

Shared control of a teleoperated echographic probe

Master's Degree in Artificial Intelligence and Robotics

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Overview

Introduction

Echography, and ultrasound imaging, is a widely used medical technique with multiple application in various field of medicine. It's a safe and non-invasive procedure for all kind of people of all ages.

This project focuses on the development of a shared control system for a teleoperated echographic probe integrated with the **Franka Emika Panda Robot**.

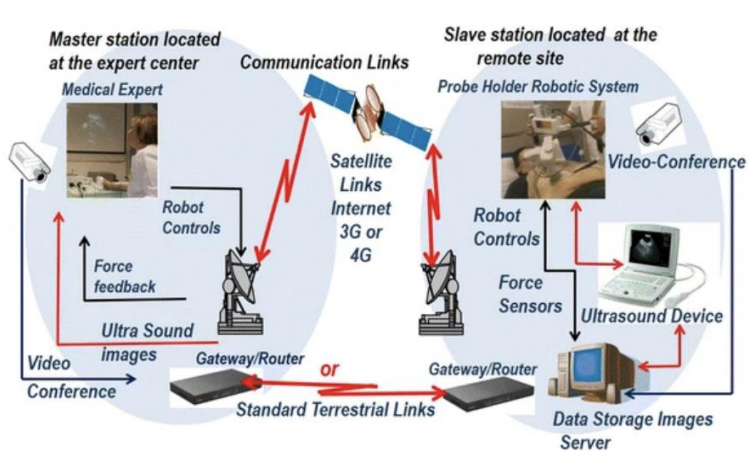
We focused on a **shared control** architecture for collaboration between robot and human operator to achieve the precise task execution typical of robots, while giving total controllability to the operator in the decision making.

Also assuring safety of the subject by introducing multiple **safety measures**.



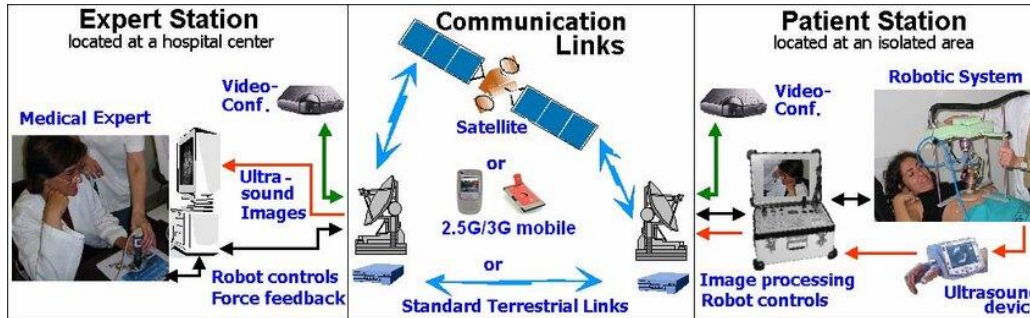
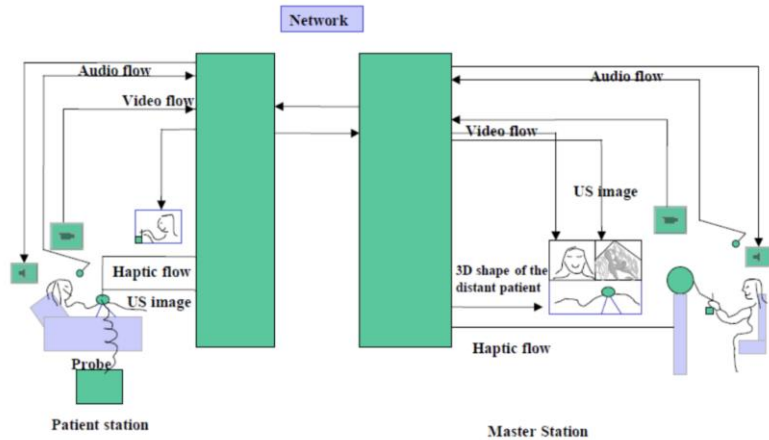
State of the art

