Practical Applications of Movement Control Technology in the Acquisition of Clinical Skills

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ABSTRACT

Intelligent environments are increasingly becoming useful scenarios for handling computers. Technological devices are practical tools for learning and acquiring clinical skills as part of the medical training process. Within the framework of the advanced user interface, we present a technological application using Leap Motion, to enhance interaction with the user in the process of a laparoscopic surgical intervention and integrate the navigation through augmented reality images using manual gestures. Thus, we intend to achieve a more natural interaction with the objects that participate in a surgical intervention, which are augmented and related to the user's hand movements.

Categories and Subject Descriptors

H.1.2. [**User/Machine Systems**]: Human information processing

General Terms

Measurement, Design, Human Factors

Keywords

Surgical simulation, Technology, Motion capture, Frames, Infrared light, Leap Motion

TEEM '15, October 07 - 09, 2015, Porto, Portugal

DOI: http://dx.doi.org/10.1145/2808580.2808583

1. INTRODUCTION

In recent years, computer calculation capacity has multiplied, processing large amounts of information and enabling the development of applications based on three-dimensional medical imaging. Therefore, manual control systems that use an array of infrared emitters and sensors to triangulate finger position, generate clinical training computer applications where manual dexterity is key [1-6].

The possibility of connecting a small device in front of the monitor through a USB cable that can capture hand and finger movement with high precision, allows the development of work tools with state of the art technology to practice clinical procedures which require manual execution to gain skills through continued training. Devices like Kinnect, Leap Motion, Wiimote, amongst others, are opening many doors, creating natural user interfaces and research in the field of health science.

These interaction devices have monochromatic cameras and infrared LEDs that interact with the computer simply and intuitively by using our hands.

In clinical practice there are maneuvers that can be reproduced through motion capture interactive technological devices. Therefore, a number of requirements and parameters to make these prototypes more efficient and personalized are needed, depending on user needs and their purpose.

The Imaging and Biomedical Knowledge Technology Center (CITEC-B) in Madrid, together with the research groups of Salamanca University, VisualMed System and the Biomedical Imaging Center in Extremadura (CIBEX), located in the J. Usón Minimally Invasive Surgery Center in Cáceres, have developed state of the art technological resources for surgical training, aimed at accomplishing a more efficient and quality medical training, allowing the practitioner to acquire hands-on skills using motion capture devices. Our objective using these tools is to develop skills in medical students and professionals through the use of computer simulation technologies with hand motion capture systems, improving the training process through continued clinical practice.

We present a practical example of an intelligent environment application using a technological device like Leap Motion that enables us to communicate directly with the application. The user's movements to control the elements of the application through complex gestures in the process of a laparoscopic surgery are recognized and seen on the computer. These simulation technology developments grant access to unique learning resources within the medical training process. In recent years, the laparoscopic surgical technique has been rapidly and continuously incorporated in different types of interventions. It is therefore necessary to have a good training in this area, focusing on different anatomical body landmarks. Our aim, with the technology we are presenting, is to provide tool that attempts to bring the user closer to a simulation as real as possible to minimally invasive surgical procedures such as a laparoscopy.

2. MATERIAL AND METHODS

In our study, we used the Leap Motion Controller. It is a small USB device that allows tracking user hand movement and position to interact with computers without the need of a keyboard or mouse. This system creates a three-dimensional virtual space, with a more natural interaction between man and computer. Its optical and infrared sensors detect and interpret hand, finger and pointer movement.

To select the instrument we used touch emulation offered by Leap Motion, which depending on the depth, detects whether it is an event of touch (touch) or is simply placed over the element (hover), as can be seen in Fig. 1.

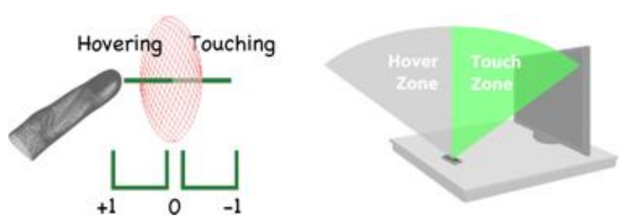

Figure 1. Schematic representation of movement control over the area shown by the device.

