UNIVERSIDAD FRANCISCO DE VITORIA

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Fundamentals of Computer Engineering

Practical work I:

New technology used in surgery

GROUP 4A

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SUMMARY

We have decided to research about the applications of new technologies, such as robots, Artificial Intelligence, Virtual Reality or Augmented Reality, in surgery, one of the most critical fields of medicine.

We have decided to divide the topics we are going to go through in five different sections.

First of all, we are going to make a brief introduction of the topics we have researched about. We are also going to put into context the actual situation of technologies and surgery and our goals on this analysis.

Secondly, we are going deep into the history of surgery; how it started, how it is right now and all the changes it has experienced throughout history. We are also going to introduce how medicine takes advantage of new technologies inside surgery rooms.

We are going to continue by explaining the advancements and the new techniques that have been developed in the surgery field and we will analyse their strengths, weaknesses, opportunities and threats.

The next topic would be an inspection of the advantages and disadvantages that working with technology brings with it. We will ask ourselves the question, is the implementation of new technologies worth it? Or does it cause more damage than it repairs?

And to end up with, we are going to put together all the information we have retrieved from all the research and the analysis made; and we will talk about our experiences while developing this project and about what we have learned, what we can improve…

INDEX

1) INTRODUCTION

Long time ago, medicine was a difficult and critical area where only unique people could operate; doctors had an enormous pressure and a huge responsibility of making the operation success. Luckily these days this pressure is anything compared to what it was some decades ago, thanks to the implementation of new technologies in medicine. Machines have better precision than humans do and they also have a huge variety of valuable techniques that improve the surgeries.

This is reflected, for example, in a medical investigation that was carried out in the United States in 2020 where 3% of surgical procedures were fully performed by robots, and another 15% of operations involved robots for assistance and support. If we keep walking alongside this path, this tells us that in some years we are going to fully depend on how technology develops and that we will determine the way we work in accordance with new discoveries. As a result, in the near future, when a new technological advance is developed, people will learn and will develop different skills to approach their objectives at work, keeping them more productive and increasing their efficiency.

Humans have revolutionised the world of surgery little by little, step by step, by implementing new techniques and discovering new knowledge that a long time ago would have been impossible to even imagine.

In this paper, we are looking forward to delving into the advantages, disadvantages, opportunities, and threats that technology has given us in our daily life, and more precisely, in the area of medicine.

2) SURGICAL TECHNOLOGY AND MEDICINE

2.1) THE HISTORY OF SURGERY

Since its inception, operations have been frowned upon by people due to the lack of pain relief such as anesthesia or antiseptics, making surgery an authentic horror. The pain suffered by the patient was unbearable and bad practices before surgery, such as hygienic habits, meant that most diseases could infect or cause death to the patient. These events were caused by microorganisms such as bacteria, since at that time hygiene habits were unknown, which are normal today. The doctors dressed in dirty black gowns, full of pus or blood and over these, they wore a coat that protected them from being stained by various fluids from the patients. The instruments used were diverse, but they were not cleaned and the patient was held by strong men or tied to a table during the operation. In the absence of remedies to relieve pain, surgeons used opium, liquor or mesmerism to hypnotize the mind of the East and in some cases used tourniquets or ice to numb the areas that were operating in. The patient was responsible for physically and mentally managing the pain.

There came a time when the insensitivity and neglect of surgeons in the search for a solution to avoid pain during interventions made authors such as Dr. John Warren, from Massachusetts General Hospital, protest about this in his book "Etherization With Surgical Remarks" and immediately asked for a remedy.

In the mid-nineteenth century, the speed of the operating room was valued, an amputation could be completed in less than 3 minutes, therefore, the patient suffered less for less time, but precision was sacrificed. Still, many people preferred to die rather than go through the surgeon.

