Abstract

Respiratory motion can lead to uncertainties in the positioning of target structures throughout the course of a radiotherapy treatment. To account for this motion and ensure an accurate delivery of the planned dose to the patient, motion management systems are often necessary. This work developed the framework for an ultrasound-based motion management system for radiotherapy treatments of liver tumors. An algorithm was developed for accurate and robust tracking of liver vessels over the course of a radiotherapy fraction using a block matching approach with multiple simultaneous templates. The simultaneous use of information from training frames and the previous frame enabled shape and temporal constancy of tracked feature motion throughout acquired ultrasound sequences. The algorithm was implemented in both 2D and 3D, achieving a mean tracking error of 0.72 mm and 1.02 mm, respectively, relative to manual annotations of liver vessels. The algorithm was accelerated with the use of a graphics processing unit (GPU) in order to reach the real-time speeds necessary for clinical implementation. The GPU implementation of the algorithm achieved mean processing rates of 168 frames per second (fps) for 2D, and 23 fps for 3D, which exceeded the image acquisition rate in all cases. Further investigations into the sum of absolute differences as an alternative similarity metric and the possibility of tracking on ultrasound data prior to scan conversion also presented possibilities for system speedup. Considerations for linac integration were made by investigating the effects of latency on the delivery of a treatment in the presence of motion. An ion chamber was positioned within a static field and traversed through a known motion trace while gating the beam. The effects of increasing system latencies were observed by artificially delaying the beam delivery relative to the known motion trace, indicating increased dose deviations with increased latencies. A second

study used the previously-developed tracking algorithm to gate the delivery, achieving a high level of agreement between the algorithm-based gating and static measurements. Overall, this work presented the tools necessary to implement ultrasound-based motion management and preliminarily demonstrated the potential for integration into a radiotherapy environment.