Keynote Speaker: Gary Glover, Ph.D., Stanford University

Ancient Ultrasound Tomography and MRI Perspectives of Breast Cancer

Gary H. Glover received his PhD in Electrical Engineering from the University of Minnesota in 1969. He joined GE's Corporate Research & Development (CR&D) Labs in Schenectady, New York and studied solid state devices, computed ultrasound tomography and X-ray computed tomography until 1976, when he moved to GE's Medical Systems in Milwaukee to help transition fan-beam CT technology from CR&D. In 1980, he began the development of MRI as one of a team of five, and was thus instrumental in defining both the CT and MR products for GE. He joined Stanford's Radiology Department as Professor in 1990 and founded the Radiological Sciences Laboratory, dedicated to advancing biomedical imaging. His field of research is in MRI physics in general, and specifically in the development and application of functional MRI (fMRI) methods since 1993. His students' recent contributions include optimized techniques for acquisition and analysis of fMRI data, characterization of the dynamics of brain networks, development of real-time fMRI biofeedback methods, and multimodal neuroimaging using fMRI combined with EEG, fNIRS, fPET and functional MR Elastography, as well as with neuromodulatory transcranial electrical and magnetic stimulation.

He is a member of the US National Academy of Engineering and a Fellow of the American Institute for Medical and Biomedical Engineering (AIMBE) as well as the International Society for Magnetic Resonance in Medicine (ISMRM), for which he is also Past President. He holds a number of other awards including RSNA's Outstanding Researcher Award and ISMRM's Gold Medal, as well as Distinguished Investigator of the Academy of Radiology and the International Academy of Biomedical Engineers.

He has authored approximately 50 patents and published some 400 papers on his research.

Invited Talk: Eugene Malyarenko, Ph.D., University of Windsor

Transcranial Ultrasound Brain Imaging (TUBI) Solution for Point-of-Care Diagnosis of Traumatic Brain Injuries

Portability, safety, speed, cost, user friendliness, and accuracy of the final diagnosis are the most important aspects of any clinical diagnostic equipment. Although dramatic progress has been made in the area of medical diagnostic imaging, contemporary equipment still often relies on ionizing radiation and is bulky, costly, and difficult to use. Hence the quest for miniaturization and safety continues, as well as the efforts to solve new challenging diagnostic problems and a few highly professional research groups working pretty hard in this field during last decade worldwide, including us.

In this presentation, the author will provide an overview of current R&D status in this field and in more details introduce our latest results in developing Transcranial Ultrasound Brain Imaging (TUBI) complex solution for accurate and rapid on-site diagnosis of certain types of Traumatic Brain Injuries, e.g. Brain Hematomas, without resorting to current gold standard imaging tools, such as computed tomography (CT) and magnetic resonance imaging (MRI).

This presentation will address a fundamental problem in ultrasonic imaging: the inverse problem, that is, the need to recover parameters/image of target objects hidden from external observation by a barrier (e.g. acoustically non-transparent obstacle like the human skull). Ultrasonic waves propagating through multilayer thick skull bone undergo multiple reflections, strong beam distortions, phase aberration, and get considerably attenuated. Target abnormalities behind the skull bone can be static (e.g. bone fragments and blood clots) and dynamic (e.g. vasculature blood flow disruptions such as hemorrhage and aneurysm), making the detection of head trauma even more difficult. Our solution involves new highly efficient real-time image formation algorithms, improving the transcranial image contrast for better pathology detection, and mathematical morphology-based interpretation for both static and dynamic target abnormalities that will ultimately produce high quality digital images of the human brain. This is will be a subject of my invited talk and our final strategic goal is the clinical development and modification of the TUBI solution into an effective portable device for emergency personnel, sonographers, and physicians and hope to report you about those our achievements in a near future.

Invited Talk: Rachel Brem, M.D., George Washington University

Clinical Implications of Screening Breast Ultrasound: Past, Present and Future

This presentation will discuss the importance and clinical implications of dense breast tissue, how screening breast ultrasound can improve the detection of breast cancer, the challenges of implementing screening breast ultrasound and what the future holds in terms of technological improvement in breast ultrasound in detecting mammographically occult breast cancer as well as the increasingly important role of ultrasound and ultrasound based technologies in individualized breast cancer risk assessment.

Biography:
Dr. Rachel Brem is the Director of Breast Imaging and Intervention at The George Washington University Medical Center, Professor of Radiology and the Vice Chairman of the Department of Radiology. In 2015 Dr. Brem was named the Program Leader for Breast Cancer at the GW Cancer Center. Dr. Brem completed her undergraduate studies at Brandeis University followed by medical school at Columbia University where she graduated with honors. Dr. Brem completed both her Diagnostic Radiology Residency and Breast Imaging Fellowship at the John Hopkins Medical Institutions. Since completion of her training Dr. Brem was on the faulty at John Hopkins as the Director of Breast Imaging. Currently she is the Director of Breast Imaging and Interventional Center at the George Washington Medical Institution and Professor of Radiology. Dr. Brem's research and clinical interest includes Minimally Invasive Breast Biopsy as well as New Technologies for the Earlier Diagnosis of breast cancer focusing Whole Breast Ultrasound for women with dense breast tissue for improved breast cancer detection and risk assessment, Artificial Intellegence for breast cancer detection and Molecular Imaging of the Breast. She currently directs multi-institutional clinical trials evaluating novel approaches to improved diagnosis of breast cancer and is the recipient of numerous honors and awards including Best Cancer Doctors (Newsweek), Castle Connolly Best Doctors for Cancer and Top Doctor, Jewish Woman International's Ten Women to Watch, the prestigious fellowship in the American College of Radiology and the Society of Breast Imaging. She is an internationally recognized expert on Breast Cancer who is sought to speak on the subject nationally and internationally. Dr. Brem has extensively published, and is also committed to mentoring of students and residents. She is on the scientific advisory board of The Prevent Cancer Foundation as well as FORCE (Facing our risk of cancer, for women who are BR CA positive) and is a member of the Board of the Katzen Cancer Research Center. She currently serves on the Board of Directors of Delphinus Medical Technologies and Dilon Technologies and served on the Board of Directors of iCAD, inc from 2002-2019.

Dr. Brem is the Director of the George Washington University Mobile Mammography program (Mammovan), a mobile van that brings mammography to underserved communities to optimize the care of all women.

Dr. Brem was part of the formation of the Brem Foundation to Defeat Breast Cancer in 2004 with a group of committed patients and friends who have worked diligently to support translational research as well as education and clinical care in the underserved community. The Brem Foundation has recently been instrumental in passing dense breast legislation in the District of Columbia which has the highest death rate from cancer nationally.

Invited Talk: Paul Carson, Ph.D., University of Michigan

A History of US Transmission Tomography Emphasizing Approaches Out of the Mainstream

As head of the second group to present on ultrasound transmission tomography (UTT), I switched from emphasizing speed of sound (SOS) imaging to attenuation and pulse echo imaging. Confocal, 19 mm diameter transducers in translate-rotate geometry performed better in those roles than did small diameter transducers used in the Mayo Clinic and General Electric efforts designed primarily for SOS imaging. While bent ray SOS imaging was being explored in the mainstream, phase insensitive receivers were considered for less edge enhancement and other artifacts in attenuation imaging. This simpler approach to quantitative attenuation imaging has only recently been revived for medical imaging. Other body parts than breast were considered, as well as imaging of other tissue characteristics. In the mid 80's, clinical trials of commercial automated breast imaging systems were judged by radiology leaders to be unsuccessful and research funding of quantitative imaging and "oversold" tissue characterization went down with those systems. S. Johnson's Techniscan worked consistently through two down decades and UCT improved considerably with good bent-ray and then full wave migration or inversion imaging. Competition from the simpler, but well sampled ring array of Delphinus Medical Technologies has moved UTT close to clinical acceptance. We began work on limited angle transmission tomography in the mammographic geometry, leading to use of pulse echo information to fill in missing data. The concept of bulk attenuation coefficient was introduced to minimize domination of attenuation images by losses at major boundaries delineated in pulse echo and transmission modes. With less than full apertures, the distinction between transmission and pulse echo imaging becomes less distinct and tomography of bulk tissue properties by pulse echo systems is again worth consideration, as is combination of transmission data with other ultrasound modes and thermoacoustic imaging.

Invited Talk: Lluis Guasch, Ph.D., Imperial College of London

Ultrasound imaging with FWI: from breast to brain

Full-waveform inversion (FWI) is an imaging technique developed in the field of seismology that exploits all available information in the data, phase and amplitude, by solving a local optimisation problem based on the numerical solution of the wave equation. This technology was first translated to medical breast imaging over a decade ago. It has dramatically improved the potential of ultrasound as an imaging tool for breast cancer diagnosis due to its ability to produce high-resolution images and to provide quantitative information of several tissue properties such as acoustic speed, density, impedance or attenuation.

Despite its many challenges, breast imaging with FWI benefits from the low tissue heterogeneity of the target and from adequate instrument access to provide sufficient illumination. Brain imaging, on the other hand, presents a more challenging problem due to the presence of the skull. The high-contrast bone tissue surrounding the imaging target, i.e. the brain, requires full 3D data acquisition as well as some a priori knowledge of the geometry and acoustic properties of the skull. Under the right circumstances, however, brain imaging with FWI is possible and has the potential to impact the diagnosis and monitoring of a wide range of neuropathologies like stroke, brain cancer or head trauma.

Biography:
Dr Lluís Guasch is a Research Fellow at Imperial College London. He performs his research across the Earth Science and Engineering, and the Bioengineering departments. He holds a B.Sc. in physics from the University of Barcelona and a Ph.D. in Geophysics from Imperial College London. His work in seismic imaging has let to a successful start-up company, S-Cube, where he is one of the founders and the COO, as well as author of the two patents that drive the technology and commercial development of the company. During the last four years his research has been focused on medical imaging, and currently leads an academic multi-disciplinary group that works on translating seismic imaging technologies to ultrasound imaging for clinical applications.

Invited Talk: Mohammad Mehrmohammadi, Ph.D., Wayne State University

Full-ring Photoacoustic Tomography: Light and Sound to Enhance Diagnosis of Breast Cancer

Photoacoustic imaging has shown a steadily growth in diagnostic imaging of various pathologies including cancer. Through excitation of the tissue with light, conversion of the light energy to thermal energy, minor but rapid thermoelastic expansion followed by generation of acoustic waves, PA provides a complementary platform to acquire optical signature of breast tumors using the same hardware used for US imaging. In recent years, PA tomography (PAT) imaging of breast cancer has shown a steady growth. We have developed a PAT system based on a ring geometry (both excitation and detection) that can potentially address limitations of existing PAT system. Within this presentation, an overview of PAT application in breast cancer detection and staging as well as initial results from our developed full-ring PAT system will be presented.

Link to professional website: http://ultrasoundwayne4.wixsite.com/mehr-lab

Oral Presentations

Abstract ID : **95**

The New Generation of The Breast Ultrasound Tomography Imaging System in HUST

Content

Background：
In 2017, our team developed the prototype of the ultrasound tomography system. To this end, we have designed and implemented a new generation of the ultrasound tomography system to meet the clinical requirement.

Material and Method：
The new system mainly includes a patient bed, image reconstruction servers and a display workstation. A ring array probe is adopted, which have 2048 elements with the center frequency 3.0 MHz and the radius 110 mm. The system has 512 independent transmit and receive channels. The excitation voltage can be up to +/-100V. After digitization, the RF signals are transmitted to the reconstruction servers, and the GPU completes the image reconstruction. The display station receives and displays the reconstructed images and provides an interface for data management and debugging.

Results：
The acquisition time for one slice can be set between 2s to 8s depending on different imaging modes. The reconstruction time of the reflection image of 2048x2048 pixels is 4s, and the reconstruction time of the sound speed image and the attenuation image of 1024x1024 pixels are 20s and 25s.

Conclusion：

Preliminary tests have shown that the performance of the new system has been significantly improved. The future work is to optimize the system based on clinical results.

Primary author(s) : Mr. SONG, Junjie; Mr. LIU, Kuolin; Mr. ZHANG, Qiude; ZHOU, Liang; Dr. ZHOU, Quan; QUAN, Zhaohui; Mr. WU, Yun; Ms. FANG, Xiaoyue; Mr. YUCHI, Ming; Mr. DING, Mingyue

Contribution Type : Oral

Status: SUBMITTED

Submitted by **SONG, junjie** on **Thursday 25 July 2019**

Abstract ID : **89**

Progress Towards an Open-Source, Low-Cost Ultrasound Computed Tomography Research System

Content

Existing clinical UCT systems are custom-built at high cost and with a long lead time, which can be prohibitive for some research groups. At UCL we are developing FlexUCT: a design framework for a benchtop UCT system that will allow novel data acquisition protocols and reconstruction algorithms to be tested immediately on a physical system, accelerating progress towards fast and accurate UCT.

FlexUCT will be an open-source, low-cost design framework for an UCT ring array, that can be manufactured in-house with a short lead time, using commonly available rapid-prototyping technology and workshop equipment, and will be easily adaptable so that research groups can customise the system to suit their requirements. The hardware distribution will provide the complete specification needed to build a UCT ring array, including 3D printing design files, printed circuit board (PCB) layouts, Gerber files for PCB manufacture, and a bill of materials with an assembly procedure.

The basic FlexUCT system will comprise of a 220mm 256-element PZT ring array with Tungsten-Epoxy matching and backing layers , an interface to the Vantage Verasonics system with electrical impedance matching, and a scanning tank with a translation stage. We will present the progress made towards building FlexUCT, and detail the design and testing of 4-element array prototypes (see Figure).

Specifically, a low-cost method has been developed to manufacture matching and backing layers. Novel tranducer-array assembly methods have been used, following investigation into the accuracy of the PZT element orientation using microCT scans. The acoustic cross talk and internal reverberations within the prototypes have been characterised and are negligible, and methods to prevent electrical cross talk for low-cost matching networks have been explored. The bandwidth of the prototypes has been measured using broadband optoacoustic sources and is shown to be 61% with a centre frequency of 2MHz, but the flexible design allows PZT elements to be used with a resonance frequency between 0.5MHz-5MHz. Field scans of the 4-element prototype have been performed, showing a -3dB beam thickness of 9mm, and the directivity and SNR have also been characterised.

Primary author(s) : Mr. ROBERTS, Morgan (University College London)

Co-author(s) : Mr. COX, Ben (University College London); Mr. BRADLEY, Treeby (University College London); Ms. MARTIN, Eleanor (University College London); Mr. BROWN, Michael (University College London)

Track Classification : Main Track

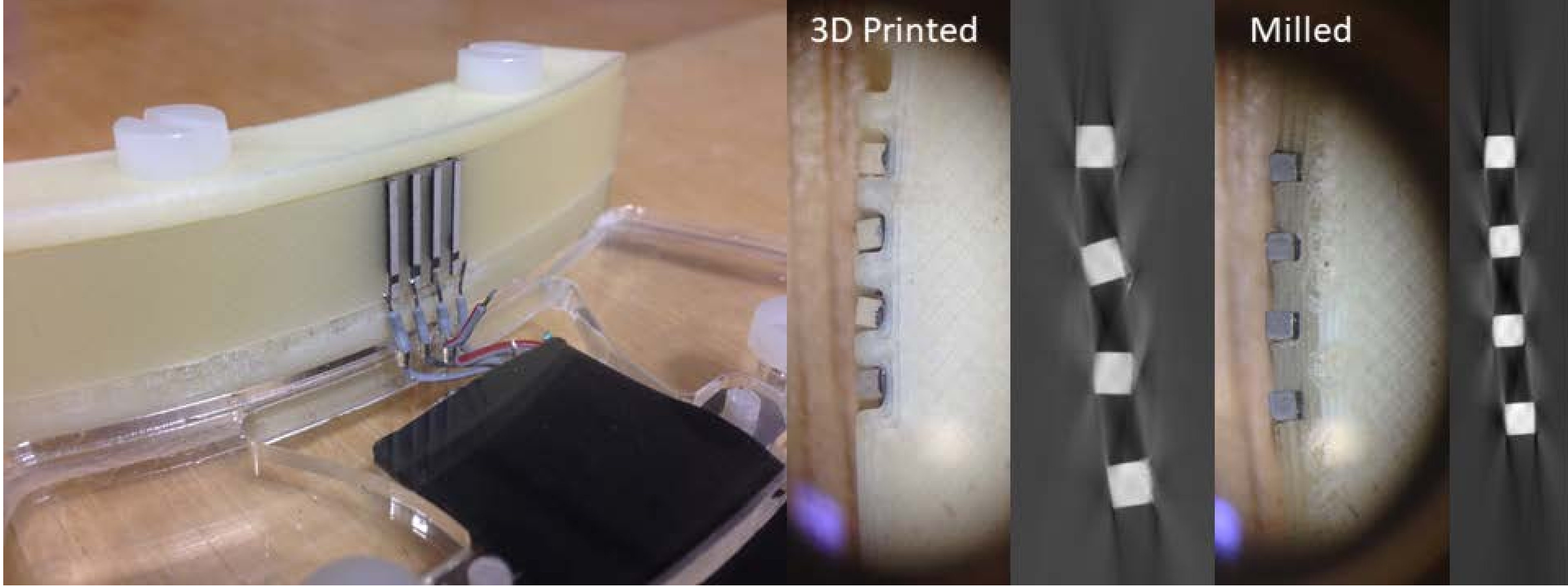
Contribution Type : Oral

Comments:

I have applied for an oral presentation, but would be happy to present a poster instead if necessary.

Status: SUBMITTED

Submitted by **ROBERTS, Morgan** on **Thursday 25 July 2019**


3D Printed
Milled

Abstract ID : **87**

A Low-cost Ultrasound Computed Tomography System using Diagnostic Linear Arrays

Content

Primary author(s) : Ms. PATEL, Preena (University College London)

Co-author(s) : Dr. COX, Ben (University College London); Dr. TREEBY, Bradley (University College London)

Track Classification : Main Track

Contribution Type : Poster

Comments:

Hi, I would prefer a poster presentation but am more than happy to do an oral presentation too. I would also like to apply/enquire about any funding schemes you have to cover travel costs for students travelling to the conference. Kind Regards, Preena Patel

Status: SUBMITTED

Submitted by **PATEL, Preena** on **Wednesday 24 July 2019**

A Low-cost Ultrasound Computed Tomography System using Diagnostic Linear Arrays

Ultrasound Computed Tomography is clinical imaging modality whose potential to complement mammography as a non-ionising, economical breast screening or diagnosis tool has recently driven renewed interest and rapid development. Costly, custom-built detector arrays with a variety of geometries have been proposed including bowl-shaped, rings, and planar arrays. Here, we investigate whether a simple low-cost system based on diagnostic linear arrays can be used to perform USCT. A proof-of-concept system was constructed using clinical-grade linear arrays, an off-the-shelf data acquisition system, and in-house image reconstruction software.

