Practical Experience of Grid-enabled Health Computing with the GEMSS Grid

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Abstract

GEMSS (Grid Enabled Medical Simulation Services) is an EU funded project (IST-2001-37153) designed to evaluate the viability of Grid computing in the health sector. This paper provides a brief overview of technical aspects of the GEMSS Grid and presents our practical experience of implementing and running a radiosurgery Grid enabled application in the GEMSS environment. Consideration of Grid accessibility, reliability and compute performance is discussed. Additionally, it has become clear that it is also important to engender confidence in the software application through validation exercises, and some results are presented. The sensitive nature of the health data being processed demands that security is given the highest priority, whilst the time critical nature of such applications demands a robust and accessible computing environment. The economics of Grid provision are less clear, but both client and Grid provider require a transparent and well defined business model.

The health context imposes particular constraints on Grid infrastructure design, and this has been incorporated within GEMSS since its inception. The features it provides makes the radiosurgery application feasible and ensures that the Grid can be a viable model for other compute intensive health applications, offering a cost effective computational resource for demanding health applications in the 21st century.

Introduction to the GEMSS Grid

The GEMSS Grid is a high performance computing environment for compute intensive health applications, and it is part of a project designed to evaluate the viability of Grid computing in the context of scientific health applications. Its availability also raises the profile of niche high performance applications software that can offer improved healthcare if integrated into the clinical domain. The GEMSS Grid currently consists of two large PC clusters located in Europe (Austria, Germany) and incorporates custom-built Grid middleware that addresses issues specific to the health sector. A software layer constructed around Web services provides a library of routines that promote accessibility and accommodate security, quality of service and business models. Security is of great importance to GEMSS, and the infrastructure includes X.509 compliance (a security standard; present in other Grid projects such as EuroGrid [1]). Access to the Grid resource is built around a client-server model that relies on a restrictive GUI (only data can be entered here – there is no shell access). The software application (as opposed to the GUI client) runs on the Grid hardware as a batch job – interactive applications are not permitted. These constraints are designed to impede unauthorised access to the Grid or its data and are consistent with guidance recommended by the GEMSS legal consultant, whose role is to explore the legality of remote processing of patient data on internationally disparate computing platforms.

improvement in patient management and patient outcome. However, the complex physics modelled by the Monte Carlo method requires long solution times and computation is insufficiently responsive on conventional platforms to provide rapid dose distributions for the planning process – hence the need for the Grid.

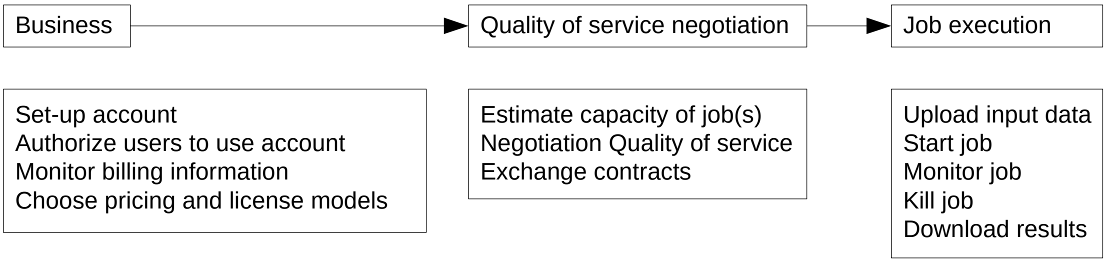


Fig 1. *Three step process to running a GEMSS Grid job*

Radiosurgery and the Grid

The example health application presented here is a Monte Carlo simulation of radiation transport for calculation of dose distribution in the head of a patient subjected to stereotactic radiosurgery. Designated ‘RAPT’ (Radiotherapy Applications for Parallel Technology, developed by IT Innovation, Southampton, UK), this is an application designed to run Monte Carlo simulations of Gamma Knife® therapy used in stereotactic radiosurgery. The Gamma Knife® (supplier: Elekta Ltd, Crawley, UK) uses 201 ^{60}Co sources to deliver a high radiation dose to lesions in the brain. At present, the GammaPlan® treatment planning system is used to calculate the radiation dose distribution. Although this provides rapid results, an improved description of the radiation distribution can be obtained using complex, compute-intense Monte Carlo simulations [2,3] but this requires a large computational resource. The improved physics of the Monte Carlo method is particularly apparent at boundaries between materials with different linear attenuation coefficients within the head and may indicate significant deviation from solutions obtained using standard methods (particularly if a high dose region is close to sensitive structures such as the eyes). This type of scenario is the motivation for Monte Carlo-based planning since improved confidence in the dose distribution will precipitate more effective plans and treatment, with concomitant

The Grid Enabled Application

The Grid infrastructure requires that the simulation be run as a batch job with data entry on the client separated from data processing on the Grid server. This utilises a restrictive GUI on the client, responsible for creation of input data files (containing head geometry, beam parameters etc.) that are dispatched to the Grid via the GEMSS middleware. The process includes removal of patient specific headers, encryption of patient data and user authentication. A Quality of Service (QoS) component is also part of job submission and declares the required turn around time of the job. This is negotiated through the user interface on the basis of cost, and results in a contract that clarifies the responsibilities of both client and service provider (i.e. the client promises to pay; the service provider promises to deliver a timely solution).

The encrypted input files are decrypted at the server and the job placed in a queue (advanced reservation is supported) and duly processed on sufficient processors to meet the QoS-negotiated deadline. This is supported by a performance model that aids prediction of compute times for each job. Job status can be sought at any time and is one of the services provided by the middleware. On completion of the job, the user is required to download the encrypted solution data set from the Grid. Results are visualised on the client.

