Linking Human Anatomy to Knowledgebases: A Visual Front End for Electronic Medical Records[*#]

Stewart Dickson, Line Pouchard, Richard Ward
Oak Ridge National Laboratory
Gary Atkins, *Fisk University*
Martin Cole, *University of Utah*
Bill Lorensen, *GE Global Research*
Alexander Ade, *University of Michigan*

Abstract. A new concept of a visual electronic medical record is presented based on developments ongoing in the Defense Advanced Research Projects Agency Virtual Soldier Project. This new concept is based on the holographic medical electronic representation (Holomer) and on data formats being developed to support this. The Holomer is being developed in two different visualization environments, one of which is suitable for prototyping the visual electronic medical record. The advantages of a visual approach as a front end for electronic medical records are discussed and specific implementations are presented.

1. Introduction

The President's Information Technology Advisory Committee June 2004 report calls for federal leadership to create needed technological innovations "to enable development of 21st century electronic medical records" [1]. In July, Department of Health and Human Services Secretary Tommy Thompson and National Coordinator for Health Information Technology David Brailer announced a framework for strategic action for delivering "consumer-centric and information-rich" health care [2]. Concepts important to this vision for 21st century medical care include: medical information moves with consumers, care is delivered electronically as well as in person, medical care is provided with fewer medical errors and with less variation utilizing the electronic medical record. The report expresses the hope that "sophisticated decision-support tools that help identify treatments....best suited to a given patient would be available to help reduce unnecessary treatments and to ensure prevention procedures, both of which will result in better outcomes [2]." One component of that vision for future medical care is decision support tools to help the physician in diagnosis. Another component needed is a visual user interface that collects varied types of information, for example text, charts, imagery such as CT and MRI, and three-dimensional (3D) reconstructions. We refer to this component as the Visual Electronic Medical Record (VEMR).

The Defense Advanced Research Projects Agency (DARPA) Virtual Soldier Project (VSP) is working on these issues in the context of providing medical care on the battlefield. The DARPA

VSP is investigating methods to predict outcomes from wounding that will revolutionize medical care for the soldier. This research is expected to have a significant impact on civilian medical care. The goal of the VSP is prediction of outcomes of penetrating wounds, which will be based on comparison of results from complex mathematical models with experimental data. In the not too distant future, this will allow prediction of consequences of a wound using a soldier's post wound imaging along with pre-wound clinical data including baseline x-ray CT.

To provide a visual environment for encapsulating the results of this prediction, the VSP is developing a holographic medical representation (or Holomer) to be used to connect a 3D model of the soldier's body, based on x-ray CT, with anatomical and physiological information for purposes of improving medical diagnosis and treatment both on and off the battlefield. This visual-based prediction and medical record for the soldier can become, in the not too distant future, a first prototype for the VEMR, where a patient's vital signs, imagery, and other information is keyed to the locations in the anatomy of the medical complication. We discuss here the development of the VSP Holomer and its modifications for use in the civilian medical community as a VEMR.

2. Method

To address the problem of linking visual representation of the anatomy to a knowledgebase of information and prediction tools, the VSP is developing the Holomer. The Holomer will connect a 3D model of the soldier's body, based on X-ray CT, with anatomical and physiological information for purposes of improving medical diagnosis and treatment both on and off the battlefield. The Holomer coupled with predictive modeling software will facilitate a new level of integration in medical procedures and create a prototype for a truly interactive VEMR.

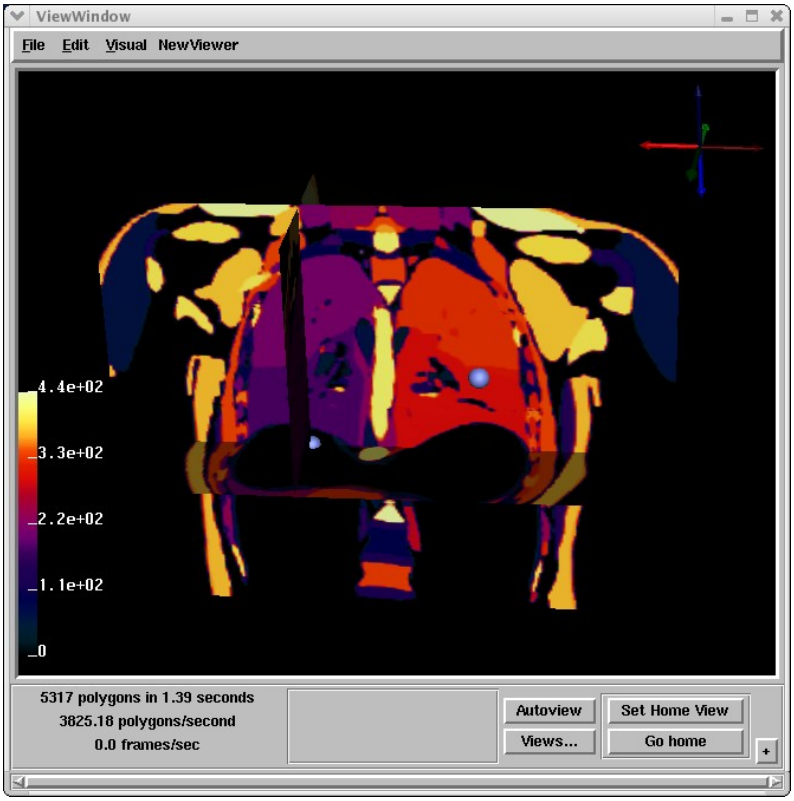

Figure 1. Thorax anatomy displayed in the SCIRun visualization environment. The blue sphere is the 3D widget (probe).

