# A GRID PLATFORM TO SEARCH A SPECIFIC ENVIRONMENT FOR A VIRTUAL SURGICAL SIMULATOR

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**Abstract: It is very important that a Training Centre is able to carry out the same surgical procedure on a variety of different case studies, studies which differ in terms of the pathology, the anatomical structure and the patient's age. The aim of this paper is to present a grid platform which makes it possible to search a specific virtual environment, built from real patients' images, in order to perform training on different cases of the cathetering procedure using a virtual simulator. The system takes into account the results of the HERMES Project and the idea is to obtain a virtual environment based on real patients' images and to use a Web Portal to search a virtual environment with specific features in terms of pathology or anatomy. The VE is located in geographically remote medical centres and must be downloaded on the training centre in order to be integrated in the local simulator.**

## Introduction

Minimally invasive surgical methods require different training from traditional techniques; frequent training should be carried out in a safe environment which mimics the anatomy and physiology of the body as closely as possible in order to ensure adequate transfer of skills. In addition, these procedures need to be learned through repetition. Virtual reality computer based simulators make it possible to model unusual and rare cases and to practise new procedures while at the same time avoiding risks for real patients.

It is very important that a Training Centre can carry out the same surgical procedure on a variety of different case studies, studies which differ in terms of the pathology, the anatomical structure and the patient's age, so that they correspond to several virtual patients, each of them exhibiting a particular difficulty.

Recent advances in information technology allow for the effective development of user interfaces for computing programs and data processing. Grid computing is an emerging technology which makes it possible to share resources such as computational power, high performance devices, data and database. Computational grids enable transparent access to a wide variety of geographically distributed resources and their sharing, facilitate selection and aggregation of distributed resources for solving large-scale computational and intensive problems in different applications.

New information architectures enable new approaches to accessing valuable data and programs. Service-oriented architectures allow developers to encapsulate services that clients can access without knowledge of their internal workings. Thus, tools formerly accessible only to the specialist can be made available to all. Grid technologies can accelerate the development and adoption of service-oriented science by enabling a separation of concerns between discipline-specific content and domain-independent software and hardware infrastructure.

The aim of this paper is to present a grid platform which makes it possible to search a specific virtual environment, built from real patients' images, in order to perform training on different cases of the cathetering procedure using a virtual simulator.

## Technology Background

The proposed architecture is based on Web Services technology; Web Services have emerged as the standard-based framework for accessing network applications.

"A Web Service is an interface that describes a collection of operations that are network-accessible through standardized XML messaging. A Web service is described using a standard, formal XML notion, called its service description. It covers all the details necessary to interact with the service, including message formats (which detail the operations), transport protocols and location. The interface hides the implementation details of the service, allowing it to be used independently of the hardware or software platform on which it is implemented and also independently of the programming language in which it is written."[1]

The Web Services approach is based on a maturing set of standards that are widely accepted and used. This widespread acceptance makes it possible for clients and services to communicate and understand each other across a wide variety of platforms and languages.

In Web Services there is the convergence of two key technologies: Web and Service-Oriented Computing, which make it possible to build new distributed applications and to integrate existing applications.


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What the Web did for program-to-user interactions, Web Services are poised to do for program-to-program interactions. They are based on a common program-to-program communications model, built on existing and emerging standards such as HTTP, Extensible Markup Language (XML), Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL) and Universal Description, Discovery and Integration (UDDI) [2], [3].

Web services refer to the invocation of remote methods (functions) using an XML-based protocol and method interface definitions. The protocol (usually SOAP) is attached to a HTTP message and contains, for instance, the name of the method and necessary parameters needed to invoke the remote service. The method interface (WSDL) is an agreed-upon set of methods, parameters and return types for a particular service and can be viewed as a list of instructions for building clients [1].

The eXtensible Markup Language (XML) has become the de facto standard for describing data to be exchanged on the web and is used to define general objects in an intuitive format and to specify resources in portals; it contains structured information and is designed to describe data and to focus on what data are.

Portals are commonly used to provide people with access to information and applications in a condensed form. Typically, portals display personalized information from various sources in a single page, thus allowing the user to efficiently access this information instead of visiting various Web sites one after the other. As Web Services become the predominant method for making information and applications programmatically available on the Internet, portals and portal development tools need to allow for the integration of Web Services as data sources.

