

Security Issues in the Health Field with the use of Augmented Reality

By

Ankur Sharma

Student ID: 2191844

Supervisor: Dr Anna Shillabeer

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Declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university. To the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

(Ankur Sharma)

(8th November 2019)

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List of Abbreviations

Abbreviation	Term
AR	Augmented Reality
VR	Virtual Reality
MR	Mixed Reality
HMD	Head Mounted Display
QR	Quick Response
GPS	Global Positioning System
IGS	Image Guided Surgery
HMD	Head Mounted Display
HIPPA	Health Insurance Portability and Accountability Act of 1996
GDPR	General Data Protection Regulation
CT Scan	Computed Tomography Scan
MRI	Magnetic Resonance Imaging
HMS	Heavy melting scrap
HCI	Human Computer Interaction
PET	Positron Emission Tomography

Abstract

In the health field, security and privacy issues are a matter of concern and should be considered a high priority. Novel technologies are implemented continuously in the health field to obtain better results and improve health care facilities. However, these new technologies may have some serious security issues that can impact the health field critically. Recently, augmented reality (AR) has become available and ready to be used widely in the health field. This paper focused on identifying the security concerns that are associated with the AR technology in the field of health. To identify the issues related to the health field, a deep study to understand the AR system was done. Working of AR generally and in the health field, was discussed. After identifying the risk aspects, risk assessment was carried out. Further, risk mitigations are provided along with the standards based on the priority rating. Two models were developed. The first is the threat model that helps in identifying the component of the system and how threats may occur. The second is the security model that helps in filling the security gaps in the working model of AR in the health field. These two models enable AR to be widely used in the health field while still safeguarding security aspects of the health care domain.

Keywords: Augmented reality/AR, AR applications, AR security issues, working of AR systems, AR in health, problems and solutions of AR in health.

1 Introduction

1.1 Overview

This project focused on understanding the working of augmented reality (AR) and identifying the loopholes and weaknesses of applying the technology in the health field. In addition, it investigated the currently available solutions and identified some of the reasons for the solutions not being implemented.

1.2 Aim

AR is being widely used in almost every field (Billinghurst and Duenser, 2012). Recently, AR has begun to be more widely used in the health field as well (Kim et al., 2017). Initially AR was used in CT-scan and MRI scans (Devernay et al., 2001). Now it is available to be used in surgeries as well. The best surgeons are in high demand. However, through AR, they can be available at any place at any time in a day. AR technology has demonstrated an ability to increase their availability (Rankin et al., 2015). With the help of AR, a surgeon can operate from a remote location as if conducting the surgery while standing in the operating theatre itself (Shuhaiber, 2004). This serves to increase the quality and accessibility of surgical procedures to remote populations.

Therefore, AR is potentially a very useful approach and an important invention. However, as every coin has two sides, so this technology can also be a boon or a bane to the society. The main aim of this research project was to explore the possible loopholes or the weaknesses of AR in the field of health. This included a thorough study of AR systems and identification of possible weaknesses. The project also aimed to produce a sustainable method for solving the identified weaknesses.

1.3 Research Questions

- a) What can be the impact of augmented reality in the field of health?
- b) Can any negative impacts be overcome or resolved?
- c) Why have the available solutions not yet been adopted?

1.4 Thesis Flow/Scope

- Understanding the System: How AR is introduced, what other fields has it been used in, and will be used in.
- Finding the potential weaknesses of the system if applied to the health domain: What are the loopholes and inherent risks present in the AR system?

- Finding the consequences of the weaknesses found: What are the worst-case scenarios of the weaknesses?
- Available solutions: What are the current implementations of AR solution to address the known weaknesses?
- Solutions adopted/ not adopted: What has been, or could be, implemented in the health domain?
- What standards exist to help to address the weaknesses?
- What tools are available to augment the standards-based solution model?
- Is there a currently optimal solution to the application of AR in the health domain?

1.5 Motivation

The original motivation for this research on the topic of AR developed from an interest in the Pokémon Go game. Later, through researching AR more broadly, it is found that this technology is used in guiding drivers to show them directions with some sign objects on the roads. This led to thinking about the pros and cons of the technology. Also, found that this technology is being used in the health field and this presented a germane set of issues that, have not yet been fully addressed. Therefore, this topic was explored more to discover the factors that could present a scenario in which a human life could be in danger. So, that a high-level implementation model could be developed to overcome the potential for disastrous outcomes in the healthcare of patients.

2 Background/Literature Review

2.1 What is Augmented Reality?

Augmented reality is the technology that brings actual and virtual objects together at the same place and same time. It also helps the two objects (real-virtual) to align together so that they can interact with each other, as illustrated in the reality-virtuality continuum shown in Figure 1. AR is a 3-D technology that enables us to see the interaction and combination of these objects as a real scenario (Azuma et al., 2001).

Figure 1 - Reality-Virtuality Continuum, adapted from (Milgram et al., 1995).

Moreover, AR is a technology that can help people to watch, hear, and even feel more about the world around them. Also, the same technology helps people to understand all the computational matters and computational elements within the original global experience. With the help of AR technology, unidentified things of this real world can be potentially repaired. As this technology helps to see the actual objects that are present along with the virtual or computer-generated objects overlaid (Jacob, 2006).

Also, this technology is growing rapidly in the health field and now assists a surgeon in a remote location to perform critical operations with ease and under expert guidance. Furthermore, this technology acts as a bridge by building a layout of the virtual things that assists in training new doctors to understand the organs in detail. This same technique is helping the army to determine the enemy's location. It helps travellers in finding the places on the streets with augmented visible names of the locations along with reviews or the comments from other people who have visited the place (Feiner, 2002).

Augmented reality is the term defining the future generation technology or it is considered as a visionary interface that enhances the reality. Implementation of this technology is growing in the real world; however, it is expensive as it is in the initial phase of development (Jacob, 2006). Within the health domain the technology began with applications using the existing ultrasound and MRI technologies (Devernay et al., 2001). The emergence, working, current progress, and future work along with the security and privacy issues of this technology in general and in the field of health, will be discussed in the following paragraphs.

2.2 Brief history

The first technical prototype of AR was developed by computer graphics students of Ivan Sutherland at Harvard University and the University of Utah (Sutherland, 1968). The prototype used optical see through head-mounted display that tracked by a mechanical and ultrasonic

tracker. Only simple wireframe drawings were achieved as a result in the real time as the processing power was limited during that time (Arth et al., 2015). To facilitate this work reaching its current evolution, several key milestones in computer science had to first be realised. During the late 1970's in the United States, researchers at different universities carried out investigations in computer science (Berryman, 2012).

However, there was no AR technology as it is known today in the picture anywhere during 1992. Subsequently, a GPS system for people with disability was soon developed in which sound was overlaid on the streets to provide navigation (Loomis et al., 1999). Rapidly the technology became widely used in mobile support graphics for the improved tracking ability. According to (Feiner et al., 1997), a 3-D model of business trips along with the building details would be seen in the future with the help of a developed mobile augmented reality system. In the late 1990s the AR was about to be popularised through various international conferences and scientific debates on the augmented reality, mixed reality, and virtual reality environments (Bimber and Raskar, 2005). During this time only the famous Mixed Real Estate Laboratory 3 (MR LAB), which was established in Japan, and the launch of fast AR apps helped this technology to grow. Even at this early stage there were many articles, papers, and journals that were revealing the major issues of the augmented reality (Azuma, 1997). In 2001, MRLAB finished the initial research on the AR. Also, they conducted many post study seminars to describe the results of their findings for the problems that were evolving in almost every article and paper. Thereafter, the technology was accepted more widely and came into use in almost every field, including education, gaming, business, navigation, and health (Azuma et al., 2001).

