Underactuated Gripper with Forearm Roll Estimation for Human Limbs Manipulation in Rescue Robotics

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1. Introduction

- Main Goal: Autonomous robots that can **detect** victims in disaster scenarios, **assist** the victims and **evacuate** them if necessary
- Challenge: Autonomous manipulation of victims - physical Human-Robot Interaction (**pHRI**)
- Applications: biometric sensors placement, needle insertion, rehabilitation, etc

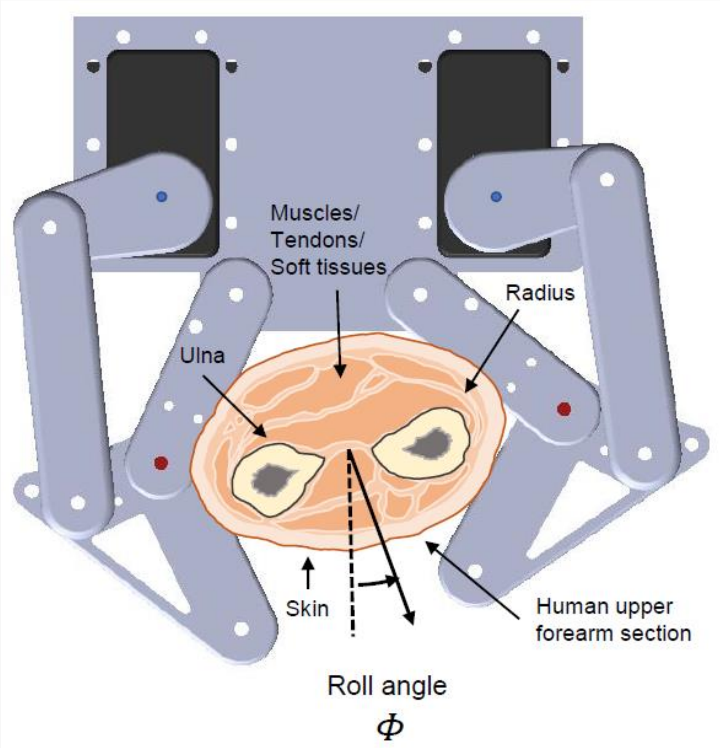
2. Problem Statement

1. Stable grasping of the forearm

The position of the forearm makes **difficult** to carry out a stable grasping following **classic** grasping **strategies**

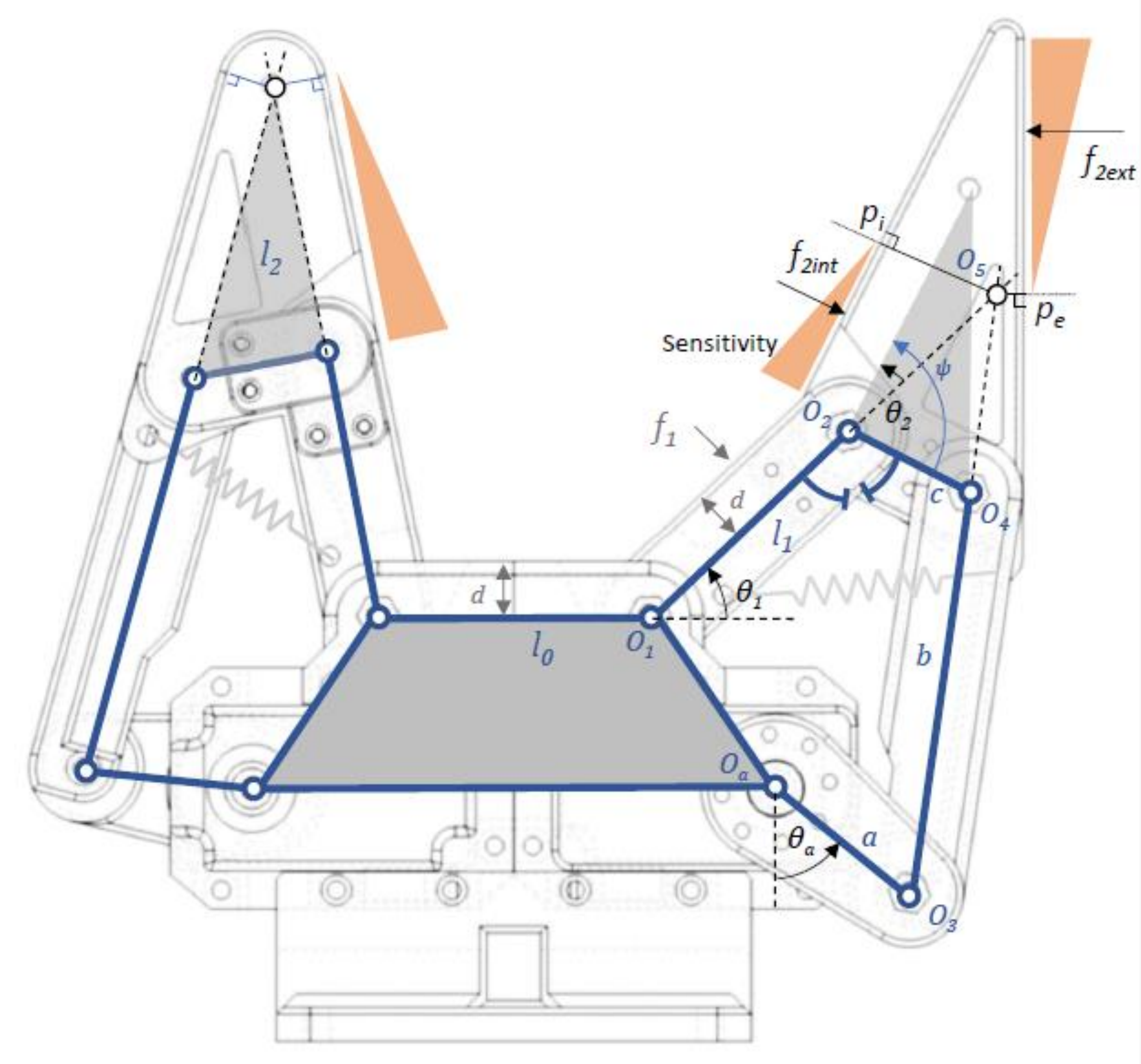
2. Forearm roll-angle estimation

It is important to estimate the roll-angle of the grasped arm in order to make a **safe motion planning**