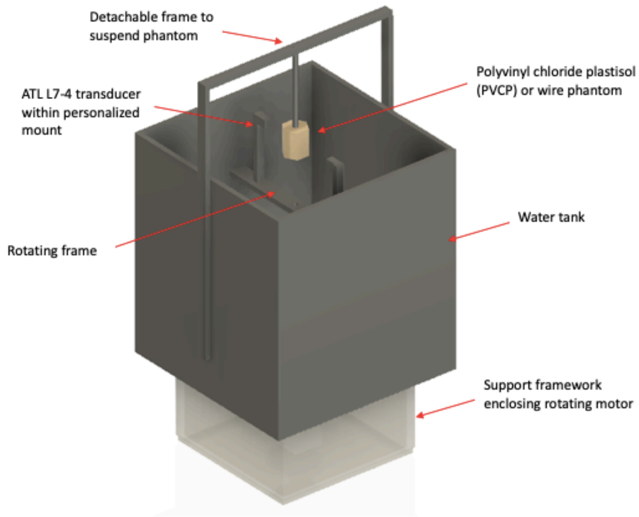


Figure 1: A schematic of the USCT

The designed USCT system (see Figure 1) houses two linear array transducers, opposing each other, rotating on a frame about a phantom. The arrays fit to the frame via a detachable mount, allowing for an adjustable array separation and hence reducing the effects of diffraction for phantoms of varying dimensions. The main operating components are located beneath the water tank and hence it can be placed under a patient bed for clinical applications in the future. The entire system excluding the transducers and phantoms is designed from recycled plastic and stainless steel, making it economical and simple to manufacture. The probes are connected to a Verasonics ultrasound system which allows for independent channel and element control. Control of the rotation motor and scan sequencing was via Matlab. Four phantoms were scanned (two PVCP and two wire phantoms). At each rotation angle, a plane wave was emitted from an array and both the back-scattered and transmitted signals were detected. Time-of-flight and amplitude values were extracted from each measured time series and, and 2D images of the sound speed and attenuation were reconstructed using both straight- and bent-ray reconstruction algorithms.

The systems components and promising preliminary results are to be presented. This will include sound speed and attenuation maps from multiple signal processing and reconstruction algorithms, data from multiple scans with varying angles of rotation as well as a comparative analysis of the above scan parameters. The system characteristics (e.g. resolution) from the wire phantom will also be discussed.

Abstract ID : **106**

Towards 3D Brain Imaging in Small Animals using Full-Waveform Inversion

Content

Full-waveform inversion (FWI) is an iterative image-reconstruction technique used in exploration seismology to produce high-quality tomographic images for acoustic properties of the subsurface by minimising the misfit between acquired and modelled data. FWI has also been shown to have some exciting applications in ultrasound imaging of soft tissue, including breast cancer diagnosis, however the method has yet to be applied to brain-imaging in small animal models where hard tissue is present and 3D reconstruction is required. Here we demonstrate the feasibility of 3D small-animal transcranial tomography using FWI *in silico* and implement our FWI algorithm to reconstruct an *in vitro* acoustic brain phantom in 2D using data acquired with independently translated medical transducers.

In this study a pair of 96-element linear probes (P4-1, ATL) were each assigned a set of 3-axis motors for independent translation, allowing for a larger imaging region and for 3D acquisitions to be performed. To test this experimental setup, an *in silico* mouse brain and skull acoustic model was created and placed between two 1152-element plane arrays, each representing the translation of a linear array over 12 positions (with 2.5 mm spacing), as shown in Fig1.a. A synthetic 3D dataset of this scene was produced so that the velocity model could be reconstructed using a robust 3D FWI algorithm. To mitigate cycle skipping due to the skull tissue, a starting model consisting of the mouse skull and homogenous water (1500 ms-1) was used. To demonstrate this method using real data, we acquired a 2D dataset of a half-scale 2.5D brain phantom made using a polyvinyl alcohol cryogel to mimic brain tissue. By translating both probes vertically when acquiring data, a two-plane array consisting of 960 elements was formed, from which a subset of 240 were selected as sources. Element delays and positions were calibrated by time of flight optimisation using a watershot dataset and the velocity model was reconstructed using our 2D FWI algorithm.

Fig1.b shows FWI results of the mouse brain and skull model. When compared to the ground truth, a relative error of 0.110 % has been achieved (starting model relative error = 2.562 %). In Fig1.c-d the photo of the brain phantom and the reconstructed velocity model can be seen to closely match. In future work we will introduce rotation to further improve our transducer scanning sequence and apply our method to image *ex-vivo* brain and skull tissue.

Primary author(s) : ROBINS, Thomas (Imperial College London); CUETO, Carlos (Imperial College London); Dr. CALDERON AGUDO, Oscar; Dr. GUASCH, Lluis; Prof. WARNER, Michael; Prof. TANG, Meng-Xing (Imperial College London)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **ROBINS, Thomas** on **Thursday 25 July 2019**

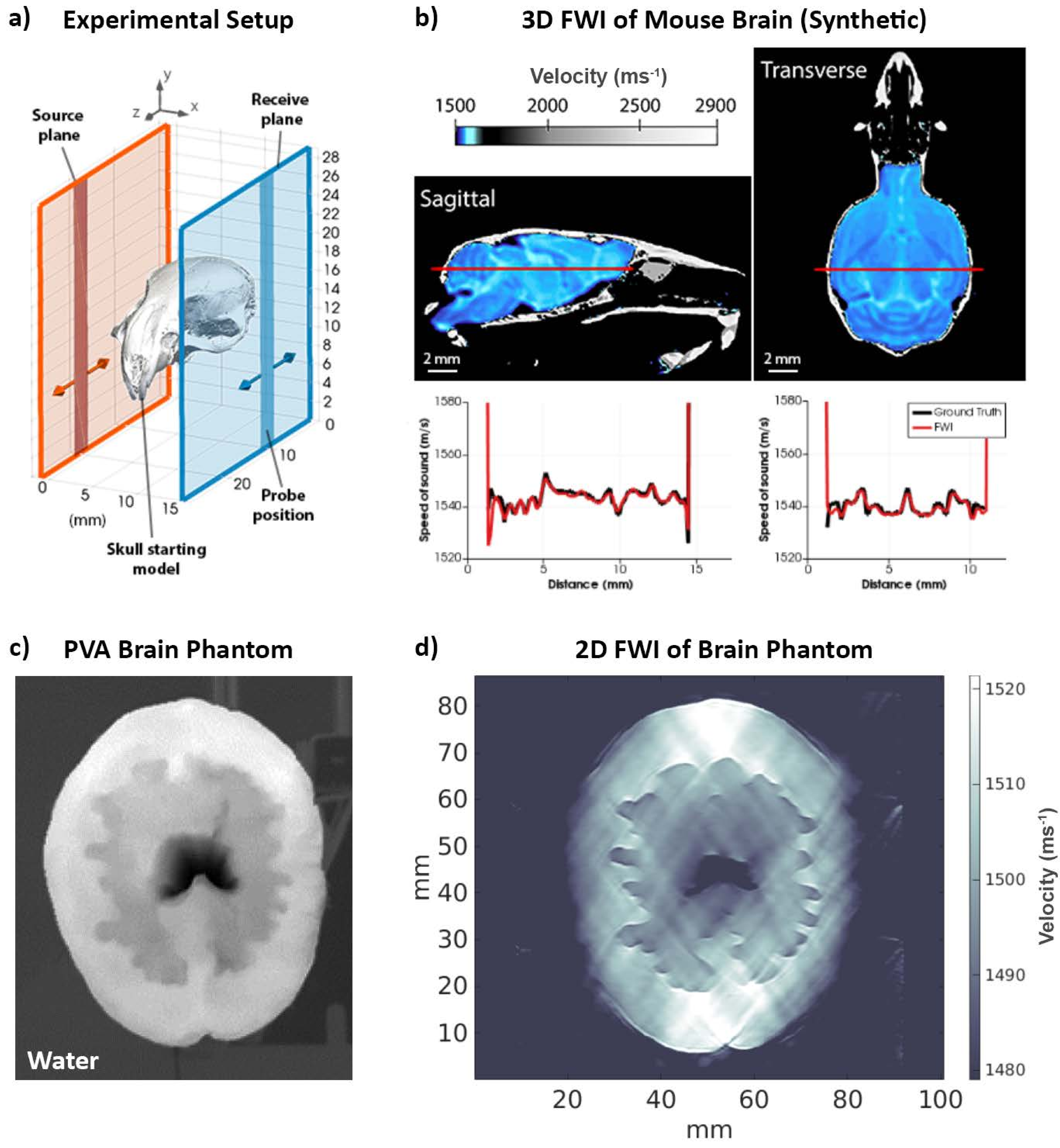


Fig 1. a) Experimental setup of 3D synthetic mouse brain model, **b)** Sagittal and transverse views of velocity model recovered using FWI with velocity samples (red) plotted against ground truth, **c)** Photo of brain phantom, **d)** Brain phantom velocity model recovered using FWI

Abstract ID : **104**

The Efficiency of an All-reflective Omnidirectional Illumination for Photoacoustic Tomography with a Ring Ultrasound Transducer

Content

Breast cancer is a common cancer and a major health concern affecting the lives of many women worldwide. According to the World Health Organization (WHO) breast cancer has an estimated annual incidence rate of 2.1 million and is responsible for about 15% of all cancer related deaths around the world. We have previously introduced a novel photoacoustic tomography (PAT) system for breast cancer imaging, in which the object is illuminated omnidirectionally by using a cone and a conical ring mirrors. A ring ultrasound (US) transducer is used to acquire PA signals and to form the PAT images. The design of the system is intended to acquire data from entirety of a pendant breast up to the chest wall, without compressing the tissue, thus allowing for deeper detection of endogenous chromophores associated with breast cancer.

This work presents the characterization of the full-ring illumination/acquisition system through three different studies. In the first study, three different illumination methods, full-ring, diffused-beam, and point source illumination, and their efficacy for PAT imaging are compared. The results indicate that the full-ring illumination method is capable of providing a more uniform fluence irrespective of the vertical depth of the cross-section imaged, while the point source and diffused illumination methods provide a higher fluence at regions closer to the point of entry, which diminishes with depth. The omnidirectional ring illumination can provide a more uniform illumination pattern within the tissue and enable PAT imaging at deeper distances in the targeted cross-sectional area. In the second study, a set of experiments were conducted to determine the optimum position of ring-illumination with respect to the position of the acoustic detectors to achieve the highest signal-to-noise ratio. The last study was performed on breast-mimicking phantom, made out of human fat and embedded blood inclusions, to truly identify the capabilities of the developed PAT system and specifically the achievable in-plane penetration depth. The results demonstrate that the system is capable of imaging blood up to a cross-sectional depth of 30 mm. These three studies demonstrate the utility and advantages of the full ring-illumination system in imaging breast mimicking objects and paves the way for future development of the system towards a clinically translatable breast PAT scanner and can be part of a future diagnostic system.

Primary author(s) : Mr. ALSHAHRANI, Suhail (Wayne State University); Dr. ALIJABBARI, Naser (Wayne State University); Mr. PATTYN, Alexander (Wayne State University); Dr. MEHRMOHAMMADI, Mohammad (Wayne State University)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **ALSHAHRANI, Suhail** on **Thursday 25 July 2019**

Abstract ID : **70**

Tissue Sound Speed: A Novel Imaging Biomarker for Measuring Tamoxifen Response

Content

Primary author(s) : Dr. SAK, Mark (Delphinus Medical Technologies); Dr. DURIC, Neb (Karmanos Cancer Institute); Dr. LITTRUP, Peter (Crittenton Hospital); Dr. GIERACH, Gretchen (NIH)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **DURIC, Neb** on **Monday 22 July 2019**

PURPOSE. Studies have shown that a decrease in mammographic density (MD) or lowering of background parenchymal enhancement (BPE) on MRI after initiation of tamoxifen therapy predicts a favorable response in the preventive or adjuvant settings. However, performing serial mammograms poses radiation concerns, while serial MRIs carry high cost as well as risk of multiple Gadolinium doses. Previous studies have shown that tissue sound speed, derived from whole breast ultrasound tomography measurements, is a surrogate biomarker of MD. Ultrasound is ideal for performing serial measurements because it is fast and poses almost no risks. The purpose of this study was to evaluate repeated measures of the sound speed biomarker at 3, 6 and 12-months following tamoxifen initiation.

METHOD AND MATERIALS. We performed a case-control comparison involving 74 participants referred by a health professional to undergo tamoxifen therapy (cases) and 150 matched participants with no history of breast cancer (controls). The cases were scanned with ultrasound tomography at baseline (i.e. before start of tamoxifen therapy), and then at 3, 6 and 12 months after tamoxifen initiation. Controls were scanned at baseline and 12 months. In the case group, sound speed was measured pre-treatment in the contralateral breast to avoid potential influences of tumor-related changes on density. In the control group, a single randomized breast was scanned. A pairwise t-test was used to assess differences in sound speed over time and between cases and controls.

RESULTS. There was a steady decline in sound speed over the 12-month period for women undergoing tamoxifen therapy (mean(SD): -3.0(8.2) m/s; P=0.001). Furthermore, significant sound speed reductions were observed as early as 4-6 months after tamoxifen initiation (mean(SD): -2.1(6.8) m/s; P=0.008); **Table 1**. In contrast, the controls demonstrated no significant change in sound speed over a 12-month period, and the difference between case-control groups was statistically significant (*P*=0.0009).

CONCLUSION. Breast sound speed decreases rapidly after tamoxifen initiation; further studies are needed to assess whether this can predict clinical response.

CLINICAL RELEVANCE/APPLICATION. Ultrasound tomography may have utility in monitoring breast sound speed change as a potential biomarker of clinical tamoxifen response.

Time	Control (m/s change)		TAM group (m/s change)	
	Value	95% CI	Value	95% CI
Baseline	0	0	0	0
3 months	-	-	-0.5	-1.1, +0.1

6 months	-	-	-1.2	-2.1, -0.2
12 months	0.1	-06, +0.8	-3.1	-4.1, -2.1

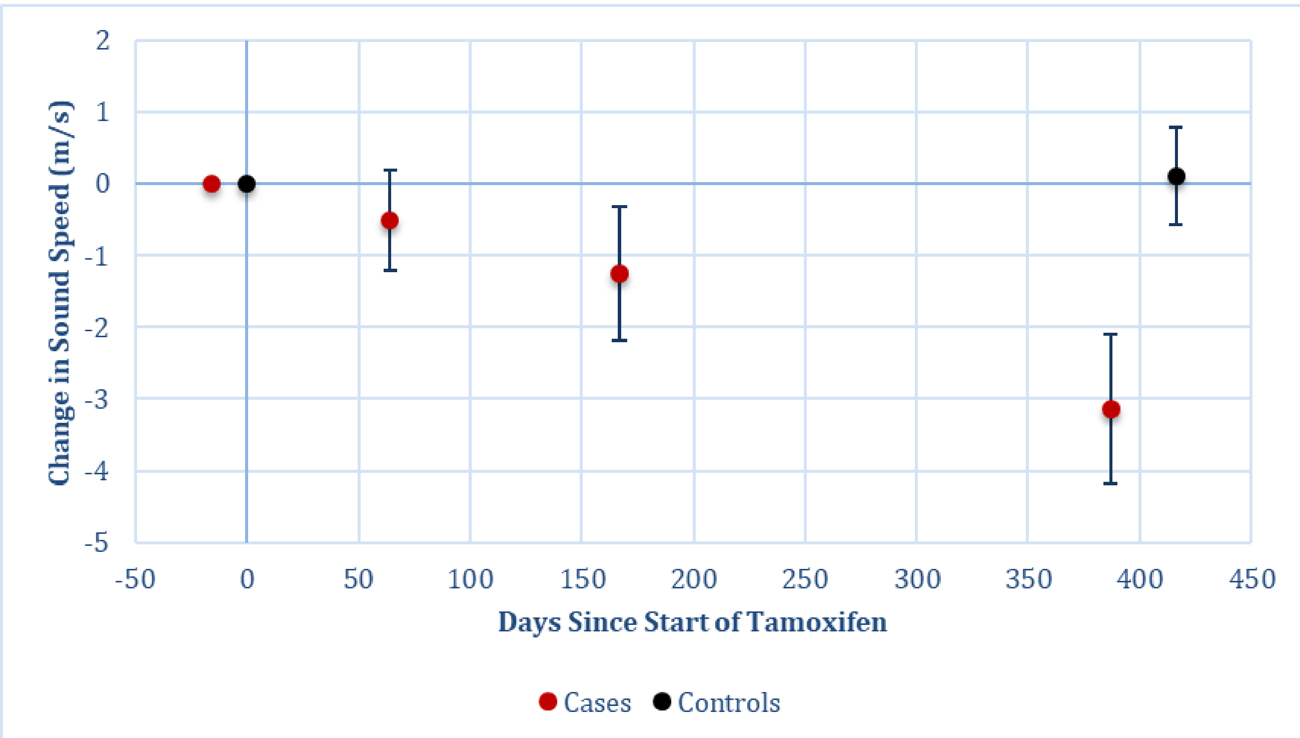


Figure 1. The change in breast sound speed averaged over the control and case groups. The cases show a systematic decline in sound speed relative to the controls.

Abstract ID : **73**

Tissue sound speed is more strongly associated with breast cancer risk than mammographic percent density: A comparative case-control study.

Content

Primary author(s) : Dr. DURIC, Neb (Karmanos Cancer Institute); Dr. SAK, Mark (Delphinus Medical); Dr. LITTRUP, Peter (Crittenton Hospital); Dr. BREM, Rachel (George Washington University)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **DURIC, Neb** on **Monday 22 July 2019**

PURPOSE. Increased mammographic percent density (MPD) is a strong independent risk factor for developing breast cancer. Previous studies have shown that tissue sound speed, derived from ultrasound tomography, is a surrogate biomarker of MPD. We examined associations of sound speed and MPD with breast cancer risk in a case-control study.

METHOD AND MATERIALS. We evaluated breast cancer risk associated with sound speed and MPD in a case-control study involving 59 participants with recent breast cancer diagnoses (cases, aged 30-70 years) and 150 participants with no history of breast cancer (controls), who were matched to cases on age, race, and menopausal status. The cases and controls were imaged with both ultrasound tomography (UST) and mammography. In cases, breast density was measured pre-treatment in the contralateral breast to avoid potential influences of tumor-related changes on MPD or sound speed. In controls, a randomly selected breast was imaged. The ultrasound tomography images were used to estimate the volume averaged sound speed of the breast, and the Cumulus software package was applied to mammograms to determine MPD. Odds Ratios (ORs) adjusted for matching factors and 95% Confidence Intervals (CIs) were calculated for the relation of quartiles of MPD and sound speed with breast cancer risk. OR differences were tested using a bootstrap approach.

RESULTS. MPD was associated with elevated breast cancer risk compared to controls, consistent with previous studies, although the trend did not reach statistical significance (OR per quartile=1.28, 95%CI: 0.95, 1.73; p_{trend}=0.10). In contrast, elevated sound speed was significantly associated with increased breast cancer risk in a dose-response fashion (OR per quartile=1.79, 95%CI: 1.30, 2.48; p_{trend}=0.0004) (**Table 1**). The OR-trend for sound speed was statistically significantly different from that observed for MPD (p=0.01).

CONCLUSION. Our case-control study showed that increasing quartiles of whole breast sound speed were consistently and more strongly associated with increasing breast cancer risk than quartiles of MPD. These results show promise for UST's role in breast cancer risk stratification.

CLINICAL RELEVANCE/APPLICATION. Elevated breast density strongly increases breast cancer risk. UST has the potential to provide a more accurate, non-ionizing method for assessing breast density and its associated breast cancer risk.

	Case (N=59)		Comparison (N=150)	
	N	%	N	%
Quartiles of baseline mammographic density, %				
<7.5	9	15.3	37	24.7
7.5-<16.4	9	15.3	38	25.3
16.4-<31.8	20	33.9	37	24.7
≥31.8	21	35.6	38	25.3
Quartiles of baseline sound speed, m/s				
<1440.63	4	6.8	39	26.0
1440.63-<1445.65	10	17.0	39	26.0
1445.65-<1452.81	16	27.1	35	23.3
≥1452.81	29	49.2	37	24.7

	Odds Ratio	95% CI		P-value
MPD	**1.00**			
Q2 vs. Q1	**0.98**	**0.35**	**2.76**	
Q3 vs. Q1	**1.92**	**0.75**	**4.92**	
Q4 vs. Q1	**1.88**	**0.73**	**4.83**	
TREND (OR per quartile)	***1.28***	***0.95***	***1.73***	***0.1038***
SS	**Ref**			
Q2 vs. Q1	**2.37**	**0.67**	**8.36**	
Q3 vs. Q1	**4.23**	**1.27**	**14.14**	
Q4 vs. Q1	**6.61**	**2.02**	**21.59**	
TREND (OR per quartile)	***1.79***	***1.30***	***2.48***	***0.0004***
P-difference, comparing OR-MPD trend vs. OR-SS trend=				***0.010255317***
				CHIDIST(6.59,1 degree of freedom)

Abstract ID : **74**

Breast cancer development at the fat-gland interface (FGI): Importance of coronal imaging and ultrasound tomography.

