CHAIN REACTIONS

THEMATIC BRIEF HEALTH 4

Virtual Reality in Healthcare **March 2021**

VIRTUAL REALITY IN HEALTHCARE

The virtuality continuum

The usage of Virtual Reality (VR) technologies began recently to grow quickly when smartphones appeared. Indeed, until then, the number of portable devices capable of incorporating these technologies was reduced.

At the beginning, these technologies offered many advantages in the video games area but also in other fields such as in archaeology by the mean of life simulation, highly detailed 3D models visualisation, or even user free movement in missing places. In the meanwhile, Virtual Reality (VR) has also quickly reached medical education for surgical training and anatomy teaching. More recently, other modalities of virtuality such as augmented reality (AR) has also made its way into medical education.

Indeed, the overall concept of virtuality can be conceptualized in the form of the reality-virtuality continuum (see figure 1) where on one end, there is the real world and on the other end, the virtual world. The virtuality continuum is then a continuous scale ranging between the completely virtual and the completely real environment, from Augmented Reality (AR) to Augmented Virtuality (AV).

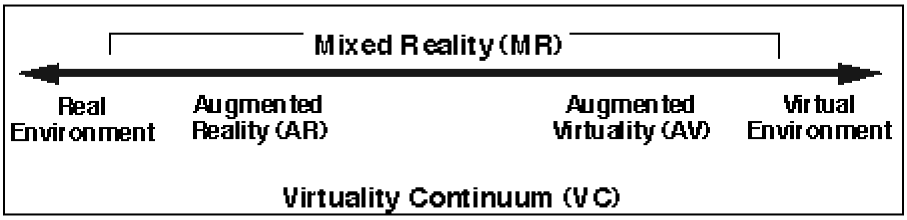

Figure 1 – The Virtuality Continuum [1]

Mixed Reality (MR) technologies can be thus classified into AR systems or AV systems. In both the AR and AV systems, the user usually wears a head mounted display (HMD), which provides the simultaneous display of a virtual image and the scene of the real-world surroundings. The differences are that in AR, the virtual image is transparent like a hologram and in AV the virtual image appears solid. In AR systems, the user can view the virtual image and interact with the real-world scene.

VR and MR are now using more and more next-generation information and communications technologies in near-eye display, perception and interaction, rendering processing, network transmission, and content creation. Although the application of virtuality in the health care field is relatively new, there are increasingly great examples of these technologies having a positive effect on patients' lives and health professionals' work.

Virtual Reality for Medical Training

The first large impact of Virtual Reality can be found regarding medical training. These technologies already began few years ago to elevate the teaching and learning experience in medicine to a whole new level.

Currently, most medical students still learn on cadavers, which are difficult to get hold of and do not react in the same way a live patient would. Only a few students can also peek over the shoulder of the surgeon during a real operation. This is thus difficult to learn technical tricks via these methods. With a virtual reality camera, surgeons can now stream operations globally and allow medical students to actually be there using their VR accounts.

Using Virtual Reality (VR), teachers can now create training scenarios which replicate common surgical procedures. They get the ability to transport students inside the human body. Students can access and view areas that otherwise would be impossible to reach and can view minute detail of any part of the body in stunning 360° reconstruction.

Basic architecture and cost of VR based training

The architecture of a VR solution for medical training usually comprises three main elements: a client VR application, which loads necessary data from the database, and an administration panel for managing the two.