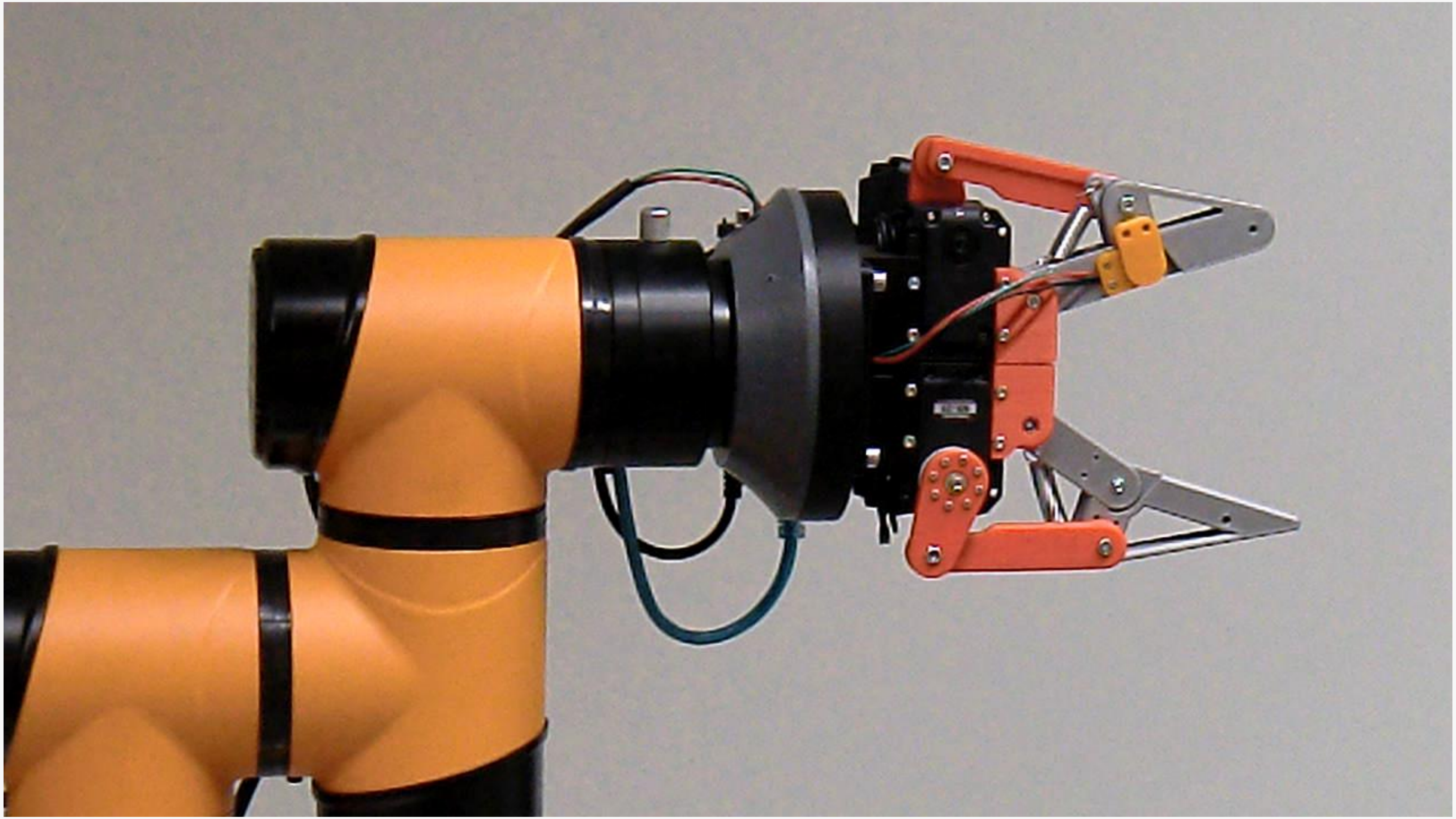


3. Underactuated Gripper

- **Two** independent **underactuated fingers** with **two phalanxes** and a **single actuator** each
- The length of the **distal phalanx** are **different** to provide **two** kind of **behaviors** under external and internal forces
- **Tendons** have been **discarded** due to the displacements of the contact surfaces which **pinch** the skin of the forearm
- By adding **proprioceptive** angular **sensors**, the angles θ_{2_i} are measured

