INVESTIGATION OF FOCUSING FOR 3D TRANSMISSON TOMOGRAPHY

Pathak PK [1], Jiřík R [1], Jan J [1]
[1] Department of Biomedical Engineering, FEEC, B U T, Brno , Czech Republic
xpatha00@feec.vutbr.cz

Abstract. The paper is focused on reconstruction of images for 3D ultrasonic transmission computer tomography (USCT) as a possible future medical imaging modality, namely for breast cancer diagnosis. In this paper, the author has tried to demonstrate the effect of Focusing in 3D data to improve the estimates of sound-speed and later attenuation maps. Ultrasound sound speed is used as a parameter, which is related to the pathological tissue state. A technique of focusing is presented and root mean square error has been calculated for all the number of combination (sender-receiver). The approach is analyzed on synthetic data sets. The result shows that focusing is highly effective for more noised data.

1 Introduction

Ultrasound transmission computer tomography (USCT) has come as an alternative to standard X-Ray imaging in breast cancer diagnosis [1]. The process of steering and focusing the acoustic pulses is known as beamforming. Focusing limits the useful near field depth, because beam converges rapidly beyond the focal zone. Presently the work has been limited to 2D and up to focusing of receiver elements only and later it can be tested for the sender focusing. The author tried various combinations of focusing on a particular sender and different number of receivers to estimate the optimal number of receiving elements that can give better focusing results for different level of noised data. The aim of work presented here is to improve estimates of sound-speed and later attenuation maps. Presently the trial of algorithm has been tested on synthetic data only. In the present work, author has tried to investigate the effect of focusing on different level of noise in synthetic data. Root mean square error was used as a measure for the comparison of estimated and calculated time of flight (TOF).

2 Methods

2.1 Simulation

The presented ultrasound tomography approach is derived for a three-dimensional (3D) setup, where the imaged object, immersed in a water tank, is enclosed by a cylinder formed by transducers rings. The testing signals were generated virtually for 96 equidistant transducer positions in each sender layer and 192 in each receiver layer. The testing data set was provided by one sender and two receiver layers of the transducer array, which leads to 96 × 192 × 2 sender-receiver combinations giving a total of 36864 equations. The ideal radiofrequency (RF) signals were generated assuming propagation of spherical waves with a constant sound speed (Fig.1). No diffraction and refraction effects were included. At a time, one transducer is always in the emitting mode, while all other transducers record the receiving radiofrequency signals. Then, the next element is emitting and all remaining transducers are recording, and so on until all transducers have been used as emitters [2]. The data was simulated for empty measurement with the sound speed of 1483 m/s and the rectangular bar phantom with a sound speed of 1568 m/s.

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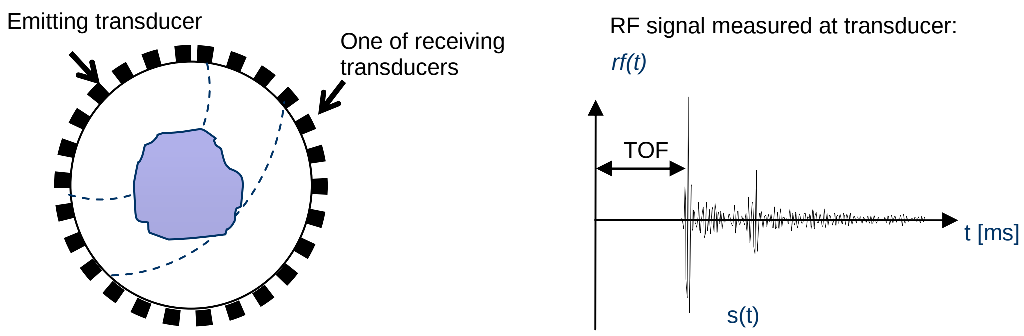

Fig 1.Data acquisition in 3D tomography.

2.2 Sound Speed Reconstruction

Speed of sound have been calculated by taking the distance between the emitter and receiver and dividing it by the estimated time-of-flight of the ultrasonic pulse (eq. 1).

Where the estimated TOF is calculated by the correlation between empty (only water) measurement and measurement with the object inside. Time of flight reconstruction was done by solving a set of equations.

$$t_i = \sum_{j=1}^{N} \frac{d_{ij}}{v_j} \quad , \; \boldsymbol{i} = 1,\ldots..M \tag{1}$$

Where t_i the time of flight for ith combination and j is the pixel number. M is total number of total number of sender-receiver combination and N is the total number of pixels for the particular combination.

$$T = A \times X \tag{2}$$

Where T is the column vector of TOF's ,A is the system matrix with d_{ij} as elements and X is the column vector for inverse of sound speed. After the reconstruction the mean square error was calculated in comparison with the pre-calculated TOF's from the simulation.

