Advanced Interfaces of Interactions with Virtual Organs for Surgical Pre-Operative Planning

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Abstract: - The visualization of 3D models of the patient’s body emerges as a priority in surgery. In this paper three different visualization and interaction systems are present: a virtual interface, a low cost multi-touch screen and a navigation system of medical imaging and 3D models. The systems are able to interpret in real-time the user’s movements and can be used in the pre-operative planning for the navigation and manipulation of 3D models of the human body built from real patient’s CT images. The surgeon has the possibility to visualize both the traditional patient information, as the TC image set, and a 3D model of the patient’s anatomy built from this. The developed virtual interface is the first prototype of a system designed to avoid contact with the computer so that the surgeon will be able to visualize models of the patient’s organs moving the finger in the free space. The developed multi-touch screen provides a user interface customized for doctor requirements that allows many users to interact at the same time with 3D models of the human body built from CT images. In the developed navigation and visualization system two different modalities are available in real time and dynamically: it is possible to have the automatic reslicing of the orthogonal planes exactly next to the actual position of the surgical instrument tip and to activate the clipping modality that allows cutting the 3D model in correspondence of a chosen visualization plane.

Key-Words: - User Interface, Medical Imaging, Tracking System, Multi-Touch Screen, Navigation System

1 Introduction
The visualization of 3D models of the patient’s body emerges as a priority in surgery both in pre-operative planning and during surgical procedures and the introduction of new modalities of interaction with the 3D models of the human organs could be required.
The tracked movements of the finger provide a more natural and less-restrictive way of manipulating 3D models created using patient’s medical images.
Various gesture-based interfaces have been developed; some of these are used in medical applications.
Grätzel et al. presented a non-contact mouse for surgeon-computer interaction in order to replace standard computer mouse functions with hand gestures [1].
Wachs et al. presented Gestix, a vision-based hand gesture capture and recognition system for navigation and manipulation of images [2].
O’Hagan and Zelinsky have presented a prototype interface based on tracking system where a finger is used as a pointing and selection device [3].
Currently there are different software used for the visualization of scientific images and 3D modelling of human organs; among these the most important are Mimics [4], 3D Slicer [5], ParaView [6],[7] and OsiriX [8],[9].
In addition, several research teams dealt in the development of advanced modalities of interaction and visualization.
The collaboration between the MIT Artificial Intelligence Lab and the Surgical Planning Laboratory of Brigham led to the development of solutions that support the preoperative surgical planning and the intra-operative surgical guidance [10].
Hartmut et al. describe the integration of image analysis methods with a commercial image-guided navigation system for neurosurgery (the BrainLAB VectorVision Cranial System [11].
In this paper are present three advanced visualization and interaction systems used for the surgical pre-operative planning: a virtual interface, a low cost multi-touch screen and a navigation system of medical imaging and 3D models. The systems are able to interpret in real-time the user’s movements; both the TC image set and the 3D models of the human body built from real patient’s medical images can be visualized.
In addition, in the navigation system of virtual organs two different visualization modalities are available in real time and dynamically.
It is possible to obtain the automatic reslicing of the orthogonal planes in order to have an accurate visualization: the 3D model of the human organs and the specific CT slice relative to the actual position of the surgical instrument tip can be visualized.
It is also possible to have the clipping of the models, a visualization modality that allows cutting the 3D model in...
correspondence of a chosen visualization plane. From CT images of real patients a 3D model of the abdominal area has been reconstructed using segmentation and classification algorithms in order to obtain information about the size and the shape of the human organs.

2 The Virtual Interface

The developed virtual interface, based on the use of an optical tracking system, is the first prototype of a system designed to avoid contact with the computer so that the surgeon will be able to visualize models of the patient’s organs more effectively. In the systems the NDI Polaris Vicra has been utilized as optical tracker [12]. The Polaris Vicra uses a position sensor to detect infrared-emitting or retro-reflective markers affixed to a tool or object; based on the information received from the markers, the position sensor is able to determine position and orientation of tools within a specific measurement volume. The systems can be used in a variety of surgical applications, delivering accurate, flexible, and reliable measurement solutions that are easily customized for specific applications.

