Seminar – Fall 2023

Robot_Assisted CT_Guided percutaneous procedures to Improve in Accuracy of Navigation system

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Contents

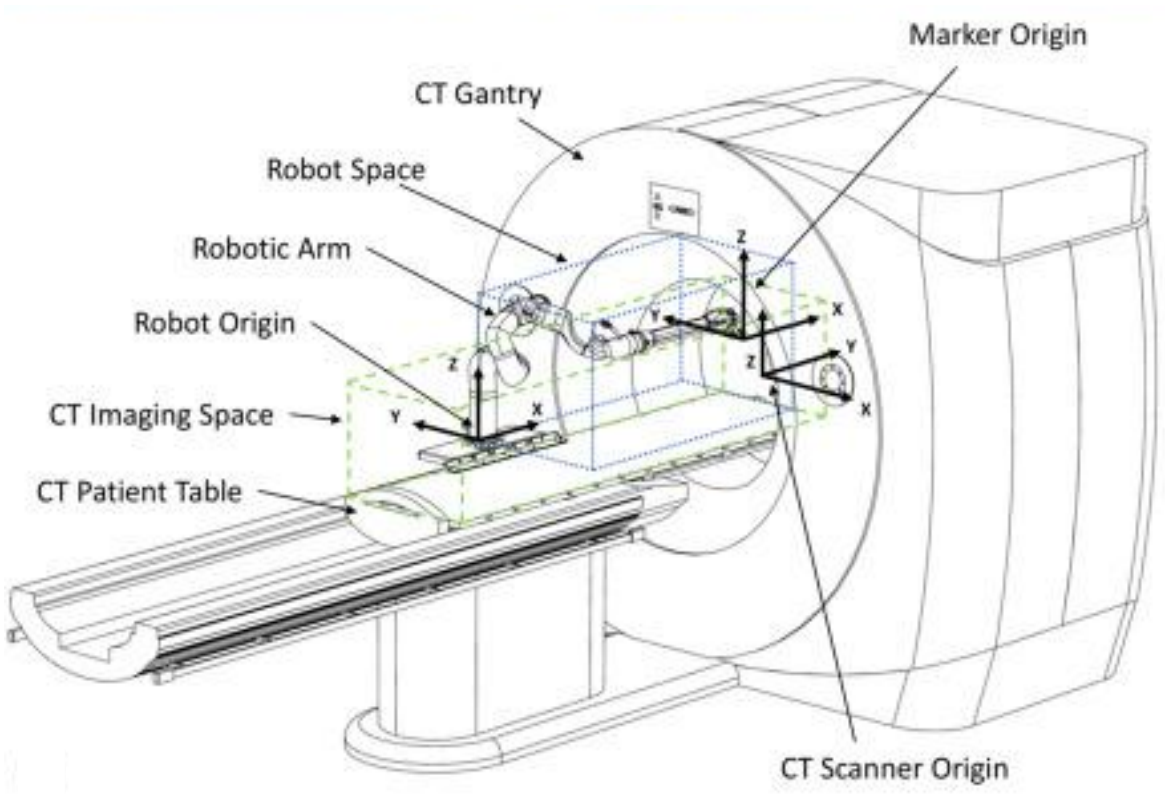
Introduction

- Robotic surgery is usually associated with minimally invasive surgery — procedures performed through tiny incisions.
- Robot-assisted surgery allows doctors to perform many types of complex procedures with more precision, flexibility and control than is possible with conventional techniques.

Advantages

- Fewer complications, such as surgical site infection
- Less pain and blood loss
- Shorter hospital stay and quicker recovery
- Smaller, less noticeable scars
- Provide Surgeon to get high-definition, magnified, 3D view of the surgical site.

Application: Robotic-assisted Biopsy needle Placement



Advantage

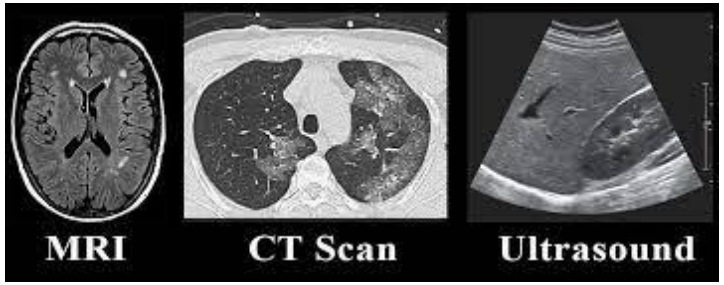
- ❑ Precision and Accuracy
- ❑ Minimizing radiation exposure