2.3 Difference between augmented reality and virtual reality

Augmented reality and virtual reality are the trending technologies nowadays and both can enhance the user's experiences, improve the performance, and produce beneficial outcomes according to the user's desire (Nazir et al., 2012). There are similarities between these two technologies. However, virtual reality is a technology that completely replaces the real-world environment with the virtual world environment, whereas augmented reality is a technology that overlays extra information onto the real-world environment (Chavan, 2016). In simple terms the virtual experience is all illusion and it cannot be differentiating between the real world and the virtual one as there is no real-world environment existing in the virtual view. In contrast, an augmented reality experience lets us identify and differentiate between the real scenario and the augmented scenario (Milgram and Kishino, 1994).

2.4 Types of augmented reality

2.4.1 Augmented reality with the use of markers

In this type of AR, the camera and visual markers (QR code or 2D code) play a vital role in producing the augmented result. The QR or 2D code are used as patterns because they are simple and processed with less processing power. The camera is used to differentiate between marker and real-world objects. Once the position and orientation of the object is calculated, then the desired information can overlay the QR code or 2D code (Patkar et al., 2013).

2.4.2 Augmented reality without the use of markers

In this type of AR, the real-world objects are partially replaced by augmented or computer-based objects. It is used in the GPS system in order to provide the location to the device. Once the device matches the location with the system data and has found some information about the location then it overlays the information on the location. Location-based AR can identify a building address, for example, and the system can verify that it is a restaurant and will lay out the restaurant name on the identified location on a map (Patkar et al., 2013). Also it is used in recognising objects by the system and match the similar augmented objects in the system and replace them. In various industries this type of AR is widely used such as replacing furniture or kitchen items with some new design items example (Senthilvel et al., 2019).

2.4.3 Augmented reality with the use of projection

In this type of AR, artificial light is projected on the real-world objects. Then, it senses the human touch by differentiating the expected and altered projection created by the AR

technology. This type of AR is widely used in many applications, such as 3-D interactive hologram technology. Projecting a mobile interface on the surface and using it in a similar way is another example of this technology (Davare and Chavan, 2016).

2.5 Applications of augmented reality in various fields

2.5.1 Augmented reality in the field of gaming

The technology of AR is probably the most complex technology for gaming applications that are based on reality. This technology involves placing 3-D objects from the games into the existing real-world environment and integrating them together in such a way that the operator is playing that game in their own surroundings. There are various devices through which these games can be played:

- Using head worn displays
- Using projection-based AR on real world surfaces
- Using devices that are handheld

Transparency plays an important role for AR in the field of gaming as it provides the gaming experience in a real world environment (Magerkurth et al., 2005).

The following development milestones were realised to achieve the advancement of AR in the gaming field:

Augmented table top games: Tabletop games are the important basis for look-alike pattern environment; however, the availability of AR was initially very limited (Braun, 2003). In the international game, the increased board games combine the player's real position as a concept within the gaming experience. The focus was on using physical parameters to exchange information with virtual game elements. A traditional board game does not work with virtual game logic but can add social status to the virtual domain. Traditional board games like chess have been popular for thousands of years with the new arrivals of exciting computer entertainment technology, it is unknown if they will stand strong and uphold the same position as they were in the past. Their continued success is likely to be assured through the need for real communication between the players directly, as they are sitting next to each other. Solid social situations are inspired by general communication, which include face-to-face discussion, laughter, and all forms of non-verbal conversation (Magerkurth et al., 2005). Therefore, they are important and essential parts of traditional portable games, such as poker. The lack of audiovisual, intellectual, and operational practice needed for multi-sensitive stimuli hinders implementation of many intensive gaming concepts. Apart from this, most of the argument

against traditional computer games is the lack of social connections in personal circumstances, which is ensured by board games. Therefore, the development should concentrate on the combined benefits of board games and computers to produce thus far completely untried and fascinating gaming experiences. Examples of augmented table top games include The STARS, False Prophets, and Smart Jigsaw Puzzle (Feiner et al., 1993).

Location-aware games: Cultural board games use extensive computing techniques to create physical gaming boards. However, the second most effective approach to a wide gaming zone is a whole world in which the player surrounding is like a sports gaming board. This work is technically feasible to set and track statistics on a temporary physical game on the virtual board. When a building or a city park becomes part of the board game, an individual takes part in an active and very unpredictable game. The approach is unique and exciting; however, it raises many technical and thoughtful problems. The position of the player playing the game is located with the help of GPS satellite signals. Some initial games have been implemented using specific small range of proximity sensors (Magerkurth et al., 2005).

Pirates game is one of the earliest examples which describes the world as a play area and is an example of an early location aware game where players go to physiological areas, and mobile computers take them to an area shown by a space game unlike in the conventional PDA traditional game. Apart from this, the games like Can You See Me Now, Uncle Roy, and Catch the Flag are great examples of location aware games using an augmented approach (Björk et al., 2001).

2.5.2 Augmented reality in the field of education

AR provides the flexibility to the field of education as this technology can be accessed from any time and from any place. Also, this technology is widely available on various platforms, such as mobile phones, wearable devices, and desktop computers. The word portable provides the perfect explanation of the term flexibility discussed above. This technology can be used in the classroom, home, or at the workplace that enhances the education and training level.

In the traditional education system, there are some limitations such as studying through printed text material that restrict the understanding and learning of students. With the help of AR in education, this limitation may be overcome. The AR technology can be used to overlay the images graphically produced by the computer onto the real scenario (Iordache and Pribeanu, 2009). It provides students with the best hands on experience with the help of graphical images and pointing devices. This also builds more curiosity and motivation in the students to learn more and explore the AR technology as it is a new experience (Di Serio et al., 2013). In a

survey that compared traditional classroom learning with the smart classroom using the AR technology, students preferred AR supported learning because both the students and teachers found it easier to understand. Teaching only from images and text was more difficult in comparison to the smart classroom teaching, as students can learn with the help of audio, images, 3-D views, and videos (Dalim et al., 2016).

According to Billingham and Duenser, AR is capable of teaching students with a disability as they can be taught while sitting on a wheelchair, lying on the bed or anywhere. Also, they would not feel extra pressure because AR would let them learn within their day to day activities. It will not only enhance their learning experience but can also help them to do more physical exercise. Students seemed to be more engaged because of the augmented environment (Billingham and Duenser, 2012). Also, it has been demonstrated in a study that wearable technology is feasible for students with a disability. Therefore, AR technology has excellent application in education, particularly for learners with a physical disability. In addition, combined learning using motion sensor and visualisation technology with AR has even greater potential for disabled students (Arvanitis et al., 2009).

CAE Healthcare is a global leader that is revolutionising the healthcare industry with Holo Lens. They recently released Vimedix AR, which is an ultrasound seminal version that enables doctors, technicians, and students to visualise complex organs like heart and lungs. This development plays an important role in the learning process of medical students, trainee doctors, and nurses (CAE Healthcare, 2019).

