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THE BIOROBOTICS INSTITUTE Scuola Superiore Sant'Anna

Workshop "ECHORD - scientific results and tech transfer opportunities"
Vilamoura, October 11, 2012

HUROBIN experiment (Call II)

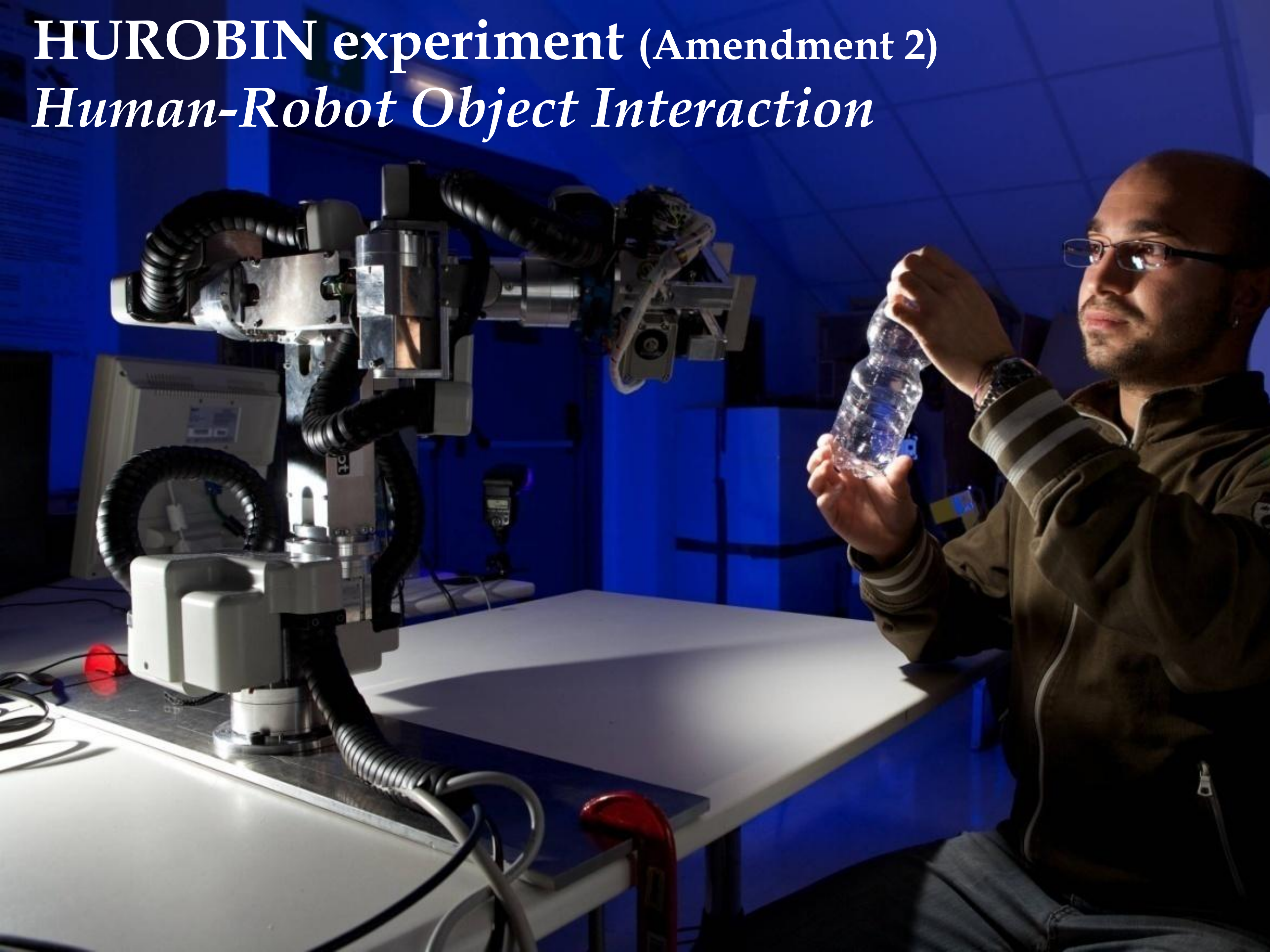
Stefano Mazzoleni, PhD

The BioRobotics Institute – Scuola Superiore Sant'Anna

IEEE/RAS co-Chair of Technical Committee on Rehabilitation & Assisitive Robotics

HUROBIN experiment (Amendment 2)

Human-Robot Object Interaction



Outline

Description of the experiment
Status of the experiment
Dissemination and follow-up

Outline

Description of the experiment

Status of the experiment

Dissemination and follow-up

Objectives:

- Safe human-robot cooperative manipulation tasks
- Human operator interacts with the robot for manipulating shared objects
- The robot adapts its configuration and dynamics to the conditions imposed by the human operator
- 7 DoFs manipulator and a gripper used in combination with a dataglove (as HMI) and a motion tracker
- Objects characterized by different shared, length and weight
    - n. 2 cylinders (*cyl_1*, *cyl_2*), external diameter 60 [mm] and bore 56 [mm]; *cyl_1:* 1000 [mm] length and 1.092 [Kg], *cyl_2* : 500 [mm] length and 0.544 [Kg];
    - n. 2 bars (*bar_1*, *bar_2*) square section, external side 50 [mm], internal side 40 [mm]; *bar_1:* 1000 [mm] length and 2.439 [Kg]; *bar_2:* 500 [mm] length and 1.219 [Kg];
    - n. 2 plates (*plt_1*, *plt2*): 1000 [mm] and 500 [mm] length, 70 [mm] width and 10[mm] thickness; *plt_1* :1.897 [Kg]; *plt_2:* 0.949 [Kg].

Assumptions

- Sensor failures and adverse conditions considered to test the safety of the human-robot cooperative tasks
- Motion tracker used by the human agent to track the trajectory of the shared object during simulation of position sensor failures
- The robot is expected to adapt the trajectory using the load cell
- Tracker connected to the object to check kinematical data: to provide redundancy (safe conditions to the human operator)
- Dataglove used as command interface for the robot gripper and as emergency button

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Participants

- The BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa – Italy *(SSSA)*: experiment's coordinator

- Humanware Srl, Pisa –Italy *(HMW)*: experiment's partner, spin-off company specialized in the design and development of advanced hardware and software for HMIs

- Team
  - Stefano Mazzoleni, PhD, Control engineer *(SSSA)*
  - Nicola Di Lecce, Control engineer *(SSSA)*
  - Andrea Scoglio, CEO, Electronic engineer *(HMW)*
  - Giovanni Cappiello, PhD, Mechanical engineer *(HMW)*
  - Zoran Curto, Electrical engineer *(HMW)*

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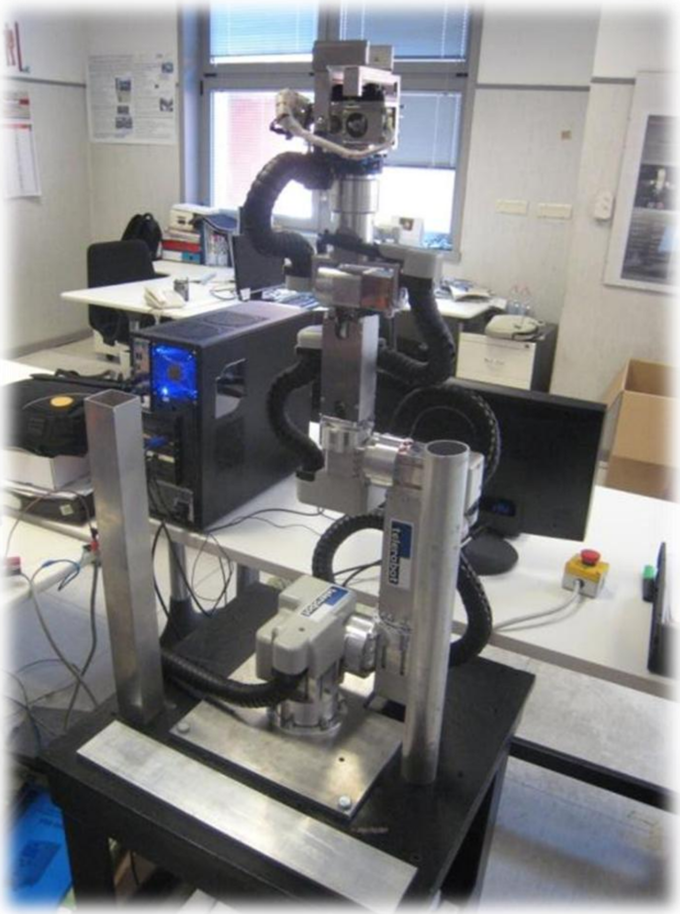
Experiment setup



7 DoFs robotic arm
(TLR LightArm, TeleRobot, Italy)

Motion tracker
(Humanware, Italy)

Dataglove
(Humanware, Italy)