Computer-aided Surgery

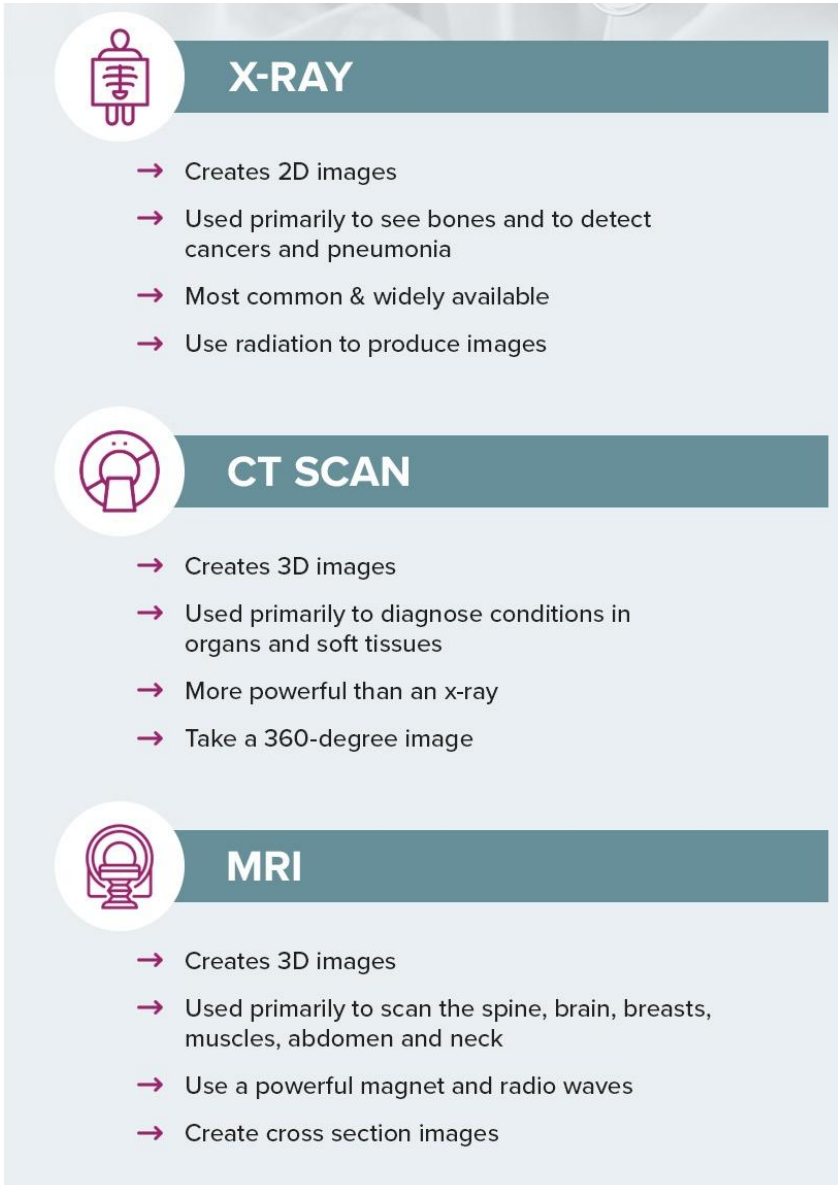
- Robotic systems improve the procedures using **imaging techniques**
- **Image guidance** is a common methodology of minimally invasive procedures

- **Create 3-D maps and models of an organ and also a surgical tool in simulation**
- Various **imaging modalities** are available

Common imaging modalities



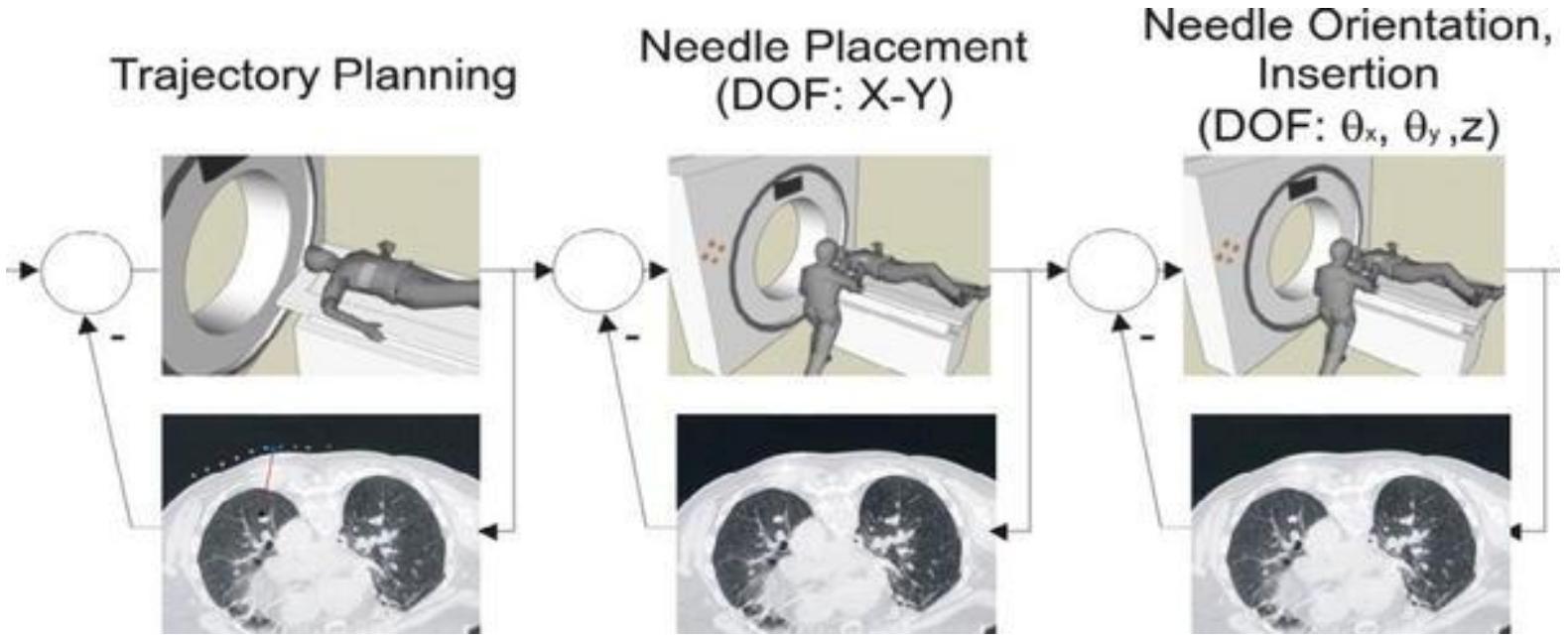
- Computed tomography (CT)
- Magnetic resonance tomography (MRI)
- Ultrasound(US)



