BIG: a Grid Portal for Biomedical Data and Images

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ABSTRACT

Modern management of biomedical systems involves the use of many distributed resources, such as high performance computational resources to analyze biomedical data, mass storage systems to store them, medical instruments (microscopes, tomographs, etc.), advanced visualization and rendering tools. Grids offer the computational power, security and availability needed by such novel applications. This paper presents BIG (Biomedical Imaging Grid), a Web-based Grid portal for management of biomedical information (data and images) in a distributed environment. BIG is an interactive environment that deals with complex user's requests, regarding the acquisition of biomedical data, the "processing" and "delivering" of biomedical images, using the power and security of Computational Grids.

Keywords: Electronic Patient Record, Biomedical Imaging, Computational Grid, Grid Portal, Globus Toolkit.

1. INTRODUCTION

The last decade has been characterized from an increasing systemic vision of biomedical issues. This new trend aims to optimize and innovate the services offered to the people, thus improving the life's quality by means of an integrated multidisciplinary approach.
Along this trend, many countries introduced Electronic Patient Records (EPR) or Electronic Health Records (EHR) systems, as part of the modernization of public health services. The term EPR means the electronic collection of all diagnostic reports including multimedia data, such as Digital Image and COMmunication (DICOM) for instance, of a patient's entire medical history combined into a universal report in electronic format [1].
Through the use of EPR, Health Management Organizations (HMOs) goal is to improve the overall quality of care by simplifying the availability, accessibility and delivering of patient records, as well as management and presentation. Indeed, these systems record the information (data and images) related to a patient so that it is more likely to be readable, accurate, safe, available when required and easy to retrieve. This information can be readily analyzed for audit, research and quality assurance purposes. Thus, EPR systems can be used as a basis for telemedicine and video consulting, to provide and support health care applications in distributed systems, by exchanging information useful to the diagnosis, treatment and prevention of diseases [2, 3]. It is worth noting here that a fundamental concern related to EPR and telemedicine consult systems is the possibility to manage the result of analyses and biomedical surveys (in particular images) through user friendly interfaces. The use of multiple imaging modalities, e.g., CT (Computerized Tomography), MRI (Magnetic Resonance Imaging) and PET (Positron Emission Tomography), for diagnosis and interactive video telemedicine consulting, makes easier disease detection, diagnosis, and ultimately, guiding treatment and non-invasive diagnosis and treatment (e.g. allowing non-invasive diagnosis, avoiding, when possible, a non therapeutic surgical treatment).
However, the use of sophisticated techniques for medical image processing (currently not commercially available), able to supply better qualitative and quantitative information for the diagnosis, is extremely expensive from a computational perspective and requires the use of high performance computing resources (generally, not present in health centers or analysis laboratories). Moreover, the results must be provided as timely as possible, besides the need to manage large data sets. An integrated system, offering such services, needs many distributed resources, such as medical instruments, advanced visualization and rendering tools, databases, hardware and so on.
The emerging grid [4], i.e., a software infrastructure allowing a secure and pervasive access to heterogeneous and geographically distributed resources, offers the computational power and security services, necessary to develop novel EPR systems.
However, using computational grids for the development of EPR systems, requires specific knowledge of grid details and a generic user would face remarkable difficulties to use them. The solution is the development of easy to use user interfaces that manage the complexity of the grid. Through Web Portals (Grid Portals [5]), the user can access a variety of grid services by means of a simple interface, hiding all implementation's details.
This paper presents BIG (Biomedical Imaging Grid), a Grid Portal [6] accessible via Web for the management of biomedical data in a distributed environment.
BIG is an interactive environment able to answer, automatically and securely, complex user's requests regarding the management of biomedical data, such as acquisition, processing and delivering of CT and MRI images, stored on the nodes of computational grids. BIG utilizes grid services offered by Globus [7], a toolkit made of a layered set of components that implements basic services, such as security, resource location, resource management and communications. In particular, for the development of the portal, we have used specific libraries layered on existing grid services, called GRB and GRB-GSIFTP [8, 9], in order to favour the realization of portals able to access Globus-based grid applications. Moreover, for accessing clinical data, stored in distributed health centers, we have used the GRelC library [10], a tool that allows the virtualisation of data sources in a grid environment, i.e. more physical data sources are mapped as a logic entity so it is possible to query a set of repositories through a unique

front end. The use of the Globus Toolkit as grid middleware and GRB, GRB-GSIFTP and GRelC libraries, besides simplifying the access to remote computational resources, does guarantee security, integrity of the data and confidential communications, fundamental in health applications.
The paper is organized as follows. In Section 2, we mainly focus on the use of computational grids and computing portals with regard to the management of biomedical data and images. In Section 3, we describe the techniques and algorithms used for collecting the patient data and processing the images. In Section 4, we describe BIG, a portal that allows the analysis and visualization of these data on the Grid. In Section 5, we describe the BIG prototype and finally we conclude and discuss future work in Section 6.