Content

Primary author(s) : Dr. LITTRUP, Peter (Crittenton Hospital); Dr. DURIC, Neb (Karmanos Cancer Institute); Dr. SAK, Mark (Delphinus Medical); Dr. BREM, Rachel (George Washington University)

Contribution Type : Oral

Status: SUBMITTED

Submitted by **DURIC, Neb** on **Monday 22 July 2019**

PURPOSE. Recent analyses of tumor location by breast magnetic resonance (MR) imaging have shown that breast cancers were significantly more likely to be located, at or near the fat-gland interface (FGI) but did not include cysts or coronal evaluations. Ultrasound tomography (UST) is a novel multi- sequence tomographic form of sonography with anatomic and physiologic information that can improve the sensitivity of breast cancer detection, particularly in women with dense breasts. The purpose of this study was to use coronal UST to map the locations of cancers, fibroadenomas and cysts relative to the FGI in order to facilitate the detection and characterization of breast masses in future UST screening.

METHODS AND MATERIALS. Mass location in coronal UST images was determined by a MQSA certified radiologist familiar with UST imaging. The relationship of the lesion to the FGI was noted for a total of 405 breast masses (132 cancers, 138 fibroadenomas and 135 cysts), confirmed by biopsy or by hand-held ultrasound for masses that fulfilled all criteria for a simple cyst. The FGI was defined as the circumferential interface between the peripheral fat and parenchyma. Mass location was placed into three groups: (i) completely surrounded by dense fibroglandular tissue, (ii) completely surrounded by fat or (iii) partially surrounded by both (i.e., the FGI). Lesion locations relative to FGI were compared using the chi-squared test.

RESULTS: Cancers were associated with the FGI in 94.7% (125/132) of the cases and were surrounded by fat in 5.3% (7/132) or parenchyma in 0.8% (1/132) ($p<0.001$) of the cases, respectively (Table 1). For fibroadenomas, 62% (85/138) were found at or near the FGI. Cysts were associated with the FGI in [29% (39/135); $p<0.001$] of the cases. Moreover, cysts (69%) and fibroadenomas (32%) were more likely to be fully surrounded by dense tissue, compared to cancers (0.8%).

DISCUSSION. With the introduction of UST, our finding that breast cancers occur more frequently at the fat-gland interface will assist in the interpretation of images by helping find cancers more readily.

CONCLUSIONS. The coronal view by UST confirmed that cancers are much more likely to be found at the FGI ($p<0.01$) compared to fibroadenomas and cysts. UST is a novel new technology that has the potential for improved breast cancer detection. This study supports increased accuracy of UST imaging as it becomes integrated into clinical practice.

Table 1

Type of mass	At FGI	In Dense tissue	In Fat
Cancer	125 (94%)	1 (1%)	7 (5%)
Fibroadenoma	85 (62%)	42 (32%)	8 (6%)
Cyst	39 (29%)	93 (69%)	3 (2%)

Abstract ID : **76**

Multi-parameter inversion

Content

Motivation

Ultrasound computed tomography (USCT) is gaining interest as a scanning modality to detect breast cancer in woman. To reconstruct the acoustic tissue parameters, full-wave inversion methods are applied on the measured data. However, in many works, only the speed of sound profile of the medium is reconstructed and the mass density is assumed to be constant. In this work, we aim to reconstruct simultaneously the compressibility and mass density from the measured pressure field.

Material and Methods

We use a full-vectorial contrast source inversion (CSI) procedure where measurements of both the velocity field and the pressure field are required to reconstruct the mass density and compressibility of the medium. In practice, only the pressure field is measured. To reconstruct the velocity field from the pressure field, we developed a method based on Hankel function decomposition of the pressure field. After the velocity field is reconstructed, the full-wave inverse problem is solved for the unknown compressibility and mass density.

Results

The proposed method is tested with a synthetic example. First, the forward problem is solved for the synthetic breast phantom given in Figure 1. Numerical values for the tissue properties (density and compressibility) are selected from literature. Next, the velocity field is computed using the pressure field measured along a circle enclosing the breast. Finally, a full-vectorial CSI is executed where the measured pressure and the computed velocity fields are used to accurately reconstruct the density and compressibility profiles of the medium. The reconstruction results are shown in Figure 1.

Discussion and Conclusion

A full-vectorial CSI is used for multi-parameter inversion. This method reconstructs density and compressibility profiles simultaneously using the measured pressure and velocity fields together. The velocity field is computed from the measured pressure field using Hankel function decomposition. The results obtained with a synthetic example show that the method can accurately reconstruct density and compressibility profiles from pressure field measurements only.

Primary author(s) : Mr. TASKIN, Ulas

Co-author(s) : Dr. VAN DONGEN, Koen W. A.

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **TASKIN, Ulas** on **Tuesday 23 July 2019**

Multi-parameter inversion

Ulas Taskin and Koen W.A. van Dongen

Motivation

Ultrasound computed tomography (USCT) is gaining interest as a scanning modality to detect breast cancer in woman. To reconstruct the acoustic tissue parameters, full-wave inversion methods are applied on the measured data. However, in many works, only the speed of sound profile of the medium is reconstructed and the mass density is assumed to be constant. In this work, we aim to reconstruct simultaneously the compressibility and mass density from the measured pressure field.

Material and Methods

We use a full-vectorial contrast source inversion (CSI) procedure where measurements of both the velocity field and the pressure field are required to reconstruct the mass density and compressibility of the medium. In practice, only the pressure field is measured. To reconstruct the velocity field from the pressure field, we developed a method based on Hankel function decomposition of the pressure field. After the velocity field is reconstructed, the full-wave inverse problem is solved for the unknown compressibility and mass density.

Results

The proposed method is tested with a synthetic example. First, the forward problem is solved for the synthetic breast phantom given in Figure 1. Numerical values for the tissue properties (density and compressibility) are selected from literature. Next, the velocity field is computed using the pressure field measured along a circle enclosing the breast. Finally, a full-vectorial CSI is executed where the measured pressure and the computed velocity fields are used to accurately reconstruct the density and compressibility profiles of the medium. The reconstruction results are shown in Figure 1.

Discussion and Conclusion

A full-vectorial CSI is used for multi-parameter inversion. This method reconstructs density and compressibility profiles simultaneously using the measured pressure and velocity fields together. The velocity field is computed from the measured pressure field using Hankel function decomposition. The results obtained with a synthetic example show that the method can accurately reconstruct density and compressibility profiles from pressure field measurements only.

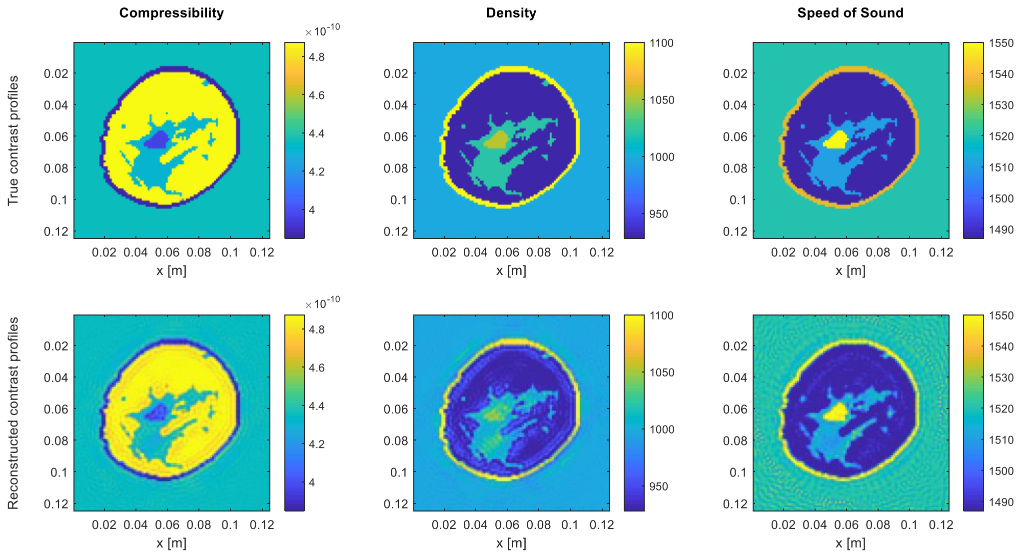


Figure 1: Multi-parameter inversion. The forward problem is solved for the known compressibility and density profiles, and hence speed of sound profile (top). After the velocity field is reconstructed from the synthetically measured pressure field, a full-vectorial implementation of contrast source inversion is used to compute the compressibility and density profiles (bottom row).

Abstract ID : **77**

Acoustic attenuation imaging using phase-insensitive ultrasound computed tomography

Content

Ultrasound computed tomography (UCT) offers a powerful alternative to X-ray mammography, however, reconstruction of the diagnostically important property of acoustic attenuation is exceedingly challenging. Early in the development of UCT, it was suggested that omnidirectional, phase-insensitive detectors could improve attenuation imaging – the potential of which has been demonstrated through the use of a novel phase-insensitive pyroelectric sensor developed at the National Physical Laboratory (NPL), UK. A proof of concept study showed that phase-insensitive ultrasound computed tomography (piUCT) could generate quantitative, nearly artefact-free images of acoustic attenuation of simple cylindrical phantoms without full-waveform inversion (FWI) [B. Zeqiri et. al. Physics in Medicine and Biology, vol. 58, no. 15, pp. 5237–68, 2013].

A prototype piUCT scanning system has been built to obtain 2D quantitative images of the attenuation of anatomically-sized commercial breast phantoms (Model 073, CIRS, Norfolk, VA, USA). The system features a single element, large area pyroelectric sensor opposite an array of 14 transducers operating at 3.2 MHz in a through-transmission, parallel beam tomographic geometry. Quantitative attenuation images of breast phantoms were obtained using the piUCT system and compared to XCT images of the same phantoms. In addition, the acoustic properties of the component materials of the phantom were independently measured at NPL and compared to the piUCT scan's attenuation voxel values.

Images obtained using the piUCT system compare well with XCT images both qualitatively and importantly quantitatively. The system was able to detect inclusions of various sizes and positions within the phantoms including bubbles as small as 1 mm in diameter, in agreement with XCT images. Absolute attenuation values derived by piUCT matched well with independent ground-truth measurements made on material samples provided by CIRS. The interface between the phantom skin and bulk material features an artefact on the piUCT scan images which most likely results from the significant sound speed difference between the two materials and consequent critical angle effects – this is an area of current research. Future work will systematically and quantitatively evaluate the performance of the system and its ability to differentiate inclusions of known sizes and acoustic properties relevant to clinical breast imaging.

Primary author(s) : Mr. SARNO, Daniel (National Physical Laboratory)

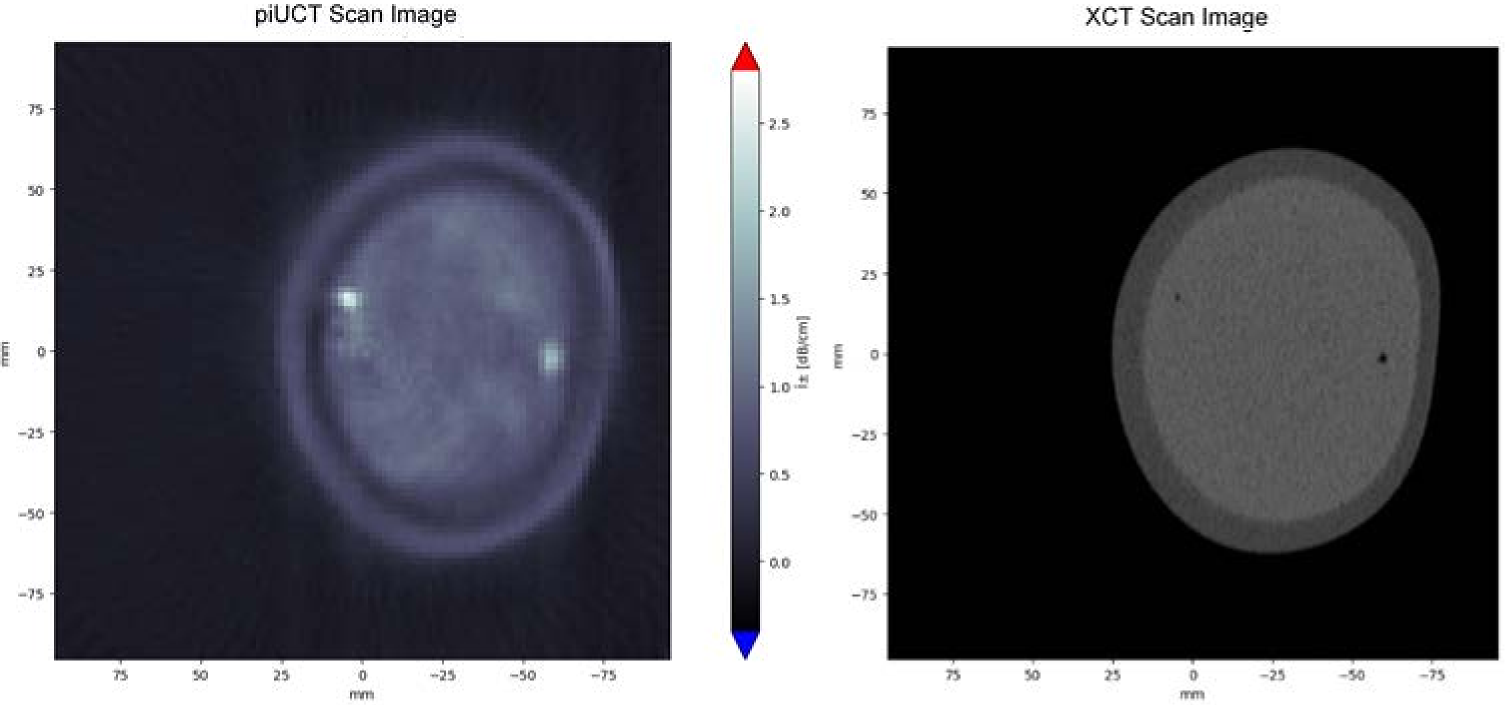
Co-author(s) : Mr. BAKER, Christian (National Physical Laboratory); Dr. ZEQIRI, Bajram (National Physical Laboratory); Mr. HODNETT, Mark (National Physical Laboratory)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **SARNO, Daniel** on **Tuesday 23 July 2019**


piUCT Scan Image
XCT Scan Image
mm
75
50
25
0
−25
−50
−75
2.5
2.0
1.5
1.0
0.5
0.0
α [dB/cm]

Abstract ID : **79**

Ultrasound transducer identification enables high-resolution full-waveform inversion

Content

Background

Full-waveform inversion (FWI), a technique developed in geophysics, has recently been applied to produce high-resolution and quantitative reconstructions in the context of medical ultrasound imaging. However, even though FWI has shown great promise, realistic acquisition conditions introduce a series of uncertainties that cannot be fully considered using existing schemes. This could lead to a degradation of resolution and accuracy, and even make the solution of the inverse problem impossible.

One such sources of uncertainty is related to the behaviour of transducers. Existing schemes make strong assumptions on their behaviour, frequently considering them to be point-like, while also neglecting their inherent electro-acoustic response. Here we extend traditional FWI algorithms by using a technique for the characterisation of transducers that ensures a highly accurate modelling of their response. Subsequently, we explore the impact that uncertainties in transducer behaviour have on the resulting reconstructions.

Methods

The proposed technique extends traditional FWI schemes through the addition of a secondary optimisation problem whose aim is to find a suitable transducer model from measurements while honouring the full wave equation. This leads to transducer models that are well suited for FWI, as well as other techniques such as optoacoustic tomography, in which close agreement between experimentally acquired and numerically modelled data is needed.

The technique is validated on experimental measurements acquired using disk transducers of different diameters, with and without lenses. We then compare the results in terms of errors in magnitude and phase with those obtained using common transducer modelling approaches: neglected response, deconvolution and holography/backpropagation.

The impact on FWI of uncertainties in transducer behaviour is explored using a numerical phantom of the human head by comparing the quality of the reconstructions when transducer response is correctly or incorrectly modelled.

Results

Figure 1-A to C suggest that a high degree of certainty on the transducer response is needed for FWI under realistic acquisition conditions. When compared to commonly employed transducer models, Figure 1-D and E confirm that the proposed technique can achieve superior transducer identification performance.

Primary author(s) : CUETO, Carlos (Imperial College London)

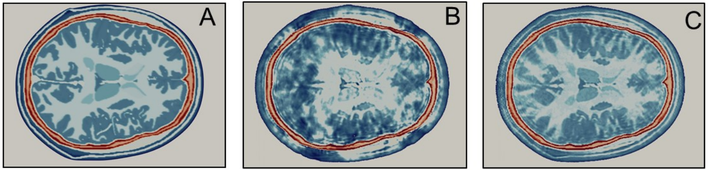
Co-author(s) : Dr. GUASCH, Lluis (Imperial College London); Mr. CUDEIRO, Javier (Imperial College London); Mr. CALDERON AGUDO, Oscar (Imperial College London); Prof. WARNER, Michael; Prof. TANG, Meng-Xing (Imperial College London)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **CUETO, Carlos** on **Wednesday 24 July 2019**



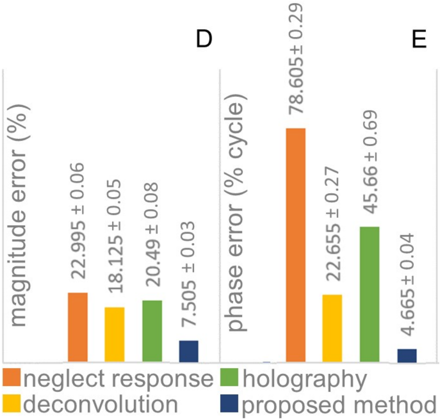


Figure 1. Numerical head phantom (**A**) whose FWI reconstruction is degraded by uncertainties in transducer behaviour (**B**); reconstruction quality is recovered when introducing correct transducer models (**C**). Comparison of different methods for transducer identification applied to a 16 mm disk transducer in terms of magnitude error (**D**) and phase error as percentage of a cycle (**E**), calculated over 16762 spatially independent samples of the wavefield.

Abstract ID : **99**

Overcoming cycle-skipping in full-waveform inversion of ultrasound data

Content

Recently, ultrasound tomography has emerged as a new imaging modality for detecting breast cancer by using non-ionizing ultrasound waves. Full-waveform inversion (FWI) tomographic algorithms hold great potential in this field, as these are able to image submillimetre morphological features and provide quantitative information of tissue properties such as speed-of-sound. Standard FWI algorithms seek a model of physical properties that minimises the L2 norm of the difference between observed and modelled data locally in an iterative fashion. Due to the non-linearity of the inverse problem, FWI requires low frequency-data to avoid the well-known cycle-skipping effect, in which the observed and modelled data are out of phase by more than half a cycle, which in turn yields incorrect recovered models. But most ultrasound transducers commercially available lack low-frequencies and, thus, FWI does not always produce reliable results.

The cycle-skipping effect is more relevant in the presence of hard tissue, but it can also degrade the quality of recovered soft tissue models. In the context of geophysics, several methodologies have been suggested to address this problem including: adaptive waveform inversion (AWI), optimal transport, and the inversion of intermediate datasets. Here we explore the application of several such methods to the 2019 USCT 2D blind dataset, beginning from a simple homogeneous starting model. We demonstrate that their use allows inversion to start at higher frequencies, and as a consequence FWI can be used with higher-frequency transducers, yielding higher-resolution models.