**Related Works**

**From Medical Imaging to Virtual Reality Environments**

In recent years, the biomedical imaging modalities such as Magnetic Resonance Imaging (MRI), Computer Tomography (CT) and Ultrasounds have become essential in identifying, diagnosing and localizing structures and abnormalities. Traditional methods for evaluating data required the viewer to mentally reconstruct a volume from a series of radiographic films or two-dimensional images. The advent of real-time three-dimensional visualization has enabled interactive examination of the internal and external structures from any viewpoint.

RadioDexter 1.0 generates a stereoscopic virtual reality environment in which a user can work interactively with real-time 3D data. RadioDexter processes data from CT or MRI, as well as volumetric ultrasounds. A variety of virtual tools for visualization and surgical planning are accessible while working inside RadioDexter's 3D virtual workspace. This allows the user to work with complex multi-modal imaging data in a fast and intuitive way, for a clear three-dimensional understanding of the patient's anatomy and for improved treatment planning [4].

The Virtual Reality in Medicine Lab (VRMedLab) at the University of Chicago uses VR displays developed by the Electronic Visualization Laboratory for their projects. They began with a virtual temporal bone, virtual pelvic floor and virtual craniofacial anatomy to teach their surgical residents as well as share their surgical expertise with other institutions throughout the world. Their networked system provides a way of taking the patient's CT data and within 10 minutes have it up on their VR system, available to be reviewed from any place in the world where they have at least a desktop VR system [5].

Freidlin et al. of Center for Information Technology of National Institutes of Health (Bethesda), have been developing NIHmagic, a visualization tool for research and clinical use, on the SGI Onyx II Infinite Reality platform. Images are reconstructed into a three-dimensional volume by volume rendering, a display technique that employs three-dimensional texture mapping to give the object a translucent appearance. A stack of slices is rendered into a volume by an opacity mapping function, where the opacity is determined by the intensity of the voxel and its distance from the viewer. NIHmagic incorporates the 3D visualization of time sequenced images, the manual registration of 2D slices, the segmentation of anatomical structures and the coloured coded remapping of intensities [6].

**Web Services for Image Searching**

Several projects deal with developing data management architectures using the grid and web services technologies.

The Biomedical Informatics Research Network (BIRN) creates a long term and robust infrastructure for data sharing and collaboration in biomedical science on a large scale (15 Universities and 22 Research Groups connected through Internet2). A processing pipeline has been developed to analyze and mine MR images acquired at multiple sites using processing and visualization tools developed at multiple sites [7].

At ICM (Interdisciplinary Centre for Mathematical and Computational Modelling), Warsaw University, Poland, a general framework for implementing a wide range of user applications has been developed; in order to support users with dedicated biomolecular services, a BioGRID portal that provides information on resources available, together with description of models, codes and links to most relevant related materials, has been set up and it is being further developed [8].

The European Grid of Solar Observations (EGSO) is employing the grid computing concepts to federate heterogeneous solar data archives into a single virtual archive, allowing scientists to easily locate and retrieve particular data set within the grid. The web services have been used in EGSO as a means of communicating between the various roles in the system [9].

Liu et al. have developed an unified referral information system in which patient care records can be shared among hospitals over the Internet. The XML-based medical records enable a computer to capture the meaning and structure of the document on the web [10].

TACWeb is a web-based grid portal developed for the management of the biomedical images in a distributed environment. Building on top of the Globus Toolkit, it is an interactive environment that deals with complex user's requests , such as the processing and delivering of biomedical images using the power and security of computational grids. The web services approach is exploited in the architecture design [11].

## Training Simulator

A simulation system to perform training on the cathetering procedure has been developed taking into account the results of the HERMES Project (HEmatology Research virtual MEdical System) managed by Consorzio CETMA, Brindisi, Italy; the aim of this project is to build an integrated system to simulate an angioplasty intervention [12].

The designed training simulator consists of a virtual environment and a haptic interface, a device able to reproduce on the user the force feedback generated during the interactions in the virtual environment.

