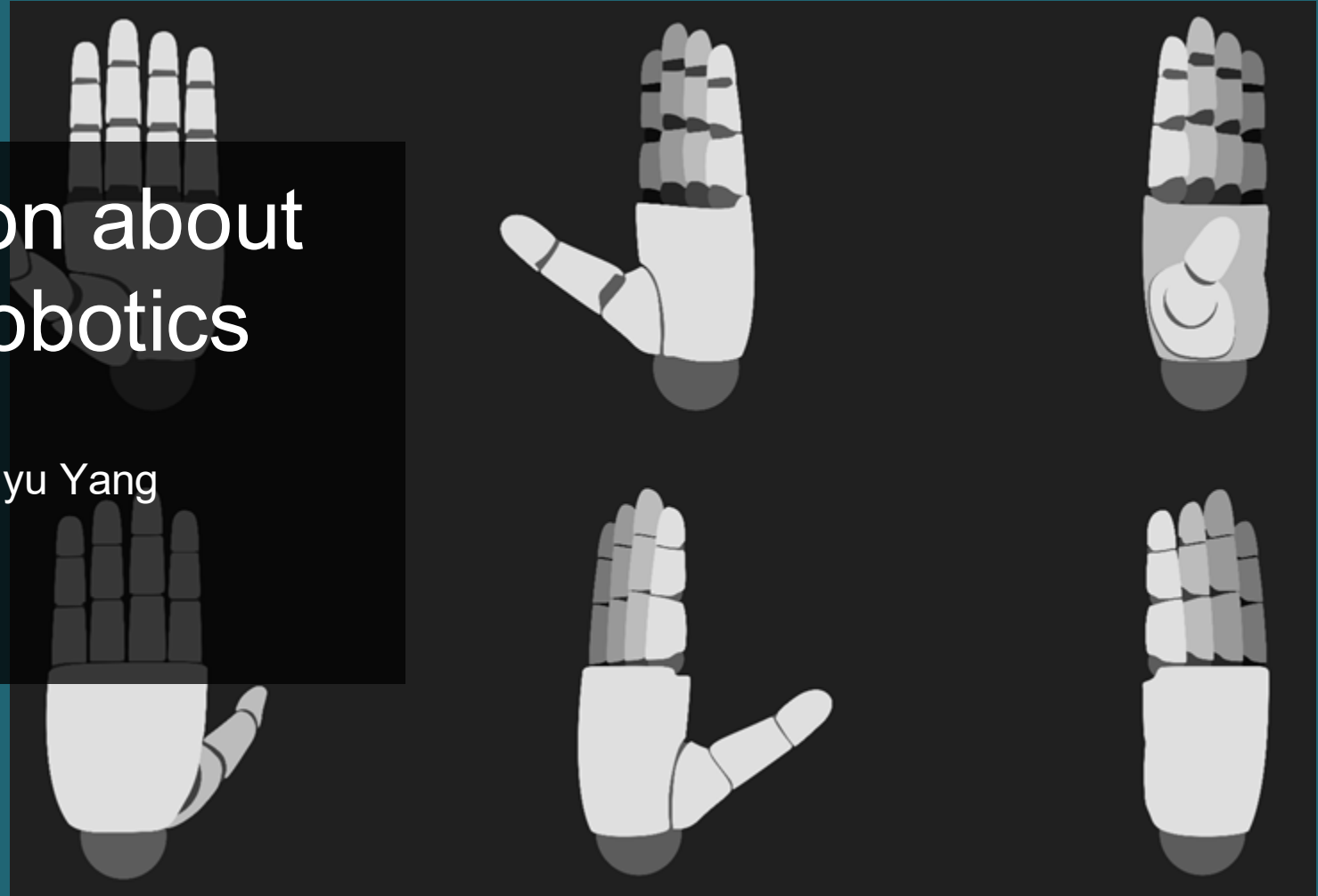




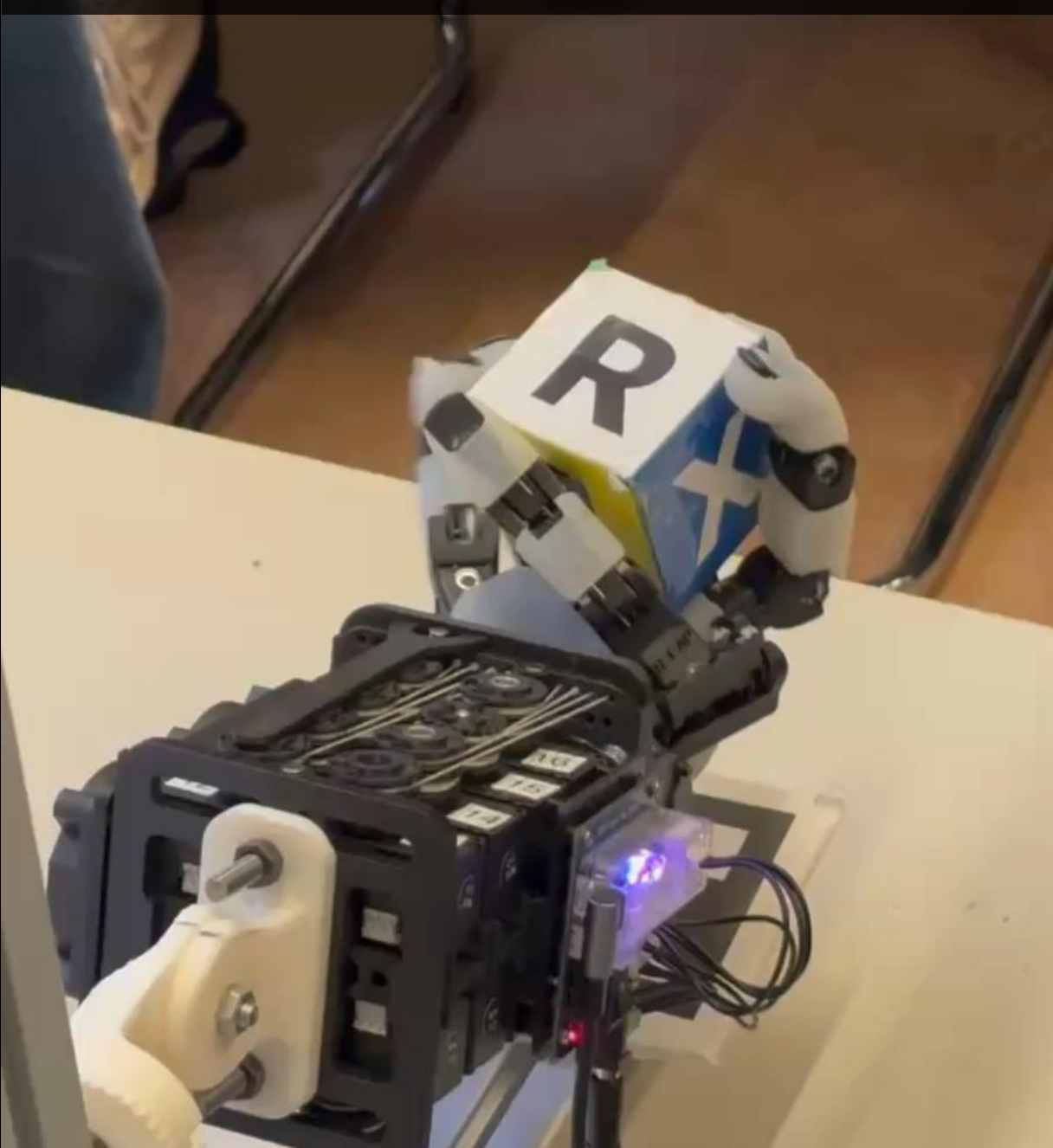
Key information about Real World Robotics

