Implementation of a Virtual Reality Operating Room for Simulation Purposes in Medical Training

Abdeljalil Azar
Medical Simulation Center of the Cheikh Zaid Foundation (CSMFCZ)
Cheikh Zaid Foundation
Rabat, Morocco
abdeljelilazar123@gmail.com

Zineb Farahat
Medical Simulation Center of the Cheikh Zaid Foundation (CSMFCZ)
Cheikh Zaid Foundation
Rabat, Morocco
farahatzineb@gmail.com

Oumama Benslimane
Medical Simulation Center of the Cheikh Zaid Foundation (CSMFCZ)
Cheikh Zaid Foundation
Rabat, Morocco
oumamabenslimane@yahoo.fr

Kawtar Megdiche
Medical Simulation Center of the Cheikh Zaid Foundation (CSMFCZ)
Cheikh Zaid Foundation
Rabat, Morocco
megdiche.kawtar@gmail.com

Nabil Ngote
Abulcasis International University of Health Sciences (UIASS)
Rabat, Morocco
ngotenabil@gmail.com

Jamal Samir
Cheikh Zaid Foundation
Rabat, Morocco
ssamirjamal@yahoo.fr

Abstract— As a technology allowing an immersion in a digitally created artificial world, virtual reality has increasingly replaced experiments on real-world objects. Thus, the implementation of a virtual reality solution can be very beneficial in education and scientific research fields. Medical simulation fits perfectly into this dynamic of integrating digital tools in the health sciences teaching. Therefore, the Cheikh Zaid Foundation's Medical Simulation Center (CSMFCZ), has focused on educational innovation by developing its own 3D environment. This paper deals with the particular case of an operating room, allowing simulation of different surgical scenarios in order to enrich the digital platform of the CSMFCZ.

Keywords—Virtual Reality, Autocad, Archicad, Medical Simulation, 3D environment, Blender

I. Introduction

Simulation can be defined as a technique to replace a real system with a model to study its behavior [1]. Several reasons justify the use of a system model to be studied instead of the system itself: either the actual system is inaccessible to direct observation, or the latter cost or the system characteristics prohibit experimental use, in particular because of possible risks to humans [2].It is therefore an essential tool for the training of risky professions, which makes it possible to reproduce the most diverse situations and to learn technical gestures without taking any real risks nor make any mistakes.

Simulation can be applied to several disciplines such as aeronautics, nuclear, shipping, armed forces and health. In the specific case of health, Simulation corresponds to "the use of a material (such as a manikin or a procedural simulator), Virtual Reality or a standardized patient to reproduce situations or care environments to teach diagnostic and therapeutic procedures, and to repeat processes, medical concepts or decision-making by a health professional or team of professionals."[3]

Simulation's use is of real educational interest because it allows the acquisition of theoretical, technical and non-technical knowledge in a sustainable way, while ensuring the safety and comfort of patients [2].

Thus, in 1759, one of the first mannequins used for teaching was born: It is Angélique du Coudray's delivery mannequin created in 1759, which allowed to train many midwives and doctors [4].

But the real upsurge of modern simulation began only in the 1960s. The first models developed by Laerdal, a Norwegian toy manufacturer, trained health care workers and the general public in cardiopulmonary resuscitation, chest compressions and mouth-to-mouth. The manikin developed by Dr. Harvey in 1968 was the first model to use the modern concept of task simulator such as blood pressure and cardiac auscultation to identify cardiac conditions [5] [6].

At the same time, Doctors Stephen Abrahamson and Judson Denson developed the first computer-controlled manikin, the Sim One [7].

In 1987, Dr. David Gaba adapted computer software used in everyday practice, mannequins and routine equipment to create the first mock operating room, initially dedicated to Continuing Medical Education and then to Initial Medical Training in 1992 [5] [6].

Since the late 1990s, and thanks to the development of computer and videogames, the supply of training in medical simulation has continued to grow with the appearance including task simulators and the creation of virtual environments [8].

Today, a plethora of techniques in simulation exist, some allow the acquisition of basic knowledge or high-level knowledge, and others focus on the transmission of know-how.

Reference [9] distinguishes between several levels of simulation ranging from Low-Fidelity to High-Fidelity, depending on the complexity of the equipment used and the possible interaction of the trainers with the participant.