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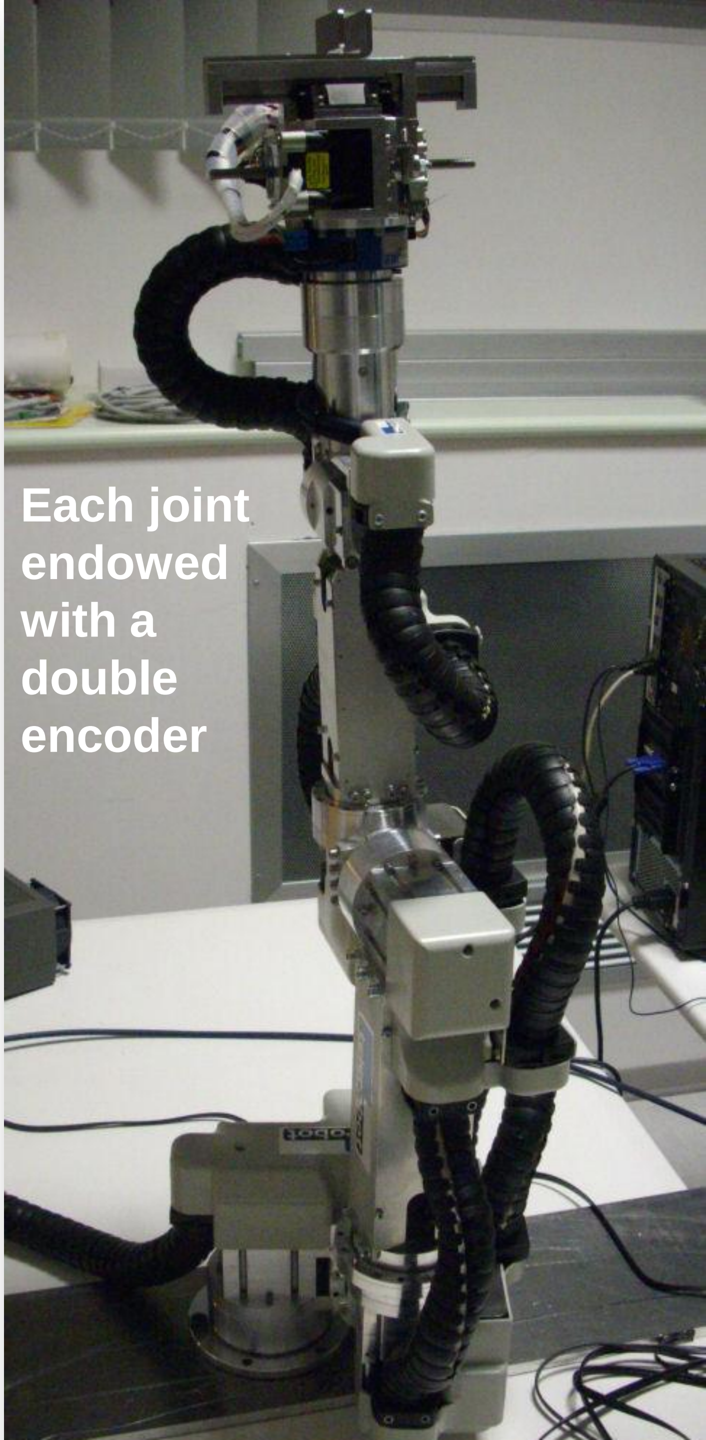
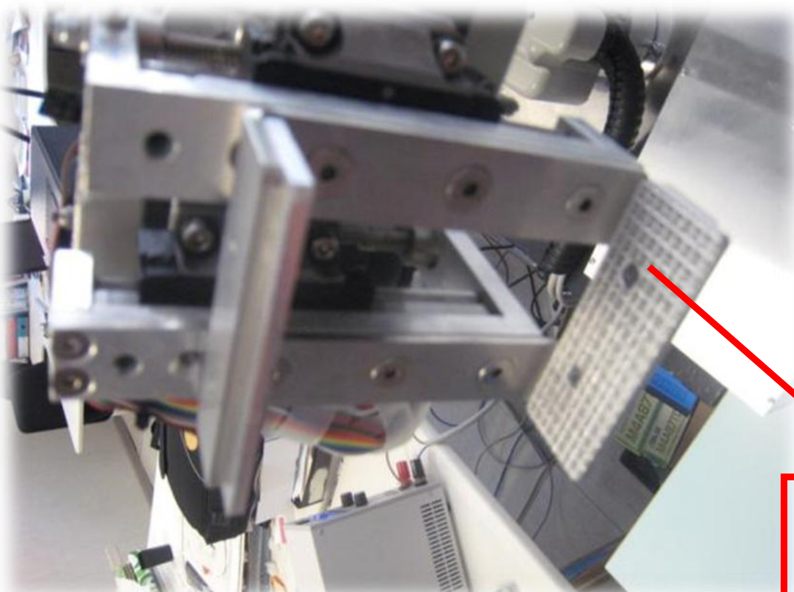
Robotic arm

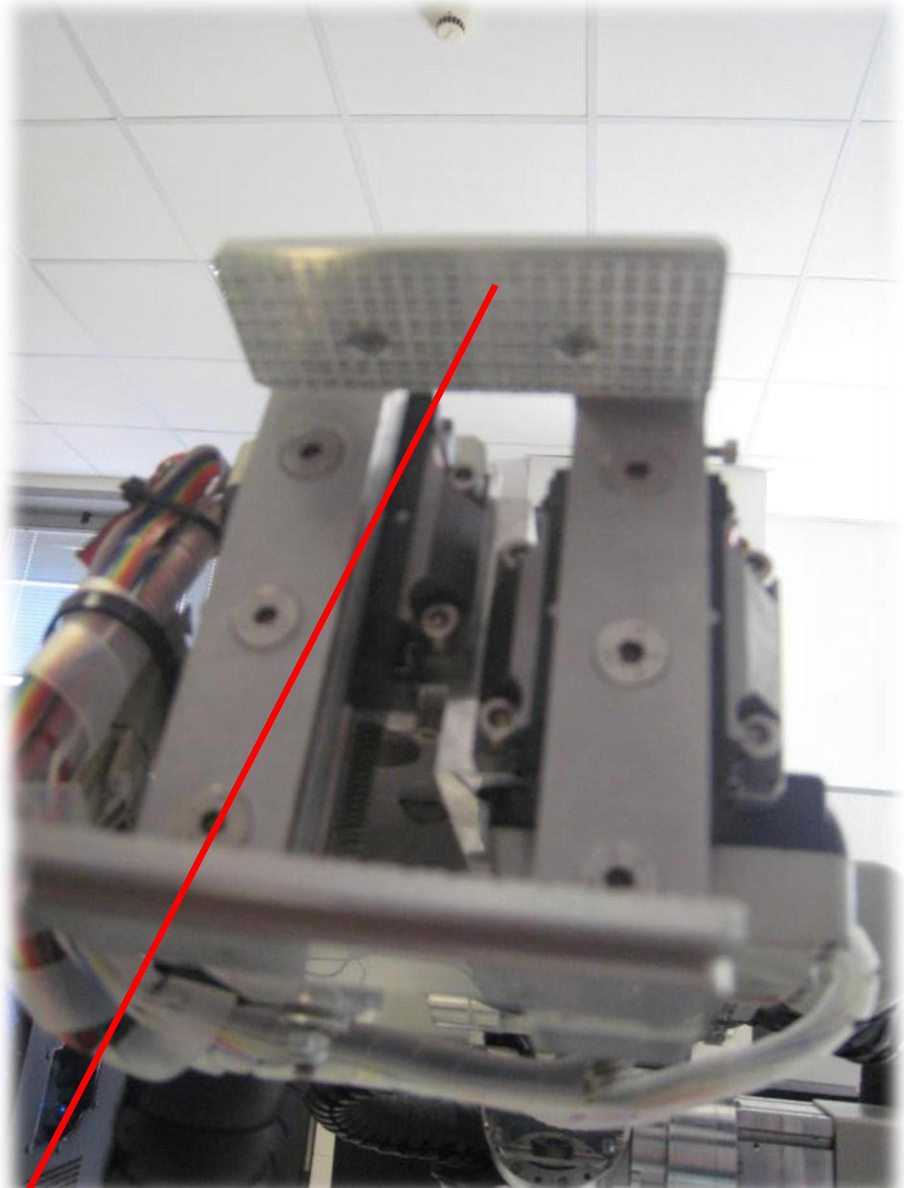
- Harmonic drive gearboxes with frameless brushless motors;
- 7 controlled axis;
- Nominal arm max length: 850 mm;
- 12 bit absolute encoder on all axis;
- Repeatability +/- 0.5 mm;
- Rough weight: 15 Kg;
- Maximum speed: 90 deg/s for each joint with 48 VDC supply;
- Max Payload: 7.5 Kg;
- DSP and motor amplifier on board at each modular joint and CANopen connection;
- Position, speed and torque direct joint control available;
- Modular design
- 6 DoF load cell on the wrist joint;
- 24/48 VDC power supply



Gripper

- Max Payload: 5 kg;
- Maximum opening: 80 mm;
- Max applied force: 30 N;
- Actuation: 2 stepper motors (MH2-1713);
- Transmission: worm system





Manufactured at SSSA precision machine shop

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Motion tracker

Its end-effector can be placed on the handled object in order to track the trajectory of this rigid body during co-manipulation task

- 6 DoFs
- Angular sensor on each joint.
- Resolution: 0.2 mm
- Linearity: ±1%
- Working Space: Spherical, ø1700 mm
- Data rate: 1.5Mbit/sec
- Power supply: USB port
- Dimensions: 160x195x580mm
- Weight: 1.5 Kg

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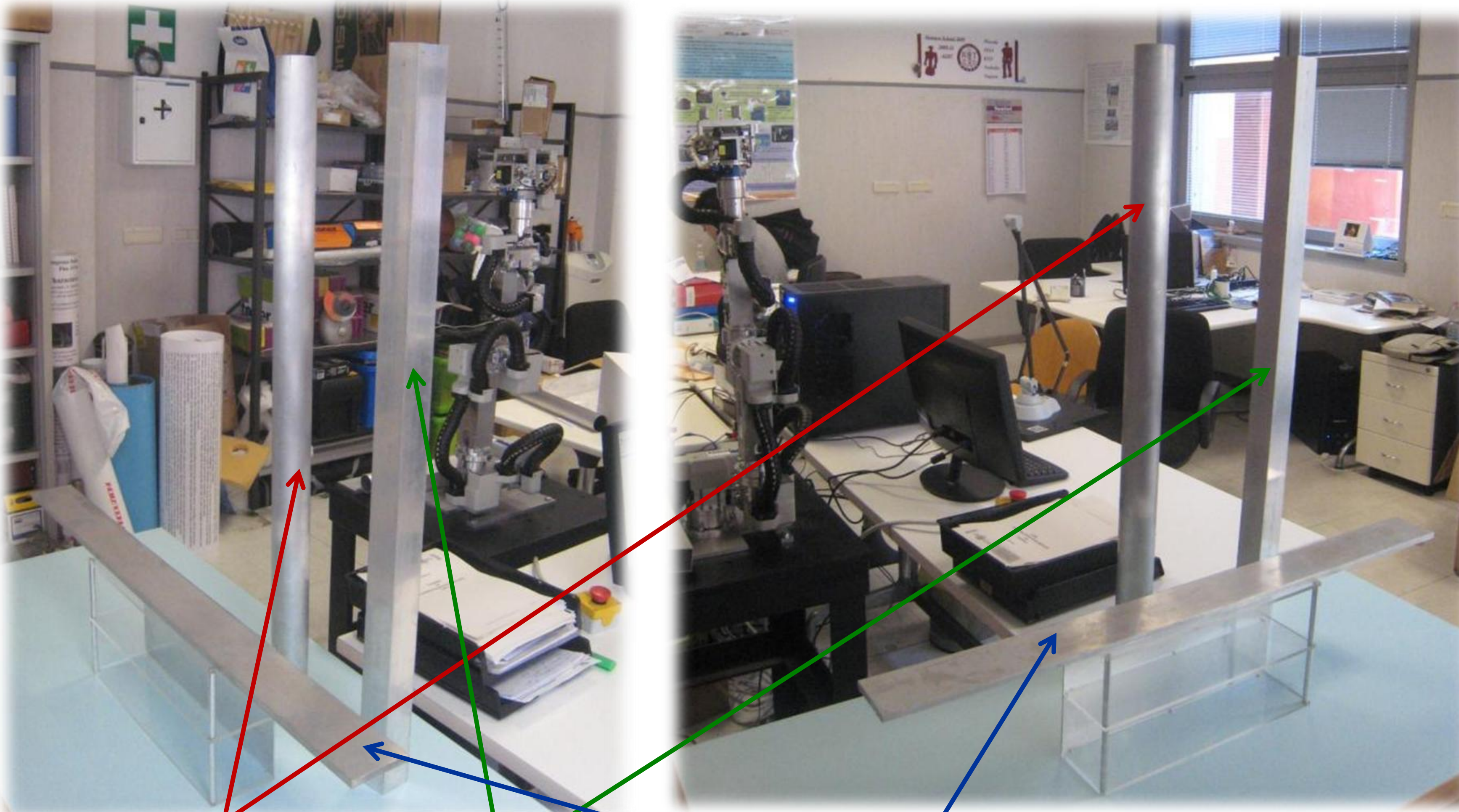
Dataglove

