Western Norway University of Applied Sciences

Workshop on Cooperation, Communication and Control of Collaborative Robots

HVL Robotics lab

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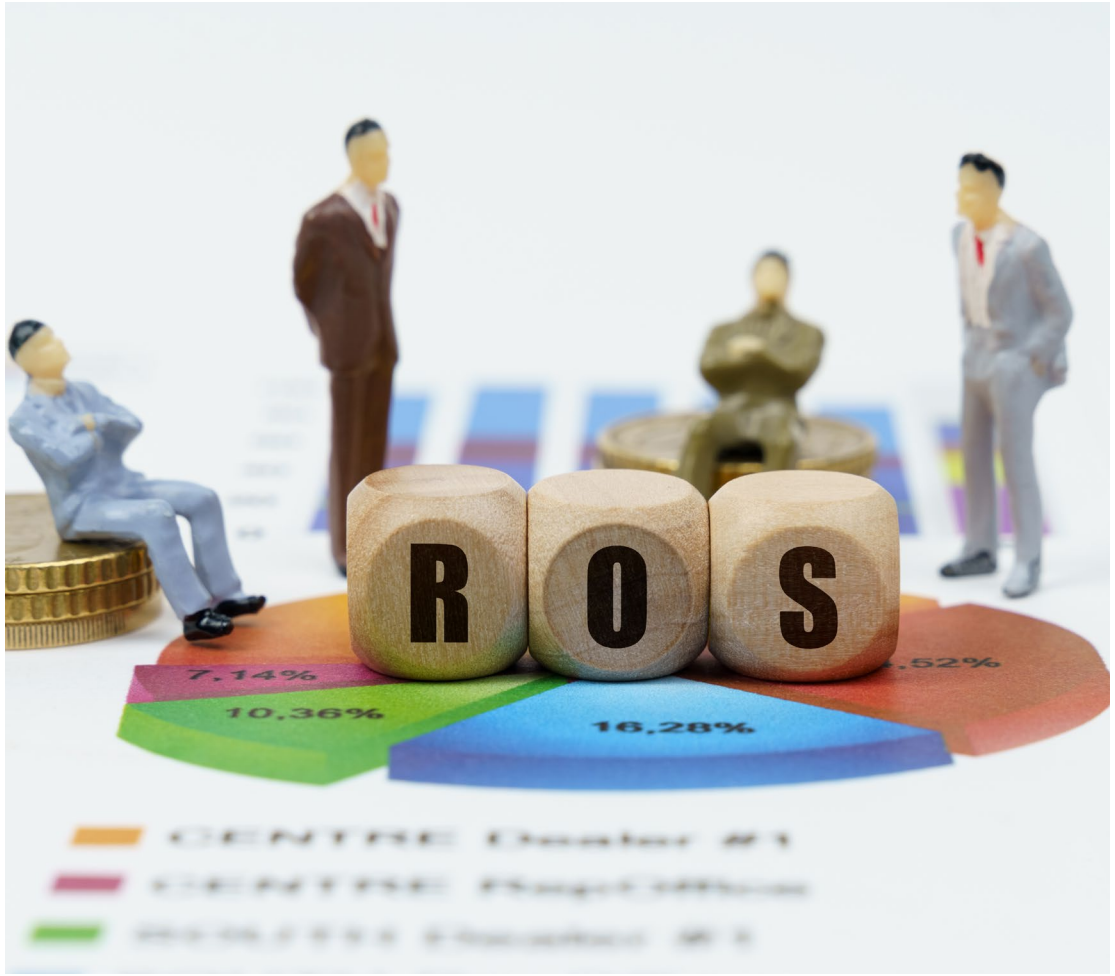
Discussion points - agenda

