The Current Trends of Virtual Reality Applications in Medical Education

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***Abstract*— The study of human computer interaction in using immersive technologies has become very essential and critical. Immersive technologies have been used significantly in medical education. In the medical field, real-life training is not always possible. The main reasons are cost and safety. Thus, alternatives in providing and achieving a better educational medical training platform are needed. There is a growing interest in using virtual reality (VR) for training and learning in the medical field. The use of virtual reality in educational training may facilitate a successful medical learning process without involving a real human. The technology allows learners to adapt different learning styles in ways that are not suited to traditional teaching. This study aims to investigate efforts and opportunities for using VR technologies for medical training purposes. This paper identifies and summarizes VR tools used for surgical training especially in laparoscopic surgery, arthroscopy and orthopedic surgery. We also present the advantages of medical training using VR.**

Keywords*— *Immersive technologies, virtual reality, medical training.

I. Introduction

The use of digital devices and technologies for education and learning purposes is growing. These include virtual learning environments, cellphones, and computer mediated communications. This can be seen especially in the period of 1997–2006, when interactive research networking machines were rigorously used, and in the period of 2007–2016, when the so-called digital online learning had exploded [1]–[3].

VR is a new application that allows users to replicate their experiences and interaction in the real world into a virtual environment through the use of VR technology. The VR has been popular among video gamers and has been widely used in educational environments in recent years because it offers immersive and interactive experiences [4]. Scientific innovations from these technologies have evolved so quickly and being used in a diverse range of industrial areas. The needs of VR in various domains has encouraged educational and industrial organizations to improve and leverage VR / AR technology [5]. This is in the form of research funds or research collaboration between organizations.

The VR platform offers a multi-sensory and 3D experience that lets people engross themselves in the digital environment by integrating multiple technologies, along with head-mounted displays (HMD) and head-tracking devices, headsets for audio, audio and noise-cancelling headphones, as well as handling / automation instruments [6]. Medical education is a challenging domain, mainly because of the difficulty of the subject matter and the shortcomings in conventional pedagogical approaches and the same time the methods and procedures used in practicing medicine or medical training should not be altered or modified in any way [7] [8]. It is worth to be noted here that the conventional medical training techniques have been producing highly qualified health workers and practitioners. However, the conventional training is learned on living patients. This may put patients at risk and danger during training routines or conventional learning of any talent [9] [10]. Consequently, it gives pressures to medical practitioners and learners.

The use of advanced technologies such as VR should not modify the methods and techniques of conventional medical training, yet it should facilitate the training process to be easier and safer [10]. As a result of technological advances in the fields of VR and medical training, the number of organizations pursuing the production of an immersive application on the educational and the teaching of medical procedures for commercial and academic levels has increased [11].

Increasing numbers of trainees have resulted in fewer chances to learn the required technical skills because of higher costs, ethical issues and working hours in residents. VR medical simulation is an alternative to improve or boost academic performance and reduce the detrimental consequences of current education practices, where the use of V R may improve medical training and learning experience through an interactive virtual environment. The virtual reality community [12] has described, a virtual reality learning environment (VRLE) as a platform that enables users to actively engage with medical objects and materials. This can increase users' knowledge and their experience in interacting with critical space and condition [11]. Thus, the VR platform is comprehensive enough to be used for surgery, medical or clinical practices, training and education, medical diagnosis, recovery, and other uses.

This study aims at reviewing the current trends of using VR for learning and training in the medical field, and to explore opportunities for specific types of applications. This paper is structured as the following. Section II presents a brief overview of VR technologies and its current trends in medical learning and training. Section III presents VR applications in medical training. Section IV presents the advantages of using VR technologies. The conclusion is presented in Section V.

II. Brief Overview of VR Technologies

There are various emerging development platforms such as Unreal (unrealengine.com) and Unity (unity.com) to implement VR systems. Unreal is entirely written in C++, utilizes various 3-D rendering graphic resources [4]. Unity uses graphic engines in accordance with its operating system

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(Microsoft Windows, OS, Linux). Such environments were not developed with VR in mind, but based on video gaming development. Since the creation of a visual game and the development of a virtual reality interaction are very similar activities, the resources are used for both purposes, which are not the only ones [5].

