# Individual Project

## Healthcare AI- robot surgery/virtual nursing

Department: 資應所
Name: 鄭皓姿
Student ID: 111065515

# Outline

## Introduction

- **Robot surgery**
- **Virtual nursing**

## Technology

- **Robot surgery**
  - Robot platform for surgery
  - 3D interactive surgical visualization
- **Virtual nursing**
  - Monitors
  - Virtual healthcare platform

## Applications

- **Da Vinci surgical system**
- **Scorpion Shaped Endoscopic Robot**
- **BANYAN's Virtual Nursing Platform**
- **Industrial analysis**
- **SWOT analysis**

## Conclusion

## Reference

# 1.Introuction

## 1-1 Robot surgery

Robotic surgery, also called robot-assisted surgery, means a robotic platform that assists doctors to perform complex surgery. The region that robot surgery mostly uses is **minimally invasive surgery**, a kind of surgery which could be performed with less pain or wound. The robot surgery usually contains **(1) camera arm (2) mechanical arm**, in the period of surgery, the surgeon controls the mechanical arm to perform the surgery, and the camera arm provides a High-definition, magnified, 3D view image to the computer console. Below is the hardware component of robot surgery.

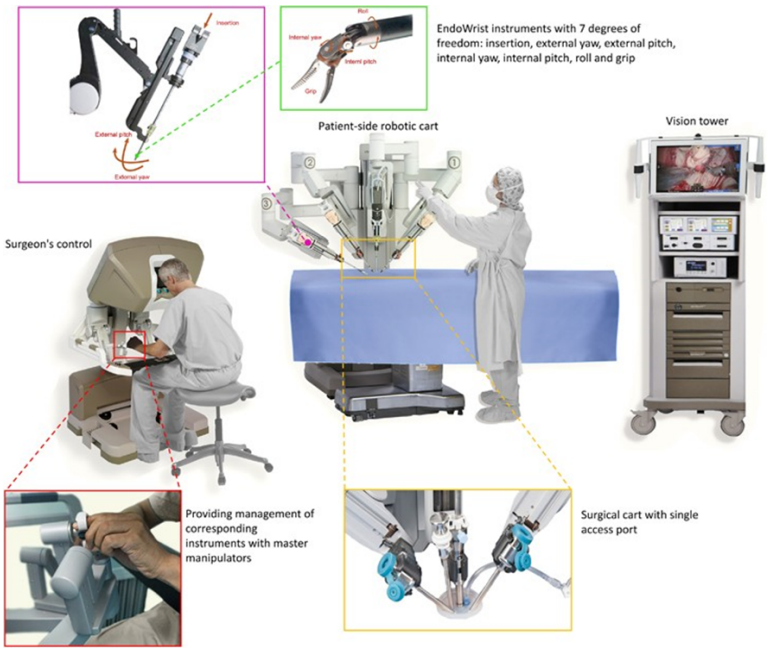



Figure 1-1 Robot surgery

In the figure of robot surgery, the surgeon operates the camera arm to get a 3D image of the patient, then, another surgeon performs the surgery by the mechanical arm. And the computer console provides the image that was detected by the camera arm.

## 1-2 Virtual nursing

Virtual nursing means clinics can offer phone-based service or other digital options to get medical service, simply, virtual nursing means healthcare from afar. Compared to traditional nursing, virtual nursing can monitor the changes of patients real-time, and it can drop the death rate efficiency.

| Outcome Metric | Team Goal | Baseline (Oct '16 – Feb '17) | Current Pilot Results (July '17 – Jan '18) |
|---|---|---|---|
| **Readmission Rate** | 10% decrease on average | 13.9% | Decreased by 37.4% (8.7%) |
| **Length of Stay** | 11% decrease on average | 3.41 | Decreased by 12.6% (2.98) |
| **Falls** | 35% decrease on average | 2.78 | Decreased by 75.18% (0.69) |
| **Call Light Response (seconds)** | | 1:23 | 0:51 |

Table 1-2 Result of using virtual nursing

The table above is the result of using virtual nursing. After using virtual nursing, the readmission rate fell to 8.7%, and the death rate decreased by 75.81%. Also, the length of patient stay in hospital has decreased by 12.6%. Even more, it takes only 51 seconds to respond to the call light from a patient.

# 2. Technology

## 2-1 Robot surgery

### a. Robotic platform for surgery

For different surgeries, surgeons can choose different robotic platforms to perform complex surgery. For example, for major surgery (involves opening the whole body), the surgeons may choose **Da Vinci single port** to perform the surgery, except for **Da Vinci single port**, the surgeons can also choose **Senhace**, **BITRACK** or **Revo-i** to complete the surgery. And for minor surgery, like endoscopic surgery, it is better for surgeons to choose **Flex robotic system**, **Scorpion shaped endoscopic robot** during the surgery.

