Shared control of a teleoperated echographic probe

Master’s Degree in Artificial Intelligence and Robotics

Paradiso Emiliano (1940454)
Piccione Brian (1889051)
Pisapia Vittorio (1918590)

SAPIENZA
UNIVERSITÀ DI ROMA

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Overview

Introduction

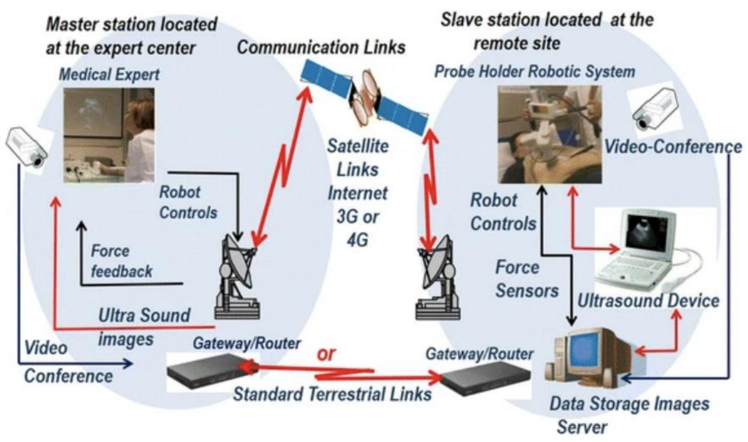
Echography, and ultrasound imaging, is a widely used medical technique with multiple application in various field of medicine. It’s a safe and non-invasive procedure for all kind of people of all ages.

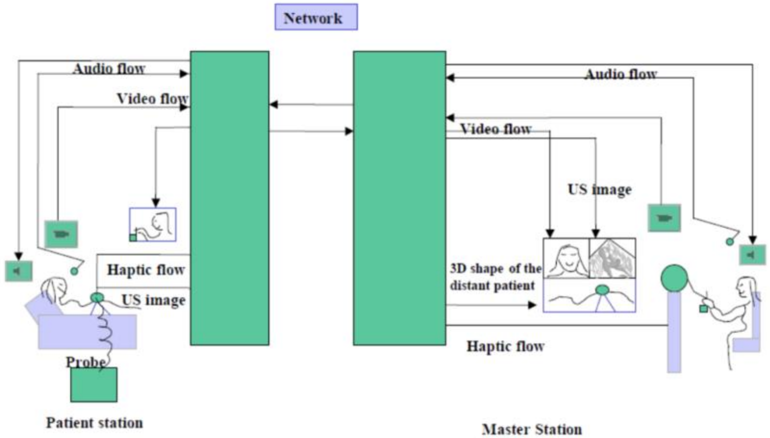
This project focuses on the development of a shared control system for a teleoperated echographic probe integrated with the **Franka Emika Panda Robot**.

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.

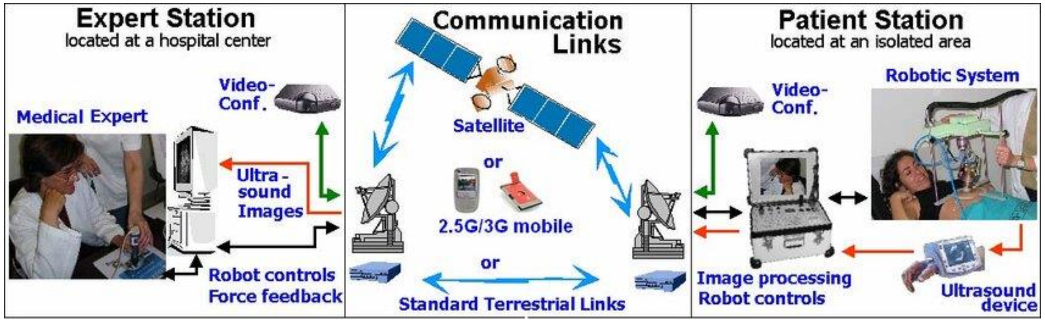
Also assuring safety of the subject by introducing multiple **safety measures.**

