Toward the Integrated Simulation of Living Matter Using the Next-Generation Supercomputer

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Abstract

The next generation supercomputer of 10 Peta flops speed is now under development as a national project in Japan. Not only the hardware development but also the software development is highly expected and the software development for the human body simulator is assigned as a grand challenge program to show the excellent performance of the super-computer. In this program, the multiscale and multi-physics natures of the living matter are emphasized. Under this concept, we are developing the simulation tools for organ and body scales with the continuum mechanical approach.

Our basic strategy is utilization of the numerical simulations for the prediction of diseases and planning the therapy suitable for the characteristics of each individual; the next-generation tailor-made medical treatment, using the medical image data of individual human bodies taken by MRI, CT, Ultrasound, etc.

One example of constructed human voxel data is shown in Fig.1. These data are used for the development of software and the developed software is expected to be used at many hospitals in the future. The mechanical simulations are being performed to predict the dynamic behaviors of organs, blood flows, muscle-skeleton system, etc. The most well-known approach for solving mechanical problems using patient specific human body data is finite element method, since the numerical solvers for solid materials are well-developed. However, finite element method usually requires mesh generation procedure, which is not always easy in the case of complicated shape materials like human organs. In this study, to avoid this mesh generation procedure, we develop the fully Eulerian approach to solve both fluid and solid problems. In general, fluid phase is easy to handle with the Eulerian representation but not for solid phase. We introduce the advection equations of, so-called, Left Cauchy-Green deformation tensor to capture the large deformation of solid phase of hyperelastic materials. One of the simulation examples using the developed method is shown in Fig.2. The result is compared with those by Zhao et al.[1]. Qualitatively good agreement is achieved on both the shape and trajectory of the elastic material. We also made some other validations using this method. These results will be presented.

Some of other simulation tools such as ultrasound therapy simulator and immersed boundary method for blood cell are also presented.

Bibliography

(1) Zhao, H., Freund, J.B. and Moser, R.D., "A fixed-mesh methods for incompressible flow-structure systems with finite solid deformation," *J. Comput. Phys.*, **227**, (2008), pp.3114-3140.

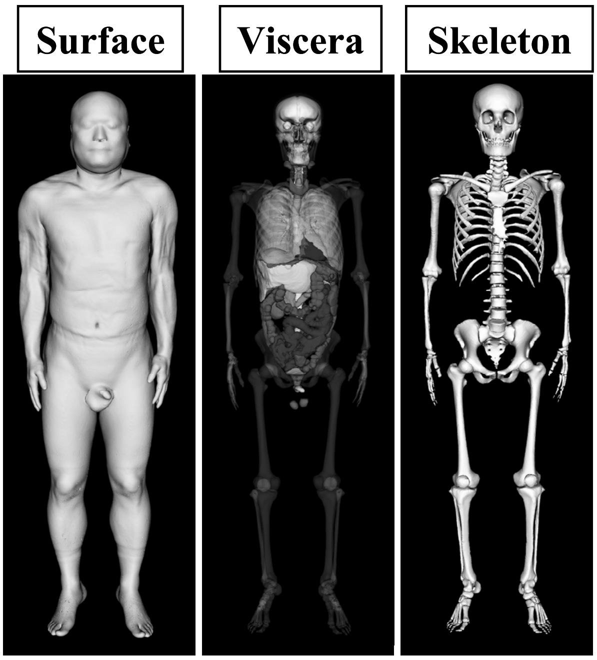

Fig.1 Example of Constructed Human VOXEL Data

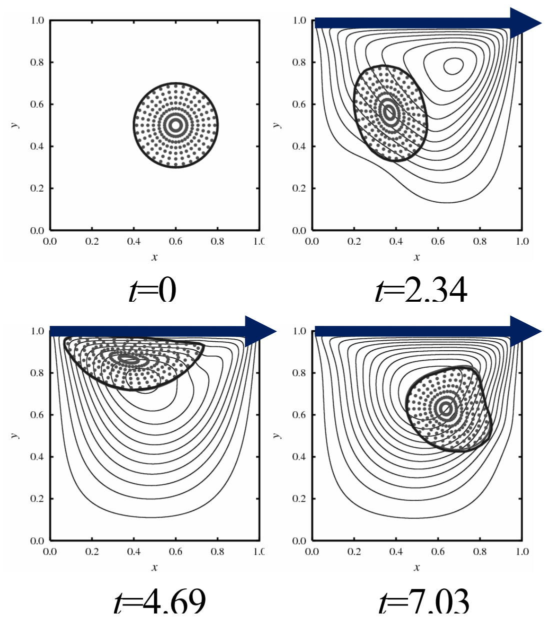

Fig.2 Examples of Full Eulerian Simulation for Fluid-Structure Interaction Problems.