Among these High-Fidelity techniques, Virtual Reality is a technique based on the use of a set of devices that can digitally simulate an environment. According to the technologies used, it allows the user to feel a virtual universe through its different senses: the sight (the mostofen), the touch, the hearing and/or the smell [10], by using a Virtual Reality headset.

The first Virtual Reality headsets appeared in the late 1950s in cinema, then in the early 1970s, they were used in flight simulators and finally, from the late 1990s in games [11].

In the 2010s, other sectors have begun to benefit from this technology, such as education and training, particularly in health sciences [11] [12] [13].

Indeed, in the medical field, users are very impressed with the Virtual Reality experience, since this technology improves traditional teaching methods. Indeed, medical care training using Virtual Reality allows users to interact as if they were immersed in the real scene [14] [15]. In this way, Virtual Reality can reduce the risk of technical errors in health care due to negligence. In addition, using Virtual Reality to build virtual organs or tissues can help doctors in their work, enable doctors and nurses to communicate more effectively with their patients, improve doctors' ability to diagnose patients, provide information about their disease and the progress of surgery [16]. Furthermore, this technology has the advantage of being relatively inexpensive and non-invasive. Finally, Virtual Reality training in the treatment of disease and technical training will not pose any real risk to the patient [17].

It is in this particular context that the Cheikh Zaid Foundation's Medical Simulation Center examined the opportunity of integrating Virtual Reality into the medical simulation curriculum. Indeed, by integrating Virtual Reality in the world of medical simulation [18], the latter will allow a high level of practice and benefit future doctors and medical executives.

This paper presents an implementation solution of an operating room as a Virtual Reality unit. The choice was on the operating room for the following reasons:

- When students attend a procedure, they can distract surgical teams focused on a complex task
- Operating rooms are sometimes too small to accommodate students who need to attend procedures to learn.
- The risk of infection for patients is much greater when additional students are present in the operating room.

The first phase of this project consists in the creation of a 2D plan, integrating the plan measurements according to the required standards as well as the equipment, the instruments and the technical installations of the operating room, then the modeling of this environment in 3D. The second phase will be dedicated to programming including creation of a scenario, choice of a dialogue system, programming of gestures and objects and finally interaction in real time.

The rest of paper is organized as follows. Section II depicts materials and methods. Section III is devoted to the results and discussion. Finally, conclusions are mentioned in Section IV.

II. TOOLS AND METHODS

A. *Environmental diagram*

First of all, a 2D plan is created using the AUTOCAD software. The choice of this software was based on the fact that it can be used as an architectural planning tool since it comes with a user-interface with built-in design lay-outs. The lay-outs contain numerous templates specially designed for architectural planning and building construction. Moreover its analytical tools can analyse the components of the building to troubleshoot stress and load levels of building supports. Furthermore, this software enables architects to design, plan, execute and analyse the strength of a building, at design stage level and in different fields such as medecine. AutoCAD can also be used either as an engineering drafting tool to draw accurate 2D drawings for any engineering domain and to render to 3D models to help in visualization of the end product ; Or as a graphic design tool to enable users to plan and map out spaces and take advantage of the space available [19]. It can be used simultaneously with 3D Max and various other application softwares including animation tools. This step consists of integrating the measures of the plan according to the standards required for the creation of an operating theater. Then, the equipments, instruments and technical installations must be integrated in order to obtain a primary design plan. The environment modeling is done through the 2D plan using the ARCHICAD software.

The implementation of the 2D plan in 3D modeling is done by a software. This software enable creating the desired environment in 3D using an integrated library which contains the various elements in need (For example: walls, floor, ceilings ... etc.). Once the environment is composed, the equipment, objects and instruments are modeled necessary in 3D in order to infuse them in the environment using the 3DS MAX software. This software supports a huge number of tools that are easily available for modeling, it is user-friendly in modeling and complex animation, and does not only support powerful and multiple tools for animation but also the Material Editor that allows the user to create and edit materials and maps in their scenes [20].

The 3DS Max software will not be used directly by the Medical Simulation Center's professors, but it will only be used for the 3D environment creation.

The followed approach is presented by the algorithm of Fig. 1.