State of the art
Introduction





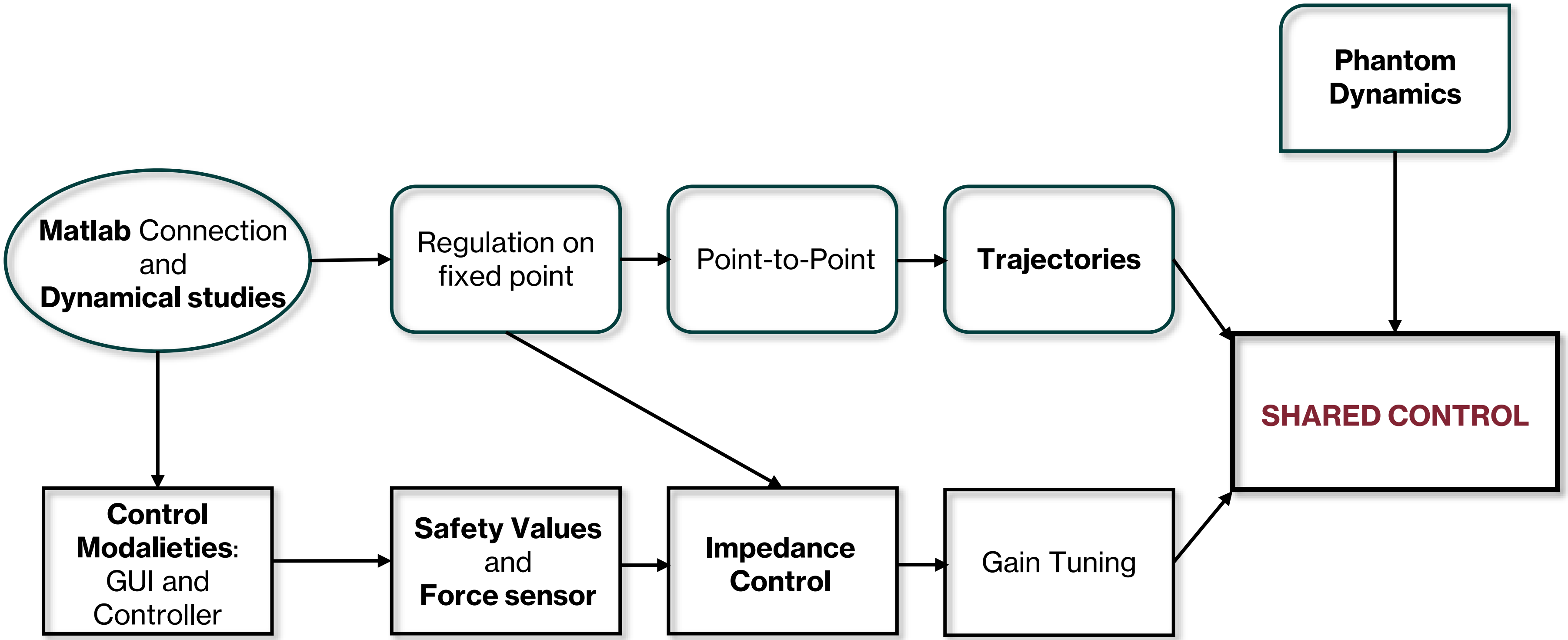
- **MELODY** System
- **TER** architecture