**Table 1**

**Surgical modalities existent and specifications**

| Surgical modality name | Major use | Company | Console | Additional features |
|---|---|---|---|---|
| Moderate size | | | | |
| Versius | Tissue manipulation | CMR Surgical | Open-Joystick | Hepatic feedback |
| SPIDER-Surgibot | LESS | TransEnterix | Open-Fingerloop | Smaller incision (5 mm) |
| MiroSurge | MIS applications | DLR Institute of Robotics and Mechatronics | Sigma.7 | Hepatic feedback |
| STRAS-iCUBE | MIS applications | iCUBE | Open-Joystick | – |
| Small size | | | | |
| Invendoscopy E210 | Colonoscopy (advanced features) | Invendo Medical | Open-Joystick | Self-propulsion |
| NeoGuide Colonoscope | Colonoscopy | Intuitive Surgical | N/A | Less force application |
| Flex Robotic System | Oropharyngeal, hypopharyngeal, and laryngeal MIS | Medrobotics | Open-Joystick | – |
| Retraction Robot | NOTES | The BioRobotics Institute | N/A | Insertable surgical base |
| Scorpion Shaped | NOTES | Kyushu University | Joystick | Hepatic feedback |

Table 2-1 The specification of robotic platform for surgery

One of the important components of a robotic platform is the robotic arm, which is made up with an elbow, a waist and a shoulder. The overall system of the robotic platform consists of a robotic arm, a controller (with 100 kernel commands), and a pendant, which can tell the robot to learn about reachable

coordinates. In the rotation of the arm, the movement of the waist is two axises, which are called pitch and roll, and others only have one axis to move.

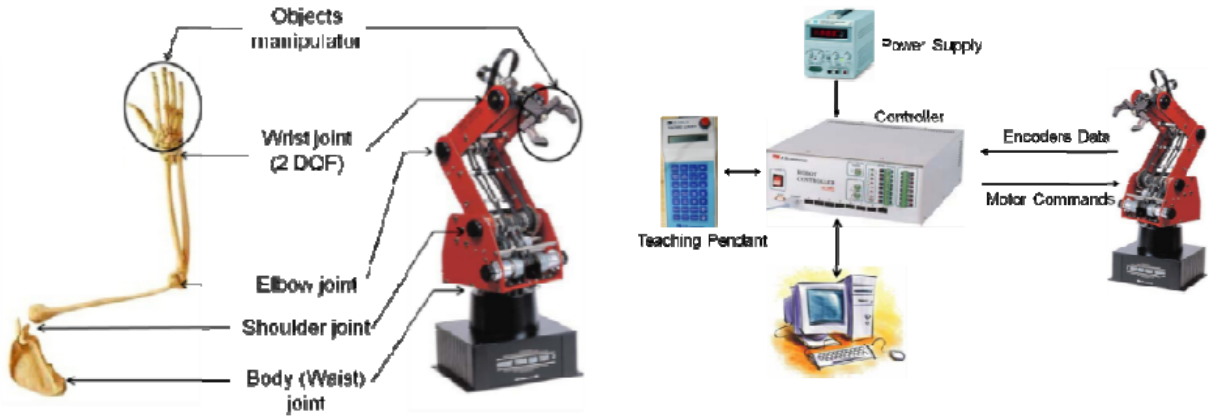



Figure 2-1 The overview of robotic system

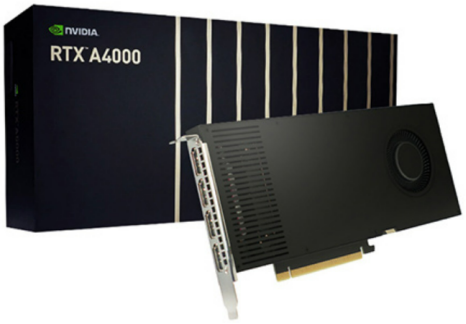
At figure 2-1, the left shows the component of the robotic arm, and the right shows the system of the robotic platform. In the right of figure, the power supplier provides the power to the controller, and the pendant teaches the arm how to move.