Results

The computed solution enables visualisation of the ionising radiation dose distribution within the head and is the basis on which subsequent therapy is performed. Given the untested nature

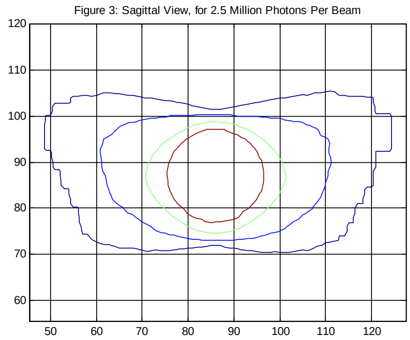


Fig 2. *RAPT solution for 201 beams of photons targeted at the centre of a spherical water phantom*

of the Monte Carlo approach in the clinical domain and the serious implications of calculation errors, it is important that the solution be validated over a wide range of conditions against standard solution techniques before it can be expected to find clinical acceptance. To this end, many tests have been performed and in general the RAPT solution demonstrates good agreement with standard techniques. Fig 2 shows a comparison between

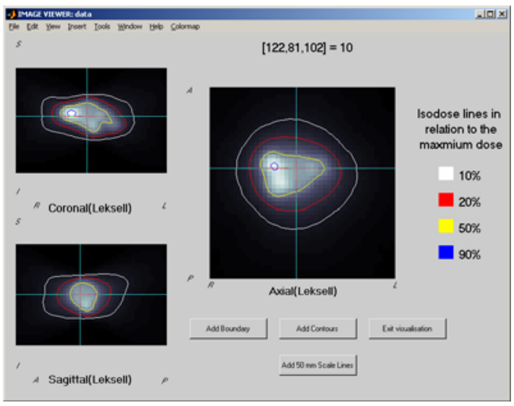
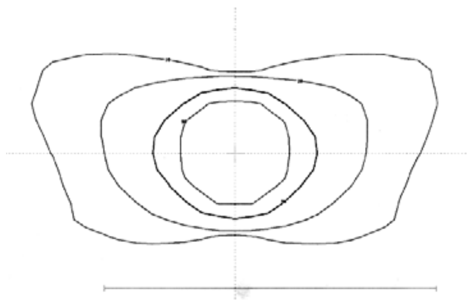


Fig 3. *RAPT solution for 201 beams of photons – clinical plan*

the RAPT solution and that of GammaPlan® for 201 beams of photons converging on the centre of a spherical water phantom of radius 8 cm. Fig 3 is an example from the clinical domain and shows good agreement between RAPT and GammaPlan® for a patient treatment plan. However, differences do occur when the assumptions implicit within the standard planning method are not valid, and in such cases the fidelity of the Monte Carlo approach offers significant advantages.

Grid availability/accessibility is critical to this clinical application and has steadily improved



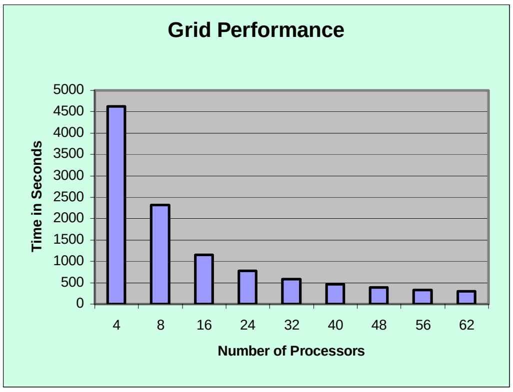
GammaPlan solution for 201 beams of photons targeted at the centre of a spherical water phantom

over the last six months as the GEMSS Grid technology has matured. The Monte Carlo simulation is suited to Grid computing because it is an 'embarrassingly parallel' problem that requires little interprocessor communication and therefore scales well with processor availability. Fig 4 reveals the relationship between CPU execution time and the number of processors used.

GammaPlan solution for 201 beams of photons – clinical plan

Conclusion

Despite the availability of Grid computing resources, the Monte Carlo approach remains untenable as the method of choice for radiosurgery planning because of the extended compute times required to obtain a satisfactory solution, in comparison to standard methods (60



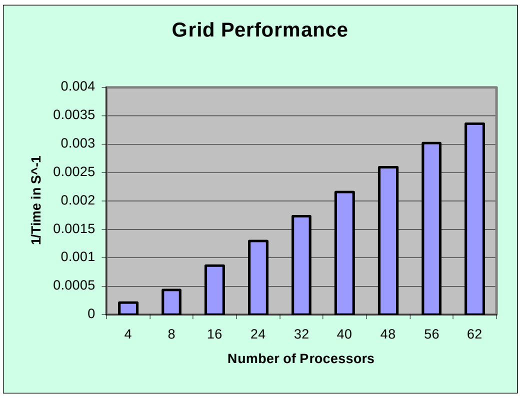


Fig 4 *Processor scalability in RAPT*

processors with RAPT can reduce job time to under 1 hour, but GammaPlan can compute a solution in seconds). This is a reflection of the simplicity of the physics incorporated in the standard GammaPlan model, and therefore the modus operandi of the Monte Carlo code is to validate the dose distributions computed by the standard method. This approach has particular relevance to those situations in which the assumptions of the standard method are not valid (e.g. heterogeneous material), resulting in incorrect calculation of treatment dose. In these cases, the Monte Carlo simulation provided by RAPT offers a superior depiction of the dose distribution and may alter clinical management of the patient.

Acknowledgements
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