

VISUAL INTERFACE TO HUMAN MEDICAL DATA: THE VIRTUAL SOLDIER HOTBOX*

Richard Ward, Line Pouchard, and Barbara Beckerman
Oak Ridge National Laboratory**

Stewart Dickson

Department of Computer Science, National Environmental Modeling and Analysis Center
University of North Carolina, Asheville

ABSTRACT

The Defense Advanced Research Projects Agency (DARPA) Virtual Soldier Project (VSP) [1] is investigating methods to predict outcomes from wounding that will revolutionize medical care for the soldier and, eventually, for civilian medical care. Prediction of outcomes of penetrating wounds will be made based on comparison of complex mathematical models and clinical data including baseline X-ray computed tomography (CT) and post wound imaging. A problem is to display this information so as to capture the three-dimensional (3D) nature of the human body and correlate 3D anatomy to extensive information including the physiology of the wounded soldier. Oak Ridge National Laboratory (ORNL) developed the **HotBox**, a user interface (UI) that links a given point in space (a voxel) to the structural knowledge ontology describing the anatomy at that particular location. This is then related to the individual's physiological state (vital signs) and a description of the wound. The implementation and use of the HotBox is explained and the implications for the future of medical records, pre-surgical planning, image-guided surgery, and post-surgical treatment and rehabilitation are discussed.

INTRODUCTION

The Defense Sciences Office of DARPA has initiated an ambitious program to redesign modern treatment of wounded soldiers. This program consists of a multi-pronged set of projects which define both an individual-specific "virtual person," or in the case of the soldier the "virtual soldier,"

and robotic surgical procedures which can be used to both practice surgery on the virtual soldier and then conduct the real surgery. The first program is entitled the **Virtual Soldier Project (VSP)** and the second, involving the development of helper robots and associated software to assist the surgeon using a daVinci robotic assisted surgical engine, is entitled the **Trauma Pod Project**.

The VSP is investigating methods to predict outcomes from wounding that will revolutionize medical care for the soldier, and in turn for civilian medical care. Prediction of outcomes of penetrating wounds will be made based on comparison of results from complex mathematical models, with experimental data, and (ultimately for the soldier) with clinical data including baseline X-ray CT and post wound imaging.

An important capability in the Project is be able to display this information in such a way as to capture the three-dimensional (3D) nature of the human body and to correlate this 3D anatomy to extensive information including the physiology of the wounded soldier.

Our solution was to implement a concept, referred to as the HotBox, used in animation software [2]. The HotBox is a menu activated by placing the cursor at a particular point in the 3D space (anatomy). In our case, the HotBox menu provides the user with a multitude of options based on associated data files to which it has access [3].

The Virtual Soldier HotBox user interface (UI) implements the "deep voxel" concept, wherein a specific geometrical feature in the anatomical

model residing at a given point in space is linked to the structural knowledge ontology describing the anatomy at that particular location. This in turn is related to the physiological state of the individual (the vital signs) and a description of the individual's wound.

The specific anatomical ontology is the Foundational Model of Anatomy (FMA) [4]. The FMA and a prototype physiological ontology were integrated into the Virtual Soldier Knowledge Base (VSKB). Connection to the VSKB was provided by a Web service to the QOAFMA Querying Agent for the Foundational Model of Anatomy (QOAFMA) at the University of Washington [5]. The unique conception of the medical record as being imbedded in the individual-specific anatomy created from a full-body CT scan of the soldier is referred to as the Holographic Medical Electronic Record (or HOLOMER).

IMPLEMENTATION

To demonstrate the HOLOMER concept, a 3D anatomical model was created from segmented and annotated National Library of Medicine Visible Human (VH) male CT data [6]. VSP team member GE Global Research, using much improved segmentation capability, created an associated label map (LM) from the VH male photographic data. Physiological data was acquired using high-level integrative physiological models developed by the University of Washington collaborators on the project. Finally, the connection to the QOAFMA Web service to the VSKB was made using a C++ client stub developed by our subcontractor, the University of South Carolina [7].

The VSP chose the SCIRun visualization software [8] for 3D visualization of human anatomy and for display of physiological data (vital signs). SCIRun was developed by the Scientific Computing and Imaging (SCI) Institute of the University of Utah, a VSP team member.

The HotBox UI is a SCIRun module which provides a user interface to the HOLOMER display. The code is programmed in C++ with the

UI interaction provided by a tel/tk program. The HotBox module is part of the SCIRun Package developed for the VSP.

The SCIRun network incorporating the HotBox module is shown in Fig. 1. An arrow points to the module. Incorporated into the HotBox is the SCIRun probe module code, which provides the user with a 3D cursor (referred to as the probe) to obtain the spatial coordinates.