CHARACTERISTICS

| | |
|---|---|
| **Applications** | for endoscopes |
| **Technology** | digital, 3D |
| **Resolution level** | HD |
| **Other characteristics** | with video processor |

Figure 2-2 Endoscope camera head 3DHD

The figure above shows the endoscope camera used in robotic surgery platforms, the camera can deliver a 3D vision (which is mentioned in the next section), a natural depth image during minimally invasive surgery, and it is the basic feature of 3DHD vision system.




| GPU Features | NVIDIA RTX A4000 |
|---|---|
| GPU Memory | 16GB GDDR6 with error-correction code (ECC) |
| Display Ports | 4x DisplayPort 1.4 |
| Max Power Consumption | 140 W |
| Graphics Bus | PCI Express Gen 4 x 16 |
| Form Factor | 4.4" (H) x 9.5" (L) Single Slot |
| Thermal | Active |
| VR Ready | Yes |

Figure 2-3 NVIDIA RTX A4000 graph card

Figure 2-3 shows the graphic card embedded on the PC in the robotic surgery platform. In the console of the robotic surgery platform, it is necessary to equip a graphic card to enhance the resolution of the image. NVIDIA RTX A4000, based on the latest Ampere architecture, provides accelerated rendering, AI, graphics, and compute performance through an optimal combination of CUDA cores. Even more, the 16GB memory of the NVIDIA RTX A4000 supports ECC and PCIe Gen 4, which enhance the security of data.

**Features**

- Stylish and user friendly outlook for hospital environment
- Support Intel® Xeon® 8th/9th Gen Core™ i7/i5/i3 processor with intel Q370/ C246
- Rich expansion for multi-purpose application
- Support Window 10 LTSC/Linux/nVidia AI (Clara SDK)
- M.2 2280/2230 expansion slot
- HDMI and DP for multiple display used
- Support WISE-Device on
- Support Software RAID 0,1,5,10, TPM1.2/2.0 (Optional)

Figure 2-4 Advantech Medical Box PC USM-500

The Advantech Medical Box PC is the first NVIDIA-Certified medical-grade computer, The PC can support NVIDIA RTX -A6000 graphics card and NVIDIA's AI tools and frameworks like RAPIDS, Tensor RT and Triton Inference Server. In addition to the features above, Advantech Medical Box PC can also provide AI for hospital applications and healthcare environments.

In the operation of the robotic arm, they use the **Inverse Kinematic Model (IK model)** to compute the position and orientation of the joint angle. In the model, we can set $\theta_1$ for the waist, $\theta_2$ for the shoulder, $\theta_3$ for the elbow, $\theta_4$ for the tool pitch, and $\theta_5$ for the tool roll. In this model, we can compute each angle for the 3x3 matrix below.

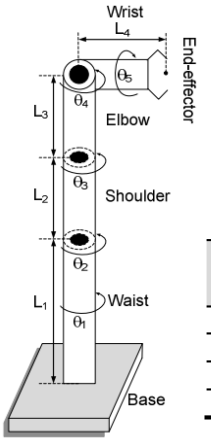
$$
{}^{0}_{6}T = \begin{bmatrix} C_1C_5S_{234} + S_1S_5 & -C_1S_{234}S_5 + S_1C_5 & C_1C_{234} & C_1A \\ -S_1C_5C_{234} - C_1S_5 & S_1C_{234}C_5 + C_1C_5 & S_1C_{234} & S_1A \\ C_{234}C_5 & -C_{234}S_5 & -S_{234} & B \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

Where

$$A = L_2S_2 + L_3S_{23} + L_4C_{234}$$

$$B = L_1 + L_2C_2 + L_3C_{23} - L_4S_{234}$$

The 3x3 matrix is a 6-DOF transform matrix; if we project the location and angle to the matrices, we can get the position and orientation after computing the polynomial.




| Symbol | Joints ($i$) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| $\alpha_{i-1}$ | 0 | -90° | 0 | 0 | -90° | 0 |
| $a_{i-1}$ | 0 | 0 | $L_2$ | $L_3$ | 0 | 0 |
| $d_i$ | $L_1$ | 0 | 0 | 0 | 0 | $L_4$ |
| $\theta_i$ | $\theta_1$ | $\theta_2$ - 90° | $\theta_3$ | $\theta_4$ | $\theta_5$ | 0 |

$$
{}^{Base}_{Tool}T = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

Figure 2-5 The symbol of each joint

Figure 2-5 shows the symbol of each joint, and the base of the 6-DOF matrix compared with the table above. After computing the polynomial, we can get the relationship between $\theta_1$ and its position, which can be expressed as $\boldsymbol{\theta_1 = Atan\ (p_x, p_y)}$.

## b. 3D interactive surgical visualization

After introducing the robotic surgery platform, the next core technique of robotic surgery is 3D interactive surgical visualization. The technique involves the 3D imaging problem of the optical endoscope in the operation. The flow chart of 3D interactive surgical visualization is below.

