Integrating patient-oriented data processing into the PREPaRe virtual hospital using XML technology

René Tschirley, Kai Köchy, Steffen Märkle

Dept. for Computer Science and Computer Assisted Medicine, Technical University of Berlin, Franklinstr. 28/29, D-10587 Berlin, Germany, http://prepare.cs.tu-berlin.de

Abstract

The PREPaRe system (Personal Repository for Electronic Patient Records) is a patient-oriented internet-based information system that is able to store, combine, process and visualize all types of medical data that are part of a "personal electronic medical record".

This paper discusses the integration of data acquisition, data preprocessing and visualization aspects using XML technology.

Key words: Electronic Medical Record, Patient-oriented visualization, XML

1 Introduction

Existing medical software systems are designed either for medical and administration personnel or for patients. The apparent reason is that in many cases, patient-related data are difficult to handle because medical image sequence data are hard to understand without a priori knowledge. With today's systems, the patient has no access to his electronically stored data. Software for patients, either available through the Web or as commercial application, offers visual information not on their own data but on exemplary data.

The PREPaRe system provides interested patients with the possibility to review their own medical data at home, at a special service center or at the physician's office. Personal computers have become inexpensive and relatively easy to use. The Internet as enabling technology for data communication can be utilized from almost any office or household. This technical and socioeconomic development has led to a situation where it appears to be appropriate to assume that a large number of patients is able to access Internet based information systems and build a "personal electronic medical record" (PEMR)

for their personal usage. As most patients are not able to control neither the preprocessing of medical data nor the visualization process due to the lack of medical knowledge, the system provides the required knowledge and derives easy to understand graphical data from different types of multidimensional medical data using well-known segmentation and registration techniques.

2 Methods

2.1 Data Acquisition

Medical image acquisition includes several modalities like CT, MRI and PET. Volume data are stored in various types of clinical information systems like hospital information systems (HIS), radiology information systems (RIS) or picture archiving and communication systems (PACS). Mostly, volume data are stored in databases which follow the DICOM standard [1]. The standard was developed for diagnostic imaging and defines data structures and encoding, message and data exchange, file and media formats for communication and storage.

The PREPaRe system is an Internet based information system that provides a single point of access to the data of a PEMR. For data retrieval it shall provide an interface which allows secure access to the clinical information systems. In collaboration with the physician, the patient creates his/her own PEMR by accessing the clinical information systems. According to the patient's needs the physician grants the patient permission to access selected data which will become incorporated into the PEMR. Recent research showed several implementations of gateways which provide access to DICOM databases [2] and realize a secure environment using commonly available cryptography and user authentication [3]. The PREPaRe system uses the DICOM standard for information retrieval.

2.2 Data Processing

With the patient's data and a knowledge database available, a media server converts the raw binary data into a presentation which fits the user's wishes.

The appropriate type of visualization of medical circumstances depends on the type of data, anatomic location of the data and the type of disease. This information may be used to select a special type of presentation by matching this triple to a set of predefined presentation sequences (see figure 1). A presentation sequence can be regarded as story board of what the patient shall be able to see. It determines the generation of the extended anatomic information (XAI) which will be shown to the patient. If more than one presentation sequence is available, user interaction is required.

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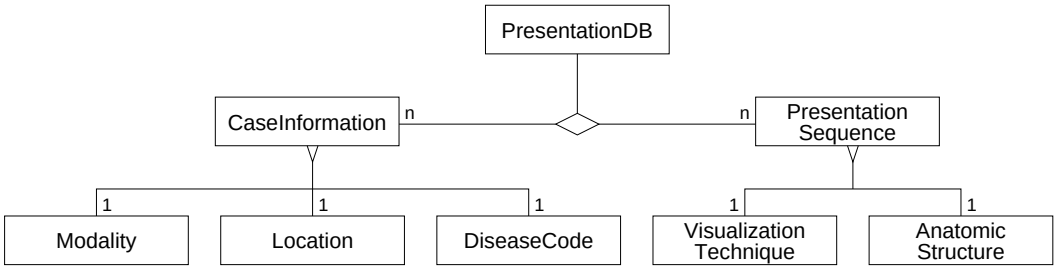

Fig. 1. Compound of patient-specific case information and presentation sequence.