The current device for VR-HMD, such as Oculus Rift or HTC Vive allows users to achieve a high degree of reality, immersion describes the existence of the user in a simulated world where time and space are frequently divided, giving the task a sense of existing, Authors in [13] defined VR as a perception that a user of the simulation can physically be present in a non-physical world. So, the person feels he and she are actually there. Similarly, HMDs for mobile devices, including Samsung Gear VR and Google Cardboard, make immersive virtual worlds possible for anyone. Present apps also provide the ability to communicate. During the creation of high-end VR devices with dedicated controllers which support gameplay (e.g. Oculus Touch), small budget HMDs such as Google Cardboard can monitor the view or require them to engage in a simulated environment through a magnetic switch [1].

VR has been advancing in the fields of learning and training, leveraging VR capabilities by offering a virtual representation of the actual healthcare world. VR users can remotely encounter simulated training scenes to accomplish or learn specific clinical tasks, first aid to improve skills, minimize errors, offset equipment and resources in certain situations [5].

Researchers have been investigating the impact of VR simulation on first aid [14], physical therapy [15], surgical procedures [16]–[18] and anatomical education [19]. Compared to conventional approaches, VR is being considered as a cost- effective and alternative in these fields [6]. For instance, VR simulators have been used in medical educational institutes to stimulate interactions between trainees with surgical instruments or anatomical layout during surgical training. Authors in [21] concluded that surgical apprentices are better and more effectively performed using VR technology. The global rating indicates that VR technologies are suitable for all surgical procedures. It has been proven that VR trained surgeons performed twice as well as non VR trained counterpart [6].

III. VR APPLICATIONS IN MEDICAL TRAINING

Despite the fact that VR cannot replace all the needed training to prepare the healthcare workforce, it offers new and exciting opportunities. These opportunities include positive impacts and substantial business values, such as new practical techniques in a risk-free environment, raising awareness of the disease, distracting from painful or long-term procedures and increasing empathy and understanding.

VR simulation offers instructions for the operation, where the medical doctor can maneuver the VR instrument with the aid of a joystick that is specifically used for this purpose. Some devices use haptic feedback emulation. During such simulations, if there is a mistake it will be identified and gives feedback by the program, and the conclusion of the whole procedure is assessed with a feedback report for results [22]. VR can be used for practicing these surgeries, because of the extremely intuitive anatomical structure displayed in 3D graphics. The simulations with VR can be practical, where trainees can touch the skin, muscle, bone, nerve or tube and all anatomical structures. VR simulators can also deal with emotion regulation and feedback for psychological disorders [6] [20].

In this section, we identify and summarize the use of VR tools for laparoscopic, arthroscopy and orthopedic surgeries.

A. Laproscopic Surgery

In a traditional training procedure, to complete laparoscopic training safely and efficiently, trainees have to face a lengthy learning curve and intensive preparation. They are directed by visual input of a visual fiber camera on a video monitor while conducting a real MIS operation. The assessment is obtained through manuals of surgical tools [6]. Often, endoscopic procedures use visual and accommodate tactile assessment. However, surgical trainees cannot exercise a simple medical surgery and laparoscopic in hospitals without exhibit real patients to any possible danger [23].

Minimally invasive surgery (MIS), like laparoscopy and arthroscopy, have been simulated through VR, by making the user interface of simulation and the actual interface of medical devices to be similar [10]. VR simulation program provides training for various procedures through modules for laparoscopic surgery such as cholecystectomy, hernia ventricular and gastric circumference [6], [22].

