



Virtual Reality as an Educational and Training Tool for Medicine

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Abstract

Until very recently, we considered Virtual Reality as something that was very close, but it was still science fiction. However, today Virtual Reality is being integrated into many different areas of our lives, from videogames to different industrial use cases and, of course, it is starting to be used in medicine. There are two great general classifications for Virtual Reality. Firstly, we find a Virtual Reality in which we visualize a world completely created by computer, three-dimensional and where we can appreciate that the world we are visualizing is not real, at least for the moment as rendered images are improving very fast. Secondly, there is a Virtual Reality that basically consists of a reflection of our reality. This type of Virtual Reality is created using spherical or 360 images and videos, so we lose three-dimensional visualization capacity (until the 3D cameras are more developed), but on the other hand we gain in terms of realism in the images. We could also mention a third classification that merges the previous two, where virtual elements created by computer coexist with 360 images and videos. In this article we will show two systems that we have developed where each of them can be framed within one of the previous classifications, identifying the technologies used for their implementation as well as the advantages of each one. We will also analyze how these systems can improve the current methodologies used for medical training. The implications of these developments as tools for teaching, learning and training are discussed.

Keywords Virtual reality medical simulator · Stereoscopic vision · Immersive system · Medical training · Virtual training tool · 360 images

Introduction

In this article we will study two very specific Virtual Reality use cases in medicine. On the one hand, we will see an interactive virtual reality simulator for a scoliosis surgical procedure, where the user can carry out the main steps of the operation in a completely virtual way. We will analyze the advantages of this system and the technologies and methodologies used for its implementation.

On the other hand, we will see how spherical recordings (or 360 recordings) can be used to create educational systems where practical vision is a key factor for learning.

The miniaturization and improvement of the processing capacity of computers has caused Virtual Reality to become a feasible technology in our society [1–4]. And it is that the Virtual Reality needs a great capacity of calculation by the devices, in addition to high quality screens that allow us to visualize the images correctly even though the devices are only a few centimeters from our eyes.

To date, technological limitations still do not allow the development of simulations that make the virtual environment of the real environment indistinguishable [5]. However, this system shows the potential of this technology in the medical field. An example is the ability to see through the skin, organs and muscles, making them semitransparent to be able to visualize the complexity of the area to be operated. [6] Another example is the ability to repeat the process as many times as desired. These characteristics would be impossible to obtain in a real environment, so we see that

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Fig. 1 Some of VR Google used for the development of our systems



virtual simulations also have their advantages over training and training with real patients.

According to some studies involving 16 surgical residents, those who have been trained using Virtual Reality techniques perform operations 29% faster than those who used traditional techniques, which shows us another example of the potential of Virtual Reality in this field [7]. Medical students and surgical residents will be frequently using VR training simulators.

The spherical virtual environments and 360 degree recordings constitute a new audiovisual dimension that allows the immersion in the recording and the possibility of observing the recorded as if it were physically in that place [8]. If until now the video was a linear material, whose movement and possibility of observation depended exclusively on the angle of capture of the recording, the management of the 360° cameras has been taken one step further, where the viewer can interact directly with the recording and choose at whim to see as if you were physically present at the recording location [9].

At the moment the medical students come as spectators to the surgeries with the objective to familiarize themselves with the environment, to know the mechanics of work, the medical procedure of action. The problem is that the number of students that can enter the operating room is limited, so that students can have this experience a few times [10–15].

Material and method

In both cases, our interactive virtual reality simulator and our system with 360 content, we have used both Cardboard SDK and Gear VR SDK. These are two different technologies that are used to develop Virtual Reality systems. The first one allow developers to create systems for a wide range of different glasses and devices (Fig. 1), while Gear VR SDK, also known as Oculus Mobile SDK, is used to create virtual experiences for Gear VR and Oculus glasses.

Interactive 360 content system

For the 360 content, we recorded a dissection room in 360 degrees to allow the user (medical student in this case), to

observe in a virtual way the most relevant elements available in an anatomical dissection room. We also recorded different operating rooms to create virtual environments, with immersive characteristics, to analyze the most representative elements of an operating room.

We have used special cameras, such us Samsung Gear 360 (Fig. 2) that can record all the environment around the camera, as they have two fisheye lens. Once we have recorded the dissection and operating room, we can not still use these images and videos. First, we have to carry out a stitching process.

In the stitching process we join the two images that we get when we take a picture with a 360 camera to get a 360 image.

