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EVALUATION AND APPLICATION OF LARGE-SCALE ULTRASOUND PROPAGATION SIMULATION IN HETEROGENEOUS MEDIA

*** Yoshiaki Tamura[1], Yusuke Nakajima[2], Junko Uebayashi[3] and Yoichiro Matsumoto[4]**

[1] Toyo University
Kujirai 2100, Kawagoe,
Saitama, 350-8585 Japan
tamtam@eng.toyo.ac.jp

[2] Toyo University
Kujirai 2100, Kawagoe,
Saitama, 350-8585 Japan
yusuke@cse.eng.toyo.ac.jp

[3] Toyo University
Kujirai 2100, Kawagoe,
Saitama, 350-8585 Japan
ts0400518@toyonet.toyo.ac.jp

[4] University of Tokyo
Hongo 7-3-1, Bunkyo-ku,
Tokyo, 113-8656 Japan
ymats@mech.t.u-tokyo.ac.jp

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ABSTRACT

The focused ultrasound wave attracts attention in the medical field in various applications such as High Intensity Focused Ultrasound (HIFU). Amount of sound energy is generated by focused ultrasound in the body of narrow area. Present HIFU treatment cannot be applied to the part surrounded by bones, such as brain, because focal point is changed by refraction and reflection of ultrasound. The present authors had developed a code for the simulations of focused ultrasound propagation, compared the computed results with experiments and extended it to fit CT scan data[1]. In the present research, accuracy and validity of the present code are verified with several test computations and the applications to real configuration are performed on very large grid system.

A governing equation is derived as

$$\frac{\partial^2 p}{\partial t^2} = c^2 \left[\rho \frac{\partial}{\partial x} \left(\frac{1}{\rho} \frac{\partial p}{\partial x} \right) + \rho \frac{\partial}{\partial y} \left(\frac{1}{\rho} \frac{\partial p}{\partial y} \right) + \rho \frac{\partial}{\partial z} \left(\frac{1}{\rho} \frac{\partial p}{\partial z} \right) \right] \tag{1}$$

where $p(\vec{r}, t)$ is acoustic pressure field (scalar), t is time, $\rho(\vec{r})$ is the density, $c(\vec{r})$ is the speed of sound and $\vec{r} = (x, y, z)$ is the position vector. Properties of media are given from CT scan data[2] (Fig.1). Equation (1) is discretized with finite difference method of 2nd- or 4th-order accuracy in time and space. With the above method, various computations, from simple two-dimensional test problems to very large-scale practical simulations are performed. Only two results are shown here.

The first one is a simple reflection and refraction problem in two-dimensional space. Flat ultrasound waves are generated, reflected and refracted at the interface of two media (Fig.2). Reflection and refraction angles are examined and compared with theoretical values. The second are practical simulations

Figure 1: Properties of media: 3D CT data (left); a slice of skull (middle); porosity of the slice (right)

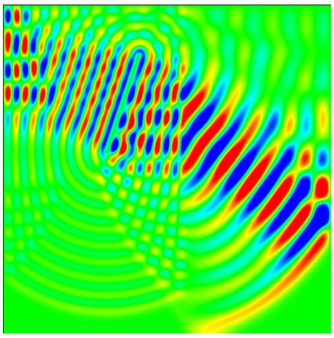

Figure 2: Simple test problem of reflection and refraction at the interface of different media

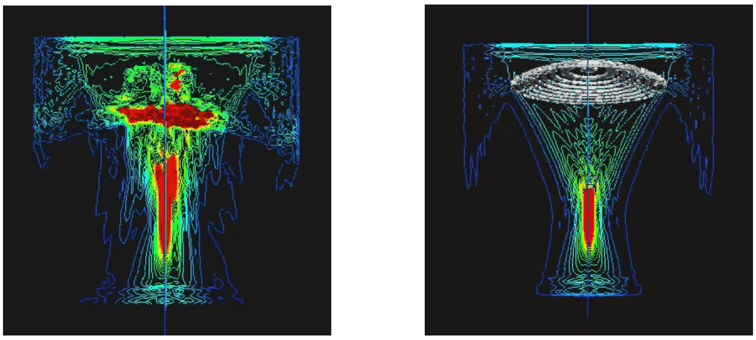

Figure 3: 500^3 grid points simulation of focused ultrasound: with (left) and without (right) skull bone

of focused ultrasound with and without skull bone (Fig.3). The effect of skull bone is clearly observed. Detailed explanation of the present method and results will be included in the final paper.

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