2.5.3 Use of augmented reality in the field of topography

The Geographic Information System (GIS) is the mapping and data collecting framework that provides private, government, and corporate bodies with information to understand the geo spatial characteristics of the planet with the help of visualisation and virtual reality (Chang, 2016). Map overlay is the most important achievement of GIS (Battersby et al., 2006). The process of improving existing GIS technology and modernisation has rapidly advanced. The way of interaction with the technology has also changed in that operators can now simply say the commands and the commands are executed for performing set of tasks or operations (Zhang et al., 2018).

GIS geographers are building 3-D models of the geo spatial data with the help of human-computer interaction (HCI). This step produced the great advancement in the GIS interface that is a combined result of 3-D geo visualisation and HCI, and then augmented as shown in Figure 2 (Hedley et al., 2002). Past researches provided benefit for the developers as they were able

to understand the compatibility of GIS with the technology. Moreover, they were able to predict the efficiency of this advancement as it will completely change the way of viewing the important geo spatial data (Huang et al., 2016). This new visualisation interface was new to the people and they needed different mechanisms to understand the input and the outcome. However, the models have been shown to be the most effective way of conducting the geo spatial data study as it provides a more feasible and informative view of the data that is easy for everyone (Ghadirian and Bishop, 2008).

Figure 2 - Showing the 3-D GIS Visualisation Output and Augmented 3D GIS Visualisation Output into the Hands Using AR Technology (Hedley et al., 2002).

2.6 How the system works generally

AR helps to solve technological problems and challenges and provides a completely new experience for the technology users. Anyone can understand the general working of the system with the help of an example device such as a smartphone. A smartphone has many applications that help to make the lives of its users easier. One of the important applications of a smartphone is GPS that helps in providing the location-based services to the users. Using this technology, a similar way of identifying QR code with the help of camera makes great use of AR. If the smartphone camera is pointed towards a building and the camera reads QR code, the device then presents the information on to the building that is fetched from the database. The database may access Google map reviews, Facebook posts or Twitter reviews and overlay additional information about that place (Liu et al., 2008). Not only will it overlay the information on to the places but also it will provide the functionality of virtual marker with which the user is able to mark that place their favourite. Furthermore, people will find it easy if they mark their hotel while they are visiting new places and they can return to that place easily with the help of this technology.

The technology of AR is not only used in smartphones, it is widely used with other devices as well, such as Google glasses. Different devices have different ways of using AR in their systems. The AR experience is enhanced by using various wearable devices (Metcalf et al., 2016). The latest research on AR use involves special contact lenses. This will increase the portability of AR. These systems are specially designed either for inside or outside environment or even both. The development is still in progress and it may produce some unimagined outcomes in the future (Berryman, 2012).

2.7 General problems of the system

2.7.1 Registration problem (hand and virtual eye coordination problem)

The main and very basic problem of AR is the alignment of the real and virtual objects. This alignment is the basis of creating the illusion using the real-world scenario along with the computer-generated graphics. If this registration problem is not solved, then there will be no balance between the scenic objects and the user, it will not serve its purpose. In addition, most of the applications require the correct registration in order to carry out the actions smoothly and provide a seamless user experience. It includes the static errors such as distortion, calibration mechanical misalignment and incorrect viewpoint parameters. These all leads to the registration problem (Lincoln, 2017).

2.7.2 System lag

System lag leads to system delays and, furthermore, they cause the registration problem in the AR system. It depends on the moving rate of the user and the amount of registration error it caused to produce delay. The tracking system of AR measures the state and the viewing mode (landscape or portrait) of the viewpoint. Also, the difference between the moment of this tracking and displaying the viewpoint onto the displays produces end to end system delay. If the user wearing the HMD turn his head $10^\circ/s$ the he require less latency as compare to turning the head at $100^\circ/s$ (Lincoln, 2017).

2.7.3 Accuracy

AR needs the accuracy for displaying the computer graphics onto the real-world objects. This accuracy is the basic requirement for the accurate performance of the trackers of the system. If trackers are accurate, then the system will achieve the accurate registration and serve its purpose. There are very difficult criteria that must be fulfilled by the trackers in order to be accurate. Distortion and calibration are the most significant problems that arise due to lack of accuracy and is at great extent in the optical technology (Wang and Dunston, 2007).

2.7.4 Connectivity issue

One of the important and basic problems is the overcoming the connectivity issues, such as power failure and internet failure as all the AR components are dependent on connectivity (Hoenig et al., 2015). In case of connectivity issues, all the above problems will come into the picture.

2.8 Security and privacy issues

AR is a technology that involves continuous communication with the user and the devices. So, this continuous communication gives the rise for the chance of security and privacy breach. However, there are multiple aspects that are responsible for causing such security issues, which are as follows:

2.8.1 Multiple sensors involvement

There are multiple sensors involved while this technology is in use. Sensors that are used to control camera, GPS, and file accessing are in use. So, there are more chances of security threats because of using these sensors almost all the time as the sensor records data, location or images continuously (Roesner et al., 2014).

2.8.2 Multiple display devices involvement

There are many display devices involved, such as when a person is playing a game using AR technology it will have its own display device; however, a similar scene will also be displayed to other people in every instance. A very good example for this factor is iB Cricket Super Over League, as currently this is using the platform of virtual reality. This game has multiple output devices used, such as the player playing the ball has its own display device. The coach or the team has the devices where they can see both the input of the input devices and the output device of the player. However, the audience then will have a player virtually created in the game and hitting the same shot virtually that he hit as per the input provided by the input device (Cricket, 2019).

2.8.3 Running various applications using single output device

The AR technology is expensive. Therefore, it is important that a device can be used for more than a single purpose or a single application. Therefore, devices such as Google glasses and smartphones should have multi-functioning capability and should enable users to multi-task (Roesner et al., 2014).

2.8.4 Wireless connectivity

Wireless connectivity can be provided with the help of Bluetooth, Wi-Fi, or mobile hotspot; however, security and privacy concerns are very well reported when using these wireless technologies (Belkhouja et al., 2017). Bluetooth works only in a limited location and may risk security attacks (Hassan et al., 2018), while Wi-Fi and mobile hotspot wireless connectivity present vulnerabilities (Srinivasan and Wu, 2018).

2.9 Available solutions

2.9.1 Authenticated content generation and transmission mechanism

This mechanism includes the proper system for handling and managing the content creation and delivery. It has the registration policies and also it complies with the third-party content providers to provide disclaimer with all the required information that will take place after this application is used (Gupta, 2017).

2.9.2 Use of independent browsers

Having launched its own browsers, AR can be processed without any issues on the various devices (Gupta, 2017).

2.10 Available solutions adopted or not adopted

As AR is providing facility to use AR browsers; however, the AR browsers are inter-dependent on the web browsers. It is very difficult to build the direct server to browser communication that acts as a barrier for using the AR web browsers independently. In addition, these AR browsers potentially do not include any security standards. Also, Augmented Reality Markup Language (ARML) neither have security controls for secure interaction. Moreover, this dependency of AR browser on web browser disables the active security protocols of the web browser as well for running AR applications. Finally, the augmented process is taking place at clients and users location, which are often private; however, the content is provided by the third-party applications that potentially leads to non-trustworthy scenario for the authenticated content generation and transmission mechanism (Gupta, 2017).