The user interacts with the training system using the haptic interface and data acquired from haptic device sensors are used to represent the instrument's position in the virtual environment and to determine possible collisions between virtual objects. Movements of haptic devices lead to changes in the virtual environment representation; collisions between virtual objects produce forces that are replicated on the surgeon's hand by the haptic interface.

The scheme of the simulator is shown in Figure 1.

The haptic interface, designed and built by the PERCRO Laboratory of Scuola Superiore S. Anna, Pisa, Italy, reproduces the real surgical instruments used by the cardiologist. This device is provided with two degrees of freedom which produce force and torque resistance [13]. As shown in Figure 2, the system responds to the following forces applied by the user:

- the longitudinal forces in the form of push and pull movements;
- the torque forces in the form of twisting around the longitudinal axis.

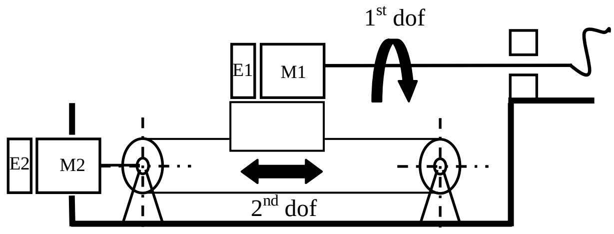


Figure 2: Degrees of Freedom of the Haptic Device

Since the arteries are soft tissues, their shape may change during an operation; for this reason physical modelling of the organs is necessary to render their behaviour under the influence of surgeon's instruments. The Finite Element Method (FEM) has been used to model the soft tissues of the artery, using linear elasticity to reduce computational time and speed up interaction rates [14].

In the previously developed simulator the virtual environment was built using advanced CAD modelling techniques and taking into account the anatomical models described in medical literature. As described in this work, an improvement could be obtained by building the virtual environment from the real patients' images.

## Virtual Environment from Real Patient's Images

Recently, the use of digital images for medical diagnosis has increased considerably. New and better applications are therefore needed in order to effectively manage such information.

To build a virtual environment from the real patients' images, the geometric models of human organs have been reconstructed using data acquired by a CT scanner; data are processed to distinguish the anatomical structures and to associate different chromatic scales to the organs.

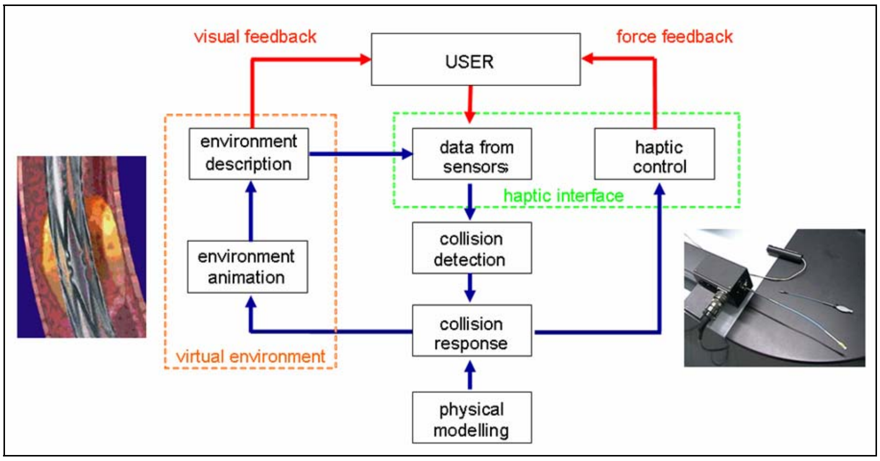


Figure 1: Scheme of the Training Simulator


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In order to carry out a high quality recognition of the tissues it is necessary to use the correlative information obtained in the three acquisition phases. Due to the distortion produced by the movement of the organs, the three images have to be aligned, using a morphing algorithm, and then recognized, using a clustering algorithm.

Multi-spectral classification uses registered 3D image volumes from more than one imaging modality or from different sequences within a modality to classify tissues within those volumes. The complementary information contained within the different image volumes may allow for the separation of tissue class types. The segmentation and classification phases are carried out in order to obtain information about the size and the shape of the human organs [15].

A Region Growing Algorithm has been used in the segmentation phase; whereas the classification phase is a user-driven process [18], [17]. In order to obtain the triangulated model of the organs, the Marching Cubes Algorithm has been used [19].

