Haptic interface data acquisition system

Master Thesis Presentation

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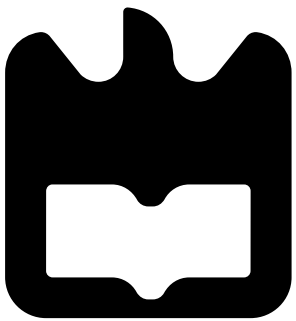

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Outline

1. Framework
   - Objectives
   - Haptics
   - PHUA robot
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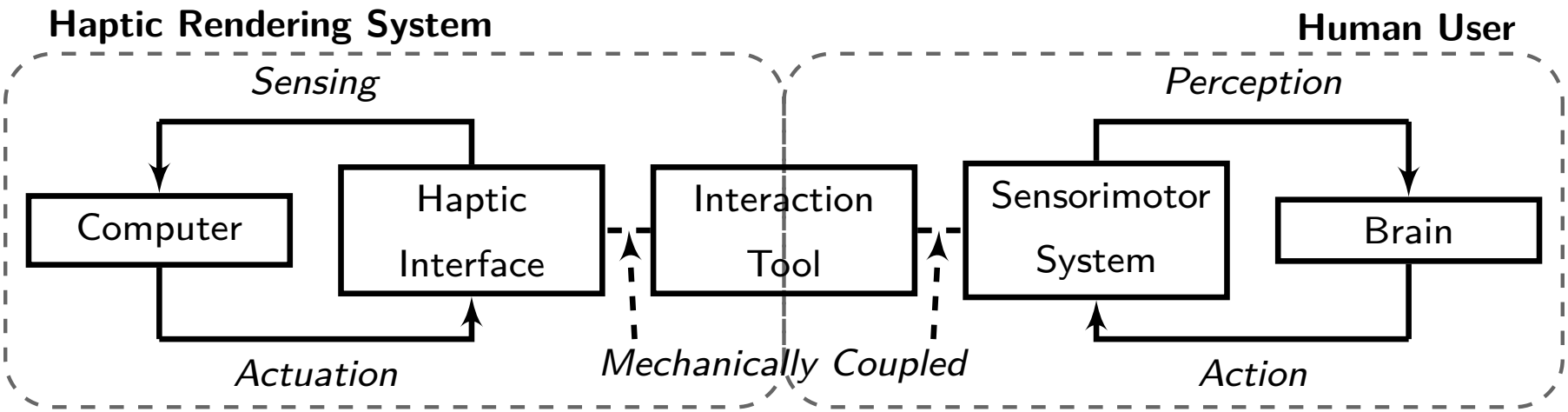
Main objectives and goals of the PHUA project

*One of the goals of the PHUA project is autonomous **balancing** and **locomotion** through **robot leaning from demonstration** using an enhanced teleoperation known as **tele-kinesthetic teaching**.*

- Objectives:
  - Dynamical robot simulator using MATLAB SimMechanics;
  - Development of a force feedback haptic command and sensing mechanism for perception/actuation data logging;
  - Haptic tele-kinesthetic demonstrations showing telerobotic haptics.

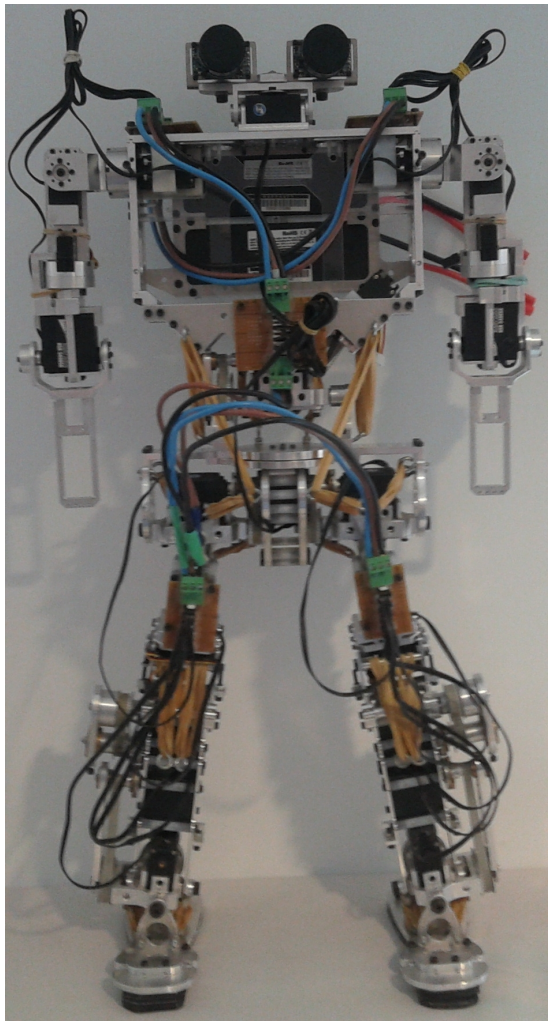
What is *haptics*?

