Journal of InterDisciplinary Research Applied to Medicine
JDREAM. Journal of interDisciplinary REsearch Applied to Medicine
JDREAM (2019), v. 3 i. 1, 19-24
ISSN 2532-7518
DOI 10.1285/i25327518v3i1p19

An Augmented Reality Platform for Preoperative Surgical Planning

Lucio Tommaso De Paolis[1]

[1] Department of Engineering for Innovation, University of Salento, Lecce, Italy

Corrisponding author: Lucio Tommaso De Paolis
lucio.depaolis@unisalento.it

Abstract

Researching in new technologies for diagnosis, planning and medical treatment have allowed the development of computer tools that provide new ways of representing data obtained from patient's medical images such as computed tomography (CT) and magnetic resonance imaging (MRI). In this sense, augmented reality (AR) technologies provide a new form of data representation by combining the common analysis using images and the ability to superimpose virtual 3D representations of the organs of the human body in the real environment. In this paper the development of a generic computer platform based on augmented reality technology for surgical preoperative planning is presented. In particular, the surgeon can navigate in the 3D models of the patient's organs in order to have the possibility to perfectly understand the anatomy and plan in the best way the surgical procedure. In addition, a touchless interaction with the virtual organs is available thanks to the use of an armband provided of electromiographic muscle sensors. To validate the system, we focused in a navigation through aorta artery for mitral valve repair surgery.

Keywords: Augmented reality, surgical planning, touchless interaction.

Introduction

Advances in computer technologies applied to medicine are offering new tools for diagnosis, preoperative planning, image-guided surgery, training and even the formulation of new treatments that help the surgeon to taking decisions before, during and after performing a surgical procedure. These advances are conferring considerable advantages on the patient, but they are also imposing an additional difficulty on the surgeon, who needs to develop new skills in order to adapt to newer systems (Lamata et al., 2010).
In this sense, the technology of augmented reality begins to be a novel alternative because it supposes in a single space a transition that combines common elements in the real world with virtual elements. In medicine, the use of the AR technology makes possible to overlay virtual models of the organs on the real patient; this allows the surgeon to have a sort of 'X-ray vision' of the patient's internal anatomy. AR 'augments' the surgeon's perception with a better spatial perception and a reduction of the duration of the surgical procedure (De Paolis and Ricciardi, 2018).
Thus, surgeons have at their disposal a mixture of techniques, between traditional and digital methods that involve new forms of representation, interaction and analysis of medical data.
Currently more and more research teams are approaching the world of augmented reality applied to medicine due to the necessity to refine surgical practices and reduce the human error factor alongside the specialist's experience with advanced techniques (De Paolis and Aloisio, 2018).
One of the first publications in this sense, presented by Wagner et al. (1995), consists of a visualization system for image-guided stereotactic navigation in tumour surgery that sought to provide an innovative tool using augmented reality instead of fully virtual environments. Some years later a research group from the University of Auvergne, began the development of a guided laparoscopy system in gynaecology (Collins et al., 2014). Subsequently, the original system was improved (Collins et al., 2016) involving a framework for the semi-automatic registering

of MRI images with the video of the laparoscopic procedure.
Another interesting works comprise specializations such as dental surgery (Wang et al., 2014), maxillo-facial surgery (Ricciardi, Copelli, De Paolis 2017; Ricciardi, Copelli, De Paolis, 2015), liver surgery (De Paolis, and Ricciardi 2018; De Paolis 2017) and neurosurgery (Kersten-Oerte et al., 2015; Indraccolo and De Paolis 2017)
In this paper a generic augmented reality platform for the manipulation of medical images (CT or MRI) and the visualization of anatomical structures in three dimensions is presented. The general concept of the system is to show the user an augmented scene (view of the real world and virtual elements) so that it can have a better spatial and shape understanding of the anatomical structures that will be involved in a surgical procedure. Also, the system provides the surgeon with a way to plan trajectories or movements that can be executed during minimally invasive procedures.
The platform has been designed in order to permit surgeon to navigate in the 3D models of the patient's organs in order to have the possibility to perfectly understand the anatomy and plan in the best way the surgical procedure. During the navigation it is possible to visualize the virtual environment in the helmet and also in a computer screen in order to provide the surgeon the possibility to discuss with other colleagues on the specific clinical case. A touchless interaction with the virtual organs is available thanks to the use of an armband provided of electromiographic muscle sensors.
In the current version, the system is capable to manage two clinical cases, which correspond to two different applications, one in heart surgery and the other in neuro-surgery that served as a basis for testing the proposed platform.