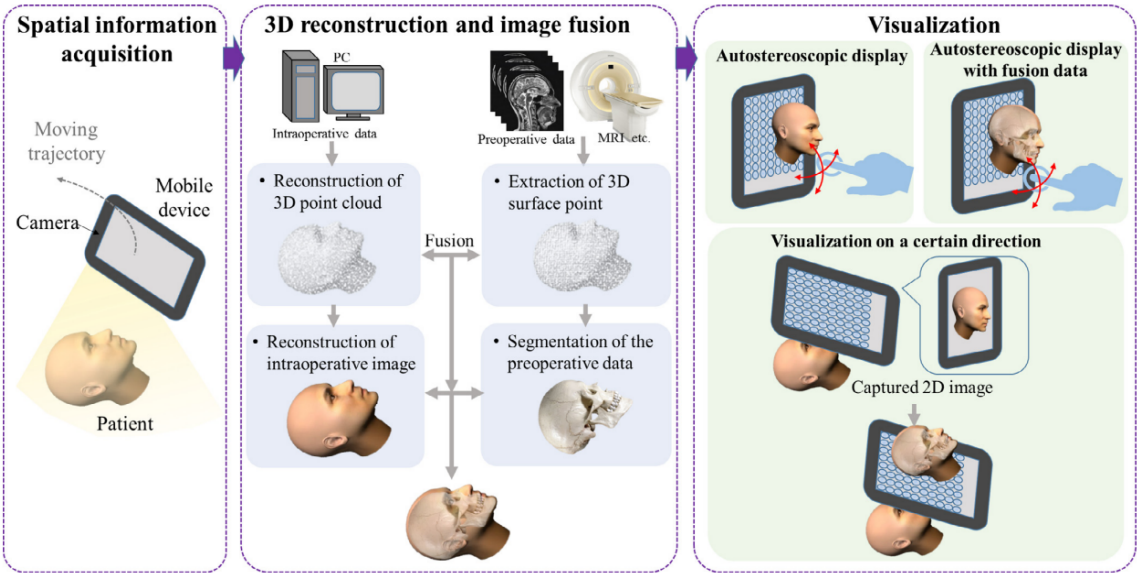



Figure 2-6 System and working flow of 3D visualization

In order to get the different angles of the patient, first, we use a camera to shoot the different angles of the patient(at least 3 photos for each angle). After getting the photos of the patient, we use a triangulation **algorithm** to reconstruct the section, and the material of the surface can be simulated by the **warn ICP algorithm**. At the visualization part, we can use **(MVP)'s IV rendering** algorithm to display 3D autostereoscopic images and autostereoscopic fusion images.

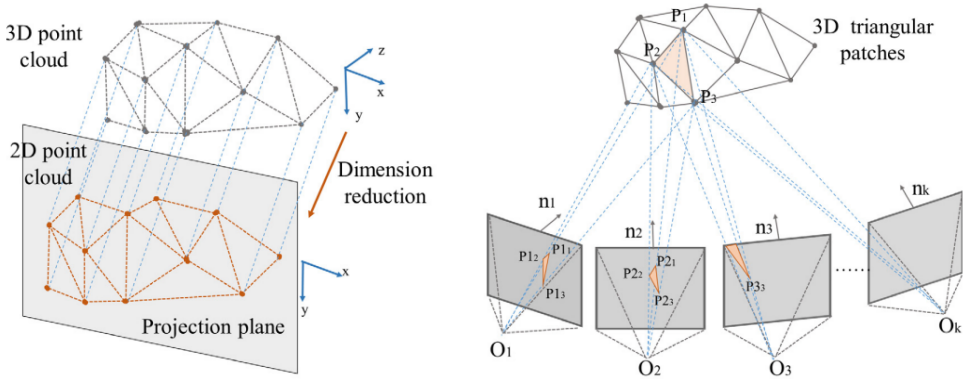



Figure 2-7 3D reconstruction

Figure 2-7 indicates the 3D reconstruction by 3D cloud segment. First, we need to connect the points in the plane into random triangles, and the vertices of the triangles can be represented by N. In the part of the surface material or shadow, we will use θ to represent the angles between the reconstructed patch and the imaging plane of the camera, and its angle can be solved by the projection formula, which is expressed below.

$$\cos\theta = \frac{\mathbf{n} \cdot (\vec{P_2P_1} \times \vec{P_3P_1})}{|\mathbf{n}||\vec{P_2P_1} \times \vec{P_3P_1}|}$$