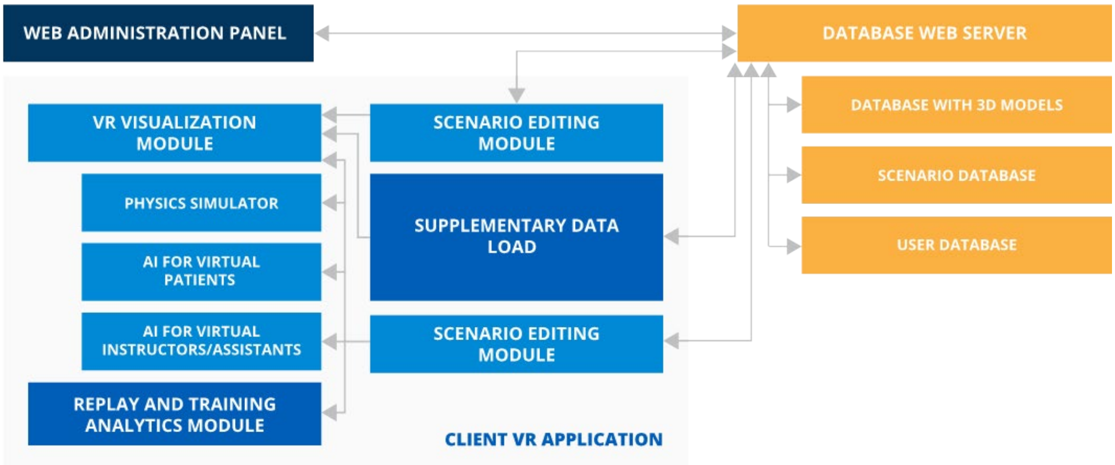

Figure 2 – ScienceSoft - Typical VR Medical Training Solution Architecture [2]

Practical studies show that high-quality VR software can bring the same qualitative results as real-life simulation and can allow for massive cost reduction.

However, while dealing with VR based training, it is still very important to consider the cost and particularly the investment costs that have to be faced:

- Method of acquiring/creating core art assets (photo and video shooting, 3D CAD rendering)
- 3D models (in case of 3D CAD rendering)
- Number and complexity of training scenarios.
- Licences for each user

Additional costs of the entire solution may also be related to:

- VR hardware (with or without haptics)
- Development of training analytics module
- Possible development needed for integrations with Learning Management System (LMS) or Content Management System (CMS)

An important operational cost is also usually related to the use of cloud services (the price usually depends on stored data volume and bandwidth).

Augmented Practice Training

Augmented reality provides a live representation of a real-world environment whose elements are supplemented by computer-generated sensory features including sound, video, graphics or GPS data. This is distinct from virtual reality in that it allows individuals and groups to interact with a remote environment in real-time with two-way communication.
Beyond the exploitation of full virtual reality environment (VR) for training, the benefits that Augmented Reality (AR) can also bring to the field of medicine education are revolutionary. Medical organisation are already beginning to implement AR into their curriculum to provide students with a valuable hands-on learning experiences. The basic idea for implementing AR in education is for medicine students (e.g. surgeons) to make all of their mistakes on AR rather than in a dissection lab or even worse, in a real-life procedure. Using AR students they can accurately learn about diagnosing patients with health conditions or take part in an AR surgical procedure. These technologies can also allow medical professionals to continuously observe and give feedback to students during their practice [3].

Proximie : telesurgery service with augmented reality

The UK-based startup Proximie, founded in 2016, develops a software solution which expands virtual surgical collaboration enabling surgeons to share expertise using augmented reality tools before, during and after surgery. The Proximie technology platform provides a cloud-based augmented reality telesurgery service. It uses a combination of machine learning, artificial intelligence and augmented reality to bring together experts remotely and allow clinicians to virtually collaborate with each other from anywhere in the world.

Even if based on augmented reality, this platform can operate on very low bandwidth to handle bad internet connection. The idea is thus that surgeons in operating theatres from all over the world can follow a more senior surgeon's directives on the screen in front of them.

To this aim, Proximie developed dedicated consoles (see figure 3) but, in fact, the proximie solution doesn't require a special device, but instead just layers digitally created content on a live video stream. It can be used with almost any device with a camera.

Proximie has raised an undisclosed amount of funding to develop their augmented reality telehealth platform. Proximie has seen a 430% increase in surgeries in 2020[5].

Figure 3 - Px Console from Proximie with up to 4 cameras [4]

Mental Health, Psychological Therapy and rehabilitation

Virtual reality's ability to transport somebody somewhere else can also be used to create powerful simulations of the scenarios in which psychological difficulties occur such as phobias, addictions, eating disorders and stress. A therapist no longer needs to accompany a patient on a trip to a crowded shopping centre or up a tall building. Even situations that are impractical or impossible to recreate like flying can be conjured at the click of a mouse. With the help of Virtual reality, the in-situ coaching that's so effective for so many disorders can be delivered directly in the consulting room. The simulations can easily be graded in difficulty and repeated as often as necessary.

The King's College (UK) in London and Hôpital de la conception (FR) in Marseille have been using VR for this purpose for years. Another VR application helping patients is the Bliss project developed by "L'effet papillon" (FR), which immerses patients before and after medical operations into paradisiac VR experiences, having positive results on pain and stress relief [6].

