td>
</tr>
<tr>
<td>The Grove, Hartley Wintney, Hants</td>
<td></td>
</tr>
<tr>
<td>RG27 8RN</td>
<td>514</td>
</tr>
<tr>
<td>RDP Electronics Ltd, Grove Street,</td>
<td></td>
</tr>
<tr>
<td>Heath Town, Wolverhampton WV10 0PY</td>
<td>503</td>
</tr>
<tr>
<td>Techni Measure, Alexandra Buildings,</td>
<td></td>
</tr>
<tr>
<td>59 Alcester Road, Studley, Warwickshire</td>
<td></td>
</tr>
<tr>
<td>B80 7NJ</td>
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<tr>
<td>Novatech Measurements Limited,</td>
<td></td>
</tr>
<tr>
<td>Castleham Road, Castleham Industrial Estate,</td>
<td></td>
</tr>
<tr>
<td>St. Leonards on Sea, East Sussex TN38 9NT</td>
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<tr>
<td>Entran Ltd, 5 Albert Road, Crowthorne,</td>
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<td>Berks, RG11 7LT</td>
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<tr>
<td>Maywood Instruments Limited,</td>
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<tr>
<td>Rankine Road, Daneshill Industrial Estate,</td>
<td></td>
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<tr>
<td>Basingstoke, Hampshire RG24 0PP</td>
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583
1 More expensive than type presently in use, so not considered further.
2 The type already in use at Surrey.
3 Not considered sufficiently cheaper to justify buying 6 of them rather than 3 more of the ones we had, so not considered further.
4 Considered significantly cheaper and therefore worthy of further investigation.
5 Used in a similar device (Edwards et al, 1990). They found it was very important how they were mounted. The behaviour of their assembled platform was non-linear. They planned to calibrate for this and use lookup tables. This cumbersome calibration procedure would have added to the cost of replication of the system.

The F241 boasts 'high compensation for off-axis load inputs', and 30mm off centre load effect of 0.5% of applied load. The required accuracy in the determination of the force on each transducer is 0.03kgf, i.e. 0.01% of full scale deflection. (See introduction of section.) The manufacturers' specification of the F241 transducers is:

- **Terminal nonlinearity=0.05% rated load**. The measured load will not usually be near the rated load, so the typical nonlinearity is likely to be lower than this.
- **Hysteresis=0.01% applied load**. This is well below 0.1% applied load so it is acceptable.
- **Creep, two minutes=0.02% applied load**. This is well below 0.1% applied load so it is acceptable.
- **Repeatability=0.02% rated load**. This is twice the desired value.
Temperature coefficient of zero: 0.005% rated load. The zero level is measured before each trial, and the error due to the temperature change in the duration of a trial (5s or 20s) is expected to be negligible.

Temperature coefficient of span: 0.002% applied load.

It was decided that the Novatech F241 transducer, being close to the desired range, was of an acceptable accuracy.

The Variohm transducer could cope with a safe side load of 50% full scale. Its height was 2.50 inches (or 2.40 inches if made of stainless steel). The height of the transducers already in use was 50mm, so the Variohm transducers would not have added significantly to the depth of the assembled force plate. It was decided to telephone the manufacturers to ask them how the device would cope with off-axis loads, off-centre loads and dynamic loads. They were unable to supply me with adequate data. It was not considered to be worth the expense and time to purchase a transducer and test it, so it was decided not to use this transducer.

The response of one of the Novatech F241s was tested under off-axis loading. It was tested by using an Instron mechanical testing machine to apply a known load perpendicular to the axis of the transducer (see sketch below).
The load was applied at various angles within the plane perpendicular to the axis of the transducer. Ideally the transducer should have been free to move axially, to ensure that no axial force was applied. In practice, axial force was minimised by ensuring that the transducer was rigidly held horizontal and that the geometry of the equipment was such that the force would be applied accurately vertically. The force was displaced from the end of the transducer case by a distance equivalent to the expected distance to the top surface of the walkway, to simulate the bending effect on the transducer due to the horizontal forces exerted by a subject walking on the force platform.

The transducer was tested up to 500N (i.e. 51.0kgf i.e. 500N/3000N = 17 percent of full scale). The angle between the transducer power lead and a reference direction was set to 0, 30, 60, 90, 120, 150, 180, 210 and 330 degrees. Values between 210 and 330 degrees could not be used due to an oversight when designing the test rig. It was thought likely that the design of the transducer would have symmetry, so it was not thought worthwhile to modify the attachment in order to measure the remaining angles.
The voltage results were converted into equivalent force readings. The worst registered load was approximately -0.7kgf at an applied side load of 51.0kgf, i.e. 1.4% of the applied load. At 10kgf applied side load, the worst registered vertical load was approximately -0.15kgf, i.e. 1.5% horizontal applied load.

Since the horizontal load exerted in walking is less than the vertical load and the transducer was not unconstrained axially, it was judged that the performance of the transducers was sufficient to justify buying 3 more of them.
Program 'Force' 

{forcetyp.typ} 
[include file containing record and key definitions for force calibration] 
[software] 
const arraylength=2000; 

{type definitions for the keys (by which the data is sorted)} 

{maxkeytype = namestr; [largest key type]} 

{maxdatatype = clinrecord; [largest data record type]} 

{Forcesa} 
{include file for force calibration program, created due to space constraints] 

type 
 doublearraytype = array[1 .. arraylength] of double; 
 doublearrayptr = "doublearraytype; {pointer to doublearraytype} 

const 
datafilenm = 'd:\janebarr\resul_91\forcecal.dat'; 
 indexfilenm = 'd:\janebarr\resul_91\forceind.idx'; 

{These values are all in kgf/V, and are taken from calibration using the Instron mechanical testing machine in October 1991} 
gain1=30.542; 
gain2=29.635; 
gain3=29.585; 
gain4=28.569; 
gain5=29.442; 
gain6=29.096; 

{the value of the least significant bit, in V.(10V/4096)} 
lsb=2.4414063e-3; 

{platform dimensions in metres;} 

a=1.101; 
{half the distance between transducers 1 and 2} 
{or 4 and 5} {from drawing} 

b=0.2295; 
{half the lateral distance between transducers 1 and 3} 
{or 4 and 6} {from drawing} 

d=0.0785; 
{half of distance between transducer and edge of platform} 
{(1/8"+304.8mm=229.5mm)} 

{antero-posterior distance between transducer and edge of platform} 
{(1/8"+1.2192m=1.101m)} 

{platform width of gap between platforms, (measured average value)} 

g=0.0030; 

{kgf} The times when the total force on a platform crosses this value, are considered to be the beginning and end of the steps. 

forcelowerthreshold=1; 

{kgf} Because for low values of force, the
positional data is of low accuracy, when the
total force on a platform is less than this,
the position of the centre of pressure is not
displayed. For the purpose of calculating eg
step lengths, the point when the force first
exceeds this value is considered as the
beginning of the step.

var exrecorq, prornot: char;
waorprint, outputdevice: string;
i: integer;
clindata: dataset;
clinreadings: clinrecord;
filetobesorted: file of clinrecord;
errcode: integer;
V1, V2, V3, V4, V5, V6,
F1, F2, F3, F4, F5, F6,
platforml, platform2,
x, y, xl, x2, y1, y2: double;
platformlforce, platform2force,
xplatforml, xplatform2,
yplatforml, yplatform2: doublearraytype;
channelnumber: integer;

{control selection of options}
{counter}
{relate to the database}
{aspect of the programme}
{relates to the data capture}
{aspect of the programme}
{voltages from each transducer}
{force from each transducer}
{forces on each platform}
{positional data}
{these variables are declared}
{as pointers to avoid the}
{'data segment too large'}
{error}

{"SIXTH LEVEL"}

procedure wait;
var s: char;
begin
writeln('Press any key to continue');
s:=readkey;
writeln('');
end;

{"FIFTH LEVEL"}

procedure finderror;
begin
errcode:=errsys; {errsys is a function from the PCI-20026S-3 Software}
{Drivers routines.}
if errcode <>0 then
begin
writeln('error: ', errcode);
wait;
end;
end;

procedure delayloop(var delaylength: integer);
begin
for i:=1 to delaylength do
begin
end;
end;

procedure cleanname(var typedname: namestr);
const allowedcharacters: set of char = [' ', '0' .. '9', 'A' .. 'Z', 'a' .. 'z'];
var i, j, originallength: integer;
begin
originallength:= length(typedname);
for i:=0 to originallength do
for j:=0 to length(typedname) do
if not(typedname[j] in allowedcharacters) then delete(typedname, j, 1);
function xiso:double;
const
Ox=30;
xscale=24;
begin
  xiso:=Ox+xscale*(x+y/sqrt(2.0));
end;

function yiso:double;
const
Oy=50;
yscale=32;
begin
  yiso:=Oy+yscale*(y/sqrt(2.0));
end;

[*FOURTH LEVEL*]
procedure abort(message:string);
begin
  gotoxy(1,24);
  write(message,', Hit any key to halt');
  repeat until keypressed;
  halt;
end;
procedure recorddatafromwalkway;

var
  n,sample,delaylength:integer;
begin
  case clinreadings.nominalsamplingrateperchannel of
    100:begin
      delaylength:=1279; {if nominal sampling rate is 100Hz, set}
      clinreadings.actuallsamplingrateperchannel:=100.0; {up appropriate value of delaylength}
      {measured, lab book, page 1745, 4/9/91}
    end;
    400:begin
      delaylength:=14; {if nominal sampling rate is 400Hz, set}
      clinreadings.actuallsamplingrateperchannel:=399.81; {up appropriate value of delaylength}
      {measured, lab book, page 2101, 28/11/91}
    end;
    else
      writeln('the programme is not capable of dealing with this value of sampling rate');
      halt;
    end;
  end;
  clinreadings.readingsperchannel := clinreadings.nominalsamplingrateperchannel*clinreadings.samplingtime;
  writeln('Beginning to record data from the walkway.');
  gettime(starthour,startminute,startsecond,startsec100);
  with clinreadings do
    begin
      for sample:=1 to readingsperchannel do
        begin
          repeat
            begin
              if (lsb*(gain1*(array1[sample]-zerol)+gain2*(array2[sample]-zero2)+
                  gain3*(array3[sample]-zero3))>200 then write("G");
              if (lsb*(gain4*(array4[sample]-zero4)+gain5*(array5[sample]-zero5)+...
gain6*(array6[sample]-zero6)))>200 then write(^G);
end;
until readkey<>'';
array1[sample]:=readch(_ai,1);
array2[sample]:=readch(_ai,2);
array3[sample]:=readch(_ai,3);
array4[sample]:=readch(_ai,4);
array5[sample]:=readch(_ai,5);
array6[sample]:=readch(_ai,6);
writeln('sample=',sample);
writeln(1Fl=(lsb*(gainl*(array1[sample]-zerol)+
gain2*(array2[sample]-zero2)+
gain3*(array3[sample]-zero3))):6:1);
writeln(1F2=',(lsb*(gain4*(array4 [sample]-zero4)+
gain5*(array5[sample]-zero5)+
gain6*(array6[sample]-zero6))):6:1);
end;
end;
gettime(finishhour,finishminute,finishsecond,finishsec100);
writeln('Finished recording data from the walkway.');
writeln('')I _
write (''G,'''G);
end;
procedure inprecs;
begin
repeat
read(filetobesorted, clinreadings);
sortreleas(clinreadings);
until eof (filetobesorted);
end;
{$F+}
{$F+}
function lessrec(var x,y:clinrecord):boolean;
begin
lessrec:=x.recordname<y.recordname;
end;
{$F-}

{$F+}
procedure outprecs;
begin
writeln('The existing record names are:');
repeat
sortreturn(clinreadings);
write(clinreadings.recordname,',');
until sorteos;
writeln;
end;
{$F-}

procedure recorddatatofile;
var
typedname:namestr;
finished:char;
begin
repeat
finished='n';
repeat
writeln('type name for this record, or type q to quit');
writeln('The name must contain only the characters 0 to 9, a to z,');
writeln('A to Z and space');
readln (typedname);
cleanname(typedname);
writeln(typedname);
if typedname='q' then halt;
writeln('press "y" if you have entered the name correctly, or any');
writeln('other key to retype it');
repeat until not keypressed;
repeat until keypressed;

finished:=readkey;
until (finished='y') or (finished='Y');
clinreadings.recordname:=typedname;
tainsert(clndata,
clinreadings,
typedname);
if not ok then writeln('This name already exists. Try again');
until ok;
end;

procedure waitorprint;
begin
  if waorprint = 'wait' then wait;
  if waorprint = 'print' then
    hardcopy(false,0); {hardcopy with black and white uninverted in}
    {mode 0 (640 points per line)}
end;

procedure drawplatform1;
var xcornersofplatforml,ycornersofplatforml:array[1 .. 5] of double;
begin
  xcornersofplatforml[1]:=-e;
  xcornersofplatforml[2]:=2*a+e;
  xcornersofplatforml[3]:=2*a+e;
  xcornersofplatforml[4]:=-e;
  xcornersofplatforml[5]:=-e;
  ycornersofplatforml[1]:=-d;
  ycornersofplatforml[2]:=-d;
  ycornersofplatforml[3]:=2*b+d;
  ycornersofplatforml[4]:=2*b+d;
  ycornersofplatforml[5]:=-d;
  for i:=1 to 4 do
    begin
      x:=xcornersofplatforml[i];
      y:=ycornersofplatforml[i];
      xl:=xiso;
      yl:=yiso;
      x:=xcornersofplatforml[i+1];
      y:=ycornersofplatforml[i+1];
      x2:=xiso;
      y2:=yiso;
      drawline(xl,yl,x2,y2);
    end;
end;

procedure drawplatform2;
var xcornersofplatform2,ycornersofplatform2:array[1 .. 5] of double;
begin
  xcornersofplatform2[1]:=-e;
  xcornersofplatform2[2]:=2*a+e;
  xcornersofplatform2[3]:=2*a+e;
  xcornersofplatform2[4]:=-e;
  xcornersofplatform2[5]:=-e;
  ycornersofplatform2[1]:=-3*d-g-2*b;
  ycornersofplatform2[2]:=-3*d-g-2*b;
  ycornersofplatform2[3]:=-g-d;
  ycornersofplatform2[4]:=-g-d;
  ycornersofplatform2[5]:=-3*d-g-2*b;
  for i:=1 to 4 do
    begin
      x:=xcornersofplatform2[i];
      y:=ycornersofplatform2[i];
      xl:=xiso;
      yl:=yiso;
      x:=xcornersofplatform2[i+1];
      y:=ycornersofplatform2[i+1];
      x2:=xiso;
      y2:=yiso;
      drawline(xl,yl,x2,y2);
    end;
end;
procedure drawvectors;
const forcescale=0.2;
begin
for i:=1 to clinreadings.readingsperchannel do
begin
x:=xplatform1^[i];
y:=yplatform1^[i];
x1:=xiso;
y1:=yiso;
y2:=y1+forcescale*platform1force^[i];
if platform1force^[i]>forceupperthreshold then drawline(x1,y1,x2,y2);
x:=xplatform2^[i];
y:=yplatform2^[i];
y2:=y1+forcescale*platform2force^[i];
if platform2force^[i]>forceupperthreshold then drawline(x1,y1,x2,y2);
end;
end;

program Forceb;
{THIS PROGRAM MUST BE COMPILED FROM DOS USING THE TURBOPASCAL 5.0 COMMAND LINE}
{COMPILER (TPC FORCEB). OTHERWISE THE TIMING OF THE DATA ACQUISITION IS}
{INCORRECT}
{$n+} (put into 8087 mode, ie enable maths coprocessor)
uses crt,dos,gdriver,printer,gkernel,gwindow,gshell,taccess,tahigh,sort;
{the programme uses the 'crt' interface}
{and the 'taccess' and 'tahigh' units from}
{the Turbo Pascal database toolbox}
{$I c:\janebarr\z_cal91\forcetyp_TYP}
{include the file clin_typ, containing the}
{record and key definitions for the}
{database aspect of the programme}
{$I c:\janebarr\z_cal91\PCIHEADT}
{These are header files that must be used}
{$I c:\janebarr\z_cal91\PCIHEADT}
{in source files for programmes that}
{$I c:\janebarr\z_cal91\P26T}
{access the PCI-20026S-3 Software Drivers}
{$I c:\janebarr\z_cal91\forces.pas}
{This is the first part of this program,}
{which was divided solely due to space}
{constraints}

{*THIRD LEVEL*}
{$F+} (force far calls)
procedure cleanup;
begin
taclose (clindata);
end;
{$F-}
procedure opendataset(var clindata:dataset);
begin
writeln('beginning procedure "opendataset"');
writeln('trying to open dataset');
taopen(clindata,
  datafilenm,
  sizeof(clinrecord),
  indexfilenm,
  sizeof(clinreadings.recordname)-1);
case ok of
  true: writeln('succeeded in opening dataset');
  false: writeln('files are not there');
begin
  writeln('trying to create dataset');
tacreate(clindata,
  {data set variable}
  {name of the data file}
  {size of the data record to be}
  {stored in the data file}
  {name of the index file}
  {length of the key to be}
  {stored in the index file}
  {data set variable}
datafilenm, {name of the data file}
sizeof(clinrecord), {size of the data record to be}
{stored in the data file}
indexfilenm, {name of the index file}
sizeof(clinreadings.recordname)-1); {length of the key to be}
{stored in the index file}

if ok=true then writeln('succeeded in creating dataset');
end;
end;
if ok=false then abort('could not create dataset');
writeln('finished procedure opendataset');
end;

procedure zero; {measures the voltage from each channel}
{when nothing is on the platforms}

var suml,sum2,sum3,sum4,sum5,sum6:double;
v1,v2,v3,v4,v5,v6:double ;
i,n:integer;
iotype:integer; {input-output type}

begin
clrscr;
writeln('Starting zeroing.');
n:=100;
suml:=0; sum2:=0; sum3:=0; sum4:=0; sum5:=0; sum6:=0;
v1:=0; v2:=0; v3:=0; v4:=0; v5:=0; v6:=0;
iotype:=_ai;
{the channels are analogue input channels}
for i:=1 to n do
begin
vl :=readch(iotype,1)
v2:=readch(iotype, 2)
v3:=readch(iotype,3)
v4 :=readch(iotype,4)
v5:=readch(iotype,5)
v6:=readch(iotype,6);
suml:=suml+vl; sum2:=sum2+v2;
sum4:=sum4+v4; sum5:=sum5+v5;
end;
with clinreadings do
begin
zerol:=suml/n; zero2:=sum2/n;
zero4:=sum4/n; zero5:=sum5/n;
sum3:=sum3+v3;
sum6:=sum6+v6;
end;

procedure promptoperatortostarttest;
begin
writeln('Ensure that subject is ready.');</n
writeln('Press any key to start the test.');
writeln('');
end;

procedure operatorstartstest;
var s:char;
begin
s:=readkey;
end;

procedure recorddata; {Data is stored in 'raw' form (as integers representing)}
{VI, V2, V3, V4, V5 AND V6).}
begin;
recorddatafromwalkway;
recorddatatofile;
end;

procedure sortnames;
var sortresult:integer;

begin;
writeln('Beginning to sort data.');
assign(filetobesorted, datafilenm);
reset(filetobesorted);
sorresult:=turbosort(sizeof(clinrecord), &inploc, &lessrec, &outploc);
{sort data into alphabetical order}
{of record names}

if sorresult = 0 then
  writeln('Sort was successful.');
else
  begin
    writeln('The program has not been able to sort existing data.');
    writeln('The error code is ', sorresult);
    writeln('Please seek assistance.');
    halt;
end;
close(filetobesorted);
end;

procedure calculateforces(var counter:integer);
begin;
  VI:=lsb*(clinreadings.array1[counter]-clinreadings.zero1);
  V2:=lsb*(clinreadings.array2[counter]-clinreadings.zero2);
  V3:=lsb*(clinreadings.array3[counter]-clinreadings.zero3);
  V4:=lsb*(clinreadings.array4[counter]-clinreadings.zero4);
  V5:=lsb*(clinreadings.array5[counter]-clinreadings.zero5);
  V6:=lsb*(clinreadings.array6[counter]-clinreadings.zero6);
  F1:=gain1*VI;
  F2:=gain2*V2;
  F3:=gain3*V3;
  F4:=gain4*V4;
  F5:=gain5*V5;
  F6:=gain6*V6;
end;

procedure calculateFxy(var counter:integer);
begin
  platformlforceA[counter]:=F1+F2+F3;
  platform2force''[counter]:=F4+F5+F6;
  if platformlforce''[counter] > forcelowerthreshold then
    begin
      xplatformlA[counter]:=a*(2*F2+F3)/platformlforce''[counter];
      yplatforml''[counter]=2*b*F3/platformlforce''[counter];
    end
  else
    begin
      xplatforml''[counter]:=-1; {These values correspond to a position off}
      yplatforml''[counter]:=-1; {the edge of the platforms}
    end;
  if platform2force''[counter] > forcelowerthreshold then
    begin
      xplatform2''[counter]:=a*(2*F6+F4)/platform2force''[counter];
      yplatform2A''[counter]:-(d+g+d)-2*b*F4/platform2force''[counter];
    end
  else
    begin
      xplatform2''[counter]:=-1; {These values correspond to a position off}
      yplatform2''[counter]:=-1; {the edge of the platforms}
    end;
end;

procedure displaypreliminaries;
begin
  clrscr; {clear screen}
  writeln(outputdevice, '-------------------------------------------------------------');
  writeln(outputdevice, 'Data from gait assessment program -------------------------------------------------');
  writeln(outputdevice, '-------------------------------------------------------------');
  with clinreadings do
    begin
      writeln(outputdevice, 'recordname=', recordname);
      writeln(outputdevice, 'entrydate is no longer a valid variable');
      writeln(outputdevice, 'numberofchannels=', numberofchannels);
      writeln(outputdevice, 'nominalsamplingrateperchannel=',');
nominal sampling rate per channel;)
writeln(outputdevice, 'actual sampling rate per channel=',
actualsamplingrateperchannel:8:3);
writeln(outputdevice, 'sampling time=', samplingtime);
writeln(outputdevice, 1readings per channel=', readingsperchannel);
writeln(outputdevice, 'zerol=', zerol:8:3);
writeln(outputdevice, 'zero2=', zero2:8:3);
writeln(outputdevice, 'zero3=', zero3:8:3);
writeln(outputdevice, 'zero4=', zero4:8:3);
writeln(outputdevice, 'zero5=', zero5:8:3);
writeln(outputdevice, 'zero6=', zero6:8:3);
end;
writeln(outputdevice);
end;
if waorprint = 'wait' then wait;
end;

procedure displayrawdata;
begin
for i:=1 to clinreadings.readingsperchannel do
begin
writeln('i=',i);
writeln('  Fl=' ,platformlforce'' [i] : 6:1,
1  x1=', (100*xplatforml'' [i]) :6:1, '  y1=', (100*yplatforml'' [i] ) :6:1);
wait;
end;
end;

procedure displayforcesversustime;
begin
initgraphic;
setclippingon;
definewindow(1,0,0,xmaxglb,ymaxglb); {window 1 to fill the whole screen}
definewindow(2,4,16,xmaxglb-2,ymaxglb-14); {window 2 to fill the area within}
setclippingoff;
defineheader (1,
'Plots of vertical force/kgf versus time/s for both platforms');
define world in window 1 to be 0
{define world in window 2 to be -10 to +200kgf}
defineworld(1,0,-10, clinreadings.samplingtime,200);
defineworld(2,0,200, clinreadings.samplingtime,-10);
selectworld(1);
selectwindow(1);
setbackgroundcolor(blue);
setforegroundcolor(yellow);
setheaderon;
drawborder;
drawaxis (8, -8,0,0, 0,0,0, 0, true);
selectworld(2);
selectwindow(2);
for i:=1 to clinreadings.readingsperchannel do
begin
write('solid line: platform 1');
if not ((numberofplstrides=0) and (numberofp2strides=0))
and not footwasonplatform then writeln(' (left foot)');
if not ((numberofplstrides=0) and (numberofp2strides=0))
and not footwasonplatform then writeln(' (right foot)');
gotoxy(44,2); {move to top right of screen in}
{preparation for message}
write('broken line: platform 2');
if not ((numberofplstrides=0) and (numberofp2strides=0))
and not footwasonplatform then writeln(' (right foot)');
if not ((numberofplstrides=0) and (numberofp2strides=0))
and not footwasonplatform then writeln(' (left foot)');
gotoxy(44,4); {move to top right of screen in}
{preparation for message}
597
procedure displayxyplotsofcentreofpressure;
begin
initgraphic;
setclippingon;
definewindow(1,0,0,xmaxglb,ymaxglb); {window 1 to fill the whole screen}
definewindow(2,4,16,xmaxglb-2,ymaxglb-14); {window 2 to fill the area within}
{the axes}
definewindow(1,,-a,-3*d-g-2*b,2*a+e,2*b+d); {define world in window 1 to be}
{(-e to 2a+e, -3d-g-2b to 2b+d)}
definewindow(2,-a,2*b+d,2*a+e,-3*d-g-2*b); selectwindow(1);
setbackgroundcolor(black);
seselectworld(1);
drawaxis(8,-8,0,0,0,0,-l,-l,true);
selectwindow(2);
for i:=l to clinreadings.readingsperchannel do
begin
if platform1force'[i]'>forceupperthreshold then
drawpoint(xplatform1'[i]',yplatform1'[i]');
{plot the points from platform 1}
if platform2force'[i]'>forceupperthreshold then
drawpoint(xplatform2'[i]',yplatform2'[i]');
{plot the points from platform 2}
end;
gotoxy(50,2); {move to top right of screen in}
{preparation for message}
writeln('top of screen: platform 1');
gotoxy(50,3); {move to top right of screen in}
{preparation for message}
writeln('bottom of screen: platform 2');
if not ((numberofplstrides=0) and (numberofp2strides=0)) then

gotoxy(50,4); {move to top right of screen in}
{preparation for message}
waitorprint;
leavegraphic; .
end;

procedure display3DPedotti; {This procedure displays diagrams of force and}
{positional data as described by Khodadadeh}
{(1988)}
begin
initgraphic;
setclippingon;
definewindow(1,0,0,xmaxglb,ymaxglb); {window 1 to fill the whole screen}
definewindow(1,0,100,100,0); {arbitrarily define world in}
{window 1 to be 0 to 100, 0 to 100}
definewindow(1,0,100,100,0); {define heading for window 1}
'3-dimensional plots of F/kgf, x/m and y/m for both platforms'};
setbackgroundcolor(magenta);
seselectworld(1);
drawborder;
for i:=l to clinreadings.readingsperchannel do
begin
if platform1force'[i]'>forceupperthreshold then
drawpoint(xplatform1'[i]',yplatform1'[i]');
{plot the points from platform 1}
if platform2force'[i]'>forceupperthreshold then
drawpoint(xplatform2'[i]',yplatform2'[i]');
{plot the points from platform 2}
end;
gotoxy(1,2); {move to top left of screen in}
writeln('length of vector represents magnitude of vertical force');
gotoxy(1,3); {move to top left of screen in}

writeln('time interval between vectors=',
        (1/clinreadings.nominalsamplingrateperchannel):6:4,'  seconds');
gotoxy(1,12); {go to left, 1/3 of way down}

writeln('platform 1');
gotoxy(1,16); {go to left, 2/3 of way down}

writeln('platform 2');
drawplatform1;
drawplatform2;
drawvectors;

if not ((numberofplstrides=0) and (numberofp2strides=0)) then
    gotoxy(50,25); {move to bottom right of screen in}
    waitorprint;
    leavegraphic;
end;

[*SECOND LEVEL*]

procedure initialisesystem;
var gain,zerochannel,range,channelnumber:integer;
begin;
opendataset(clindata);
    {open the data set containing the}
    {clinical data if it exists, and creates}
    {it if it does not}
    {This calls a function from the}
    {PCI-20026S-3 Software Drivers routines}
    {to initialise the software}
finderror;
    {This initialises (numbers the channels}
    {of) the PCI-20098C carrier board, which}
    {is the only board in the system. The}
    {numbers start at 0. All the analogue}
    {input channels are initially configured}
    {as single-ended, +/-10V range, gain of} 
    {1, with no automatic zero-offset}
    {correction.}
finderror;
    gain:=1;
    zerochannel:=-1;
    range:=4;
    for channelnumber:=1 to 6 do
        begin
            cnfai(channelnumber, gain, zerochannel, range);
            finderror;
        end;
end;

procedure initialisevariables;
begin
    with clinreadings do 
        begin
            recordname:='';
            getdate(year,month,day,dayofweek);
            gettime(hour,minute,second,seclOO);
            subjectname:='';
            ageinyears:='';
            sex:='';
            NHSNumber:='';
            footwear:='';
            handedness:='';
            commentsbeforeexpt:='';
            commentsafterexpt:='';
            numberofchannels:=6; {can be up to 6}
            nominalsamplingrateperchannel:=100; {Hertz}
            actuallsamplingrateperchannel:=0; {Hertz}
            samplingtime:=20; {seconds}
            readingsperchannel:=nominalsamplingrateperchannel*samplingtime; {must be less than arraylength}
            zero1:=0.0;zero2:=0.0;zero3:=0.0;zero4:=0.0;zero5:=0.0;zero6:=0.0;
for i:=1 to arraylength do
begin
  array1[i]:=0;
  array2[i]:=0;
  array3[i]:=0;
  array4[i]:=0;
  array5[i]:=0;
  array6[i]:=0;
end;
end;
new(platform1force);
new(platform2force);
new(xplatform1);
new(xplatform2);
new(yplatform1);
new(yplatform2);
end;

procedure examinerecordorquit;
begin
  writeln('Type "e" to examine existing data, "r" to record new data, or "q"
  to quit');
  writeln('');
  exrecorq:='?';
  while (exrecorqO'e') and (exrecorqO'E') and
  (exrecorqO'r') and (exrecorqO'R') and
  (exrecorqO'q') and (exrecorqO'Q') do
    exrecorq:=readkey;
end;

procedure recalldata;
var
  searchname:namestr;
begin
  writeln('You have chosen to recall existing data.');
  sortnames; {displays an alphabetical list of)
  record names)
  writeln('Please enter record name of data for analysis.');
  readln(searchname);
  taread(clindata, {data set variable})
  clinreadings, {database record which is returned)
  searchname, {key to the record)
  true); {boolean value set to true because)
  {I am looking for an exact match)
  while ok=false do
  begin
    writeln('no record found with the name searchname);
    writeln('re-enter name or type q to quit');
    readln(searchname);
  end;
  if searchname='q' then halt;
  writeln('Finished selecting data for analysis.');
  writeln('');
  writeln('Finished recalling existing data.');
  writeln('');
end;

procedure doexperiment;
begin
  writeln('You have chosen to record new data.');
  zero; {measures voltage of each channel}
  promptoperatororstarttest; {when nothing is on the platforms}
  promptoperatororstarttest; {prompts operator to ensure that)
  subject is ready and then start} {test}
  operatororstarttest;
  recorddata;
  writeln('Finished recording new data.');
  writeln('');
end;
procedure processdata;
var counter:integer;
begin
  writeln('Beginning to process data.');
  for counter:=1 to clinreadings.readingperchannel do
  begin
    calculateforces(counter); // calculates the individual forces on the
    calculateFxy(counter); // calculates instantaneous values of force
    writeln('Finished processing data.');
  end;
end;

procedure directdatatoscreen;
begin
  outputdevice:=""; // set output device to be screen
  waorprint:="wait";
end;

procedure displaydata;
begin
  writeln('Beginning to display data.');
  displaypreliminaries;
  displayrawdata;
  displayforcesversustime;
  displayxplotsocentreofpressure;
  display3Dpedotti;
  writeln('Finished displaying data.');
end;

procedure freememory;
begin
  dispose(platform1force); platform1force:=nil;
  dispose(platform2force); platform2force:=nil;
  dispose(xplatform1); xplatform1:=nil;
  dispose(xplatform2); xplatform2:=nil;
  dispose(yplatform1); yplatform1:=nil;
  dispose(yplatform2); yplatform2:=nil;
end;

procedure remindoperator;
begin
  writeln('When you have finished using the system, type "bye" and then "y".');
  writeln('When "please remove power from the system" is displayed, switch');
  writeln('off the monitor (at bottom right corner of screen) but do not');
  writeln('switch off the computer.');
  writeln('DO NOT MOVE THE COMPUTER WITHOUT SWITCHING IT OFF FIRST.');
  writeln('To restart the system, hold down "ctrl" and "alt" and press');
  writeln("delete", then type "go");
end;

{"PRIMARY LEVEL (MAIN PROGRAMME)*}
begin
  taerrorproc:=@cleanup; // execute procedure 'cleanup'in case of fatal
  initialise system;
  initialise variables;
  examinerecordorquit:
  case exrecorq of
    'e','E':recalldata;
    'r','R':doexperiment;
  end;
  case exrecorq of 'e','E','r','R':
    begin

processdata;
directdatatoscreen;
displaydata;
end
end;
cleanup;
freememory;
remindoperator;
end.

{of what do if e, E, c or R}
{of case exrecord}
{close the files}
{posityp.typ}
#include file containing record and key definitions for positional calibration
{software}

cost arraylength=2000;

type
  namestr=string[20];
arraytype=array[1 .. arraylength] of integer;
clinrecord=record
  recstatus:longint; {used by the database system}
  recordname:namestr; {the database key}
  year,month,day,dayofweek,hour,minute,second,sec100:word;
  subject:namestr; {not used}
  ageinyears:string[3]; {not used}
  sex:string[1]; {not used}
  NHSnumber:string[10]; {not used}
  footwear:string[20]; {not used}
  handedness:string[1]; {not used}
  commentsbeforeexpt:string[255]; {not used}
  commentsafterexpt:string[255]; {not used}
  numberofchannels:integer;
  nominalsamplingrateperchannel:integer;
  actualsamplingrateperchannel:double;
  samplingtime:integer;
  readingsperchannel:integer;
  zero1,zero2,zero3,zero4,zero5,zeros:double;
array1: arraytype;
array2: arraytype;
array3: arraytype;
array4: arraytype;
array5: arraytype;
array6: arraytype;
end;
maxdatatype = clinrecord; {largest data record type}
maxkeytype = namestr; {largest key type}

{Posita}
#include file for positional calibration program, created due to space constraints

type
doublearraytype = array[1 .. arraylength] of double;
doublearrayptr = doublearraytype; {pointer to doublearraytype}

const
datafilenm = 'd:\janebarr\rs_sum92\positcal.dat1';
indexfilenm = 'd:\janebarr\rs_sum92\positind.idx';
gain1=30.542; [These values are all in kgf/V, and are taken from]
gain2=29.635; [calibration using the Instron mechanical testing machine]
gain3=29.585; [In October 1991]
gain4=28.569;
gain5=29.442;
gain6=29.096;
lsb=2.4414063e-3; [the value of the least significant bit, in V.(10V/4096])

{platform dimensions in metres:}
a=1.101; [half the distance between transducers 1 and 2]
b=0.2295; [(or 4 and 5) (from drawing)]
c=0.0785; [half the lateral distance between transducers 1 and 3]
d=0.1214; [(or 4 and 6) (from drawing)]
e=0.0030; [lateral distance between transducer and edge of platform]
f=0.129; [[1/8" +304.8mm-229.5mm]
g=0.0030; [antero-posterior distance between transducer and edge of platform]
forcelowtherthreshold=1; [(kgf) The times when the total force on a]
forceupperthreshold=20; [platform crosses this value, are considered to]

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{total force on a platform is less than this,}
{the position of the centre of pressure is not}
{displayed. For the purpose of calculating eg}
{step lengths, the point when the force first}
{exceeds this value is considered as the}
{beginning of the step.)

var exrecorq,pronnot:char;
waorprint,outputdevice:string;
i:integer;
clindata:dataset;
clinreadings:clinrecord;
filetobesorted:file of clinrecord;
errcode:integer;
V1,V2,V3,V4,V5,V6,
F1,F2,F3,F4,F5,F6,
Fplatforml,Fplatform2,
x,y,x1,x2,y1,y2,double;
xplatforml,xplatform2,
yplatforml,yplatform2:'doublearraytype;
channelnumber:integer;

{"SIXTH LEVEL*}

procedure wait;
var s:char;
begin
   writeln('Press any key to continue');
s:=readkey;
   writeln('');
end;

{"FIFTH LEVEL*}

procedure finderror;
begin
   errcode:=errsys;  {errsys is a function from the PCI-20026S-3 Software}
   [Drivers routines.]
   if errcode <>0 then
   begin
      writeln('error:  ',errcode);
      wait;
   end;
end;

procedure delayloop(var delaylength:integer);
begin
   for i:=l to delaylength do
   begin
   end;
end;

procedure suggestquit;
var q:char;
begin
   writeln('The input voltage from channel ',channelnumber,
   ' is outside the expected range.');
   writeln('This suggests that the equipment is damaged.');
   writeln('It is recommended that you seek assistance.');
   writeln('Type "c" to continue with the program or anything else to quit');
   readln (q);
   if (qO'C'J and (qO'C'J then halt;
end;
procedure cleanname(var typedname: namestr);
const allowedcharacters: set of char = [' ', '0' .. '9', 'A' .. 'Z', 'a' .. 'z'];
var i, j, originallength: integer;
begi
  originallength := length(typedname);
  for i := 0 to originallength do
    for j := 0 to length(typedname) do
      if not(typedname[j] in allowedcharacters) then delete(typedname, j, 1);
end;

function xiso: double;
const
  Ox = 30;
  xscale = 24;
begi
  xiso := Ox + xscale * (x + y / sqrt(2.0));
end;

function yiso: double;
const
  Oy = 50;
 yscale = 32;
begi
  yiso := Oy + yscale * (y / sqrt(2.0));
end;

{FOURTH LEVEL*}
procedure abort(message: string);
begi
  gotoxy(1, 24);
  write(message, ' , Hit any key to halt!');
  repeat until keypressed;
  halt;
end;

procedure checkzerovaluesaresensible;
const
  zerolowerlimit = 921.6;
  zeroupperlimit = 1126.4;
begi
  channelnumber := 1;
  if (clinreadings.zero1 < zeroupperlimit) or (clinreadings.zero1 > zeroupperlimit) then suggestquit;
  channelnumber := 2;
  if (clinreadings.zero2 < zeroupperlimit) or (clinreadings.zero2 > zeroupperlimit) then suggestquit;
  channelnumber := 3;
  if (clinreadings.zero3 < zeroupperlimit) or (clinreadings.zero3 > zeroupperlimit) then suggestquit;
  channelnumber := 4;
  if (clinreadings.zero4 < zeroupperlimit) or (clinreadings.zero4 > zeroupperlimit) then suggestquit;
  channelnumber := 5;
  if (clinreadings.zero5 < zeroupperlimit) or (clinreadings.zero5 > zeroupperlimit) then suggestquit;
  channelnumber := 6;
  if (clinreadings.zero6 < zeroupperlimit) or (clinreadings.zero6 > zeroupperlimit) then suggestquit;
end;

procedure changeormovedown(var tempstring: string);
var
  s: char;
begi
writeln('Press "c" to change this piece of information or any other key to 
move down the list');
tempstring:='???'
repeat until not keypressed;
repeat until keypressed;
s:=readkey;
if s='c' then
begin
writeln('type in new information for this item');
readin(tempstring);
end;
end;

procedure recorddatafromwalkway;

var
n,sample,delaylength,counter:integer;
starthour,startminute,startsecond,startsec100,
finishhour,finishminute,finishsecond,finishsec100:word;
measuredsamplingtime,timeratio:double;

begin
case clinreadings.nominalsamplingrateperchannel of
100:begin
  delaylength:=1279; {if nominal sampling rate is 100Hz, set 
  up appropriate value of delaylength}
  clinreadings.actualsamplingrateperchannel:=100.0;
  {measured, lab book, page 1745, 4/9/91}
end;
400:begin
  delaylength:=14; {if nominal sampling rate is 400Hz, set 
  up appropriate value of delaylength}
  clinreadings.actualsamplingrateperchannel:=399.81;
  {measured, lab book, page 2101, 28/11/91}
end;
else
begin
  writeln('the programme is not capable of dealing with this value of');
  writeln('sampling rate');
  halt;
end;
end;
clinreadings.readingsperchannel:=
  clinreadings.nominalsamplingrateperchannel*clinreadings.samplingtime;
writeln('Beginning to record data from the walkway.');
gettime(starthour,startminute,startsecond,startsec100);
with clinreadings do
begin
for sample:=1 to readingsperchannel do
begin
array1(sample):=readch(_ai,1);
array2(sample):=readch(_ai,2);
array3(sample):=readch(_ai,3);
array4(sample):=readch(_ai,4);
array5(sample):=readch(_ai,5);
array6(sample):=readch(_ai,6);
for counter:=1 to 10 do
begin
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
  delayloop(delaylength);
end;
{ if (lsb*(gain1*(array1[sample]-zerol)+gain2*(array2[sample]-zero2)+
    gain3*(array3[sample]-zero3))>25 then write(">G");
  if (lsb*(gain4*(array4[sample]-zero4)+gain5*(array5[sample]-zero5)+
    gain6*(array6[sample]-zero6)))>25 then write(">G");
end;
gettime(finishhour, finishminute, finishsecond, finishsec100);
writeln('Finished recording data from the walkway.');
writeln('');
write(t^G,^G);
end;

procedure inprecs;
begin
repeat
  read(filetobesorted, clinreadings);
  sortrelease(clinreadings);
until eof (filetobesorted);
end;

function lessrec(var x,y:clinrecord):boolean;
begin
  lessrec:=x.recordname<y.recordname;
end;

procedure outprecs;
begin
writeln('The existing record names are:');
repeat
  sortreturn(clinreadings);
  write(clinreadings.recordname, ', ');
until sorteos;
writeln;
end;

procedure recorddatastatofile;
var
  typedname:namestr;
  finished:char;
begin
  finished:='n';
  repeat
    writeln('type name for this record, or type q to quit');
    writeln('The name must contain only the characters 0 to 9, a to z,');
    writeln('A to Z and space');
    readln (typedname);
    cleanname(typedname);
    writeln(typedname);
    if typedname='q' then halt;
    writeln('press "y" if you have entered the name correctly, or any');
    writeln('other key to retype it');
    repeat until not keypressed;
    repeat until keypressed;
    finished:=readkey;
    until (finished='y') or (finished='Y');
  clinreadings.recordname:=typedname;
tainsert(clindata, {data set variable}
            clinreadings, {database record}
            typedname); {key to the record}
  if not ok then writeln('This name already exists. Try again');
until ok;
end;

procedure waitorprint;
begin
  if waorprint = 'wait' then wait;
  if waorprint = 'print' then
    hardcopy!false,0); {hardcopy with black and white uninverted in}
procedure drawplatform1;

var xcornersofplatform1, ycornersofplatform1: array[1 .. 5] of double;

begin
  xcornersofplatform1[1] := -e;
  xcornersofplatform1[2] := 2*a + e;
  xcornersofplatform1[3] := 2*a + e;
  xcornersofplatform1[5] := -e;
  ycornersofplatform1[1] := -d;
  ycornersofplatform1[3] := 2*b + d;
  for i := 1 to 4 do
    begin
      x := xcornersofplatform1[i];
      y := ycornersofplatform1[i];
      x1 := xiso;
      y1 := yiso;
      x := xcornersofplatform1[i + 1];
      y := ycornersofplatform1[i + 1];
      x2 := xiso;
      y2 := yiso;
      drawline(x1, y1, x2, y2);
    end;
end;

procedure drawplatform2;

var xcornersofplatform2, ycornersofplatform2: array[1 .. 5] of double;

begin
  xcornersofplatform2[1] := -e;
  xcornersofplatform2[2] := 2*a + e;
  xcornersofplatform2[3] := 2*a + e;
  xcornersofplatform2[5] := -e;
  ycornersofplatform2[1] := -3*d - g - 2*b;
  ycornersofplatform2[2] := -3*d - g - 2*b;
  ycornersofplatform2[3] := -g - d;
  ycornersofplatform2[4] := -g - d;
  ycornersofplatform2[5] := -3*d - g - 2*b;
  for i := 1 to 4 do
    begin
      x := xcornersofplatform2[i];
      y := ycornersofplatform2[i];
      x1 := xiso;
      y1 := yiso;
      x := xcornersofplatform2[i + 1];
      y := ycornersofplatform2[i + 1];
      x2 := xiso;
      y2 := yiso;
      drawline(x1, y1, x2, y2);
    end;
end;

procedure drawvectors;

const forcescale = 0.2;

begin
  for i := 1 to clinreadings.readingsperchannel do
    begin
      x := xplatform1'[i];
      y := yplatform1'[i];
      x1 := xiso;
      y1 := yiso;
      x := xplatform2'[i];
      y := yplatform2'[i];
      x2 := yiso;
      y2 := y1 + forcescale*platform1force'[i];
      if platform1force'[i] > forceupperthreshold then drawline(x1, y1, x2, y2);
      x := xplatform2'[i];
      y := yplatform2'[i];
    end;
end;
program Positb;
{THIS PROGRAM MUST BE COMPILED FROM DOS USING THE TURBOPASCAL 5.0 COMMAND LINE}
{COMPILER (TPC POSITB). OTHERWISE THE TIMING OF THE DATA ACQUISITION IS}
{INCORRECT}

{put into 8087 mode, ie enable maths}
{coprocessor}

uses crt,dos,gdriver,printer,gkernel,gwindow,gshell,taccess,tahigh,sort;
{the programme uses the 'crt' interface}
{and the 'taccess' and 'tahigh' units}
{from the Turbo Pascal database toolbox}

{include the file clin.typ, containing}
{the record and key definitions for the}
{database aspect of the programme}

{These are header files that must be}
{used in source files for programmes}
{that access the PCI-2002S-3 Software}
{Drivers routines, ie they relate to}
{the data capture aspect of the program}

