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Module 4 -Technology - led advancements and innovations in healthcare

Augmented reality and virtual reality in healthcare – Case Studies

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Augmented reality and virtual reality in healthcare – Case Studies

Learning Objectives:

- To know what is Augmented reality AR and virtual reality and differences between them
- Explore AR & VR technologies and their impact on health sciences, with some real world examples
- A Case study on VR application in virtual reality to reduce pain and stress relief
- A Case study of VR/AR simulator for Laparoscopic surgery

Overview of Session:

This lecture is an attempt to motivate the medical practitioners to become aware with the latest visualization and interaction technology.
Although These technologies were actually meant for entertainment industries, now it finds enormous application in the field of medicines.
The lecture also contains some detail description on the use of AR/VR for patient rehabilitation and stress relief followed by various state of the art available surgical simulators. The lecture concludes with some new ideas and advices on how one should use in practice.
Disclaimer: Most of the content given for reading here is taken from the internet and some research paper. Very little modification or amendment is done in order to convey the core points of the lecture. These notes will be useful for the reader to know more details on various topics. I like to acknowledge all the contributors for sharing their content on the internet. These notes are purely for academic use.

Virtual reality:

To describe Virtual reality we can state that it is a simulated/synthetic environment that is created using various modeling software and presented to the user in such a way that the user is immersed in this synthetic environment and the user believes and accepts it as a real environment. The most popular type of VR is desktop VR. In this type of VR, a computer is used to carry out virtual reality simulation, and the user is primarily experienced the same through two of the five senses: sight and sound.

In its simplest form of virtual reality, a three-dimensional image can be explored interactively at a personal computer, usually by manipulating keys or the mouse so that the content of the image moves in some direction or zooms in or out. More sophisticated efforts involve such approaches as wrap-around display screens, actual rooms

augmented with wearable computers, and haptics devices that let you feel the display images.

Virtual reality uses can be divided into following:

- The simulation of a real environment for training and education.
- The development of an imagined environment for a game or interactive story.
- the simulation of a real environment for medical usage such as training and therapy.

There are many state of the art software and tools now available for developing the VR model. For example the Virtual Reality Modelling Language (VRML) allows the creator to specify images and the rules for their display and interaction using textual language statements. Moreover, software like blender, vizard etc. can be used to create the simulations.

In today's time, Virtual reality (VR) is a state-of-the-art technologically advanced system that allows users to be transported into a 'virtual world.' Here, the users are engaged in a fully immersive VR experience through a combination of technologies, including a head-mounted display (HMD), headphones with sound/music and noise reduction, a rumble pad, joystick or another device for manipulation/navigation of the virtual environment (VE). VR also includes head-tracking systems, which are often built into the HMD. These systems follow the user's head movements, giving them the illusion of being completely surrounded by a virtual world. Multimodal (visual, auditory, tactile and olfactory) stimuli contribute to a sense of actual presence/immersion in the virtual world, thus making the VR experience distinct from passively watching television or movies, or playing a 2D handheld video game or game console. A variety of VR systems have been developed and investigated from low- to high-tech systems, including non-immersive 2D VR systems administered without helmets to fully immersive VR systems with multimodal stimuli, resulting in mixed outcome efficacy. Figures below show applications of the VR technology. In medical technology the use of immersion will be of very importance as the user/subject needs to experience the real-world environment in a way that they can make better decisions. Moreover, when it is used for therapy a care must be given such that the patients do not get distracted or adversely affected by the immersion or rendering of the simulated environment.

In the below fig. 1-3 we show a couple of examples where the subject is wearing the head mounted display and a relevant real world environment is being delayed for the treatment purpose.

Fig.1 A person wearing the Head mounted display for the pain relief therapy

Fig.2 An elderly person wearing the HMD curing aging related disorders

Fig.3 A woman is being treated using VR after showing the improvements in her posture using VR/rehabilitation etc.

How is virtual reality achieved?

In recent times virtual reality is usually implemented using computer technology. There are a range of systems that are used for this purpose, such as headsets, omni-directional treadmills and special gloves. These are used to actually stimulate our senses together in order to create the illusion of reality.

This is more difficult than it sounds, since our senses and brains are evolved to provide us with a finely synchronised and mediated experience. If anything is even a little off we can usually tell. This is where you'll hear terms such as **immersiveness** and realism enter the conversation. These issues that divide convincing or enjoyable virtual reality experiences from jarring or unpleasant ones are partly technical and partly conceptual. Virtual reality technology needs to take our physiology into account. For example, the human visual field does not look like a video frame. We have (more or less) 180 degrees of vision and although you are not always consciously aware of your peripheral vision, if it were gone you'd notice. Similarly when what your eyes and the vestibular system in your ears tell you are in conflict it can cause motion sickness. Which is what happens to some people on boats or when they read while in a car.

If an implementation of virtual reality manages to get the combination of hardware, software and sensory synchronicity just right it achieves something known as a sense of presence. Where the subject really feels like they are present in that environment.

Why have virtual reality?

This may seem like a lot of effort, and it is! What makes the development of virtual reality worthwhile? The potential entertainment value is clear. Immersive films and video games are good examples. The entertainment industry is after all a multi-billion dollar one and consumers are always keen on novelty. Virtual reality has many other, more serious, applications as well.

There are a wide variety of applications for virtual reality which include:

- Architecture
- Sport
- Medicine
- The Arts
- Entertainment

Virtual reality can lead to new and exciting discoveries in these areas which impact upon our day to day lives.

Wherever it is too dangerous, expensive or impractical to do something in reality, virtual reality is the answer. From trainee fighter pilots to medical applications **trainee surgeons**, virtual reality allows us to take virtual risks in order to gain real world experience. As the cost of virtual reality goes down and it becomes more mainstream you can expect more serious uses, such as education or productivity applications, to come to the fore. Virtual reality and its cousin augmented reality could substantively change the way we interface with our digital technologies. Continuing the trend of humanising our technology. Moreover, the repeatability and sense of presence at no extra cost is one such big advantage. Moreover, the precision that these technologies give is amazing. In various R&D labs and flight simulators the VR technology has proven to be very effective. Furthermore, many medical applications have been developed where highly complex tasks such as virtual surgery etc are carried out without much of a difficulty.

Features of virtual reality systems:

There are many different types of virtual reality systems but they all share the same characteristics such as the ability to allow the person to view three-dimensional images. These images appear life-sized to the person.

Plus they change as the person moves around their environment which corresponds with the change in their field of vision. The aim is for a seamless join between the person's

head and eye movements and the appropriate response, e.g. change in perception. This ensures that the virtual environment is both realistic and enjoyable.

A virtual environment should provide the appropriate responses – in real time- as the person explores their surroundings. The problems arise when there is a delay between the person's actions and system response or latency which then disrupts their experience. The person becomes aware that they are in an artificial environment and adjusts their behaviour accordingly which results in a stilted, mechanical form of interaction.

The aim is for a natural, free-flowing form of interaction that will result in a memorable experience.

Augmented reality basics:

Augmented reality can simply be defined as a combination of interactive digital features like graphic overlays, haptic interchange, or other sensory projections overlaid into our real-world environment.

AR is the enhanced reality where a real-world environment is augmented with superimposed computer-generated imagery/graphics over a user's view; collectively it ends up enhancing perception and adds layers of information in one's reality. AR is a subset of VR and it allows see through kind of an option which is not possible in the case of the VR. Moreover, these techs can be deployed on handheld devices such as Mobile, iPad etc. In medical technology we can import an MRI scan on to the real brain image using proper registration techniques. This allows us to investigate a subject much more effectively. Further, it also allows us to import not only one modality of image, rather we can use multiple combinations of scans and all can be displayed simultaneously for a better diagnosis.

One of the most popular platforms for working out medical AR solutions is the Google Glass, with which Rafael Grossmann[1] carried out the first operation streamed live in 2013. The wearable computer with an optical head-mounted display was made available to testers and developers in 2013. However, it failed to catch on with the broader mainstream market, in the last years, the old technology is taking on a new function in healthcare.

Since December 2013, doctors have used Google Glass at Boston's Beth Israel Deaconess Medical Centre to see whether it can facilitate either doctor-patient interactions or the input of data. Huge QR codes hang on the walls and doors of patient

[1] https://medicalfuturist.com/top-9-augmented-reality-companies-healthcare/

rooms. These can be scanned when the doctor steps into the room, and Google Glass transmits the relevant patient records and information. The device makes it possible for doctors to keep eye contact with the patient while receiving pertinent information right away.

Yet, there are plenty of other innovative ventures as well aiming to bring AR to healthcare. I decided to put together a list with the most relevant companies developing ground-breaking augmented reality solutions. You may please refer to this link to know more about AR applications in health care[2].

Fig. 4 A tab is being used to see the patient heart using an Augmented reality tech.