2. GRID FOR BIOMEDICAL INFORMATION

Grid-based EPR systems should offer two main functions:

- management of patient's data spread over distributed health centers;
- management of biomedical complex data, such as images, CT, MRI, PET, etc., distributed and produced by different health centers.

Both functions can leverage Grid technologies, as described in the rest of the section.

Virtual EPR on the Grid

To build a distributed EPR system (Fig. 1), offering on line access to multiple patient's data (e.g. to compare different examinations), a loose integration of local health systems (databases) is needed. The content of these systems, often geographically spread, is an important asset of a wide health system because the analysis of all the data through data mining techniques could reveal better health treatments or protocols.
Moreover, often many patient medical reports are still on paper, so a complete clinical folder is not available during a consult and laboratory examinations can be repeated many times because results are not available at the doctor in a timely fashion.
The integration has to face numerous issues, such as schema integration and differences in data formats, and legal constraints regarding the use of private (patient) data.
Grids could offer an interoperable framework among health centers, geographically spread, that need appropriate hardware and software for the processing of data sources (for instance to extract new knowledge and improve the procedure for diagnosis-care), exchanging of information, often available in a different format, securely and efficiently. The computing needs of a distributed health system are:

- handle large volumes of data produced in many centers;
- define common standards for their interoperability;
- provide to a large community of users (biologists, physicians) a secure and efficient access to their contents.

We think that the grid paradigm is a good response to these needs.
In our scenario, the grid is composed of different information systems (one for each health center) that store patient information (data and images) and a collector that carries out a distributed query at various centers, gathers the requested information and visualizes it into a unique report (clinical folder).

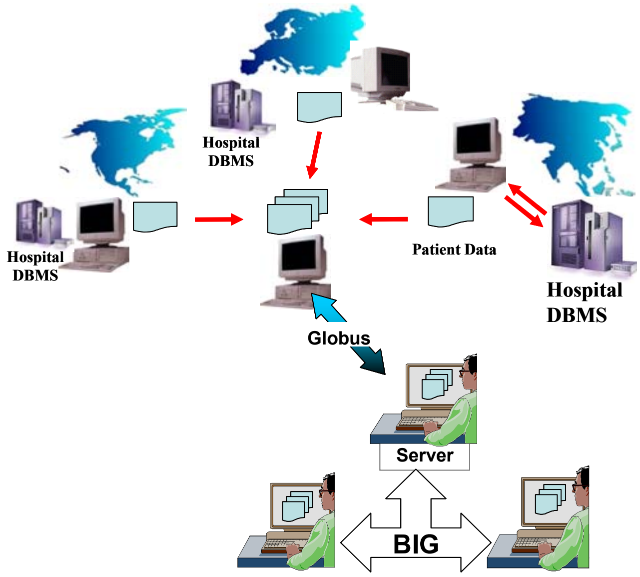

Fig. 1. Computational Grid for distributed EPR.

A virtual clinical folder collects all of the descriptions about health events of a patient simplifying the availability, accessibility and delivering.
The most interesting feature related to our system is the possibility to search through all the patient's data independently of the centre where the data have been generated.
The clinical folder can be accessed through a web portal, by users (doctors) which authenticate themselves by providing their username and password.
Thus, they can examine their own patients, searching them on the basis of some criteria expressed in the submitted query. A list of patients which matches the requested query is then returned. For each patient, a summary of her general information and characteristic data such as diagnosis, anamnesis, objective of examinations, clinical diary, visits of specialists, therapy and other events are returned. Moreover, the creation of new patients or activities is guided in order to maintain the integrity of the data repository.

Managing images and biomedical data on the Grid

The main goal of this work is to leverage the power and ubiquity of the grid to design and build a novel EPR system, regarding in particular the management of biomedical images, which acts as a collaborative working environment in the health field. Indeed, doctors often want to aggregate not only medical data, but also human expertise and might want colleagues around the world to visualize the examinations in the same way and at the same time so that the group can discuss the diagnosis in real time. As shown in Fig. 2, the grid offers both high speed networks to connect remote health centers, such as Hospitals, Medical Research Centers, etc., and the computing power needed to process and deliver biomedical images, that are acquired through specialized medical equipments. As Grid Portals are becoming usual to deploy applications in the grid community, we developed an integrated, web-accessible interface to our collaborative environment for biomedical imaging.
In this prototype version, we have focused on the analysis and visualization of CT and MRI images, planning the system to support, in the near future, other kinds of images (PET for

