Gestix in the Operating Room

Abstract

A hand gesture system for medical images manipulation called “Gestix” was tested during a brain biopsy surgery. In the in vivo experiment, this type of interface avoided surgeon’s focus shift and change of location while achieving, rapid intuitive reaction, and natural interaction. The major advantages of this approach was naturalness (surgeon use his hands), and rapid reaction (hand gesture commands intuitive and faster than verbal voice commands). The Gestix system responded to the surgeon’s gesture commands in real-time. Data from two usability tests were completed with the main surgeon, and insights regarding the interaction between surgeon and human-computer devices were acquired.

Introduction

An experiment was carried out at the Washington Hospital Center in Washington DC. Two operations were observed during one full morning at the neurosurgery departments. The focus was to study the interaction amongst the doctors (interruptions and cooperation), and their use of a hand gesture recognition system in the operating theatre, inspired by [Hansen and Bardram 2005] and [Nishikawa et al. 2003] but adding hand gesture recognition instead of voice or face control. Many studies have been conducted using novel human computer devices to assist doctors in the operating theatre however, this is the first time that a hand gesture recognition system was used successfully implemented in a “in vivo” neurosurgical biopsy. The human–machine interface is of supreme importance because it is the means by which the surgeon controls the medical information while staying sterile. We have designed a novel human–machine interface, called “Gestix,” for manipulating medical imaging through the use of hand gestures. The proposed human interface is an image recognition based system which tracks the surgeon’s hand motions robustly in real time and prevents contact with external devices, so the surgeon remains sterile. The surgeon can easily browse, zoom or rotate MRI or X-rays by simply making the appropriate hand gesture. To evaluate the performance of the proposed system and its applicability in clinical use, we set up an in vivo experiment, in which the surgeon used the system to visualize MRI images concerning a brain biopsy on a patient.

Layout of the operation room

There were 8 people involved in the surgical procedure: three non-sterile nurses, a sterile
nurse, an anaesthetist, a surgeon and two assisting surgeons. The operating room was full of displays, controls and buttons to operate different devices distributed around the room. Through this report the terminology used was adopted from the work in [Hansen and Bardram 2005]. The main control wall was placed on one side of the room and included a typical bank of x-ray view boxes to show MRI images

Figure 1. The main control wall

The MRI images in the main control wall were inspected mainly by the non sterile nurses during the surgery and by the surgeon before the surgery. Next to the main wall, two nurses were in charge of entering data and looking for relevant medical information among the electronic patient records in the Azyxxi system.
The control screen interfaces and controls were placed around the anaesthetist. The displays monitored critical information regarding the patient, like blood pressure oxygen, etc. The anaesthetist used these controls to adjust the mixture of gas given to the patient. The control screens shown in Figure 2.

Figure 2. The control screens

The surgeon and his assistants used the “mobile control setting” layout controls which consisted of monitors displaying, endoscopic images, the controls of the burner used to burn blood vessels and other instruments. Some of these devices were controlled by a foot pedal under the patient bed by the surgeon. The surgical lighting and other controls were manipulated mostly by the non sterile nurses when requested by the surgeon in order to keep him sterile. The raw data and endoscopic images from the monitors were used by the three surgeons. The layout of the mobile control setting was settled in the pre-operating phase stage.

Figure 3. The mobile control setting

The surgeon was able to interact through a touch screen interface with a neurosurgical microscope and navigate through real time MRI images of the patient.
The main interaction problem observed was the fact that the main surgeon was not able to manipulate the displays and the controls from the mobile control setting naturally. Every time that was necessary a change in the settings, the help of the non sterile nurses was required. The only device that the surgeon had direct interaction was the neurosurgical microscope visualization tool, however was required for this to change his standard position and this created a delay in the surgery procedure and a change of focus from the surgeon.

Figure 4. Touchscreen-based-intra-operative planning and navigation system

The Procedure

During the pre-operational stage, the surgeon staff discussed different causes for "stains" obtained in the MRI images from the patient and decided that re a biopsy from the patient's brain was necessary. In the beginning of the surgical procedure, a set of MRI images were displayed in the main control wall and the surgical plan was determined. Next to the entrance of the patient, the anesthetist put the patient to asleep, and the surgical procedure started. The operating surgeon used both hands and the foot pedal to manipulate a variety of surgical instruments, while images of the patient's body were displayed through a TV monitor screen. The touchscreen-based-intra-operative navigation system was used by the surgeon to navigate inside the brain of the patient to the spots in the brain that were the area from which the doctors wanted to obtain liquid samples for the biopsy. The sample for the biopsy was

obtained and given to the specialist immediately for in deep lab analysis. This kind of procedure usually lasts for 20-25 minutes in which the doctors discuss possible scenarios to follow according to the results obtained from the analysis. Usually during this time the doctors display new information from the surgery and updated MRI images on the main control wall. This requires from the doctors to move to the side of the room close to the control wall and discuss possible ways of action. Hence, there is a shift of focus of attention, and a change of location. To avoid this, a new system was introduced in the operating theatres that allowed the surgeons to browse through MRI images with only hand gestures commands.