{This is the first part of this}
{program, which was divided solely due}
{to space constraints}

procedure cleanup;
begin
  taclose (clindata);
end;

procedure opendataset(var clindata:dataset);
begin
  writeln('beginning procedure "opendataset"');
  writeln('trying to open dataset');
  taopen(clindata,
    datafilenm,
    sizeof(clinrecord),
    indexfilenm,
    sizeof(clinreadings.recordname)-1);
  case ok of
    true:writeln('succeeded in opening dataset');
    false:
      begin
        writeln('trying to create dataset');
        tacreate(clindata,
          datafilenm,
          sizeof(clinrecord),
          indexfilenm,
          sizeof(clinreadings.recordname)-1);
        if ok=true then writeln('succeeded in creating dataset');
        end;
    end;
  if ok=false then abort('could not create dataset');
  writeln('finished procedure opendataset');
end;

procedure zero;{measures the voltage from each channel when nothing is on}
{the platforms}

var sum1, sum2, sum3, sum4, sum5, sum6: double;
vl, v2, v3, v4, v5, v6: double;
i, n: integer;
iotype: integer;  {input-output type}

begin
  clrscr;
  writeln('Starting zeroing.');
  n:=100;
  sum1:=0; sum2:=0; sum3:=0; sum4:=0; sum5:=0; sum6:=0;
  vl:=0; v2:=0; v3:=0; v4:=0; v5:=0; v6:=0;
iotype:=_ai;  {the channels are analogue input channels}
  for i:=1 to n do
  begin
    vl:=readch(iotype, 1);  {read the values of analogue input channels}
    v2:=readch(iotype, 2);
    v3:=readch(iotype, 3);
    v4:=readch(iotype, 4);
    v5:=readch(iotype, 5);
    v6:=readch(iotype, 6);
    sum1:=sum1+vl; sum2:=sum2+v2;
    sum3:=sum3+v3; sum4:=sum4+v4; sum5:=sum5+v5; sum6:=sum6+v6;
  end;
  with clinreadings do
  begin
    zero1:=sum1/n; zero2:=sum2/n; zero3:=sum3/n;
    zero4:=sum4/n; zero5:=sum5/n; zero6:=sum6/n;
  writeln('zero1=',zero1:5:1, 'zero2=',zero2:5:1,'zero3=',zero3:5:1);
  writeln('zero4=',zero4:5:1,'zero5=',zero5:5:1,'zero6=',zero6:5:1);
  end;
  checkzerovaluesaresensible;
  writeln('Finishing zeroing.');
  writeln('');
end;

procedure promptoperatorstarttest;
begin
  writeln('Ensure that subject is ready.');
  writeln('Press any key to start the test.');
end;

procedure operatorstartstest;
var s:char;
begin
  s:=readkey;
end;

procedure recorddata;  {Data is stored in 'raw' form (as integers representing)}
  {VI, V2, V3, V4, V5 AND V6).}
begin;
  recorddatafromwalkway;
  recorddatatofile;
end;

procedure sortnames;
var sortresult: integer;
begin;
  writeln('Beginning to sort data.');
  assign(filetobesorted, datafilename);
  reset(filetobesorted);
  sortresult:=turbosort(sizeof[clinrecord], &inpres, &lessrec, &outpres);
  if sortresult = 0 then
    writeln('Sort was successful.')
  else
    begin
      writeln('The program has not been able to sort existing data.' );
      writeln('The error code is ',sortresult);
      writeln('Please seek assistance.');
      halt;
    end;
end;
procedure calculateforces(var counter:integer);
begin;
V1:=lsb*(clinreadings.array1[counter]-clinreadings.zero1);
V2:=lsb*(clinreadings.array2[counter]-clinreadings.zero2);
V3:=lsb*(clinreadings.array3[counter]-clinreadings.zero3);
V4:=lsb*(clinreadings.array4[counter]-clinreadings.zero4);
V5:=lsb*(clinreadings.array5[counter]-clinreadings.zero5);
V6:=lsb*(clinreadings.array6[counter]-clinreadings.zero6);
end;

procedure calculateFxy(var counter:integer);
begin
platform1force[counter]:=F1+F2+F3;
platform2force[counter]:=F4+F5+F6;
if platform1force[counter]>forcelowerthreshold then
begin
xplatform1[counter]:=a*(2*F2+F3)/platform1force[counter];
yplatform1[counter]:=2*b*F3/platform1force[counter];
end
else
begin
xplatform1[counter]:=-l;  [These values correspond to a position]
yplatform1[counter]:=-l;  [off the edge of the platforms]
end;
if platform2force[counter]>forcelowerthreshold then
begin
xplatform2[counter]:=a*(2*F6+F4)/platform2force[counter];
yplatform2[counter]:=-d-g-d-2*b*F4/platform2force[counter];
end
else
begin
xplatform2[counter]:=-l;  [These values correspond to a position]
yplatform2[counter]:=-l;  [off the edge of the platforms]
end;

procedure displaypreliminaries;
begin
clrscr;  [clear screen]
writeln(outputdevice, '---------------------------------');
writeln(outputdevice, 'Data from gait assessment program');
writeln(outputdevice, '---------------------------------');
with clinreadings do
begin
writeln(outputdevice,'recordname=',recordname);
writeln(outputdevice,'entrydate is no longer a valid variable');
writeln(outputdevice,'numberofchannels=',numberofchannels);
writeln(outputdevice,'nominalsamplingrateperchannel=',nominalsamplingrateperchannel);
writeln(outputdevice,'actualsamplingrateperchannel=',actualsamplingrateperchannel);[8:3];
writeln(outputdevice,'samplingletime=',samplingletime);
writeln(outputdevice,'readingsperchannel=',readingsperchannel);[8:3];
writeln(outputdevice,'zero1=',zero1);[8:3];
writeln(outputdevice,'zero2=',zero2);[8:3];
writeln(outputdevice,'zero3=',zero3);[8:3];
writeln(outputdevice,'zero4=',zero4);[8:3];
writeln(outputdevice,'zero5=',zero5);[8:3];
writeln(outputdevice,'zero6=',zero6);[8:3];
end;
end;
procedure displayrawdata;
begin
for i:=1 to clinreadings.readingsperchannel do
begin
if (platform1force^[i]>forceupperthreshold) then
begin
writeln('F=',platform1force^[i]:6:1, ' x=', (100*xplatform1^[i]):6:1, ' y=', (100*yplatform1^[i]):6:1);
wait;
end;
if (platform2force^[i]>forceupperthreshold) then
begin
writeln('F=',platform2force^[i]:6:1, ' x=', (100*xplatform2^[i]):6:1, ' y=', (100*yplatform2^[i]):6:1);
wait;
end;
end;
end;

procedure displayforcesversustime;
begin
initgraphic;
setclippingon;
definewindow(1,0,0,xmaxglb,ymaxglb); [window 1 to fill the whole screen]
definewindow(2,4,16,xmaxglb-2,ymaxglb-14); [window 2 to fill the area within]
defineheader(1, 'Plots of vertical force/kgf versus time/s for both platforms'); [define heading for window 1]
defineworld(1,0,-10,clinreadings.samplingtime,200); [define world in window 1 to be]
[0 to samplingtime, -10 to +200kgf]
defineworld(2,0,200,clinreadings.samplingtime,-10);
selectworld(1);
selectwindow(1);
setbackgroundcolor(blue);
setforegroundcolor(yellow);
drawborder;
drawaxis(8,-8,0,0,0,0,0,0,true);
selectworld(2);
selectwindow(2);
for i:=1 to clinreadings.readingsperchannel do
begin
drawpoint((i/clinreadings.nominalsamplingrateperchannel),
platform1force^[i]); [plot the points from platform 1]
if i=4*round(i/4) then
drawpoint((i/clinreadings.nominalsamplingrateperchannel),
platform2force^[i]); [if i is a multiple of 4, plot the]
[points from platform 2]
gotoxy(44,2); [move to top right of screen in]
[preparation for message]
write('solid line: platform 1');
gotoxy(44,3); [move to top right of screen in]
[preparation for message]
write('broken line: platform 2');
gotoxy(44,4); [move to top right of screen in]
[preparation for message]
waitorprint;
leavegraphic;
end;
end;

procedure displayxyplotsofcentreofpressure;
begin
initgraphic;
setclippingon;
definewindow(1,0,0,xmaxglb,ymaxglb); [window 1 to fill the whole screen]
definewindow(2,4,16,xmaxglb-2,ymaxglb-14); [window 2 to fill the area within]
[the axes]
defineheader(1, "x/metres versus y/metres for centre of pressure on each platform"); [define heading for window 1]
defineworld(1,-e,-3*d-g-2*b, 2*a+e, 2*b+d); [define world in window 1 to be]
[-e to 2a+e, -3d-g-2b to 2b+d]
procedure display3DPedotti; {This procedure displays diagrams of force and positional data as described by Khodadadeh (1988) (68)}

begin
    initgraphic;
    setclippingon;
    definewindow(1,0,0,xmaxglb,ymaxglb); {window 1 to fill the whole screen}
    defineheader(1,
                '3-dimensional plots of F/kgf, x/m and y/m for both platforms'); {define heading for window 1}
    defineworld(1,0,100,100,0); {arbitrarily define world in window 1 to be 0 to 100, 0 to 100}
    selectworld(1);
    selectwindow(1);
    setbackgroundcolor(magenta); {move to top left of screen in}
    setforegroundcolor(green); {preparation for message}
    for i:=1 to clinreadings.readingsperchannel do
    begin
        if platform1force"[i]>forceupperthreshold then
            drawpoint(xplatform1"[i], yplatform1"[i]); {plot the points from platform 1}
        if platform2force"[i]>forceupperthreshold then
            drawpoint(xplatform2"[i], yplatform2"[i]); {plot the points from platform 2}
    end;
    gotoxy(1,2); {move to top left of screen in}
    writeln('length of vector represents magnitude of vertical force'); {preparation for message}
    gotoxy(1,3); {move to top left of screen in}
    writeln('time interval between vectors=',
            (1/clinreadings.nominalsamplingrateperchannel):6:4,' seconds'); {preparation for message}
    gotoxy(1,12); {go to left, 1/3 of way down}
    writeln('platform 1'); {screen}
    gotoxy(1,16); {go to left, 2/3 of way down}
    writeln('platform 2'); {screen}
    waitorprint;
    leavegraphic;
end;
procedure initialisesystem;
var gain, zerochannel, range, channelnumber: integer;

begin;
opendataset(clndata);
sysinit;
findererror;
init(SceOO);

{opens the data set containing the clinical data if it exists, and creates it if it does not}
{This calls a function from the PCI-20026S-3 Software Drivers routines}
{to initialise the software}
{This initialises (numbers the channels} of the PCI-20098C carrier board, which}
{is the only board in the system. The} {numbers start at 0. All the analogue} {input channels are initially configured}
{as single-ended, +/-10V range, gain of 1, with no automatic zero-zero function}
{correction.}

findererror; gain:=1;
zerochannel:=1;
range:=4;
for channelnumber:=1 to 6 do
begin
  cnfai(channelnumber, gain, zerochannel, range); {configure analogue input}

{set the gain to be unity}
{disable hardware auto-zero function}
{+/-5V single-ended}
end;

procedure initialisevariables;
begin
with clinreadings do
begin
recordname:='';
getdate(year,month,day,dayofweek);
gettime(hour,minute,second,sec100);
subjectname:='';
ageinyears:='';
sex:='';
NHSnumber:='';
footwear:='';
handedness:='';
commentsbeforeexpt:='';
commentsafterexpt:='';

numberofchannels:=6; {can be up to 6}
nominalsamplingrateperchannel:=100; {Hertz}
actualesamplingrateperchannel:=0; {Hertz}
samplingtime:=20; {seconds}
readingsperchannel:=nominalsamplingrateperchannel*samplingtime;

zerol:=-0.0;zero2:=-0.0;zero3:=-0.0;zero4:=-0.0;zero5:=-0.0;zero6:=-0.0;

for i:=1 to arraylength do
begin
  array1[i]:=0;
  array2[i]:=0;
  array3[i]:=0;
  array4[i]:=0;
  array5[i]:=0;
  array6[i]:=0;
end;

new(platform1force);
new(platform2force);
new(xplatform1);
new(xplatform2);
new(ypplatform1);
new(ypplatform2);

procedure examinerecordorquit;
procedure recalldata;
var
  searchname: namestr;
begin
  writeln('You have chosen to recall existing data.');
  sortnames;
  writeln('Please enter record name of data for analysis.');
  readln(searchname);
  taread(clindata, clinreadings, searchname, true);
  while ok=false do
  begin
    writeln('no record found with the name ', searchname);
    writeln('re-enter name or type q to quit');
    readln(searchname);
    taread(clindata, clinreadings, searchname, true); // I am looking for an exact match
  end;
  if searchname='q' then halt;
  writeln('Finished selecting data for analysis.');
  writeln('Finished recalling existing data.');
end;

procedure doexperiment;
begin
  writeln('You have chosen to record new data.');
  zero; // measures voltage of each channel when nothing is on the platforms
  promptoperatorstostarttest; // prompts operator to ensure that subject is ready and then start test
  operatorstartstest;
  recorddata;
  writeln('Finished recording new data.');
end;

procedure processdata;
var counter: integer;
begin
  writeln('Beginning to process data.');
  for counter:=1 to clinreadings.readingsperchannel do
  begin
    calculateforces(counter); // calculates the individual forces on the transducers
    calculateFXY(counter); // calculates instantaneous values of force and position of centre of pressure
  end;
  writeln('Finished processing data.');
end;

procedure directdatatoscreen;
begin
begin
  writeln('Type "e" to examine existing data, "r" to record new data, or "q" to quit');
  writeln('exrecorq:=?');
  while (exrecorqO'e') and (exrecorqO'E') and (exrecorqO'r') and (exrecorqO'R') and (exrecorqO'q') and (exrecorqO'Q') do
  exrecorq:=readkey;
end;
outputdevice:=''; waorprint:='wait';
end;

procedure displaydata;
begin
  writeln('Beginning to display data.');
  displaypreliminaries;
  displayrawdata;
  displayforcesversustime;
  displayxyplotsofcentreofpressure;
  display3DPedotti;
  writeln('Finished displaying data.');
end;

procedure freememory;
begin
  dispose(platform1force); platform1force:=nil;
  dispose(platform2force); platform2force:=nil;
  dispose(xplatform1); xplatform1:=nil;
  dispose(xplatform2); xplatform2:=nil;
  dispose(yplatform1); yplatform1:=nil;
  dispose(yplatform2); yplatform2:=nil;
end;

procedure remindoperator;
begin
  writeln('When you have finished using the system, type "bye" and then "y".');
  writeln('When "please remove power from the system" is displayed, switch');
  writeln('off the monitor (at bottom right corner of screen) but do not');
  writeln('switch off the computer.');
  writeln('DO NOT MOVE THE COMPUTER WITHOUT SWITCHING IT OFF FIRST.');
  writeln('To restart the system, hold down "ctrl" and "alt" and press.');
  writeln('"delete", then type "go"');
  writeln;
end;

{"PRIMARY LEVEL (MAIN PROGRAMME)"}

begin
  taerrorproc:=@cleanup;  {execute procedure 'cleanup'in case of fatal}
  initialisesystem; {error}
  initialisevariables;
  examinerecordorquit; {asks whether the operator wishes to examine}
end;

{case exrecorq of
  'e','E':recalldata;
  'r','R':doexperiment; {existing data, record new data or quit}

  case exrecorq of 'e','E','r','R':
    processdata;
    directdatatoscreen;
    displaydata;
  end
  end
  end
  cleanup;
  freememory;
  remindoperator;
  end;
# dyn.typ

(include file containing record and key definitions for dynamic calibration)

(constants)

```pascal
const arraylength=2000;

type
  namestr=string[20];
  arraytype=array[1..arraylength] of integer;
  clinrecord=record
    recstatus:longint; {used by the database system}
    recordname:namestr; {the database key}
    year,month,day,dayofweek,hour,minute,second,sec100:word;
    subjectname:namestr; {not used}
    ageinyears:string[3]; {not used}
    sex:string[1];
    NHSNumber:string[10]; {not used}
    footwear:string[20]; {not used}
    handedness:string[1]; {not used}
    commentsbeforeexpt:string[255]; {not used}
    commentsafterexpt:string[255]; {not used}
    numberofchannels:integer;
    nominalsamplingrateperchannel:integer;
    actualsamplingrateperchannel:double;
    samplingtime:integer;
    readingsperchannel:integer;
    zero1,zero2,zero3,zero4,zero5,zero6:double;
    array1: arraytype;
    array2: arraytype;
    array3: arraytype;
    array4: arraytype;
    array5: arraytype;
    array6: arraytype;
  end;

maxdatatype = clinrecord; {largest data record type}
maxkeytype = namestr; {largest key type}
```

# Dyna

(include file for dynamic calibration program, created due to space constraints)

```pascal
type
  doublearraytype = array[1..arraylength] of double;
  doublearrayptr = 'doublearraytype'; {pointer to doublearraytype}

const
  datafilenm = 'd:\janebarr\resul_91\dyn.dat';
  indexfilenm = 'd:\janebarr\resul_91\dynind.idx';

  gain1=30.542; {These values are all in kgf/V, and are taken from}
  gain2=29.635; {calibration using the Instron mechanical testing machine}
  gain3=29.585; {in October 1991}
  gain4=28.569;
  gain5=29.442;
  gain6=29.096;

  lsb=2.4414063e-3; {the value of the least significant bit, in V.(10V/4096)'}

{platform dimensions in metres:}
  a=1.101; {half the distance between transducers 1 and 2}
  b=0.2295; {or 4 and 5} {from drawing}
  d=0.0785; {or 4 and 6} {from drawing}
  e=0.1214; {lateral distance between transducer and edge of platform}
  g=0.0030; {width of gap between platforms, (measured average value)}

  forcelowthresh=1; {kgf} The times when the total force on a platform crosses this value, are considered to
  forceupperthresh=20; {kgf} be the beginning and end of the steps.
```

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The position of the centre of pressure is not displayed. For the purpose of calculating eg step lengths, the point when the force first exceeds this value is considered as the beginning of the step.

```pascal
var exrecorq, prnot: char;
worprint, outputdevice: string;

begin

  i: integer;
  clindata: dataset;
  clinreadings: clinrecord;
  filetobesorted: file of clinrecord;

  errcode: integer;

  V1, V2, V3, V4, V5, V6,
  F1, F2, F3, F4, F5, F6,
  Fplatform1, Fplatform2,
  x, y, x1, x2, y1, y2: double;
  platform1force, platform2force,
  platform1, platform2,
  yplatform1, yplatform2: double array type;

  step, numberofstepsplatform1, numberofstepsplatform2: integer;
  beginningofstepplatform1, ffirstexceedsfutpl,
  endofstepplatform1, ffirstexceedsfutp2, endofstepplatform2: array[1 .. 10] of integer;
  middleofstep: integer;
  firstpeakforceplatform1, secondpeakforceplatform1,
  minimumforcebetweenplatform1: array[1 .. 10] of double;
  firstpeakforceplatform2, secondpeakforceplatform2,
  minimumforcebetweenplatform2: array[1 .. 10] of double;
  fpfplsamplenumber, spfplsamplenumber, fpfp2samplenumber, spfp2samplenumber,
  mfbtplsamplenumber, mbftp2samplenumber: array[1 .. 10] of integer;
  impulseplatform1, impulseplatform2: array[1 .. 10] of double;
  channelnumber: integer;

  { *SIXTH LEVEL* }
  procedure wait;
  var s: char;
  begin
    writeln('Press any key to continue');
    s := readkey;
    writeln('');
  end;

  { *FIFTH LEVEL* }
  procedure finderror;
  begin
    errcode := errsys; { errsys is a function from the PCI-20026S-3 Software }
    { Drivers routines. }
    if errcode <> 0 then
      begin
        writeln('error: ', errcode);
        wait;
      end;
  end;

  procedure delayloop( var delaylength: integer );
  begin
    for i := 1 to delaylength do
      begin
        end;
  end;
```
procedure suggestquit;
var q:char;
begin
  writeln('The input voltage from channel ',channelnumber,
    ' is outside the expected range.');
  writeln('This suggests that the equipment is damaged.');
  writeln('It is recommended that you seek assistance.');
  writeln('Type "c" to continue with the program or anything else to quit');
  readln (q);
  if (q='<c') and (q<> 'C') then halt;
end;

procedure cleanname(var typedname:namestr);
const allowedcharacters:set of char=' ',',','0'..'9','A'..'Z','a'..'z';
var i,j,originallength:integer;
begin
  originallength:=length(typedname);
  for i:=0 to originallength do
    for j:=0 to length(typedname) do
      if not(typedname[j]  in allowedcharacters)  then delete(typedname, j, 1);
end;

procedure calcfirstpeak (var beginningofstep,platform:integer);
begin
  if platform=1 then firstpeakforceplatform1[step]:=-10;
  if platform=2 then firstpeakforceplatform2[step]:=-10;
  for i:=beginningofstep to middleofstep do
    if platform=1 then
      begin
        if platformlforce'[i] >firstpeakforceplatforml[step] then
          begin
            firstpeakforceplatforml[step]:=platformlforce'[i];
            fpfplsamplenumber[step]:=i;
          end;
      end;
    if platform=2 then
      begin
        if platform2force'[i] >firstpeakforceplatform2[step] then
          begin
            firstpeakforceplatform2[step]:=platform2force'[i];
            fpfp2samplenumber[step]:=i;
          end;
      end;
end;

procedure calcsecondpeak (var endofstep,platform:integer);
begin
  if platform=1 then secondpeakforceplatforml[step]:=-10;
  if platform=2 then secondpeakforceplatform2[step]:=-10;
  for i:=middleofstep+1 to endofstep do
    if platform=1 then
      begin
        if platformlforce'[i] >secondpeakforceplatforml[step] then
          begin
            secondpeakforceplatforml[step]:=platformlforce'[i];
            spfplsamplenumber[step]:=i;
          end;
      end;
    if platform=2 then
      begin
        if platform2force'[i] >secondpeakforceplatform2[step] then
          begin
            secondpeakforceplatform2[step]:=platform2force'[i];
            spfp2samplenumber[step]:=i;
          end;
      end;
end;

procedure calcmin(var fpfsamplenumber,spfsamplenumber,platform:integer);
begin
if platform=1 then minimumforcebetweenthemplatform1[step] := 10000;
if platform=2 then minimumforcebetweenthemplatform2[step] := 10000;
for i := fpfsamplenumber to spfsamplenumber do
begin
    if (platform=1) and (platformlforce"[i]<minimumforcebetweenthemplatforml[step]) then
        begin
            minimumforcebetweenthemplatforml[step] := platformlforce"[i];
            mfbtp1samplenumber[step] := i;
        end;
    if (platform=2) and (platform2force"[i]<minimumforcebetweenthemplatform2[step]) then
        begin
            minimumforcebetweenthemplatform2[step] := platform2force"[i];
            mfbtp2samplenumber[step] := i;
        end;
end;
end;

function xiso: double;
const
  Ox = 30;
  xscale = 24;
begin
  xiso := Ox + xscale*(x+y/sqrt(2.0));
end;

function yiso: double;
const
  Oy = 50;
  yscale = 32;
begin
  yiso := Oy +yscale*(y/sqrt(2.0));
end;

{FOURTH LEVEL}

procedure abort(message: string);
begin
  gotoxy(1,24);
  write(message, ', Hit any key to halt');
  repeat until keypressed;
  halt;
end;

procedure checkzerovaluesaresensible;
const
  zerolowerlimit = 921.6;
  zeroupperlimit = 1126.4;
begin
  channelnumber := 1;
  if (clinreadings.zerol<zeroupperlimit) or (clinreadings.zerol>zeroupperlimit) then suggestquit;
  channelnumber := 2;
  if (clinreadings.zero2<zeroupperlimit) or (clinreadings.zero2>zeroupperlimit) then suggestquit;
  channelnumber := 3;
  if (clinreadings.zero3<zeroupperlimit) or (clinreadings.zero3>zeroupperlimit) then suggestquit;
  channelnumber := 4;
  if (clinreadings.zero4<zeroupperlimit) or (clinreadings.zero4>zeroupperlimit) then suggestquit;
  channelnumber := 5;
  if (clinreadings.zero5<zeroupperlimit) or (clinreadings.zero5>zeroupperlimit) then suggestquit;
  channelnumber := 6;
  if (clinreadings.zero6<zeroupperlimit) or (clinreadings.zero6>zeroupperlimit) then suggestquit;
end;
procedure changeormovedown(var tempstring:string);
var
s:char;
begin
writeln('Press "c" to change this piece of information or any other key to');
writeln('move down the list');
tempstring:='???';
repeat until not keypressed;
repeat until keypressed;
s:=readkey;
if s='c' then
begin
writeln('type in new information for this item');
readln(tempstring);
end;
end;

procedure recorddatafromwalkway;
var
n,sample,delaylength:integer;
starthour,startminute,startsecond,startseclOO,
finishhour,finishminute,finishsecond,finishseclOO:word;
measuredsamplingtime,timeratio:double;
begin
  case clinreadings.nominalsamplingrateperchannel of
  100:begin
    delaylength:=1279; {if nominal sampling rate is 100Hz, set}
    clinreadings.actualsamplingrateperchannel:=100.0;
    {measured, lab book, page 1745, 4/9/91}
  end;
  400:begin
    delaylength:=14; {if nominal sampling rate is 400Hz, set}
    clinreadings.actualsamplingrateperchannel:=399.81;
    {measured, lab book, page 2101, 28/11/91}
  end;
  else
    begin
      writeln('the programme is not capable of dealing with this value of');
      writeln('sampling rate');
      halt;
    end;
  end;
  clinreadings.readingsperchannel:=
    clinreadings.nominalsamplingrateperchannel*clinreadings.samplingtime;
delay(9000);
write('G');
delay(1000);
writeln('Beginning to record data from the walkway.');
gettime(starthour,startminute,startsecond,startseclOO);
with clinreadings do
begin
  for sample:=1 to readingsperchannel do
  begin
    array1[sample]:=readch(_ai,1);
    array2[sample]:=readch(_ai,2);
    array3[sample]:=readch(_ai,3);
    array4[sample]:=readch(_ai,4);
    array5[sample]:=readch(_ai,5);
    array6[sample]:=readch(_ai,6);
    delayloop(delaylength);
  end;
end;
gettime(finishhour,finishminute,finishsecond,finishseclOO);
writeln('Finished recording data from the walkway.');
writeln('');
write('G,G');
measuredsamplingtime:=(3600.0 * (round(finishhour ) - round(starthour ))
+60.0 * (round(finishminute) - round(startminute))
+1.0 * (round(finishsecond) - round(startsecond))
+0.01*(round(finishseclOO) - round(startseclOO));
timeratio:=measuredsamplingtime/(clinreadings.samplingtime+0.0);
if (timeratio>1.05) or
  (timeratio<0.95) then
begin
  writeln('The timing of the sampling has been set up incorrectly.';)
  writeln('Nominal sampling time=',clinreadings.samplingtime);
  writeln('Measured sampling time=',measuredsamplingtime);
  writeln('Timeratio=',timeratio);
  writeln('The program is therefore terminating. Please seek assistance.');
  halt;
end;
{fool check for complete number of steps}
clinreadings.array1[1]:=round(clinreadings.zerol);
clinreadings.array2[1]:=round(clinreadings.zero2);
clinreadings.array3[1]:=round(clinreadings.zero3);
clinreadings.array4[1]:=round(clinreadings.zero4);
clinreadings.array5[1]:=round(clinreadings.zero5);
clinreadings.array6[1]:=round(clinreadings.zero6);
clinreadings.array1[clinreadings.readingsperchannel]:=round(clinreadings.zerol);
clinreadings.array2[clinreadings.readingsperchannel]:=round(clinreadings.zerol);
clinreadings.array3[clinreadings.readingsperchannel]:=round(clinreadings.zerol);
clinreadings.array4[clinreadings.readingsperchannel]:=round(clinreadings.zerol);
clinreadings.array5[clinreadings.readingsperchannel]:=round(clinreadings.zerol);
clinreadings.array6[clinreadings.readingsperchannel]:=round(clinreadings.zerol);
end;
{$F+}
procedure inprec;
begin
  repeat
    read(filetobesorted, clinreadings);
    sortrelease(clinreadings);
  until eof(filetobesorted);
end;
{$F-}
{$F+}
function lessrec(var x,y:clinrecord):boolean;
begin
  lessrec:=x.recordname<y.recordname;
end;
{$F-}
{$F+}
procedure outprec;
begin
  writeln('The existing record names are:');
  repeat
    sortreturn(clinreadings);
    write(clinreadings.recordname,',');
  until sorteos;
  writeln;
end;
{$F-}

procedure identifysteps;
var
  counter:integer;
  found:boolean;
begin
  numberofstepsplatforml:=0;
  {check the force on platform 1 is zero at the beginning and end of the trial}
  {if not, halt}
  if (xplatforml''[1]>-0.9) or
    (xplatforml''[clinreadings.readingsperchannel]>-0.9) then
begin
  ....
end;
writeln('The trial is invalid: it does not record a whole number of');
writeln('footfalls on platform 1. The program is therefore terminating');
halt;
end;

{find beginnings of steps on platform 1}
step:=1;
for counter:=2 to clinreadings.readingsperchannel do
begin
if (numberofstepsplatform1<ll) and (xp[platform1][counter]<>-0.9)
and (xp[platform1][counter-1]<-0.9) then
begin
beginningofstepplatform1[step]:=counter;
numberofstepsplatform1:=numberofstepsplatform1+1;
step:=step+1;
end;
end;
if numberofstepsplatform1=ll then
begin
writeln('The program cannot deal with all the data because there');
writeln('are more than ten steps on platform 1');
wait;
numberofstepsplatform1:=10
end;

{Find where the force first exceeds forceupperthreshold for each step on}
(platform 1)
for step:=1 to numberofstepsplatform1 do
begin
found:=false;
for counter:=beginningofstepplatform1[step] to
clinreadings.readingsperchannel do
begin
if (not found) and
(platformlforce'[counter]'=forceupperthreshold) and
(platformlforce'[counter-1]'<forceupperthreshold) then
begin
ffirstexceedsfutpl[step]:=counter;
found:=true;
end;
end;
end;

{find ends of steps on platform 1}
for step:=1 to numberofstepsplatform1 do
begin
found:=false;
for counter:=beginningofstepplatform1[step] to
clinreadings.readingsperchannel do
begin
if (not found) and
(xplatforml'[counter]'<>-0.9) and (xplatforml'[counter+1]'<-0.9) then
begin
endofstepplatform1[step]:=counter;
found:=true;
end;
end;
end;

numberofstepsplatform2:=0;
{check the force on platform 2 is zero at the beginning and end of the trial}
if (xplatform2'[1]'<>-0.9) or
(xplatform2'[clinreadings.readingsperchannel]'<>-0.9) then
begin
writeln('The trial is invalid: it does not record a whole number of');
writeln('footfalls on platform 2. The program is therefore terminating');
halt;
end;

{find beginnings of steps on platform 2}
step:=1;
for counter:=2 to clinreadings.readingsperchannel do
begin
if (numberofstepsplatform2<ll) and (xp[platform2][counter]<>-0.9)
and (xp[platform2][counter-1]<-0.9) then
begin
beginningofstepplatform2[step]:=counter;
numberofstepsplatform2:=numberofstepsplatform2+1;
step:=step+1;
end;
end;
end;
if numberofstepsplatform2=11 then
begin
  writeln('The program cannot deal with all the data because there');
  writeln('are more than ten steps on platform 2');
  wait;
  numberofstepsplatform2:=10
end;

{Find where the force first exceeds forceupperthreshold for each step on}
{platform 2}
for step:=1 to numberofstepsplatform2 do
begin
  found:=false;
  for counter:=beginningofstepplatform2[step] to clinreadings.readingsperchannel do
  begin
    if (not found) and (platform2force^counter>forceupperthreshold) and
      (platform2force^[counter-1]<=forceupperthreshold) then
      begin
        ffirstexceedsfutp2[step]:=counter;
        found:=true;
      end;
  end;
end;

{find ends of steps on platform 2}
for step:=1 to numberofstepsplatform2 do
begin
  found:=false;
  for counter:=beginningofstepplatform2[step] to clinreadings.readingsperchannel do
  begin
    if (not found) and (xplatform2^[counter]>-0.9) and (xplatform2^[counter+1]<-0.9) then
    begin
      endofstepplatform2[step]:=counter;
      found:=true;
    end;
  end;
end;

procedure calcimpulses;
var counter:integer;
begin

{calculate impulse of each step on platform 1}
for step:=1 to numberofstepsplatform1 do
begin
  impulseplatform1[step]:=0;
  for counter:=beginningofstepplatform1[step] to endofstepplatform1[step] do
  begin
    impulseplatform1[step]:=impulseplatform1[step]+(platform1force^counter)/clinreadings.actualsamplingrateperchannel
    {kilogrammes force.seconds}
  end;
end;

{calculate impulse of each step on platform 2}
for step:=1 to numberofstepsplatform2 do
begin
  impulseplatform2[step]:=0;
  for counter:=beginningofstepplatform2[step] to endofstepplatform2[step] do
  begin
    impulseplatform2[step]:=impulseplatform2[step]+(platform2force^counter)/clinreadings.actualsamplingrateperchannel
    {kilogrammes force.seconds}
  end;
end;

procedure calcpeakforces;
var platform:integer;

begin
  platform:=1;
  for step:=1 to numberofstepsplatform1 do
    begin
      middleofstep:=trunc((beginningofstepplatform1[step] +
                          endofstepplatform1[step])/2);
      calcfirstpeak(beginningofstepplatform1[step],platform);
      calcsecondpeak(endofstepplatform1[step],platform);
      calcmin(fpfp1samplenumber[step],spfp1samplenumber[step],platform);
    end;
  platform:=2;
  for step:=1 to numberofstepsplatform2 do
    begin
      middleofstep:=round((beginningofstepplatform2[step] +
                          endofstepplatform2[step])/2);
      calcfirstpeak(beginningofstepplatform2[step],platform);
      calcsecondpeak(endofstepplatform2[step],platform);
      calcmin(fpfp2samplenumber[step],spfp2samplenumber[step],platform);
    end;
end;

procedure recorddatatofile;

var
typedname:namestr;
finished:char;

begin
  repeat
    repeat
      writeln('type name for this record, or type q to quit');
      writeln('The name must contain only the characters 0 to 9, a to z,');
      writeln('A to Z and space');
      readline (typedname);
      cleanname(typedname);
      writeln(typedname);
      if typedname='q' then halt;
      writeln('press "y" if you have entered the name correctly, or any');
      writeln('other key to retype it');
      repeat until not keypressed;
      finished:=readkey;
    until (finished='y') or (finished='Y');
  clinreadings.recordname:=typedname;
  tainsert(clindata, clinreadings, typedname); {data set variable}
  if not ok then writeln('This name already exists. Try again');
  until ok;
end;

procedure waitorprint;

begin
  if waorprint = 'wait' then wait;
  if waorprint = 'print' then
    hardcopy(false,0); {hardcopy with black and white uninverted in}
    hardcopy with black and white uninverted in
    mode 0 (640 points per line)}
end;

procedure drawplatforml;

var xcornersofplatform1,ycornersofplatform1:array[1 .. 5] of double;

begin
  xcornersofplatform1[1]:=e;
  xcornersofplatform1[2]:=2*a+e;
  xcornersofplatform1[3]:=2*a+e;
  xcornersofplatform1[4]:=e;
  xcornersofplatform1[5]:=e;
  ycornersofplatform1[1]:=d;
  ycornersofplatform1[2]:=d;
  ycornersofplatform1[3]:=2*b+d;
  ycornersofplatform1[4]:=2*b+d;
  
  625
var xcornersofplatform1, ycornersofplatform1: array[1..5] of double;

begin
  xcornersofplatform1[1]:=-e;
  xcornersofplatform1[2]:=2*a+e;
  xcornersofplatform1[3]:=2*a+e;
  xcornersofplatform1[4]:=-e;
  xcornersofplatform1[5]:=-e;
  ycornersofplatform1[1]:=-3*d-g-2*b;
  ycornersofplatform1[2]:=-3*d-g-2*b;
  ycornersofplatform1[3]:=-g-d;
  ycornersofplatform1[4]:=-g-d;
  ycornersofplatform1[5]:=-3*d-g-2*b;
for i:=1 to 4 do
begin
  x:=xcornersofplatform1[i];
  y:=ycornersofplatform1[i];
  xl:=xiso;
  yl:=yiso;
  x:=xcornersofplatform1[i+1];
  y:=ycornersofplatform1[i+1];
  x2:=xiso;
  y2:=yiso;
  drawline(xl,yl,x2,y2);
end;
end;

procedure drawplatform2;
var xcornersofplatform2, ycornersofplatform2: array[1..5] of double;

begin
  xcornersofplatform2[1]:=-e;
  xcornersofplatform2[2]:=2*a+e;
  xcornersofplatform2[3]:=2*a+e;
  xcornersofplatform2[4]:=-e;
  xcornersofplatform2[5]:=-e;
  ycornersofplatform2[1]:=-3*d-g-2*b;
  ycornersofplatform2[2]:=-3*d-g-2*b;
  ycornersofplatform2[3]:=-g-d;
  ycornersofplatform2[4]:=-g-d;
  ycornersofplatform2[5]:=-3*d-g-2*b;
for i:=1 to 4 do
begin
  x:=xcornersofplatform2[i];
  y:=ycornersofplatform2[i];
  xl:=xiso;
  yl:=yiso;
  x:=xcornersofplatform2[i+1];
  y:=ycornersofplatform2[i+1];
  x2:=xiso;
  y2:=yiso;
  drawline(xl,yl,x2,y2);
end;
end;

procedure drawvectors;
const forcescale=0.2;

begin
  for i:=1 to clinreadings.readingsperchannel do
begin
    x:=xplatform1''[i];
    y:=yplatform1''[i];
    xl:=xiso;
    yl:=yiso;
    x2:=xl;
    y2:=yl+forcescale*platform1force''[i];
    if platform1force''[i]>forceupperthreshold then drawline(xl,yl,x2,y2);
    x:=xplatform2''[i];
    y:=yplatform2''[i];
    xl:=xiso;
    yl:=yiso;
    x2:=xl;
    y2:=yl+forcescale*platform2force''[i];
    if platform2force''[i]>forceupperthreshold then drawline(xl,yl,x2,y2);
end;
end;

program Dynb;
{THIS PROGRAM MUST BE COMPILED FROM DOS USING THE TURBOPASCAL 5.0 COMMAND LINE}
{COMPIILER (TPC DYNB). OTHERWISE THE TIMING OF THE DATA ACQUISITION IS}
{INCORRECT}
{$n+} {put into 8087 mode, ie enable maths coprocessor

uses crt, dos, gdriver, printer, gkernel, gwindow, gshell, taccess, tahigh, sort;
{the programme uses the 'crt' interface}
{and the 'taccess' and 'tahigh' units from}
|include the file dyn.typ, containing the
{record and key definitions for the}
{database aspect of the programme}|

[69x711]{SI
c:\janebarr\z\clin92\dyna.pas}

[69x678]{$1 c:\janebarr\z\clin92\PCIHEADT}
[69x670]{These are header files that must be used}
{in source files for programmes that}
{access the PCI-20026S-3 Software Drivers}
{routines, i.e., they relate to the data}
{capture aspect of the programme}
{which was divided solely due to space}

[69x662]{include the file dyna.pas, containing the}
{record and key definitions for the}
{database aspect of the programme}

[THIRD LEVEL*]

[69x534]{$F+}
procedure cleanup;
begin
  taclose (clindata);
end;
{$F-}$

procedure opendataset(var clindata:dataset);
begin
  writeln('beginning procedure "opendataset"');
  taoen(clindata, datafilenm, sizeof(clinrecord),
        indexfilenm, sizeof(clinreadings.recordname)-1);
  case ok of
    true: writeln('succeeded in opening dataset');
    false:
      begin
        writeln('trying to create dataset');
        tacreate(clindata, datafilenm, sizeof(clinrecord),
                 indexfilenm, sizeof(clinreadings.recordname)-1);
        if ok=true then writeln('succeeded in creating dataset');
      end;
    end;
    if ok=false then abort('could not create dataset');
  writeln('finished procedure opendataset');
end;

procedure zero;[measures the voltage from each channel when nothing is on]
{the platforms}
var suml,sum2,sum3,sum4,sum5,sum6:double;
  vl,v2,v3,v4,v5,v6:double;
  i,n:integer;
  iotype:integer; {input-output type}
begin
  clrscr;
  writeln('Starting zeroing.');
  n:=100;
  suml:=0; sum2:=0; sum3:=0; sum4:=0; sum5:=0; sum6:=0;
  vl:=0; v2:=0; v3:=0; v4:=0; v5:=0; v6:=0;
  iotype:=_ai; {the channels are analogue input channels}
  for i:=1 to n do
    begin
      vl:=readch(iotype,1); [read the values of analogue input channels]
      v2:=readch(iotype,2); [numbers 1 to 6]
      v3:=readch(iotype,3);
      v4:=readch(iotype,4);
    end;
  writeln('finished zeroing.');
end;
v5 := readch(iotype, 5);
v6 := readch(iotype, 6);
sum1 := sum1 + v1;
sum2 := sum2 + v2;
sum3 := sum3 + v3;
sum4 := sum4 + v4;
sum5 := sum5 + v5;
sum6 := sum6 + v6;
end;
with clinreadings do
begin
  zero1 := sum1 / n;
  zero2 := sum2 / n;
  zero3 := sum3 / n;
  zero4 := sum4 / n;
  zero5 := sum5 / n;
  zero6 := sum6 / n;
  writeln('zero1=', zero1:5:1, 'zero2=', zero2:5:1, 'zero3=', zero3:5:1);
  writeln('zero4=', zero4:5:1, 'zero5=', zero5:5:1, 'zero6=', zero6:5:1);
  checkzerovaluearereasonable;
end;
writeln('Finishing zeroing.');
end;

procedure promptoperatorbootstarttest;
begin
  writeln('Ensure that subject is ready.');
  writeln('Press any key to start the test.');
  writeln('');
end;

procedure operatorstartstest;
var s : char;
begin
  s := readkey;
end;

procedure recorddata; {Data is stored in 'raw' form (as integers representing)
{VI, V2, V3, V4, V5 AND V6).}
begin;
  recorddatafromwalkway;
  recorddatatofile;
end;

procedure sortnames;
var sortresult: integer;
begin;
  writeln('Beginning to sort data.');
  assign(filetobesorted, datafilename);
  reset(filetobesorted);
  sortresult := turbosort(sizeof(clinrecord), Sinprecs, Slessrec, Soutprecs);
  {sort data into alphabetical order}
  {of record names}
  if sortresult = 0 then
    writeln('Sort was successful.');
  else
    begin
      writeln('The program has not been able to sort existing data.');
      writeln('The error code is ', sortresult);
      writeln('Please seek assistance.');
      halt;
    end;
  close(filetobesorted);
end;

procedure calculateforces(var counter: integer);
begin;
  FL := gainl * Vl;
  F2 := gain2 * V2;
  F3 := gain3 * V3;
  F4 := gain4 * V4;
  F5 := gain5 * V5;
  F6 := gain6 * V6;
end;
procedure calculateFxy(var counter:integer);
begin
platform1force[counter]:=F1+F2+F3;
platform2force[counter]:=F4+F5+F6;
if platform1force[counter]>forcelowerthreshold then
begin
xplatform1[counter]:=a*(2*F2+F3)/platform1force[counter];
yplatform1[counter]:=2*b*F3/platform1force[counter];
end
else
begin
xplatform1[counter]:=l;  
{These values correspond to a position off}
yplatform1[counter]:=l;  
{the edge of the platforms}
end;
if platform2force[counter]>forcelowerthreshold then
begin
xplatform2[counter]:=-a*(2*F6+F4)/platform2force[counter];
yplatform2[counter]:=-d*F4/platform2force[counter];
end
else
begin
xplatform2[counter]:=l;  
{These values correspond to a position off}
yplatform2[counter]:=l;  
{the edge of the platforms}
end;
end;

procedure furtherprocess; { calculates measured impulses and peak forces }
begin
identifysteps;  
{identify the individual steps}
calclimpulses;  
{integrate to find the vertical impulse of each step}
calcpeakforces;  
{find the magnitudes of the largest forces in each }
{half of each step and the minimum between them}
end;

procedure displaypreliminaries;
begin
clrscr;  
{clear screen}
writeln(outputdevice,
' _**_**
---
data from gait assessment program
---
---
with clinreadings do
begin
writeln(outputdevice,'recordname=',recordname);
writeln(outputdevice,'entrydate is no longer a valid variable');
writeln(outputdevice,'numberofchannels=',numberofchannels);
writeln(outputdevice,'nominalsamplingrateperchannel=',nominalsamplingrateperchannel);
writeln(outputdevice,'actualsamplingrateperchannel=',actualsamplingrateperchannel);
writeln(outputdevice,'actualsamplingrateperchannel=8:3');
writeln(outputdevice,'readingsperchannel=',readingsperchannel);
writeln(outputdevice,'zerol=',zero1:8:3);
writeln(outputdevice,'zero2=',zero2:8:3);
writeln(outputdevice,'zero3=',zero3:8:3);
writeln(outputdevice,'zero4=',zero4:8:3);
writeln(outputdevice,'zero5=',zero5:8:3);
writeln(outputdevice,'zero6=',zero6:8:3);
end;
writeln(outputdevice);  
{blank line}
if waorprint ='wait' then wait;
end;

procedure displayrawdata;
begin
for i:=l to clinreadings.readingsperchannel do
begin
if (platform1force[i]>forceupperthreshold) then
begin
writeln('Fl=',platform1force[i]:6:1,' x1=',(100*xplatform1[i]):6:1,' y1=',(100*yplatform1[i]):6:1);
wait;
end;
for i:=1 to clinreadings.readingsperchannel do
begin
if (platform2force''[i]>forceupperthreshold) then
begin
writeln('F2=',platform2force''[i]:6:1, ' x2=',(100*xplatform2''[i]):6:1, ' y2=',(100*yplatform2''[i]):6:1);
wait;
end;
end;
end;

procedure displayforcesversustime;
begin
initgraphic;
setclippingon;
definewindow(1,0,0,xmaxglb,ymaxglb); {window 1 to fill the whole screen}
definewindow(2,4,16,xmaxglb-2,ymaxglb-14); {window 2 to fill the area within}
{the axes}
defineheader(1, 'Plots of vertical force/kgf versus time/s for both platforms');
{define heading for window 1}
defineworld(1,0,-10,clinreadings.samplingtime,200); {define world in window 1 to be}
{0 to samplingtime, -10 to +200kgf}
defineworld(2,0,200,clinreadings.samplingtime,-10); {points from platform 2}
selectworld(1);
selectwindow(1);
setbackgroundcolor(blue);
setforegroundcolor(yellow);
setheaderon;
drawborder;
drawaxis(8,-8,0,0,0,0,0,0,true);
selectworld(2);
selectwindow(2);
for i:=1 to clinreadings.readingsperchannel do
begin
drawpoint((i/clinreadings.nominalsamplingrateperchannel),
platformlforce''[i]); {plot the points from platform 1}
if i=4*round(i/4) then
drawpoint((i/clinreadings.nominalsamplingrateperchannel),
platform2force''[i]); {if i is a multiple of 4, plot the)
{points from platform 2}
end;
gotoxy(44,2); {move to top right of screen in)
{preparation for message}
write('solid line: platform l');
gotoxy(44,3); {move to top right of screen in)
{preparation for message}
write('broken line: platform 2');
gotoxy(44,4); {move to top right of screen in)
{preparation for message}
waitorprint;
leavegraphic;
end;

procedure displayxyplotsofcentreofpressure;
begin
initgraphic;
setclippingon;
definewindow(1,0,0,xmaxglb,ymaxglb); {window 1 to fill the whole screen}
definewindow(2,4,16,xmaxglb-2,ymaxglb-14); {window 2 to fill the area within}
{the axes}
defineheader(1, 'x/metre s versus y/metre s for centre of pressure on each platform');
{define heading for window 1}
defineworld(1, -e, -3*d-g-2*b, 2*a+e, 2*b+d); {define world in window 1 to be}
{-e to 2*a+e, -3*d-g-2*b to 2*b+d}
defineworld(2, -e, 2*b+d, 2*a+e, -3*d-g-2*b);
selectworld(1);
selectwindow(1);
setbackgroundcolor(black);
setforegroundcolor(cyan);
setheaderon;
drawborder;
drawaxis(8,-8,0,0,0,-1,-1,true);
selectworld(2);
selectwindow(2);
for i:=l to clinreadings.readingsperchannel do
begin
if platform1force^i>forceupperthreshold then
drawpoint(xplatform1^i,yplatform1^i);
end;
if platform2force^i>forceupperthreshold then
drawpoint(xplatform2^i,yplatform2^i);
end;
gotoxy(50,2);
writeln('top of screen: platform 1');
gotoxy(50,3);
writeln('bottom of screen: platform 2');
waitorprint;
leavegraphic;
end;

procedure display3DPedotti;
{This procedure displays diagrams}
of force and positional data as
{described by Khodadadeh (1988)}
begin
initgraphic;
setclippingon;
definewindow(1,0,0,xmaxglb,ymaxglb);
defineheader(1,
'3-dimensional plots of F/kgf, x/m and y/m for both platforms');
defineworld(1,0,100,100,0); {arbitrarily define world in}
window 1 to be 0 to 100, 0 to 100
selectworld(1);
selectwindow(1);
setbackgroundcolor(magenta);
ssetforegroundcolor(green);
setheaderon;
drawborder;
for i:=l to clinreadings.readingsperchannel do
begin
if platform1force^i>forceupperthreshold then
drawpoint(xplatform1^i,yplatform1^i);
end;
if platform2force^i>forceupperthreshold then
drawpoint(xplatform2^i,yplatform2^i);
end;
gotoxy(1,2); {move to top left of screen in}
gotoxy(1,3); {move to top left of screen in}
gotoxy(1,4); {move to top left of screen in}
gotoxy(50,2); {move to bottom right of screen in}
waitorprint;
leavegraphic;
end;

procedure displaymeasuredimpulses;
beginclear
write(outputdevice,
'Measured vertical impulses');
writeln(outputdevice);
for step:= 1 to numberofstepsplatform1 do
begin
writeln(outputdevice,'impulse of step ',step,' on platform 1=','
impulseplatform1[step]:6:2,'kgf*seconds');
end;
writeln(outputdevice);
for step:= 1 to numberofstepsplatform2 do
begin
writeln(outputdevice,'impulse of step ',step,' on platform 2=','
impulseplatform2[step]:6:2,'kgf*seconds');
end;
writeln(outputdevice); {blank line} if waorprint = 'wait' then wait;
end;

procedure displaypeakforces;
begin
clrscr; {clear screen}
writeln(outputdevice,
************* Measured peak forces *************);
writeln(outputdevice);
for step:= 1 to numberofstepsplatform1 do
begin
writeln(outputdevice,'*** platform 1, step ',step,' ***')•
writeln(outputdevice,'beginning of step is at time=','
(beginningofstepplatform1[step]/
clinreadings.nominalsamplingrateperchannel:6:3,' seconds' );
writeln(outputdevice,'end of step is at time=','
(endofstepplatform1[step]/
clinreadings.nominalsamplingrateperchannel:6:3,' seconds' );
writeln(outputdevice);
writeln(outputdevice,'maximum force in first half of step=','
(firstpeakforceplatform1[step]:6:1,'kgf after ','
(fpfp1samplenumber[step]-beginningofstepplatform1[step])*100.0/
(endofstepplatform1[step]-beginningofstepplatform1[step]):2:0,
' % of the step');
writeln(outputdevice,'maximum force in second half of step=','
(secondpeakforceplatform1[step]:6:1,'kgf after ','
(spfp1samplenumber[step]-beginningofstepplatform1[step])*100.0/
(endofstepplatform1[step]-beginningofstepplatform1[step]):2:0,
' % of the step');
writeln(outputdevice,'minimum force between these two peaks=','
(minimumforcebetweenthemplatform1[step]:6:1,'kgf after ','
(mfbtplsamplenumber[step]-beginningofstepplatform1[step])*100.0/
(endofstepplatform1[step]-beginningofstepplatform1[step]):2:0,
' % of the step');
if waorprint='wait' then wait;
writeln(outputdevice);
end;
writeln(outputdevice); {blank line} writeln(outputdevice);
for step:= 1 to numberofstepsplatform2 do
begin
writeln(outputdevice,'*** platform 2, step ',step,' ***');
writeln(outputdevice,'beginning of step=','
(beginningofstepplatform2[step]/
clinreadings.nominalsamplingrateperchannel:6:3,' seconds' )  ;
writeln(outputdevice,'end of step is at time=','
(endofstepplatform2[step]/
clinreadings.nominalsamplingrateperchannel:6:3,' seconds' );
writeln(outputdevice);
writeln(outputdevice,'maximum force in first half of step=','
(firstpeakforceplatform2[step]:6:1,'kgf after ','
(fpfp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
(endofstepplatform2[step]-beginningofstepplatform2[step]):2:0,
' % of the step');
writeln(outputdevice,'maximum force in second half of step=','
(secondpeakforceplatform2[step]:6:1, 'kgf after ','
(spfp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
(endofstepplatform2[step]-beginningofstepplatform2[step]):2:0,
' % of the step');
writeln(outputdevice,'minimum force between these two peaks=','
(minimumforcebetweenthemplatform2[step]:6:1,'kgf after ','
(mfbtp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
(endofstepplatform2[step]-beginningofstepplatform2[step]):2:0,
' % of the step');
if waorprint = 'wait' then wait;
writeln(outputdevice);
end;
writeln(outputdevice); {blank line}
begin;
    opendataset(clindata); {opens the data set containing the clinical data if it exists, and creates it if it does not}
end;

