Open Source Ultrasound Simulation Using Surface Meshes

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Purpose: Ultrasound (US) is frequently used for image guided therapy (IGT) as it is a safe, relatively cheap, and portable modality. However, this popular approach is difficult to develop algorithmically, and difficult to master. A part of the problem is the accessibility and quality of the images. US machines as well as patients or phantoms are necessary to acquire the images, and are often expensive. Even once acquired, real US images are hardly reproducible and have uncontrollable parameters. A solution to these problems is simulation. It provides the controllable environment needed for verification and better facilitates learning. Current physically accurate simulators require significant processing power and time, making them poorly suited for IGT. Commercial systems are not only expensive, but are lacking in versatility, often being limited to only one application, and open source simulators were not found in a search of the literature.

Method: The objects to appear in the simulated US image are defined geometrically. Anatomical data is acquired from segmentations of CT or MRI data converted into surface meshes. Other objects, such as surgical tools, are also represented using surface meshes, allowing for the preservation of model details. The pose of the objects is represented using linear transforms, which could be specified either as constants, in a configuration file, or coming from a tracker. Transducer parameters, such as radius, imaging depth, number of elements and shape (curvilinear vs. linear) are also defined, as was the material properties associated with each model. Next, the points of intersection between the surface meshes and the scan lines of the US image are determined.

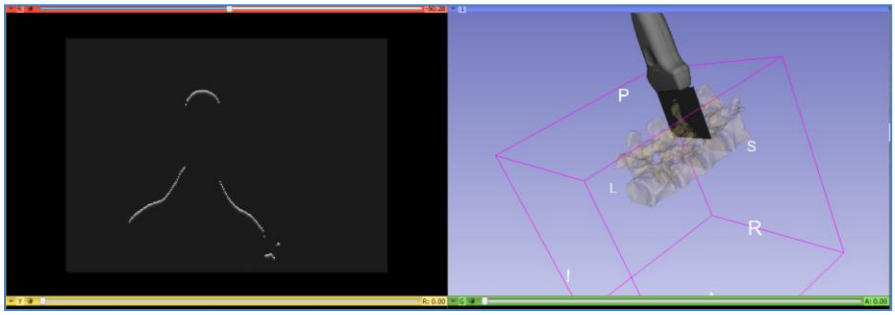

Fig 1. Screen capture of US simulator, with properties set for a constant intensity and bone

For time efficiency binary space partitioning (BSP) tree is used. The intersection points divide the scan line into segments, which are then filled with a grey value; the result of an intensity calculation based on the material properties defined earlier. The scan lines are finally converted to a regular brightness-mode US image. All the above steps were implemented in C++, as part of the open-source PLUS (Public software Library for Ultrasound) toolkit available at www.assembla.com/spaces/plus.

Results: The simulator was tested in an US-guided spinal injection training scenarios. The anatomical objects (spine), tools (US transducer, needle), and simulated US image were visualized in 3D Slicer (Fig.1.). An electromagnetic tracker was connected to the computer and provided position information. The spine mesh consisted of over 97,000 points in 195,000 cells. The US images were generated at a speed of 50 frames per second, and a resolution of 820 x 616 pixels on a PC with a 3.4 GHz processor.

Conclusion: A basic US simulator has been implemented and integrated into the open-source PLUS toolkit, to aid teaching US-guided procedures and for producing test data for various US image processing and analysis algorithms, such as volume reconstruction and spatial and temporal calibration. Presently, only bone contour is generated. Blending speckle and trace of the surgical tools is in progress.