3 Use of augmented reality in the health field

AR is a technology that has great scope within many fields of human activity, particularly in the area of healthcare where it is being used to educate and train the doctors and other healthcare professionals (Hsieh and Lee, 2018). Similarly, it is used at various other sub parts of health fields, such as 3-D modelling. The 3-D modelling is used in the surgical area and is carried out with five steps: making a time-variant 3-D model of the beating heart using coronarography and CT-scan or MRI, calibrating the stereoscopic endoscope, reconstructing the 3-D operating field, registering the operating field surface with the 3-D heart model, and adding information on the endoscopic images by AR. This modeling technique is not only used in cardiac surgery, but several other critical operations can be carried out using such modeling techniques (Devernay et al., 2001).

In the health field, AR began with the live video and real time images through the 3-D reconstruction of MRI and CT-scan. Earlier CT-scan or MRI helped in order to carry out the pre-operative reconstruction of the images. AR helped the existing technology to carry out intra-operative reconstruction of the images (Wendler et al., 2007). This is a great achievement in terms of providing surgeons with precise imagery to assist with conducting medical operations. Pre-operative means before the surgery or the operation is performed, whereas intra-operative means while performing the operation. Therefore, the imaging technique was useful for the surgeon to provide extra details for the best outcome. The use of AR during surgery was reported for the first time in 1986 (Roberts et al., 1986). Furthermore, the AR platform has been described in cardiac interventions based on ultrasonography that was carried out with the help of virtual reality technology (Linte et al., 2010).

Proximie uses cloud-based technology with neutral hardware requirement for providing AR solutions that allow hospitals to be at the forefront of patient care through specialised real-time collaboration, regardless of location, performance, and efficiency. This solution, as demonstrated in Figure 3, assists healthcare professionals to form the digital layer content on the live video screening of the patient's surgery. The images help as a virtual assistant and enable a real time collaboration of the world's best professionals at the same time without any geographical barriers. It has received the compliance of Health Insurance Portability and Accountability Act of 1996 (HIPPA) and General Data Protection Regulation (GDPR) for implementation at the global level (Proximie, 2019).

Figure 3 - Demonstrating the Working of Proximie Augmented Reality Solution During a Surgery (Proximie, 2019).

3.1 How the system works in the health field

In order to understand the working of AR system in the health field, an understanding is needed of the ground technology that helped AR to evolve in the field of surgery. The ground technology referred here is known as IGS (Image Guided Surgery) which was introduced by neurosurgeons and this technology soon started benefiting almost all the areas of health (Berry et al., 2003); (Drouin et al., 2011). Image guided surgery is the study that is carried out before performing the actual operation or surgery. Examples of conventional IGS are CT-scan and MRI scans from which AR systems have evolved. Thus, IGS and AR provide the accuracy and reliability to the field of surgery (Citardi et al., 2016).

Now, with the help of the evidence that the images are accurate and reliable it keeps the hopes alive for the future technology providing more ease and incremental improvement in results. The AR system pre-compiled data generates a complete view of the patient, including live preview or other registration. Sensory data is a variation and expansion of AR that indicates a link between virtual reality and computer graphics. It artificially produces the real world and the virtual world images (Pandya, 2004).

Figure 4 - Demonstrating the Working of IGS and Mixed Reality Hand in Hand to Form Augmented Reality (Pandya, 2004).

Steps required for implementing AR in the surgery field as shown in figure 4:

1. Imaging data (CT, MRI, Positron Emission Tomography [PET])
2. Segmentation
3. Camera parameter estimation
4. Camera mounting and pose estimation
5. Live video with mixed graphics
6. Real-time augmented reality.

Figure 5 - Live Image Taken from Surgery Based on Augmented Reality (Pandya, 2004).

Based on the above six steps the AR system works in the surgery field, firstly the imaging data is produced that may be done in the form of CT scan or MRI scan. Then the segmentation is done in order to understand the scan thoroughly. Thereafter the camera parameter, mounting, and posing estimation is done in order to capture the scans and produce graphics. Moreover, these captured scans then add to the live video in order to perform the AR. Finally, a surgeon with the help of various tools such as marker draws the AR, as shown in the Figure 5 actual live image with AR taken during a surgical procedure (Pandya, 2004).

3.2 General problems of the technology affecting the health field

There are several problems in AR that have been identified in various fields, which include:

- Registration problem
- System lag
- Accuracy
- Recovery from power failure
- Recovery from Internet failure
- Security and privacy issues.

These are discussed in the context of the health care field in the next sections.

3.2.1 Registration problem (Hand and virtual eye coordination problem)

Registration problem refers to the alignment issue that will create a situation of imbalance in the scene. This may affect the patient's health care at a great extent, such as when a surgeon is performing a surgery from a remote location and must guide the doctor and medical staff. If the surgeon is unable to get a balanced scene then successfully guiding the operation would be difficult and there are chances of wrong guidance (Behringer et al., 2007).

3.2.2 System lag

System lag is the issue that brings delay in the smooth working of the technology and may also be a lead factor for generating registration issues as well. However, this may impact in the same way as a registration problem that may cause the guiding doctor to either not be able to guide successfully or guide in a wrong way (Behringer et al., 2007).

3.2.3 Accuracy

Accuracy is the key requirement for this technology to be used in the health field as this may directly affect the patient's welfare. Accuracy provides the computer graphics on the real-world scene. This may also have a great impact in the health care, such as when a guiding doctor marks at a location to make an incision. However, if the accuracy is missing then the graphics may appear at any other location and will play an important role in the failure of the procedure (Monkman and Kushniruk, 2015).

3.2.4 Connectivity issue

Connectivity is a vital resource that is required in running most of the novel technology being used today, be it power, internet or I/O connectivity. So, these connectivity issues should be considered as a vital aspect while using any novel technology in the field of health (Gleue and

Dähne, 2001). This factor raises some important questions, such as: Will the display and the user remain in the same position as they were at the time of power failure or not? In addition, if the technology is used in the heart surgery, will the doctor stop the surgery and wait for the system to restart? Many questions arise with this basic problem as the patient may lose their life. For example, with the help of this new technology a surgeon from a remote location can operate a patient by providing live instructions and with the help of marking tool availability of the AR technology. However, if there is an internet loss at either end then how will the surgery progress?

3.3 Security and privacy issues

Security and privacy issues are the vital concerns in the health care as patient records and personal information must be kept confidential and securely protected (Al Ameen et al., 2012). However, if there is a security or privacy breach it will not only impact the patient, but it will impact all the people associated including hospital administration, doctors, and other medical staff members (Roesner et al., 2014). Data breaches and cyber security concerns are increasingly important in organisations such as hospitals where patient data could be attacked, particularly with output devices that are wirelessly connected and vulnerable to being hacked (Srinivasan and Wu, 2018). Furthermore, failures in connectivity or power outages are examples of unanticipated events that could jeopardise the effective and safe application of the AR technology in healthcare.

As this research focused on the use of AR in the field of health, a summary of factors that could arise due to these issues and concerns is shown in Table 1.

3.4 Factors arising due to the above issues or concerns

Issues and problems discussed above brings many challenges to the AR applications that have great impact to AR application than the desktop or mobile scenarios. As it is harder to realise such issues because distinguishing between the real and virtual world is very complicated. For example, malicious application sending unrelated text posts, animated Gifs that produce headache, different user may see same level of information (includes confidential information), alignment may not be accurate as required, connectivity problems and delay in any process of the system (Roesner et al., 2014). These all challenges from the above problems will impact application of AR as in case of any challenge AR will not able to produce the desired end results and in the health field it may affect the patient' life.

