Project 5: Human Inspired Robot Reaching Motions

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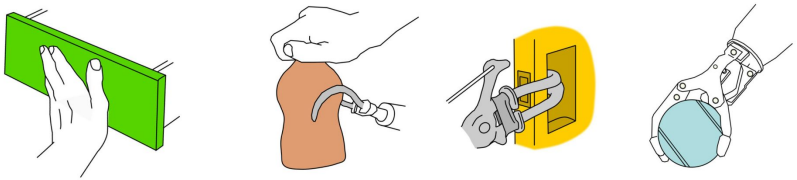
MANIPULATION & TOUCH LAB

Introduction

- For robots to be integrated into human environments, their motion should be **predictable** and **human-like**.

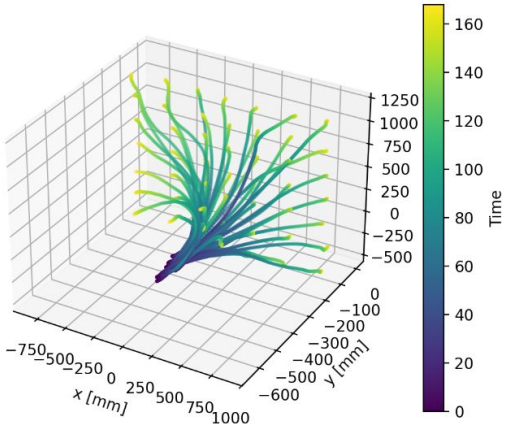
- Goals:
  - Understand human reaching motion
  - Creating generalisable motion controllers
  - Program robotic manipulator software

