Application: NSF PI Meeting: The Science of Cloud Computing

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Topics Interested: Cloud Security, Privacy, and Auditing, Green Clouds, and Cloud Test-Beds

Current Research Activities Related to the Cloud:

My research area is in the interface between computer science and biomedical engineering with a special focus on designing and developing efficient and effective algorithmic solutions to mathematical problems from radiosurgery and interventional radiology.

As radiosurgery becomes more complex, its computing needs are also more resource intensive. In a recent study by Massachusetts General Hospital, it was reported that 100 CPU hours were needed for evaluating a proton radiosurgery plan even without an estimate of secondary cancer risks to organs a little bit farther away from the targeted tumor. Such lengthy computation is unacceptable for daily clinical uses. As a result, commercial treatment planning systems have to cut corners and trade accuracy for speed.

At the 2009 Presidential Symposium of the American Association of Physicists in Medicine (AAPM), Dr. Ian Foster gave the keynote about the need for high performance computing level resources by medical applications. This was also reflected in our own literature search and discussions with our collaborators (including UCSF Radiation Oncology and Stanford Linear Accelerator Center), and engineers from medical industry (including Elekta Corporation and Prowess/Siemens Inc). However, the infrastructure investment and operating expenses are prohibitively high for in-house HPC clusters. We believe the cloud computing model is an ideal solution. The on-demand computing cluster is appropriate for bursty usage modes (such as in clinics), while the pay-as-you-go pricing model is economically attractive.

We are developing a paradigm for deploying resource intensive, independent computations that typically occur in radiotherapy, making accurate, full Monte Carlo simulations feasible for daily clinical use. The general data flow of the new paradigm is: 1) Hospital client uploads calculation parameters to online storage and notifies the master node(s) in the cloud. 2) The master requests a virtual cluster and distributes the input. 3) Once the dose calculations are completed, the master collects the result and returns it to the client. Patient data privacy will be maintained by stripping planning data of all identifying metadata, assigning a hash tag, and encrypting where appropriate.

In our research, several proof-of-concept radiation therapy calculations were performed on a cloud-based virtual Monte Carlo cluster. Representative clinical calculations were performed, including depth-dose curves for photons, electrons, and protons and a simple proton treatment plan. The expected 1/n performance scaling with number of nodes in the cluster was observed with some caveats. The cloud computing model was successfully demonstrated as a replacement or supplement for an in-house Monte Carlo computing cluster. We contend that this emerging technology will play a prominent role in the future of medical physics computing.

Our research results were presented in *the XVth International Conference on the Use of Computers in Radiation Therapy*, 2010, and *the 52nd Annual Meeting of American Association of Physicists in Medicine (AAPM)*, 2010.

Future Research Activities:

For future research, we would like to use cloud computing for improving heavy ion radiation therapy, one of the thrust areas of modern radiation therapy.

Modern radiation therapy is driven by the quest to improve dose conformity. It was because of this that intensity-modulated radiation therapy (IMRT) was invented. Using a focused beam geometry and computer based optimization software, IMRT has proven to be one of our most effective tools for combating cancers. One of biggest problems with IMRT is that the total dose delivered to the nearby normal tissues is always more than that to the tumor. Further photon-based radiation therapies are not very effective against radio-resistant tumors.

These drawbacks of IMRT can be overcome by using charged particles, such as protons or carbon ions. Currently, particle therapies are mainly planned based on physical dose distributions. However, it is well known that with the same amount of dose, the biological damage of different depending on the particles used. A physical quantity that is closely related to the radiobiological effect is the linear energy transfer, which describes locally the imparted energy along the particle track. Using LET for treatment planning is a significantly advancement in planning particle therapy, however, because at the microscopic level, the energy per unit length along the track varies over a wide range, the only way to accurately calculate LET is through a full Monte Carlo simulation. Monte Carlo simulations using random sampling to simulate the stochastic energy deposition of particles can only reaches high accuracy when large number of primary particles are simulated and can be extremely slow. Because of these, a planning system based on LET is still lacking.

For future research, we will explore technologies enabling LET painting for particle therapy planning. Specifically, we will leverage the emerging cloud computing technology for medical physics computations. We will develop a cloud computing based framework for the planning, simulation and evaluation of particle therapy and in particular LET calculations and LET painting. We will validate the method and software developed with the help of our medical collaborators from the Heidelberg Ion Therapy Center in Germany and other accelerator centers providing high LET particle beams, like CERN.