We have also recorded a video of a real lung surgery, so the user can visualize the intervention as if he was there.

This program is divided by two different scenes or modules. In the first scene we have a 360 image of an operating room, and we have placed virtual elements near the different machines we can find in an operating room. These virtual elements reacts when the user looks at them, so when the user



Fig. 2 Samsung Gear 360 camera 2017 edition used for capturing 360 images and videos

looks at one of these machines an interactive panel will appear with some information of that machine or tool.

In the second scene the user will be placed in the middle of an operating room during a scoliosis surgery.

For the implementation of this system (and also the simulator) we have used the Unity3D video game engine. This program allows you to create three-dimensional environments and programming interfaces and different behaviors for each of the 3D elements in the scene.

Interactive virtual reality medical simulator

For the virtual simulator of the scoliosis surgery we first got the different 3D models used in the system, such as the 3D models of the different tools or the 3D model of the human body, including musculature, skeleton, ligaments, arteries, veins ... This supposes a more complete view of the patient and its interior, although also requires a greater amount of memory in the Device on which the software is to be run.

The programming language used for the implementation of the system has been C#. The code has been organized following the design pattern MVC (Model View Controller) [13], by which we have organized the different scripts in which the source code is divided into three large groups. The first one, the Model, contains all the scripts that store information and give access to it. In this case it has not been necessary to use database, since they are all static and not store a lot of information. Text, audio, images and videos have been used, so these scripts also provide access to this multimedia content, necessary to contribute or complement the medical explanations offered by the system. On the other hand, we have the Vista, which contains the scripts in charge of displaying the graphical elements on screen to the user.

Results

Interactive 360 content system

In this system, we highlight the most typical elements that can be found in every operating room. So when the user looks at a specific device, the system will show him/her information about that device. It will also be able to show a video that

allows him/her to see how the device must be used or even a spherical video to immerse the user in a real surgery. It is very important to create a virtual experience as realistic as possible, so we took this into consideration while programming the different functionalities. For example, videos will be visualized in the monitors.

As it is difficult to describe these systems only with images, we created a video for our readers about a virtual immersive system developed by us as an example. Follow this link to see the video: <https://youtu.be/IQCSzc7oACA>

Interactive virtual reality medical simulator

On the one hand it has been achieved that anyone is able to understand the operation of the system and use it perfectly after only a few minutes of execution. This is what in software engineering is known as usability (UNE-EN ISO 9241–9:2001), and basically measures how easy is to use the system.

On the other hand, the tool is capable of transmitting to the user what are the steps that must be taken in a lumbar transpedicular fixation procedure, which of course is the main objective. This has been achieved in three different ways:

- 1) Visualization by 3D animations of the tasks that must be carried out.
- 2) Videos of a real surgery for each step of the procedure.
- 3) Interactive simulation in which the user must test what he has learned by performing each step himself.

In the first case, the system teaches the retrosomatic musculature, which includes the emigrated musculature and own musculature, each formed by its own muscles (Fig. 3).

Once the video is visualized (you can avoid playing it), the user must carry out the action he has just seen, in this case perforating a vertebra using the punch (Fig. 4). This drilling will be the one that will later be used to introduce the screw.

Although there are other steps that must follow depending on the evolution of surgery, the previous steps summarize the actions that must be performed in this procedure. However, in the virtual simulation developed we have selected only the main steps (most of them can be seen in Fig. 5), with the aim of creating a more general-oriented experience, which does not have to have any kind of medical knowledge. The

Fig. 3 Retrosomatic musculature is first shown to the user before the surgery

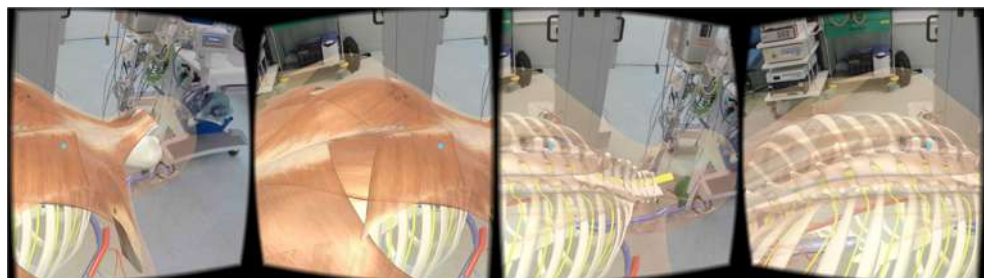


Fig. 4 First step of the interactive simulation visualizing a real video of this step

