Remote Radiotherapy Planning: The eIMRT Project

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Abstract: In this paper, we present the eIMRT project which is currently carried out by diverse institutions in Galicia (Spain) and the USA. The eIMRT project will offer radiotherapists a set of algorithms to optimize and validate radiotherapy treatments, both CRT- and IMRT-based, hiding the complexity of the computer infrastructure needed to solve the problem using GRID technologies. The new platform is designed to be independent from the medical accelerator models, scalable and open. Having a web portal as client, it is designed in three layers using web services, which will allow users to access the platform directly from any front-end and client. It has three main components, namely remote characterization of linear accelerators for Monte Carlo and convolution/superposition (C/S) dose-calculation techniques, remote Grid-enabled radiotherapy treatment planning optimization and verification and data depository.

Keywords: Radiotherapy, Monte Carlo, treatment plan optimization and verification, CRT, IMRT, gLite.

Introduction

Current radiotherapy treatment planning is based on *local* software tools (such as Pinnacle, XiO, Oncentra, Corvus, etc.), running on workstations at hospital premises. Specialized personnel compute treatment plans either employing their previous knowledge and experience or trial-and-error class-solution or, for more complex treatment plans, built-in optimization tools. These software tools, called treatment planning systems (TPS), are subject to very severe constraints on computer power and time to produce practical results, due to hospital workload and limited access to new algorithms. The requirements in maximum computation time forces TPS tools to perform approximations both in dose calculation engines and optimization algorithms. The most accurate dose calculation techniques of that those codes are based on convolution/superposition (C/S) [1] techniques, which suffer from certain limitations in high density gradient regions. Usually, the treatment is based on Conformal Radio Therapy (CRT) which, from a preselection of incident angles, fixed beam energy and exposure time,, conform the beam to the shape of the tumour for each angle. The more recent Intensity Modulated Radiation Therapy (IMRT) techniques select the intensity for each incident angle in great detail.

State-of-the-art conformal and complex radiotherapy treatments such as IMRT are calculated and optimized employing TPS tools. Treatments are tailored to maximize the dose to the planned target volume (PTV) while minimizing the dose to surrounding tissues, specially the organs at risk (OAR), within the limits specified by the doctors. This is the main issue in the definition of the objective function of the optimization problems involved, which are solved using several well-known techniques such as simulated-annealing [2,3], linear programming [4] or mixed integer programming [5].

The limitations and drawbacks of current TPS could be avoided if computationally intensive user-friendly environments were available. The eIMRT project focuses on that issue by integrating and implementing several tools to help radiotherapists in selecting the best treatment. The project started in Summer 2005 and will deliver the first services in 2006. Fully operational service is expected by the end of 2008. The project partners are CESGA, University of Santiago de Compostela, University of Vigo and *Complexo Hospitalario Universitario de Santiago* (all of them in Galicia, Spain) with the collaboration of the Computer Sciences Department of the University of Wisconsin-Madison. At the end of the project, a single portal will offer radiotherapists several techniques to optimize treatments and verify them, following the new Service Oriented Architectures (SOA) paradigm. At the first stage, we plan to include the following tools:

- Monte Carlo methods [6] for treatment verification. They accurately model the interaction of radiation with matter and are the dominant standard in dose calculation techniques. They achieve more accurate results than convolution/superposition methods, at a higher computational cost. Although forthcoming achievements may render Monte Carlo a valid near-real-time treatment planning alternative, it currently plays an outstanding role as a *validation* technique. Therefore, the eIMRT platform will use it to verify the results of commercial treatment planning systems for any kind of radiotherapy plan of external photon beams.
- CRT and IMRT optimization algorithms. New web services will implement an open access point to exhaustive yet computationally intensive IMRT and CRT optimization algorithms based on mixed Monte Carlo C/S dose computation algorithms, which will produce optimized treatment plans of a quality (in terms of dose conformation and organ sparing) hardly achievable with commercial TPS.
- Finally, there is a joint effort of the groups involved in this project to establish an international public data repository with anonimyzed CT scans, treatments and other relevant information, which may be useful in the future to reproduce results, mine knowledge and train specialists.

