

3D Ultrasound Computer Tomography - a data & computing intensive approach at multimodal ultrasound imaging

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Background & Motivation

3D Ultrasound Computer Tomography (3D USCT) is developed at the Karlsruhe Institute of Technology for early breast cancer detection. Unlike conventional ultrasound sonography methods with manual guided ultrasound (US) probes, the patient is placed on a patient bed with a stable and reproducible measurement configuration. A reproducible stable measurement configuration is achieved by surrounding the patient's breast with many spherical placed ultrasound transducers – 2304 individual US transducer elements. This allows screening and diagnosis in a reproducible way – long term, longitudinal tracking of a patient's status of its breast health is possible with a non-ionizing, 3D and easy to delivery imaging modality is now becoming thinkable.

Method

Despite the promising design and vision of the project, early pre-studies in hospitals (Hospital Jena, Hospital Mannheim) indicated that there are still some technical challenges to be tackled to realise the full potential of the method - the enormous computational burden of the various imaging approaches is hindering the scientific progress and the method.

More specifically, one challenge is the large amount of data (40 to 80 GB per measurement of pressure of time signals, so called a-scans) combined with large three dimensional imaging domain, the Region-of-interest, of $20 \times 20 \times 20 \text{ cm}^3$. With the desired resolution of $\sim 0.2 \text{ mm}$ this leads to an image volume of 1GVoxel in need of being computed. In case of reflectivity image reconstruction with SAFT (Synthetic Aperture Focussing Technique) both combined lead to 0.112 Terabyte (double floatingpoint data type) in write and read accesses in the computing process of the image.

While the SAFT algorithm is parallelised in GPU, the other modalities imaging methods having their challenges in the dimensionality and non-trivial partitioning schemes - the transmission based tomography is formulated as optimization problem, which is challenging due to the inherent three dimensional nature of the USCT's aperture.

Even more demanding approaches of promising full wave inversion schemes, inspired also from prior work in the field of geo-science, which struggle with high-frequency nature of the data provided by the USCT device and method.

Next Steps

HPC and grid computing should be offering the infrastructure and interfaces to tackle the multifold computational partitioning and big data challenges of USCT. The USCT project tries now to enable fellow scientist and associated communities and kick off collaborations. We are committed to open science, open access and open data: example data sets and access code are provided available under liberal licenses on github and a webservice.

A Matlab script with some reference imaging and visualization code:

“3D-USCT-III-access-script” KIT-3DUSCT/3D-USCT-III-access-script
(github.com)

The following datasets are provided:

1: Gelatine phantom with four inclusions made from PVC (spheres of different size 8 mm to 22 mm)

2: Empty measurement with the same acquisition parameters as the gelatin phantom.

3D KIT USCT – USCT data exchange and collaboration

- Contact:
- https://www.ipe.kit.edu/projekte_2833.php (Michael Zapf / Nicole Ruiter)

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Primary author: ZAPF, Michael

Co-authors: HOPP, Torsten; GEMMEKE, Hartmut; RUITER, Nicole

Presenter: ZAPF, Michael

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