- **OTELO** System

Pipeline

Introduction



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Control

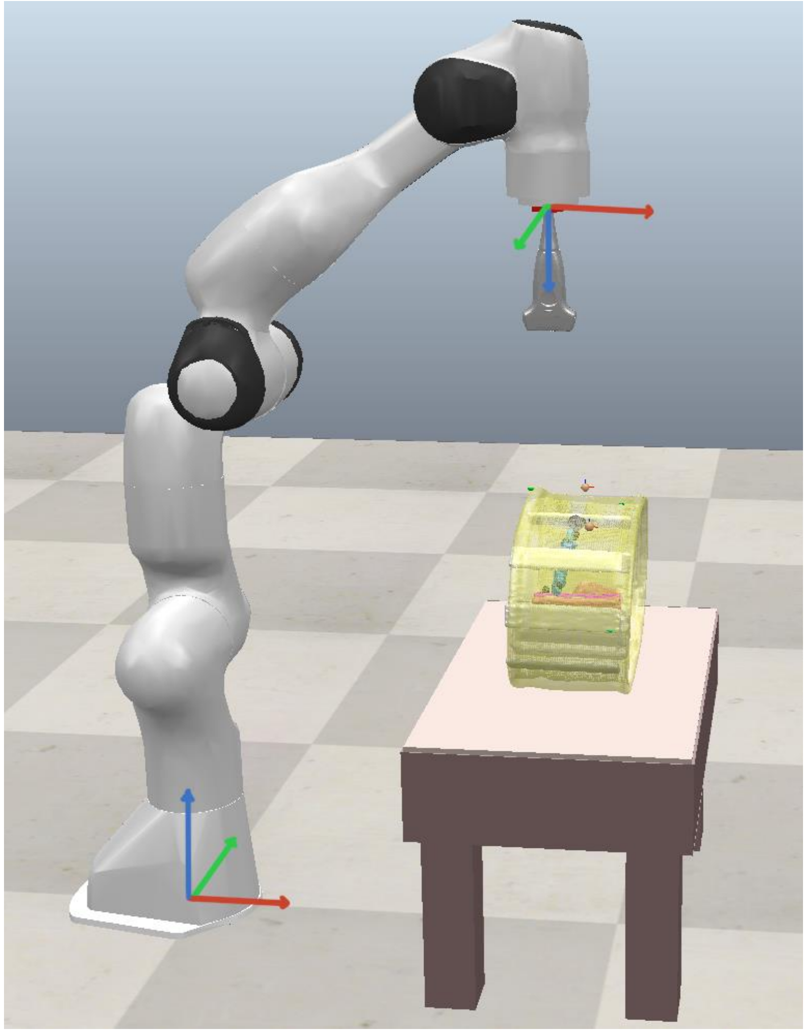
Task definition
Control Method

The ecography task is defined in terms of:

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

$$r = \begin{pmatrix} \boldsymbol{p_e} \\ \theta \\ z^{4th} \\ \phi \end{pmatrix}$$

⇒**Task Augmentation** technique!



