11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Large-scale Full-wave Simulation using Numerical Human Models in HPCI

Amane Takei[1], Kouhei Murotani[2], Shin-ichiro Sugimoto[3],

Masao Ogino[4] and Hiroshi Kawai[3]

[1] Tomakomai National College of Technology, 443 Nishikioka, Tomakomai, Hokkaido, Japan,
takei@el.tomakomai-ct.ac.jp
[2] The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan
[3] Tokyo University of Science, Suwa, 5000-1 Toyohira, Chino-shi, Nagano, Japan
[4] Nagoya University, Furo-cho Chikusa-ku, Nagoya, Japan

Key Words: *full-wave analysis, finite element method, hierarchical domain decomposition method, numerical human model.*

Recently, medical equipment using electromagnetic fields including hyperthermia is spreading. During treatment, it is effective to focus the electromagnetic field onto the lesions inside the human body. The purpose of this research is to accurately calculate the electromagnetic field inside the human body using a numerical electromagnetic analysis method. The numerical human body model database has been released free-of-charge for researchers by NICT [1]. This database is constructed using voxels that have 2 mm edge length. The numerical human model is multi-material including skin, blood vessels, bones, internal organs etc. The adult male model is named "TARO", and has 44 million voxels. Over 200 million tetrahedral elements are generated from the voxel data. In general, numerical analysis using ordinary finite element codes is difficult to apply to such a numerical human model because of the very large size of the mesh. However, by using parallelization techniques based on the iterative domain decomposition method (IDDM) we were able to perform large-scale finite element full-wave analyses for electromagnetic fields [2]. In this paper, we apply our parallel finite element code based on IDDM to the calculation of full-wave electromagnetic fields. We report analyses of the numerical human body models with more than 200 million complex DOF by using a High Performance Computing Infrastructure (HPCI).
The electromagnetic fields in the human body is analyzed by numerical human models. All computations are performed using 320-cores (20-nodes) of the Fujitsu FX10 supercomputer in Kyushu University [3]. We analyzed frequencies of 1 (MHz), 8 (MHz), 70 (MHz) and 300 (MHz) using the full-wave electromagnetic field analysis based on the IDDM. The electromagnetic field source is a dipole antenna assumed to have a current source of 0.8 (A). The antenna is put on above 6 (cm) above the surface of the breast. The Antenna length is 50 (cm), which is same as half wavelength at 300 (MHz). The full-wave electromagnetic analyses are done for four types of model “a” and “b”. The calculation time and the average memory requirements for each frequency are shown in Table I. Tables II and III show strong scaling results for the calculation of 100 time step of the IDDM loop on the FX10. The measured speedups when increasing the number of cores from 320 to 5120 are 5.405 and 6.014, respectively, while the ideal speed-up is 16.0. These results need to be further improved.

TABLE I

CALCULATION TIMES AND AVERAGE MEMORY REQUIREMENTS

Model	Complex DOFs	Memory size / core (GByte)	Num. of Core	Frequency (MHz)	Iteration counts	Calcula-tion time (hour)
A	27.21 M	20	320	1	2,875	2.7
				8	1,641	1.4
				70	2,199	1.9
				300	9,684	8.5
B	220 M	120	320	1	9,028	34.7
				8	4,817	18.7
				70	7,411	28.6
				300	18,306	70.4

TABLE II

STRONG SCALING OF THE MESH (MODEL A)

Num. of parts	IDDM loop (sec)	Speed up	Ideal speed up
320	227	1.000	1
640	144	1.576	2
1280	102	2.225	4
2560	66	3.439	8
5120	42	5.405	16

TABLE III

STRONG SCALING OF THE MESH (MODEL A)

Num. of parts	IDDM loop (sec)	Speed up	Ideal speed up
320	227	1.000	1
640	144	1.576	2
1280	102	2.225	4
2560	66	3.439	8
5120	42	5.405	16

REFERENCES

[1] NICT EMC Group Home Page: http://emc.nict.go.jp/bio/index.html

[2] A. Takei, S. Sugimoto, M. Ogino, S. Yoshimura and H. Kanayama, "Full Wave Analyses of Electromagnetic Fields with an Iterative Domain Decomposition Method," *IEEE Trans. on Magn.*, Vol. **46**, No. 8, pp. 2860-2863, 2010.

[3] Kyushu University, Research Institute for Information Technology Home Page: http://www.cc.kyushu-u.ac.jp/index-e.html