Real-time ultrasound simulation on GPU

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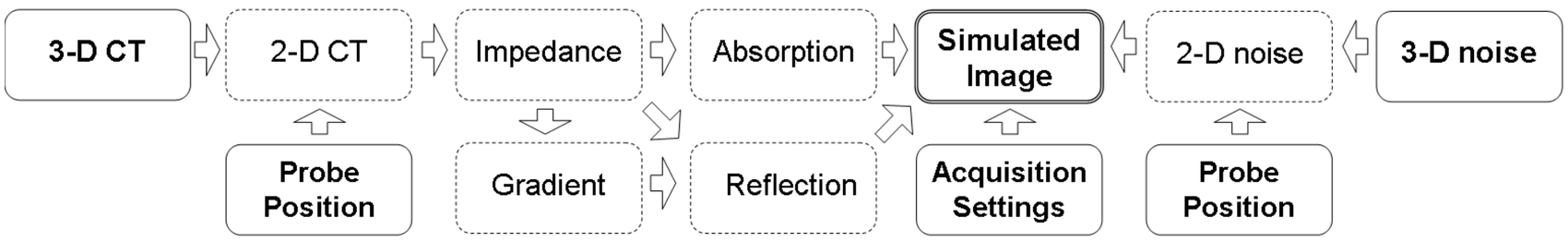
Introduction

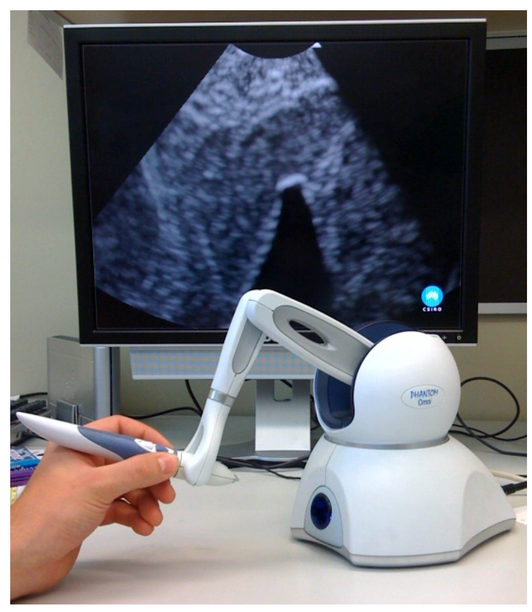
Despite the increasing adoption of other imaging modalities, ultrasound guidance is widely used for surgical procedures and clinical imaging due to its low cost, non-invasiveness, real-time visual feedback. Many ultrasound-guided procedures require extensive training and where possible training on simulations should be preferred over patients.

Problem and Solution

Computational resources for existing approaches to ultrasound simulation are usually limited by real-time requirements. Unlike previous approaches we simulate freehand ultrasound images from CT data on the Graphics Processing Unit (GPU).

We build upon the method proposed by Wein et al. for estimating ultrasound reflection properties of tissue and modify it to a computationally more efficient form. In addition to previous approaches, we also estimate ultrasound absorption properties from CT data.





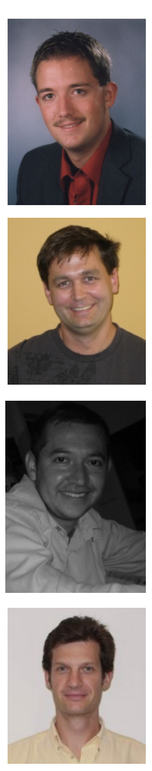
Above: simulation pipeline, from 3-D CT data, 3-D noise, probe position, and acquisition settings an US image is simulated. Right: setup with haptic input device (Phantom Omni).

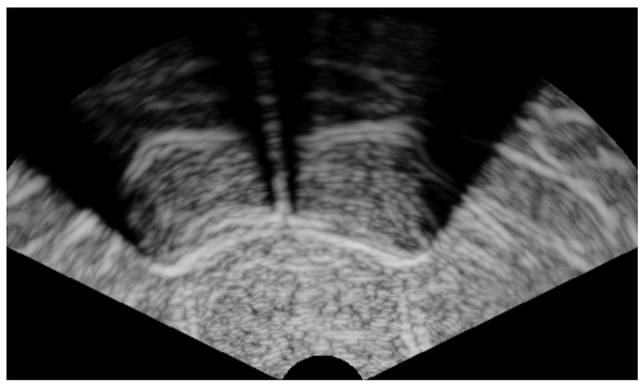
Results

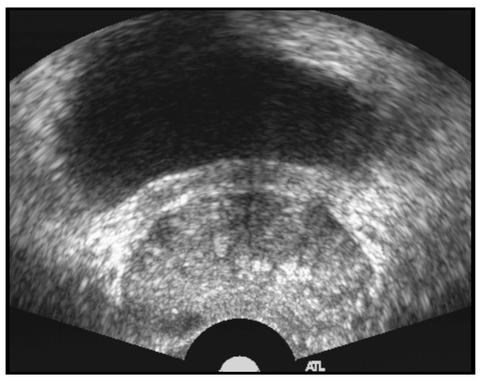
Using NVIDIA's Compute Unified Device Architecture' (CUDA), we provide a physically plausible simulation of ultrasound reflection, shadowing artifacts, speckle noise and radial blurring. The same algorithm can be used for simulating either linear or radial imaging, and all parameters of the simulated probe are interactively configurable at run-time, including ultrasound frequency and intensity as well as field geometry.

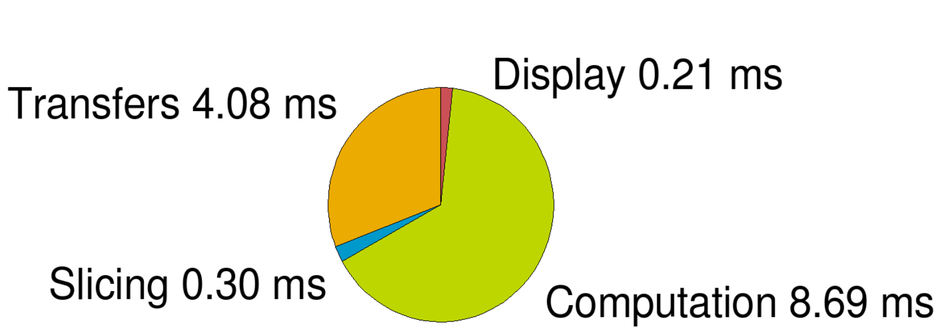
With current hardware we are able to achieve an image width of up to 1023 pixels from raw CT data in real-time, without any pre-processing and without any loss of information from the CT image other than from interpolation of the input data.

Visual comparison of our simulation (left), configured like a transrectal ultrasound probe, with a similarimage from a real transrectal ultrasound examination of a different patient (right)









Simulated image (left), image from a real transrectal ultrasound examination (middle), timing information for our ultrasound simulation (right).

References

W. Wein, S. Brunke, A. Khamene, M. Callstrom, and N. Navab, “Automatic CT-ultrasound registration for diagnostic imaging and image-guided intervention”, Medical Image Analysis 12, September 2008. In Press.