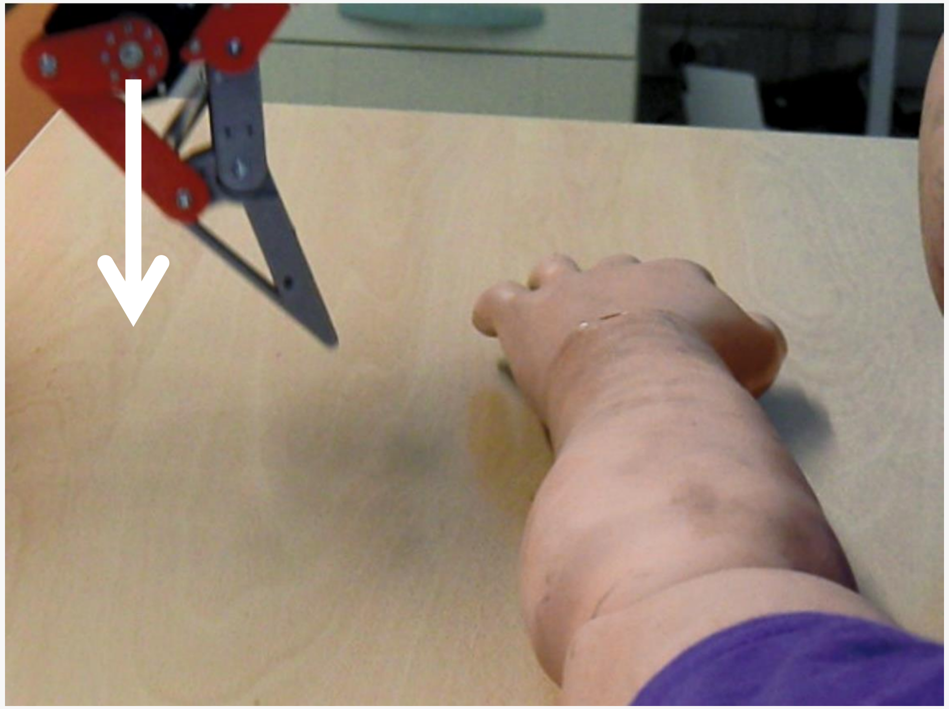


3. Underactuated Gripper



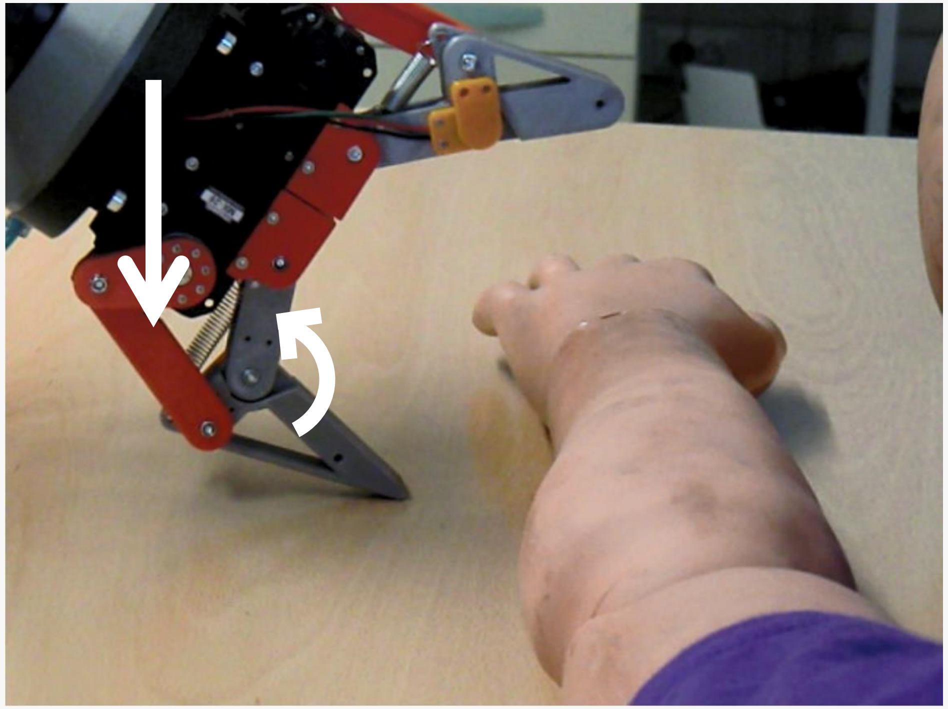
4. Grasping Strategy

1. Approach



Vertical movement toward the surface

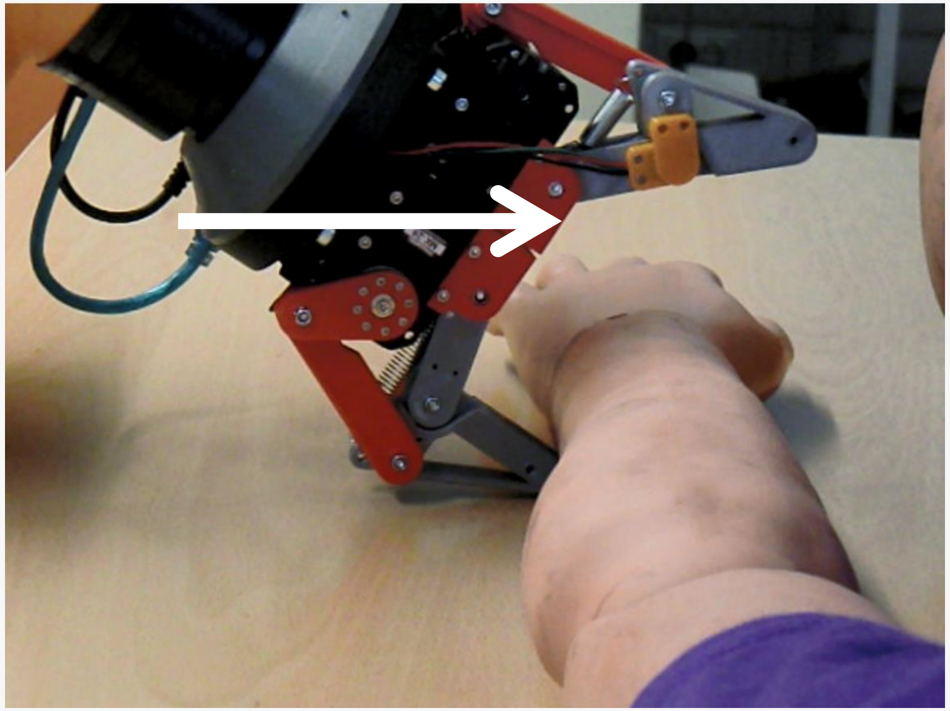
2. Find the surface



Measure the distance to the table

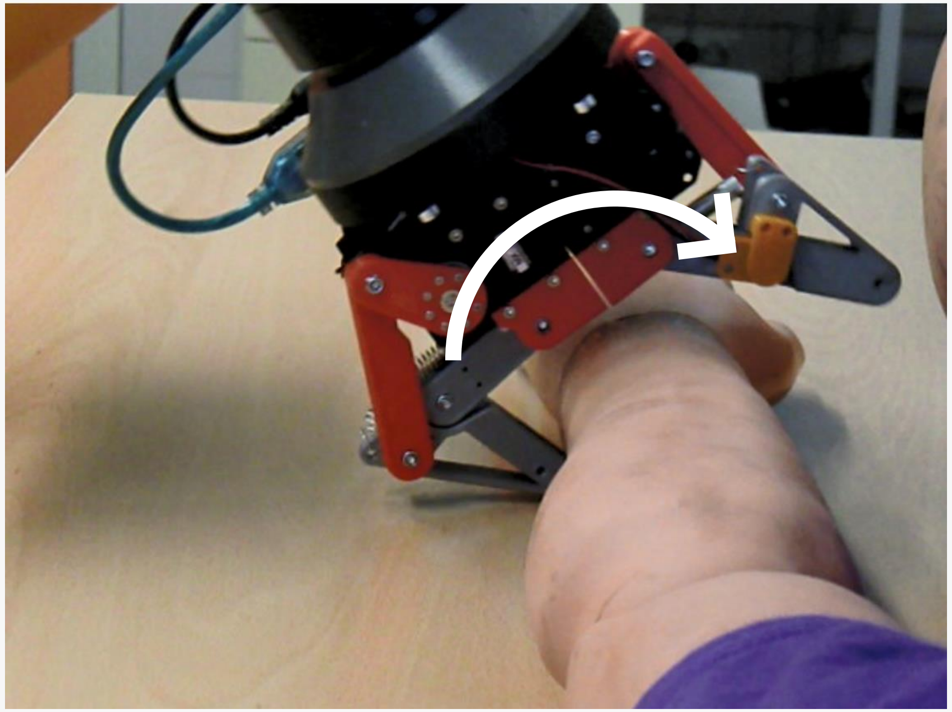