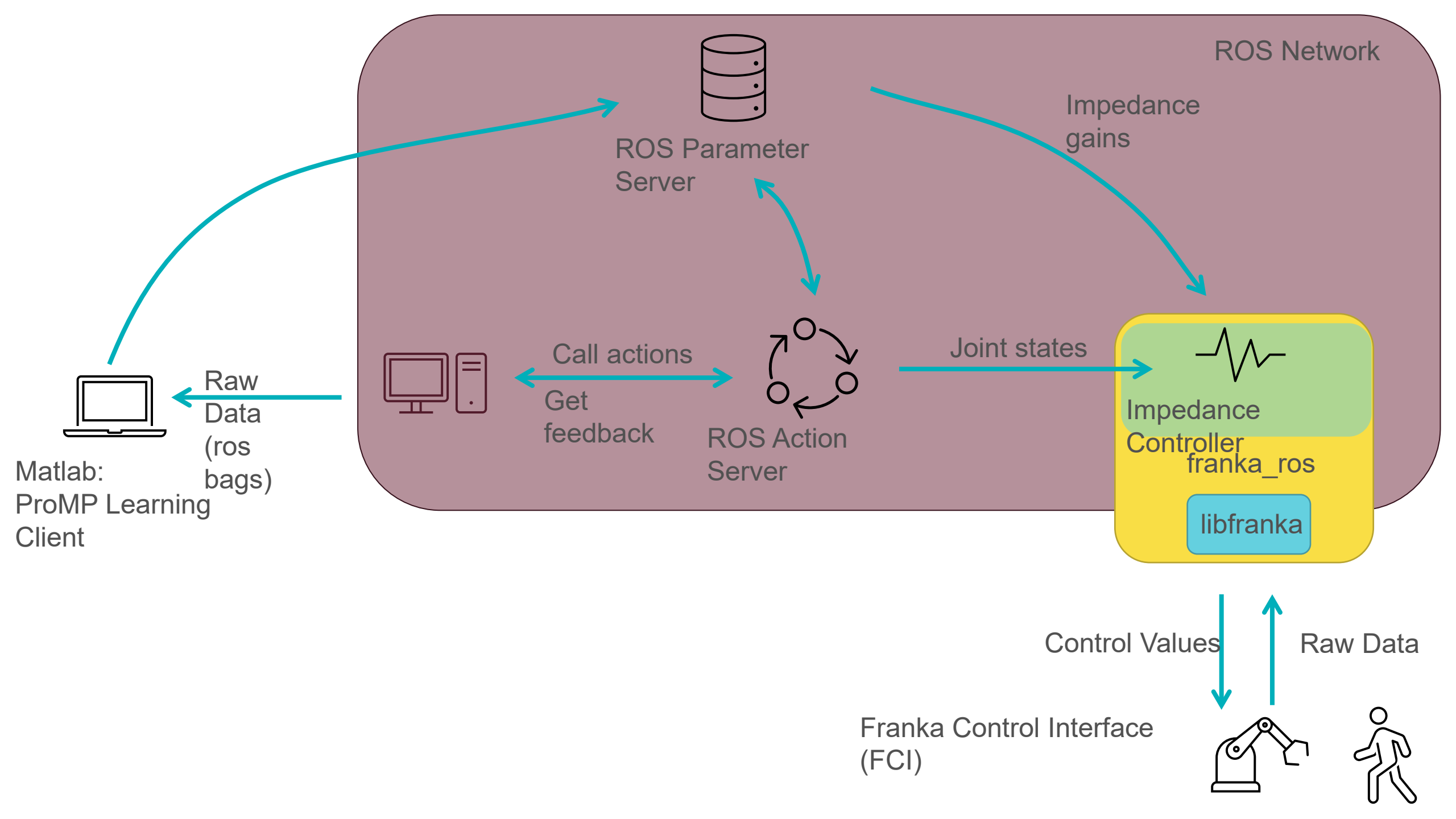
- Short intro on how we do things in our robotics lab
  - Communication through ROS
  - Control methods for human-robot cooperation
  - Simulation tools used
  - Strengths and limitations of different types of collaborative robots
  - Calibration and safety aspects of robots
  - Use-cases for human-robot cooperation in the lab

- Questions, viewpoints and interactions are strongly encouraged!