Table1 describes the factors that are based on the issues and problems discussed above:

Factors arising due to the above issues or concerns	
F1	Unauthorised advertising can be a major issue while the treatment is in process.
F2	Failing of any component will affect in the process of treatment.
F3	Interruption because of cyber-attack.
F4	If a doctor is guiding from a remote location, the AR system may be vulnerable to cyberattack that would allow someone to control the commands and manipulate the guiding vision.
F5	Maybe the doctor is too tired because of handing many other surgeries on that day and could not give the best. As the system has no such tools to access the active state of guiding doctor.
F6	As the system is accessed from a remote location, ensuring the privacy of the patient is the high priority. However, if the network is compromised then this will lead to breaching the privacy act along with the HIPPA act 1996.
F7	Storage and accessing of such data are also an important task, particularly in case any record is leaked of an important person who has undergone a serious health treatment that can damage their image and also it will affect all those persons who have faith in him.
F8	Performing doctor may be careless or lack experience.
F9	Patient may be afraid of the new technology.

Table 1 - Factors Arising Due to the Above Issues and Concerns (Cyan, 2018)

3.5 There are some standards that are developed in order to address some of these problems. The most commonly discussed standards are as follows:

3.5.1 Therapeutic Goods Act 1989 (Section-41BD)

If any software acts as a hardware part of medical device or system or it controls the medical devices, then that software will be regulated by the (TGA, 2018) of Australia. The software may be used for diagnosis, prevention, monitoring or treatment purposes. Therefore, devices involved in performing augmented reality in the health field would also fall under this act.

3.5.2 Informed Consent - Medical Board of Australia

Informed consent refers to the written decision of the patient about any medical treatment that they will undergo. The patient approves that they have the knowledge about the positive and the negative aspects of the treatment. This consent is signed by the patient after the doctor provides the detailed information regarding the treatment that a patient should know and is set by the regularity authority (Medical Board of Australia, 2014).

3.5.3 HIPPA Act

The HIPPA Act is a United States based law that was introduced in 1996. This act provides the summary of the health information and how it is protected, what is protected, where it can be used, and how it needs to be disclosed. This act ensures the secured privacy of the patient's information that has been shared with the healthcare domain (HHS, 1996).

3.5.4 NIST.SP.800-83r1

This publication provides the brief summary of the malware and computer viruses affecting the systems. It lists various consequences, or the destruction done by the malware. Further, this provides the proper guidelines, steps and policy for the preventive measures to avoid malware (NIST, 2013).

3.5.5 AS IEC 60812-2008 -Analysis techniques for system reliability (Procedure for failure mode and effects analysis (FMEA))

This standard provides the techniques for system reliability in the case of system failure. It lists various preventive measures to mitigate the failure mode. Also, it describes the steps that should be followed at the system failure scenario (AS IEC, 2008).

3.5.6 AS ISO/IEC 25022:2019 - Systems and software engineering (Systems and software quality requirements and evaluation (SQUARE) - Measurement of quality in use)

This standard provides the techniques for maintaining systems and software to avoid any failure situation of the system. It lists the steps that should be followed while installing new software or systems and maintaining the software or systems (AS ISO/IEC, 2016).

3.5.7 P2048.3 - Standard for Virtual Reality and Augmented Reality: Immersive Video File and Stream Formats

This standard provides the format details of the immersive video files and streams that will be used in the virtual reality or AR technology (IEEE Standard Association, 2019).

3.5.8 P2048.5 - Standard for Virtual Reality and Augmented Reality: Environment Safety

This standard explains about the environment that is suitable for virtual, augmented, and mixed reality technology. It provides the limits for testing assurance the technology. Basically, it helps to work with the technology safely (IEEE Standard Association, 2019).

3.5.9 P2048.6 - Standard for Virtual Reality and Augmented Reality: Immersive User Interface

This standard provides the full list of methods that are required for running the immersive user interface of AR and VR within MR (IEEE Standard Association, 2019).

3.5.10 P2048.7 - Standard for Virtual Reality and Augmented Reality: Map for Virtual Objects in the Real World

This standard provides the needs of the complete system that includes system, methods and verification for AR and VR within MR application for mapping purposes (IEEE Standard Association, 2019).

The application of the standards to health care as per risks associated will be discussed further in the result section.

4 Methodology

4.1 Overview

This study used the mixed method review approach based on the existing body of literature about AR, as shown in Figure 6. To access the existing papers both qualitative and quantitative methods are required. This approach has given me a broad search area of papers where the detailed system study can be done.

4.1.1 Qualitative approach

Qualitative research approach refers to accessing the value of the literature and its ability to inform the work associated in the field. It helps in providing not only the thinking of the people, but it also brings the reason why do the people think like that.

4.1.2 Quantitative approach

Quantitative research approach refers to measuring the impact of the previous work on the field. Also, it helps in providing the comparison between the different solutions identified in the research and the previous work.

4.2 Methodology design to answer the research questions:

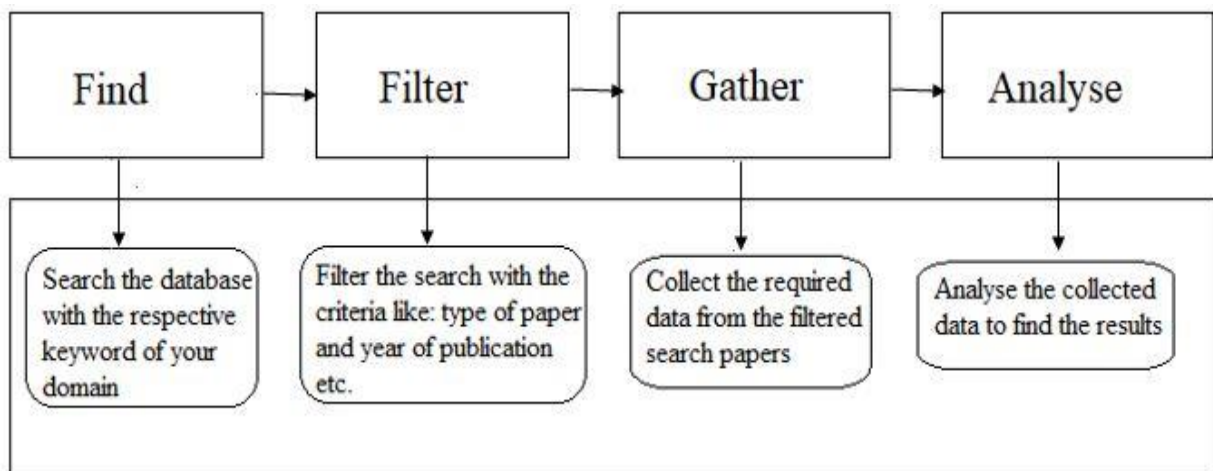


Figure 6 Methodology Based on Mixed Study Review (Grant & Booth, 2009).

- **Find:** In the initial step database are searched with the important and relevant keywords of the research and it will be getting may be a large or very less result based on the keywords.
- **Filter:** In this second step the search result is further refined based on the criteria such as: type of the research paper, year of publication, number of citation and relevance to the topic of the research.

- **Gather:** In this step the filtered data is collected and studied. Then a tabular form of data is extracted out of the data that was collected.
- **Analyse:** The tabular form is further analysed, and a result is produced in this final step.

4.3 Discussion of methodology

The main objective of this research is to produce the knowledge about the topic by studying the available material and existing research findings. This approach is most suitable for answering the research questions as it provides the interlinkage of various issues described by various researchers (Grant & Booth, 2009).