In a normal procedure, visual of a patient's anatomy cannot be directly received [10], whereas in a VR environment, trainee surgeons can learn fundamental skills, MIS procedures such as camera searching, instrument handling, artifacts, cutting and clipping using a simulator. Their training is accomplished as if it is a normal procedure [22]. Reference [24] presented several teaching modules about various skills such as stitching, extracorporeal suturing, and knot tying techniques. The laparoscopic cholecystectomy module provides reconstructions of the virtual recipient collected from medical images such as those of magnetic resonance imaging (MR) or computerized tomography (CT) to promote the comprehension of several anatomical variants for the training of surgeons. A gastric bypass module is used to educate doctors to learn basic laparoscopic surgery and to perform and improve the barbaric operation stages in a healthy, regulated environment.

Video tutorials of all treatments involving laparoscopic operations are accessible before and after each training session. Online training also improves the expertise of surgeons through the information and skills gained during the online process, facilitating trainees to deal with surgical complication such as bleeding at the surgery room or rupture of the organs that funnel blood into the abdominal cavity [22]. Such a simulation needs to overcome a range of different challenges due to interactions in tightly wrapped environments in which it is especially challenging to manage self-consolidation at a refresh rate, while practical MIS or endoscopic simulation interfaces are easier to design [10].

Examples of the best-known simulators for Laparoscopic surgery are Minimally intrusive virtual reality surgery trainer (MIST-VR) [16], LapSim [17], VR laparoscopy [22], Simendo [18] and FOREAl [25], and we will discuss each of them in the following subsections.

1) MIST-VR:

In 1997, Manchester Royal Infirmary and Virtual Presence researcher unveiled MIST-VR (Fig. 1), the first VR simulator [6], [16] was introduced. Using basic balls and cylinders in a simulated world, surgical training students; can learn laparoscopic techniques inside a "3-D box" where they can perform different steps [22]. The simulator offers feedback to students and quantifies errors in the measures taken and had the ability of simulating a few of the movements conducted during a laparoscopy by "grasping" and "manipulating." In addition, individual task performance could be registered, compared, and analyzed [16].

Fig. 1: Minimally invasive surgery trainer virtual reality [26]

2) Lapsim:

The simulated environment created by the LapSim system closely resembles the actual clinical environment. The LapSim (Fig. 2) emerged around 2002 as the most used VR simulators [6], [17]. It has very useful simulations for clinical practice, as the skills gained can be directly implemented during surgical procedures [22].

Fig. 2: LapSim [28]

LapSim contains courses which can be changed by various institutions and instructors as required for versatility in the training material. This program contains the basics, sutures and anastomosis, as well as laparoscopic cholecystectomy and gynecology [27], as regular modules and A high number of measurable and detailed performance criteria may assess the level of competence of trainees [6]. The LapSim's "power area" module has eight different skill functions which can be performed and it can increase the levels of difficulty for each function [22].

3) LapVR:

Laparoscopy VR or LapVR (Fig. 3) is a method of VR simulation to help trainees to learn and upgrade the requisite skills in laparoscopic operations. To include surgical experience in VR, LapVR integrates haptic hardware with laparoscopy simulation software [22]. Trainees (surgeons) develop and assess their skills and experience of laparoscopically surgical movements.

Fig.3 LapVr [30]

LapVR provides preparation programs for an individual or a team of trainees. Other features include camera navigation, hook electrode use, cutting, sewing, and tying knot. There are, however, three difficulty-level and 18 types of cases as well as one for gynecology and obstetrics, which involve laparoscopic surgeries performed for tubal occlusion, ectopic disease and adnexal pathology [22], [29], which can also be done in laparoscopic cholecystectomy.

4) Simendo:

Simendo (Fig. 4) is an advanced laparoscopic simulator that appeared as the latest simulator among the above mentioned VR simulators. It was originally developed to simulate endoscopy and was identical to LapSim and Lap VR in training mode [6], [18], [31].

Fig. 4 Simendo [33]

It comprises seven educational modules: coordination of the eye, hand, camera handling, grip, pull, cut, dissect and part. It can also differentiate between students' talent levels [32]. Warm-up principles are often given for the enhancement of the surgeon's efficiency, where the surgeon can construct a pre-operative simulated procedure before the actual procedure is performed. CT 3-D rebuilds are employed to enhance the virtual training pre-operative stage and to create more realistic simulations that include patient anatomical differences [22].