To demonstrate the Holomer concept, a 3D model was created from segmented and annotated National Library of Medicine Visible Human male photographic data [3]. The 3D model is displayed in SCIRun [4] using existing volume visualization techniques (Fig. 1), and is linked to knowledgebases using a specially developed module, referred to as the HotBox. The HotBox interacts with the geometric model via a 3D widget (the probe or blue sphere seen in Fig. 1) which is user controlled such that it can be moved to any location in the model. This provides the user with a means to input the location of interest. Given the location from the user controlled 3D widget, the HotBox implements the linkage to the 3D anatomy and the many levels of information provided in the knowledgebases.

Presently the information returned by the Hotbox is the tissue at the location of the probe and the adjacent tissues (see Fig. 2). In the future, this information could also include a list of a patient's allergic reactions to drugs or allergens, or records of visits to the physician, or vital signs recorded during a hospital stay.

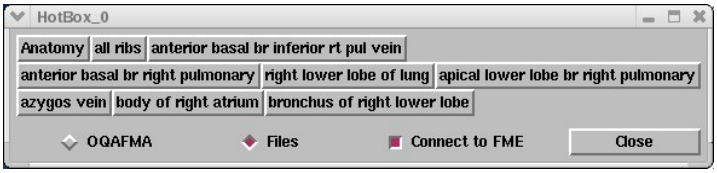

Figure 2. The Hotbox interface returns the tissue located at the 3D widget (probe), i.e. right lower lobe of the lung, and all adjacent tissues.

Different forms of information content from text-based to 3D imagery can be linked in the Holomer, thus providing a unique visual-based electronic medical record which the medic or physician can utilize for purposes of diagnosis and treatment. The specific focus of this unique visual approach to medical informatics in the VSP is penetrating wounds to the heart.

To develop the SCiRun-based Holomer, we have prototyped this concept using a visual front end developed using Visualization ToolKit (VTK) software [5]. The Visible Human (male) photographic data were used to create surface models and associated label maps for the thorax. For a soldier who has received a projectile wound, the wound is described using an Extensible Markup Language (XML) file standard based on a wound ontology developed by the VSP. Information in the wound ontology is used to show the regions of stunned and ablated tissue as the projectile enters the body and either lodges in an organ or exits the body. Information on the properties of the wounded tissue and various physiological and tissue material properties can be entered by the physician and stored in this XML file to control the display of the region of wounded tissue. Figure 3 demonstrates a wound to the left ventricle of the heart, where the wound track is shown as a series of concentric cylinders representing tissue which has been ablated or simply stunned by the projectile.

In the future the wound description could be obtained from comparison of post trauma ultra sound (US) with baseline US or X-ray CT imagery for this soldier. The combination of the comparison of the wounded region and the baseline would then be automatically encoded into the wound ontology instance or wound XML file that controls the visual interface. Existing XML standards for medical records (such as HL7) would also be used for integrating standard medical records data. We will demonstrate how this can be done in connection with the wound ontology XML developed under the VSP.

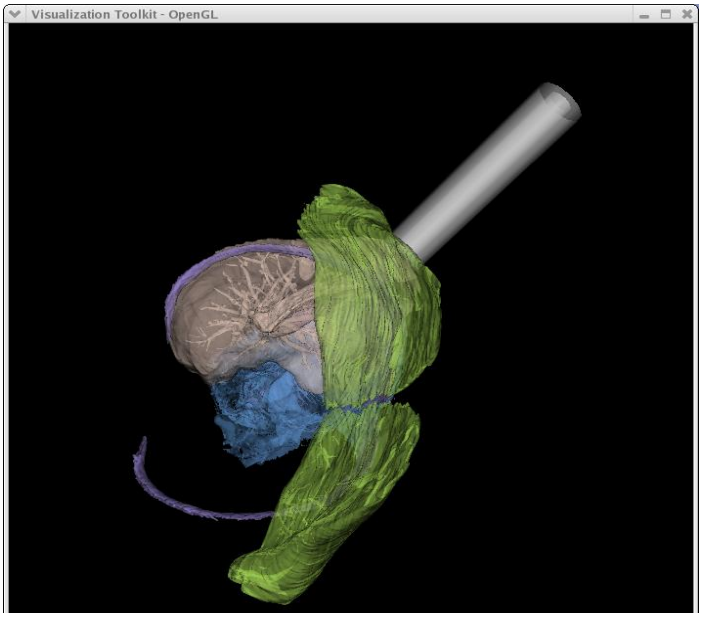

Figure 3. VTK-based visualization environment for prototype development. The wound has the projectile stopping in the left ventricle.