Robert Katzschmann, Chenyu Yang

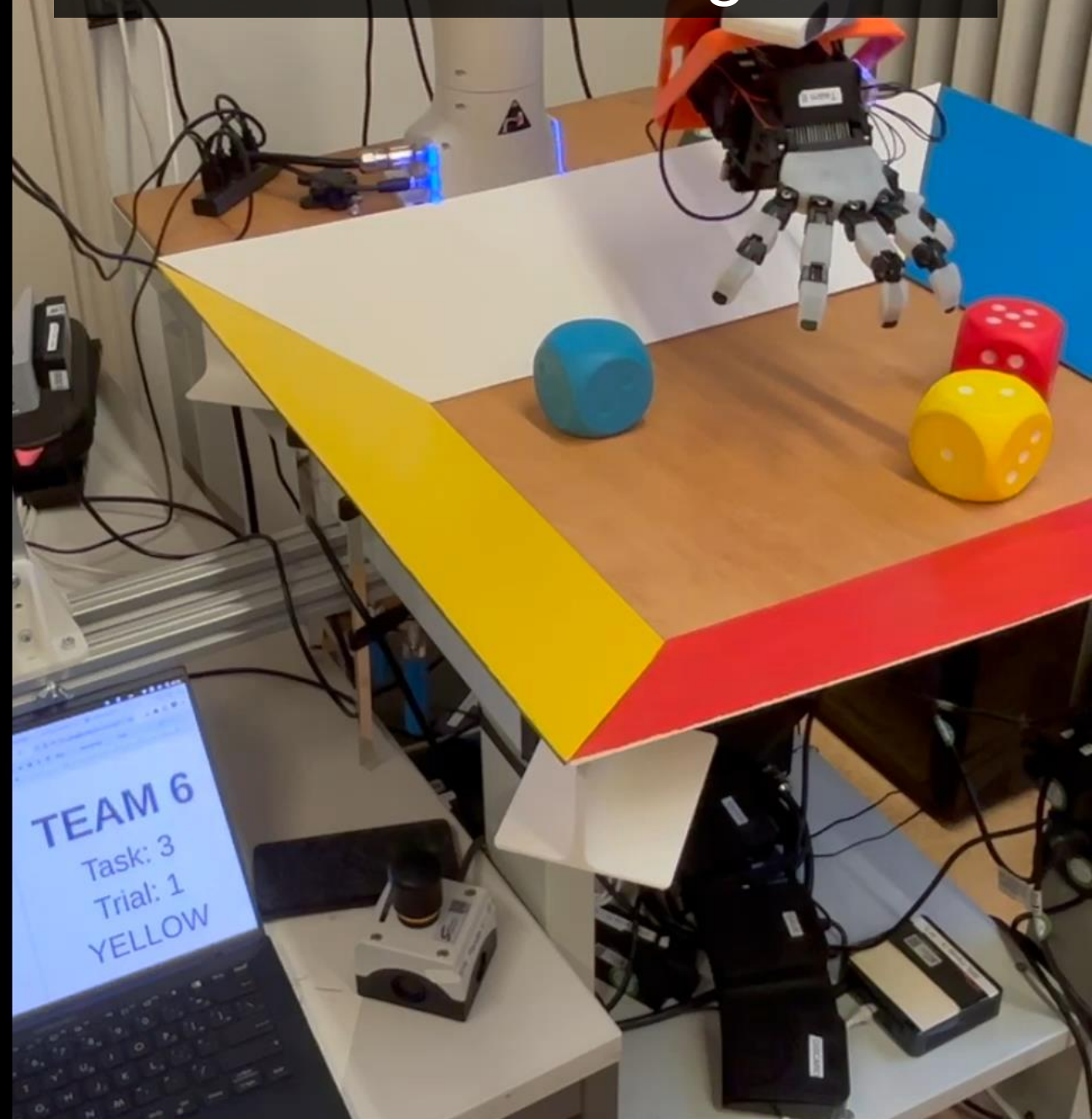
Unit 00 - 21.09.2026



Task 1: Cube Rotation with RL



Task 2: Cube Sorting with IL



Task X in 2025

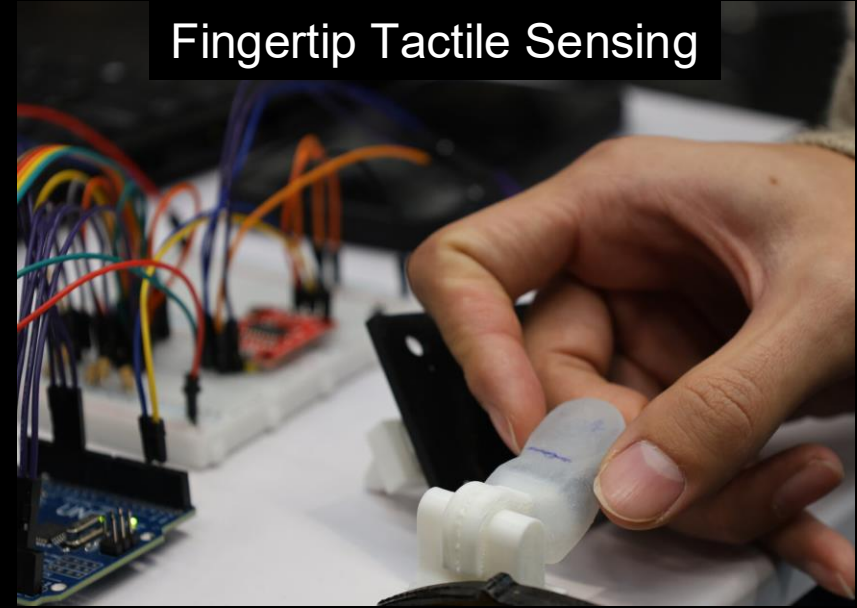
Hand Tensioning & Calibration



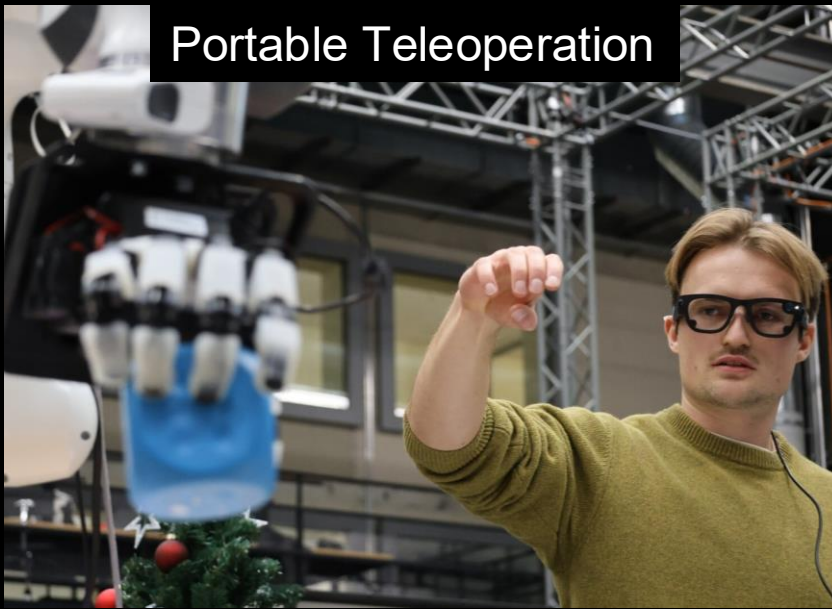
Hand Design Improvements



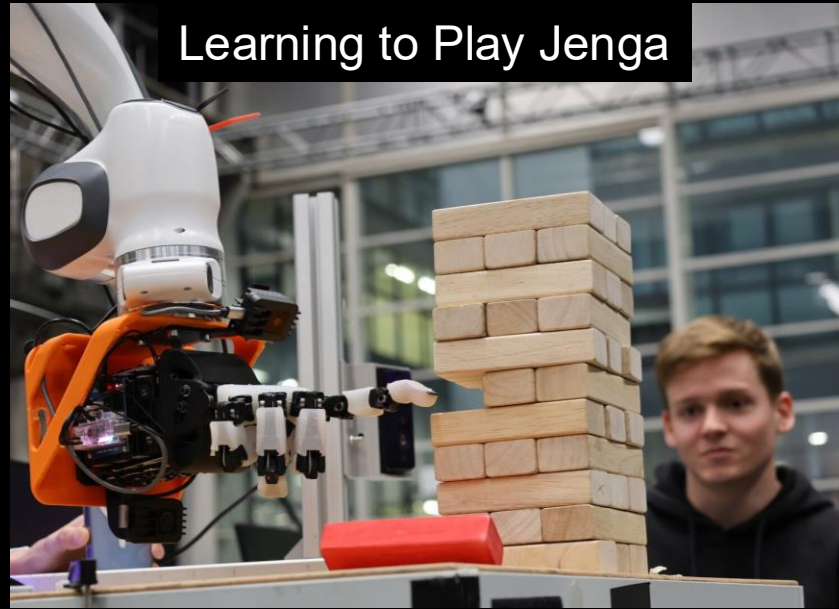
Fingertip Tactile Sensing



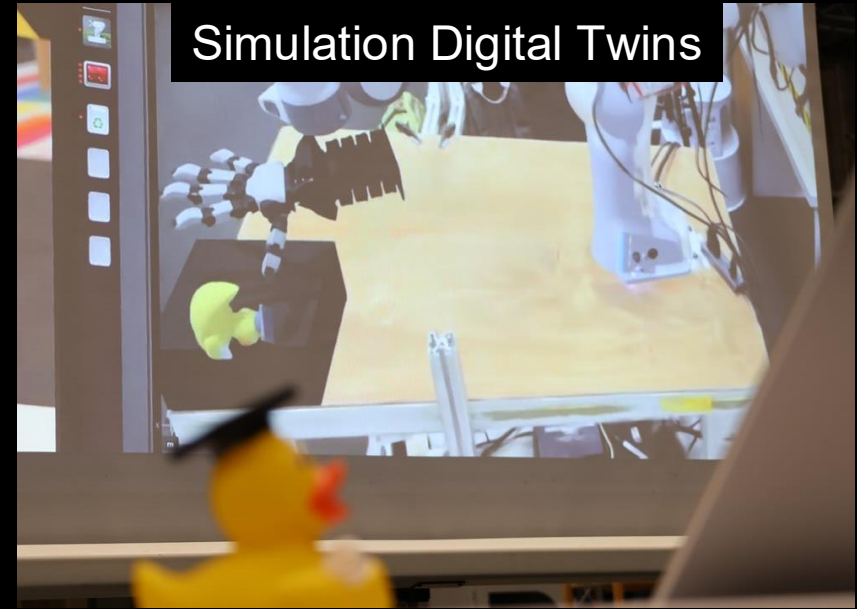
Portable Teleoperation



Learning to Play Jenga



Simulation Digital Twins



Class Structure



1. Focus Talks including Q&A
 - deepens your knowledge through discussions
 - post your questions on Moodle prior to class
 - From the second week: Mondays, 14:15 - 15:00 @ PFA
(Technopark) E12
2. Workshops
 - teaches you a practical skill useful to complete the challenge
 - From the second week: Mondays, 15:15 - 16:00 @ PFA
(Technopark) E12

The class will be public at <https://rwr.ethz.ch>



Technopark



Best

14 min