Communication – ROS

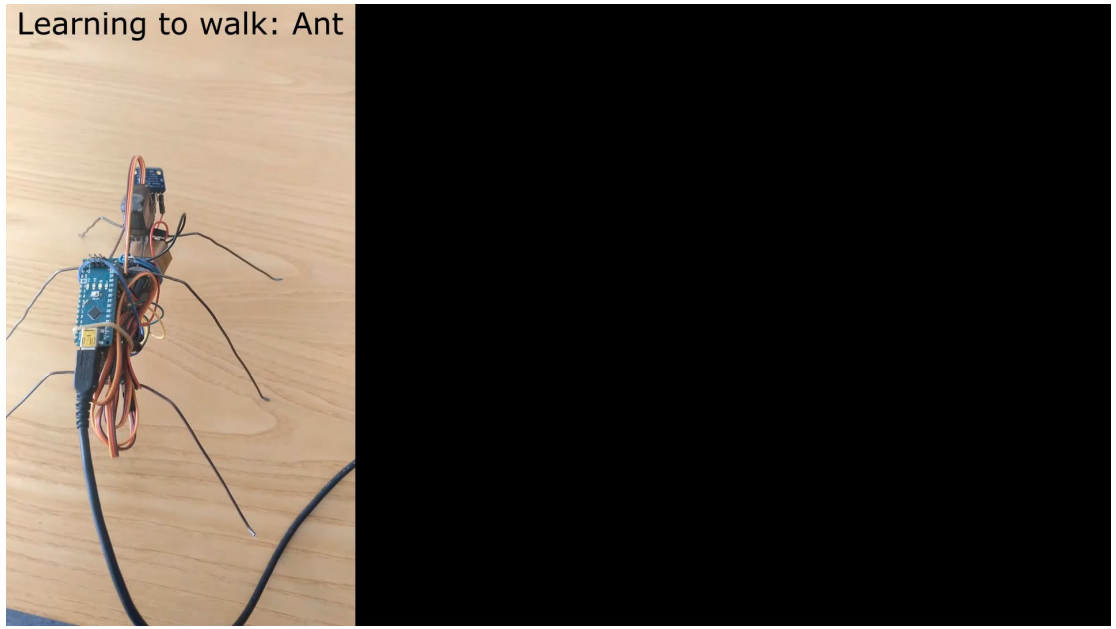
- ROS is the core communcation network in the lab
  - ROS master on lab PC (or on AGV)
- Different interfaces for Real-time data exchange with different manipulators
  - KUKA – Fast Robot Interface (FRI)
  - Panda – Franka Control Interface (FCI)
  - UR – Real-Time Data Exchange Protocol (RTDE)
- ROS comes with different communication types which cover our different needs:
  - Topics
  - Services
  - Actions
  - Parameters




ROS Network
ROS Parameter Server
Impedance gains
Call actions
Get feedback
ROS Action Server
Joint states
Impedance Controller
franka_ros
libfranka
Raw Data (ros bags)
Matlab: ProMP Learning Client
Control Values
Raw Data
Franka Control Interface (FCI)

Control methods for human-robot cooperation

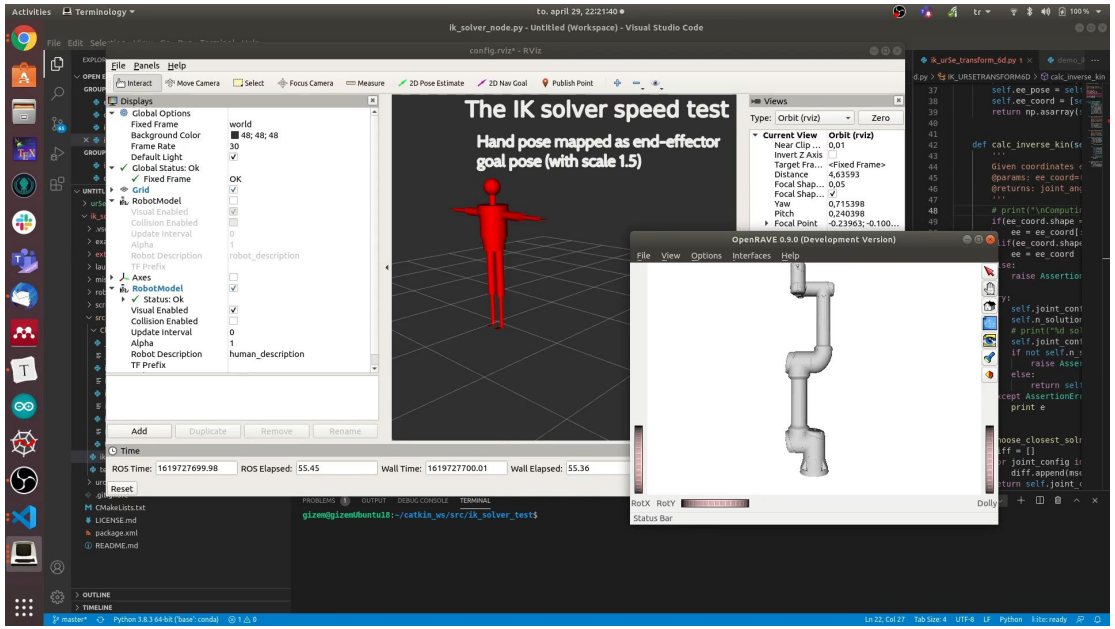
- Control
  - MoveIt!
  - Impedance – admittance control
  - Cartesian space vs Joint space (even tendon length or force for the GH2)
- Learning
  - Supervised learning
  - Reinforcement learning