However, the surgery dates back thousands of years:

ANCIENT SURGERY: dental and surgical procedures date back to the Neolithic and Preclassic. The first evidence of a surgical procedure was the trepanation of a human skull in 3000 aC. They continued to be used in the Middle Ages or the Renaissance in parts of Europe, Africa and South America with the supposed purpose of removing the spirits of the body and with this heal them. Unfortunately, only very few survived

this procedure. They also had religious meanings or were part of rituals, such as the Egyptians to treat migraines or enjoy health. The ancient Greeks performed surgical procedures such as setting broken bones, bloodletting, draining lungs, etc. Hippocrates' theory of the four humors influenced medicine for hundreds of years (black bile, yellow bile, phlegm, and blood that matched the elements of earth, fire, water, and air, respectively) exist in the body. Romans like Galen, surgeon to Roman gladiators and to the emperor, gained hands-on surgical experience and continued trepanation, amputations, and eye surgery. In the year 900 AD. C. , a famous Islamic surgeon named Al-Zahrawi wrote books focusing on orthopedics, military surgery of ear, nose, and throat surgery, influencing other Islamic and Western physicians.

THE MIDDLE AGES AND RENAISSANCE: surgeons, to a greater extent barber-surgeons, from the Middle Ages to the 17th century, carried out trips and minor procedures such as tooth extraction, treatment of war wounds or bloodletting. Unlike doctors who studied at universities, surgeons learn by observing and learning. Surgery was still dangerous due to the lack of antiseptics and anesthetics, so it was practiced in a minority, although some women performed surgical operations until 1700, when surgery was threatened by university education.

Andreas Vesalius, one of the founding fathers of modern surgery, a surgeon in the French army and a professor in Padua in the 16th century, completely revolutionised the way human anatomy was understood, since previously much of anatomical knowledge was based on in animal dissection, but he suggested the practice of dissection on human cadavers to physicians and surgeons. Andreas carried out a study in which he corrected two sustained ideas of Roman and Greek concepts based on the dissection of animals and in 1543 he wrote the most complete anatomy text for the time entitled "De Humani Corporis Fabrica Libri Septem" which was based on 200 years of anatomical study.

In the 16th century, he greatly influenced surgery, developing a soothing compound of egg yolk, rose oil and turpentine for bullet wounds instead of burning them with boiling oil, and revives the practice of tying off blood vessels during the amputation of bleeding effectively. Although Pare accomplished feats in the medical field, his motto was “I treated him. God cured him”, which conveyed the view that doctors couldn't do much.

MODERN SURGERY: the expansion in the Anatomy branch, the surgeons became empowered, but many procedures remained out of their reach such as complex internal operations or prolonged operations. With the adoption of asepsis at the end of the 19th century, patients no longer had to fear pain, but the threat of infection

was still present, so in 1865 Joseph Lister, who thought that microorganisms could cause disease, He developed his method called "listerism" and recommended "antisepsis" or elimination of bacteria in the air, instruments and patient wounds. This process consists of using carbolic acid as a sterilizing agent and was rejected by many doctors as it was a very complicated process. In the 20th century, asepsis gained prominence giving rise to various methods to disinfect and make the environment sterile such as boiling, they began to use white coats, clean sheets on beds and operating tables. Thanks to this, a great advance was achieved in internal surgery and success in surgical procedures that we see today.

2.2) THE MEETING POINT: MEDICINE USES TECHNOLOGY TO OPERATE

Some experts have affirmed that the first half of the 21st century is gonna be defined by what they have called “The Fourth Industrial Revolution”. The fusion of digital, physical and biological technologies, that will lead to a complete automatization of almost every process, has acquired its maximum potential when talking about the surgical health care field, that has adopted the name of “surgery 4.0”. The objectives of this revolution focus on two important problems that surgery has been dealing with since 150 years ago: cancer treatment and the reduction of the harmness resulting from the medical interventions themselves.