23 min

41 min

15 min

—

Your location

ETH Zurich, Technoparkstrasse 1, 8005 Z

Leave now

Options

Send directions to iPhone

Copy link

2:37 PM—3:00 PM

23 min

2:46 PM from Stampfenbachplatz · on time

10 min every 8 min

Details

2:36 PM—3:00 PM

24 min

2:41 PM—3:03 PM

22 min

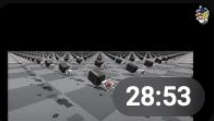
2:36 PM—3:04 PM

28 min

Youtube Playlist

▶ 13:50
Why do we build robotic hands? | ETH Zurich Real Wor...
Soft Robotics Lab [SRL] / ETH Z...

12:32
Building and Fabricating an Articulated Robot Hand | ETH...
Soft Robotics Lab [SRL] / ETH Z...

28:53
Simulating Robots and Soft Interactions with the World |...
Soft Robotics Lab [SRL] / ETH Z...

22:45
Identifying Kinematics and Dynamics of Robots | ETH...
Soft Robotics Lab [SRL] / ETH Z...

30:04
Implementing Control Strategies for Manipulation |...
Soft Robotics Lab [SRL] / ETH Z...

Course Website

Course Schedule

Lectures will occur during the Autumn Semester 2025.