The literature review was started by conducting a broad search for the research papers on the subject published within 15 to 20 years as in between this time the AR technology was emerging. Also, many researches were taken place on this technology during that time period. The keywords that are used are augmented reality, and augmented reality in the health field in Google scholar database initially. Later, the search was expanded to various research databases with the help of the Flinders library website, including IEEE, Science Direct, and Emerald Fulltext. The following keywords were used: applications of augmented reality, application of augmented reality in education, application of augmented reality in health, and application of augmented reality in gaming. In the beginning of the research, definitions and background of the AR system was revealed along with its history of evolution. Then the research was carried forward to various other aspects of AR, such as types of AR, and differences between AR and VR that are essential to understand, as most people are unable to differentiate AR and VR technology. Further, the research used keywords such as general working of AR and AR in the health field. Upon gaining a full understanding of the working of AR, the research focused on identifying the problems of the system along with the security and privacy concerns. After thorough searching the literature, a number of important issues and concerns were found that needed investigation.

4.4 Data collection: Existing data

The topic AR was chosen due to its rapid growth in the health field and a search of the literature found that there were many researches describing the issues and the problems of the system. These factors led this research in order to explore all the impact of the problems and issues of the system in the health field. In the literature review, a total of 72 research papers were identified that were relevant to the study, with 36 research papers discussing AR and its application; three research papers discussing the working of AR generally; nine research papers

discussing the working of AR in the health field; 12 research papers discussing the security issues, privacy concerns and general problems of the AR system; one research paper discussing the available solution scenario and 11 papers discussing standards. Research papers were classified as per their relevancy to the topic and their popularity among other researchers in terms of frequency of citations. Criteria for choosing a paper is based on the type of publication, year of the publication, relevancy of the topic and the link that publication creates with the previous topic. Also, there were many papers stating similar things, however, the minor differences of such papers were taken into consideration to fill the gaps to make the review complete.

Further, 9 problem factors and 20 risks of AR were identified based on the literature search to include in the review, based on the likelihood of these risks occurring in real life. While researching this topic, it was found that these issues and risks are not associated with just one health field but are applicable in other fields as well. There was one common potential consequence that could be seen in almost every risk, which was loss of a patient's life. As this technology is used in the health field and caring for the patient, the major impact of risk is to the patient. However, failure of AR could impact the reputation of the hospital and doctors as well. There are also risks of breaching laws with the use of the AR system in the health field. A significant outcome of the study was that two models were developed in order to explain the threat factors and the security factors of the AR in the health field. Also, security policy was developed in order to maintain the security aspects in the health field. Therefore, the results are produced with the standards and policy, so that the impact can be overcome by following the proper standards and regulations.

5 Framework

5.1 Framework-Threat Model

Figure 7 describes the components involved in the process of using AR along with the threat factors that explains how these components are a threat or under a threat. Data (sending and receiving), system (hardware, software), and Manpower referred here to healthcare professionals (people who all are involved) are communicating through the network channel. So, the network channel is the most important component of the technology. Further, few threat factors have explained that act as prize such as:

1. Reputation loss: There might be someone out in the public that is unhappy with the hospital or with the doctor and want to damage the reputation of either of them. So, this factor may pose a threat.
2. Ransomware: There are professional hackers that attack any loopholes in the network to target large organisations to ask ransom payments.
3. Personal revenge: This factor is common and is very important to consider as there may be conflict between people which can create enemies. The enemies can be their so-called friend or their staff member that can be never known until they do something harmful to them. Therefore, personal revenge can be taken by any of the friend, staff member or anyone from the family to degrade the position by manipulating anything in the technology.

These factors can lead to the worst case that is loss of a patient's life as the technology here plays a vital role in successfully treating the person.

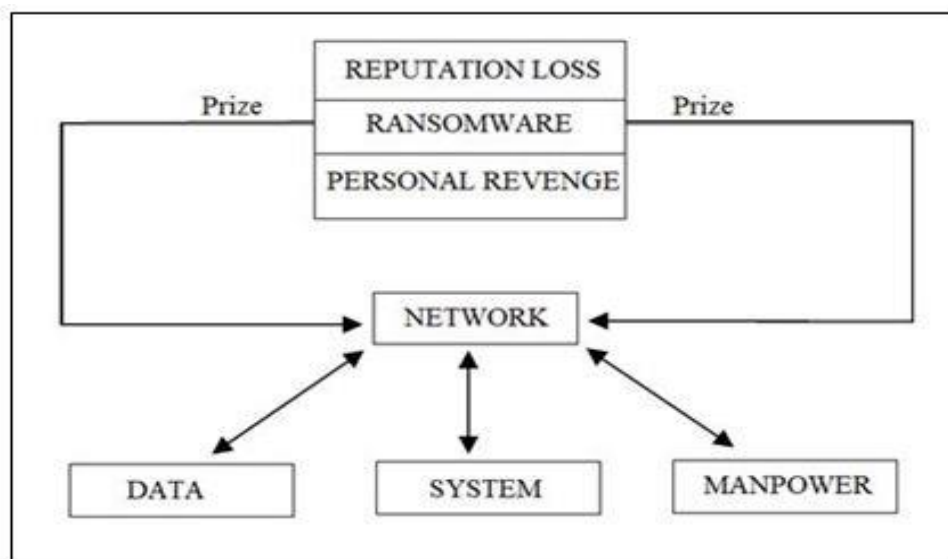


Figure 7 - Threat Model

5.2 Framework-Security Model

Figure 8 illustrates the complete successful process of working AR between the hospital (performing doctor) and the guiding doctor (remote location). There is a software program that acts as a bridge between the performing doctor and the guiding doctor for performing the medical treatment using AR. Below are some steps that will make the process secured and uninterrupted:

1. Guiding doctor plays a crucial role here as most of the treatment is dependent on their experience and guidance. Therefore, the doctor's active participation and full dedication is very important for the treatment to become successful. So, for testing their state of mind there should be a preparatory level quiz that helps in assuring compliant participation. Also, there should be a limit that applies for the number of surgeries or treatments that are performed from the remote location, so that they can give their best and there should be no consequences on to the process because of their day schedule.
2. Software has two aspects, video and audio, that are important and should have 1:1 which means that exactly what is being sent should be received. However, the new technology of live transcript should also be added into these aspects so that if there is a miscommunication, then either doctor can read the transcript and overcome the situation.
3. Although there are software teams of the provider that are taking care for their software for its successful running, there should also be a software control unit introduced in the hospital for managing and monitoring the process until it is completed.
4. Further, there can be a situation of conflict between the doctors on some point during the treatment, so in that case final authority should be determined so that the situation of disagreement can be overcome.
5. As AR depends on various other technologies and resources, even after taking all the measures to minimise risk, there is still a chance of failure due to unanticipated reasons. Therefore, there should be an alternate communication channel available during the process of treatment of the patient. The alternate communication channel can be telephone communication or mobile communication.