Methodology

The system proposed in this paper consists of a set of blocks that execute tasks in real time to create an augmented scene. The architecture shown in figure 1 consists of three types of devices (sensors) that permit the user (a surgeon) to visualize the 3D models of the organs and interact with these.

- a Myo armband is used to recognize some user's gestures and provide the system with commands used to manipulate transformations of the virtual models (Myo);
- a set of stereo cameras used to obtain the view of the real environment where the subject is located;
- an Oculus Rift helmet used to define a reference be-tween the space of virtual models and the position of the user's head.

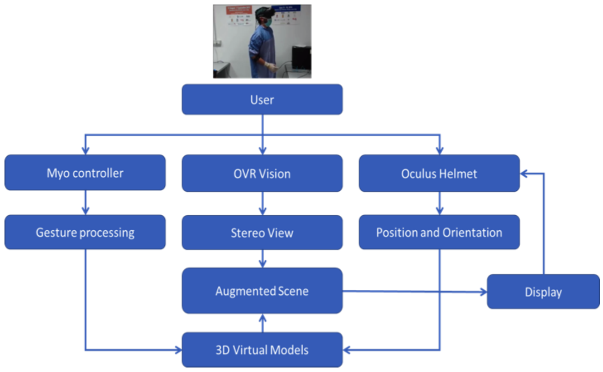

Figure 1. Architecture of the AR system

Additionally, the graphics device is responsible for duplicating the user's view of the RV helmet on a standard screen. From a functional point of view, AR application can be divided into three processing steps: tracking, alignment and rendering.
In the tracking step, Oculus OVRPlugin analyses the IR video data flow coming from the Oculus camera and processes the detected tracking system. Oculus's positional tracking system, used to track the position of the user's head, consisting of external infrared tracking sensors that optically track the headset. The Oculus is fitted with a series of infrared LEDs that permit to determine with sub-millimeter accuracy and near-zero latency the precise position of the device and, consequently, of the user's head.
During the alignment phase, some algorithms are used to align the virtual camera with the real one. This aims to make the portion of the augmented scene to appear perfectly coincident with the user's point of view that changes in real time. In every frame, the camera transformation matrix is calculated to consequently update the virtual objects parameters of position,

rotation and scale and make them proportional to the user's real movements.
In addition to this phase, it's necessary to consider a sub-phase that can be called “augmentation" of the Oculus point of view. This step consists into a second alignment phase to match the Oculus virtual camera with the ORVision virtual image plane, in which there is the video stream captured by the lenses of the stereo camera system attached on Oculus front cover. In this way, it's possible to convert a VR viewer, such as the Oculus Rift, into an immersive AR see-through system.
Finally, in the last phase of rendering, digital information is displayed in the augmented scene in such a way that the user hardly can distinguish the virtual objects from the real ones. For this purpose, some efficient graphics libraries and three-dimensional rendering engines are used to create the virtual elements, and moreover, to render the appropriate texture based on the virtual object.
Figure 2 shows the navigation and interaction system with all the involved devices:
1) Oculus tracking for virtual object positioning;
2) reference display of the model;
3) Myo armband for gestures detection;
4) Oculus Rift with the OVRVision Pro stereo camera.