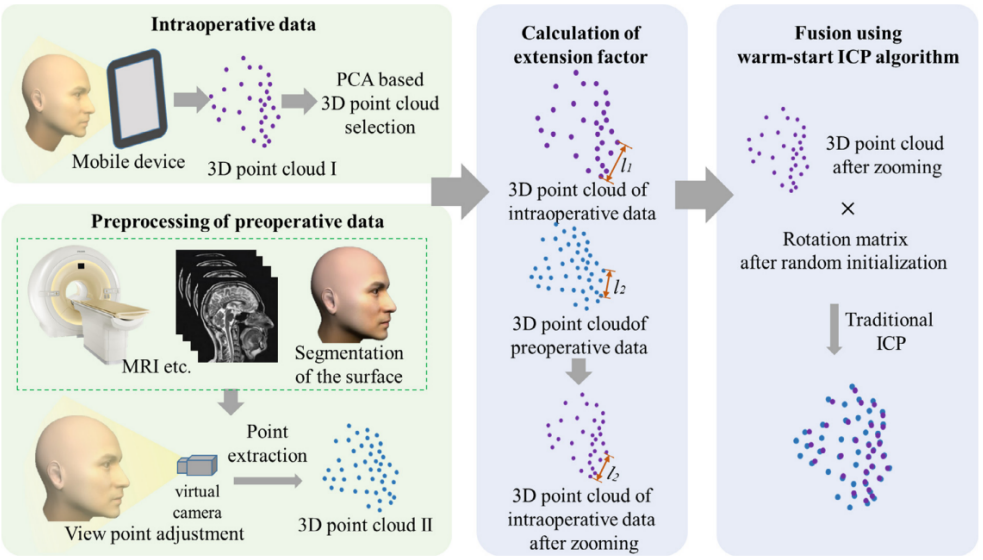
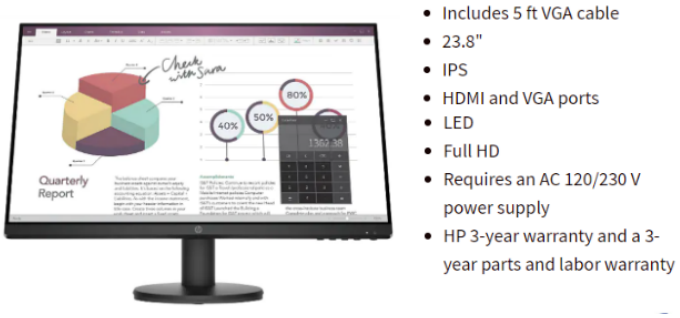



Figure 2-8 Image fusion

After reconstructing the 3D image, we will have two images. The first is the preoperative image, which is the result of the reconstruction in the previous step, and the other is the postoperative image. The RMS of the preoperative image and the postoperative image will be calculated separately using RMS, and this value will be used as the correlation between the two images. Then, we will use PCA to filter the less relevant data, we can assume that RMS is the correlation between the two data. In PCA, if the two quantities are orthogonal, it means that the two The item size correlation coefficient is low, so it is filtered. In this application, we can select the most relevant images from the two data groups for fusion. In ICP, we will transfer the 3D cloud data to another spatial dimension through a transformation matrix. When there is a spatial dimension, the converted preoperative image and post-operative image can be superimposed.

## 2-2 Virtual nursing

In the case of **Teladoc Health** (a virtual nursing platform established by Jason Gorevic), they only use monitors to detect the health of patients, and a cellphone application for contact to nurses. Figure 2-9 and figure 2-10 show the specification respectively.




- Includes 5 ft VGA cable
- 23.8"
- IPS
- HDMI and VGA ports
- LED
- Full HD
- Requires an AC 120/230 V power supply
- HP 3-year warranty and a 3-year parts and labor warranty

Figure 2-9 HP P24v G4 - P-Series - LED Monitor - Full HD (1080p) – 23.8“

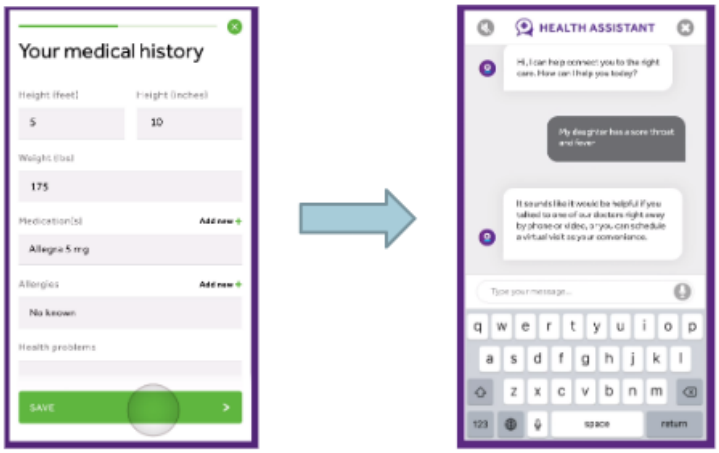



Figure 2-10 User interface of virtual nursing platform

Figure 2-10 shows the user interface of the virtual nursing platform, patients should accept the permissions of microphone and camera. After login the account, patients can send the messages to the nurse for consultation or health-care real time.

# 3.Application

## 3-1 Da Vinci surgical system

The most famous application for robot surgery is the **Da Vinci surgical system**.