The data processing procedure is performed in an off-line phase before starting the real-time simulation. This process of virtual environment building has been applied to the abdominal region of a human body in a previous project [20]. Figure 3 shows the different steps necessary to integrate in the surgical simulation a virtual environment built from real patient's CT scan images.

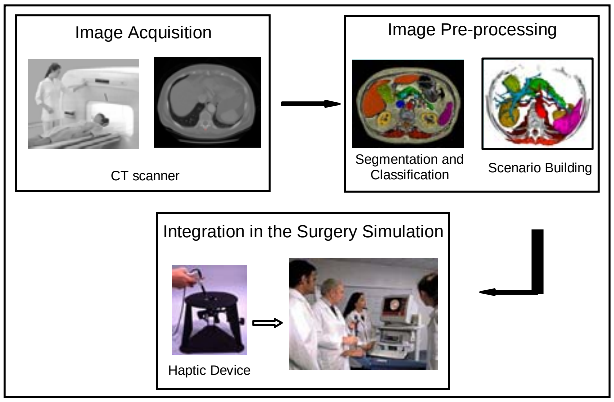


Figure 3: Integration of the Virtual Environment

**System Architecture**

We are developing a service-oriented architecture that wraps virtual medical environments and data applications as Web services. These services are capable of satisfying multiple client requests at the same time.

Our idea is to obtain a virtual environment based on real patients' images and to use a Web Portal to search a virtual environment with specific features in terms of pathology or anatomy.

The VE is located in geographically remote medical centres and is downloaded on the training centre in order to be integrated in the local simulator; this happens independently of the medical centre where the data has been generated.

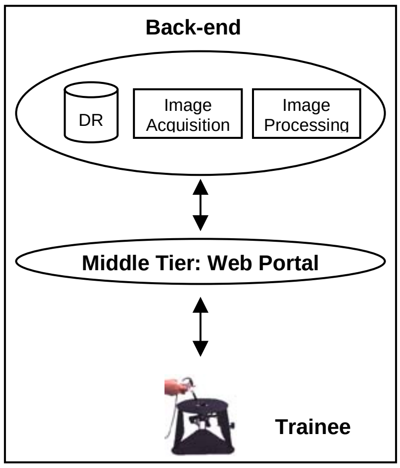


Figure 4: The Proposed 3-Tier Architecture

The proposed system exploits a 3-tiers architecture [21] as shown in Figure 4:

- the trainee tier where the search starts using a browser and the decompression of the virtual environment happens;
- the middle tier where the web portal is located with the list of metadata;
- the back-end where the building of the virtual environment is carried out and the data repository is located.

Due to the complexity of the data stored in the medical centre databases, the searching of the desired virtual environment is based on the descriptive information stored with the data (metadata). Virtual environments are saved on a database with the relevant metadata.

The scenario is shown in Figure 5 where the main components of the system are:

- **Training Centre** where the user can perform training on the different surgical procedures and where the specific haptic devices are available;
- **Data Gather Server** where metadata of the virtual environment of different medical centres are collected;
- **Medical Centre** which provides the access to the local Data Repository;
- **Data Repository** where the different virtual environments are physically contained with the relevant metadata.