The figure shows the results of applying FWI and AWI with different starting frequencies. In (a), FWI starts at 200 kHz and there is no cycle-skipping at this frequency, yielding a recovered model with morphological features resembling a breast section, including a possible tumour. If the inversion is started at 350 kHz, panel (b) shows that cycle-skipping results in a model with artefacts, but these disappear when using AWI in panel (c) and, thus, very-low frequencies are not necessary in order to obtain a clean model of the breast.

Primary author(s) : Dr. CALDERON AGUDO, Oscar (Imperial College London)

Co-author(s) : Mr. STRONGE, George (Imperial College London); Mr. BATES, Oscar (Imperial College London); Dr. STANZIOLA, Antonio (Imperial College London); Prof. WARNER, Michael; Dr. GUASCH, Lluis

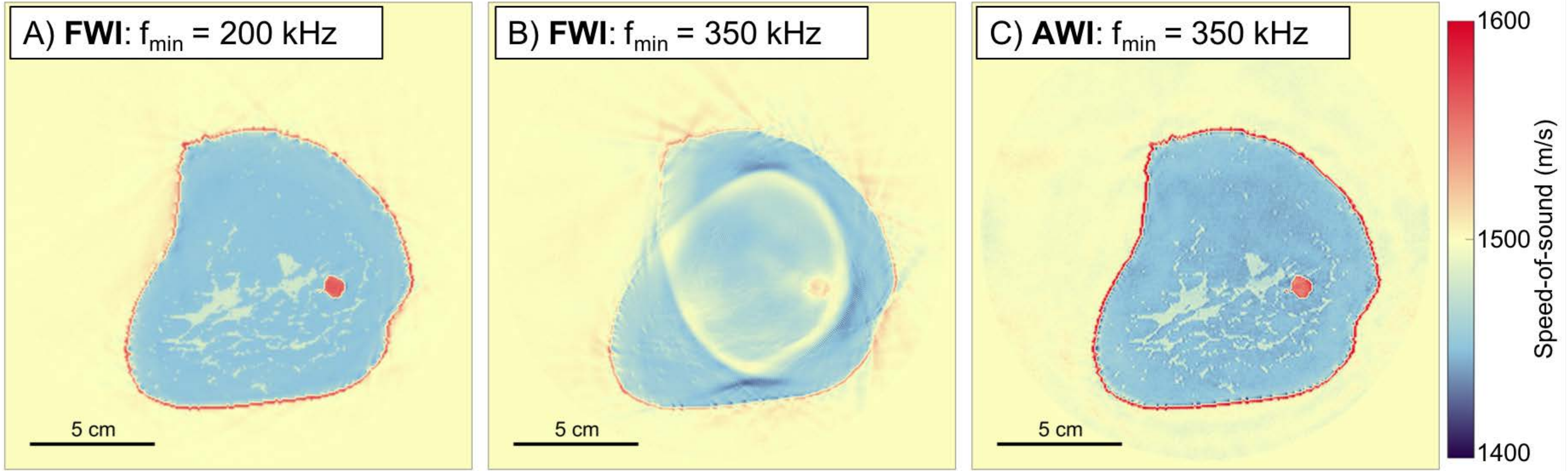
Contribution Type : Oral

Comments:

We have attached the figure in the attachments section.

Status: SUBMITTED

Submitted by **CALDERON AGUDO, Oscar** on **Thursday 25 July 2019**



A) FWI: f_{min} = 200 kHz
5 cm
B) FWI: f_{min} = 350 kHz
5 cm
C) AWI: f_{min} = 350 kHz
5 cm
1600
1500
1400
Speed-of-sound (m/s)

Abstract ID : **90**

Time-Domain Full Waveform Inversion for High Resolution 3D Ultrasound Computed Tomography of the Breast

Content

Ultrasound computed tomography (USCT) systems, which can image the breast without delivering harmful radiation, are typically designed to provide images of 2D slices, rather than full 3D images, to reduce the challenges of data acquisition and image reconstruction. Recently, however, novel scanners are being developed which allow the breast to be probed ultrasonically in three-dimensions. In particular combining photo-acoustic tomography and USCT in 3D promises access to high-quality images of tissue properties with important diagnostic value. However, the image reconstruction problems involved come with severe computational challenges.

In this talk, we focus on the problem of 3D speed-of-sound (SOS) imaging. The large size of the breast precludes using very high frequency US signals as they are damped too strongly. Time-of-flight reconstruction methods that rely on ray-based approaches are less accurate in the low-frequency regime and need very many data acquisitions as they rely on identifying single events in the recorded pressure-time series. Full Waveform Inversion (FWI) approaches are promising in this situation, because they do not assume ray-like propagation and can exploit the full time series data. However, they are challenging from multiple perspectives. Here, we demonstrate how to combine different computational techniques to obtain accurate 3D FWI results of the human breast with high spatial resolution. First, we rely on fast time-domain k-space pseudospectral methods implemented on GPUs for simulating the wave propagation. Second, we bypass the prohibitive memory requirement of standard adjoint-state-based gradient computation methods using a novel approach based on time-reversal. Finally, we combine numerical source encoding techniques with a stochastic variant of the L-BFGS method into a fast numerical optimization scheme.

Primary author(s) : Dr. LUCKA, Felix (Centrum Wiskunde & Informatica and University College London); Dr. PEREZ LIVA, Mailyn; Dr. TREEBY, Bradley (University College London); COX, Ben (University College London)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **LUCKA, Felix** on **Thursday 25 July 2019**

Abstract ID : **91**

High-Frequency Full-Waveform Inversion for Ultrasound Transmission Tomography

Content

Full-waveform inversion (FWI) algorithms are known to yield the best image quality for Speed-of-Sound (SoS) reconstruction in Ultrasound Transmission Tomography (USTT). Nevertheless, FWI solves a complex variational problem, and its memory and time requirements largely increase with the frequency of the US signal, making it impractical for many high-frequencies (>3MHz) acquisitions. The spatial resolution required to correctly appreciate details in small animals force the use of high ultrasound (US) frequencies. For example, at least 5 MHz is needed to observe details of 0.5 mm or less in the reflectivity images. This has limited the massive application of FWI methods in the preclinical field.

In this work, we have introduced a methodology that allows overcoming two of the most important limitations of FWI methods: the stability of their convergence and the dependence of their computational cost on the frequency content of the signals. The first proposed modification was the generalization of the cost function (CF) to make the convergence more robust. In the initial iterations, the CF is dominated by a time-of-flight (TOF) misfit, which provides low-resolution images, but avoids convergence issues. As iterations progress, the CF becomes dominated by the standard FWI mean-square-error between the measured and the estimated data, which yields higher resolution images. The second modification was to simplify the wave propagation model. We obtained the estimated ultrasound field as the convolution of a reference waveform with the TOF information from many different paths between the emitter and the receiver. This approach is fast, flexible (it can be easily applied to 3-D data), and sufficiently accurate for most applications.

We implemented the proposed FWI algorithm using the large computing capabilities of current GPUs. It was evaluated with a tissue-mimicking gelatin phantom and a mouse acquired with a hybrid optoacoustic-ultrasound (TROPUS) device, which consists of a ring of 512 transducers operating at a central frequency of 5 MHz.

The SoS maps were reconstructed with this FWI method in about 1 minute/slice. The images obtained are quantitatively accurate and show significantly better resolution (around 1mm) compared to bent-rays methods. In conclusion, we proposed FWI algorithm that can be used to reconstruct SoS maps from real data acquired at high-frequencies, achieving high-quality images fast-enough for practical applications.

Primary author(s) : Dr. HERRAIZ, Joaquin L. (Complutense University of Madrid. Grupo de Fisica Nuclear and IPARCOS)

Co-author(s) : Dr. PEREZ-LIVA, Mailyn (Hôpital Européen Georges Pompidou. Paris-Centre de recherche Cardiovasculaire); Dr. MERCEP, Elena (iThera Medical GmbH, Munich, Germany); Dr. DEÁN-BEN, Xosé Luís (University of Zurich and ETH Zurich); Dr. RAZANSKY, Daniel (University of Zurich and ETH Zurich); Dr. UDIAS, Jose M. (Complutense University of Madrid. Grupo de Fisica Nuclear and IPARCOS)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **HERRAIZ, Joaquin L.** on **Thursday 25 July 2019**

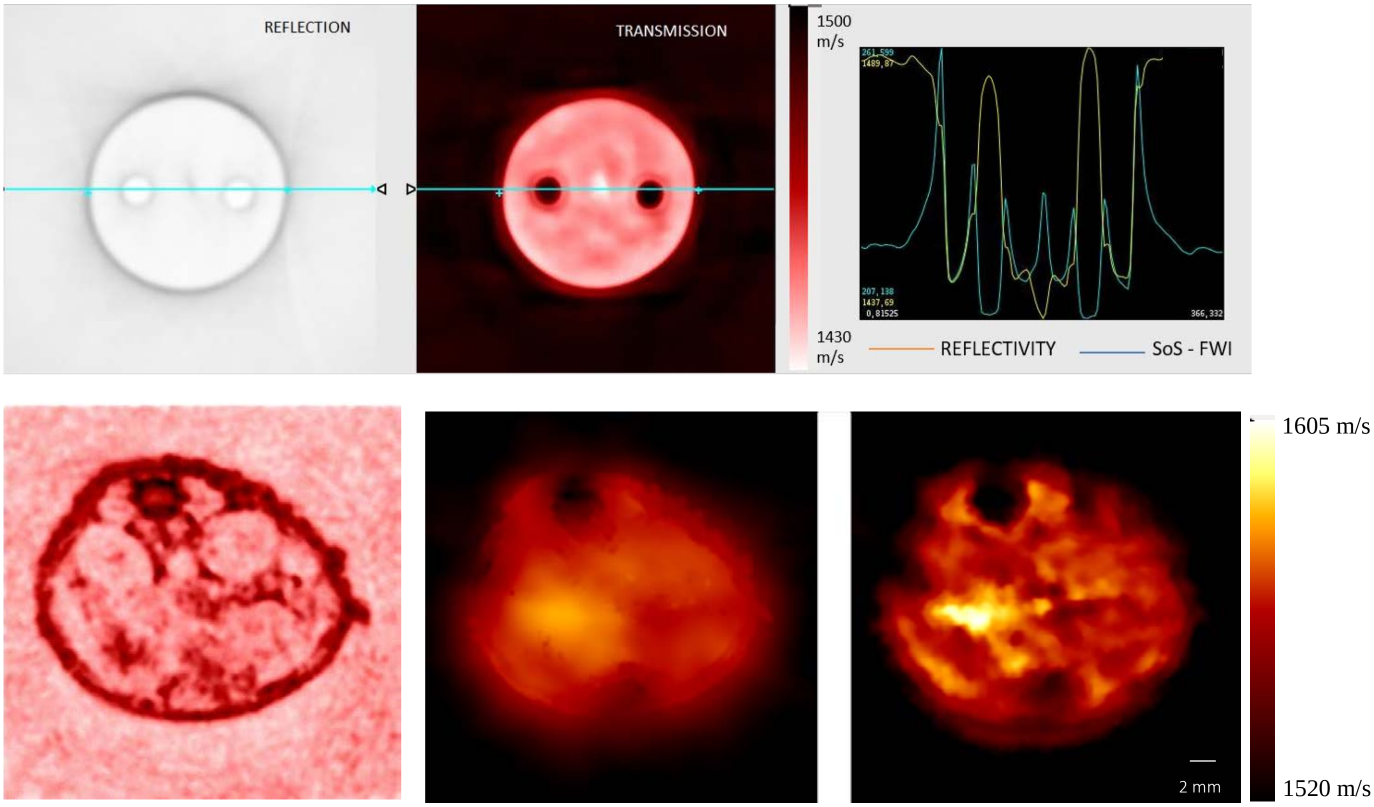


Figure 1. – Reconstructed images of data acquired with the TROPUS scanner from iThera Medical with a 5MHz central frequency. **[TOP]:** Tissue-mimicking gelatin phantom (20 mm diameter). The reflectivity image (Left), the FWI SoS image (Center) and a line-profile along the phantom (Right) are shown. **[BOTTOM]:** Mouse acquisition corresponding to a kidney cross-section. Reflectivity image (Left), SoS map obtained with TOF-based bent-rays algorithm (Center), and SoS map obtained with the proposed FWI algorithm (Right). A significant resolution improvement is obtained with FWI. The FWI images are obtained in around 1 minute / slice.

REFERENCES:

1) C. Li, et al. SPIE Medical Imaging, 2014.
2) O. Roy, et al., SPIE Medical Imaging, 2010.
3) J. Wiskin, et al., Acoustical Imaging, 2007
4) M. Perez-Liva, M., et al JASA, 141(3), 2017.
5) E. Bozdağ., et al., GJI, 2011.
6) M. Perez-Liva et al., Proceedings MUST, 2017.
7) E. Mercep et al, Light: Science & Applications, 2019.

Abstract ID : **92**

Analysis of linearized inverse problems in ultrasound transmission imaging

Content

For ultrasound transmission imaging we compute the forward solution via a paraxial approximation of the Helmholtz equation. The reconstruction of speed of sound and attenuation then becomes an ill-posed nonlinear inverse problem, where we apply an iterative Gauss-Newton approximation in an outer loop resulting in a set of linear equations that is tackled with a conjugate gradient (CG) strategy in an inner loop. Due to the ill-posed nature of the problem, regularization is necessary. We choose three common methods of regularization for solving the linearized sub-problems in an inner loop: conjugate gradient applied to normal equation (CGNE), damped least-squares and gradient magnitude. The latter two use Tikhonov regularization.

In this work, we analyze the linearized problems during the iterative solution process. The goal is to obtain theoretical and experimental bounds on how well the predicted data match the true data and how close a particular estimate of the model parameters comes to the true solution. We use standard methods of analyzing linear inverse problems, which are the data resolution and model resolution with Dirichlet and Backus-Gilbert spread, and covariance matrices, at different Gauss-Newton iterations.

The CGNE method gives more reliable solutions for the linearized systems than the Tikhonov regularization methods, which generally produce biased solutions for the linearized systems compared with the CGNE method. The linearized systems are more sensitive when treated by CGNE than by Tikhonov regularization methods: the sensitivity for the latter depends on the regularization parameter. The Tikhonov regularization is less effective at the beginning of the outer-loop iteration, where the nonlinearity is dominating while the CG for the linearized system stops early. Only after the linear approximation is good enough to describe the whole system the Tikhonov regularization give slightly better reconstruction results than CGNE in noisy cases. Our analysis of the linear problems during the iterative solution process gives valuable information about the problem itself and yields good indications of the success of the solution process, see Fig. 1. Based on the analysis, a combination of different strategies, starting with CGNE and ending with Tikhonov would be reasonable.

Primary author(s) : Dr. WANG, Hongjian; Prof. GEMMEKE, Hartmut; VAN DONGEN, Koen (Delft University of Technology); Dr. HOPP, Torsten; HESSER, Jürgen (Heidelberg University)

Status: SUBMITTED

Submitted by **WANG, HONGJIAN** on **Thursday 25 July 2019**

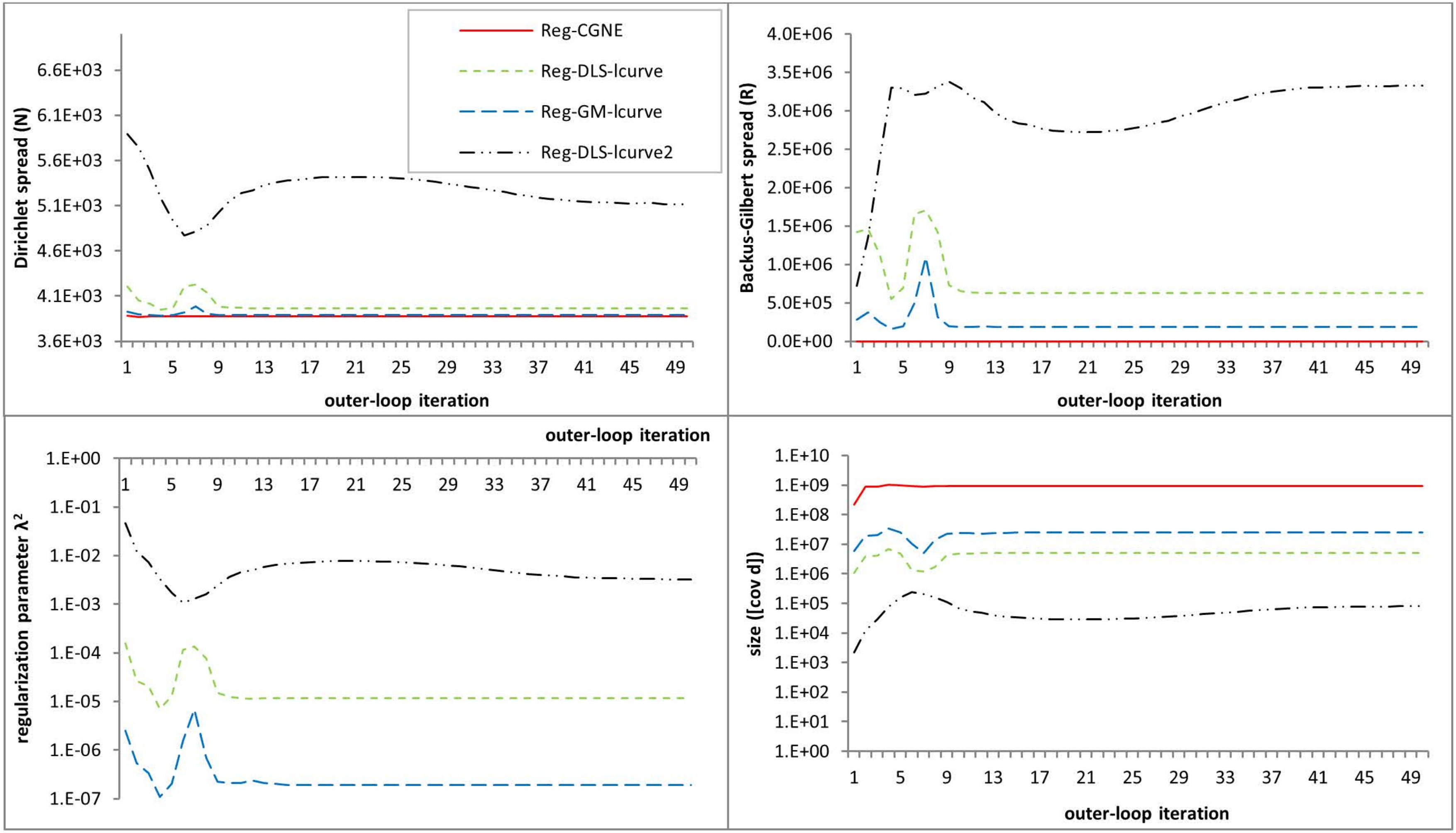


Figure 1. We plot the spread of data resolution and model resolution matrices, as well as the size of covariance matrix during 50 Gauss-Newton iterations in a noisy case using data with SNR = 40dB. In all the charts, the horizontal axis indicates the outer-loop iterations. **Upper-left:** the Dirichlet spread of data resolution matrix. **Upper-right:** the Backus-Gilbert spread of model resolution matrix. **Lower-left:** the regularization parameter. **Lower-right:** the size of unit covariance matrix. Note that the Backus-Gilbert spread uses a weighting factor that weights the element of resolution matrix according to its physical distance from the diagonal element; hence it favors a natural ordering in the model parameters. We test three regularization methods: conjugate gradient applied to normal equation (CGNE); damped least-squares (DLS); and gradient magnitude (GM). The latter two use Tikhonov regularization, for which we set the regularization parameter λ for this figure: the L-curve function is called at every outer-loop iteration to determine the λ value for the linearized system at the current outer-loop iteration (denoted as "lcurve"). We perform extra tests for Reg-DLS with significantly larger λ values: $\lambda = 12\lambda_{corner}$ denoted as "Reg-DLS-lcurve2". Some more cases are described in the paper.