[2] https://medicalfuturist.com/augmented-reality-in-healthcare-will-be-revolutionary

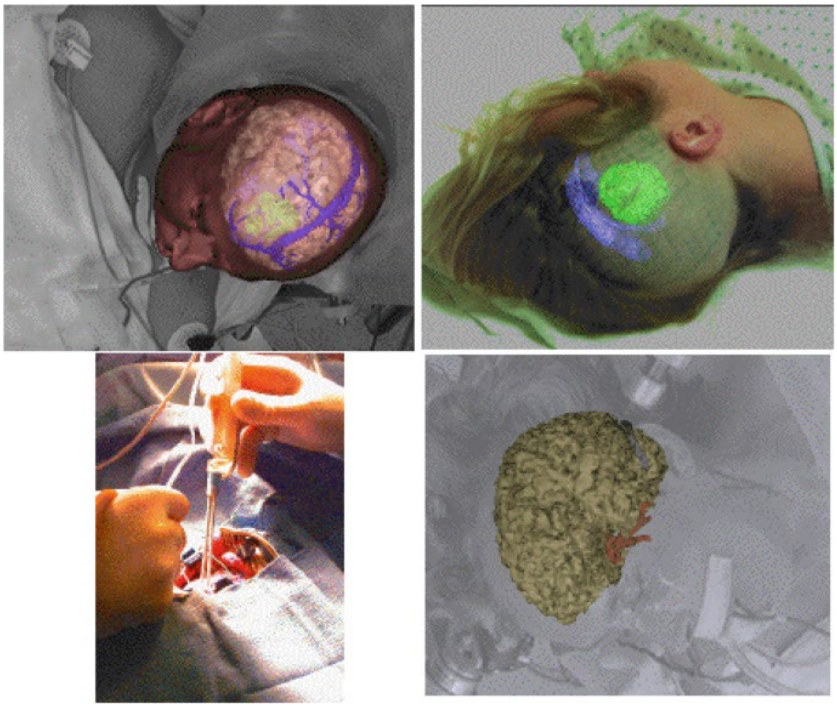

Fig. 5 An application of AR for brain diagnosis

Augmented Reality Explained

Let's get into the literal meaning of Augmented Reality (AR). Augmented is derived from the word augment, which means to add, enrich or enhance something. In the case of Augmented Reality, 3D models, videos, images, sounds, and touch feedback are added to provide an overall immersive user experience.

The Working and Usage of AR

This promising and futuristic technology works in conjunction with augmented reality devices such as AR headset/smart glasses or smart devices such as tablets, smartphones and even PCs. The devices are preloaded with specific augmented reality software, sensors hardware devices that generate digital content altogether.

The usage of augmented reality is quite broad and it is being implemented in numerous industries with the help of both AR glasses and smart devices. For example, Google Glass displays 2D images onto see-through glasses, whilst Microsoft HoloLens (a mixed reality headset) embeds 3D images into the world around you. Platforms such as EvolveAR allow affordable (if not free) AR content creation for small businesses, agencies, and many other industries. Users can access and implement interactive assets like videos,

gifs, animation, sounds and much more into their Augmented Reality campaigns. Apart from all this, AR features within existing smartphone games and apps, such as Pokémon Go, Snapchat, etc.

The AR process puts the smartphone's camera into play. So, if you want to use some augmented reality apps like the EvolveAR App, you'll need to point the camera at different objects in the room. Once the app recognizes a triggering object from the database, a digital experience appears onto the object – that is the AR campaign created for that particular object.

For developers, this process involves a ton of coding and underlying algorithms, and sometimes the system has to detect thousands of different target images simultaneously, and that can cause software breakdown. Therefore, it is kind of a big deal to develop a cohesive Augmented Reality software, and for this very reason, it is quite expensive. However, with the increasing competition and angel investments, companies are trying to bring AR in the hands of anyone who has access to the internet and owns a smartphone.

That being said, some of us may already be using Augmented Reality technology in our daily life without even realizing it. Let's take the example of the world-famous Pokémon Go, which by the way majorly relies on geolocation but also has an element of AR in it, Snapchat's selfie filters, and Facebook's AR Studio to create face masks and animations.

Types of Augmented Reality

Several types of augmented reality technology exist, each with specific objectives and usage. Below, we will discuss major categories, their usage, and application in industry.

Marker and Marker less AR

This type of AR relies on the object recognition technique in combination with augmented reality. The system (AR device, smartphone) identifies a scene and then displays information to engage the user in an immersive experience. This only happens when a specific marker (poster, image or object) is put in front of the device and the user can interact with it to engage into an AR experience.

These markers may include QR codes, images, serial numbers, or any other object that is isolated from its environment for the camera to see. Once shown, the augmented reality device overlays information from that marker directly on the screen displaying campaign created for that marker. It might include sounds, video, CTAs, animations and photo albums, etc.

On the other hand, Marker less augmented reality allows a user to use location or real-world environment to deploy the AR campaign. GPS compass and accelerometer is used for anchor points. This type of augmented reality system is applied when the location holds the primary importance such as with navigation systems.

Projection or Spatial AR

Projection AR is often confused with the likes of layered or superimposed augmented reality, but it is different in one way. In this type of AR, actual light is projected on the surface of an object of interaction. We can describe this type of AR just the way we understand the concept of a hologram.

A popular use of this kind of AR is to project a keyboard onto a surface so that a user might use it to enter data using the projected virtual keyboard. Other uses in the industry include maintenance, inspection, training, logistics etc.

Layered AR

This type of AR uses a device to recognize a physical space and then overlay digital information on top of it. Using this type of AR, users can try on virtual clothes (EvolveAR Magic Mirror), display navigation steps upfront, check how a new piece of furniture would look in a specific part of the house (IKEA App), try on shoes (Nike AR App), and more.

Applications of Augmented Reality

There are many advantages to using augmented reality and we've witnessed an application of AR in nearly every industrial sector including:

- Archaeology, Art, Architecture
- Commerce, Workplace, Office
- Construction, Industrial Design
- Education, Training, Translation
- Emergency Management, Disaster Recovery, Search and Rescue
- Games, Sports, Entertainment, Tourism
- Healthcare, Medicine
- Military, Navigation
- Hoteling and Restaurants

- Fashion and Retail
- Automotive Industry

Case study 1:

VR for Laparoscopy

Laparoscopy has become the standard approach for many conditions in most surgical specialties. This development has been driven by the desire for less surgical trauma, faster postoperative recovery, shorter hospital stay, and better cosmetic results, and a sales drive by the medical industry. It is evident, however, that laparoscopy is associated with a longer operation time and a higher rate of surgical complications during the learning curve of the surgeons. This has been verified in many different specialties, including general urological, paediatric, and gynaecological surgery. The possibility of overcoming these problems during the learning curve by appropriate training and ensuring that surgeons perform a sufficient number of procedures has also been documented. The technical skills needed for laparoscopic surgery are fundamentally different from those for traditional open surgery, leading to a prolonged learning curve. The primary obstacles in learning laparoscopy are psychomotor and perceptual. The unique nature of laparoscopic surgery combined with an increasing focus on patients' safety and rights, the present decrease in working hours, and concern over costs of operating theatre time are factors that challenge the traditional surgical approach and contribute to a growing need for novel methods in the training of laparoscopic surgeons. Although virtual reality simulation has the potential to offer important advantages in the area of training for new skills and procedures, evidence on the transfer of skills from the simulated environment to the operating theatre is still limited. The fig 6. shows a VR laparoscopy simulator which is turned to be a much better option that of a box-type laparoscopy device.

Fig. 6 A sample simulator

Fig. 7 A sample surgical environment. The breath-taking setting of a Virtual Operating Room defines the new concept for laparoscopic training. The trainee practicing on the LAP Mentor[3]™ simulator wears a VR headset, and is fully immersed in an operating room environment including a virtual OR team, a patient, equipment and real life sound distractions. This setting provides the most true-to-life experience and teaches trainees how to cope with the stressful, and at times distracting, operating room atmosphere.

[4]LapSim(R):

Fig.8 A LapSim Simulator

The popular LapSim Haptic System includes a Haptic hardware platform with LapCam, a separate laparoscope; Basic Skills, Task Training and Camera Anatomy Training software modules; all necessary computer and monitor hardware; and a height-adjustable rolling SimFrame to house the system.

[3] https://www.medicalexpo.com/prod/simbionix/product-81276-810138.html

[4] http://www.sg-trade.com/media/files/LapSim-Brochure-2016.pdf (read the full pdf to know more about the LapSm)

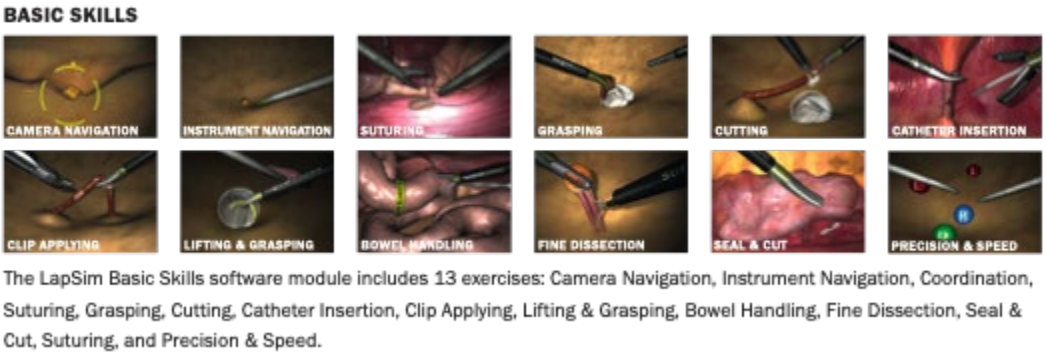

Fig.8 Showing the basic skills that Lapsim can create

The above examples show how a VR system can benefit in enhancing the skills required for carrying out keyhole kind of surgery. Moreover, it also allows us to include more complex simulations or skills for enhancing the multiple skills using the same device.

