Psychomotor Surgical Training in Virtual Reality

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Abstract

In this chapter we present a novel s/w system aiming to disrupt the healthcare training industry with the first Psychomotor Virtual Reality (VR) Surgical Training Solution. We provide the means for performing surgical operations in VR, thereby facilitating training in a fail-safe environment that very accurately simulates reality and significantly reduces training costs, offering surgeons and the healthcare ecosystem a way to drastically improve operations outcomes.

With the presented system, we focus on a completed Total Knee Arthroplasty (TKA) virtual reality operating module, opening the way for making available a full suite of virtual reality operations. Our methodology transforms medical training to a cost-effective, easily and broadly accessible process. The latter is accomplished by employing latest VR, Gamification and Tracking technologies for virtual character-based, interactive 3D medical simulation training. It requires standard h/w (PCs, laptops) irrelevant of the operating system. For optimal user experience, a commodity VR head-mounted display (HMD) should be employed along with motion or other hand-controller sensors. The open ovidVR architecture supports all current and forthcoming VR HMDs and standard 3D content generation. Our novel technologies facilitate Presence, that is the feeling of 'being there' and 'acting there' in the virtual world, thereby offering the means for unprecedented training.

Keywords: Virtual Reality, Surgical Training, Psychomotor, Simulation, Gamification

20.1 Introduction

Surgical training has evolved considerably from the historical apprenticeship of the early surgeons to a complex structured training programme with multiple assessments. As trainee numbers increase, opportunities to develop procedural and technical skills become increasingly limited. Furthermore, introduction of the European Working Time Directive across Europe [1] and the 40 h per week limit introduced by the Accreditation Council for Graduate Medical Education in the

United States of America [2] have led to a reduction in training hours available during the designated training period. Working hour restrictions and a drive towards senior-led care demands that proficiency be gained in a shorter period of time whilst requiring a greater skill set than that in the past.

Innovation has meant that there are more occasions where surgical intervention may be indicated. This, coupled with an ageing population more expectant of treatment, has resulted in greater demand for surgery than ever before, leading to a conflict between service provision and training. The resulting conflict between service provision and training has necessitated the development of alternative methods in order to compensate for the reduction in ‘hands-on’, psycho-motor experience.

In the same period, there has been a significant development of novel techniques requiring current trainees to master a greater array of specialist skills, despite having less time in which to do so. Many different solutions including e-Learning, simulation and compulsory fellowship training programmes have been proposed to maximize learning opportunities within existing resource constraints.

Simulation training provides the opportunity to develop surgical skills in a controlled environment whilst minimising risks to patient safety, operating theatre usage and financial expenditure [3]. Many options for simulation exist within orthopedics from cadaveric or prosthetic models, to arthroscopic simulators, to advanced virtual reality and three-dimensional software tools. There are limitations to this form of training, but it has significant potential for trainees to achieve competence in procedures prior to real-life practice. The evidence for its direct transferability to operating theatre performance is limited but there are clear benefits such as increasing trainee confidence and familiarity with equipment. With progressively improving methods of simulation available, it is likely to become more important in the ongoing and future training and assessment of surgeons.

Simulation in medicine can be broadly defined as “any technology or process that recreates a contextual background in a way that allows a learner to experience mistakes and receive feedback in a safe environment” [4]. This definition is constantly evolving due to advances in technology, which allow increasingly complex situations to be modeled and tested. Simulation aims to recreate the experience of patient care without compromising patient safety. The ability to modify a situation allows trainees to experience novel and often-important situations that may not be commonly experienced in clinical practice. The advantages of a VR-based simulation, recent serious games and gamification approaches for interactive learning events extend beyond simple technical and procedural skills. Simulation allows trainees to engage with a multi-disciplinary team and focus on individual and team-based cognitive skills including problem solving, decision-making, and team behaviour skills in realistic, reactive virtual environment and have a unique hands-on experience.

20.2 Previous Work

Cadaver models were historically used as part of surgical training. In recent decades, significant progress has been made in developing new and varied simulation-based techniques to provide virtual training [5] in a safe and modifiable environment [6], [7], [8]. The simulation improves trainee confidence and understanding of techniques whilst also allowing practice and development of specific technical skills [9].

The current 3D simulation of surgical procedures is mostly confied to non-operator interaction of static, non-interactive image or video-based examples that can teach the customer several steps of a procedure and very few examples of gamified, VR approaches have been showcased [10]. Surgery, however, in real life is not predictable for two reasons: First human anatomy is unique per individual and surgery replication can never be 100% due to surgeons or patient related factors. All the latter parameters make the current 3D simulations not realistic enough to the most trainees and definitely of no use for the specialist surgeons. As an example we can say that the current, cognitive-only virtual simulations are equivalent to a linear, video manual for a flying simulation for a pilot, lucking however any degree of immersive reality or ability to follow and react on different scenarios according to user hand-actions (psychomotor). Our aim is to increase 3D realism but most importantly to provide natural, gesture-based interaction between the consumer surgeon and the virtual patient.