Abstract ID : **94**

Time-of-Flight Picking for Ultrasound Computed Tomography of the Breast

Content

Ultrasound Computed Tomography (USCT) is a promising imaging modality for detection of tumors in the breast. There are several approaches to reconstructing images from USCT data. Techniques that use the Time-of-Flight (TOF) of the ultrasound pulses across the breast are popular because of their computational efficiency, and historically because of their connection to the Radon transform, for a long time the workhorse of tomography. They have also been used to generate a starting point for more computationally-intensive, but potentially more accurate, approaches based on full-wave inversion.

One key aspect of TOF methods is the accurate extraction of the TOF from the measured ultrasound pulses. Methods using cross-correlation perform well for homogeneous or low-scattering media, but their performance can dramatically deteriorate for more complex media because of the delay spread, or coda, that appears in the measured signal. Therefore, techniques using the first arrival time of the signals are often used. Typically, the performance of these algorithms is contingent on the shape and duration of the excitation pulse, the scattering properties of the intervening medium, and the signal-to-noise ratio (SNR) of the received signals. Despite the existence of many first-arrival-picking algorithms for the geophysical applications, finding an accurate arrival-time picking algorithm that performs well for all measured time traces remains a challenge. To cope with this limitation, picking the first arrival in an individual time trace is often followed by pragmatic techniques for detection and recalculation of mis-picks using correlation information from the entire measured data.

In this study, we exploit the additional information that exists for medical USCT, as opposed to geophysical applications, in order to apply additional constraints on the travel time picking. The information includes, but is not limited to the known excitation pulses, loose bounds on the maximal and minimal sound speed of the medium, the position of the transducers, and the limited number of large-amplitude peaks in the envelope of the time traces. Several time-of-flight picking algorithms are demonstrated using numerical simulations on a digital breast phantom obtained from MRI images. We show the performance of the proposed strategies using realistic excitation pulses with different pulse durations and different ranges of SNR in the measured signals.

Primary author(s) : LUCKA, Felix (CWI & UCL); COX, Ben (University College London)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **JAVAHERIAN, Ashkan** on **Thursday 25 July 2019**

Abstract ID : **103**

Regularization by Registration: Utilizing prior knowledge to accelerate ultrasound full-waveform inversion

Content

Ultrasound computed tomography (USCT) is an emerging imaging modality to characterize human soft tissue, in particular for the application of breast cancer screenings. Typical USCT apertures collect both transmission and reflection data from various transducers acting either as emitters or receivers in a fixed acquisition geometry. Full-waveform inversion exploits the complete waveforms provided by those data to provide high-resolution quantitative images of several parameters, such as speed of sound, density, or attenuation.

Despite recent advances in hardware and algorithmic developments, time-domain acoustic waveform inversion remains computationally challenging, in particular when using high-frequency data and reconstructing 3-D domains.
In contrast, conventional ray-based methods like time-of-flight inversion or B-mode imaging may suffer from limited resolution due to the simplified wave physics, but they are considerably cheaper to compute and readily utilize different parts of the measured signals.
In this contribution, we present strategies to utilize prior information on the model space generated from such auxiliary imaging problems to accelerate 3-D full-waveform inversion. This includes (1) construction of quantitative prior models based on time-of-flight inversions, (2) dimension reduction of the model space using shapes identified by B-mode imaging, and (3) reparameterization of the model space by using sparsifying constraints from segmentation. This is tied into a trust-region inversion framework that features a stochastic quasi-Newton method, encoded sources, total variation regularization, and spectral-element waveform simulations.

Several examples using numerical phantoms demonstrate the applicability of our approach to ring-shaped and fully 3-D acquisition geometries.

Primary author(s) : Dr. BOEHM, Christian (ETH Zurich)

Co-author(s) : KORTA MARTIARTU, Naiara (ETH Zurich); Prof. FICHTNER, Andreas (ETH Zurich)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **BOEHM, Christian** on **Thursday 25 July 2019**

Abstract ID : **88**

A preclinical simulation study of ultrasound tomography for pulmonary bedside monitoring

Content

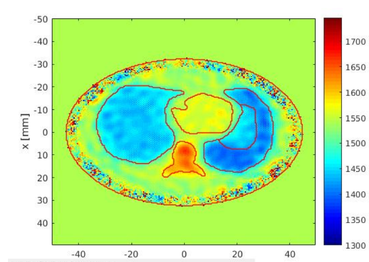
Primary author(s) : Dr. MUELLER, Jennifer (Colorado State University); Dr. FURUIE, Sergio (University of Sao Paulo); Mr. CARDENAS, Diego Armando Cardona (University of Sao Paulo)

Contribution Type : Oral

Status: SUBMITTED

Submitted by **MUELLER, Jennifer** on **Wednesday 24 July 2019**

Mechanical ventilation in the intensive care unit (ICU) is a life-saving technique for patients experiencing acute respiratory failure, but it is also associated with a high incidence of complications. Currently, there is no widely-used monitoring technique to guide the setting of the ventilator to facilitate a precision-medicine approach or to provide a real-time alert for developing adverse pulmonary conditions. Conventional ultrasound has been studied as a thoracic bedside technology for diagnosis and monitoring, but due to the lack of signal penetration into lung tissue, ultrasound images often contain more information in their artifacts than in the images themselves. However, low frequency (10 – 750 kHz) ultrasound has been shown to penetrate the lung, motivating its use as a non-ionizing tomographic technique for pulmonary monitoring. The rich acoustic data provided by the tomographic geometry, yields images that are easier to interpret and of higher resolution than conventional ultrasound and will enable continuous imaging by removing the need for a highly skilled technician. In this work, tomographic reconstructions of sound speed from numerically simulated low frequency ultrasound data on a belt of transducers on chest phantoms simulating three types of pneumothorax are compared. The distorted Born iterative method (DBIM) is used to compute the reconstructions in a K-wave implementation, and regularized reconstructions using Tikhonov regularization, the L^2 norm of the Laplacian, and total variation (TV) regularization are compared. We also demonstrate that excitation patterns in which all transducers both send and receive result in higher SNR and improved reconstructions over single-transmission patterns. These results support the feasibility of USCT as a non-ionizing bedside pulmonary monitoring technique for patients in the ICU, and the ability to identify a pneumothorax and its location and size. Below is a reconstruction of a large pneumothorax using TV regularization from data computed on a different mesh in 3-D with 1% additive Gaussian noise.



Abstract ID : **98**

Life-like Phantoms for Biomedical Applications

Content

In the various stages of developing diagnostic and therapeutic military and civilian equipment, the use of synthetic tissue mimicking materials can play a pivotal role in improving the process, help in implementation, testing and calibrations and in training paramedics, nurses and new doctors. The human-like structures made out of those synthetic tissues are called phantoms, which depending on their application (i.e. MRI, Ultrasound, or CT Scan), have to be made out of specific materials to match the respective physical characteristics of the tissues they have to mimic. In this paper we introduce imaging phantoms for ultrasound, MRI and CT. The authors show that by choosing the appropriate material, we can create phantoms which are able to mimic most of the desired properties of healthy and unhealthy biological tissues. The paper shows the examples of the fabricated phantoms, their properties and their comparison with the corresponding real tissues. In contrast to ex vivo tissues, the proposed phantoms can be custom designed and maintain their properties unchanged for long periods of time.

Primary author(s) : Mr. ADRIAN, Wydra (True Phantom Solutions Inc.); Prof. ROMAN, Maev (True Phantom Solutions Inc.)

Status: SUBMITTED

Submitted by **WYDRA, Adrian** on **Thursday 25 July 2019**

Abstract ID : **108**

Quantitative Assessment of Skin using High-Resolution Handheld Ultrasonic Scanner

Content

High-resolution ultrasonic imaging has been increasingly used in dermatology as a complementary technique for cutaneous lesions assessment. It may reduce the number of invasive procedures such as biopsies and assist in surgery planning. The success of ultrasonic methods highly relies on the ability of modern imaging systems to deliver precise and interpretable information. The new portable high-resolution ultrasonic imager was designed to be used for dermatological applications. The portable scanner operates at 50-100 MHz and provides B-scan images with up to 4 mm depth penetration with an axial resolution of 20 μm. Adaptive signal processing algorithms allow highlighting elements and features of the tissues. The primary skin layers, as well as the skin appendages, are identified on the obtained acoustical images. The benign melanocytic lesions (ephelides and nevi), skin burns and scars have been identified and characterized by their acoustic properties. Measurements of the thickness of skin layers at a different part of the body provide a base for statistical analysis and give information about skin conditions.
Characterization of skin morphology based on elastic modality can potentially estimate the overall condition of the skin and be used for diagnostic purposes. The new device is intended for the following dermatological applications: surgery planning and image-guided intervention, assessment of wound healing and skin grafts, various vascular anomalies, inflammatory diseases, and numerous cosmetic complications.

Primary author(s) : Dr. SEVIARYN, Fedar (University of Windsor); Mr. SCHREINER, Gregory (University of Windsor); YOUSSEF, Sarah (University of Windsor); MAEVA, Anna (University College London); SEVIARYNA, Ina (University of Windsor); Prof. MAEV, Roman Gr.

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **SEVIARYNA, Ina** on **Friday 26 July 2019**

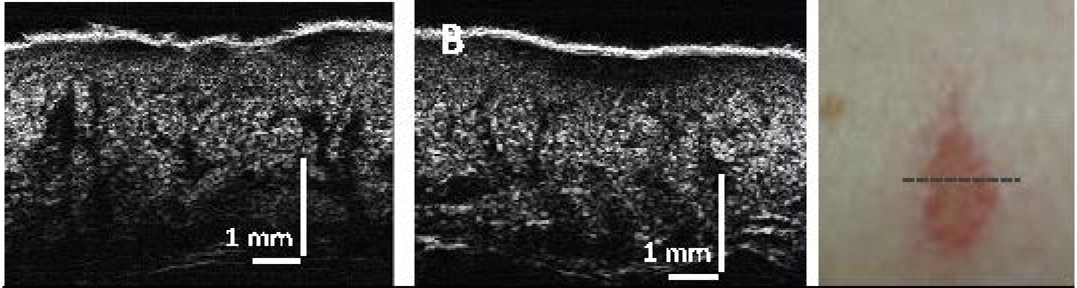


Fig. 1. Ultrasonic images skin burn on the forearm. A. One day after the burn occur. B. Seven days after. C. Orientation of the cross section across the lesion.

Abstract ID : **109**

High-Resolution Mapping of Changes in Properties in Dermal Collagen Due to Light Damage

Content

Age-related changes affect both the function and structure of human organs such as skin. Collagen plays a crucial role in providing elastic and mechanical strength to human skin. It is essential to understand and characterize any changes in collagen structure and properties related to ageing using a minimally invasive method. Mechanical properties of living tissues and cells like elasticity, viscosity and density directly associate with cell function. One efficient method to evaluate tissue's mechanics is scanning acoustic microscopy (SAM), which allows non-invasive qualitative and quantitative assessment of tissue's stiffness without significant tissue preparation or damage. Porcine skin model was used to evaluate dermal collagen damage post-treatment with an Intense Pulse Light (IPL). Back-neck fold biopsies from a 4-week-old, 25 kg pig were irradiated at increasing doses of 40 J/cm2 once, thrice and ten times (□= 584 nm). Samples were then cryo-sectioned at a thickness of 10 µm. Ex-vivo biopsies were assessed with scanning acoustic microscope (Honda AMS-50SI equipped with 320MHz focused transducer), both imaging atomic force microscopy (AFM) and mechanical AFM, and polarized light microscopy.

It was demonstrated that collagen fibres degrade depth-wise into the reticular dermis. At maximum irradiation, loss of banding and gelatinization was observed. Sound attenuation decreases with higher exposure. Damaged collagen demonstrated much lower sound speed and attenuation compared to healthy controls. Sound speed decreases at much faster rates than the attenuation.

The ability of high-frequency ultrasound to quantitatively assess biological processes in the tissue places the method to a molecular level diagnostic device. Mapped sound speed and attenuation along with tissue and cells morphology significantly contribute to diagnostic imaging and can be a valid biomarker to assess alignment and state of collagen, which leads to ageing and inflammatory processes.

Primary author(s) : MAEVA, Anna (University College London); SEVIARYNA, Ina (University of Windsor); Dr. HOPPER, Colin (University College London); Dr. PERRETT, Conal (University College London Hospital); Dr. LEVINE, Oliver (University College London); Dr. AKBAR, Arne (University College London)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **SEVIARYNA, Ina** on **Friday 26 July 2019**

Poster Presentations

Abstract ID : **71**

Whole breast tissue characterization with ultrasound tomography

Content

Primary author(s) : Dr. DURIC, Neb (Karmanos Cancer Institute); Dr. LITTRUP, Peter (Crittenton Hospital); Dr. LI, Cuiping (Delphinus Medical); Dr. BREM, Rachel (George Washington University)

Track Classification : Main Track

Contribution Type : Oral

Status: SUBMITTED

Submitted by **DURIC, Neb** on **Monday 22 July 2019**

PURPOSE. Hand held ultrasound (HHUS) provides localized diagnostic information of tissue stiffness and elasticity. Screening requires global assessment of tissue properties for which HHUS is not suitable while automated breast ultrasound (ABUS) does not measure stiffness. This study is the first to evaluate imaging of tissue stiffness throughout the breast using the technique of ultrasound tomography (UST).

METHOD AND MATERIALS. Patients with findings on mammography during the time period of January, 2018 to March 2018, were scanned with UST. Patient were selected on the basis of having dense breasts and the most common benign breast masses, as well as cancers. A total of 195 masses, smaller than <1.5cm in size, (41 cancers, 79 fibroadenomas, 65 cysts and 10 other benign findings) were evaluated. with SoftVue and all women also received standard breast imaging evaluation prior to biopsy. Pathology and/or radiology reports were used as the ground truth for verifying lesion type. Lesion localization on UST SoftVue images was provided by a board-certified breast radiologist. Our UST measurements extract information on the tissue bulk modulus which was then converted to an index of relative tissue stiffness (from 0 = very soft to 1 = extremely stiff). Additionally, the mean homogeneity of the stiffness was calculated for each mass using the Gray-Level Co-Occurrence Matrix (GLCM) approach.

RESULTS. UST demonstrated the ability to measure tissue stiffness throughout the breast and to characterize lesion stiffness in all 195 patients. Table 1 lists the stiffness index for each type of mass. Cysts, fibroadenomas and cancers were found to have mean stiffness indices of 0.10 (95% CI of 0.05 to 0.30), 0.35 (CI of 0.25-0.770) and 0.60 (CI of 0.4 to 1.0) respectively. The mean homogeneity of stiffness (also shown in Table 1), was found to be, 0.83 (0.72 – 0.95), 0.77 (0.65 – 0.86) and 0.68 (0.51 – 0.87), respectively.

DISCUSSION. Masses were characterized using mean stiffness and mean homogeneity of stiffness. Both measures were able to separate the populations of the three types of masses, but the homogeneity parameter was more effective in that regard. While significant overlap was found in the distribution of these parameters across the three mass types, their inclusion in a future CAD tool is likely to improve diagnostic performance. Since this UST approach measures tissue stiffness throughout the volume of the breast, mass characterization on the basis of stiffness may be appropriate in a screening scenario. something that is currently not possible with other ultrasound devices.

CONCLUSION. Measuring tissue stiffness throughout the whole breast is not currently available clinically. The study demonstrates that stiffness characterization of lesions derived from whole breast stiffness imaging with UST is feasible. The addition of this information in a screening environment has the potential to reduce call backs and biopsies by utilizing stiffness, in addition to other characteristics to improve specificity.

Table 1						
Type of Mass	**Stiffness index value**	**Standard deviation**	**5% - 95% CI**	**Mean Homogeneity**	**Standard Deviation**	**5% - 95% CI**
Cyst	0.10	0.20	0.05-0.30	0.83	0.05	0.73 - 0.91
FB	0.35	0.24	0.25-0.77	0.77	0.06	0.65 - 0.85
Ca	0.61	0.19	0.41-1.00	0.66	0.09	0.52 - 0.79

Abstract ID : **72**

Whole breast sound speed measurement from ultrasound tomography corelates strongly with volumetric breast density from mammography

Content

Primary author(s) : Dr. SAK, Mark (Delphinus Medical); Dr. DURIC, Neb (Karmanos Cancer Institute); Dr. LITTRUP, Peter (Crittenton Hospital); Dr. BREM, Rachel (George Washington University)

Contribution Type : Oral

Status: SUBMITTED

Submitted by **DURIC, Neb** on **Monday 22 July 2019**

PURPOSE. Quantitative sound speed volume measurements from ultrasound tomography (UST) have been shown to correlate strongly with 2-D mammographic percent density measurements (r_S=0.7) of breast density (BD). Volpara is an automated mammographic density measurement software tool that measures BD volumetrically and therefore provides a better external standard to compare with UST's volumetric sound speed measurements. Since increased BD is known to increase the risk of developing breast cancer, sound speed images can potentially offer new insight into measurements of breast tissue without the use of ionizing radiation. The purpose of this work is to provide a direct comparison of UST vs Volpara measurements to determine the viability of sound speed as an imaging biomarker of BD.

METHOD AND MATERIALS. A group of 100 women with benign and malignant findings in their breast underwent both a UST breast scan and had a Volpara reading of a mammogram at our local cancer center. Only those patients that received a UST scan within one year relative to the Volpara mammogram reading were selected. The UST scans occurred over a period ranging from May 2014 to February 2016 as Volpara was only used at our center during 2015. Spearman correlation coefficients were calculated to determine the strength of the correlations. between the Volpara and UST measurements of BD.

RESULTS. The results show a very strong correlation (R_S=0.85) between Volpara volumetric percent density and UST whole breast sound speed values. This correlation is significantly stronger than those from previous 2-D studies (r_S=0.85 vs r_S=0.7, respectively). The strong correlation suggests that UST sound speed is a viable imaging biomarker for measuring BD.

CONCLUSION. A comparison between UST and Volpara volumetric measurements shows a stronger correlation than those found in earlier studies that used 2-D mammographic BD measurements. This result strengthens the potential role of UST as an alternative biomarker of BD.

CLINICAL RELEVANCE/APPLICATION. Elevated BD strongly increases a woman's risk of developing breast cancer. Since UST is non-ionizing, BD could be studied in a broader population of women, including those below screening age. UST provides quantitative information obtained without compression and radiation that has the potential to provide more accurate BD information, leading to better stratification of breast cancer risk.

