Ultrasound Characterisation of Soft and Hard Biological Tissues

Ultrasound computertomography: image reconstruction using local absorption and sound speed profiles

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Introduction: Ultrasound computertomography (USCT) is capable of producing volume images with both high spatial and temporal resolution, if new methods of image reconstruction are applied. It is non-invasive and therefore frequently applicable without harm in contrast to other imaging methods like e.g. X-ray imaging. Additionally in breast cancer screening, the breast is not deformed during examination which simplifies matching with images of other imaging methods.

Experimental setup: The idea of USCT consists of applying ultrasound to an object and of recording every single diffracted signal from it. Several thousand ultrasound transducers are arranged around the object in a cylindrical ultrasound array. We build an experimental setup for cross section imaging consisting of two ultrasound transducer arrays with 16 transducers each, which are relocatable manually on a circular path at 100 different positions [2]. We examined several ultrasound phantoms with this setup [3].

Reconstruction: Several algorithms for image reconstruction are known. Our main algorithm is based on full aperture sum-and-delay [2]. For simplification we assumed a homogeneous sound speed in both the coupling medium and the examined object. Additionally no absorption by the object or transducer properties like angle dependency have been regarded at the first approach. Figure 1 shows the schematic cross section of one of the ultrasound phantoms we examined. It consists of a plastic box with a lid, which is divided into four departments by plastic film. Each department is filled with gelatine, but with different concentration of contrast agent thus leading to different absorptions and sound speeds. Figure 2 shows the reconstructed image of a cross section. The outlines are clearly recognizable, but the separating lines between the departments appear twice and have low contrast. The doubled lines are caused by the assumption of homogeneous sound speed. Because of the local variations of the sound speed due to the involved different material compositions the resulting lines are reconstructed at wrong positions. Additionally the contrast is low due to absorption differences of the ultrasound pulse on its different path lengths in the medium.

Enhanced Reconstruction: The reconstruction algorithm can be improved by the use of local sound speed and absorption maps. We derive these maps with our adapted transmission tomography algorithm. Each A-scan is first auto-correlated, because the wanted signal is very close to the noise level. Then we search for the first peak appearing in the signal, which is assumed to be the transmission peak of the direct line between emitter and receiver. The sound speed between both transducers is then computed from the known distances and the measured travel time. For absorption the strength of the transmission peak is related to the strength of the corresponding measurement with an “empty” test vessel only filled with water. The empty measurements are taken during calibration. After computation of all A-scan sound speeds and absorptions the maps are reconstructed with standard algorithms for tomography, which are modified in respect to our environment [1]. Figure 3 displays the sound speed map of the examined phantom. The resolution of the maps is low, because we measured only 100 emitting positions. Nevertheless they are sufficient for our needs. During reconstruction with full aperture sum-and-delay the correct sound speeds are determined by summing and weighting the pixel values of the sound speed map along the signals travel line. The computation

of the absorption value is similar, but the whole A-scan is multiplied with a correction factor dependent on the determined absorption, thus increasing the signals strength.

Results and Conclusion: We modified our algorithm for full aperture sum-and-delay to use sound speed and absorption maps and reconstructed the cross section of the phantom. The resulting image is displayed in figure 4. The sharpness of the inner structures is increased about 5.9 times where we define sharpness as ration of the peaks height to width at half. The inner structures still appear slightly blurred. This probably is caused by inaccurate transducer locations or accidental displacements during the measurement. The results show that the use of sound speed and absorption maps can significantly increase the quality of images reconstructed with a full aperture sum-and-delay algorithm.

[1] A.C. Kak and M. Slaney, Principles of computerized tomographic imaging, 1999
[2] R. Stotzka, J. Würfel, T.O. Müller and H. Gemmeke, Medical Imaging by Ultrasound-Computertomography, SPIE 2002, Vol. 4687, pp. 110-119
[3] R. Stotzka, T.O. Müller, K. Schlote-Holubek and H. Gemmeke, Ultrasound computer tomography for breast cancer diagnosis, ESEM ESAO 2003, to be published

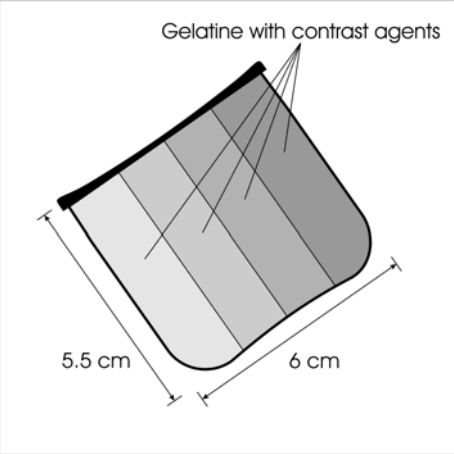

Figure 1. Cross section of the examined ultrasound phantom. It consists of a box with four departments filled with gelatine containing different concentrations of contrast agent.

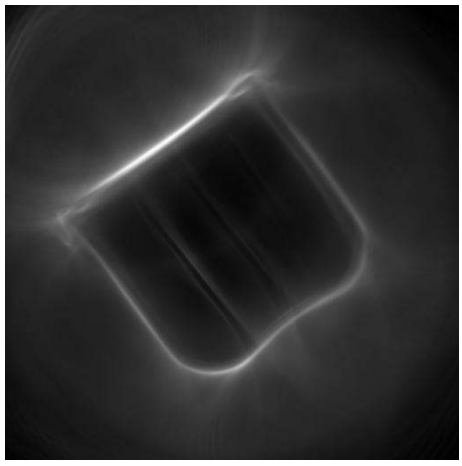

Figure 2. Reconstructed cross section of the phantom. 100 emitting positions with 720 receiving positions each were used for reconstruction. The inner lines appear doubled.

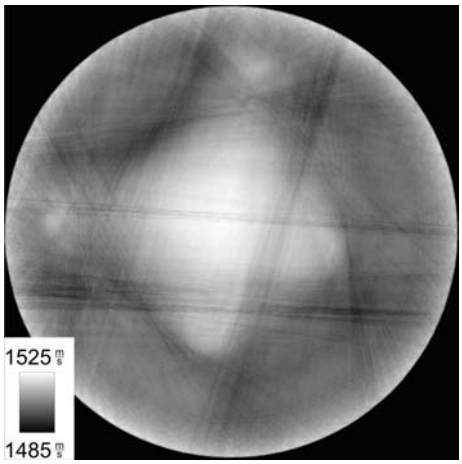

Figure 3. Local sound speeds of the examined phantom. The image was reconstructed using transmission tomography.

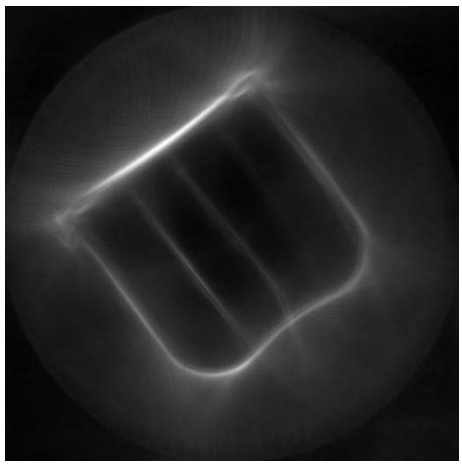

Figure 4. Reconstructed cross section using local sound speeds and absorptions. Contrast and sharpness are increased compared to figure 2. The doubled lines are merged.