{This calls a function from the PCI-20026S-3 Software Drivers routines to initialise the software}

This initialises (numbers the channels of) the PCI-20098C carrier board, which is the only board in the system. The numbers start at 0. All the analogue input channels are initially configured as single-ended, +/-10V range, gain of 1, with no automatic zero-offset correction.

set the gain to be unity
disable hardware auto-zero function

{channels 1 to 6 to the above values}

begin with clinreadings do
begin
    recordname:= '  1;
    getdate(year,month,day,dayofweek);
    gettime(hour,minute,second,sec100);
    subjectname:= '  1;
    ageinyears:= '  1;
    sex:= '  1;
    NHSnumber:= '  1;
    footwear:= '  1;
    handedness:= '  1;
    commentsbeforeexpt:= '  1;
    commentsafterexpt:= '  1;
    numberofchannels:=6; {can be up to 6}
    nominalsamplingrateperchannel:=400; {Hertz}
    actualsamplingrateperchannel:=0; {Hertz}
    samplingtime:=5; {seconds}
    readingsperchannel:=nominalsamplingrateperchannel*samplingtime; {must be less than arraylength}
    zerol:=0.0;zero2:=0.0;zero3:=0.0;zero4:=0.0;zero5:=0.0;zero6:=0.0;
    for i:=1 to arraylength do
    begin
        arrayl[i]:=0;
        array2[i]:=0;
        array3[i]:=0;
        array4[i]:=0;
        array5[i]:=0;
        array6[i]:=0;
    end;
end;
procedure examinerecordorquit;
begin
writeln('Type "e" to examine existing data, "r" to record new data, or "q"
');
writeln('to quit');
writeln('');
exrecorq:="?";
while (exrecorq>'e') and (exrecorq<'E') and
(exrecorq>'r') and (exrecorq<'R') and
(exrecorq>'q') and (exrecorq<'Q') do
exrecorq:=readkey;
end;

procedure recalldata;
var
searchname:namestr;
begin
writeln('You have chosen to recall existing data.');
sortnames;
writeln('Please enter record name of data for analysis. ');
readln(searchname);
taread(clindata, clinreadings, searchname, true); {database record which is returned}
while ok=false do
begin
writeln('no record found with the name ',searchname);
writeln('re-enter name or type q to quit');
readln(searchname);
taread(clindata, clinreadings, searchname, true); {database record which is returned}
if searchname='q' then halt;
end;
writeln('Finished selecting data for analysis. ');
writeln('Finished recalling existing data. ');
end;

procedure doexperiment;
begin
writeln('You have chosen to record new data. ');
zero; {measures voltage of each channel when)
nothing is on the platforms}
promptoperator ctxtostarttest; {prompts operator to ensure that subject is)
ready and then start test}
operatorstartstest;
recorddata;
writeln('Finished recording new data. ');
end;

procedure processdata; {No software filtering is to be used at present.}
vart:integer;
begin
writeln('Beginning to process data. ');
for counter:=1 to clinreadings.readingsperchannel do
begin
calculateforces(counter); {calculates the individual forces on the)
[transducers]}
calculateFxy(counter); {calculates instantaneous values of force)
(and position of centre of pressure)
end;
furtherprocess;
writeln('Finished processing data. ');
end;
procedure directdatatoscreen;
begin
    outputdevice:=""; {set output device to be screen}
    waorprint:='wait';
end;

procedure displaydata;
begin
    writeln('Beginning to display data.');
    displaypreliminaries;
    displayrawdata;
    displayforcesversustime;
    displayplotsforcentrofpressure;
    display3DPedotti;
    displaymeasuredimpulses;
    displaypeakforces;
    writeln('Finished displaying data.');
end;

procedure freememory;
begin
    dispose(platform1force); platform1force:=nil;
    dispose(platform2force); platform2force:=nil;
    dispose(xplatform1); xplatform1:=nil;
    dispose(xplatform2); xplatform2:=nil;
    dispose(yplatform1); yplatform1:=nil;
    dispose(yplatform2); yplatform2:=nil;
end;

procedure remindoperator;
begin
    writeln('When you have finished using the system, type "bye" and then "y".');
    writeln('When "please remove power from the system" is displayed, switch');
    writeln('off the monitor (at bottom right corner of screen) but do not');
    writeln('switch off the computer.');
    writeln('DO NOT MOVE THE COMPUTER WITHOUT SWITCHING IT OFF FIRST.');
    writeln('To restart the system, hold down "ctrl" and "alt" and press');
    writeln('"delete", then type "go"');
    writeln;
end;

{"* PRIMARY LEVEL (MAIN PROGRAMME)*

begin
    taerrorproc:=@cieanup; {execute procedure 'cleanup'in case of fatal}
    initialise;
    initialisevariables;
    examinerecordorquit; {asks whether the operator wishes to examine}
    case exrecorq of
        'e','E':recalldata; {recall existing data}
        'r','R':doexperiment; {record new data}
    end;
    case exrecorq of
        'e','E', 'r','R':
            begin
                processdata;
                directdatatoscreen;
                displaydata;
            end; {of what do if e, E, r or R}
    end;
    cleanup; {close the files}
    remindoperator;
end.
program convert2;

{  $n+$  }
const
filetoreadmainname='LT101';
filetoreadname=filetoreadmainname+'.dat';
filetowritename=filetoreadmainname+'.JBL';

var
inarray:array[1 .. 4224] of integer;
Fxarray:array[1..512] of double;
Fyarray:array[1..512] of double;
Fzarray:array[1..512] of double;
axarray:array[1..512] of double;
ayarray:array[1..512] of double;

{THIRD LEVEL}
procedure wait;
var s:char;
begin
  writeln('Press any key to continue');
  readln(s);
end;

{SECOND LEVEL}
procedure readfile;
var
  counter:integer;
  filetoread:file of integer;
  temp:integer;
begin
  assign(filetoread,filetoreadname);
  reset(filetoread);
  for counter:=1 to 4224 do
  begin
    read(filetoread,temp);
    inarray[counter]:=temp;
  end;
  close(filetoread);
end;

procedure convertfile;
var
  counter,channel:integer;
  Fx,Fy,Fz:double;
  My,Mx: double;
channelzero,channelsum:array[1..8] of double;
begin
  for channel:=1 to 8 do
  begin
    channelsum[channel]:=0;
    for counter:=463 to 512 do
    begin
      channelsum[channel]:=channelsum[channel] + (inarray[128+512*(channel-1)+counter]-channelzero[channel]);
    end;
    channelzero[channel]:=channelsum[channel]/50.0;
  end;
  for counter:=1 to 512 do
  begin
    Fx:=0.1*((inarray[128+counter]-channelzero[1]) + (inarray[128+512+counter]-channelzero[2]));
    Fy:=0.1*((inarray[128+(512*2)+counter]-channelzero[3]) + (inarray[128+(512*3)+counter]-channelzero[4]));
    Fz:=0.4*((inarray[128+(512*4)+counter]-channelzero[5]) + (inarray[128+(512*5)+counter]-channelzero[6]) + (inarray[128+(512*6)+counter]-channelzero[7]) + (inarray[128+(512*7)+counter]-channelzero[8]));
    My:=120.0*0.4*((inarray[128+(512*4)+counter]-channelzero[5]) + (inarray[128+(512*7)+counter]-channelzero[8]) - (inarray[128+(512*5)+counter]-channelzero[6]) + (inarray[128+(512*6)+counter]-channelzero[7]) + 0.0);
    Mx:=200.0*0.4*((inarray[128+(512*4)+counter]-channelzero[5]) + (inarray[128+(512*7)+counter]-channelzero[8]) - (inarray[128+(512*5)+counter]-channelzero[6]) + (inarray[128+(512*6)+counter]-channelzero[7]) + 0.0);
\begin{verbatim}
+(inarray[128+(512*5)+counter]-channelzero[6])
-(inarray[128+(512*6)+counter]-channelzero[7])
-(inarray[128+(512*7)+counter]-channelzero[8])
+0.0);
Fxarray[counter]:=round(Fx);
Fyarray[counter]:=round(Fy);
Fzarray[counter]:=Fz*5000.0/(32768.0*9.81);
axarray[counter]:=-((Fx*100.0-My+0.0)/(Fz*1000.0));
ayarray[counter]:=(Fy*100.0-Mx+0.0)/(Fz*1000.0);
end;
end;

procedure writefile;
var
filetowrite: file of double;
counter: integer;
begin
assign(filetowrite, filetowritename);
rewrite(filetowrite);
for counter:=1 to 512 do
write(filetowrite, Fzarray[counter],
axarray[counter],
ayarray[counter]);
close(filetowrite);
end;

(PRIMARY LEVEL)
begin
readfile;
convertfile;
writefile;
end.
\end{verbatim}
{uosgws4.typ}
(include file containing record and key definitions for clinical software)

const arraylength=512;

type
  namestr=string[20]; {type definitions for the keys (by which the data)
  will be sorted}

  arraytype=array[1 .. arraylength] of integer;

  clinrecord=record
    recordname:string; {the database key)

    {personal data}
    subjectcode:namestr; {code used instead of name.,)
    weightonleftfootinkgf,weightonrightfootinkgf,weightinkgf:double;
    heightinnamestr;
    dateofbirth:string[8]; {not used)
    sex:string[1]; {not used)
    footwear:string[20];
    legdominance:string[1];

    {clerical data}
    NHSnumber:string[8]; {not used)
    year,month,day,dayofweek,hour,minute,second,secl00: word;
    firsttestdate:string[8];

    {clinical data}
    primarypathology:namestr;
    secondarypathologyaffectinggait:namestr;
    procedurecompleted:namestr;
    dateofprocedure:string[8];

    {test data}
    testtype:namestr;
    commentsaboutseries:string[255];
    commentsabouttrial:string[255];

    {force plate data}
    nominalsamplingrateperchannel:integer;
    actualsamplingrateperchannel:double;
    samplingtime:double;
    readingsperchannel:integer;
end;

{uosgws4a}
(include file for program, created due to space constraints)
type
doublearraytype = array[1 .. arraylength] of double; {pointer to doublearraytype)

const
[Surrey platform dimensions in metres]
a=1.101;
b=0.2295;
d=0.0785;
e=0.1214;
g=0.0030;

forcelowerthreshold=1; {{kgf The times when the total force on a)
  [platform crosses this value, are considered to)
  [be the beginning and end of the steps.)

  (kgf) Because for low values of force, the)
  [positional data is of low accuracy, when the)
  [total force on a platform is less than this,)
  [the position of the centre of pressure is not)
  [displayed. For the purpose of calculating eg)
  [step lengths, the point when the force first)
  [exceeds this value is considered as the)
  [beginning of the step.)

  (metres) This is the threshold defining when a)
  [warning is given that some of the readings are)
  [close to the ends of the platform)

endthreshold=0.10;

crossoverthreshold=0.50; {([metres] This is the threshold defining when a)
{warning is given that the feet may have crossed}
{over the midline}

var exrecord, promont, mfornt, runagain: char;
  waitintofile: string;
  outputdevice: text;
  i: integer;
  clinreadings: clinrecord;
  errcode: integer;

fplatform1, fplatform2,
  x, y, xl, x2, y1, y2: double;
  platform1force, platform2force,
  xplatform1, xplatform2,
  yplatform1, yplatform2: double array[1 .. 10] type;

step, numberofstepsplatform1, numberofstepsplatform2: integer;
beginningofstepplatform1, ffirstexceedsfutpl, flastexceedsfutpl,
  endofstepplatform1,
beginningofstepplatform2, ffirstexceedsfutp2, flastexceedsfutp2,
  endofstepplatform2: array[1 .. 10] of integer;
middleofstep: integer;
firstpeakforceplatform1, secondpeakforceplatform1,
  minimumforcebetweenthemplatform1: array[1 .. 10] of double;
firstpeakforceplatform2, secondpeakforceplatform2,
  minimumforcebetweenthemplatform2: array[1 .. 10] of double;
fpfp1samplenumber, spfplsamplenumber, fpfp2samplenumber, spfp2samplenumber,
  mfbsplsamplenumber, mfbsptsamplenumber: array[1 .. 10] of integer;
impulseplatform1, impulseplatform2: array[1 .. 10] of double;
firststepwasonplatform1, leftfootwasonplatform1:
  platform1steplengths, platform1stepwidths,
  platform1timeaveragedx, platform1timeaveragedy,
pltotalstancetimes, p2totalstancetimes,
plsteplengths, p2steplengths,
plstepwidths, p2stepwidths,
p2timeaverageddx, p2timeaverageddy:
  double stancetimes: array[1 .. 19] of double;
doublestancetimes: array[1 .. 19] of double;
plstridetimes, p2stridetimes,
plstridelengths, p2stridelengths:
  ptotalstancetimes, p2totalstancetimes,
plvelocity, p2velocity, velocity: double;
numberofdst, numberofplstrides, numberofp2strides,
numberofplcompletesteps, numberofp2completesteps: integer;
recnmfl: text;
anyerrormessages, lowforcesteps, toomanysteps, stepsnearend,
  negativedoublestancetimes, highlyunequalnumbersofsteps, crossover,
  outoftime: boolean;
filetobereadname: string;

{[\textit{SIXTH LEVEL}]}

procedure wait;
var s: char;
begin
  writeln('Press any key to continue');
  s:=readkey;
  writeln('');
end;

procedure flushkeyboard;
var s: char;
begin
  while keypressed do s:=readkey;
end;

{[\textit{FIFTH LEVEL}]}

procedure findererror;
begin
  errcode:= errsys; {errsys is a function from the PCI-20026S-3 Software}
  {Drivers routines.}
  exrecord, promont, mfornt, runagain: char;
  waitintofile: string;
  outputdevice: text;
  i: integer;
  clinreadings: clinrecord;
  errcode: integer;

  fplatform1, fplatform2,
  x, y, xl, x2, y1, y2: double;
  platform1force, platform2force,
  xplatform1, xplatform2,
  yplatform1, yplatform2: double array[1 .. 10] type;

  step, numberofstepsplatform1, numberofstepsplatform2: integer;
  beginningofstepplatform1, ffirstexceedsfutpl, flastexceedsfutpl,
  endofstepplatform1,
  beginningofstepplatform2, ffirstexceedsfutp2, flastexceedsfutp2,
  endofstepplatform2: array[1 .. 10] of integer;
  middleofstep: integer;
  firstpeakforceplatform1, secondpeakforceplatform1,
  minimumforcebetweenthemplatform1: array[1 .. 10] of double;
  firstpeakforceplatform2, secondpeakforceplatform2,
  minimumforcebetweenthemplatform2: array[1 .. 10] of double;
  fpfp1samplenumber, spfplsamplenumber, fpfp2samplenumber, spfp2samplenumber,
  mfbsplsamplenumber, mfbsptsamplenumber: array[1 .. 10] of integer;
  impulseplatform1, impulseplatform2: array[1 .. 10] of double;
  firststepwasonplatform1, leftfootwasonplatform1:
  platform1steplengths, platform1stepwidths,
  platform1timeaveragedx, platform1timeaveragedy,
pltotalstancetimes, p2totalstancetimes,
plsteplengths, p2steplengths,
plstepwidths, p2stepwidths,
p2timeaverageddx, p2timeaverageddy:
  double stancetimes: array[1 .. 19] of double;
doublestancetimes: array[1 .. 19] of double;
plstridetimes, p2stridetimes,
plstridelengths, p2stridelengths:
  ptotalstancetimes, p2totalstancetimes,
plvelocity, p2velocity, velocity: double;
numberofdst, numberofplstrides, numberofp2strides,
numberofplcompletesteps, numberofp2completesteps: integer;
recnmfl: text;
anyerrormessages, lowforcesteps, toomanysteps, stepsnearend,
  negativedoublestancetimes, highlyunequalnumbersofsteps, crossover,
  outoftime: boolean;
filetobereadname: string;

{[\textit{SIXTH LEVEL}]}

procedure wait;
var s: char;
begin
  writeln('Press any key to continue');
  s:=readkey;
  writeln('');
end;

procedure flushkeyboard;
var s: char;
begin
  while keypressed do s:=readkey;
end;

{[\textit{FIFTH LEVEL}]}

procedure findererror;
begin
  errcode:= errsys; {errsys is a function from the PCI-20026S-3 Software}
  {Drivers routines.}
  exrecord, promont, mfornt, runagain: char;
  waitintofile: string;
  outputdevice: text;
  i: integer;
  clinreadings: clinrecord;
  errcode: integer;

  fplatform1, fplatform2,
  x, y, xl, x2, y1, y2: double;
  platform1force, platform2force,
  xplatform1, xplatform2,
  yplatform1, yplatform2: double array[1 .. 10] type;

  step, numberofstepsplatform1, numberofstepsplatform2: integer;
  beginningofstepplatform1, ffirstexceedsfutpl, flastexceedsfutpl,
  endofstepplatform1,
  beginningofstepplatform2, ffirstexceedsfutp2, flastexceedsfutp2,
  endofstepplatform2: array[1 .. 10] of integer;
  middleofstep: integer;
  firstpeakforceplatform1, secondpeakforceplatform1,
  minimumforcebetweenthemplatform1: array[1 .. 10] of double;
  firstpeakforceplatform2, secondpeakforceplatform2,
  minimumforcebetweenthemplatform2: array[1 .. 10] of double;
  fpfp1samplenumber, spfplsamplenumber, fpfp2samplenumber, spfp2samplenumber,
  mfbsplsamplenumber, mfbsptsamplenumber: array[1 .. 10] of integer;
  impulseplatform1, impulseplatform2: array[1 .. 10] of double;
  firststepwasonplatform1, leftfootwasonplatform1:
  platform1steplengths, platform1stepwidths,
  platform1timeaveragedx, platform1timeaveragedy,
pltotalstancetimes, p2totalstancetimes,
plsteplengths, p2steplengths,
plstepwidths, p2stepwidths,
p2timeaverageddx, p2timeaverageddy:
  double stancetimes: array[1 .. 19] of double;
doublestancetimes: array[1 .. 19] of double;
plstridetimes, p2stridetimes,
plstridelengths, p2stridelengths:
  ptotalstancetimes, p2totalstancetimes,
plvelocity, p2velocity, velocity: double;
numberofdst, numberofplstrides, numberofp2strides,
numberofplcompletesteps, numberofp2completesteps: integer;
recnmfl: text;
anyerrormessages, lowforcesteps, toomanysteps, stepsnearend,
  negativedoublestancetimes, highlyunequalnumbersofsteps, crossover,
  outoftime: boolean;
filetobereadname: string;
if errcode <> 0 then 
begin 
writeln('error: ', errcode); 
wait; 
end; 
end;

procedure delayloop(var delaylength: integer); 
begin 
for i:=1 to delaylength do 
begin 
end; 
end;

procedure calcfirstpeak(var beginningofstep, platform: integer); 
begin 
if platform=1 then firstpeakforceplatform1[step]:=-10; 
if platform=2 then firstpeakforceplatform2[step]:=-10; 
for i:=beginningofstep to middleofstep do 
begin 
if platform=1 then 
begin 
if platform1force[i]>firstpeakforceplatform1[step] then 
begin 
firstpeakforceplatform1[step]:=platform1force[i]; 
fpfp1samplenumber[step]:=i; 
end; 
end; 
if platform=2 then 
begin 
if platform2force[i]>firstpeakforceplatform2[step] then 
begin 
firstpeakforceplatform2[step]:=platform2force[i]; 
fpfp2samplenumber[step]:=i; 
end; 
end; 
end;

procedure calcsecondpeak (var endofstep, platform: integer); 
begin 
if platform=1 then secondpeakforceplatform1[step]:=-10; 
if platform=2 then secondpeakforceplatform2[step]:=-10; 
for i:=middleofstep+1 to endofstep do 
begin 
if platform=1 then 
begin 
if platform1force[i]>secondpeakforceplatform1[step] then 
begin 
secondpeakforceplatform1[step]:=platform1force[i]; 
spfplsamplenumber[step]:=i; 
end; 
end; 
if platform=2 then 
begin 
if platform2force[i]>secondpeakforceplatform2[step] then 
begin 
secondpeakforceplatform2[step]:=platform2force[i]; 
spfp2samplenumber[step]:=i; 
end; 
end; 
end;

procedure calcmin(var fpfsamplenumber, spfsamplenumber, platform: integer); 
begin 
if platform=1 then minimumforcebetweenthemplatforml[step]:=10000; 
if platform=2 then minimumforcebetweenthemplatform2[step]:=10000; 
for i:=fpfsamplenumber to spfsamplenumber do 
begin 
if (platform=1) and (platform1force[i]<minimumforcebetweenthemplatforml[step]) then 
begin 
minimumforcebetweenthemplatforml[step]:=platform1force[i]; 
mfbtplsamplenumber[step]:=i; 
end; 
end;
if (platform=2) and (platform2force[i]<minimumforcebetweenthemplatform2[step]) then begin
  minimumforcebetweenthemplatform2[step]:=platform2force[i];
  mfbtp2samplenumber[step]:=i;
end;
end;

procedure findoutwhichplatformfirststepwason;
begin
  firststepwasonplatforml:=?'1';
  if (numberofstepsplatforml<>0) and (numberofstepsplatform2<>0) then begin
    if beginningofstepplatforml[1]<beginningofstepplatform2[1] then begin
      firststepwasonplatforml:='T';
    end
    else
    begin
      firststepwasonplatforml:='F';
    end;
  end;
end;

procedure calcplatformltotalstancetimes;
begin
  for step:=1 to numberofstepsplatforml do begin
    pltotalstancetimes[step]:=(endofstepplatforml[step]-beginningofstepplatforml[step])
      /clinreadings.actualsamplingrateperchannel;
  end;
end;

procedure calcplatform2totalstancetimes;
begin
  for step:=1 to numberofstepsplatform2 do begin
    p2totalstancetimes[step]:=(endofstepplatform2[step]-beginningofstepplatform2[step])
      /clinreadings.actualsamplingrateperchannel;
  end;
end;

procedure calcdoublestancetimes;
begin
  for i:=1 to numberofdst do begin
    if (firststepwasonplatforml='T') and (i<>2*round(i/2)) then begin
      doublestancetimes[i]:=(endofstepplatforml[round(0.5*i+0.5)]
        -beginningofstepplatform2[round(0.5*i+0.5)])
        /clinreadings.actualsamplingrateperchannel;
    end
    else
    begin
      doublestancetimes[i]:=(endofstepplatforml[round(0.5*i)]
        -beginningofstepplatform2[round(0.5*i)])
        /clinreadings.actualsamplingrateperchannel;
    end;
  end;
end;
procedure calcplatformlstridetimes;
begin
for i:=1 to numberofplstrides do
begin
plstridetimes[i] := (beginningofstepplatforml[i+1]
- beginningofstepplatforml[i])
/ clinreadings.actualsamplingrateperchannel;
end;
end;

procedure calcplatform2stridetimes;
begin
for i:=1 to numberofp2strides do
begin
p2stridetimes[i] := (beginningofstepplatform2[i+1]
- beginningofstepplatform2[i])
/ clinreadings.actualsamplingrateperchannel;
end;
end;

procedure calcpltimeaveragedxandy;
var counter: integer;
begin
for step:=1 to numberofstepsplatforml do
begin
pltimeaveragedx[step]:=0;
pltimeaveragedy[step]:=0;
counter:=0;
for i:=beginningofstepplatforml[step] to endofstepplatforml[step] do
begin
if platformlforce'[i] > forceupperthreshold then
begin
pltimeaveragedx[step] := pltimeaveragedx[step] + xplatforml'[i];
pltimeaveragedy[step] := pltimeaveragedy[step] + yplatforml'[i];
counter:=counter+1;
end;
end;
if counter=0 then
begin
pltimeaveragedx[step] := -1;
pltimeaveragedy[step] := -1;
end;
if counter>0 then
begin
pltimeaveragedx[step] := pltimeaveragedx[step]/counter;
pltimeaveragedy[step] := pltimeaveragedy[step]/counter;
end;
end;
end;

procedure calcp2timeaveragedxandy;
var counter: integer;
begin
for step:=1 to numberofstepsplatform2 do
begin
p2timeaveragedx[step]:=0;
p2timeaveragedy[step]:=0;
counter:=0;
for i:=beginningofstepplatform2[step] to endofstepplatform2[step] do
begin
if platform2force'[i] > forceupperthreshold then
begin
p2timeaveragedx[step] := p2timeaveragedx[step] + xplatform2'[i];
p2timeaveragedy[step] := p2timeaveragedy[step] + yplatform2'[i];
counter:=counter+1;
end;
end;
if counter=0 then
begin
p2timeaveragedx[step] := -1;
p2timeaveragedy[step] := -1;
end;
if counter>0 then
begin
p2timeaveragedx[step] := p2timeaveragedx[step]/counter;
p2timeaveragedy[step] := p2timeaveragedy[step]/counter;
end;
end;
end;

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end;
if counter>0 then
begin
p2timeaveragedx[step]:=p2timeaveragedx[step]/counter;
p2timeaveragedy[step]:=p2timeaveragedy[step]/counter;
end;
end;
end;

procedure calcplatform1steplengths;
begin
for i:=1 to numberofplcompletesteps do
begin
if firststepwasonplatforml='T' then
plsteplengths[i]:=pltimeaveragedx[i+1]-p2timeaveragedx[i];
if firststepwasonplatforml='F' then
plsteplengths[i]:=pltimeaveragedx[i]-p2timeaveragedx[i];
end;
end;

procedure calcplatform2steplengths;
begin
for i:=1 to numberofp2completesteps do
begin
if firststepwasonplatforml='F' then
p2steplengths[i]:=p2timeaveragedx[i+1]-pltimeaveragedx[i];
if firststepwasonplatforml='T' then
p2steplengths[i]:=p2timeaveragedx[i]-pltimeaveragedx[i];
end;
end;

procedure calcplatform1stepwidths;
begin
for i:=1 to numberofplcompletesteps do
begin
if firststepwasonplatforml='T' then
plstepwidths[i]:=pltimeaveragedy[i+1]-p2timeaveragedy[i];
if firststepwasonplatforml='F' then
plstepwidths[i]:=pltimeaveragedy[i]-p2timeaveragedy[i];
end;
end;

procedure calcplatform2stepwidths;
begin
for i:=1 to numberofp2completesteps do
begin
if firststepwasonplatforml='F' then
p2stepwidths[i]:=p2timeaveragedy[i+1]-pltimeaveragedy[i];
if firststepwasonplatforml='T' then
p2stepwidths[i]:=p2timeaveragedy[i]-pltimeaveragedy[i];
end;
end;

procedure calcplatform1stridelengths;
begin
for i:=1 to numberofplstrides do
begin
plstridelengths[i]:=pltimeaveragedx[i+1]-pltimeaveragedx[i];
end;
end;

procedure calcplatform2stridelengths;
begin
for i:=1 to numberofp2strides do
begin
p2stridelengths[i]:=p2timeaveragedx[i+1]-p2timeaveragedx[i];
end;
end;

procedure calcplatform1velocity;
var displacementonplatforml,timeonplatforml:double;
begin

displacementonplatforml:=0;
timeonplatforml:=0;
for i:=1 to numberofplstrides do begin
  displacementonplatforml:=displacementonplatforml+plstridelengths[i];
  timeonplatforml:=timeonplatforml+plstridetimes[i];
end;
p1velocity:=displacementonplatforml/timeonplatforml;
end;

procedure calcplatform2velocity;
var displacementonplatform2,timeonplatform2:double;
begin
  displacementonplatform2:=0;
  timeonplatform2:=0;
  for i:=1 to numberofp2strides do begin
    displacementonplatform2:=displacementonplatform2+p2stridelengths[i];
    timeonplatform2:=timeonplatform2+p2stridetimes[i];
  end;
p2velocity:=displacementonplatform2/timeonplatform2;
end;

procedure calcvelocity;
begin
  if (numberofplstrides<>0) and (numberofp2strides=0) then velocity:=p1velocity;
  if (numberofp2strides<>0) and (numberofplstrides=0) then velocity:=p2velocity;
  if (numberofplstrides<>0) and (numberofp2strides<>0) then velocity:=(p1velocity+p2velocity)/2.0;
end;

procedure findoutwhichplatformleftfootwason;
begin
  leftfootwasonplatforml:='?';
  if velocity>0 then leftfootwasonplatforml:='T';
  if velocity<0 then leftfootwasonplatforml:='F';
  if leftfootwasonplatforml='T' then
    if leftfootwasonplatforml='F' then
      end;
end;

procedure displaywhichplatformfirststepwason;
begin
  if (numberofstepsplatforml<>0) and (numberofstepsplatform2<>0) then begin
    if beginningofstepplatforml[1]<beginningofstepplatform2[1] then begin
      writeln(outputdevice,'first step was on platform 1');
    end
    else begin
      writeln(outputdevice,'first step was on platform 2');
    end;
  end;
end;

procedure displayplatformltotalstancetimes;
begin
  for step:=1 to numberofstepsplatforml do begin
    writeln(outputdevice,'Total stance time of step ',step,' on platform 1=',
    pltotalstancetimes[step]:6:4,' seconds');
  end;
end;

procedure displayplatform2totalstancetimes;
begin
  for step:=1 to numberofstepsplatform2 do
    writeln(outputdevice,'Total stance time of step ',step,' on platform 2=',
    p2totalstancetimes[step]:6:4,' seconds');
end;

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begin
  writeln(outputdevice,'Total stance time of step ',step,' on platform 2='
p2totalstancetimes[step]:6:4, ' seconds');
end;
writeln(outputdevice);
end;

procedure sendstancetimestoexcelfile;
begin
  for step:=1 to numberofstepsplatforml do
  begin
    write(outputdevice,pltotalstancetimes[step]:6:4,',');
  end;
  for step:=numberofstepsplatforml+1 to 10 do write(outputdevice,',1);
  for step:=1 to numberofstepsplatform2 do
  begin
    write(outputdevice,p2totalstancetimes(step):6:4,', ');
  end;
  for step:=numberofstepsplatform2+1 to 10 do write(outputdevice,1,');
end;

procedure displaydoublestancetimes;
begin
  for i:=1 to numberofdst do
  begin
    writeln(outputdevice,'double stance time t',i,')='
doublestancetimes[i]:6:4,' seconds');
  end;
  writeln(outputdevice);
end;

procedure displayplatform1stridetimes;
begin
  for i:=1 to numberofplstrides do
  begin
    writeln(outputdevice,'platform 1 stride time t',i,')='
plstridetimes[i]:6:4, ' seconds');
  end;
  writeln(outputdevice);
end;

procedure displayplatform2stridetimes;
begin
  for i:=1 to numberofp2strides do
  begin
    writeln(outputdevice,'platform 2 stride time t',i,')='
p2stridetimes[i]:6:4, ' seconds');
  end;
  writeln(outputdevice);
end;

procedure displaypositionsofcofg;
begin
  for step:=1 to numberofstepsplatforml do
  begin
    writeln(outputdevice,'platform 1, step ',step);
    writeln(outputdevice,
      'position where force first exceeds force upper threshold is');
    writeln(outputdevice,'(x,y)=(',xplatforml"[ffirstexceedsfutpl[step]"]:6:3
    ',' metres,',yplatforml"[ffirstexceedsfutpl[step]"]:6:3,' metres',');
    writeln(outputdevice,
      'position where force last exceeds force upper threshold is');
    writeln(outputdevice,'(x,y)=(',xplatforml"[flastexceedsfutpl[step]"]:6:3
    ',' metres,',yplatforml"[flastexceedsfutpl[step]"]:6:3,' metres',');
    writeln(outputdevice);
  end;
  writeln(outputdevice);
end;

begin
  writeln(outputdevice,'Total stance time of step ',step,' on platform 2='
p2totalstancetimes[step]:6:4, ' seconds');
end;
writeln(outputdevice);
end;

procedure sendstancetimestoexcelfile;
begin
  for step:=1 to numberofstepsplatforml do
  begin
    write(outputdevice,pltotalstancetimes[step]:6:4,',');
  end;
  for step:=numberofstepsplatforml+1 to 10 do write(outputdevice,',1);
  for step:=1 to numberofstepsplatform2 do
  begin
    write(outputdevice,p2totalstancetimes[step]:6:4,', ');
  end;
  for step:=numberofstepsplatform2+1 to 10 do write(outputdevice,1,');
end;

procedure displaydoublestancetimes;
begin
  for i:=1 to numberofdst do
  begin
    writeln(outputdevice,'double stance time t',i,')='
doublestancetimes[i]:6:4,' seconds');
  end;
  writeln(outputdevice);
end;

procedure displayplatform1stridetimes;
begin
  for i:=1 to numberofplstrides do
  begin
    writeln(outputdevice,'platform 1 stride time t',i,')='
plstridetimes[i]:6:4, ' seconds');
  end;
  writeln(outputdevice);
end;

procedure displayplatform2stridetimes;
begin
  for i:=1 to numberofp2strides do
  begin
    writeln(outputdevice,'platform 2 stride time t',i,')='
p2stridetimes[i]:6:4, ' seconds');
  end;
  writeln(outputdevice);
end;

procedure displaypositionsofcofg;
begin
  for step:=1 to numberofstepsplatforml do
  begin
    writeln(outputdevice,'platform 1, step ',step);
    writeln(outputdevice,
      'position where force first exceeds force upper threshold is');
    writeln(outputdevice,'(x,y)=(',xplatforml"[ffirstexceedsfutpl[step]"]:6:3
    ',' metres,',yplatforml"[ffirstexceedsfutpl[step]"]:6:3,' metres',');
    writeln(outputdevice,
      'position where force last exceeds force upper threshold is');
    writeln(outputdevice,'(x,y)=(',xplatforml"[flastexceedsfutpl[step]"]:6:3
    ',' metres,',yplatforml"[flastexceedsfutpl[step]"]:6:3,' metres',');
    writeln(outputdevice);
  end;
  writeln(outputdevice);
end;
'  metres',yplatform2^[ffirstexceedsfutp2[step]]:6:3,
'  metres',']'});
writeln(outputdevice,
'  position where force last exceeds force upper threshold is'};
writeln(outputdevice, '  (x, y) = (' ,xplatform2"^[flastexceedsfutp2[step]] : 6:3,
1  metres,1,yplatform2"^[flastexceedsfutp2[step]]:6:3, •  metres
writeln(outputdevice);
if waprintorfile='wait' then wait;
end;
end;

procedure sendfirstandlastpositionstoexcelfile;
begin
for step:=1 to numberofstepsplatforml do
begin
write (outputdevice,xplatforml"^[ffirstexceedsfutpl[step]] :6:3, ',
  yplatforml"^[ffirstexceedsfutpl[step]]:6:3, ',
  xplatforml"^[flastexceedsfutpl[step]]:6:3, ',
  yplatforml"^[flastexceedsfutpl[step]]:6:3.');
end;
for step:=numberofstepsplatforml+l to 10 do write(outputdevice,',,,,');
for step:=1 to numberofstepsplatform2 do
begin
write(outputdevice,xplatform2"^[ffirstexceedsfutp2[step]]:6:3,',
  yplatform2"^[ffirstexceedsfutp2[step]]:6:3, ',
  xplatform2"^[flastexceedsfutp2[step]]:6:3, ', 1,
  yplatform2"^[flastexceedsfutp2[step]]:6:3,*');
end;
for step:=numberofstepsplatform2+l to 10 do write(outputdevice,',,,,1);
end;

procedure displaypltimeaveragedxandy;
var counter:integer;
begin
for step:=1 to numberofstepsplatforml do
begin
writeln(outputdevice,'platform 1, step ',step,'  time averaged (x,y) = (' ,pltimeaveragedx[step]:6:3,'  metres,',pltimeaveragedy[step]:6:3,'  metres');
writeln(outputdevice);
if waprintorfile='wait' then wait;
end;
end;

procedure displayp2timeaveragedxandy;
var counter:integer;
begin
for step:=1 to numberofstepsplatform2 do
begin
writeln(outputdevice,'platform 2, step ',step,'  time averaged (x,y) = (' ,p2timeaveragedx[step]:6:3,'  metres,',p2timeaveragedy[step]:6:3,'  metres',')');
writeln(outputdevice);
if waprintorfile='wait' then wait;
end;
end;

procedure displayplatformlsteplengths;
begin
for i:=1 to numberofplcompletesteps do
begin
writeln(outputdevice,'platform 1 step length [' ,i,' ]=' ,
  plsteplengths[i]:6:3, ' metres');
end;
writeln(outputdevice);
end;

procedure displayplatform2steplengths;
begin
for i:=1 to numberofp2completesteps do
begin

writeln(outputdevice,'platform 2 step length [',i,']=','
p2steplengths[i]:6:3,' metres');
end;
writeln(outputdevice);
end;

procedure displayplatform1stepwidths;
begin
  for i:=1 to numberofplcompletesteps do
  begin
    writeln(outputdevice,'platform 1 step width [',i,']=','
               plstepwidths[i]:6:3,' metres');
  end;
  writeln(outputdevice);
end;

procedure displayplatform2stepwidths;
begin
  for i:=1 to numberofp2completesteps do
  begin
    writeln(outputdevice,'platform 2 step width [',i,']=','
               p2stepwidths[i]:6:3,' metres');
  end;
  writeln(outputdevice);
end;

procedure displayplatform1stridelengths;
begin
  for i:=1 to numberofplstrides do
  begin
    writeln(outputdevice,'platform 1 stride length [',i,']=','
               plstridelengths[i]:6:3,' metres');
  end;
  writeln(outputdevice);
end;

procedure displayplatform2stridelengths;
begin
  for i:=1 to numberofp2strides do
  begin
    writeln(outputdevice,'platform 2 stride length [',i,']=','
               p2stridelengths[i]:6:3,' metres');
  end;
  writeln(outputdevice);
end;

procedure displayplatform1velocity;
var displacementonplatform1,timeonplatform1:double;
begin
  writeln(outputdevice,'velocity based on platform 1=',plvelocity:6:2,'  metres per second');
  writeln(outputdevice);
end;

procedure displayplatform2velocity;
var displacementonplatform2,timeonplatform2:double;
begin
  writeln(outputdevice,'velocity based on platform 2=',p2velocity:6:2,'  metres per second');
  writeln(outputdevice);
end;

procedure displayvelocity;
begin
  writeln(outputdevice,'velocity=',velocity:6:2,'  metres per second')
  writeln(outputdevice);
end;
procedure displaywhichplatformleftfootwason;
begin
  if leftfootwasonplatforml='T' then
    writeln(outputdevice,'left foot was on platform 1');
  if leftfootwasonplatforml='F' then
    writeln(outputdevice,'left foot was on platform 2');
  writeln(outputdevice);
end;

function xiso:double;
const
  Ox=30;
  xscale=24;
begin
  xiso:=Ox+xscale*(x+y/sqrt(2.0));
end;

function yiso:double;
const
  Oy=50;
  yscale=32;
begin
  yiso:=Oy+yscale*(y/sqrt(2.0));
end;

uosgws4b
{'FOURTH LEVEL'}

*******************************************************************************
(* GRAPHIX TOOLBOX 4.0 *)
(* Copyright (c) 1985, 87 by Borland International, Inc. *)
*******************************************************************************
{Gfile} {modified by Jane Barrance in order to be able to print}
{graphics screens from files}

procedure sendgraphicstofile(Inverse :  boolean; Mode :  byte);
{ Graphics file dump routine for EPSON compatible }
{ printers. Pre-FX series of EPSON printers should }
{ only use Mode 1. }
{
  Mode: 1 = Double-Density 120 dots per inch
  2 = High-Speed D-D 120 dots per inch
  3 = Quadruple-Density 240 dots per inch
  0, 4, 5 = 80 dots per inch
  6 = 90 dots per inch
}
const
  Esc = 27;
var
  ScanLine :  integer; { The current scan line }
l1, n2 :  byte; { 2 byte printer control code }
procedure SendByte(B :  byte);
{ Send one byte to the file }
const
  LPTPortNum = 1; { Defaults to LPT1. 2 = LPT2 }
var
  Regs : Registers;
begin
  Regs.AH := 0;
  Regs.AL := B;
  if (B=9) then B:=0;
  if (B=26) then B:=0;

  write(outputdevice,chr(B));
  write(outputdevice,B,' ');     {this is the line I've changed}
end; { SendByte }
{$B+} { Turn off short circuit boolean evaluation }


function ConstructByte(X, Y : integer) : byte;
{ Construct a print byte by reading bits from the graphics screen buffer }
const
  Bits : array[0..7] of byte = (128, 64, 32, 16, 8, 4, 2, 1);
var
  CByte, Bit : byte;
begin
  Y := Y shl 3;    { Y := Y * 8 }
  CByte := 0;
  for Bit := 0 to 7 do
    if ((Mem[GrafBase:BaseAddress(Y+Bit) + X shr 3] and Bits[X and 7]) <> 0) then
      CByte := CByte + Bits(Bit);
  ConstructByte := CByte;
end;    { ConstructByte }

(*SB-*)  { Turn on short circuit boolean evaluation }

procedure DoLine;
{ Dumps one print line to the printer }
var
  XPixel : integer;
  PrintByte : byte;
begin
  if Mode = 1 then
    begin
      SendByte(Esc);  { Select double-density graphics print mode }
      SendByte(Ord('L'));
    end
  else
    begin
      SendByte(Esc);  { Select 8-Pin graphics print mode }
      SendByte(Ord('*'));
      SendByte(Mode);
    end;
  SendByte(nl);  { Send 2 byte control code }
  SendByte(n2);
  for XPixel := 0 to XScreenMaxGlb do
    begin
      PrintByte := ConstructByte(XPixel, ScanLine);
      if Inverse then
        PrintByte := not PrintByte;
      SendByte(PrintByte);  { Send print byte }
    end;
  SendByte(10);  { Send line feed }
end;  { DoLine }

begin  { HardCopy }
  Mode := Mode mod 7;  { Modes 0 through 6 supported }
  if (Mode = 0) or (Mode = 5) then
    Mode := 4;  { Modes 0 and 5 use Mode 4 }
  SendByte(Esc);  { Select 24/216-inch line spacing }
  SendByte(Ord('3'));
  n1 := Lo(Succ(XScreenMaxGlb));  { Determine 2 byte control code for }
  n2 := Hi(Succ(XScreenMaxGlb));  { the number of dots per print line }
  for ScanLine := 0 to (YMaxGlb div 8) do
    DoLine;  { Do a print line }
  SendByte(Esc); SendByte(2);  { Select 1/6-inch line spacing }
end;

uosgws4c.pas
{FOURTH LEVEL CONTINUED*}

procedure abort(message:string);
begin
  gotoxy(1,24);
  write(message, ', Hit any key to halt');
  repeat until keypressed;
  halt;
end;

procedure calcclowforcesteps;
var step:integer;
begin
  for step := 1 to numberofstepsplatform do
    begin

if \( \text{pltimeaveragedx}[\text{step}] < -0.9 \) then begin
  \text{lowforcesteps} := \text{true};
  \text{anyerrormessages} := \text{true};
end;
end;

for \( \text{step} := 1 \) to \( \text{numberofstepsplatform2} \) do begin
  if \( \text{p2timeaveragedx}[\text{step}] < -0.9 \) then begin
    \text{lowforcesteps} := \text{true};
    \text{anyerrormessages} := \text{true};
  end;
end;

procedure \text{calchighlyunequalnumbersofsteps};
begin
  if abs(\( \text{numberofstepsplatform1} - \text{numberofstepsplatform2} \)) > 1 then begin
    \text{highlyunequalnumbersofsteps} := \text{true};
    \text{anyerrormessages} := \text{true};
  end;
end;

procedure \text{calcrossover};
begin
  for \( \text{step} := 1 \) to \( \text{numberofstepsplatform1} \) do begin
    if abs(\( \text{xplatform1}[\text{ffirstexceedsfutpl}[\text{step}]] - \text{xplatform1}[\text{flastexceedsfutpl}[\text{step}]] \)) > \text{crossoverthreshold} then
    begin
      \text{crossover} := \text{true};
      \text{anyerrormessages} := \text{true};
    end;
  end;
  for \( \text{step} := 1 \) to \( \text{numberofstepsplatform2} \) do begin
    if abs(\( \text{xplatform2}[\text{ffirstexceedsfutp2}[\text{step}]] - \text{xplatform2}[\text{flastexceedsfutp2}[\text{step}]] \)) > \text{crossoverthreshold} then
    begin
      \text{crossover} := \text{true};
      \text{anyerrormessages} := \text{true};
    end;
  end;
end;

procedure \text{identifysteps};
var
  \text{counter}: \text{integer};
  \text{found}: \text{boolean};
begin
  \text{numberofstepsplatform1} := 0;
  (\text{find beginnings of steps on platform 1})
  \text{step} := 1;
  for \( \text{counter} := 2 \) to \( \text{cinreadings.readingsperchannel} \) do begin
    if \( \text{numberofstepsplatform1} < 11 \) and \( \text{xplatform1}[\text{counter}] > -0.9 \)
      and \( \text{xplatform1}[\text{counter-1}] < -0.9 \) then begin
      \text{beginningofstepplatform1} := \text{counter};
      \text{numberofstepsplatform1} := \text{numberofstepsplatform1} + 1;
      \text{step} := \text{step} + 1;
    end;
  end;
  if \( \text{numberofstepsplatform1} = 11 \) then begin
    \text{anyerrormessages} := \text{true};
    \text{toomanysteps} := \text{true};
    \text{numberofstepsplatform1} := 10
  end;
  (\text{find ends of steps on platform 1})
  \text{for step} := 1 \text{ to } \text{numberofstepsplatform1} \text{ do}
begin
found:=false;
for counter:=beginningofstepplatforml[step] to 
clinreadings.readingsperchannel do
begin
if (not found) and
(xplatforml[counter] >= 0.9) and (xplatforml[counter+1] <= 0.9) then
begin
endofstepplatforml[step]:=counter;
found:=true;
end;
end;
end;