VR can also be very beneficial for patients while dealing with rehabilitation. Rehabilitation VR applications can be useful to patients with moving impairment or phantom limb syndrome

MindMaze - VR based rehabilitation

MindMaze, a spinoff from the École Polytechnique Fédérale de Lausanne (Switzerland) is one of the global pioneers in the medical use of VR for rehabilitation. Its VR solution is fully certified as a medical product. Mindmaze uses VR headsets and brain imaging to help stroke victims recover after an injury. Its technology has also been used to relieve phantom pain for amputees [7].

A sophisticated machine learning based motion detection measures the kinematic movement of the patient while exercising, and game performance. Imagine a stroke victim has upper arm impairments. The computer provides a gamified motion-based experience, e.g., a game like racing cars, flying planes or slicing fruit falling from the sky with a samurai sword. The victim's actual kinematic movements are detected, and recommendations are made to exercise normative motions (e.g., a patient may compensate upper arm movement impairment by twisting the torso).

The Mindmaze company soared to unicorn valuation in 2018, after closing a $100 million funding round. They are now in the process of building additional Artificial Intelligence (AI) mechanisms that collect data about that behaviour which can be fed back into the game to recalibrate optimal game levels based on performance and therapy targets. The company is also expanding into new markets, and begin researching the use of its technology for Parkinson's patients.

C2Care – Stress relief and psychological treatment

The French C2Care company is specialized in designing and implementing various therapy solutions and treatments in virtual reality. This includes exposure therapy for confronting patient phobias, the recreation of experiences in VR to help individuals quit smoking, drugs or decrease/eliminate consumption of alcohol.

Figure 4 -Virtual Reality Exposure Treatment (VRET) - anxiety provoking stimuli [8]

Indeed, this type of VR tools are capable of helping treat complex stress and anxiety disorders as well as assisting patients in conquering their fears and phobias through exposure therapy techniques. In line with this method, virtual reality experiences are created for individuals to face their fears and become immune to negative stimuli. This is not limited to treating phobias, and can be used in the field of preventing or diminishing the effects of relapse for drug users.

Augmented Surgery

Beyond training and mental health support, as data access technologies are quickly progressing, the next step for AR is now to provide real-time, life-saving patient information to surgeons which they can use during simple or complex procedures. Surgeons will be soon able to precisely study their patients' anatomy by entering their MRI data and CT scans into an AR headset. Surgeons will be able to visualize bones, muscles, and internal organs without even having to cut open a body. This will help them determine exactly where to make injections and incisions.

AR is not only useful to perform accurate and low-risk surgeries but also to display life-saving information for paramedics and first responders during a medical emergency. Especially surgeons could then save time in the case of an emergency surgery. Instead of searching among papers or through electronic medical records, they could have access to all needed information on their AR screen within seconds.

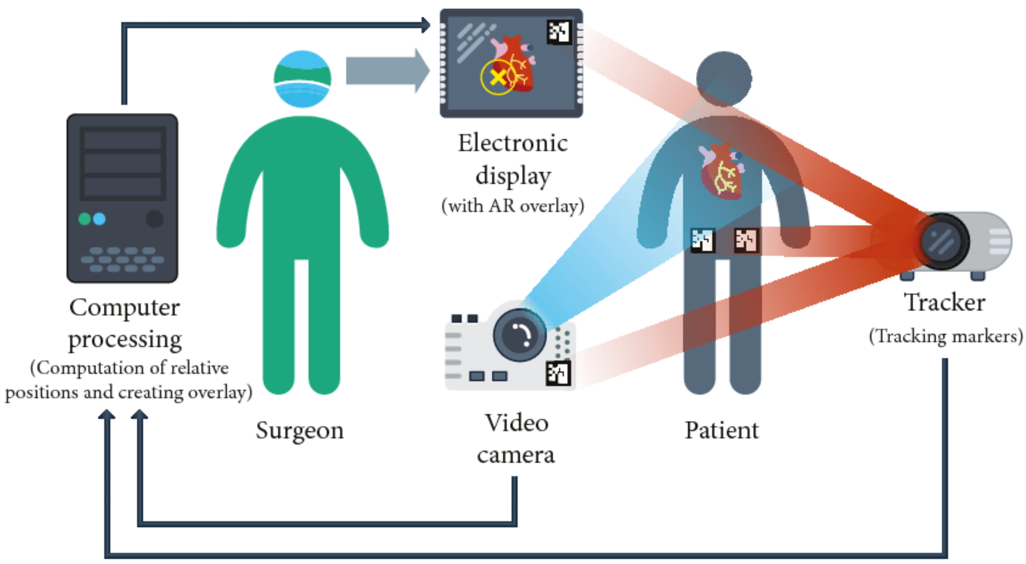

Figure 5 - A scheme showing the basic principles of augmented reality in surgery [9]