Common imaging modalities

	CT	MRI	US
Scan Time	Avg 5 Min	Avg 25-35 min	Avg 20-40 min
Radiation	X-rays (Ionizing)	Radio Waves(Non-Ionizing)	High Frequency Sound (Non-Ionizing)
Targeted Imaging	Bones and Organs	Muscle, Ligaments, Tissues	Soft Tissues and Fluid-filled Area
Disadvantage	Radiation Exposure	Metal restriction Expensive	Low accuracy Cannot be used for whole body imaging

CT_Guided Interventions

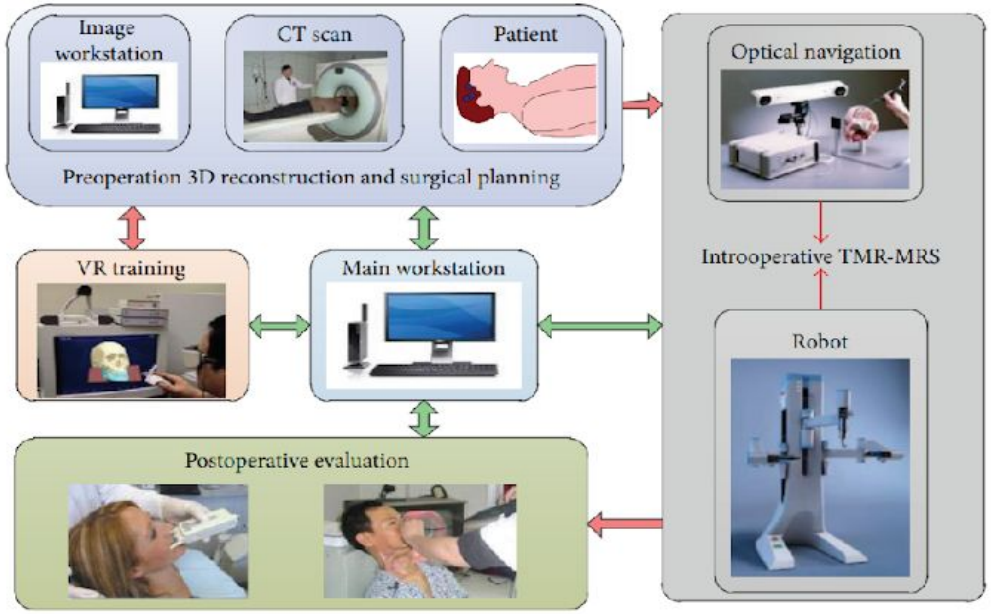


- CT offers high-resolution, detailed anatomical images and is often used for pre-operative planning and procedures requiring precise anatomical knowledge.

Medical Imaging System in Robotic Surgery

- Image Registration
- 3D Reconstruction
- Pre-operative Planning
- Simulation
- Instrument Tracking
- Navigation

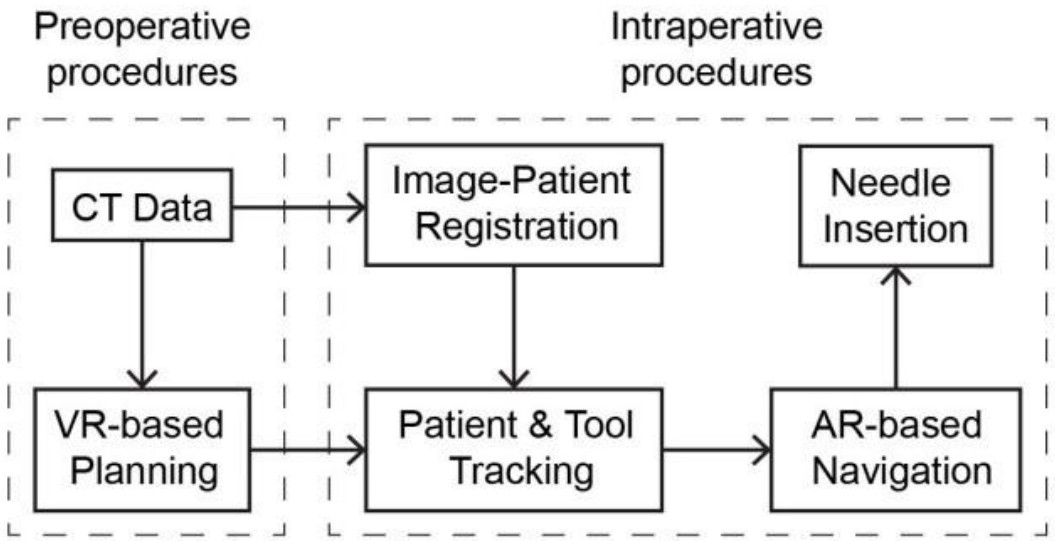
Robot-assisted Surgical Procedure



Computer assisted surgery can be divided into three basic steps:

- Pre-operative presurgical planning
- Intraoperative
- Postoperative

Preoperative and Intraoperative in Biopsy Needle Insertion



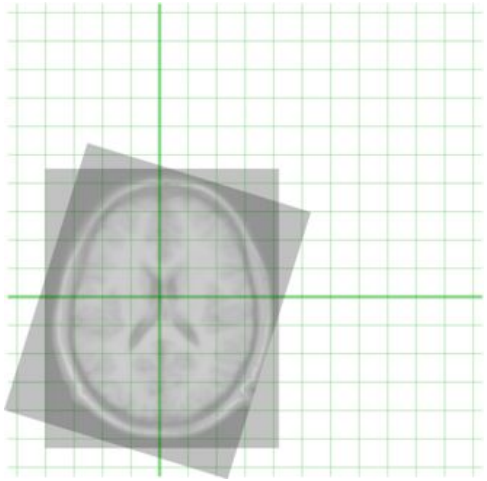
- Pre-operative planning — to establish the operating target and its surrounding anatomical structures for planning out detailed access and operating trajectories;

- Intra-operative planning — registration and reconstruction, tool tracking, navigation

2D/3D Registration and Reconstruction in Medical Imaging

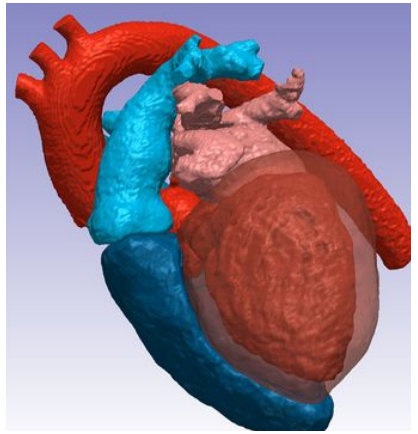
2D-3D Registration

- **Applications**: Image-guided surgery, Radiation therapy
- **Techniques**:Intensity-based,Feature-based methods, Deformable registration