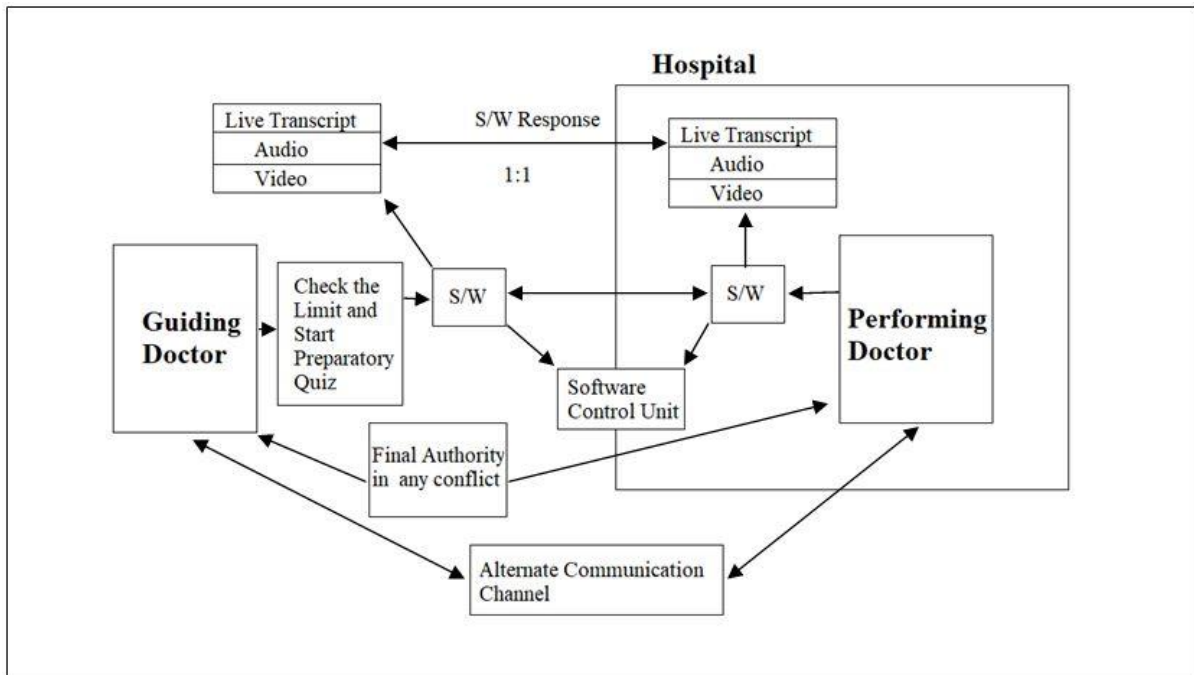


Figure 8 - Security Model

5.3 Security policy for augmented reality in health care

Security policy has been discussed below based on (My Health Record, 2016):

Policy checklist

- Data system security policy- Publishing, distributing and updating the Organisation policy
- Accessibility policy- Access rights of performing doctor, guiding doctor, patient and staff
- Credentials check policy- Identification of staff for accessing the software
- Training of staff policy- Training should be provided to staff
- Breach handling and complaint policy- This policy should handle data breaches and ensure security of the organisation. It should also handle various complaints and provide a solution for complaints
- Risk assessment policy- Organisation should investigate the possible problems and provide solutions to them.

5.3.1 Data System security Policy

- Organisation should have the data system security policy
- Policy should be discussed with all the staff members
- Policy should be applicable to all the staff member
- Policy should be regularly reviewed after a year at least

- Proper date should be specified if any amendment is made to the policy
- Organisation should provide a copy of the policy to the concerned higher authority.

The policy should cover:

- Organisation's process for storing and accessing live data
- Organisation's process for accessibility to the software
- Organisation's process for maintaining and checking software and hardware of the system
- Organisation's process for maintaining networks and connectivity
- Organisation's process for providing training to the staff for accessing and operating the software
- Organisation's strategy for mitigation in case of any security issue
- Organisation's process for obtaining the license of the software and process for renewing the license.

5.3.2 Accessibility policy

- Organisation should have an updated log that contain login details and details of authorised users
- The users access rights should be limited based on their tasks that are set to a limit by their authority
- Each user must be provided with unique user account and login details
- The system should contain captcha and specific images for login in new devices
- User accounts should be deactivated immediately once the user left the organisation
- There should be an access request required if accessing any files that are not in the access right.

5.3.3 Credentials check policy

- Identification of the staff
- Unique identification number should be provided by the organisation for each staff member
- Organisation should also provide secure login credentials
- Organisation should also have biometric login for access to systems
- One Time Password should be made compulsory to access high priority files.

5.3.4 Training of staff policy

- Staff should complete training provided by the organisation before using the software and taking consent from the patient
- Access control should be provided by the organisation as per credentials check policy
- Training should be provided with respect to mitigating and managing breaches and obligations of the organisation
- Accurate response should be generated by the system while training is in process
- Scenario simulation should be used to provide effective training for the staff by the organisation
- Training should be provided on a regular basis whenever some change or update is applied to the software
- Log of training details should be recorded by the organisation
- Training videos and system usage videos should be available to access all time for the staff
- At the end of training the staff should be given a quiz exam to ensure the training was successful
- Organisation should collect the feedback from the users and try to make changes as per the staff convenience.

5.3.5 Breach handling and compliant policy

- Organisation should contain a reporting procedure for reporting security and privacy issues of the system
- Incident register should be used by the organisation for storing the records of suspected breaches along with the date and time of the incident
- Incident register should also contain the staff details of all activities related to the incident
- Organisation should have and adhere accessibility limitation
- Organisation should identify the team responsible for solving issues or problems and monitor the software response. The team should also be responsible for maintaining secure software communication
- Organisation should investigate all the incidents occurred and proper action should be taken in a timely manner.

5.3.6 Risk assessment policy

- Organisation should undertake privacy and security risk assessments of staff and the assets at least annually
- All risk assessments and outcomes should be documented appropriately
- Organisation should provide the solution, or the mitigation required in the risk assessment as soon as possible based on the priority ratings
- All actions required to respond to an incident must be managed and documented to completion.

The application of the security policy to health care as per risks associated will be discussed further in the result section.

6 Results

6.1 Risk analysis

The Table 2 shows the risk analysis along with the consequences and the priority ratings:

Risk		Vulnerabilities	Consequences	Priority Rating
F6, F7	Data Loss	Storage issue	Private information can be publicised.	2
		Data transferring issue		
		Misplace of patient's data		
F5	No or uncertain guidance	Doctor unable to guide properly	Failure of end results	14
		Doctor guided wrong way	Loss of patient's life	
		Doctor may be busy		
		Doctor may be tired		
		Lack of interest		
		Doctor may be unwell		
F2	Losing the network	Network server failure	Halt in between the surgery/ operation.	11
		Internet failure		
F2	System Lag	Low bandwidth	Latency while operating	3
		System is slow	Waiting period may cause infection or other serious illness to the patient	
		Multiple applications running		
F3, F4	Malicious actions	Virus attacks	The connection may be interrupted, and the outcome will be impacted.	5
		Trojan		
		Spam		
		Denial of service		
F2	Natural hazards	Floods	Lead to system failure	20
		Earthquakes	Loss of patient's life	
		Tsunami		
F2	Other hazards	Fire accident	Lead to system failure	19
		Electrical short circuit	Loss of patient's life	
		Water leakage		
F2	Hardware failure	System failure	Unable to use all the system features	7
		Marker failure	Unable to use the overall system	
		Sensor failure	Loss of patient's life	
		Display failure		
		Server failure		

Table 2 continued...