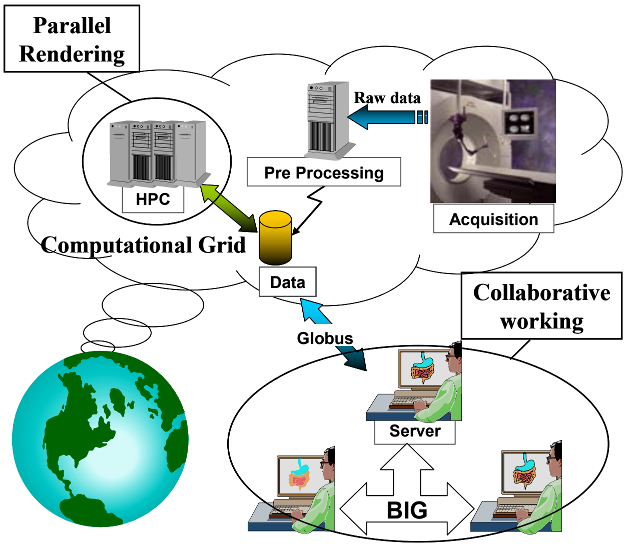

Fig. 2. Use of Computational Grids to build a collaborative environment for biomedical imaging.

instance). To be useful for such medical environment, a grid should include and integrate:

- equipments (e.g. tomographs) for the acquisition and first processing of medical examinations;
- high-capacity storage systems to store the examinations;
- high performance computers for their analysis;
- broad-band networks for the delivery of data, that are often analysed interactively in real-time.

Moreover, the interoperability between different medical applications should be guaranteed.
Integrating such different resources requires to identify and access the patient data set, to know and use the specialized technologies developed in the medical field (such as metadata and formats of biomedical data, e.g. DICOM), in other words, the final user, that usually is a physician and not a computer scientist, should know many unfamiliar technical details. Web-based Grid Portals are the answer to this problem. They simplify the access to grid applications hiding the details of implementation, through web-based interfaces, that use library functions to access core grid services. The use of high-level grid libraries, as those we have realized in the Grid Resource Broker project (GRB) [11] and used to implement our system, makes it possible to decrease the development costs and times allowing secure and efficient data management.

Requirements of a grid for biomedical imaging

The operation schema of a grid for the management of biomedical images is often as follows: a central grid node (primary node) offering a centralized, web-based access to the designed services, is responsible for the coordination of secondary nodes representing, respectively, Hospital Centers and Medical Research Centers hosting specialized medical and diagnostic equipments and storing the results of medical examinations (CT and MRI), and High Performance Computing Centers, offering the computational power to process such examinations. The grid acts as the communication and security framework and is responsible for hiding the details regarding the localization, access, processing and delivery of medical examinations from the source where they reside to the user (doctor) requesting them.
When a user (doctor and/or health operator) requires to visualize a CT of a given patient, the primary node locates, querying a local authorization database, the secondary node storing the requested data. Then, the primary node, using the Globus services (in our project by means of the GRB e GRB-GSIFTP libraries that wrap the Globus functions), will authenticate over the grid using *single-sign-on* (allowing a user to authenticate herself to a set of grid resources once and use them for a specified period) offered by Globus and will finally access the requested data. Usually, the primary node needs to analyse the proper metadata, to choose and find an appropriate tool, to submit a corresponding job to a secondary node (often different from the node containing the data), and to apply such tool to the data to obtain, for example a 2D/3D rendering of a biomedical image.
Finally, the primary node has to obtain and deliver the requested (transformed if needed) data to the final user.
Note that the primary node could implement different protocols to obtain the final data from the secondary nodes. For example a CT could be split in a set of slices on a secondary node and sent using a stream-based protocol, to overlap computation with communication.
Moreover, the system could offer different tradeoffs between flexibility and response time, varying, for example, the percentage of processing made on the grid or on the user node.
In summary, the requirements of a grid for biomedical images are:

- integration of medical equipments in the grid environment;
- use of authentication and data security services offered by grid middleware (e.g. *single-sign on*);
- use of data-specific grid services (e.g. the GridFTP protocol [12] through GRB-GSIFTP library to effectively transfer big images);
- exploitation of computing power offered by grid resources (e.g. using parallel rendering algorithms);
- loose integration (hospitals, medical research centers) of health databases allowing the search and localization of biomedical data, without affecting the privacy constraints imposed (e.g. by the government laws) when using sensitive patient's data;
- presentation of offered services through a web-based graphical interface.