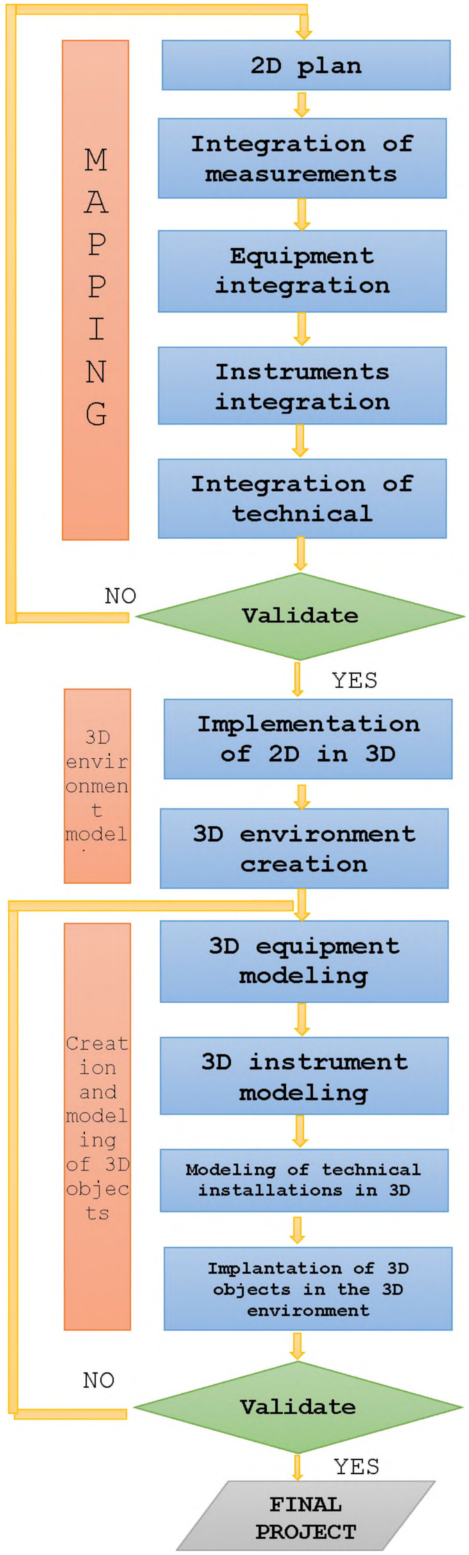

Fig. 1.Flowchart of the environmental diagram realization

III. RESULTS AND DISCUSSION

A. First stage: Autocad Software

It is at this level that the essential characteristics of the operating theater can be identified, such as: Dimensions, structures, required installations, locations of equipment, etc. It should be noted that the stages of modeling depend on each others, this is why the specification of what the operating room must contain, must be done from the start whether on the technical aspect (measurements, plans, etc.) or functional aspect (equipment, installations, etc.)

To make a 2D plan, the integrate of a nomenclature is important to make the plan more readable and understandable. And since this work consists of a light plan which does not require a lot of nomenclature, a color code was used for each of the components: red for the doors, green for polyvinylchloride and blue for exhaust air, as seeing in Fig. 2. in order to ensure an easy understanding of the plan.

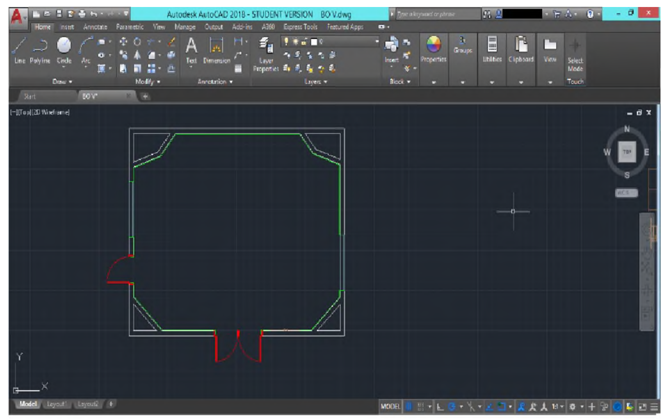

Fig. 2. The 2D environment

The installation of the equipments furnishing the operating room as shown in Fig. 3. (Operative lighting, operating table, surgeon arm, electrosurgical unit, anesthesia breathing machine, monitors, resuscitation breathers, defibrillator, endoscope, aspirator, surgical instruments, mayo table, instruments table, emergency cart, waste bins, medical counter [21], mobile chair with backrest, medical fluids, negatoscopes.) must first be created in 2D. This allows to precise positioning of each object relative to the surface of the space. 2D modeling of objects, equipment, and the lighting required in the operating room is done after modeling the environment to facilitate installation of the 3D plan.

