

# Patient-oriented Segmentation and Visualization of Medical Data

René Tschirley    Kai Köchy    Steffen Märkle  
Dept. of Computer Graphics & Computer Assisted Medicine  
Technical University of Berlin  
Franklinstr. 28/29, 10598 Berlin, GERMANY  
email: cg@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".

Focusing on patients as the system's end users results in requirements which are hard to meet and make extensive data preprocessing essential. Extended anatomic information is created from the patient's data and an enhanced anatomic atlas. Based on this information, patient-oriented, disease specific visualization of the patient's anatomy is derived. Embedded into a three dimensional virtual world it provides easily recognizable access to the medical circumstances.

## KEY WORDS

Information Visualization, Medical Imaging, Visualization and Knowledge Discovery, Visual Software

## 1 Introduction

As described in [1], computers are used in medicine to improve quality and efficiency in health care processes. Increasingly, medical institutions integrate computer generated image data into an "electronic patient record" (EPR).

Existing software systems are designed either for medical and administration personnel or for patients. The apparent reason is that understanding real world medical data needs a-priori knowledge which the medical and administration personnel have but the patient is not acquainted with. As a consequence, software for expert users offers detailed information about the patient's medical data which are stored in the patient's EPR [2].

If interested, patients should have the possibility of participating more actively in their personal health care process. Participation starts with the dialog between patient and physician and continues at home where the patient can review the dialog utilizing his patient record. Available software for patients offers visual information not on their own data but on exemplary data.

Designed to bridge the gap between both types of applications the PREPaRe system provides patients with access to their medical data. This paper focuses on visualization aspects of the PREPaRe system. Firstly the data that

are used for preprocessing and the data's type and origin are described. Techniques being utilized to derive an extended set of information are discussed in detail and an outline of the scope of duties of the visualization engine is given.

## 2 Concept

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.

The PEMR is based on references to medical data from various types of clinical information systems like hospital information systems (HIS), radiology information systems (RIS) or picture archiving and communication systems (PACS). The PREPaRe system is an internet based information system that provides a single point of access to the data of a PEMR. Whenever the data source is not directly available through the internet patients are able to provide their own medical data e.g. on a CD-R, DVD/R or magneto-optical disc.

To follow the patient's needs, the PREPaRe system provides a concept to generate easy to understand graphical data from different types of multidimensional medical data. Starting either with computed tomographies (CT), magnetic resonance images (MRI), positron emission tomographies (PET) or similar types of volume data and using the presentation database and anatomic atlases the system derives *extended anatomic information* (XAI). Besides the multidimensional data, the XAI includes tissue classification which is needed for a proper visualization.

When entering the PREPaRe system, the user has to prove his identity by either a user name/password combination or a mechanism similar to the health professional card (HPC) which is used for authentication of medical personnel. After user identification information entities are created from which the user may select the one to be shown. These entities can be personal, e.g. medical examinations

with data extracted from the PEMR which is explained in subsection 2.1 or generic such as information about diseases or hospitals which is explained in subsection 2.3. The user selects the desired topic and the computer starts the related presentation sequence.

## 2.1 Data Preprocessing

In many cases, patient-related data are difficult to handle because medical volume data like a CT or MRI is hard to understand without a priori knowledge. To be able to interpret MR images for example, the viewer should be familiar with terms like proton concentration, inversion recovery sequence, spin echo sequence or at least with the difference between T1- and T2-weighted images. When interpreting a PET the viewer should be aware of the meaning of areas of higher positron emission. Due to the fact that patients rarely possess this knowledge, the PREPaRe system has to provide any information necessary to transform the medical data into easy to understand information.

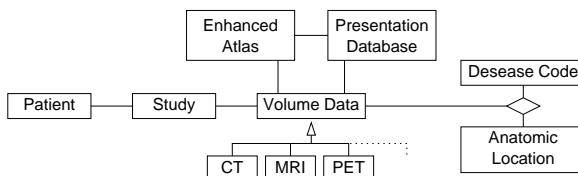
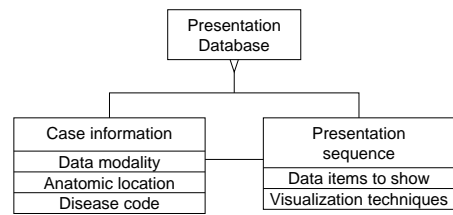


Figure 1. Diagram of data preprocessing object dependencies.

