Healthcare AI- robot surgery/virtual nursing

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Outline

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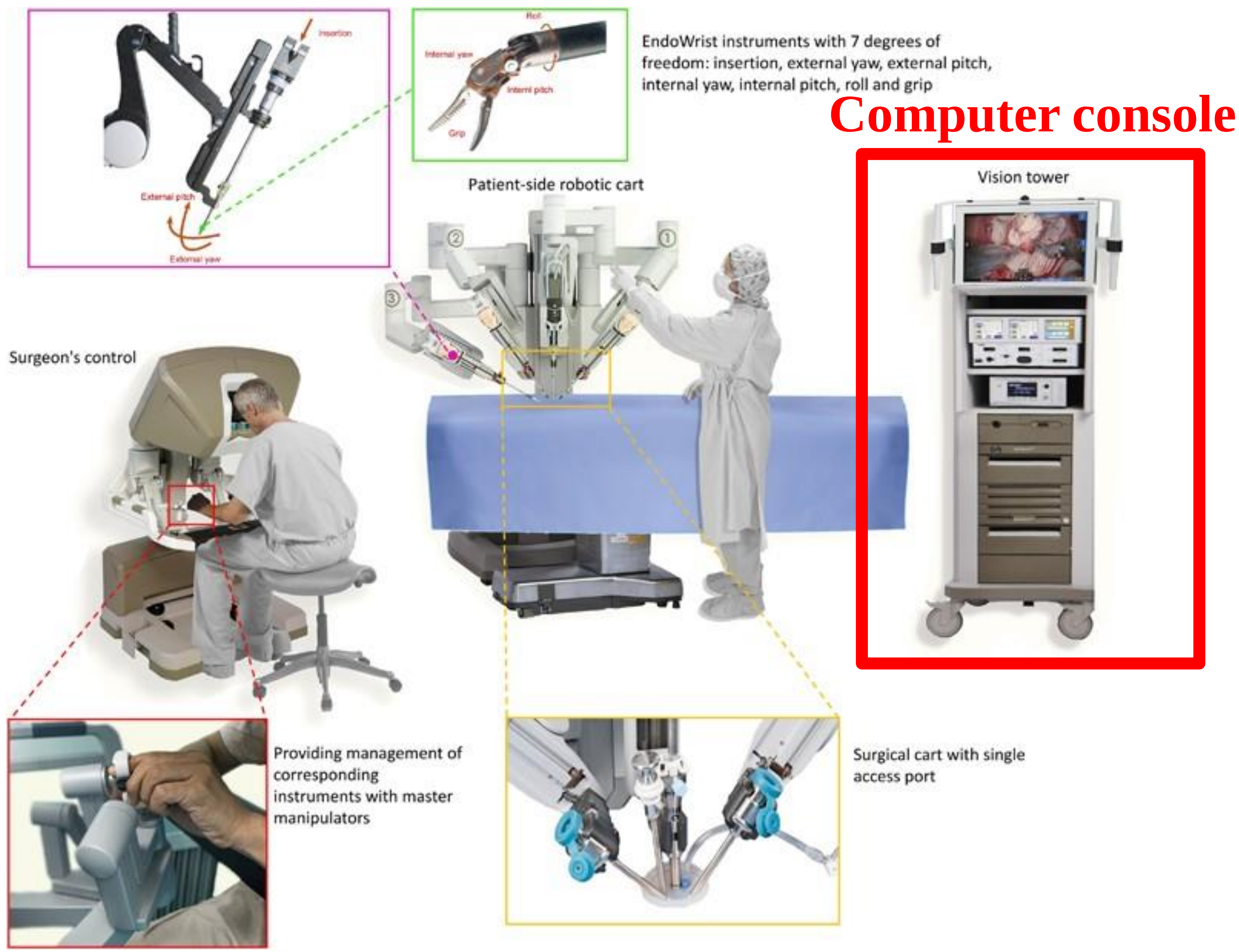
Introduction

- **robot surgery (robot-assisted surgery)**
  - Doctor perform the complex surgery with a **robotic platform**
  - Usually use **camera arm** and **mechanical arm**
  - Surgeon controls the arm during the surgery
  - **Computer console**
    - **High-definition**
    - **Magnified**
    - **3D view**