Simulation tools

- Gazebo, Rviz (visualization)
- RoboSuite – Mujoco
- Augmented reality for path planning

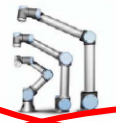
- Those simulation tools are used mainly for two purposes:
  - Safety: testing without endangering the material or the operators, checking for collisions in the environment
  - Learning: learning a task from scratch without endangering the material or environment



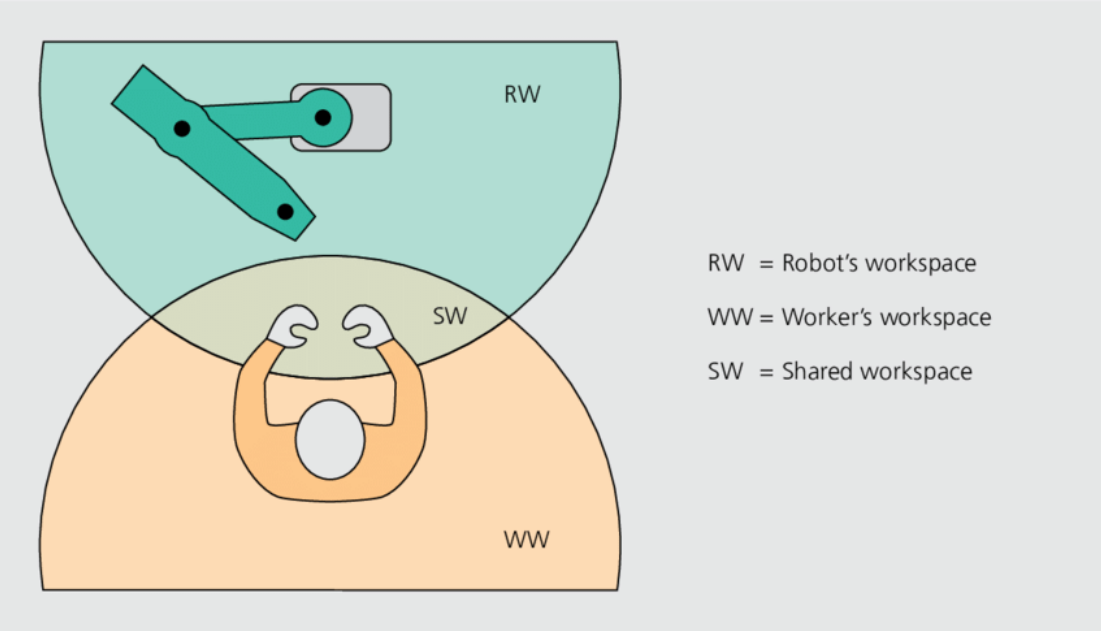
Collaborative robots

- Importance of number of DOFs
- Importance of payload
- Trade-off between stickiness and precision
- Different programming levels:
  - Block programming
  - Low-level programming
  - Interfacing to ROS or Matlab/Simulink

Available commercial cobots (extended from [67–71]).