New **tutorial, slides, and lectures** will be open-sourced every week starting **22nd September!**

📺 : Tutorial

💬 : Focus Talk

🔧 : Workshop

🏆 : Task Showcase



The Challenge

Unit 00

22 Sept., 2025



[\[Slides \(FT\)\]](#) [\[Slides \(Info\)\]](#) [\[Video\]](#)



Project Management

Unit 01

22 Sept., 2025



[\[Slides \(FT\)\]](#) [\[Slides \(W\)\]](#)



Design and Fabrication for Robots

Unit 02

29 Sept., 2025



[\[Slides \(FT\)\]](#) [\[Slides \(W\)\]](#)



Kinematics, Dynamics and Control

Unit 03

06 Oct., 2025



[\[Slides \(FT\)\]](#) [\[Slides \(W\)\]](#)



Sensors in Dexterous Manipulation

Unit 04

13 Oct., 2025



[\[Slides \(FT\)\]](#) [\[Slides \(W\)\]](#)



Simulation for Dexterous Manipulation

Unit 05

20 Oct., 2025



[\[Slides \(FT\)\]](#) [\[Slides \(W\)\]](#)

<https://rwr.ethz.ch>

Challenges and Assignments



	Start Date	Due Date
Individual Assignment	Oct 5 th	October 23 rd
Group Task 1 (RL)	October 19 th	November 9 th
Group Task 2 (IL)	November 9 th	November 30 th
Group Task X (different for each team)	September 25 th	December 14 th

Class Syllabus (2026)



Date	Focus & Q&A Talk	Workshop	Assignments
Sep 21	Introduction to RWR	Q/A and Ice breaking	Task X starts (Sep 25) Simulation & Control & ROS released Task 1 (RL) starts Assignment due Oct 23
Sep 28	Design and Fabrication	ORCA assembly	
Oct 05	Kinematics, Dynamics, and Control	ORCA software	
Oct 12	Sensors	Sensor practice	
Oct 19	Simulation	Cloud compute and Isaac Sim	
Oct 26	Reinforcement Learning	Bridging the sim-to-real gap	
Nov 02	Teleoperation, Data Collection and Imitation Learning	Franka setup and data collection	
Nov 09	Task 1 Demo day		Task 2 (IL) starts
Nov 16	Vision-Language Action (VLA) Models	imitation learning	
Nov 23	Guest Lecture	Q&A	
Nov 30	Task 2 Demo day		
Dec 07	Product Development & Class Wrap up	TBC	
Dec 14	Task X Rollout day		Semester ends Dec 18

Note: Topics and content subject to minor change, link to spreadsheet will be on Moodle

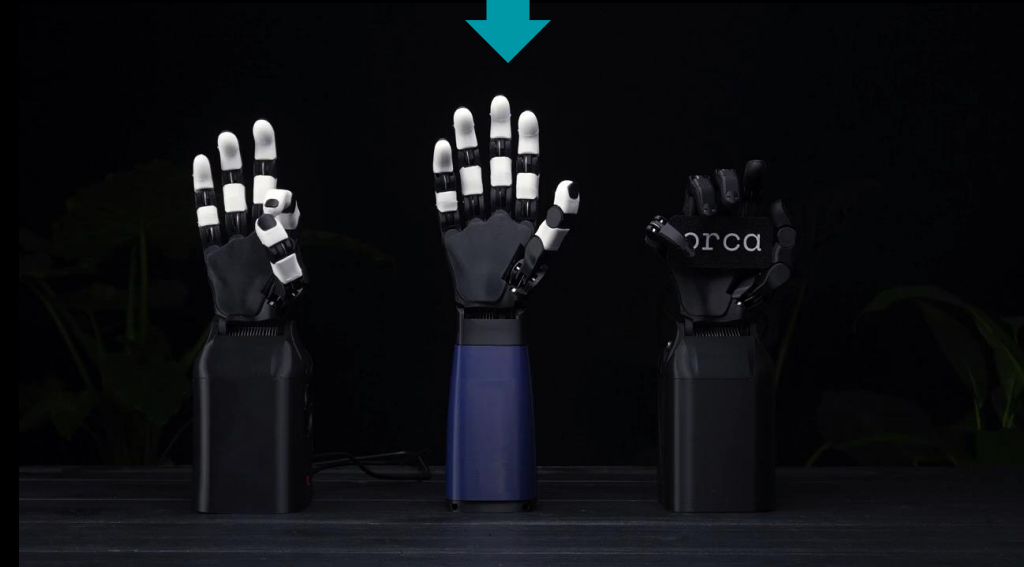


It's a team effort

Team Challenge



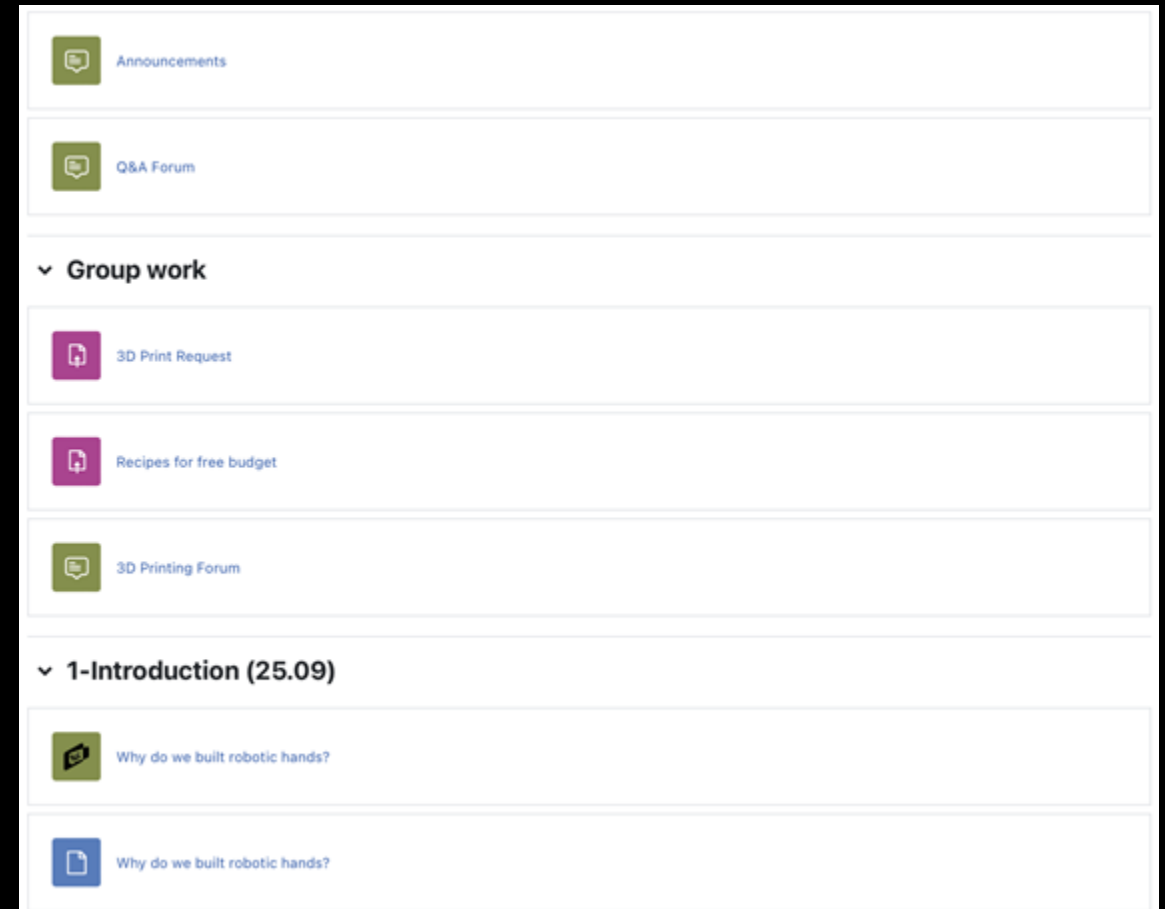
- Assemble your own ORCA V2 hand as a team!
- All hand materials are provided (3D printed parts, tendons, bearings, etc..)
 - A set of basic tools + 2 x 3D printers are provided
- Team size: 5 Students
 - Submit your preference on Google Form (link will be provided)
- Work in our workshop room whenever you want!
 - One key per team → more information soon
 - Coffee Machine
- **Be ready for an intense and rewarding commitment!**