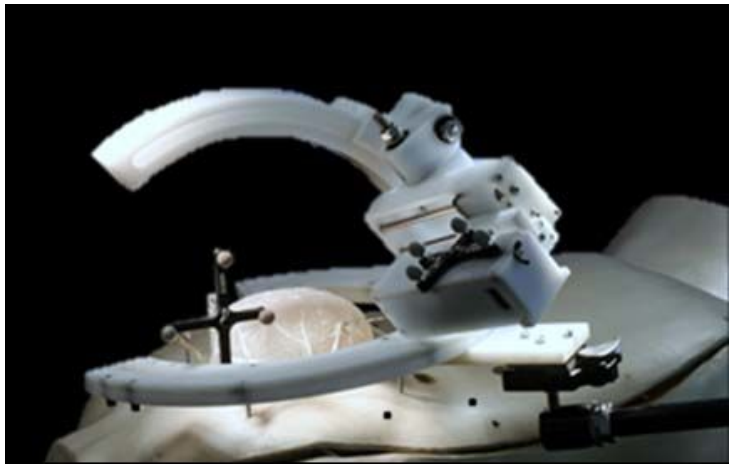


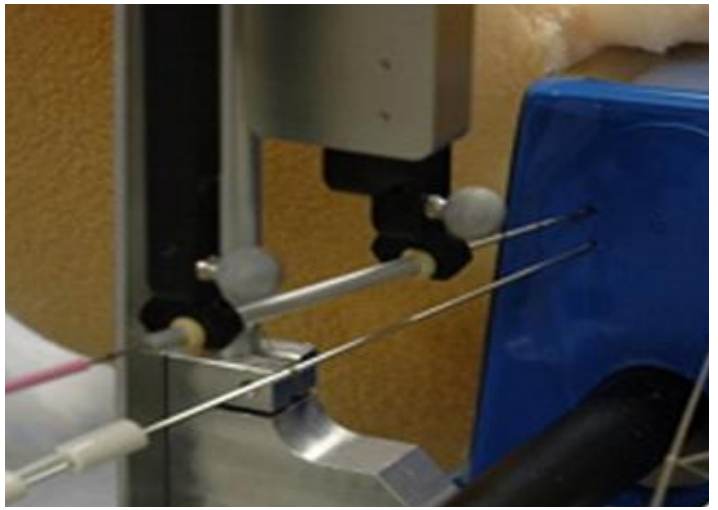
2D-3D Reconstruction

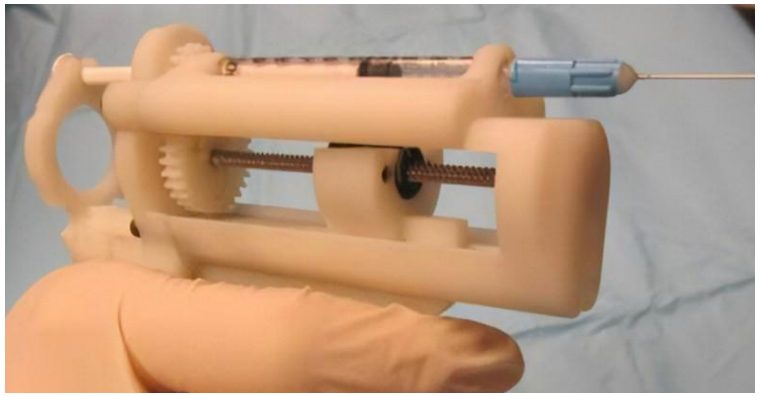
- **Applications**: In Computed Tomography (CT) , multiple X-ray projections are used to reconstruct cross-sectional 3D images of the body.
- **Techniques**: Iterative Reconstruction improve image quality and reduce artifacts



Related studies of Biopsy needle Interventions

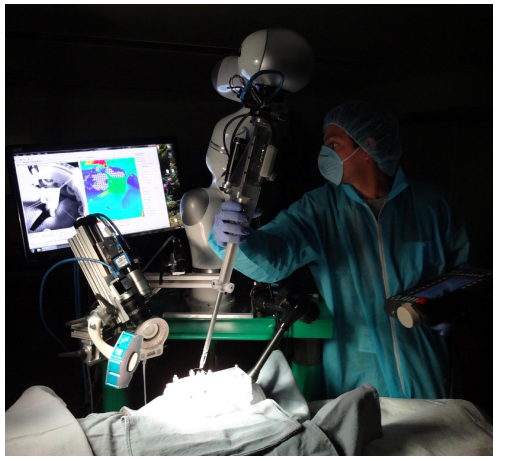




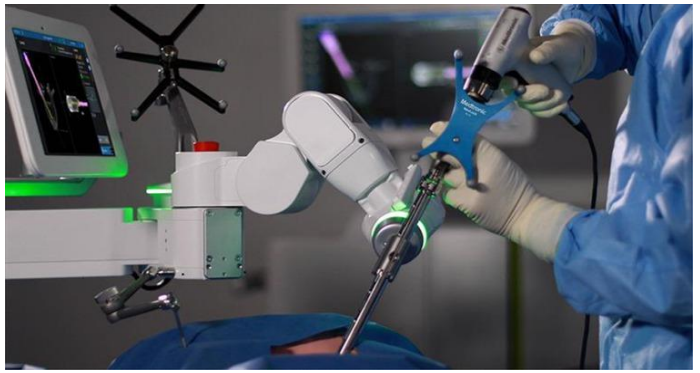


Mechanical Contributions

To improve accuracy and precision of medical surgical process, the recent design contributions are focusing on :



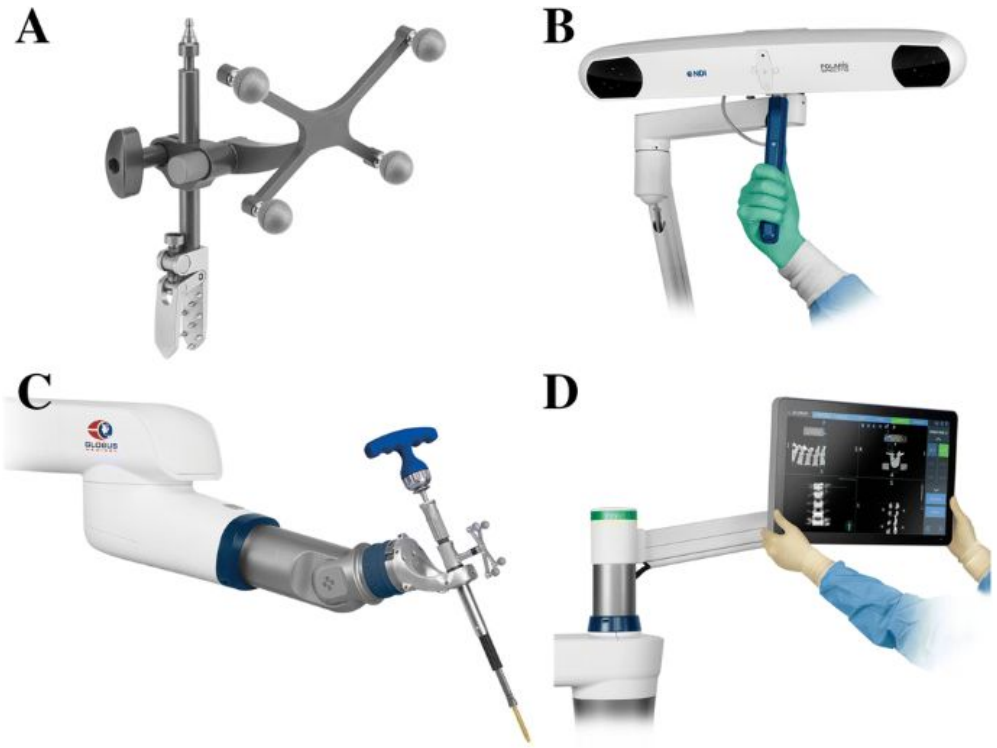
- Robotic Manipulators
- Surgical Tools and mounts
- Rigid bodies (Markers and Fiducials)