Case study 2:

Virtual Reality for Pain, Stress, and Depression management: Virtual reality (VR) has been used to manage pain and distress associated with a wide variety of known painful medical procedures. In clinical settings and experimental studies, participants immersed in VR experience reduced levels of pain, general distress/unpleasantness and report a desire to use VR again during painful medical procedures. Investigators hypothesize that VR acts as a nonpharmacologic form of analgesia by exerting an array of emotional affective, emotion-based cognitive and attentional processes on the body's intricate pain modulation system. While the exact neurobiological mechanisms behind VR's action remain unclear, investigations are currently underway to examine the complex interplay of cortical activity associated with immersive VR. Recently, new applications, including VR, have been developed to augment evidenced-based interventions, such as hypnosis and biofeedback, for the treatment of chronic pain. In recent research work it has been found that VR is very effective for acute and chronic pain management. However, in some instances the VR can cause distraction too.

VR for acute pain management[5]

The two popular approaches are possible for using VR for pain management. In one case we can deploy the distraction strategy and in another we can bet on relaxation type strategy. Both are found to be effective in pain management.

Burn care

The use of VR for pain and anxiety attenuation during burn care procedures and rehabilitation of burn survivors is one of the most widely researched uses of VR technology. Clearly, burn wound care causes a tremendous amount of pain, anxiety and discomfort to patients. It has been reported in a case study examining the efficacy of VR compared with a standard video game for two adolescents (16 and 17 years old) undergoing burn wound care. VR was found to decrease pain levels, anxiety and time spent thinking about pain. Specifically in children Vr found to be very effective in managing the burn pain. Analgesia coupled with VR was more effective in reducing pain and distress than analgesia alone. More recently, a water-friendly VR system was investigated during wound debridement for 11 patients (9–40 years), demonstrating that

[5] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3138477/

VR lowered pain ratings and increased fun ratings for those who reported feeling engrossed in the VR game.

Virtual reality technology has also been studied with burn patients undergoing physical therapy. In a recent study it was examined the use of pharmacologic analgesia alone versus VR in addition to analgesia during physical therapy. Patients in the VR group reported lower ratings of pain and an increased range of motion. After the VR condition, patients reported decreased pain and a greater range of motion. Multiple researchers have found similar results among burn patients undergoing physical therapy/rehabilitation that the use of VR does improves the recovery of a patient. Patterson and colleagues were the first to use VR technology to augment hypnosis (virtual reality hypnosis [VRH]). This was a novel and cutting-edge approach to the integration of VR with a pre-existing evidence-based treatment for reducing pain and anxiety. Procedurally, VRH is administered by providing the patient with an audio recording of hypnotic induction, suggestions for pain relief and then drifting the participant into the virtual world. It can also be stated that the VR as a means of delivering hypnosis to patients with burns during wound care in a clinical case will be an effective alternative. In some studies it is found that the patients reported lower levels of pain and anxiety when treated using a VRH. The Patterson[6] used a VR distraction sequence, SnowWorld©, developed by Hoffman, which allows users to glide through a 3D icy canyon while throwing snowballs at virtual snowmen, igloos, robots and penguins. Similarly, Konstantatos[7] et al. examined the efficacy of VR relaxation in addition to morphine for pain reduction during burn wound dressing changes. Instead of using a distraction type program, such as SnowWorld, the researchers developed a VR relaxation sequence prepared by psychologists and based on hypnotherapy theory. This provided calming visual scenery, which instructed the participant to concentrate on a moving spiral. Contrary to previous results, this study found an increase in pain intensity for participants receiving VR with morphine during wound care. Mixed findings may be related to the VE, the degree of immersion and varying methodologies. While VR distraction is effective for reducing pain during burn wound care, VR relaxation may not deliver the same result.

In general, VR has been reported to be an effective modality to decrease pain during burn care. However, continued research in burn care is warranted with VR and VR enhanced interventions for managing the associated pain and anxiety. Moreover, a serious involvement of technology and medical practitioners would benefit his research at large.

[6] https://pubmed.ncbi.nlm.nih.gov/11587113/
[7] https://pubmed.ncbi.nlm.nih.gov/19111995/

Cancer pain

Virtual reality technology has also been studied as a way to decrease pain, unpleasantness and anxiety associated with common painful cancer procedures and treatments, such as chemotherapy, lumbar puncture and port access. A study by Schneider and Workman[8] examined 11 children (aged 10–17 years) receiving chemotherapy with and without VR. A total of 82% of the children stated that treatment with VR was better than previous treatments and that they would like to use VR during future treatments. Several other findings indicated that VR distraction was significantly better than standard of care in terms of reducing physiological arousal (i.e., pulse rate) and pain ratings. VR has also been demonstrated to decrease symptom distress and perceived time spent receiving chemotherapy, termed the time–elapse compression effect.

Routine medical procedures

Many routine medical procedures, such as a blood draw, intravenous placement and immunization can be painful and anxiety provoking. Gold et al[9]. investigated the use of VR distraction during outpatient blood draw in children. The sample consisted of 100 children (8–12 years old) stratified for age and gender into four conditions: no distraction, cartoon distraction, VR via computer or VR via HMD. The children in all conditions placed their arm through a pass wall for the blood draw in order to control for visual occlusion. Children in the VR HMD group reported a lower frequency of moderate-to-severe pain intensity levels compared with the other three groups. Gold et al. examined the use of VR with 20 children (8–12 years of age) requiring intravenous placement of contrast for an MRI CT scan. Children were randomly assigned to one of two conditions: standard of care (topical anesthetic) or VR presented via HMD plus standard of care. While children in the control condition had a fourfold increase in pain ($p < 0.01$), children in the VR condition reported no significant changes in pain intensity between pre- and post intravenous placement. Furthermore, children, caregivers and nurses were more satisfied with the use of VR for pain management during the procedure.

Many studies also show the effectiveness of VR in dental as well. Where during scaling and root planning a painful dental procedure. Pain scores were significantly lower in the VR group compared with the movie group and controls. multiple studies suggest that the application of VR has reported lower pain ratings than the movie and control conditions.

[8] https://psycnet.apa.org/record/2000-16544-004
[9] https://academic.oup.com/jpepsy/article/43/3/266/4558507

VR for chronic pain management[10]

While there is growing evidence supporting VR's effectiveness in managing acute procedural pain, little is known about the use of VR for treating patients with chronic pain and/or for long-term pain rehabilitation. To date, only a few studies have investigated VR for chronic pain management and the data are preliminary. These studies conclude that VR can help in chronic pain as well. However, more studies on a larger pool of patients are needed to look at the effectiveness of immersive VR programs for the treatment of complex regional pain syndrome and other chronic pain conditions.

Sarig-Bahat et al[11],[12]. investigated VR's ability to treat chronic neck pain in 67 patients (22–65 years) with and without symptoms. The investigators used a VR environment, which encouraged patients to increase their range of motion by 'spraying' flies with a virtual spray canister. In theory, the more they engaged in the activity, the greater their range of motion would become. The investigators found that a single session of VR resulted in increased cervical range of motion and decreased neck pain. In a very recent study the same author has studied the Cervical Motion Assessment Using Virtual Reality. They propose a novel method using virtual reality and electromagnetic tracking and introduce a more functional method for assessing cervical motion. Their study established that vr can be useful in maintaining the the inter and intratester reliability. The results suggest a better repeatability for the VR method, with rotation being more precise than flexion/extension.

Several other aspects such as how much time the patients need to be in the VR environment and how many sessions per week is needed also needs some attention. Moreover, what kind of scenarios and familiarity the patients should have is an important aspect. As in India many people are not aware of the latest VR technology and deploying such schemes in India will be a lot more challenging. Nevertheless the VR can be used for various tasks such as range-of-motion exercise and task completion kind of exercises etc. here both sitraction and engagement type strategy will be useful. Several investigators found that pain ratings were significantly lower when patients were immersed in VR and the magnitude of pain reduction did not decrease over multiple sessions. These findings are promising as they indicate a potential for VR to be applied to long-term physical therapy.

[10] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3138477/

[11] https://pubmed.ncbi.nlm.nih.gov/29018956/

[12] https://journals.lww.com/spinejournal/Abstract/2009/05010/Cervical_Motion_Assessment_Using_Virtual_Reality.7.aspx

Fig. 9[13] A medical expert is using VR for pain management on a subject (Investigator attaches the Medoc 30 × 30 mm ATS thermal stimulator probe to administer a noxious stimulus.)