4. Grasping Strategy

3. Surface following



Movement toward the forearm

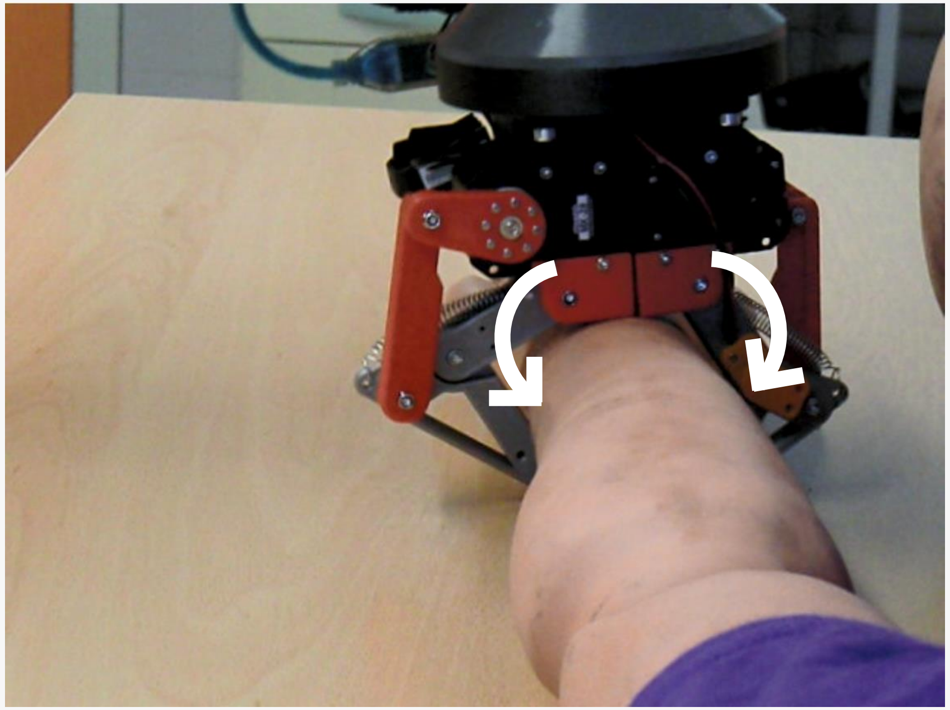
4.1. Grasping I



Rotation over the TCP

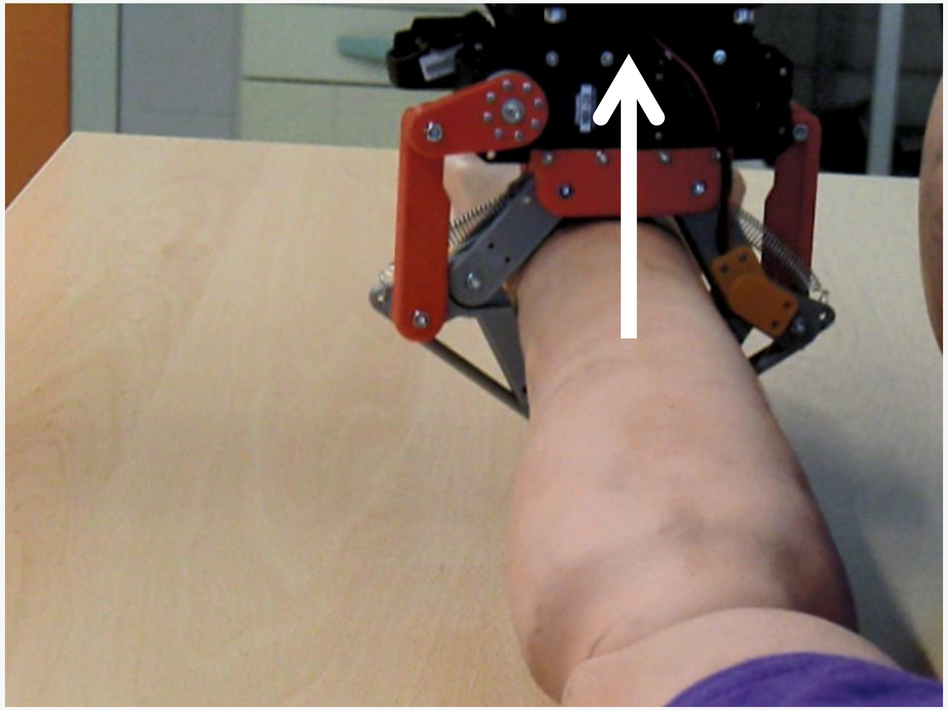
4. Grasping Strategy

4.2. Grasping II



Closing the gripper

5. Lift