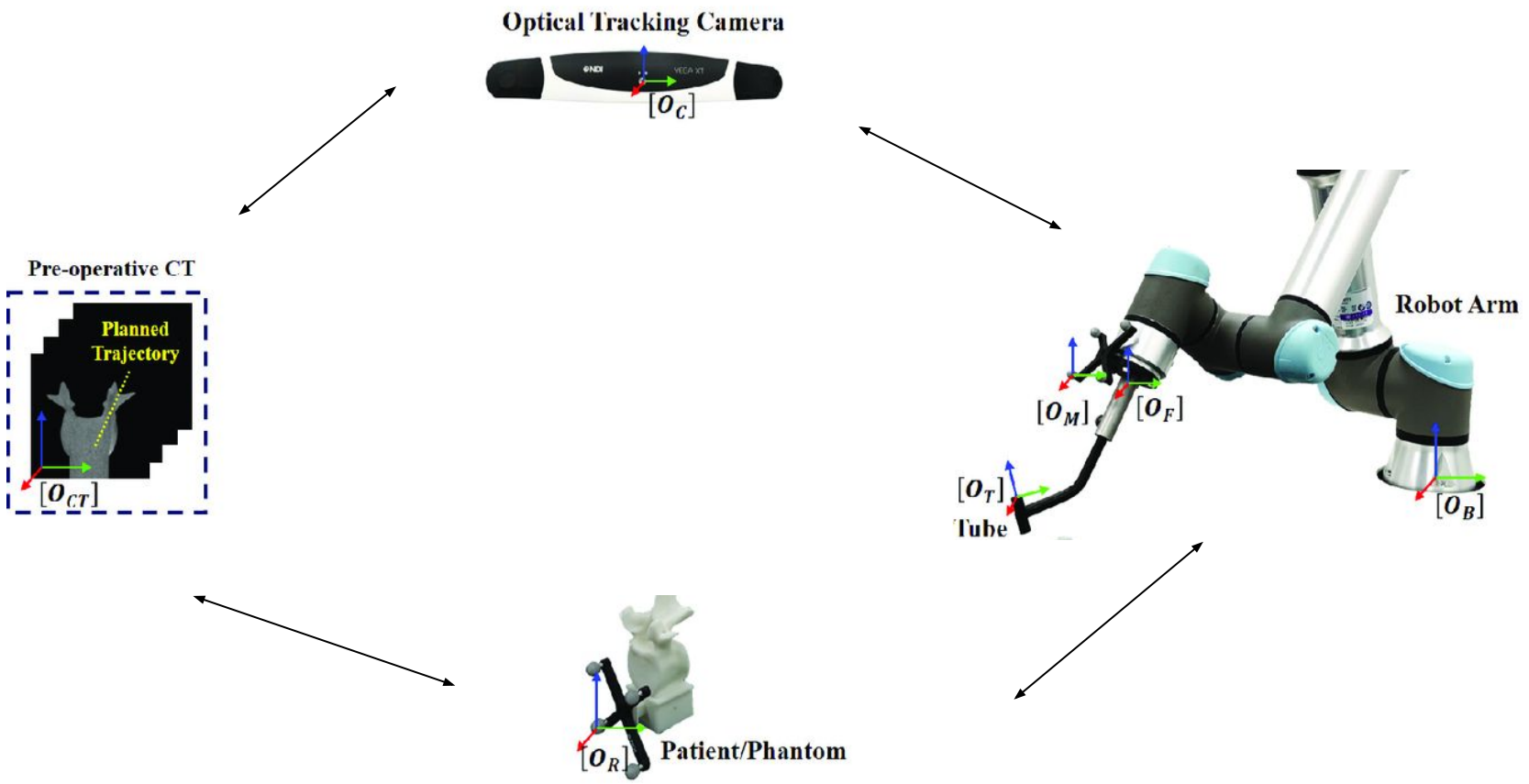
- Passive Arms
- Gripper and End-effectors
- Guided-holders