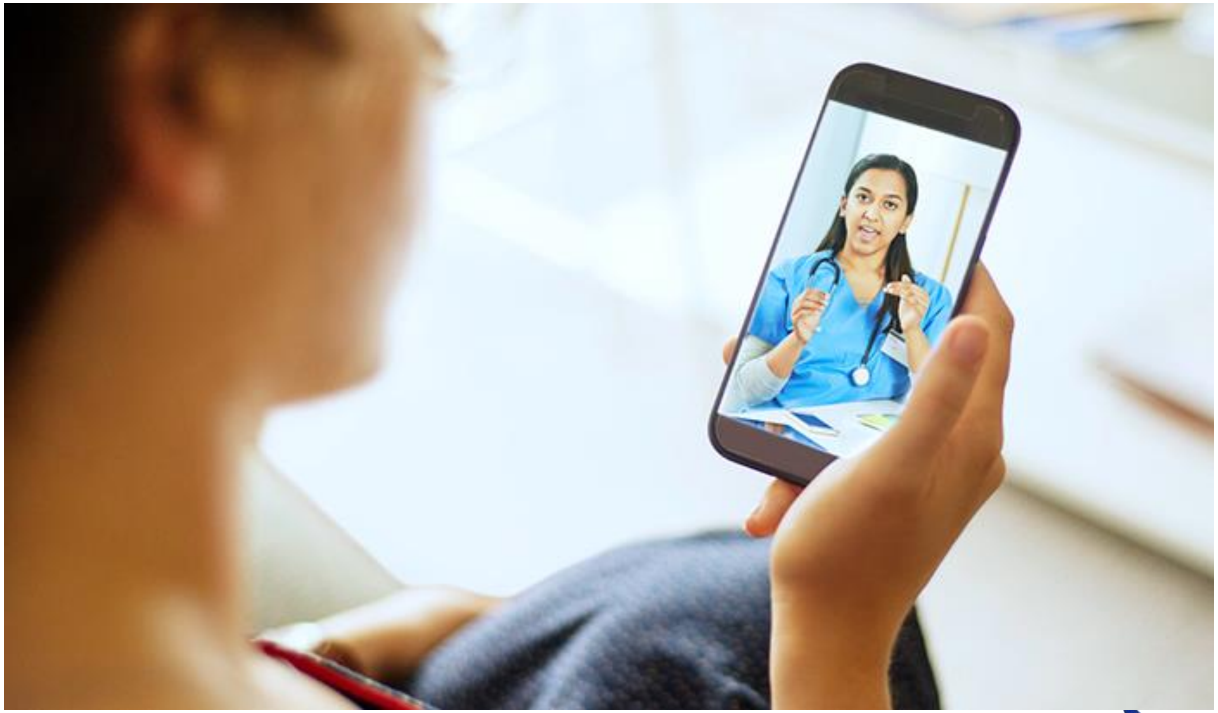
Robot surgery



Robot surgery

Introduction

- **virtual nursing**
  - Means healthcare from afar
  - Monitor the changes of patients



https://www.canadian-nurse.com/blogs/cn-content/2020/05/25/connected-mobile-nurses-virtual-nursing-care-in-th

Virtual nursing

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

Technology

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

Robot surgery

- **For different surgery, surgeon can choose different specification of robotic platform**
  - **Large robotic systems**
    - **Da Vinci (Da Vinci single port), Senhance, BITRACK, Revo-i**
  - **Medium systems**
    - **Versius**, SurgiBot-SPIDER**, MiroSurge, STRAS-iCUBE**
  - **Small systems**
    - **Invendoscopy E210 System, NeoGuide Colonoscope, Flex robotic system, Retraction Robot, Scorpion Shaped Endoscopic Robot…**

Robot surgery

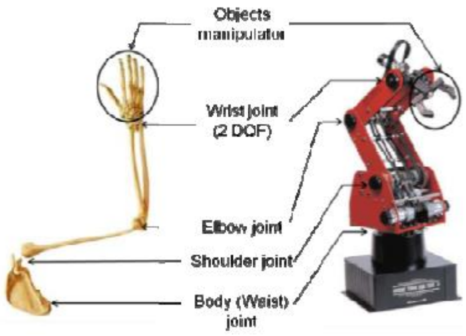
Table 1

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

Robot surgery

- 6 DOF Robotic Arm Manipulator
  - Made up of waist, shoulder, elbow
    - Waist: move in two plane (roll and pitch)
    - Others: single DOF
  - Overall System
    - Consists of the robot (controller interfaced with a standard PC), teaching pendant
    - Controller: 100 higher kernel command
    - Pendant: let the robot learn about any reachable coordinates