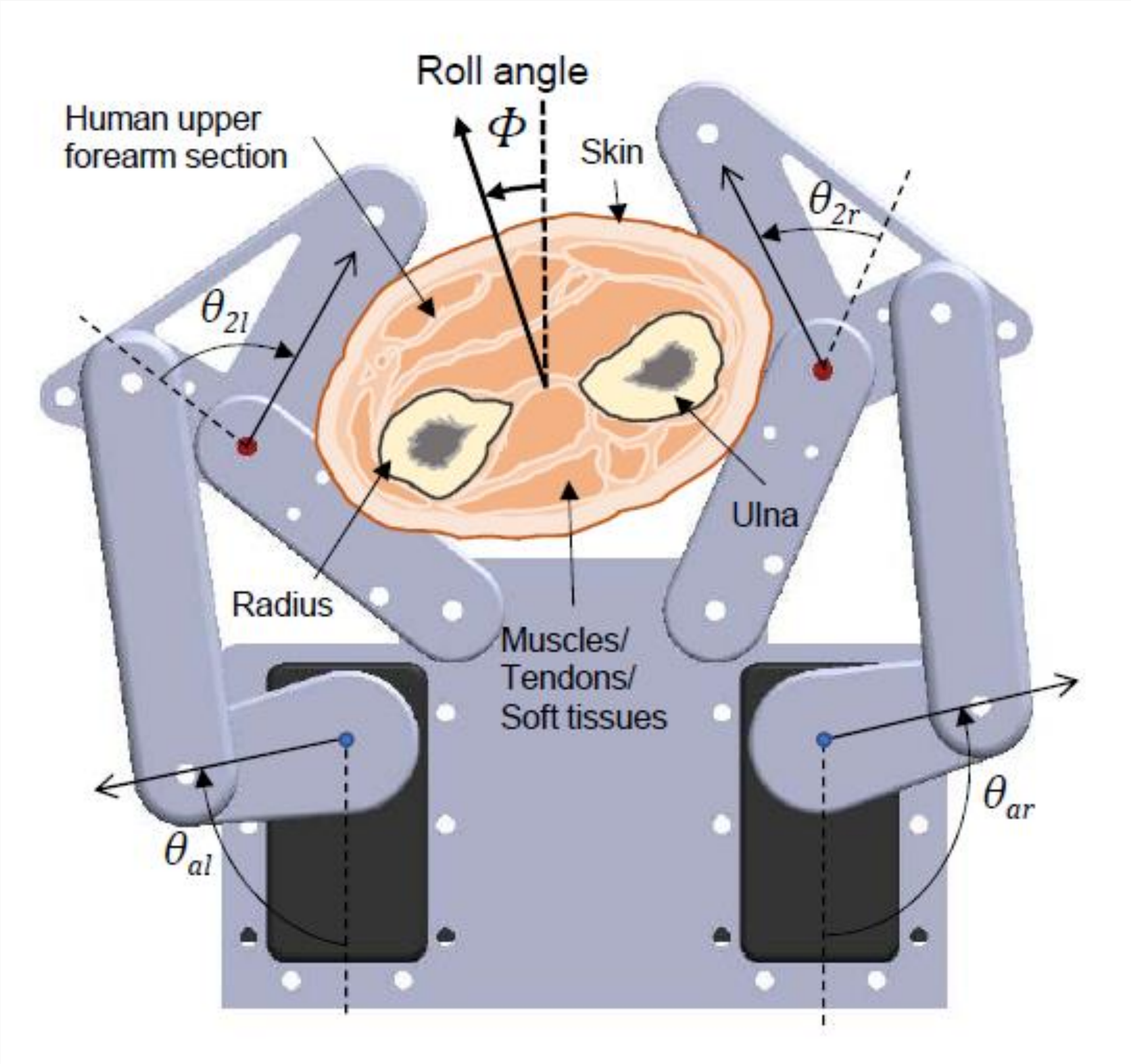


Vertical movement and relocation

4. Grasping Strategy

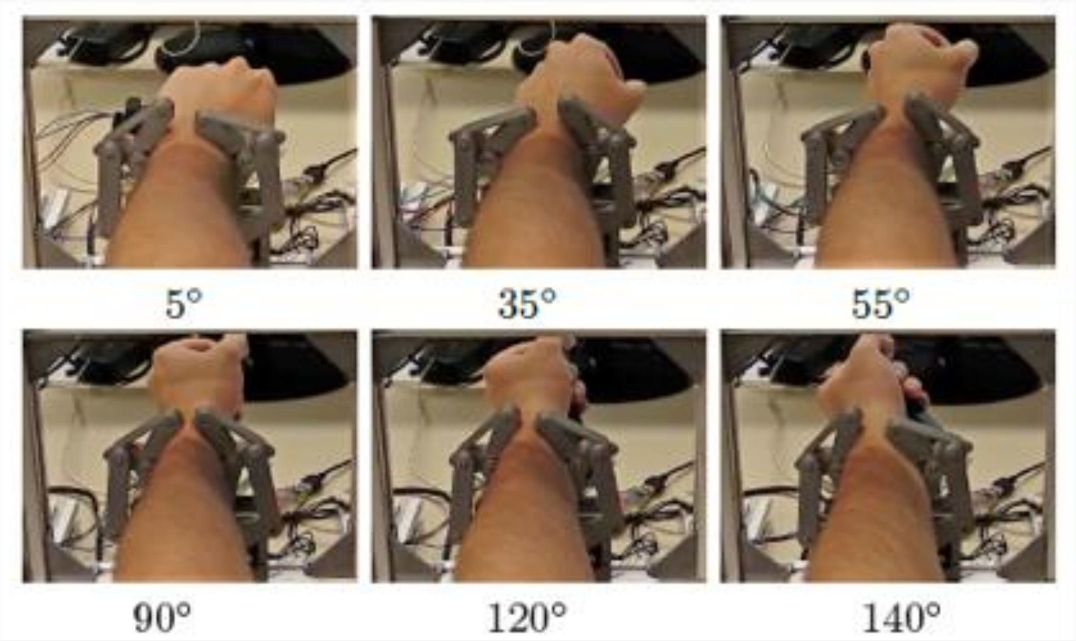
5. Roll-angle Estimation

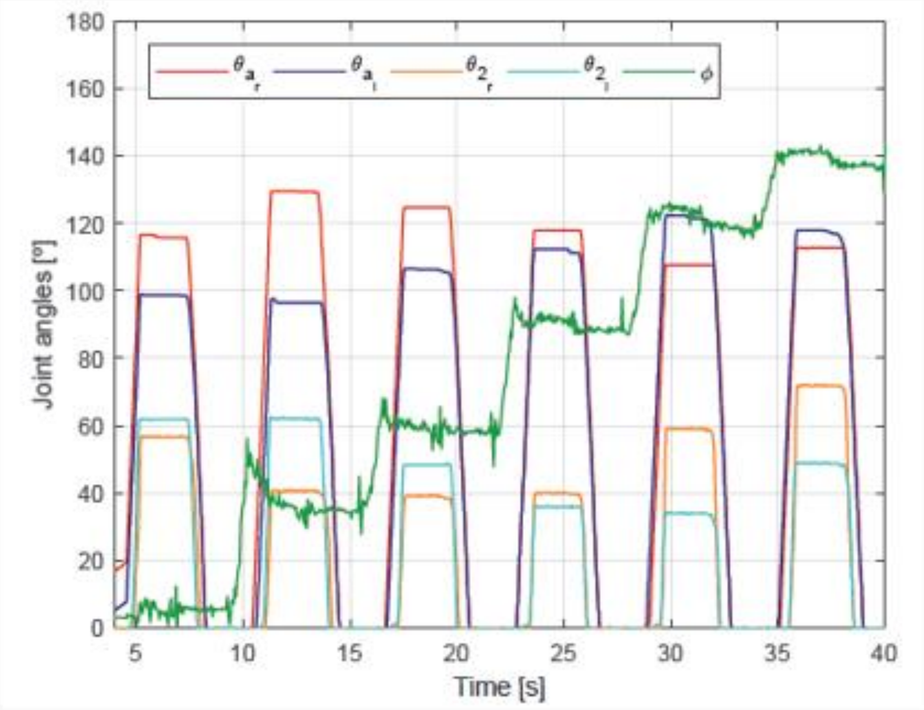
- Roll-angle is critical to manipulate the forearm due to **mechanical limitations** of the human arms
- Some configurations may or may not be reached, depending on this angle
- **Methodology:** Try to estimate ϕ from the measurements read by the angular sensors
- Three machine learning **methods** have been trained to estimate ϕ
    - Gaussian Process (GPR)
    - Regression Tree (RT)
    - Bagging Regression Tree (BRT)