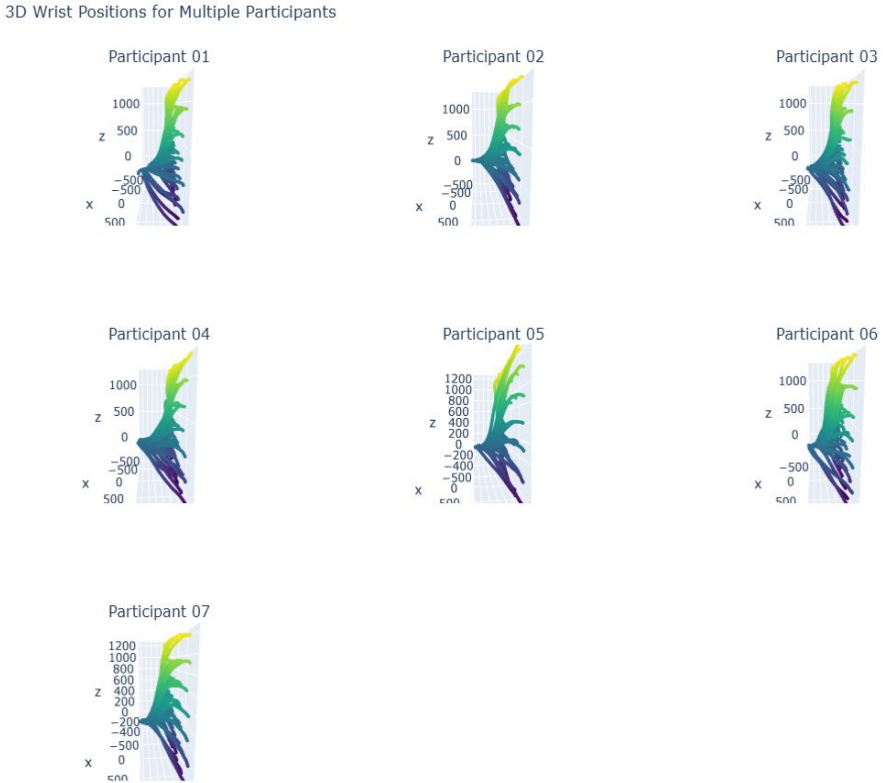


ROAG Dataset

2,500 Human Reaching Motions

- 9 Participants
- Shoulder, Elbow, Wrist Positions/Angles
- 49 Goal Positions





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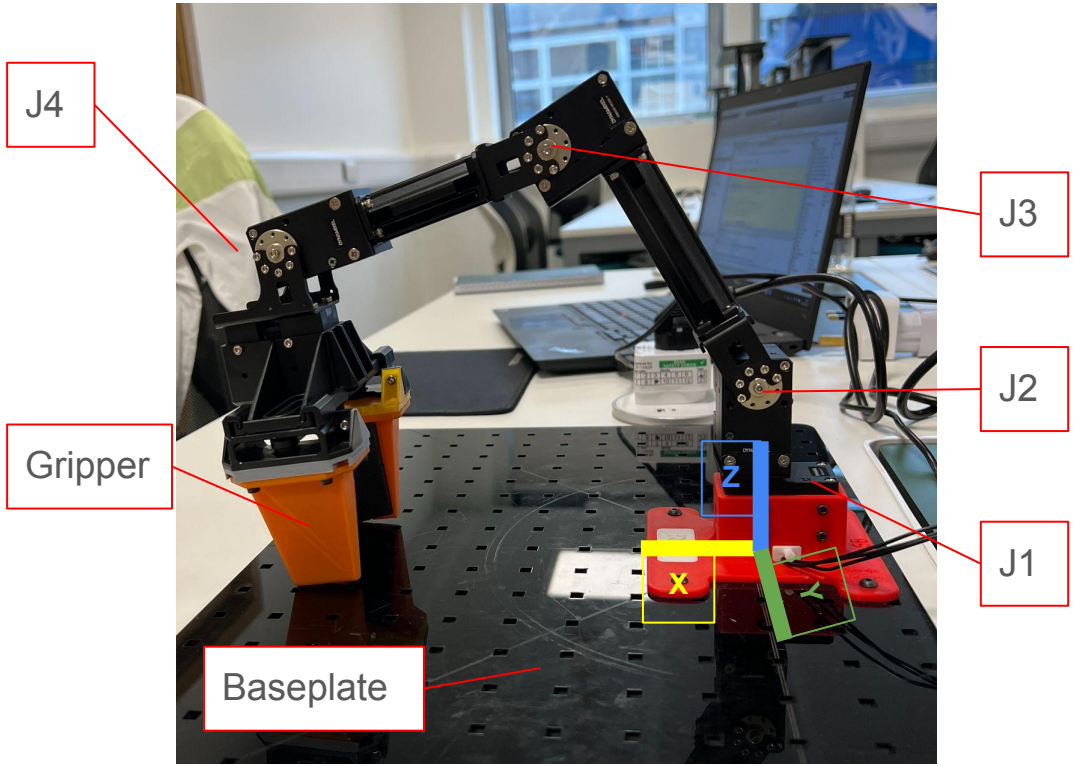
OpenManipulator-X

- **4 DOF Revolute Joints**
  - PID Servo Motors
  - Position Control Mode
- 1 DOF Parallel Gripper
- **Controller Interface:**
  - Matlab Software + Dynamixel SDK
- **Defined WCS Origin:**
  - J1 Motor + Baseplate Attachment



