

Project Title:

Numerical simulation of electromagnetic wave propagation in human body and its application

Name: Fumie Costen

Laboratory at RIKEN: Image processing research team, center for advanced photonics

Description of the project

1. Background and purpose of the project

The neuro-stimulation is performed in various scenarios and cases 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, Alzheimers' 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 electromagnetic 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 an experiment on humans, we have to perform the numerical simulations with digital human phantom. The human tissues are 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 condition, 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 greatwave system this whole year. 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 subcell methods and subgridding methods in order to reduce the total FDTD cell number without significant reduction in accuracy and also the efficient boundary condition as well as implicit schemes and filtered FDTD schemes. Regarding the computational method, we use OpenMP, MPI and GPU for the speed up.

3. Result

Whilst we did not have any publications last fiscal year, during this year we have published 1 full journal letter and 2 journal letters, all in IEEE Transaction on Antennas and Propagation, the most prestigious journal in this research field. It is expected that we shall be able to publish another 3 journal publication (2 full journal papers and 1 journal letter) again at the top journal in the next coming fiscal year.

Usage Report for Fiscal Year 2016

4. Conclusion

This year was very productive and we deeply appreciate your help. However, in many occasions, we were not able to run jobs due to the restriction of the CPU time per job. We would like to get your help on this aspect in the next year. We deeply apologise that our usage exceeded the limit and thank you for your general permission for the extra hours for computation during the second half of the year.

5. Schedule and prospect for the future

Next year we are going to continue working on the same topics, applying OpenMP, MPI and GPU. The usage of the GPU will be increased as one of our target is to publish journal papers on GPU+FDTD+MPI.

Usage Report for Fiscal Year 2016

Fiscal Year 2016 List of Publications Resulting from the Use of the supercomputer

[Publication]

K. Tekbas, F. Costen, J.-P. Berenger, R. Himeno, H. Yokota,

" Subcell Modelling of Frequency Dependent Thin Layers in the FDTD Method ,

IEEE Transaction on Antennas and Propagation, Vol. 65, pp. 278-286, 2017

A. Abduljabbar, M. Yavuz, F. Costen, R. Himeno, H. Yokota,

" Frequency Dispersion Compensation Through Variable Window Utilization in Time Reversal Techniques for Electromagnetic Waves ,

IEEE Transaction on Antennas and Propagation, Vol. 64, pp. 3636-3639, 2016

B. Abdulkareem, J.-P. Berenger, F. Costen, R. Himeno, H. Yokota,

" Huygens Excitation in Debye Media in the FDTD Method ,

IEEE Transaction on Antennas and Propagation, Vol. 64, pp. 3632-3635, 2016