Introductory lecture
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Virtual Medical Examination by Using 3D Multimodal Analysis

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Successful diagnostics requires a complete set of medical data and the possibility for the remote MD to easily manipulate all the available data. The Internet technology based computer networks and electronic medical data records are becoming a part of the healthcare system. Different 3D diagnostic devices have an increasing role and equidistant 2D slices traditionally present the examination results. The overlapping of 3D diagnostic data obtained from different medical devices could be successfully done on a computer that has support for fully interactive access to results of all 3D medical devices. The paper presents a Web based solution for virtual medical examination and the remote interaction with 3D data sets. Our solution for remote vector and scalar three/dimensional fields analysis by using VRML and tools developed in JAVA is also presented. Active interaction of a remote MD with overlapped multimodal data in the electronic medical record is also presented.

KEY WORDS: *Telemedicine; Telecardiology; Multimodal Analysis*

INTRODUCTION

The prototype of a distributed medical data system was developed at Belgrade University Computing Center. Three tier architectures, where the medical data is accessed through a browser is one of the basic components of the system. Since the medical record of a patient is distributed, one of the crucial points in the project was to provide transparent access to the medical data, wherever it is located. This objective was achieved through the concept of the Personal Home Page Site, where Web links and corresponding data descriptions are stored for a person. The access to all medical data by the user of the system is with this solution performed without apriori knowledge about the locations of the data. Remote analysis and presentation of 3D data in such a distributed environment was the second part of our project. It will be presented in this paper.

Our first step in 3D medical imaging was based on an examination performed at the Magnetic Resonance Imaging Centre of the Clinical Centre of Serbia, for a patient with brain cancer. The examination followed a non standard procedure - the slices were generated at the minimal possible distance to get the finest initial three dimensional voxel structure that was latter used for further processing. The proprietary format of Siemens was the decoded and then we have done the segmentation and extracted the 3D surfaces of the head, brain tumor, etc.

Once the 3D surfaces were defined and presented in as polygonal surfaces, we converted them into the VRML format. VRML is defined as a standard to enable manipulation of 3D objects by using a Web browser. The add-ons of Web browsers (or now even in the browsers), offer a standard set of tools for rotation, translation, walking through, etc., if the object is presented in VRML. Finally, we created in JAVA tools for user interaction to manipulate the 3D object and dynamically extract 2D data from the 3D dataset. Our concept is based on the assumption that the final presentation of data must be in 2D, due to the fact that the computer monitors are 2D, and that the 3D set is needed for the orientation in 3D space and for the selection and generation of the 2D object.

TOOLS FOR INTERACTION WITH 3D OBJECTS

Our first tool was a 2D cutting plane for MRI that offers a MRI slice for an arbitrary position of the cutting plane in the 3D voxel dataset. The reconstructed surface of the patients head was used for orientation, and the manipulation of that surface (rotation, translation, walk through etc.) was done by using the built in tools of the Web browser. The tools that we developed in Java were used for manipulating of the 2D cutting plane - rotation, translation, resizing, etc. The 2D image on the cutting plane was generated in real time, during the translation and rotation, and after that also the mapping on the 2D surface of the monitor. The manipulation of the 3D object was primarily used for getting observation angles that give us precise views of the cutting plane position. Then the cutting plane is positioned in the 3D dataset. Finally, the 3D object is then rotated to place the cutting plane in a position parallel to the monitor plane, to get the best 2D image.

This procedure for observing 3D objects on 2D monitors reduces the virtual reality effects, but our concept prooved to be very effi-

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cient concerning the requested capacity of the computer network. The partitioning and allocation of the job was done in the following manner: the server has a 3D data-set and gets the information of the cutting plane position from the client. Each movement of the cutting plane in the 3D dataset initiates the computation of the 2D image on the cutting plane on the server side. Only the computed cutting plane is then sent over the network. The transmission over the network is actually sending the position of the cutting plane to the server and sending back the 2D information back for that position of the cutting plane. The server was responsible for the complete calculation of the 2D image. Our concept proved to be a very succesful solution both for: adaptation of 3D imaging to 2D displays and lower capacity transmission channels.