Communication



- Moodle
 - Video tutorials, quizzes, ...
 - Q&A forums for discussion
 - Announcements
 - Reimbursement request for free budget
 - Group forming
 - 3D printing submission
- Slack: <https://rwr2026.slack.com>
 - Preferred communication with TAs and staff
- Website: rwr.ethz.ch
- Email the class team: rwr@srl.ethz.ch



Team Formation



- **By Wednesday, September 23rd, the acceptance decision will be out.** If you realize that you don't want to take the class let us know in the next few hours!
- Wednesday 5:00 PM to 7:00 PM, CLA D floor. there will be an Apéro to form team.
- The accepted students will get a google form with team and task preference by Thursday September 24th
- We will assign the teams based on team preference and task preference
- Final teams will be communicated on Friday, September 25th, along with the assigned Task X



Grading

Grading



Task	Type	Relative Weight	Absolute Weight
Challenge	Group		70%
<i>Task 1 (RL)</i>		33.3%	23.3%
<i>Task 2 (IL)</i>		33.3%	23.3%
<i>Task X</i>		33.3%	23.3%
Report	Group		10%
Assignments	Individual		20%
Attendance			10%
Total			110%



Living Respect



At ETH Zurich, people from different cultural backgrounds and in many varied roles and disciplines study, research and work together. Diversity is one of our strengths – and at the same time a challenge: wherever different people come together, there has to be mutual respect.

ETH Zurich – Living Respect

<https://ethz.ch/students/en/campus/eth-culture-and-values/living-respect.html>

This applies to every interaction in this class: lectures, workshops, team work, Slack and Moodle.

ETH Zurich does not tolerate, in particular:



Discrimination

Discrimination of people because of actual, attributed or group-specific characteristics such as: function; education; origin; race*; gender; age; language; social status; lifestyle; religious, ideological or political views; sexual orientation and gender identity; physical, intellectual or mental disability; or professional status.

Bullying

Bullying involves persistent and systematic harassment over an extended period with the aim of discrediting, isolating or socially excluding a person or gradually driving them out of their job or study programme. Examples include put-downs and exclusion, withholding information, assignment of humiliating tasks and unjustified criticism.

Sexual harassment

Any behaviour that adversely affects the dignity of persons studying or working at the university. This includes sexist jokes; suggestive, disparaging or contemptuous remarks or actions; displaying or disseminating pornographic material; undesired physical contact or the exploitation of a dependent relationship.

Threats, stalking and violence

Actions through which other people are assaulted, threatened, or physically or psychologically harmed during the course of their studies or work. These include verbal and non-verbal insults, humiliation, threats and abuse, social exclusion or the deliberate and persistent stalking or harassment of a person.

**The term "race" implies the fact that racial categorisation of people is a social construct and has no biological basis.*

Not a grey zone



Inappropriate behaviour is characterised **not** by the intention of the acting person(s), but by the way the targeted person perceives, receives or feels about this behaviour. Even if an individual is neither aware of nor deliberately attempting to inconvenience another person through their inappropriate language or attitudes, it may still occur.

Never prioritise your intent over someone else's potential discomfort.



What to do?

- Consider whether your behaviour might be hurtful.
- Apologise.
- Step in and offer help and support (if the situation allows it).
- Report it — you do not have to handle it alone.

ETH internal advice and conciliation service Respect

+41 44 632 20 38 · respekt@ethz.ch

<https://respekt.ethz.ch/en/contact-and-advice-services.html>

Contact points



ETH Zurich

Inappropriate behaviour & conflict

Psychological Counselling Services (with UZH)

VSETH

SpeakUpETH

Help

EPFL

Cellule de soutien et respect

This class

Talk to any TA or to the lecturers:

rwr@srl.ethz.ch



Tasks to learn RL + IL



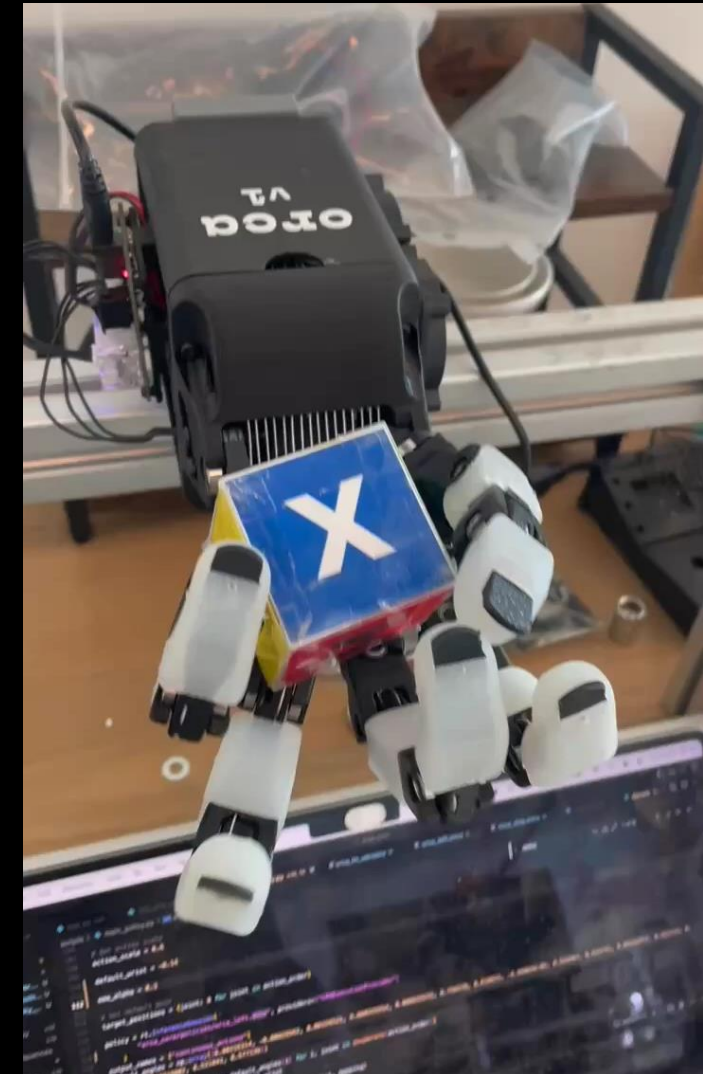
Task 1: In-hand reorientation with reinforcement learning (IHR)

Goal: Train RL policy to rotate a cube in the hand

Tasks:

- Setup RL environment with Isaac lab
- Define reward function and train the policy
- Track the cube rotation angle in the real world (Will be provided)
- Apply sim2real techniques to have a robust policy