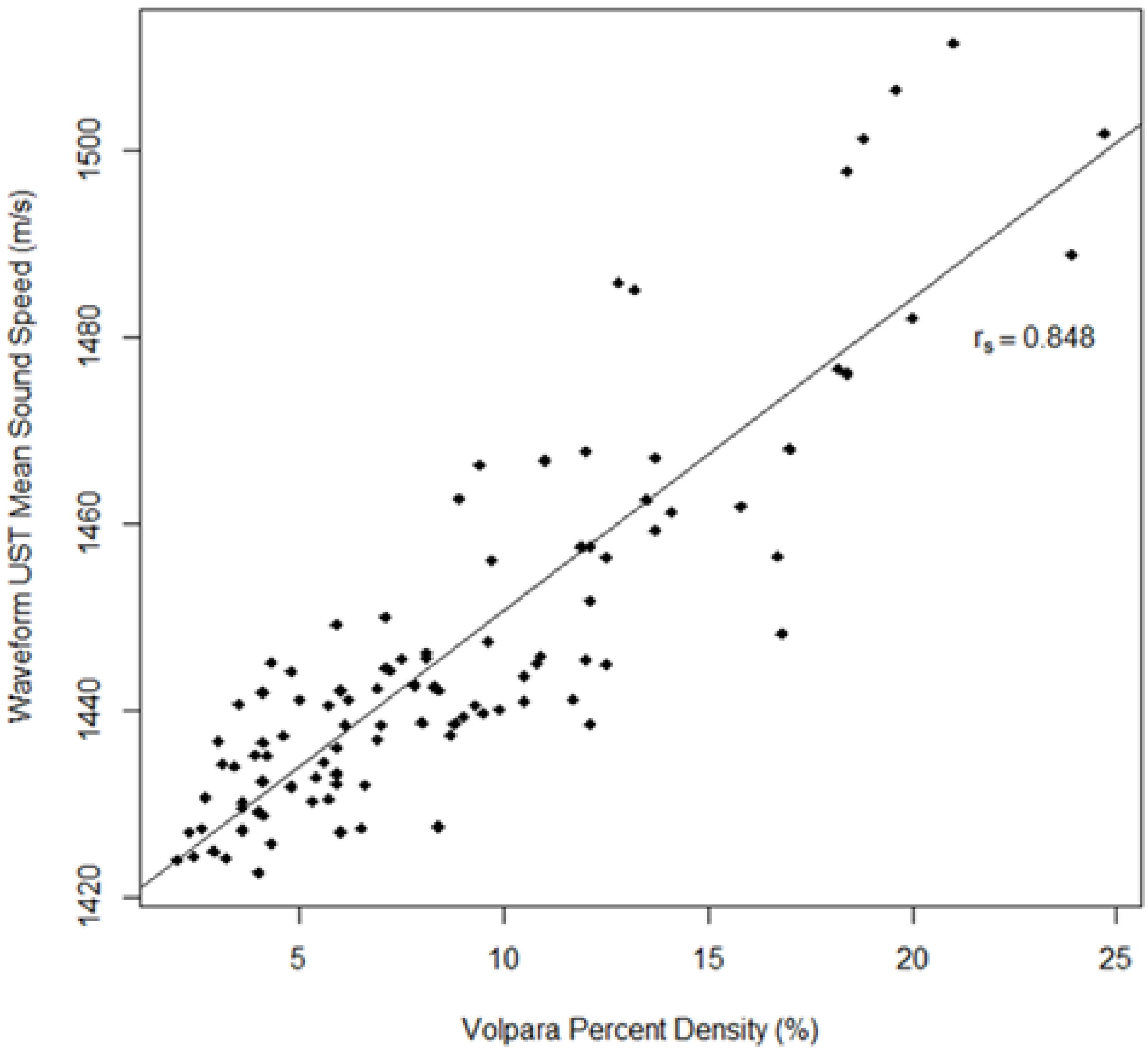


Figure 1. Correlation between breast sound speed and Volpara percent density. Note the quantitative values provided by UST.

Abstract ID : **75**

A Novel Imaging Biomarker for Monitoring response to Neoadjuvant chemotherapy

Content

Primary author(s) : Dr. LI, Cuiping; Dr. SAK, Mark (Delphinus Medical); Dr. DURIC, Neb (Karmanos Cancer Institute); Dr. CHEN, Di (Karmanos Cancer Institute); Dr. LITTRUP, Peter (Crittenton Hospital); Dr. BREM, Rachel (George Washington University)

Contribution Type : Oral

Status: SUBMITTED

Submitted by **DURIC, Neb** on **Monday 22 July 2019**

PURPOSE. PET and MRI studies have shown that imaging biomarkers can be used to characterize response of tumors to Neoadjuvant chemotherapy (NAC) and predict pathological outcomes. However, serial PET and MRI exams are time consuming, carry high cost and are associated with risks such as exposure to Gadolinium or radiation. Our previous studies have shown that tissue sound speed, derived from ultrasound tomography (UST) measurements, is an imaging biomarker that can be used to track tumor changes in the breast. Since ultrasound is relatively inexpensive, the purpose of this study was to evaluate sound speed as a reliable and cost-effective imaging biomarker for assessing NAC.

METHOD AND MATERIALS. Twenty-one patients undergoing neo-adjuvant chemotherapy for invasive breast cancer, were serially examined with UST throughout their treatment. The two parameters measured were the volume (V) and the volume averaged sound speed (VASS) of the tumor. Response curves of VASS and V were plotted for each study participant. Pathology results were used to classify participants as complete or partial responders based on whether they achieved complete pathologic response (pCR) or not. The response curves were then averaged together within each group. A t-test was used to determine if the response curves were statistically different between the complete responders and partial responders.

RESULTS. In the partial response group, VASS and V showed a gradual change with time while the complete response group showed a much steeper change with time (Table 1). The difference between the two groups was significant ($p<0.001$) for all parameters. Furthermore, large drops in V and VASS in the first 3 weeks of treatment appeared to be predictive of pCR.

DISCUSSION. UST has potential for non-invasive, rapid identification of partial vs complete responders in women undergoing NAC without the use of either a radiotracer or gadolinium. Clinical decision making would improve by transitioning non-responders to alternative treatment quickly and by demonstrating effective response to NAC.

CONCLUSION. Our study demonstrates that UST can be used to monitor NAC and that the partial vs complete responders could be separated based on how V and VASS change with time. A future larger study will test the predictive power of UST prospectively.

Table 1				
	Change in sound speed (m/s)		Change in volume (m/s)	
Days on Chemo	Complete Responders	Partial Responders	Complete Responders	Partial Responders
0	0	0	0	0
10	-2.5	0.4	-8.8	-1.9
20	-6.6	-0.6	-17.4	-4.5
30	-9.5	1.1	-23.1	-6.6
40	-8.9	1.8	-23.1	-7.9
50	-13.2	3.4	-19.3	-9.4
60	-14.3	4.0	-17.8	-10.9
70	-10.0	3.2	-21.6	-11.5
80	-11.6	0.4	-21.3	-12.0
90	-9.5	-4.3	-12.3	-12.9
100	-14.0	-9.6	-15.3	-13.5

Abstract ID : **78**

Parallel calculation of ultrasound computed tomography based on distributed system

Content

Primary author(s) : Dr. ZHOU, quan

Co-author(s) : Dr. WANG, shanshan; Ms. SUN, xia; Dr. SONG, junjie; Dr. ZHOU, liang; Dr. ZHANG, qiude; Prof. DING, mingyue; Prof. YUCHI, ming

Contribution Type : Poster

Status: SUBMITTED

Submitted by **ZHOU, quan** on **Wednesday 24 July 2019**

Parallel optimization for ultrasound computed tomography using GPU

Yang Zhou[1], Haixiang Hou[3], Shanshan Wang[4], Quan Zhou[2], Ming Yuchi[2,*], Mingyue Ding[2], Youhui Zheng[1]

[1]Wuhan WeSee Medical Imaging Co., Ltd
[2]Department of Biomedical Engineering, School of Life Science and Technology, Key Laboratory of Molecular Biophysics of the Ministry of Education, Huazhong University of Science and Technology, Wuhan, Hubei, China
[3]Cluster and Grid Computing Lab, Huazhong University of Science and Technology, China
[4]Hubei University of Technology, Wuhan, Hubei, China
*****m.yuchi@hust.edu.cn

1.Background

GPU has been widely used in imaging and image processing because of its powerful parallel computing ability. The application of GPU in ultrasound computer tomography (USCT) has attracted many researchers in recent years. The USCT system (Lucid) developed in the Medical Ultrasound Laboratory uses a ring transducer which contains 2048 elements to capture the radio-frequency (RF) data. The amount of the RF date for one slice can reach up to 30Gbytes, which brings great difficulties for image reconstruction. This paper introduces the image reconstruction acceleration of USCT with GPU.

2.Method

The process for the image reconstruction on GPU is as follows. First, all RF data are captured and saved on the server. Then the RF data are transferred to GPU memory and filtered. Finally, the image is reconstructed based on synthetic aperture focusing technique (SAFT) algorithm in GPU. The total RF data can be regarded as a 3-dimensional matrix. Considering that the memory of GPU is limited, the data are distributed into blocks and transferred to the memory sequentially and processed parallelly in GPU. Each block contains a certain number (N) of element RF data. If N is too small, the frequency of the data swap between the host memory, which results in low efficiency usage of GPU. If N is too large, the GPU memory cannot store the required raw data, which makes the hit rate of GPU memory low. The optimization of N is the main object of this work.

3.Result

The experimental results show that N = 128 is the optimal solution in our system. The processing time reduced to 38 seconds for the 2048×2048 image reconstruction, comparing to 4 minutes 10 seconds without GPU acceleration.

Abstract ID : **80**

Random field interferometry for medical ultrasound

Content

Ultrasound computed tomography (USCT) is frequently used for medical purposes to image soft tissue body parts, as for instance the breast.

Breast cancer detection using USCT usually works with a collection of ultrasound scans that measure the pressure wavefield emitted by individual transducers. This often requires a large number of emitter-receiver pairs to obtain a good coverage of the domain of interest, and careful calibration of the emitting transducers using reference measurements in water.

We present a novel approach to obtain time-of-flight measurements between receiver pairs in an USCT setup by applying the interferometry principle. By substituting active emitters with virtual ones, specific source imprints are eliminated, thus avoiding the need for reference measurements and calibration. Using interferometry and virtual emitters, we retrieve Green's functions between any two measurement locations, which can be used as new data for the inverse problem. The proposed method gives new perspectives to shorten the acquisition time of an entire USCT data set as well as to increase the data coverage.

We perform numerical experiments using a phantom representing a 2D cross-section of a breast and include some variations in the speed of sound inside the phantom to model regions with malignant cells. Using cross-correlations and stacking of A-scans, we show that one can extract the travel time between any pair of transducer positions from random wavefields, created by a superposition of individual source wavefields. Those data are then used in a time-of-flight inversion to reconstruct the speed of sound of the breast phantom.

Primary author(s) : Ms. ULRICH, Ines Elisa; Dr. BOEHM, Christian; Prof. FICHTNER, Andreas

Track Classification : Main Track

Contribution Type : Poster

Status: SUBMITTED

Submitted by **ULRICH, Ines Elisa** on **Wednesday 24 July 2019**

Abstract

Ultrasound computed tomography (USCT) is frequently used for medical purposes to image soft tissue body parts, as for instance the breast.

Breast cancer detection using USCT usually works with a collection of ultrasound scans that measure the pressure wavefield emitted by individual transducers. This often requires a large number of emitter-receiver pairs to obtain a good coverage of the domain of interest, and careful calibration of the emitting transducers using reference measurements in water.

We present a novel approach to obtain time-of-flight measurements between receiver pairs in an USCT setup by applying the interferometry principle. By substituting active emitters with virtual ones, specific source imprints are eliminated, thus avoiding the need for reference measurements and calibration. Using interferometry and virtual emitters, we retrieve Greens functions between any two measurement locations, which can be used as new data for the inverse problem. The proposed method gives new perspectives to shorten the acquisition time of an entire USCT data set as well as to increase the data coverage.

We perform numerical experiments using a phantom representing a 2D cross-section of a breast and include some variations in the speed of sound inside the phantom to model regions with malignant cells. Using cross-correlations and stacking of A-scans, we show that one can extract the travel time between any pair of transducer positions from random wavefields, created by a superposition of individual source wavefields. Those data are then used in a time-of-flight inversion to reconstruct the speed of sound of the breast phantom.

Abstract ID : **81**

Attenuation Image Reconstruction for Ultrasound Computed Tomography using FBP algorithm

Content

Background

Ultrasound Computed Tomography (USCT) is a promising medical imaging tool, which reconstructs the images of the object using both reflected and transmitted ultrasound signals. Attenuation tomography of USCT has been studied by many researchers since its great clinical potential of early breast cancer detection.

Material and Method

The Lucid USCT system developed in Medical Ultrasound Lab was used to capture the breast phantom signals. The system contains one 2048-element ring array with the center frequency 3.0 MHz. The diameter of the ring is 220 mm, and the sampling frequency is 25 MHz. Filtered back projection (FBP) is widely adopted as a classical analytic reconstruction method for image reconstruction. In this study, a fan-beam FBP algorithm is used for attenuation tomography of the breast phantom which has 3 cylinders with different attenuation coefficients to mimic the cyst, benign, and malignant tumors.

Results

The size of the reconstructed image is 1024x1024, and the 3 cylinders can be clearly shown and distinguished from the background. There exits circle artifacts around the cylinders.

Conclusion

The result shows that the fan-beam FBP algorithm can reconstruct the image of the breast phantom and distinguish the imaging objects with different attenuation coefficients. The artifacts in the reconstructed image are to be resolved in the future work.

Primary author(s) : Mr. WU, Yun; Ms. FANG, Xiaoyue; Mr. SONG, Junjie; Mr. ZHOU, Liang; Mr. ZHANG, Qiude; Mr. ZHOU, Quan; LIU, Kuolin; QUAN, Zhaohui; Mr. DING, Mingyue; Mr. YUCHI, Ming

Contribution Type : Poster

Status: SUBMITTED

Submitted by **WU, yun** on **Wednesday 24 July 2019**

Abstract ID : **82**

Refraction corrected transmissions imaging based on Bézier curves: first results with KIT 3D USCT

Content

The computational complexity of wave-based image reconstructions is very high. For this reason, approximations for 3D are required. Here, ray-based approaches are commonly used. The straight ray approximation neglects physical effects like refraction. Bent ray approaches like the widely used fast marching method may include this effect yet are still computationally demanding, especially in 3D. The Bézier curve technique, introduced by Perez-Liva et al., could be a compromise between computational effort and image quality. In this work, the method was extended to 3D. Additionally, it was evaluated with respect to third order Bézier curves and an optimization of parameters was carried out.

The Bézier curve technique uses a brute-force search to determine the path from the emitter to the receiver with minimum time-of-flight (TOF) given an estimated sound speed map. The path is chosen out of a set of Bézier curves with different curvature and the emitter and receiver as start- and endpoint. The Bézier curve with the minimal TOF is selected. The reconstruction is formulated as a linear equation system (Mx = b) which is solved for the image x with the TVAL algorithm, given the refracted path matrix M and the TOF difference to an empty measurement b.

The evaluation was carried out on two datasets. One bent ray iteration was performed based on the straight ray reconstruction. First, simulation data was created with the k-wave toolbox, with a speed of sound inhomogeneity and senders and receivers arranged in a hemisphere. The Bézier curve method produces similar results to the fast marching method. The mean squared error of the Bézier curve technique is 9.98 m/s in comparison to fast marching (11.85 m/s) and straight ray (15.09 m/s). Both bent ray techniques were able to represent the object size better, however differ in the speed of sound values in the border regions, see Fig. 1. Applied to a real data of the KIT 3D USCT both methods performed similarly: the object size was better preserved using bent ray methods (Fig. 2).

The method shows first promising results on 3D simulation data as well as real data. For simple objects, the Bézier method leads to similar result like the fast marching method. The representation of the object size has improved, i.e. the Bézier curve method well approximates the main refraction on the object-water interface. A 3D GPU implementation is currently developed to compare the computation time for 3D USCT.

Primary author(s) : ZUCH, Franziska

Co-author(s) : Dr. HOPP, Torsten; Mr. ZAPF, Michael; Dr. RUITER, Nicole

Track Classification : Main Track

Contribution Type : Poster

Status: SUBMITTED

Submitted by **ZUCH, Franziska** on **Wednesday 24 July 2019**

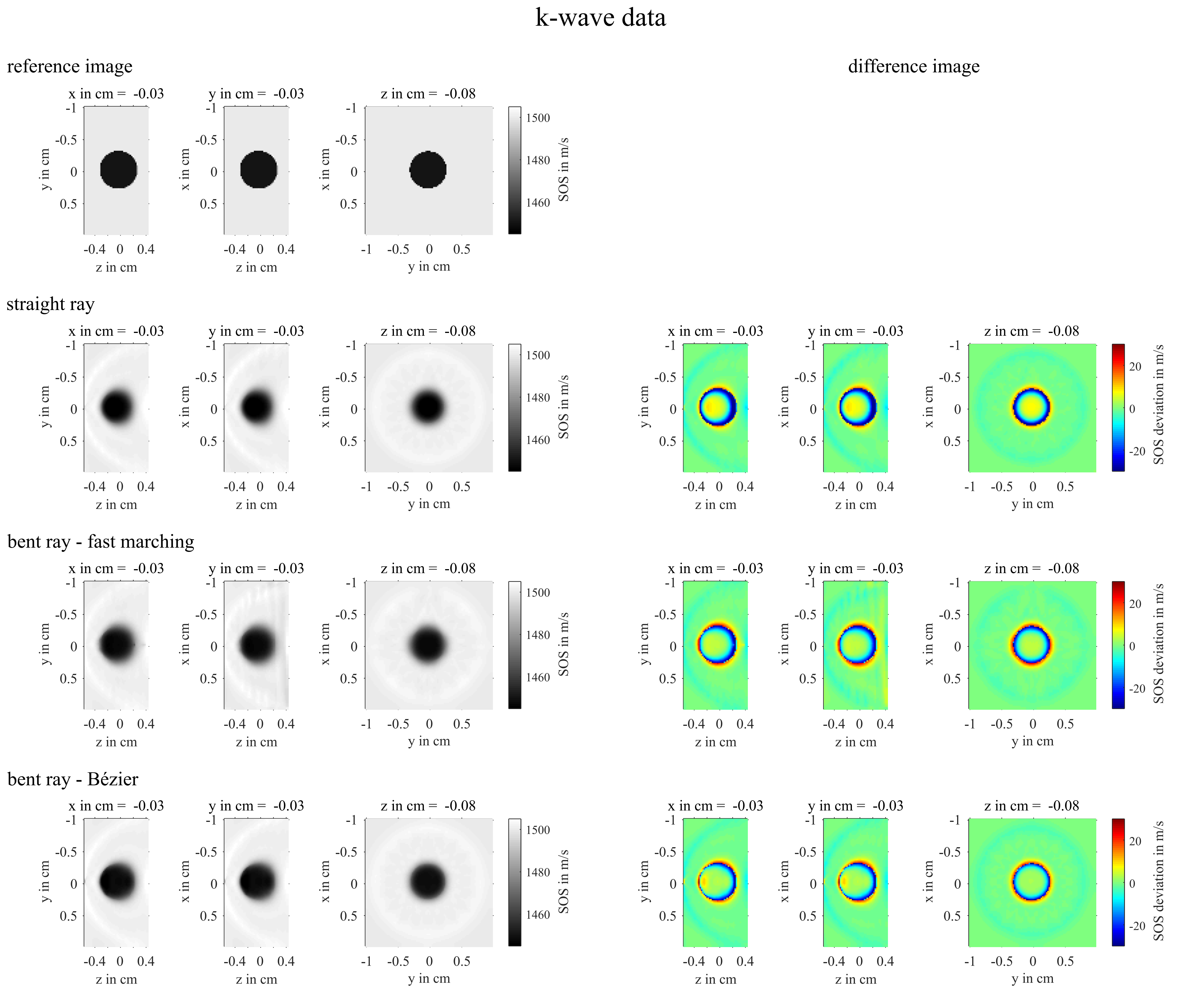


Fig. 1: Evaluation of 3D reconstruction with simulated k-wave data. Left column from top to bottom: simulated ground truth, reconstructions with straight ray approximation, fast marching bent ray approximation, and Bézier curve method bent ray approximation. The right colum shows the respective difference to the ground truth with the errors color coded. Each set of images shows a y/z, x/z and x/y slice from the 3D image.