The use and adoption of new technologies is a process that has brought great benefits. Technological developments in surgery rooms have resulted in the installation of more advanced tools that facilitate surgeons’ labour and have improved patients’ treatments.

Modern operation rooms are nowadays equipped with the sufficient technology to diagnose and intervene on a patient at the same time, what makes the process less invasive and allows patients to have a faster recovery and to leave the hospital sooner than they would have some years ago.

The technologies that are already taking part in surgeries are:

- High-Definition images and magnetic resonances are nowadays present in surgery rooms. 4K images and 3D technologies allow surgeons to see the inside of a patient’s body and to proceed with a higher precision, thanks to the higher visibility of the patient’s anatomy. This improves the surgery’s efficiency and increases the percentage of success during medical interventions, what results in a reduction of the process’ duration.

- Virtual Reality and Augmented Reality have revolutionised the way in which new surgeons and doctors are taught. The simulations that new technologies have brought, make learning safer and allow medicine students to practise at no risk situations.

- Artificial Intelligence can help to define the diagnosis in real time while the patient is still on the operation table, so as to guide the necessary interventions and the following treatment and recovery process.

- High-precision robotic technology exponentially increases the accuracy in critical surgeries. These systems amplify an image up to 15 times and verify the precision of the surgeons movements approximately 1500 times every second. Robotic developments are key in laser operations and have become essential assistants in neurosurgery interventions.

- Pacemakers and artificial cardiac stimulation systems are a very common example of the presence, and the importance, of technology in medicine. However, these devices have not been the latest discovery; in 1958, the first pacemaker was successfully installed.

- Hospitals and healthcare centres are implementing virtual care softwares in order to prevent post-surgery complications. These systems have devices such as cameras, microphones, thermometers and pulsometers, that analyse patients' status and send information to doctors and nurses. In this way, people recovering from a high-risk surgery can go home earlier, something that during the pandemic was key to increase hospitals' availability.

- Cancer and technology go hand-in-hand. New technological developments not only help during tumour identification and localization, but also, thanks to radio directed surgery, the extraction of tumours has become more precise and incredibly less risky.

- Prosthetic and robotic limbs have dramatically changed thousands of lives. These new developments have enabled people who could only dream of having what we call a "normal life", to carry out everything by themselves, and to stop depending on a 24-hours attention.

However, not everything has been enhanced nor invented yet. In some years, technologies will be able to prevent illnesses and to modify determined genetic traits, in order to delete hereditary diseases. And even sooner, elements such as titanium plates and screws will be replaced by other less harmful materials for our bodies.

3) TYPES OF ADVANCEMENTS AND NEW TECHNIQUES

There are thousands of technological advancements that have influenced surgery in some way; starting with technologies like Virtual Reality (VR) or Augmented Reality (AR), through surgical robotics and 3D printing (bioprinting), all the way to some others that have not been developed yet. Each different technology mentioned above will be described and analysed by the use of a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats).

Firstly, let's start with the use of Virtual Reality (VR).

Virtual Reality, also known as VR, is the creation of a simulated environment through the use of computer technology. Virtual reality combines both software and hardware to create the simulated environment mentioned above. VR, in some way, makes the user believe that he actually is inside that artificial world. The piece of hardware that is most commonly seen is the VR headset. It is a head-mounted device (HMD) similar to goggles. If the VR headset is taken apart, it is just a screen or a display that shows the user what it is supposed to play. It also includes head motion tracking, which means that if the user turns his head right, what the screen is showing will move right and display whatever is on the right. Some of these headsets also include speakers to increase the user's immersion.

Now let's take a look at the SWOT analysis.

<u>Strengths:</u>

- Virtual Reality can take teaching and learning to a whole new level. You may ask, how could this be possible? Well, instead of restricting students to peek over the surgeon to look at what he is doing and just learn from that, with the use of VR, surgeons can stream operations while the students don't interfere and apprentices can operate in simulated situations, in order to learn the different techniques.