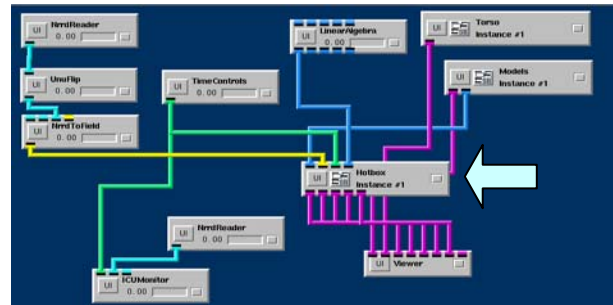


Figure 1. SCIRun network including HotBox module.

The HotBox UI is shown in Fig. 2 for the VH male data. When the user drags the probe in the SCIRun “Viewer” window and stops at a particular location, the coordinates at that location are used to obtain the organ segment using the LM.

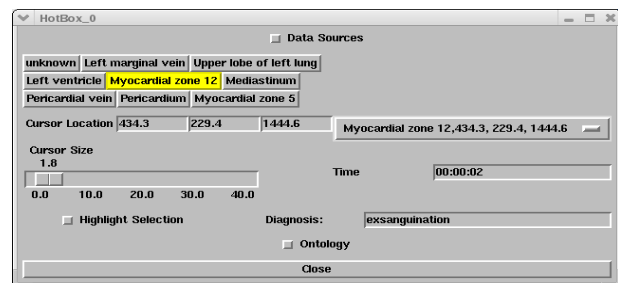


Figure 2. The HotBox UI shows the highlighted organ segment (in yellow) and indicates that injury has been determined to be exsanguination.

The organ segment at that location is highlighted as shown in Fig. 3. In this case the user has moved the probe into the lower left lobe of the lung. Note that the heart is shown in cross section the left ventricle has been divided into 12 myocardial zones.

In addition to highlighting the selected segment, buttons are created for eight of the adjacent organ

segments. The user can use these to “jump” to the center of an adjacent segment. Finally, the HotBox uses different highlight colors to indicate the organ segment suspected of being the source of the wound based on the physiological response.

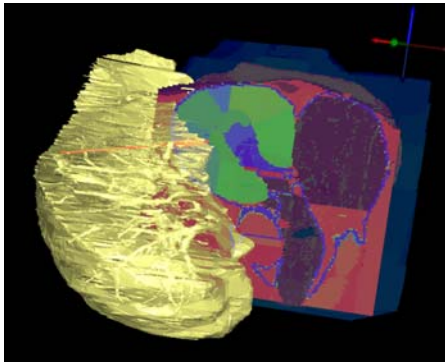


Figure 3. SCIRun Geometry Viewer window with the probe moved to the lower left lobe of the lung.

To access the anatomical ontology, the HotBox UI must be opened up to allow further interaction. The “Ontology” checkbox opens the connection to the VSKB ontology (as shown in Fig. 4). Likewise a “Data Sources” check box opens the “Data Sources”, i.e., data sources used by the HotBox.

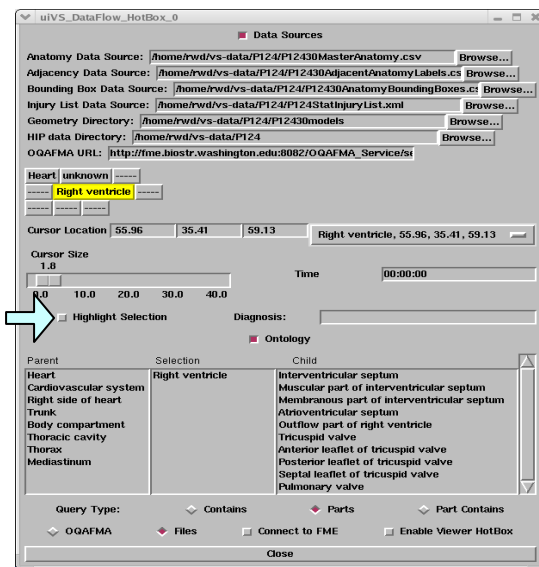


Figure 4. HotBox with the Data Sources and Ontology portions opened.

In the wound region, determined by the HotBox from specifications in the "injury list" XML file, the HotBox will display the injury “geometry

icon” (see Fig. 5), which is a set of primitives (cylinders of various diameter) representing the wound track through the tissue. Both ablated tissue (i.e., tissue removed) and “stunned tissue” (altered tissue) are displayed.