Its end-effector is placed on the handled object in order to track the trajectory of this rigid body during co-manipulation task

- 6 DoFs
- Angular sensor on each joint.
- Resolution: 0.2 mm
- Linearity: ±1%
- Working Space: Spherical, ø1700 mm
- Data rate: 1.5Mbit/sec
- Power supply: USB port
- Dimensions: 160x195x580mm
- Weight: 1.5 Kg

Objects (1/2)



Cyl_1

Bar_1

Plate_1

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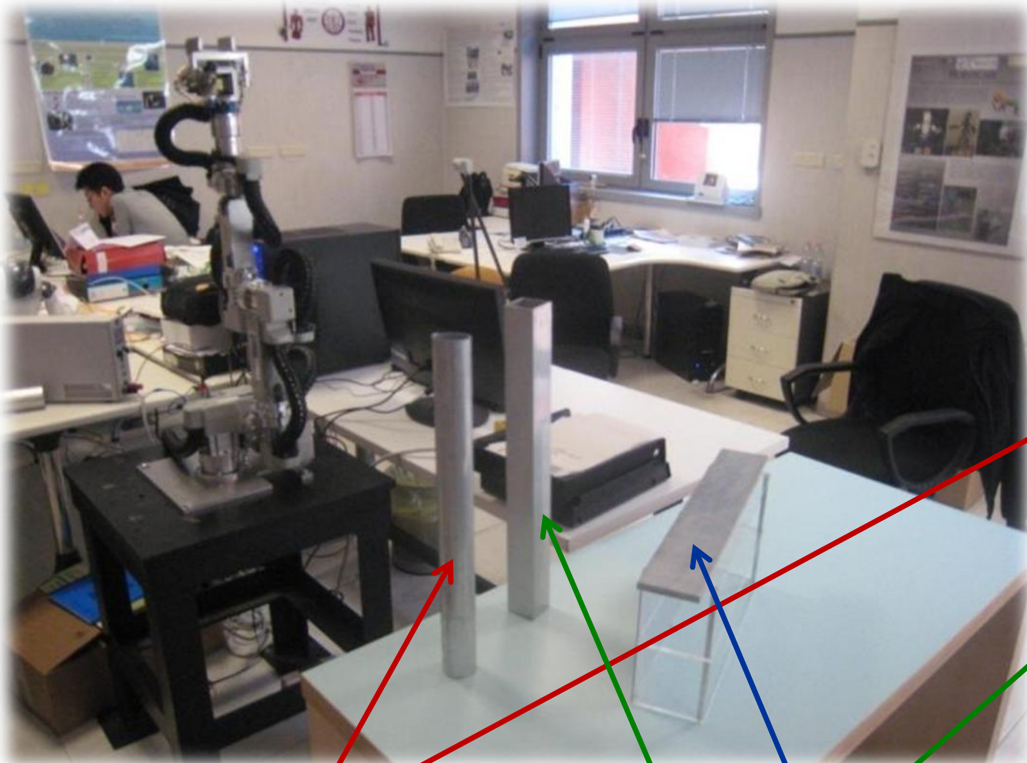
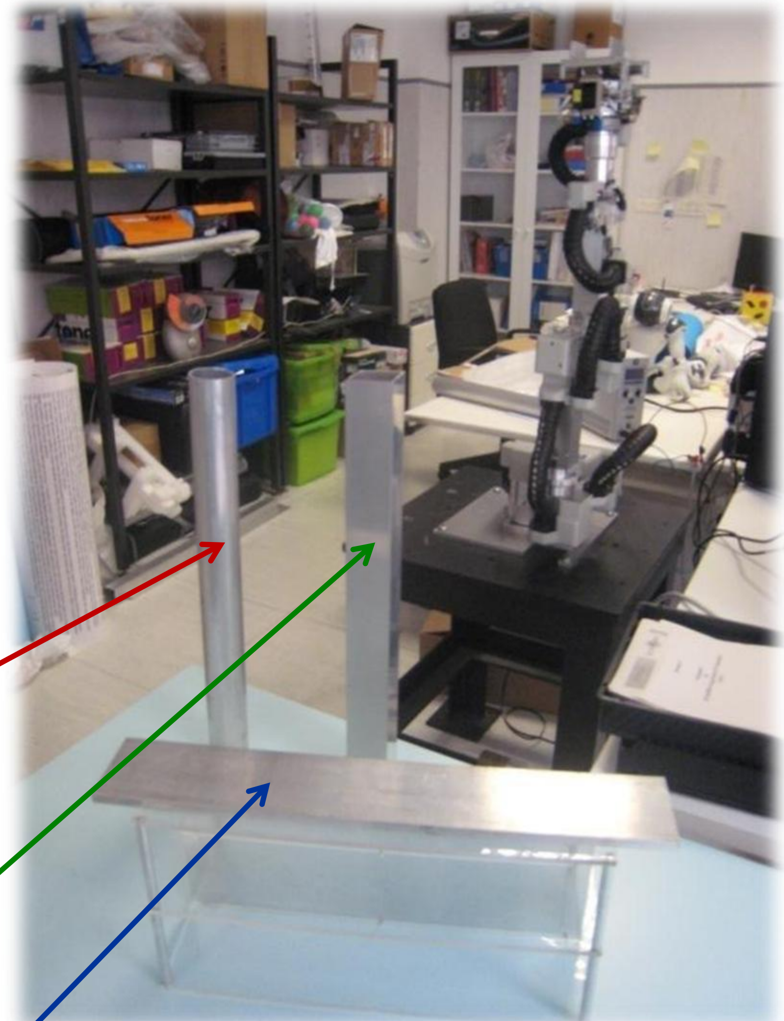
Objects (2/2)





Cyl_2

Bar_2

Plate_2

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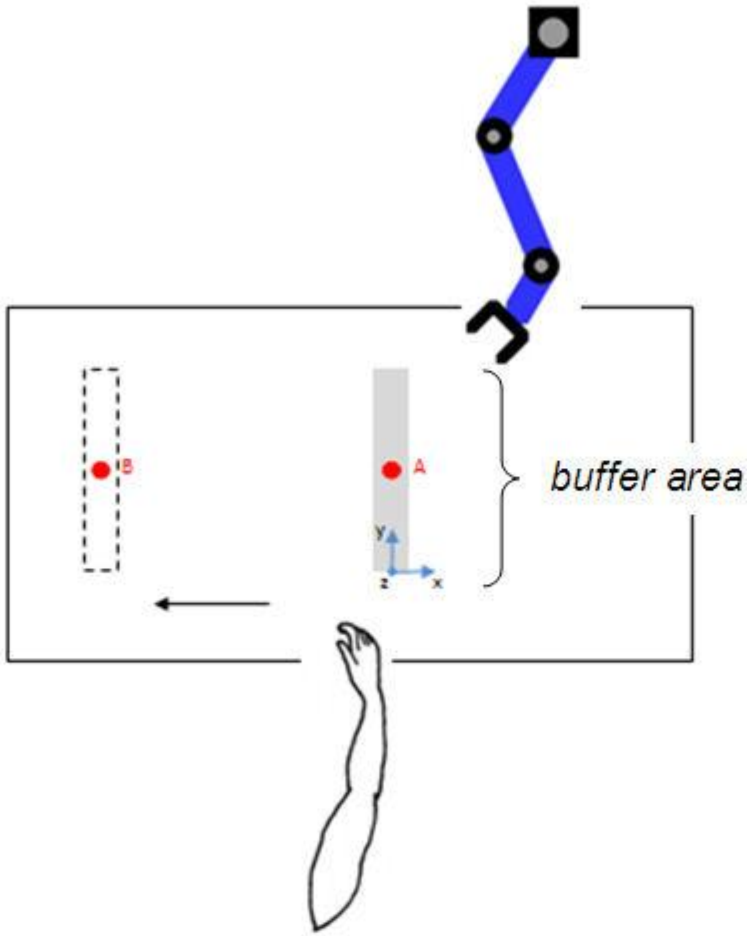
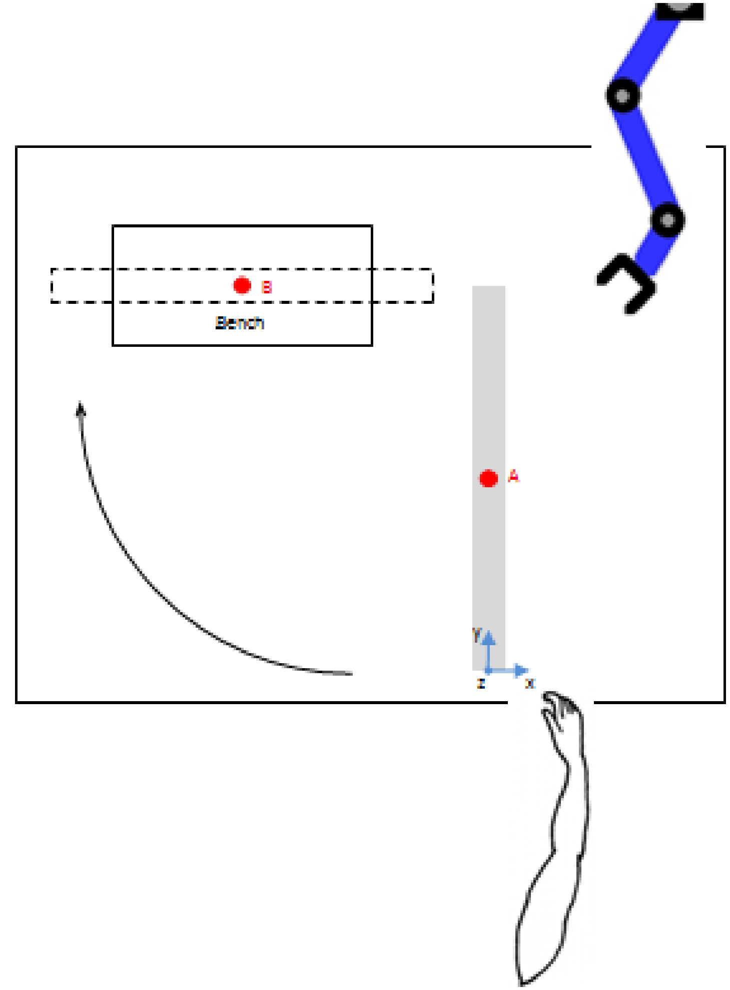
Scenario #1



