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Development of algebraic reconstruction technique considering curved ray for ultrasound computed tomography with ring array transducer

リング型トランスデューサを用いた超音波CTにおける屈折を考慮した音速再構成法の検討

Hirofumi Nakamura[1†], Hiroki Shimizu[1], Tetsuya Kanagawa[1], Satoshi Tamano[2], Takashi Azuma[1], Kiyoshi Yoshinaka[3], Akira Sasaki[1], Shu Takagi[1], Yoichiro Matsumoto[1] ([1]The Univ. of Tokyo; [2]Hitachi Aloka Medical; [3]Advanced Industrial Science and Technology)

中村弘文 [1†]，清水悠輝 [1]，金川哲也 [1]，玉野聡 [2]，東隆 [1]，葭仲潔 [3]，佐々木明 [1]，高木周 [1]，松本洋一郎 [1]([1] 東京大学, [2] 日立アロカメディカル, [3] 産業技術総合研究所)

1. Introduction

Ultrasound Computed Tomography (UCT) is widely researched as a diagnosis method for breast cancer. Our objective is development of ultrasound diagnosis and treatment integrated system for breast cancer. We think UCT in imaging and High Intensity Focused Ultrasound (HIFU) in therapy was integrated to achieve ideal treatment system. Profiles of sound speed and attenuation obtained by UCT have informative parameters for precise control of HIFU beam. We try to develop an imaging system using ring array transducer with 1024 elements.

Firstly, an iterative Simultaneous Algebraic Reconstruction Technique (SART) reconstruction methods with an assumption of straight path was employed. SART was applied to projection data calculated by a FEM simulator treating actual curved ray caused by tissue inhomogeneity. In these results, error between sound speed differences of estimated value and model was 53%. Then we introduced Linear Travel-time Interpolation (LTI) to SART to implement effects of curved ray. LTI is a ray tracing method based on Fermat's Principle. We are going to evaluate the LTI and SART integrated method for sound-speed tomography. Travel-time for reconstruction was achieved from simulation based on finite difference method.

2. Method

2.1 SART

SART is an iterative reconstruction method. We set an initial model as reconstruction image, and get the projection data. This process is called forward projection. In this process of SART, we assumed that ultraosound transmit along straight line between transmitter and receiver. Comparing the projection data from reconstruciton model and the actual projection data, we caluculated a correction value. It is used for correcting the defference between actual model and reconstrucion model. The correction value is distributed among the pixels on the path of rays.

Thus, reconstruction model is corrected and it gradualy corresponds with actual model if the ray path in forward projection is the same as actual ray path. In X-ray CT, X-ray goes approximately straight in human body. On the other hand, in UCT for women breast, ultrasound will be diffracted or refracted becouse of imhomogeneous distribution of sound property. We investigated the effect of diffraction and refraction for SART based on FEM simulation.

2.2 FEM simulation

To evaluate the effect of curved ray caused by tissues' homogenity, we tried to reconstruct the distribution of sound speed from projection data achieved by FEM simulation. In the simulation, we set the model shown in **Fig.1**. Sound speed in each area were set as **Table.1**. We defined a circle as a ring array transducer with the diameter of 35 mm. 256 sound source points were put along with the circle at regular intervals. A 2 MHz wave is transmitted from one of the source points. Ultrasound propagation is iterated 256 times from all sorce points. The receivers were on the same circle, and acoustic pressures at 256 points were recorded. Thus 256 x 256 projection data were achieved. We reconstructed sound speed from ultrasound arrival time from transmitter to receiver. we extracted travel-time from the acounstic pressures at receivers. Reconstructed image besed on SART is showed in **Fig.2**.

2.3 LTI

To estimate the path of ultrasound, we used ray tracing method. In the research of Li and Muller, this idea is introduced in UCT[3]. LTI is one of the ray tracing methods based on Fermat's principle proposed by Asakawa and kawanaka[4].

This method have two steps. First step is the forward travel-time calculation, and second step is backward ray tracing. In forward step, travel-time for almost all paths are caluculated. The minimum travel-time was recorded at image pixels. In backward step, the path between transmitter and receiver is estimated using travel-time distribution based on Fermat's principle.

