System for touchless interaction with medical images in surgery using Leap Motion

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Abstract

In the operating room surgeons need to have access to pre- and intra-operative images such as computer tomography (CT), magnetic resonance imagery (MRI), x-ray images and fluoroscopy along with various procedure-specific imaging applications. This visual data supports diagnostics and planning and provide virtual "insight" into the body of the patient during surgery. Although surgeons rely on capture, browsing and manipulation of these images they are constrained by typical interaction mechanisms such as keyboard and mouse. At the heart of this constraint is the need to maintain a strict boundary between the sterile and non sterile environment. In this paper we present a new system based on combining the Leap Motion gesture recognition controller and medical imaging toolkit for touchless visualization and browsing for medical image data.

1. Introduction

During recent years, doctors and particularly surgeons have become increasingly reliant on a range of digital imaging systems for navigation, reference, diagnosis and documentation. The need to interact with images in the operating room offers one particular challenge arising from the need to maintain boundaries between sterile and non-sterile environment. The usual input devices such as keyboard, mouse and touch screen surfaces are reliant on physical contact. Such contact-based interaction introduces the possibility for contamination to be transferred between the sterile and non-sterile objects in the operating room. This constraint creates difficulties for surgical staff who are scrubbed up and are dependent upon others to manipulate images on their behalf. This can create inefficiencies, which in turn can entail potential medical complications. Additionally, it can interfere with the surgeon's interpretive and analytic use of the images [1, 2]. To get around this constraint, the surgeons have developed several strategies for interacting with images, though they are often not ideal; for example, surgeons commonly request other members of the surgical team to manipulate images under their instruction. But this is not without complications: team members are not always available. Issuing instructions, though fine for relatively discrete and simple image-interaction requests, can be cumbersome and time consuming. More significant, indirect manipulation is not conducive to the more analytic and interpretive tasks performed by surgeons using medical images. The way they interact with, browse, and selectively manipulate them is closely bound up with their clinical knowledge and clinical interpretation. So in these cases the surgeon tries to manipulate the controls by him/her self by pulling their surgical gown over their hands and moving the mouse through the gown. Such practices are not risk free. For non-invasive procedures, such practice can be justified due to the clinical benefits it brings in terms of time savings and direct control of the images. For more invasive procedures, such practice is less appropriate and could be potentially dangerous for the patient [3].

The challenge is to design a system that will be more or less effortless and will overcome some of the drawbacks related to the touchless technology like the inherent *live mic* [4] and lack of haptic feedback [5], where manipulations made are harder to be finely tuned. This is because there is nothing for the user to hold, feel, or grasp and the movement of the user's hands has no momentum of a held object. Thus, the accuracy of the user in touchless interaction systems is entirely dependent on the agility of their limbs.

The rest of the paper is organized as follows: In the next section we present a brief overview of existing systems for touchless interaction in surgical settings. In Section 3 we present the developed system in details. In Section 4 we will evaluate the performance of the system. Finally section 5 will conclude the paper.

2. Brief overview of existing systems

Giving surgeons direct control over image manipulation and navigation while maintaining sterility within the operating theatre is a key goal, one that has captured the imagination of research groups and commercial entities worldwide during the last couple of years.

Graetzel et al. [6] developed an early example of touchless medical imaging system that let surgeons control standard mouse functions (such as cursor movement and clicking) through camera-tracked hand gestures. Shortly afterward, more sophisticated air-based gestures were used for surgical-imaging technology in the form of Wachs et al.'s [7]. These initial systems paved an important path, and, more recently, the number of systems and research efforts considering touchless control of medical images for surgical settings has grown significantly by including more bespoke gesture-based control (such as for navigation, zooming, and rotation) [8, 9, 10]. One enabler of this growth is the Kinect sensor and software development kit [11].

The Kinect sensor is based on a laser and an infrared (IR) camera. The laser projects a known pattern onto the scene. The depth of each point in the scene is estimated by analyzing the way the pattern deforms when viewed from the Kinect's IR camera. The software development kit allows computing the position of the "skeleton," a stickman representation of the human controller.

