Reconfiguring experimental archaeology using 3D motion reconstruction

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Abstract: The Motion in Place Platform was an infrastructure experiment which sought to provide a ‘deep’ mapping of reconstructed human movement. It was a collaboration between Animazoo, a Brighton-based motion hardware company, researchers from the University of Sussex’s Informatics lab, digital humanities researchers at King’s College London, and the University of Bedfordshire. Both 3D reconstruction and Virtual Reality (VR) in archaeology have been used to a great extent in the presentation and interpretation of archaeological sites in the past twenty years. However, there remains a predominant focus on their use as a means of illustration which, while enhancing the visual perception of the site, facilitates only passive consumption by the audience. There is little critical discussion in the literature of how 3D digital environments might aid our interpretation of the occupation of space or the usage of artefacts, and of what the evidential constraints that bind such interpretation. This paper reports on two linked experiments which sought to use motion capture technology to test the validity of digital reconstruction in exploring such interpretations, using domestic round house buildings of the British Iron Age. No such buildings survive physically, so interpretation about their occupation and usage is solely dependent on reconstruction and experimentation. Contemporary human movement was captured in a studio-based representation of a round house, and compared with comparable movements captured in an experimental reconstruction of the same environment. The results indicate significant quantitative variation in physical human responses to the two environments, which should help inform the practice of using 3D reconstruction for archaeological sites in the future.

1 Introduction

Experimental archaeology has long yielded valuable insights into the tools and techniques that featured in past peoples’ relationship with the material world around them. We can determine, for example, how many trees would need to be felled to construct a large round-house of the southern British Iron Age (over one hundred); infer the exact angle needed to strike a flint core in order to knap an arrowhead in the manner of a Neolithic hunter-gatherer; or recreate the precise environmental conditions needed to store grain in underground silos over the winter months, with only the technologies and materials available to Romano-Briton villagers [1], [2]. However, experimental archaeology has hitherto confined itself to empirical and quantitative questions such as those posed in these examples. Although this is in line with good scientific practice, which stipulates that any ‘experiment’ must be based
on replicable data, and have a reproducible methodology, it explicitly excludes visualisation of the human element in the interpretation of past environments.

It is likely for this reason that digital reconstruction technologies, including games, have yet to play a significant role in experimental archaeology. Whilst many excellent examples of digital 3D reconstruction of heritage sites exist (for example the Digital Roman Forum project: http://dlib.etc.ucla.edu/projects/Forum) most, if not all, of these are characterized by a drive to establish a photorealistic re-creation of physical features. The Motion in Place Platform project (MiPP: http://www.motioninplace.org) was a capital grant under the AHRC's DEDEFI scheme to develop motion capture and analysis tools for exploring how people move through spaces outside studio environments where, hitherto, most motion capture work had been done. In the course of MiPP, a series of experiments were conducted using motion capture hardware and software at the Silchester Roman town archaeological excavation in Hampshire, and in two ‘versions’ of the kind of round house widely in use in Britain in the centuries leading up to the Roman invasion in AD 43. One version was reconstructed in a studio in a manner in keeping with ‘conventional’ motion capture experimentation; whereas the other was a physically reconstructed round house in an outdoor setting, at the Butser Ancient Farm facility, where Romano-British and Iron Age dwellings have been constructed according to the best experimental practice. The aim was to reconstruct the kind of activities that – according to the material evidence – are likely to have been carried out by the occupants, and in the process explore human reactions to ‘immersion’ in the physical and virtual versions of the round house. Bespoke motion capture suits developed for the project were employed, and the traces captured and rendered with a combination of Autodesk and Unity3D software. Comparing the two sets of traces allow us to examine how both reconstructed spaces guided human movement. In particular the exercises allowed the evaluation and visualisation of changes in behaviour which occur as a result of familiarity with an environment, and the acquisition of expertise over time.