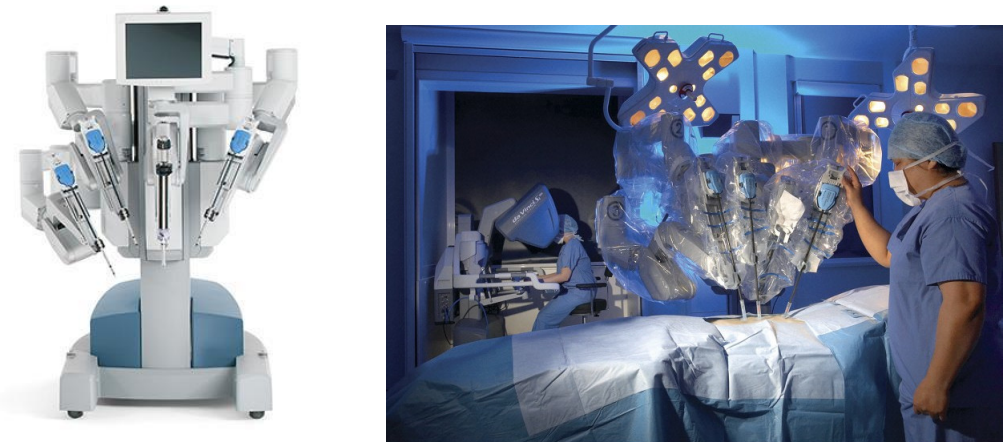


Figure 3-1 Da Vinci surgical system

Da Vinci surgical system is a surgical platform that provides robot-assisted function for surgeons during complex surgery. This is the typical application of robot surgery currently. There are multiple applications of the Da Vinci surgical system, the most used is urological, gynecological, and gastrointestinal surgeries. Even more, on the statistics of RADIUS ANESTHESIA, there are more than 70% Da Vinci surgical use in prostatectomies and hysterectomies. In addition to the application above, due to the strength of 3D surgical visualization, Da Vinci surgical is suitable for neurosurgery and orthopedics.

Figure 3-2 Application of Da Vinci surgical system

## 3-2 Scorpion Shaped Endoscopic Robot

Figure 3-3 Scorpion Shaped Endoscopic Robot

In addition to the Da Vinci surgical system, Scorpion shaped endoscopic robots can also be used in surgery. The difference between the Da Vinci surgical system is Scorpion shaped endoscopic is designed for endoscopic surgery. The feature of Scorpion shaped endoscopic robots is the tip of a soft tubular structure to enforce the function. Moreover, Scorpion shaped endoscopic robots are equipped with a haptic sense function, which is measured by detecting the change of tension of wire. Compared to the Da Vinci surgical system, Scorpion shaped endoscopic robots are smaller and have a higher degree of freedom to move.

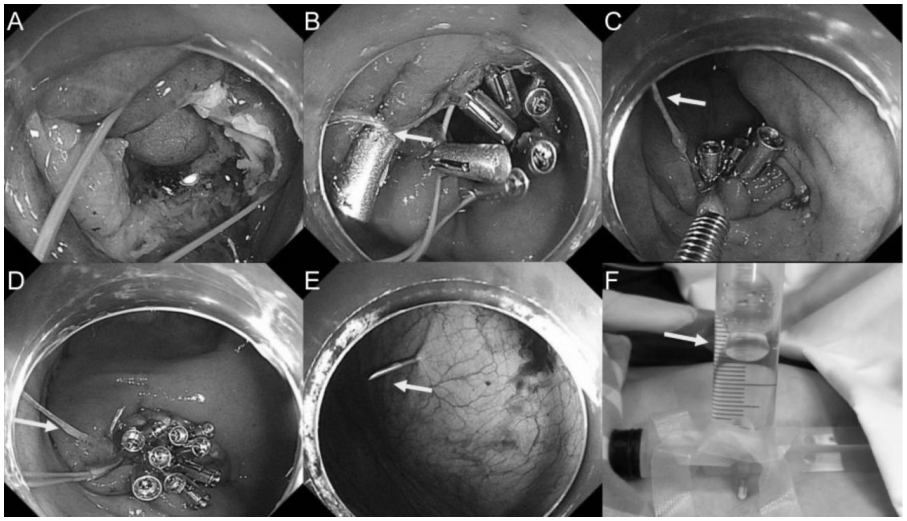



Figure 3-4 Endoscopic Surgery

## 3-2 BANYAN’s Virtual Nursing Platform

Figure 3-5 BANYAN’s Virtual Nursing Platform

BANYAN's Virtual Nursing Platform is a platform that can let patients use technology to contact a nurse. BANYAN's Virtual Nursing Platform equipped a speaker, microphone and a camera for each patient room. When the virtual nurse asks to get into the room, the alert of the camera will be lightened. Therefore, patients can have a face-to-face contract with a nurse.