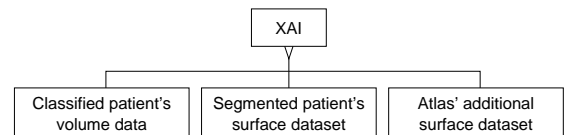
The appropriate type of visualization of medical circumstances depends on the type of data and the type of disease. Both types can be extracted from the PEMR. Standards for storage of medical image data propose to keep information explaining the data's origin (e.g. different modalities like CT, MRI or ultrasound) along with the image data. Standards for electronic patient records contain diagnosis codes which are used to specify diseases uniquely. This code is used to select a special type of presentation which will fit the patient's needs.

As shown in figure 2(a) the presentation sequence depends on two other parameters, the patient's volume data, modality and the anatomic location. These three parameters build the *case information* that is used to determine the proper presentation sequence. The presentation database associates one or more presentation sequences with the case information.

A presentation sequence can be regarded as story board of what the patient shall be able to see. It determines the XAI to show to the patient. An exemplary sequence would be the presentation of a semi-transparent bone surface of the patient's hip joint, extracted from the patient's CT volume and a highlighted area of cartilage defect. In this example, the presentation database would provide all information about the requirements for such a visualization.



(a)



(b)

Figure 2. Class diagram of system components (a) presentation database and (b) extended anatomic information.

Combination of the preprocessed patient's data and additional data from the enhanced atlas is defined as XAI as shown in figure 2(b). Taking the presentation sequence which determines what information to show to the patient in what manner and the XAI which contains the concrete data, the visualization engine can easily derive and display a three dimensional model using standard visualization techniques.

In most cases the generation of the XAI requires computer-based image and volume segmentation and registration which is discussed later. As described, the sole presentation of the output of standard visualization techniques as e.g. the maximum intensity projection of a CT volume can not be regarded as being easy to understand for a medical layman. The presentation should provide a clear view to different organs like skin and bone. To make use of the tissue classification stored in the enhanced atlas the patient's volume data has to be registered to the atlas. After registration, the correspondence between atlas volume data and tissue classification can be adopted to the patient's volume data.

During 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. Main objectives in the development and enhancement of these algorithms is accuracy and reliability. Sometimes, algorithms for segmentation or registration produce a useless result. Even if being not satisfying it can be tolerated when a clinical software system does not detect this condition, as it can be assumed that the user of a clinic software application is a well-educated person and can easily notice this condition. For the PREPaRe system this can not be tolerated. The al-

gorithms 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. Nevertheless the patients have to be made aware of the fact that the presented data is for information purposes only and not for diagnosis. 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.

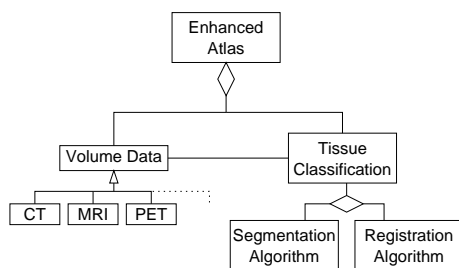


Figure 3. Class definition of the extended anatomic atlas.

Different body locations and organs are best segmented with specific segmentation algorithms. With respect to the aspired presentation sequence, the correct segmentation algorithms are chosen from the enhanced anatomic atlas. Any parameters the algorithm relies on, shall either be provided by the atlas or shall be computer-generated using the presentation database's information. One parameter possibly provided by the atlas is for example the information how a simple segmentation of skin or bone tissue from CT data can be achieved by a threshold operation using the adequate Hounsfield units. With smoothing operations followed by polygon-generating algorithms like marching cubes the system creates a dataset which fits the patient's understanding of the human body.

Some segmentation algorithms rely on starting points which are set by a human operator in medical applications, as seen in region growing and contour tracking algorithms. These interactions can be avoided in some cases if the patient's medical data and the anatomic atlas are registered. It can be assumed that the contours of the atlases organs are good starting points for segmentation.

If human interaction is still required, the medical data have to be prepared by specially educated personnel before the patients can get full access to their data.

## 2.2 Preprocessing pipeline

Figure 4 shows the preprocessing pipeline as a result of the described concept. With the selection of a proper presentation sequence according to the nature of the available patient's data (step 1), segmentation and registration algorithms are defined by the presentation database (step 2). Multiple segmentation and registration steps follow subsequently until the atlas' volume data and the patient's data are congruent (step 3). Adoption of the classification data to the patient's data follows and produces the XAI (step 4).