Introduction



- **MELODY System**

- **TER architecture**



- **OTELO System**



Pipeline

Introduction

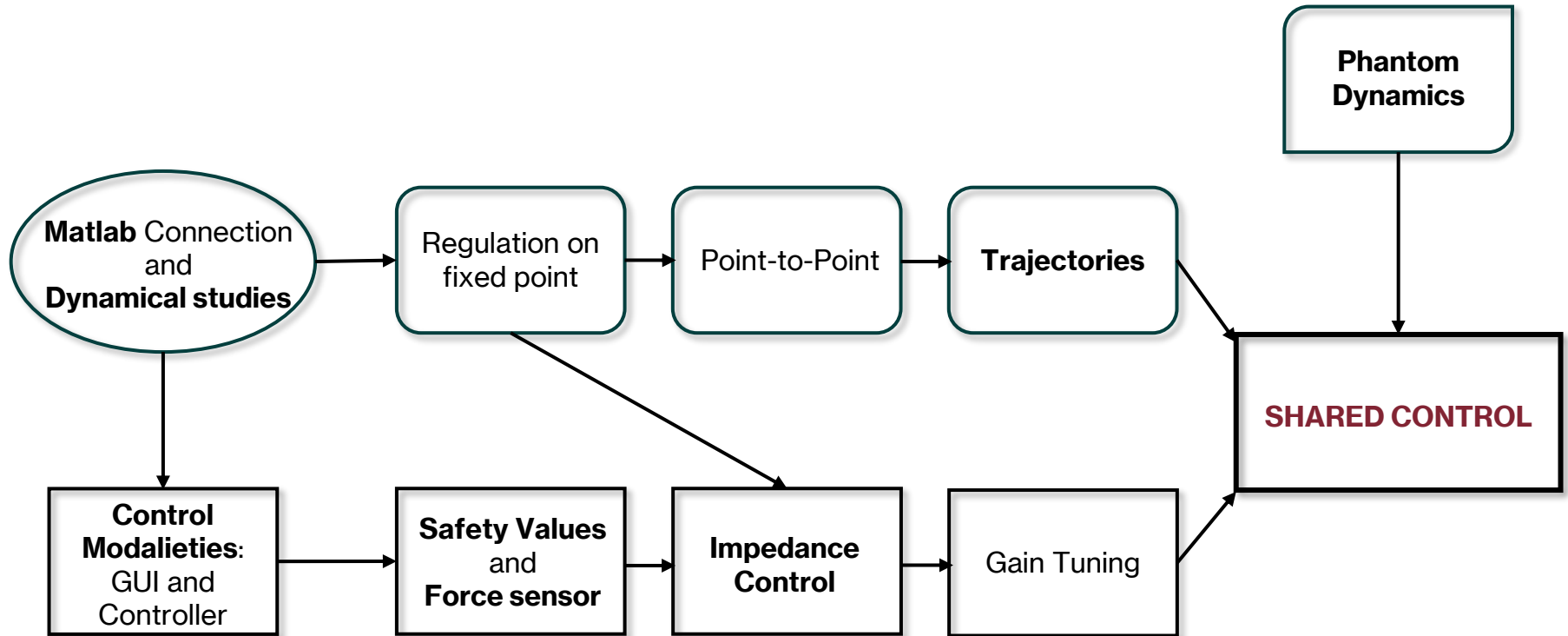




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Task definition

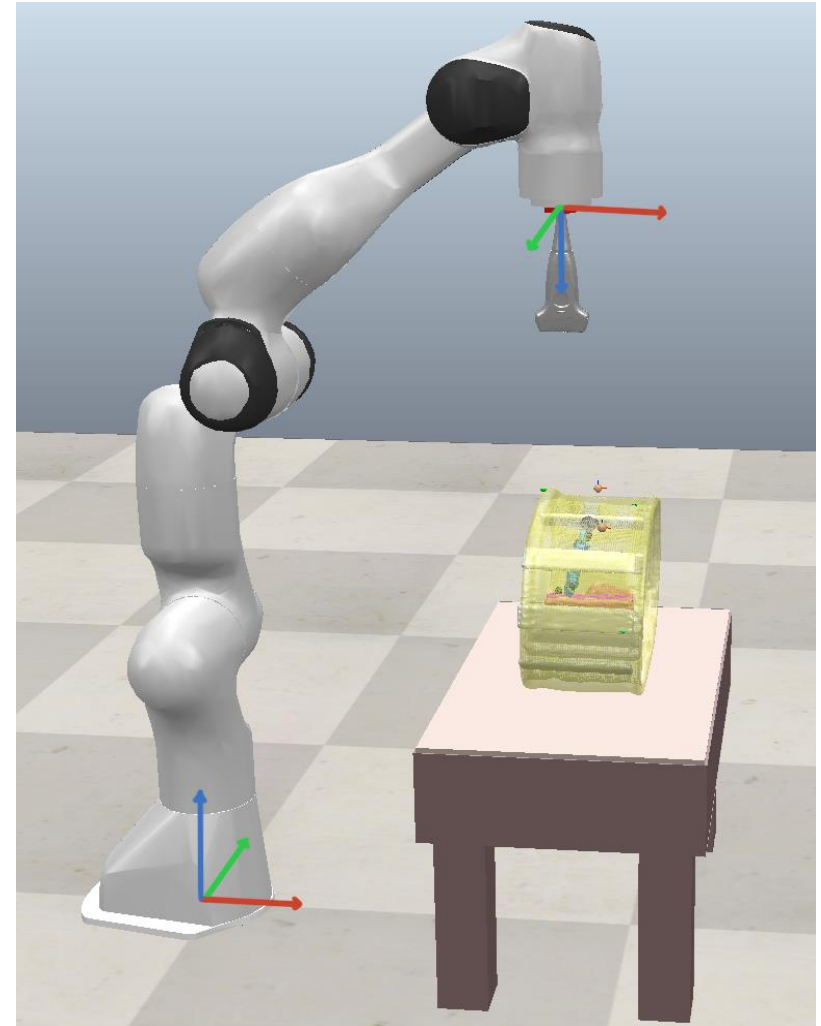
Control Method

The **ecography task** is defined in terms of:

- End-effector position: $\mathbf{p}_e \in \mathbb{R}^3$
- Euler angles orientation: $(\phi, \theta) \in SO(3)$
- 4-th link height: $z^{4th} \in \mathbb{R}$

$$\mathbf{r} = \begin{pmatrix} \mathbf{p}_e \\ \theta \\ z^{4th} \\ \phi \end{pmatrix}$$

⇒ **Task Augmentation** technique!





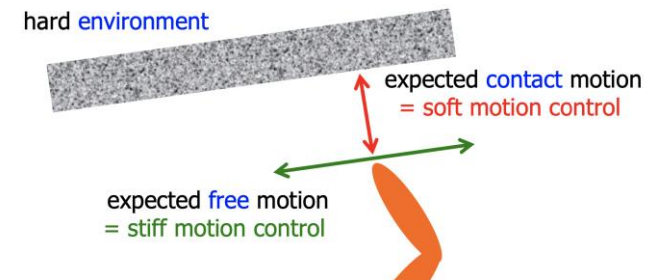
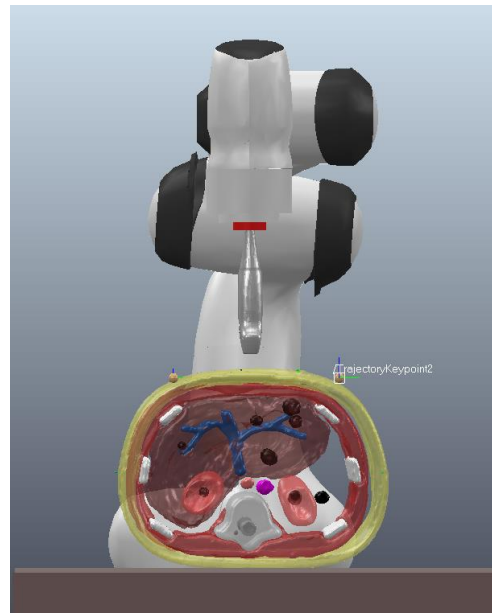
Impedance control

Control Method

- **Impedance** control law + joint velocity **damping**:

$$u = M(q)J_r(q)^\# \{ \ddot{r}_d - \dot{J}_r(q)\dot{q} \} + S(q, \dot{q})\dot{q} + g + J_r(q)^T [D_m(\dot{r}_d - \dot{r}) + K_m(r_d - r)] - D_q\dot{q}$$

- K_m, D_m and D_q are diagonal, positive definite gain matrices.
- A special attention is reserved for K_z (interaction expected in z direction!!!)