2 Understanding movement in the past and present

Understanding movement is a recurrent and topical theme in archaeology. At all scales, how and why humans move from A to B through a landscape, and what they did in between times, lies at the core of building narratives about the past. However, the evidence on which we can build such narratives is as varied and as patchy as archaeological evidence itself. In more recent periods, the material record can be supplemented with textual narratives, or even oral memory and tradition. The layering functions of Geographical Information Systems (GIS) can be used to illustrate changes over time between occupation patterns at a variety of scales. Any part of archaeological narrative that attempts to describe or understand movement must be supplemented by material from non-material sources. Human motion is contingent upon both time and space, and individual movements can be remembered and documented in various ways. For example recent research in the theory of performance has focused on the ontological and transitory nature of performance pieces, and various ways in which they can be captured through notation and documentation [3]. In the same way, human movement in distant history needs to be understood at some level: a key question for this work is to establish if comparably valuable observations can be made about human movement in periods for which we have no written or social historical records; and if so, how.
3D visualisation has been used to address this elsewhere [4]. However most 3D reconstructions of archaeological features, where they include humans at all, simply include them as decorative accoutrements, as adjuncts to the physical or architectural features being (re)constructed, or at best as measures of scale. Rarely is there any meaningful attempt made to understand or represent how those humans might have interacted with that physical environment, and what might have driven those interactions. Many such reconstructions simply omit humans and human movement all together. As M. Gillings has stated:

“[I]t is worth noting that one of the most striking things about archaeological Virtual-models is the lack of people in them. As a result, wandering around reconstructions … can be a ghostly and unsettling experience” [5].

The ‘undocumentable’ movement of humans in or through their contemporary environments is the product of a combination of those environments’ materiality and those humans’ experience, personal histories, purposes, intents and other immediate circumstances. There is an important distinction between such unprescribed movement and highly specialized, location-specific instances of ritual and cult activity, which are initiated by imperatives over and above the personal and the material. Such motions provide the focus of most existing research in this area [4], [6]. It is true that the documented presence of such rituals in the historic period allow us to test theoretical and practical aspects of reconstruction. As Johanson and Favro have noted in relation to reconstructing Roman funerary processions: ‘[t]he consideration of events in situ illustrates how the Romans choreographed their processions to exploit scale, orientation, sequencing and symbolic associations of structures and places’ [6]. However, unscripted narratives of the mundane, the day to day, and the domestic, especially from periods of the distant past, remain largely confined to conjecturing what might fill the gaps in our material evidence.

3 The Motion in Place Project

Methodologies involving experience and interaction in space have been employed in the study and conservation of heritage sites, and in museums and galleries for some time. There is recognition that the paths visitors use (or create themselves) to navigate around sites can be used to plan conservation practices, and to design pathways for tours and visitors to follow. The problems of documenting these are not dissimilar to those encountered by performance researchers seeking to document and capture individual performances, as noted above [3]. However, despite numerous innovative and effective ways of gathering such data, the visualised output of such work is almost always static, in the form of maps, plotted pathways and diagrams. Ironically enough, this is the kind of static, positivist form of illustration that has been criticized by researchers who have considered the role of movement in the past and cognitive approaches to it. Witness, for example, Copeland (2009)’s critique of Ivan Margary’s 1955 Roman Roads of Britain:

Clearly the road is being treated as an abstract entity, a form of ‘land art’ … which could be numbered, listed, quantified, mapped, safe and satisfying. The route of the road is extracted from the landscape, is a measured space, excluded from its surroundings both materially and cognitively’ [7].

Prior to the MiPP project, there was little use of the direct observation of human motion in such environments to understand or reconstruct human interaction with them. In general, we can observe a similar lack of sophistication in the mapping of
routes far below the scale of Roman road, where such mappings exist at all: of routes between and within small settlements between and within buildings, between and points of day to day significance such as wells and hearths.