A VR setup can be more stable in pain management. However, more studies are required to establish this fact. Moreover, people with some resistance to Head mounted displays need to provide an alternate no Head Mounted VR technology for pain management using video games or augmented reality. Some researchers have used VR managing the pain related to brain imaging as well. this use of Virtual reality has been found to attenuate pain, and this effect has been called 'VR analgesia'. to capture the effect of VR the subjective ratings of pain reduction by VR has been corroborated with functional MRI (fMRI) data showing reduced brain activity increases in regions commonly strongly activated by experimental thermal pain stimulation. Attention gating is found to be also very effective in managing the pain. Hence, diverting the attention using VR can be effective in pain management too. In other words, attention does not necessitate task loading, but task loading does require attention. Additional studies are required to shed light on these issues to advance our understanding of the underlying cortical processes responsible for pain attenuation.

[13] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3138477/

Fig. 10 The researcher studies the fMRI to see the effect of VR in pain management. (Investigators reviewing structural brain MRI.)

The important points to remember:

- Immersive virtual reality (VR) technology often includes a head-mounted display with head tracking, headphones with sound/music and noise reduction, and a joystick, rumble pad or other device for manipulation/navigation.
- VR uses immersive multimodal stimuli, such as visual, auditory, tactile and/or olfactory, to engage the participant in immersive gaming.
- With a strained surgical-education system, rapid medical innovation and a pending surgeon shortage, VR may offer an important educational tool to augment surgeon training and continue to offer patients the very best care.
- HMDs with either VR or AR will have great potential in the field of surgery.
- Their functionality has the potential for benefit in a range of clinical settings across the multidisciplinary team and in medical education.
- The digital surgical environment is about to drastically change due to the advances in the AR/VR. Many new simulators are now being prepared for expertising the comlex surgical task under a very realistic environment.
- Experiments investigating the neurobiological mechanisms underlying VR analgesia are underway.
- VR can be used to augment other evidence-based clinical interventions, such as hypnosis and biofeedback.

- VR can be used for attenuating pain and distress for a variety of acute painful procedures.
- VR for managing chronic pain and facilitating pain rehabilitation are underway.
- New innovations like Microsoft HoloLens and the emerging mass market of VR headsets would indicate that these technologies will become familiar to surgeons and inevitability we will find a way to integrate them into our day-to-day practice.

Summary:

AR/VR technology has a lot of important roles to play in the area of medical science. The recent trends show that there is vast benefit the patients are getting out of these technologies. However, more serious studies has to be carried out to establish this fact. Moreover, many hospitals need to be equipped with VR/AR therapy rooms where patients with pain and stress can be trained more effectively. Further, all medical training schools should adopt AR/VR surgical training modules for better content delivery and students to practice these tech and enhance their learning curve.

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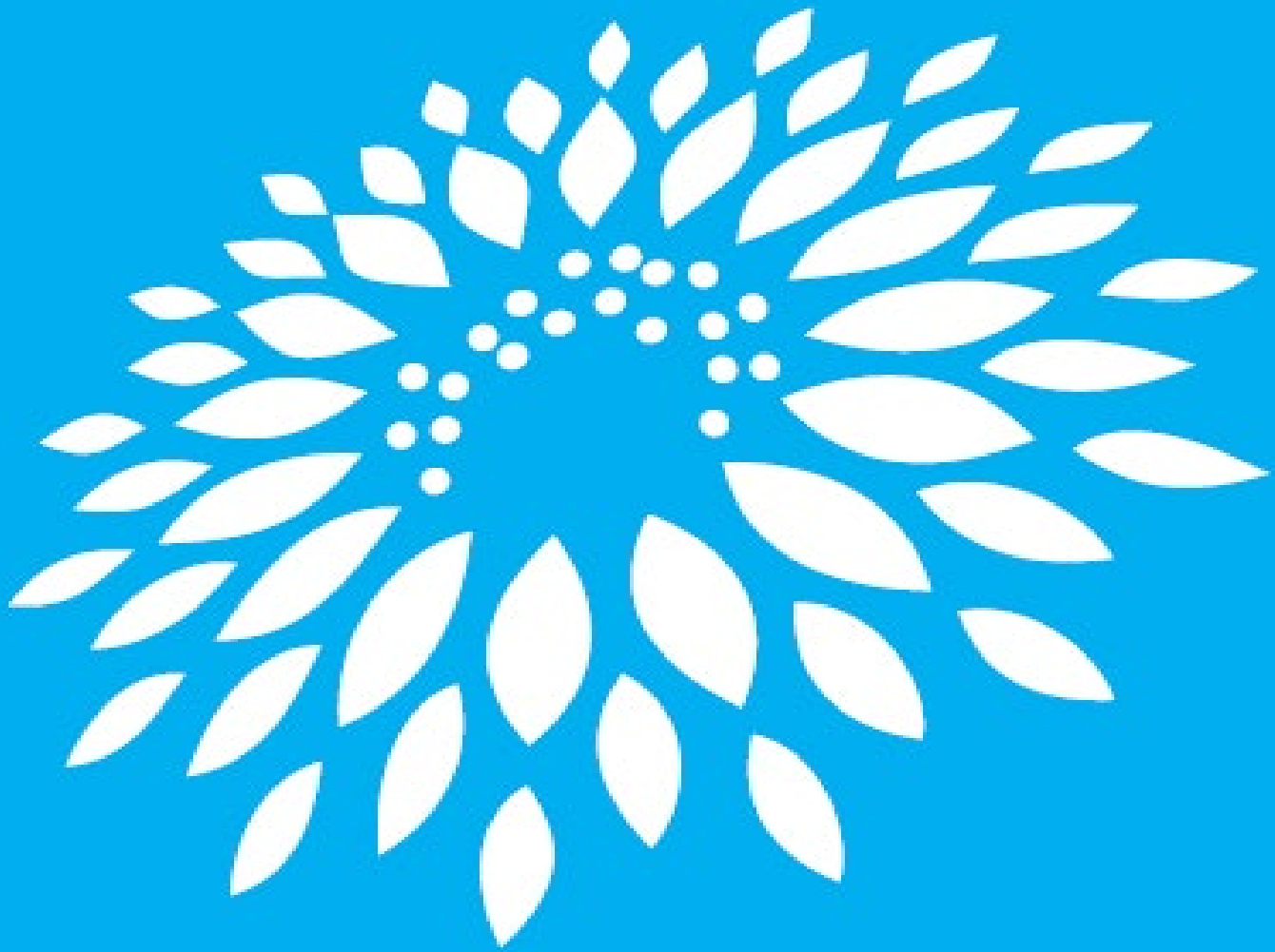
- Virtual and Augmented Reality in Education, Art, and Museums (Advances in Computational Intelligence and Robotics) 1st Edition
- Emerging Technologies for Health and Medicine: Virtual Reality, Augmented Reality, Artificial Intelligence, Internet of Things, Robotics, Industry 4.0 1st Edition

Food for Thought

1. Make the list of stresses where VR/AR will be useful in rehabilitating patients
2. List down the sensory inputs that are important for a doctor to understand while carrying out the procedure. Discover if existing AR/VR can give these sensory feedbacks or not?
3. List down the various VR application that are used cure stress relief and pain relief.

Presentations



PUBLIC HEALTH FOUNDATION OF INDIA

ASSOCIATION OF HEALTHCARE PROVIDERS INDIA

Indian Institute of Science

Indian Institute of Space Science and Technology

Certificate Course in Healthcare Technology (CCHT)

Module 4 -Technology led advancements and innovations in healthcare

Augmented reality and virtual reality in healthcare – Case Studies

CERTIFICATE COURSE IN HEALTHCARE TECHNOLOGY

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Computer vision and Virtual Reality CoE, Dept. Of Avionics
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Dr. Deepak Mishra joined the Department of Avionics, Indian Institute of Space Science and Technology, Trivandrum in August 2010. He is responsible for both research and teaching UG and PG students. Moreover, he was the coordinator for the Mtech program in digital signal processing and developed a virtual reality center of excellence during his stay at IIST. Dr. Mishra heads Computer vision and Virtual Reality CoE which focused on developing new algorithms for computer vision and virtual reality applications. Before joining IIST, he worked as a postdoctoral scientist at the University of Louisville, Kentucky, USA (2007-2009) and in the Image processing division of CMC Limited (TCS) Hyderabad (2009-2010). He obtained his Ph.D. in Electrical Engineering from the Indian Institute of Technology Kanpur (2007).

His current research focuses on developing deep learning based algorithms for computer vision applications and new architecture for Deep learning. He had taught Virtual reality, computer vision and Machine learning courses, Some of his research work involves Virtual reality application for Disaster simulation and walk through. He is a recipient of the prestigious SSI young scientist award in the year 2012. Many of his graduate and postgraduate students have won INAE best Project award. His group consisting of 16 research scholars (UG,PG and PhD level) are actively working. His research work has resulted in 02 book chapters, and around 70+ publications in peer-reviewed journals and conferences. While his recent work with his students on developing an application for COVID- AR challenge 2020 was listed in top 15 among 300+ participants.

He is interested to use VR/AR and AI capabilities for medical diagnosis and rehabilitation purpose. He is also partnering with reflection info systems Trivandrum on ECG data analysis and computer vision application.