Augmented Reality can be combined with robotic surgery that allows surgery to be performed using a robotic device, e.g. robotic arm which is controlled by a human surgeon. This means fewer risks of complications during surgery and a faster procedure. The robotic device is accurate, meaning smaller incisions, reduced blood loss and faster recovery.

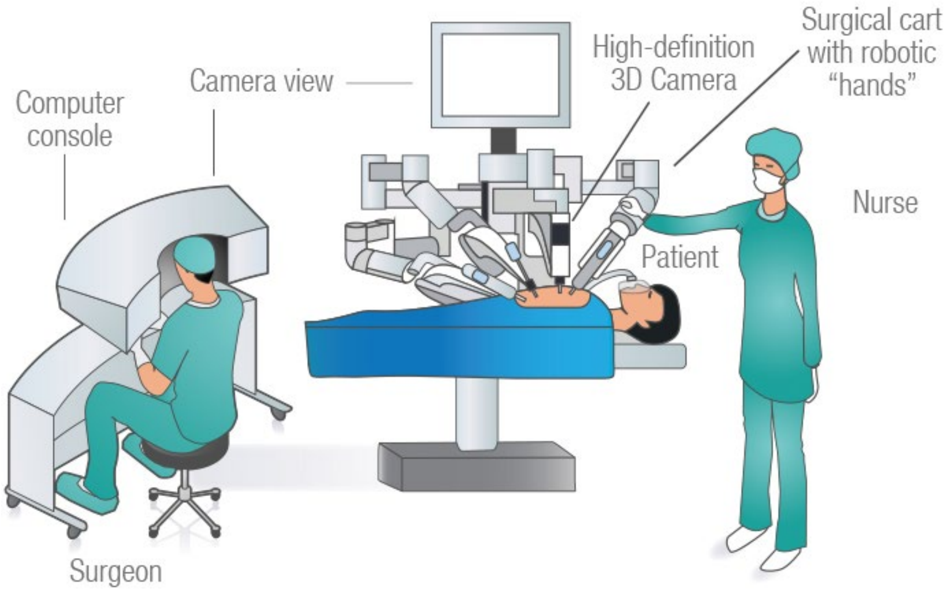

Figure 6 – Example of robotic surgery: the "da Vinci" Surgical System [10]

In the next future, pre-operative planning will be performed with advanced imaging techniques of AR combined with robotic surgery. The radiologist and surgeon will thus flag certain aspects of an operative site to be noted during the surgery like a neck of the aneurysm, the boundaries of the tumor or a fragile blood vessel in close proximity to the operative site. AR will be able to flag these structures to the surgeon during the operation.
As the field of surgery enhances through methods such as robotic surgery with refining movements through scaling down the magnitude of the gestures, the role of AR will be ever increasing.

VR/ AR Category	**Techniques**
Anatomy	• Wire frame or mesh • Isotropic risk potential and anisotropic tissue field
Visualization	• Transparency of objects between surgeon and target • Occlusion to aid in the perception of the order of objects • Linear gradient texture (light closer to viewer - dark further) • Lighting and shading cues
Locate Object	• Camera image is augmented with wireframe preoperative models and displayed • Preoperative models of vessels/ROIs are displayed on patient
Target Marking	• Colored points to mark target • Different colors for hardness of target • Target registration error – e.g., 95% confidence ellipsoid

Navigate	• Yellow lines planned osteotomy a blue line for the saw tool • Planned trajectories for bone cutting, boreholes and biopsy
Distance data	• Surgical tool to tumor by bar graph • Numerical distance to tumor • Surgical needle changes color when pointed at target • Dynamic sphere for distance of tool to target • Change target from solid to wireframe at specified distance • Color code objects in field of regard