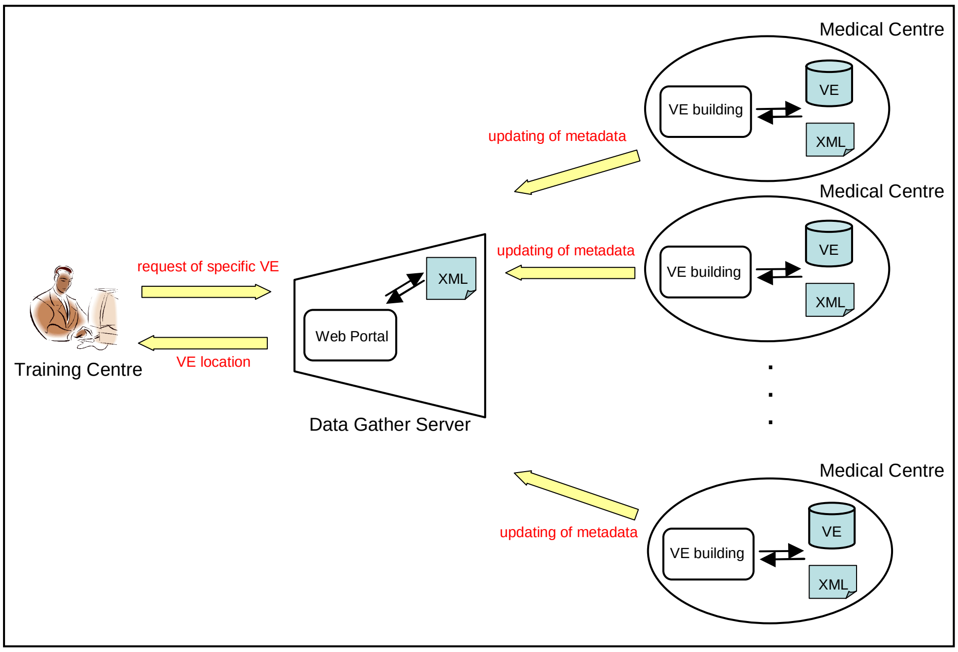


Figure 5: Grid Platform to Search Medical Images

The functional architecture of the system defines several Medical Centres in which virtual environments built from the medical images and related metadata with specific features in terms of pathology or anatomy are stored. An upgraded list of the metadata is present on the web portal and indicates the Medical Centre where the virtual environment is stored.

The searched data are downloaded from the Medical Centre to the Training Centre using a compression technique based on Edgebreaker algorithm, which is a method for compressing 3D data sets and specifically triangle meshes [22].

Each Training Centre is provided with a specific haptic device and with the software necessary both to manage the interaction in the virtual environment (collision detection and response algorithms) and to obtain realistic deformations of the organs (physical modelling algorithm). After the integration of the virtual environment in the simulation system it is possible to perform training on the specific surgical procedures.

The web portal is written using JSP technology and it interacts with the Medical Centres using the Web Services technology, the fundamental building blocks in Internet distributed computing. In this way the data exchange between Medical Centres and web portal occurs automatically when new data are generated in a Medical Centre; these data are collected in a centralized database examined from the web portal. The implementation details of the service are hidden, so the services can be used on a platform-independent basis.

A descriptive information of the virtual environment (metadata) is defined using the XML technology and it is stored with the data. Figure 6 shows an example of an XML file where information about patient, pathology, stenosis and type of stent are included.

```
<?xml  version="1.0" encoding="UTF-8"?>
   <medical centre>
      <id>CM1</id>
      <name>Ospedale V. Fazzi</name>
     <town>Lecce</town>
   </medical centre >
   <pathology>angina</pathology>
   <image acquisition>
        <type>CT</type>
        <date>16/12/2003</date>
   </image acquisition>
   <patient>
         <code>123453</code>
         <gender>F</gender>
         <age>38</age>
         <other pathologies >
              <pathology 1>cardiopathy</pathology 1>
         </other pathologies >
   </patient>
   <stenosis>
         <degree>50%</degree>
   </stenosis>
   <stent>
         <type>small</type>
         <material>steel inox 316 LVM</material>
         <diameter>4-7 mm</diameter>
         <length>10-20 mm.</length>
   </stent>
   <surgical procedure>
       catheter in femoral artery
   </surgical procedure >
```

Figure 6: example of XML file

## Conclusions and Future Work

A 3-tier architecture which makes it possible, using a Web Portal, to look for a virtual environment with specific features in terms of pathology or anatomy is presented. This virtual environment was built from real patients' images and, after downloading from the medical centre, it can be integrated in the surgical simulator to perform training on the cathetering procedure.

Each virtual environment has the relevant metadata and the Web Services technology is used to interact with the Medical Centres. The building of the web portal with an upgraded list of all metadata is in progress. In collaboration with physicians a more accurate definition of the specific metadata is in progress.

The building of the surgical simulator and the implementation of the different steps to obtain the virtual environment have been carried out; a remarkable improvement in terms of the visual rendering has been obtained using virtual environments built from real patients' images.

It will be necessary to adopt a correct security policy to exchange data between the training and the medical centres. At the end the platform must be validated in collaboration with physicians.

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