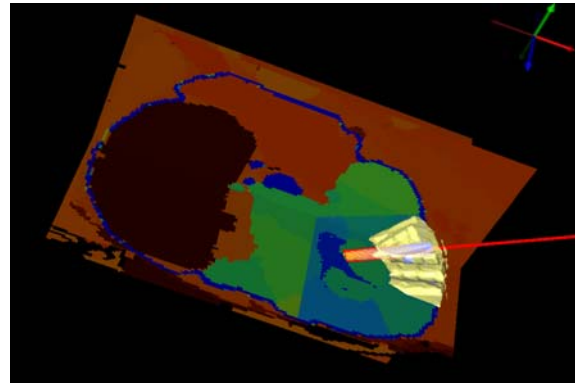


Figure 5. SCIRun Geometry Viewer window showing the injury geometry icon (red) for the case of wound through myocardial zone 12 of the left ventricle.

AUTOMATED OPERATION

One goal of the VSP is automated prediction of outcomes of penetrating wounds. To facilitate imaging based on these predictions, a SCIRun timer module was created by the SCI Institute at the University of Utah. All other VSP modules were connected to the **Global Timer Control** including a physiology monitor window. We connected the HotBox to the SCIRun Timer Control module to drive a location-specific physiology display window.

To allow control by the timer, a “Highlight Selection” checkbox (arrow Fig. 4) was added to the HotBox UI. If checked, user selections are highlighted and the injury icon geometry (Fig. 5) is drawn. If unchecked, highlighting the suspect wound location and the location-specific physiology display window are under timer control.

CONCLUSION

We have described the prototype concept of the HotBox, a module in the SCIRun visualization environment which links 3D anatomy and knowledgebases of the anatomy, physiological response (vital signs) data, and other medical

informatics. As presently implemented in Phase I of the Project, the Virtual Soldier HotBox UI, in combination with other features of the SCIRun network, provides connections to the following information for VSP:

1. **Virtual Soldier Knowledge Base:** Connection to the VSKB is made using the Web services to the OQAFMA interface for the FMA[4, 5];
2. **Physiological Vital Signs:** HotBox launches a separate physiology monitor to show the vital signs for the organ segment at probe location;
3. **Wound Description:** Provides information about a wounded region, including indication of tissue alterations resulting from the wound;
4. **Biomechanical Properties:** The network (not the HotBox) contains modules for display of the tissue stress/strain properties obtained from biomodeling; and
5. **Connection to Global Timer Control:** Connecting to the SCIRun Timer Control module allows update of the HotBox UI.

This design of the HotBox can serve as a prototype for a new type of electronic medical record, one based on a 3D representation of the individual soldier or patient, providing unique visual access to the condition, be it a wound or a disease, afflicting the individual.

For example, once the patient's vital signs are collected (including ECG) and the region of concern has been imaged using CT or other imaging modalities, automatic segmentation (presently being developed by GE Global Research and Harvard as part of the VSP) would be used to create the anatomical LM for this patient. Specific geometrical information about the wound is captured and stored as part of the "injury list." The HotBox can then provide for the physician a "virtual" window into this patient for pre-surgical planning and analysis.

Eventually, the HOLOMER or medical electronic record described here can be utilized within the robotic surgical suite for conducting image-guided surgery. And since all information is captured regarding the patient from anatomical to physiological during the course of treatment, the

HOLOMER can be used for post-operative analysis, treatment, and rehabilitation.

Thus, the prototype HOLOMER and its implementation in the SCIRun environment, the Virtual Soldier HotBox, is a unique demonstration of the concept of a "Visual Electronic Medical Record." Using the HOLOMER and the HotBox, 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 and treatment for wounds or other medical conditions.

REFERENCES

- [1] See: www.virtualsoldier.net
- [2] See: www.alias.com
- [3] L.C. Pouchard and S. P. Dickson, "Ontology based three-dimensional Modeling for Human Anatomy" ORNL Technical Report ORNL/TM-2004/139, 2004
- [4] C. Rosse and J. L. V. Mejino, "Ontology for Bioinformatics: The Foundational Model of Anatomy," *J Biomed Inform* 36:478-500, 2003
- [5] See: sig.biostr.washington.edu/projects/oqafma/
- [6] See: www.nlm.nih.gov/research/visible/
- [7] S. P. Dickson, et al., "Linking Human Anatomy to Knowledgebases: A Visual Front End for Electronic Medical Records", Medicine Meets Virtual Reality 13, (Eds. James D. Westwood, et al.), IOS Press, Amsterdam, 2005.
- [8] See: software.sci.utah.edu/scirun.html

*This work was supported by a grant from the DARPA, executed by the U.S. Army Medical Research and Materiel Command/TATRC Cooperative Agreement, Contract # W81XWH-04-2-0012.

**The submitted manuscript has been authored by the Oak Ridge National Laboratory, managed for the U.S. Department of Energy by UT-Battelle, LLC, under contract No. DE-AC05-00OR22725. Accordingly, the U.S. Government retains a non-exclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purpose.