In the following, we discuss these general requirements for BIG, the proposed collaborative working environment for the analysis of biomedical images.
Medical equipments. In our system the grid will connect health centers, allowing storing and replication of raw image data available in digital format. In this first phase the basic infrastructure will include a set of tomographs (CT, PET, SPECT) allowing the acquisition of images in local databases.
Data and communication security. An important issue in medical environments is the security, integrity and privacy of the patient's biomedical data. Indeed, such data cannot be made public without the patient authorization nor they can be modified or altered in any way. Moreover, these data can be accessed only by trusted users.
The BIG portal allows the access to registered doctors and health operators, that can visualize only the information about their patients. For these reasons, we adopted a double authentication schema: a local authentication (checked through

a password stored in a local database) controls the access to the BIG services, whereas a global authentication is used when accessing the patient's data on the grid. To date, we locally adopted a standard username/password pair but we plan to use more secure technologies such as smart cards [13]. After the local authentication, the user will access grid resources using the Globus authentication/authorization mechanism, based on public key criptography, providing her grid login and PEM (Privacy Enhanced Mail) pass phrase that control the access to the Globus X.509v3 certificate. The user pass phrase for the credentials is sent from the client application using HTTPS to prevent network sniffing and cookies are used to establish and maintain session information. So, a user wishing to use our system should obtain a BIG account (i.e. an account at the ISUFI/CACT laboratory of the University of Lecce), should set up her Globus environment, and should have access, through Globus, to a set of secondary nodes (health centers) .

High-performance data transfer. An important requirement in a grid medical environment is the efficient and secure staging of large data sets of biomedical images. To do this, we leverage existing high performance transport protocols, as the Globus GridFTP, through GRB-GSIFTP library, providing the user with the capability of starting a parallel third-party file transfer, transferring single files or directories.

High-performance biomedical data analysis. As explained before, an important advantage of a computational grid is the availability of large computing power. In our system the most computing intensive application is the processing of biomedical images, in particular the three-dimensional rendering of images. This could require to move the images to the computing nodes, or to move, if needed, the rendering application where images are stored. Using GRB library, our portal runs on a node the rendering and/or slicing algorithms that produce, respectively, the 3D rendering of the image or a slice used on the client browser to build the 2D view.

On the other hand, the user needs to interact with such images (e.g. rotate, zoom, inspect them, etc.), so the computation on images is conducted partly on the grid and partly on the user's computer.

In summary, the integration and cooperation between grid services and EPR systems, and their presentation through web-based, user-friendly interfaces, allows building a grid for biomedical data offering novel and large-usable health services.

3. METHODOGIES FOR THE TREATMENT OF BIOMEDICAL DATA

In the following, we describe the methodology applied for the management of data. In particular we present the overall schema for the clinical data and the algorithms used for the 3D rendering of our images.

Clinical Folder Information

Our system will provide support for storing, maintaining and retrieving a lot of clinical data which can be classified as follows:

1. *Patient*: personal data of a patient (e.g. name, address, telephone numbers, work activity etc.);
2. *Anamnesis*: relevant past clinical data (e.g. type and stage of a tumour, past therapy, etc.);
3. *Diagnosis*: diagnosis when the patient enters the hospital and when she is discharged;
4. *Therapy*: planned therapy, prescribed therapy and maintenance therapy;
5. *Clinical diary*: summary of prescribed therapy, request for performing treatment, recording sequence of biological parameters (blood pressure, temperature, etc);
6. *Diagnostic examinations*: reports produced when the patient is under observation. These comprise alphanumeric, numerical, graphical information, physiological tracings or images;
7. *Follow-up*: consulting archives to get data of patients already discharged to access information of bibliographical and druggist type;
8. *Quality of Life*: analysis of the quality of life of patients during a given period;
9. *General Practitioner (GP)*: relevant personal data of GP, to facilitate the exchange of useful information among the care centers and the GPs.

The local database (present in every health unit) has been planned following this information scheme and it is based on a relational database management system (RDBMS) which takes care of the clinical data (see Fig. 3). Details about the clinical folder have been presented in previous works [14, 15].

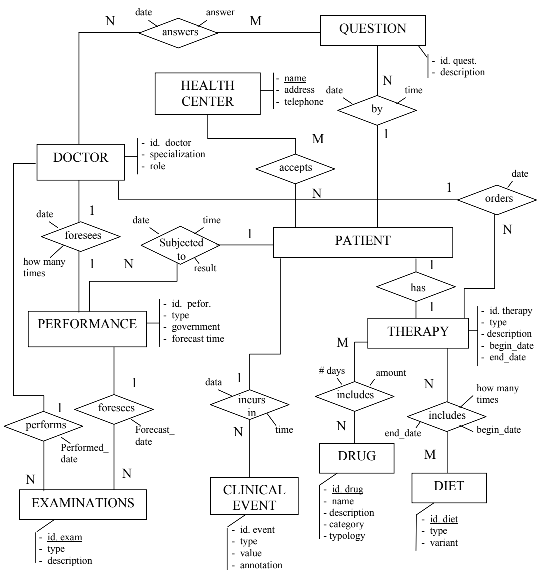

Fig. 3. Entity relation diagram of information stored in a Electronic Patient Record (EPR).

