Contribution ID: **54** Type: **Oral**

Real-Time Ultrasound Transmission Tomography based on Bézier Curves

Wednesday, November 1, 2017 3:40 PM (20 minutes)

Refraction-corrected ray-tracing methods in Ultrasound Transmission Tomography (USTT) are able to reconstruct the acoustic properties of tissues with good accuracy when using medium and high frequencies (>3MHz). However, these techniques, such as the Fast Marching Method (FMM), are time-consuming. In this work, we propose a real-time reconstruction methodology that exploits the large computing capabilities of current GPUs.

(2) Material and Methods

In the proposed method, each one of the hundreds of thousand threads that can be executed in parallel in modern GPUs, evaluates the time-of-flight (TOF) of the US pulse along smooth Bézier curves connecting emitter-receiver pairs. The evaluated curves with the shortest TOF are used for the reconstruction of both, sound speed (SS) and acoustic attenuation (AA) maps with an iterative OSEM algorithm. The method was evaluated with phantom data acquired with the USTT prototype MUBI, consisting of two coplanar rotating 3.5 MHz medical grade linear arrays, on a tissue-mimicking gelatin phantom. We then applied it to datasets acquired with a hybrid optoacoustic-ultrasound (OPUS) device (iThera Medical) using a full-ring array.

(4) Discussion and Conclusion

This method is faster than typical acquisition and processing in USTT, so it can be considered a real-time reconstruction method suited for clinical practice. The SS maps are quantitatively accurate, although AA maps have significant deviations at the edges due to wave-interference effects not considered in the bent-rays propagation model. In conclusion, the use of Bézier curves and GPUs is an effective way to perform bent-rays reconstruction of USTT data in real-time.

(3) Results

The SS maps are reconstructed in less than 5 seconds/slice using 6 OSEM iterations with 5 subsets. Using the pre-calculated Bézier bent-rays from the SS reconstruction, the AA maps can be obtained in 1 second/slice. Images reconstructed with straight-rays (i.e. without refraction correction) misestimate the actual size of the structures inside the phantom acquired with the MUBI USTT prototype. In the case of the OPUS scanner working in USTT mode, the images also showed significant artifact-reduction with regard to fast reconstruction methods based on straight-rays.

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Session Classification: Session 4: Imaging and inversion IV

Track Classification: Main Track