5) IFOREAL:

Authors in [25] presented IFOREAL (Fig. 5), a modern immersive gynecology education VR-assisted training program. The research team has used the Unity 3D development engine to design two versions of IFOREAL using various systems. The trainee uses a standard computer mouse and LCD display, while the technical version was fitted with an HMD and joystick controller. IFOREAL contained a variety of primary gynecology learning modules, such as childbirth, normal spontaneous, delivery and etc.

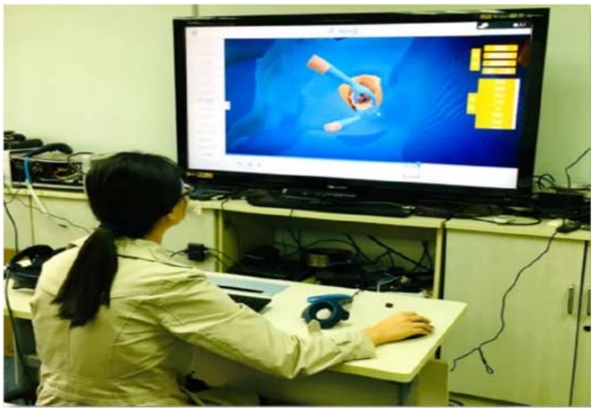

Fig. 5 IFOREAL [25]

The summary of laparoscopic medical training simulators is presented in Table I.

TABLE I. LAPAROSCOPIC MEDICAL TRAINING SIMULATORS

VR Simulation	**Operate**
MIST-VR [16]	Evidence-based validity and high-fidelity simulation
LapSim [17]	Basic skills, tasks training and imaging
LapVR [29]	Tasks, skills and suturing simulation
Simendo [18]	Novice and intermediate skills
FOREAL [22]	Tasks, skills and suturing simulation

B. Orthopedic and Arthroscopy surgery

The development and deployment of orthopedic surgery simulators was a little bit lagging, compared to laparoscopic and other surgical disciplines, which is shown by a limited number of studies that have tried in the past couple of decades to establish or verify orthopedic surgery simulators [6], [34]. Arthroscopy and orthopedic training are enhanced using VR-based simulators such as Procedicus virtual arthroscopy simulator [35], HipNav [36], TraumaVision [37], Insight ARTHRO VR shoulder simulator [22], Geomagic Touch X [37], Total Knee Replacement (TKR) [38] and LUCY [39].

1) Procedicus virtual arthroscopy:

Procedicus simulator is intended for knee arthroscopy training and was the first to work with spatial visual simulation [35]. This requires an optical tool, a sensor and a specimen. Testing is carried out on a simulated knee using a haptic feedback system [22].

2) HipNav:

HipNaw was developed by Digioia [36] for the total hip replacement training. The software included movable hip jointing models and tools to estimate the femoral motion range, bone mobility and optimum implant-based alignment. It may assist surgeons in the pre-operative determination and transition to surgical navigation in vivo of an ideal, patient-specific acetabular implant [6], [18].

3) Trauma Vision fractured femur orthopedic:

The Trauma Vision fractured femur orthopedic was developed in Sweden. It has been a popular VR simulator that has haptic assessment designed to restore the feeling of grinding and reaming cortical and cancellous bones. It is managed via a stylus, which is used as a machine guide [6].

4) The Insight ARTHRO VR Shoulder:

The Insight ARTHRO VR Shoulder is a 3D Systems. It uses a real-life shoulder plastic copy with the portals already defined. The input system is fitted with two robotic arms to give the person using the system haptic feedback. The simulator will shape different positions, for example; lateral decubitus or beach chair, to improve vital skills in young doctors [22].

5) Geomagic Touch X :

The haptic feedback provided by Geomagic Touch X is a simulator that makes trainees feel rational when interaction with bone and soft tissue. The haptic device's sensitivity can also create a tactile difference between the cortex and the bone of callousness [6].