Creation of an instance of the cutting plane is easily done during user interaction and an arbitrary number of them could be created. This offers the customization of the interface to the needs of the MD. One example is the creation of 3 orthogonal planes, to get a sort of coordinate system type of presentation. In this case, the 2D images in each of the orthogonal cutting planes offers the user a familiar interface to the 3D data. One example of a SPECT 3D data set with three orthogonal planes is presented in Fig. 1.

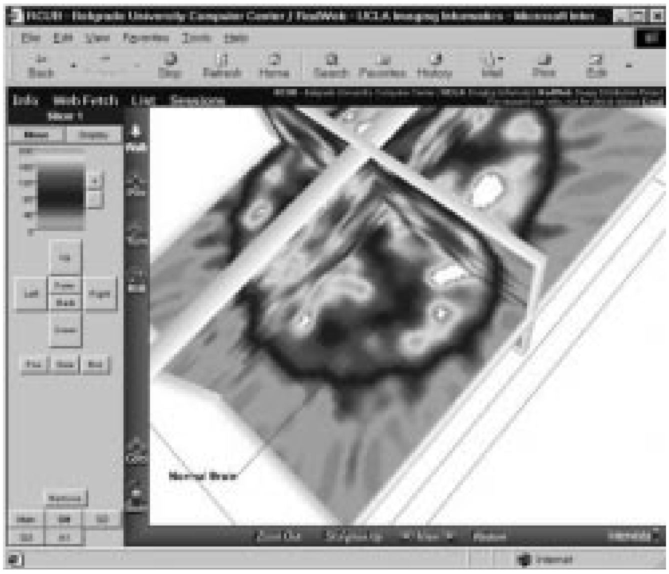

Figure 1. Three orthogonal cutting planes of a SPECT of the normal brain

The concept was enriched by offering various types of presentations on the cutting plane. First, we generalized the concept by displaying arbitrary scalar fields (doppler velocity, contrast concentration, etc.). Then we introduced arbitrary vector fields, to present true directions and intensities of blood flows in the heart and vessels. The presentation of the vector direction in 3D was a problem due to the 2D nature of the display. This is why we accepted that the size of the vector in 3D should be the same and we used color coding to offer the information about vector intensity. The size of the projection of the vector on the display for different angles of the 3D object gives the user information about the true direction of the vector in 3D space.

This method for displaying 3D fields was implemented in the virtual aneurism project, that was done in cooperation with the Neurosurgical Department and Computer Science Department at UCLA. The 3D velocity data field was generated by using the fluid dynamics software, and the anatomic structure of the aneurism was defined by 3D medical examination and suface reconstruction. The pressures at the ends of the vessel with the aneurism, as boundary conditions, were generated based on standard pressure in time diagrams. The developed system offered the presentation of simulation results through Web by displaying vectors of changing direction and colour in a mesh on the cutting plane. The results were used for developing new methods for semi-invasive therapy of brain aneurisms.

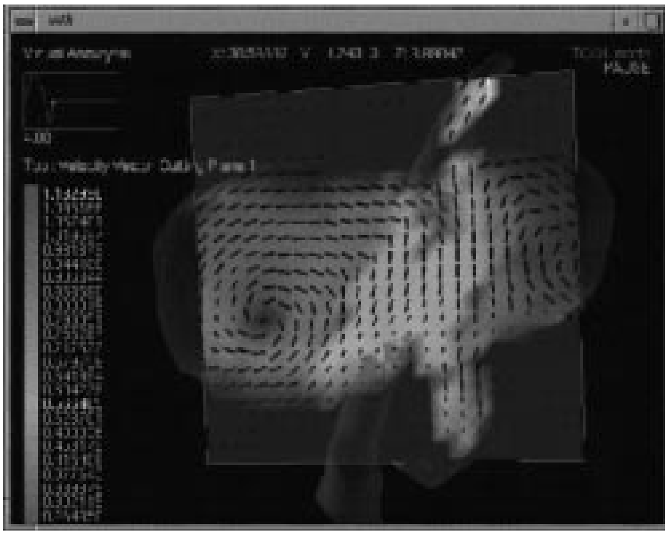

Figure 2. Turbulences in an aneurysm - vector-cutting plane

When the concepts and technology for manipulating 3D objects were developed, we easily made new tools for manipulating 3D medical objects and here we will mention the dicer and the distance measurements in 3D. The dicer is actually a cube, where the surfaces of the cube are cutting planes in the 3D space. The sufaces can present arbitrary scalar of vector fields, while the 3D structure of the cube makes orientation in 3D easier.