Manufacturers, robot models and specifications	*Manufacturers, robot models and specifications*
ABB (Switzerland) ⟅ YuMi - IRB 14000  *DOFs:* 7+7 *Payload:* 0.5 kg *Reach:* 559 mm *Repeatability:* ±0.02 mm *Weight:* 38 kg *Velocity:* 1500 mm/s	**ABB (Switzerland) ⟅ Roberta 1 / Roberta 2 / Roberta 3** ell  *DOFs:* 6 *Payload:* 4 kg ‖ 8 kg ‖ 12 kg *Reach:* 600 mm ‖ 800 mm ‖ 1200 mm *Repeatability:* ±0.1 mm *Weight:* 14.5 kg ‖ 19.5 kg ‖ 30.5 kg *Velocity Joints:* 110°/s
FANUC (Japan) ⟅ CR-35iA  *DOFs:* 6 *Payload:* 35 kg *Reach:* 1813 mm *Repeatability:* ±0.04 mm *Weight:* 990 kg *Velocity:* 750 mm/s	**FANUC (Japan) ⟅ CR4iA / CR-7iA / CR-7iA/L**  *DOFs:* 6 *Payload:* 4 kg ‖ 7 kg ‖ 7 kg *Reach:* 550 mm ‖ 717 mm ‖ 911 mm *Repeatability:* ±0.02 mm ‖ ±0.02 mm ‖ ±0.03 mm *Weight:* 48 kg ‖ 53 kg ‖ 55 kg *Velocity:* 1000 mm/s
Rethink Robotics (Boston-USA) ⟅ Baxter / Sawyer  *DOFs:* Baxter 7+7 ‖ Sawyer 7 *Payload:* 2.2 kg per arm ‖ 4 kg *Reach:* 1210 mm per arm ‖ 1260 mm *Repeatability:* ±0.1 mm *Weight:* 75 kg ‖ 19 kg *Velocity:* 1500 mm/s	**UNIVERSAL ROBOT (Denmark) ⟅ UR 3 / 5 / 10**  *DOFs:* 6 *Payload:* 3 kg ‖ 5 kg ‖ 10 kg *Reach:* 500 mm ‖ 850 mm ‖ 1300 mm *Repeatability:* ±0.1 mm *Weight:* 11 kg ‖ 18.4 kg ‖ 28.9 kg *Velocity:* 1000 mm/s
MABI Robotics (Switzerland) ⟅ SPEEDY 6 / 10 / 12  *DOFs:* 6 *Payload:* 6 kg ‖ 10 kg ‖ 12 kg *Reach:* 800 mm ‖ 1384.5 mm ‖ 1250 mm *Repeatability:* ±0.1 mm *Weight:* 28 kg ‖ 28 kg ‖ 35 kg *Velocity Joints:* 145 → 275°/s ‖ 120 → 180°/s ‖ 75 → 275°/s	**KUKA (Germany) ⟅ LBR IIWA**  *DOFs:* 7 *Payload:* 7 kg ‖ 14 kg *Reach:* 800 mm ‖ 820 mm *Repeatability:* ±0.1 mm ‖ ±0.15 mm *Weight:* 22 kg ‖ 30 kg *Velocity Joints:* 90 → 180°/s ‖ 70 → 180°/s
Techman Robot (Taiwan) ⟅ TM5-900 / 700  *DOFs:* 6 *Payload:* 4 kg ‖ 6 kg *Reach:* 900 mm ‖ 700 mm *Repeatability:* ±0.05 mm *Weight:* 22.5 kg ‖ 22 kg *Velocity Joints:* 180 → 225°/s	**Productive Robotics (Carpinteria-USA) ⟅ OB7**  *DOFs:* 7 *Payload:* 5 kg *Reach:* 1000 mm *Repeatability:* ±0.1 mm *Weight:* 24 kg *Velocity:* 2000 mm/s
Yaskawa (Japan) ⟅ Motoman HC10  *DOFs:* 6 *Payload:* 10 kg *Reach:* 1200 mm *Repeatability:* ±0.1 mm *Weight:* 45 kg *Velocity Joints:* 130 → 250°/s	**AUBO Robotics (China) ⟅ AUBO-i5**  *DOFs:* 6 *Payload:* 5 kg *Reach:* 880 mm *Repeatability:* ±0.05 mm *Weight:* 24 kg *Velocity:* 2800 mm/s
FRANKA EMIKA (Germany) ⟅ FRANKA ARM  *DOFs:* 7 *Payload:* 3 kg *Reach:* 855 mm *Repeatability:* ±0.1 mm *Weight:* 18 kg *Velocity Joints:* 2000 mm/s	**Precise Automation (Fremont-USA) ⟅ PP100 - Cartesian**  *DOFs:* 3 *Payload:* 1 kg *Reach:* *X* 635 mm - *Y* 300 mm - *Z* 225 mm *Repeatability:* ±0.1 mm *Weight:* 20 kg *Velocity:* 1500 mm/s
Kawasaki Robotics (Japan) ⟅ duAro – Dual Arm SCARA Robot  *DOFs:* 4+4 *Payload:* 2 kg *Reach:* 760 mm *Repeatability:* ±0.05 mm *Weight:* 200 kg *Velocity:* N/A	**BOSCH (Germany) ⟅ APAS**  *DOFs:* 6 *Payload:* 2 kg *Reach:* 911 mm *Repeatability:* ±0.03 mm *Weight:* 230 kg *Velocity:* 500 mm/s

Calibration and Safety



- Calibration
  - End-effector calibration
  - Payload calibration
- Safety
  - Max speed
  - Max acceleration
  - Max force
  - Safety planes
  - Limited workspace (restricted access, different speed, acceleration, etc limits)
  - Change torque
  - Emergency stop button
  - Restricted access to the lab and training for unexperienced operators
  - Risk assessment

Sticky-box safety

Use-cases for human-robot cooperation in the lab