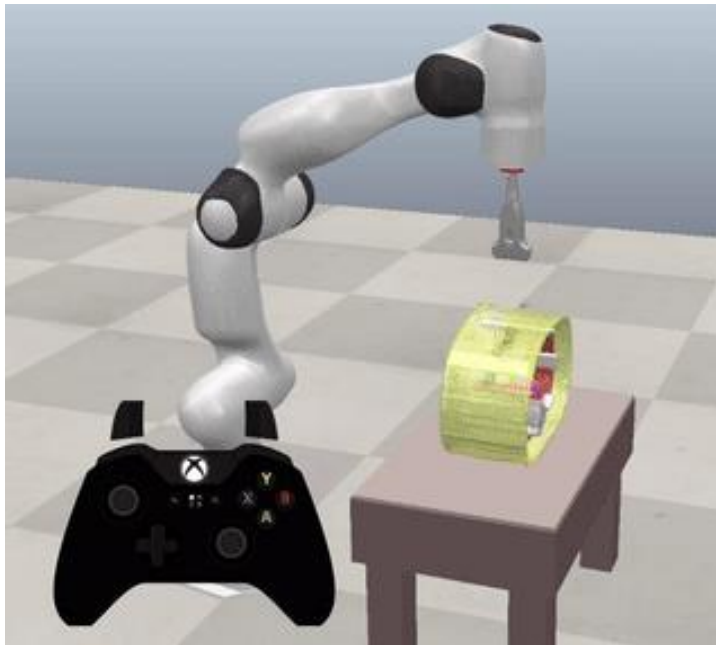




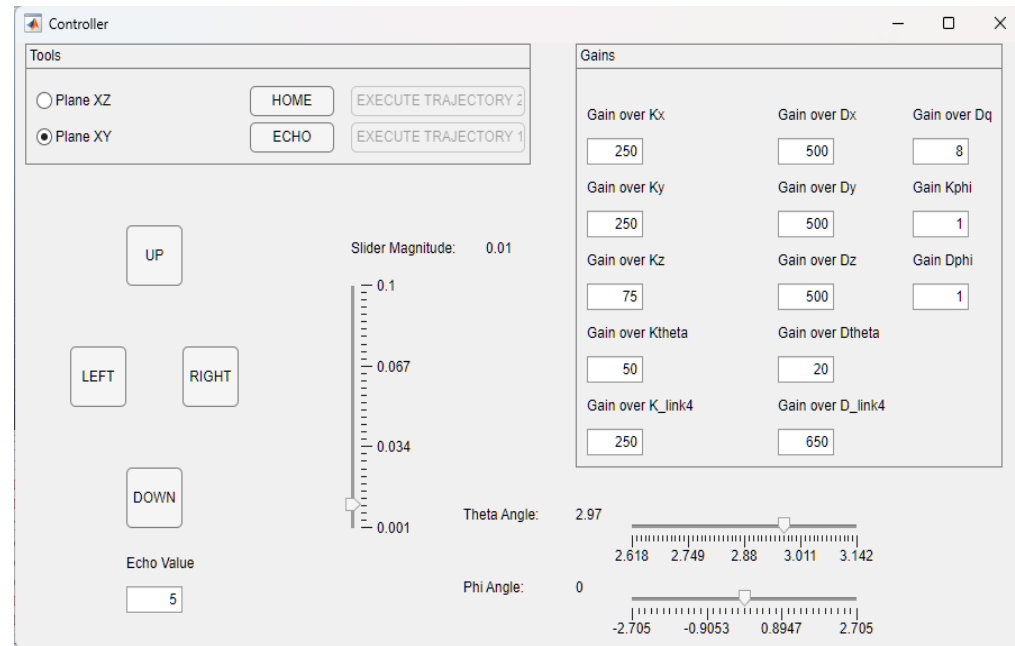
Control Modalities

Control Method

- **Xinput controller**



- **GUI**





Shared control

Control Method

- **Safety Value**

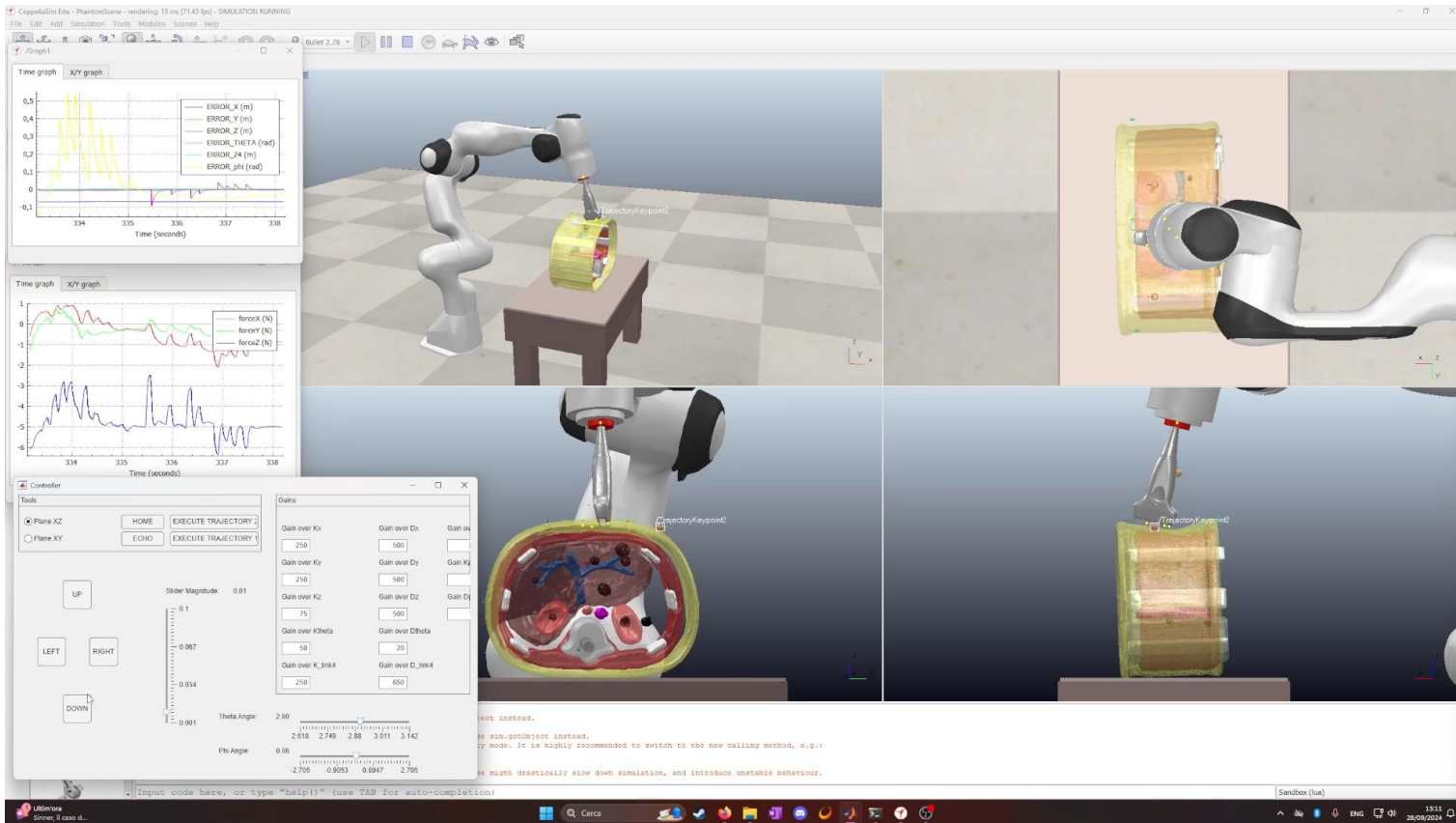




