Usage Report for Fiscal Year 2022

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 such 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 the system some of the time this year. However we have lost an access to the world for several months now. We had moved into a new building and the new building does not allow us to access the computers outside the university. This means we even can not visit bbc.co.uk. This affects many academics in our university but the University IT team is slow trying to solve the issues. In this coming year we are not sure when we re-gain the access to the world.

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. Result

During this fiscal year we are expecting one journal papers. The manuscripts were published at the prestigious journals of IEEE Antennas and Propagation Magazine. However this might be published in the next fiscal year.

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. Furthermore we ideally require GPU resources free of charge. As this year's possible outcome is the production from a year before we need to think of the research content and control students in this coming year in order to have fruitful outcome at the end of the next coming year.

5. Schedule and prospect for the future

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

We expect to have one or two more new PhD students in my research group . So our usage of computational resources might increase. However this all depends on the accessibility to the world and the possibility to use GPU free of charge.

6. If no job was executed, specify the reason.

Fiscal Year 2022 List of Publications Resulting from the Use of the supercomputer

- Journal publication
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- R. Hu, V. Monebhurrun, R. Himeno, H. Yokota, F. Costen,
  " Uncertainty analysis on computational electromagnetics with artificial neural network ",
  IEEE Antennas and Propagation Magazine, 2023 (Not clear on the publication date yet as it is not published)