An exemplary sequence would be the presentation of a slightly visible skin surface for recognition of the anatomic location, a semi-transparent bone surface of the patient's knee joint, extracted from the patient's CT volume and a highlighted area of a cartilage defect. With respect to the aspired presentation sequence, the correct segmentation algorithms are chosen from the enhanced anatomic atlas [4]. Skin and bone surfaces can easily be obtained by applying a simple pipeline including the marching cubes algorithm and a few corrections such as thresholding, smoothing, noise and small objects filtering and triangle decimation according to the system performance. Segmentation of certain anatomic regions can be realized by first registering the patient's volume data to a generic anatomic atlas. After successful registration, both volumes can be merged. Then the manually assigned anatomic information of the anatomic atlas can be transferred to the patient's data which enables the usage of different well-known segmentation algorithms by providing seed points and surfaces.

During the last years, much effort in research and development has been expended to create segmentation algorithms which do not need human interaction or which require at least few human interaction [5]. Main objectives in the development and enhancement of these algorithms is accuracy and reliability. Sometimes, algorithms for segmentation or registration produce a useless result. This can be tolerated due to the fact that the user of a clinical software application is well-educated and can easily notice the error. For the PREPaRe system this can not be tolerated. The algorithms have to lead to usable results or at least have to detect such error conditions.

This apparently difficult problem is compensated by a reduced demand of accuracy. While for diagnostic visualization high accuracy is essential, reduced accuracy is acceptable for the patient-oriented visualization. This reduces constraints for the segmentation process allowing more flexibility e.g. for thresholding and smoothing algorithms. The legal and ethical implications of this, however, require further investigations which are out of the scope of this paper and therefore not discussed. It is indisputable that a patient-oriented information system can only be a supplement of the patient's relation to the physician. The physician is still in charge of informing and treating the patients as good as possible.

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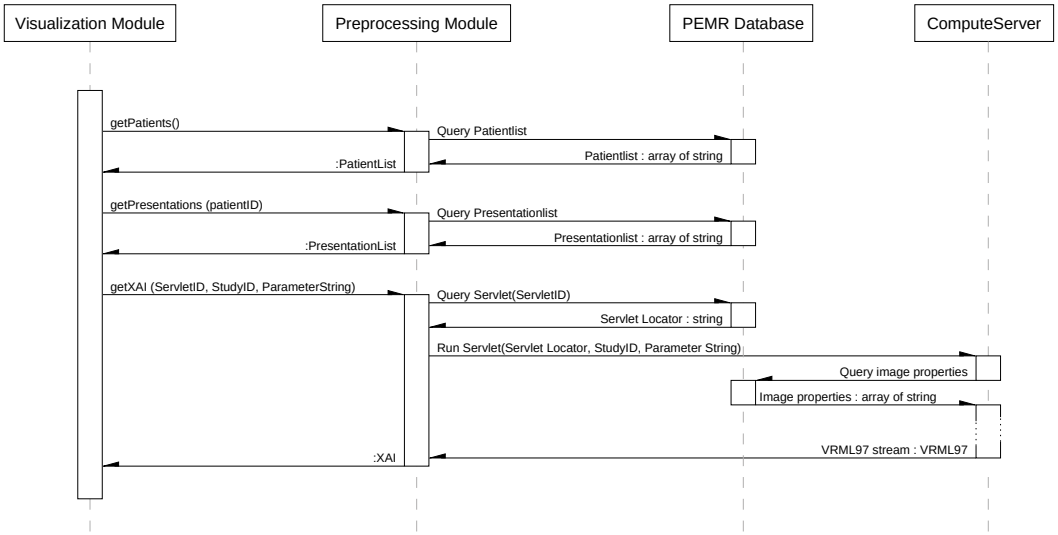

Fig. 2. Communication for XAI generation based on XML-RPC.