Weaknesses:

- A weakness of the use of VR is that students are not truly engaged in the real world. What we want to transmit by that is that at the end, the students are just watching a screen to see what the surgeon is doing or that due to the non-existent risk, maybe they do not pay the necessary attention to the intervention in which they are participating.
- Another downside to the use of Virtual Reality is the small delay that there is between the transmitter and the receiver. This may have an effect on the time precision that the students will be required to have while actually performing a surgery..

Opportunities:

- The future that Virtual Reality can have in surgery is that the surgeon can virtually explore the patient's anatomy before the operation takes place. This leads to a better precision and a better knowledge of the patient's anatomy.

Threats:

- One possible future threat may be the side effects of using VR. This may include sight problems and a detriment of surgeons' attention in the long term.

Now we are moving onto Augmented Reality (AR).

Augmented Reality is somewhat like Virtual Reality. Virtual Reality creates a fully artificial environment, but unlike that, Augmented Reality uses a real-world environment. Summarising that idea, AR is the real-world surroundings with artificially generated information on top of that authentic environment.

Augmented Reality has different functionalities. One of them can be to visually change environments, or another use can be to provide additional information to users (Gillis), but we are just going to focus on how it can impact the world of surgery.

Strengths:

- Augmented Reality users do not lose touch while using this technology.
- AR healthcare apps can help save lives and treat patients seamlessly, thanks to the extra information that these devices give us.

Weaknesses:

- AR devices and softwares are still very expensive and have a limited field of view, what restricts them to rich businesses and hospitals.
- There are some security concerns when Augmented Reality data is manipulated, what can influence decision-making.

Opportunities:

- The strength of not losing the sense of touch with Augmented Reality is really effective to help surgeons become more efficient at surgeries.

Threats:

- While wearing the AR headset, the user can experience stress due to information overload. This in a way defeats the main purpose of making quick decisions using real-time information and can make surgeons less effective.

Let's now take a look at surgical robots.

Surgical robots are the most common surgical systems. Most of the time they include a mechanical arm that has a camera attached to it, and another robotic arm with several surgical instruments embedded. The human surgeon controls the arm from a computer near the table where the operation is going on. On the screen, the surgeon in control of the mechanical arms, has a high-definition view of the surgery that is taking place. Normally, the surgeon in control also has a 3D view of the operation so as to increase the amount of data he receives (seeing and hearing) and in order to make better decisions.

Strengths:

- Thanks to the use of robotic arms, we have achieved better precision during surgeries as a result of the wider range of movements of the robotic arm, such as rotating the hand much more than a human hand is able to. It also uses smaller and thinner instruments that can only be handled by a robot, which increases precision. At all times, the surgeon on the computer is 100% in control of the robotic system and is responsible if anything happens.

Weaknesses:

- Robotic arms will never be able to act as human surgeons, what can lead to an incorrect behaviour during critical situations.
- Also, these complex and expensive machines need to be constantly revised, repaired and monitored in order to make sure they are always in a good state and working as they should .

Opportunities:

- This amazing technology has allowed surgery to reach a level of precision and accuracy that doctors have always dreamed about. This has resulted in a decrease of the harm that patients' bodies experience, thanks to smaller and thinner incisions that are faster to heal.

Threats:

- If these new devices start to have more and more protagonism in surgery, in some years from now, humans could become expendable in this area of medicine, as well as in others, causing the disappearance of hundreds of jobs all around the world.

And to end up, let's talk about 3D bioprinters.

Bioprinting is one of the most recent technologies used in the medical area. It has a similar use as a normal 3D printer, but the difference between them is that the first one is used to print alive organs or tissues starting with the injection or pump of cells that are housed on a non-damaged material and the other one creates inorganic materials and objects.

Some researchers from Penn State University not far ago, managed to repair bones and parts of skin during a model surgery in a rat. They did this through the use of bioprinting. "It took less than 5 minutes for the bioprinter to lay down the bone layer and soft tissue," the professor explained ("The Technological Future of Surgery - the Medical Futurist").