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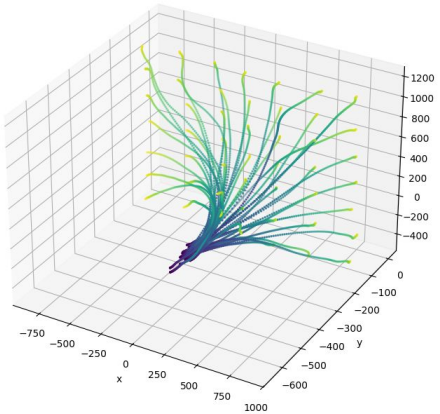
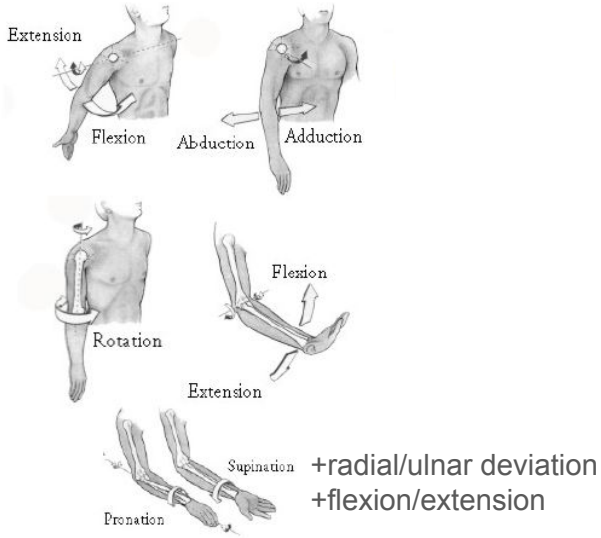
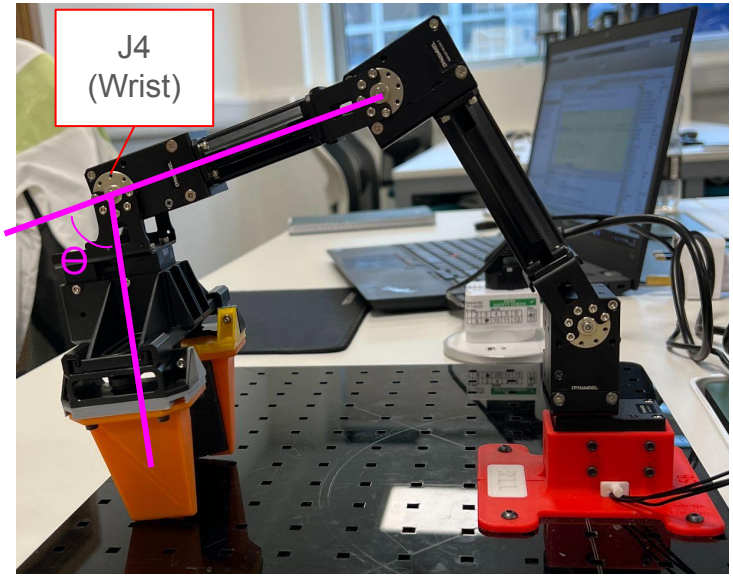
Methods - Reducing the number of Joints

- Human arm: 7 DOF's V.S. robot: 4 DOF's.
- Impossible to replicate the general movement of the human arm.
- Replicate wrist position + angle only
- Inverse kinematics: position xyz wrist → shoulder + elbow angles





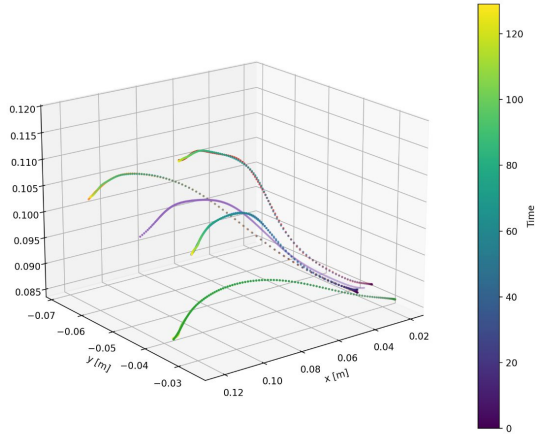
+radial/ulnar deviation
+flexion/extension