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Trajectories

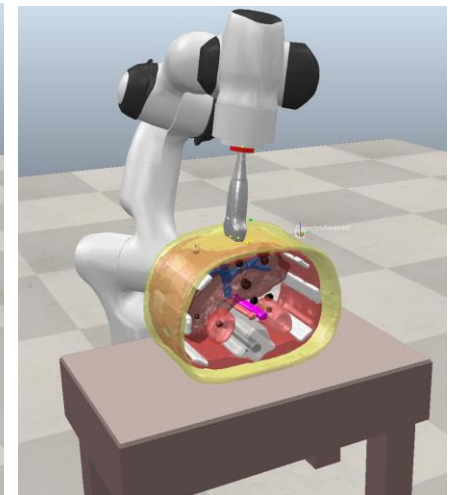
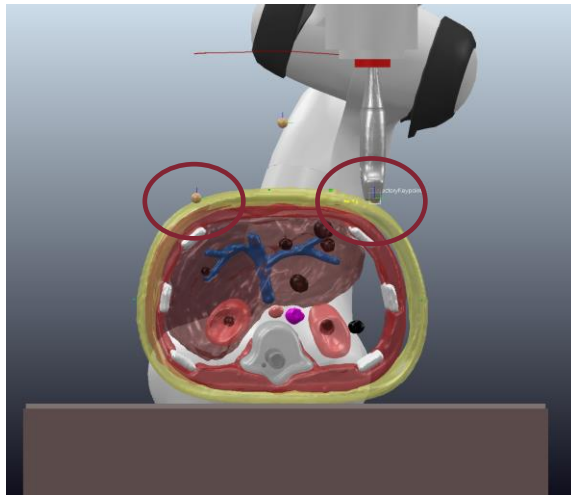
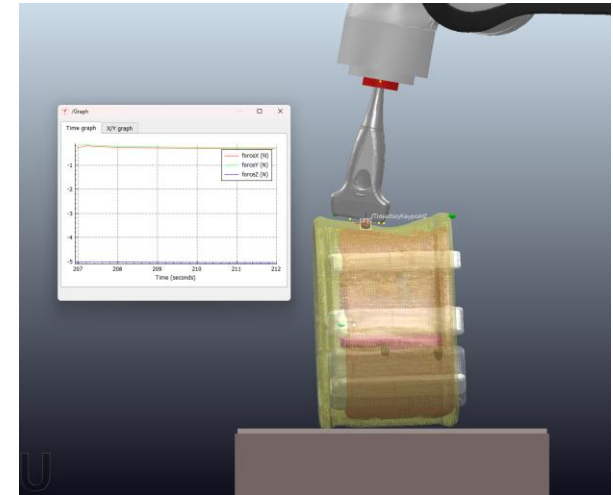
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Trajectories introduction