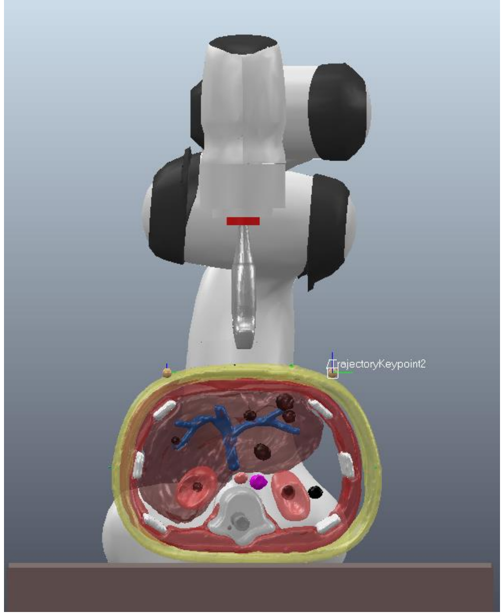
Impedance control

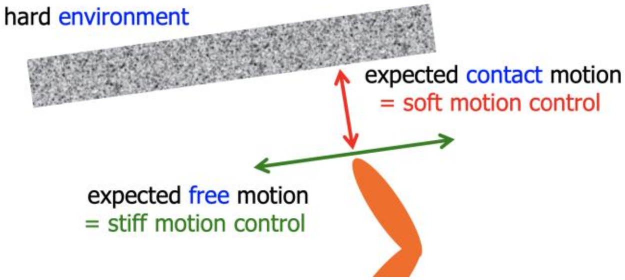
Control Method

- **Impedence** control law + joint velocity **dumping:**

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

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

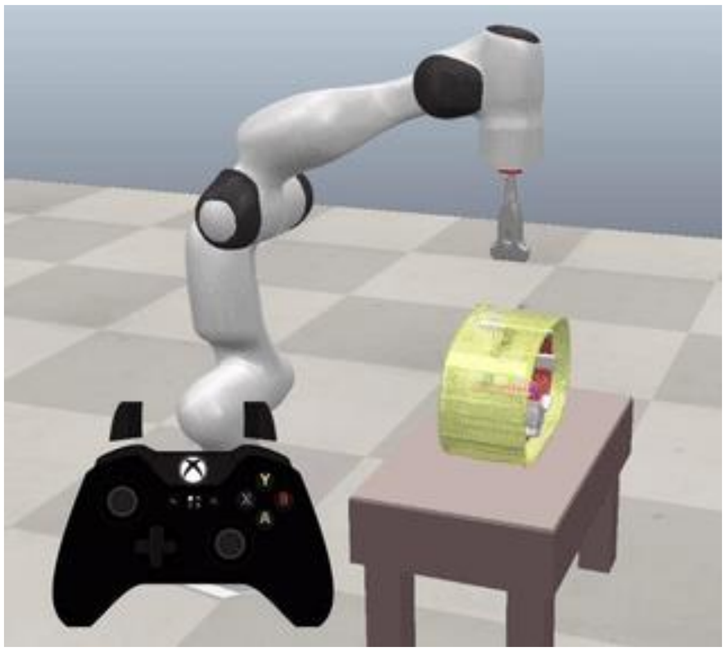