Applications of Augmented reality and Virtual Reality

Case study-I: VR to reduce pain and stress relief

Case study-II: VR/AR in surgeries/Popular simulators

Learning Objectives

- To know what is Augmented reality AR and virtual reality and differences between them
- Explore AR & VR technologies and their impact on health sciences, with some real world examples
- A Case study on VR application in virtual reality to reduce pain and stress relief
- A Case study of VR/AR simulator for Laparoscopic surgery

Overview of Session

- This lecture is an attempt to motivate the medical practitioners to become aware with the latest visualization and interaction technology.
  - Although These technology were actually meant for entertainment industries, now it finds enormous application in the field of medicines.
- The lecture also contain some detail description on the use of AR/VR for patient rehabilitation and stress relief followed by various state of the art available surgical simulators,.
- The lecture concludes with some new ideas and advices on how one should use in practice.

Subtopics

- Introduction to Augmented reality and Virtual reality
- Patient Rehabilitation using AR/VR
- VR/AR application to Laparoscopic surgery

Lecture Plan

- Motivation
- Role of Virtual reality and augmented reality in surgery
- Introduction to the VR, AR and Mixed Reality
- Role of AR and VR in entertainment industry and elsewhere
- Role of AR/VR in medical in general
- Case study 1 : VR application in rehabilitation and stress relief
- Case study 2: Popular VR/AR simulator for laparoscopic surgery
- Summary
- Conclusion
- References

Motivation

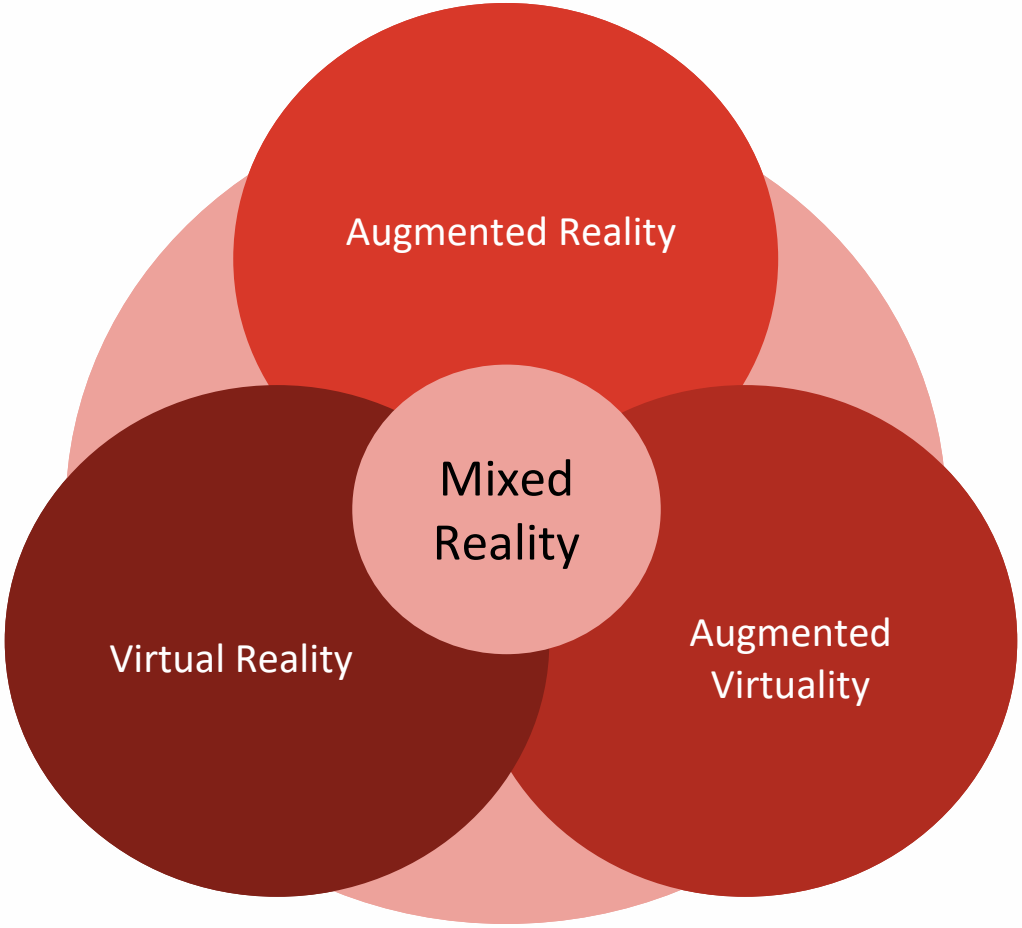
Many surgical procedures are always complicated and requires following

- careful judgment,
- professional knowledge
- and high levels of attention to ensure safe and efficient operation.

- Typically an extensive training/apprenticeship is essential is adopted to educate young doctors/practitioners. Moreover this training has to be done under a careful supervision.

- However, such an approach is not popular now as it can impact the patient's comfort, and may also cause increased operational time and cost.

- Cadavers and synthetic mock-ups are used to complement/supplement some of the problems. However, they are not flexible and and are expensive as well and suffered from aging effect.



A conceptual note showing the relations among various technologies

Virtual reality (VR)

In the mid-1960's, Sutherland first described VR as "a window through which a user perceives the virtual world that looked, felt, sounded real and in which the user could act realistically"

- VR provides a viewer-centered experience which is immersive and interactive, involving multiple sensory experiences

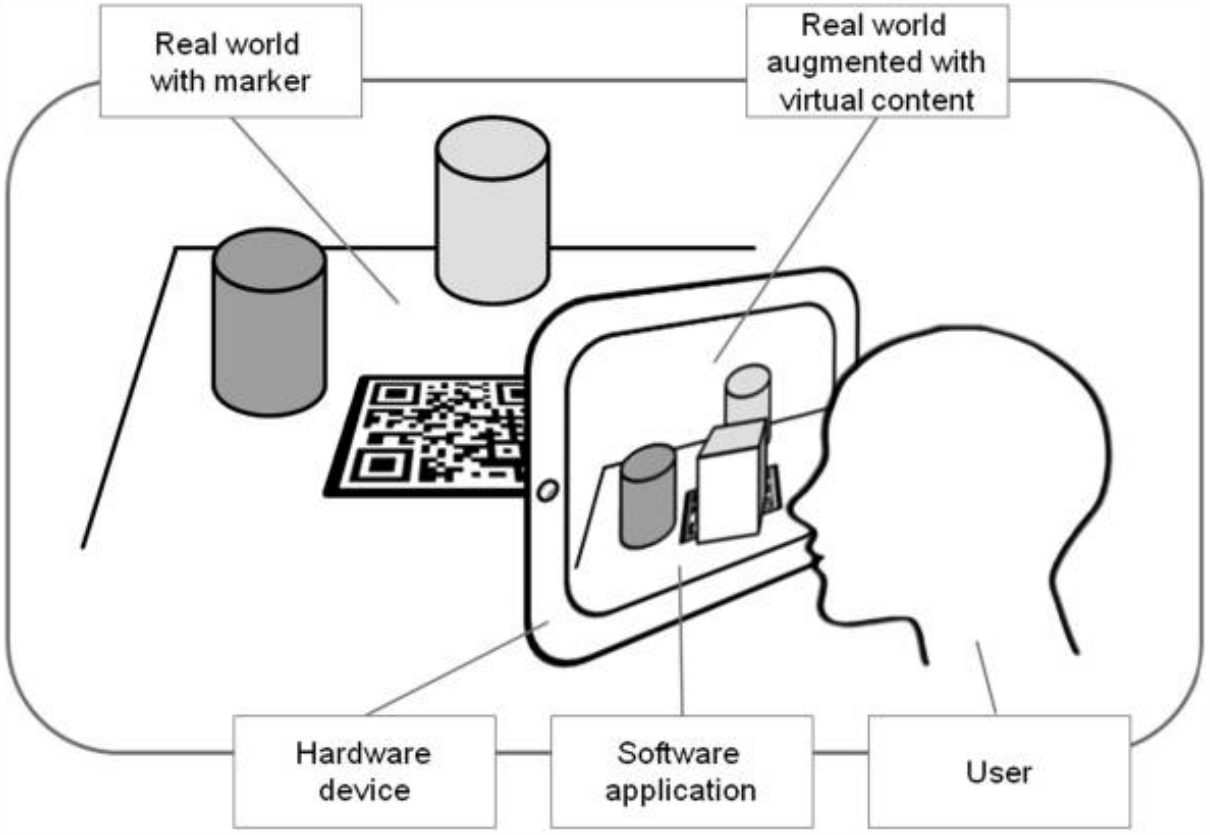
- The observer experiences a "stereoscopic" three dimensional (3D) image, coupled with head positioning which gives a sense of interactive motion

Virtual reality in use. a) Nursing student wearing a virtual reality headset. b) Performing a cardiac examination on a virtual patient. c) Projecting a virtual reality experience on multiple screens for group learning. d) Pupil responses to light in a virtual patient.

source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6798020/

source: https://blog.frontiersin.org/2020/02/05/to-the-frontiers-of-virtual-reality/

Augmented Reality basics



Virtual content (block) is added to the real world (table). A hardware device (tablet) including software is used to make the content visible for the user

Augmented reality (AR)

- **The augmented reality(AR)** with HMDs adds digital information to the real world while VR completely replaces the real world with a digital reality, implying an immersive experience that completely shuts out the physical world.
- Augmented reality differs from the virtual reality experience by augmenting and overlaying the real clinical environment rather than placing a surgeon in a virtual world. There are a range of such technologies, including mobile variants like Pokemon Go, holographic headset displays like the HoloLens, and heads-up displays like Google Glass.
- When using AR artificial information is incorporated into the actual world as perceived by one or more senses. In this manner, video or computer generated images are superimposed onto the real world.

