For 2023 American Institute of Ultrasound in Medicine (AIUM)

annual convention in Orlando, Florida, USA

New Methods from Applied Geophysics for Medical Ultrasound Imaging

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Objectives:
Medical ultrasound imaging and seismic imaging in applied geophysics shared similar roots in their early development of electronics and imaging methods in the 1950s to early 1960s. These two disciplines later diverged, with medical ultrasound focusing on electronics and hardware solutions for real time requirements and seismic imaging focusing on advanced methods and super-computing. Tomography from medical imaging was introduced to applied geophysics in the early 1980s. Attempts were reciprocally made to introduce geophysical imaging methods into medical ultrasound with little success, mainly due to the real time requirements in medical imaging. In this presentation we will attempt to introduce geophysical technologies into medical ultrasound imaging, demonstrating superior image quality in in-vivo diagnostic applications, with frame rates that are comparable to those of commercial scanners.

Methods:
We have implemented advanced seismic imaging methods on ultrasound radio frequency (RF) data for real time diagnostic applications. Adequate frame rates are maintained due to the high performance of Nvidia graphic processing units (GPU). After geophysical beamforming one can easily measure, on scattering matrices, amplitude variations with angles (AVA) and residual moveouts (RMO). The AVA attributes contain information about elastic property of tissues. The RMO attributes allow one to adjust sound speeds for imaging in order to achieve maximum focus at every output location. These are a few examples of geophysical methods that are not well-known in medical ultrasound community. These physical attributes can be further used for additional diagnostic applications: for example, co-rendering echogenicity (B-mode) in real time with tissue elasticity estimate and sound speed estimate to form a new type of ultrasound display called F-mode, which is similar to the rendition of Hubble telescope images of deep space published by NASA.

Results:
The first example was an in-vitro experiment of ultrasound guided intervention on 5-pound beef tissues. We used a linear array transducer made by GE Healthcare (GE L3-12D). We achieved clear definitions of tissues, needle trajectory, and needle tip. The resolution was clearly higher than published images of the same transducer. The F-mode display showed a vivid color image of tissues and needles. The frame rate was over 20 FPS (frames per second). The second example was an in-vivo diagnostic image of the heart of a young healthy volunteer. We used a phased array transducer made by Mindray (P4-2v). We achieved outstanding image of the heart, very much comparable to the best heart images published in literature. The frame rate was over 40 FPS.

Conclusions:

We have demonstrated that geophysical methods can lead to new advancements in medical ultrasound imaging, in the same way as tomography from medical discipline has revolutionized geophysical imaging for resource exploration. Advanced geophysical algorithms are enabled by GPU implementations. The impact of additional computation load becomes small so that adequate frame rates can be maintained. For extremely computation intensive algorithms, such as full waveform inversion (FWI), we need large GPU clusters in the cloud to achieve reasonable turnaround time. Three dimensional (3D) medical ultrasound technology is currently under development. 3D geophysical technologies were very mature and were used in commercial applications for a long period of time. Our development shows promising new opportunities to adapt 3D geophysical technologies into medical ultrasound applications.