Both Monte Carlo and IMRT optimization methods are computationally intensive and, furthermore, demand radiotherapists to acquire knowledge in fields that are beyond their usual experience, such as mathematical programming. A good solution to both problems is software *decoupling*, i.e. leaving the user interface in local machines (at the hospital in our case) and taking the computing core to institutions that can effectively handle it. Software decoupling for user-friendly high-throughput computing is not new [7] but, as far as we know, it is an original approach in the field of radiotherapy planning.

Nowadays, approximately 50% cancer patients receive radiotherapy. In 1999, more than 56.000 patients were irradiated only in Spain [8]. All treatments follow a planning protocol to ensure the quality and effectiveness of the session, and the treatments should be planned in a short period of time (the mean time between the first visit and the begining of radiotherapy treatment is 18,87 days in Spanish public hospitals [8]). Many radiotherapists have to plan over 600 to 1200 patients per year, with a mean value of 925 [9]. This situation puts a high pressure on them, raising the need of new tools to optimize. The tool we propose may have a significant impact due to the high number of hospitals that may benefit from it. Only in Spain, there are over 115 particle accelerators in 70 hospitals with radiotherapy facilities [10], four of them in Galicia including the *Complexo Hospitalario Universitario de Santiago*, which is a partner in the project. As a result of the extremely long CPU time for optimization and verification, distributed computing is a clear best-case of Grid technologies exploitation.

Architecture

Figure 1 shows a general overview of the eIMRT architecture. Note that the client interface is rather simple (HTML, Flash and Java support). Complexity is completely enclosed at the server side, which accesses high-throughput computing services via web services [11]. We plan to use the gLite middleware [12], since one of the project partners (*Centro de Supercomputación the Galicia*) is also an EGEE partner.

We foresee three types of users, with different privilege levels. Figure 2 summarizes them with the interactions they may perform.