Augmented Reality can be used for interaction and telementoring

- Surgeons often seek the advice of experts when facing complex or unfamiliar cases. Interaction with those experts is often via email, phone, or even text message before or after the procedure.

- Telementoring, a leading use of AR, allows the expert to see what the surgeon is seeing and provide tailored guidance during the procedure.

CASE STUDY-I

VR Application In Rehabilitation And Stress Relief

VR for palliative care

Medical rehabilitation helps individuals with disabilities attain and then maintain optimal functioning of their body. It does so by reducing the impact of their health condition and teaching the person basic life-tasks like eating and walking.

- Whether you are living with migraine, fibromyalgia, or another chronic pain condition, virtual reality (VR) may be worth looking into. Often used in palliative care or with hospitalized patients, it may be an effective adjunctive therapy for pain management at home as well.
- “Virtual Reality is an excellent approach to pain management. It captures the mind’s attention and blocks pain signals from reaching the brain. It’s almost like a form of active hypnosis. VR provides tactile and sensory feedback and allows the patient to rally the neurotransmitter mechanisms that decrease pain.”

Role of Virtual reality in Rehabilitation

- Recent technological advances in the computer and games industries have transformed our homes and workplaces and are now making an impact in clinical settings.
- Computer-assisted rehabilitation programmes that make use of Virtual Reality are poised to revolutionise how therapy is delivered.
- The use of VR in rehabilitation has proved to be very effective, and for a good reason. Simulated virtual objects, environment, and events allow patients to plunge into an alternate reality, where they can interact with things and carry out actions not otherwise available to them in real life.
- This is one of the very few, if not the only, ways to let patients “escape” from the restrictive hospital environment.

Advantages that the Virtual reality offers in Rehabilitation

- allows patients with different disorders to execute actions that they cannot perform in real life due to their disabilities.
- gives an opportunity to use more advanced digital rehabilitation methods as an alternative to traditional therapy, thus maximizing the effect of the rehabilitation measures.
- can be used in individualized treatment plans developed on the basis of careful assessment and following case-by-case treatment goals;
- helps analyze and better understand the needs of people with disabilities in public places and at home.

VR

source: https://program-ace.com/blog/virtual-reality-in-healthcare-a-new-solution-for-rehabilitation/


+95

Virtual Reality for Stress Reduction

- **Relaxing VR**: In this approach, the user is presented with contents inspired or directly derived from classical relaxation techniques, such as progressive muscle relaxation, autogenic training, yoga, and meditation. The user is shown these environments to help them feel safe and as a result help them relax.
- **Engaging VR**: This approach requires the user to interact with the virtual contents to train emotional regulation. In this scenario, the environment is flexible and modifiable based off the users interactions.
- **Personalized VR**: A newer approach to VR relaxation is personalized VR, which is a user-centered approach that is built on distinctive features picked up by users' memories of relevant life events.

Summary of Case study-1

- Virtual Reality has been used effectively to promote relaxation and reduce stress.
- People with severe pain reaped the most benefits from VR
- VR can help distract people from their pain
- There's still a lot to learn about the possibilities of VR

CASE STUDY-II

VR/AR simulator for laparoscopic surgery

Role of Virtual reality and Augmented reality in surgery

- The use of Virtual Reality(VR), Augmented Reality(AR) and Mixed Reality(MR) technology in training junior doctors can provide a unprecedented flexibility and the opportunity to practice without the involved supervision.

- Additional benefits of these simulators/systems include objective performance evaluation, the possibility to fail without consequences, the training of uncommon surgical procedures and repeated practice.

Important Constituent of AR/VR for surgical use

- an immersive 3D environment
  - This can be used to replicates a realistic surgical scene or mixes with the real surgical scenario
- A AR simulations can include
  - Sound
  - Vieo
  - Graphics
  - GPS data
- Advanced rendering and view/device control algorithms
  - This is useful in attaining seamless view of the subject
  - Provide enough control to give surgeons the ability to perform accurate surgical preoperative planning/intraoperative conduction
  - Ensures an efficient training of many distinct surgical procedures.


• Fusing radiologic imaging with a live patient
• Multiple Patents Pending
• Multi-modality fusion

Augmedics presents

xvision

The First Augmented Reality Guidance System for Surgery

Major educational field where VR and AR simulator were used

Fields of educational training	VR and AR simulator examples
Physiology and anatomy	Visible Human Project, Visible Korean Human, The Virtual Body, The Virtual Human Embryo, The Visible Human Server, AR glasses, mobile phone and tablet based AR applications
Open surgery	Virtual Reality Educational Surgical Tools
Laparoscopic surgery	MIST-VR, LaparoscopyVR™, LapMentor™, LapSim™, SINERGIA, Xitact LS500®, ProMIS®
Robotic surgery	RoSS™, DV-Trainer®, SEP Robot, da Vinci Skills Simulator (dVSS) ™
Oesophagogastroduodenoscopy, colonoscopy, ERCP	GI Mentor™, EndoVR™, Olympus Endo TS-1

Neurosurgery	NeuroVR (NeuroTouch, NeuroTouch Cranio)™, ImmersiveTouch®, RoboSim, Vascular Intervention Simulation Trainer®, EasyGuide Neuro, ANGIO Mentor™, VIVENDI, Dextroscope®, Anatomical Simulator for Pediatric Neurosurgery
Interventional cardiology and cardiothoracic surgery	ANGIO Mentor™, Vascular Intervention Simulation Trainer (VIST)®, Vimedix (equipped with Hololens) ™, Nakao Cardiac Model, Minimally Invasive Cardiac Surgery Simulator, dVSS™, EchoCom
Urology	URO Mentor™, University of Washington TURP Trainer, UROSim™, PelvicVisionTURP simulator, GreenLight laser simulator, Kansai HoLEP, ProMIS®
Orthopedics	ImmersiveTouch®, Phantom haptics interface®, Gaumard HAL S2001® and S3000® Mannequins, Novint Falcon®, Medtronic model, Arthro-VR®, Arthro MENTOR™, ArthroSIM, ArthroS™

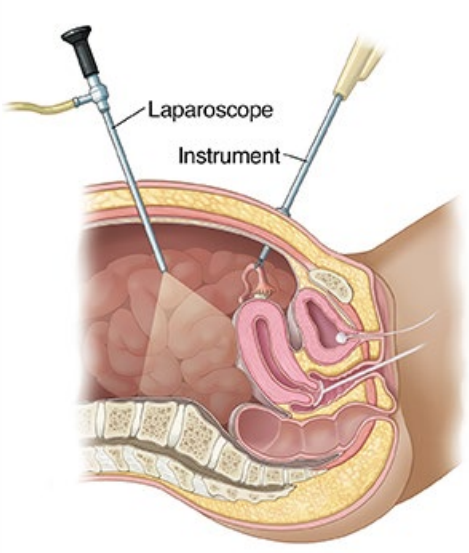
Endovascular surgery	ANGIO Mentor™, Vascular Intervention Simulation Trainer (VIST)®, Cardio CT, SimSuite, Compass 2™
Obstetrics and gynecology	HystSim™, EssureSim™, AccuTouch (and newly version from CAE Healthcare), MIST-VR, LapSim™
ENT	OtoSim™, VOXEL-MAN (supports Phantom haptics), Ohio State University surgical simulator, Stanford Surgical Simulator, Mediseus, ImmersiveTouch, Endoscopic Sinus Surgery Simulator (supports Phantom haptics), Dextroscope®, dVSS ™
Ophthalmology	EyeSi®, MicrovisTouch™, PhacoVision®
Intubation and bronchoscopy	EndoVR Simulator™, BRONCH Mentor™, ORSIM®

What is Laparoscopic surgery ?

- Small incisions of up to half and inch are made and plastic tubes called ports are placed through these incisions. A camera and instruments are put into the ports and this allows access to the inside of a patient.
- The video camera serves as the eyes of the surgeon.

Key Advantages

a. Quick recovery times
b. Less post op discomfort
c. Smaller scars
d. Less internal scarring
e. Quicker return to full activities



First laparoscopic procedure performed in 1902 by Georg Kelling of Dresden, Germany in a dog.

1910-First laparoscopic procedure performed in a human by Hans Christian Jacobaues of Sweden.

Hans Christian Jacobaeus

Laparoscopic: Pros and Cons

- Advantage: Smaller incisions, less blood loss, less infection risk, shorter recovery time.
- Challenge: 2-dimensional visualization; depth perception, eye-hand coordination, counterintuitive instrument movements, etc.