4 Round-house trial

The round house experiment, conducted in the spring and summer of 2011 compared movement captured in a studio with a virtual backdrop projected on to the studio wall (see figure 1) with movement captured in ‘real world’ equivalents of the studio environment at the Butser Ancient Farm facility in Hampshire, where Romano-British and Iron Age dwellings – mainly round houses - have been constructed according to the best experimental practice [1], [2] (see figure 2). Butser is an example of experimental archaeology, the practice of constructing features or artefacts by a process of using trial and error to approximate ‘construct’ artefacts as accurately as possible, in the process inferring the techniques (including the movements) used in the creation process. We sought to create motion capture data from the studio-based round house and the physically reconstructed version which were comparable in the sense that they represented the same tasks, but we wished to investigate how (or if) they differed according to how the human undertaking them responded the respective virtual and physical natures of the environments themselves.

In contrast, the studio based trial, on the other hand, provided a ‘clean’ environment in which movement could be captured with few physical or haptic stimuli. A ‘footprint’ was taped out corresponding to the wall of the roundhouse, and props used to stand in for obstructions such as the hearth (although this seemed to have little impact on the trajectories of the subjects – see below).
In the domestic culture of the British Iron Age, there is no direct archaeological evidence or historic or material evidence of how round houses were built, how they were used, or how artefacts such as arrowheads or ceramics were made. Nor is there any evidence for any rituals which can be reconstructed to the extent of Roman funerary practices alluded to by Favro and Johanson [6]. Reconstructing the use of domestic spaces is therefore fraught, with much attention inevitably being concentrated on the better documented (both materially and textually) Roman periods that followed [8]. The corresponding methods of construction and use must therefore be inferred by a process of logical deduction, and examination of the available empirical evidence. How we approach this process of deduction can, and often does, involve a human factor. The reconstruction process in experimental archaeology has a long tradition of researching and utilizing past methods of construction and craft to construct (the term ‘reconstruct’ is explicitly avoided in the literature – see [2]) non-extant buildings using those methods. However the experimental approach, now well established and widely referred to, requires the ‘human factor’, in that it requires human intervention in, and interaction with, the physical world. We cannot travel back in time to capture the exact motions involved in archaeologically relevant activities, however we can capture current activities and the physical processes in order to gain more insight into probable past activities. Such an approach is particularly useful for testing the validity of different kinds of archaeological evidence, and also the efficacy of means of reconstructing, rendering and visualising past environments in 3D.

The experiment sought to explore how human movement could be visualized and observed directly in the context of these spatial and temporal scales. The remainder of this paper will focus on the second experiment, at Butser farm, which deployed the methods and hardware developed in the Silchester trial, and used additional techniques for placing the movement in space or “place”. In particular, this allowed us to observe the impact on movement of experience and familiarity with an environment gained over time. This is linked to notions of expertise and location-specific knowledge, such as an archaeologist with expertise and experience of a particular site in a particular place employing their knowledge to explore and understand that site.

The activities captured are – according to the material evidence – likely to correspond to those carried out by the occupants who used domestic round house spaces historically (the nature of this correspondence is of course critical). These
tasks included querning (grinding flour), sweeping, fetching water (according to available evidence, round houses had no water sources inside, so all water used for cooking, washing and drinking would have been fetched from an external source) and bread making – see figure 3. The intangible nature of these tasks is intrinsically conditioned by the physical environment in which they are embodied, and the information they receive about it via the media of sight, smell, sound, touch and, to a lesser extent perhaps, by taste. We infer that re-recreating a round house’s physical properties also involves creating the conditions parallel to those which provoked cognitive responses this information in the past.