Robot surgery

- **Denavit-Hartenberg (DH) pa screw displacements**
  - Suitable for modeling serial manipulators
  - Figure 3 illustrates the **simplified kinematic model of the robotic arm in an inverted 'L' pose**
  - Figure 4: **$\{\alpha_{i-1}, a_{i-1}, d, \theta_i\}$**
    - α_{i-1} : twist angle
    - a_{i-1} : link length
    - d: link offset
    - θ_i : joint angle

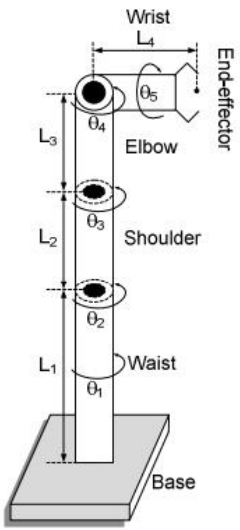


Fig. 3. ED7220C — Kinematic model.

TABLE II.
ED 7220C — LINK LENGTHS

Joint	Waist	Shoulder	Elbow	Wrist
Symbol	L_1	L_2	L_3	L_4
Link Length [mm]	385	220	220	155

Robot surgery

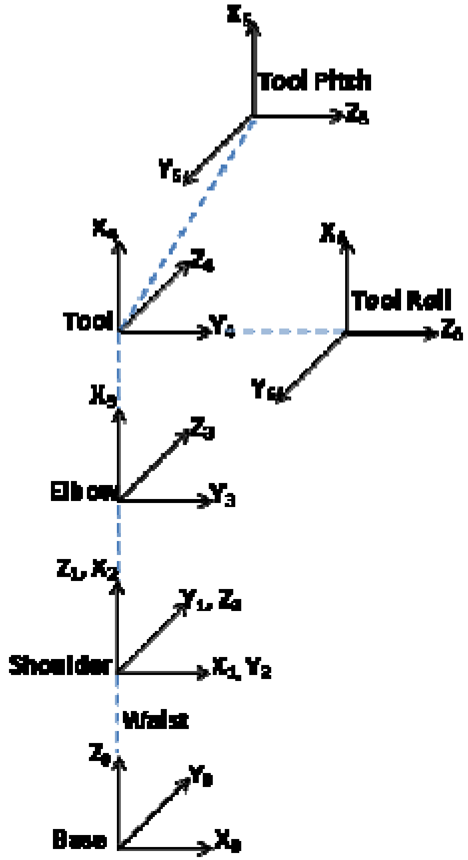


TABLE III.
ED 7220C — DH PARAMETERS

Symbol	Joints (i)					
	1	2	3	4	5	6
α_{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
θ_i	θ_1	θ_2 - 90°	θ_3	θ_4	θ_5	0

Robot surgery

- **Overall matrix representing the end terms of its base**
  - Corresponding transformation matrices for each link
  - Written in 3 x 3 matrices

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

Where

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

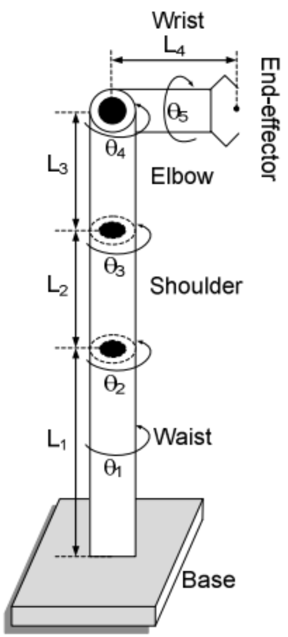
$$ \mathrm{B} = L_1 + L_2C_2 + L_3C_{23} - L_4S_{234} $$

Robot surgery

- **Inverse Kinematic Model (IK model)**
  - Target: Compute joint angle (get position and orientation
  - Base of transformation:

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

  - **Angle: θ_1(waist), θ_2(shoulder), θ_3(elbow), θ_4(tool pitch), θ_5(tool roll)**
  - After computing, get $\theta_1 = Atan2(p_x, p_y)$