Algorithms for the management of images

Three-dimensional volumetric visualization of CT and MRI data has become the standard for routine patient diagnostic care [16].

For such reasons and above all in order to test the potentialities of BIG, we have focused on the analysis and the visualization of CT and MRI images, planning to support other types of images (e.g. PET, SPECT). In the following we describe the techniques used in our portal to visualize two and three-dimensional images.

As can be seen in Fig. 4, the acquisition of CT images occurs by means of tomograph scan, one of the digital medical devices most used in the diagnostic for images, relatively expensive and available to almost all the health structures. The output of a CT is a series of transaxial matrices (slices) aligned perpendicular to the axis defined from the patient

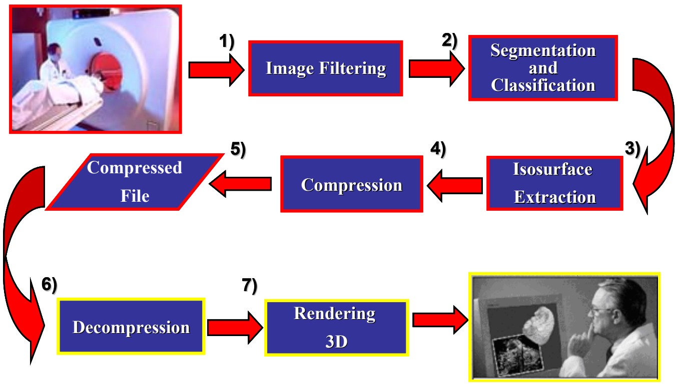

Fig. 4. Phasis of the 3D Rendering

backbone. Every slice typically represents one patient's body section of a determined thickness (1-10 mm).
The dimension obtained is 512x512 pixels and every pixel ideally represents the absorption features of a small volume of the human body characterized by the physical limits of the same voxel. The matrix will provide a resolution of 0.64 millimeters for every horizontal point; a vertical lower resolution is used, of about 2.5 millimeters, which produces nearly 60 sections in total for abdominal region scan. In order to express 2000 levels of X-ray abortions, 11 bit are needed, so that 2 byte per point are used.
Therefore, the set of data for a single scanning of the abdominal region will be: 512*512*60*2 byte ≅ 30MB. Moreover, to carry out a high quality recognition of the tissues is necessary to use the correlative information obtained in three acquisition phases, with use of contrast medium, hence the whole set of data for a single scanning becomes about 90 MB.
In order to measure the pixel value we have made reference to a standard measure unit (expressed in Hounsfield Units or HU) that has as reference the density of water (0 HU), around -1000 for the density of the air and more then 200 HU for the bones. The whole acquisition process requires on average 50-60 sections, stored in a DICOM file in a local database of a health structure. The biomedical data must therefore be interpreted integrating techniques of image processing and techniques of two and three-dimensional rendering.
In particular the *Filtering* process (phase 1) consists in the cleaning up of the noise, that in the case of CT images, is the misalignment of the images obtained in the three volume data due to the update of the shape of the inner organs, because the analysed subject, breathes or move herself during the examination. So, the alignment of the three phases is necessary. To resolve this issue we have experimented a technique based on genetic algorithms described in a previous work [17]. This technique is characterized by a high computational load so actually we are working on the implementation of a parallel genetic algorithm relying on a number of high performance computational resources. Phase 2, *Segmentation* and *Classification*, consists in the subdivision of the image in homogenous regions and cataloguing of every single region, aggregating those regions corresponding to the same tissue. For image segmentation we have investigated an approach that use a neural network whereas for the classification, we used a semi-automatic method (i.e with the help of an expert operator such as radiology physician) that allows to characterize contours, threshold values or to assign values interactively to the single pixel. Once the data have been classified, they are recognized and visualized along three dimensions.

Various techniques of volumetric visualization exist; here we will describe the technique implemented from the BIG portal highlighting the obtained results. The phase 3, *Isosurface extraction*, is used for extracting a 3D shape; we have used the Marching Cubes algorithm [18] (considering classified regions as input) for extracting the triangle mesh; moreover, medical images are very large files and the bandwidth is limited; so it's necessary to reduce the dimension of files using a compression algorithm. Compression of the obtained triangle mesh file (phase 4), is obtained through the Edgebreaker technique [19] (we have chosen this method because we would like to optimise the transmission of the images considering also their topology). This processing is made on the server side. On the client side the decompression Edgebreaker algorithm (phase 6) is used and finally the browser reconstructs the image pixel by pixel (phase 7) thus guaranteeing a basic level of user's interaction, and the image is rendered.
For 2D visualization, BIG implements an algorithm that associates to every element of the transaxial matrix one grey tonality building on display the single slices.
In particular for the visualization of a single slice, BIG, thanks to the processing on the client, allows knowing for every point P(x, y, z) of the image the relative value of density. That allows a doctor estimating the tissue relative to the same point, comparing such value with that defined in the Hounsfield scale.