Figure 2. Navigation and interaction system

Virtual Models

The reconstruction of virtual models has been made from CT images; two patient-specific cases were selected, a case of study for mitral valve surgery.
In the case of heart surgery the focus was the representation of the aorta, from the level of the groin to the heart, passing through the aortic valve to reach the mitral valve that empties into the left atrium.
The segmentation of the images was performed using semi-automatic algorithms based on thresholds, morphological operations (erosion and dilation) for noise reduction, elimination of islands and smoothing. Using the software 3D Slicer (3D Slicer), marching cubes algorithm was applied for the reconstruction of the surface of the segmented anatomical structures.
The resulting surfaces were submitted to post-processing using the MeshLab (Cignoni er al., 2008) software; later the models were refined and placed in their final position using Blender (Hess 2010) framework, where the experimental setup was built and later exported to Unity3D (Unity) engine.

Gesture Recognition

The interaction with the virtual contents implements a touchless method through hand gestures and forearm movements. Myo armband uses electromiographic muscle sensors that, in contact with the skin, are able to read the electrical activity of the forearm muscles and to translate in real-time them into digital commands (Indraccolo and De Paolis 2017).
The association between the gestures and the tasks to be performed on the 3D models has been realized in such a way to implement a form of interaction as natural as possible as shown in Figure 3.

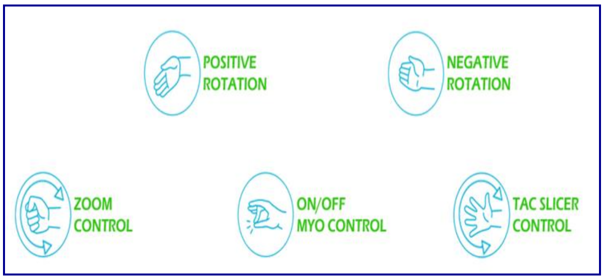

Figure 3. Recognized gestures and performed task

Two kinds of user feedback have been introduced to inform that the gesture has been detected and recognized: the first consists in a haptic feedback through a small vibration pattern inside Myo's hardware and the second one provides a graphic user interface on the top of the display device that allows to see if the Myo control is activated or deactivated. This is important because the surgeon can decide if the Myo controller must remain deactivated in order prevent incorrect or unwanted gestures.

Visualization System

Unity3D and Oculus Rift DK2 were used for the development of the visualization system.
The tracking system allows 6 degrees of freedom that are divided into rotational and positional tracking. The rotational tracking (with 1000 Hz refresh rate) is embedded inside the lenses using a gyroscope, an accelerometer and a magnetometer. For the positional tracking (with 60 Hz refresh rate) there is a camera with a near-infrared CMOS sensor that continually perceives the infrared points emitted by the HMD.
OVRVision Pro VR stereo camera were used to enable the augmented vision capability with the Oculus DK2, as shown in figure 4. The cameras were configured on full mode according to the manufacturer's description that adds a more realistic interaction. By means of the incorporation of the cameras on the scene of Unity it is possible to regulate the distance of each one of the cameras, as well as their vertical movement with respect to each other.

Figure 4. Oculus Rift and OVRVision Pro

Conclusions

The surgeons showed great interest in the application of augmented reality and made suggestions for improvements and adaptations in other specialties. This is possible thanks to the general architecture of the system that allows the adaptation of new cases of study following the described methodology.
About the devices used, most of the users did not pre-sent problems to adapt to its use and managed to be-come familiar with the interface in short periods of time.
A variant of the system, that incorporates tracking using infrared technology, could be used to guide the surgeon during a procedure by superimposing the virtual models of the organs on the real patient; in this way the surgeon could have an increased view of the patient's anatomy and know in real time the position of the instrument inside the patient's body. That allows him to take more accurate decisions taking into account the anatomical structure of interest. However, this last task introduces some complications, such as the correct alignment of the virtual models with respect to the position of the patient in the operating room. Algorithms based on fiducial points are used in order to have a correct registration phase (Wagner et al., 1995). However, the use of pre-acquired CT images in order to obtain the 3D model of the organs is not possible if the surgery involves tissues that are deformed during the procedure; in that case is required the adoption of other algorithms able to adapt with precision the geometry obtained in the process of segmentation and reconstruction to the new situation in the patient's body.