Robot surgery

$$s_{234} = c_1 a_x + s_1 a_y$$

$$c_{234} = a_z$$

$$\theta_{234} = Atan2(s_{234}, c_{234})$$

$$c_3 = \frac{(c_1 p_x + s_1 p_y + l_4 s_{234})^2 + (p_z - l_1 + l_4 c_{234})^2 - {l_2}^2 - {l_3}^2}{2 l_2 l_3}$$

$$s_3 = \pm\sqrt{1 - {c_3}^2}$$

$$\theta_3 = Atan2(s_3, c_3)$$

$$c_2 = \frac{(c_1 p_x + s_1 p_y + l_4 s_{234})(c_3 l_3 + l_2) - (p_z - l_1 + l_4 c_{234}) s_3 l_3}{(c_3 l_3 + l_2)^2 + {s_3}^2 {l_3}^2}$$

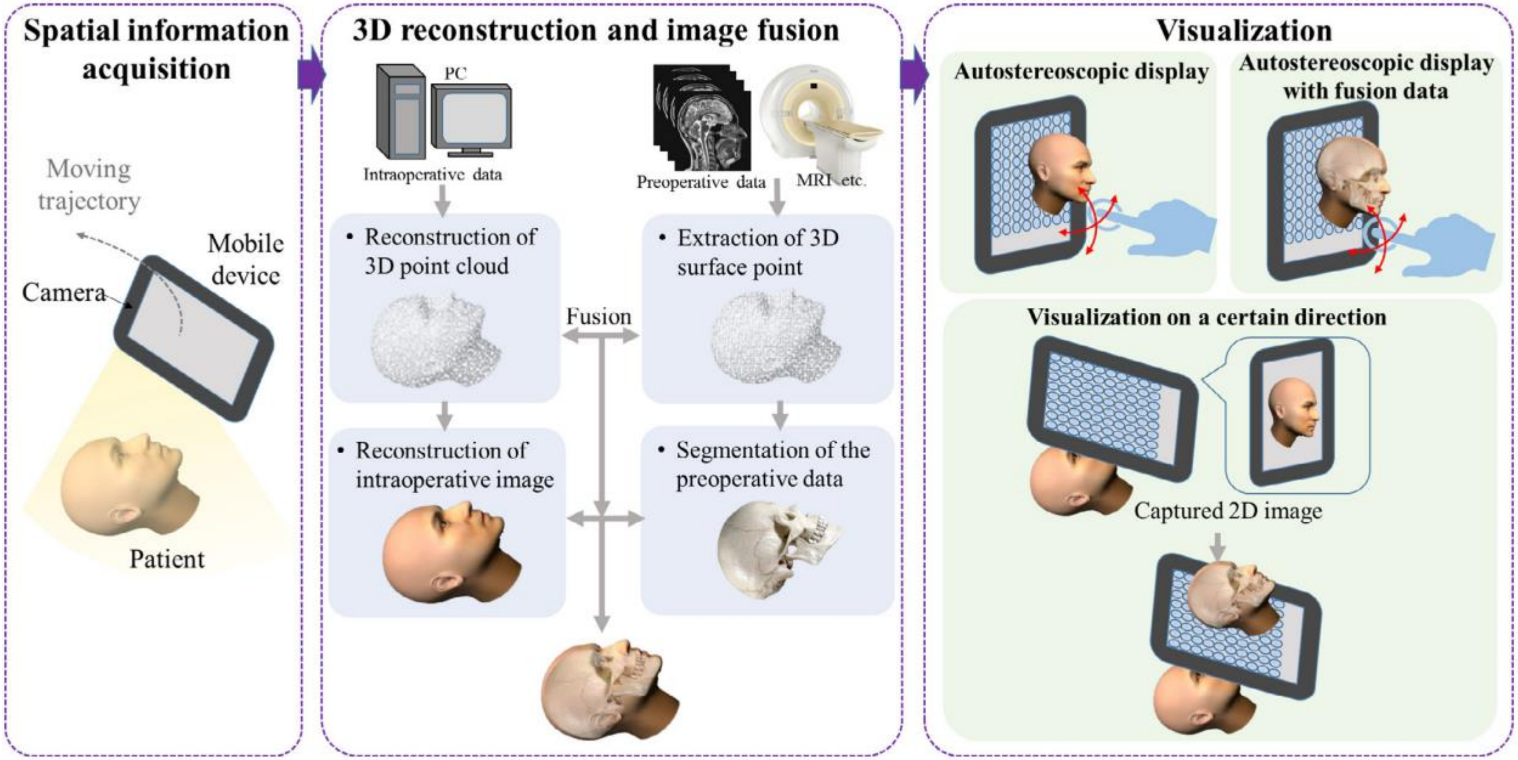
$$s_2 = -\frac{(c_1 p_x + s_1 p_y + l_4 s_{234}) s_3 l_3 + (p_z - l_1 + l_4 c_{234})(c_3 l_3 + l_2)}{(c_3 l_3 + l_2)^2 + {s_3}^2 {l_3}^2}$$