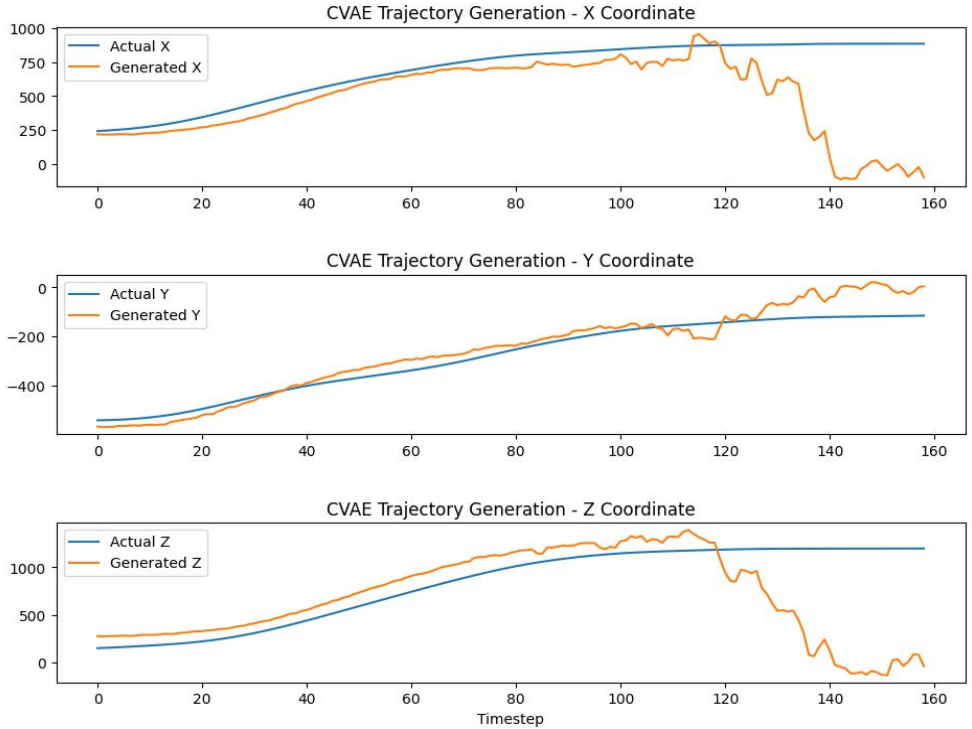
Methods - Reaching Arbitrary Goal Positions

Data Interpolation

- Trajectory lengths varied
- Polynomial Interpolation
- Final Trajectory: Weighted Average



Conditional Variable Auto-encoder (CVAE)



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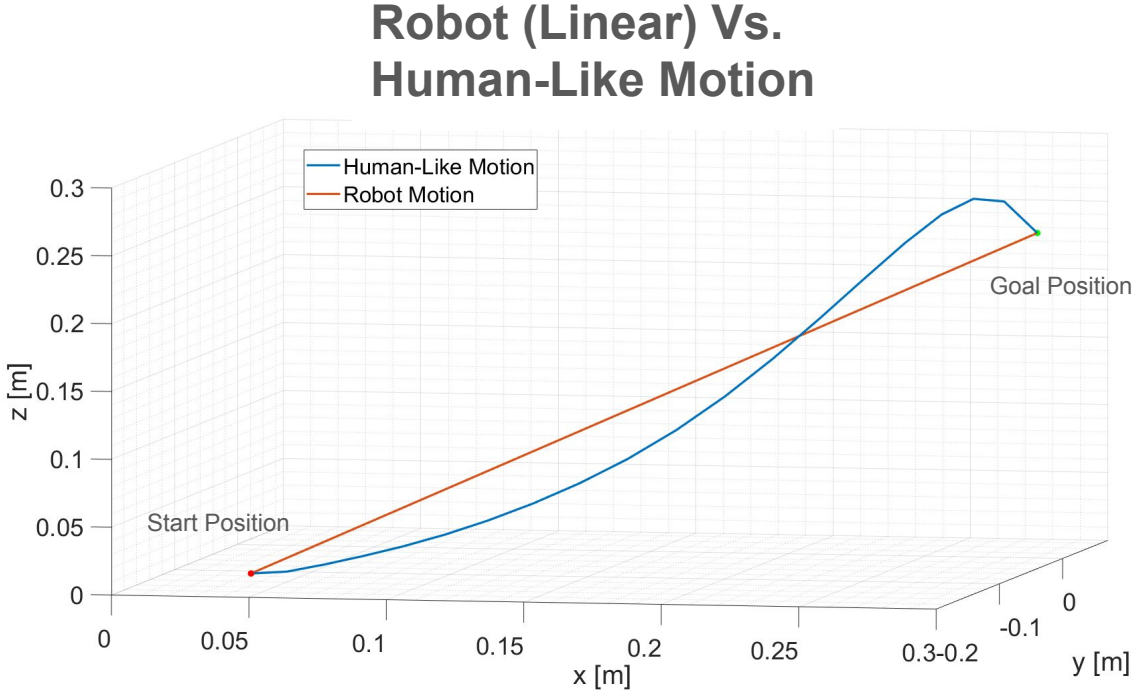
Results - Linear vs. Human Trajectory Planning