5. Roll-angle Estimation

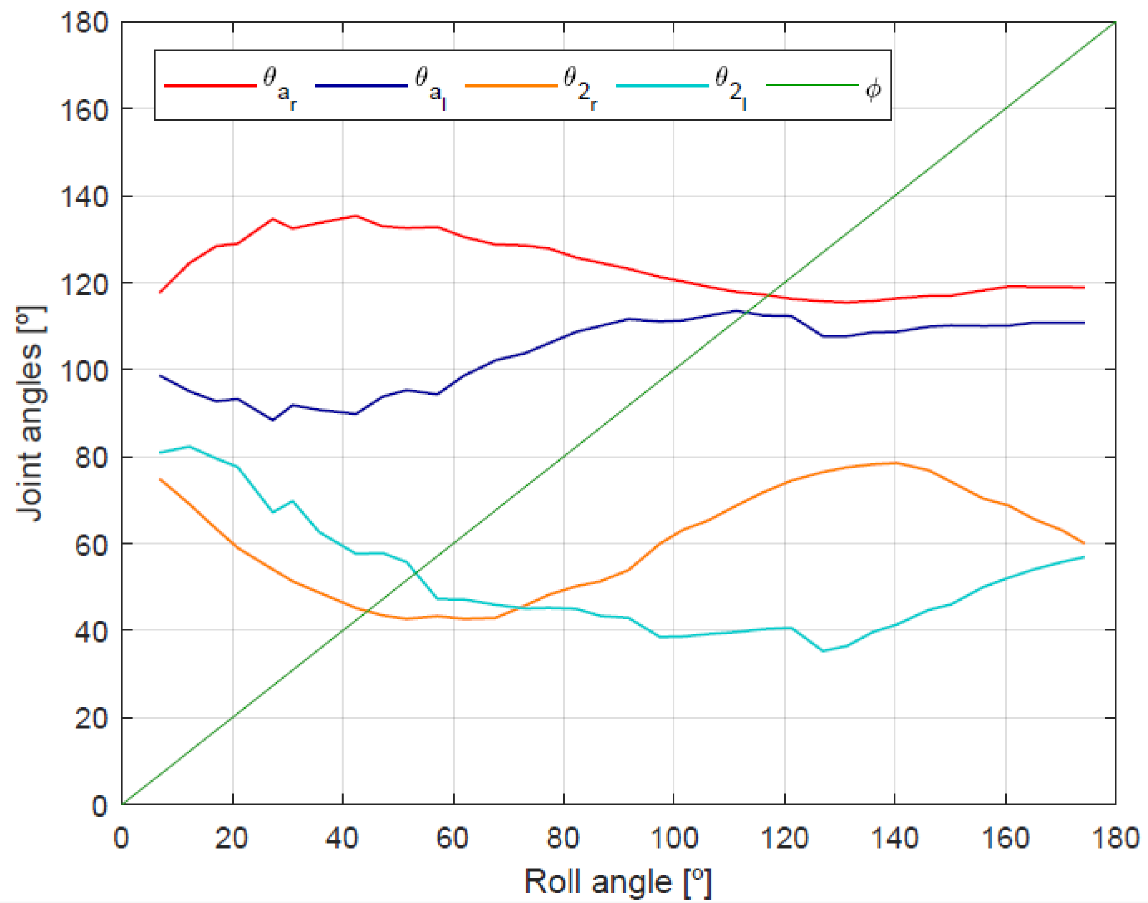
- **Experiment:** Several grasps with multiple configurations to record data
- The human holds a device with an **IMU** to measure the **ground-truth** angle of the human forearm
- A **dataset** formed by 1110 combinations of joint angles and ϕ from the left arm of **one person** are used to train and test the methods



