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

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Description of the project

1. Background and purpose of the project

The neuro-stimulation is performed in various scenario 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, 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 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 uncertainty of the complex permittivity of human tissues depending on the patients and tracking of humans behing the wall . As 4 PhD students has graduated within this academic year most of the work is carroed out by new PhD students who do not have any good experience in MPI. Regarding the computational method, therefore, we use OpenMP for the speed up.

3. Result

During this year we have published 2 full journal papers, all in IEEE Transaction on Antennas and Propagation, the most prestigeous journal in this research field. It is expected that we shall be able to publish another 2 journal publication again at the top journal in the next coming fiscal year.

4. Conclusion

This year was very productive and we deeply appreciate your help. We sincerely appologise that our usage exceeded the limit of the shared memory architecture. As the new PhD students do not have any skills around MPI we used the shared memory architecture as oenMP was easy to implement. We are currently seeking of any possibilities to quickly change our code from openMP to MPI. If you have any idea on this issue we would be extremely grateful.

5. Schedule and prospect for the future

Next year we are going to continue working on the same topics, applying OpenMP, MPI and possibly GPU.

Fiscal Year 2017 List of Publications Resulting from the Use of the supercomputer

[Publication]

V. Odedo, M. Yavuz, F. Costen, R. Himeno, H. Yokota,
" Time Reversal Technique based on Spatio-Temporal Windows for Through the Wall Imaging ",
IEEE Transaction on Antennas and Propagation, Vol. 65, pp. 3065‐3072, 2017

A. Abduljabbar, M. Yavuz, F. Costen, R. Himeno, H. Yokota,
" Continuous Wavelet Transform Based Frequency Dispersion Compensation Method for Electromagnetic Time-Reversal Imaging ",
IEEE Transaction on Antennas and Propagation, Vol. 65, pp. 1321‐1329, 2017