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Proposition de stage Master 2 au laboratoire CREATIS

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Radiotherapy has become a major technique for cancer treatment. Among others, the "Rayonnement, Image, Oncologie" research team co-located at Léon Bérard Cancer Center[1] and CREATIS laboratory[2] investigates radiotherapy simulation, which allows prototyping of new sequences and improvement of treatment planning. In particular, the GATE simulation code[3] [3] is a joint initiative to develop open-source software for nuclear medicine simulations, especially TEP and SPECT. A new GATE module for radiotherapy simulation is currently being developed.

Based on the Monte-Carlo method to simulate particle trajectories, GATE experiments are very compute-intensive and benefit from the exploitation of parallel machines such as clusters or grids (clusters of clusters). Following the approach initiated in [4] and existing cluster deployments, the use of the EGEE grid[4] to support GATE simulations is currently under testing at CREATIS.

This internship deals with the conduction of large-scale radiotherapy experiments on computing platforms including grids and clusters. Three complementary axes will be studied: (i) performance optimization of the simulations, (ii) user-friendliness of the execution environment and (iii) an application challenge on intensity-modulated radiation therapy (IMRT).

1 Performance: dynamic parallelization

Context. As Monte-Carlo simulations, GATE runs can easily be parallelized. Particle parallelism can be exploited to spread the simulation on a large number of computing resources. As for other parallel applications, however, determining a good task granularity is challenging. While a too coarse granularity (i.e. each task simulates a lot of particles) limits parallelism, a too fine granularity (i.e. each task simulates only a few particles) is penalizing because of application startup time and data transfers. To cope with this problem, we recently

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[3] `http://opengatecollaboration.healthgrid.org/`
[4] `http://www.eu-egee.org`

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came up with a dynamic parallelization algorithm to optimize granularity tuning of GATE simulations, leading to time gains of 30% for the simulations [1]. However, new GATE features prevent this algorithm from being exploited to parallelize the latest GATE release. In this release, simulations are made of successive runs representing a given fraction of the whole simulation, which improves realism of the simulation but disturbs the parallelization scheme.

Workplan. This internship will investigate how the dynamic parallelization algorithm can be applied to the latest GATE release. As a result, a parallel implementation of the latest GATE release featuring dynamic particle load-balancing will be provided. Additional performance improvements dealing, e.g., with the merge procedure could be proposed too.

Involved skills (prerequisites or to be acquired during the internship). GATE code, C++ programming, load-balancing algorithms for Monte-Carlo simulations.

2 User-friendliness: integration in GATE-Lab

Context. Though grids provide important computing power and data storage facilities to applications, their interface is still very low-level, which prevents their large adoption by scientists. To address this issue, we are developing a "GATE-Lab" aiming at offering one-click access to GATE simulations on the EGEE grid and on local clusters. Based on high-level workflow [2] and VBrowser data virtualization software [5] this interface takes care of parameter checking, input files bundling and upload from local disk to grid storage, GATE release selection and history management.

Workplan. The above-described dynamic parallelization algorithm will be deployed within the GATE-Lab which will be adapted accordingly if found necessary. Tests will be carried-out together with end-users to improve the reliability and user-friendliness of the interface.

Involved skills. Java programming, PHP, bash, EGEE grid, workflow development.

3 Application: IMRT simulation challenge

As reported by the Radiological Society of North America[5],

> Intensity-modulated radiation therapy (IMRT) is an advanced mode of high-precision radiotherapy that utilizes computer-controlled linear accelerators to deliver precise radiation doses to a malignant

[5] http://www.radiologyinfo.org/

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> tumor or specific areas within the tumor. IMRT allows for the radiation dose to conform more precisely to the three-dimensional (3-D) shape of the tumor by modulatingor controllingthe intensity of the radiation beam in multiple small volumes. IMRT also allows higher radiation doses to be focused to regions within the tumor while minimizing the dose to surrounding normal critical structures.

Enabling Monte-Carlo simulations of IMRT treatment plans is challenging since it requires a very good accuracy, thus computing power.

Workplan. This axis of the internship aims at simulating Intensity-Modulated Radiation Therapy with GATE, which implies managing many irradiation fields and a temporal handling of the scene (rotation of the gantry and blades movement). Based on existing GATE implementation, the goal here will be to apply the previously developed environment on a large-scale applicative challenge on IMRT.

4 Practical context

The internship will be co-located at the Creatis laboratory and at the Léon Bérard Cancer Center. It will be co-supervised by David Sarrut[6] (radiotherapy simulation), Sorina Camarasu-Pop and Tristan Glatard[7] (grid computing). Financial compensation according to CNRS practices.

References

[1] Sorina Camarasu-Pop, Tristan Glatard, Jakub Mosciki, Hugues Benoit-Cattin, and David Sarrut. Dynamic partitioning of GATE Monte-Carlo simulations on EGEE. *Journal of Grid Computing*, 2009. submitted.

[2] Tristan Glatard, Johan Montagnat, Diane Lingrand, and Xavier Pennec. Flexible and efficient workflow deployement of data-intensive applications on grids with MOTEUR. *International Journal of High Performance Computing Applications (IJHPCA)*, 22(3):347–360, August 2008.

[3] S. Jan, G. Santin, D. Strul, S. Staelens, K. Assi, D. Autret, S. Avner, R. Barbier, M. Bardis, P. M. Bloomfield, D. Brasse, V. Breton, P. Bruyndonckx, I. Buvat, A. F. Chatziioannou, Y. Choi, Y. H. Chung, C. Comtat, D. Donnarieix, L. Ferrer, S. J. Glick, C. J. Groiselle, D. Guez, P. F. Honore, S. Kerhoas-Cavata, A. S. Kirov, V. Kohli, M. Koole, M. Krieguer, D. J. van der Laan, F. Lamare, G. Largeron, C. Lartizien, D. Lazaro, M. C. Maas, L. Maigne, F. Mayet, F. Melot, C. Merheb, E. Pennacchio, J. Perez, U. Pietrzyk, F. R. Rannou, M. Rey, D. R. Schaart, C. R. Schmidtlein, L. Simon, T. Y. Song,

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J. M. Vieira, D. Visvikis, R. Van de Walle, E. Wiers, and C. Morel. Gate: a simulation toolkit for pet and spect. *Phys Med Biol*, 49(19):4543–4561, Oct 2004.

[4] L. Maigne, D. Hill, P. Calvat, V. Breton, D. Lazaro, R. Reuillon, Y. Legré, and D. Donnarieix. Parallelization of monte Carlo simulations and submission to a grid environment. In *Parallel Processing Letters HealthGRID 2004*, volume 14, pages 177–196, Clermont-Ferrand France, 2004. presentation L. Maigne.

[5] Silvia Olabarriaga, Tristan Glatard, Kamel Boulebiar, and Piter T. de Boer. From 'low-hanging' to 'user-ready': initial steps into a healthgrid. In *HealthGrid'08*, pages 70–79, Chicago, June 2008.

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