$$\theta_2 = Atan2(s_2, c_2)$$

$$\theta_4 = \theta_{234} - \theta_2 - \theta_3$$

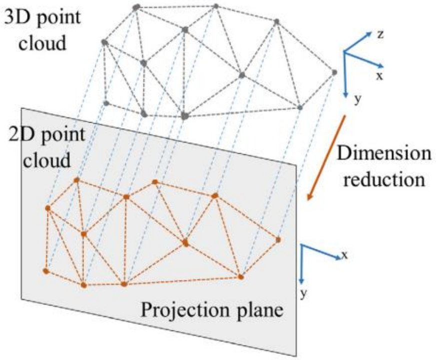
3D visualization

System and working flow

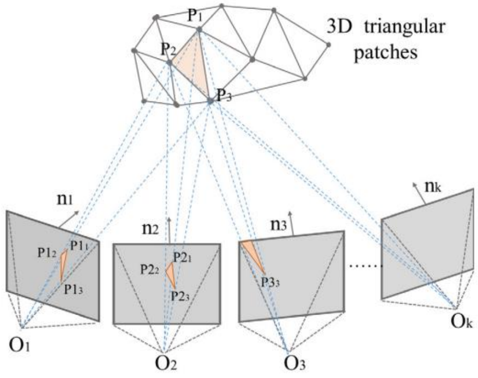


3D visualization

- **3D reconstruction**
  - SfM algorithm: estimate the new 3D structure
  - 2D Delaunay triangulation algorithm
  - Reconstructed triangular patches
    - Can mapping the texture
    - **Projection-weighted mapping algorithm**
      - **N: (N = 0, 1, 2 or 3): angle of each triangle**
      - **θ : angle between reconstructed patch and the imaging plane of the camera**