2.3 Visualization

A visualization engine generates the graphic output from the XAI dataset according to the presentation sequence, e.g. an isolevel reconstruction of muscle and bone tissue or x-ray views using e.g. maximum intensity or composite projection.

To be easy to understand and immersive, the PREPaRe system's user interface is an Internet based virtual hospital. As described in [6] and [7], a virtual environment is the natural way of recognizing and examining spatial representations of anatomic information. Besides a micro world of anatomical structures of the patient, the hospital's facilities which represent a macro world, are visualized. Combination of the macro world and the micro world creates an immersive multidimensional holistic view of the PEMR's medical image data and is more intuitive than a common web application which uses only two dimensional windows and buttons.

2.4 Media Server Message Exchange

XAI generation is performed in several passes which require communication between user client and media server (see figure 2). First, the user client matches the patient's identity with the database to obtain the datasets which the patient has access to. Subsequently, the media server checks the contents of these datasets and computes a list of available presentation sequences. The list of presentation sequences is returned.

After selection of the favored presentation sequence the media server triggers the compute server to create the XAI dataset. The compute server retrieves the patient's data from the PEMR database and returns the XAI after processing

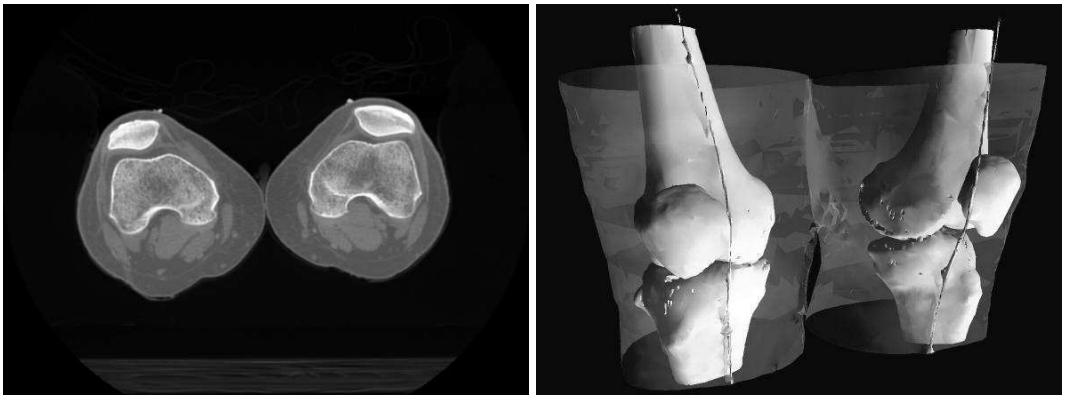

Fig. 3. Conventional CT slice for diagnosis (left) and machine generated VR view (right).

the volume data to the user client for visualization.

3 Results

With respect to the distributed architecture of the PREPaRe system, a platform independent implementation is essential. The implementation exclusively uses noncommercial Open Source Software. The implementation of server and client software is realized in platform independent languages like Java and Ruby [8].

The viewer applet was implemented in Java3D and first prototypes run with Microsoft Windows and Linux/i386. Communication with the media server uses XML-RPC [9]. The media server uses a SQL interface [10] which establishes a link to the PEMR database. Both the personal repository and the presentation database are realized as MySQL databases [11]. The compute server uses C++ as native language for segmentation and registration algorithms and utilizes the Linux version of Kitware's Visualization Toolkit [12] and custom extensions for creation of the XAI dataset. Extracted anatomic information is transmitted as XML document.

4 Conclusion

The PREPaRe system provides components that allow a patient to experience health care as an integrated process that is not only carried out in wards and hospitals but continues at home. The presented application enables the patients to view and understand their medical data using a complex visualization tool until now only available to experts.

Provision of 3D models of hospitals and visualization of medical data enable patients to virtually visit the health care center at will. To achieve a user inter-

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face which does not require a priori knowledge, extended anatomic information is generated by appropriate usage of segmentation and registration algorithms and knowledge databases. Focus of the current research is the improvement of the segmentation and registration process.

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