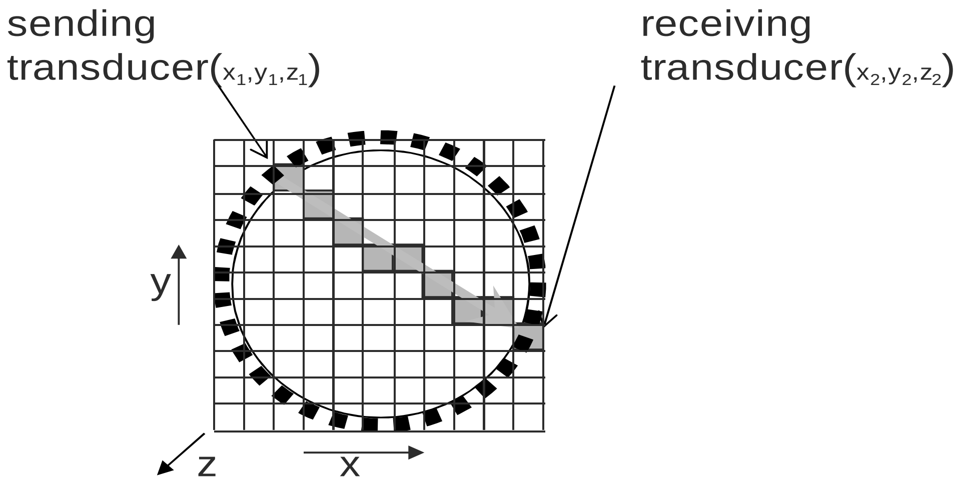

Fig 2. Illustration of Transmitter-Receiver combination.

2.3 Focusing

The focusing of USCT transducer was done by introducing the calculated delay to RF signals on the basis of the geometry of the system and the position of the focus. It is well known fact from the literature that increasing the number of elements for focusing improves the directivity [3], therefore the number of elements used for focusing should be optimal. For the present work the accuracy of the time-of-flight estimation was evaluated as the quality measure of focusing. Presently the trial algorithm is limited to synthetic data with added noise to the RF signals. The synthetic data was prepared using simulation for various values of added noise for rectangular bar phantoms. Focusing was performed on the basis of geometry of ultrasound system for multiple receivers and a single sender. Delay for each transducer combination while assuming the speed of sound remains constant during the flight based on the geometry of the system was calculated. Various delays to the corresponding A-scans were implemented and added. Comparison with the reference signal on the basis of time of flight was made.

3 Results

The present method of focusing was tested on synthetic data. The result shows that, with the increase of noise level in the signal, focusing is more effective, that is when the higher noised data is used the reconstruction gives lower value of root mean square error. The results were compared with pre-calculated TOF from simulation for each combination of transducers on the basis of root mean square error (RMSE). It is clear (fig.3) that the optimum number of transducers used for focusing for 2dB data is 10. The work presented here is only limited to 2D system and can be extended to 3D system.

$$e_{RMS} = \sqrt{\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}\left[T_{ref}(m,n)-\hat{T}(m,n)\right]^2} \qquad (3)$$

Where T_{ref} is the pre-calculated time of flight , T is the estimated time of flight and e_{RMS} is the root mean square error.

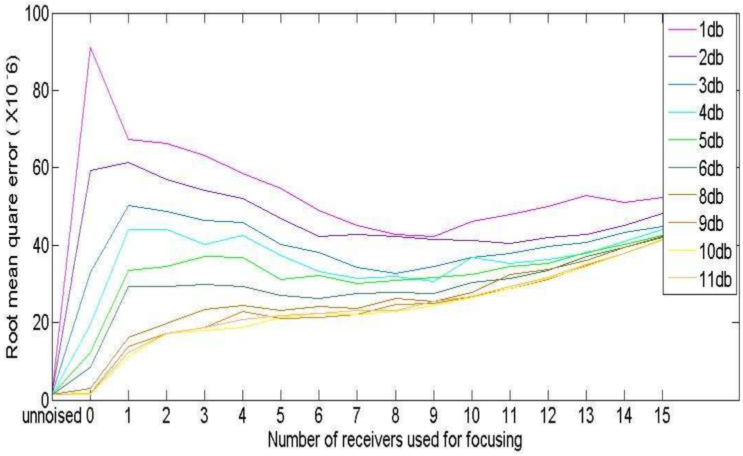

Fig 3. Effect of focusing on different level of noise.

4 Conclusions

The algorithm for focusing has been developed and tested on synthetic data. It has been found that the number of transducers used for focusing may vary with the distance of flight. If the transducer pair are close to each other number of focusing elements are needed and if the transducer pair are farther more number of focusing elements are needed. Author is also trying to investigate the effect of dynamic focusing on the system presented here

References

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