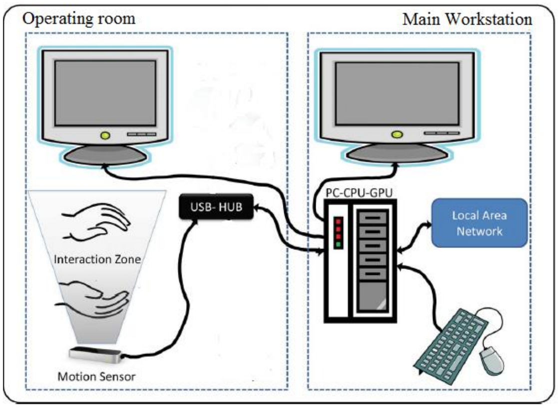
A leading example involves the system used for multiple kinds of surgery at Guy's and St Thomas' hospital in London [12] in which a Kinect helps navigate a predefined stack of MRI or CT images is illustrated on Figure 1. This system uses simple constrained gesture vocabulary to move forward or backward through the images and engage and disengage from the system.

“Figure 1. Kinect-based touchless medical imaging system [12]”

One of the main conclusion that one can make after doing a survey of the available systems of this kind is that a limited number of gestures yields benefits in terms of ease of use and the learning and adaptive ability of the user. By using a constrained gesture vocabulary can have also some reliability benefits: such as enabling use of reliably distinctive gestures while avoiding the problem where gestures in a vocabulary share common kinaesthetic components, possibly leading to system misinterpretation.

3. Gesture recognition system

The proposed system contains a Leap Motion gesture controller and an open-source interface for visualization of medical data. Based on research and gathered information through literature review and conversations with surgeons and medical practitioners at the St. George University Hospital in Plovdiv, Bulgaria, a conceptual model can be set up. This model of the proposed system is an outline for the current research conducted in this project (see the acknowledgments). The conceptual model is illustrated on Figure 2.



“Figure 2. Schematic diagram of the custom image workstation for the touchless interface in the operating room”

3.1. Leap motion gesture controller

The Leap Motion controller, the main device used for this conceptual model, is a type of touchless interaction device owned and manufactured by Leap Motion Inc. (https://www.leapmotion.com/). It offers an open library for gesture recognition. The Leap can detect a user’s hands, fingers, and finger-like objects (pen or pointer) in its inverted square pyramid field of view. The field of view has an effective range of 25 to 600 mm measuring from the top of the device. The Leap is designed so that it sits in front of the user’s computer screen. Interaction is done by making gestures with the hands fingers, or finger-like objects. The Leap can recognize three aspects of hand input. The first aspect is the ability to recognize hands, fingers, and finger-like tools and provide software interfaces to get information on each of these input types. The second aspect is the recognition of gestures, such as circles, key taps, and screen taps. The last aspect is the recognition of motions of the hands, fingers, and finger-like tools such as scaling, translation, and rotation.

3.2. Medical Imaging Toolkit (MITO)

As mentioned above the system needs an appropriate viewer for visualization of the medical image data. For the first test of the system we have chosen the Medical Imaging Toolkit (MITO) (http://ihealthlab.icar.cnr.it/index.php/projects/9-mito.html). MITO is able to let the user interact with the DICOM images using gestures and have volume navigation in surgery. MITO is an open source software released under the terms of the GNU General Public License. However, this interface requires the user to select an image using mouse and keyboard before the gesture interaction can take place. After this selection, the user is able to interact with the image. The user can measure distances, change the contrast, do translations, rotate and zoom. Normally during a surgery, the surgeon has to ask the assistant to perform these tasks.