A few companies are recently targeting products that are indirectly competing with our system. They are broadly classified in two categories:

1. Cognitive VR/AR and medical simulation:

- TouchSurgery: https://www.touchsurgery.com/ focuses on a tablet-based, interactive gamified simulation of various medical procedures, using touch-based cognitive metaphors. It is not an immersive solution or natural, hand-based, psychomotor interaction.
- SURGEVRY: http://www.surgevry.com/#root, focuses on immersive, 360, stereoscopic videos, experienced first person by the trainee. However, this is not an interactive VR application (video-based).
- SurgicalTheater: http://www.surgicaltheater.net, focuses on an immersive VR fly-through of 3D MRI data, with no natural interaction or gamification options.
- VR-Med: http://www.vr-med.com is a recently developed startup that seems to promote simulation-based medical applications without however specifying or describing any related products or services.
- VRMedapp: http://vrmedapp.com is another recently created startup utilizing recent advances in VR HMDs. However, no product is yet developed and the company primarily focuses in well-being medical applications, such as pain-management and rehabilitation.

- SimX: http://simxar.com is a recently developed startup utilizing recent Meta-AR HMDs for first-aid, cognitive medical training in AR.
- Augmedix: http://www.augmedix.com allows for hands-free medical charting while interacting with patients, utilizing Google Glasses in monocular AR.
- ossoVR: http://www.ossovr.net is a very recent startup that aims to tackle medical surgical simulation using the Oculus Touch controllers that allow hand manipulation of objects, without finger tracking. The company has just appeared online with a concept video and no other product information or demo.

2. Education and medical simulation using custom, expensive h/w:

- Surgical-Science: http://www.surgical-science.com/products/ employs 3D navigation systems and desktop based educational simulations of specific operations. However, it does not focus on orthopedic surgeries at all, or VR gamification and natural interaction.
- SimSurgery: http://www.simsurgery.com/ectopic-pregnancy.html provides haptic based, navigation and desktop-based medical simulations, without any VR gamification solution.
- IntuitiveSurgical: http://www.intuitivesurgical.com/products/skills_simulator/ provides their custom h/w, desktop 3D simulation for specific surgery types, without providing VR gamification/interaction.
- SimPortal: http://www.simportal.umn.edu/surgery.htm is a solution from the University of Minnesota for medical students to be trained using desktop 3D simulations systems in specific medical procedures. However, no VR gamification with natural interaction is provided or any applications related to orthopedic surgeries.

Our system greatly capitalizes on previously developed and assessed, state-of-the-art technologies, that are owned by ovidVR. Such technologies regard enhanced character interpolation animation, gamification, sensor fusion and tracking algorithms that endow the relevant product with notable, unprecedented characteristics [11], [12], [13] and [14].

20.3 Methodology and Results

The presented ovidVR system offers to surgeons the unique opportunity to perform with their hands, realistically, “as if they are Present in the operating theatre” as many demanding operations as necessary in order to master the different techniques. At the same time, manufacturers such as artificial joint makers, will have a complete VR simulation customized to their joint implant. All in all, we aim at establishing VR psychomotor medical simulation as a key component of medical

training and continuing assessment throughout a surgeon's or physician's career, in a similar manner to the mandatory nature of flight simulators to modern pilots.
A beta product version currently exists, integrating our advanced VR simulation and tracking technologies. Figure 1 below illustrates a snapshot from the ovidVR system in operation. The named product is a novel, gamified, VR-based, interactive 3D medical simulation training s/w. It requires standard h/w (PCs, laptops) irrelevant of the operating system. For optimal user experience, a commodity VR head-mounted display (HMD) should be employed along with latest HMD motion or other hand sensors. The open architecture supports all current and forthcoming VR HMDs and standard 3D content generation pipelines.

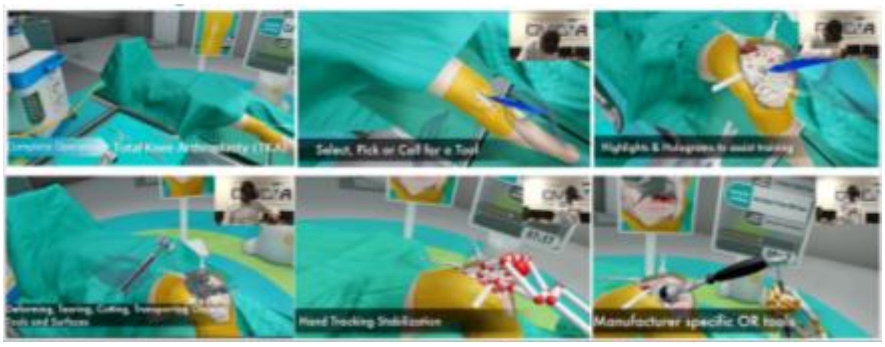

Fig. 20.3 The ovidVR psychomotor VR simulation system (Figure created by the authors)

It is not a question of whether VR will enter the medical training space but when! ovidVR is exceptionally positioned to pioneer and has a recipe for succeeding, all it needs is investment support to monetarize on its technology and business plans, delivering unprecedented impact to the healthcare and VR ecosystems.

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Figure captions

Fig. 20.3 The ovidVR psychomotor VR simulation system (Figure created by the authors)