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Development of automated abdominal sound speed tomographic imaging system
腹部音速トモグラフィーの自動画像化システムの開発

Toshihiko Yokoyama[†],Daichi Shimizu, and Akira Yamada(Grad.Bio-Appl.Sys. Eng., Tokyo Univ. of A&T)
横山 敏彦[†], 清水 大地, , 山田 晃 (東京農工大 生物シ応用)

1. Introduction

Medical studies have unveiled the visceral or ectopic fat cause adult disease like diabetes mellitus or heart diseases. So the measurement of the fat in daily checkup is expected to serve as preventive medical care of the diseases. The reconstructions of abdominal sound speed images are considered to be effective especially for measuring visceral fat. To this end, new ultrasound tomographic techniques including measurement in the air have been developed. Furthermore, for the practical clinical use, the integrated automatic measurement mechanism has been developing[1]-[4]. In this review, recent development of the automated abdominal sound speed tomographic imaging system is reported. In order to evaluate the performance of the system, reconstructions of phantom image are carried out using an abdominal phantom specimen. And the results show the validity of the proposed automated body surface scanner.

2. Method of Tomographic Imaging

2.1 *Basic principle*

In X-ray computed tomography (CT), the observed X-ray attenuation ratios which are transmitted through body are the projections of X-ray absorption profile of the body. In the case of ultra sound computed tomography (UCT), the travel time differences are the projections of inverse sound speed profile $1/c(x,y)$ of the body. Let T_b is propagation time through body, and T_0 is its background in which sound speed is c_0. Then the time difference ΔT of T_b and T_0 is described by the following straight ray path integration equation.

$$\Delta T = T_b - T_0 = \int_l \left(\frac{1}{c(x,y)} - \frac{1}{c_0} \right) dl \qquad (1)$$

Therefore, the reconstructed image of $1/c(x,y)$ can be created by tomographic calculations with measured ΔT collection.

[†] 50010701392@st.tuat.ac.jp

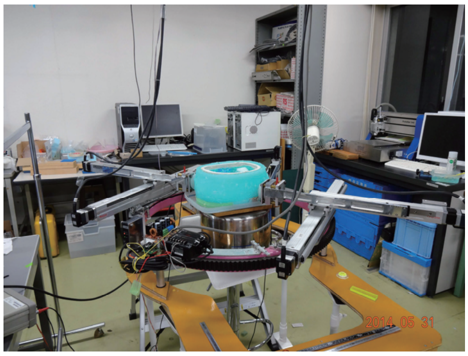

Fig.1.Automated abdominal sound speed tomographic imaging system.

2.2 *Structure of automated abdominal body scanning system*

The automated abdominal body scanning system as shown in Fig.1 has been developing. It consists of a diametrically opposed pair of transducers (the frequency band is 10-500 kHz and aperture diameter 40 mm) and a pulsar/receiver unit for sending and receiving ultrasound waves. Automated actuating machinery for positioning of transducers to a desired points on the body surface. Especially, for the good transmission of ultrasound from transducers to the body in the air, the coupling devices which are made of arum root and 40 mm radius hemisphere are putted in front of each transducers[1]. Transmitter and receiver are mounted on the linear stages for translation action (stroke 600 mm). The laser range sensor (measurement distance: 0.2-1 m, linearity: 1 mm) is prepared for the measurement of body surface contour. All units are mounted on a rotation ring stage (diameter 720 mm). These actuators are operated simultaneously by sending commands from the main personal computer.

2.3 *Measurement procedure*

The body contour data which is measured by laser range sensor is used for estimation of the spine position and calculations of the sound propagation paths (i.e. positioning of transducers on the body surface). By rotating transducers around body and contacting them against body surface, the time difference *ΔTs* can be measured. All measurement were done automatically.

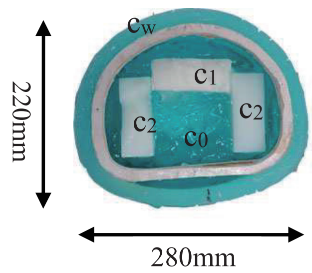

Fig.2 Phantom specimen used in the experiment

3. Test Expriment

3.1 *Phantom specimen*

Measurement of reconstruction using an abdominal phantom specimen (Fig.2). A tissue-mimicking wall container (OST Inc., 280 x 220 mm, c_w=1540 m/s) was prepared. As a background medium, ultrasound gel with sound speed c_0=1500 m/s was filled. In the interior region, assuming a high sound speed abdominal muscle region and low sound speed visceral fat region, polyethylene glycol object (100 x 40 mm) with sound speed c_2=1580 m/s, low sound speed lard object (100 × 40 ×75 mm) with c_1=1470 m/s were located.

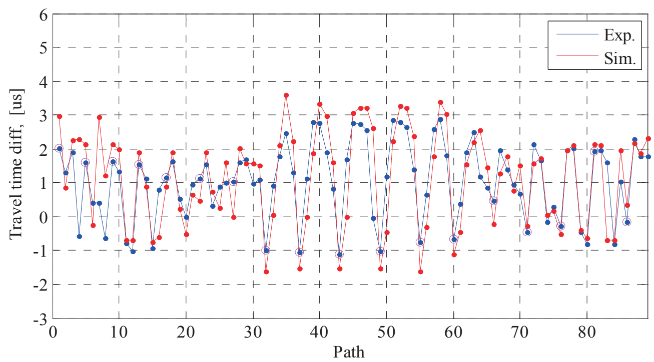

Fig.3 Propagation time for each paths: blue line shows experimental time data and red line shows simulated time data.

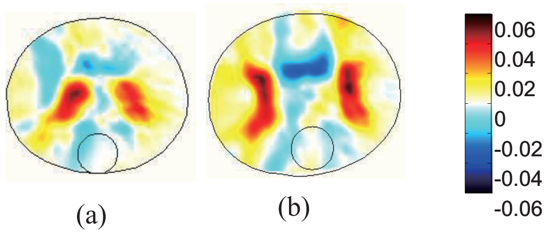

Fig.4 Reconstructed image of phantom specimen: (a) Experiment (b) simulation

3.2 *Propagation time measurement*

The propagation time differences *ΔT* defined by formula (1) are measured for 87 propagation paths. Fig.3 shows the comparison between experimental data (the blue solid line) and simulated data (the red solid line). These two lines are in good agreement except a few points. So we can say that present automated system works fine as our expectation. And, at the same time, we need to more improvement in achieving the positioning accuracy.

3.2 *Sound Speed Image reconstruction*

By using propagation time data, the reconstructions of inverse sound profile of the phantom were carried out. Fig.4 shows the result of the calculations and the comparison between (a) experimental and (b) simulated images. In comparing these images to original image (Fig.2), the simulation image is good accordance with the original image. On the other hand, the experimental image is rather insufficient especially in fat area. We are considering the reason of this as follows. The propagation time difference ΔT_{fat} through 40mm fat is small at ΔT_{fat}= 0.04 (1/1470 -1/1500) = 0.5μs. To this, from another measurement, we found the mechanical measurement error was around 0.5 μs. Thus mechanical error is almost same as propagation time difference of 40mm fat area. This estimation supposed the room temperature 25 °C. The propagation time difference will be increased in human body temperature at 36°C. Therefore we are expecting the reconstructed image will be improved in actual human body.

4.Conclusion

Although, there still exist some improvement in precision, it was demonstrated that high precision travel time measurement and sound speed image reconstruction can be achieved by using developed automated body scanner machinery.

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