Hence, if the placement of a finger over a button is registered and the depth is within the touch zone, it will be assessed as an event of touch, like a mouse click, selecting the instrument.

Once the instrument was selected, the Unity API was used to grab it with the hand. A component named Collider was added to both 3D models (instrument and hand), which is used by Unity's physics engine to detect collisions amongst different objects. The Rigibody component was also added, providing a mass to the objects so they can interact between each other with a specific force and thrust.

Rigibody can also be used to add the effect of gravity to the objects. However, this property has been deactivated because it was not relevant in our application.

Depending on the tool selected, a series of actions were implemented to simulate movements that real instruments would have: clipper (clip), right angle dissector (cut, cauterize), curved dissector (pull, cut), hook (cauterize), scissors (cut, cauterize) and needle holder (suture).

In this first version of the surgical simulator, it was decided that the instruments themselves be the ones to detect, through the colliders, if they have to act or not, although we are working on adding a new function to the controller: detecting the Pinch event, provided by Leap Motion's SDK, which activates the instrument and thus makes the application more realistic.

The Pinch shows if two fingers are in contact or not. A pincer grasp can be used to detect this, as seen in Fig. 2.

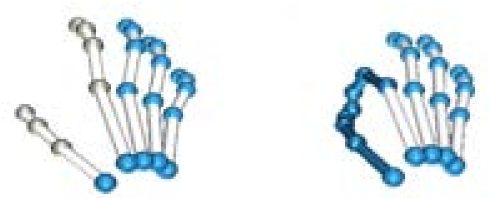

Figure 2. Pinch event to control finger position.

The SDK (Software Development Kit), available in Leap Motion's website, gives the necessary API (Application Programming Interface) to develop applications that use the tracking information offered by the Leap Motion Controller.

Leap uses a Cartesian coordinate system focused on the device to encode the distance, speed, duration and angle of the different elements it detects (hand, fingers, pointers, movement and gestures).

Its field of view is approximately 150 degrees, and its range extends from 2, 5 cm to 60 cm (1 inch – 2 feet).

Besides de aforementioned properties (distance, speed, duration and angle), depending on the type of object detected, Leap provides a number of additional properties of great interest.

In the case of the hand, for example, it gives information regarding identity, position and other features of the detected hand, such as the arm it belongs to (right – left), and the list of associated fingers (thumb, index, ring…). This way a specific action can be assigned based on these characteristics.

From this data, three types of movement can be estimated from the tracked elements: rotation, scale and translation. Moreover, it recognizes movement patterns named gestures, classified in circular movements, Swipe and Taps.

All the functions offered by the SDK are always the same, although depending on the operating system it will be developed for (Windows, Mac, Linux), there are different packages available on their website, directed to several development environments and programming languages that they support. Amongst these, we chose Unity5 together with C# for this project.

What led us to choose Unity was its compatibility with the most used 3D model programs such as 3Ds, Max, Maya or Blender. The three-dimensional anatomy contents used in this study were already developed with these programs.

Unity supports multiple platforms, developing applications from the same tool for different operating systems (Windows, Android, iOS).

3. RESULTS

Nowadays, most intestinal surgeries can be done laparoscopically. These include surgery for Crohn's disease, ulcerative colitis, diverticulitis, cancer, rectal prolapse and chronic constipation; in addition to specific gynecological and gallbladder surgeries.

Our procedure compiles a number of applications related to laparoscopic surgery that try to bring the user closer to a simulation, as real as possible, of minimally invasive surgical procedures. During these types of operations, the surgeon watches the movements being made inside the patient on a screen. In this application some of the real screenshots are shown and there is a virtual simulation of the tools the user works with.

Fig. 3 shows a scenario of this application where the user has a series of icons on the sides of the screen that can select the instrument needed. As happens in real life, you can choose to use the instruments with the left or right hand.

It should be noted that the instruments selected through the buttons on the right side of the screen can only be taken with the right hand, as well as those which are on the left can only be held with the left hand. The methods isRight and isLeft were used respectively, available in Leap Motion's SDK, version 2.0.

This application is unique because it has the possibility of virtually taking the instruments using Leap Motion.

