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Image Reconstruction of Biological Soft Tissues by Diffraction Tomography
回折トモグラフィによる生体軟組織の画像再構成の基礎研究

Tetsuya Kanagawa[1†‡], Hirofumi Nakamura, Ryosuke Aoyagi[1], Takashi Azuma[1], Kiyoshi Yoshinaka[2], Akira Sasaki[1], Kazuyasu Sugiyama[1], Shu Takagi[1], and Yoichiro Matsumoto[1] ([1]Dept. Mech. Eng., Univ. Tokyo; [2]AIST)
金川 哲也 [1†], 中村 弘文 [1], 青柳 良佑 [1], 東 隆 [1], 葭仲 潔 [2], 佐々木 明 [1], 杉山 和靖 [1], 高木 周 [1], 松本 洋一郎 [1] ([1] 東大工, [2] 産総研)

1. Introduction

Ultrasound diffraction tomography (USCT) has been intensively employed in many industial fields such as medical diagnosis and non-destructive detection, as an important alternative to the straight ray tomography. In the field of diagnosis for biological tissues, USCT has expected to detect cancer in tissues, especially on the soft tissue such as breast, liver, and so on. It is effective for the case of soft tissues compared with the detection method by the X-ray mammography, because the difference among the sizes of sound speed in each soft tissue is relatively small compared with that in each hard tissue.

Recently, the breast cancer is one of the most important problems, which requires less invasive diagnosis and treatment as much as possible from the viewpoint of not only medicine but also beauty. The breast cancer is critical for woman, and hence the breast cancer detector breast is now developed. Many studies have thereby been carried out [1-8]. On the other hand, High intensity focused ultrasound (HIFU) has developed as a tool of less invasive cancer treatment and may replace surgery.

Our group proposes the combination of HIFU and USCT system toward an establishment of accurate and safe breast cancer therapy. The real-time monitoring during HIFU exposure enables us to depict the sound field, especially focusing on temperture field. The prediction of temperture rise leads to control HIFU exposure for destruction of cancer without damages of surrounding tissues.

In the present paper, we conduct the numerical analysis on the sound field of a simplified breast model, and depict the inhomogeneous profile of sound speed. Figure 2 shows a recent report by Li *et al.* [6] that illustrated the inhomogeneous profiles of reflection, sound speed, attenuation, and fusion for breast cancer model [5]. Furthermore, the framework of the method to estimate these inhomogeneous profiles based on inhomogeneous Helmholtz equation with the Born approximation [1,3,7] are introduced.

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[1]kanagawa@fel.t.u-tokyo.ac.jp

2. Preliminary computation

We computed the sound field of a simplified breast model composed of fat, lesion, and tissue, with ring transducer (see, Fig.1). The calculation was performed by commercial software PZFLEX. The image reconstruction was performed by an inverse Radon transform modified for the case of beams.

As a result, the wave profile is shown in Fig.2, where the longitudinal and transverse axes represent the channel number of the receiver and the position, respectively. Figure 3 provides the result of image reconstruction of the sound speed. The difference between maximum and minimum values of sound speed is about 0.4 m/s, which implies small accuracy of computation.

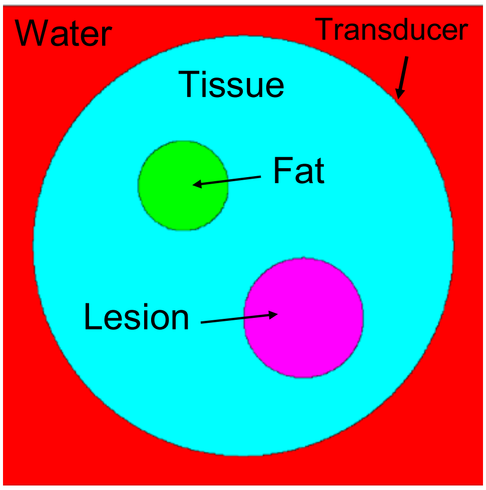

Fig. 1 Computational domain: frequency is 2 MHz; the sound speed in water, tissue, fat, and lesion, are, 1,540 m/s, 1,540m/s, 1,420 m/s, and 1,650 m/s, respectively; the number of elements is 256, the diameter of transducer is 35 mm. Grid resolution is given by the ratio of each wavelength by 10.

