3D Ultrasound–Computertomography: Data Acquisition Hardware

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***Abstract*— Ultrasound computertomography (USCT) is an imaging method capable of producing volume images with both high spatial and temporal resolution. The promising results of a 2D experimental setup of an ultrasound computertomography system with at least 0.25 mm resolution encouraged us to build a new 3D demonstration system. The main problem of such a demonstrator is the high burst data rate of up to 32 GBytes/s for parallel recording in order of thousand A–scans. We present a 3D hardware demonstrator setup which is capable of handling these data rates. For the first time this demonstrator allows high resolution (sub wavelength) 3D imaging in realtime.**

I. Introduction

Ultrasound imaging is an imaging method which has several advantages over e.g. x–ray imaging. It is non invasive and therefore repeatedly applicable without harm. It shows structures like cysts that may not be detected with other imaging methods. Also it is of low cost and can be applied easily. But we also have some problems.

A. Problem Statement

Manually operated ultrasound imaging lacks both reproducibility and spatial resolution. Images are hard to interpret because of shadowing effects and speckle noise. This can be overcome by a fixed setup and the recording of not just reflections but of all reflected, scattered and transmitted signals from within the setup. Images will become reproducible and reconstruction using all signals leads to high spatial resolution. However this setup requires the recording of all signals in parallel which leads to high burst data rates of up to 32 GBytes/s. These high data rates could not be handled until know.

B. State Of The Art

We built a 2D demonstrator setup consisting of a virtual ring array with 1600 transducer elements using two relocatable ultrasound transducer arrays each with 16 elements [3]. Both arrays were manually moved. The sequential recording reduced the burst data rate and made recording of A–scans with a conventional PC card possible. Reconstructed cross sections of examined ultrasound phantoms showed very small structures below wavelength (figure 1). Nevertheless the recording of all positions takes approx. 12 hours thus making it impossible to image living tissue.

For the detection of cosmic rays we already developed a special hardware for recording data at very high rates [5]. The hardware can be modified to be used for USCT. On one hand this will cut down expenses, on the other hand we can rely on a well proven system.

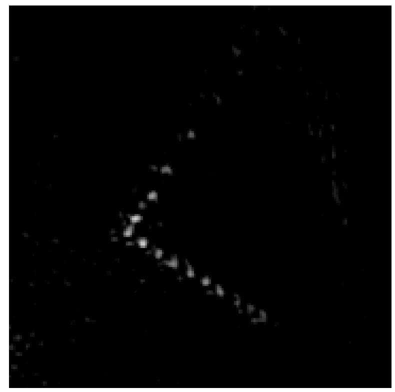

Fig. 1. Reconstructed nylon threads of 0.1 mm in diameter and 0.5 mm distance recorded at 3 MHz with the 2D USCT demonstrator [3].

C. Rationale

The promising results of the 2D demonstrator encouraged us to build the demonstrator of a 3D ultrasound computertomograph. We propose the setup of this demonstrator and focus on the hardware (USCT Crate) capable of handling the high burst data rates and the development of the necessary transducer arrays.

II. Methodology

A. Transducer systems and container

The front end of the USCT hardware is a container filled with water as coupling medium. 48 transducer systems are mounted in 3 stacked layers across the container walls, each system holding 8 emitters and 32 receivers [1]. The container is mechanically rotated in six steps covering the gaps between the transducer systems. The transducers are designed to operate at 3.2 MHz. Included in the transducer systems are pre–amplifiers, 8 times multiplexing and microcontrollers which enable/disable and multiplex transducers after obtaining a broadcasted address. The transducer systems are merged in 4 amplification systems which connect to the USCT crate.

B. USCT crate: fast data acquisition hardware

The USCT crate contains a controller board (CB) and several digitization boards (DBs) (figure 2). The CB is in charge

Fig. 2. USCT crate for fast recording of ultrasound data containing several digitization boards (DBs) and one controller board (CB, left with cables).

for the communication between crate and PC. Additionally it controls the measuring process of the DBs. A DB contains 24 digitization channels each with 12 bit sampling at 10 MHz and 8 circular buffers of 64 KBytes. CB and DBs have FPGAs onboard which contain the programming. The boards are connected via a single master VME–Bus backplane.

To perform a measurement the CB is initialized with several parameters and the actual water temperature is read from the CB. The following steps are then repeated until every emitter has been used: The address of the desired configuration is broadcasted to the transducer systems. After that the exciting waveform is transferred to the selected emitter. Coded excitation at 40 MHz is used to load arbitrary waveforms. At the same time the DBs start recording the A–scans. The recording is repeated n times and the A–scans are averaged to reduce the noise. The recorded data is transferred to the PC if the memory of the DBs is used to full capacity.

We defined two different recording modes: the first mode is used for full 3D imaging. The recording duration for each A–scan is 300 μs and digitization is performed at 12 bit. This leads to approx. 6 KBytes memory usage per A–scan. 8 A–scans can be stored in a channel's memory before the data has to be transferred to the PC. The second mode is used for fast 2D cross section imaging. The recording duration is 200 μs per A–scan and digitization is performed at 12 bit. This leads to approx. 4 KBytes per A–scan. Thus a complete cross section of 16 A–scans per channel can be recorded in a single pass.

C. Controlling PC

The recording process is controlled by a standard PC with a MicroEnable framegrabber card connected to the CB. The card's driver is written in C++. A Java command shell is provided for deploying commands to the crate.

D. Reconstruction

Several reconstruction methods are available. First we implemented a transmission tomography algorithm for fast reconstruction of cross sections based on [2], [4]. Second we implemented full aperture sum–and–delay methods which we used for 2D reconstruction [3]. We modified the 2D Algorithms to allow not only stacked slices but real 3D reconstruction by basically overlapping ellipsoids. However the reconstruction algorithms were implemented in Matlab for developing reasons.

III. Results

So far the transducer systems have been manufactured, mounted into the container and tested. The design of CB and DBs is finished. The test of these boards is underway. The reconstruction algorithms are ready to use and have been tested in several simulations. We expect first imaging of 3D phantoms to be possible in midsummer 2004.

IV. Discussion

The transfer time between USCT crate and PC takes far too much time. For realtime 3D imaging some kind of data reduction and compression is essential to reduce the amount of transferred data. For clinical acceptance the reconstruction time has to be speed up by several magnitudes. Leaving Matlab and using native coding will improve speed as will optimizing the implementation. Furthermore the use of the processing power of the built–in FPGAs (at Auger–Experiment 9 GOPs/s) for part of the analysis and compression algorithms is under preparation. Additionally data reduction will cause the reconstruction algorithms to process less data hence decreasing reconstruction time.

V. Conclusion

We developed a hardware setup for ultrasound computertomography which is capable of handling very high burst data rates. By modifying an established hardware the USCT crate will be very reliable and cost effective. For the first time it will be possible to record cross sections of living tissue in real time. The presented demonstrator is a major step for making ultrasound computertomography clinically possible.

References

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