Leap Motion traces a virtual image of our hand and articulations starting at the wrist and tracks all the movements. In order to do this, the necessary gestures must be created to control the application that manages and integrates them. Integrating Leap Motion into any application would therefore be very simple. When a gesture is created, the user can define a number of parameters like speed, movement axes, or similarity between the gesture and the real activity. The application will store the data of the user's movements so when a movement is carried out, it can be compared with the stored gestures. If the gesture is recognized, an event is launched, which the application captures and depending on the gesture made, it acts accordingly The device controls different frames or images using infrared light and the camera detects what the device is seeing.

In addition to the minimum functions, more advanced requirements can be established to make the prototype even more efficient and customizable depending on user needs. For example, when creating a specific movement, the user can decide if speed is important or not.

Some companies have added Leap Motion to their computers, such as Asus in some high-end notebooks and All in One and HP in desktops. This will certainly facilitate user navigation. However, it is still unknown the degree to which physical fatigue compromises the use of this technology; or if it produces less fatigue than the mouse or keyboard, after several hours of use. These aspects have yet to be evaluated. Therefore, we believe it is more appropriate to use this technology for specific interventions that require the use of hands, or to carry out training systems, for example in a laparoscopic surgical intervention where it is easy to emulate the movements that are performed in this type of operation, as shown in Fig. 4.

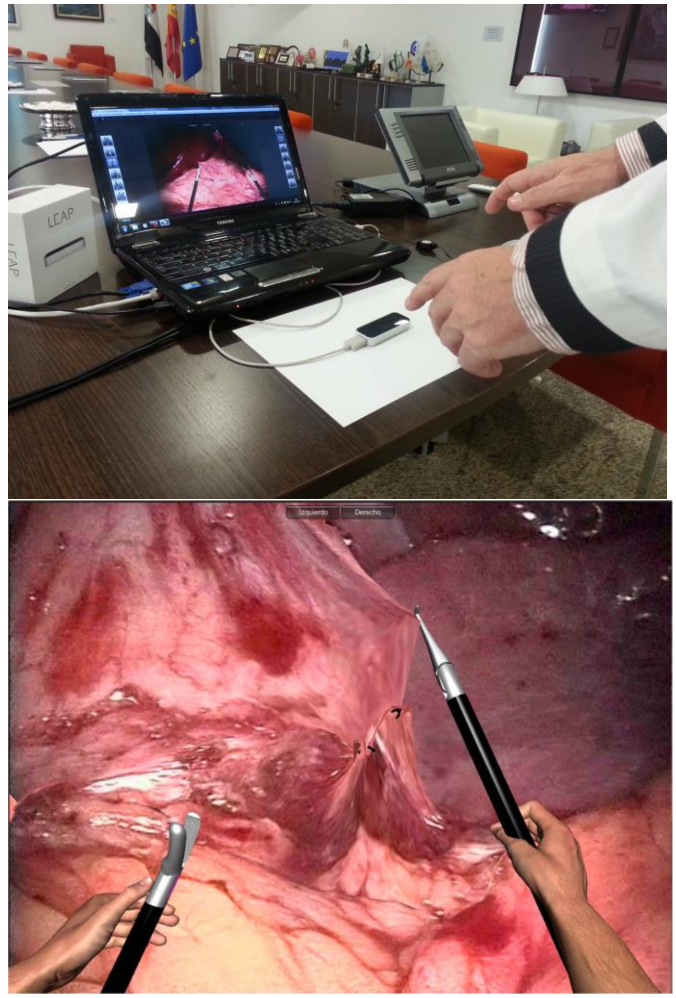

Figure 3. Example of its use (I)

We are aware that a simulator, however complex and perfect it may be, can never be fully compared to reality, so we must always bear in mind its limitations and the fact that it will never completely replace contact with the real situation. It is also true that the combination of simulation methods close to reality, like the one we present, connects them to clinical practice, benefitting more from the medical training process as well as real clinical practice. Thus, the use of technology systems with manual manipulation of computer images, as an additional clinical training resource allows for better results in these tasks subsequently. Leap Motion reveals a third dimension, adding greater depth and interaction with the scene.