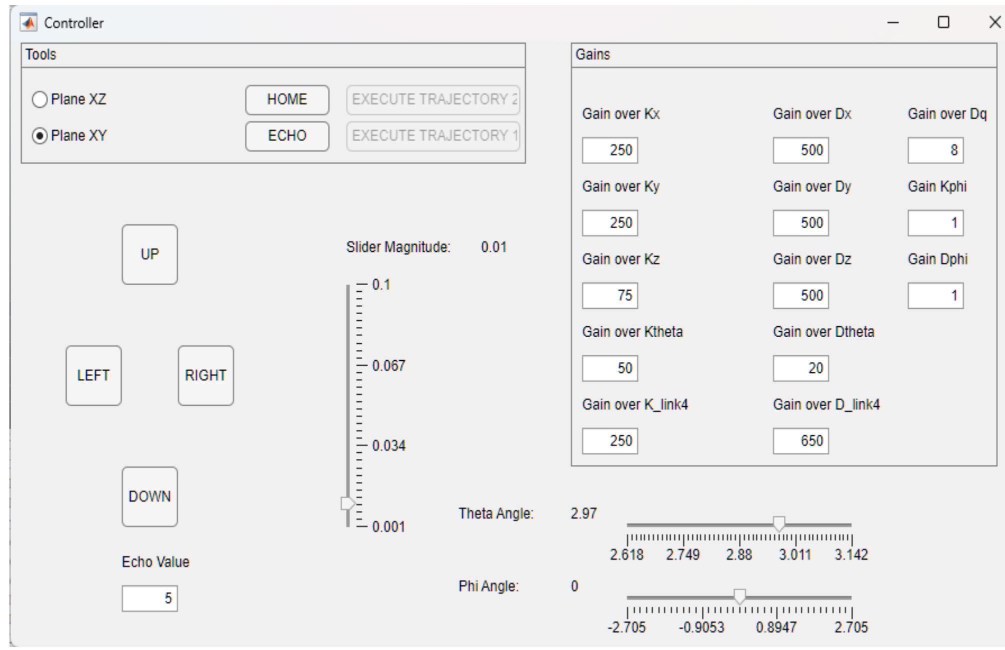
Control Modalities

Control Method

- **Xinput controller**



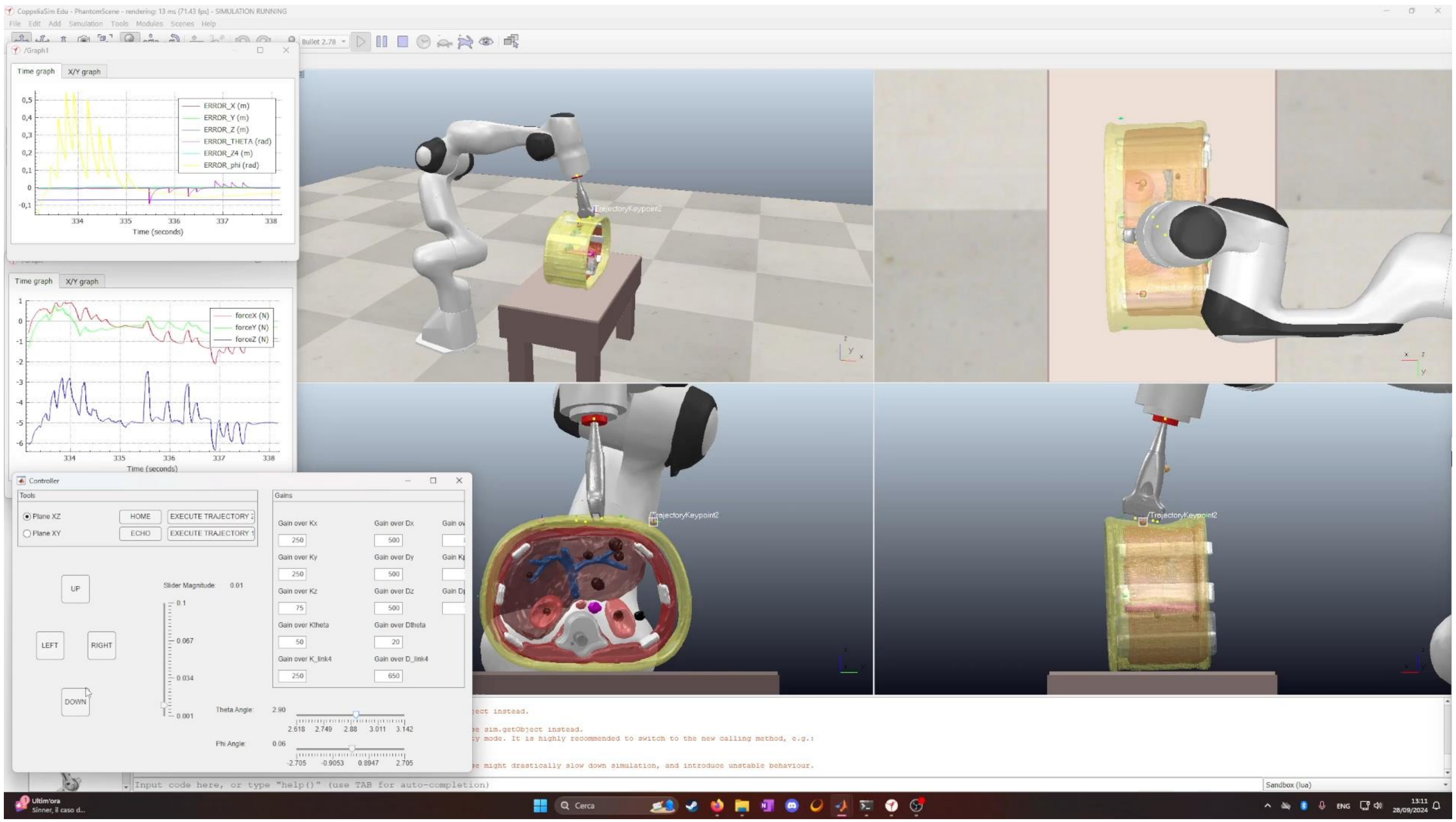
- **GUI**



Shared control

Control Method

- **Safety Value**



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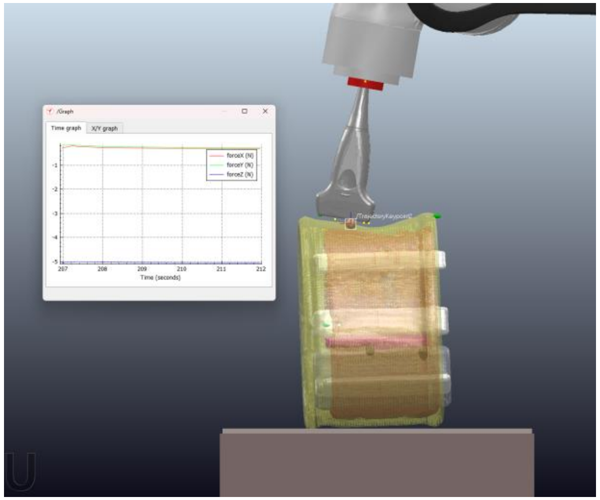
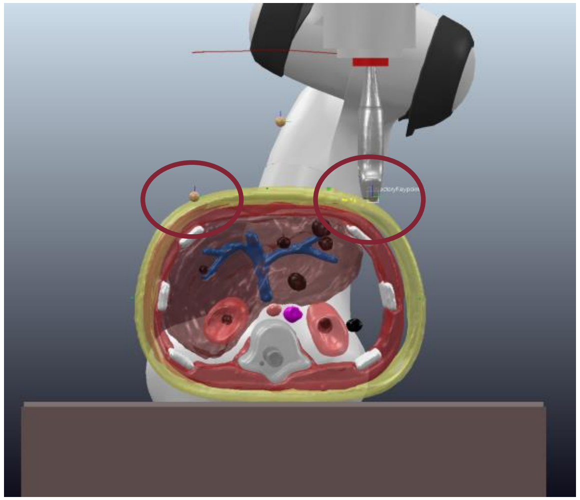
Trajectories