When applied to a patient in a hospital setting, the interface could capture and display the patient's vital signs, making it possible for the physician to keep a detailed record of the patient's physiological responses during surgery or during recovery. The visualization of the physiological data (see Fig. 4) is accomplished using standard ICU monitor software, which we demonstrate here with simple Tcl/Tk plotting program which interfaces with the original VTK Holomer.

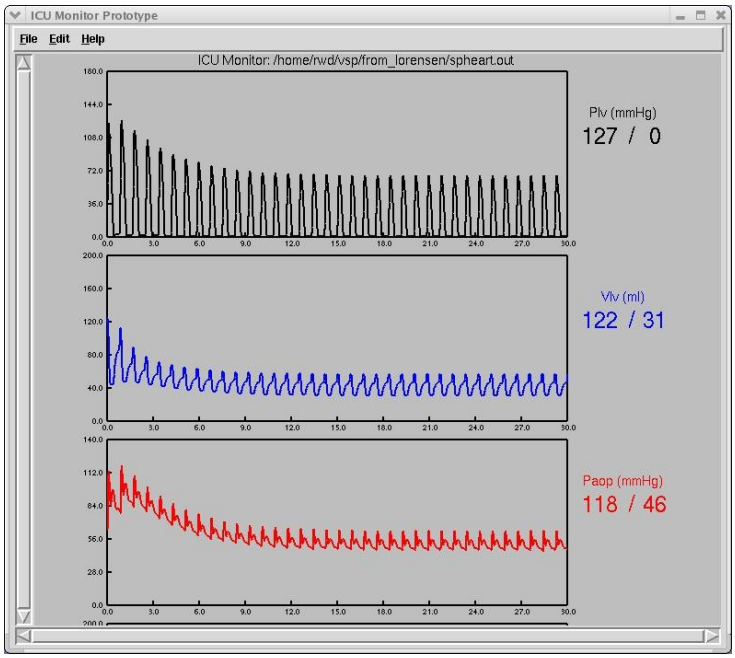

Figure 4. The prototype ICU Monitor screen displaying physiological results, in this case, for a model of the physiology in the thorax. In clinical medical implementation, this display would show patient vital signs.

The advantage of this simple demonstration based on VTK is that it can be used to develop more sophisticated interfaces such as the SCIRun visualization interface being developed for the VSP and for prototyping a civilian VMER which is based on electronic medical record standards, yet incorporating new standards for the visual representation of information, such as the wound ontology XML and the physiological (vital signs) data format.

3. Results

A prototype of the HotBox has been developed within SCIRun. The HotBox, which comes from animation software [6], is a menu activated by placing the cursor at a particular point in the 3D space (anatomy). The menu provides the user with a multitude of options based on retrieving the anatomical structure at the spatial point from the "Master Anatomy" list created from segmenting and labeling the Visible Human data. For example, a menu item can be selected to invoke a connection, by Web services, to the Foundational Model of Anatomy [7] to provide the anatomical structures adjacent to the structure at the cursor location.

Physiological information from measured vital signs will also be available via the Web service from the HotBox menu. In addition, we have also developed an alternative approach for connecting to knowledgebases that is independent of SCIRun and can be run on PC platforms. In this approach the 3D images are created using VTK [5].

We have found that the VSP VTK-based Holomer concept has been useful in developing the more sophisticated visual Holomer based on SCIRun. It can also serve as a useful prototype development environment for a civilian version of the VEMR integrating significant new concepts such as the wound ontology XML and the physiological (vital signs) monitor with standard patient medical record. Further, the Holomer coupled with predictive modeling software will facilitate a new level of integration in medical procedures and create a prototype for a truly interactive VEMR.

4. Conclusions

We described the prototype concept of the HotBox, which can be integrated into the SCIRun Holomer to provide a link between 3D anatomy and knowledgebases of anatomical information, physiological response (vital signs) data and other standard medical records. We further describe a development environment based on VTK which has been used to prototype the SCIRun-based Holomer. The VTK-base visual interface is platform independent and has served well as a prototype for a new type of visual electronic medical record, one based on a 3D representation of the individual soldier or patient, providing unique visual access to the patient or soldier’s condition, be it a wound or a disease.

The prototype Holomer being developed within the VSP is a unique demonstration of the concept of a "Visual Electronic Medical Record". Visual electronic medical records will improve the ease and use of medical records data by the physician, providing an interactive interface to records based on 3D anatomical reconstruction of the patient. Using the Holomer, a physician or medic will have access, at the touch of a button, to all available information about a patient or wounded soldier, greatly facilitating accurate and efficient diagnosis of medical conditions.

References

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