Trajectories

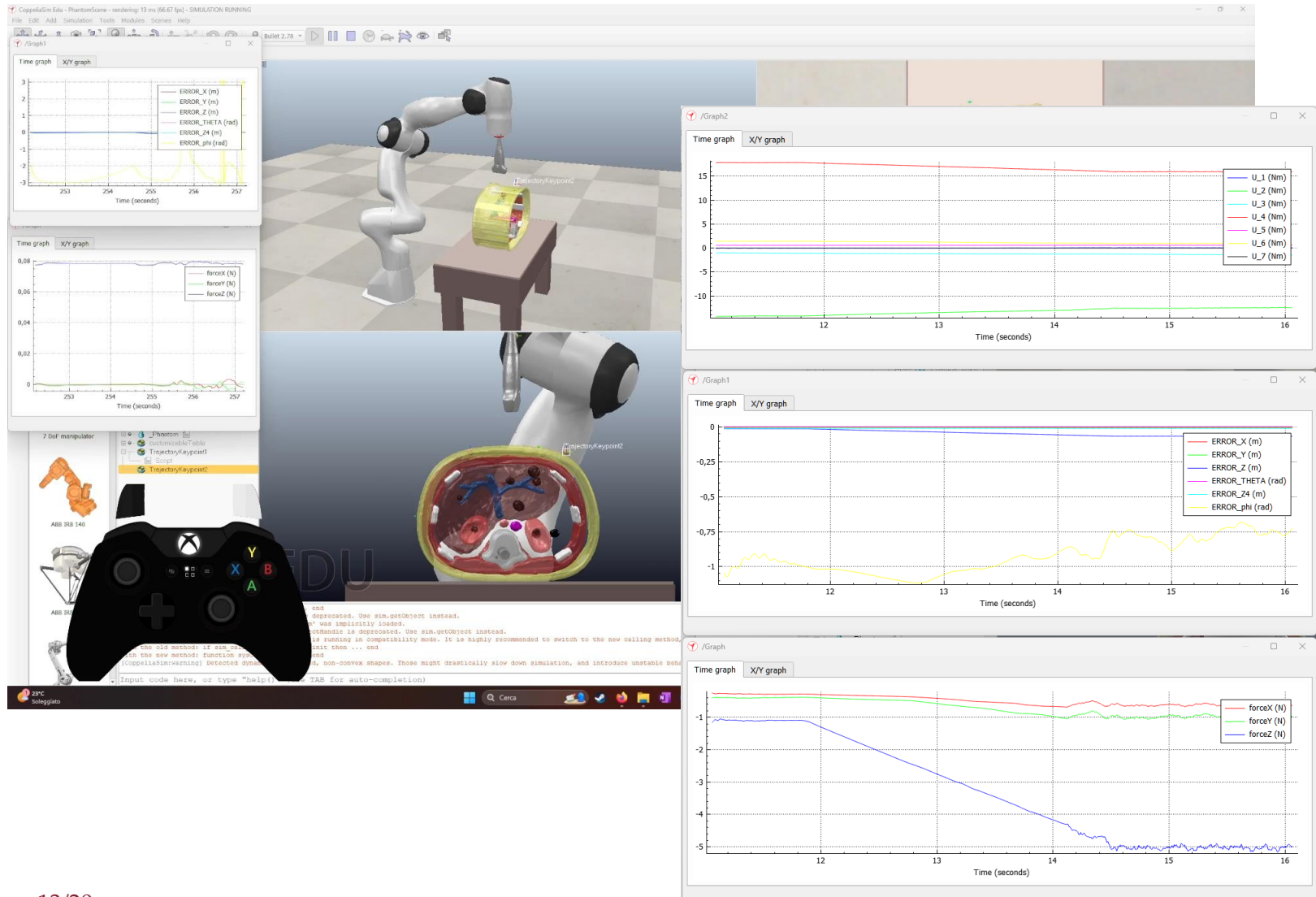
- **Echo Modality:** tool that permits to slowly approach the patient, reaching a predefined threshold on applied Z-force. It ensures safety and repeatability.
- **Linear Trajectory:** linear cartesian path between two adjustable point.
- **Wrist Trajectory:** sinusoidal movement for the ϕ angle