Main Components in Medical Imaging Robotic Surgery

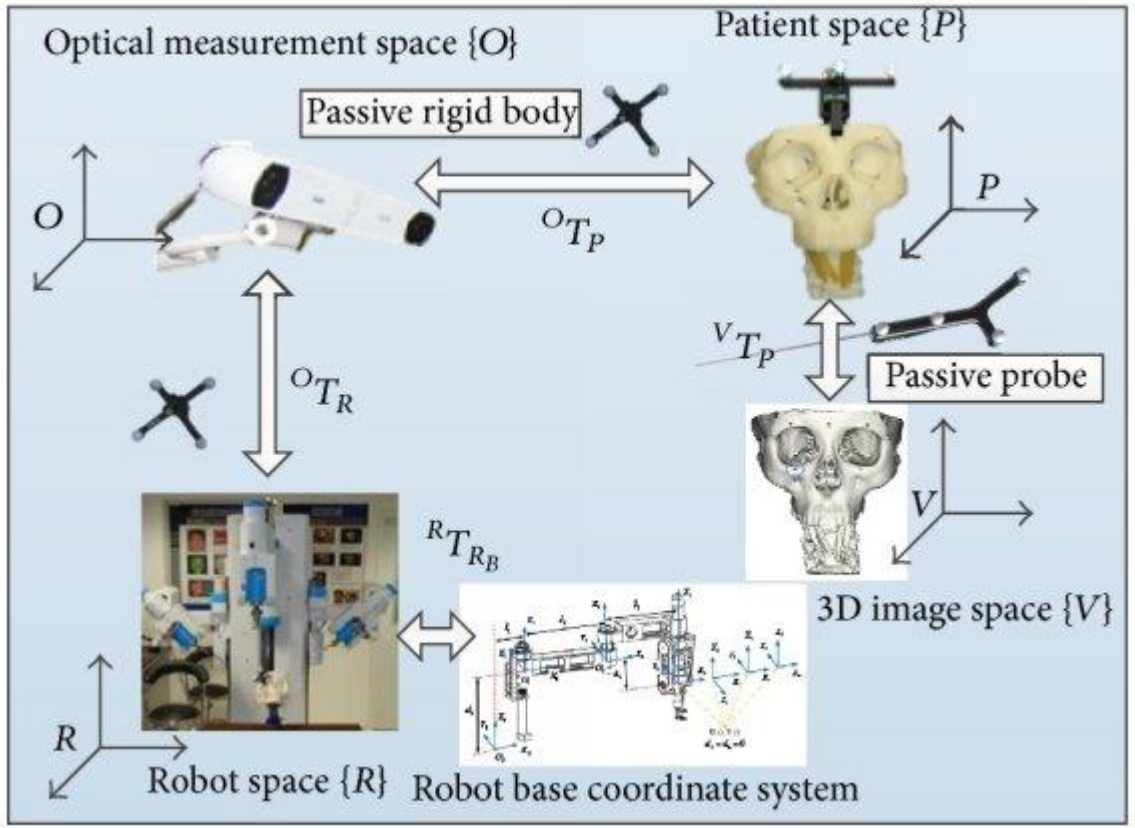
A. Rigid-body Markers
B. Optical Tracker
C. Manipulator and End-effector
D. Console



System Configuration



Transformation relationship between coordinate systems



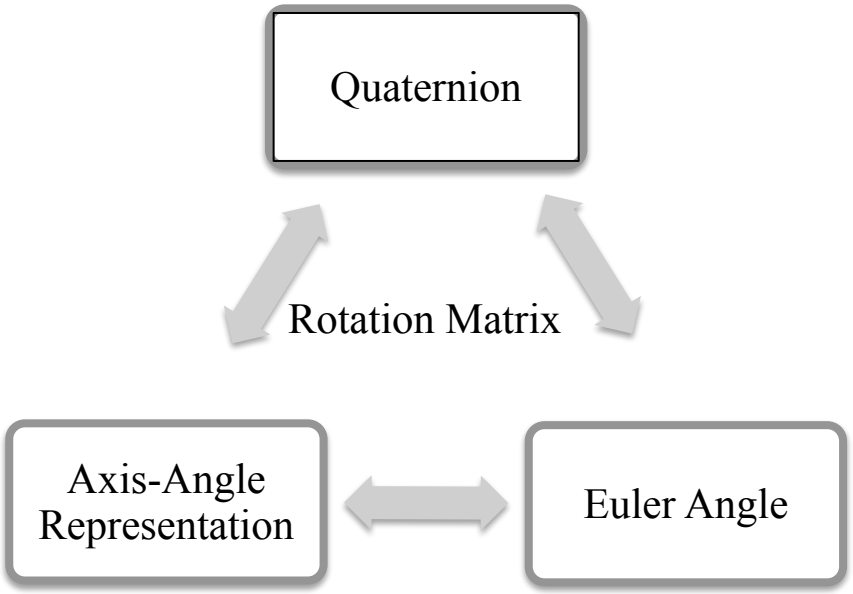
Transformation Matrix

$$T = \begin{bmatrix} R & Pos \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} \begin{bmatrix} X_x & Y_x & Z_x \\ X_y & Y_y & Z_y \\ X_z & Y_z & Z_z \end{bmatrix} & \begin{matrix} X \\ Y \\ Z \end{matrix} \\ \begin{matrix} 0 & 0 & 0 \end{matrix} & 1 \end{bmatrix}$$