## 2.3 Visualization

Visualization uses rendering techniques which are well-known in patient-oriented medical software. The following techniques for visualization of three dimensional data are commonly accepted:

- surface rendering of polygonal data
- volume rendering, e.g. ray casting
- visualization of slices of 3D volume data
- blending semi-transparent objects

Using these techniques, the visualization engine generates the graphic output from XAI according to the presentation sequence, e.g. a surface and isolevel reconstruction of muscle and bone tissue or x-ray views using e.g. maximum intensity projection. The set of presentations is offered to the user according to the presentation sequence. If more than one presentation sequence exist, the user can choose from different types of visualization.

Since the patient's medical data are registered to the atlases volume data, the congruence is used as a benefit for the visualization process. The patient's medical data represent only a fraction of the whole body. Recognition of anatomical structures is quite difficult for a medical layman if the spatial context remains concealed. Even if e.g. the paranasal sinuses are much more easy to recognize as segmented objects with surface visualization than on a set of CT slices, a layman will probably miss the relation to the residual body. This relation becomes clear when the whole body is shown.

Consequently the presentation is not restricted to the medical volume data included in the PEMR but offers a holistic view of the whole human body. If required, anatomic information from the atlas supplements the patient's data.

To be easy to understand and immersive, the PRE-PaRe system's user interface is an internet based virtual hospital. As described in [4], 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

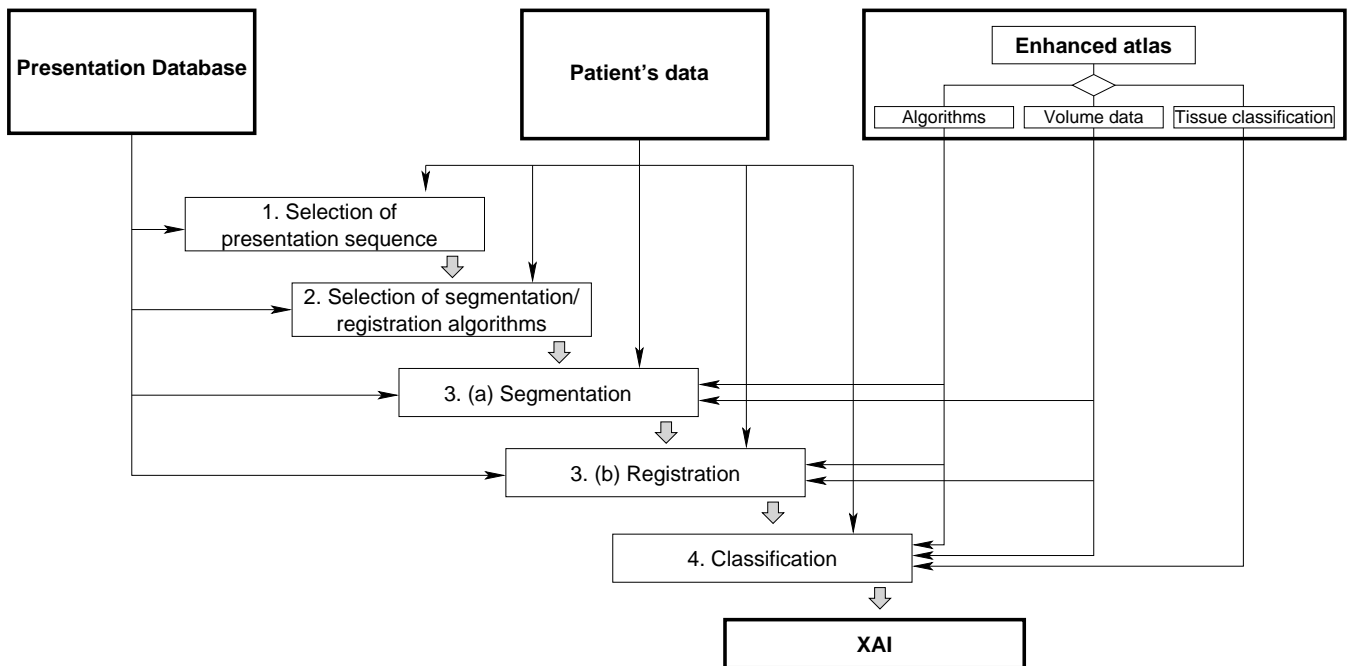


Figure 4. The preprocessing pipeline.