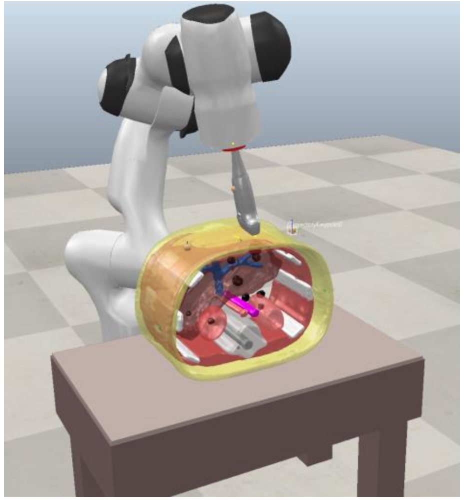
Trajectories introduction

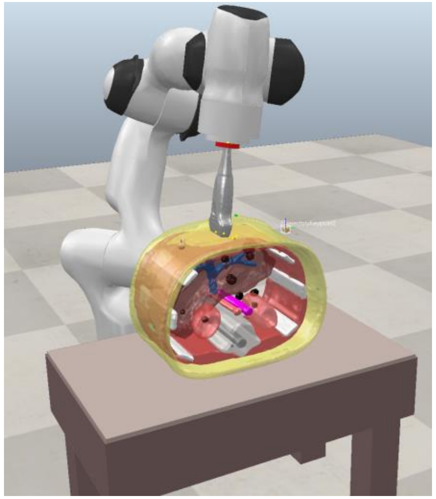
Trajectories



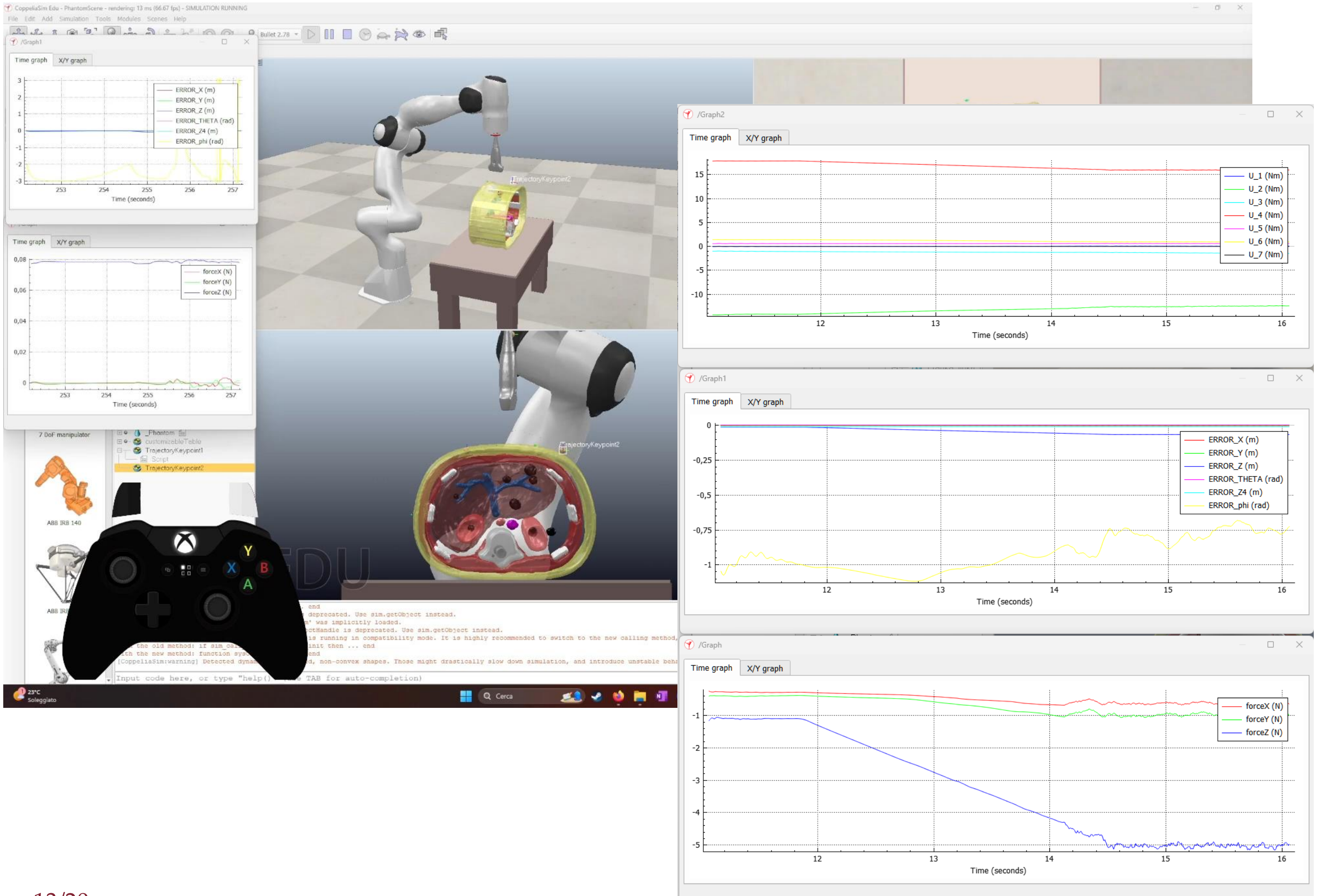
- **Echo Modality**: tool that permits to slowly approach the patient, reaching a predefined threshold on applied Z-force. It ensures safety and repatability.
- **Linear Trajectory**: linear cartesian path between two adjustable point.
- **Wrist Trajectory**: sinusoidal movement for the ϕ angle