Rotation

Translation

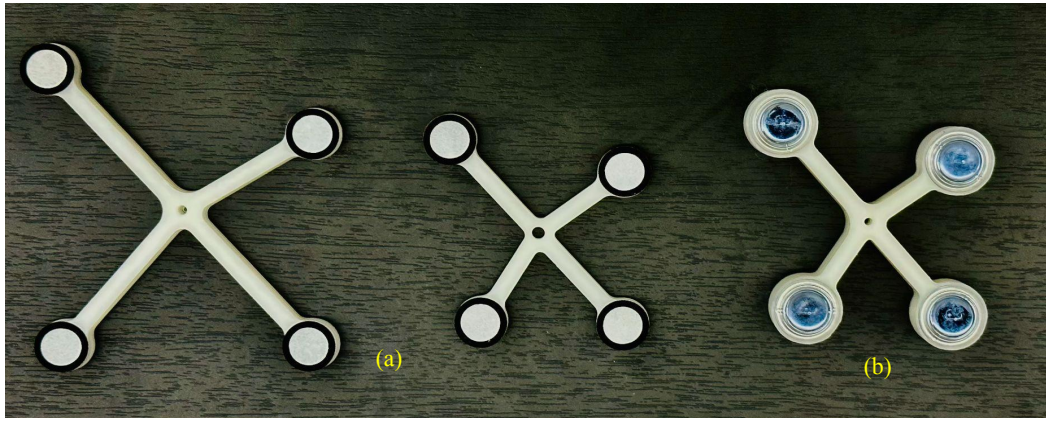
How to Find Rotation Matrix



Ongoing Studies

- Design of Dual-sensors and its calibration
- Design of Biopsy Needle-guided holder in CT_Based Intervention
- Design of Surgical Tool attached with Rigid bodies

Design of Rigid-bodies

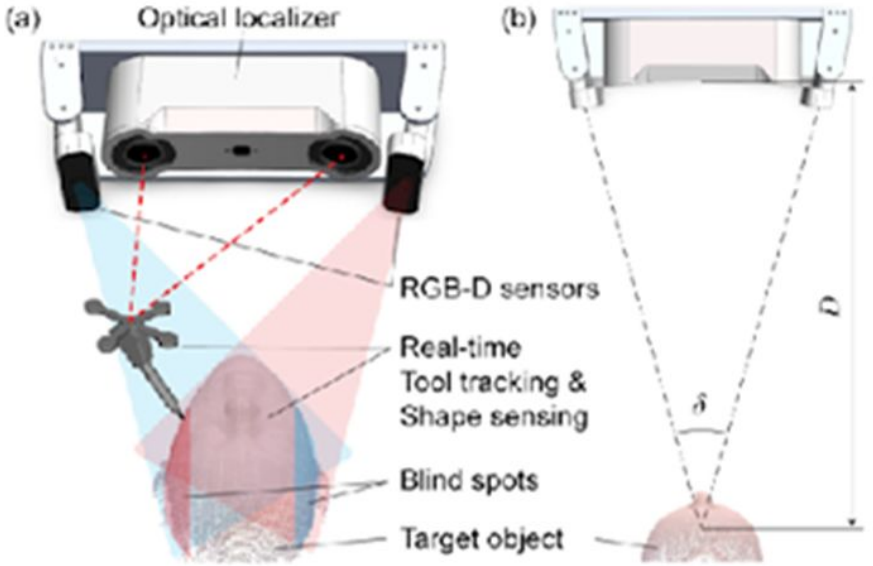


Rigid-bodies with (a) Reflective Adhesive Markers and (b) Radix Lens (NDI, Ontario, Canada)

- Typically small, visible, or detectable objects or substances that are placed inside or on the patient's body to aid in navigation, localization, and tracking during surgery.

Ongoing Studies_1

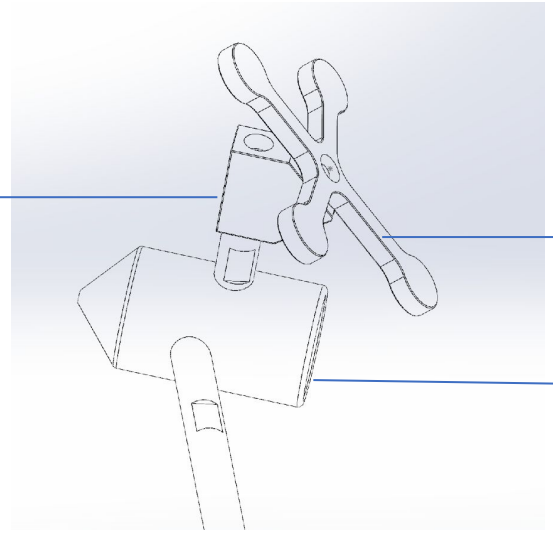
Design of Dual-sensors and its calibration



- Dual Sensors: Combination of Two RGB_D sensors and Optical Tracker
- Size of Frame: 100mmx400mmx120mm
- Expected Weight: 1.6 kg (Aluminium Frame)

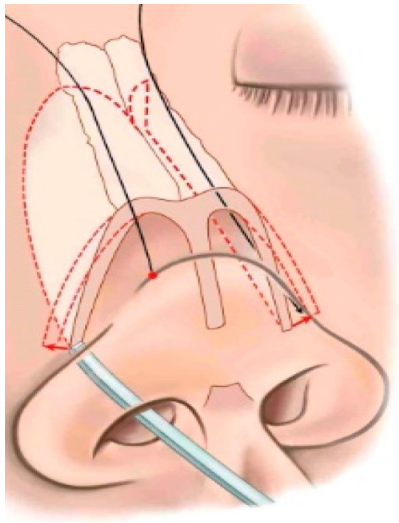
Ongoing Studies_2

Design of Biopsy Needle-guided holder in CT_Based Intervention



Ongoing Studies_3

Design of Surgical Tool Design attached with Rigid bodies



- User-friendly for Surgeons during Operation
- Design with easy add/remove Rigid-bodies during intra-operation
- Bio-degradable and Materials that can be used in CT guided surgical system
- 3D CAD-models of surgical tools for Simulation and Imaging Techniques

Thank You