4. THE BIG GRID PORTAL

The goal of BIG is to offer an integrated, web-based access to distributed computing resources to support doctors and/or health operators in their diagnosis activities, offering quantitative and qualitative information. To such aim, the proposed system allows:

- the search of basic health information of patients;
- the analysis and two-dimensional and three-dimensional rendering (horizontal, frontal and lateral) of biomedical images (with respect to the axis defined from the patient backbone).

The BIG portal integrates and arranges methodologies and techniques necessary for the realization of an EPR system, in particular it can be considered as a:

1. web-based application, regarding the user interface and delivery of the information;
2. grid-based application, for the access and processing of biomedical images available on the nodes of a grid.

In particular, the key advantages offered by BIG are:

- visualization of biomedical images, using a standard interface as the web browser;
- creation of a collaborative environment for the video consulting: the visualization of on-line images of a patient, allows doctors, geographically spread, to exchange opinions with the aim to carry out a more accurate diagnosis in real time;
- fast execution of the video consulting;
- real-time access to data: that would reduce, consistently, the time necessary to obtain the patient data and her examinations;
- storing of diagnostic cases and optional examinations;
- integration of data coming from different imaging methodologies: the use of multiple modalities of visualization, fosters a more accurate diagnosis of care;

- friendly interface for a user who is not skilled in computer science or with little familiarity about the computer.

We think that BIG is a good example of a high-end, data intensive application that exploiting the computing power and ubiquity of computational grids, represents a first step for the realization of novel EPR systems. The portal has been implemented using Java, improving the portability, reuse and maintenance.

In the following we first describe the main components of the architecture and then describe the BIG operations.

Architecture

Our system exploits a three-tier architecture (Fig. 5): the browser executed on a client, at the first level or client tier; the Web server (including an application server), placed at the intermediate level or middle tier and the file system or DBMS including the Web page, at the third level or back-end. The back-end includes some sub-layers and the grid resources necessary for the 2D/3D rendering of biomedical images.

At the top layer we have web-based interfaces to easily access the lower level services and application logic coordinating the data flow between the grid components (e.g. Globus security) and the EPRs (e.g. local EPR security). This layer has been implemented using the Grid Portal paradigm whose main goal is to hide the grid details, and, in our case, also to integrate the EPR systems. Other than a standard web browser, this layer comprises: client side image processing (e.g. Java Applets), grid/EPR resource discovery and brokering, distributed workflow. The second layer represents the web server, which is the primary node with the functionalities described above.

The next layer comprises the services offered by BIG.

These are:

- management of basic health information of the patients (personal data);
- management of patient's reports (examinations, clinical folder, etc) coming from different departments in a health center;
- patient care: this service allows storing the current health state of a patient and is used to enhance the diagnosis;
- 2D/3D Image Rendering: allows the analysis and 2D/3D visualization of biomedical images, in particular CT and MRI. The fundamental phases of 3D rendering are actually obtained using classification and segmentation algorithms. This service is interactive, in fact it allows to produce images in which only the organs of interest are visualized.

These two layers implement the application logic needed to coordinate secondary nodes, i.e. storage and processing ones. The next layer comprises the high level libraries to access a computational grid, described above. The next layer involves grid middleware (Globus toolkit), offering services such as security, flow coordination, resource location access and management, data transmission and communication. Specialized biomedical data analysis tools, such as 2D and 3D rendering algorithms, are provided as applications processed by the grid computers.

Moreover, the grid middleware allows connecting to different external databases (e.g. private medical centres or laboratories of the area of the EPR).

This is useful to integrate biomedical data coming from several health centres, that allows both to reduce the acquisition time of different reports and to conduct statistical analysis.