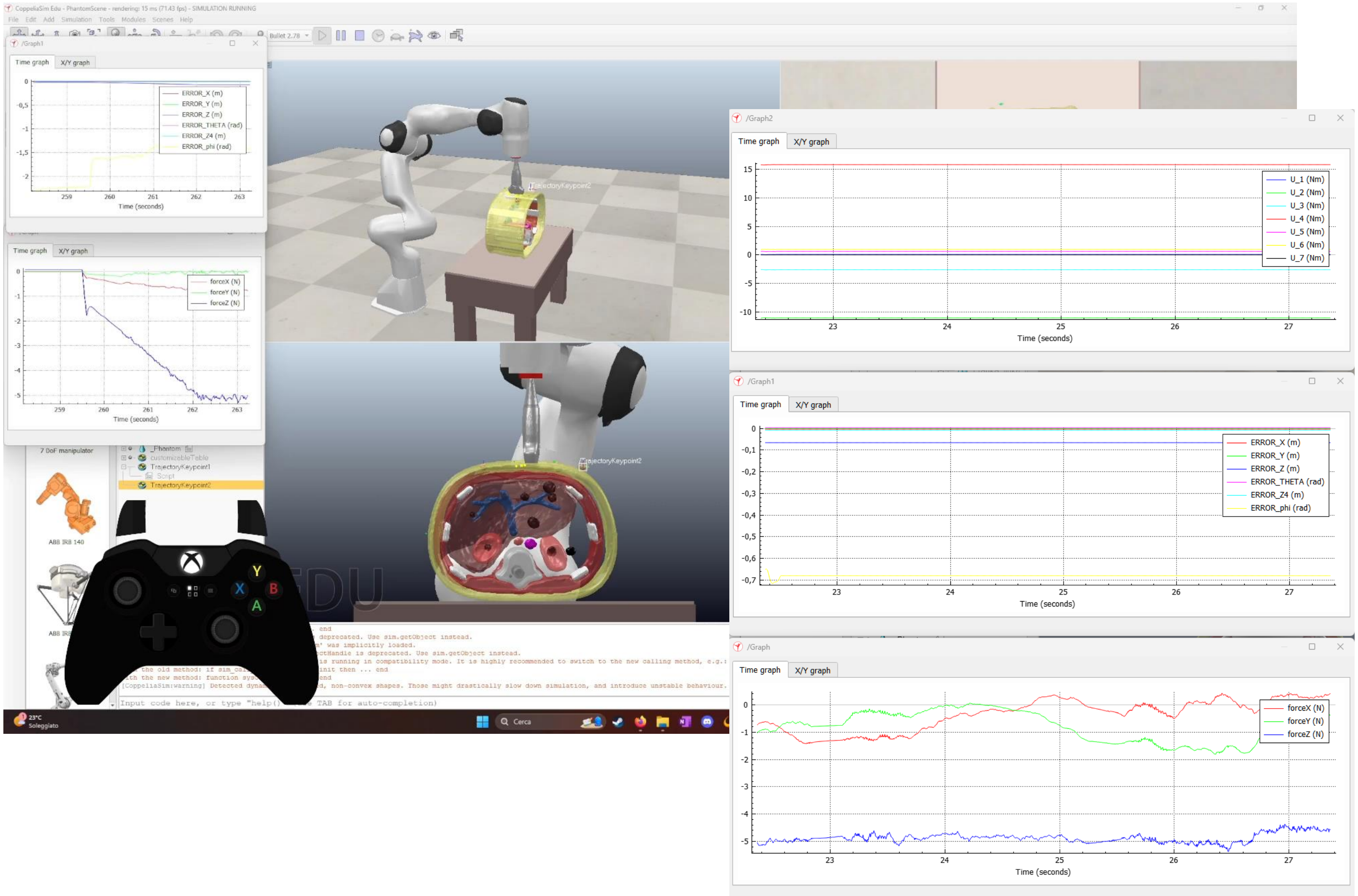
Echo Modality
Trajectories



Linear Trajectory

Trajectories

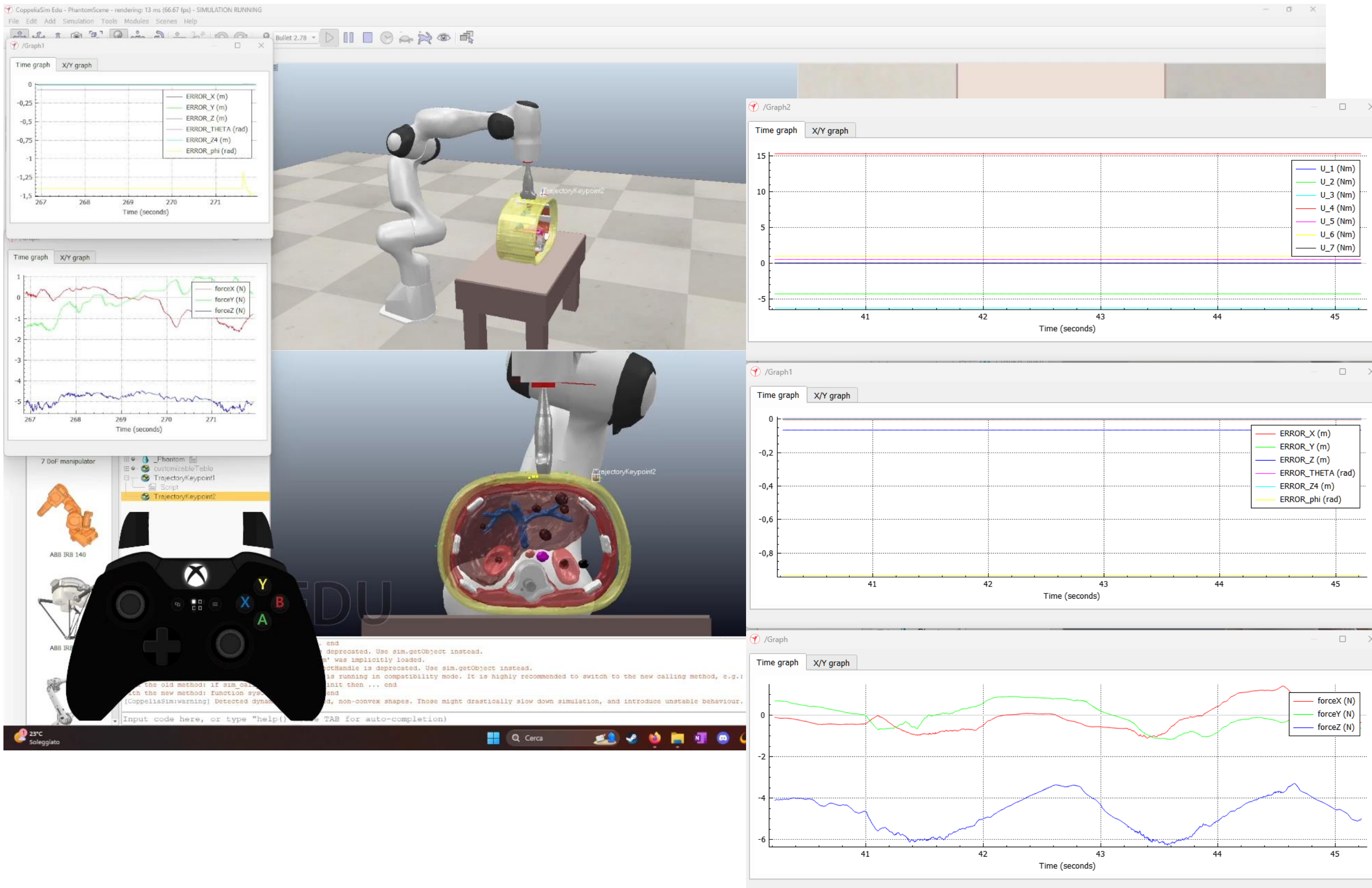
$$y(t) = r_{d2} + A * \sin(\pi * \frac{t}{T})$$



Wrist Trajectory

Trajectories

$$\phi(t) = C * \sin(2\pi * \frac{t}{T})$$



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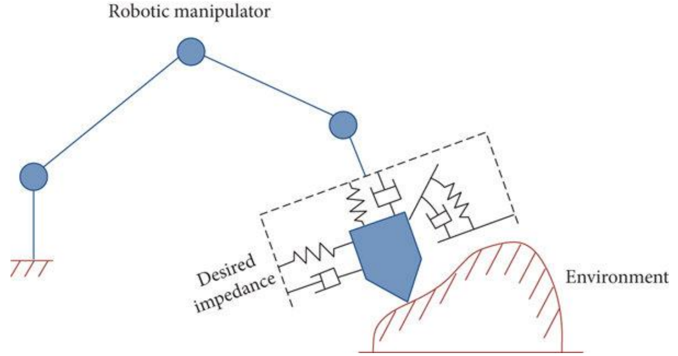
Conclusions

Conclusions

Conclusions

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



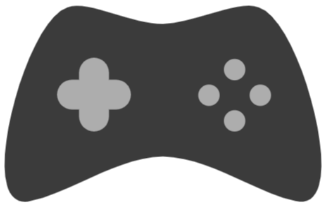
- **Precision with Impedence Control**
  – Safe and smooth interaction with patients, providing compliant and responsive behavior.
  – Torque-level control and task augmentation for smooth task execution.

- **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 Agumentation**:
  - Explore alternative approaches like task priority.
  - Minimizes critial task errors while tolerating non-critical ones.

Thanks for your attention!

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