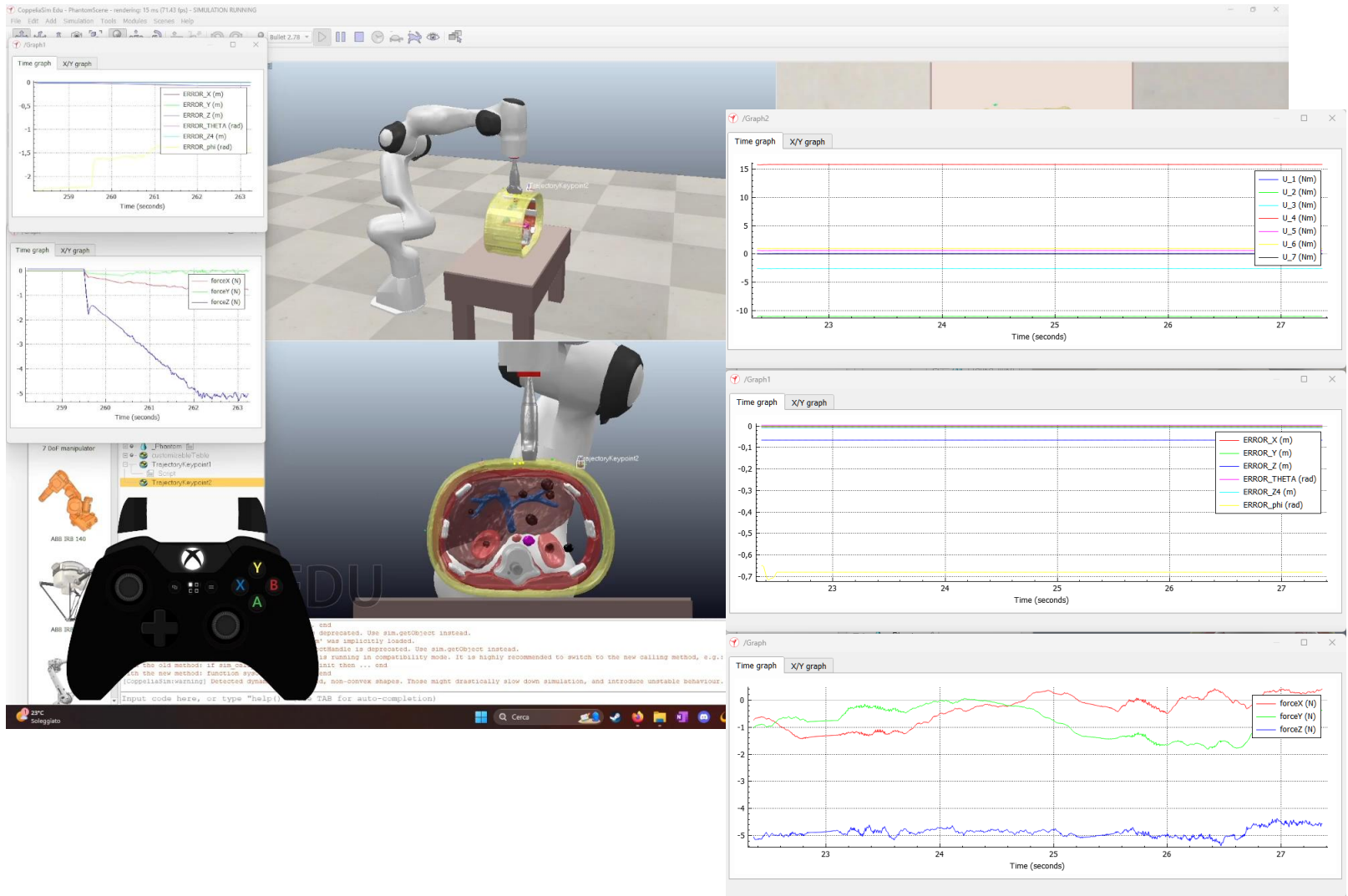
Echo Modality

Trajectories





Linear Trajectory Trajectories





Wrist Trajectory

Trajectories

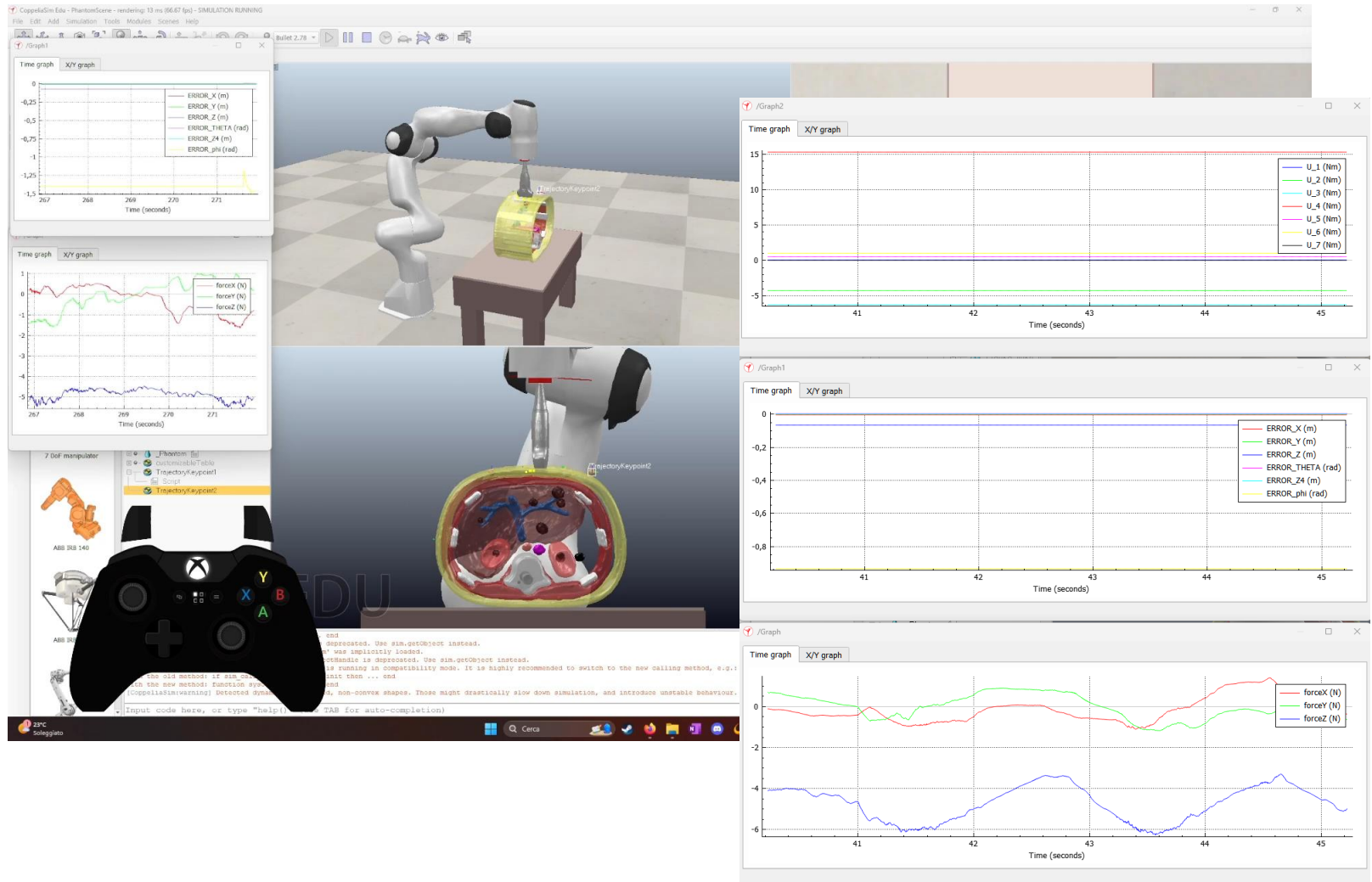




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Conclusions

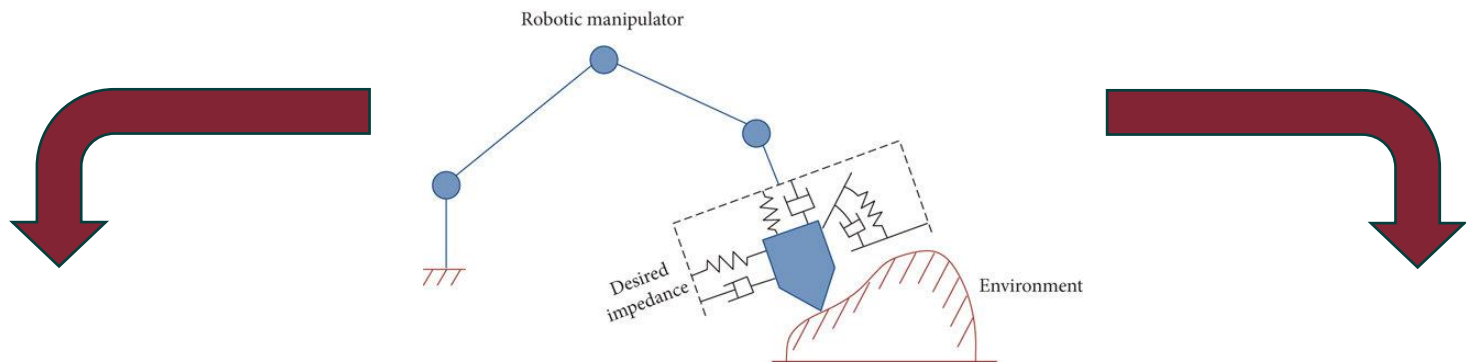
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Conclusions

Conclusions

- **Human touch meets automation** \Rightarrow develop an integrated framework combining automation and operator direct control thanks to **shared control**.



- **Precision with Impedance Control**

- Safe and smooth interaction with patients, providing compliant and responsive behavior.
- Torque-level control and task augmentation for smooth task execution.

- **Ensuring safety**

Operator can manually adjust the robot's actions without compromising safety

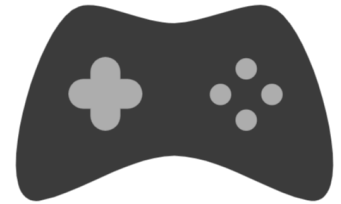


Future Works

Conclusions

Opportunities for Growth:

- **Force feedback Integration:**
 - Vibrations proportional to sensed force (Z-axis or total force vector).
 - Provides operator **tactile feedback**.
 - Enhances control and safety during operations.
- **Master-Slave Control System:**
 - Offers a more intuitive control method.
 - **Geomagic** system as a potential solution.
 - Improves precision and ease of operation.
- **Task Augmentation:**
 - Explore alternative approaches like **task priority**.
 - Minimizes critical task errors while tolerating non-critical ones.





Final Thanks

Conclusions

Thanks for your attention!



Reference

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