High-Speed Tracking of Moving Markers During Radiotherapy Using a CMOS Active Pixel Sensor

JPF Osmond[1], G Lupica[2], EJ Harris[1], H Zin[1], NM Allinson[3], PM Evans[1]

[1]The Institute of Cancer Research, Sutton, United Kingdom,
[2]The University of Sheffield, Sheffield, United Kingdom,
[3]The University of Lincoln, Lincoln, United Kingdom

Purpose/Objective(s): In order to minimize the dose delivered to healthy tissue near a moving tumor during radiotherapy it is first necessary to accurately measure tumor position as a function of time. For example, a portal imager can be used to detect surrogate markers implanted around the tumor in order to track its motion with a moving collimator. Lung tumors can move at up to 30mm/s, requiring a sampling rate of 30 frames/s to achieve mm accuracy. However the passive a-Si Flat Panel Imagers (FPIs) available with current linear accelerators operate at 2-10 frames/s, significantly slower than the required rate. Furthermore a-Si FPIs provide low image quality at their fastest frame rates and are susceptible to damage by the treatment beam, requiring replacement every 1 - 2 years. Emerging CMOS active pixel sensors use an addressable and partial read-out architecture to achieve significantly improved frame-rates relative to their passive counterparts. They are also capable of higher resolution, image quality and radiation-hardness. This study investigates the feasibility of using a CMOS APS to quickly and accurately track radio-opaque markers during radiotherapy.

Materials/Methods: A custom CMOS imaging system was designed and constructed in collaboration with the MI3 consortium. The performance of this system was characterized and compared with an a-Si FPI. Four cylindrical gold markers of diameter 0.8 to 2 mm and length 8 mm were positioned on a motion-platform and moved according to the Lujan approximation to respiratory motion. Images were acquired using the megavoltage treatment beam at a range of frame and dose rates. The success rate of an automatic detection routine, absolute mean-error from the expected position and contrast-to-noise ratio of the marker images were then evaluated as a function of marker size, marker speed, frame rate and dose rate.

Results: The CMOS imager was found to offer improved resolution and signal-to-noise than the standard a-Si FPI at a comparable dose. The long integration time of the FPI resulted in marker images being too blurred to detect. The CMOS was able to detect the three largest markers 100% of the time and estimate their position to within 0.3 mm at 150 - 300 MU/min and 20 - 50 frame/s. However success rate declined with decreasing dose or frame rate.

Conclusions: A CMOS megavoltage imaging system was found to offer superior signal-noise and resolution than the standard a-Si FPI. Furthermore the high speed of CMOS provided sub mm tracking of moving markers at a clinically acceptable dose rate and marker size
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Author Disclosure: J.P.F. Osmond: None. G. Lupica: None. E.J. Harris: None. H. Zin: None. N.M. Allinson: None. P.M. Evans: None.