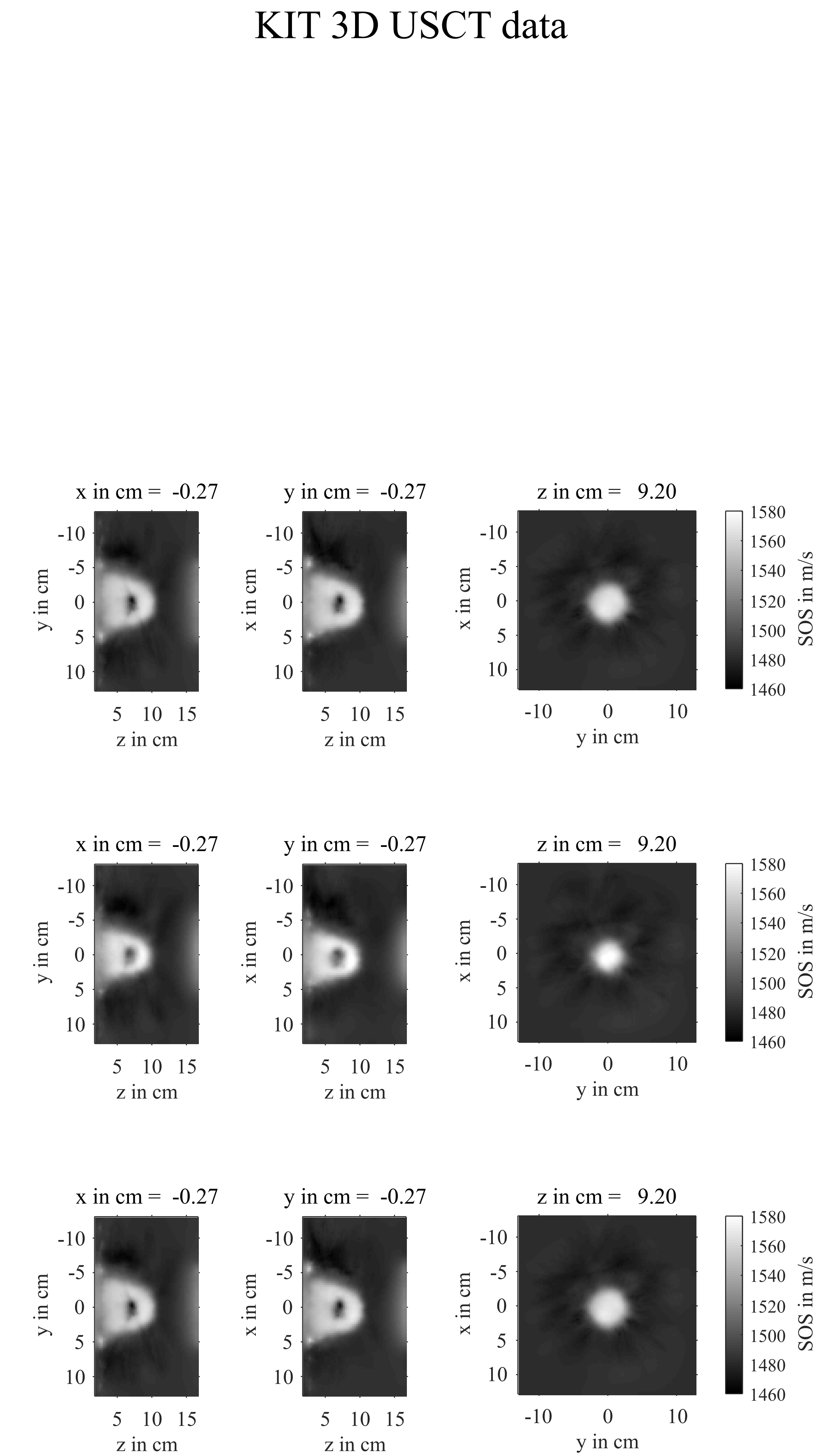


Fig. 2.: Reconstruction of real experiment data with the KIT 3D USCT. The phantom imaged consists of a mixture of gelatine, glycerine and propanol with an approximate sound speed of 1560 - 1570 m/s. An olive was embedded centrally in the phantom. The images from top to bottom show reconstructed sound speed images with the straight ray approximation, the fast marching bent ray approximation and the Bézier curve bent ray approximation.

Abstract ID : **83**

3D Wave-Equation-Based Finite-Frequency Tomography for Ultrasound Computed Tomography

Content

Ultrasound Computed Tomography (USCT) has great potential for 3D quantitative imaging of acoustic breast tissue properties. Typical devices include high-frequency transducers, which makes tomography techniques based on numerical wave propagation simulations computationally challenging, especially in 3D. Therefore, despite the finite-frequency nature of ultrasonic waves, ray-theoretical approaches to transmission tomography are still widely used.

This work introduces finite-frequency traveltime tomography to medical ultrasound. In addition to being computationally tractable for 3D imaging at high frequencies, the method has two main advantages: (1) It correctly accounts for the frequency dependence and volumetric sensitivity of traveltime measurements, which are related to off-ray-path scattering and diffraction. (2) It naturally enables out-of-plane imaging and the construction of 3D images from 2D slice-by-slice acquisition systems.

Our method rests on the availability of calibration data in water, used to linearize the forward problem and to provide analytical expressions of cross-correlation traveltime sensitivity. As a consequence of the finite frequency content, sensitivity is distributed in multiple Fresnel volumes, thereby providing out-of-plane sensitivity. To improve computational efficiency, we develop a memory-efficient implementation by encoding the Jacobian operator with a 1D parameterization, which allows us to extend the method to large-scale domains. We validate our tomographic approach using lab measurements collected with a 2D setup of transducers and using a cylindrically symmetric phantom. We then demonstrate its applicability for 3D reconstructions by simulating a slice-by-slice acquisition systems using the same dataset. The result is shown in the Figure, where we also analyse the vertical resolution using estimations of point-spread functions calculated from Hessian-vector products. We conclude showing that the vertical resolution could be controlled by appropriate designs of the acquisition system.

Primary author(s) : KORTA MARTIARTU, Naiara

Co-author(s) : Dr. BOEHM, Christian; Prof. FICHTNER, Andreas

Contribution Type : Oral

Status: SUBMITTED

Submitted by **KORTA MARTIARTU, Naiara** on **Wednesday 24 July 2019**

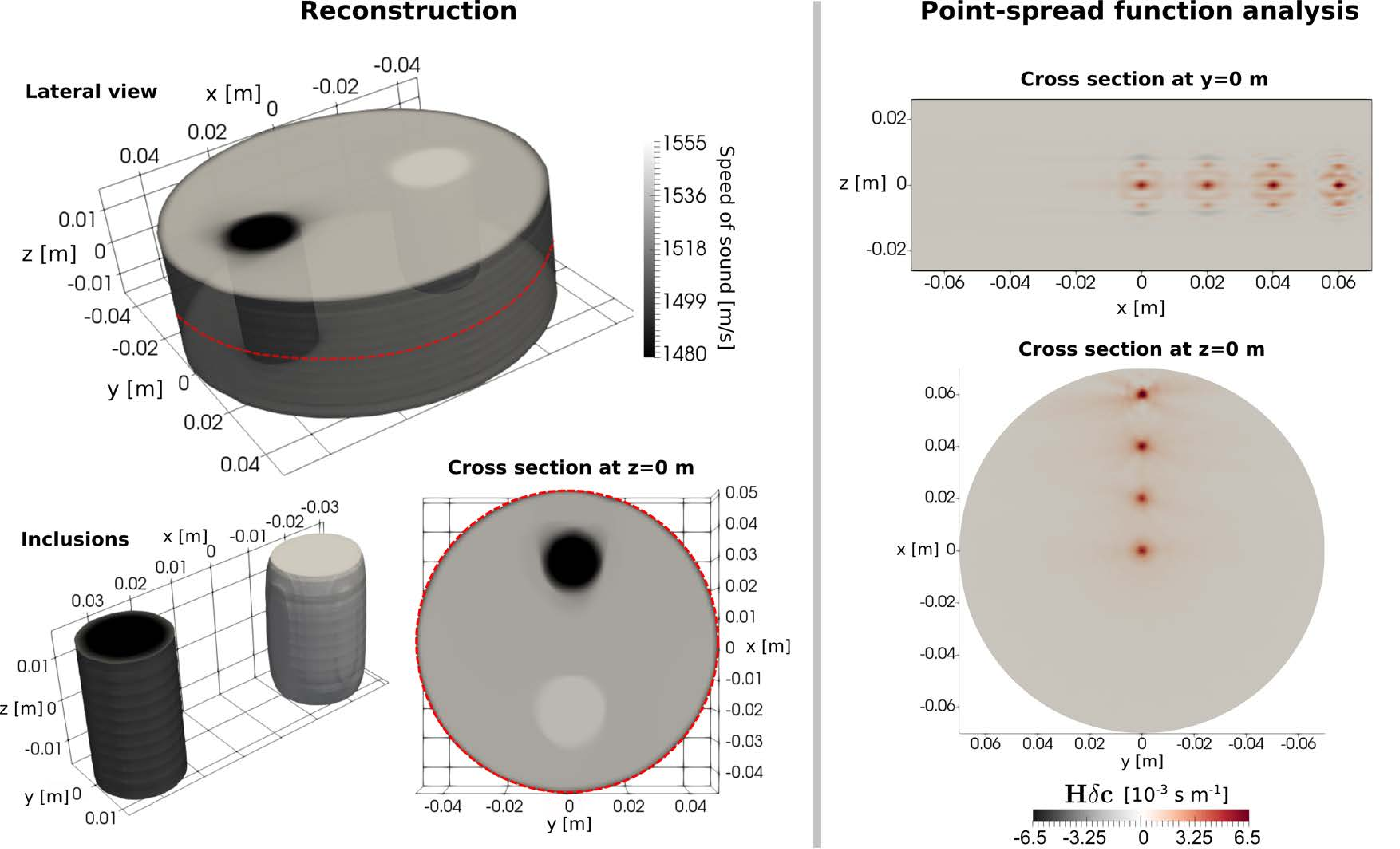


Figure. (Left column) Lateral view of the 3D velocity reconstruction, isolated view of inclusions and cross section at z = 0 m, indicated by the red line. (Right column) Cross-sections of point-spread functions estimated by Hessian-vector products at positions (x,y,z) = (0,0,0),(0.02,0,0),(0.04,0,0),(0.06,0,0) m.

Abstract ID : **84**

Pseudo-linear-frequency-modulation pulse emission and signal matching in ultrasound computed tomography system

Content

Background:
Pseudo-linear-frequency-modulation pulses (pseudochirps) is widely applied as transmitted signals in conventional ultrasound imaging system because of the low cost of the signal generation hardware and better depth of penetration. The spectrum of the pseudoshirps can be modified for better matching to the transducer. Echo signals of pseudochirps after pulse compression may last similar time comparing to the pulse wave but with higher SNR, which has the potential to increase the image quality of the ultrasound computed tomography .
Material and Method:
The Lucid system developed in Medical Ultrasound Lab consists of a 2048-elements ring transducer of which the diameter is 220mm and the center frequency is 3.0MHz with 70% bandwidth. The pseudochirp wave lasts for 10us and the frequency ranges from 780KHz to 5.1MHz. The imaging object is the rectal scan phantom (MODEAL ATS 540) made by CIRS. The phantom has a full 360° acoustic window, and contains five groups of circular targets of varying sizes and depths and five levels of gray scale targets.
Results:
The duration of the echo signal of pseudochirp after pulse compression is about 2us, as for the echo signal of two-cycle square wave is about 1.8us. The amplitude of the transmissive waves is higher than the two-cycle square wave. The reconstructed B-mode images show that pseudochirps bring better resolution and contrast.
Conclusion:
The results show that the pseudochirp has good potentials in ultrasound computed tomography because of its low cost of hardware, good depth of penetration, high SNR after pulse compression. We will modify the wave and match filter of pseudochirp for better imaging in the future.

Primary author(s) : Mr. ZHOU, Liang; Mr. LIU, Kuolin; Mr. SONG, Junjie; Prof. DING, Mingyue; Prof. YUCHI, Ming

Contribution Type : Poster

Status: SUBMITTED

Submitted by **ZHOU, Liang** on **Wednesday 24 July 2019**

Abstract ID : **85**

Parallel optimization for ultrasound computed tomography using GPU

Content

Parallel optimization for ultrasound computed tomography using GPU

Yang Zhou1, Haixiang Hou3, Shanshan Wang4, Quan Zhou2, Ming Yuchi2,*, Mingyue Ding2, Youhui Zheng1,

1Wuhan WeSee Medical Imaging Co., Ltd
2Department of Biomedical Engineering, School of Life Science and Technology,
Key Laboratory of Molecular Biophysics of the Ministry of Education,
Huazhong University of Science and Technology, Wuhan, Hubei, China
3Cluster and Grid Computing Lab, Huazhong University of Science and Technology, China
4Hubei University of Technology, Wuhan, Hubei, China
*m.yuchi@hust.edu.cn

1.Background
GPU has been widely used in imaging and image processing because of its powerful parallel computing ability. The application of GPU in ultrasound computer tomography (USCT) has attracted many researchers in recent years. The USCT system (Lucid) developed in the Medical Ultrasound Laboratory uses a ring transducer which contains 2048 elements to capture the radio-frequency (RF) data. The amount of the RF date for one slice can reach up to 30Gbytes, which brings great difficulties for image reconstruction. This paper introduces the image reconstruction acceleration of USCT with GPU.

2.Method
The process for the image reconstruction on GPU is as follows. First, all RF data are captured and saved on the server. Then the RF data are transferred to GPU memory and filtered. Finally, the image is reconstructed based on synthetic aperture focusing technique (SAFT) algorithm in GPU. The total RF data can be regarded as a 3-dimensional matrix. Considering that the memory of GPU is limited, the data are distributed into blocks and transferred to the memory sequentially and processed parallelly in GPU. Each block contains a certain number (N) of element RF data. If N is too small, the frequency of the data swap between the host memory, which results in low efficiency usage of GPU. If N is too large, the GPU memory cannot store the required raw data, which makes the hit rate of GPU memory low. The optimization of N is the main object of this work.

3.Result
The experimental results show that N = 128 is the optimal solution in our system. The processing time reduced to 38 seconds for the 2048×2048 image reconstruction, comparing to 4 minutes 10 seconds without GPU acceleration.

Primary author(s) : Mr. ZHOU, Yang

Co-author(s) : Mr. HOU, Haixiang; Prof. WANG, Shanshan; Dr. ZHOU, Quan; Prof. YUCHI, Ming; Prof. DING, Mingyue; Mr. ZHENG, Youhui

Contribution Type : Poster

Status: SUBMITTED

Submitted by **ZHOU, yang** on **Wednesday 24 July 2019**

Abstract ID : **86**

A PID Controller Approach for Regularizing Quantitative Sound Speed Imaging using Full Waveform Inversion

Content

Although quantitative sound speed images generated by full waveform inversion (FWI) provide higher resolution images than those produced by other methods like ray-based methods, the overshoot problem of the FWI-based sound speed imaging hinders the convergence of sound speed and degrades the overall image resolution. In this work, we propose a proportional-integral-derivative (PID) approach for improving the convergence, resolution, and accelerating the FWI. The proposed PID controller approach for our custom-made ultrasound tomography (UST) consisting of single element receive and transmit transducers is implemented to produce quantitative sound speed images. The novel regularization method with PID controller is verified by the sound speed images of limb cross-section for both numerically generated model and experimentally collected data from ex-vivo animal tissue. As the results, the proposed PID approach will reduce much the overshoot phenomena of FWI which typically utilizes gradient descent method as the update, and achieve much robust performance than those generated from the conventional regularization.

Primary author(s) : Dr. SHIN, Bonghun (MIT); Mr. ZHANG, Xiang (MIT); Dr. ELY, Gregory (MIT); Dr. FINCKE, Jonathan (Philips); Prof. ANTHONY, Brian W. (MIT)

Contribution Type : Poster

Submitted by **SHIN, Bonghun** on **Wednesday 24 July 2019**

Abstract ID : **93**

Transceiver ASIC in HVCMOS Technology for 3D Ultrasound Computer Tomography

Content

3D Ultrasound Computer Tomography (3D USCT) is an imaging method for the early detection of breast cancer. It provides three-dimensional multimodal images of the breast. The 3D USCT device developed at Karlsruhe Institute of Technology contains more than two thousand ultrasound transducers placed in a water-filled semi-ellipsoidal reservoir where the patient submerges one breast. The ultrasound transducers are grouped as transducer array systems (TAS) of 18 receiver (RX) and transmitter (TX) elements. The transducer front-end electronics contains high voltage (HV) and low voltage (LV) amplifiers and switches which are implemented as an application-specific integrated circuit (ASIC). This contribution presents a patented mixed signal, multichannel, transceiver ASIC (USCT9CV2) developed in a commercial 350 nm high voltage CMOS (HV-CMOS) process. The HV-CMOS process provides low voltage and high voltage transistors that can be combined on the same substrate. The HV transistors can sustain voltages up to 120 V. The ASIC consists of nine high voltage amplifiers as TX elements and three low noise low voltage amplifiers as RX elements. The high voltage amplifier is designed as an inverting amplifier with a gain of 20. It can generate signals with an amplitude up to 120 V. The 3-stage low noise amplifier is designed for amplification of signals from 10 μV to 10 mV with variable gain from 100 to 10000. In addition, the ASIC contains a digital interface for the configuration. This digital block implements a serial protocol interface (SPI) decoder. The use of the ASIC offers the following advantages for USCT over a discrete component solution: more RX/TX channels, high bandwidth, variable gain in linear steps, low power, small size, reduced crosstalk due to shorter and isolated signal lines. The ASIC enables a more cost-effective solution of our measuring problem than a discrete design. Recent measurements with prototype transducers (Figure a) are promising and fulfill the requirements of 3D USCT. The TX excitation, a linear chirp signal (Figure c) between 200 kHz to 4.7 MHz, was generated off chip and amplified by the high voltage amplifier. The output amplitude (Figure d) is 90.4 V (peak to peak for lower frequencies) and the gain is 18.4. The amplification is relatively constant with 18\% drop in the frequency range of the chirp signal (Figure b). The RX signals of 100 μV were amplified by the LV amplifiers up to 300 mV with a gain factor of around 3000.