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, frames and buttons.

If desired, the preprocessed data may be linked to external information databases such as online encyclopedias which offer information about anatomical structures or may be embedded in surgical simulations so that the patient can be shown available therapies. When becoming part of the virtual world, the patient can also experience an almost realistic impression of the real health care processes as a visitor to the virtual hospital.

### 3 REALIZATION

Figure 5 shows exemplary views of possible presentation sequences. As shown in figure 5(a) the patient can navigate through a generic operation room to get accustomed with the interior. In order to recognize the spatial coherence a generic body taken from the anatomic atlas is placed on the operation table (figure 5(b)).

On demand, the generic body is replaced by a surface reconstruction of the patient's medical data as shown in figure 5(c). The skin is displayed semi-transparent and permits a view into the body revealing the bone surface. This was achieved with a concrete instance of the preprocessing pipeline: starting with a CT volume of head and upper body the skin was extracted applying the marching cubes algorithm with an appropriate threshold value. Small objects which were not connected to the largest polygon mesh were regarded as unrequested artifacts and were removed.

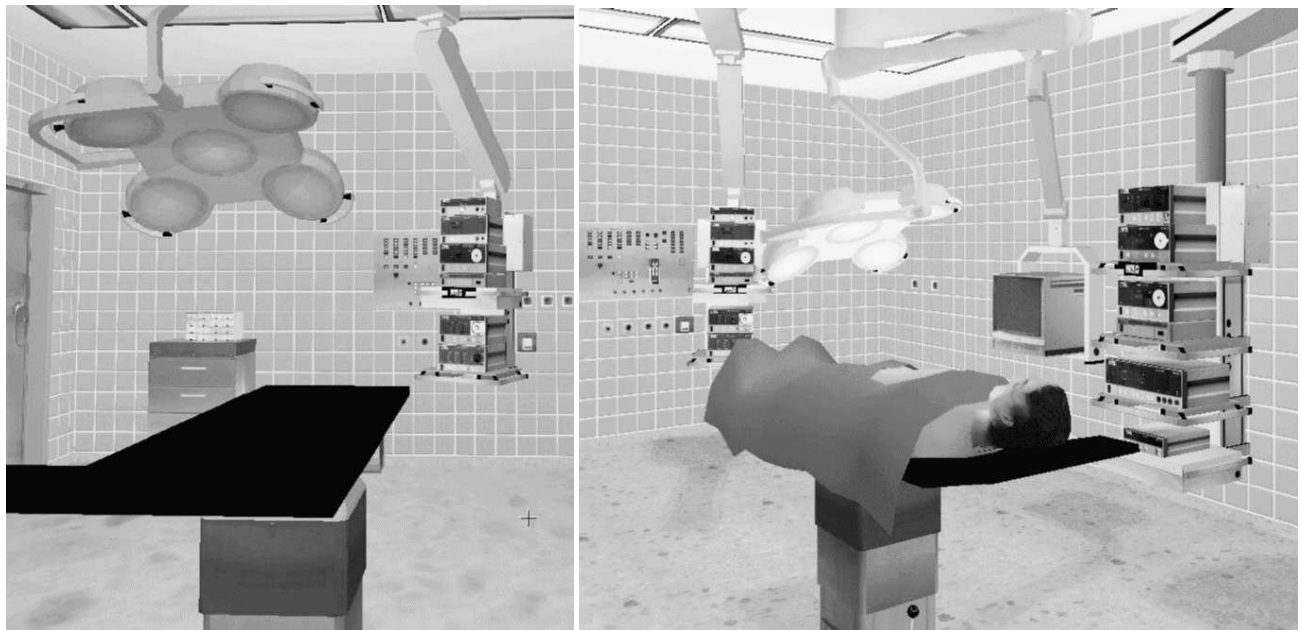
A rigorous decimation of the resulting polygon mesh was applied in order to increase the realtime performance of the prototype. As there is no fusion with anatomical atlas data, it was not necessary to perform a registration. The bone surface was created in analogy but in this case small objects were not regarded as artifacts and were not removed. Instead, the enhanced atlas was instructed by the preprocessing pipeline's definition to remove all generated objects for which the skin surface is no convex hull. Both surface datasets were merged and became part of the XAI for this presentation sequence. A set of slices were added which allow the illustration of the inner structure of the patient's body. The slices are displayed on the monitor in the virtual room.