Figure 3: Making bread inside a virtual round house

Two performers were given a broom, constructed using materials and methods sufficiently generic as to approximate to those likely to have been used in historic periods including the Iron Age, to sweep the virtual studio-based round house as well as the physical round house (see figure 4). In the virtual round house, their movements had no effect on the virtual environment. The lack of haptic feedback clearly meant that influence of the environment was minimal: The smooth, flat floor of the studio offered little resistance to the brooms and the even surface and lack of material barriers such as the inner post ring gave rise to a lack of physical consequences related to sweeping through objects or walking into walls. This appeared to invite the performers to move aggressively and openly. In the physical round house at Butser, the floor was uneven and the performers had to move the broom around inner posts while not stepping into the hearth (this is not accounting for the conjectured possibility that the ring supported by the inner posts may have had objects hanging from it, such as meat being smoked or animal skins, which would have further impeded human motion around the posts). Furthermore, there was great deal of variation in the resistance to the movement of the broom on the floor. At the same time, the performers learned that large, fast movements created dense clouds of dust and damaged the floor of the house; and that an inward sweeping motion, towards the central hearth and away from the walls, was the most efficient way of avoiding large dust clouds. Clearly the 3D rendering of the roundhouse constructed in the studio was unable in any way to capture or represent these haptic response.
5 Analysis of the capture data

In order to analyse the capture data created in both the studio and the ‘real’ versions of the roundhouse, the authors developed a bespoke application to track the position of the dancer’s hands while sweeping and to determine the distance the hands travelled and the amount of time required for an average “sweeping” motion or cycle. A single sweep motion or cycle was defined as the time between when a broom was placed down on the floor until the next time it was placed on the floor. Figure 5 shows a plot of sweeping in both the virtual roundhouse and the physical roundhouse. Both graphs show the position of the dancer’s right hand over approximately 45 seconds of sweeping. This is the most convenient approximation to ascertain the trajectory of the broom itself, and the same point was captured consistently across all traces. The plots in the bottom right show the composite 3D motion trajectories the hand (i.e., its position in 3D space). The other two graphs plot the distance away from the centre of the body. The top graphs show these positions on a traditional timeline while the graph in the bottom left plots y-offset, (the height above the body’s centre) on the y-axis against xy-offset (the length of a vector from the centre of the body to the body part being tracked). This plot also highlights the current sweep cycle or stroke and the current position in this cycle.
The layout of round houses makes them interesting environments in which to experiment. As Webley has noted [9], most round houses are usually configured with the door facing to the south east. This means that most advantageous use of daylight is made, and this is generally reflected in the layout of finds from structures of this type. Finds reflecting domestic occupation, such as ceramics, loom weights and cooking paraphernalia typically cluster in the eastern section of the house, with the western section, which is often inferred to have contained sleeping quarters, relatively free of finds [9]. It has been argued that this so-called ‘sunwise’ model of configuration reflected not only a practical solution to the problem of round houses not containing windows, but also that it may have reflected the cycle of life and death, given that some contain burials of humans and dogs in the northeast quadrants. It was not our intention to test such hypotheses in the Butser experiment, but rather to test the execution of domestic, and seemingly mundane, tasks referred to above, and how familiarity with the environment might impact on that execution. We were, in essence, interested in what Eugene Ch’ng has termed ‘experiential archaeology’, which is explicitly differentiated from experimental archaeology by its focus on the immaterial rather than the material [10]; although we would hesitate to go as far as Ch’ng and argue that advances in visual technology will make possible ‘virtual time travel’.

What does this mean? This data demonstrates that the performer did, indeed, make larger sweeping strokes in the virtual roundhouse (as expected). However, the performer also made sweeping strokes of shorter duration in the physically reconstructed roundhouse. This may be a result of the dust stirred up by sweeping in the physically constructed space, or it may be a result of the amount of resistance of the rough, uneven floor. Because the sample size is so small, it is not possible to make any definitive statements, but the data does appear to demonstrate that
engagement with the environment has altered the performer’s movement: in other words their internal spatial configuration has changed.

6 Geographic Knowledge

In our experiment, we captured three types of person: performers who are trained to respond to with physical expressiveness to their physical environs; two students on internship placements, with very limited previous familiarity of the round house environment, and finally an experimental archaeologist who has worked at Butser for many years, and who is intimately familiar with the environment, and with the tasks involved in maintaining it (see figures 7a and 7b).