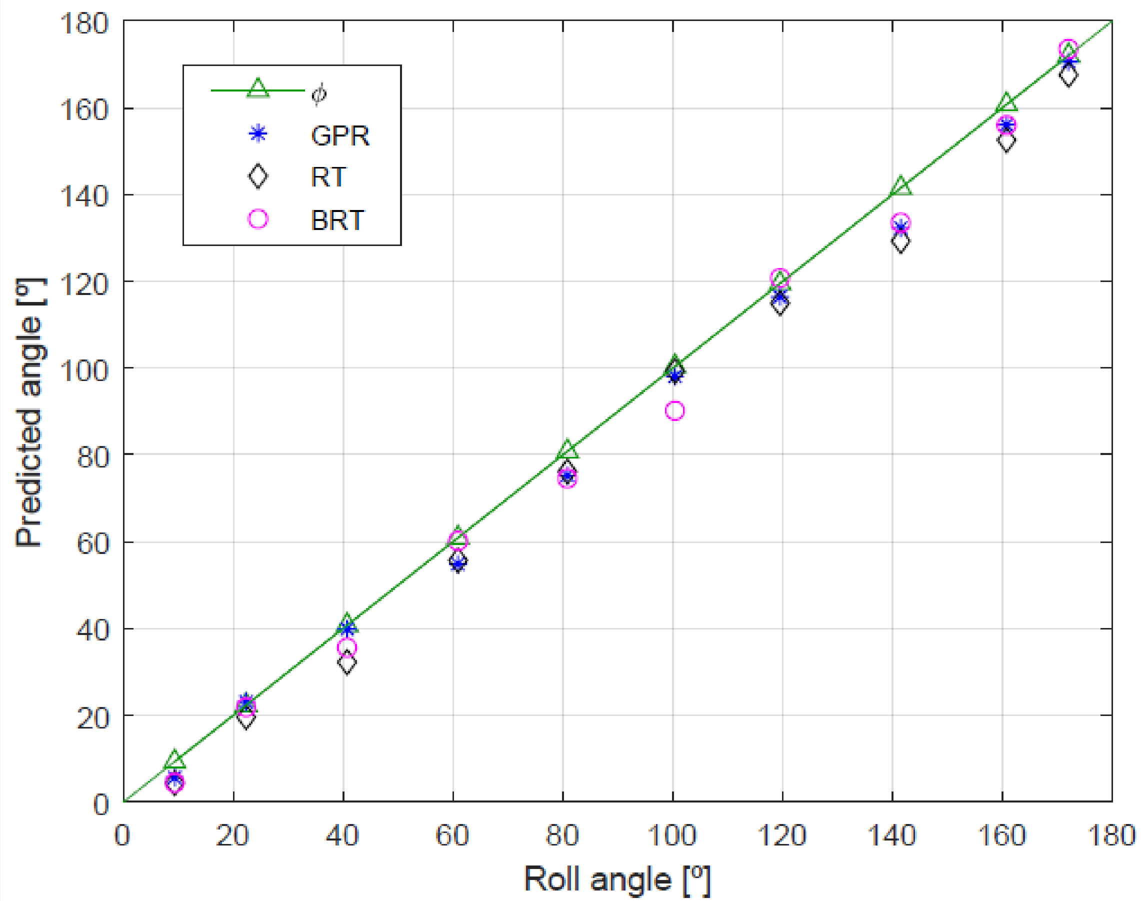


5. Roll-angle Estimation

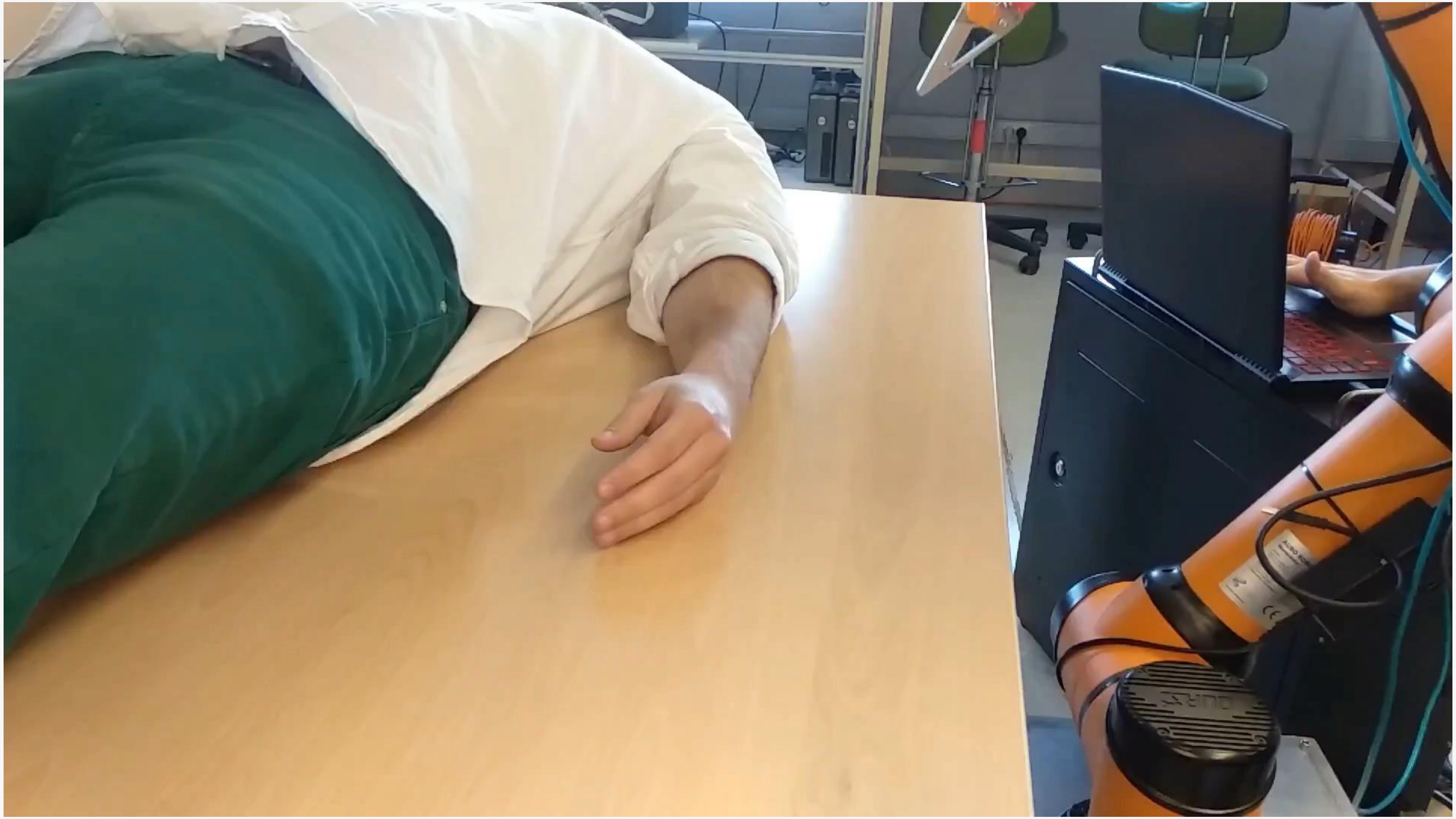
- Relationships between θ_{a_r}, θ_{a_l}, θ_{2_r}, and θ_{2_l} of a set of data



- Performance of the regression models



6. Forearm Manipulation



7. Conclusions and Future Work

Conclusions:

- First work about the **manipulation of human upper limbs** with robot-initiated task
- **Asymmetrical gripper** with low-cost sensing capabilities for autonomous pHRI
- Method to **estimate the roll-angle** of the human forearm during grasping

Future work:

- The **interaction** and **haptic perception** capabilities of the gripper can be improved
- **Soft** gripper for more comfortable grasping
- Including **learning-based** methods at control, trajectory and task levels
- Including **computer vision** systems like OpenPose
- Considering **other aspects** related to the task: the victim is conscious or unconscious?, is the human moving or not?, what are the forces and torques exerted to the human arm?, Does the motion planning respect the mechanical limits of the human arm? etc.

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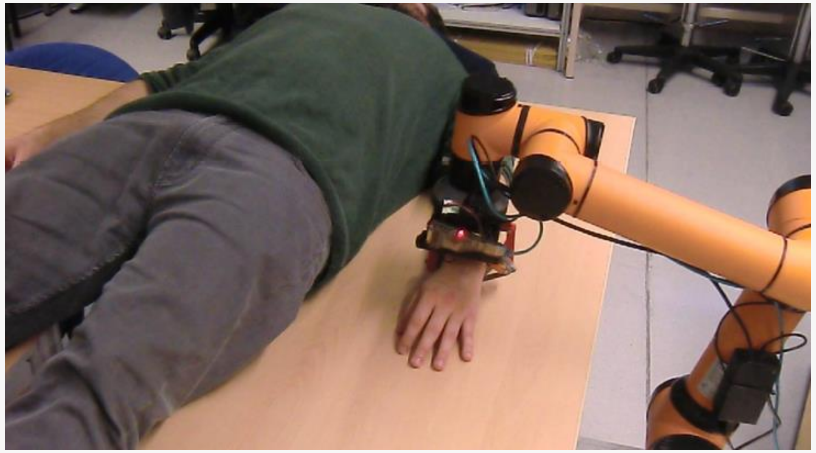

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