In this example the presentation database offers another presentation sequence which uses a volume rendering technique (figure 5(d)). This visualization requires special graphic hardware support. Employing OpenGL's three dimensional textures the current implementation produces a maximum intensity projection from the patient's volume data.

The example shown in this paper is an early result of the PREPaRe system. Work is still in progress as especially segmentation and registration algorithms require further evaluation and investigation.

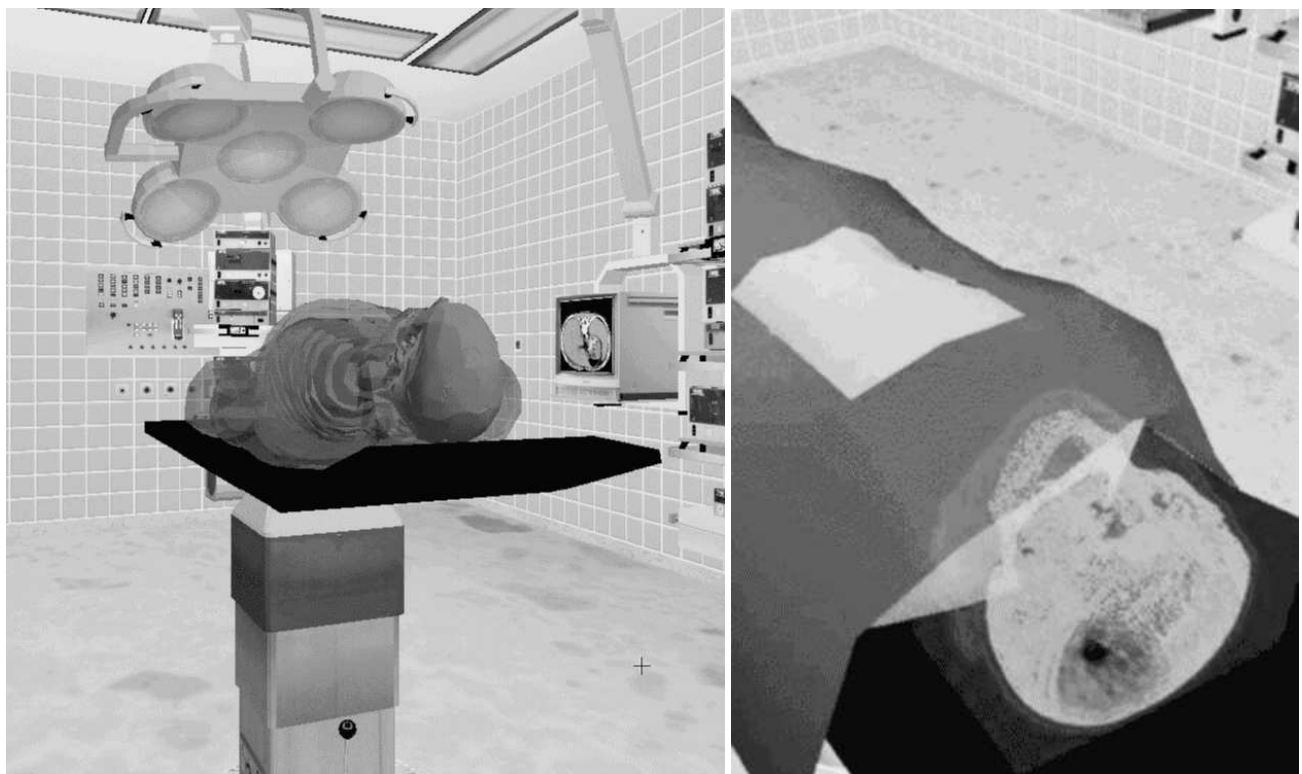
### 4 CONCLUSION

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



(a)

(b)



(c)

(d)

Figure 5. Example of XAI visualization: (a) A generic operation room in the virtual hospital. (b) A generic patient (atlas). (c) The patient's medical data embedded in the virtual hospital. (d) Maximum intensity projection of the patient's data using 3D textures.

at home.

Provision of 3D models of hospitals and visualization of medical data enable patients to virtually visit the health care center at will. To achieve an easy user interface which does not require a priori knowledge, an extended anatomic information is generated by appropriate usage of segmentation and registration algorithms and knowledge databases.

The presented application enables the patients to view and understand their medical data using a complex visualization tool until now only available to experts.

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