Table 1 - Techniques Associated with VR/ AR support of Surgical Procedures [11]

Augmented Diagnosis

Patients indeed often struggle to accurately describe their symptoms to doctors. Diagnostic radiology therefore plays a key role in medicine: it provides precise anatomic and physiologic information to physicians enabling diagnosis of complex disease so that they can monitor response to treatment. The radiologist is usually reviewing volumetric datasets by a slice-by-slice viewing method for axial, sagittal and coronal imaging planes or on occasion oblique reformats. Most radiologists are supposed to spend more than 95% of their total time on cross-sectional imaging datasets using this conventional slice-by-slice approach [12].
Augmented reality makes now it possible for doctors and radiologists to better determine their patients' symptoms and accurately diagnose them in a much more efficient way. In the future "VR/AR radiology", the radiologist will wear a head display unit, which can be either a VR or MR system. He will be able to interact with medical images in ways never before including voice commands, gestures or through handheld devices with haptic feedback. Computer aided diagnosis will help him to identify the abnormalities and appreciate subtle changes so that he can diagnose accurately and assess treatment response.

Realview Imaging - Medical Holography

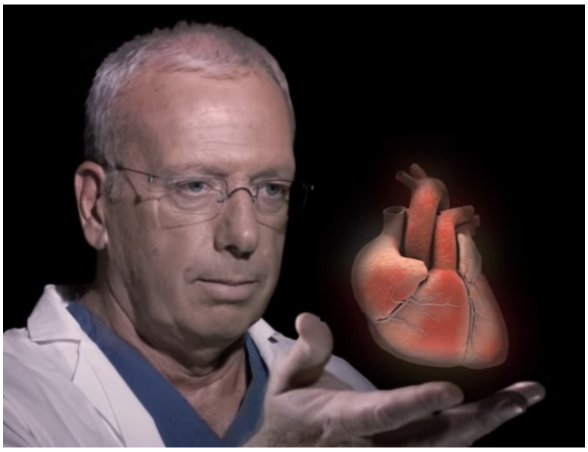

Figure 7 - HOLOSCOPE-i I - 3D holographic images of the heart [13]

Israeli startup RealView Imaging is already aiming at revolutionising medical imaging and diagnostic work by using three-dimensional holographic imaging. Realview Imaging provides interactive 3D holography display based solutions for medical imaging applications. It provides intimacy systems that allow users to engage with 3D floating in air images, interventional cardiology products, and diagnostic imaging products. Its solutions find applications in areas like clinical fields, including cardiac electrophysiology procedures, structural heart disease interventions, interventional radiological procedures, and complex surgical procedures.

Conclusion

With the continuous development of technologies and the health care ecosystem, the virtuality concept will keep quickly evolving in this area.

Ideally, VR-based and real-life training should be combined but the risk-free environment that defines VR training as well as its key possibility of infinite task repetition has a clear and immense deployment potential. The health industry's discussion on virtuality is no longer limited to the form factor of terminals or how virtuality will be realized but also address the concrete on site deployment scenarios through training, diagnostic and surgical procedure activities.

However, despite the development of haptic technology, it’s still not recommended to use VR for practicing procedures that rely on thorough palpation or involve surgical drilling, since highly-detailed surfaces and vibration feedback are hard to simulate. However, even with this limitation, the range of areas where VR training proves to be very effective is immense.

Beyond the medical training challenge, the experimentation of the use of AR in diagnostic radiology is rapidly growing. One of the most common reasons for performing diagnostic imaging is for cancer. Early determination of whether a particular therapy regimen is working would be extremely helpful to improve survival and would save costs.

The next step will obviously be the deployment of AR in surgery operation. AR enhanced surgery with simultaneous display of real and virtual images will be important in improving surgical outcomes. Surgeons face significant challenges of how to operate on complex anatomical structures. Pre-operative planning is progressing with advanced imaging techniques including VR and AR. Surgeons will be able to appreciate finer details of complex structures.

As whole, it is foreseeable that AR/VR will play a major role in the health industry. Features of AR/VR including depth perception, head tracking, improved GUIs create an overall immersive environment allowing for new opportunities in medicine. It is hopeful that continued advances in virtual and augmented reality technologies, as applied to medical training, diagnostic and surgery will decrease morbidity, decrease length of hospital stay, improve patient outcomes, and decrease overall health expenditures.

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