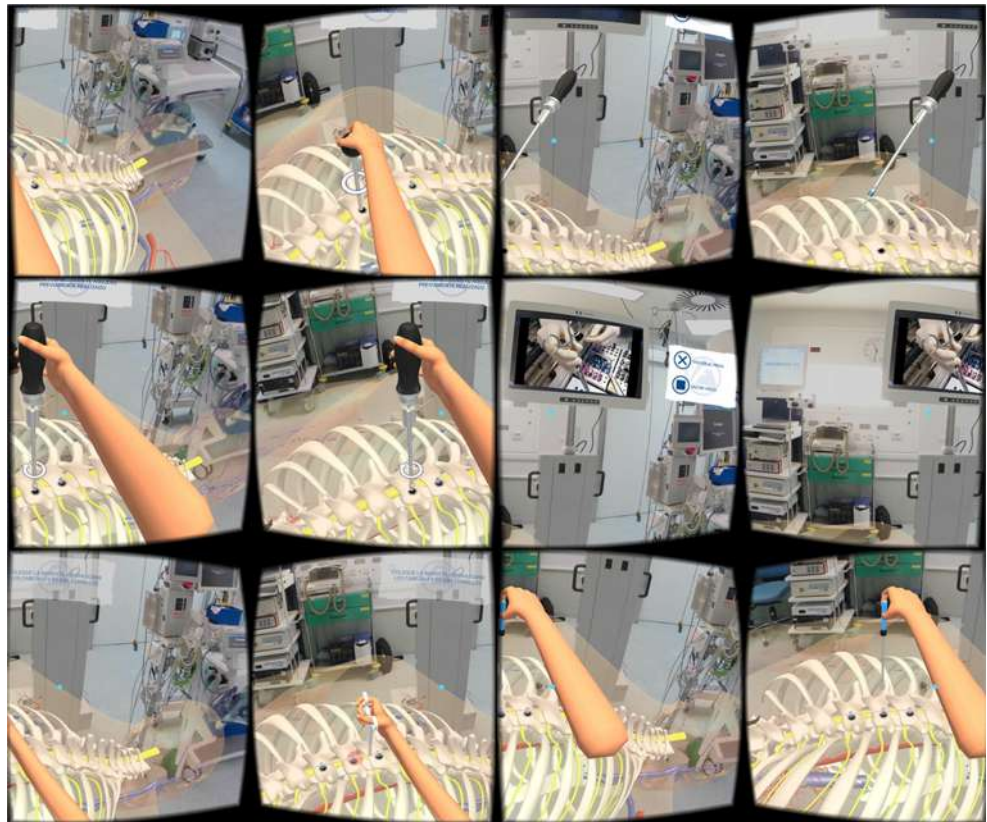


steps selected were as follows: i) use the punch or estefi's ball to work the way for the screw through the pedicle, ii) attach the screw to the screw locker, iii) fastening the screw through the path previously worked, iv) release the screw, leaving the screw in the polyaxial position, v) repeat steps 1 to 4 for the different screws to be placed, vi) capturing of the bar with the clip holder, vii) fastening the bar onto the screws, viii) attach the closure cap to the holder, ix) fixing the plug on the screw to fix the rod and x) release the cap.

Discussion

The management of technological devices such as the ones we have used will allow students to manage their knowledge and practical skills, developing new forms of teacher innovation and raising the quality of the academic process.

Fig. 5 Screenshots of the steps of the procedure



In the future, we will not only be able to visualize images, videos and virtual environments to form ourselves in different medical environments, but we will also be able to see a live operation directly, and use this technology for remote operations.

This virtual simulator is a first step towards developing more complex and detailed simulations of surgeries. Nevertheless, it is a great example of how interactive simulations with Virtual Reality may help medical professionals to better understand the surgical processes, and serve as a tool to practice in a virtual environment and become familiar with the different tools used.