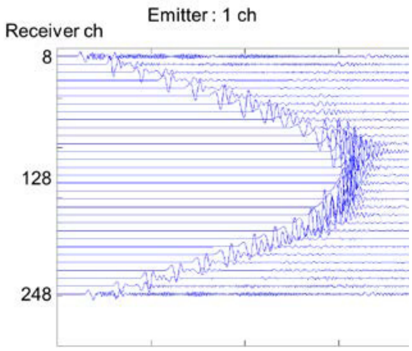

Fig. 2 The result of wave profiles. The longitudinal and transverse axes represent the channel number of the receiver and the position, respectively.

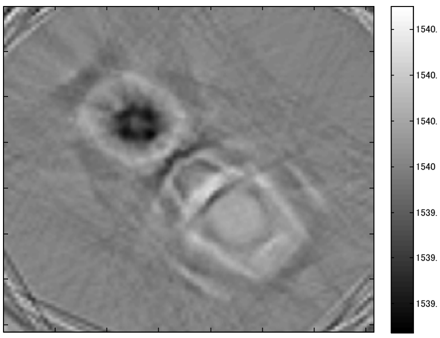

Fig. 3 The result of image reconstruction of sound speed is shown. The difference between maximum and minimum values of sound speed is about 0.4 m/s.

3. Prediction by scattering theory

Our particular interest is the strongly inhomonegeous soft tissue composed of muscle, skin, fat, and so on. Here, we briefly introduce the methodology of scattering theory. As in many previous studies [1,3,7], we solve the inhomogeneous wave equation under assumption of harmonic oscillations with respect to time, i.e., the inhomogeneous Helmholtz equation:

$$[\nabla^2 + k(\boldsymbol{r})]f(\boldsymbol{r}) = 0, \quad (1)$$

with the complex wave-number k,

$$k(\boldsymbol{r}) = \omega / c(\boldsymbol{r}) + i\alpha(\boldsymbol{x}),$$

where $\boldsymbol{r} = (x, y)$ is the spatial coordinate, noting that the distance from transducer, z, is specified; f is the Fourier transform of acoustic pressure; ω is the frequency; c and α are the inhomogeneous sound speed and attenuation coefficient, respectively; and i is the imaginary unit.

By the use of the Born approximation [1,3], we decompose the total field f into

$$f \simeq f_0 + f_1, \quad (2)$$

where f_0 and f_1 are the incident field and a small perturbation due to weak scattering, respectively. Substitution of Eq. (2) into Eq. (1) yields the inhomogeneous pressure field.

4. Conclusion

We have numerically investigated the sound field of simplified model of breast during HIFU exposure. The preliminary result is not accurate. More precise formulation and computation for profiles of sound speed and attenuation through calculating sound and temperature fields based on the scattering theory briefly introduced in Section 3 are underway.

The detailed results, especially focusing on the inhomogeneous distributions of sound speed and attenuation, will appear in the presentation. Furthermore, we will clarify various relations between transducer specification (e.g., the number of elements, directivity, frequency), and sensitivity of detection, toward design for effective development of equipment.

Acknowledgements

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References

1. R. K. Mueller, M. Kaveh and G. Wade: *Proc. IEEE* **67** (1979) 567.
2. P. Carson, C. Meyer, A. Scherzinger, and T. Oughton: *Science* **214** (1981) 1141.
3. A. C. Kak and M. Slaney: *Principles of Computerized Tomographic Imaging* (IEEE Press, New York, 1988) Chap. 6.
4. M. Andre, H. S. Janee, P. J. Martin, G. P. Otto, B. A. Spivey, and D. A. Palmer: *Int. J. Imaging Syst. Technol.* 8 (1997) 137.
5. N. Duric, P. littrup, L. Poulo, A. Babkin, R. Pevzner, E. Holsapple, O. Rama, and C. Glide: *Med. Phys.* **34** (2007) 773.
6. C. Li, N. Duric, P. Littrup and L. Huang: *Ultrasound in Med. & Biol.* **35** (2009) 1615.
7. P. Huthwaite and F. Simonetti: *J. Acoust. Soc. Am.* **130** (2011) 1721.
8. J. Wiskin, D. T. Borup, S. A. Johnson, and M. Berggren: *J. Acoust. Soc. Am.* **131** (2012) 3802.