Metric: number of success (reach next target angle) in a given time





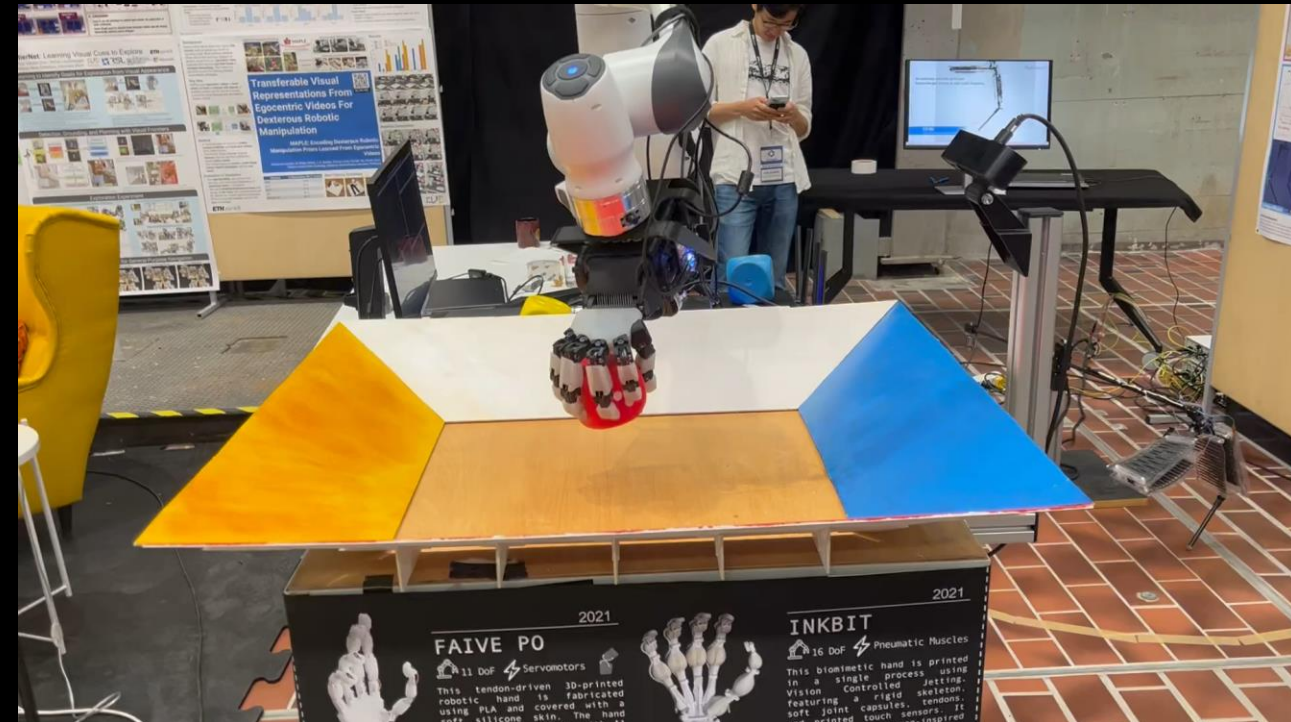
Task 2: Color-based sorting with imitation learning (CBS)

Goal: Train IL policy to pick-and-place objects based on colors

Tasks:

- Collect an extensive dataset of demonstrations
- Setup the IL training and train policy
- Deploy policy in the real world

Metric: number of successful relocations in a given time





Tasks X: Stepping beyond what is known

IMITATE: Human Demonstrations to Robot Motion with Aria Gen 2



Aria Gen 2 hand and head tracking
2 glasses available for student data collection

Task Description

Use Aria Gen 2 glasses to record first-person RGB, hand poses and head motion during human manipulation. Build a calibrated pipeline that maps wrist and finger motion to the Franka arm and ORCA V2 hand. Reproduce a simple grasp-and-place from recorded demonstrations.

Expected Results

A documented dataset from multiple demonstrators and a reusable retargeting pipeline.

A robot replay of one recorded skill at the final demo. Report success rate over repeated trials and compare against a simple retargeting baseline.

Possible Extension

Train an imitation-learning policy using the validated robot replays and test new object positions.

FAST: Direct drive actuation for high-speed robot hand movements



Motor driver



BLDC motor



The hand from *Kyber Labs* performing high-speed manipulations

Task Description

Replace the Dynamixel Actuation of the Hand with Direct-Drive Brushless DC Motors. By removing the 1:300 gear ratios of the Dynamixel, we trade off force with speed. The Moteus-c1 drivers have a up to 30 kHz Control rate which we can use for high-speed movements.

Expected Results

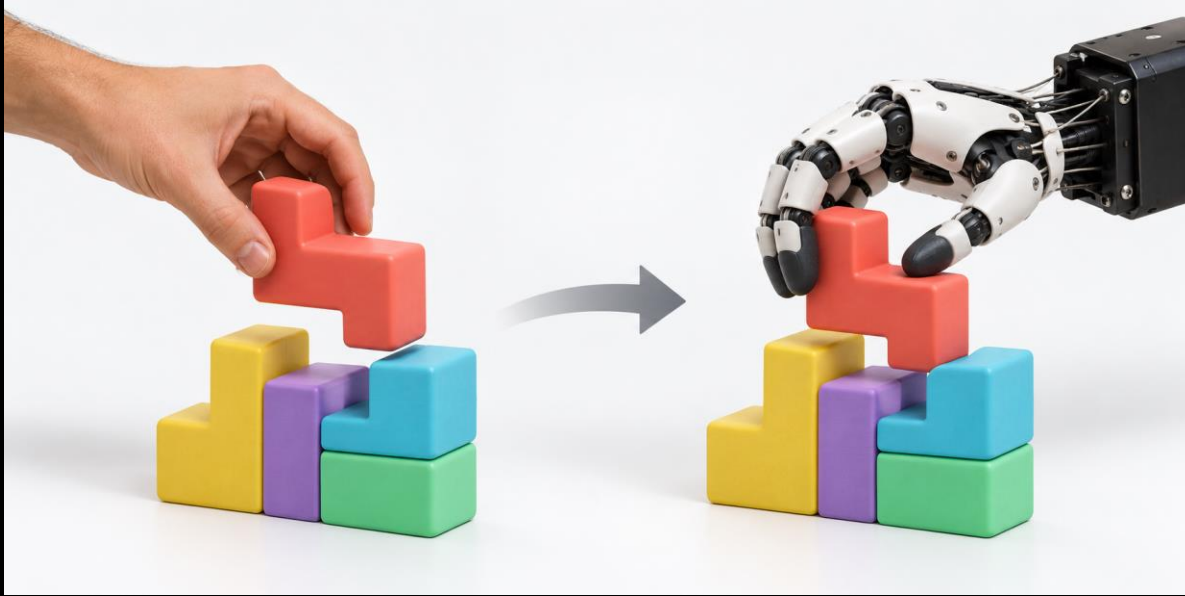
A single finger setup actuated with BLDC motors and moteus-c1 drivers.

Demonstrate the increased speed and flexibility of the modified finger.

Possible Extension

Use the drivers in-line current sensing to estimate forces on the finger.