- **Concept**
  - Greek root *haptikos*: ***"able to grasp or perceive"***.
  - Includes ***kinesthesia***: perception of a ***body position, movement and weight***.
- **Haptic Interaction**
  - Can be defined as ***manipulation*** using the ***human sense of touch***.
  - Use of natural sense of touch ***to feel and manipulate computed quantities***.



University of Aveiro humanoid platform

- Anthropometrically built
  - 65cm height
  - 6kg weight
- 27 Degrees-of-freedom
  - 25 active joints
  - 2 passive joints (toes)
- Hybrid actuation system
  - Elastic elements on the ankle, knee and torso
- Other features
  - Force sensors in the feet
  - Artificial vision system
  - 5000mAh *LiPo* batteries
  - ...



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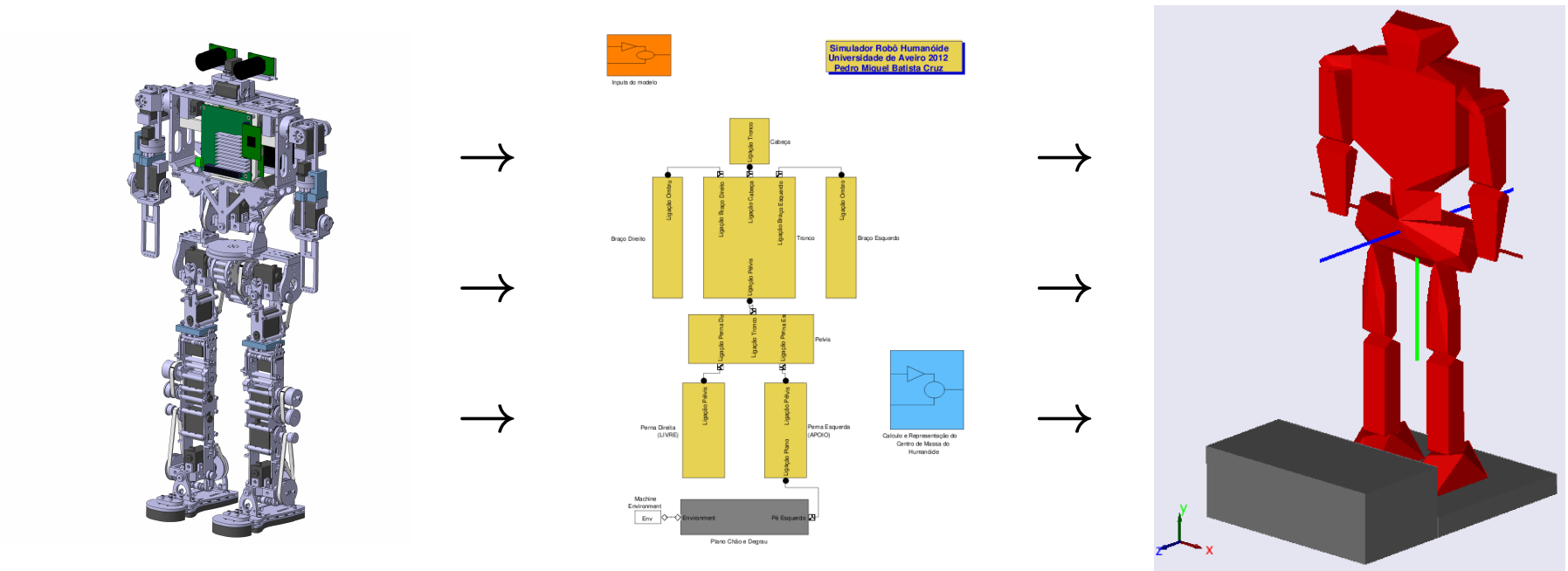
SimMechanics model construction