{Find where the force first exceeds forceupperthreshold for each step on}
{platform 1}
for step:=1 to numberofstepsplatforml do
begin
found:=false;
ffirstexceedsfutpl[step]:=1;
for counter:=beginningofstepplatforml[step] to 
endofstepplatforml[step] do
begin
if (not found) and
(platformlforce[counter] > forceupperthreshold) and
(platformlforce[counter-1] <= forceupperthreshold) then
begin
ffirstexceedsfutpl[step]:=counter;
found:=true;
end;
end;
end;
end;

{Find where the force last exceeds forceupperthreshold for each step on}
{platform 1}
for step:=1 to numberofstepsplatforml do
begin
found:=false;
flastexceedsfutpl[step]:=1;
for counter:=endofstepplatforml[step] downto 
beginningofstepplatforml[step] do
begin
if (not found) and
(platformlforce[counter] > forceupperthreshold) and
(platformlforce[counter+1] <= forceupperthreshold) then
begin
flastexceedsfutpl[step]:=counter;
found:=true;
end;
end;
end;
end;

numberofstepsplatform2:=0;
{find beginnings of steps on platform 2}
step:=1;
for counter:=2 to clinreadings.readingsperchannel do
begin
if (numberofstepsplatform2<ll) and (xplatform2[counter] >= 0.9)
and (xplatform2[counter-1] <= 0.9) then
begin
beginningofstepplatform2[step]:=counter;
numberofstepsplatform2:=numberofstepsplatform2+1;
step:=step+1;
end;
end;
if numberofstepsplatform2<ll then
begin
anyerrormessages:=true;
toomanysteps:=true;
numberofstepsplatform2:=10
end;
end;

{find ends of steps on platform 2}
for step:=1 to numberofstepsplatform2 do
begin
found:=false;
for counter:=beginningofstepplatform2[step] to 
clinreadings.readingsperchannel do
begin
if (not found) and

(xplatform2^\{counter\} > -0.9) and (xplatform2^\{counter+1\} <= -0.9) then
begin
  endofstepplatform2[step] := counter;
  found := true;
end;
end;

[Find where the force first exceeds forceupperthreshold for each step on platform 2]
for step := 1 to numberofstepsplatform2 do
begin
  found := false;
  ffirstexceedsftp2[step] := 1;
  for counter := beginningofstepplatform2[step] to endofstepplatform2[step] do
  begin
    if (not found) and
        (platform2force^\{counter\} > forceupperthreshold) and
        (platform2force^\{counter-1\} <= forceupperthreshold) then
    begin
      ffirstexceedsftp2[step] := counter;
      found := true;
    end;
  end;
end;

[Find where the force last exceeds forceupperthreshold for each step on platform 2]
for step := 1 to numberofstepsplatform2 do
begin
  found := false;
  flastexceedsftp2[step] := 1;
  begin
    if (not found) and
        (platform2force^\{counter\} > forceupperthreshold) and
        (platform2force^\{counter+1\} <= forceupperthreshold) then
    begin
      flastexceedsftp2[step] := counter;
      found := true;
    end;
  end;
end;

procedure calcimpulses;
var counter: integer;
begin
[calculate impulse of each step on platform 1]
for step := 1 to numberofstepsplatform1 do
begin
  impulseplatform1[step] := 0;
  for counter := beginningofstepplatform1[step] to endofstepplatform1[step] do
  begin
    impulseplatform1[step] := impulseplatform1[step] +
      \{platform1force^\{counter\}/clinreadings.actualsamplingrateperchannel\}
      \{kilogrammes force.seconds\}
  end;
end;

[calculate impulse of each step on platform 2]
for step := 1 to numberofstepsplatform2 do
begin
  impulseplatform2[step] := 0;
  for counter := beginningofstepplatform2[step] to endofstepplatform2[step] do
  begin
    impulseplatform2[step] := impulseplatform2[step] +
      \{platform2force^\{counter\}/clinreadings.actualsamplingrateperchannel\}
      \{kilogrammes force.seconds\}
  end;
end;
procedure calcpeakforces;

var platform: integer;

begin
platform:=1;
for step:=1 to numberofstepsplatform1 do
if (endofstepplatform1[step]-beginningofstepplatform1[step])>=2 then
begin
middleofstep:=trunc((beginningofstepplatform1[step]+endofstepplatform1[step])/2);
calcfirstpeak(begningofstepplatform1[step],platform);
calsecondpeak(endofstepplatform1[step],platform);
calmn(fpfp1samplenumber[step],spfp1samplenumber[step],platform);
end;

platform:=2;
for step:=1 to numberofstepsplatform2 do
if (endofstepplatform2[step]-beginningofstepplatform2[step])>=2 then
begin
middleofstep:=trunc((beginningofstepplatform2[step]+endofstepplatform2[step])/2);
calcfirstpeak(begningofstepplatform2[step],platform);
calsecondpeak(endofstepplatform2[step],platform);
calmn(fpfp2samplenumber[step],spfp2samplenumber[step],platform);
end;
end;

procedure calctemporaldistancefactors;

begin
findoutwhichplatformfirststepwason;
calculatetotalstancetimes;
calculatetimemeanaveragedxandy;
calculatetimemeanaveragedyandxy;

if numberofdst=numberofstepsplatform1 then
begin
numberofplstrides:=numberofstepsplatform1;
if numberofplstrides=0 then numberofplstrides:=0;
if numberofplstrides<0 then numberofplstrides:=0;
end;

if numberofplstrides<>0 then
begin
numberofplcompletesteps:=numberofplcompletesteps-1;
if numberofplcompletesteps<0 then numberofplcompletesteps:=0;
end;

if numberofplstrides<>0 then
begin
numberofplstridelengths:=numberofplstridelengths;
if numberofplstridelengths<0 then numberofplstridelengths:=0;
end;

if numberofplstrides<>0 then
begin
numberofplstepwidths:=numberofplstepwidths;
if numberofplstepwidths<0 then numberofplstepwidths:=0;
end;

if numberofplstrides<>0 then
begin
numberofplvelocities:=numberofplvelocities;
if numberofplvelocities<0 then numberofplvelocities:=0;
end;

velocity:=0;
if not((numberofplstrides=0) and (numberofplstridelengths=0)) then
begin
findoutwhichplatformleftfootwason;
end;
end;

procedure displaytemporaldistancefactors;

begin
writeln(outputdevice, ' +---------+--- Temporal factors +---------+---');
writeln(outputdevice);
displaywhichplatformfirststepwason;
displayplatform1totalstancetimes;
displayplatform2totalstancetimes;
end;
if numberofdst<>0 then displaydoublestancetimes;
if waprintorfile='wait' then wait;
if numberofplstrides<>0 then displayplatform1stridetimes;
if numberofp2strides<>0 then displayplatform2stridetimes;
if waprintorfile='wait' then wait;
writeln(outputdevice,'----------------- Distance factors -----------------');
displaywhichplatformleftfootwason;
displaypositionsofcofg;
displaypltimeaveragedxandy;
displayp2timeaveragedxandy;
if waprintorfile='wait' then wait;
if numberofplcompletesteps<>0 then displayplatform1steplengths;
if numberofp2completestepso0 then displayplatform2steplengths;
if waprintorfile='wait' then wait;
if numberofplcompletesteps<>0 then displayplatform1stepwidths;
if numberofp2completestepso0 then displayplatform2stepwidths;
if waprintorfile='wait' then wait;
if numberofplstrides<>0 then displayplatform1stridelengths;
if numberofp2strides<>0 then displayplatform2stridelengths;
if waprintorfile='wait' then wait;
writeln(outputdevice,'----------------- Velocity factors -----------------');
writeln(outputdevice);
if numberofplstrides<>0 then displayplatform1velocity;
if numberofp2strides<>0 then displayplatform2velocity;
if waprintorfile='wait' then wait;
if not((numberofplstrides<>0) and (numberofp2strides=0)) then displayvelocity;
writeln(outputdevice);
if waprintorfile='wait' then wait;
end;

procedure waitprintorfile;
begin
if waprintorfile = 'wait' then wait;
if waprintorfile = 'print' then
  hardcopy(false,0); (hardcopy with black and white uninverted in)
  (mode 0 (640 points per line))
  (works with Epson FX80 but not MX-80F/T)
if waprintorfile = 'file' then sendgraphictostofile(false,0);
end;

procedure drawplatforml;
var xcornersofplatform1,ycornersofplatform1:array[1..5] of double;
begin
  xcornersofplatform1[1]:=-0.2;
  xcornersofplatform1[2]:=0.2;
  xcornersofplatform1[3]:=0.2;
  xcornersofplatform1[4]:=-0.2;
  xcornersofplatform1[5]:=-0.2;
  ycornersofplatform1[1]:=-0.3;
  ycornersofplatform1[2]:=-0.3;
  ycornersofplatform1[3]:=0.3;
  ycornersofplatform1[4]:=0.3;
  ycornersofplatform1[5]:=-0.3;
  for i:=1 to 4 do
    begin
      x1:=xcornersofplatform1[i];
      y1:=ycornersofplatform1[i];
      x2:=xcornersofplatform1[i+1];
      y2:=ycornersofplatform1[i+1];
      drawline(x1,y1,x2,y2);
    end;
end;

procedure showdirectionoftravel;
begin
gotoxy(50,23);
write('Direction of travel:');
if velocity>0 then writeln('---->');
if velocity<0 then writeln('<----');
end;

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procedure drawplatformliso;

var xcornersofplatforml:array[1 .. 5] of double;

begin
  xcornersofplatforml:=
    [-0.2; 0.2; 0.2; -0.2; -0.2];
  ycornersofplatforml:=
    [-0.3; -0.3; 0.3; 0.3; -0.3];
  for i:=1 to 4 do
    begin
      x:=xcornersofplatforml[i];
      y:=ycornersofplatforml[i];
      x1:=xiso;
      y1:=yiso;
      x2:=xiso;
      y2:=yiso;
      drawline(x1,y1,x2,y2);
    end;
end;

procedure drawvectors;

const forcescale=0.2;

begin
  for i:=1 to clinreadings.readingsperchannel do
    begin
      x:=xplatforml[i];
      y:=yplatforml[i];
      xl:=xiso;
      yl:=yiso;
      x2:=xl;
      y2:=yl+forcescale*platformlforce[i];
      if platformlforce[i]>forceupperthreshold then drawline(xl,yl,x2,y2);
      x:=xplatform2[i];
      y:=yplatform2[i];
      xl:=xiso;
      yl:=yiso;
      x2:=xl;
      y2:=yl+forcescale*platform2force[i];
      if platform2force[i]>forceupperthreshold then drawline(xl,yl,x2,y2);
    end;
end;

program uosgws4d;

{THIS PROGRAM MUST BE COMPILED FROM DOS USING THE TURBOPASCAL 5.0 COMMAND LINE}
{COMPILER (TPC USGW54D). OTHERWISE THE TIMING OF THE DATA ACQUISITION IS}
{INCORRECT}

{$n+} {put into 8087 mode, ie enable maths co-processor}

uses crt,dos,qdriver,printer,gkernel,gwindow,gshell;
  {the programme uses the 'crt' interface}

{$I c:\janebarr\z_uosgws\uosgws4.typ} {include the file uosgws4.typ, containing}
  {the record and key definitions for the}
  {database aspect of the programme}

{$I c:\janebarr\z_uosgws\PClHEADT} {These are header files that must be used}
{$I c:\janebarr\z_uosgws\PCl2ST} {in source files for programmes that}
  {access the PCI-20026S-3 Software Drivers}
  {routines, ie they relate to the data}
  {capture aspect of the programme}

{$I c:\janebarr\z_uosgws\uosgws4a} {This are the other parts of this program,}
{$I c:\janebarr\z_uosgws\uosgws4b} {which was divided solely due to space}
{$I c:\janebarr\z_uosgws\uosgws4c} {constraints}

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procedure initialiseerromessages;
begin
    anyerrormessages:=false;
    lowforcesteps:=false;
    toomanysteps:=false;
    stepsnearend:=false;
    negativedoublestancetimes:=false;
    highlyunequalnumbersofsteps:=false;
    crossover:=false;
    outoftime:=false;
end;

procedure calculatexy(counter:integer); {must consolidate the positions}
    {into one global coordinate}
begin
    if platformlforce[counter]>forcelowerthreshold then
        begin
            if ((abs(yplatforml[counter]-(-0.3))<endthreshold)
                and (platformlforce[counter]>forceupperthreshold))
                or ((abs(yplatforml[counter]-(0.3))<endthreshold)
                    and (platformlforce[counter]>forceupperthreshold))
                then
                    begin
                        anyerrormessages:=true;
                        stepsnearend:=true;
                    end;
        end
    else
        begin
            xplatforml[counter]:=-1; {These values correspond to a position off}
            yplatforml[counter]:=-1; {the edge of the platforms}
        end;
end;

procedure calculateerrormessages;
begin
    calclowforcesteps;
    calchighlyunequalnumbersofsteps;
    calcrossover;
end;

procedure furtherprocess; {calculates measured impulse and peak force}
begin
    identifiysteps; {identify the individual steps}
    calcimpulses; {integrate to find the vertical impulse of each step}
    calcpeakforces; {find the magnitudes of the largest forces in each
                    {half of each step and the minimum between them}
end;

procedure displayrecordname;
begin
    clrscr; {clear screen}
    writeln(outputdevice,'record nams=',recordname);
end;
procedure sendrecordnametoxcelfile;
begin
  write(outputdevice, clinreadings.recordname, ', ');
end;

procedure displayerrormessages;
begin
  clrscr;  {clear screen}
  writeln(outputdevice, '********** Error Messages **********');
  if anyerrormessages=false then
    begin
      writeln(outputdevice, 'No error messages');
      writeln(outputdevice);  {blank line}
    end;
  if anyerrormessages=true then
    begin
      if wasprintorfile='wait' then writeln(outputdevice, 'G', 'G', 'G');
      writeln(outputdevice, 'THE RAW DATA HAS PROPERTIES WHICH MAY CAUSE THE CALCULATION');
      writeln(outputdevice, 'ALGORITHMS TO GIVE MISLEADING RESULTS. THE CALCULATED PARAMETERS')
      writeln(outputdevice, 'SHOULD THEREFORE BE TREATED WITH CAUTION');
      writeln(outputdevice);  {blank line}
    end;
  if lowforcesteps then
    begin
      writeln(outputdevice, 'Some of the steps do not exceed the upper force threshold, so');
      writeln(outputdevice, 'positions cannot be calculated for them. The positions of these');
      writeln(outputdevice, 'steps are given as (-1 metre, -1 metre) to distinguish them');
      writeln(outputdevice);  {blank line}
    end;
  if toomanysteps then
    begin
      writeln(outputdevice, 'More than ten steps were found on at least one of the platforms. ');
      writeln(outputdevice, 'The program can only deal with up to ten steps on each platform, ');
      writeln(outputdevice, 'so data beyond this has not been analysed. ');
      writeln(outputdevice);  {blank line}
    end;
  if stepsnearend then
    begin
      writeln(outputdevice, 'Some of the points are within ', endthreshold:4:2, ' metres of the');
      writeln(outputdevice, 'ends of the platforms. It may be that these steps are partially');
      writeln(outputdevice, 'off the ends of the platform and should therefore be interpreted');
      writeln(outputdevice, 'with care. ');
      writeln(outputdevice);  {blank line}
    end;
  if negativedoublestancetimes then
    begin
      writeln(outputdevice, 'Some of the calculated double stance times are negative. This');
      writeln(outputdevice, 'cannot be physically true. ');
      writeln(outputdevice);  {blank line}
    end;
  if highlyunequalnumbersofsteps then

There are numberofstepsplatform1 steps on platform 1 and numberofstepsplatform2 steps on platform 2. This means that the algorithms cannot have registered alternate steps.

if crossover then
begin
Some of the steps show a distance travelled of over crossoverthreshold:2 metres. This is surprisingly large and suggests that the feet have not remained on each side of the centre.
end;

if outoftime then
begin
The subject was on the platform at the beginning or end of the sampling period.
end;

procedure senderrormessagestoexcelfile;
begin
write(outputdevice,anyerrormessages,',');
write(outputdevice,lowforcesteps,',');
write(outputdevice,toomanysteps,',');
write(outputdevice,stepsnearend,',');
write(outputdevice,negativedoublestancetimes, ' , ');
write(outputdevice,highlyunequalnumbersofsteps,',');
write(outputdevice,crossover,',');
write(outputdevice,outoftime,',');
end;

procedure displaypersonaldata;
begin
clrscr;
' Personal data '
with clinreadings do
begin
write(outputdevice,'subject code=',subjectcode);
write(outputdevice,'weight=' ,weightinkgf:5:1,'kg');
write(outputdevice,'height=',heightinm,'m');
write(outputdevice,'footwear=',footwear);
write(outputdevice,'leg dominance=',legdominance);
end;
end;

procedure displayclericaldata;
begin
clrscr;
' Clerical data '
with clinreadings do
begin
write(outputdevice,'test date=');
if dayofweek=0 then write(outputdevice,'Sunday');
if dayofweek=1 then write(outputdevice,'Monday');
if dayofweek=2 then write(outputdevice,'Tuesday');
if dayofweek=3 then write(outputdevice,'Wednesday');
if dayofweek=4 then write(outputdevice,'Thursday');
if dayofweek=5 then write(outputdevice,'Friday');
if dayofweek=6 then write(outputdevice,'Saturday');
write(outputdevice,' ','day', ' ')
if month=1 then write(outputdevice,'January');
if month=2 then write(outputdevice,'February');
if month=3 then write(outputdevice,'March');
if month=4 then write(outputdevice,'April');
if month=5 then write(outputdevice,'May');
if month=6 then write(outputdevice,'June');
if month=7 then write(outputdevice,'July');
if month=8 then write(outputdevice,'August');
if month=9 then write(outputdevice,'September');
if month=10 then write(outputdevice,'October');
if month=11 then write(outputdevice,'November');
if month=12 then write(outputdevice,'December');
writeln(outputdevice,' ',year);
writeln(outputdevice,' test time=',hour,':',minute);
end;
writeln(outputdevice); {blank line}
end;

procedure displayclinicaldata;
begin
clrscr; {clear screen}
writeln(outputdevice, 'Clinical data ____________________________')
with clinreadings do
begin
write(outputdevice,'primary pathology=',primarypathology);
write(outputdevice,'secondary pathology affecting gait=',secondarypathologyaffectinggait);
write(outputdevice,'procedure completed=',procedurecompleted);
write(outputdevice,'date of procedure=',dateofprocedure);
end;
writeln(outputdevice); {blank line}
end;

procedure displaytestdata;
begin
clrscr; {clear screen}
writeln(outputdevice, 'Test data ________________________________')
with clinreadings do
begin
write(outputdevice,'comments about series=',commentsaboutseries);
write(outputdevice,'comments after trial=',commentsabouttrial);
end;
writeln(outputdevice); {blank line}
end;

procedure displayforceplatedata;
begin
clrscr; {clear screen}
writeln(outputdevice, 'Force plate data ________________________')
with clinreadings do
begin
write(outputdevice,'nominalsamplingrateperchannel=',nominalsamplingrateperchannel,'Hz');
write(outputdevice,'actualsamplingrateperchannel=',actualsamplingrateperchannel,'Hz');
write(outputdevice,'samplingtime=',samplingtime,'s');
write(outputdevice,'readingsperchannel=',readingsperchannel);
end;
writeln(outputdevice); {blank line}
end;

procedure displayrawdata;
begin
for i:=1 to clinreadings.readingsperchannel do
begin
if (platformforce''[i]>forceupperthreshold) then
begin
write(outputdevice,'F=',platformforce''[i]:6:1,' x=',(100*xplatform''[i]):5:1,' y=',(100*yplatform''[i]):6:1);
wait;
end;
end;
end;
procedure formfeed;
begin
  write(outputdevice,chr(12));
end;

procedure displayforcesversustime; {I should leave clipping on for safety,}
{unless it is very slow, in which case I}
{should turn it off for speed. This relates}
{to use of the graphics, and points which}
{would tend to be plotted off the screen.}
begin
  entergraphic;
  setclippingon;
  definewindow(1,0,0,xmaxglb,ymaxglb); {window 1 to fill the whole screen}
  definewindow(2,4,16,xmaxglb-2,ymaxglb-14); {window 2 to fill the area within}
  {the axes}
  defineheader(1,
    'Plots of vertical force/kgf versus time/s for both platforms');
  {define heading for window 1}
  defineworld(1,0,-10,clinreadings.samplingtime,200); {define world in window 1 to be 0}
  {to samplingtime, -10 to +200kgf}
  defineworld(2,0,200,clinreadings.samplingtime,-10); {define world in window 1 to be 0}
  selectworld(1);
  selectwindow(1);
  setbackgroundcolor(blue);
  setforegroundcolor(yellow);
  setheaderon;
  drawborder;
  drawaxis(8,-8,0,0,0,0,0,0,true);
  selectworld(2);
  selectwindow(2);
  for i:=1 to clinreadings.readingsperchannel do
  begin
    drawpoint((i/clinreadings.nominalsamplingrateperchannel),
      clinreadings.weightinkgf); {draw a horizontal line}
    {representing the weight of the}
    {subject}
    if not pointdrawn((i/clinreadings.nominalsamplingrateperchannel),
      platform1force''[i]) then
      drawpoint((i/clinreadings.nominalsamplingrateperchannel),
        platform1force''[i]); {plot the points from platform 1}
    if (i=4*round(i/4)) {and not
      pointdrawn((i/clinreadings.nominalsamplingrateperchannel),
        platform2force''[i])} then
      drawpoint((i/clinreadings.nominalsamplingrateperchannel),
        platform2force''[i]); {if i is a multiple of 4, plot the}
    {points from platform 2}
  end;
  gotoxy(44,2); {move to top right of screen in}
  {preparation for message}
  write('solid line: platform 1');
  if not ((numberofplstrides=0) and (numberofp2strides=0))
    and (leftfootwasonplatforml='T') then writeln(' (left foot)');
  if not ((numberofplstrides=0) and (numberofp2strides=0))
    and (leftfootwasonplatforml='F') then writeln(' (right foot)');
  gotoxy(44,4); {move to top right of screen in}
  {preparation for message}
  write('broken line: platform 2');
  if not ((numberofp2strides=0) and (numberofp2strides=0))
    and (leftfootwasonplatforml='T') then writeln(' (left foot)');
  if not ((numberofp2strides=0) and (numberofp2strides=0))
    and (leftfootwasonplatforml='F') then writeln(' (right foot)');
  gotoxy(44,5); {move to top right of screen in}
  {preparation for message}
  flushkeyboard;
  waitprintorfile;
  leavegraphic;
end;

procedure displayxyplotsofcentreofpressure;
begin
  entergraphic;
  setclippingon;
  definewindow(1,0,0,xmaxglb,ymaxglb); {window 1 to fill the whole screen}
definewindow(2,4,16,xmaxglb-2,ymaxglb-14); {window 2 to fill the area within}  
{the axes}
defineheader(1, 'x/metres versus y/metres for centre of pressure on each platform'}; 
{define heading for window 1} 
defineworld(1, -e-0.1, -3*d-g-2*b-0.37, 2*a+e+0.1, 2*b+d+0.37); 
{define world in window 1 to be} 
{-e-0.1 to 2a+e+0.1, -3d-g-2b-0.37} 
{to 2b+d+0.37 is the area of the} 
{platforms plus a surround} 
defineworld(2, -e-0.1, 2*b+d+0.37, 2*a+e+0.1, -3*d-g-2*b-0.37); 
selectworld(1); selectwindow(1); setbackgroundcolor(black); setforegroundcolor(cyan); settheheaderon; drawborder; drawaxis (8,-8,0,0,0,0, -1,-1, true); selectwindow(2); selectwindow(2); drawplatforml; for i:=l to clinreadings.readingsperchannel do 
begin 
if platformlforce''[i]>forceupperthreshold then 

drawpoint (xplatforml'' [i], yplatforml'' [i] )  ; {plot the points from platform 1} 
if platform2force''[i]>forceupperthreshold then 

drawpoint (xplatform2/ '[i],  yplatform2''  [i] ) ; {plot the points from platform 2} 
end; gotoxy(50,2); {move to top right of screen in} 
{preparation for message} 
writeln('top of screen: platform I1); 
{move to top right of screen in} 
{preparation for message} 
writeln('bottom of screen: platform 2'); 
if not ((numberofplstrides=0) and (numberofp2ststrides=0))  then 
showdirectionoftravel; gotoxy(50,5); {move to top right of screen in} 
{preparation for message} 
flushkeyboard; waitprintorfile; leavegraphic; 
end;

procedure display3DPedotti; {This procedure will display diagrams of} 
{force and positional data as described by} 
{Khodadadeh (1988) (68)} 
begin 
entergraphic; 
setclippingon; 
definewindow(1,0,0,xmaxglb,ymaxglb); {window 1 to fill the whole screen} 
defineheader(1, '3-dimensional plots of F/kgf, x/m and y/m for both platforms'}; 
{define heading for window 1} 
defineworld(1,0,100,100,0); {arbitrarily define world in} 
{window 1 to be 0 to 100, 0 to 100} 
selectworld(1); selectwindow(1); setbackgroundcolor(magenta); setforegroundcolor(green); settheheaderon; gotoxy(1,2); {move to top left of screen in} 
{preparation for message} 
writeln('length of vector represents magnitude of vertical force'); 
go toxy(1,4); {move to top left of screen in} 
{preparation for message} 
writeln('time interval between vectors=', 
(1/clinreadings.nominalsamplingrateperchannel):6:4,' seconds'); 
go toxy(2,12); {go to left, 1/3 of way down screen} 
go toxy(2,16); {go to left, 2/3 of way down screen} 
gotoxy(2,16); {go to left, 2/3 of way down screen} 
write('platform 1'); 
write('platform 2'); 
write('platform 2'); 
drawplatformi; 
if not ((numberofplstrides=0) and (numberofp2ststrides=0))  then 
showdirectionoftravel;
gotoxy(50,25); {move to bottom right of screen in preparation for message}
flushkeyboard;
waitprintorfile;
leavegraphic;
end;

procedure displayweightoneachfootinstanding;
beg
clrscr;
writeI(outputdevice, "- - - - - - - - - - - - - - Weight on each foot in standing - - - - - - - - - - - - - -");
writeI(outputdevice, 'Average weight on left foot in standing=',
clinreadings.weightonleftfootinkgf:5:1,'kgf');
writeI(outputdevice, 'Average weight on right foot in standing=',
clinreadings.weightonrightfootinkgf:5:1,'kgf');
writeI(outputdevice, '{Blank line}
end;

procedure displaymeasuredimpulses;
beg
clrscr; {clear screen}
writeI(outputdevice, "- - - - - - - - - - - - - - Measured vertical impulses - - - - - - - - - - - - - -");
for step:= 1 to numberofstepsplatforml do
begin
writeI(outputdevice, 'impulse of step ','step,' on platform 1=',
impulseplatforml[step]:5:1,'kgf*seconds');
end;
writeI(outputdevice, '{Blank line}
end;

procedure sendmeasuredimpulsestoexcelfile;
beg
for step:= 1 to numberofstepsplatforml do
begin
write(outputdevice,impulseplatforml[step]:5:1, ',');
end;
for step:=numberofstepsplatforml+1 to 10 do write(outputdevice,',');
for step:= 1 to numberofstepsplatform2 do
begin
write(outputdevice,impulseplatform2[step]:5:1, ',');
end;
for step:=numberofstepsplatform2+1 to 10 do write(outputdevice,',');
end;

procedure displaypeakforces;
beg
clrscr; {clear screen}
writeI(outputdevice, "- - - - - - - - - - - - - - Measured peak forces - - - - - - - - - - - - - -");
for step:= 1 to numberofstepsplatforml do
begin
writeI(outputdevice, '*** platform 1, step ','step,' ***');
writeI(outputdevice, 'beginning of step is at time=',
beginningofstepplatforml[step]/
clinreadings.nominalsamplingrateperchannel:6:3,' seconds');
writeI(outputdevice, 'end of step is at time=',
endofstepplatforml[step]/
clinreadings.nominalsamplingrateperchannel:6:3,' seconds');
writeI(outputdevice);
if (endofstepplatforml[step]-beginningofstepplatforml[step])<2 then
begin
writeI(outputdevice,'Peak forces not calculated for this step due to');
writeI(outputdevice,'insufficient duration');
end;
if (endofstepplatforml[step]-beginningofstepplatforml[step]) >= 2 then begin
  writeln(outputdevice,'maximum force in first half of step=','
  firstpeakforceplatforml[step]:6:1,'kgf after ',
  (fpfplsamplenumber[step]-beginningofstepplatforml[step])*100.0/
  (endofstepplatforml[step]-beginningofstepplatforml[step]):2:0,
  ' % of the step');
  writeln(outputdevice,'maximum force in second half of step=
  secondpeakforceplatforml[step]:6:1,'kgf after ',
  (spfplsamplenumber[step]-beginningofstepplatforml[step])*100.0/
  (endofstepplatforml[step]-beginningofstepplatforml[step]):2:0,
  ' % of the step');
  writeln(outputdevice,'minimum force between these two peaks',
  minimumforcebetweenthemplatforml[step]:6:1,'kgf after ',
  (mfbtplsamplenumber[step]-beginningofstepplatforml[step])*100.0/
  (endofstepplatforml[step]-beginningofstepplatforml[step]):2:0,
  ' % of the step');
end;
writeln(outputdevice);
end;
for step:= 1 to numberofstepsplatform2 do
begin
  writeln(outputdevice,'*** platform 2, step ',step,'  ***');
  writeln(outputdevice,'beginning of step is at time=',
  beginningofstepplatform2[step]/
  clinreadings.nominalsamplingrateperchannel:6:3,'  seconds');
  writeln(outputdevice,'end of step is at time=',
  endofstepplatform2[step]/
  clinreadings.nominalsamplingrateperchannel:6:3,'  seconds');
  writeln(outputdevice);
  if (endofstepplatform2[step]-beginningofstepplatform2[step])<2 then begin
    writeln(outputdevice,'Peak forces not calculated for this step due to');
    writeln(outputdevice,'insufficient duration');
  end;
  if (endofstepplatform2[step]-beginningofstepplatform2[step])>=2 then begin
    writeln(outputdevice,'maximum force in first half of step=',
    firstpeakforceplatform2[step]:6:1,'kgf after ',
    (fpfp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
    (endofstepplatform2[step]-beginningofstepplatform2[step]):2:0,
    ' % of the step');
    writeln(outputdevice,'maximum force in second half of step=',
    secondpeakforceplatform2[step]:6:1,'kgf after ',
    (spfp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
    (endofstepplatform2[step]-beginningofstepplatform2[step]):2:0,
    ' % of the step');
    writeln(outputdevice,'minimum force between these two peaks',
    minimumforcebetweenthemplatform2[step]:6:1,'kgf after ',
    (mfbtp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
    (endofstepplatform2[step]-beginningofstepplatform2[step]):2:0,
    ' % of the step');
  end;
  writeln(outputdevice);
end;
writeln(outputdevice); 
end;
procedure sendpeakforcesetoexcelfile;
var counter:integer;
begin
  for step:= 1 to numberofstepsplatforml do
  begin
    (  write(outputdevice,beginningofstepplatforml[step]/
        clinreadings.nominalsamplingrateperchannel:6:3,',');
    write(outputdevice,endofstepplatforml[step]/
        clinreadings.nominalsamplingrateperchannel:6:3,',');}
    if (endofstepplatforml[step]-beginningofstepplatforml[step])<2 then
      for counter:=1 to 6 do
        begin
          write(outputdevice,'insufficient duration',', ');
        end;
    if (endofstepplatforml[step]-beginningofstepplatforml[step])>=2 then
      begin
        write(outputdevice,firstpeakforceplatforml[step]:6:1,', ');
        write(outputdevice,
        (fpfplsamplenumber[step]-beginningofstepplatforml[step])*100.0/
        (endofstepplatforml[step]-beginningofstepplatforml[step]):2:0,
        ' % of the step');
      end;
    end;
  writeln(outputdevice);
end;
{endofstepplatforml[step]-beginningofstepplatforml[step]:2:0, '}, ');
write(outputdevice,secondpeakforceplatforml[step]:6:1, ', ');
write(outputdevice,
{spfpisamplenumber[step]-beginningofstepplatforml[step]}*100.0/
{endofstepplatforml[step]-beginningofstepplatforml[step]}:2:0, ', ');
write(outputdevice,minimumforcebetweenthemplatforml[step]:6:1, ', ');
write(outputdevice,
{mfbtpisamplenumber[step]-beginningofstepplatforml[step]}*100.0/
{endofstepplatforml[step]-beginningofstepplatforml[step]}:2:0, ', ');
end;
end;
for step:=numberofstepsplatforml+l to 10 do
for counter:=1 to 6 do write(outputdevice, ', ');
for step:=1 to numberofstepsplatform2 do
begin
{endofstepplatform2[step]-beginningofstepplatform2[step]/
clinreadings.nominalsamplingrateperchannel:6:3, ', ');
write(outputdevice,endofstepplatform2[step]/
clinreadings.nominalsamplingrateperchannel:6:3, ', ');
if {endofstepplatform2[step]-beginningofstepplatform2[step]}<2 then
for counter:=1 to 6 do
begin
write(outputdevice,'insufficient duration', ', ');
end;
end;
if {endofstepplatform2[step]-beginningofstepplatform2[step]}>=2 then
begin
write(outputdevice,firstpeakforceplatform2[step]:6:1, ', ');
write(outputdevice,
{fpfp2samplenumber[step]-beginningofstepplatform2[step]}*100.0/
{endofstepplatform2[step]-beginningofstepplatform2[step]}:2:0, ', ');
write(outputdevice,secondpeakforceplatform2[step]:6:1, ', ');
write(outputdevice,
{spfp2samplenumber[step]-beginningofstepplatform2[step]}*100.0/
{endofstepplatform2[step]-beginningofstepplatform2[step]}:2:0, ', ');
write(outputdevice,minimumforcebetweenthemplatform2[step]:6:1, ', ');
write(outputdevice,
{mfbtp2samplenumber[step]-beginningofstepplatform2[step]}*100.0/
{endofstepplatform2[step]-beginningofstepplatform2[step]}:2:0, ', ');
end;
end;
end;
for step:=numberofstepsplatform2+l to 10 do
for counter:=1 to 6 do write(outputdevice, ', ');
end;

{*SECOND LEVEL*}

procedure initialisesystem;
var gain,zerochannel,range,channelnumber:integer;
begin;
syinit;
finder;[This calls a function from the]
finder;$Scd80;[PCI-20026S-3 Software Drivers routines]
finder;[to initialise the software]
finder;init($Scd80);[This initialises (numbers the channels]
finder;[of) the PCI-20098C carrier board, which]
finder;is the only board in the system. The]
finder;numbers start at 0. All the analogue]
finder;input channels are initially configured]
finder;[as single-ended, +/-10V range, gain of]
finder;[1, with no automatic zero-offset]
finder;[correction.]}
finder;gain:=1;[set the gain to be unity]
finder;zerochannel:=-1;[disable hardware auto-zero function]
finder;range:=4;[+/ -5V single-ended]
for channelnumber:=1 to 6 do
begin
.cnfail(channelnumber,gain,zerochannel,range);[configure analogue input]
end;
procedure initialisevariables;
var counter:integer;

begin
with clinreadings do
begin
recordname:='';
{personal data}
subjectcode:='';
weightonleftfootinkgf:=0;
weightonrightfootinkgf:=0;
weightinkgf:=0;
heightinm:='';
dateofbirth:='not used';
sex:='f';
footwear:='*';
legdominance:='1';
{clerical data}
NHSnumber:='not used';
year:=0;month:=0;day:=0;dayofweek:=0;
hour:=0;minute:=0;second:=0;sec100:=0;
fisttestdate:='';
{clinical data}
primarypathology:='not used';
secondarypathologyaffectinggait:='not used';
procedurecompleted:='not used';
dateofprocedure:='not used';
{test data}
testtype:='not used';
commentsaboutseries:='';
commentsabouttrial:='';
{force plate data}
nominalsamplingrateperchannel:=500; {Hertz}
actualsamplingrateperchannel:=500; {as far as I know} {Hertz}
samplingtime:=1.024; {seconds}
readingsperchannel:=round(nominalsamplingrateperchannel*samplingtime); {must be less than arraylength}
end;
new(platform1force);
new(platform2force);
new(xplatform1);
new(xplatform2);
new(yplatform1);
new(yplatform2);
for counter:=1 to 512 do
begin
platform1force[counter]:=0;
platform2force[counter]:=0;
end;
anyerrormessages:=false;
lowforcesteps:=false;
toomanysteps:=false;
stepsnearend:=false;
negativedoublestancetimes:=false;
highlyunequalnumbersofsteps:=false;
crossover:=false;
outoftime:=false;
end;

procedure examinerecordorquit;
begin
write('Type "e" to examine existing data, "r" to record new data, or "q" to quit');
write('n');
write('e');
exrecorq:='r';
flushkeyboard;
while (exrecorqO'e') and (exrecorqO'f') and
(exrecorqO'f') and (exrecorqO'g') and
(exrecorqO'q') and (exrecorqO'Q') do
exrecorq:=readkey;
end;
procedure recalldata;
  var
    typedname:string;
    option:char;
    filetoberead:text;
  begin
    writeln('Please enter the file name');
    readln(typedname);
    filetobereadname:='d:\janebarr\normcal\'+typedname+'.jb1;
    assign(filetoberead,filetobereadname);
    reset(filetoberead);
    rewrite(recnmf1);
    write(recnmf1,filetobereadname);
    close(recnmf1);
  end;

procedure recallspecifieddata;
  var
    searchname:namestr;
    filetoberead:file of double;
    counter:integer;
  begin
    reset(recnmf1);
    readln(recnmf1,filetobereadname);
    close(recnmf1);
    if searchname='?' then
      begin
        writeln ('You must first choose some data');
        wait;
        halt;
      end;
    assign(filetoberead,filetobereadname);
    reset(filetoberead);
    for counter:=1 to 512 do
      begin
        read(filetoberead,platformlforce[counter],
             xplatforml[counter],yplatforml[counter]);
      end;
  end;

procedure processdata; {No software filtering is to be used at present.)
  var counter:integer;
  begin
    writeln('Beginning to process data');
    clinreadings.recordname:=filetobereadname;
    for counter:=1 to clinreadings.readingsperchannel do
      begin
        calculatexy(counter); {calculates instantaneous values of force)
                                     {and position of centre of pressure}
      end;
    if platformlforce[1]>forcelowerthreshold then
      begin
        anyerrormessages:=true;
        outoftime:=true;
        platformlforce[1]:=0;
        xplatforml[1]:=-1;
        yplatforml[1]:=-1;
      end;
    if platformlforce[clinreadings.readingsperchannel]>forcelowerthreshold then
      begin
        anyerrormessages:=true;
        outoftime:=true;
        platformlforce[clinreadings.readingsperchannel]:=0;
        xplatforml[clinreadings.readingsperchannel]:=-1;
        yplatforml[clinreadings.readingsperchannel]:=-1;
      end;
    if platform2force[1]>forcelowerthreshold then
      begin
        anyerrormessages:=true;
        outoftime:=true;
        platform2force[1]:=0;
procedure directdatatoscreen;
begin
assign(outputdevice,'');  {set output device to be screen}
rewrite(outputdevice);
waprintorfile='wait';
end;

procedure displayheading;
begin
clear;
writeln(outputdevice,"-----------------------------
Data from University of Surrey gait assessment walkway --*");
writeln(outputdevice,"-----------------------------
Data from University of Surrey gait assessment walkway --*");
writeln(outputdevice);
end;

procedure displaydata(var counter:integer);
begin
if counter=1 then displayheading;
if counter=2 then displayrecordname;
if counter=3 then
begin
displayforcesversustime;
writeln(outputdevice); {blank line}
writeln(outputdevice); {blank line}
end;
if counter=4 then
begin
displayxyplotsofcentreofpressure;
if waprintorfile='wait' then formfeed;
end;
if counter=5 then
begin
display3DPedotti;
if waprintorfile='wait' then
write(outputdevice,chr(27),'J',chr(36)); {change line spacing to 1/6"
end;
if counter=6 then displayerrormessages;
if counter=7 then displaypersonaldata;
if counter=8 then displayclericaldata;
begin
displayclinicaldata;
if counter=9 then displaytestdata;
if counter=10 then displayforceplatedata;
displayrawdata;
if counter=11 then displayweightoneachfootinstanding;
if counter=12 then displaytemporaldistancefactors;
if counter=13 then displaypeakforces;
if counter=14 then
begin
displaymeasuredimpulses;
if waprintorfile='print' then formfeed; {to prevent the laser printer}
{from hanging up}
end;
end;

procedure printornot;
begin
writeln('Do you want the results printed out on paper?');
writeln('Type "Y" for yes or "N" for no.');
writeln('');
prornot:='?';
flushkeyboard;
while (prornot<>'y') and (prornot<>'Y') and (prornot<>'n') and (prornot<>'N') do
  prornot:=readkey;
end;

procedure makefileornot;
begin
  writeln('Do you want to send the results to a file to be printed later?');
  writeln('Type "Y" for yes or "N" for no.');
  writeln('');
  mfornot:='?';
  flushkeyboard;
  while (mfornot<>'y') and (mfornot<>'Y') and (mfornot<>'n') and (mfornot<>'N') do
    mfornot:=readkey;
  end;

procedure directdatatoprinter;
begindirectdatatoprinter;
begin
  waprintorfile:='print';
  assign(outputdevice,'prn'); {set output device to be printer}
  rewrite(outputdevice);
end;

procedure directdatatoprintfile;
begindirectdatatoprintfile;
begin
  waprintorfile:='file';
  assign(outputdevice,'d:\janebarr\prinfils\'+clinreadings.recordname);
  rewrite(outputdevice); {set output device to be a file}
end;

procedure directdatatoexcelfile;
var
typedname:string;
fileexists:boolean;
begin
  waprintorfile:='file';
  writeln('Please type the name of the file to which the data is to be sent.');
  flushkeyboard;
  readln(typedname);
  typednameex2';
  assign(outputdevice,'d:\janebarr\exclfis\'+typedname+'.xl');
  rewrite(outputdevice); {set output device to be a file}
  [try to open the file]
  [if the file does not exist, create it]
end;

procedure freememory;
beginfreememory;
begin
  dispose(platformlforce); platformlforce:=nil;
  dispose(platform2force); platform2force:=nil;
  dispose(xplatforml); xplatforml:=nil;
  dispose(xplatform2); xplatform2:=nil;
  dispose(yplatform1); yplatform1:=nil;
  dispose(yplatform2); yplatform2:=nil;
end;

{*PRIMARY LEVEL*}

procedure findextantrecord;
begin
clrscr; {clear screen}
initialisesystem;
initialisevariables;
recalldata;
freememory;
end;

procedure displayonscreen;
var
  counter:integer;
  nextpreviousorquit:char;
begin
  clrscr; {clear screen}
  initialisesystem;
  initialisevariables;
  initgraphic;
  leavegraphic;
  recallaspecifieddata; {recall existing data}
  processdata;
  directdatatoscreen;
  writeln('Press "n" to go to next part, "p" to go to previous part or');
  writeln('"q" to quit displaying data on the screen');
  wait;
  counter:=1;
repeat
  begin
    nextpreviousorquit:=readkey;
    while (nextpreviousorquit='n') and (nextpreviousorquit='N')
      and (nextpreviousorquit='p') and (nextpreviousorquit='P')
      and (nextpreviousorquit='q') and (nextpreviousorquit='Q') do
      nextpreviousorquit:=readkey;
    if (nextpreviousorquit='n') or (nextpreviousorquit='N')
    then counter:=counter+1;
    if (nextpreviousorquit='p') or (nextpreviousorquit='P')
    then counter:=counter-1;
    if counter=15 then counter:=1;
    if counter=0 then counter:=14;
    displaydata(counter);
    if (counter=3) or (counter=4) or (counter=5) then
      begin
        writeln('Press "n" to go to next part, "p" to go to previous part or');
        writeln('"q" to quit displaying data on the screen');
      end;
  end;
until (nextpreviousorquit='q') or (nextpreviousorquit='Q');
freememory;
end;

procedure printdata;
var
  counter:integer;
begin
  clrscr; {clear screen}
  initialisesystem;
  initialisevariables;
  initgraphic;
  leavegraphic;
  recallaspecifieddata; {recall existing data}
  processdata;
  directdatatoprinter;
  for counter:=1 to 14 do displaydata(counter);
  freememory;
end;

procedure makeprintfile;
var
  counter:integer;
begin
  clrscr; {clear screen}
  initialisesystem;
  initialisevariables;
  initgraphic;
  leavegraphic;
  recallaspecifieddata; {recall existing data}
  processdata;
  directdatatoprinter;
  for counter:=1 to 14 do displaydata(counter);
  freememory;
end;
leavegraphic;
recallspecifieddata; \{recall existing data\}
processdata;
directdatatoprintfile;
for counter:=1 to 14 do displaydata(counter);
close(outputdevice);
freememory;
end;

procedure makeexcelfile;
begin
clrscr; \{clear screen\}
initialisesystem;
initialisevariables;
recallspecifieddata; \{recall existing data\}
processdata;
directdatatoexcelfile;
sendrecordnametoexcelfile;
senderrormessagestoexcelfile;
sendstancetimestoexcelfile;
sendfirstandlastpositionstoexcelfile;
sendpeakforcetoexcelfile;
sendmeasuredimpulsestoexcelfile;
\{ sendpersonalidatoexcelfile; \}
\{ sendweightoneachfootinstandingtoexcelfile; \}
writeln(outputdevice,'end of line'); \{each record goes on its own line\}
close(outputdevice);
freememory;
end;

\{*ZEROTH LEVEL (parameter switching)*\}
begin
if paramcount<>1 then begin
    writeln('An incorrect number of parameters (',paramcount,
    ') have been used.');
    writeln('Please seek assistance');
    wait;
    halt;
end;
assign(recnmfl,'recnmfl1');
if paramstr(1)='INIT' then begin
rewrite(recnmfl);
write(recnmfl,'?');
close(recnmfl);
end;
if paramstr(1)='FER' then findextantrecord;
if paramstr(1)='DOS' then displayonscreen;
if paramstr(1)='PD' then printdata;
if paramstr(1)='MPF' then makeprintfile;
if paramstr(1)='MEF' then makeexcelfile;
if (paramstr(1)<>'INIT') and (paramstr(1)<>'FER') and (paramstr(1)<>'DOS')
    and (paramstr(1)<>'PD') and (paramstr(1)<>'MPF') and (paramstr(1)<>'MEF')
    then writeln('The parameter ''',paramstr(1),
    '' is not recognised. Please seek assistance');
end.
PROGRAM UOSGWS5 AND BATCH FILES

Batch file 'GO.BAT'
  tpc uosgws5e
  pci26s_t/g/n/x"gws"