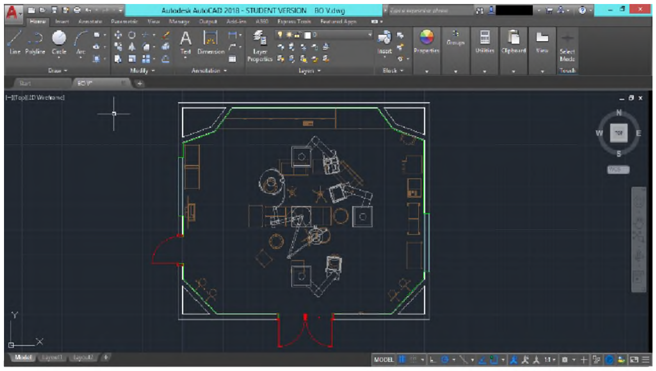

Fig.3.Inserted objects

B. Second stage: Archicad Software

Two-dimensional (2D) drawing has several limitations; it does not allow defining complex surfaces and volumes. Since the main objective is to obtain an operating theater in 3D, Using the previous 2D plan, the walls, doors and floor can be diagramed in 3D [22].

The elimination of right angles is done by modeling crossed walls as seeing in Fig. 4. This provides complete modeling of the operating room.

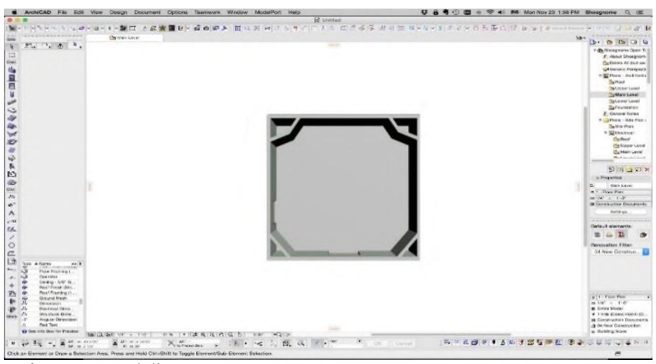

Fig. 4.3D modeling

At this level, 3D environment can be considered as completed as seeing in Fig. 5. The figures illustrate a front-top-left view of the full version of operating theater. Note that so far only the 3D sketch of the operating room was created. This will be used to set up the equipments to have a well-functioning environment.

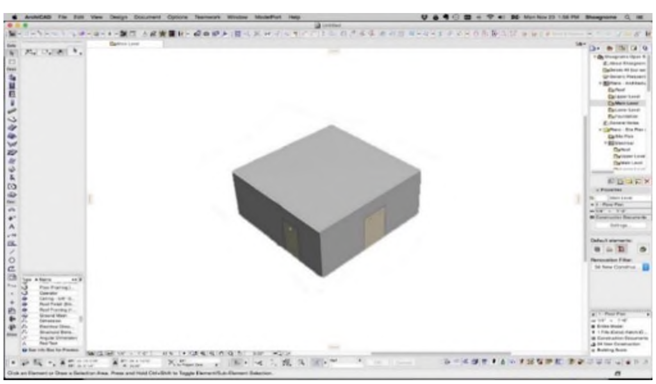

Fig. 5. The 3D environment

C. Third stage: 3ds Max Software

This modeling consists in integrating the 3D environment; that had been modeled in the previous step, using the software interface. The latter is the tool used to model instruments, objects…, in 3D. The modeling of objects and equipment is carried out using real photos of medical equipments and software, they are then integrated into the environment. As shown in Fig. 6.

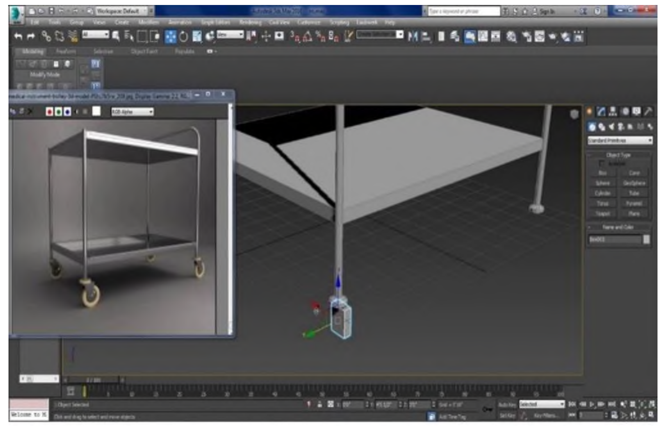

Fig.6. 3D object modeling

The figure illustrate the final version of the operating room in 3D as shown in Fig. 7. These are seen from the front which allows the user to differentiate and visualize each medical device individually. The equipment must be positioned in a structured way that makes the operating room a functional space that enable the user doing an immersion close to reality [23]. This version can be modified according to the equipments and material that the user need [24], the ultimate goal being to make this room an environment that meets the educational needs of the user.