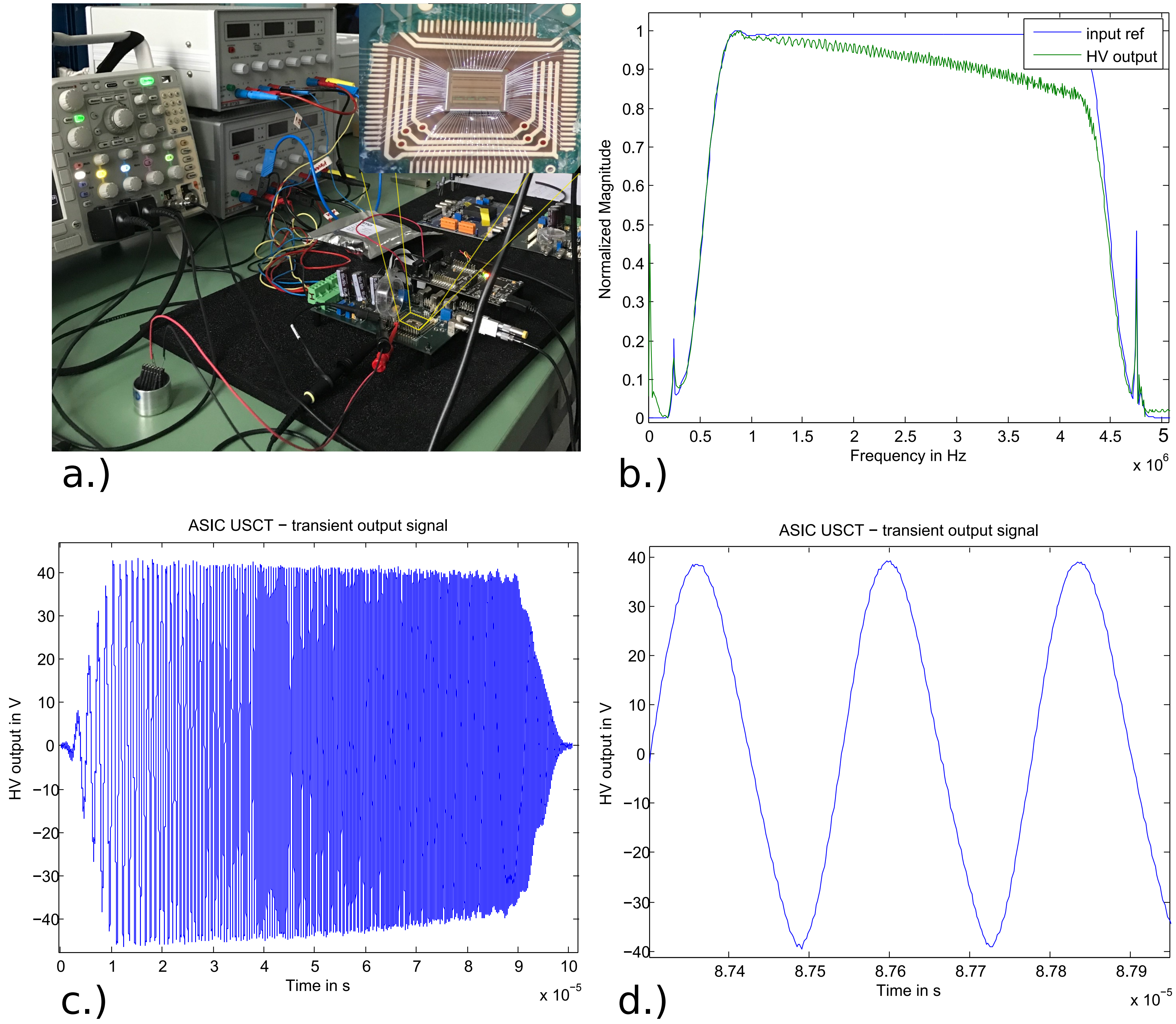
Primary author(s) : BLANCO, Roberto

Co-author(s) : LEYS, Richard; Mr. BECKER, Lukas (KIT - Kalrsruhe Institute of Technology); Mr. ZAPF, Michael; Prof. GEMMEKE, Hartmut; Dr. V. RUITER, Nicole; Prof. PERIC, Ivan

Contribution Type : Poster

Status: SUBMITTED

Submitted by **BLANCO, Roberto** on **Thursday 25 July 2019**


a.)
input ref
HV output
Normalized Magnitude
Frequency in Hz
x 10^6
b.)
ASIC USCT − transient output signal
HV output in V
Time in s
x 10^-5
c.)
ASIC USCT − transient output signal
HV output in V
Time in s
x 10^-5
d.)

Abstract ID : **96**

Fast auto-adaptive gain adaption for improved signal dynamics

Content

In our 3D Ultrasound Computer Tomography system (USCT), the 12 bit ADC and factor 10 VGA are insufficient to resolve the smallest interesting signals. An adaptive front-end gain can solve this by object specific adaptions during the measurement.

The 3D USCT II of the KIT device contains 157 Transmitter Array System (TAS). Each TAS has 13 piezoelectric transducers, corresponding analog signal front end (AFE) and an MSP430FG66xx series microcontroller (MCU). All TAS are connected to a control board through a two-wire serial bus system.

Direct Memory Access (DMA) was used in the hardware to control the interrupt of the Universal Serial Communication Interfaces module (USCI). To complete the data transfer without occupying the MCUs of the TAS. A location-based general call was developed in the control system. The host transmits one frame long message to all TAS in a general call mode. This message contains the configurations of all TAS for the next measurement step. The address of each TAS corresponds to the location of each configuration in the long message. Thus, in the broadcast mode, each TAS only obtains the configuration information required by itself. With these two improvements, to configure all of the TAS can be reduced to less than 3 ms, which is the shortest measurement interval.

The here proposed solution allows a fast dynamic control of the front-end electronics during measurement without extending the measurement time significantly.

Primary author(s) : LU, Zewei; Mr. ZAPF, Michael; Dr. RUITER, Nicole

Contribution Type : Poster

Status: SUBMITTED

Submitted by **LU, Zewei** on **Thursday 25 July 2019**

Fast auto-adaptive gain adaption for improved signal dynamics

Zewei Lu, Michael Zapf, and Nicole Ruiter
Karlsruhe Institute of Technology, Karlsruhe, Germany

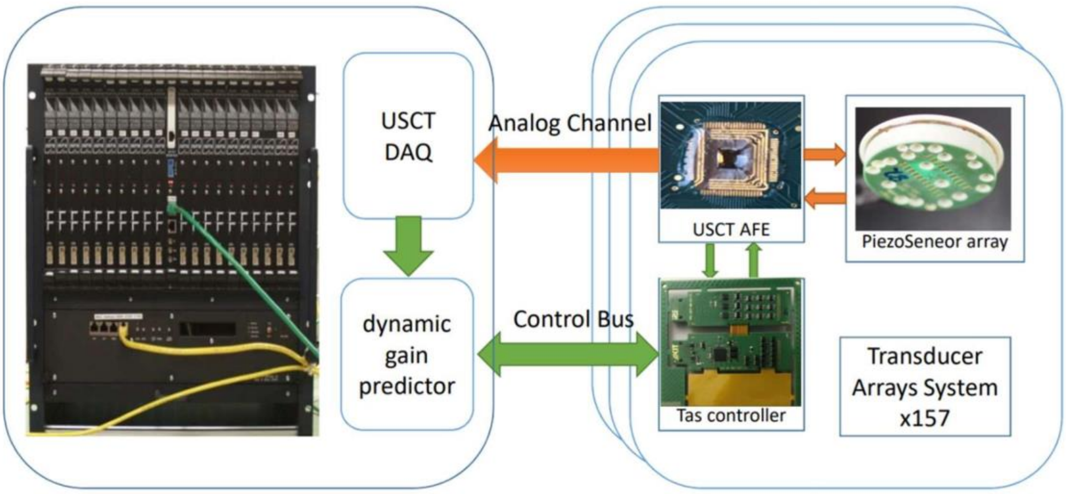
In our 3D Ultrasound Computer Tomography system (USCT), the 12 bit ADC and factor 10 VGA are insufficient to resolve the smallest interesting signals. An adaptive front-end gain can solve this by object specific adaptions during the measurement.

The 3D USCT II of the KIT device contains 157 Transmitter Array System (TAS). Each TAS has 13 piezoelectric transducers, corresponding analog signal front end (AFE) and an MSP430FG66xx series microcontroller (MCU). All TAS are connected to a control board through a two-wire serial bus system.

Direct Memory Access (DMA) was used in the hardware to control the interrupt of the Universal Serial Communication Interfaces module (USCI). To complete the data transfer without occupying the MCUs of the TAS. A location-based general call was developed in the control system. The host transmits one frame long message to all TAS in a general call mode. This message contains the configurations of all TAS for the next measurement step. The address of each TAS corresponds to the location of each configuration in the long message. Thus, in the broadcast mode, each TAS only obtains the configuration information required by itself. With these two improvements, to configure all of the TAS can be reduced to less than 3 ms, which is the shortest measurement interval.

The here proposed solution allows a fast dynamic control of the front-end electronics during measurement without extending the measurement time significantly.

The figure shows the basic architecture of our system: combined with the USCT AFE, which is custom designed for USCT devices, the dynamic gain system can amplify the input signal in the range from 12dB to 69dB. Every channel has at least 5 MHz bandwidth.



Abstract ID : **97**

First US performance measurements of next generation 3D USCT 2.5 transducers

Content

The KIT's 3D Ultrasound Computer Tomography (USCT) II system has a multistatic setup of 2041 ultrasound transducers with approx. 1.5 MHz 6dB bandwidth and 36° 3 dB opening angle for 2.5 MHz. To increase the region of interest for a next USCT generation, the opening angle should be increased to approx. 60° and the bandwidth doubled..
To increase the opening angle the size of the transducer elements was decreased to approximately half the size. A circular aperture was chosen for homogenicity of the radiation pattern in 3D. The transducer design utilizes piezo-fibres by the established Fraunhofer IMT piezo-fibre composite technology. The fibres were fabricated from PZT powder using the polysulfone spinning process. 17 fibres were positioned with a mechanical mask and filled with a matrix of epoxy. From this rod piezo composite discs were sawed and polarized. Electrodes were generated by silver-filled epoxy adhesive on the top and bottom side. Materials for acoustic backing is a Tungsten-Polyurethane composite and for acoustic matching ia aluminium oxide composite material (TMM4).

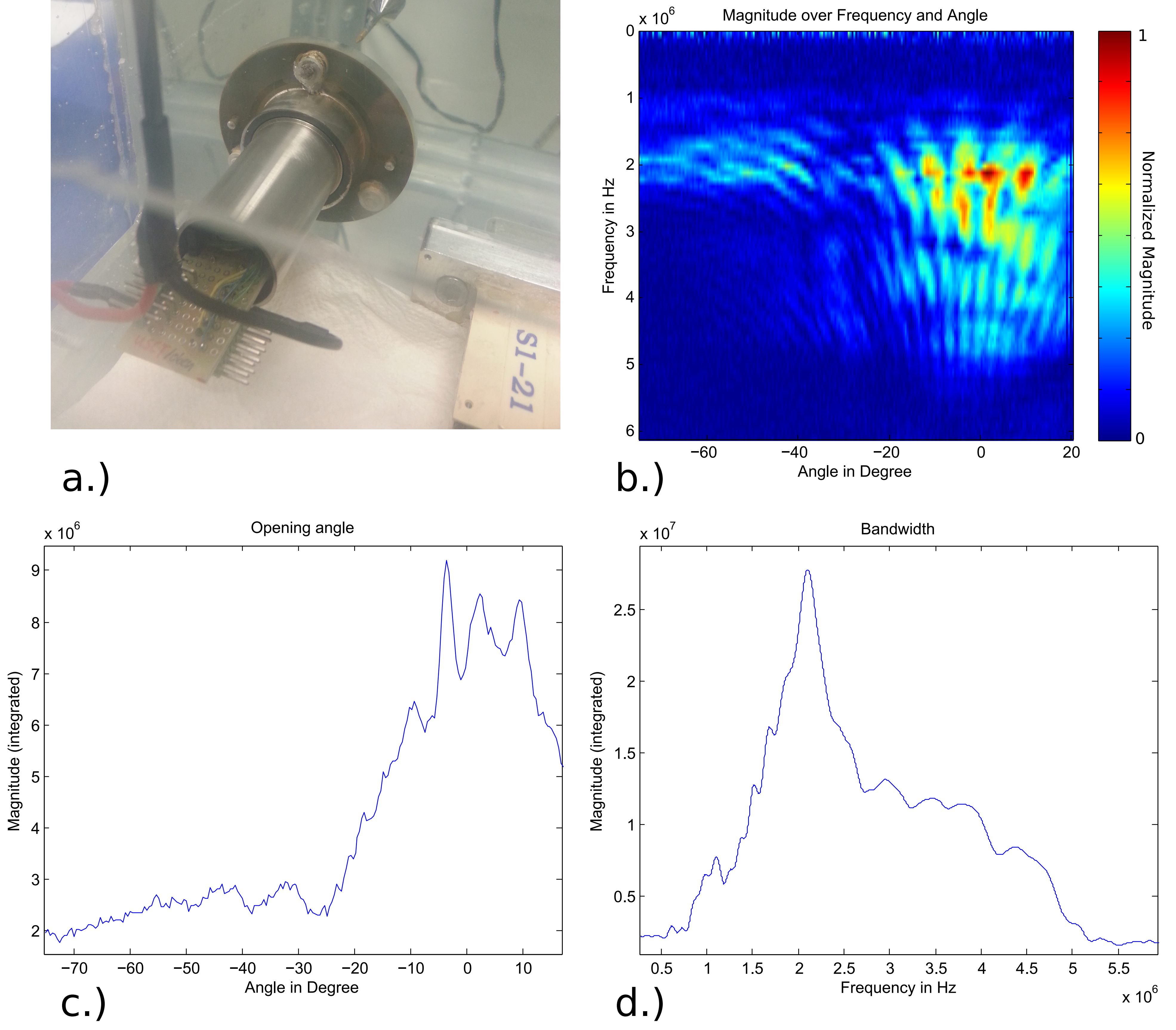
Ultrasound characteristics were evaluated quantitatively with a Onda HNC-400 hydrophone in a 3-axis water tank for a randomly selected sample transducer (see Fig. a.)). Characteristics evaluated were the pressure field as function over frequency and angle in the far-field (see Fig. b.)), following the use-case. For excitation a linear encoded chirp was used, for SNR improvements averaging of measurements (64 to 256 times) was conducted. The analysis compensated for the hydrophon's frequency and angular damping characteristics.
The presented results show that the desired characteristics were mostly achieved: the 6 dB bandwidth could be vastly improved by roughly 200% (see Fig. d.)). The 6 dB pressure opening angle was approx. 50° (see Fig. c.)), not completly fullfilling the simulated expectations, an improvement by 31% was achieved. The results are promising for the next 3D USCT III generation.

Primary author(s) : Mr. ZAPF, Michael (KIT); Mr. ANGERER, Martin (KIT); Mr. HOHLFELD, Kai (Fraunhofer IKTS); Dr. GEBHARDT, Sylvia (Fraunhofer IKTS); Prof. GEMMEKE, Hartmut (KIT); Dr. RUITER, Nicole V. (KIT)

Contribution Type : Poster

Status: SUBMITTED

Submitted by **ZAPF, Michael** on **Thursday 25 July 2019**


S1-21
Magnitude over Frequency and Angle
x 10^6
Frequency in Hz
Angle in Degree
Normalized Magnitude
a.)
b.)
Opening angle
x 10^6
Magnitude (integrated)
Angle in Degree
c.)
Bandwidth
x 10^7
Magnitude (integrated)
Frequency in Hz
x 10^6
d.)

Abstract ID : **100**

Compensating for Variable Acoustic and Optical Properties towards Quantitative Photoacoustic Tomography

Content

Photoacoustic tomography (PAT) is a noninvasive, high-resolution imaging modality, capable of providing functional and molecular information of various pathologies such as cancer. In PAT imaging one optical limitation is the attenuation effect depth has on fluence and therefore the generation of PA signals from deeper regions of tissue. This makes it impossible to equally compare signals from various depths. In addition, most ultrasound and photoacoustic image reconstruction algorithms assume a homogeneous speed of sound distribution. This leads to a mismatch between the true location and size of the object and what the reconstructed image shows. This mismatch also plays a role in how effective and accurate fluence compensation can be. Since light diffusion is not affected by acoustic properties and the PAT image is, this leads to inaccuracies when fluence compensation is applied. In this study we investigate using a model-based method, that employs Monte Carlo light (MCXCL) and acoustic wave propagation (K-wave) simulations, to demonstrate the benefits of fluence compensation, in addition to the affect speed of sound correction has on fluence compensation. To generate our results we numerically modeled a full-ring illumination and ring-based acoustic detection system that our group has been developing. This model was then used to run an experiment that looked at a numerical phantom which was designed to test the affects of depth, concentration, and varying speed of sound on PAT image reconstruction. Our results indicate improvements in PAT optical fluence compensation and more importantly the feasibility of achieving qPAT images.

Primary author(s) : PATTYN, Alexander; Mr. MUMM, Zackary (Wayne State University); Dr. MEHRMOHAMMADI, Mohammad (Wayne State University)

Track Classification : Main Track

Contribution Type : Poster

Status: SUBMITTED

Submitted by **PATTYN, Alexander** on **Thursday 25 July 2019**

Abstract ID : **101**

Deep learning based sound speed image reconstruction in ultrasound tomography for breast cancer detection

Content

Acoustic sound speed is an important bio-marker that can be used to characterize tissue types in the breast and differentiate between them.

The conventional way to obtain sound speed image is by using tomographic imaging methods. Higher resolution imaging uses non linear methods that range from ray-based travel time tomography to full-waveform inversion (FWI). Although the complexity varies, these methods have high to extremely high computational complexity and are time consuming.

In this work, we investigate a novel method based on a fully convolutional neural network to reconstruct sound speed images from raw data. This method is based on big-data training rather than physics based modelling and prior-knowledge as it is the case in conventional inversion methods. During the training stage in the deep learning method, the network learns to extract important features from the raw data and assembles them to more complex patterns by comparing it with ground truth data. Using this supervised learning techniques, a non linear projection from multiple shots of tomographic data to the corresponding sound speed images is established. During the prediction stage, the trained network can be used to estimate the sound speed images from the new input tomographic data.

A key characteristic of the deep-learning method is that it can generate a sound speed image without the need for having an initial sound speed map. Although the training of the deep neural networks is rather intensive, the application of the trained deep neural networks is nearly instant. Therefore, the computational time of sound speed estimation can be dramatically reduced.

By using numerical experiments on synthetic models, we can show promising initial results of the proposed method even when the input data are from more realistic scenarios.

Primary author(s) : Dr. BALIC, Ivana (SonoView Acoustic Sensing Technologies, LLC); Mr. LEIMER, Pascal (Switzerland Innovation Park in Biel/Bienne)

Track Classification : Main Track

Contribution Type : Poster

Status: SUBMITTED

Submitted by **BALIC, Ivana** on **Thursday 25 July 2019**

Abstract ID : **102**

Design and performance of a Tonpilz transducer for low frequency medical ultrasound tomography

Content

Primary author(s) : Mr. FILHO, Ely Lopes (University of Sao Paulo); Dr. MUELLER, Jennifer (Colorado State University); Dr. LIMA, Raul (University of Sao Paulo)

Contribution Type : Poster

Status: SUBMITTED

Submitted by **MUELLER, Jennifer** on **Thursday 25 July 2019**

The design and performance of a Tonpilz transducer for low frequency medical ultrasound tomography is presented. Recent research [Rueter et al., Eur. J. Ultrasound, **31** 2010] has shown that there are three frequency bands in which acoustic signals behave in distinct ways in the human thorax, and the desirable frequency range is between 10 and 750 kHz, with signal attenuation increasing as frequency increases. Above 1 MHz, there is also no transmission through healthy lungs. These properties pose an opportunity both for the diagnosis of COPD and bedside pulmonary monitoring in the ICU using low frequency ultrasound tomography. However, the low frequency signal, the geometry of the thorax, and the safety constraints of medical ultrasound pose a challenge in transducer design, and commercial transducers are not available for this application. A Tonpilz transducer was designed and simulated with the finite element method in Comsol, consisting of a 1 cm thick cylinder of radius 1.25 cm with two masses joined and compressed by means of a screw on the axis of symmetry perpendicular to each of the two flat, parallel faces. The two piezoelectric PZT8 ceramic discs are centered on the screw, compressed between the masses. Experimental tests with the Tonpilz transducers revealed that they perform very closely to the results of the Comsol simulations. The significant resonant frequency of the transducer was found to be at 165 kHz, with a minimum impedance of 430 Ohms. A tank was constructed with 64 transducers placed around the circumference of the tank, which was then filled with water, and measurements were taken on a pair of transducers housed on opposite sides of the well, exciting one with a burst signal of 12 Volts peak and 167 kHz. The signal received showed amplitude with a peak value of 400 mV, which is suitable for the operation of the hardware reception loop proposed for the experiments. The transducers demonstrated high directivity, which is a focus of current research for our design. Shown below is the sound pressure level from the Comsol simulation and the transducer at right.