Batch file 'DOS.BAT'
  uosgws5e DOS

Batch file 'FER.BAT'
  uosgws5e FER

Batch file 'INIT.BAT'
  uosgws5e INIT

Batch file 'MEF.BAT'
  uosgws5e MEF

Batch file 'MPF.BAT'
  uosgws5e MPF

Batch file 'PD.BAT'
  uosgws5e PD

Batch file 'PD.BAT'
  uosgws5e RNDAD

Batch file 'PD.BAT'
  uosgws5e RNDDD

{uosgws5.typ}
{include file containing record and key definitions for clinical software}

const arraylength=2000;

type
  namestr=string[20]; {type definitions for the key (by which the data}
  {is sorted)}
  arraytype=array[1 .. arraylength] of integer;

  clinrecord=record
    recstatus:longint; {used by the database system}
    recordname:namestr; {the database key}

{personal data}
  subjectcode:namestr; {not used at present}
  weightonleftfootinkgf, weightonrightfootinkgf, weightinkgf: double;
  heightinnamestr; {not used at present}
  dateofbirth:string[8]; {not used at present}
  sex:string[1]; {not used at present}
  footwear:string[20]; {not used at present}
  legdominance:string[1]; {not used at present}

{clerical data}
  NHSnumber:string[8]; {not used at present}
  year, month, day, dayofweek, hour, minute, second, sec100: word;
  firsttestdate:string[8]; {not used at present}

{clinical data}
  primarypathology:namestr; {not used at present}
  secondarypathologyaffectinggait:namestr; {not used at present}
  procedurecompleted:namestr; {not used at present}
  dateofprocedure:string[8]; {not used at present}

{test data}
  testtype:namestr; {not used at present}
  commentsaboutseries:string[255]; {not used at present}
  commentsabouttrial:string[255]; {not used at present}

{force plate data}
  numberofchannels:integer;
  nominalssamplingrateperchannel:integer;
  actualssamplingrateperchannel:double;
  samplingtime:integer;
  readingsperchannel:integer;
  zero1, zero2, zero3, zero4, zero5, zero6: double;
  array1: arraytype;
  array2: arraytype;
  array3: arraytype;
arrays: arraytype;
array5: arraytype;
array6: arraytype;
end;
maxdatatype = clinrecord;  {largest data record type}
maxkeytype = namestr;    {largest key type}

{uosgws5a}
{include file for program, created due to space constraints}
type
doublearraytype = array[1 .. arraylength] of double;
doublearrayptr = ^doublearraytype;  {pointer to doublearraytype}

const
{indexfilenm = 'c:\clin2.idx';}  {wrong record size}
{datafilenm = 'c:\clin2.dat';}  {wrong record size}
{indexfilenm = 'c:\janebarr\resul_92\clin3.idx';}  {wrong record size}
{datafilenm = 'c:\janebarr\resul_92\clin3.dat';}  {wrong record size}
{indexfilenm = 'c:\janebarr\resul_92\clin4.idx';}
{datafilenm = 'c:\janebarr\resul_92\clin4.dat';}
{datafilenm = 'd:\uosgw3.dat';}
{indexfilenm = 'd:\uosgw3.idx';}
{datafilenm = 'd:\janebarr\demoday\data.dat';}
{indexfilenm = 'd:\janebarr\demoday\data.idx';}

gain1=30.542;  {These values are all in kgf/V, and are taken from}
gain2=29.635;  {calibration using the Instron mechanical testing machine}
gain3=29.585;  {in October 1991}
gain4=28.569;
gain5=29.442;
gain6=29.096;

lsb=2.4414063e-3;  {the value of the least significant bit, in V.(10V/4096)}

{platform dimensions in metres:}
a=1.101;  {half the distance between transducers 1 and 2}
{or 4 and 5} (from drawing)
b=0.2295;  {half the lateral distance between transducers 1 and 3}
{or 4 and 6} (from drawing)
d=0.0785;
{lateral distance between transducer and edge of platform}
(1/8"+304.8mm-229.5mm)
e=0.1214;
{antero-posterior distance between transducer and edge of}
platform(1/8"+1.2192m-1.101m)
g=0.0030;
{width of gap between platforms, (measured average value)}

forcelowerthreshold=4;
{forceupperthreshold=1;}  {kgf} The times when the total force on a)
{platform crosses this value, are considered to)
{be the beginning and end of the steps.}

{forceupperthreshold=5;}
forceupperthreshold=20;  {kgf} Because for low values of force, the}
{position of data is of low accuracy, when the}
{total force on a platform is less than this;}  {the position of the centre of pressure is not}
{displayed. For the purpose of calculating eg}
{step lengths, the point when the force first}
{exceeds this value is considered as the}
{beginning of the step.}

endthreshold=0.12;  {metres} This is the threshold defining when a)
{warning is given that some of the readings are}
crossoverthreshold=0.50; 
[maxnumberofsteps=10;]  
[maxnumberofsteps=6;]  
[maxnumberofsteps=3;]  
[maxnumberofsteps=4;]  
3 should be enough for normal subjects)  
(use 6 perhaps for pathological subjects)  
(use 10 perhaps for children)

var exrecorq,pronot,mfornot,runagain:char;  
waprintorfile:string;  
outputdevicetype:text;  
i:integer;  
clindata:dataset;  
clinreadings:clinrecord;  
filetobesorted:file of clinrecord;  
earr:integer;  
{control selection of options}  
{counter}  
{relate to the database}  
{aspect of the programme}  
{relates to the data capture}  
{aspect of the programme}  
voltage from each transducer}  
{force from each transducer}  
{forces on each platform}  
{positional data}  
{these variables are declared}  
as pointers to avoid the}  
{‘data segment too large’}  
{error}

step, numberofstepsplatform1, numberofstepsplatform2:integer;  
beginningofstepplatform1, ffirstexceedsfutpl, flastexceedsfutpl,  
endofstepplatform1,  
beginningofstepplatform2, ffirstexceedsfutp2, flastexceedsfutp2,  
endofstepplatform2:array[1 .. maxnumberofsteps] of integer;  
middleofstep:integer;  
firstpeakforceplatform1, secondpeakforceplatform1,  
minimumforcebetweenthemplatform1:array[1 .. maxnumberofsteps] of double;  
firstpeakforceplatform2, secondpeakforceplatform2,  
minimumforcebetweenthemplatform2:array[1 .. maxnumberofsteps] of double;  
fpfp1samplenumber, spfp1samplenumber, fpfp2samplenumber,  
spfp2samplenumber, mfbtp1samplenumber,  
mfbtp2samplenumber:array[1 .. maxnumberofsteps] of integer;  
impulseplatform1, impulseplatform2:array[1 .. maxnumberofsteps] of double;  
channelnumber:integer;  
firststeponplatform1, leftfootwasonplatform1:char;  
pltotalstancetimes, p2totalstancetimes,  
plsteplengths, p2steplengths,  
plstepwidths, p2stepwidths,  
pltimeaveragedx, pltimeaveragedy,  
p2timeaveragedx, p2timeaveragedy:array[1 .. maxnumberofsteps] of double;  
doublestancetimes:array[1 .. (2*maxnumberofsteps-1)] of double;  
p2doublestancetimes:array[1 .. (2*maxnumberofsteps-1)] of double;  
p Estridetimes, p2stridetimes,  
p1stridelengths, p2stridelengths:array[1 .. maxnumberofsteps-1] of double;  
p1veloc, p2veloc, velocity:double;  
numberofdst, numberofplstrides, numberofp2strides,  
numberofplcompletesteps, numberofp2completesteps:integer;  
recmfl:text;  
anyerrormessages, lowforcesteps, too manysteps, steps near end,  
negative doublestancetimes, highly unequal numbers of steps, crossover,  
outoftime,  
firststeponplatform1ismarked, laststeponplatform1ismarked,  
firststeponplatform2ismarked, laststeponplatform2ismarked: boolean;

{* SIXTH LEVEL*}

procedure wait;  
var s:char;  
begin  
write('Press any key to continue');  
s:=readkey;  
write('');

673
procedure flushkeyboard;
var s:char;
begin
  while keypressed do s:=readkey;
end;

procedure findxwhereffirstexceedsfut;
begin
  if numberofstepsplatform1=0 then
    xwhereffirstexceedsfut:=xplatform2^[ffirstexceedsfutp2[1]];  
    \[if there are no steps on platform 1, use the value\]  
    \[from platform 2\]
  if numberofstepsplatform2=0 then
    xwhereffirstexceedsfut:=xplatform1^[ffirstexceedsfutpl[1]];  
    \[if there are no steps on platform 2, use the value\]  
    \[from platform 1\]
  if (numberofstepsplatform1<>0) and (numberofstepsplatform2<>0) then
    begin
      xwhereffirstexceedsfut:=xplatform1^[ffirstexceedsfutpl[1]];  
      \[if there are no steps on platform 2, use the value\]  
      \[from platform 1\]
      if ffirstexceedsfutp2[1]<ffirstexceedsfutpl[1] then
        begin
          xwhereffirstexceedsfut:=xplatform2^[ffirstexceedsfutp2[1]];  
          \[if both exist, use the later value\]
        end;
    end;
end;

procedure findxwhereflastexceedsfut;
begin
  if numberofstepsplatform1=0 then
    xwhereflastexceedsfut:=
    xplatform2^[flastexceedsfutp2[numberofstepsplatform2]];  
    \[if there are no steps on platform 1, use the value\]  
    \[from platform 2\]
  if numberofstepsplatform2=0 then
    xwhereflastexceedsfut:=
    xplatform1^[flastexceedsfutpl[numberofstepsplatform1]];  
    \[if there are no steps on platform 2, use the value\]  
    \[from platform 1\]
  if (numberofstepsplatform1<>0) and (numberofstepsplatform2<>0) then
    begin
      xwhereflastexceedsfut:=
      xplatform1^[flastexceedsfutpl[numberofstepsplatform1]];  
      \[if there are no steps on platform 2, use the value\]  
      \[from platform 1\]
      if flastexceedsfutp2[numberofstepsplatform2]>flastexceedsfutpl[numberofstepsplatform1] then
        xwhereflastexceedsfut:=
        xplatform2^[flastexceedsfutp2[numberofstepsplatform2]];  
        \[if both exist, use the later value\]
    end;
end;

{FIFTH LEVEL}

procedure finderroc;
begin
  errcode:=errsys;  \[errsys is a function from the PCI-20026S-3 Software\]  
  \[Drivers routines.\]
  if errcode <> 0 then
    begin
      writeln('error: ',errcode);
      wait;
    end;
end;

procedure delayloop(var delaylength:integer);
var counter:integer;
begin
  for i:=1 to delaylength do
    begin
      for counter:=1 to 10 do;
    end;
end;
procedure suggestquit;
var q:char;
begin
  writeln('The input voltage from channel ',channelnumber,
    ' is outside the expected range.');
  writeln('This suggests that the equipment is damaged.');
  writeln('It is recommended that you seek assistance.');
  writeln('Type "c" to continue with the program or anything else to quit');
  readln (q);
  if (q='c') and (q<>'c') then halt;
end;

procedure changeormovedown(var tempstring:string);
var s:char;
begin
  writeln('Press "c" to change this piece of information or any other key to');
  writeln('move down the list');
  tempstring:='???';
  flushkeyboard;
  s:=readkey;
  if s='c' then
    begin
      writeln('type in new information for this item');
      readln(tempstring);
    end;
end;

procedure cleanname(var typedname:namestr);
const allowedcharacters:set of char=[' ','0' .. '9','A'..'Z','a'..'z'];
var i,j,originallength:integer;
begin
  originallength:=length(typedname);
  for i:=0 to originallength do
    for j:=0 to length(typedname) do
      if not(typedname[j] in allowedcharacters) then delete(typedname,j,1);
end;

procedure cleanup;
begin
  taclose(clindata);
end;

procedure calcfirstpeak (var beginningofstep,platform:integer);
begin
  if platform=1 then firstpeakforceplatform1[step]:=-10;
  if platform=2 then firstpeakforceplatform2[step]:=-10;
  for i:=beginningofstep to middleofstep do
    begin
      if platform=1 then
        begin
          if platform1force[i]>firstpeakforceplatform1[step] then
            begin
              firstpeakforceplatform1[step]:=platform1force[i];
              fpfp1samplenumber[step]:=i;
            end;
        end;
      if platform=2 then
        begin
          if platform2force[i]>firstpeakforceplatform2[step] then
            begin
              firstpeakforceplatform2[step]:=platform2force[i];
              fpfp2samplenumber[step]:=i;
            end;
        end;
    end;
end;

procedure calosecondpeak (var endofstep,platform:integer);
begin
  if platform=1 then firstpeakforceplatform1[step]:=-10;
  if platform=2 then firstpeakforceplatform2[step]:=-10;
  for i:=beginningofstep to middleofstep do
    begin
      if platform=1 then
        begin
          if platform1force[i]>firstpeakforceplatform1[step] then
            begin
              firstpeakforceplatform1[step]:=platform1force[i];
              fpfp1samplenumber[step]:=i;
            end;
        end;
      if platform=2 then
        begin
          if platform2force[i]>firstpeakforceplatform2[step] then
            begin
              firstpeakforceplatform2[step]:=platform2force[i];
              fpfp2samplenumber[step]:=i;
            end;
        end;
    end;
end;
begin
if platform=1 then secondpeakforceplatform1[step] := -10;
if platform=2 then secondpeakforceplatform2[step] := -10;
for i := middleofstep+1 to endofstep do
begin
  if platform=1 then
  begin
    if platform1force[i] > secondpeakforceplatform1[step] then
    begin
      secondpeakforceplatform1[step] := platform1force[i];
      spfplsamplenumber[step] := i;
    end;
  end;
  if platform=2 then
  begin
    if platform2force[i] > secondpeakforceplatform2[step] then
    begin
      secondpeakforceplatform2[step] := platform2force[i];
      spfp2samplenumber[step] := i;
    end;
  end;
end;
end;

procedure calcmin(var fpfsamplenumber, spfsamplenumber, platform: integer);
begin
if platform=1 then minimumforcebetweenthemplatform1[step] := 10000;
if platform=2 then minimumforcebetweenthemplatform2[step] := 10000;
for i := fpfsamplenumber to spfsamplenumber do
begin
  if (platform=1) and (platform1force[i] < minimumforcebetweenthemplatform1[step]) then
  begin
    minimumforcebetweenthemplatform1[step] := platform1force[i];
    mfbtplsamplenumber[step] := i;
  end;
  if (platform=2) and (platform2force[i] < minimumforcebetweenthemplatform2[step]) then
  begin
    minimumforcebetweenthemplatform2[step] := platform2force[i];
    mfbtp2samplenumber[step] := i;
  end;
end;
end;

procedure findoutwhichplatformfirststepwason;
begin
  firststepwasonplatforml := '?';
  if (numberofstepsplatforml<>0) and (numberofstepsplatform2<>0) then
  begin
    if beginningofstepplatforml[1] < beginningofstepplatform2[1] then
    begin
      firststepwasonplatforml := 'F';
    end
    else
    begin
      firststepwasonplatforml := 'F';
    end;
  end;
end;

procedure change(var tempstring: string);
var
  s: char;
begin
  tempstring := '???
  writeln('Press "c" to change this piece of information or any other key to');
  writeln('bypass it');
  readln(s);
  if s = 'c' then
  begin
    writeln('type in new comments');
    readln(tempstring);
  end;
end;
end;
procedure calcplatform1totalstancetimes;
begin
for step:=1 to numberofstepsplatform1 do
begin
pltotalstancetimes[step]:= (endofstepplatform1[step]-beginningofstepplatform1[step]) / clinreadings.actualsamplingrateperchannel;
end;
end;

procedure calcplatform2totalstancetimes;
begin
for step:=1 to numberofstepsplatform2 do
begin
p2totalstancetimes[step]:= (endofstepplatform2[step]-beginningofstepplatform2[step]) / clinreadings.actualsamplingrateperchannel;
end;
end;

procedure calcdoublestancetimes;
begin
for i:=1 to numberofdst do
begin
if (firststepwasonplatforml='T') and (i<>2*round(i/2)) then
doublestancetimes[i]:= (endofstepplatform1[round(0.5*i+0.5)] -beginningofstepplatform2[round(0.5*i+0.5)]) / clinreadings.actualsamplingrateperchannel;
if (firststepwasonplatforml='F') and (i=2*round(i/2)) then
doublestancetimes[i]:= (endofstepplatform1[round(0.5*i)] -beginningofstepplatform2[i+round(0.5*i)]) / clinreadings.actualsamplingrateperchannel;
if (firststepwasonplatforml='T') and (i=2*round(i/2)) then
doublestancetimes[i]:= (endofstepplatform2[round(0.5*i)] -beginningofstepplatform1[round(0.5*i+0.5)]) / clinreadings.actualsamplingrateperchannel;
if (firststepwasonplatforml='F') and (i<>2*round(i/2)) then
doublestancetimes[i]:= (endofstepplatform2[round(0.5*i+0.5)] -beginningofstepplatform1[round(0.5*i+0.5)]) / clinreadings.actualsamplingrateperchannel;
if doublestancetimes[i]<0 then
begin
negativedoublestancetimes:=true;
anyerrormessages:=true;
end;
end;
end;

procedure calcplatform1stridetimes;
begin
for i:=1 to numberofplstrides do
begin
plstridetimes[i]:=(beginningofstepplatforml[i+1] -beginningofstepplatforml[i]) / clinreadings.actualsamplingrateperchannel;
end;
end;

procedure calcplatform2stridetimes;
begin
for i:=1 to numberofp2strides do
begin
p2stridetimes[i]:=(beginningofstepplatform2[i+1] -beginningofstepplatform2[i]) / clinreadings.actualsamplingrateperchannel;
end;
end;

procedure calcpltimeaveragedxandy;
end;
begin
for step:=1 to numberofstepsplatforml do
begin
pltimeaveragedx[step] :=0;
pltimeaveragedy[step]:=0;
counter:=0;
for i:=beginningofstepplatforml[step] to endofstepplatforml[step] do
begin
if platformlforce[i]>forceupperthreshold then
begin
pltimeaveragedx[step] :=pltimeaveragedx[step]+xplatforml[i];
pltimeaveragedy[step] :=pltimeaveragedy[step]+yplatforml[i];
counter:=counter+1;
end;
end;
if counter=0 then
begin
pltimeaveragedx[step] :=-1;
pltimeaveragedy[step] :=-1;
end;
if counter>0 then
begin
pltimeaveragedx[step] :=pltimeaveragedx[step]/counter;
pltimeaveragedy[step] :=pltimeaveragedy[step]/counter;
end;
end;
end;
end;
end;
end;
procedure calcp2timeaveragedxandy;
begin
for step:=1 to numberofstepsplatform2 do
begin
p2timeaveragedx[step]:=0;
p2timeaveragedy[step]:=0;
counter:=0;
for i:=beginningofstepplatform2[step] to endofstepplatform2[step] do
begin
if platform2force[i]>forceupperthreshold then
begin
p2timeaveragedx[step] :=p2timeaveragedx[step]+xplatform2[i];
p2timeaveragedy[step] :=p2timeaveragedy[step]+yplatform2[i];
counter:=counter+1;
end;
end;
if counter=0 then
begin
p2timeaveragedx[step]:=0;
p2timeaveragedy[step]:=0;
end;
if counter>0 then
begin
p2timeaveragedx[step] :=p2timeaveragedx[step]/counter;
p2timeaveragedy[step] :=p2timeaveragedy[step]/counter;
end;
end;
end;
end;
procedure calcplatformlsteplengths;
begin
for i:=1 to numberofplcompletesteps do
begin
if firststepwasonplatforml='I' then
plsteplengths[i] :=pltimeaveragedx[i]-p2timeaveragedx[i-1];
if firststepwasonplatforml='F' then
plsteplengths[i] :=pltimeaveragedx[i-1]-p2timeaveragedx[i];
end;
end;
end;
procedure calcplatform2steplengths;
begin
for i:=1 to numberofp2completesteps do
begin
if firststepwasonplatforml='I' then
plsteplengths[i]:=p2timeaveragedx[i]-p2timeaveragedx[i-1];
if firststepwasonplatforml='F' then
plsteplengths[i]:=p2timeaveragedx[i-1]-p2timeaveragedx[i];
end;
end;
end;
if firststepwasonplatforml='F' then
  p2steplengths[i]:=p2timeaveragedx[i+1]-pltimeaveragedx[i];
if firststepwasonplatforml='T' then
  p2steplengths[i]:=p2timeaveragedx[i]-pltimeaveragedx[i];
end;
end;

procedure calcplatformlstepwidths;
begin
  for i:=1 to numberofplcompletesteps do
    begin
      if firststepwasonplatforml='T' then
        plstepwidths[i]:=abs(pltimeaveragedy[i+1]-p2timeaveragedy[i]);
      if firststepwasonplatforml='F' then
        plstepwidths[i]:=abs(pltimeaveragedy[i]-p2timeaveragedy[i]);
    end;
end;

procedure calcplatform2stepwidths;
begin
  for i:=1 to numberofp2completesteps do
    begin
      if firststepwasonplatforml='F' then
        p2stepwidths[i]:=abs(p2timeaveragedy[i+1]-pltimeaveragedy[i]);
      if firststepwasonplatforml='T' then
        p2stepwidths[i]:=abs(p2timeaveragedy[i]-pltimeaveragedy[i]);
    end;
end;

procedure calcplatformlstridelengths;
begin
  for i:=1 to numberofplstrides do
    begin
      plstridelengths[i]:=pltimeaveragedx[i+1]-pltimeaveragedx[i];
    end;
end;

procedure calcplatform2stridelengths;
begin
  for i:=1 to numberofp2strides do
    begin
      p2stridelengths[i]:=p2timeaveragedx[i+1]-p2timeaveragedx[i];
    end;
end;

procedure calcplatformlvelocity;
var displacementonplatforml,timeonplatforml:double;
begin
  displacementonplatforml:=0;
  timeonplatforml:=0;
  for i:=1 to numberofplstrides do
    begin
      displacementonplatforml:=displacementonplatforml+plstridelengths[i];
      timeonplatforml:=timeonplatforml+plstridetimes[i];
    end;
  plvelocity:=displacementonplatforml/timeonplatforml;
end;

procedure calcplatform2velocity;
var displacementonplatform2,timeonplatform2:double;
begin
  displacementonplatform2:=0;
  timeonplatform2:=0;
  for i:=1 to numberofp2strides do
    begin
      displacementonplatform2:=displacementonplatform2+p2stridelengths[i];
      timeonplatform2:=timeonplatform2+p2stridetimes[i];
    end;
  p2velocity:=displacementonplatform2/timeonplatform2;
end;
procedure calcvelocity;
begin
  if (numberofplstrides<>0) and (numberofp2strides=0) then
    velocity:=plvelocity;
  if (numberofp2strides<>0) and (numberofplstrides=0) then
    velocity:=p2velocity;
  if (numberofplstrides<>0) and (numberofp2strides<>0) then
    velocity:=(plvelocity+p2velocity)/2.0;
end;

procedure findoutwhichplatformleftfootwason;
begin
  leftfootwasonplatforml:='?';
  if numberofstepsplatforml+numberofstepsplatform2>=0 then
  begin
    findxwhereffirstexceedsfut;
    findxwhereflastexceedsfut;
    if (xwhereflastexceedsfut>xwhereffirstexceedsfut) then
      leftfootwasonplatforml:='T';
    if (xwhereflastexceedsfut<xwhereffirstexceedsfut) then
      leftfootwasonplatforml:='F';
  end;
end;

procedure displaywhichplatformfirststepwason;
begin
  if (numberofstepsplatforml<>0) and (numberofstepsplatform2<>0) then
  begin
    if beginningofstepplatforml<beginningofstepplatform2 then
    begin
      writeln(outputdevice,'first step was on platform 1');
    end
    else
    begin
      writeln(outputdevice,'first step was on platform 2');
    end;
  end;
end;

procedure displayplatform1totalstancetimes;
begin
  for step:=1 to numberofstepsplatform1 do
  begin
    writeln(outputdevice,'Total stance time of step ',step,' on platform 1=',
    ptotaltancetimes[step]:6:4,' seconds');
  end;
end;

procedure displayplatform2totalstancetimes;
begin
  for step:=1 to numberofstepsplatform2 do
  begin
    writeln(outputdevice,'Total stance time of step ',step,' on platform 2=','
    p2totaltancetimes[step]:6:4,' seconds');
  end;
end;

procedure sendstancetimeratiostoexcelfile;
var numberofratios:integer;
begin
  numberofratios:=numberofstepsplatform1;
  if numberofstepsplatform2>numberofstepsplatform1 then
    numberofratios:=numberofstepsplatform2;
  for step:=1 to numberofratios do
  begin
    write(outputdevice,((p2totaltancetimes[step]-pltotaltancetimes[step])/(
    0.5*(p2totaltancetimes[step]+pltotaltancetimes[step]))):6:4,',');
  end;
end;
for step:=numberofratios+1 to maxnumberofsteps do
    write(outputdevice,','');
end;

procedure sendstancetimestoexcelfile;
begin
    for step:=1 to numberofstepsplatform1 do
        begin
            write(outputdevice,pltotalstancetimes[step]:6:4,','');
        end;
    for step:=numberofstepsplatform1+1 to maxnumberofsteps do
        write(outputdevice,'');
    for step:=1 to numberofstepsplatform2 do
        begin
            write(outputdevice,p2totalstancetimes[step]:6:4,','');
        end;
    for step:=numberofstepsplatform2+1 to maxnumberofsteps do
        write(outputdevice,'');
end;

procedure displaydoublestancetimes;
begin
    for i:=1 to numberofdst do
        begin
            writeln(outputdevice,'double stance time [',i,']=',
                doublestancetimes[i]:6:4,' seconds');
        end;
    writeln(outputdevice);
end;

procedure senddoublestancetimestoexcelfile;
begin
    for i:=1 to numberofdst do
        begin
            write(outputdevice,doublestancetimes[i]:6:4);
        end;
    for i:=numberofdst+1 to maxnumberofsteps*2 do
        begin
            write(outputdevice,',');
        end;
end;

procedure displayplatform1stridetimes;
begin
    for i:=1 to numberofplstrides do
        begin
            writeln(outputdevice,'platform 1 stride time [',i,']=',
                plstridetimes[i]:6:4,' seconds');
        end;
    writeln(outputdevice);
end;

procedure displayplatform2stridetimes;
begin
    for i:=1 to numberofp2strides do
        begin
            writeln (outputdevice,'platform 2 stride time [',i,']*•',
                p2stridetimes[i]:6:4,' seconds');
        end;
    writeln(outputdevice);
end;

procedure sendplatform1stridetimestoexcelfile;
begin
    for i:=1 to numberofplstrides do
        begin
            write(outputdevice,plstridetimes[i]:6:4);
        end;
    for i:=numberofplstrides+1 to maxnumberofsteps do
        begin
            write(outputdevice,'');
        end;
end;
procedure sendplatform2stridetimestoexcelfile;
begin
for i:=1 to numberofp2strides do
begin
write(outputdevice,p2stridetimes[i]:6:4);
write(outputdevice,'',');
end;
for i:=numberofp2strides+1 to maxnumberofsteps do
begin
write(outputdevice,'',');
end;
end;

procedure displaypositionsofcofg;
begin
for step:=1 to numberofstepsplatforml do
begin
writeln(outputdevice,'platform 1, step ',step);
writeln(outputdevice,'position where force first exceeds force upper threshold is');
writeln(outputdevice,'position where force last exceeds force upper threshold is');
writeln(outputdevice);
if waprintorfile='wait' then wait;
end;
for step:=1 to numberofstepsplatform2 do
begin
writeln(outputdevice,'platform 2, step ',step);
writeln(outputdevice,'position where force first exceeds force upper threshold is');
writeln(outputdevice,'(x,y) = (' ,xplatform2'[ffirstexceedsfutp2[step]] :6:3, ' metres, ' ,yplatform2'[ffirstexceedsfutp2[step]] :6:3, ' metres', ')');
writeln(outputdevice,'position where force last exceeds force upper threshold is');
writeln(outputdevice,'(x,y) = (' ,xplatform2'[flastexceedsfutp2[step]] :6:3, ' metres, ' ,yplatform2'[flastexceedsfutp2[step]] :6:3, ' metres', ')');
writeln(outputdevice);
if waprintorfile='wait' then wait;
end;
end;

procedure sendpositionsofcofgtoexcelfile;
begin
for step:=1 to numberofstepsplatforml do
begin
end;
for step:=numberofstepsplatforml+l to maxnumberofsteps do
write(outputdevice,',,,,');
for step:=1 to numberofstepsplatform2 do
begin
end;
for step:=numberofstepsplatform2+l to maxnumberofsteps do
write(outputdevice,',,,,');
end;

procedure cisplaypltimeaveragedxandy;
var counter:integer;
begin
for step:=1 to numberofstepsplatforml do
begin
write(outputdevice,'platform 1, step ',step,' time averaged (x,y)=(',
   pltimeaveragedx[step]:6:3, ' metres,',pltimeaveragedy[step]:6:3,
   ' metres');
writeln(outputdevice);
if waprintorfile='wait' then wait;
end;
end;

procedure sendpltimeaveragedxandytoexcelfile;
var counter:integer;
begin
for step:=1 to numberofstepsplatforml do
begin
write(outputdevice,pltimeaveragedx[step]:6:3,',',pltimeaveragedy[step]:6:3,'');
end;
for step:=numberofstepsplatforml+1 to maxnumberofsteps do
write(outputdevice,
   p2timeaveragedx[step]:6:3,',',p2timeaveragedy[step]:6:3,'');
end;

procedure displayp2timeaveragedxandy;
var counter:integer;
begin
for step:=1 to numberofstepsplatform2 do
begin
writeln(outputdevice,'platform 2, step ',step,' time averaged (x,y)=(',
   p2timeaveragedx[step]:6:3, ' metres,',p2timeaveragedy[step]:6:3,
   ' metres');
writeln(outputdevice);
if waprintorfile='wait' then wait;
end;
end;

procedure sendp2timeaveragedxandytoexcelfile;
var counter:integer;
begin
for step:=1 to numberofstepsplatform2 do
begin
write(outputdevice,p2timeaveragedx[step]:6:3,',',p2timeaveragedy[step]:6:3,'');
end;
for step:=numberofstepsplatform2+1 to maxnumberofsteps do
write(outputdevice,
   p2steplengths[i]:6:3, ',');
end;

procedure displayplatformlsteplengths;
begin
for i:=1 to numberofplcompletesteps do
begin
writeln(outputdevice,'platform 1 step length [',i,']=',
   p2steplengths[i]:6:3, ' metres');
end;
writeln(outputdevice);
end;

procedure sendplatformlsteplengthstoxcelfile;
begin
for i:=1 to numberofplcompletesteps do
begin
write(outputdevice,p2steplengths[i]:6:3,'');
end;
for i:=numberofplcompletesteps+1 to maxnumberofsteps do
begin
write(outputdevice,'');
end;
end;
procedure displayplatform2steplengths;
begin
for i:=1 to numberofp2completesteps do
begin
  writeln(outputdevice,'platform 2 step length ['','i',''] = ',
          p2steplengths[i]:6:3,' metres');
end;
writeln(outputdevice);
end;

procedure sendplatform2steplengthstoexcelfile;
begin
for i:=1 to numberofp2completesteps do
begin
  write(outputdevice,p2steplengths[i]:6:3,',');
end;
for i:=numberofp2completesteps+1 to maxnumberofsteps do
begin
  write(outputdevice,',');
end;
end;

procedure displayplatform1stepwidths;
begin
for i:=1 to numberofplcompletesteps do
begin
  writeln(outputdevice,'platform 1 step width ['','i',''] = ',
          plstepwidths[i]:6:3,' metres');
end;
writeln(outputdevice);
end;

procedure sendplatform1stepwidthstoexcelfile;
begin
for i:=1 to numberofplcompletesteps do
begin
  write(outputdevice,plstepwidths[i]:6:3, ',');
end;
for i:=numberofplcompletesteps+1 to maxnumberofsteps do
begin
  write(outputdevice,',');
end;
end;

procedure displayplatform2stepwidths;
begin
for i:=1 to numberofp2completesteps do
begin
  writeln(outputdevice,'platform 2 step width ['','i',''] = ',
          p2stepwidths[i]:6:3,' metres');
end;
writeln(outputdevice);
end;

procedure sendplatform2stepwidthstoexcelfile;
begin
for i:=1 to numberofp2completesteps do
begin
  write(outputdevice,p2stepwidths[i]:6:3,',');
end;
for i:=numberofp2completesteps+1 to maxnumberofsteps do
begin
  write(outputdevice,',');
end;
end;

procedure displayplatform1stridelengths;
begin
for i:=1 to numberofplstrides do
begin
  writeln(outputdevice,'platform 1 stride length ['','i',''] = ',
          plstridelengths[i]:6:3,' metres');
end;
writeln(outputdevice);
end;

procedure sendplatform1stridelengthstoexcelfile;
begin
for i:=1 to numberofplstrides do
begin
  write(outputdevice,plstridelengths[i]:6:3, ',');
end;
for i:=numberofplstrides+1 to maxnumberofsteps do
begin
  write(outputdevice,',');
end;
end;

procedure displayplatform2stridelengths;
begin
for i:=1 to numberofp2strides do
begin
  writeln(outputdevice,'platform 2 stride length ['','i',''] = ',
          p2stridelengths[i]:6:3,' metres');
end;
writeln(outputdevice);
end;

procedure sendplatform2stridelengthstoexcelfile;
begin
for i:=1 to numberofp2strides do
begin
  write(outputdevice,p2stridelengths[i]:6:3,',');
end;
for i:=numberofp2strides+1 to maxnumberofsteps do
begin
  write(outputdevice,',');
end;
end;
plstridelengths[i]:6:3,' metres');
end;
writeln(outputdevice);
end;

procedure sendplatform1stridelengthstoexcelfile;
begin
for i:=1 to numberofplstrides do
begin
write(outputdevice,plstridelengths[i]:6:3,', ');
end;
for i:=numberofplstrides+1 to maxnumberofsteps do
begin
write(outputdevice,', ');
end;
end;

procedure displayplatform2stridelengths;
begin
for i:=1 to numberofp2strides do
begin
writeln(outputdevice,'platform 2 stride length [',i,']=','
p2stridelengths[i]:6:3,' metres');
end;
writeln(outputdevice);
end;

procedure sendplatform2stridelengthstoexcelfile;
begin
for i:=1 to numberofp2strides do
begin
write(outputdevice,p2stridelengths[i]:6:3,', ');
end;
for i:=numberofp2strides+1 to maxnumberofsteps do
begin
write(outputdevice,', ');
end;
end;

procedure displayplatform1velocity;
begin
writeln(outputdevice,'velocity based on platform 1=',plvelocity:6:2,
' metres per second');
writeln(outputdevice);
end;

procedure sendplatform1velocitytoexcelfile;
begin
write(outputdevice,plvelocity:6:2,', ');
end;

procedure displayplatform2velocity;
begin
writeln(outputdevice,'velocity based on platform 2=',p2velocity:6:2,
' metres per second');
writeln(outputdevice);
end;

procedure sendplatform2velocitytoexcelfile;
begin
write(outputdevice,p2velocity:6:2,', ');
end;

procedure displayvelocity;
begin
writeln(outputdevice,'velocity=',velocity:6:2,' metres per second');
writeln(outputdevice);
end;

procedure sendvelocitytoexcelfile;
begin

procedure displaywhichplatformleftfootwason;
begin
  if leftfootwasonplatforml='T' then
    writeln(outputdevice,'left foot was on platform 1');
  if leftfootwasonplatforml='F' then
    writeln(outputdevice,'left foot was on platform 2');
end;

procedure sendwhichplatformleftfootwasontoexcelfile;
begin
  if leftfootwasonplatforml='T' then
    write(outputdevice,'1');
  if leftfootwasonplatforml='F' then
    write(outputdevice,'2');
  write(outputdevice,'');
end;

function xisodouble;
const
  Ox=30;
  xscale=24;
begin
  xiso:=Ox+xscale*(x+y/sqrt(2.0));
end;

function yisodouble;
const
  Oy=50;
  yscale=32;
begin
  yiso:=Oy+yscale*(y/sqrt(2.0));
end;

uosgws5b
{"FOURTH LEVEL*}

("Gfile"
 {modified by Jane Barrance in order to be able to print}
 {graphics screens from files})

procedure sendgraphicstofile(Inverse : boolean; Mode : byte);
{ Graphics file dump routine for EPSON compatible }
{ printers. Pre-FX series of EPSON printers should }
{ only use Mode 1. }
{ Mode: 1 = Double-Density 120 dots per inch }
{ 2 = High-Speed D-D 120 dots per inch }
{ 3 = Quadruple-Density 240 dots per inch }
{ 0, 4, 5 = 80 dots per inch }
{ 6 = 90 dots per inch }
const
  Esc = 27;
var
  ScanLine : integer; { The current scan line }
  nl, n2 : byte; { 2 byte printer control code }
procedure SendByte(B : byte);
{ Send one byte to the file }
const
  LPTPortNum = 1; { Defaults to LPT1. 2 = LPT2 }
var
  Regs : Registers;
begin
  Regs.AH := 0;
}
Regs.AL := B;
Regs.DX := Pred(LPTPortNum);
if (B=9) then B:=0;
if (B=26) then B:=0;
write(outputdevice,chr(B)); [this is the line I've changed]
end; { SendByte }

{$B+} { Turn off short circuit boolean evaluation }

function ConstructByte(X, Y : integer) : byte;
{ Construct a print byte by reading bits from the graphics screen buffer }
const
Bits : array[0..7] of byte = (128,64,32,16,8,4,2,1);
var
CByte, Bit : byte;
beginn
Y := Y shl 3; { Y := Y * 8 }
CByte := 0;
for Bit := 0 to 7 do
if ((Mem[GrafBase:BaseAddress(Y+Bit) + X shr 3] and Bits[X and 7]) <> 0) then
CByte := CByte + Bits[Bit];
ConstructByte := CByte;
end; { ConstructByte }
{$B-} { Turn on short circuit boolean evaluation }

procedure DoLine;
{ Dumps one print line to the printer }
var
XPixel : integer;
PrintByte : byte;
beginn
if Mode = 1 then
begin
SendByte(Esc); { Select double-density graphics print mode }
SendByte(Ord('L'));
end
else
begin { Select 8-Pin graphics print mode }
SendByte(Esc);
SendByte(Ord('*'));
SendByte(Mode);
end;
SendByte(n1); { Send 2 byte control code }
SendByte(n2);
for XPixel := 0 to XScreenMaxGlb do
begin
PrintByte := ConstructByte(XPixel, ScanLine);
if Inverse then
PrintByte := not PrintByte;
SendByte(PrintByte); { Send print byte }
end;
SendByte(10); { Send line feed }
end; { DoLine }
beginn
[ HardCopy ]
Mode := Mode mod 7; { Modes 0 through 6 supported }
if (Mode = 0) or (Mode = 5) then
Mode := 4; { Modes 0 and 5 use Mode 4 }
SendByte(Esc);
SendByte(Ord('3'));
SendByte(24);
n1 := Lo(Succ(XScreenMaxGlb)); { Determine 2 byte control code for }
n2 := Hi(Succ(XScreenMaxGlb)); { the number of dots per print line }
for ScanLine := 0 to (YMaxGlb div 8) do
DoLine; { Do a print line }
SendByte(Esc); SendByte(2); { Select 1/6-inch line spacing }
end;
{ FOURTH LEVEL CONTINUED*}

procedure abort(message:string);
begin
  gotoxy(1,24);
  write(message,', Hit any key to halt');
  repeat until keypressed;
  halt;
end;

procedure operator enters personal data;
var finished:char; tempstring:string;

begin
  finished:=" ";
  repeat
    clrscr;
    writeln('Please enter subject's personal data.');
    writeln('code to identify subject: ');
    writeln(clinreadings.subjectcode);
    changeormovedown(tempstring);
    if tempstring='???' then clinreadings.subjectcode:=tempstring;
    writeln('height in metres: ');
    writeln(clinreadings.heightinm);
    changeormovedown(tempstring);
    if tempstring='???' then clinreadings.heightinm:=tempstring;
    write('date of birth: ');
    writeln(clinreadings.dateofbirth);
    changeormovedown(tempstring);
    if tempstring='???' then clinreadings.dateofbirth:=tempstring;
    write('sex: ');
    writeln(clinreadings.sex);
    changeormovedown(tempstring);
    if tempstring='???' then clinreadings.sex:=tempstring;
    write('footwear (or "barefoot"): ');
    writeln(clinreadings.footwear);
    changeormovedown(tempstring);
    if tempstring='???' then clinreadings.footwear:=tempstring;
    write('leg dominance (L/R): ');
    writeln(clinreadings.legdominance);
    changeormovedown(tempstring);
    if tempstring='???' then clinreadings.legdominance:=tempstring;
    writeln('Press "y" if you have entered the above information correctly.');
    flushkeyboard;
    finished:=readkey;
  until finished='y';
end;

procedure operator enters clerical data;
var finished:char; tempstring:string;

begin
  finished:=" ";
  repeat
    clrscr;
    writeln('Please enter clerical data.');
    writeln('NHS number: ');
    writeln(clinreadings.NHSnumber);
    changeormovedown(tempstring);
    if tempstring='???' then clinreadings.NHSnumber:=tempstring;
    writeln('first test date: ');
    writeln(clinreadings.firsttestdate);
    changeormovedown(tempstring);
    if tempstring='???' then clinreadings.firsttestdate:=tempstring;
    writeln('Press "y" if you have entered the above information correctly.');
    flushkeyboard;
    finished:=readkey;
  until finished='y';
end;

procedure operator enters clinical data;
var finished:char; tempstring:string;

begin
  finished:=" ";
  repeat
  clrscr;
  writeln('Please enter clinical data.');
  writeln('NHS number: ');
  writeln(clinreadings.NHSnumber);
  changeormovedown(tempstring);
  if tempstring='???' then clinreadings.NHSnumber:=tempstring;
  writeln('first test date: ');
  writeln(clinreadings.firsttestdate);
  changeormovedown(tempstring);
  if tempstring='???' then clinreadings.firsttestdate:=tempstring;
  writeln('Press "y" if you have entered the above information correctly.');
  flushkeyboard;
  finished:=readkey;
  until finished='y';
end;
repeat
clrscr;
writeln('Please enter clinical data.');
write('Primary pathology: ');
writeln(clinreadings.primarypathology);
if tempstring='???' then clinreadings.primarypathology:=tempstring;
write('Secondary pathology affecting gait (if any): ');
writeln(clinreadings.secondarypathologyaffectinggait);
if tempstring='???' then clinreadings.secondarypathologyaffectinggait:=tempstring;
write('Procedure completed: ');
writeln(clinreadings.procedurecompleted);
if tempstring='???' then clinreadings.procedurecompleted:=tempstring;
write('Date of procedure: ');
writeln(clinreadings.dateofprocedure);
if tempstring='???' then clinreadings.dateofprocedure:=tempstring;
writeln;
writeln('Press "y" if you have entered the above information correctly.');
flushkeyboard;
finished:=readkey;
until finished='y';
end;

procedure operatorenterstestdata;
var finished:char;tempstring:string;
begin
  finished:= ' ';
  repeat
    clrscr;
    write('Test type');
    writeln(clinreadings.testtype);
    if tempstring='???' then clinreadings.testtype:=tempstring;
    write('Other comments about this series (if any): ');
    writeln(clinreadings.commentsaboutseries);
    if tempstring='???' then clinreadings.commentsaboutseries:=tempstring;
    writeln;
    writeln('Press "y" if you have entered the above information correctly.');
    flushkeyboard;
    finished:=readkey;
    until finished='y';
end;

procedure checkzerovaluesaresensible;
const
  zerolowerlimit = 921.6;
  zeroupperlimit = 1126.4;
begin
  channelnumber:=1;
  if (clinreadings.zero1<zerolowerlimit) or (clinreadings.zero1>zeroupperlimit) then suggestquit;
  channelnumber:=2;
  if (clinreadings.zero2<zerolowerlimit) or (clinreadings.zero2>zeroupperlimit) then suggestquit;
  channelnumber:=3;
  if (clinreadings.zero3<zerolowerlimit) or (clinreadings.zero3>zeroupperlimit) then suggestquit;
  channelnumber:=4;
  if (clinreadings.zero4<zerolowerlimit) or (clinreadings.zero4>zeroupperlimit) then suggestquit;
  channelnumber:=5;
  if (clinreadings.zero5<zerolowerlimit) or (clinreadings.zero5>zeroupperlimit) then suggestquit;
  channelnumber:=6;
  if (clinreadings.zero6<zerolowerlimit) or (clinreadings.zero6>zeroupperlimit) then suggestquit;
end;
procedure recorddatafromwalkway;

var
 n,sample,delaylength:integer;
 starthour,startminute,startsecond,startsec100,
 finishhour,finishminute,finishsecond,finishsec100:word;
 measuredsamplingtime,timeratio:double;

begin
 case clinreadings.nominalsamplingrateperchannel of
 100:begin
  clinreadings.actualsamplingrateperchannel:=100.0;
  delaylength:=3136; {if nominal sampling rate is 100Hz, set}
  {up appropriate value of delaylength}
  {values for Mesh 486, 10/9/92}
  clinreadings.actualsamplingrateperchannel:=100.0;
  delaylength:=1279; } {values for Tandon computer, measured,}
  {lab book, page 1745, 4/9/91}
 end;
 400:begin
  delaylength:=616; {if nominal sampling rate is 400Hz, set}
  {up appropriate value of delaylength}
  {values for Mesh 486, 10/9/92}
  clinreadings.actualsamplingrateperchannel:=400.0;
  clinreadings.actualsamplingrateperchannel:=399.81; {values for Tandon computer, measured,}
  {lab book, page 2101, 28/11/91}
 end;
 else
  writeln('the programme is not capable of dealing with this value of');
  writeln('sampling rate');
  halt;
 end;
end;
clinreadings.readingsperchannel:=
  clinreadings.nominalsamplingrateperchannel*clinreadings.samplingtime;
writeln('Beginning to record data from the walkway.');
with clinreadings do
begin
  getdate(year,month,day,dayofweek);
  gettime(hour,minute,second,secl00);
end;
gettime(starthour,startminute,startsecond,startsec100);
with clinreadings do
begin
  for sample:=1 to readingsperchannel do
  begin
    array1[sample]:=readch(_ai,1);
    array2[sample]:=readch(_ai,2);
    array3[sample]:=readch(_ai,3);
    array4[sample]:=readch(_ai,4);
    array5[sample]:=readch(_ai,5);
    array6[sample]:=readch(_ai,6);
    delayloop(delaylength);
  end;
end;
gettime(finishhour,finishminute,finishsecond,finishsec100);
writeln('Finished recording data from the walkway.');
writeln('');
write('G, '■G);
measuredsamplingtime:=(3600.0 *(round(finishhour ) - round(starthour ))
       +60.0 *(round(finishminute) - round(startminute))
       +1.0 *(round(finishsecond) - round(startsecond))
       +0.01*(round(finishsec100) - round(startsec100)))
       /clinreadings.samplingtime;
timeratio:=measuredsamplingtime/(clinreadings.samplingtime+0.0);
if (timeratio>1.05) or
   (timeratio<0.95) then
begin
  writeln('The timing of the sampling has been set up incorrectly.');
  writeln('nominal sampling time=',clinreadings.samplingtime, ' seconds');
  writeln('measured sampling time=',measuredsamplingtime:6:2, ' seconds');
  writeln('timeratio=',timeratio:6:2);
  writeln('The program is therefore terminating. Please seek assistance.');
  wait;
  halt;
end;
end;
procedure imprc;
begin
  repeat
    read(filetobesorted, clinreadings);
    sortrelease(clinreadings);
  until eof (filetobesorted);
end;

function lessrec(var x,y:clinrecord):boolean;
begin
  lessrec:=x.recordname<y.recordname;
end;

procedure outprecs;
begin
  writeln('The existing record names are:');
  repeat
    sortreturn(clinreadings);
    write(clinreadings.recordname, ',');
  until sorteos;
  writeln;
end;

procedure calclowforcesteps;
var
  step,counter:integer;
  maxforceinstep:double;
begin
  for step:=1 to numberofstepsplatforml do
  begin
    maxforceinstep:=0;
    for counter:=beginningofstepplatforml[step] to endofstepplatforml[step] do
      if platformlforce'[counter]'>maxforceinstep then
        maxforceinstep:=platformlforce'[counter]';
    if maxforceinstep<forceupperthreshold then
      begin
        lowforcesteps:=true;
        anyerrormessages:=true;
      end;
  end;
  for step:=1 to numberofstepsplatform2 do
  begin
    maxforceinstep:=0;
    for counter:=beginningofstepplatform2[step] to endofstepplatform2[step] do
      if platform2force'[counter]'>maxforceinstep then
        maxforceinstep:=platform2force'[counter]';
    if maxforceinstep<forceupperthreshold then
      begin
        lowforcesteps:=true;
        anyerrormessages:=true;
      end;
  end;
end;

procedure calchighlyunequalnumbersofsteps;
begin
  highlyunequalnumbersofsteps:=false;
  if abs(numberofstepsplatforml-numberofstepsplatform2)>1 then
  begin
    anyerrormessages:=true;
    highlyunequalnumbersofsteps:=true;
  end;
end;
procedure calccrossover;
begin
for step:=1 to numberofstepsplatform1 do
begin
if abs(xplatform1^[ffirstexceedsfutpl(step)]-
xplatform1^[flastexceedsfutpl(step)])>crossoverthreshold then
begin
  crossover:=true;
  anyerrormessages:=true;
end;
end;
for step:=1 to numberofstepsplatform2 do
begin
if abs(xplatform2^[ffirstexceedsfutp2(step)]-
xplatform2^[flastexceedsfutp2(step)])>crossoverthreshold then
begin
  crossover:=true;
  anyerrormessages:=true;
end;
end;
end;

procedure identifysteps;
var
  counter:integer;
  found:boolean;
begin
  numberofstepsplatform1:=0;
  [find beginnings of steps on platform 1]
  step:=1;
  for counter:=2 to clinreadings.readingsperchannel do
begin
  if (numberofstepsplatform1<maxnumberofsteps+l)
  and (xplatform1[counter]>-0.9)
  and (xplatform1[counter-1]<-0.9) then
  begin
    beginningofstepplatform1[step]:=counter;
    numberofstepsplatform1:=numberofstepsplatform1+l;
    step:=step+l;
  end;
end;
if numberofstepsplatform1=maxnumberofsteps+l then
begin
  anyerrormessages:=true;
toomanysteps:=true;
  numberofstepsplatform1:=maxnumberofsteps;
end;