The distance measurement tool is not trivial in 3D, since the main problem is how to position the points in 3D space, with a 2D display available. The solution was to make a restriction that the point must be in a cutting plane or on a reconstructed surface in 3D. The reconstructed surfaces are not only the surface of the body, but also typically - blood vessels, cancer surfaces, etc.

An arbitrary number of tool instances of different type could be generated at the same time, with arbitrary scalar and vector fields, distance measurements, etc. This opens new horisons in the posibility to overlap different modalities (results of different 3D

Figure 3. Reconstruction of a brain aneurism based on CTA, with the 3D distance measurement tool

examination methods), by using cutting planes in the same position for overlapping results of different diagnostic methods. This could be defined as the world of integral diagnostics based on three-tier architectures and concepts and tools developed in the EUROMED project and in cooperation with UCLA.

The overlapping could be even a result of post processing performed on one modality, and one of the presentation tools in another modality. An example is the overlapping of a reconstructed surface of a tumor in 3D and the results of SPECT scanner in cutting planes. One of the main problems in this case is alignment of the raw data and post processing results from both data sets. This is presented in Fig. 4.

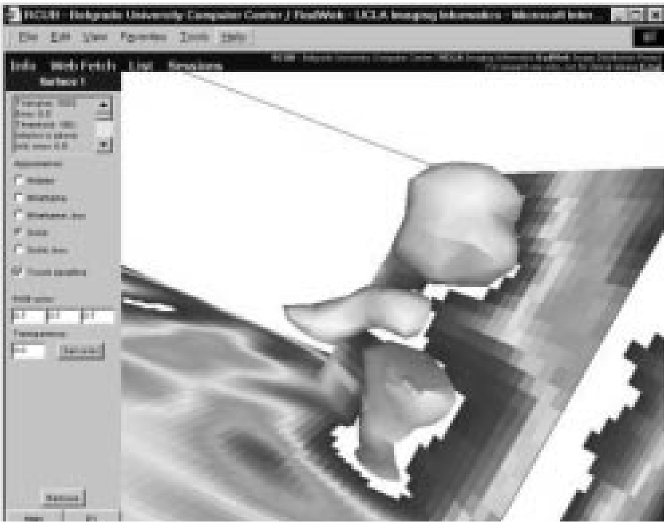

Figure 4. Increased activity in cutting planes of SPECT caused by a brain tumor - reconstructed from CTI

VIRTUAL EXAMINATION WITH A 3D DATASET

The most complex medical imaging devices (SPECT, MRI, CTI, 3D ultrasound) generate 3D datasets, and the MD during his interaction with that dataset defines his area of interest and presents it in 2D form. This is actually a form of virtual examination. The evolution of diagnostics is going in that direction. Our results prove that there are no technological obstacles that the remote MD can have the same facilities as the local MD and have the same active role in interaction with the available 3D dataset. The remote MD is not any more forced to use the 2D images selected by the MD that is at the site where the patient is.

Virtual examination is one of the main elements of future telemedicine, since the remote MD has the same input as the local MD. The capacity of existing WAN networks is still a restriction for presenting dynamical 3D data, but the advances in the capacity of optical computer networks will remove this obstacle in the next few years.

CONCLUSION

A necessary prerequisite for implementing the electronic medical record is computer based archiving of all medical data, including the 2D and 3D images, sound, etc. from the medical devices. There should be an information system based on three-tier architectures in the medical centre, and the client machines should use Web browsers for user interaction. The electronic medical record can be easily remotely accessed with this solution.

Our results prove that even for the most complex 3D examinations, the manipulation and analysis could be done even over networks with moderate capacities, by chosing a good concept of the system and with good partitioning of the overall job between the clients and servers. The developed tools put the remote medical doctor in a very active role, when manipulating the medical data. There is no true obstacle to make all the analysis of 3D data remotely. The limitation of all medical devices is that their presentation methods are limited to a single diagnostic method. The multimodal analysis and overlapping fluid dynamic simulations with them is a step to a new approach in medical examination. The MD will have to change their approach to diagnostics and closely cooperate with computer specialists to integrate the results of all diagnostic methods in a user friendly environment. This will be a new revolution in the healthcare system.

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