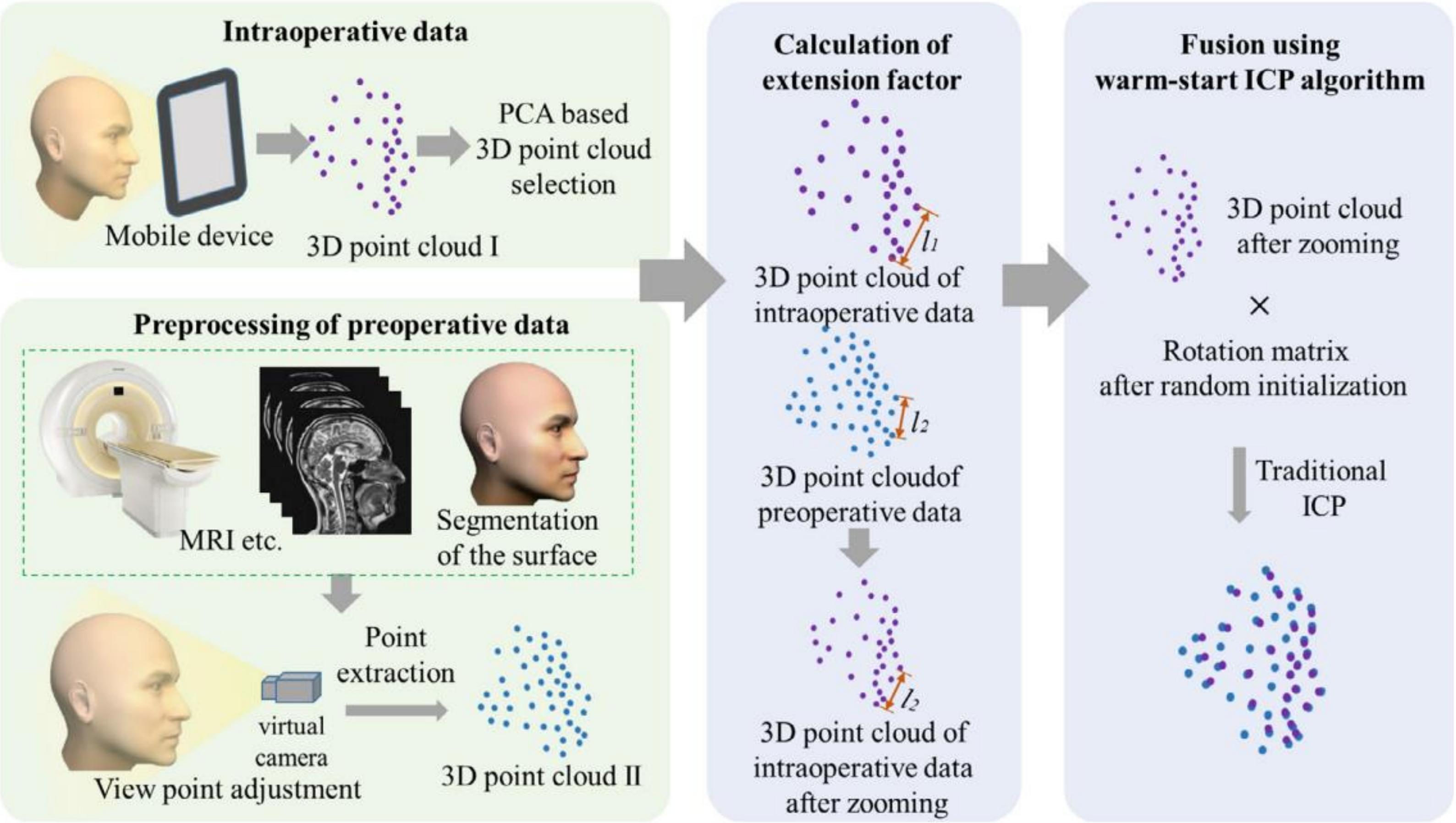
$$\cos\theta = \frac{\mathbf{n}\cdot(\overrightarrow{P_2P_1}\times\overrightarrow{P_3P_1})}{|\mathbf{n}||\overrightarrow{P_2P_1}\times\overrightarrow{P_3P_1}|}$$



3D visualization

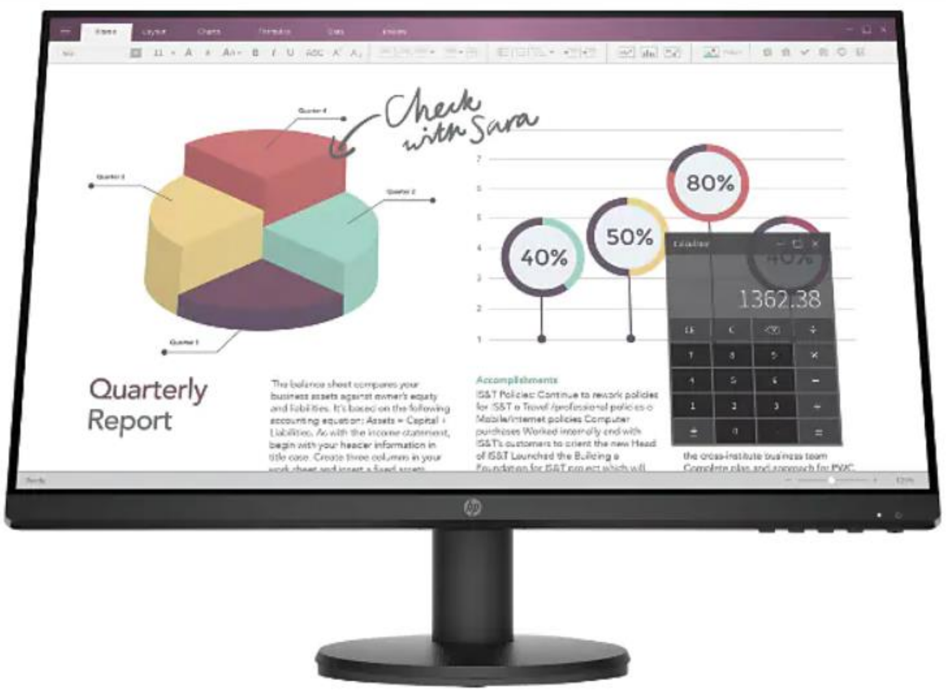
- Image fusion
  - **Principal component analysis (PCA)-based point cloud selection algorithm**
    - To acquire the 3D point cloud of the preoperative data's surface, we segment the 3D model from the preoperative data
    - Use the **3D model** to calculate the z coordinate
    - Use RMS to extracted data
      - **RMS of intraoperative data and the RMS of preoperative data**
  - **Iterative closest point (ICP) algorithm**
    - Preoperative medical data and intraoperative reconstructed image with texture