For the building of the graphic environment we have utilized OpenSceneGraph, an open-source high-performance 3D graphics toolkit for visual simulation, computer games, virtual reality, scientific visualization and modelling [13]. For the building of the 3D models of the human organs we have utilized 3D Slicer, a multi-platform open-source software package for visualization and image analysis [14].

All of the interactions with the models happen in real-time using the virtual interface which appears as a touch-screen suspended in the free space and situated in a location chosen by the user at the starting up of the application. The finger movements are detected by means of the optical tracker and are used to simulate the touch with some buttons present in the developed virtual interface. In figure 1 is shown the interaction using the virtual interface and the tracking system.

The doctor, using this system, is able to rotate, to translate and to zoom in on the 3D models of the patient’s organs simply by moving his finger in free space and he can select the visualization of all of the organs or only some of them. The optical tracker has already been used in computer aided systems and, for this reason, it is easy to integrate the described virtual interface with these systems. The introduction of other functionalities of interaction with the models is in progress, after further investigation and consideration of surgeons’ requirements.

3 The Multi-Touch Screen

The developed multi-touch screen provides a user interface customized for doctor requirements that allows many users to interact at the same time with 3D models of the human body built from CT images.

The designed multi-touch screen is based on the rear-side illumination technique and the open-source and multi-platform TouchLib library has been used to identify the finger contacts with the screen and to translate these in specific events. Using specific filters the calibration phase is carried out in order to obtain the correct detection of the finger tips; the calibration procedure is shown in figure 2. The user interface is provided of many buttons in order to visualize both the 3D models of the human organs and the CT slice set used to build these virtual models. The interaction with the models is possible using one finger (to rotate or translate) or two fingers (to zoom in or zoom.
The use results very simple and evident for the user and the system can be a helpful tool for the diagnosis and the surgical pre-operation planning.

The developed multi-touch screen is shown in figure 3.

![Fig.3: The multi-touch screen](image)

### 4 Visualization and Navigation System

As modern medical imaging provides an accurate knowledge of patient’s anatomy and pathologies, the medical image processing could lead to an improvement in patient care by guiding the gestures of the surgeon.

An advanced visualization and navigation system, based on the 3D modelling of the patient’s internal anatomy, has been developed; the system could be used as support for a more accurate diagnosis and in the surgical preoperative surgical planning.

The surgeon has the possibility to visualize both the traditional patient information, as the TC image set, and a 3D model of the patient’s anatomy built from this.

The software interface is provided of buttons and presents four windows used for the visualization of the CT slices in the axial, coronal and sagittal planes and the 3D model of the organs built from these images.

According to the surgeon needs, it is possible to obtain the automatic reslicing of the orthogonal planes in order to have an accurate visualization of the 3D model and slices exactly next to the actual position of the surgical instrument tip.

Figure 4 shows the software interface for the visualization and navigation of 3D model of the organs.

In order to have a perfect correspondence between virtual and real organs it is necessary to carry out a correct and accurate registration phase that provides as result the overlapping of the virtual 3D model of the organs on the real patient [15].

In addition, in order to have a more clear visualization of the interest area, it is possible to activate the clipping modality where the 3D model is cut in correspondence of a chosen visualization plane pointed by the surgical instrument.

The clipping is dynamic as well as the reslicing.

Figure 5 shows the result of the clipping visualization modality.

![Fig.5: The clipping modality](image)

### 5 Conclusions and Future Work

The created virtual interface provides an interaction modality with models of the human body, a modality which is similar to the traditional one which uses a touch screen, but there is no contact with the screen and the user’s finger moves through open space.
The introduction of other functionalities of interaction with the 3D human models is in progress, after further investigation and consideration of surgeons’ requirements. The developed multi-touch screen provides a user interface customized for doctor requirements and the system is able to detect the position of two fingers on the screen. Using the advanced visualization and navigation system the surgeon can visualize both the traditional patient information, as the TC image dataset, and the 3D model of the patient’s internal anatomy. Two different visualization modalities (reslicing and clipping) are available in real time and dynamically. As future work is in progress the building of a complete Augmented Reality system with the acquisition in real time of the real patient’s video and the integration of virtual organs. These information will be dynamically overlapped the patient’s body taking into account the surgeon point of view and the location of medical instrument.

References:
[14] 3D Slicer; http://www.slicer.org