cylinder 500 [mm] length

Scenario #2



cylinder 1000 [mm] length

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Scenario #3

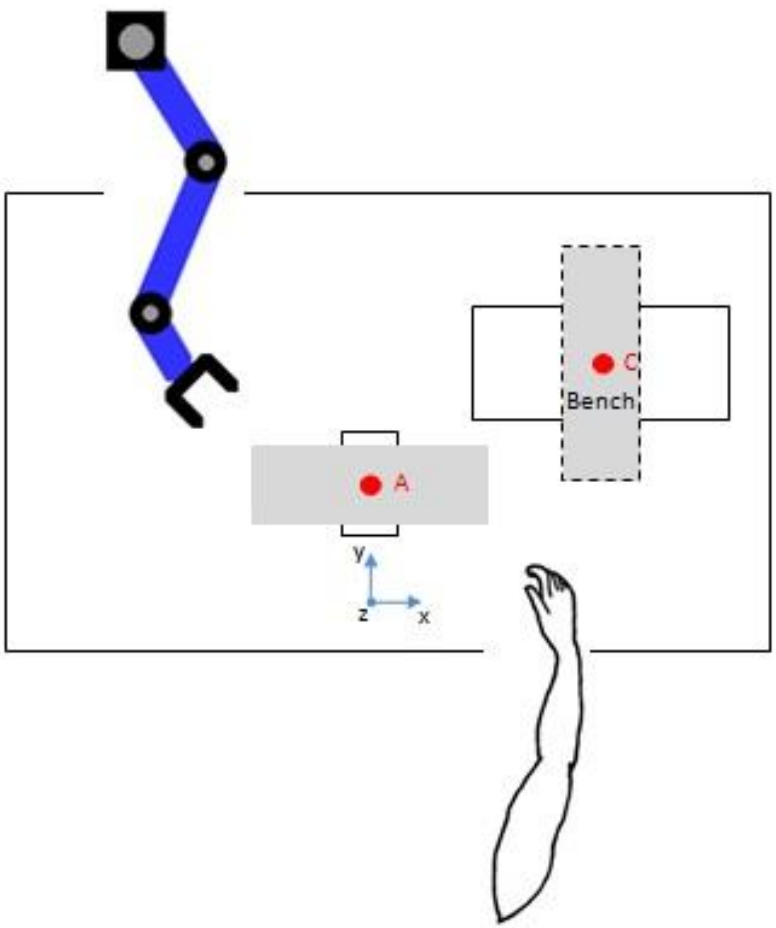

plate 500 [mm] length

Scenario #4

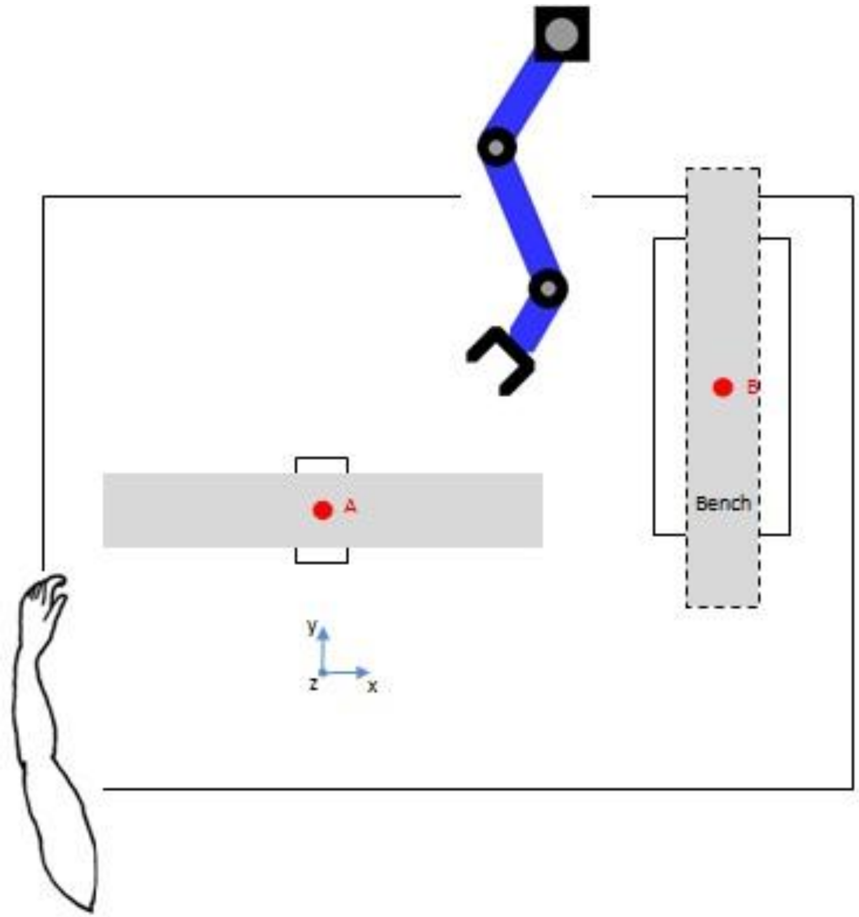

plate 1000 [mm] length

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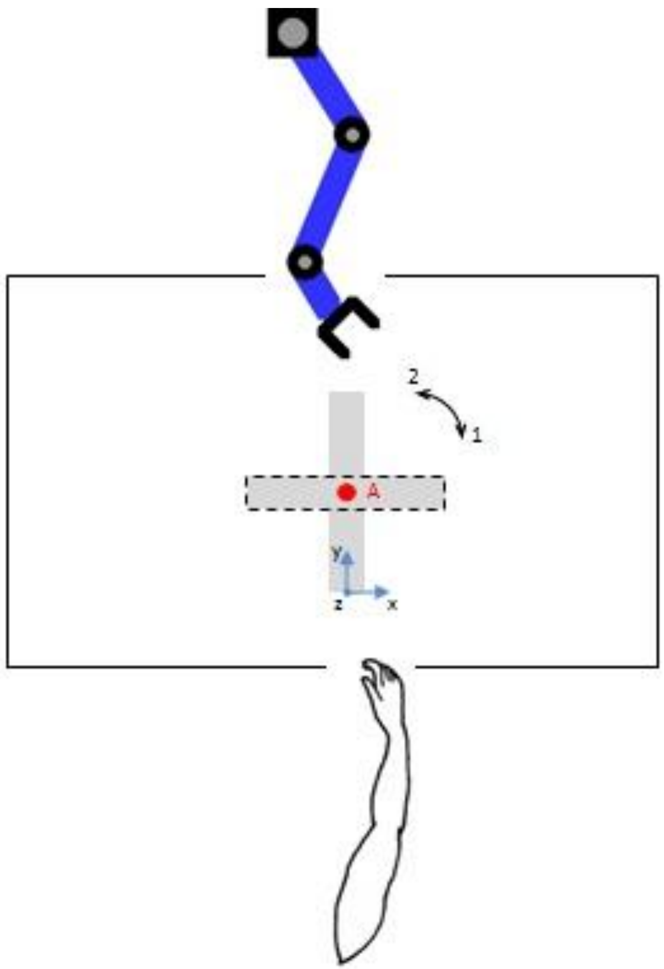
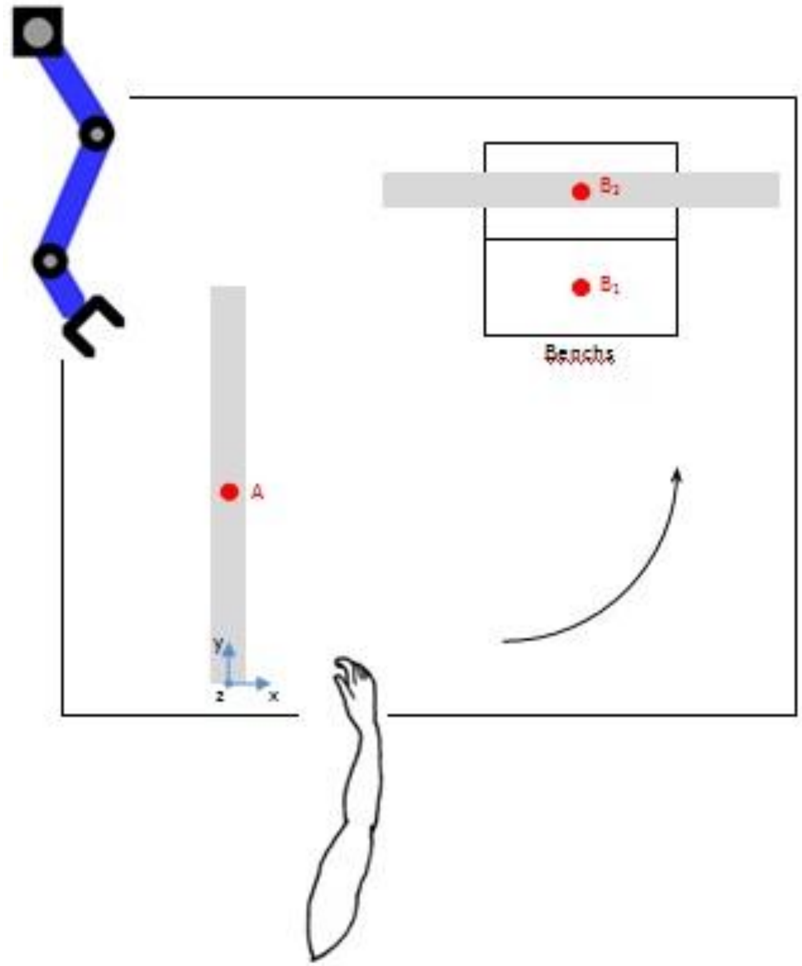
Scenario #5



bar 500 [mm] length

Scenario #6



bar 1000 [mm] length

Types of position sensor failures addressed:

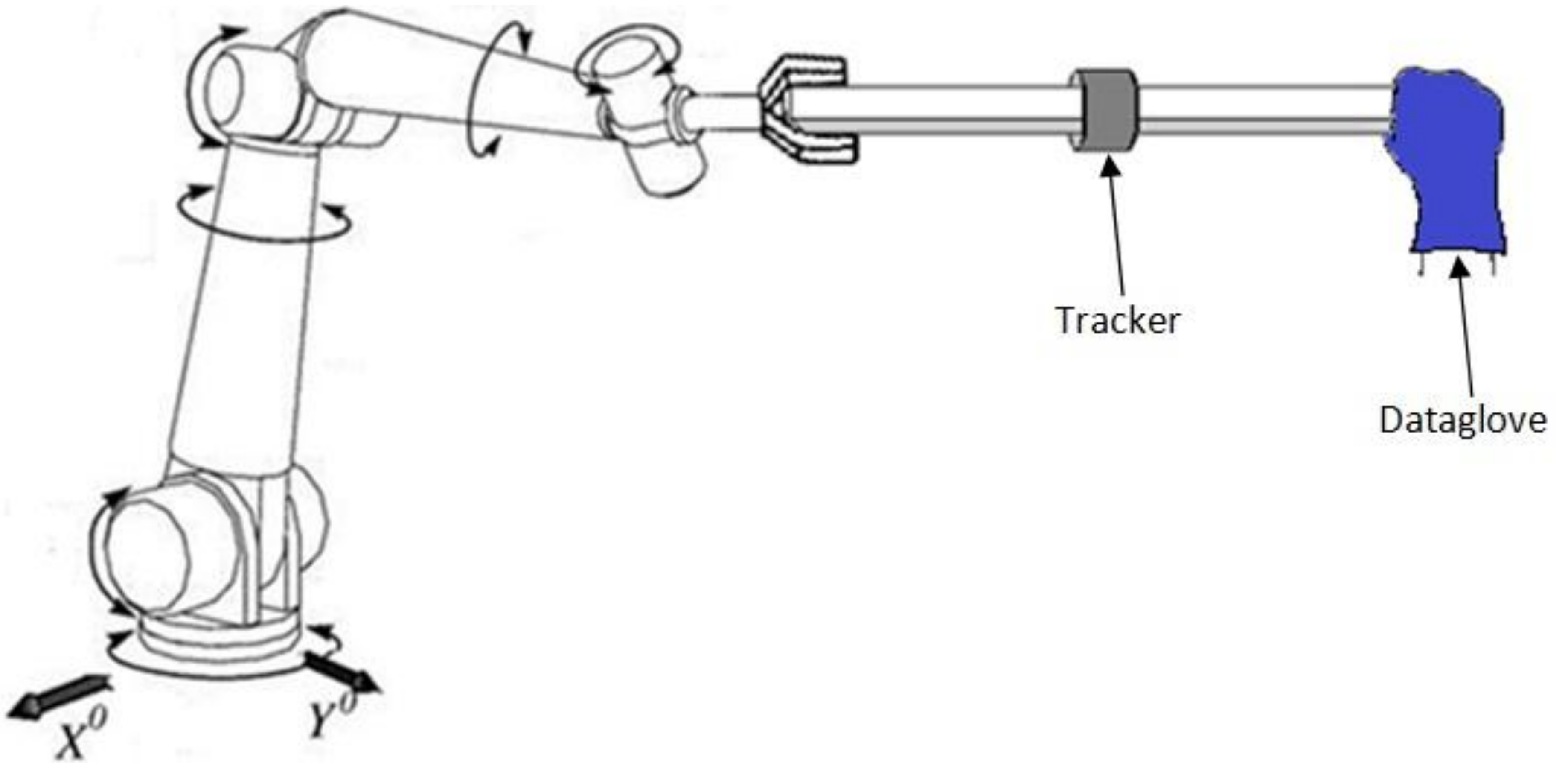
1. Mechanical failure *(e.g. the axis of the encoder and the axis of the joint are disconnected)*
2. Electrical failure *(e.g. cable unplugging or breaking)*
3. Electromagnetic interferences *(e.g. spike losses, noise introducing false spikes)*

The human operator grasps the target object using the **dataglove**: when the human hand is grasping the object, the robot securely grasps the same object

When the human operator suddenly opens the hand wearing the dataglove, the robot motion is immediately stopped

The **tracker** is used as "third" position sensor (triple sensor redundancy)

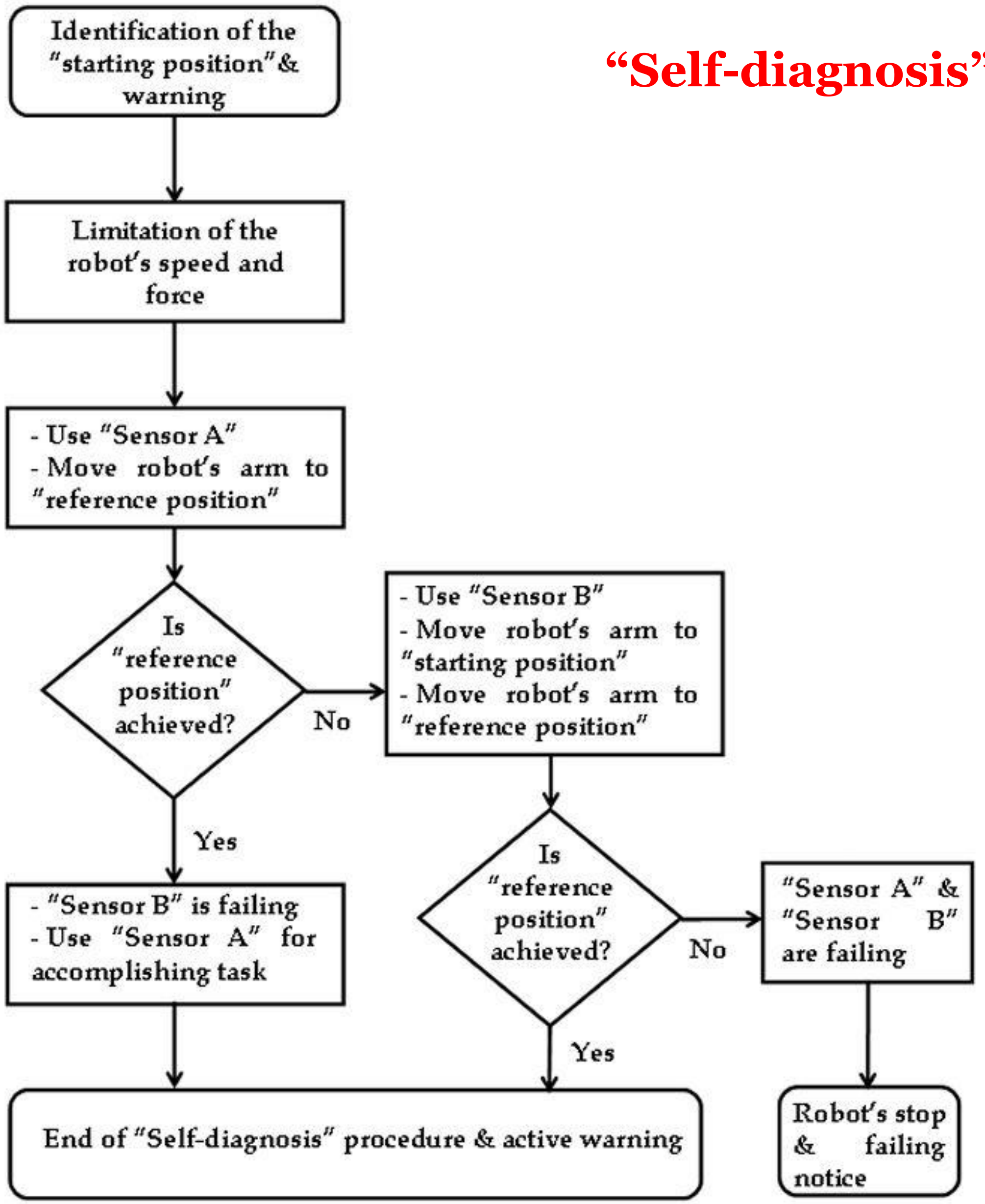
The operator intentions are extracted from information read by a load cell on the wrist joint


Tracker
Dataglove
X^0
Y^0

- Failure simulated by ignoring information from one or more **position sensors** *(e.g. encoders)*
- Control strategy to be implemented for **detecting inconsistency between encoders** on the same joint
- In case of **triple redundancy**, the task can still be accomplished: the inconsistency is detected by comparing the three signals (two coherent signals assumed as correct information)
- Usually triple redundancy is implemented only in critical applications *(e.g. avionics):* the experiment addresses the case of robot endowed with double redundancy
- Current safety procedures in manufacturing automatic cells prevent human-robot cooperation