They are planning to continue the research and one day be able to move it to human application.

Strengths:

- This technology has allowed us to generate organs in an incredibly fast way, what has helped doctors to solve the problem of compatibility among patients when talking about organ transplants.

Weaknesses:

- This technology limits' have not been defined yet, so until an accurate legislation is created that controls its application, surgeons are really limited when using it.

- Transplants are a really complex field of medicine. They do not only imply finding a healthy organ to transplant to the unhealthy patient; but they also have to take into account the compatibility among patients, what 3D bioprinters aren't still capable of.

Opportunities:

- Thanks to 3D bioprinters, the advances in almost every field of medicine are going to exponentially increase. Its application is going to encompass from immunodeficiency illnesses treatments, through the creation of bionic limbs, to critical interventions resulting from different accidents.

- These devices can also be used in medical education as they can provide students and teachers an alternative to a human to work on. This can also be used to get a better understanding of the human anatomy as well as for the surgeon to increase their confidence when involved in operations.

Threats:

- Transplants usually entail the development of a new illness or pathology. For example, in DiGeorge syndrome, when the thymus transplant takes place, patients develop cardiopathy, that causes them to die.

4) ADVANTAGES AND DISADVANTAGES OF WORKING WITH TECHNOLOGY

Technology has become essential in lots of different aspects of our lives; but in fact, we know that everything around us has both good and bad things regardless of how much they do or do not help us.

In this section we are going to talk about the advantages and disadvantages of working with technology.

4.1) ADVANTAGES

Thanks to technology, our living standards have really gone up. Our needs are right now fulfilled in an easier, faster way, than they were some years ago. The applications of technology in our daily lives have completely changed everything that surrounds us.

To start with, from an employment point of view, new IT solutions make employees more efficient and productive. This happens because as they have more and better tools to solve problems and carry out their tasks, this reduces each assignment's duration and complexity, what has been proved to save us a 30% of our time while performing different functions. Furthermore, new technologies have completely revolutionised project development in businesses. Communication among team members and synchronously work has opened a new wide range of possibilities and instruments to make team collaboration much easier and effective.

We can also analyse technologies' advantages from a personal point of view. In the last century, we have developed super complex security systems with a clear purpose: protect us, the things we love, the people we love. This applies from individuals, through houses and offices, to computers. Cybersecurity is nowadays a growing area in technology and is making us feel safer, more comfortable and is even allowing us to sleep better.

We sometimes think that technological advances are just present in rich areas, such as big cities or big enterprises, but these can be found anywhere. Everything nowadays is influenced by technology and has been enhanced due to these

developments. The quantity of food produced has been multiplied thanks to advances in agriculture; we now have faster and more secure transports thanks to new technologies; and we even have completely changed education thanks to the new technological methodologies that have changed the way in which children learn.

To conclude this section and to highlight the area of medicine we have been studying throughout this document, surgery is the field in which robots and humans have been capable of "connecting" with each other and working cheek by jowl. This can be reflected on practices like telesurgery operations. These consist of the intervention of robots that are controlled by a surgeon that is responsible for using them to operate, such as the robot Da Vinci or the PUMA 560, the first surgery arms and pioneers of robotic surgery, that are capable of performing precise movements that a human cannot do during the operation. Also, a big difference and good advantage that working with robots has is that machines have no feelings and, consequently, no nerves nor panic attacks during critical situations.

4.2) DISADVANTAGES

But the use of technology is no bed of roses. New tools, apps, softwares and hardwares are actually really dangerous. Humans have no limits, they have proven it all throughout history, and we have become addicted to IT. We overuse our technological devices such as mobile phones, laptops… and we are not conscious of the dangers that this entails.

