

Master Thesis Proposal

A flexible framework for realistic convolution-based real-time ultrasound simulation

Contact

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Motivation

Medical ultrasound imaging is receiving increasing importance, due to its versatile usability both in pre-operative diagnostics and monitoring, as well as intra-operative navigation and real-time update of the surgical plan.

The simulation of medical ultrasound imaging is an important task and has several application areas, such as pre-operative planning and simulation of the surgical procedure, intra-operative registration of a multi-modal pre-operative plan to the intra-operative scene (e.g. involving CT imaging), multi-modal registration (US-CT, US-MRI) as well as visual servoing of robotic ultrasound acquisition.

Ultrasound simulation approaches are prone to trade-offs between speed and realism. Very fast approaches based on ray-casting of US images from CT deliver rough approximations of US images, which are useful e.g. for registration in real-time and intra-operatively. In contrast to that, physically realistic simulations based on e.g. models of wave-propagation in human tissue yield images which match the real image closely, but these methods are typically very slow in execution.

Convolution-based approaches take an in-between position between the two approaches, allowing for very fast (i.e. real-time) simulation, but offering realistic features such as speckle patterns.

Task Description

This thesis aims at understanding the physical process of ultrasound imaging fully and improving a previously existing implementation of convolution-based simulation, which is currently available to the CAMP chair (MATLAB-based). Approaches to making the simulation physically more realistic include respecting phenomena such as attenuation, refraction and reflection or integrating new features such as confidence maps. Validation of the simulation method will include 1) comparison to images simulated using state-of-the-art frameworks (Field II) and wave-based approaches (e.g. k-wave) and 2) comparison to real ultrasound images acquired on appropriate phantoms. Next to development and validation of the methods (which can be performed in MATLAB), a further requirement is to implement the methods as a framework for real-time and realistic simulation of ultrasound images. This framework should be integrated into the C++ software framework currently under development at CAMP.

Objectives at a Glance

- Understand the physical process of ultrasound imaging
- Understand the principle of convolution-based ultrasound image simulation
- Improve the realism of image formation and simulation parameters (this part can be done in MATLAB)
 - Improve convolution-based simulation to better reflect real-life parameters such as transducer frequency, focus depth etc.
 - Improve realism further by integrating features such as attenuation, reflection and refraction as well as confidence maps
- Contribute to the CAMP software framework (C++) by implementing a real-time version of the convolution-based simulation, including versatile parameterization (different transducer geometries, physical parameters such as frequency, penetration depth, focus depth, beam width etc.)

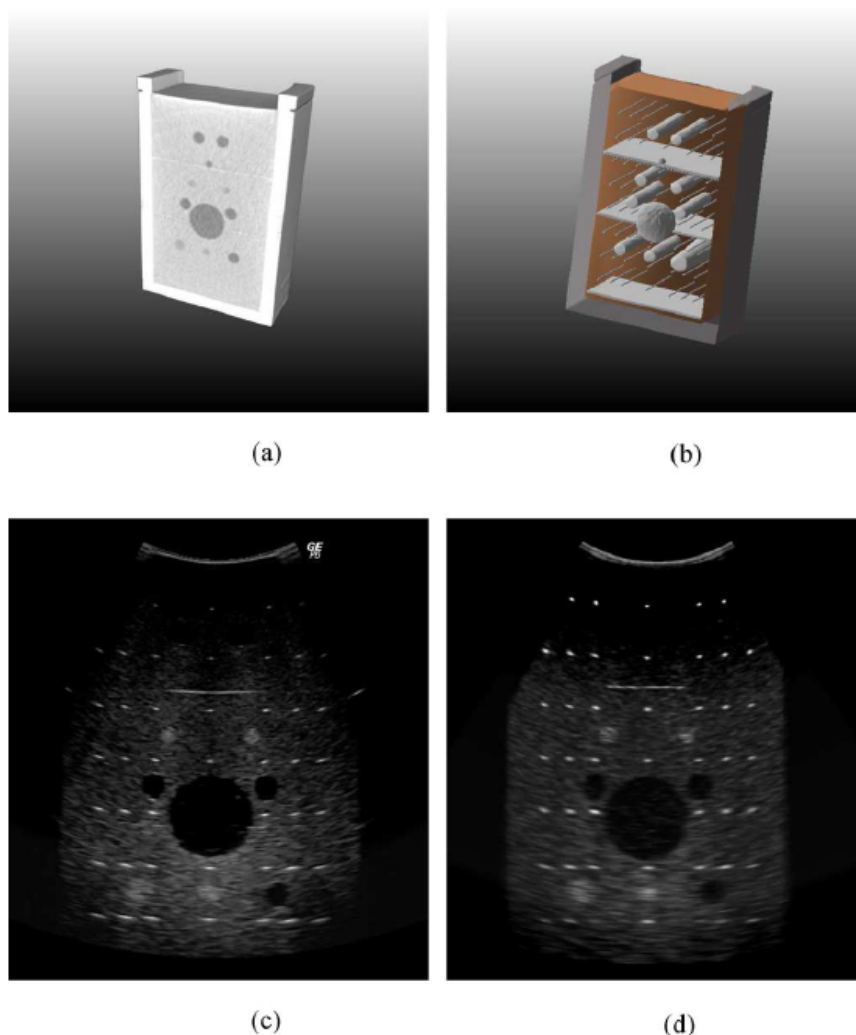


Fig. 6. Sliced BAT phantom and corresponding images from the phantom; both created using the same transducer orientation. (a) Sliced CT volume of BAT phantom. (b) Sliced mesh model of BAT phantom. (c) Image of BAT phantom recorded with a curved array transducer operating at 5 MHz. (d) Image of BAT phantom simulating a curved array transducer operating at 5 MHz.

Possible quality of ultrasound simulation using convolution-based approaches (taken from Bürger et al., 2012 (cf. Related Work)).

Related Work

Bürger et al. – Most important reference – Very elaborate simulation system, ray-based, convolution-based, including physical principles

Bürger B, Bettinghausen S, Rädle M, Hesser J.

Real-time GPU-based ultrasound simulation using deformable mesh models.

IEEE Trans Med Imaging. 2013 Mar;32(3):609-18. doi: 10.1109/TMI.2012.2234474. Epub 2012 Dec 20.

Gao et al. – COLE method

Gao H, Choi HF, Claus P, Boonen S, Jaecques S, Van Lenthe GH, Van der Perre G, Lauriks W, D'hooge J.

A fast convolution-based methodology to simulate 2-D/3-D cardiac ultrasound images.

IEEE Trans Ultrason Ferroelectr Freq Control. 2009 Feb;56(2):404-9. doi: 10.1109/TUFFC.2009.1051.

Hergum et al. – FUSK method

Hergum T, Langeland S, Remme EW, Torp H.

Fast ultrasound imaging simulation in K-space.

IEEE Trans Ultrason Ferroelectr Freq Control. 2009 Jun;56(6):1159-67. doi: 10.1109/TUFFC.2009.1158.

Comparison between FUSK and COLE

Gao H, Hergum T, Torp H, D'hooge J.

Comparison of the performance of different tools for fast simulation of ultrasound data.

Ultrasonics. 2012 Jul;52(5):573-7. doi: 10.1016/j.ultras.2012.01.009. Epub 2012 Feb 2.