Development of safe scenario for the human-robot cooperative manipulation, including sensor redundancy and implementation of a robust control strategy

"Self-diagnosis" procedure



Outline

Description of the experiment

Status of the experiment

Dissemination and follow-up

Overall strategy of the workplan

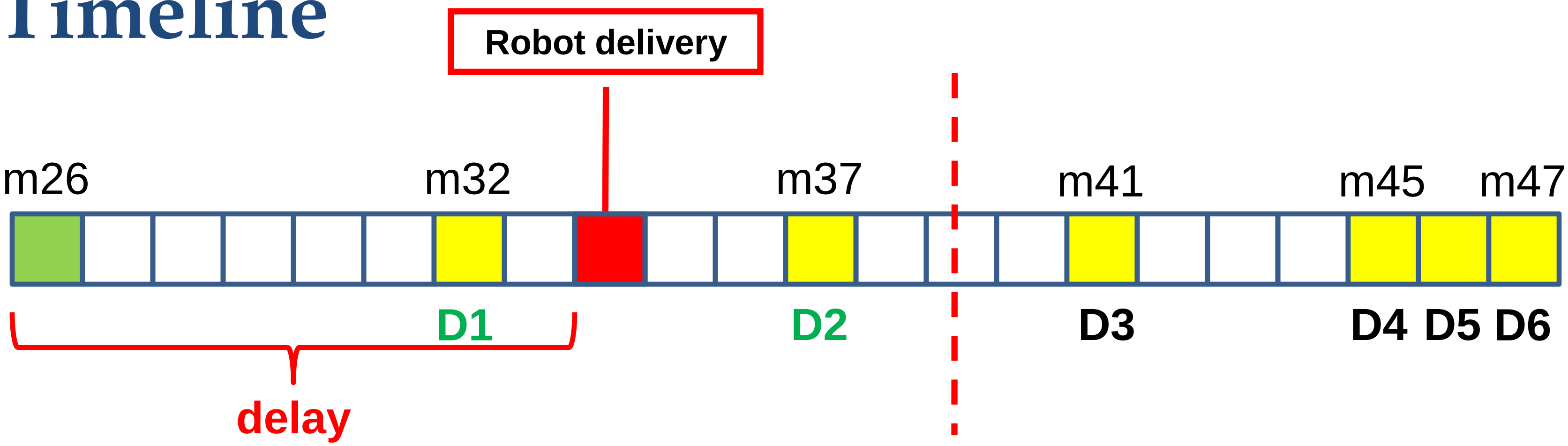
Task list

Task No	Task title	Lead participant Short Name
T1	State of the art and equipment setup	SSSA
T2	Dataglove and tracker integration with robotic arm	HMW
T3	Design and development of robust control strategies for the robotic manipulator	SSSA
T4	Experimental trials in the integrated scenario	SSSA
T5	Implementation of improved safe human-robot cooperation	HMW
T6	Dissemination	SSSA

T1, T2: *completed*

T3, T6: *in progress*

Timeline



D1: Experiment description and setup *(R, PU)*

D2: Software development for dataglove and tracker systems *(R, RE)*

D3: Control strategies for the robotic platform *(R+O, RE)*

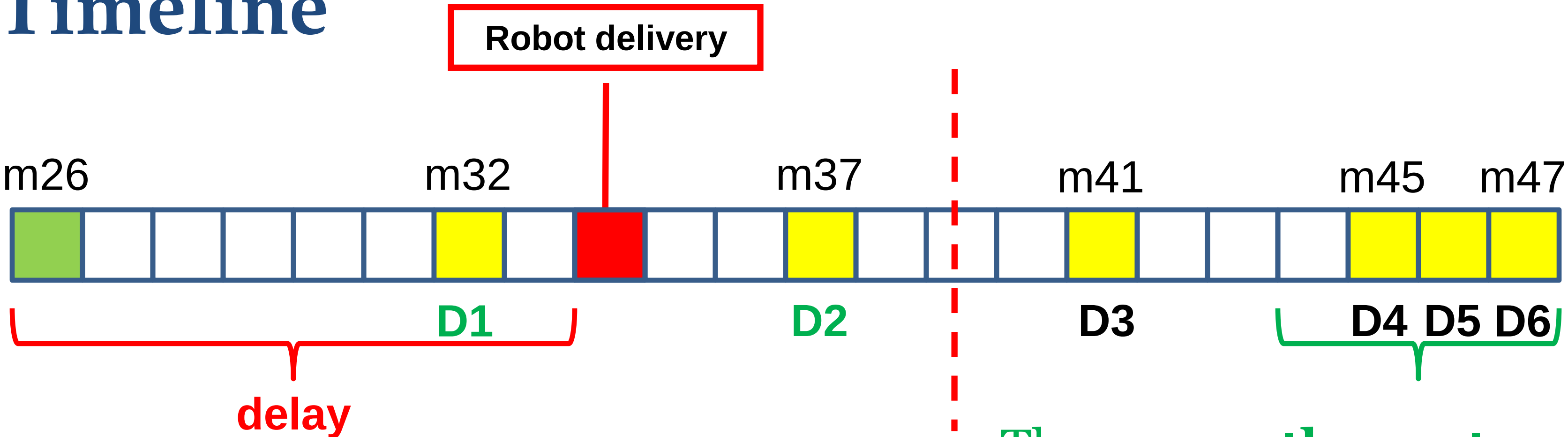
D4: Results from experimental trials on human-robot cooperative manipulation *(R+O, PU)*

D5: Integrated scenario for the human-robot cooperative manipulation *(D, PU)*

D6: Report on dissemination *(R, PU)*

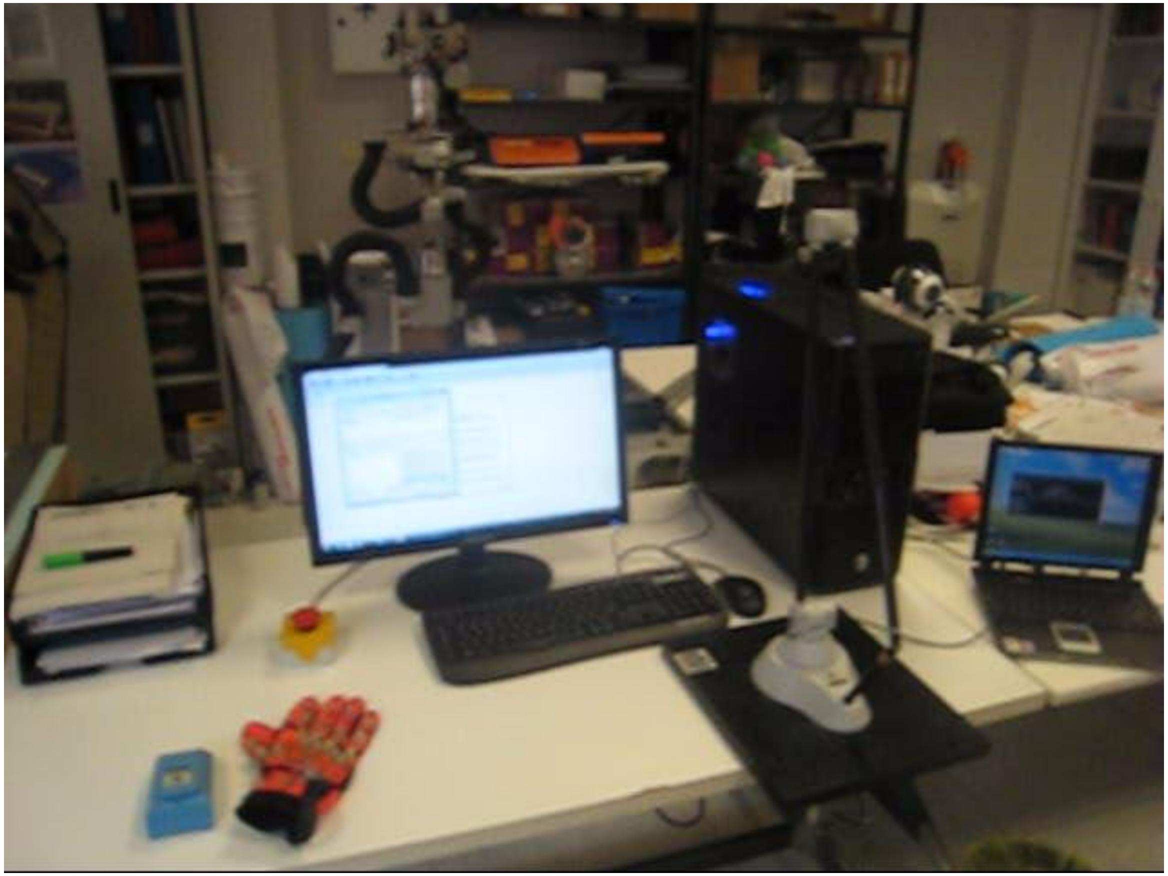
R = Report, P = Prototype, D = Demonstrator, O = Other (video and pictures)
PU = Public
RE = Restricted to a group specified by the consortium (including the Commission Services

Timeline



The **4 months cost-neutral extension** allows the experiment to recover the delay caused by a late delivery of the robotic platform