Figure 5. Panoramic view of the operation room during the surgical procedure

The Gestix System

The surgeon, usually needs to avoid the rotation of the focus of attention and the change of his position during the operation because this causes additional mental effort and delay the surgery. In the studied standard brain biopsy surgery, the surgeon usually stands in a fixed place, in front of the TV monitor displaying the scope image, and observes the surgical point of interest on the touch-screen of the intra-operative navigation system. Therefore, we can assume a distance-constant interaction during the entire interaction time, except for the brief period that the surgeons gather close to the main control wall. The purpose of this discussion is to browse and navigate through updated MRI images of the patient and decide about the next steps to follow in the surgery, while the analysis of the brain substance is been carried on. Hand gestures are nonverbal and seem suitable for the precise control of the image navigation system. Furthermore, gestures do not require the use of pedals, and so they are convenient for the operating surgeon which sees natural the use of his hands a part of his work as a surgeon.

Gestix is a sterile gesture interface for users, such as doctors/surgeons, to browse medical images in a dynamic medical environment. A vision-based gesture capture system interprets user's gestures in real-time to navigate through and manipulate an image and data visualization environment. Dynamic navigation gestures are translated to commands based on their relative positions on the screen. The gesture system relies on tracking of the user's hand based on color-motion cues. [Wachs et al. 2006].

The Gestix system was placed in front of the main surgeon, in middle distance between the patient bed and the main control wall, see Figure 6. The Gestix system can be broken down into the following three states;

1) BROWSE state: Navigation through MRI images while maintaining the image of interest in the center of the video frame. This state corresponds to pan and tilt functions.

2) ZOOM state: Providing the required magnification of the image of interest. This state corresponds to getting closer and further from the camera.

3) ROTATION state: Rotating the image of interest CW or CCW according to the rotation of the palm of the hand.

All the visualization work needed for the surgeons can be summarized into any of these states.