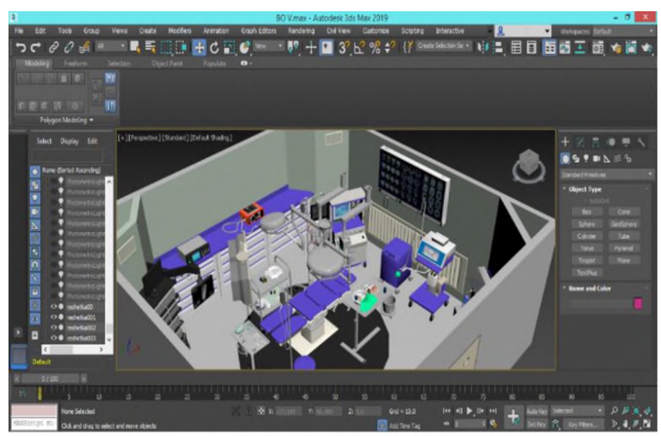

Fig.7. The 3D operating room

D. Fourth Stage : Unity Software

The Unity software is used to develop and build a virtual reality solution using the plugins and packages that are already integrated in the software. The importation of the 3D environment, which was created in the previous step, is done by using an import/export function that allows users to integrate this environment into the UNITY work window. The virtual headset will connected to the software using the "STEAMVR Asset".

a) Human hands programming:

In order to allow an easy interaction with the objects and the different gestures and programmed actions, the more practical way is to integrate a model of human hands replacing the control levers although their color. In this case, the white color has been chosen to represent the medical gloves, as shown in Fig. 8.

Fig. 8. Programming the hands

b) Command programming:

The first programmed command is the one that enable users to take in their hands and let go of the different objects in the environment, such as syringes, scissors, tweezers, etc. as shown in Fig. 9. It is very important to program this command first, because it is the most used in this case because we want to present an operating room.

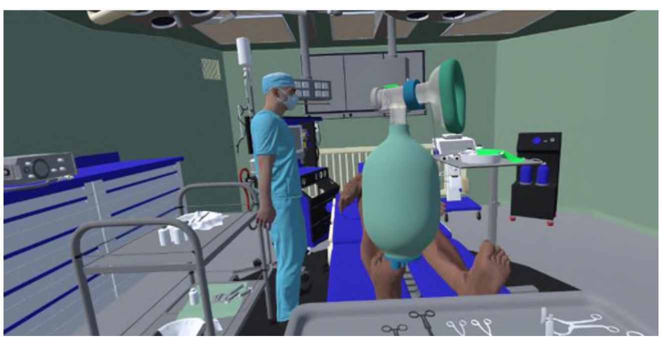

Fig. 9. Command Programming

c) Teleportation:

Finally, the teleportation allows to move around in space in case the drawn area of the helmet is insufficient. Teleportation is then used to change the view and positioning without having to move in real life, as shown in Fig. 10.

Fig. 10. The Teleportation

IV. CONCLUSIONS

The present paper depicted with the implementation of a 3D modelisation of an operating room, which is certainly very useful for medical simulation training. The presented solutions are of great use in the medical field, more specifically in surgery. They are all intended to help learners practice, improve their knowledge through practical activity sessions in a virtual environment. Interesting prospects are envisaged. The system can be more cooperative with the integration of a virtual reality multiplayer mode. Another perspective would be to make the solution customizable to allow health professionals and teachers to share their knowledge in the medical sector. Furthermore this will enable them to set up their own experiences in different hospital departments.

The two approaches 2D and 3D (and more precisely that of 3D) gave a vision in advance of what the virtual environment is going to look like. The combination of these two approaches with the VR approach, which are projected one on the other, enables to present these results and this achievement. Virtual reality is a complex aspect that brings together several approaches leading to a single result that itself offers several options to make an environment adapted to the wishes and expectations. It has many advantages for the learning of certain techniques, and offers new solutions to the whole simulation problems of command/control and communication. It is an improvement of traditional simulation techniques.

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