CROSS: Cross embodiment reward model for real world policy improvements



Reference: SARM2: Multi-Task Stage Aware Reward Modeling for Self Improving Robotic Manipulation

Task Description

The project involves two parts: First is to train a reward model with human demonstrations on a long horizon task. The second one is the use the reward model to finetune a dexterous policy in the real world.

Expected Results

- A reward model of the game is pretrained on human collected data. The reward model improves an imitation learning policy in the real world.
- A policy is trained to stack the bricks as high as possible. Each turn a random Tetromino block is provided and the robot needs to learn to build a high tower with it.

Possible Extension

Demonstrate generalization capabilities of the approach: e.g.: teaching to stack two blocks on each other shall without additional human demonstrations generalize to stacking many blocks on each other.



RWRUMI: A Wearable ORCA-Hand Interface for Dexterous Manipulation Data Collection



Task Description

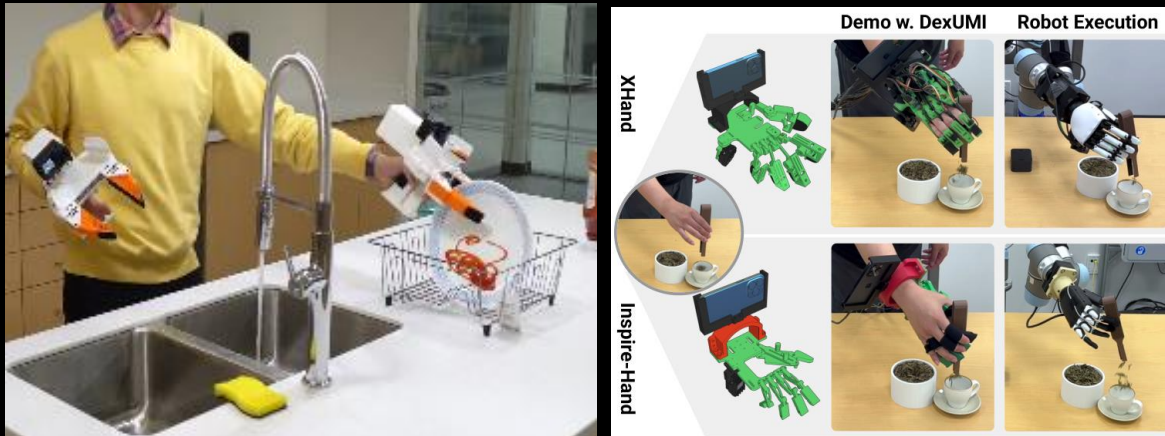
Develop a wearable data-collection interface for the ORCA hand. The ORCA hand will be mounted on the palm side of the human hand and mechanically connected to it so that human finger motions closely follow the ORCA kinematics. The project also includes joint-state sensing and software for recording joint data, as well as a method for tracking the global pose of the ORCA hand using, for example, AprilTags, an IMU, or a Franka arm.

Expected Results

A hardware and software system is developed to collect human manipulation motions that are kinematically consistent with the ORCA hand. This method enables demos with higher dexterity than through teleoperation. If time allows, the collected joint and global-pose data can then be used to train a manipulation policy.

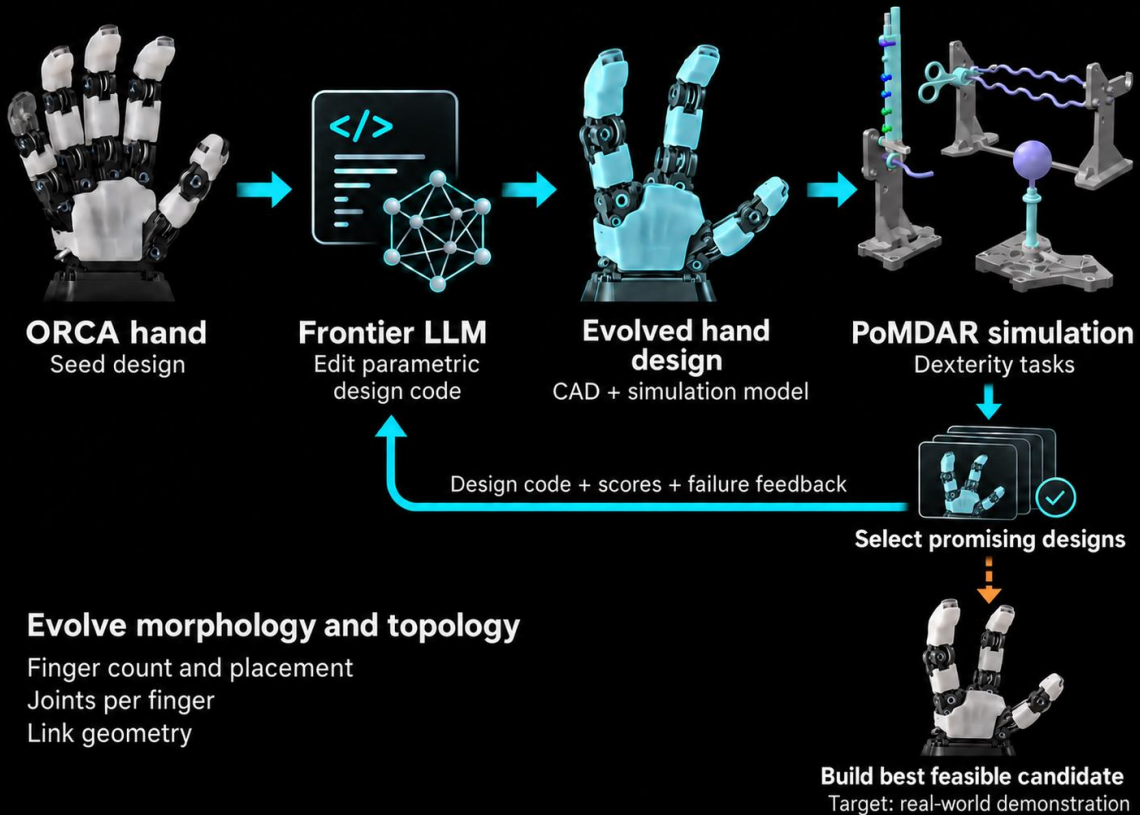
Possible Extensions

Integrate tactile sensing into the device to further improve the collected proprioceptive data



Universal Manipulation Interface: In-The-Wild Robot Teaching Without In-The-Wild Robots
DexUMI: Using Human Hand as the Universal Manipulation Interface for Dexterous Manipulation

EVOLVE: Evolving Robotic Hand Designs



AlphaEvolve-inspired hand design search

Task Description

Start from ORCA and evolve parametric hand-design code with a frontier language model. Search over finger count and placement, joints per finger, and link geometry. Generate manufacturing CAD and a matching simulation model for each candidate. Use PoMDAR scores and failure feedback to guide evolution.