Risk		Vulnerabilities	Consequences	Priority Rating
F2	Software failure	Application failure	Unable to use all the applications features	8
		Integration issue	Unable to use the application properly	
			Loss of patient's life	
F2	Connectivity failure	System failure	Unable to connect to the host or client end	6
		Rigorous result changes	Loss of patient's life.	
F2	Viruses	Opening of multiple screen	Component failure	12
		No proper audio	Loss of patient's life	
		Suddenly application shutdown		
		Black screen may appear		
F6	Unauthorised Access	Information replacement	Loss of doctor's reputation	4
		Information copy	Ransomware	
		Information hide	Loss of patient's life	
F2	Audio failure	Too much background noise	Failure of end results	10
		Multiple voice coming at same time	Loss of patient's life	
		Resound		
		Low voice input or output		
F2	Display failure	Screen may turn off	Failure of end results	9
		Screen may appear black	Loss of patient's life	
		Opening of multiple screen		
		Distorted view		
F8, F5	Unable to follow instructions	Lack of practise	Failure of end results	15
		Nervousness	Loss of patient's life	
		Miss-communication		
		Unable to understand high level language		
F8, F5	Repeat of instruction	Nervousness	Failure of end results	16
		Miss-communication	Loss of patient's life	
		Unable to understand high level language		
		System issues		

Table 2 continued...

Risk		Vulnerabilities	Consequences	Priority Rating
F1	Unauthorised advertising	Opening of other application	Unable to use all the applications features	13
		Redirecting to another directories	Unable to use the application properly	
		Making system slow	Loss of patient's life	
		Diverging the doctor's concentration	The connection may be interrupted, and the outcome will be impacted.	
F8	Lack of proper details	Unaware about the patient's issue	Failure of end results	17
		Only little knowledge about the patient's issue	Loss of patient's life	
		Miss-understanding of the problem		
F8, F5	Conflict issue	Guiding doctor and performing doctor may have different opinion	Failure of end results	18
			Loss of patient's life	
F9	Patient consent	Patient not confident about the AR technology	Operation abort	1

Table 2 - Risk Analysis

6.2 Summary of the risk analysis as per the high priority rating

The Table 3 illustrate the summary of the risk analysis as per the high priority rating:

Priority Rating	Risk
1	Patient consent
2	Data Loss
3	System lag
4	Unauthorised Access
5	Malicious actions
6	Connectivity failure
7	Hardware failure
8	Software failure
9	Display failure
10	Audio failure
11	Losing the network
12	Viruses

Table 3 - Summary of the Risk Analysis as per the High Priority Rating

6.3 Risk mitigation using standards and policy

Table 4 showing the results for the risk analysis through standards and policy:

Priority Rating	Risk	Standard	Policy
1	Patient consent	Informed Consent- Medical Board of Australia (Medical Board of Australia, 2014)	Training of staff policy
2	Data Loss	P2048.3 - Standard for Virtual Reality and Augmented Reality: Immersive Video File and Stream Formats (IEEE Standard Association, 2019)	Data system security policy
3	System lag	P2048.5 - Standard for Virtual Reality and Augmented Reality: Environment Safety (IEEE Standard Association, 2019)	
4	Unauthorized Access	P2048.5 - Standard for Virtual Reality and Augmented Reality: Environment Safety (IEEE Standard Association, 2019)	Accessibility policy and Credentials check policy
		HIPPA ACT (HHS, 1996)	
5	Malicious actions	NIST.SP.800-83r1 (NIST, 2013).	Breach handling and compliant policy
12	Viruses		
6	Connectivity failure	AS IEC 60812-2008 -Analysis techniques for system reliability (Procedure for failure mode and effects analysis (FMEA)) (AS IEC, 2008)	Data system security policy
7	Hardware failure		
8	Software failure	AS ISO/IEC 25022:2019 -Systems and software engineering (Systems and software quality requirements and evaluation (SQUARE) - Measurement of quality in use) (AS ISO/IEC, 2016)	
9	Audio failure		
10	Display failure		
11	Losing the network		

Table 4 - Risk Mitigation Using Standards and policy

6.4 How will the solution be sustainable in the long term?

The proposed solution in this paper will be a sustainable solution as there are standards in the solutions. Standards are reviewed after a period and, if necessary, there are amendments done to the standards periodically. Therefore, this solution becomes a sustainable solution as it will

be automatically updated after the standard is amended. Moreover, these standards are very easy to choose. However, they need resources in the health field for the successful implementation and maintenance of the solution. Further, medical professionals, policy or law makers, and the technology should work together to fill any gap if required. Working of these professionals in cooperation and collaboration will provide positive ways to achieve the solution and make this solution sustainable over the longer term.

7 Discussion

In this report, after understanding the system and its working, there were many factors identified that may impact the use of AR technology in health. Therefore, after further studying those factors, several risks were identified that may arise in hospitals and surgeries. Thereafter, vulnerability of the risks was identified based on the nature of the risk. On further researching, the potential consequences were listed for those risks and vulnerabilities, and the risks and consequences were then prioritised. There were limited criteria available for establishing the priority rating. As the risks were associated with the health field and patient welfare, the value or cost criteria did not fit, as human life is precious and cannot be quantified in monetary terms. Therefore, the priority rating was based on the likelihood of risk events happening that would create consequences for the patient.

Although, the risk vulnerability analysis was finished after the priority rating, mitigating those risks was as important as identifying them. Therefore, the top 12 risks were chosen based on the priority rating. Then, mitigation was provided with the help of available standards. Though all the standards available are not necessarily applicable in the health field, the standards are able to provide assurance in mitigating those types of risks in other fields and were assessed as suitable in the healthcare field.

While performing the risk analysis, two models were also identified that could play a vital role in understanding the risks and providing solutions to them. The threat model reveals the components involved in the AR process and provides the reason why they can be exposed to threat during the process. The security model reveals the complete system of the process, including the security aspects that are required to be applied in order to make the treatment secure and successful. Further, security policy was introduced that will help in addressing and maintaining the security and privacy aspects. Security policy discussed the key areas such as data, system, accessibility, credentials, training of staff, breach handling and complaint along with the risk assessment. These key areas further provided with the steps that will cover the security and privacy aspects in order to safeguard the security and privacy concerns. The security policy will go hand in hand along with the standards as standards provide the correct pathway, however policy will describe how to follow that pathway.

8 Future work

There are many opportunities available for future work in this area of research, such as how the models helped in the field of health, comparisons with the use of AR before and after implementation of the models, and surveys of how well the model is working in the health field.

9 Conclusion

Security issues are a matter of concern in every field. Therefore, safeguards to protect the security, safety, and the privacy of patients and the medical staff in hospitals are of paramount importance. In particular, where there is risk to a patient's life, every effort needs to be made to secure a safe outcome. The development and application of advanced AR technologies in healthcare has already shown many benefits and will continue to revolutionise the methods used by doctors to care for their patients. There are some significant risks associated with AR that need to be mitigated with careful planning, training, and application of internationally recognised standards of management, security, and patient care.

This study has identified and ranked potential risks relating to the AR technologies, and has argued that these threats and their consequences are entirely avoidable if steps are taken to accommodate AR, while still assuring safety and privacy. Providing solutions to these risks in hospitals where AR is used involves the integration of safety and security operating standards, digital cybersecurity to protect networks and prevent breaches, and an active training strategy for medical personnel.

Therefore, the study has proposed models and a framework of practical approaches in health to achieve a safe and successful result for patients. These approaches can assist health professionals and enable the revolutionary benefits of AR technology to be increasingly adopted by surgeons to improve the treatment of their patients.

This research was based on the existing data. However, if the live data were to be integrated in this research then the results could be more accurate, and the sustainability of the solution would be tested more rigorously.

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