Technologies have completely ended up with our privacy and freedom. Our data and information is no longer of our property, as each time we enter a webpage we have to allow cookies, which collect our data and sell it to bigger companies that use the retrieved information to create personalised advertisements for each user.

We cannot forget that new technologies and process automatization have provoked the disappearance of hundreds of jobs. As robots carry out determined tasks way better than humans, they are substituting them, which is pretty bad news taking into account the current inflation and the increase in everything's prices.

Pollution has also been increased due to new technologies; but, how is this possible? Technology evolution has a side effect that directly affects the environment. Industrialization has boosted climate change, deforestation and the overconsumption of raw materials. Furthermore, the installation of determined technological devices in some areas has affected the present ecosystem and has harmed nature.

Bringing all of these back to the area we are studying, surgery, it is not only the initial purchase price of surgery robots what constitutes the problem, but their constant maintenance actually is. Any of the mentioned robots can cost approximately 2 million euros to maintain, which is a huge budget in order to ensure its correct functionality.

During surgery interventions it is known that you may need the haptic feedback of your hands to work with the patient, but in this case, robots make this type of task almost impossible. While working with this technology, surgeons are not capable of knowing what or when we are touching a delicate organ; or while making an incision, there is a differentiated tactile feedback when cutting different types of tissues like skin, muscles, etc. The good thing is that they are working on semi-haptic robots to make a more realistic haptic feedback!

5) CONCLUSION

5.1) GENERAL THOUGHTS

Researching about a topic we do not usually know much about, such as surgery, has resulted really interesting and has given us a wider view of how technology is present in every single part of our lives.

We feel that the work we've done is very complete, as we have gone deeper into the different technologies that are right now present in surgery, we have analysed their impact in this field of medicine and we have highlighted their strengths, weaknesses, opportunities and threats.

Taking into account the circumstances that we've been through, the results we have achieved are interesting and of good quality. Our group was made up of students belonging to three different degrees: computer engineering, computer engineering with mathematical engineering and computer engineering with business management, what made it really difficult to adjust our timetables to work together.

It is important to highlight the difficulties we had. Firstly, before the group was divided, only three of us worked on the mandatory tasks. After the group was splitted into two separate groups, we still wanted to do the practical work with the same depth as the other groups were required to. Another difficulty we had was that when we needed to meet up to discuss different stuff, both online and presentially, since we were from different degrees, our schedules were difficult to fit in.

We all agree that the three of us work pretty good together and we get things done as fast as possible, never forgetting the importance and depth they need to have. We also agree that the communication we had between us three was very good, which was clear evidence of the interest we had in the project and the attention we paid to it.

5.2) DO WE THINK IT WILL BE USEFUL?

In the future, as new technologies are constantly evolving and being implemented in surgery, their upsides will increase massively and a whole new world of research and development will be opened. This is a result of the fact that technology helps us humans to go deeper into the things we want to research and give us solutions to the problems we face.

On the other side, with more and new technologies to try on animal or human patients, more downsides can arise while these technologies are fully developed, tested and implemented.

During the project we have researched information and dealt with various points that we didn't know that would have such a huge importance and impact on our lives, such as for example the history of the first operations, from the first "surgeons" to the ones that exist today; how the technological sector revolutionises medicine every day without even noticing; or for example, the advantages or disadvantages that technology brings us when we make any use of it. All of this project has made us understand what the real essence of medicine and surgery operations is, allowing us to analyse different points of view.

Therefore, it can be concluded that the implementation of new technology is going to be really useful as long as it is used correctly. What we cannot forget is that technology is just meant to be a complementation to human work; and that the way in which we use it and the ethical behaviour we must adopt towards it, is our responsibility. As Dr. Bertalan Meskó said, “medical professionals using A.I. will replace the ones who don’t. The two will complement each other’s work in such a successful way that we have never seen nor dreamed about before.” (“The Technological Future of Surgery - the Medical Futurist”).

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GRUPO 4A

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