Major Challenges in Conventional Laparoscopic surgery

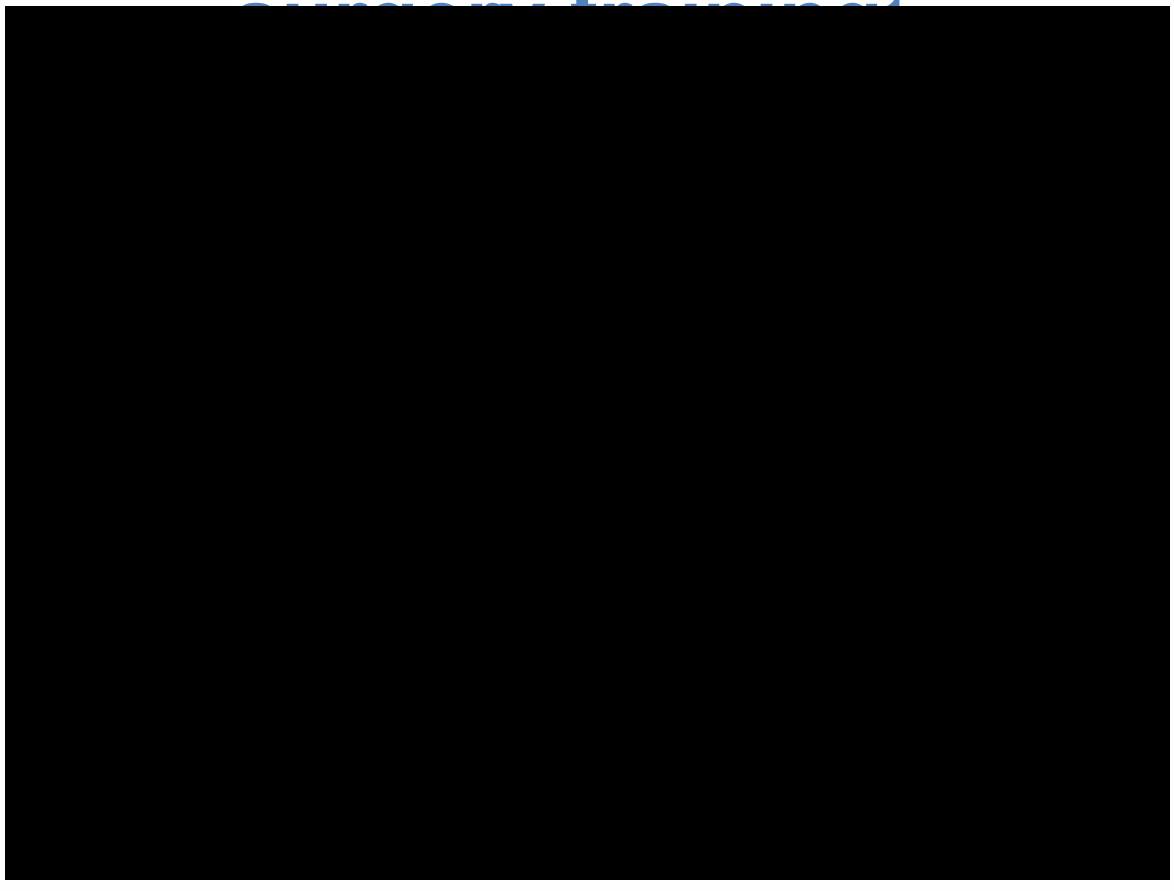
- Training for Laparoscopic surgery is time consuming and costly without the use of VR because surgical trainees must practice under the supervision of a trained surgeon.
- Different methods of this surgical training include the use of live animals and human and animal cadavers.
  a. Box trainer
  b. AR/VR Simulator

A Demo laparoscopic video (box) trainer

Conventional Video-box trainer

- Video-box trainers include a box with a lid and holes cut on the lid for the trocar's insertion.
- A laparoscope inside the box is connected with a digital camera and provides video output to a monitor on which the trainees are watching their own movements, while performing the teaching task.
- Laparoscopic instruments, such as laparoscopic graspers and laparoscopic scissors are inserted through the trocars into the box, where the tasks are taught.
- These inexpensive models are designed to develop hand-eye coordination and bimanual dexterity and can simulate a variety of techniques, such as laparoscopic peg transfer, circle cutting, intra-corporeal and extra-corporeal-suturing, knot-tying using a prettied loop and clip-applying.

Case Study-I VR and AR in laparoscopic surgery training[1]



source: https://www.medicalexpo.com/prod/simbionix/product-81276-810138.html

[1]MedhatGreg R.WynnTanArulampalam, **Virtual reality training in laparoscopic surgery: A systematic review & meta-analysis,** **International Journal of Surgery**, Volume 29, May 2016, Pages 85-94

Key opportunities: AR in Laparoscopic Visualization

- Emerging augmented reality (AR) technologies have brought the direct visualization advantage of open surgery
- They augment the physician's view of his surroundings with information gathered from imaging and optical sources, and can allow the physician to move arbitrarily around the patient while looking into the patient.
- A physician is now able, for example, to see the exact location of a lesion on a patient's liver, in three-dimensions and within the patient, without making a single incision.
- A laparoscopic surgeon is now able to view the pneumoperitoneum from any angle merely by turning his head in that direction, without needing to physically adjust the endoscopic camera.
- Augmented reality can actually free the surgeon from the technical limitations of his imaging and visualization equipment, thus recapturing the physical simplicity of open surgery.

Benefits of using Virtual Reality simulator for Laparoscopic surgery training

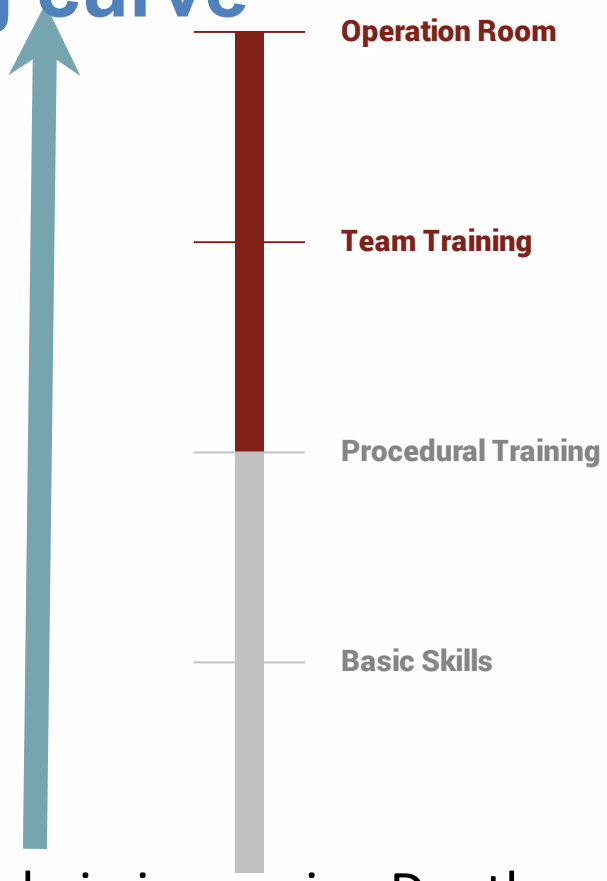
- Training using a Virtual Reality simulator is an option to supplement standard training.
- VR improves technical skills of surgical trainees such as decreased time and improved accuracy.
- Surgical trainees who practice using VR simulators go into their first surgeries with the experience of having performed 30-50 surgeries.

LapSim Virtual Reality Laparoscopic Simulator

- The LapSim Haptic System includes a Haptic hardware platform with LapCam, a separate laparoscope;
- Basic Skills, Task Training and Camera Anatomy Training software modules; all necessary computer and monitor hardware; and a height-adjustable rolling SimFrame to house the system.


Touch screen
Exercise menu touchpad
Input devices: instruments and camera
LAPSIM® computer

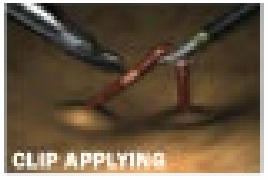
How Surgery simulators Help in the boost the Learning curve



simulators can help in improving Depth perception, Eye-Hand Coordination, Instrument handling, Precision and speed etc.

Software Features of LapSim

BASIC SKILLS

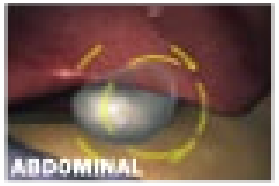


The LapSim Basic Skills software module includes 13 exercises: Camera Navigation, Instrument Navigation, Coordination, Suturing, Grasping, Cutting, Catheter Insertion, Clip Applying, Lifting & Grasping, Bowel Handling, Fine Dissection, Seal & Cut, Suturing, and Precision & Speed.