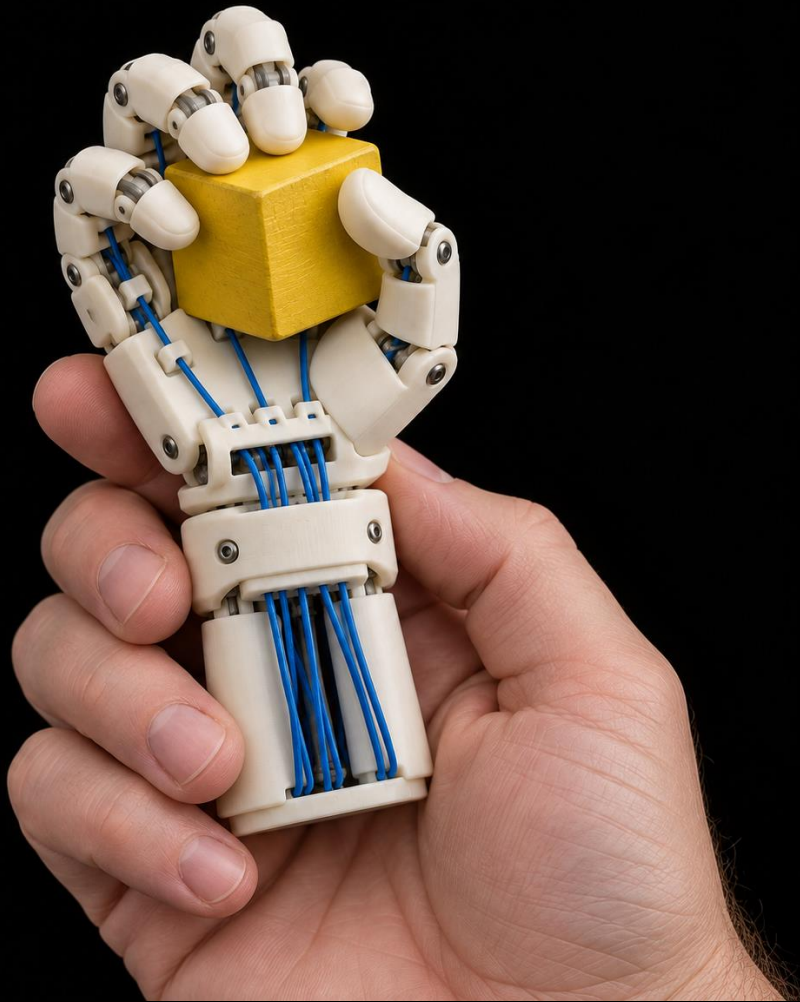
Expected Results

- An automated design-evolution pipeline and a reproducible comparison with ORCA, testing whether simpler hand designs can improve dexterity.
- Adapt the controller to each topology under comparable training and hardware budgets.

Possible Extensions

Fabricate and assemble the best feasible candidate, then demonstrate its performance on physical tasks.

SKIN: A Toddler-Sized Tendon-Driven Hand for Biohybrid Skins



Concept illustration (AI-generated)

Task Description

Design and fabricate a tendon-driven robotic hand at toddler-hand scale. Use external actuators to keep the palm compact. Design the outer geometry and interfaces for integration with cell-cultured skin, minimizing the surface area to be covered while testing real skin on a robotic hand.

Expected Results

- An assembled hand, with CAD, tendon routing and an actuator setup.
- Repeatable opening and closing, plus a simple grasp demonstration. Measure hand size, joint range of motion and tendon force.
- Test a thin synthetic covering to assess attachment and motion before future cultured-skin integration.

Possible Extensions

Bring tissue-cultured skin (provided by SRL's biohybrid team) onto the hand and test its grasping abilities. (collaboration with TLab @ UTokyo)

Course Output: Academic Papers



**Rotograbe: Combining Biomimetic
Hands with Industrial Grippers using
a Rotating Thumb
IROS 2024**



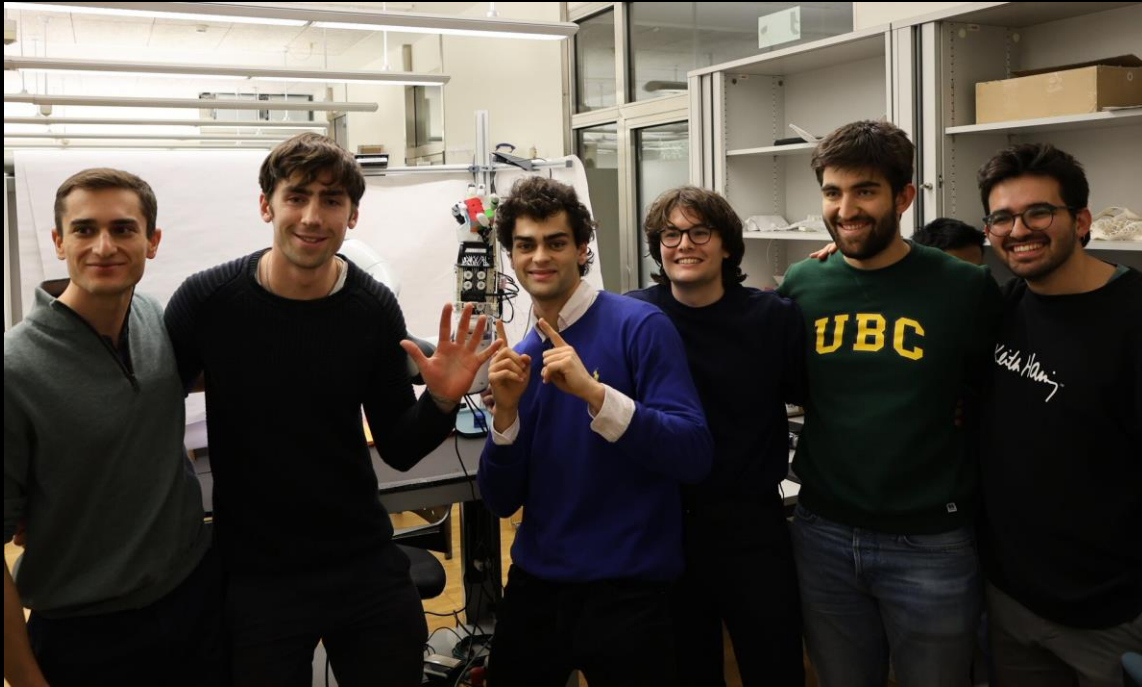
**Beyond Anthropomorphism: Enhancing
Grasping and Eliminating a Degree of
Freedom by Fusing the Abduction of Digits
Four and Five
IROS 2025**

Course Output: Academic Papers



**ORCA: An Open-Source, Reliable, Cost-Effective, Anthropomorphic
Robotic Hand for Uninterrupted Dexterous Task Learning
IROS 2025**

ORCA : from an RWR team to successful startup



The ORCA team during RWR 2024 course



www.orcahand.com

Teaching Team



Prof. Robert Katzschmann
Principal Investigator @ SRL



Dr. Ronan Hinchet
Senior scientist @ SRL



Yasunori Toshimitsu
Doctoral student @ SRL



Chenyu Yang
Doctoral student @ SRL



Davide Liconti
Doctoral student @ SRL



Jaehoon Kim
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Aurel Appius
Doctoral student @ SRL



Denis Tarasov
Doctoral student @ SRL



Max Firkowski
Teaching Assistant



Vikash Jeyathevan
Teaching Assistant



Yucheng Xia
Teaching Assistant