Project Title: Numerical simulation of electomagnetic wave propagation in human body and its application

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1. Background and purpose of the project, relationship of the project with other projects

The neuro-stimulation is performed in various scenarios for a wide range of the illness treatment. One of the examples include the deep brain stimulation. Illness related to the brain such as Parkinson's disease, depression, Altzheimers' illness can be treated by the deep brain stimulation. However, the treatment is severely invasive. In our research group, we are trying to develop a system which can stimulate a part of the brain non-invasively. This may be realized by sending the electomagnetic signals from multiple locations on the skull and focusing the energy inside the brain. However, in order to develop a system, we need to understand the suitable frequency range, location of the excitations and so on. Since we cannot try out such experiments on humans, we have to perform the numerical simulations with digital human phantom. The human tissues can be very small and in order to obtain an appropriate accuracy, we need to have a very fine mesh for modelling human. One of the most appropriate numerical methods for this type of problems is the finite difference time domain method. It is the time domain solution of the Maxwell's equations. However, given the small spatial sampling, the stability condition forces the time step to be unreasonably small. In the end, the explicit FDTD method can take quite long time. On the other hand, implicit schemes can take a larger temporal step. We are working on the improvement of the speed and accuracy of the FDTD method from many aspects such as boundary conditions, subgridding, subcell method, usage of SSE instruction, OpenMP,MPI and GPU acceleration. Since we have to handle a human in a very small spatial resolution, we need a big computational facility for activities such as algorithm development, accuracy assessment and real numerical experiments for clinicians.

2. Specific usage status of the system and calculation method

We have used HOKUSAI system this whole year, mainly at the beginning of the year because we quickly used up our allocated resources and we had to reduce our usage so that we do not exceed the limit. Calculation method is the finite difference time domain method and its radar application of the time reversal algorithms for localisation and tracking of the targets behind the walls and the cancers in the human body. Since the finite difference time domain method is the memory and CPU hungry method, we are developing new algorithms and new computational methods. Regarding the new algorithms, we are currently working on the uncertainty of the complex permittivity of human tissues depending on the patients and tracking of humans behing the wall as well. Furthermore we applied our skills in handling the digital human phantom to the 3-way classification of the medical images of the brain into the Normal condition (healthy brain), Alzheimers' disease and the intermediate stage called MCI. 3-way classification for 3D data involved too many hyper-parameters for the Convolutional Neural Network and deep learning and during the optimization of the hyper-parameters we were reaching the upper limit of resources allocated. At that stage our accracy of classification was 80 percent. Therefore we were not able to publish our work.

3. Result

After the graduation of 4 PhD students last fiscal year we were lack of man-power. Still we have managed to publish 2 journal papers, one on the FDTD and one on the uncertainty quantification of the FDTD method. However both journal papers are published in a prestigious journal of IEEE Transaction on Antennas and Propagation.

4. Conclusion

Once we started the work on the machine learning our productivity of the journal publication has become slower whilst we need a good amount of computational resources. On the other hand we faced the real problems associated with the machine learning at the expense of the computational resources in HOKUSAI. We deeply appreciate your help to enable us to do this. In this fiscal year 3 new PhD students has joined my research group and they are all in the learning mode, not a productive mode. So I hope we improve our productivity next fiscal year with the improvement/brushing up of the new students' research skills and computational skills.

5. Schedule and prospect for the future

We continue our FDTD work and on top of it we shall increase our activities in machine learning in medical imaging.

Fiscal Year 2018 List of Publications Resulting from the Use of the supercomputer

[Paper accepted by a journal]

R. Hu, V. Monebhurrun, R. Himeno, H. Yokota, F. Costen,
" An adaptive least angle regression method for uncertainty quantification in FDTD computation ",
IEEE Transaction on Antennas and Propagation, Vol. 66 , pp. 7188 - 7197, 2018

B. Abdulkareem, J.-P. Berenger, F. Costen, R. Himeno, H. Yokota,
" An Operator Absorbing Boundary Condition for the Absorption of Electromagnetic Waves in Dispersive Media ",
IEEE Transaction on Antennas and Propagation, Vol. 66 , pp. 2147 - 2150, 2018