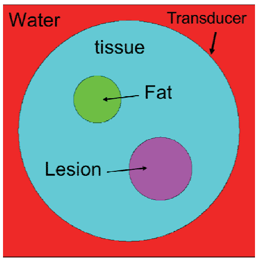

Fig.1 Simulation tissue phantom

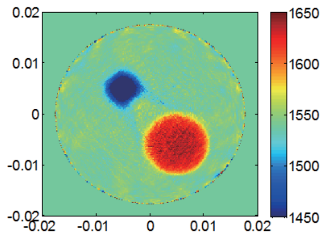

Fig.2 Reconstruction image by SART

	Set ultrasound speed	Reconstructed ultrasound speed	Standard variation
Tissue	1540 m/s	1544 m/s	79
Fat	1420 m/s	1471 m/s	61
Lesion	1650 m/s	1611 m/s	52

Table.1 Evaluation of image reconstruction

3. Result

The projection data from FEM simulation is showed in **Fig.3**. **Fig.4** shows projection data from the same target but with assumumption that the path of ultrasound was straight. Difference between two data was possibly caused by curved ray effect. Arrival time with curved ray was shorter than that with straight ray. According to Fermat's principle, waves transmit the path cost shortest time.

Fig.5 is ray tracing result using LTI method. this model had the same sound speed distribution as Fig.1. This result suggests that curved ray should be taken into consideration. **Fig.6** shows projection data achieved by forward projection with LTI. It is similar shape with Fig.3.

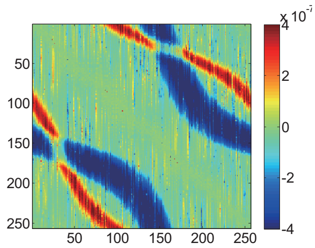

Fig.3 Projection data from FEM simulation

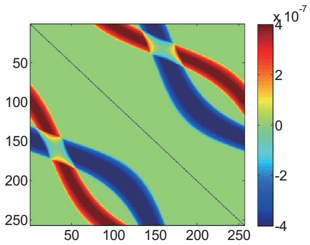

Fig.4 Projection data assumed straight ray

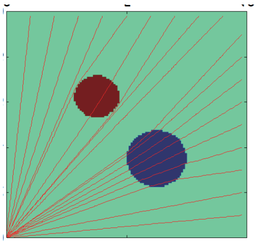
Fig.5 Result of ray tracing

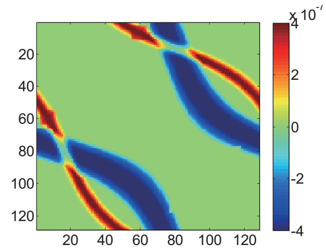

Fig.6 projection data using LTI

4. Experiment

We try to get projection data experimentaly. We made ring array transducer composed of 1024 elements. The transducer is divided into 4 concaved probes with the diameter of 100 mm. These probes are connected to Verasonics programmable imaging system with 256 channels via multiplexer.

The concave probe has 256 elements with the center frequency of 2 MHz. We expect to achieve 1024 x 1024 projection data and these data will be demonstrated in the USE meeting.

5. Summary

In our reseach, we want to reveal the limitation of straight ray assumption reconstruction algorithmm for weakly inhomogeneous tissue as breast. If it is not necessary to consider curved ray, we can save computing cost for reconstruction. We evaluated the effect of curved ray caused by tissues' homogenity by comparing actual projection data and straight ray projection data. Comparing two projection data, travel-time from actual projection data treating curved ray was shorter than one from straight ray projection. The typical error between actual projection data and straight ray projection data is 60 %. This result suggested that SART was not reliable method for UCT because of straight ray asssumption. We achieved a projection data considering curved ray based on LTI method. In this case, the typical error is 83 %.

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References

1. N. Duric: Med. Phys. **34** (2007) 773.
2. C. Kak and M. Slaney: *Principles of Computerized Tomographic Imaging* (1988) p. 275.
3. S. Li and K. Muller: Med. Phys. **37** (2010) 2233.
4. E. Asakawa: Geophysical Prospecting **41** (1993) 99.