Nevertheless, in order to see the benefits of adopting new control and manual manipulation devices, there needs to be a change in mentality and competence of the parties involved. This change will be easier as the results using these technologies become more visible and when the different physicians (doctors and surgeons) can directly test the advantages the use of these technological devices brings to their ongoing training process. In the not too distant future, the technical features of these devices will likely encourage the participation in the learning process through direct contact with contents from the application; making them an excellent resource for medical training.

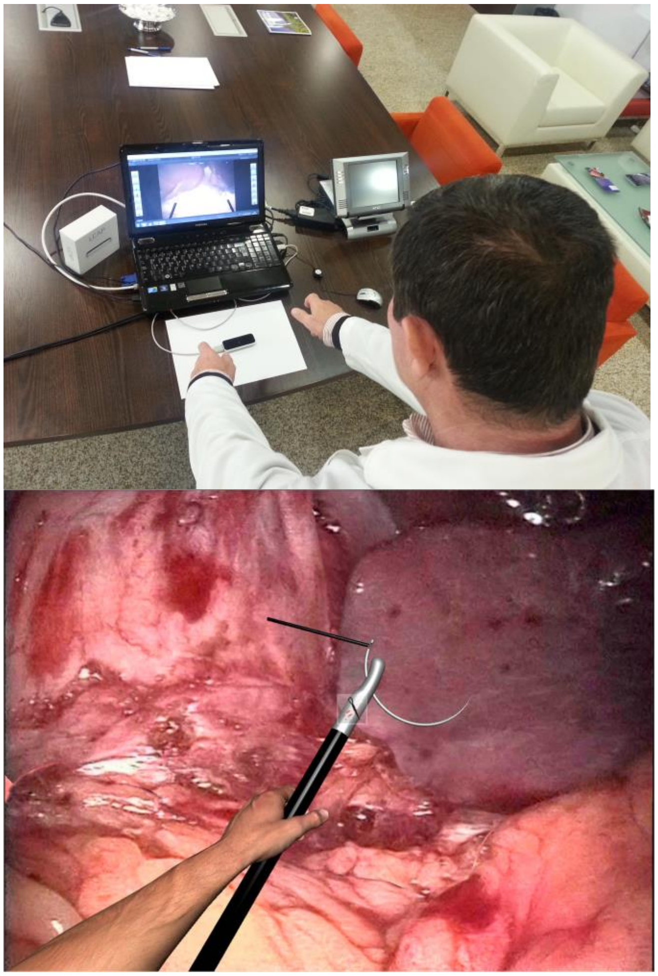

Figure 4. Example of its use (II)

4. CONCLUSIONS

The integration of CITEC-B; CIBEX and VisualMed System groups aims to support and encourage technological resources that improve the medical training process through the interaction between physician and computer so they can acquire the necessary skills and experiences, enabling them to get the knowledge they need for their clinical practice as well as for planning surgical interventions guided by computers. The integration of clinical training technologies to the medical education process supports teaching and provides the necessary tools so medical students and physicians receive a positive response in their ongoing training process through technological devices like Leap Motion that detect and interpret hand movement. The virtual medical environments not only encourage collaborative work, but are true learning communities which further enhance the learning process.

Currently, computer developments used as teaching tools in medical training play a greater role as indicators of the effort towards efficiency and the improvement in the quality of medical training processes. The handling of these devices through manual manipulation with Leap Motion has led to changes in the knowledge transfer systems as well as the development of medical surgical software, whose vision is close to reality, for medical training in different specialties, gaining skills in diverse fields of medicine. Moreover, the creation and visualization of three-dimensional images using computers takes on a new dimension in medical and surgical training, facilitating the analysis of any morphological structure in a way that is close to reality. It is clear that the new motion sensor developments, linked to the digital revolution, are transforming the visualization and manipulation techniques in medical imaging. As a result, our aim is to encourage the development of skills in medical professionals through the use of simulation technologies, benefitting from motion sensor systems to improve the training process.