This coincides with much writing on movement and environments as summed up by the architecture theorist, Juhani Pallasmaa:

“Our bodies and movements are in constant interaction with the environment; the world and the self-inform and redefine each other constantly. The percept of the body and the image of the world turn into one single continuous existential experience; there is no body separate from its domicile in space, and there is no space unrelated to the unconscious image of the perceiving self.’ [11]

If the in situ aspect of which kind of environment the performer is working in affects their internal spatial referencing with consequent impact on their documentable movements, then another fact which is like to change the spatial referencing again is time, and how time and familiarity with an environment alters human interaction with it. The motion experiments detailed above sections were conducted with trained performers, who were used not because of their virtuosic movement abilities or vocabularies, but because of their ability to take physical direction, and remember and re-create the movements. However, the experience of working with a number of the experimental archaeologists working at the site allowed us a broader perspective. In addition, the performers were captured upon first arriving on site, then captured again after having been given training by the archaeologists who worked on the site on a daily basis, performing the same tasks. The dancers’ movements were then compared against the archaeologist’s movement and their earlier, uninformed motion as depicted in figure 6a.
The experience with the broom showed that the connection to material objects such as tools and buildings are of crucial importance in elucidating our understanding of possible behaviours, usages of space, and movements in periods for which there is no empirical evidence. In other words, whilst we cannot reconstruct actual day to day events in prehistory, we can infer a broad spectrum of **procedural geographic knowledge**: this is the combination of cues, learned or taught responses, conscious decisions and personal imperatives which people used to navigate their ways around their immediate environments [12]. This adds to an individual’s store of **declarative geographic knowledge**, the set of geographic facts, which may be associated with location at any level (*ibid*.). The students and the experienced archaeologist in this experiment had procedural geographic knowledge, but differed vastly in their levels of declarative knowledge. This accounts for the variations visible in the visualisations of their motion traces in (**Figure 6a and 6b**).

This is, in effect, an extension of traditional experimental archaeology, which allows us to infer how people are likely to have interacted with their physical environments and how those environments (or tools) were constructed. It also resonates with Marcel Mauss’ theory of techniques of the body, transmitted through tradition:

“I call technique an action which is effective and traditional … There is no technique and no transmission in the absence of tradition. This above all is what distinguishes man from the animals: the transmission of his techniques … we are dealing with techniques of the body. The body is man's first and most natural instrument. Or more accurately, not to speak of instruments, man's first and most natural technical object, and at the same time technical means, is his body.” [13].

Integrating visualized movement in this way, and applying some basic theory of spatial cognition, shed new light on how the reconstructed spaces - and, by inference, their ancient counterparts - were likely to have been used. In particular the
exercises allowed the evaluation and visualisation of changes in behaviour which occur as a result of familiarity with an environment and the acquisition of expertise over time; and to assess how interaction between different actors affects how everyday tasks are carried out.

7 Movement and phenomenology

That knowledge and experience of a landscape alters a human being’s relationship with it has long been at the heart of so-called phenomenological archaeology [14], and the limitations of any attempt to investigate experience empirically are well-rehearsed. One could easily argue, however, that even the most conventional analysis of high-status artefacts requires us to make value judgements about the ‘quality’ of the craftsmanship, and therefore the experience of the craftsman with those materials, or possibly the experience of the wearer in wearing the jewellery. Topology as well as topography also plays a major role in landscape studies. For the ‘experience’ related to manual tasks in the round house, we have no material object to examine from the past: the use of motion data allows us to create (im)material digital objects from direct observation.