Motion tracker



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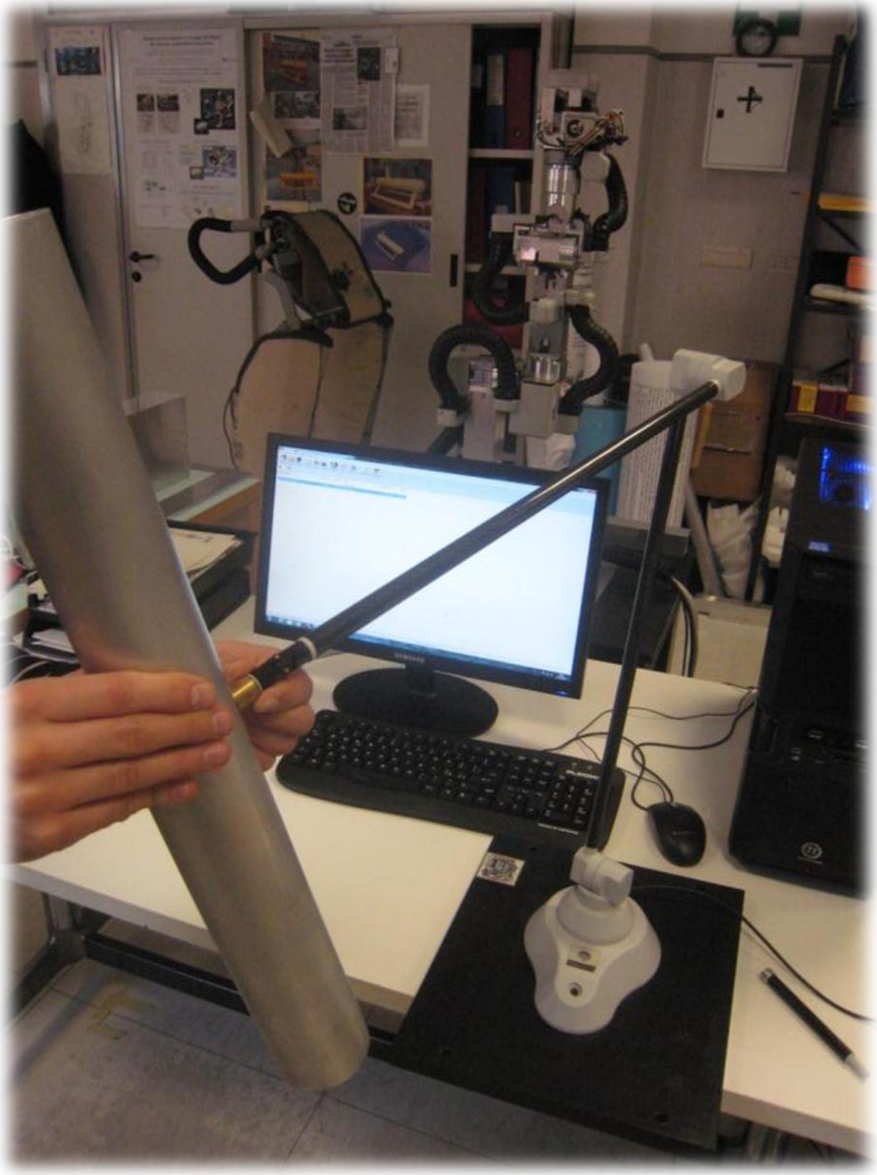
Motion tracker



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Dataglove

Calibration phase

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Dataglove

Power grasp:
cylindrical grasp

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Dataglove

Precision grasp:
palmar pinch

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Scenario

Gripper closure

Activities completed

- **Setup of the robotic arm and tests**

- Interface protocol using IXXAT USB-CAN compact device connected to the dedicated PC,
-driver installation,
- tests for operative steps.
- As integration platform, the Labview environment was used for collecting the different devices:
  - Joints actuators drivers (through IXXAT USB-CAN compact device);
  - JR3 force/torque sensor (through PCI card);
  - Gripper actuators drivers (through IXXAT USB-CAN compact device).

The following tests were carried out:

a) Control of single joints;
b) Control of the gripper;
c) Validation of data transfer from JR3 force/torque sensor

Activities completed

- **Implemention of control strategies for cooperative tasks**

- Development of Matlab S-function including embedding initialization commands for IXXAT USB-CAN compact device and the Process Data Objects (PDOs) sending commands to drivers.

The S-function provides the base interface module for the implementation of specific control strategies currently being designed.

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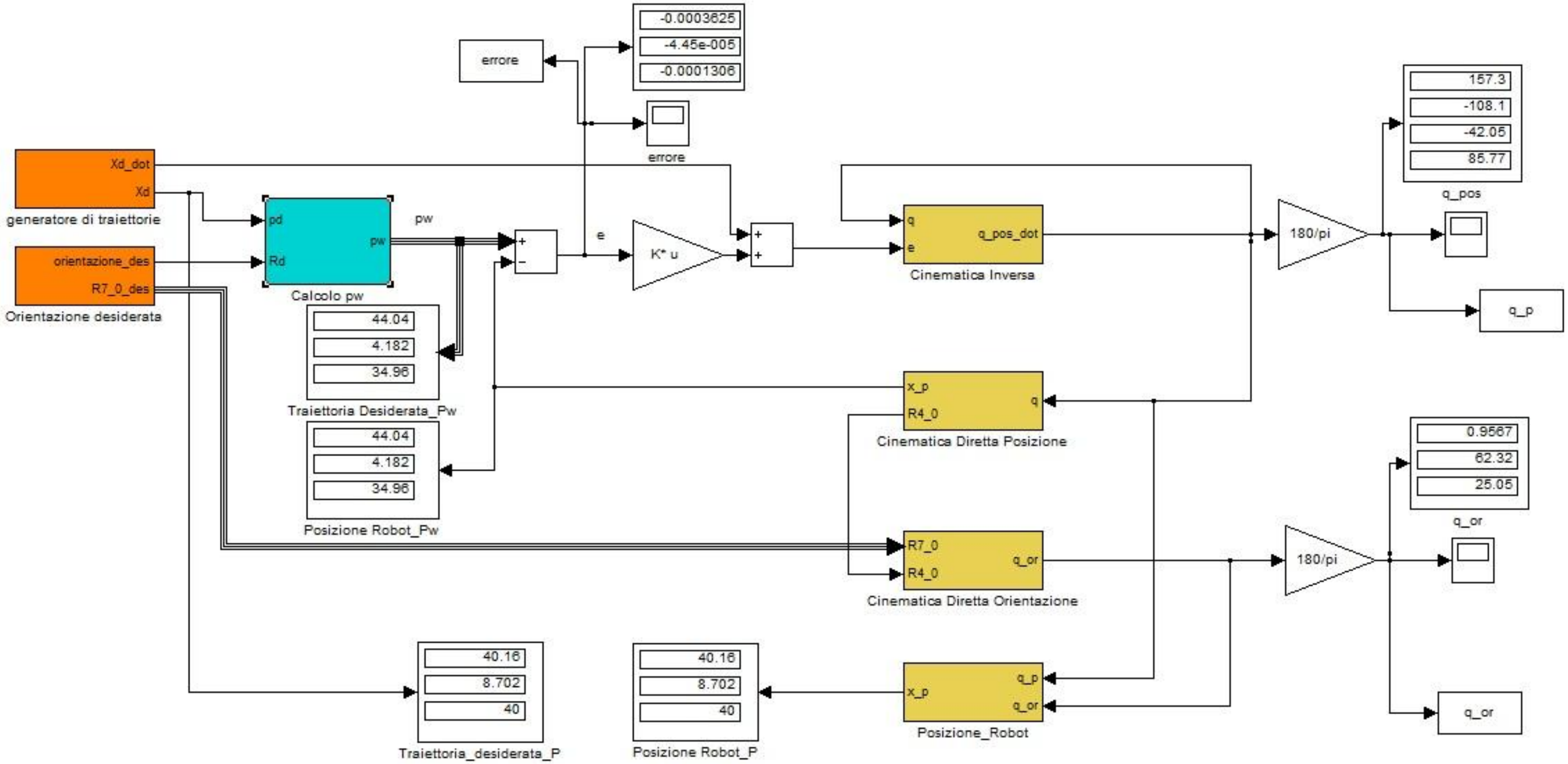
Activities completed

- **Matlab/Simulink trajectories tracking simulation**



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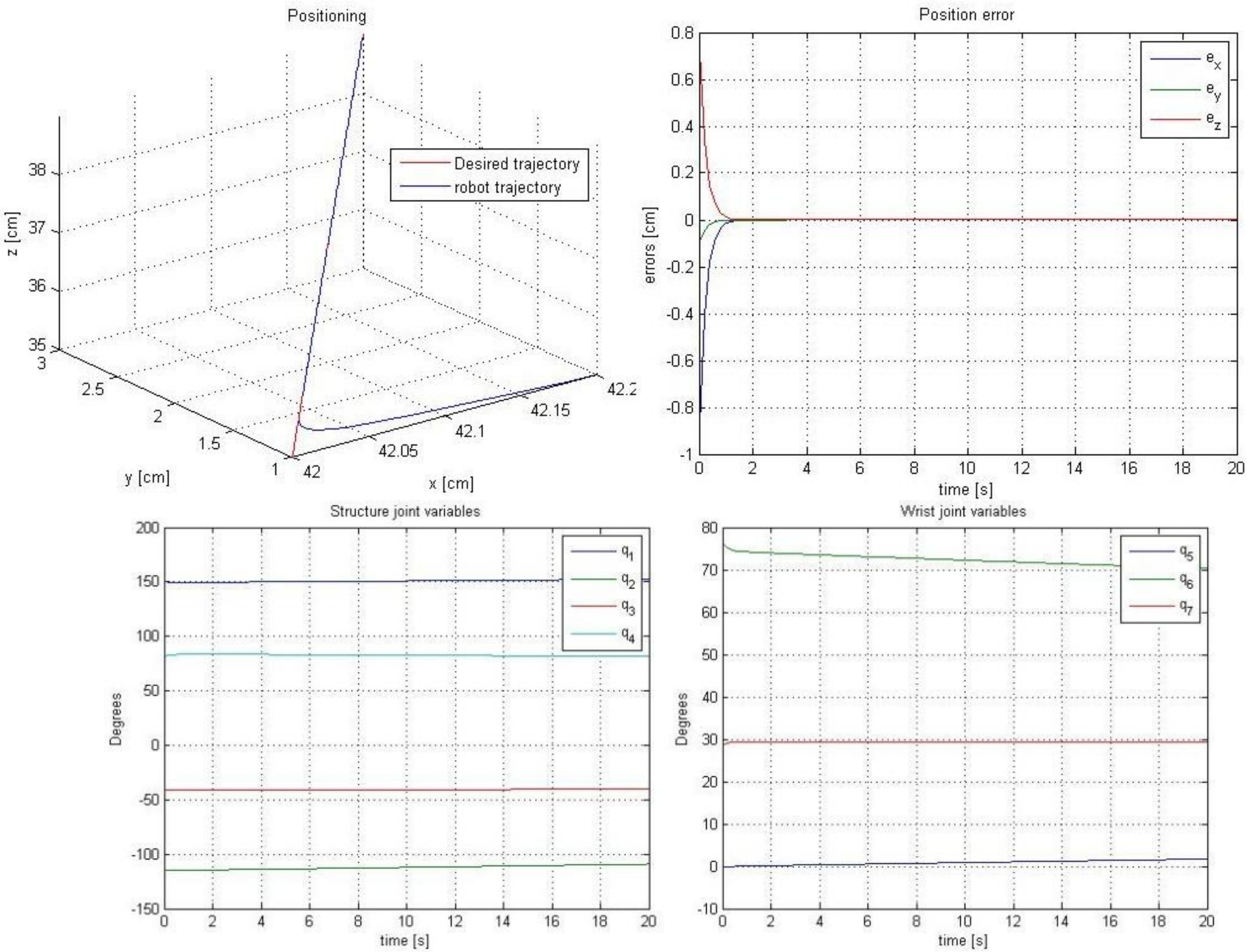
Activities completed