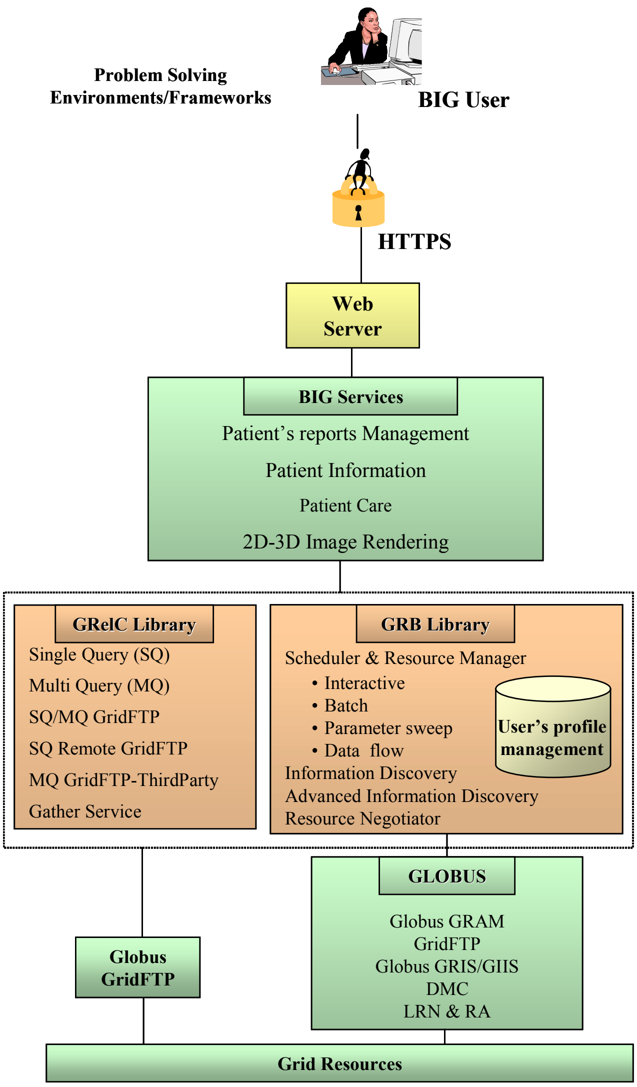

Fig. 5. BIG architecture.

Finally, the last layer includes the computational resources available to a user on the grid.

Operations

The analysis and visualization of the images is offered through a Java Applet allowing local processing and advanced capabilities. For security reasons, a generic applet can only communicate with the server from which it has been downloaded; therefore we made the choice to establish TCP/IP sockets between applet and an application server for inter-exchange of data. The application server, receiving a client's request, queries a local database and locates the machine where the examination file is stored.

Moreover, the application uses some functions of the GRB and GRB-GSIFTP libraries, that authenticate and authorize the user to access the grid and therefore the machine where the file is stored, for carrying out the partial transfer of the image on the machine where the web server is running (2D images) or processing a 3D algorithm on the remote machine where the image is stored and using specific functions of the GRB-GSIFTP libraries to transfer data (3D images).

At the back-end or data level, a database prototype, containing patient information, has been implemented using PostgreSQL 7.4. The main tasks of the this level are:

- to verify the authentication information;
- to find the grid node/s where the image is stored;
- to transfer the image file to the high-performance computing node on the grid;
- to start on such node the rendering and/or slicing algorithms that produce, respectively, a 3D rendering of the image or a slice used on the client browser to build a 2D view;
- to deliver the computation results to the application level and in turn to the user level.

5. THE BIG PROTOTYPE

From the Home Page, an authorized user, accesses a login page. These data are delivered to a Java Servlet that carries out authentication and authorization. If this operation succeeds, it is possible to access a menu page where the user can select a patient in a given health centre or search all of the information of a patient, carrying out searches/services such as statistics on achieved diagnosis.

Figure 6 shows a frame with the most significant sections of the clinical folder, when searching for a patient's data. The portal allows navigation into the medical records independently of the centre where the data are stored; so that the user, typically a doctor, can examine her own patients, search them, or insert a new entry.

The clinical folder of the patient is composed by many sections (as described in Section 2) each one devoted to a particular examination, where appointments and their most relevant data are listed in reverse chronological order. This way, the clinical situation and history of the patient is available at a glance and the user can select a particular activity of interest to see detailed information. Any modification of the patient data and related appointments is possible; of course it is also possible to add a new clinical activity or delete an existing one, if necessary. Moreover, the user can visualize at a glance all of the examinations made by the patient. Finally, a snapshot of 2D and 3D images of same examination is reported.

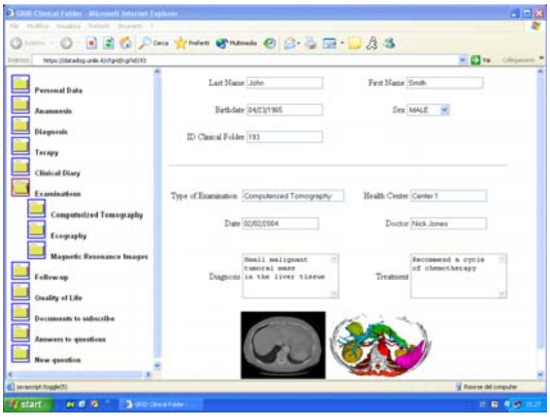

Fig. 6. The clinical folder of a patient. The summary and all clinical sections are visible.