## 3-3 Industrial analysis

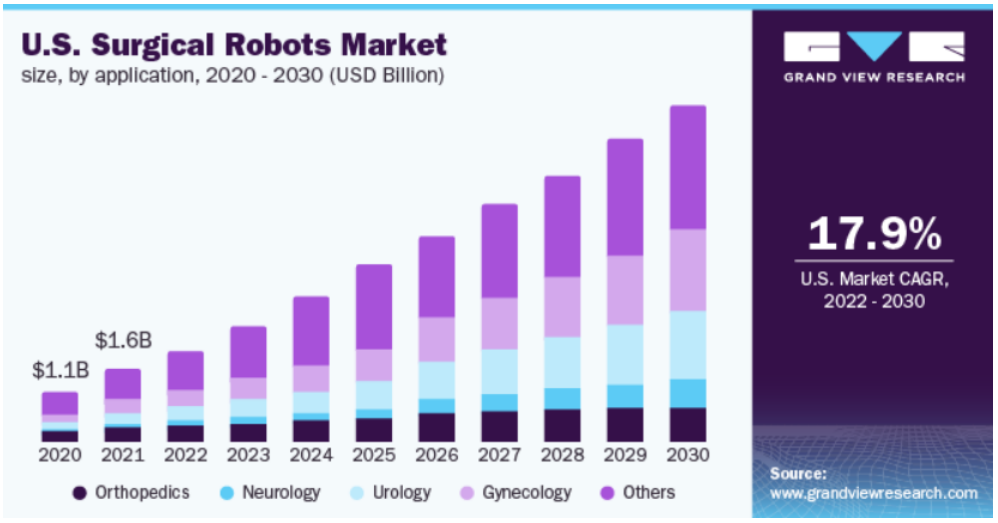



Figure 3-6 Surgical robots market analysis

In the research of the global surgical robots market, the market of surgical robots is expected to grow at a rate of 19.3% from 2022 to 2030. The reason why surgical robots have been promised is the increasing investment in development in the region and internationally. There are two main reasons that the investors are going

places for the new technologies. First, the increase of regulatory approvals for the robots used in surgery is promoting the use of surgical robots. Second, the development of 3D imaging, computing technology, sensors, and remote navigation technology systems also attract some companies to invest in them, like **Johnson & Johnson**.

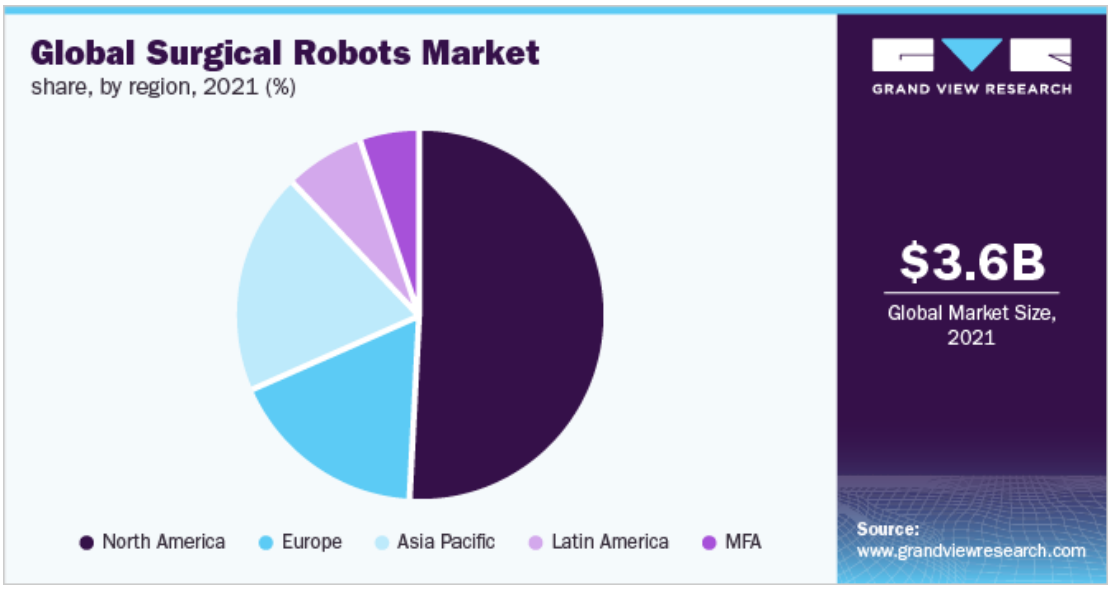



Figure 3-7 Global Surgical Robots Market

| Pandemic Impact | Post COVID Outlook |
|---|---|
| The global surgical robots market decreased by 7.7% from 2019 to 2020. | The market is estimated to witness a y-o-y growth of approximately 25% to 30% in the next 5 years. |
| A significant decrease in robot adoption has been noticed during 2020 due to the COVID-19 pandemic as compared to 2019. This can be attributed to the decrease in surgical procedures and shortage of manpower in the manufacturing facilities. | Growing demand for automated instruments with high accuracy and less human effort for surgical applications is expected to accelerate the market growth over the forecast years. |
| Furthermore, the lockdowns and shutdowns in major markets across the globe have negatively impacted the supply chain, thereby restricting the manufacturing of surgical robots in 2020. | An increasing trend has been observed in automated instrument adoption. This may be due to the effect of the COVID-19 pandemic during which people have become more conscious about the life-threatening viral infections and chances of contamination. |