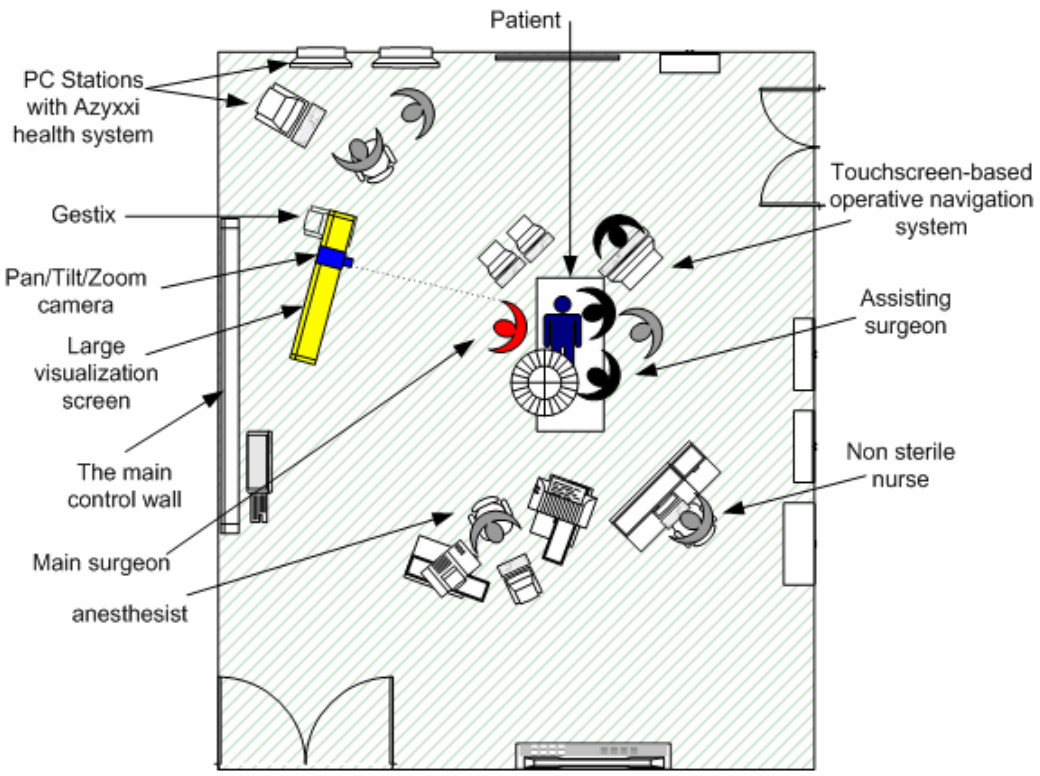

Figure 6. Operation room layout with Gestix on it

Usability Tests

Two different type of usability tests have been done with the Gestix system, the first is contextual interviews and the second was an individual interview. Contextual interviews were the main tool used as a usability assessment of the interaction of the surgeons with the Gestix system. Similar to usability tests, are based on watching and listening the users while they work. A lot of information was obtained from seeing the surgeons working in their natural environment and the technologies used by them during the surgery. Has been found that the operation room is a pervasive computing environment filled with monitors, computers and electronic devices for patient monitoring. There were a total of 8 people from the neurosurgery department staff involved in the surgery. The main surgeon, which was the central person in this setting had to remain sterile during the whole operation, close to the patient and sometimes distractions from his focus of attention is life critical. Even though the surgery was not simple, the main surgeon and his assistants were willing to answer questions from the Gestix designer team and that contributed to the understanding of what the surgeons were doing and thinking. Because of the type of usability method used, the results presented here are more qualitative rather than quantitative.

Individual interviews typically refer to talking with one user at a time and do not involve necessary watching a user work. In our case, the main surgeon was interviewed for 20 minutes face to face. This interview resulted in a deep understanding of the current problems in the operation theater, and how they can be solved by enhancing human computer interfaces based system. The main problems found through this usability test was the need of replacing every time a plastic adhesive cover for the touch-screen monitor, in order to keep it sterile; and the delay resulted from the time that took to the surgeon to go to main control wall and to return to the patient side.

A questionnaire was created to measuring satisfaction containing semantic distance scales with five points, similar to the ASQ created by Lewis [Lewis 1991] (see Table 1 below). This questionnaire included questions on task experience, ease of task, time completion task, and overall task satisfaction. The answers for all the three questions got 5 points.

Table 1. A subjective satisfaction questionnaire

How would you describe how difficult or easy was to complete the task?				
Very difficult				Very easy
1	2	3	4	5
How satisfied are you with the use of the Gestix application to complete the task?				
Not satisfied at all …….....Very satisfied				
1	2	3	4	5
How would you rate the amount that took to complete the task.				
Very time consuming				Very short time
1	2	3	4	5

In addition, a usability test using the Gestix system was conducted to collect the task completion times, error counts and level of completion of the task. While the biopsy analysis was carried on, there was 20-25 minutes period were the main surgeon and assisting surgeons were asked to complete a task. This task consisted of browsing the MRI images using only hand gesture commands, to the best of their ability. At the end of the operation procedure, a questionnaire to measure satisfaction was asked to the main surgeon about overall product usability.

(a)

(b)

Figure 7. Using Gestix in the OR. (a) Browse function. (b) Rotation function

Conclusions

A hand gesture system for medical images manipulation was tested during a brain biopsy surgery. This system is based on a real-time, hand-tracking and recognition techniques. In the in vivo experiment, this type of interface avoided surgeon's focus shift and change of location while achieving, rapid intuitive reaction, and natural interaction. The hand gesture control interface showed to be more efficient in the operation room than voice control, since the OR is highly noisy (there are conversations between the doctors, radio FM turned on, etc). The major advantages of our approach are summarized as follows: 1) easy to use: the system allows the surgeon to use his hands, which are their natural work tool, which makes the surgeon more comfortable; 2) rapid reaction: nonverbal instructions by hand gesture commands are more intuitive and faster than verbal instructions (typically voice commands). In practice, the Gestix system can process images and track the hands at a frame-rate of 150 Hz, hence responding to the surgeon's gesture commands in real-time; 3) natural communication: the proposed system does not require the surgeon to attach a microphone, use head-mounted (body-contact) sensing devices or the use of foot pedals. It is natural, intuitive and nonstressful for the surgeon; and 4) controlled by distance: the hand gestures can be performed up to 5 meters far from the camera and still be recognized accurately.

Data from two usability tests indicates that our system provided a versatile method that can be used in the OR to manipulate medical images in real-time, in "in-vivo" environments. Both usability tests were totally completed with the main surgeon, and the lack of users may be criticized, however as soon as the data from a single test user was collected, our insights increased significantly. Nielsen showed that when only one user participates in a usability test, almost a third of all there is to know about the usability of the design is learned [Nielsen 2000]. "The difference between zero and even a little bit of data is astounding". Now we are considering the addition of static posture recognition to increase the functionality and the system capabilities. Another feature being added to the system is the visual tracking of both the surgeon's hand and straight surgical instruments for the rotation command. A more exhaustive comparative experiment between our system and other human–machine interfaces is left for future work.

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