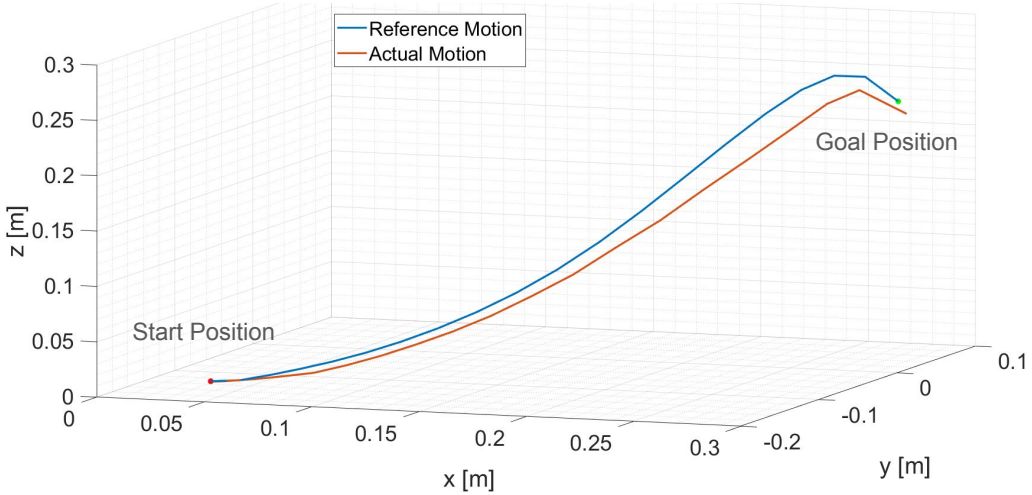
- **Linear Input:**
  - Start Position
  - Goal Position
  - PID profile
- **Human Input:**
  - Segmented Generalized Traj.
  - Goal Position
  - PID profile

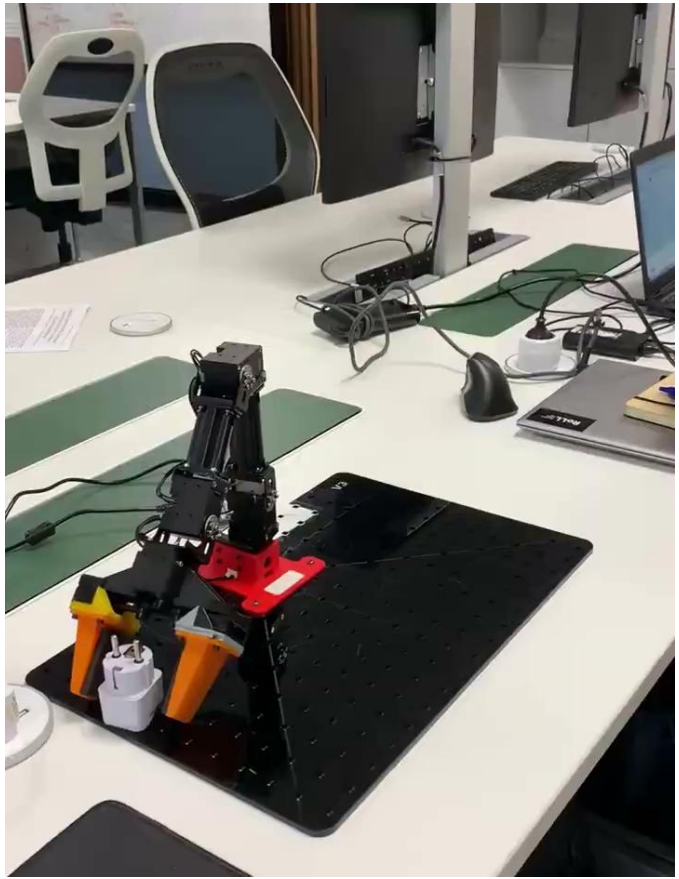


Results

- Mapping human wrist position and angle to robot trajectory = smoother, friendlier motion