3D visualization



Virtual nursing

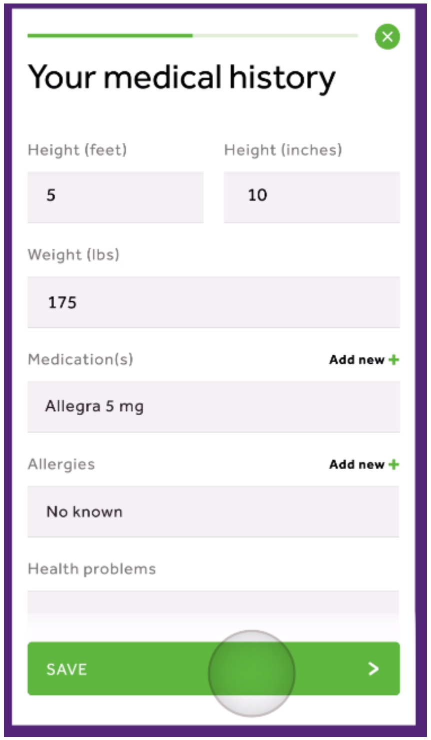
- **HP P24v G4 - P-Series - LED Monitor - Full HD (1080p) – 23.8“**

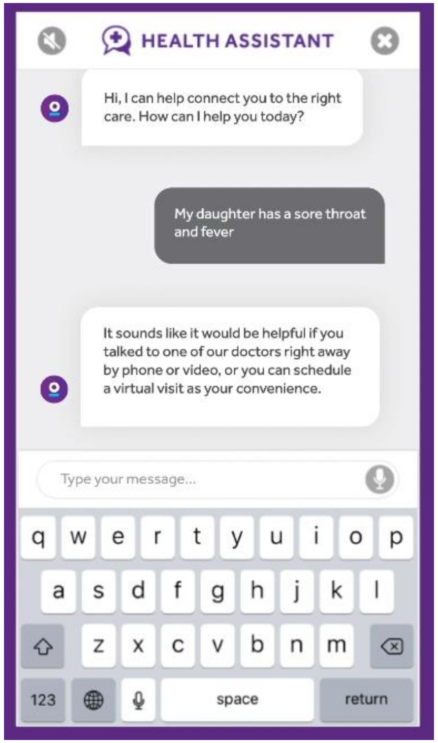


- Includes 5 ft VGA cable
- 23.8"
- IPS
- HDMI and VGA ports
- LED
- Full HD
- Requires an AC 120/230 V power supply
- HP 3-year warranty and a 3-year parts and labor warranty

Virtual nursing

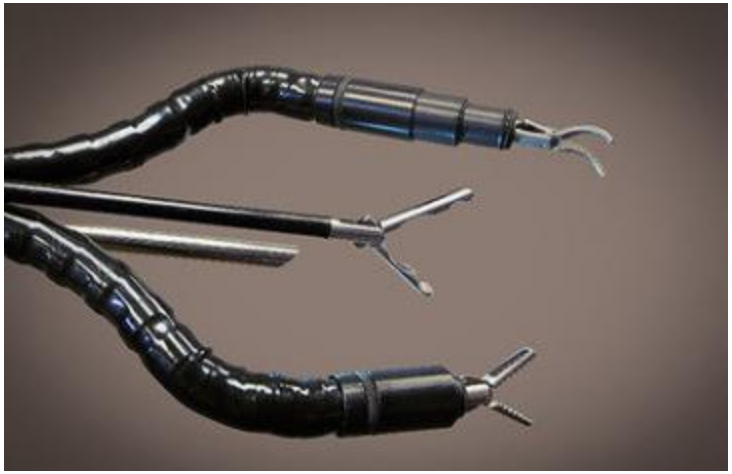
- **Teladoc virtual healthcare platform**
  - Should accept the permissions of microphone and camera