In particular, the Personal Data section contains both a summary of general information about the patient and her general practitioner to allow collaboration and health care continuity. Figure 6 shows the form related to a list of examinations. For each examination, the health centre of acquisition and the date, the doctor that made the examination, the diagnosis and the treatment are reported.

When the user has selected the type of examination, the image analysis applet is downloaded and activated on the user browser, then the examination identifier number is stored by means of a cookie.

In Fig. 7a, the horizontal section of the first section is visualized. Moving the mouse on the image, it is possible to visualize the coordinates of every point (x and y), the associate Hounsfield unit (HU) value and the total number of sections. In Fig. 7b the frontal (e.g. x=300 fixed) section is shown. In Fig. 8a, the horizontal view of the 3D image is represented. Finally, in Fig. 8b the frontal view of the 3D image of Fig. 6a is presented.

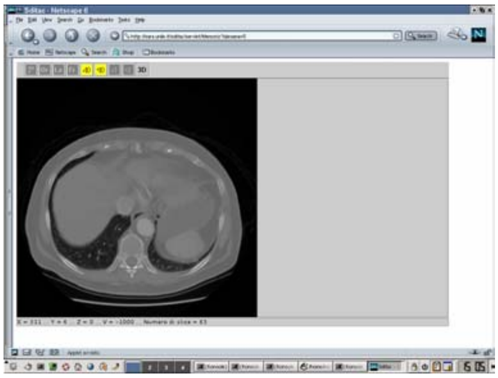

Fig. 7a. CT Image (2D) horizontal section.

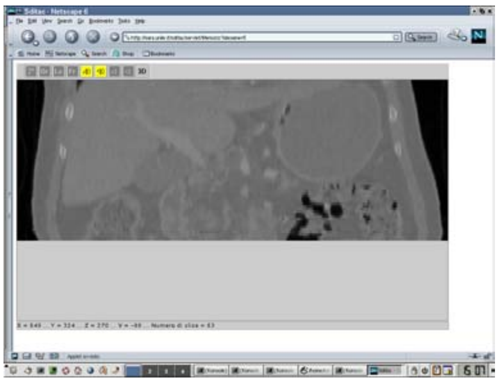

Fig. 7b. CT Image (2D) frontal section.

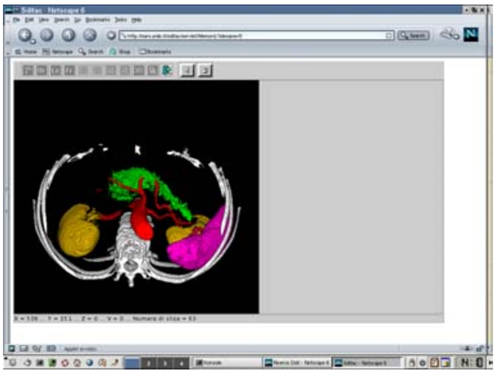

Fig. 8a. CT Image (3D) horizontal section.

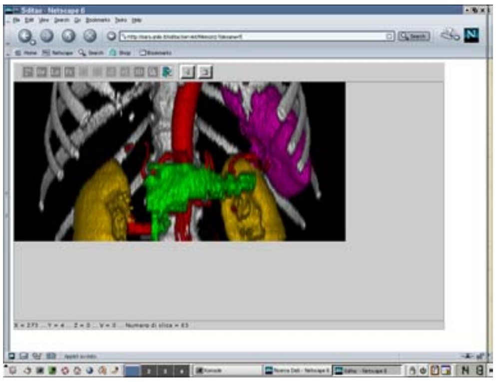

Fig. 8b. CT Image (3D) frontal section.

6. CONCLUSIONS

The main result of this work has been the design and implementation of BIG, a web portal for the management of data, collect into a clinical folder, the processing and delivering of biomedical images on the grid. Moreover, the system allows sophisticated processing (2D and 3D rendering) of CT and MRI images, realized partly on the server side, to improve the performance, and partly on the client side, to improve interactivity. Future work includes the parallelization of the reconstruction phase of the images on the nodes of the grid. Moreover, we are planning to encapsulate and expose the basic functionalities of BIG as Web Services [20] allowing the development of new health applications as a composition of such services. In the future, we plan to migrate some of the BIG services as Grid services, using OGSA [21] (Open Grid Service Architecture) and the emerging WSRF [22], allowing to use BIG Grid Services (analysis of patient data, 2D and 3D rendering) in other grid applications.

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