Human-Like Motion
Planned vs. Actual





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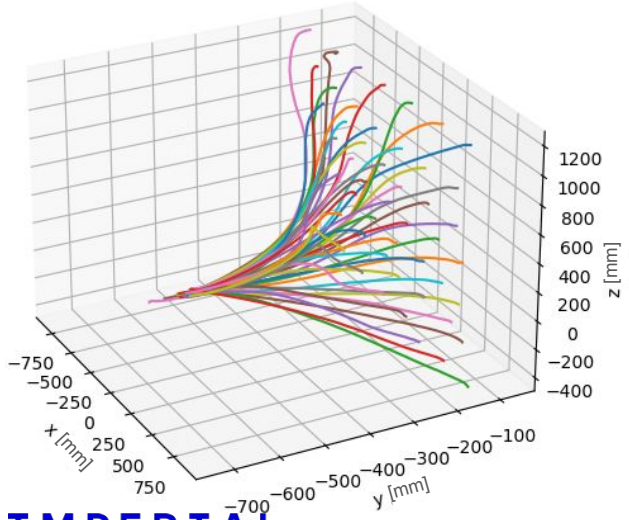
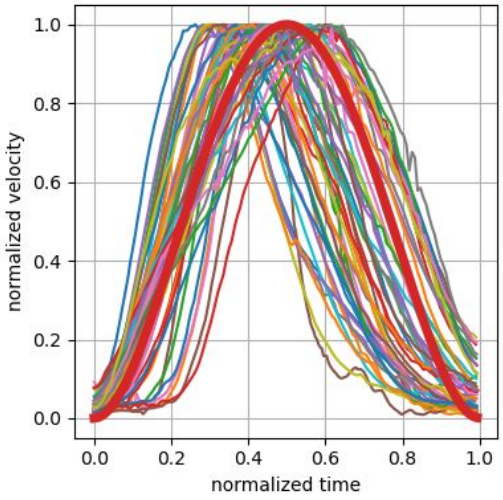
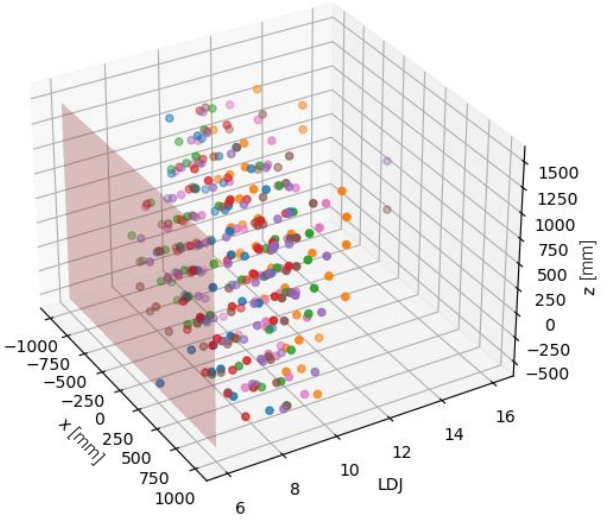
Discussion: kinematic assessment of the trajectory

- Compare real trajectories with reference trajectories
- References: straight lines w. bell-shaped velocity profile (minimum jerk)
- Measure of smoothness: $\mathrm{LDJ} = \log\left(\frac{D^3}{v_{\mathrm{mean}}^2}\int |j(t)|^2 \mathrm{d}t\right)$
- Reference: LDJ = 6. Subjects: LDJ varies with subject and position







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Thank you

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- Future work
  - Incorporate shoulder and elbow positional information and joint angles information
  - Imitation learning: kinesthetic teaching
  - Test the trajectory predictions from the CVAE model
  - Motion smoothing through PID tuning, Dynamic Smoothing to account for self- and payload weights, or blending the velocity through a sub-goal position to prevent it dwelling
  -

- Max. Reach Radius (to J4):
  - 25.2cm
- Max Reach Radius (incl. Gripper):
  - 37.8cm
- Defined Safe Work Zone:
  - X = 0 to 25cm
  - Y = -20 to 20cm
  - Z = 0 to 30cm

https://emanual.robotis.com/docs/en/platform/openmanipulator_x/specification/

https://emanual.robotis.com/docs/en/dxl/x/xm430-w350/#