It is concluded that the system is of great help to know the tools used in a surgery, as well as the most important steps of the procedure. It is also worth noting that medical professionals or students can perform the simulation as many times as they wish, unlike practices with real patients, which, for

obvious reasons, can only be done a few times. Thanks to this unlimited repetition, it is much easier to automate all the steps that must be performed in a surgical procedure, as well as to remember the points of importance to take into account in each of them.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

References

1. Buschmann, F., Meunier, R., Rohnert, H., Sommerlad, P., and Stal, M., *Pattern-oriented software architecture. A system of patterns*. Vol. 1. Wiley, New York, USA, 1996.
2. Morales-Ávalos, R., Elizondo-Omaña, R.E., Vilchez-Cavazos, F., Martínez-Ponce de León, A.R., Elizondo-Riojas, G., Delgado-Brito, M., Cortés-González, P., Guzmán-Avilán, R.I., Pinales-Razo, R., de la Garza-Castro, O., and Guzmán-López, S., Fijación vertebral por vía transpedicular. Importancia de los estudios anatómicos y de imagen. *Acta Ortop. Mex.* 26(6):402–411, 2012.
3. Joo-Nagata, J., Martínez Abad, F., García-Bermejo Giner, J., and García-Peñalvo, F.J., Augmented reality and pedestrian navigation through its implementation in m-learning and e-learning: Evaluation of an educational program in Chile. *Comput. Educ.* 111:1–17, 2017.
4. Basdogan, C., Ho, C.H., and Srinivasan, M.A., Virtual environments for medical training: Graphical and haptic simulation of laparoscopic common bile duct exploration. *IEEE/ASME Trans. Mechatron.* 6(3):269–285, 2001.
5. Chan, S., Conti, F., Salisbury, K., and Blevins, N.H., Virtual reality simulation in neurosurgery: Technologies and evolution. *Neurosurgery.* 72:A154–A164, 2013.
6. Marescaux, J., Clément, J.M., Tassetti, V., Koehl, C., Cotin, S., Russier, Y., Mutter, D., Delingette, H., and Ayache, N., Virtual reality applied to hepatic surgery simulation: the next revolution. *Ann. Surg.* 228(5):627–634, 1998.
7. Seymour, N.E., Gallagher, A.G., Roman, S.A., O'Brien, M.K., Bansal, V.K., Andersen, D.K., and Satava, R.M., Virtual reality training improves operating room performance: results of a randomized, double-blinded study. *Ann. Surg.* 236(4):458–464, 2002.
8. Wilkerson, W., Avstreich, D., Gruppen, L., Beier, K.P., and Woolliscroft, J., Using immersive simulation for training first responders for mass casualty incidents. *Acad. Emerg. Med.* 15(11): 1152–1159, 2008. <https://doi.org/10.1111/j.1553-2712.2008.00223.x>.
9. Yang, Y., Guo, X., Yu, Z., Steiner, K.V., Barner, K.E., Bauer, T.L., and Yu, J., An immersive surgery training system with live streaming capability. *Stud. Health Technol. Inform.* 196:479–485, 2014. <https://doi.org/10.3233/978-1-61499-375-9-47>.
10. Mosadeghi, S., Reid, M.W., Martinez, B., Rosen, B.T., and Spiegel, B.M., Feasibility of an immersive virtual reality intervention for hospitalized patients: An observational cohort study. *JMIR Ment. Health.* 3(2):e28, 2016. <https://doi.org/10.2196/mental.5801>.
11. Kilmon, C.A., Brown, L., Ghosh, S., and Mikitiuk, A., Immersive virtual reality simulations in nursing education. *Nurs. Educ. Perspect.* 31(5):314–317, 2010.
12. Silverstein, J.C., Walsh, C., Dech, F., Olson, E., Parsad, N., and Stevens, R., Multi-parallel open technology to enable collaborative volume visualization: How to create global immersive virtual anatomy classrooms. *Stud. Health Technol. Inform.* 132:463–468, 2008.
13. Izard, S. G., and Méndez, J. A. J., Virtual reality medical training system. In *Proceedings of the fourth international conference on technological ecosystems for enhancing multiculturality*. 479–485, 2016. <https://doi.org/10.1145/3012430.3012560>
14. Ruíz-Parra, A., Ángel-Muller, E., and Guevara, O., La simulación clínica y el aprendizaje virtual. Tecnologías complementarias para la educación médica. *Rev. Fac. Med.* 57:67–79, 2009.
15. Becker, A.A., Jones, I.A., Glover, A.T., Benford, S.D., Greenhalgh, C.M., and Vloeberghs, M., A virtual reality surgery simulation of cutting and retraction in neurosurgery with force-feedback. *Comput. Methods Programs Biomed.* 84(1):11–18, 2006. <https://doi.org/10.1016/j.cmpb.2006.07.006>.