Interactive 3D Medical Image Visualization in Operating Rooms using the Kinect Sensor

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ABSTRACT: In the operating room (OR) a touchless interface is an ideal solution since it does not demand any physical contact and still can provide the necessary control features in a cleansed and sterilized environment. Using the Kinect sensor and image processing techniques, we implemented a hand tracking and gesture recognition system based on the Kinect device that enables surgeon to successfully touchlessly navigate through the image in the intraoperative setting through a personal computer. We integrated this feature to the open-source InVesalius software, which provides high-quality 3D reconstruction of medical images. The system was effectively used in three real surgeries, and CT images were fruitfully accessed during surgerical procedure for tumor enucleations in patients whom elective nephron sparing surgery was performed for small non-exophitic tumors. The system was reported to be very efficient and enabled a low-cost and accurate control of the software InVesalius intraoperative just using hand gestures.

1 INTRODUCTION

Computer interfaces based on gestures have been intensively researched [1,2] but limitations like high cost, bad accuracy and setup complexity have contributed to keep this technology impractical for real world applications. This situation changed drastically recently with the release of a low-cost, small and easy-to-setup device by Microsoft, called Kinect.

Gesture user interfaces have applications in many areas, but the present work is primarily focused in one particular application which is the visualization of 3D medical images during a surgical procedure. This scenario is particularly important because the operating room is a cleansed and sterilized environment and the contact of the surgeon with traditional computer interfaces (like mouse and keyboard) could lead to contamination increasing the risk of patient infection.

Also, during the surgical procedure, the physician often needs to examine the medical images. This is traditionally done using previously printed images on the negatoscope. However, medical image software can provide a far richer and more suitable visualization of medical images, not only providing a better view but also providing important information such as distance and angle measurements, tissue densities and others. Nevertheless, these software are usually controlled using mouse and keyboard, requiring an undesired physical contact during the surgery.

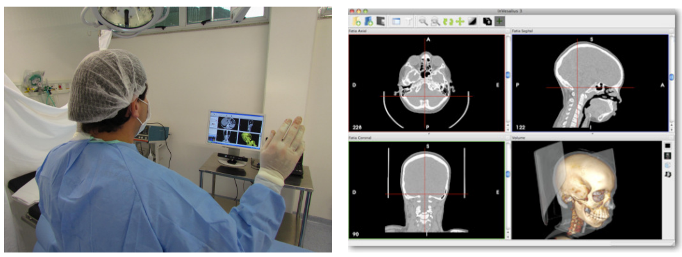

Figure 1. The surgeon (left) controlling the software InVesalius (right) by hand gestures in the operating room

InVesalius is an open-source software for visualization of 3D medical images developed by the Renato Archer Center for Information Technology. This software enables the accomplishment of diagnostics, surgery planning, prosthesis design, scientific studies, forensic analysis, among other applications. InVesalius is free and its source-code is open for download[1]. It is multi-platform (Windows, Linux and MacOS) and multi-language. The software enables the visualization in 2D slices (multi-planar reconstruction) and also in 3D using high-quality volume and surface rendering visualization, as well as exporting these surfaces in STL file format. The software also offers measurements tools, enabling the user to perform linear and angular measurements on the 2D and 3D views.

In this work, we propose a solution to this problem, by presenting a touchless gesture user interface that allows the surgeon to control the medical imaging software InVesalius just by

[1] http://www.portaldosoftwarepublico.gov.br

performing hand gestures in midair. The system is also open-source, low-cost and simple to deploy which allows this solution to be widely adopted by surgeons and hospitals allowing the use of medical image software in the operating room and yet reducing the risks of contamination.

3 GESTURE USER INTERFACE

Microsoft Kinect SDK and C++ language were used to implement this software. We used a skeleton tracking algorithm [3] that uses probabilistic templates of the human body shape (based on thousands of modeled bodies samples) to track the users in the image. It is capable of detecting and segmenting different users on the scene and can also track 20 body joints in real-time with a impressive robustness and accuracy.

We have implemented a gesture interface inside InVesalius that uses Kinect SDK to track the skeleton of the user and generates mouse event (move and clicks) based on the position of the joints. The right hand of the user controls the position of the mouse pointer. As we have all the joints coordinates, we can calculate the length of the arms and calibrate the range of the hand movement to fit each user. Furthemore, the cursor position is calculated as the relative position of the user's hand to his torso joint position, so the user can be anywhere in the camera angle of view and he can even move around the room, and the calibration remains the same. A smoothing filter in time was also applied to circumvent the problem of mouse shakiness, due to imprecision of the skeleton tracking and Kinect depth-image resolution.

The user can also use his left hand to generate virtual mouse clicks. Raising the left hand up to the level of his torso, a right button press event is generated. When the user returns the left hand down to relaxed position, a left-button release is performed. This feature allows the user to perform 3D rotations, 2D slices change and other toolbar selections. When the user raises the left hand up to the head level, a right-button event is generated, enabling the user to control the zoom. These combinations of the left hand position are easy to detect just by comparing the joint coordinates.

The system was validated in three real surgeries for endorenal tumor enucleation. All surgeries were guided by image review through gesture interface during the procedure, allowing anatomical support based on the 3D imaging previously obtained by computed tomography (CT) scan. To learn the routine of the device was very easy, taking less then a few minutes for the surgeon get used to it. The system successfully detected gestures accurately and was robust to unwanted commands.

The wide impact of such system is not limited to a precise tumor identification, but also helps to prevent wrong site surgeries which are usually the result of a cascade of small errors that in addition to ineffective communication and distractions, deficiencies related to the pre-operation and scheduling processes, relies on the limited access to the images in the OR, reducing the available information to those of the surgeon memory, mainly after intraoperative antiseptic measures, when the team is prepared and is not acceptable to touch anything but the patient and surgical instruments, adding to the wellbeing of the patient and the surgical team.

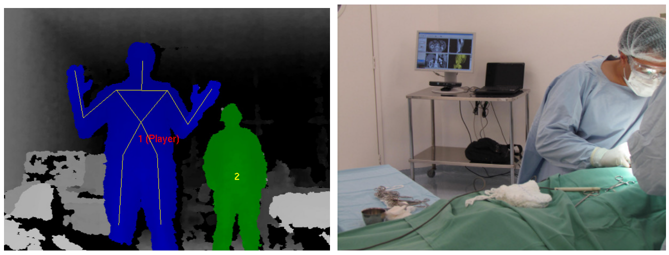

Figure 6. User and skeleton tracking using the Kinect SDK (left) and t he system inside the operating room (right).

4 CONCLUSION

In this work, we presented a touchless user interface solution of the Invesalius software to enable a surgeon to control the software. The Kinect sensor showed to be very efficient and enabled a very low-cost and easy-to-use solution. The system was used in three surgeries and was reported to work successfully, guiding the surgeon for a more accurate surgical procedure.

As future works, we plan to integrate other technologies like fingers tracking, face detections and speech recognition, as well as improve accuracy and responsiveness of the method.

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