  [find ends of steps on platform 1]
  for step:=1 to numberofstepsplatform1 do
begin
  found:=false;
  for counter:=beginningofstepplatform1[step] to clinreadings.readingsperchannel do
begin
  if (not found) and
  (xplatform1[counter]>-0.9) and (xplatform1[counter+1]<-0.9) then
  begin
    endofstepplatform1[step]:=counter;
    found:=true;
  end;
end;
end;

  [Find where the force first exceeds forceupperthreshold for each step on]
  [platform 1]
  for step:=1 to numberofstepsplatform1 do
begin
  found:=false;
  ffirstexceedsfutpl[step]:=1;
  for counter:=beginningofstepplatform1[step] to endofstepplatform1[step] do
begin
  if (not found) and
  (platform1force[counter]>forceupperthreshold) and
  (platform1force[counter-1]<forceupperthreshold) then
begin

end;
ffirstexceedsfutpl[step]:=counter;
found:=true;
end;
end;
end;

{Find where the force last exceeds forceupperthreshold for each step on
platform 1}
for step:=1 to numberofstepsplatforml do
begin
found:=false;
flastexceedsfutpl[step]:=1;
begin
if (not found) and
(platformlforce''[counter]>forceupperthreshold) and
(platformlforce''[counter+1]<=forceupperthreshold) then
begin
flastexceedsfutpl[step]:=counter;
found:=true;
end;
end;
end;
end;
end;

numberofstepsplatform2:=0;
{find beginnings of steps on platform 2}
step:=1;
for counter:=2 to clinreadings.readingsperchannel do
begin
if (numberofstepsplatform2<maxnumberofsteps+l)
and (xplatform2''[counter]>-0.9)
and (xplatform2''[counter-1]<-0.9) then
begin
beginningofstepplatform2[step]:=counter;
numberofstepsplatform2:=numberofstepsplatform2+l;
step:=step+l;
end;
end;
end;

if numberofstepsplatform2=maxnumberofsteps+l then
begin
anyerrormessages:=true;
toomanysteps:=true;
numberofstepsplatform2:=maxnumberofsteps
end;

{find ends of steps on platform 2}
for step:=1 to numberofstepsplatform2 do
begin
found:=false;
for counter:=beginningofstepplatform2[step] to clinreadings.readingsperchannel do
begin
if (not found) and
(xplatform2''[counter]>-0.9) and (xplatform2''[counter+1]<-0.9) then
begin
endofstepplatform2[step]:=counter;
found:=true;
end;
end;
end;
end;

{Find where the force first exceeds forceupperthreshold for each step on
platform 2}
for step:=1 to numberofstepsplatform2 do
begin
found:=false;
ffirstexceedsfutp2[step]:=1;
for counter:=beginningofstepplatform2[step] to endofstepplatform2[step] do
begin
if (not found) and
(platform2force''[counter]>forceupperthreshold) and
(platform2force''[counter-1]<=forceupperthreshold) then
begin
ffirstexceedsfutp2[step]:=counter;
found:=true;
end;
end;
end;
end;
end;
Find where the force last exceeds forceupperthreshold for each step on platform 2.

for step:=1 to numberofstepsplatform2 do
begin
  found:=false;
  flastexceedsfutp2[step]:=1;
  begin
    if (not found) and (platform2force''[counter] > forceupperthreshold) and (platform2forceA[counter+1] <= forceupperthreshold) then
    begin
      flastexceedsfutp2[step]:=counter;
      found:=true;
    end;
  end;
end;

procedure markfirstorlaststeponeachplatformiflow;
var
  maxforceinstep:double;
  counter:integer;
begin
  if numberofstepsplatformlo<>0 then
  begin
    maxforceinstep:=0;
      if platformlforce''[counter] > maxforceinstep then
        maxforceinstep:=platformlforce''[counter];
    if maxforceinstep<forceupperthreshold then firststeponplatformlismarked:=true;
    maxforceinstep:=0;
    for counter:=beginningofstepplatforml[numberofstepsplatforml] to endofstepplatforml[numberofstepsplatforml] do
      if platformlforce''[counter] > maxforceinstep then
        maxforceinstep:=platformlforce''[counter];
    if maxforceinstep<forceupperthreshold then laststeponplatformlismarked:=true;
  end;

  if numberofstepsplatform2<>0 then
  begin
    maxforceinstep:=0;
      if platform2force''[counter] > maxforceinstep then
        maxforceinstep:=platform2force''[counter];
    if maxforceinstep<forceupperthreshold then firststeponplatform2ismarked:=true;
    maxforceinstep:=0;
    for counter:=beginningofstepplatform2[numberofstepsplatform2] to endofstepplatform2[numberofstepsplatform2] do
      if platform2force''[counter] > maxforceinstep then
        maxforceinstep:=platform2force''[counter];
    if maxforceinstep<forceupperthreshold then laststeponplatform2ismarked:=true;
  end;
end;

procedure markfirstorlaststeponeachplatformifnearend;
var
  counter:integer;
begin
  if numberofstepsplatforml<>0 then
  begin
      if ((abs(xplatforml''[counter]-(1-e))<endthreshold) or (abs(xplatforml''[counter]-(2*a+e))<endthreshold)) then
        firststeponplatformlismarked:=true;
    for counter:=ffirstexceedsfutpl[numberofstepsplatforml] to flastexceedsfutpl[numberofstepsplatforml] do
      if ((abs(xplatforml''[counter]-(1-e))<endthreshold)
or \( \text{abs}(x_{\text{platform1}}[\text{counter}] - (2*a+e)) < \text{endthreshold} \) then
\text{laststeponplatform1ismarked} := \text{true};
end;
if \text{numberofstepsplatform2} > 0 then
begin
for \text{counter} := \text{ffirstexceedsfutp2}[1] to \text{flastexceedsfutp2}[1] do
if \( \text{abs}(x_{\text{platform2}}[\text{counter}] - (-e)) < \text{endthreshold} \) or \( \text{abs}(x_{\text{platform2}}[\text{counter}] - (2*a+e)) < \text{endthreshold} \) then
\text{firststeponplatform2ismarked} := \text{true};
for \text{counter} := \text{ffirstexceedsfutp2}[\text{numberofstepsplatform2}] to \text{flastexceedsfutp2}[\text{numberofstepsplatform2}] do
if \( \text{abs}(x_{\text{platform2}}[\text{counter}] - (-e)) < \text{endthreshold} \) or \( \text{abs}(x_{\text{platform2}}[\text{counter}] - (2*a+e)) < \text{endthreshold} \) then
\text{laststeponplatform2ismarked} := \text{true};
end;
end;

procedure discardfirststeponplatform1;
begin
for \text{step} := 1 to \text{numberofstepsplatform1} - 1 do
begin
\text{beginningofstepplatform1}[\text{step}] := \text{beginningofstepplatform1}[\text{step} + 1];
\text{ffirstexceedsfutpl}[\text{step}] := \text{ffirstexceedsfutpl}[\text{step} + 1];
\text{flastexceedsfutpl}[\text{step}] := \text{flastexceedsfutpl}[\text{step} + 1];
\text{endofstepplatform1}[\text{step}] := \text{endofstepplatform1}[\text{step} + 1];
end;
\text{numberofstepsplatform1} := \text{numberofstepsplatform1} - 1;
end;

procedure discardlaststeponplatform1;
begin
\text{numberofstepsplatform1} := \text{numberofstepsplatform1} - 1;
end;

procedure discardfirststeponplatform2;
begin
for \text{step} := 1 to \text{numberofstepsplatform2} - 1 do
begin
\text{beginningofstepplatform2}[\text{step}] := \text{beginningofstepplatform2}[\text{step} + 1];
\text{ffirstexceedsfutp2}[\text{step}] := \text{ffirstexceedsfutp2}[\text{step} + 1];
\text{flastexceedsfutp2}[\text{step}] := \text{flastexceedsfutp2}[\text{step} + 1];
\text{endofstepplatform2}[\text{step}] := \text{endofstepplatform2}[\text{step} + 1];
end;
\text{numberofstepsplatform2} := \text{numberofstepsplatform2} - 1;
end;

procedure discardlaststeponplatform2;
begin
\text{numberofstepsplatform2} := \text{numberofstepsplatform2} - 1;
end;

procedure calcimpulses;
begin
\text{var} \text{counter} : \text{integer};
begin
\text{[calculate impulse of each step on platform 1]}
for \text{step} := 1 to \text{numberofstepsplatform1} do
begin
\text{impulseplatform1}[\text{step}] := 0;
for \text{counter} := \text{beginningofstepplatform1}[\text{step}] to \text{endofstepplatform1}[\text{step}] do
begin
\text{impulseplatform1}[\text{step}] := \text{impulseplatform1}[\text{step}] + \text{platform1force}[\text{counter}] / \text{clinreadings.actualsamplingrateperchannel}
\text{[kilogrammes force.seconds]}
end;
end;
\text{[calculate impulse of each step on platform 2]}
for \text{step} := 1 to \text{numberofstepsplatform2} do
begin
\text{impulseplatform2}[\text{step}] := 0;
for \text{counter} := \text{beginningofstepplatform2}[\text{step}] to \text{endofstepplatform2}[\text{step}] do
begin
\text{end};
impulseplatform2[step] := impulseplatform2[step] + (platform2force'[counter]/clinreadings.actualsamplingrateperchannel) [kilo grammes force.seconds]
end;
end;
end;

procedure calcpeakforces;
var platform: integer;
begin
platform := 1;
for step := 1 to numberofstepsplatform1 do
if (endofstepplatform1[step]-beginningofstepplatform1[step]) >= 2 then
begin
  middleofstep := trunc((beginningofstepplatform1[step] + endofstepplatform1[step])/2);
calcfpeak(platform);
calcspeak(platform);
calcmin(platform);
end;
end;
platform := 2;
for step := 1 to numberofstepsplatform2 do
if (endofstepplatform2[step]-beginningofstepplatform2[step]) >= 2 then
begin
  middleofstep := trunc((beginningofstepplatform2[step] + endofstepplatform2[step])/2);
calcfpeak(platform);
calcspeak(platform);
calcmin(platform);
end;
end;

procedure calctemporaldistancefactors;
begin
findoutwhichplatformfirststepwason;
calclftotalstancetimes;
calclftimeaveragedxandy;
calctp2timeaveragedxandy;
numberofdst := numberofstepsplatform1 + numberofstepsplatform2 - 1;
if numberofdst < 0 then numberofdst := 0;
if numberofdst > 0 then calcdoublestancetimes;
numberofplstrides := numberofstepsplatform1 - 1;
if numberofplstrides < 0 then numberofplstrides := 0;
if numberofplstrides > 0 then calclftotrestrialtimes;
numberofp2strides := numberofstepsplatform2 - 1;
if numberofp2strides < 0 then numberofp2strides := 0;
if numberofp2strides > 0 then calctp2totrestrialtimes;
numberofplcompletesteps := 0;
numberofp2completesteps := 0;
if firststepwasonplatform1 = 'T' then
begin
  numberofplcompletesteps := numberofstepsplatform1 - 1;
  numberofp2completesteps := numberofstepsplatform2;
end;
if firststepwasonplatform1 = 'F' then
begin
  numberofplcompletesteps := numberofstepsplatform1;
  numberofp2completesteps := numberofstepsplatform2 - 1;
end;
end;
procedure displaytemporaldistancefactors;
begin
  writeln(outputdevice, '%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% Temporal factors %%%%%%%%%%%%%%%%%%%%%%%%%%');
  writeln(outputdevice);
  displaywhichplatformfirststepwason;
  displayplatformltotalstancetimes;
  if numberofdst<>0 then displaydoublestancetimes;
  if waprintorfile='wait' then wait;
  if numberofplstrides<>0 then displayplatformlstridetimes;
  if waprintorfile='wait' then wait;
  writeln(outputdevice, '%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% Distance factors %%%%%%%%%%%%%%%%%%%%%%%%%%');
  writeln(outputdevice);
  displaywhichplatformleftfootwason;
  displaypositionsofcofg;
  displaypltimeaveragedxandy;
  displayp2timeaveragedxandy;
  if waprintorfile='wait' then wait;
  if numberofplcompletesteps<>0 then displayplatformlsteplengths;
  if numberofp2completesteps<>0 then displayplatform2steplengths;
  if waprintorfile='wait' then wait;
  if numberofplcompletesteps<>0 then displayplatformlstepwidths;
  if numberofp2completesteps<>0 then displayplatform2stepwidths;
  if waprintorfile='wait' then wait;
  if numberofplstrides<>0 then displayplatformlstridelengths;
  if waprintorfile='wait' then wait;
  writeln(outputdevice, '%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% Velocity factors %%%%%%%%%%%%%%%%%%%%%%%%%%');
  writeln(outputdevice);
  if numberofplstrides<>0 then displayplatformlvelocity;
  if numberofp2strides<>0 then displayplatform2velocity;
  if waprintorfile='wait' then wait;
  if not((numberofplstrides<>0) and (numberofp2strides<>0)) then displayvelocity;
  writeln(outputdevice);
  writeln(outputdevice);
end;

procedure sendtemporaldistancefactorstoexcelfile;
var counter:integer;
begin
  if not((numberofplstrides<>0) and (numberofp2strides<>0)) then
    sendvelocitytoexcelfile
  else write(outputdevice,','); (*variable 1*)
  if numberofplcompletesteps<>0 then sendplatformlstepwidthstoexcelfile; (*var 2*)
  if numberofp2completesteps<>0 then sendplatform2stepwidthstoexcelfile;
  if numberofplcompletesteps=0 then
    for counter:=1 to maxnumberofsteps do write(outputdevice,',');
  if numberofp2completesteps=0 then
    for countertol to maxnumberofsteps do write(outputdevice,',');
  sendstancetimertoexcelfile; (*variable 3*)
  if numberofplcompletesteps<>0 then sendplatformlsteplengthstoexcelfile {var 4}
  else for counter=1 to maxnumberofsteps do write(outputdevice,'',');
  if numberofp2completesteps<>0 then sendplatform2steplengthstoexcelfile {var 5}
  else for counter:=1 to maxnumberofsteps do write(outputdevice,'',');
  sendwhichplatformleftfootwastoexcelfile; (*variable 1*)
  if numberofdct<>0 then senddoublestancetimesetoexcelfile
  else for counter:=1 to 2*maxnumberofsteps do write(outputdevice,'',');
  if numberofplstrides<>0 then sendplatformlstridestimetoexcelfile
  else for counter:=1 to maxnumberofsteps do write(outputdevice,'',');
  if numberofp2strides<>0 then sendplatform2stridestimetoexcelfile
  else for counter:=1 to maxnumberofsteps do write(outputdevice,'',');
  sendpositionssofcofgtoexcelfile;
  sendpltimeaveragedxandytoexcelfile;
  sendp2timeaveragedxandytoexcelfile;
  sendplatformlsteplengthstoexcelfile
  else for counter:=1 to maxnumberofsteps do write(outputdevice,'',');
  sendplatform2steplengthstoexcelfile
  else for counter:=1 to maxnumberofsteps do write(outputdevice,'',');
  sendwhichplatformleftfootwastoexcelfile;
end;


procedure commentsabouttrial;

var finished:char; tempstring:string;

begin
  finished:=' '; clinreadings.commentsabouttrial:='';
  repeat
    clrscr;
    writeln('Please enter any comments about this trial');
    writeln(clinreadings.commentsabouttrial);
    change(tempstring);
    if tempstringO'???' then clinreadings.commentsabouttrial:=tempstring;
    writeln;
    writeln('press "y" if you have entered the above information correctly');
    flushkeyboard;
    finished:=readkey;
  until finished='v';
  writeln;
end;

procedure recorddatatofile;

var typedname:namestr;

begin
  repeat
    finished:='n';
    repeat
      writeln('type name for this record, or type q to quit');
      writeln('The name must contain only the characters 0 to 9, a to z, ');
      writeln('A to Z and space');
      readln (typedname);
      cleanname(typedname);
      writeln(typedname);
      if typedname='q' then halt;
    until (finished='y') or (finished='Y');
  until ok then writeln('This name already exists. Try again');
  until ok;
  cleanup;
  writeln;
end;

procedure waitprintorfile;

begin
  if waprintorfile = 'wait' then wait;
  if waprintorfile = 'print' then
    hardcopy(false,0); {hardcopy with black and white uninverted in}
    {mode 0 (640 points per line)}
  if waprintorfile = 'file' then sendgraphicstofile(false,0);
end;

procedure drawplatforml;

var xcornersofplatforml, ycornersofplatforml:array[1 .. 5] of double;

begin
  xcornersofplatforml[1]:=-e;
  xcornersofplatforml[2]:=2*a+e;
  xcornersofplatforml[3]:=2*a+e;
  xcornersofplatforml[4]:=-e;
  xcornersofplatforml[5]:=-e;
  ycornersofplatforml[1]:=-d;
  ycornersofplatforml[2]:=-d;
end;
for i := 1 to 4 do
begin
  xl := xcornersofplatforml[i];
yl := ycornersofplatforml[i];
x2 := xcornersofplatforml[i+1];
y2 := ycornersofplatforml[i+1];
drawline(xl, yl, x2, y2);
end;
end;

procedure drawplatform2;

var xcornersofplatform2, ycornersofplatform2: array[1..5] of double;

begin
  xcornersofplatform2[l] := -e;
  xcornersofplatform2[2] := 2*a+e;
  xcornersofplatform2[3] := 2*a+e;
  xcornersofplatform2[5] := -e;
  ycornersofplatform2[l] := -3*d+g-2*b;
  ycornersofplatform2[2] := -3*d+g-2*b;
  ycornersofplatform2[3] := g-d;
  ycornersofplatform2[4] := g-d;
  ycornersofplatform2[5] := -3*d+g-2*b;
  for i := 1 to 4 do
begin
  xl := xcornersofplatform2[i];
yl := ycornersofplatform2[i];
x2 := xcornersofplatform2[i+1];
y2 := ycornersofplatform2[i+1];
drawline(xl, yl, x2, y2);
end;
end;

procedure showdirectionoftravel;

begin
  gotoxy(50, 23);
  write('Direction of travel:');
  if leftfootwasonplatforml = 'T' then writeln('--- >');
  if leftfootwasonplatforml = 'F' then writeln(' <--- ');
end;

procedure drawplatformliso;

var xcornersofplatforml, ycornersofplatforml: array[1..5] of double;

begin
  xcornersofplatforml[l] := -e;
  xcornersofplatforml[2] := 2*a+e;
  xcornersofplatforml[3] := 2*a+e;
  xcornersofplatforml[4] := -e;
  xcornersofplatforml[5] := -e;
  ycornersofplatforml[l] := -d;
  for i := 1 to 4 do
begin
  x := xcornersofplatforml[i];
y := ycornersofplatforml[i];
xl := xiso;
yl := yiso;
x := xcornersofplatforml[i+1];
y := ycornersofplatforml[i+1];
x2 := xiso;
y2 := yiso;
drawline(xl, yl, x2, y2);
end;
end;

procedure drawplatform2iso;
var xcornersofplatform2, ycornersofplatform2: array[1..5] of double;

begin
  xcornersofplatform2[1] := -e;
  xcornersofplatform2[2] := 2*a + e;
  xcornersofplatform2[3] := 2*a + e;
  xcornersofplatform2[5] := -e;
  ycornersofplatform2[1] := -3*d - g - 2*b;
  ycornersofplatform2[2] := -3*d - g - 2*b;
  ycornersofplatform2[3] := -g - d;
  ycornersofplatform2[4] := -g - d;
  ycornersofplatform2[5] := -3*d - g - 2*b;
for i := 1 to 4 do
  begin
    x := xcornersofplatform2[i];
    y := ycornersofplatform2[i];
    xl := xiso;
    yl := yiso;
    x := xcornersofplatform2[i + 1];
    y := ycornersofplatform2[i + 1];
    x2 := xiso;
    y2 := yiso;
    drawline(xl, yl, x2, y2);
  end;
end;

procedure drawectors;
const forcescale = 0.2;

begin
  for i := 1 to clinreadings.readingsperchannel do
    begin
      x := xplatform1^[i];
      y := yplatform1^[i];
      x1 := xiso;
      y1 := yiso;
      y2 := y1 + forcescale * platform1force^[i];
      if platform1force^[i] > forceupperthreshold then drawline(x1, y1, x2, y2);
      x := xplatform2^[i];
      y := yplatform2^[i];
      x1 := xiso;
      y1 := yiso;
      y2 := y1 + forcescale * platform2force^[i];
      if platform2force^[i] > forceupperthreshold then drawline(x1, y1, x2, y2);
    end;
end;

uosgw5d
{"THIRD LEVEL*}

procedure operatorentersdata;
var
  finished: char;
  tempstring: string;
begin
  operatorenterspersonaldata;
  { operatorentersclericaldata; }
  { operatorentersclinicaldata; }
  operatorentertestdata;
end;

procedure operatorchoosessamplingtime;
var
  changingsamplingtimeornot: char;
begin
  writeln('Do you wish to change the sampling time from 5s to 20s?');
  writeln('appropriate for slow subjects?');
  writeln('"Y" for yes or "N" for no.');
  writeln('');
  changingsamplingtimeornot := ?;
flushkeyboard;
while (changesamplingtimeornot<>'y') and (changesamplingtimeornot<>'Y')
and (changesamplingtimeornot<>'n') and (changesamplingtimeornot<>'N') do
changesamplingtimeornot:=readkey;
case changesamplingtimeornot of 'y','Y':
begin
clinreadings.samplingtime:=20;  
{seconds}
clinreadings.nominalsamplingrateperchannel:=100;  
{Hertz}
writeln('sampling time=',clinreadings.samplingtime,  
'seconds');
writeln('sampling rate=', clinreadings.nominalsamplingrateperchannel,  
'Hz per channel');
wait;
end;
end;
end;

procedure initialiseerrormessages;
begin
anyerrormessages:=false;
lowforcesteps:=false;
toomanysteps:=false;
stepsnearend:=false;
negativedoublestancetimes:=false;
highlyunequalnumbersofsteps:=false;
crossover:=false;
outoftime:=false;
end;

procedure zero;{measures the voltage from each channel when nothing is on}
{the platforms}
var sum1,sum2,sum3,sum4,sum5,sum6:double;
v1,v2,v3,v4,v5,v6:double;
i,n:integer;

begin
clrscr;
writeln('Starting zeroing.');
n:=100;
sum1:=0; sum2:=0; sum3:=0; sum4:=0; sum5:=0; sum6:=0;
v1:=0; v2:=0; v3:=0; v4:=0; v5:=0; v6:=0;
iotype:=_ai;  
{the channels are analogue input channels}
for i:=1 to n do
begin
v1:=readch(iotype,1);  
{read the values of analogue input channels}
v2:=readch(iotype,2);  
{numbers 1 to 6}
end;
with clinreadings do
begin
zerol:=sum1/n; zero2:=sum2/n; zero3:=sum3/n;
zero4:=sum4/n; zero5:=sum5/n; zero6:=sum6/n;
writeln('zerol=',zerol:5:1,'zero2=',zero2:5:1,'zero3=',zero3:5:1);
writeln('zero4=', zero4:5:1,'zero5=',zero5:1,'zero6=',zero6:5:1);
checkzerovaluesaresensible;
end;
writeln('Finishing zeroing.');
writeln('');
end;

procedure measureweight;
var sum1,sum2,sum3,sum4,sum5,sum6:double;
v1,v2,v3,v4,v5,v6:double;
i,n:integer;

begin
clrscr;
writeln('Ask the subject to stand on the walkway facing the door with one');
writeln('foot on each platform so that their weight can be measured');
wait;
writeln('Beginning to measure weight.');
n:=5000;
sum1:=0; sum2:=0; sum3:=0; sum4:=0; sum5:=0; sum6:=0;
v1:=0; v2:=0; v3:=0; v4:=0; v5:=0; v6:=0;
itype:=_ai;  // the channels are analogue input channels
for i:=1 to n do
begin
  vl:=readch{itype,1};  // read the values of analogue input channels
  v2:=readch{itype,2};  // numbers 1 to 6
  v3:=readch{itype,3};
  v4:=readch{itype,4};
  v5:=readch{itype,5};
  v6:=readch{itype,6};
  sum1:=sum1+vl; sum2:=sum2+v2; sum3:=sum3+v3;
  sum4:=sum4+v4; sum5:=sum5+v5; sum6:=sum6+v6;
end;
sum1:=gainl*(sum1/n-clinreadings.zerol);
sum2:=gain2*(sum2/n-clinreadings.zero2);
sum3:=gain3*(sum3/n-clinreadings.zero3);
sum4:=gain4*(sum4/n-clinreadings.zer04);
sum5:=gain5*(sum5/n-clinreadings.zero5);
sum6:=gain6*(sum6/n-clinreadings.zero6);
clinreadings.weightonleftfootinkgf:=lsb*(sum4+sum5+sum6);
clinreadings.weightonrightfootinkgf:=lsb*(sum1+sum2+sum3);
clinreadings.weightinkgf:=lsb*(sum1+sum2+sum3+sum4+sum5+sum6);
writeln('Finishing measuring the weight of the subject.');
end;

procedure promptoperatorortostarttest;
begin
  writeln('Ensure that the subject is ready to walk along the walkway.');
  writeln('Press any key to start the test.');
end;

procedure operatorstartstest;
var s:char;
begin
  flushkeyboard;
  s:=readkey;
end;

procedure listnames;
var
counter:integer;
recordname:namestr;
begin
  counter:=0;
tareset(clindata) ;
  repeat
    tanext(clindata,clinreadings,recordname);
    if ok then
      begin
        write(clinreadings.recordname,', ');
        counter:=succ(counter);
      end;
  until not ok;
  if counter>0 then
    begin
      writeln;
      writeln(counter,'  records');
    end;
end;

procedure sortnames;
var sortresult:integer;
begin
  writeln('Beginning to sort data.');
assign(filetobesorted, datafilenm);
reset(filetobesorted);

sortresult := turbosort(sizeof(clinrecord), @inrecs, @lessrec, @outrecs);
{ sort data into alphabetical order
  of record names }

if sortresult = 0 then
  writeln('Sort was successful.' )
else
  begin
  writeln('The program has not been able to sort existing data.' );
  writeln('The error code is ', sortresult);
  writeln('Please seek assistance.' ) ;
  halt;
  end;
  close(filetobesorted);
end;

procedure calculateforces(var counter: integer);
begin
  Vl := lsb*(clinreadings.arrayl[counter] - clinreadings.zerol);
  V2 := lsb*(clinreadings.array2[counter] - clinreadings.zero2);
  V3 := lsb*(clinreadings.array3[counter] - clinreadings.zero3);
  V4 := lsb*(clinreadings.array4[counter] - clinreadings.zero4);
  V5 := lsb*(clinreadings.array5[counter] - clinreadings.zero5);
  V6 := lsb*(clinreadings.array6[counter] - clinreadings.zero6);

  Fl := gainl*V1;
  F2 := gain2*V2;
  F3 := gain3*V3;
  F4 := gain4*V4;
  F5 := gain5*V5;
  F6 := gain6*V6;
end;

procedure calculateFxy(var counter: integer);
begin
  platformlforce' [counter] := F1+F2+F3;
  platform2force' [counter] := F4+F5+F6;

  if platformlforce' [counter] > forcelowerthreshold then begin
    xplatforml'[counter] := a*(2*F2+F3)/platformlforce'[counter];
    yplatforml'[counter] := 2*b*F3/platformlforce' [counter];
    if (abs(xplatforml'[counter] - (-e))<endthreshold) and
         (platformlforce'[counter] > forceupperthreshold) then
      anyerrormessages:=true;
      stepsnearend:=true;
    end;
  end
else begin
  xplatforml'[counter] := -1;               {These values correspond to a position off}
  yplatforml'[counter] := -1;              {the edge of the platforms}
end;

  if platform2force' [counter] > forcelowerthreshold then begin
    xplatform2'[counter] := a*(2*F6+F4)/platform2force'[counter];
    yplatform2'[counter] := (d+g+d)-2*b*F4/platform2force'[counter];
    if (abs(xplatform2'[counter] - (2*a+e))<endthreshold) and
         (platform2force'[counter] > forceupperthreshold) then
      anyerrormessages:=true;
      stepsnearend:=true;
    end;
  end
else begin
  xplatform2'[counter] := -1;               {These values correspond to a position off}
  yplatform2'[counter] := -1;              {the edge of the platforms}
end;

procedure calculateerrormessages;
end;
begin
  calclowforcesteps;
  calchighlyunequalnumbersofsteps;
  calc crossover;
end;

procedure furtherprocess; {calculates measured impulse and peak force}
begin
  identifysteps; {identify the individual steps}
  calculateerrormessages;
  if lowforcesteps then
    markfirstorlaststeponeachplatformiflow;
  if stepsareend then markfirstorlaststeponeachplatformifnearend;
  if firststeponplatform1ismarked then discardfirststeponplatform1;
  if ((numberofsteponplatform1<>0) and (laststeponplatform1ismarked)) then
    discardlaststeponplatform1;
  if firststeponplatform2ismarked then discardfirststeponplatform2;
  if ((numberofsteponplatform2<>0) and (laststeponplatform2ismarked)) then
    discardlaststeponplatform2;
  calcimpulses; {integrate to find the vertical impulse of each step}
  calcpeakforces; {find the magnitudes of the largest forces in each}
    (half of each step and the minimum between them)
end;

procedure displayrecordname;
begin
c1rscr; {clear screen}
  writeln(outputdevice,
    ' '.*-.---.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.---'}
  with clinreadings do
    writeln(outputdevice,'record name=',recordname);
  writeln(outputdevice); {blank line)
end;

procedure sendrecordnametoexcelfile;
begin
  write(outputdevice,clinreadings.recordname,', ');
end;

procedure displayerrormessages;
begin
c1rscr; {clear screen)
  writeln(outputdevice,
    ' '.*-.---.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.---'}
  if anyerrormessages=false then
    begin
      writeln(outputdevice,'No error messages');
      writeln(outputdevice); {blank line
    end;
  if anyerrormessages=true then
    begin
      if wprintorfile='wait' then writeln(outputdevice, 'G, G, G); {beep beep beep)
            writeln(outputdevice,
              'THE RAW DATA HAS PROPERTIES WHICH MAY CAUSE THE CALCULATION');
            writeln(outputdevice,
              'ALGORITHMS TO GIVE MISLEADING RESULTS. THE CALCULATED PARAMETERS');
            writeln(outputdevice,
              'SHOULD THEREFORE BE TREATED WITH CAUTION');
            writeln(outputdevice); {blank line
    end;
  if lowforcesteps then
    begin
      writeln(outputdevice,
        'Some of the steps do not exceed the upper force threshold, so');
      writeln(outputdevice,
        'positions cannot be calculated for them. The positions of any');
      writeln(outputdevice,
        'of these steps not discarded are given as (-1 metre,-1 metre)');
      writeln(outputdevice,'to distinguish them');
      writeln(outputdevice); {blank line
    end;
end;
if toomanysteps then begin
  writeln(outputdevice,
    'More than ', maxnumberofsteps,
    ' steps were found on at least one of the platforms.');
  writeln(outputdevice,
    'The program can only deal with up to ', maxnumberofsteps,
    ' steps on each platform.');
  writeln(outputdevice,
    'so data beyond this has not been analysed.');
  writeln(outputdevice); {blank line}
end;

if stepsnearend then begin
  writeln(outputdevice,
    'Some of the points are within ', endthreshold:4:2, ' metres of the');
  writeln(outputdevice,
    'ends of the platforms. It may be that these steps are partially');
  writeln(outputdevice,
    'off the ends of the platform and should therefore be interpreted');
  writeln(outputdevice,
    'with care.');
  writeln(outputdevice); {blank line}
end;

if negativedoublestancetimes then begin
  writeln(outputdevice,
    'Some of the calculated double stance times are negative. This');
  writeln(outputdevice,
    'cannot be physically true.');
  writeln(outputdevice); {blank line}
end;

if highlyunequalnumbersofsteps then begin
  writeln(outputdevice,
    'After discarding any steps considered by the algorithms as invalid,
    there are ', numberofstepsplatform1, ' steps on platform 1 and
    ', numberofstepsplatform2, ' steps on platform 2. This means that the');
  writeln(outputdevice,
    'algorithms cannot have registered alternate steps.');
  writeln(outputdevice); {blank line}
end;

if crossover then begin
  writeln(outputdevice,
    'Some of the steps show a distance travelled of over ');
  writeln(outputdevice,
    'crossoverthreshold:4:2, metres. This is surprisingly large and');
  writeln(outputdevice,
    'suggests that the feet have not remained on each side of the centre');
  writeln(outputdevice,
    'line.');
  writeln(outputdevice); {blank line}
end;

if outoftime then begin
  writeln(outputdevice,
    'The subject was on the platform at the beginning or end of the');
  writeln(outputdevice,
    'sampling period');
  writeln(outputdevice); {blank line}
end;
end;

procedure senderrormessagestoexcelfile;
begin
  write(outputdevice, anyerrormessages, ',');
  write(outputdevice, lowforcesteps,',');
  write(outputdevice, toomanysteps,',');
  write(outputdevice, stepsnearend,',');
  write(outputdevice, negativedoublestancetimes,',');
  write(outputdevice, highlyunequalnumbersofsteps,',');
end;
write(outputdevice,crossover,'');
write(outputdevice,outoftime,'');
end;

procedure displaypersonaldata;
begin
clrscr;  {clear screen}
writeln(outputdevice,
'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*');
with clinreadings do
begin
writeln(outputdevice,'subject code=',subjectcode);
writeln(outputdevice,'weight=',weightinkgf:5:1, 'kg');
writeln(outputdevice,'height=',heightinm, 'm');
{ writeln(outputdevice,'date of birth=',dateofbirth));
{ writeln(outputdevice,'sex=',sex));
 writeln(outputdevice,'footwear=',footwear);
 writeln(outputdevice,'leg dominance=',legdominance);
end;
writeln(outputdevice);
{ if waprintorfile='wait' then wait;}
end;

procedure displayclericaldata;
begin
clrscr;  {clear screen}
writeln(outputdevice,
'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*');
with clinreadings do
begin
{ writeln(outputdevice,'NHS number=',NHSnumber));
 write(outputdevice,'test date='); ■
 if dayofweek=0 then write(outputdevice,'Sunday');
 if dayofweek=1 then write(outputdevice,'Monday');
 if dayofweek=2 then write(outputdevice,'Tuesday');
 if dayofweek=3 then write(outputdevice,'Wednesday');
 if dayofweek=4 then write(outputdevice,'Thursday');
 if dayofweek=5 then write(outputdevice,'Friday');
 if dayofweek=6 then write(outputdevice,'Saturday');
 write(outputdevice,' ',year);
 writeln(outputdevice,'test time=',hour,':',minute);
{ writeln(outputdevice,'first test date=',firsttestdate) ; }
end;
writeln(outputdevice); {blank line}
end;

procedure displayclinicaldata;
begin
clrscr;   {clear screen}
writeln(outputdevice,
'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*'-'*');
with clinreadings do
begin
 writeln(outputdevice,'primary pathology=',primarypathology);
 writeln(outputdevice,'secondary pathology affecting gait=',
 secondarypathologyaffectinggait);
 writeln(outputdevice,'procedure completed=',procedurecompleted);
 writeln(outputdevice,'date of procedure=',dateofprocedure);
end;
writeln(outputdevice); {blank line}
end;

procedure displaytestdata;
begin
clrscr;
writeln(outputdevice, '------------ Test data -------------');
with clinreadings do
begin
  writeln(outputdevice, 'test type=', testtype);
  writeln(outputdevice, 'comments about series=', commentsaboutseries);
  writeln(outputdevice, 'comments after trial=', commentsabouttrial);
end;
writeln(outputdevice); {blank line}
end;

procedure displayforceplatedata;
begin
  clrscr; {clear screen}
  writeln(outputdevice, '------------ Force plate data -------------');
  with clinreadings do begin
    writeln(outputdevice, 'numberofchannels=', numberofchannels);
    writeln(outputdevice, 'nominalsamplingrateperchannel=', nominalsamplingrateperchannel, 'Hz');
    writeln(outputdevice, 'actualsamplingrateperchannel=', actualsamplingrateperchannel, 'Hz');
    writeln(outputdevice, 'samplingtime=', samplingtime, 's');
    writeln(outputdevice, 'readingsperchannel=', readingsperchannel);
    writeln(outputdevice, 'zerol=', zerol, 'kgf');
    writeln(outputdevice, 'zero2=', zero2, 'kgf');
    writeln(outputdevice, 'zero3=', zero3, 'kgf');
    writeln(outputdevice, 'zero4=', zero4, 'kgf');
    writeln(outputdevice, 'zero5=', zero5, 'kgf');
    writeln(outputdevice, 'zero6=', zero6, 'kgf');
  end;
  writeln(outputdevice); {blank line}
end;

procedure displayrawdata;
begin
  for i:=1 to clinreadings.readingsperchannel do begin
    if (platform1force[i] > forceupperthreshold) then begin
      writeln(outputdevice, 'F=', platform1force[i], ' x=', 100*xplatform1[i], ' y=', 100*yplatform1[i]);
      wait;
    end;
  end;
end;

procedure formfeed;
begin
  write(outputdevice, chr(12));
end;

procedure displayforcesversustime;
begin
  entergraphic;
  setclippingon;
  definewindow(1, 0, 0, xmaxglb, ymaxglb); {window 1 to fill the whole screen}
  definewindow(2, 4, 16, xmaxglb-2, ymaxglb-14); {window 2 to fill the area within the axes}
  defineheader(1, 'Plots of vertical force/kgf versus time/s for both platforms');
  definewindow(1, 0, -10, clinreadings.samplingtime, 200); {define window in window 1 to be 0 to 200kgf}
  definewindow(2, 0, 200, clinreadings.samplingtime, -10); {to samplingtime, -10 to +200kgf}
  selectwindow(1);
  selectwindow(1);
  setbackgroundcolor(blue);
  setforegroundcolor(yellow);
  setheaderon;
  drawborder;
begin
  for i:=1 to clinreadings.readingsperchannel do
    begin
      drawpoint((i/clinreadings.readingsperchannel), clinreadings.weightinkgf);  // draw a horizontal line representing the weight of the subject
      if not pointdrawn((i/clinreadings.readingsperchannel), platform1force''[i]) then
        drawpoint((i/clinreadings.readingsperchannel), platform1force''[i]);  // plot the points from platform 1
      if (i=4*round(i/4)) and not pointdrawn((i/clinreadings.readingsperchannel), platform2force''[i]) then
        drawpoint((i/clinreadings.readingsperchannel), platform2force''[i]);  // if i is a multiple of 4, plot the points from platform 2
    end;
  gotoxy(44,2);  // move to top right of screen in preparation for message
  write('solid line: platform 1');  // write message
  if not ((numberofplstrides=0) and (numberofp2strides=0) and (leftfootwasonplatforml='T')) then writeln(' (left foot)');
  if not ((numberofplstrides=0) and (numberofp2strides=0) and (leftfootwasonplatforml='F')) then writeln(' (right foot)');
  gotoxy(44,4);  // move to top right of screen in preparation for message
  write('broken line: platform 2');  // write message
  if not ((numberofplstrides=0) and (numberofp2strides=0) and (leftfootwasonplatforml='T')) then writeln(' (left foot)');
  if not ((numberofplstrides=0) and (numberofp2strides=0) and (leftfootwasonplatforml='F')) then writeln(' (right foot)');
  flushkeyboard;
  waitprintorfile;
  leavegraphic;
end;

procedure displayxyplotsofcentreofpressure;
begin
  entergraphic;
  setclippingon;
  definewindow(1,0,0,xmaxglb,ymaxglb);  // window 1 to fill the whole screen
  definewindow(2,4,16,xmaxglb-2,ymaxglb-14);  // window 2 to fill the area within the axes
  defineheaderfl,
    'x/metres versus y/metres for centre of pressure on each platform');  // define heading for window 1
  defineworld(l, -e-0.1,-3*d-g-2*b-0.37, 2*a+e+0.1, 2*b+d+0.37);  // define world in window 1 to be -e-0.1 to 2a+e+0.1, -3d-g-2b-0.37 ie the area of the platforms plus a surround
  defineworld(2, -e-0.1, 2*b+d+0.37, 2*a+e+0.1, -3*d-g-2*b-0.37);  // define world in window 2 to be -e-0.1 to 2a+e+0.1, -3d-g-2b-0.37
  selectworld(1);
  selectwindow(1);
  setbackgroundcolor(black);
  setforegroundcolor(cyan);
  setheaderon;
  drawborder;
  drawaxis(8,-8,0,0,0,-1,-1, true);
  selectworld(2);
  selectwindow(2);
  drawplatform1;
  drawplatform2;
  for i:=1 to clinreadings.readingsperchannel do
    begin
      if platform1force''[i]>forceupperthreshold then
        drawpoint(xplatform1''[i], yplatform1''[i]);  // plot the points from platform 1
      if platform2force''[i]>forceupperthreshold then
        drawpoint(xplatform2''[i], yplatform2''[i]);  // plot the points from platform 2
    end;
  gotoxy(50,2);  // move to top right of screen in preparation for message
end;
writeln('top of screen: platform 1');
gotoxy(50,4); {move to top right of screen in preparation for message}
writeln('bottom of screen: platform 2');
if not ((numberofstepsplatform1=0) and (numberofstepsplatform2=0)) then showdirectionoftravel;
gotoxy(50,5); {move to top right of screen in preparation for message}
flushkeyboard;
waitprintorfle;
leavegraphic;
end;

procedure display3DPedotti;
{
This procedure displays diagrams of force and positional data as described by Khodadadeh (1988)
((68))
}
begin
entergraphic;
setclippingon;
definewindow(1,0,0,xmaxglb,ymaxglb);
definewindow;
defineheader(1, '3-dimensional plots of F/kgf, x/m and y/m for both platforms');
defineworld(1,0,100,100,0); {arbitrarily define world in window 1 to be 0 to 100, 0 to 100}
selectworld(1);
selectwindow(1);
setbackgroundcolor(magenta); setforegroundcolor(green);
setheaderon;
drawborder;
gotoxyd,2); {move to top left of screen in preparation for message}
writeln('length of vector represents magnitude of vertical force');
gotoxyd,4); {move to top left of screen in preparation for message}
writeln('time interval between vectors=', (1/clinreadings.nominalsamplingrateperchannel):6:4, ' seconds');
gotoxy(2,12); {go to left, 1/3 of way down screen}
writeln('platform 1');
gotoxy(2,16); {go to left, 2/3 of way down screen}
writelnf'platform 2');
drawplatformliso;
drawplatform2iso;
drawvectors;
if not ((numberofstepsplatform1=0) and (numberofstepsplatform2=0)) then showdirectionoftravel;
gotoxy(50,25); {move to bottom right of screen in preparation for message}
flushkeyboard;
waitprintorfle;
leavegraphic?
end;

procedure displayweightoneachfootinstanding;
begin
clrscr;
writeln(outputdevice, ' Weight on each foot in standing ');
writeln(outputdevice);
writeln(outputdevice,'Average weight on left foot in standing= ',clinreadings.weightonleftfootinkgf:5:1,' kgf');
writeln(outputdevice,'Average weight on right foot in standing= ',clinreadings.weightonrightfootinkgf:5:1,' kgf');
writeln(outputdevice); {blank line}
end;

procedure displaymeasuredimpulses;
begin
clrscr;
writeln(outputdevice, ' Measured vertical impulses ');
writeln(outputdevice);
for step:= 1 to numberofstepsplatform1 do begin
writeln(outputdevice,'impulse of step ',step,' on platform 1= ',709


impulseplatform1[step]:5:1,'kgf*seconds');
end;
writeln(outputdevice);
for step:= 1 to numberofstepsplatform2 do
begin
  writeln(outputdevice,'impulse of step ',step,' on platform 2=','
impulseplatform2[step]:5:1,'kgf*seconds');
end;
writeln(outputdevice); {blank line}
writeln(outputdevice,

procedure sendmeasuredimpulsestoexcelfile;
begin
for step:= 1 to numberofstepsplatform1 do
begin
  write(outputdevice,impulseplatform1[step]:5:1, ', 1)  ;
end;
for step:=numberofstepsplatform1+1 to maxnumberofsteps do
begin
  write(outputdevice,');
for step:= 1 to numberofstepsplatform2 do
begin
  write(outputdevice,impulseplatform2[step]:5:1, ', ' );
end;
for step:=numberofstepsplatform2+1 to maxnumberofsteps do
begin
  write(outputdevice, ',');
end;

procedure sendimpulseratiostoexcelfile;
var numberofratios:integer;
begin
  numberofratios:=numberofstepsplatform1;
  if numberofratios>numberofstepsplatform2 then
  numberofratios:=numberofstepsplatform2;
  for step:= 1 to numberofratios do
  begin
    write(outputdevice, ((impulseplatform2 [step]-impulseplatform1 [step])/\n(0.5*(impulseplatform2 [step]+impulseplatform1 [step]))):6:4, ', '  >

procedure sendstandingforceratiotoexcelfile;
begin
if ((clinreadings.weightonrightfootinkgf>forcelowerthreshold) and
(clinreadings.weightonleftfootinkgf>forcelowerthreshold))  then
  write(outputdevice,((clinreadings.weightonrightfootinkgf-
clinreadings.weightonleftfootinkgf)/(0.5*\ncinreadings.weightonrightfootinkgf+\ncinreadings.weightonleftfootinkgf))):6:4, ', ')\nelse write (outputdevice,'not enough force on each foot',' ','');
end;