Figure 3-8 The influence of Covid 19

In addition to robotic surgery, due to Covid 19, the HealthCare team is faced with the problem of the lack of nurses. Therefore, virtual nursing may become the tendency of hospitals or long-term care institutions.

## 3-3 SWOT analysis

- **Strength**
  - Helping doctor to perform surgery
  - Flexibility
  - Convenience
  - Smaller wound
  - Increase of patients volume
- **Weakness**
  - Higher risk of damage
  - Only available in centers that can afford the technology and have specially trained surgeons
  - Convert to an open procedure with larger incisions if there are complications
  - Expensive
- **Opportunities**
  - Scope for expansion
  - Newer robotic system
- **Threats**
  - Real surgeons or nurses
  - Risk of infection

# 4.Conclusion

Robotic surgery brings a new way for the surgeon to perform complex surgery. Moreover, during the COVID-19 pandemic, the need for high-accuracy equipment is estimated to increase. However, the problem is that robotic surgery has a higher risk, and it is the reason why most people still choose a traditional way for surgery. For me, I tend to choose traditional surgery too. In the case of dancer Liu Chen, who died from Aortic stenosis. I think the reason why she failed the operation is because she chose the minimally invasive surgery, which is performed by robotic surgery. Although the wound from robotic surgery is smaller, for me, I don’t want to risk my life.

For virtual nursing, I think it is a useful idea in recent years because of the lack of medical resources. In the case of Spain, during the pandemic of Covid-19, because many people were infected by the disease, many elderly patients died for lack of care. If virtual nursing is promoted then, I think the death caused by Covid-19 would decrease this year.

# 5.Reference


1. Robotic surgery (https://www.mayoclinic.org/tests-procedures/robotic-surgery/about/pac-20394974)
2. Robotic surgical systems in maxillofacial surgery: a review (https://www.nature.com/articles/ijos201724)
3. Virtual Nursing: How Telehealth Can Transform the HealthCare Industry(https://post.edu/blog/virtual-nursing/)
4. What Is A Virtual Nurse(https://banyanmed.com/what-is-a-virtual-nurse/)
5. Emerging surgical robotic technology: a progression toward microbots(https://ales.amegroups.com/article/view/5499/html)
6. Modeling and analysis of a 6 DOF robotic arm manipulator(https://www.researchgate.net/publication/280643085_Modeling_and_analysis_of_a_6_DOF_robotic_arm_manipulator)
7. Endoscope camera head 3DHD(https://www.medicalexpo.com/prod/viking-systems/product-80975-512208.html)
8. Medical Surgical Navigation and Robotic Control Solutions(https://www.advantech.com/en/resources/case-st

udy/surgical-navigation-and-robotic-control)

9. NVIDIA RTX A4000 Graphics Card(https://www.nvidia.com/en-us/design-visualization/rtx-a4000/)
10. Advantech Medical Box PC USM-500 datasheet (https://advdownload.advantech.com/productfile/PIS/USM-500/file/USM-500_DS(082222)20220822112611.pdf)
11. 3D interactive surgical visualization system using mobile spatial information acquisition and autostereoscopic display(https://pubmed.ncbi.nlm.nih.gov/28533140/)
12. HP P24v G4 - P-Series - LED Monitor - Full HD (1080p) - 23.8“(https://www.cdw.com/product/hp-p24v-g4-p-series-led-monitor-full-hd-1080p-23.8/6159136?pfm=srh)
13. Teladoc(https://www.teladoc.com/how-it-works/)
14. Applications of the Da Vinci Surgical Machine(https://radiusnm.com/da-vinci-surgical-machine/)
15. Scorpion Shaped Endoscopic Surgical Robot for NOTES and SPS With Augmented Reality Functions(https://link.springer.com/chapter/10.1007/978-3-642-15699-1_57)
16. BANYAN’s Virtual Nursing

Platform(https://banyanmed.com/banyans-virtual-nursing-platform/)

17. What Is the Banyan Virtual Care Solution?(https://banyanmed.com/virtual-nursing/)
18. Surgical Robots Market Size, Share & Trends Analysis Report By Application(https://www.grandviewresearch.com/industry-analysis/surgical-robot-market)
19. Robot-assisted surgery in India: A SWOT analysis(https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6961426/)