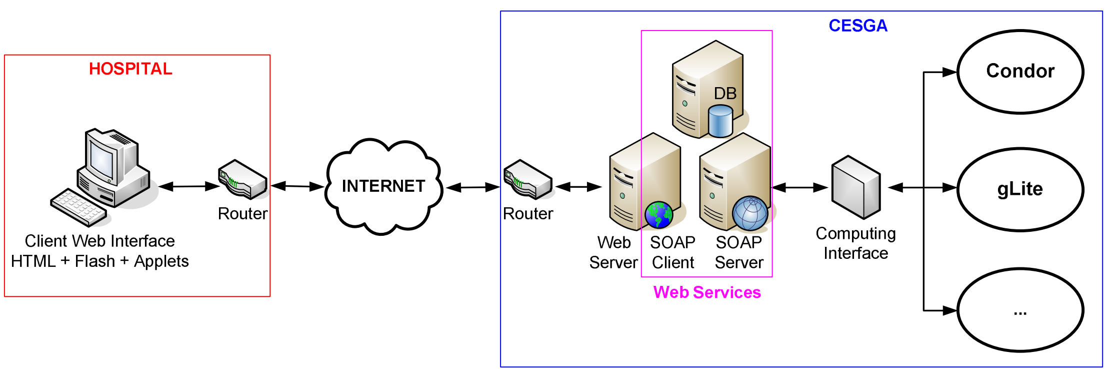

Figure 1. High-level eIMRT architecture

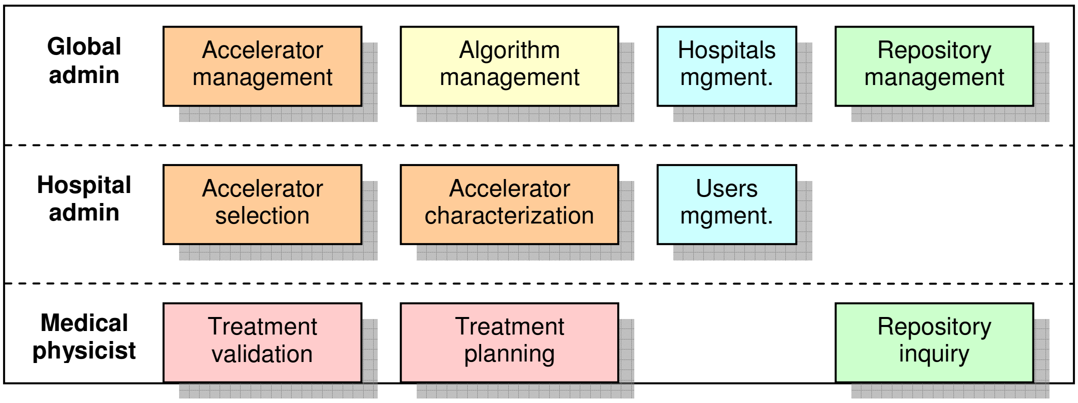

Figure 2. User types and their interactions

Most interactions in Figure 2 are self-explicative. To **validate a treatment**, the user requires the system to check the dose distribution he has calculated (for instance, with a local tool) against the dose distribution associated to the same treatment resulting from a more accurate method (Monte Carlo at the current stage). If the radiotherapist provides the system with a dose map, he obtains the gamma maps [13] (which account for local dose differences). In any case, he submits a treatment file (typically DICOM RTplan, RTP CONNECT or MLC), and he is allowed to visualize all input information before proceeding (to avoid possible mistakes in file identification). Regarding t**reatment optimization,** at this moment we are considering CRT-enhancement and IMRT planning via integer programming and global optimization algorithms, which are completely transparent to the radiotherapist. However, the platform has been designed to implement any optimization algorithm in the future. Treatment optimization returns dose data, as well as dose and gamma maps, so the radiotherapist can take decisions from the results.

Due to the length of the interactions, the system has session support, to let radiotherapists leave the system and track the progress of their processes. They may enter again at any time to retrieve the results or initiate new interactions.

The system server hosts the web server for user access. As shown in figure 3, the web server calls *web service SOAP clients*, according to the petitions that take place during *authenticated* web sessions. These SOAP clients do not create an internal session to access web services, but send authenticated messages[1] instead to the corresponding services. After performing the requested operations, each service returns its results.

We employ Cocoon [14] to combine the web server with the SOAP client, so that the user may access services directly with XML. Besides, it is straightforward to convert XML responses from web services to HTML and other formats for the end-user to visualize them.

[1] Using WS-Security.

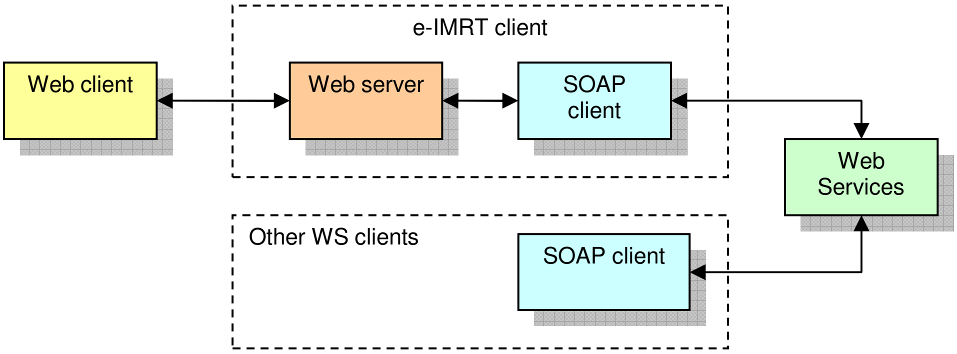

Figure 3. Relationships between elements participating in web services invoking

Although it is feasible to place the web server and the web services in the same machine, it is likely that, once published, the web services will be reachable from other machines (with their own SOAP clients). Thus, authentication is mandatory.

Conclusions

The eIMRT decoupled architecture is a cost-effective solution to speed-up the CPU-greedy processes in advanced radiotherapy planning: accelerator characterization, treatment validation and treatment optimization. As a bonus, it hides implementation details, freeing radiotherapists from acquiring non-essential technical knowledge. Last but not least, it lowers maintenance costs, since eIMRT clients run on standard browsers of low-end machines and operating systems. At the present stage, the server side will completely run at the CESGA supercomputing facilities, but the system is ready to become fully distributed across heterogeneous networks, since it relies on Grid technology

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