6) TKR:

Total Knee Replacement or TKR is a simulator which focused on 3D operation models of the knee. The models were reconstructed from CT scans. This program lets medical surgeons understand the 3D anatomy of the patient and to identify personalized implant components interactively by extracting the anatomical parameters of the knee from 3D triangular models [38]. A virtual 3D simulation technique for acquiring surgical parameters and tibial models may be performed. Upon resection, the robotic implants are individually attached to the distal femur and the proximal tibia. The implant components 'axial connection is arranged mechanically [6].

7) LUCY:

LUCY is a simulator which was developed by a group of researchers at Stanford University. They created a complicated 3D volumetric female pelvic models which help trainees to perform intrapelvic operations like tubal ligation and oophorectomy which can be considered as the best virtual pelvic models of the present day to live [10], [39]. The summary of orthopedic and arthroscopy surgery medical training simulators is presented in Table II.

TABLE II: ARTHROSCOPY AND ORTHOPEDIC MEDICAL TRAINING SIMULATORS

VR Simulation	Operate
The Procedicus virtual arthroscopy [38]	Laparoscopic surgery skills
The insight ARTHRO VR Shoulder Simulator [29]	Fundamentals of arthroscopic surgery training and diagnostic procedures
HipNav [39]	Hip fracture simulator training
The trauma vision fractured femur orthopedic simulator [27]	Hip fracture simulator training
Geomagic Touch X [27]	Bone and soft tissue simulator training
TKR [40]	Knee laparoscopic surgery skills
LUCY [41]	Intrapelvic surgery

IV. VR APPLICATIONS IN MEDICAL TRAINING

A critical feature of the immersive VR applications being explored is the benefits they bring to existing non-immersive VR training frameworks [11]. Trainees who have obtained traditional surgical training have been shown to perform substantially slower surgery and are more possible to cause harm, tissue damage or fail to proceed with the operation [6], so providing them with an immersive training environment to develop their technical skills and teamwork is advantageous for the user, immersive VR systems have many advantages as described below [11].

A. *User engagement and immersion*

Qualitative analysis backed by user experience questionnaires established that the virtual simulator offered a high- quality experience that combined with its efficient usability created an enjoyable experience that kept the user engaged as explained by Byl [40]. It shows that a VR can support the growth of a user when it offers an engaging environment and enhances the consistency of the training [11].

B. *Bespoke traning platfrom*

According to [41], VR may also be custom-made to provide training for users in a specific field or position, which enables the creation and use of training programs evidence. They noted that the use of a cataract surgery training simulator helps trainees to learn a certain range of skills required for this type of operation to be successfully performed [11].

C. *Free training and assesment*

A common belief among most VR platforms is that it offers an atmosphere free of risks to training users in which they can respond to risky circumstances with little to no possibility of harm [11]. Li [11] describes the notion of risk-free training as the advantage of medical training in a VRLE is to have an indoor secure, simulated environment. The most dramatic improvements will come from the implementation of VR treatment and training. Increasing health and safety and social trust in the healthcare industry [42].

V. CONCLUSION

This paper has presented well-known VR simulators which can be used for surgical training. The analysis addressed the existing medical device simulators focused on the virtual reality, in particular in the fields of operating training and first aid. Innovations have shown that they not only enhance education and training but also create new opportunities and services. They will also increase the quality and efficacy of health care and nursing programs in addition to the solution of the problems related to traditional education and practice of medicine. One of the most important aspects of using simulators is that trainees can control the simulated world and communicate with it, current technical developments, advancements with VR approaches have proven to be widely applicable to different healthcare sectors. Such innovations, however, have technical issues that will be overcome in the future. Though many studies have shown that the proper use of VR technologies will enable students to learn and train, there is still little awareness of research concerning user experience and acceptance in the pedagogical context of such creative use of VR [43]. When more and more emerging technologies are being integrated into classrooms and training, VR technology developers, educational experts and even policy are expected to better understand the use and viewpoint of students on VR training and their ability to use it for learning [25].

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