References

- Lamata P, Ali W, Cano A, Cornella J, Declerck J, Elle O J, Freudenthal A, Furtado H, Kalkofen D, Naerum E (2010) Augmented reality for minimally invasive surgery: overview and some recent advances. *Augmented Reality, InTech*

- De Paolis L T, Ricciardi F (2018) Augmented visualisation in the treatment of the liver tumours with radiofrequency ablation. *Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization* 6(4), pp 396-404

- De Paolis L T, Aloisio G (2010) Augmented reality in minimally invasive surgery. *Advances in Biomedical Sensing, Measurements, Instrumentation and Systems*, pp 305-320, Springer

- Wagner A, Ploder O, Enislidis G, Truppe M, Ewers R (1995) Virtual image guided navigation in tumor surgery technical innovation. *Journal of cranio-maxillo-facial surgery,* 23(5), pp 271-273

- Collins T, Pizarro D, Bartoli A, Canis M, Bourdel N (2014) Computer-assisted laparoscopic myomectomy by augmenting the uterus with pre-operative MRI data. *IEEE International Symposium on Mixed and Augmented Reality*, pp 243-248

- Collins T, Chauvet P, Debize C, Pizarro D, Bartoli A, Canis M, Bourdel N (2016) A system for augmented reality guided laparoscopic tumour resection with quantitative ex-vivo user evaluation. *International Workshop on Computer-Assisted and Robotic Endoscopy,* pp 114-126, Springer

- Wang J, Suenaga H, Hoshi K, Yang L, Kobayashi E, Sakuma I, Liao H (2014) Augmented reality navigation with automatic marker-free image registration using 3D image overlay for dental surgery. *IEEE Transactions on Biomedical Engineering,* 61(4), pp 1295-1304

- Ricciardi F, Copelli C, De Paolis L T (2017) An Augmented Reality System for Maxillo-Facial Surgery. *Fourth International Conference Augmented and Virtual Reality and Computer Graphics (AVR 2017),* pp 53-62, Springer

- Ricciardi F, Copelli C, De Paolis L T (2015) A pre-operative planning module for an augmented reality application in maxillo-facial surgery. *International Conference on Augmented and Virtual Reality*, pp 244-254, Springer

- De Paolis L T (2017) Augmented visualization as surgical support in the treatment of tumors. *International Conference on Bioinformatics and Biomedical Engineering*, pp 432-443, Springer

- Kersten-Oertel M, Chen S J, Drouin S, Sinclair D S, Collins D L (2012) Augmented reality visualization for guidance in neurovascular surgery. *Studies in Health Technology and Informatics,* 173, pp 225-229

- Kersten-Oertel M, Gerard I, Drouin S, Mok K, Sirhan D, Sinclair D S, Collins D L (2015) Augmented reality in neurovascular surgery: feasibility and first uses in the operating room. International *Journal of Computer Assisted Radiology and Surgery,* 10(11), pp 1823-1836

- Indraccolo C, De Paolis L T (2017) Augmented reality and myo for a touchless interaction with virtual organs. *International Conference on Augmented Reality, Virtual Reality and Computer Graphics*, pp 63-73, Springer

- Myo at http://www.myo.com

- 3D Slicer at http://www.slicer.org

- Cignoni P, Callieri M, Corsini M, Dellepiane M, Ganovelli F, Ranzuglia G (2008) MeshLab: an Open-Source Mesh Processing Tool. Scarano V, Chiara R D, Erra U (eds.) *Eurographics Italian Chapter Conference*

- Hess R (2010) Chapter 1 - An Introduction to 3D: Recreating the World Inside Your Computer, or Not. Hess, R. (ed.) *Blender Foundations*, pp 1-11, Focal Press, Boston

- Unity at http://docs.unity3d.com