procedure displaypeakforces;
begin
clrscr; [clear screen]
writeln(outputdevice.
Measured peak forces
writeln(outputdevice);
for step:= 1 to numberofstepsplatform1 do
begin
  writeln(outputdevice,'*** platform 1, step ',step,' ***');
  writeln(outputdevice,'beginning of step is at time=','
clinreadings.nominalsamplingrateperchannel:6:3, ' seconds');
  writeln(outputdevice,'end of step is at time=','
clinreadings.nominalsamplingrateperchannel:6:3, ' seconds');
  writeln(outputdevice);
if (endofstepplatform1[step]-beginningofstepplatform1[step])<2 then
begin
  writeln(outputdevice,'Peak forces not calculated for this step due to');
writeln(outputdevice,'*** platform 2, step ',step,' ***');
writeln(outputdevice,'beginning of step is at time=',
beginningofstepplatform2[step]/
clinreadings.nominalsamplingrateperchannel:6:3,' seconds');
writeln(outputdevice,'end of step is at time=',
endofstepplatform2[step]/
clinreadings.nominalsamplingrateperchannel:6:3,' seconds');
writeln(outputdevice);
end;
writeln(outputdevice); end;
for step:= 1 to numberofstepsplatform2 do
begin
writeln(outputdevice,firstpeakforceplatform2[step]:6:1,'kgf after ',
(fpfp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
(endofstepplatform2[step]-beginningofstepplatform2[step]):4:1,
' % of the step');
writeln(outputdevice,secondpeakforceplatform2[step]:6:1,'kgf after ',
(spfp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
(endofstepplatform2[step]-beginningofstepplatform2[step]):4:1,
' % of the step');
writeln(outputdevice,minimumforcebetweenthemplatform2[step]:6:1,'kgf after ',
(mfbtp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
(endofstepplatform2[step]-beginningofstepplatform2[step]):4:1,
' % of the step');
end;
writeln(outputdevice);
end;
end;
writepeakforcestoexcelfile;
begin
for step:= 1 to numberofstepsplatform1 do
begin
if (endofstepplatform1[step]-beginningofstepplatform1[step])<2 then
  writeln(outputdevice,'insufficient duration');
if (endofstepplatform1[step]-beginningofstepplatform1[step])>=2 then
begin
  writeln(outputdevice,'maximum force in first half of step=',
  firstpeakforceplatform1[step]:6:1,'kgf after ',
  (fpfp1samplenumber[step]-beginningofstepplatform1[step])*100.0/
  (endofstepplatform1[step]-beginningofstepplatform1[step]):4:1,
  ' % of the step');
  writeln(outputdevice,'maximum force in second half of step=',
  secondpeakforceplatform1[step]:6:1,'kgf after ',
  (spfp1samplenumber[step]-beginningofstepplatform1[step])*100.0/
  (endofstepplatform1[step]-beginningofstepplatform1[step]):4:1,
  ' % of the step');
  writeln(outputdevice,'minimum force between these two peaks',
  minimumforcebetweenthemplatform1[step]:6:1,'kgf after ',
  (mfbtp1samplenumber[step]-beginningofstepplatform1[step])*100.0/
  (endofstepplatform1[step]-beginningofstepplatform1[step]):4:1,
  ' % of the step');
end;
end;
for step:= 1 to numberofstepsplatform2 do
begin
if (endofstepplatform2[step]-beginningofstepplatform2[step])<2 then
  writeln(outputdevice,'insufficient duration');
if (endofstepplatform2[step]-beginningofstepplatform2[step])>=2 then
begin
  writeln(outputdevice,'maximum force in first half of step=',
  firstpeakforceplatform2[step]:6:1,'kgf after ',
  (fpfp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
  (endofstepplatform2[step]-beginningofstepplatform2[step]):4:1,
  ' % of the step');
  writeln(outputdevice,'maximum force in second half of step=',
  secondpeakforceplatform2[step]:6:1,'kgf after ',
  (spfp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
  (endofstepplatform2[step]-beginningofstepplatform2[step]):4:1,
  ' % of the step');
  writeln(outputdevice,'minimum force between these two peaks',
  minimumforcebetweenthemplatform2[step]:6:1,'kgf after ',
  (mfbtp2samplenumber[step]-beginningofstepplatform2[step])*100.0/
  (endofstepplatform2[step]-beginningofstepplatform2[step]):4:1,
  ' % of the step');
end;
end;
end;
end;
}
{blank line}
if (endofstepplatform2\[step\]-beginningofstepplatform2\[step\])>=2 then
write(outputdevice,firstpeakforceplatform2\[step\]:6:1,'isseur'); {variable 9b}
end;
for step:=numberofstepsplatform2+l to maxnumberofsteps do
write(outputdevice,'']);

for step:= 1 to numberofstepsplatform1 do
begin
if (endofstepplatform1\[step\]-beginningofstepplatform1\[step\]<2 then
write(outputdevice,'insufficient duration',',');
if (endofstepplatform1\[step\]-beginningofstepplatform1\[step\])>=2 then
write(outputdevice,secondpeakforceplatform1\[step\]:6:1,'isseur');{variable 10a}
end;
for step:=numberofstepsplatform1+l to maxnumberofsteps do
write(outputdevice,'']);

for step:= 1 to numberofstepsplatform2 do
begin
if (endofstepplatform2\[step\]-beginningofstepplatform2\[step\]<2 then
write(outputdevice,'insufficient duration',',');
if (endofstepplatform2\[step\]-beginningofstepplatform2\[step\])>=2 then
write(outputdevice,secondpeakforceplatform2\[step\]:6:1,'isseur');{variable 10b}
end;
for step:=numberofstepsplatform2+l to maxnumberofsteps do
write(outputdevice,'']);

for step:= 1 to numberofstepsplatform1 do
begin
if (endofstepplatform1\[step\]-beginningofstepplatform1\[step\])<2 then
write(outputdevice,minimumforcebetweenthemplatform1\[step\]:6:1,'isseur');
{variable 11a}
end;
for step:=numberofstepsplatform1+l to maxnumberofsteps do
write(outputdevice,'']);

for step:= 1 to numberofstepsplatform2 do
begin
if (endofstepplatform2\[step\]-beginningofstepplatform2\[step\])<2 then
write(outputdevice,minimumforcebetweenthemplatform2\[step\]:6:1,'isseur');
{variable 11b}
end;
for step:=numberofstepsplatform2+l to maxnumberofsteps do
write(outputdevice,'']);

for step:= 1 to numberofstepsplatform1 do
begin
if (endofstepplatform1\[step\]-beginningofstepplatform1\[step\])<2 then
write(outputdevice,'insufficient duration',',');
if (endofstepplatform1\[step\]-beginningofstepplatform1\[step\])>=2 then
write(outputdevice,minimumforcebetweenthemplatform1\[step\]:6:1,'isseur');
{variable 12}
end;
for step:=numberofstepsplatform1+l to maxnumberofsteps do
write(outputdevice,'']);

for step:= 1 to numberofstepsplatform2 do
begin
if (endofstepplatform2\[step\]-beginningofstepplatform2\[step\])<2 then
write(outputdevice,'insufficient duration',',');
if (endofstepplatform2\[step\]-beginningofstepplatform2\[step\])>=2 then
write(outputdevice,minimumforcebetweenthemplatform2\[step\]:6:1,'isseur');
{variable 12}
end;
for step:=numberofstepsplatform2+l to maxnumberofsteps do
write(outputdevice,'']);
for step:=numberofstepsplatforml+1 to maxnumberofsteps do
write(outputdevice,');
for step:=numberofstepsplatform2+1 to maxnumberofsteps do
write(outputdevice,');

procedure sendpeakforceratiostoexcelfile;
var counter,numberofratios: integer;
begin
numberofratios:=numberofstepsplatforml;
if numberofstepsplatform2<numberofratios then
numberofratios:=numberofstepsplatform2;
for step:= 1 to numberofratios do
begin
if ((endofstepplatforml[step]-beginningofstepplatforml[step])<2) or
((endofstepplatform2[step]-beginningofstepplatform2[step])<2) then
write(outputdevice,'insufficient duration',',');
if ((endofstepplatforml[step]-beginningofstepplatforml[step])>=2) and
((endofstepplatform2[step]-beginningofstepplatform2[step])>=2) then
write(outputdevice,
((firstpeakforceplatforml[step]-firstpeakforceplatforml[step])/(0.5*
(firstpeakforceplatform2[step]+firstpeakforceplatforml[step]))):6:4,
', '); (variable 6)
end;
for step:=numberofratios+1 to maxnumberofsteps do
write(outputdevice,');
for step:= 1 to numberofratios do
begin
if ((endofstepplatforml[step]-beginningofstepplatforml[step])<2) or
((endofstepplatform2[step]-beginningofstepplatform2[step])<2) then
write(outputdevice,'insufficient duration',',');
if ((endofstepplatforml[step]-beginningofstepplatforml[step])>=2) and
((endofstepplatform2[step]-beginningofstepplatform2[step])>=2) then
write(outputdevice,
((secondpeakforceplatform2[step]-secondpeakforceplatforml[step])/(0.5*
(secondpeakforceplatform2[step]+secondpeakforceplatforml[step]))):6:4,
', '); (variable 7)
end;
for step:=numberofratios+1 to maxnumberofsteps do
  write(outputdevice,',');

for step:=1 to numberofratios do
  begin
    if ((endofstepplatform1[step]-beginningofstepplatform1[step])<2) or
       ((endofstepplatform2[step]-beginningofstepplatform2[step])<2) then
      write(outputdevice,'insufficient duration',',');

    if ((endofstepplatform1[step]-beginningofstepplatform1[step])>=2) and
       ((endofstepplatform2[step]-beginningofstepplatform2[step])>=2) then
      write(outputdevice,
            ((minimumforcebetweenthemplatform2[step]-
              minimumforcebetweenthemplatform1[step])/0.5*
              (minimumforcebetweenthemplatform2[step]+
              minimumforcebetweenthemplatform1[step])):6:4,*,1); (variable 8)
  end;
for step:=numberofratios+1 to maxnumberofsteps do
  write(outputdevice,'');
end;

program uosgws5e;
PROGRAM MUST BE COMPILED FROM DOS USING THE TURBOPASCAL 5.0 COMMAND LINE
[COMPILE (TPC UOSGW5E). OTHERWISE THE TIMING OF THE DATA ACQUISITION IS
INCORRECT]

[$^+$] {put into 8087 mode, ie enable maths}
{coprocessor}

uses crt,dos,gdriver,printer,gkernel,window,gshell,taccess,tahigh,sort;
{the programme uses the 'crt' interface}
{and the 'taccess' and 'tahigh' units from}
{the Turbo Pascal database toolbox}

[$1 c:\j anebarr\z_uosgws\uosgws5\uosgws5.t yp] {include the file uosgws5.t yp, containing}
{the record and key definitions for the}
{database aspect of the programme}

[$1 c: \j anebarr\z_uosgws\PC HEADT] {These are header files that must be used}
{in source files for programmes that}
{access the PCI-20026S-3 Software Drivers}
{routines, ie they relate to the data}
{capture aspect of the programme}

[$1 c: \j anebarr\z_uosgws\uosgws5\uosgws5a] {These are the other parts of this}
[$1 c: \j anebarr\z_uosgws\uosgws5\uosgws5b] {program, which was divided solely}
[$1 c: \j anebarr\z_uosgws\uosgws5\uosgws5c] {due to space constraints}

{*SECOND LEVEL*}

procedure titlepage;
begin
  entergraphic;
  setclippingon;
  definewindow(1,0,0,xmaxglb,ymaxglb); [window 1 to fill the whole screen]
  definewindow(2,4,16,xmaxglb-4,ymaxglb-16); [window 2 to fit inside window 1]
  [leaving a border]
  defineheader(1,'written by Jane Barrance, 1991-2');
  [define heading for window 1]
  selectworld(1);
  selectwindow(1);
  setbackgroundcolor(magenta);
  setforegroungcolor(white);
  showheader;
  drawborder;
  selectwindow(2);
  drawborder;
  gotoxy(10,6);
  writeln('******************************************************************************');
  gotoxy(10,7);
  writeln('******** UNIVERSITY OF SURREY GAIT ASSESSMENT WALKWAY **********');
  gotoxy(10,8);
  writeln('******************************************************************************');
  gotoxy(10,12);
  writeln('************ Questions should be directed to: ************');
  gotoxy(10,13);
procedure initialiseSystem;
var gain, zerochannel, range, channelnumber: integer;
begin;
  sysinit; {This calls a function from the)
  {PCI-20026S-3 Software Drivers routines)
  {to initialize the software}
  finderror; {This initializes (numbers the channels)
  init($ce00); {of) the PCI-20098C carrier board, which)
  {is the only board in the system. The}
  {numbers start at 0. All the analogue}
  {input channels are initially configured}
  {as single-ended, +/-10V range, gain of}
  {1, with no automatic zero-offset}
  {correction.}
  finderror; {set the gain to be unity}
  gain:=1; {disable hardware auto-zero function}
  zerochannel := -1; {+/-5V single-ended}
  range:=4;
  for channelnumber:=1 to 6 do
  begin
    cnfai(channelnumber, gain, zerochannel, range); {configure analogue input}
    {channels 1 to 6 to the above}
    {values}
    finderror;
  end;
end;

procedure opendataset(var clindata:dataset);
begin
  writeln('trying to open dataset');
  taopen(clindata, {data set variable of type 'dataset'}
  datafilenm, {name of the data file}
  sizeof(clinrecord), {size of the data record to be}
  indexfilenm, {name of the index file}
  sizeof(clinreadings.recordname)-1); {length of the key to be stored in}
  {the index file}
  case ok of
    true: writeln('succeeded in opening dataset');
    false: {files are not there}
    begin
      writeln('trying to create dataset');
      tacreate(clindata, {data set variable of type 'dataset'}
      datafilenm, {name of the data file}
      sizeof(clinrecord), {size of the data record to be}
      indexfilenm, {name of the index file}
      sizeof(clinreadings.recordname)-1); {length of the key to be}
      {stored in the index file}
      if ok=true then writeln('succeeded in creating dataset');
      end;
      if ok=false then abort('could not create dataset');
      end;
end;
procedure initialisevariables;
begin
  with clinreadings do
  begin
    recordname:='';
    subjectcode:='';
    weightonleftfootinkgf:=0;
    weightonrightfootinkgf:=0;
    weightinkgf:=0;
    heightinm:='';
    dateofbirth:='not used';
    sex:='';
    footwear:='';
    legdominance:='';
  end;
end;

procedure initialisesomevariables;
begin
end;
procedure examineRecordorQuit;
begin
  writeln('Type "e" to examine existing data, "r" to record new data, or "q" to quit');
  writeln('');
  exrecorq:=?'?';
  flushkeyboard;
  while (exrecorqO 'e') and (exrecorqO 'E') and
    (exrecorqO 'r') and (exrecorqO 'R') and
    (exrecorqO 'q') and (exrecorqO 'Q') do
    exrecorq:=readkey;
end;

procedure recallData;
var
  searchname:namestr;
  option:char;
begin
  writeln('Type "y" to display a list of record names, or anything else to display no list');
  readln(option);
  if (option='y') or (option='Y') then listnames;
  writeln('Please enter the record name');
  readln(searchname);
  taread(clindata, clinreadings, searchname, true); {data set variable}
  {database record which is returned}
  {key to the record}
  {I am looking for an exact match}
  while ok=false do
    begin
      writeln('no record found with the name ',searchname);
      writeln('re-enter name or type q to quit');
      readln(searchname);
      taread(clindata, clinreadings, searchname, true); {data set variable}
      {database record which is returned}
      {key to the record}
      {I am looking for an exact match}
      if searchname='q' then halt;
    end;
  rewrite(recnmfl);
  write[recnmfl,searchname];
  close(recnmfl);
end;

procedure recallSpecifiedData;
var
  searchname:namestr;
begin
  reset(recnmfl);
  readln(recnmfl,searchname);
  close(recnmfl);
  if searchname='?' then
    begin
      writeln ('You must first choose some data');
      wait;
      halt;
    end;
  taread(clindata, clinreadings, searchname, true); {data set variable}
  {database record which is returned}
  {key to the record}
true); (.boolean value set to true because)

if ok=false then
begin
writeln('No record found with the name ', searchname);
writeln('Please seek assistance');
wait;
halt;
end;
end;

procedure doexperiment;
begin
zero;
measureweight;
promptoperatorortostarttest;
operatorstartstest;
recorddatafromwalkway;
{ comments about trial; }
end;

procedure processdata;
var counter:integer;
begin
writeln('Beginning to process data');
for counter:=1 to clinreadings.readingsperchannel do
begin

calculateforces(counter); { calculates the individual forces on the
{ transducers}

calculateFxy(counter); { calculates instantaneous values of force
{ and position of centre of pressure}
end;
if platform1force[1] > forcelowerthreshold then
begin
anyerrormessages:=true;
outoftime:=true;
firststeponplatform1ismarked:=true;
platform1force[1]:=0;
xplatform1[1]:=l;
yplatform1[1]:=l;
end;
if platform1force[clinreadings.readingsperchannel] > forcelowerthreshold then
begin
anyerrormessages:=true;
outoftime:=true;
laststeponplatform1ismarked:=true;
platform1force[clinreadings.readingsperchannel]:=0;
xplatform1[clinreadings.readingsperchannel]:=l;
yplatform1[clinreadings.readingsperchannel]:=l;
end;
if platform2force[1] > forcelowerthreshold then
begin
anyerrormessages:=true;
outoftime:=true;
firststeponplatform2ismarked:=true;
platform2force[1]:=0;
xplatform2[1]:=l;
yplatform2[1]:=l;
end;
if platform2force[clinreadings.readingsperchannel] > forcelowerthreshold then
begin
anyerrormessages:=true;
outoftime:=true;
laststeponplatform2ismarked:=true;
platform2force[clinreadings.readingsperchannel]:=0;
xplatform2[clinreadings.readingsperchannel]:=l;
yplatform2[clinreadings.readingsperchannel]:=l;
end;
end;
calchighlyunequalnumbersofsteps;
end;

procedure rotatedatal80degrees;
var
counter,dummyreading:integer;
dummyzero:double;
begin	dummyzero:=clinreadings.zero1;
clinreadings.zero1:=(gain6/gain1)*clinreadings.zero6;
clinreadings.zero6:=(gain1/gain6)*dummyzero;
dummyzero:=clinreadings.zero2;
clinreadings.zero2:=(gain5/gain2)*clinreadings.zero5;
clinreadings.zero5:=(gain2/gain5)*dummyzero;
dummyzero:=clinreadings.zero3;
clinreadings.zero3:=(gain4/gain3)*clinreadings.zero4;
clinreadings.zero4:=(gain3/gain4)*dummyzero;
for counter:=1 to clinreadings.readingsperchannel do
begin	dummyreading:=clinreadings.array1[counter];
clinreadings.array1[counter]:=round((gain6/gain1)*clinreadings.array6[counter]);
clinreadings.array6[counter]:=round((gain1/gain6)*dummyreading);
dummyreading:=clinreadings.array2[counter];
clinreadings.array2[counter]:=round((gain5/gain2)*clinreadings.array5[counter]);
clinreadings.array5[counter]:=round((gain2/gain5)*dummyreading);
dummyreading:=clinreadings.array3[counter];
clinreadings.array3[counter]:=round((gain4/gain3)*clinreadings.array4[counter]);
clinreadings.array4[counter]:=round((gain3/gain4)*dummyreading);
end;
end;

procedure directdatatoscreen;
begin
assign(outputdevice,'.');[set output device to be screen]
rewrite(outputdevice);
waprintorfile:='wait';
end;

procedure displayheading;
begin
clrscr;
writeln(outputdevice,'*_*_ Data from University of Surrey gait assessment walkway *_*');
writeln(outputdevice, '--- Data from University of Surrey gait assessment walkway ---');
writeln(outputdevice);
end;

procedure displaydata(var counter:integer);
begin
if counter=1 then begin
write(outputdevice,chr(27),'3',chr(36));[change line spacing to 1/6"
displayheading;
end;
if counter=2 then displayrecordname;
if counter=3 then
begin
displayforcesversustime;
writeln(outputdevice);[blank line]
writeln(outputdevice);[blank line]
end;
if counter=4 then begin
displayxyplotsofcentreofpressure;
if waprintorfile='wait' then formfeed;
end;
if counter=5 then
begin
display3DPedotti;
if waprintorfile='wait' then
  write(outputdevice,chr(27), '3', chr(36)); (change line spacing to 1/6")
eend;
if counter=6 then displayerrormessages;
if counter=7 then displaypersonaldata;
if counter=8 then displayclericaldata;
{ displayclinicaldata;}
if counter=9 then displaytestdata;
if counter=10 then displayforceplatedata;
{ displayrawdata;}
if counter=11 then displayweightoneachfootinstanding;
if counter=12 then displaytemporaldistancefactors;
if counter=13 then displaypeakforces;
if counter=14 then
begin
displaymeasuredimpulses;
  if waprintorfile='print' then formfeed; (to prevent the laser printer)
  {from hanging up}
end;
end;

procedure printornot;
begin
writeln('Do you want the results printed out on paper?');
writeln('Type "Y" for yes or "N" for no.');
writeln('');
pronot:='?';
flushkeyboard;
while (pronot<>'y') and (pronot<>'Y') and (pronot<>'n') and
  (pronot<>'N') do
  pronot:=readkey;
end;

procedure makefileornot;
begin
writeln('Do you want to send the results to a file to be printed later?');
writeln('Type "Y" for yes or "N" for no.');
writeln('');
mfornot:='?';
flushkeyboard;
while (mfornot<>'y') and (mfornot<>'Y') and (mfornot<>'n') and
  (mfornot<>'N') do
  mfornot:=readkey;
end;

procedure directdatatoprinter;
begin
  waprintorfile:='print';
  assign(outputdevice,'prn'); (set output device to be printer)
  rewrite(outputdevice);
end;

procedure directdatatoprintfile;
begin
  waprintorfile:='file';
  assign(outputdevice,'d:\janebarr\prinfil\'+clinreadings.recordname);
  rewrite(outputdevice);
end;

procedure directdatatoexclfile;
var
typedname:string;
fileexists:boolean;
begin
  waprintorfile:='file';
typedname:='gaitdata';
  assign(outputdevice,'d:\janebarr\exclfile\'+typedname+'xl');
  append(outputdevice);
end;
fileexists:=(IOresult=0) and (typename<> '');
if not fileexists then rewrite(outputdevice);
    {if the file does not exist, create it}
end;

procedure setlastrecordcurrent;
var
    lastrecordname:namestr;
begin
    lastrecordname:=clinreadings.recordname;
    rewrite(recnmfl);
    write(recnmfl,lastrecordname);
    close(recnmfl);
end;

fileexists:=(IOresult=0) and (typednameO'  ');
if not fileexists then rewrite(outputdevice);
    {if the file does not exist, create it}
end;

procedure freememory;
begin
    dispose(platformlforce); platformlforce:=nil;
    dispose(platform2force); platform2force:=nil;
    dispose(xplatforml); xplatforml:=nil;
    dispose(xplatform2); xplatform2:=nil;
    dispose(yplatforml); yplatforml:=nil;
    dispose(yplatform2); yplatform2:=nil;
end;

procedure remindoperator;
begin
    clrscr;
    writeln('TO RERUN THE PROGRAM, TYPE "GO"');
    writeln;
    writeln('When you have finished using the system, type "bye" and then "y".');
    writeln('When "please remove power from the system" is displayed, switch');
    writeln('off the monitor (at bottom right corner of screen) but do not');
    writeln('switch off the computer.');
    writeln;
    writeln;
    writeln('DO NOT SWITCH OFF THE COMPUTER UNTIL THE "PLEASE REMOVE POWER FROM"');
    writeln('DO NOT MOVE THE COMPUTER WITHOUT FIRST SWITCHING IT OFF.');
    writeln;
    writeln('To restart the system, hold down "ctrl" and "alt" and press.');
    writeln('delete."');
    writeln;
end;

("PRIMARY LEVEL")

procedure findextantrecord;
begin
    taerrorproc:=@cleanup; {execute procedure 'cleanup'in case of fatal}
    clrscr; {clear screen}
    initialiseystem; {opens the data set containing the}
    opendataset(clindata); {clinical data if it exists, and creates}
    {it if it does not}
    initialisevariables;
    recalldata;
    cleanup;
    freememory;
end;

procedure displayonscreen;
var
    counter:integer;
    nextpreviousorquit:char;
begin
    taerrorproc:=@cleanup; {execute procedure 'cleanup'in case of fatal}
    clrscr;
    initialiseystem;

opendataset(clindata); {opens the data set containing the clinical data if it exists, and creates it if it does not}
initialisevariables;
initgraphic;
leavegraphic;
recallspecifieddata; {recall existing data}
cleanup; {close the files}
processdata;
directdatatoscreen;
writeln('Press "n" to go to next part, "p" to go to previous part or ');
writeln("'q' to quit displaying data on the screen');
wait;
counter:=1;
while (nextpreviousorquit<>'q') and (nextpreviousorquit<>'Q') do
begin
nextpreviousorquit:='?';
flushkeyboard;
while (nextpreviousorquit<>'n') and (nextpreviousorquit<>'N')
and (nextpreviousorquit<>'p') and (nextpreviousorquit<>'P')
and (nextpreviousorquit<>'q') and (nextpreviousorquit<>'Q') do
nextpreviousorquit:=readkey;
if (nextpreviousorquit='n') or (nextpreviousorquit='N')
then counter:=counter+1;
if (nextpreviousorquit='p') or (nextpreviousorquit='P')
then counter:=counter-1;
if (nextpreviousorquit='n') or (nextpreviousorquit='N')
or (nextpreviousorquit='p') or (nextpreviousorquit='P')
then begin
if counter=15 then counter:=1;
if counter=0 then counter:=14;
displaydata(counter);
if (counter=3) or (counter=4) or (counter=5) then
writeln('Press "n" to go to next part, "p" to go to previous part or ');
writeln("'q' to quit displaying data on the screen');
end;
end;
freememory;
end;

procedure recordnewdataabbreviateddisplay;
var
    numberoftrials,trialsrecorded:integer;
    accepttrial:char;
begin
    taerrorproc:=@cleanup; {execute procedure 'cleanup'in case of fatal error}
crscr;
initialisesystem;
initialisevariables;
initgraphic;
leavegraphic;
writeln('How many trials in this series?');
readln(numberoftrials);
trialsrecorded:=0;
operatorchoosesamplingtime;
{ operatorenteresamplingtime }
while trialsrecorded<numberoftrials do
begin
    initialiseerrormessages;
doeexperiment; {record new data}
    processdata;
directdatatoscreen;
displayforceversustime;
displayxyplotsofcentreofpressure;
displayerrormessages;
writeln('Do you want to accept this trial?');
writeln('Type "Y" for yes or "N" for no');
writeln('');
accepttrial:='?';
flushkeyboard;
while (accepttrial<>'y') and (accepttrial<>'Y') and (accepttrial<>'n') and
(accepttrial<>'N') do
accepttrial:=readkey;
if (accepttrial='y') or (accepttrial='Y') then
begin
opendataset(clindata); {opens the data set containing the} {clinical data if it exists, and creates} {it if it does not}
recorddatatofile;
setlastrecordcurrent; {sets the last record to be the current record} {at the top of the menu screen}
trialsrecorded:=trialsrecorded+l;
writeln('Number of trials recorded so far=', trialsrecorded, ' of ', numberoftrials);
wait;
end;
end;

freememory;
end;
opendataset{clindata); {opens the data set containing the} {clinical data if it exists, and creates} {it if it does not}

procedure recordnewdatadetaileddisplay;
var
counter:integer;
numberoftrials,trialsrecorded:integer;
nextpreviousorquit,accepttrial:char;
begin
errorproc:=@cleanup; {execute procedure 'cleanup'} {in case of fatal error}
clearscr; {clear screen}
initialisesystem;
initialisevariables;
initgraphic;
leavegraphic;
writeln('How many trials in this series?');
readln(numberoftrials);
trialsrecorded:=0;
operatorchoosesamplingtime;
{ operator enters data;}
while trialsrecorded<numberoftrials do
begin
initialiseromessages;
doexperiment; {record new data}
processdata;
directdatatoscreen;
writeln(outputdevice,'Press "n" to go to next part, "p" to go to previous part or');
writeln(outputdevice,'"q" to quit displaying data on the screen');
wait;
counter:=1;
repeat
begin
nextpreviousorquit:='?';
flushkeyboard;
while (nextpreviousorquit<>n) and (nextpreviousorquit<>N) and (nextpreviousorquit<>p) and (nextpreviousorquit<>P) and (nextpreviousorquit<>q) and (nextpreviousorquit<>Q) do
nextpreviousorquit:=readkey;
if (nextpreviousorquit=n) or (nextpreviousorquit=N) then counter:=counter+1;
if (nextpreviousorquit=p) or (nextpreviousorquit=P) then counter:=counter-1;
if counter<15 then counter:=15;
if counter=0 then counter:=14;
displaydata(counter);
if (counter=3) or (counter=4) or (counter=5) then
begin
writeln(outputdevice,'Press "n" to go to next part, "p" to go to previous part or');
writeln(outputdevice,'"q" to quit displaying data on the screen');
end;
end;
until (nextpreviousorquit=q) or (nextpreviousorquit=Q);
writeln('Do you want to accept this trial?');
writeln('Type "Y" for yes or "N" for no');
accepttrial:=?;
flushkeyboard;
while (accepttrial=<y) and (accepttrial><Y) and (accepttrial=<n) and (accepttrial><N) do
accepttrial:=readkey;
end;
if (accepttrial='y') or (accepttrial='Y') then
begin
  opendataset(clindata);  
  recorddatatofile;  
  setlastrecordcurrent;  
  trialsrecorded:=trialsrecorded+l;
  writeln('Number of trials recorded so far= ', trialsrecorded,' of ', numberoftrials);
  wait;
end;
end;
freememory;
end;

procedure printdata;
var counter:integer;
begin
  taerrorproc:=@cleanup;
  clrscr;
  initialisesystem;
  opendataset(clindata);
  initialisevariables;
  initgraphic;
  leavegraphic;
  recallspecifieddata;
  cleanup;
  processedata;
  directdatatoprinter;
  for counter:=l to 14 do if (counter<>7) and (counter<>9) then displaydata(counter);
  freememory;
end;

procedure makeprintfile;
var counter:integer;
begin
  taerrorproc:=@cleanup;
  clrscr;
  initialisesystem;
  opendataset(clindata);
  initialisevariables;
  initgraphic;
  leavegraphic;
  recallspecifieddata;
  cleanup;
  processedata;
  directdatatoprintfile;
  for counter:=l to 14 do displaydata(counter);
  close(outputdevice);
  freememory;
end;

procedure makeexcelfile;
begin
  taerrorproc:=@cleanup;
  clrscr;
  initialisesystem;
  opendataset(clindata);
  initialisevariables;
  initgraphic;
  leavegraphic;
  recallspecifieddata;
  cleanup;
  processedata;
  directdatatoprintfile;
  for counter:=l to 14 do displaydata(counter);
  freememory;
end;
clrscr;
initialisesystem;
open dataset(clindata);
initialise variables;
recalls specified data;
cleanup;
processed data;
if left foot was on platform = 'F' then
begin
    rotatedata180 degrees;
    initialise some variables;
    processed data;
end;
direct datato excel file;
send record name to excel file;
send temporal distance factorsto excel file;
{ variables 1 to 5}
send peak force ratiosto excel file;
{ variables 6 to 8}
send measured impulse to excel file;
{ variable 14}
send standing force ratio to excel file;
write(output device,'end of line');
close(output device);
free memory;
end;

[*THIRD LEVEL (parameter switching)*]
begin
    if paramcount<>1 then
    begin
        writeln('An incorrect number of parameters (',paramcount,' ) have been used.');
        writeln('Please seek assistance');
        wait;
        halt;
    end;
    assign(recnmfl, 'recnmfl');
    if paramstr(1)='INIT' then
    begin
        rewrite(recnmfl);
        write(recnmfl,'7');
        close(recnmfl);
    end;
    if paramstr(1)='FER' then findextant record;
    if paramstr(1)='DOS' then display on screen;
    if paramstr(1)='RNDAD' then record new data abbreviated display;
    if paramstr(1)='PD' then print data;
    if paramstr(1)='M?F' then make print file;
    if (paramstr(1)<> 'INIT') and (paramstr(1)<> 'FER') and (paramstr(1)<> 'DOS')
        and (paramstr(1)<> 'RNDAD') and (paramstr(1)<> 'RNDAD')
        and (paramstr(1)<> 'PD') and (paramstr(1)<> 'M?F') and (paramstr(1)<> 'M?F')
    then writeln('The parameter ''',paramstr(1),
        ' is not recognised. Please seek assistance');
end.
Appendix 6.4: materials costs of system

Materials (excluding VAT)
Top plates
Package of Vox 501 adhesive, 2 x 825ml canisters, quantity 2
(Permabond Adhesives)
£198

8' x 4' x 0.5" Aerolam 'M'' board aluminium honeycomb sandwich
£165

SWG 14 S1-C bending grade aluminium sheet, 6' x 3', quantity 1 +
SWG 14 S1-C bending grade aluminium sheet, 8' x 4', quantity 3
(CBA metals)
£157.40

Aluminium angle 5/8" x 5/8" x 1/8", 13 foot length, quantity 5
(CBA metals)
£48

SWG 18 NS4 grade aluminium sheet, 8' x 4', quantity 1
(CBA metals)
£32.60

Package of 10 mixing nozzles for Vox 501 adhesive, quantity 1
(Permabond Adhesives)
£18.76

SWG 20 NS4 grade aluminium sheet, 6' x 3', quantity 1
(CBA metals)
£17.00

Araldite 2005 adhesive, 0.5kg pack (Ciba Geigy)
£9.42

TOTAL
£646.18

Transducers
Novatech F241 +/-300kgf force transducers without calibration curve, quantity 6 (Novatech)
£1974

Amplification/filtering
Alpha rack (basic 19" rack with motherboard), quantity 1
£245
Alpha P (power supply module), quantity 1
£150
Alpha B (2 channel pre-amplifier with 2-pole low-pass filters), quantity 3 @ £885
£885
Special 2 channel 4 pole low-pass Butterworth filter, quantity 3 @ £332.50
£997.50
Alpha blank panel, quantity 4 @ £10
£40
(All from CIL electronics)
£2317.50

19" racking case, style 2, type 3U, catalogue number 501-165
(RS Components)
£80.96

TOTAL
£2397.96

Signal capture hardware
PCI 20098C-1 carrier board, quantity 1 (Industrial Data Processing)
£840

Software
PCI 20026S-C software tools for Turbo Pascal, quantity 1
(Industrial Data Processing)
£175
Fixings
M6 x 20 socket countersunk screws, quantity 40 (Margnor) £4.34
M8 x 60 socket countersunk screws, quantity 20 (Margnor) £10.38
T1040L Rawl throughbolts, quantity 25 (F.P. Hartings) £25
estimate for materials supplied from departmental stores £50
TOTAL £89.72

Electrical safety
Circuit breaker catalogue number 415-749 (RS Components), 100m reel. £17.59
Earthing cable catalogue number 363-250 (RS Components), quantity 1 £13.21
Solder tags, RS catalogue number 533-011 (University of Surrey Electronic and Electrical Engineering Department Stores), 4 at 4p each £0.16
Estimate for other materials for earthing plates supplied by University of Surrey Mechanical Engineering Department Stores £5
28 x 25mm x 3m trunking, quantity 4, catalogue number 619-250 (RS Components) £36.64
Internal angles for trunking, 38mm x 25mm, quantity 10 catalogue number 605-504 (RS Components) £11.13
16 x 16mm trunking, quantity 6, catalogue number 619-222 (RS Components) £29.04
Flat angles for trunking, 16mm x 16mm, quantity 10 catalogue number 605-396 (RS Components) £3.12
TOTAL £115.89

Safety stops
6mm thick 20" square solid rubber sheet (Payne Products), quantity 1 £10.00
1 foot x 4 foot x 25mm plywood (University of Surrey Maintenance Stores) £10.08
TOTAL £20.08

Wooden surround
linoleum, approximately 30 feet x 6 feet, supplied and fitted £390
22mm thick flooring 8 feet x 2 feet, quantity 10 (Harcros Timber Merchants) £64.00
5.5" x 1" sawn timber x 200ft (Harcros Timber Merchants) £36.00
Estimate for other materials supplied from Mechanical Engineering Department, University of Surrey £50
TOTAL £540

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**Electrical connections**

PCI 20024T-1 screw termination panel, quantity 1 (Industrial Data Processing) £140

PCI 20008A-1 cable, quantity 1 (Industrial Data Processing) £65

Metal case style 1 300mm x 200mm x 100mm, catalogue number 502-685, quantity 1 £33.49

BNC cable plug, catalogue number 455-624, quantity 24 (RS Components) £33.12

Radio frequency cable, catalogue number 388-237, quantity 1 (RS Components) £21.49

BNC bulkhead jack RS number 477-135, quantity 6 (RS Components) £1.91

**TOTAL** £295.01

**Computer workstation**

Secure work-station, catalogue number 3814-1 (Inmac) £499

**Computer**

Mini-tower 486-33 with 110Mb hard disc, 4Mb RAM, Super VGA monitor, 1.2Mb 5.25" and 1.44Mb 3.5" floppy discs (Mesh Computers and Electronics) £1729

**Printer**

Star Laser 8 III Starscript laser printer (BATS Nationwide) £1299
Appendix 7.1: Documentation of data

The data from chapter 3 is documented below in order that it can be analysed further if desired.

The data is situated on the hard disc of the Mesh 486 computer in the gait lab 48 AC 20 of the University of Surrey. Each traverse is stored as a record in a file recorded using the Turbo Pascal Database Toolbox 4.0. To access the data, one must change the file names (*.dat, *.idx) in UOSGWS5A.PAS to the desired values, then re-compile and run UOSGWS5, probably by running the 'go' batch file. The data can then be recalled, viewed on screen and printed out. To plot graphs or perform statistical analysis on the data, it is necessary to amend the 'makeexcelfile' procedure in UOSGWS5 as appropriate, then to export the data traverse by traverse to Excel (by selecting each record, sending it to Excel, selecting the next one etc.). It is possible to automate this process using a batch file. The data is now in a text file. To import it to Excel, one must set the text file settings (in the file open option) to comma-separated, DOS format, then open the file gaitdata.dat, then copy the data into a spreadsheet for analysis.

Determination of source of poor dynamic behaviour of platform 2
floppy disc 'gait data 11', 16/8/93

Run direction
'swapped' position
1110 weight = 67.8kg
1111>
1112<

floppy disc 'gait data 12', 16/8/93:
1114>
1113<
1115>
1116<
1117>
Consistency tests

Subject 16
clin5.dat, clin5.idx, 7/4/92

Run direction
4 >
5 <
6 >
7 <
8 >
9 <
10 >
11 <
12 >
13 <
14 >
15 <
Subject 16 second trial
uosgws1.dat, .idx, 29/4/92

Run direction speed
90 >
91 <
92 >
93 <
94 >
95 <
96 >
Subject 17, first test
clin6.dat, clin6.idx, 7/4/93

Run _______ direction
4      >
5      <
Subject 17, second test
clin7.dat, clin7.idx, 13/4/92

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>&gt;</td>
</tr>
<tr>
<td>7</td>
<td>&lt;</td>
</tr>
<tr>
<td>8</td>
<td>&gt;</td>
</tr>
<tr>
<td>9</td>
<td>&lt;</td>
</tr>
<tr>
<td>10</td>
<td>&gt;</td>
</tr>
<tr>
<td>11</td>
<td>&lt;</td>
</tr>
<tr>
<td>12</td>
<td>&gt;</td>
</tr>
<tr>
<td>13</td>
<td>&gt;</td>
</tr>
<tr>
<td>14</td>
<td>&lt;</td>
</tr>
<tr>
<td>15</td>
<td>&lt;</td>
</tr>
<tr>
<td>16</td>
<td>&gt;</td>
</tr>
<tr>
<td>17</td>
<td>&lt;</td>
</tr>
<tr>
<td>18</td>
<td>&gt;</td>
</tr>
<tr>
<td>19</td>
<td>&lt;</td>
</tr>
<tr>
<td>20</td>
<td>&gt;</td>
</tr>
<tr>
<td>21</td>
<td>&lt;</td>
</tr>
<tr>
<td>22</td>
<td>&gt;</td>
</tr>
<tr>
<td>23</td>
<td>&lt;</td>
</tr>
<tr>
<td>24</td>
<td>&gt;</td>
</tr>
<tr>
<td>25</td>
<td>&gt;</td>
</tr>
<tr>
<td>26</td>
<td>&lt;</td>
</tr>
<tr>
<td>27</td>
<td>&gt;</td>
</tr>
<tr>
<td>28</td>
<td>&lt;</td>
</tr>
<tr>
<td>29</td>
<td>&gt;</td>
</tr>
<tr>
<td>30</td>
<td>&lt;</td>
</tr>
<tr>
<td>31</td>
<td>&gt;</td>
</tr>
<tr>
<td>32</td>
<td>&lt;</td>
</tr>
</tbody>
</table>
Subject 25
uosgws4.dat, .idx, 7/10/92

Run    direction

102    weight  52.8kgf
103    weight  52.9kgf
104    weight  52.8kgf
105    >
106    <
107    >   (clasping hands to chest)
109    <
110    >
111    <
108    >   (clasping hands again)
112    <
113    >   (clasping hands again)
114    <
115    >
116    <   (possible crossover, possibly just put heel
down differently)
117    >
118    <   (scuffed heel slightly at beginning)
119    >
120    <
121    >
122    <
though

(was leaning, looked from results as
she crossed over)

(slight scuff from last foot?)

slight scuff of last right foot

results look strange. Reckon undetected
crossover.

slight scuff onto second right foot

(results look strange; I'd say crossover)

14/10/92, in uosgws4.dat, .idx:

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>138</td>
<td>weight</td>
<td>53.1kgf</td>
</tr>
<tr>
<td>136</td>
<td>weight</td>
<td>53.0kgf</td>
</tr>
<tr>
<td>137</td>
<td>weight</td>
<td>53.0kgf</td>
</tr>
<tr>
<td>135</td>
<td>&gt;</td>
<td>normal (as are all trials)</td>
</tr>
<tr>
<td>139</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>&gt;</td>
<td>slight scuff on last right foot</td>
</tr>
<tr>
<td>141</td>
<td>&lt;</td>
<td>crossover, it looked like</td>
</tr>
<tr>
<td>142</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>143</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>144</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>145</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>146</td>
<td>&gt;</td>
<td></td>
</tr>
</tbody>
</table>

736
I didn't see it, but the results look like crossover

looked like she lengthened last step

Subject 27
28/10/92, in uosgws4.dat, .idx. Gait seemed a bit self-conscious and slow.

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>weight</td>
<td>62.0kgf</td>
</tr>
<tr>
<td>201</td>
<td>weight</td>
<td>62.1kgf</td>
</tr>
<tr>
<td>202</td>
<td>weight</td>
<td>62.0kgf</td>
</tr>
<tr>
<td>Time</td>
<td>Action</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>203</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>204</td>
<td>&lt; (very slight scuff with right foot)</td>
<td></td>
</tr>
<tr>
<td>205</td>
<td>&gt; scuff of first foot</td>
<td></td>
</tr>
<tr>
<td>206</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>207</td>
<td>&gt; scuff of left foot</td>
<td></td>
</tr>
<tr>
<td>208</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>209</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>210</td>
<td>&lt; slight scuff</td>
<td></td>
</tr>
<tr>
<td>211</td>
<td>&gt; slowed down before end of room</td>
<td></td>
</tr>
<tr>
<td>212</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>213</td>
<td>&gt; scratching face with right hand</td>
<td></td>
</tr>
<tr>
<td>214</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>215</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>216</td>
<td>&lt; scuff of first foot</td>
<td></td>
</tr>
<tr>
<td>217</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>218</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>219</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>220</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>221</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>222</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>224</td>
<td>&lt; subject showing signs of boredom</td>
<td></td>
</tr>
<tr>
<td>225</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>226</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>227</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>228</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>229</td>
<td>&gt; didn't walk all the way to end</td>
<td></td>
</tr>
<tr>
<td>230</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>231</td>
<td>&gt;</td>
<td></td>
</tr>
</tbody>
</table>
3/11/92, uosgws4.dat, .idx:

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>358</td>
<td></td>
<td>62.6kgf</td>
</tr>
<tr>
<td>359</td>
<td></td>
<td>62.7kgf</td>
</tr>
<tr>
<td>360</td>
<td></td>
<td>62.7kgf</td>
</tr>
<tr>
<td>361</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>362</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>363</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>364</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>365</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>366</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>367</td>
<td>&gt;</td>
<td>slight scuff, left</td>
</tr>
<tr>
<td>368</td>
<td>&lt;</td>
<td>slight scuff, right</td>
</tr>
<tr>
<td>369</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>370</td>
<td>&lt;</td>
<td>slight scuff, right</td>
</tr>
<tr>
<td>371</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>372</td>
<td>&lt;</td>
<td>slight scuff, right</td>
</tr>
<tr>
<td>373</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>374</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>375</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>376</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>377</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>378</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>379</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>380</td>
<td>&gt;</td>
<td>scuff, left</td>
</tr>
<tr>
<td>381</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>382</td>
<td>&lt;</td>
<td></td>
</tr>
</tbody>
</table>
Kistler comparison

Subject 16 on Surrey walkway

In files clin5.dat, clin5.idx.

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>5</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>6</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>7</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>8</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>9</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>10</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>11</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>12</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>13</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>14</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>15</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>16</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>17</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>18</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>19</td>
<td>&lt;</td>
<td>normal</td>
</tr>
</tbody>
</table>
Subject 16 test at West London Institute of Higher Education.

Run ______________________________ foot
Subl, series 1, trials 1 to 15 right
subl series 2 and 3 left

Subject 17, first test at Surrey

In files clin6.dat, clin6.idx

Run direction speed
4 > normal
5 < normal
6 > normal
7 < normal
8 > normal
9 < normal

741
|   |   |  
|---|---|---
|10 | > | normal 
|11 | < | normal 
|12 | > | normal 
|13 | < | normal 
|14 | > | normal 
|15 | < | normal 
|16 | > | normal 
|17 | < | normal 
|18 | > | normal 
|20 | < | normal 
|21 | > | normal 
|22 | < | normal 
|23 | > | normal 
|24 | < | normal 
|25 | > | normal 
|26 | < | normal 
|27 | > | normal 
|28 | < | normal 
|29 | > | normal 
|30 | < | normal 
|31 | > | normal 
|32 | < | normal 
|33 | > | normal 
|34 | < | normal 

Subject 17, test at West London Institute of Higher Education.

Run ________________________ foot

Sub3 series 2, 1 trial          right
sub3 series 3, 15 trials        right

742
Instructions experiments

Subject 19

21/5/92, in UOSGWS1.dat., .idx

Run direction

170 >
171 <
172 >
173 <
174 >
175 <
176 >
177 <
178 >
179 <
180 >
181 <
182 >
183 <
184 >
185 <
186 >
187 <
188 >
189 <
190 >
191 <
192 >
(She crossed over on every single one.)

After 2nd set of instructions:

200 >
201 <
202 >
203 <
204 > (actually a crossover)
205 <
206 >
207 <
208 >
209 <
210 >

(interruption)

211 <
212 >
213 <
214 >
215 <
216 >
217 <
(crossed over, probably due to boredom. Told her.)

(extended her stride to get onto the walkway, I think.)

Subject 20
24/6/92, in UOSGWS3.dat, .idx

Run direction

43 >
45 <
44 >
46 <
47 >
48 <
49 >
50 < (non-crossover?) Yes, appears to have been.
51 >
52 < (crossover)
53 >
(non-crossover but toe-scuff?) appears OK.
(non-crossover?) appears OK
(non-crossover?) appears OK
(non-crossover?) appears to have been crossover
(non-crossover?) looks OK
looks OK
looks OK
looks OK
crossover
crossover
crossover

After 2nd set of instructions:
She appeared to be
shortening her
strides to fit
on the platform
Subject 21

29/6/92, in uosgws3.dat, .idx

Run direction

He seems to toe out with his left foot.

(stumbled) omitted.