This allows us to make some preliminary observations about the nature of evidence that underpins 3D reconstruction in archaeology, and indeed the humanities more generally. We have argued elsewhere that, in general, 3D visualisations in archaeology have tended towards the positivist, with scant attention paid to the human of such spaces [15]. We propose here that, rather than supporting the establishment of an ‘experiential archaeology’, the application of motion capture hardware outside the studio expands the capacity of experimental archaeology to allow documentation of the human responses to physical spaces – spaces which are, themselves, artefacts of human creation. This, we would argue, is archaeologically inferential evidence. Conceptually beneath the archaeologically inferential is the archaeologically empirical. An example of this would be the spatial footprint of the round house, which can be determined from empirical observation. We are also able to tell that the house contained twelve posts supporting its inner ring, and that it had a hearth in the centre. Empiricism and objectivity are, of course, notoriously difficult concepts to deal with in archaeology, but these are examples of statements that can be made for certain, even if one disagrees with the interpretation placed on these. A third layer is the archaeologically conjectural. Conjecture is widely used in archaeological theory and practice, and in the context of our reconstructions, we had no surfaces from which to make direct observations from which to derive textures. There is no way that we can know that the walls were the same colour, or that their surfaces had the consistency that we attributed to them. We consider that this is acceptable, so long as the lack of certainty is made explicit, and that it is divided out from our motion traces, which are inferred, and the footprint of the structure, which is empirical. This is a useful framework in which to consider 3D reconstruction in archaeology, especially where a more ‘constructivist’ approach is attempted, where the purpose of the reconstruction is to provoke the audience (whether that audience is public or specialist) into building its own interpretations; rather than simply presenting a positivist interpretation of the structure as a fait accompli.
8 Conclusion

As we have seen, experimental archaeology has a strong emphasis on the material. It shares this characteristic with other branches of archaeology, which is, after all, the study of material remains. Materiality is an underpinning concept throughout all archaeological interpretation, and it thus influences – often unconsciously or subconsciously – those interpretations. We talk of material culture, a term which itself not unproblematic. One attribute inextricably linked with materiality is spatiality: every material thing exists in space and must be located somewhere. Our thesis in this paper is that we cannot understand places without understanding movement, and the framework of empirical, inferential and conjectural represents an approach which frees us from the ‘forced’ spatial certainty on (potentially) uncertain data which is implicit in many GIS approaches, and with which 3D visualisation often falls foul.

Some concrete conclusions can be drawn about the how a physical environment affects movement: the example of the sweeping shows that there are attributes to the action involved which are altered when transferred from a virtual/studio environment to a physical one; the shorter brush strokes being a primary example. This shows that the 3D reconstruction of a non-extant round house can be said to adequately represent only the visual aspect of the experience of being in it. The motion data captured from Butser augments this understanding by documenting human interaction with it, a point underscored by the changes observable in the motion as the experience of the person captured is varied. Further investigations might investigate further distinctions: a light environment versus a darker one or warm versus cold. Capturing such traces using the motion hardware we trialled allows us to augment the otherwise static 3D reconstruction of the round house, and communicate more effectively the implications of its physicality.

The obvious limitation of this approach is that it does not provide the kind of direct reconstruction of past construction and manufacturing techniques that experimental archaeology provides for building and artefacts. Whereas the physical reconstruction of the Moel-y-Gerddi round house provides a hypothesis which can be tested, examined and reproduced, our motion traces are one-off embodiments. It will require the development of a large reference collection of traces for any one site before supportable general inferences can be made about that site. These experiments have shown that such information can be gathered from motion capture, they have not shown the effects of growing them incrementally over time.

The purpose of MiPP was emphatically not to attempt to re-enact possible scenarios of history or prehistory, but to capture and visualize human interaction with place and material culture as documented by archaeological evidence; and thus to provide a critique of how well VR represents the experiential past. No, it is not possible to definitively know how Iron Age Britons used their round houses. We can infer past movements from an understanding and analysis of current movement in much the same way we infer the structure of past buildings and material objects through the fragments that have survived to our current time. However, just as archaeologists make clear distinctions between what material objects have actually been uncovered and what contextual information they have based their conjectures upon, we need to be clear about exactly what motion data we are capturing and the contexts in which it has been captured. If we want to understand how motion influences place and place influences motion, we need to capture and study them together.
References