Application

da Vinci systems



SPIDER-Surgibot

Application

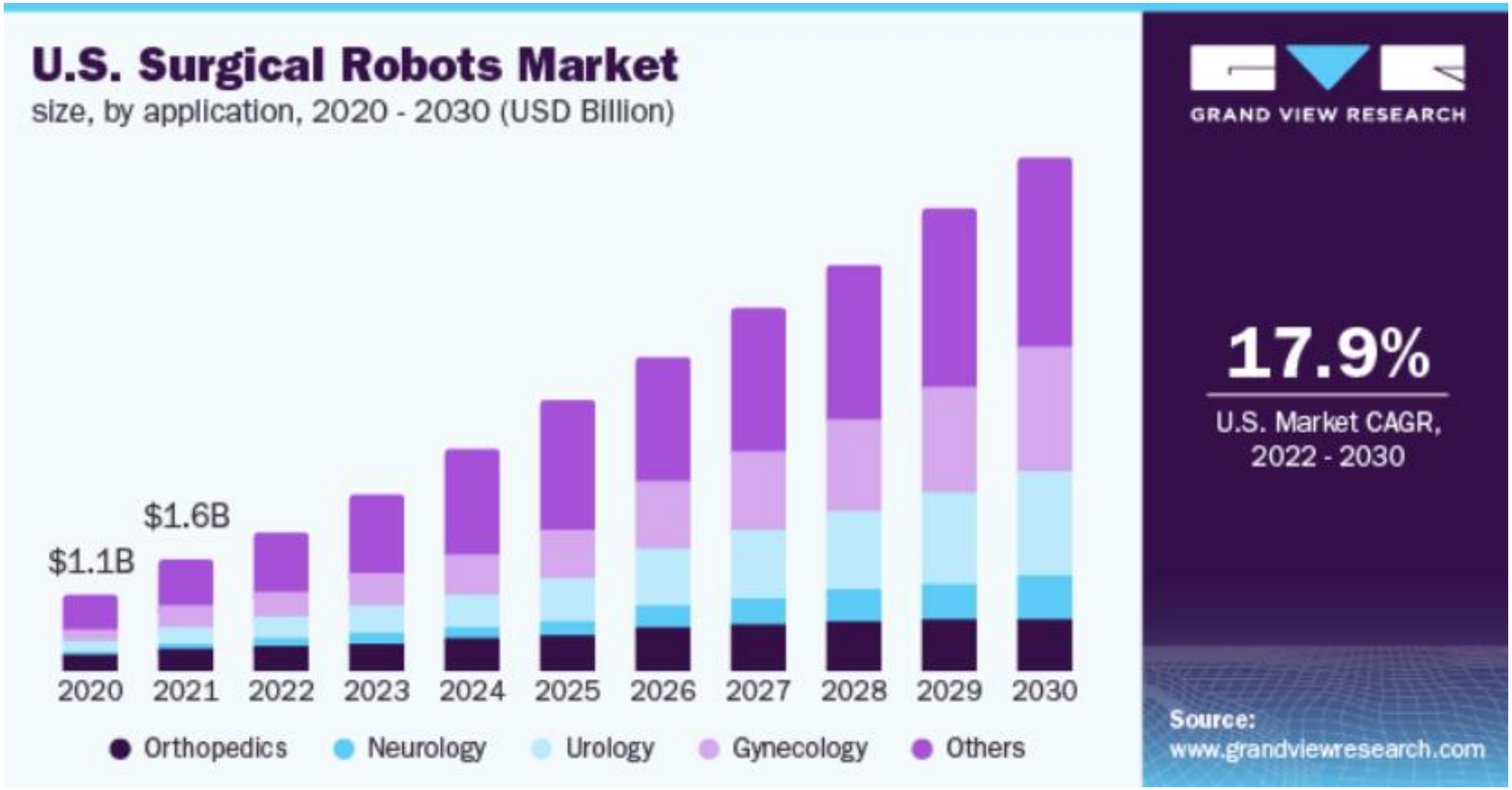
Scorpion Shaped Endoscopic Robot

Invendoscopy E210

Application

BANYAN's Virtual Nursing Platform

Application



Application

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.

Application

- **SWOT**
  - Strengths
    - Helping doctor to perform surgery, flexibility, convenience, smaller wound
  - Weaknesses
    - 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
  - Opportunities
    - Scope for expansion, newer robotic systems
  - Threats
    - Real surgeons or nurses

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 of surgery.**

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