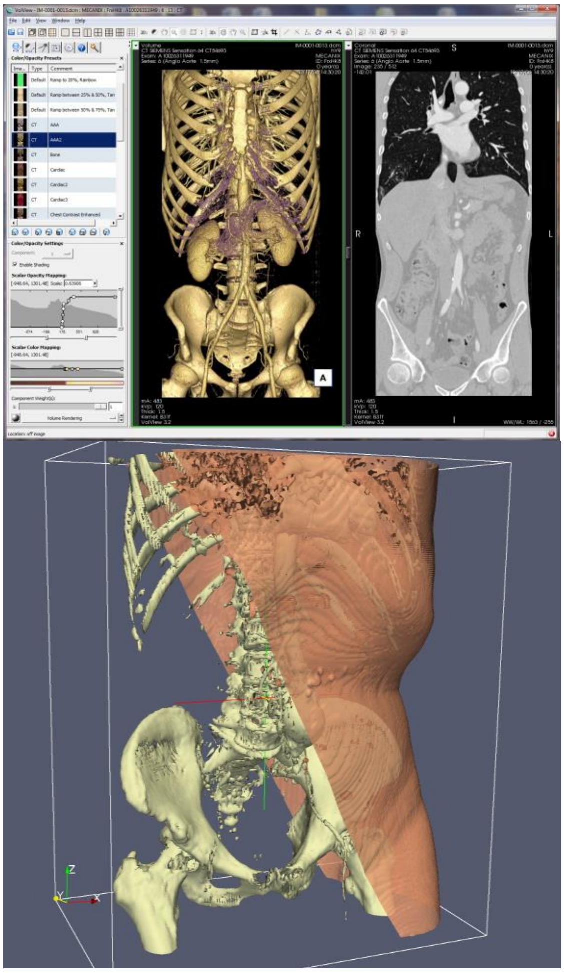
4. Evaluation of the system

Preliminary usability testing was carried out for accessing all kinds of supported DICOM images, simulating typical laparoscopic surgery situations. During this phase, the positions of all system’s components were calibrated and adjusted to facilitate working with the system. After trying different positions, we chose the final location of the Leap controller, taking into account the fact that the interaction space of the controller allowed the operator to move his/her hands in an ergonomic way in order to avoid fatigue during the gestures. Different light conditions were tested to verify whether the controller performance was affected. Different Leap Motion control settings were tested for a smooth and stable interaction, and the proposed system was set at 42 fps with a processing time of 23.2 ms; the interaction height was set as automatic. The touchless application for the Leap Motion controller was set in advanced mode. This proposed system recognized gestures that emulated touching a vertical virtual touch surface in the air (in the interaction zone above the sensor). When the operator pointed one or two fingers towards the screen, the system drew a cursor on the screen so that the operator could point items or buttons in the imaging software, and when the operator moved the finger farther towards the screen, the pointed item was selected (similar to a mouse click). The functions that required two points of control (modification of scale, zoom, or rotation) could be controlled with two fingers of one hand, or one finger of each of the two hands. By the use of this hand gesture, the operator is able to navigate through the windows, zooming in and out, manipulate the different images and slices, and use imaging tools such as the adjustment of image contrast or brightness, image enhancements, and measurement. It was possible to move and rotate the 3D simulation model from the MITO toolbox (Figure 3).

The combined system performed very well, and it was found to be very useful in controlling the system without touching anything and maintaining the surgical environment. The habituation period for the user should not very long; it may depend on how the user is accustomed to other multipoint input devices such as touchscreens.

In surgery settings, it is recommended that the user spend several training sessions (4-6 sessions of 30 min each), assuming that he/she had a previous knowledge about the usage of the software with the standard input devices (mouse, touchpad, and touchscreen). With a little training by the user, without a doubt, it is easier and faster than changing sterile gloves or having an assistant outside the sterile environment.

During our experiments we have also considered using the MS Kinect sensor for this system. The Kinect uses a horizontal tracking approach and needs a minimal working distance in approximately 1.2 m. In contrast, the Leap Motion tracks in much smaller interaction zone. The interaction zone of the MS Kinect is larger (approximately 18 m^3) than that of the Leap Motion (approximately 0.23 m^3). So the Leap requires much smaller operating space.



"Figure 3. Touchless manipulation of 3D simulation model from MITO toolbox"

5. Conclusions

The goal of this study is not simply to demonstrate the feasibility of touchless control in the operating room. During the initial steps of the development of the system important design challenges have arisen. They range from choosing the appropriate gesture vocabulary for the surgeon to finding the appropriate combination of input modalities and specific sensing mechanisms. These choices can play important role in the development of the systems but must be addressed further, especially when the system will be used in real-world clinical settings. These are the first step to develop an autonomous system for touchless interaction the operating room capable of servicing the needs of any medical practitioner required to work in sterile environment.

It will be challenging to consider the fatigue due to prolonged use of the touchless system that could affect its use, as well as other physical features of surgical practice.

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