(slight toe scuff)
108 >
109 < crossover
110 > looks OK
111 <
112 > looks OK
113 <
115 > looks OK
116 <
117 > crossover
118 <
119 >
120 <
121 >
122 <
123 >
124 <
125 >
126 <
127 > looks OK
128 <
129 >
130 < looks OK
131 > looks OK
132 <
133 > genuine non-crossover? looks OK
134 < crossover
135 >
136 <
After 2nd set of instructions:

137 >
138 <
139 > (very obviously looking down)
140 <
141 >
142 <
143 >
144 <
145 >
146 <
147 >
148 <
149 > (many interruptions)
150 <
151 >
152 <
153 >
154 <
155 >
156 <
157 >
158 <
159 >
160 <
161 >
162 <
163 >
164 <

749
weight = 61.9 kgf
weight = 62.0 kgf
weight = 62.0 kgf

Subject 22
2/7/92, in uosgws3.dat, .idx

75% of the lights in the room were out.

Run direction

203 >
204 <
205 >
206 <
207 >
208 <
209 >
210 < (looks like no crossover) looks OK
211 > looks OK
212 < crossover
213 > looks OK
214 <
215 > crossover
216 <
217 > (looks like no crossover) looks OK
218 < (looks like no crossover) looks OK
219 > (looks like no crossover) looks OK

(someone started using the printer)

220 < crossover
After 2nd set of instructions:
possibly walking faster. obviously looking down.

After 2nd set of instructions:
possibly walking faster. obviously looking down.
weight = 69.4kgf
weight = 69.5kgf
weight = 69.4kgf
Appendix 8.1: Variation of coefficient of determination, F-test significance and t-test significance with number of traverses and breadth of speed range

Calculation of coefficient of determination

In regression analysis, Microsoft Excel calculates for each point the squared difference between the y-value estimated for that point and its actual y-value. The sum of these squared differences is called the residual sum of squares. Microsoft Excel then calculates the sum of the squared differences between the actual y-values and the average of the y-values, which is called the total sum of squares (regression sum of squares + residual sum of squares). The smaller the residual sum of squares is compared with the total sum of squares, the larger the value of the coefficient of determination, \( r^2 \), which is an indicator of how well the equation resulting from the regression analysis explains the relationship among the variables.' (Microsoft Excel Function reference).

Calculation of F statistic

This is a standard test shown in chapter 9 of Kleinbaum et al (1988).

Calculation of t-value

This was described in section 3.3.3.4.

Variation of coefficient of determination with number of traverses

From the description above of the calculation of the coefficient of determination, one would not expect it to increase with increased number of traverses.
gait variable, fewer trials

'Fewer points'
"More points"

755
Consider the two sets of points:

<table>
<thead>
<tr>
<th>Fewer points</th>
<th></th>
<th>More points</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>speed</td>
<td>gait variable</td>
<td>speed</td>
<td>gait variable</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

The data are illustrated above.

The coefficient of determination for the set of fewer points is 0.78 while for the set containing more points it is 0.69. This shows that the coefficient of determination does not necessarily increase as the number of points increases.

**Variation of F-test significance with number of traverses**

The observed F statistic for the set of fewer points is 7.03 while for the set containing more points it has increased to 8.76. For the set of fewer points, the critical F value is 18.5 while for the set containing more points it has decreased to 7.71. This means that for the set containing fewer points, 7.03<18.5 so the F-test is not significant while for the set containing more points, 8.76>7.71 so the F-test is significant. This illustrates that the proportion of positive F-tests is likely to increase as the number of traverses increases.

**Variation of t-test significance with number of traverses**

The two data sets were each t-tested against a third data set ('other line').
Other line

<table>
<thead>
<tr>
<th>speed</th>
<th>gait variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

For the set containing fewer points, a t-test with 'other line' for slope gives $t = 2.25$. The critical value of $t$ is $t_{5\%}$, 4+4-4=4 degrees of freedom = 2.78 so the test is not significant. For the set containing more points, a t-test with 'other line' for slope gives $t = 2.25$. The critical value of $t$ is $t_{5\%}$, 6+4-4=6 degrees of freedom = 2.45 so the test is still not significant but it is closer to significance.

For the set containing fewer points, a t-test with 'other line' for intercept at speed = 1.291m/s gives $t = -2.15$. The critical value of $t$ is $t_{1\%}$, 4+4-4=4 degrees of freedom = 4.60 so the test is not significant. For the set containing more points, a t-test with 'other line' for intercept at speed = 1.291m/s gives $t = -2.45$. The critical value of $t$ is $t_{1\%}$, 6+4-4=6 degrees of freedom = 3.71 so the test is still not significant but it is closer to significance.

This illustrates that the proportion of positive t-tests is likely to increase as the number of traverses increases.

Variation of coefficient of determination with breadth of speed range

From the description above of the calculation of the coefficient of determination, one would expect it to increase with increased speed range.
'Narrower range'
'Broader range'
Consider the two sets of points:

<table>
<thead>
<tr>
<th>Narrower range</th>
<th>Broader range</th>
</tr>
</thead>
<tbody>
<tr>
<td>speed</td>
<td>gait variable</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

The data are illustrated above.

The coefficient of determination for the set with narrower speed range is 0.36 while for the set with broader speed range it is 0.95. This shows that the coefficient of determination increases with speed range.

**Variation of F-test significance with speed range**

The observed F-statistic for the set with narrower range is 1.13 while for the set with wider speed range it has increased to 41. For both sets of points, the critical F-statistic is 18.5. This means that for the set with narrower range, 1.13<18.5 so the F-test is not significant while for the set with broader range, 41>18.5 so the F-test is significant. This illustrates that the proportion of positive F-tests is likely to increase as the speed range increases.
Variation of t-test significance with speed range

The two data sets were each t-tested against a third data set ('other line').

<table>
<thead>
<tr>
<th>speed</th>
<th>gait variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

For the set containing with narrower range, a t-test with 'other line' for slope gives \( t = 1.49 \). The critical value of \( t \) is \( 5\% \), \( 4+4=8 \) degrees of freedom = 2.78 so the test is not significant. For the set with wider range, a t-test with 'other line' for slope gives \( t = 2.70 \). The critical value of \( t \) is \( 5\% \), \( 4+4=8 \) degrees of freedom = 2.78 so the test is not significant but it is closer to significance.

For the set with narrower range, a t-test with 'other line' for intercept at speed = 1.291m/s gives \( t = -2.50 \). The critical value of \( t \) is \( 1\% \), \( 4+4=8 \) degrees of freedom = 4.60 so the test is not significant. For the set with wider range, a t-test with 'other line' for intercept at speed = 1.291m/s gives \( t = -2.10 \). The critical value of \( t \) is \( 1\% \), \( 6+4=10 \) degrees of freedom = 4.60 so the test is further from significance.

This illustrates that the proportion of positive t-tests for slope is likely to increase as the number of traverses increases, but this does not apply to intercepts.
<table>
<thead>
<tr>
<th>Subject</th>
<th>Pathology</th>
<th>sex</th>
<th>age</th>
<th>stature</th>
<th>weight inc. prosthesis a</th>
<th>hand dominance</th>
<th>leg dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>right BK amputee</td>
<td>m</td>
<td>36</td>
<td>1.68m</td>
<td>80.5kgf</td>
<td>not available</td>
<td>not available</td>
</tr>
<tr>
<td>28</td>
<td>right BK amputee</td>
<td>m</td>
<td>45</td>
<td>1.91m</td>
<td>116.6kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>33</td>
<td>left BK amputee</td>
<td>m</td>
<td>58</td>
<td>1.79m</td>
<td>81.3kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>26</td>
<td>right through knee</td>
<td>m</td>
<td>61</td>
<td>1.73m</td>
<td>75.6kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>41</td>
<td>right through knee</td>
<td>f</td>
<td>47</td>
<td>1.57m</td>
<td>49.9kgf</td>
<td>r</td>
<td>didn't know</td>
</tr>
<tr>
<td>3</td>
<td>right AK amputee</td>
<td>m</td>
<td>53</td>
<td>1.75m</td>
<td>89.7kgf</td>
<td>not available</td>
<td>not available</td>
</tr>
<tr>
<td>4</td>
<td>left AK amputee</td>
<td>m</td>
<td>39</td>
<td>1.80m</td>
<td>71.6kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>5</td>
<td>right AK amputee</td>
<td>m</td>
<td>45</td>
<td>1.85m</td>
<td>84.3kgf</td>
<td>l</td>
<td>l</td>
</tr>
<tr>
<td>6</td>
<td>right AK amputee</td>
<td>m</td>
<td>45</td>
<td>1.82m</td>
<td>73.7kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>7</td>
<td>right AK amputee</td>
<td>m</td>
<td>45</td>
<td>1.83m</td>
<td>84.2kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>8</td>
<td>left AK amputee</td>
<td>m</td>
<td>28</td>
<td>1.71m</td>
<td>55.2kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>24</td>
<td>right hip disarticulation</td>
<td>m</td>
<td>54</td>
<td>1.83m</td>
<td>107.0kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>29</td>
<td>left hip disarticulation (effectively)</td>
<td>m</td>
<td>26</td>
<td>1.85m</td>
<td>90.0kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>18</td>
<td>bilateral absent feet</td>
<td>m</td>
<td>33</td>
<td>1.69m</td>
<td>58.8kgf</td>
<td>l</td>
<td>r</td>
</tr>
<tr>
<td>42</td>
<td>right above knee, left below knee amputee</td>
<td>m</td>
<td>32</td>
<td>1.83m</td>
<td>77.1kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>40</td>
<td>bilateral AK amputee</td>
<td>f</td>
<td>38</td>
<td>1.55m</td>
<td>40.2kgf</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>Subject</td>
<td>Reason for amputation</td>
<td>years since amputation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------</td>
<td>------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>road accident</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>osteomyelitis after trauma</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>osteomyelitis and non-union after road accident</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>vascular ischaemia and Buerger's Disease</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>congenital deformity</td>
<td>42</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>road accident</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>congenital absence of the tibia</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>road accident</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>road accident</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>road accident</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>road accident</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>malignant fibrosarcoma of the fibula</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>fibrous sarcoma of proximal femur</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>congenital absence of both feet due to arthrogryphosis</td>
<td>absent at birth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>road accident</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Meningococcus Septicaemia (gangrene due to infection)</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Appendix 8.2: details of amputees and their prostheses
Technical details of leg a

Old conventional limb, no. 8, Vessa 9/83, required major overhaul including new foot

PTB prosthesis with sleeve suspension and fitted with a multiflex ankle joint.

Vessa conventional no. 8 metal leg dated 1/10/81

Endolite no. 6. Block leather socket, GRP cells, short knee chassis, Swing Phase Control, multiflex ankle

Hanger no. 3 metal limb dated 3/3/71 fitted with WTKC control and conventional wood foot

Quantum stabilised knee, 1/11/89, Vessa Ultraelite no. 3, quantum foot

No. 2 Endolite, fitted with Maloh S and S unit, dated 18/8/88

No. 3 Endolite, dated 2/3/88. Fitted with an Endolite Stabilised Knee and a Pneumatic Swing Phase Control Unit.

Vessa Endolite no. 3 fitted with a Malch S and S unit and a Quantum Foot

No. 3 Endolite dated 2/12/92 fitted with a metal socket, Malch S and S unit with a Multiflex foot

No. 3 Endolite fitted with an Isney Socket, Malch Knee S and S unit, Quantum foot. Dated 8/7/87

No. 1 Endolite with Polypropylene Embracing Socket, 4-bar linkage hip joint and Endolite Stabilised Knee with an ICS, multiflex ankle and foot

Vessa Ultra Roelite no. 1 limb 4/9/86 with block leather socket, GRP shell, modular hip limiter, 4 bar linkage knee, Quantum foot

Shoes: double Symes elephant peg rocker ends

Set a: left: PTB Endolite, polypropylene socket, petite liner, cuff suspension, multiflex ankle, Seattle light foot.

Set a: limbs dated 2/11/87: fitted with Quantum Stabilised Knee and Quantum Foot
### Technical details of leg b

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTB and corset, 11/90, Blatchford Endolite no. 8 GRP PTB socket, reinforced</td>
<td>Seattle light foot</td>
</tr>
<tr>
<td>with carbon fibre, slide steels and thigh corset</td>
<td>N/A</td>
</tr>
<tr>
<td>Conventional no. 3 metal limb dated 5/2/70 fitted with WTKC control and</td>
<td>N/A</td>
</tr>
<tr>
<td>conventional wood foot</td>
<td>N/A</td>
</tr>
<tr>
<td>Vessa no. 3 Roelite 6/8/90, metal socket, 4-bar linkage knee, quantum foot</td>
<td>N/A</td>
</tr>
<tr>
<td>No. 3 Endolite, Endolite stabilised knee and pneumatic swing phase control</td>
<td>N/A</td>
</tr>
<tr>
<td>with a multiflex ankle</td>
<td>N/A</td>
</tr>
<tr>
<td>No. 3 Endolite, dated 1/1/90. Fitted with a Malch S and S unit, multiflex</td>
<td>N/A</td>
</tr>
<tr>
<td>ankle and foot</td>
<td>N/A</td>
</tr>
<tr>
<td>Experimental 4-bar knee with a Seattle light foot</td>
<td>N/A</td>
</tr>
<tr>
<td>No. 3 Endolite dated 24/2/88 with an Endolite Stabilised Knee, Pneumatic</td>
<td>N/A</td>
</tr>
<tr>
<td>Swing Phase Control, multiflex ankle. Socket at fitting stage, probably</td>
<td>N/A</td>
</tr>
<tr>
<td>poor.</td>
<td>N/A</td>
</tr>
<tr>
<td>No. 3 Endolite fitted with an Isney Socket, Endolite Stabilised Knee and</td>
<td>N/A</td>
</tr>
<tr>
<td>Pneumatic Swing Phase Control, Quantum foot. Dated 26/3/90</td>
<td>N/A</td>
</tr>
<tr>
<td>Quantum no. 1 limb. block leather socket with GRP shell, modular hip joint,</td>
<td>N/A</td>
</tr>
<tr>
<td>4-bar knee, quantum foot</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Slippers:** double Symes leather slippers

<table>
<thead>
<tr>
<th>Details</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>technical details of leg c</td>
<td>11/89 Blatchfords P.T. bearing supracondylar GRP socket, Seattle light foot.</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------------------------------------------------------------</td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>conventional, 4/89. Vessa metal no. 3, metal suction socket, free knee with WTKC (friction knee), quantum foot</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>No. 3 Metal Conventional limb with wheel type knee control and Hanger moulded uniaxial foot</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
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<td>N/A</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Subject</td>
<td>other details of leg a</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------</td>
</tr>
<tr>
<td>23</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>very creaky, couldn't get shoe on fully</td>
</tr>
<tr>
<td>3</td>
<td>subject felt he had to work harder and alignment was worse</td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>subject said fit was slightly different, thought it swung through b</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>subject said the slippers were more comfortable</td>
</tr>
<tr>
<td>42</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
</tr>
<tr>
<td>other details of leg c</td>
<td>occupation</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>computer programmer</td>
<td></td>
</tr>
<tr>
<td>professor</td>
<td></td>
</tr>
<tr>
<td>unemployed engineering technician</td>
<td></td>
</tr>
<tr>
<td>retired police officer</td>
<td></td>
</tr>
<tr>
<td>housewife</td>
<td></td>
</tr>
<tr>
<td>taxi driver</td>
<td></td>
</tr>
<tr>
<td>business consultant</td>
<td></td>
</tr>
<tr>
<td>policeman: road traffic officer</td>
<td></td>
</tr>
<tr>
<td>prosthetic manager</td>
<td></td>
</tr>
<tr>
<td>unemployed decorator</td>
<td></td>
</tr>
<tr>
<td>unemployed clerk</td>
<td></td>
</tr>
<tr>
<td>lecturer</td>
<td></td>
</tr>
<tr>
<td>unemployed butcher</td>
<td></td>
</tr>
<tr>
<td>trainee prosthetist</td>
<td></td>
</tr>
<tr>
<td>accountant</td>
<td></td>
</tr>
<tr>
<td>secretary</td>
<td></td>
</tr>
</tbody>
</table>

Appendix 8.2: details of amputees and their prostheses
Subject questionnaire

Subject code ..........................................................................................................

Date ....................................................................................................................

Please tick the appropriate boxes.

1. Did you find the testing environment intimidating?
   Yes  No

2. Did you feel tired at the beginning of the test?
   Yes  No

3. Did you feel tired at the end of the test?
   Yes  No

4. Did you feel as though you were walking with your normal gait during the test?
   Yes  No
Appendix 8.4: Percentages of extra traverses needed by joint replacement subjects due to failing to clear the centre line

<table>
<thead>
<tr>
<th>Subject</th>
<th>First occasion</th>
<th>Second occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>3/10 = 30%</td>
<td>1/10 = 10%</td>
</tr>
<tr>
<td>35</td>
<td>0/10 = 10%</td>
<td>3/10 = 30%</td>
</tr>
<tr>
<td>36</td>
<td>1/10 = 10%</td>
<td>N/A</td>
</tr>
<tr>
<td>37</td>
<td>4/4 = 100%</td>
<td>3/3 = 100%</td>
</tr>
<tr>
<td>38</td>
<td>1/10 = 10%</td>
<td>2/10 = 20%</td>
</tr>
<tr>
<td>39</td>
<td>0/10 = 10%</td>
<td>3/10 = 30%</td>
</tr>
</tbody>
</table>
Appendix 8.5: data documentation

The data from this chapter is documented below in order that can be used for further work such as validation of future algorithms.

The data is situated on the hard disc of the Mesh 486 computer in the gait lab 48 AC 20 of the University of Surrey. See appendix 7.1 for details of storage, recall and analysis of data.

**Adult amputees**

**Subject 23**

22/9/92. In uosgws4.dat, .idx.

<table>
<thead>
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<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>2</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>3</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>4</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>5</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>6</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>7</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>8</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>9</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>10</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>11</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>12</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>13</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>14</td>
<td>a</td>
<td>&gt;</td>
<td>slow (20s, 100Hz)</td>
</tr>
<tr>
<td>15</td>
<td>a</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>16</td>
<td>a</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>17</td>
<td>a</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>18</td>
<td>a</td>
<td>&gt;</td>
<td>backwards</td>
</tr>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>c</td>
</tr>
<tr>
<td>---</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>19</td>
<td>&lt;</td>
<td>weight</td>
<td>weight</td>
</tr>
<tr>
<td>20</td>
<td>weight</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>21</td>
<td>weight</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>22</td>
<td>weight</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>23</td>
<td>&gt;</td>
<td>normal</td>
<td>(toe scuff)</td>
</tr>
<tr>
<td>24</td>
<td>&lt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>&gt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>&lt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>&gt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>&lt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>&gt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>&lt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>&gt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>&lt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>&gt;</td>
<td>slow (20s, 100Hz)</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>&lt;</td>
<td>slow</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>&gt;</td>
<td>fast</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>&lt;</td>
<td>fast</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>&gt;</td>
<td>backwards</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>&lt;</td>
<td>backwards</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>&gt;</td>
<td>normal (hands behind back)</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>&lt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>&gt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>&lt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>&gt;</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>&lt;</td>
<td>normal</td>
<td></td>
</tr>
</tbody>
</table>
48  c  >  normal
49  c  <  normal
50  c  >  normal
51  c  <  normal
52  c  >  slow (20s, 100Hz)
53  c  <  slow
54  c  >  fast
55  c  <  fast
56  c  >  backwards (20s, 100Hz)
57  c  <  backwards

Subject 28


<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>233</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>234</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>235</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>236</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(algorithms suggesting</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>crossover)</td>
</tr>
<tr>
<td>237</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(felt wobbly)</td>
</tr>
<tr>
<td>238</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>239</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>240</td>
<td>a</td>
<td>&gt;</td>
<td>normal. felt that he was walking</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>unsteadily because of the line.</td>
</tr>
<tr>
<td>241</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>242</td>
<td>a</td>
<td>&gt;</td>
<td>normal. coming up with crossover</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>errors: seems to be just that he's got</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>large feet (size 10.5-11)</td>
</tr>
<tr>
<td>243</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
</tbody>
</table>
244 a > normal
245 a < normal
246 a > slow (5s, 400Hz)
247 a < slow (20s, 100Hz) (he thought that wasn't terribly slow)
248 a > slow
249 a < slow
250 a > fast
251 a < fast
252 a > fast
253 a < fast
255 a > backwards
254 a < backwards
256 a < backwards
257 a > backwards

Subject 33
12/1/93, in uosgws5.dat, .idx, on floppies 'gait data 1' and 'gait data 2'.

<table>
<thead>
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<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>553</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>554</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>555</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>556</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>557</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>558</td>
<td>a</td>
<td>&gt;</td>
<td>normal. algorithms giving crossover error</td>
</tr>
<tr>
<td>559</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>560</td>
<td>a</td>
<td>&gt;</td>
<td>normal. appeared to adjust step to fit platform</td>
</tr>
</tbody>
</table>

774
a > normal
a > normal
a < normal
a < normal
a > normal
a < normal
a > slow (100Hz, 20s)
a < slow
a > slow
a < slow
a > slow, seems to be giving a false crossover error
a < fast
a > fast
a < fast
a > fast
a < fast
a > backwards (100Hz, 20s)
a < backwards, subject stumbled
a > backwards
a < backwards

Subject 26
20/10/92, in uosgws4.dat, .idx

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>169</td>
<td>a</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>170</td>
<td>a</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>171</td>
<td>a</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>172</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>173</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>174</td>
<td>a</td>
<td>&gt;</td>
<td>normal (slight scuff)</td>
</tr>
<tr>
<td>175</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>176</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>177</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>178</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>179</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>180</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>181</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>183</td>
<td>a</td>
<td>&gt;</td>
<td>slow (20s, 100Hz)</td>
</tr>
<tr>
<td>182</td>
<td>a</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>184</td>
<td>a</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>185</td>
<td>a</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>186</td>
<td>a</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>187</td>
<td>a</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>188</td>
<td>a</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>189</td>
<td>a</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>190</td>
<td>a</td>
<td>&gt;</td>
<td>very fast (skip, trying to run)</td>
</tr>
<tr>
<td>191</td>
<td>a</td>
<td>&gt;</td>
<td>very fast</td>
</tr>
<tr>
<td>194</td>
<td>a</td>
<td>&lt;</td>
<td>very fast</td>
</tr>
<tr>
<td>195</td>
<td>a</td>
<td>&lt;</td>
<td>very fast (scuff?)</td>
</tr>
<tr>
<td>196</td>
<td>a</td>
<td>&gt;</td>
<td>backwards (20s, 100Hz)</td>
</tr>
<tr>
<td>197</td>
<td>a</td>
<td>&lt;</td>
<td>backwards</td>
</tr>
<tr>
<td>198</td>
<td>a</td>
<td>&gt;</td>
<td>backwards</td>
</tr>
<tr>
<td>199</td>
<td>a</td>
<td>&lt;</td>
<td>backwards</td>
</tr>
</tbody>
</table>
Subject 41

9/3/93, in uosgws5.dat, .idx on floppies 'gait data 4' and 'gait data 5'

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

She started next to the camera at the right-hand end, rather than in front of it.

740 a weight
741 a weight
742 a weight
743 a > normal (hands clasped in front)
744 a < normal
745 a > normal (hands clasped behind)
746 a < normal (hands clasped behind)
747 a > normal (hands clasped behind)
748 a < normal (hands loose, slight scuff)
749 a > normal (hands at sides)
750 a < normal (hands at sides)
751 a > normal
752 a < normal
753 a > slow (20s, 100Hz) (scuff)
754 a < slow
755 a > slow
756 a < slow (hands by side, slight scuff)
757 a > fast (400Hz, 5s)
758  a  <  fast
759  a  >  fast
760  a  <  fast
761  a  >  backwards (20s, 100Hz)
762  a  <  backwards
763  a  >  backwards
764  a  <  backwards
765  b  weight
766  b  weight
767  b  weight
768  b  >  normal (arms by side)
769  b  <  normal
770  b  >  normal
771  b  <  normal
772  b  >  normal
773  b  <  normal
774  b  >  normal
775  b  <  normal
776  b  >  normal
777  b  <  normal
778  b  >  slow (20s, 100Hz)
779  b  <  slow
780  b  >  slow (scuff)
781  b  <  slow
782  b  >  fast (400Hz, 5s)
783  b  <  fast
784  b  >  fast
785  b  <  fast
786  b  >  backwards (20s, 100Hz)

778
787  b  <  backwards
788  b  >  backwards
789  b  <  backwards

Subject 3

31/3/92. In clin 4.dat, .idx.

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>136</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>137</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>138</td>
<td>a</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>141</td>
<td>a</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>142</td>
<td>a</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>143</td>
<td>a</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>144</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>145</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>146</td>
<td>b</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>147</td>
<td>b</td>
<td>&lt;</td>
<td>slow, checked weight, bit of a foot scuff.</td>
</tr>
<tr>
<td>149</td>
<td>b</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>150</td>
<td>b</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>151</td>
<td>c</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>152</td>
<td>c</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>153</td>
<td>c</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>154</td>
<td>c</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>155</td>
<td>c</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>157</td>
<td>c</td>
<td>&lt;</td>
<td>fast</td>
</tr>
</tbody>
</table>

The subject feels that with leg b he has to work harder and the alignment is worse.
The subject feels that with leg c the socket is more comfortable and that it feels slower.

**Subject 4**

5/5/92. Data recorded into uosgws1.dat, .idx.

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>122</td>
<td>a</td>
<td>&gt;</td>
<td>normal. weight = 71.7kgf</td>
</tr>
<tr>
<td>123</td>
<td>a</td>
<td>&lt;</td>
<td>normal. weight = 71.5kgf</td>
</tr>
<tr>
<td>124</td>
<td>a</td>
<td>-</td>
<td>weight = 71.6kgf</td>
</tr>
<tr>
<td>125</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>126</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
</tbody>
</table>

(then took tracksuit bottoms off)

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>127</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>128</td>
<td>a</td>
<td>&lt;</td>
<td>normal. weight = 71.1kgf</td>
</tr>
<tr>
<td>129</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>130</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>131</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>132</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>135</td>
<td>a</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>136</td>
<td>a</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>137</td>
<td>a</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>138</td>
<td>a</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>139</td>
<td>a</td>
<td>&gt;</td>
<td>very fast</td>
</tr>
<tr>
<td>140</td>
<td>a</td>
<td>&lt;</td>
<td>very fast</td>
</tr>
<tr>
<td>141</td>
<td>a</td>
<td>&gt;</td>
<td>backwards</td>
</tr>
<tr>
<td>142</td>
<td>a</td>
<td>&lt;</td>
<td>backwards</td>
</tr>
<tr>
<td>143</td>
<td>b</td>
<td>&gt;</td>
<td>normal. weight = 70.9kgf</td>
</tr>
<tr>
<td>144</td>
<td>b</td>
<td>&lt;</td>
<td>normal. weight = 71.0kgf</td>
</tr>
<tr>
<td>145</td>
<td>b</td>
<td>&gt;</td>
<td>normal. weight = 70.9kgf</td>
</tr>
</tbody>
</table>
Subject 5

30/6/92. Data recorded into uosgws3.dat, uosgws3.idx

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>170</td>
<td>a</td>
<td>&gt;</td>
<td>normal. weight = 84.5kgf</td>
</tr>
<tr>
<td>171</td>
<td>a</td>
<td>&lt;</td>
<td>normal. weight = 84.1kgf</td>
</tr>
<tr>
<td>172</td>
<td>a</td>
<td>&gt;</td>
<td>normal. weight = ? kgf</td>
</tr>
<tr>
<td>173</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>174</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>175</td>
<td>a</td>
<td>&lt;</td>
<td>normal (poss. crossover?)</td>
</tr>
<tr>
<td>176</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>178</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>179</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>180</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>Run</td>
<td>leg</td>
<td>direction</td>
<td>speed</td>
</tr>
<tr>
<td>-----</td>
<td>-----</td>
<td>-----------</td>
<td>----------------</td>
</tr>
<tr>
<td>181</td>
<td>a</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>182</td>
<td>a</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>183</td>
<td>a</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>184</td>
<td>a</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>185</td>
<td>a</td>
<td>&gt;</td>
<td>backwards</td>
</tr>
<tr>
<td>186</td>
<td>a</td>
<td>&lt;</td>
<td>backwards</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>187</td>
<td>b</td>
<td>&gt;</td>
<td>normal, weight = 84.5kgf</td>
</tr>
<tr>
<td>188</td>
<td>b</td>
<td>&lt;</td>
<td>normal, weight = 84.2kgf</td>
</tr>
<tr>
<td>189</td>
<td>b</td>
<td>&gt;</td>
<td>normal, weight = 84.5kgf</td>
</tr>
<tr>
<td>190</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>191</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>192</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>193</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>194</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>195</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>196</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>197</td>
<td>b</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>198</td>
<td>b</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>199</td>
<td>b</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>200</td>
<td>b</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>201</td>
<td>b</td>
<td>&gt;</td>
<td>backwards</td>
</tr>
<tr>
<td>202</td>
<td>b</td>
<td>&lt;</td>
<td>backwards</td>
</tr>
</tbody>
</table>

**Subject 6**

6/10/92. In uosgws4.dat, .idx.

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
</tbody>
</table>
(went and got changed from suit to sweatshirt, shorts and trainers)

Remeasured weight because of changing clothes part-way through:

17/11/92, in uosgws 4.dat, .idx

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>472</td>
<td>b</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>473</td>
<td>b</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>474</td>
<td>b</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>Run</td>
<td>leg</td>
<td>direction</td>
<td>speed</td>
</tr>
<tr>
<td>-----</td>
<td>-----</td>
<td>-----------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>475</td>
<td>b</td>
<td>&gt;</td>
<td>normal (he feels a bit slow)</td>
</tr>
<tr>
<td>476</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>477</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>478</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>479</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>480</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>481</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>482</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>483</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>484</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>485</td>
<td>b</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>486</td>
<td>b</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>487</td>
<td>b</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>488</td>
<td>b</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>489</td>
<td>b</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>490</td>
<td>b</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>491</td>
<td>b</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>492</td>
<td>b</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>493</td>
<td>b</td>
<td>&gt;</td>
<td>backwards (20s, 100Hz) (not from ends)</td>
</tr>
<tr>
<td>494</td>
<td>b</td>
<td>&lt;</td>
<td>backwards</td>
</tr>
<tr>
<td>495</td>
<td>b</td>
<td>&gt;</td>
<td>backwards</td>
</tr>
<tr>
<td>496</td>
<td>b</td>
<td>&lt;</td>
<td>backwards</td>
</tr>
<tr>
<td>497</td>
<td>c</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>498</td>
<td>c</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>499</td>
<td>c</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>500</td>
<td>c</td>
<td>&gt;</td>
<td>normal</td>
</tr>
</tbody>
</table>
Subject 7

3/11/92, in uosgws4.dat, .idx

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>258</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>259</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>260</td>
<td>a</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>261</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
</tbody>
</table>
262  a  <  normal
263  a  >  normal
264  a  <  normal
265  a  >  normal
266  a  <  normal
267  a  >  normal
268  a  <  normal
269  a  >  normal
270  a  <  normal
271  a  >  slow
272  a  <  slow
273  a  >  slow
274  a  <  slow
275  a  >  fast
276  a  <  fast
277  a  >  fast
278  a  <  fast
279  a  >  backwards
280  a  <  backwards
281  a  >  backwards
282  a  <  backwards

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>308</td>
<td>b</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>309</td>
<td>b</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>310</td>
<td>b</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>311</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>312</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>313</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>314</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>315</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>316</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>317</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>318</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>319</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>320</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>321</td>
<td>b</td>
<td>&gt;</td>
<td>slow (20s, 100Hz)</td>
</tr>
<tr>
<td>322</td>
<td>b</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>323</td>
<td>b</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>324</td>
<td>b</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>325</td>
<td>b</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>326</td>
<td>b</td>
<td>&lt;</td>
<td>fast (hopped as came off walkway)</td>
</tr>
<tr>
<td>327</td>
<td>b</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>328</td>
<td>b</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>329</td>
<td>b</td>
<td>&gt;</td>
<td>backwards (20s, 100Hz)</td>
</tr>
<tr>
<td>330</td>
<td>b</td>
<td>&lt;</td>
<td>backwards</td>
</tr>
<tr>
<td>331</td>
<td>b</td>
<td>&gt;</td>
<td>backwards</td>
</tr>
<tr>
<td>332</td>
<td>b</td>
<td>&lt;</td>
<td>backwards</td>
</tr>
</tbody>
</table>

**Subject 8**

5/1/93, in uosgws5.dat, .idx on the floppy 'gait data 1'

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>522</td>
<td>a</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>523</td>
<td>a</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>524</td>
<td>a</td>
<td>&gt;</td>
<td>weight and normal</td>
</tr>
<tr>
<td>526</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>527</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
</tbody>
</table>
528 a < normal
529 a > normal
530 a < normal
531 a > normal
532 a < normal
533 a > normal
534 a < normal
535 a > slow (20s, 100Hz)
536 a < slow
537 a > slow
538 a < slow
539 a > fast
540 a < fast
542 a > fast
543 a < fast
544 a > backwards
545 a < backwards
546 a > backwards
547 a < backwards

2/2/93. in uosgws5.dat, .idx on the floppies 'gait data 3' and 'gait data 4'

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>687</td>
<td>b</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>688</td>
<td>b</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>689</td>
<td>b</td>
<td></td>
<td>weight</td>
</tr>
<tr>
<td>690</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>691</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>692</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>693</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>Run</td>
<td>Leg</td>
<td>Direction</td>
<td>Speed</td>
</tr>
<tr>
<td>-----</td>
<td>-----</td>
<td>-----------</td>
<td>-------</td>
</tr>
<tr>
<td>82</td>
<td>a</td>
<td>weight (with stick off floor)</td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>a</td>
<td>weight (with stick off floor)</td>
<td></td>
</tr>
<tr>
<td>84</td>
<td>a</td>
<td>weight (with stick off floor)</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>a</td>
<td>&lt;</td>
<td>normal (100Hz, 20s) (not using whole length of raised floor) (putting stick on floor)</td>
</tr>
<tr>
<td>86</td>
<td>a</td>
<td>&gt;</td>
<td>normal (hand on wall)</td>
</tr>
</tbody>
</table>

**Subject 24**

6/10/92, in uosgws4.dat, .idx
<table>
<thead>
<tr>
<th></th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>283</td>
<td>a</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>284</td>
<td>a</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>285</td>
<td>a</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>286</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>287</td>
<td>a</td>
<td>&lt;</td>
<td>normal, algorithms say</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>crossover</td>
</tr>
<tr>
<td>288</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>289</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>290</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
</tbody>
</table>

**Subject 29**


Run leg direction speed

---

790
<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>291</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>292</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>293</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>294</td>
<td>a</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>295</td>
<td>a</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>296</td>
<td>a</td>
<td>&gt;</td>
<td>slow (20s, 100Hz)</td>
</tr>
<tr>
<td>297</td>
<td>a</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>298</td>
<td>a</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>299</td>
<td>a</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>300</td>
<td>a</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>301</td>
<td>a</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>302</td>
<td>a</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>303</td>
<td>a</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>304</td>
<td>a</td>
<td>&gt;</td>
<td>backwards (20s, 100Hz)</td>
</tr>
<tr>
<td>305</td>
<td>a</td>
<td>&lt;</td>
<td>backwards</td>
</tr>
<tr>
<td>306</td>
<td>a</td>
<td>&gt;</td>
<td>backwards</td>
</tr>
<tr>
<td>307</td>
<td>a</td>
<td>&lt;</td>
<td>backwards</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Run</th>
<th>leg</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>333</td>
<td>b</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>334</td>
<td>b</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>335</td>
<td>b</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>336</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>337</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>338</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>339</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>340</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>341</td>
<td>b</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>342</td>
<td>b</td>
<td>&gt;</td>
<td>normal</td>
</tr>
</tbody>
</table>

791
Subject 18
28/4/92, in uosgws.dat, .idx

Had a habit of walking with hand(s) in pockets, or with hands clasped behind him.

<table>
<thead>
<tr>
<th>Run</th>
<th>footwear</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>shoes</td>
<td>&gt;</td>
<td>normal. weight = 58.8kgf</td>
</tr>
<tr>
<td>2</td>
<td>shoes</td>
<td>&lt;</td>
<td>normal. weight = 58.8kgf</td>
</tr>
<tr>
<td>3</td>
<td>shoes</td>
<td>&gt;</td>
<td>normal. weight = 58.8kgf</td>
</tr>
<tr>
<td>5</td>
<td>shoes</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>6</td>
<td>shoes</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>7</td>
<td>shoes</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>9</td>
<td>shoes</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>10</td>
<td>shoes</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td></td>
<td>shoes</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>---</td>
<td>----------</td>
<td>--------</td>
<td>--------------</td>
</tr>
<tr>
<td>11</td>
<td>shoes</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>12</td>
<td>shoes</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>14</td>
<td>shoes</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>16</td>
<td>shoes</td>
<td>&gt;</td>
<td>fast (Had to ask him again to walk the whole length)</td>
</tr>
<tr>
<td>19</td>
<td>shoes</td>
<td>&lt;</td>
<td>very fast</td>
</tr>
<tr>
<td>20</td>
<td>shoes</td>
<td>&gt;</td>
<td>very fast</td>
</tr>
<tr>
<td>21</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal (weight 58.0)</td>
</tr>
<tr>
<td>23</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal (weight 57.9)</td>
</tr>
<tr>
<td>24</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal (weight 58.0)</td>
</tr>
<tr>
<td>25</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>26</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>27</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>28</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>29</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>30</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>31</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>32</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>33</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>34</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>35</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>36</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>37</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>38</td>
<td>slippers</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>39</td>
<td>slippers</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>40</td>
<td>slippers</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>41</td>
<td>slippers</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>42</td>
<td>slippers</td>
<td>&gt;</td>
<td>very fast</td>
</tr>
<tr>
<td>43</td>
<td>slippers</td>
<td>&lt;</td>
<td>very fast</td>
</tr>
</tbody>
</table>

The new weight is affected by the fact that we had lunch as well as that the footwear was different.

<table>
<thead>
<tr>
<th>Run</th>
<th>footwear</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tends to walk with right hand in pocket/crossing his hands behind him.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal (weight 58.0)</td>
</tr>
<tr>
<td>24</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal (weight 57.9)</td>
</tr>
<tr>
<td>25</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal (weight 58.0)</td>
</tr>
<tr>
<td>26</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>30</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>31</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>33</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>34</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>35</td>
<td>slippers</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>36</td>
<td>slippers</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>37</td>
<td>slippers</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>38</td>
<td>slippers</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>39</td>
<td>slippers</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>40</td>
<td>slippers</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>42</td>
<td>slippers</td>
<td>&gt;</td>
<td>very fast</td>
</tr>
<tr>
<td>43</td>
<td>slippers</td>
<td>&lt;</td>
<td>very fast</td>
</tr>
</tbody>
</table>
**Subject 42**

16/3/93, in uosgws5, discs 'gait data 5' and 'gait data 6'

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>790</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>791</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>792</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>793</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>794</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>795</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>796</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>797</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>798</td>
<td>&lt;</td>
<td>normal</td>
</tr>
</tbody>
</table>

(sat down while Denis sorted the video out)

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>799</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>800</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>801</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>802</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>803</td>
<td>&gt;</td>
<td>slow (20s, 100Hz) caught stick slightly on curtain. eliminated this traverse from analysis.</td>
</tr>
<tr>
<td>804</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>805</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>806</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>807</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>808</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>809</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>810</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>815</td>
<td>&gt;</td>
<td>backwards (100Hz, 20s)</td>
</tr>
</tbody>
</table>
Subject 40
16/2/93, in uosgws5.dat, .idx on disc 'gait data 4'

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>712</td>
<td>weight</td>
<td>normal (all trials at 20s, 100Hz)</td>
</tr>
<tr>
<td>713</td>
<td>weight</td>
<td>normal</td>
</tr>
<tr>
<td>714</td>
<td>weight</td>
<td>normal</td>
</tr>
<tr>
<td>715</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>716</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>717</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>718</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>719</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>720</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>721</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>722</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>723</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>724</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>725</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>726</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>727</td>
<td>&gt;</td>
<td>slow (stumbled), eliminated this traverse from the analysis.</td>
</tr>
<tr>
<td>728</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>729</td>
<td>&gt;</td>
<td>fast (she didn't think it was fast)</td>
</tr>
<tr>
<td>730</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>731</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>732</td>
<td>&lt;</td>
<td>fast</td>
</tr>
</tbody>
</table>
Joint replacement subjects

Subject 34
22/1/93, in uosgws5.dat, .idx on disc 'gait data 2'

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>579</td>
<td>weight</td>
</tr>
<tr>
<td>580</td>
<td>weight</td>
</tr>
<tr>
<td>581</td>
<td>weight</td>
</tr>
<tr>
<td>585</td>
<td>&lt;</td>
</tr>
<tr>
<td>586</td>
<td>&gt;</td>
</tr>
<tr>
<td>587</td>
<td>&lt;</td>
</tr>
<tr>
<td>588</td>
<td>&gt;</td>
</tr>
<tr>
<td>589</td>
<td>&lt;</td>
</tr>
<tr>
<td>590</td>
<td>&gt;</td>
</tr>
<tr>
<td>591</td>
<td>&lt;</td>
</tr>
<tr>
<td>592</td>
<td>&gt;</td>
</tr>
<tr>
<td>593</td>
<td>&lt;</td>
</tr>
<tr>
<td>594</td>
<td>&gt;</td>
</tr>
</tbody>
</table>

14/5/93, in uosgws 5, on disc 'gait data 7'

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>874</td>
<td>weight</td>
</tr>
<tr>
<td>875</td>
<td>weight</td>
</tr>
<tr>
<td>876</td>
<td>weight</td>
</tr>
<tr>
<td>878</td>
<td>&lt;</td>
</tr>
<tr>
<td>879</td>
<td>&gt;</td>
</tr>
<tr>
<td>880</td>
<td>&lt;</td>
</tr>
<tr>
<td>881</td>
<td>&gt;</td>
</tr>
</tbody>
</table>
Subject 35

22/1/93, in uosgws5.dat, .idx on disc 'gait data 2'

Run direction

595 weight
596 weight
597 weight
598 > stopped before end of runout
599 <
600 >
601 <
602 >
603 <
604 >
605 <
607 >
608 <

14/5/93, in uosgws5.dat, .idx on disc 'gait data 7'

Run direction

858 weight (moved)
859 weight
860 weight
Subject 36

22/1/93 in uosgws5.dat, .idx on disc 'gait data 2'

Run direction

609 weight (moved)
610 weight
611 weight (moved?)
612 > 20s, 100Hz
613 <
614 >
615 <
616 >
617 <
618 > (stopped on run-up)
620 >
621 <
622 <
subject 37

22/1/93, in uosgws5.dat, .idx, on disc 'gait data 2'
can stop short and start short because disabled. But I think she did do the whole length. Sister Harris thought I might not get 10 trials from her.

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>623</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>624</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>625</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>626</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>627</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>628</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>629</td>
<td>&lt;</td>
<td>stopped as she walked on there, because she lost balance, so omitted from analysis.</td>
</tr>
<tr>
<td>630</td>
<td>&gt;</td>
<td>hands behind back</td>
</tr>
</tbody>
</table>

(Mr Hughes decided she'd had enough.)

14/5/93, in uosgws5.dat, .idx on disc 'gait data 6'
Mr Graham Deane said she couldn't manage many and indeed she couldn't.

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>846</td>
<td>weight</td>
</tr>
<tr>
<td>847</td>
<td>weight</td>
</tr>
<tr>
<td>848</td>
<td>weight (unusable due to operator error)</td>
</tr>
<tr>
<td>849</td>
<td>&gt;</td>
</tr>
<tr>
<td>850</td>
<td>&lt;</td>
</tr>
<tr>
<td>851</td>
<td>&gt;</td>
</tr>
</tbody>
</table>

too tired, so carried on with stick in left hand

(852 > crossover)

(853 < last left foot crossover)

(854 > starting even closer. still crossover)
855 < with stick
856 > with stick
(857 < crossover)

Subject 38
22/1/93, in uosgs5 on disc 'gait data 3'
Run _______ direction
636 weight
637 weight
638 weight
639 > normal
640 < normal
641 > normal
(went and noted everyone's shoes)
642 <
644 <
645 >
646 <
647 > scuff
648 <
649 >

14/5/93, in uosgs5 in disc 'gait data 6'
Run _______ direction
819 weight
820 weight
821 weight
(one lost due to abnormal gait)
822 > (400Hz, 5s)

800
this may have fouled the algorithms
double registration of low force step at the beginning.

Subject 39
22/1/93, in uosgws5.dat, .idx on disc 'gait data 3'
Run direction
650 weight
651 weight
652 weight
656 >
657 <
658 >
659 <
670 >
671 <
672 >
673 < appeared to 'target'
674 >
675 <
14/5/93, in uosgws5.dat, .idx on disc 'gait data 6'
quite unsteady on feet.

**Run** __________ direction

832 weight
833 weight
834 weight
835 >
(836 < touched wall)
837 >
838 <
839 >
840 <
841 >
842 < seems to have fouled algorithms
843 > "
844 <
845 < didn't walk right to end.

**Adult subject with cerebral palsy**

Subject 15

25/2/92, in clin4.dat, .idx

**Run** __________ direction __________ speed

planks1 < normal. weight, including crutches.
planks < normal
planks3 > normal
planks 5 > normal
planks6 > fast
planks7 < fast
planks8 > fast

802
Subject with specialised hip implant

Subject 32
17/11/92, in uosgws4.dat, .idx

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>445</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>446</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>447</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>448</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>449</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>450</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>451</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>452</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>453</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>454</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>455</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>456</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>457</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>460</td>
<td>&gt;</td>
<td>slow</td>
</tr>
<tr>
<td>461</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>462</td>
<td>&gt;</td>
<td>slow (first stance possibly crossover but probably lost by algorithms anyway)</td>
</tr>
<tr>
<td>463</td>
<td>&lt;</td>
<td>slow</td>
</tr>
<tr>
<td>464</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>465</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>466</td>
<td>&gt;</td>
<td>fast</td>
</tr>
<tr>
<td>467</td>
<td>&lt;</td>
<td>fast</td>
</tr>
<tr>
<td>468</td>
<td>&gt;</td>
<td>backwards (think stumbled a bit)</td>
</tr>
</tbody>
</table>
Child subjects

Subject 30

10/11/92, in uosgws4.dat, .idx

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>401</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>402</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>403</td>
<td>weight</td>
<td></td>
</tr>
</tbody>
</table>

(two trials lost due to subject not understanding)

| 406 | normal (starting from just near it) |
| 407 | normal (starting from just near it) |

(one trial lost due to crossover)

(one trial lost due to out of time)

| 410 | > | normal. no shoes or sock or T-shirt. OK |
|     |   | because only analysed first 4 steps on each platform. |

| 411 | > | normal. slight crossover? Yes, found to be crossover and omitted from analysis. |

| 412 | < | normal |
| 413 | > | normal |
| 414 | < | normal. ? Found on inspection to be no good and omitted from analysis. |
Subject 31
10/11/92, in uosgws4.dat, .idx

<table>
<thead>
<tr>
<th>Run</th>
<th>direction</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>bare feet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>418</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>419</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>420</td>
<td>weight</td>
<td></td>
</tr>
<tr>
<td>421</td>
<td>&gt;</td>
<td>normal, also not from end</td>
</tr>
<tr>
<td>422</td>
<td>&lt;</td>
<td>normal</td>
</tr>
<tr>
<td>423</td>
<td>&gt;</td>
<td>normal</td>
</tr>
<tr>
<td>424</td>
<td>&lt;</td>
<td>normal</td>
</tr>
</tbody>
</table>

put on socks and shoes with insoles in

| 425 | ?         | normal               |
| 426 | <         | normal               |
| 427 | >         | normal               |
| 429 | <         | normal               |

then took insoles out

| 432 | <         | normal               |
| 433 | >         | normal               |
| 434 | <         | normal               |
| 435 | >         | normal               |

R.I.P.s:

| 438 | weight    |                      |
| 439 | weight    |                      |
| 440 | weight    |                      |
| 441 | >         | normal, made a false start |
| 442 | <         | obviously non-equal timing |
| 443 | >         |                      |
| 444 | <         |                      |