TASK TRAINING

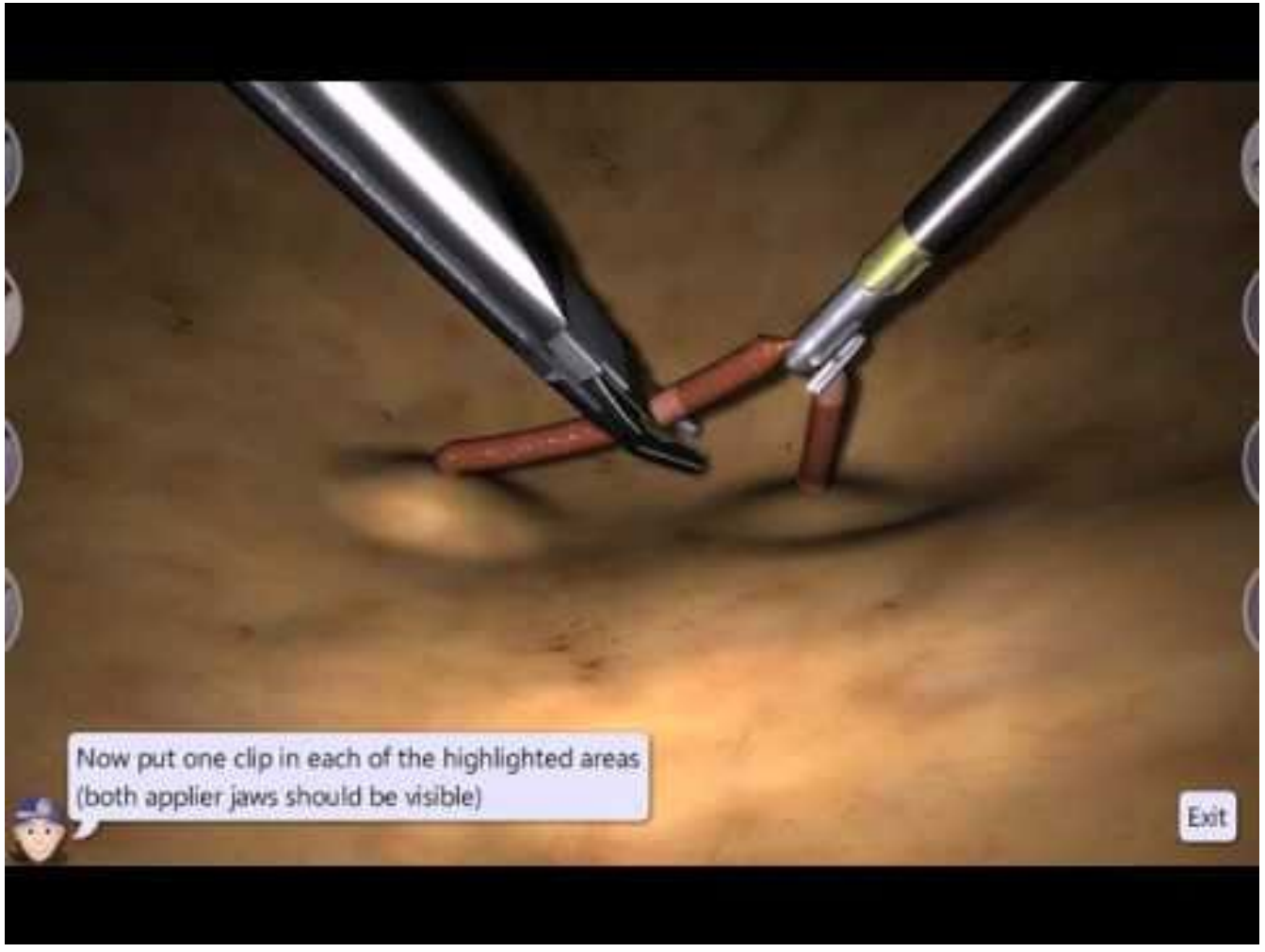
Inspired by guidelines established by SAGES and ideal for FLS skills training, Task Training exercises include Peg Transfer, Pattern Cutting and Ligating Loop.

CAMERA ANATOMY TRAINING



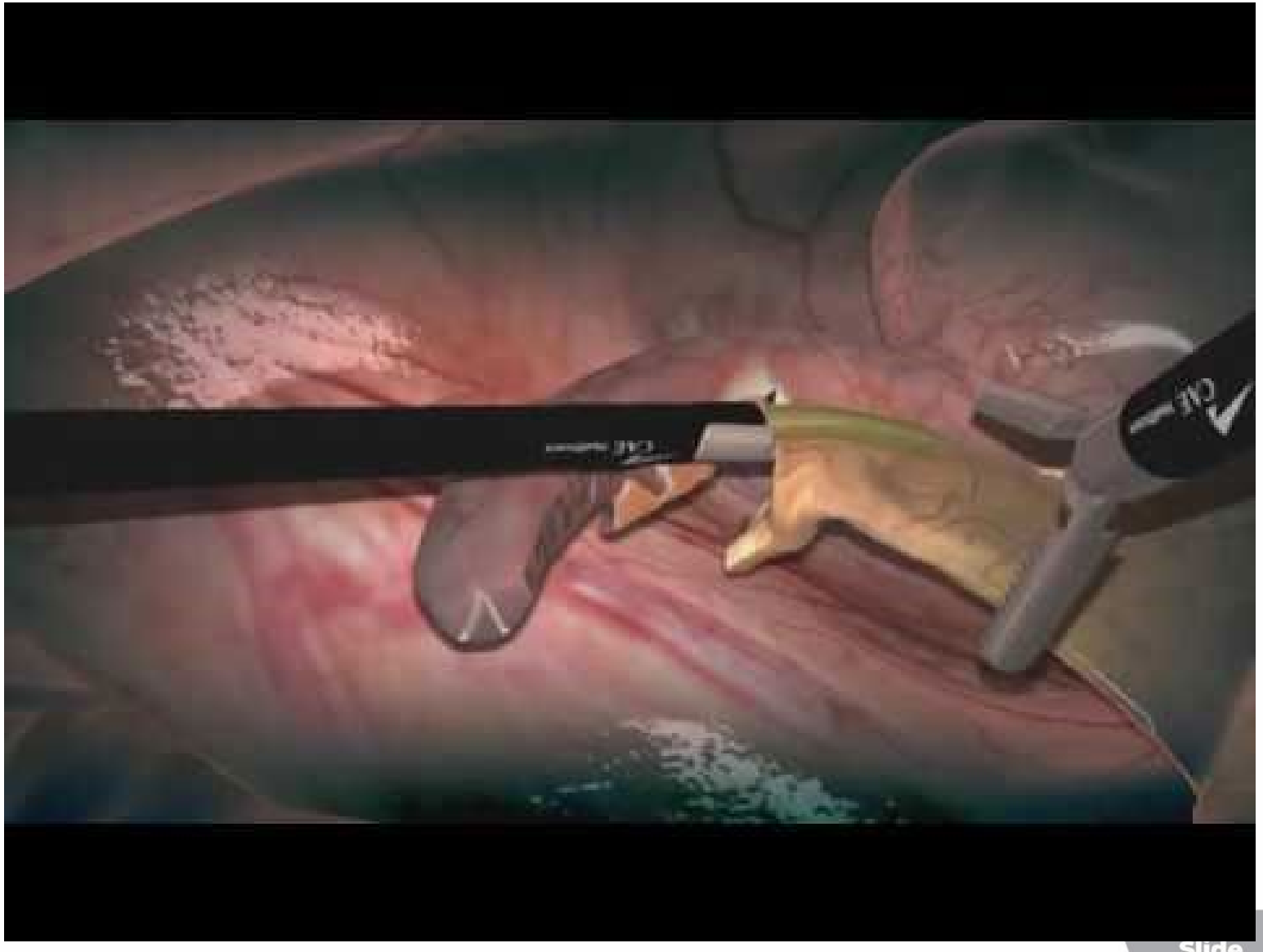
Camera Anatomy Training modules focus on teaching camera handling with straight and angled optics within a virtual anatomy.

A sample Demo of LapSim



This video show a simulated clip applying training exercise from the LapSim laparoscopic simulator by Surgical Science

LAP-VR simulator



Some advantages and disadvantages of training using virtual reality

Advantages	Disadvantages
Decrease in the frequency of training and the ease of training using VR	The high cost of the simulators
Decrease in the time of surgery in the real environment,	The high cost of these studies (high cost of monitors, programming, implementation environment, participants, etc.)
Decrease of harm to those being treated by people who are trained by VR, decrease in mistakes and more successful surgeries	The course of studies is very limited; therefore, further studies and more accurate evaluations are necessary
Increase in skills of learners, Better understanding of the exterior and interior space relationships between the organs, Increase in the skill of surgeon, Better learning of anatomical positions	It can never replace the real environment training

Recap

In this lecture we have gone through following aspects of AR/VR

- Why AR/VR are useful in the field of medicines
- we learnt about VR technology role in rehabilitation and stress relief
- We also delve into AR/VR application into surgery
- We witnessed some details box trainer which is followed by VR/AR based laparoscopic simulator
- The lecture gave us various aspects in which AR/VR may benefit both the patients to overcome stress and attain a faster rehabilitation
- We have also seen how These technology benefit us in reducing the expensive training cost of new medical practitioner.

Take home messages

- AR/VR technology is useful and has lot of potential in medicines. However, it takes a while to get acquaintance with them.
- The rapid deployment of AR/VR in the rehabilitation center will assist multiple patient
- Finally the use of this technology can help hospitals to train expensive human resources
- However, a close interaction among the technologist and medical practitioners is needed to take these technology to a higher level where the engagement is as close to the real world

Activity/ assignment

Activity

1. Make the list of stresses where VR/AR will be useful in rehabilitating a patients
2. List down the sensory inputs that are important for a doctor to understand while carrying out the procedure. Discover if existing AR/VR can give these sensory feedback or not?
3. List down the various VR application that are used cure stress relief and pain relief.

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