- **Matlab/Simulink trajectories tracking simulation**

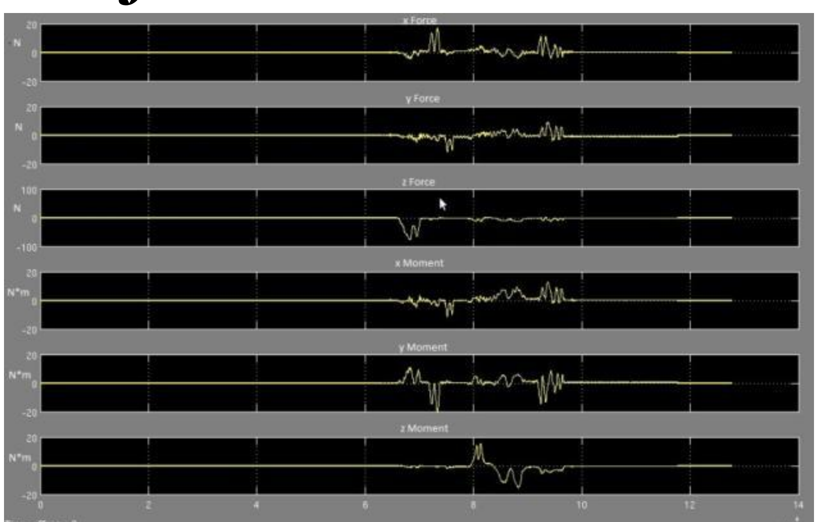


Activities completed

- Improvement of the ***MATLAB S-function*** for communication (open, initialize and close IXXAT USB-CAN compact device communication) and low level control of servo-motors (start motors, joints low level position control, motors stopping, motors braking);

- Implementation and integration of the ***JR3 force/torque sensor*** through dedicated MATLAB S-function;

- Implementation through embedded MATLAB function *“**Damped Least Square for inverse kinematics**”* for tuning parameters.



Activities completed

- Tests on F/T sensor
- Inizialiation and calibration of motion tracker and dataglove
- Motion tracker and dataglove interfacing with robotic arm's control system under Linux - Ubuntu, using UDP functions
- Optimizazion of low level function for actuators control
- Additional Service Data Objects (SDO)
- Tests on direct and inverse kinematics and angles remapping (based on encoders data)
- Offsets on the encoders of actuators

Ongoing and future activities

- Tests on dynamics of robotic platform (T3)
- Implementation of position control scheme (T3)
- Dissemination (T6)

- Implementation of **impedance-based control scheme** for safe human-robot cooperative tasks (T3)
- Validation of proposed control strategy through experimental tests (T4)
- Implementation of improved safe human-robot cooperation (T5)
- Dissemination (T6)

Outline

Description of the experiment

Status of the experiment

Dissemination and follow-up

Follow-up

1) Further developments to be proposed under research European funding programmes

- Manunet 2012 *(proposal submitted, in collaboration with HMW and Asturian company* → possible exploitation plan

2) Use of integrated platform for upper limb rehabilitation

- Stroke patients
- Pointing and grasping tasks
- Activities of Daily Living tasks *(drinking, moving a bottle)*
- Experimental trials at the Laboratory of Rehabilitation Bioengineering, "Auxilium Vitae" Rehabilitation Centre, Volterra

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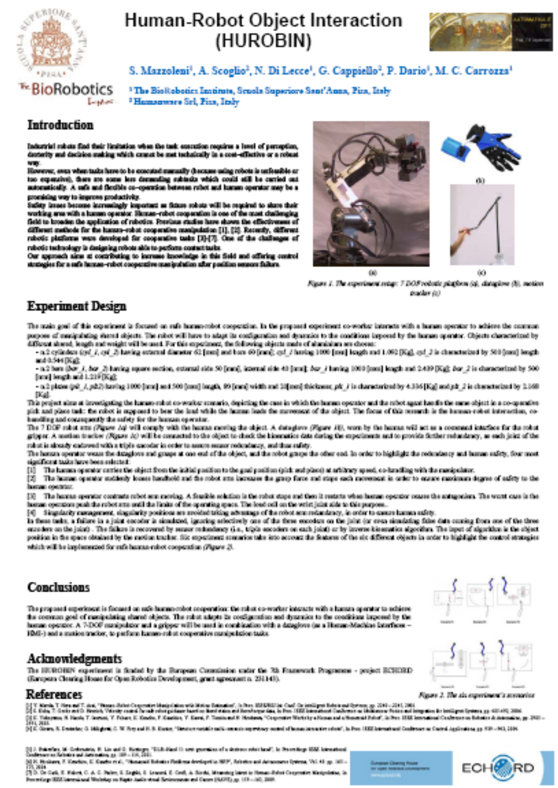
Dissemination activities

September 7-9, 2011

Automatica.it (Pisa, Italy):

poster presentation

www.convegnoautomaticaitaliana.org/



November 28-December 4, 2011

European Robotics Week:

permanent photo gallery *(HUROBIN experiment presented)* and primary school students' competition at SSSA

www.eurobotics-project.eu/eurobotics-week/events-calendar/

eu Robotics Week

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Dissemination activities: 2012-2013 IEEE target conferences

2013 IEEE International Conference on Robotics and Automation
(deadline: Sept 16, 2012)

2013 IEEE International Conference on Mechatronics (ICM)

2012 IEEE/SICE International Symposium on System Integration
(deadline: Sept 23, 2012)

2012 12th International Conference on Control Automation Robotics & Vision
(deadline: Apr 1, 2012)

2012 IEEE International Conference on Mechatronics and Automation
(deadline: Apr 15, 2012)

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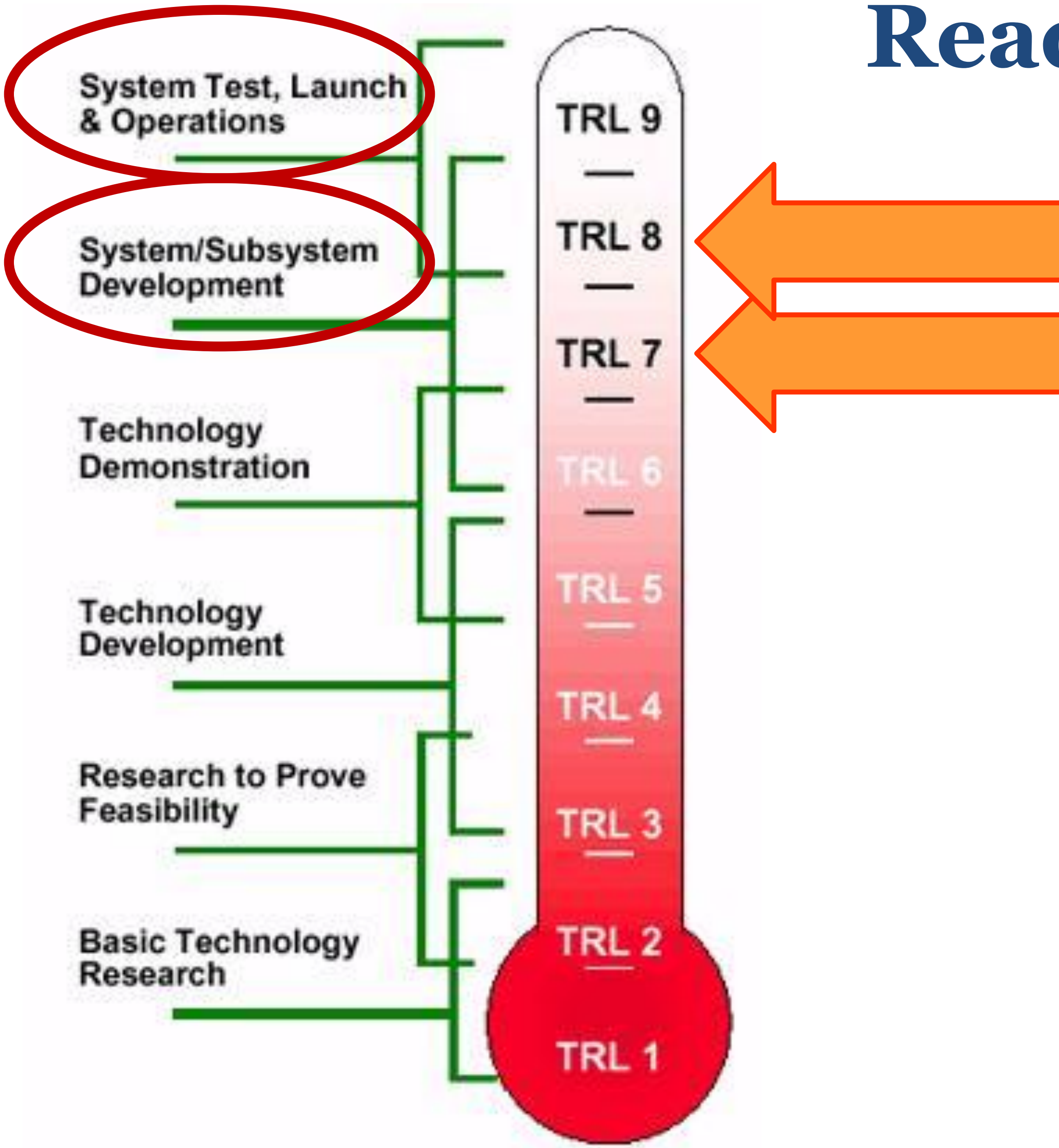
Technology Readiness Level (TRL)



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Thank you for your attention!

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