Ideally, this device would have motion sensors, however, this would make it bigger and more expensive. This distinguishes it from other devices like Kinect, which incorporates sensors, but has other drawbacks. Being a newly created device, there are still few developers that offer applications for it. Nevertheless, some of them enable us to come closer to our needs when acquiring surgical skills. Some of these API *(Application Programming Interface*) allow recording different gestures and movements to be later recognized, as is the case of LeapTrainer.js, in JavaScript programming language. It works simply, when a new gesture is created, its data is saved in JSON (acronym for *JavaScript Object Notation*). It is a light format to exchange data. JSON's simplicity has led to its widespread use, as an alternative to using XML (*e**X**tensible **M**arkup **L**anguage*). When a movement is made, the data of the recorded gestures is compared to the movement through a simple algebraic algorithm and depending on the success rate, it is detected or not.

Airkeys.js is another program that can run in the background using Leap Motion for Windows. This application cannot add more gestures than the ones it already has, only predefined ones; it can be easily configured using XML language.

JestPlay is another application that records our gestures and movements saved in the data that Leap Motion sends back to our computer through BVH (*Biovision Hierarchical Data*) or JSON, which also uses JavaScript.

JestPlay is more precise, because when the movement data is introduced, it can reproduce it in 3D, needing the data of each finger and their angles. Nevertheless, the LeapTrainer is simpler and saves little data, necessary to be able to compare gestures. The difference between both is that the first can recognize gestures and the second cannot.

Currently, there are similar devices on the market, such as *Nintendo Wii2* or *Microsoft Kinect*, however *Leap Motion* has several advantages that rank it as the most suitable tracking device to simulate gestures which are performed during surgery.

Unlike the *Wii*, which needs a physical console, *Leap Motion* works directly with computers by simply connecting it to a USB port and installing the necessary *drivers.*

Regarding *Microsoft Kinect*, in addition to the clear advantages in terms of price and size (*Leap Motion* costs less than half and is much smaller), there is another clear difference in terms of its features. While *Microsoft Kinect* detects the entire body, optimal for tracking complete skeleton movements, for example in *fitness games* or *dance games* applications, *Leap Motion* is more precise when detecting finger position and movement, an improvement in the simulation of gestures made when using a surgical instrument, as is the case of this article, the simulation of a laparoscopic surgery.

The construction of a platform to detect hand gestures and movements with a camera demands the implementation of several subsystems. First, it needs a component that can distinguish the target object from the rest of the objects on the scene. Then, mechanisms to locate the displacements and recognize the movements are required. A user interface is also necessary in order to use the platform. For the system to be effective, its performance must be efficient and reliable, which is achieved with low-complexity algorithms and tolerant to different environments. The algorithm generates data regarding position, speed and hand movement direction, selected according to their consistency with the parameters in the medical images; thus, every time the user stops or temporarily moves the hand without making a net displacement, the program notifies the system and acts accordingly.

Studies about the knowledge society have shown that the use of technologies, as well as virtual learning environments, using manual control devices, are powerful and effective tools at all levels in medical training, specially contributing to improving performance through the interaction with clinical simulation systems.

Technologies provide important possibilities in the generation of computer procedures for medical training. This is of great interest in different medical and surgical specialties, especially in mastering clinical diagnosis and acquiring surgical skills. Furthermore, these technological procedures create artificial situations that to some extent are similar to the real ones, increasing user motivation and providing a better understanding of concepts and technical skills that given their complexity, are difficult to understand and apply.

The use of these technologies in medicine, involves changes in the medical and surgical training process and in the traditional teaching model. Manual control technologies with devices such as Leap Motion, are currently one of the great technological revolutions in biomedicine, which has been able to take better advantage over other knowledge areas.

Different user interface designs generated in medical applications for teaching purposes that we have developed between the research groups of VisualMed System, University of Salamanca and the Biomedical Knowledge Technology Center in Madrid, have proven to have high satisfaction levels amongst users, reflected in the surveys conducted. The success of these innovative technology developments within medical and surgical specialties is possibly due to the quality of our computer procedures, their design and presentation, always seeking to improve medical training with the use of these resources.

Although the device is within everyone's reach because of its low cost in the market, it has not received the necessary support from developers, so currently it offers few applications. However, we believe this innovative device has many development possibilities and a promising future in the acquisition of clinical skills. Nowadays, there are more computers on the market that integrate motion sensor technologies. There is no doubt that in a not too distant future different modifications will be made and new features added that will improve these technologies [1-5].

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