- SimMechanics
  - Multibody simulation environment for mechanical systems.
- Complete robot model
  - Joint trajectory curves as input, joint torques as output
  - Centre-of-gravity calculations



Step climbing simulation examples

- Step climbing:
  - Step height up to 125mm.
- 4 stage motion.
  - From home position to foot over the step.
  - 5^{th} degree polynomial joint trajectories.
- The hybrid actuation results for the knees are incorrect.
  - The elastic elements are simulated as being pressed instead of pulled when the knee bends.

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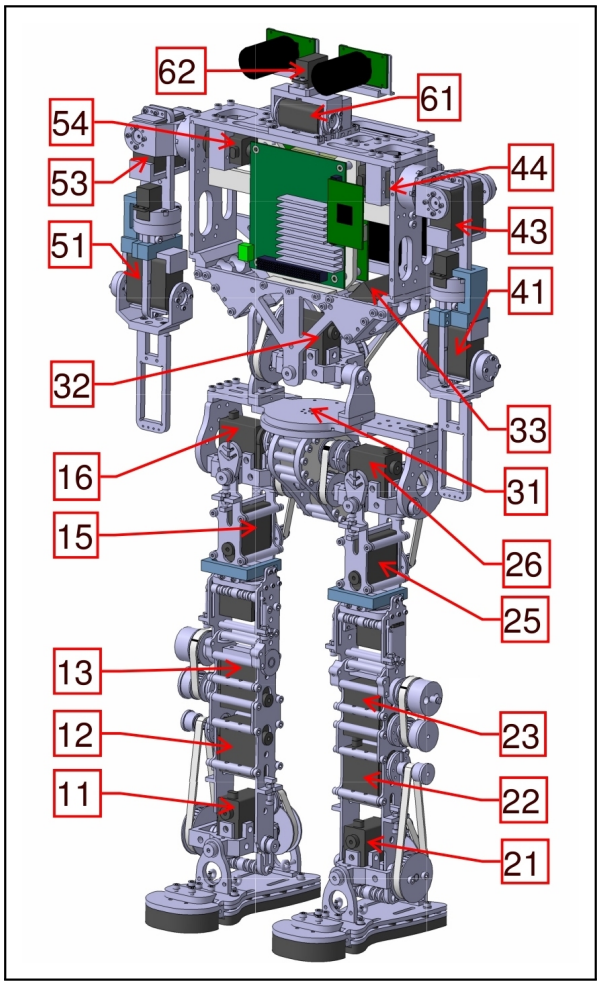
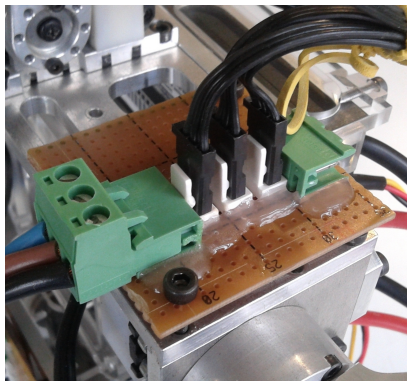
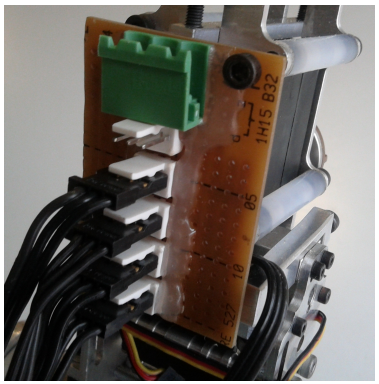
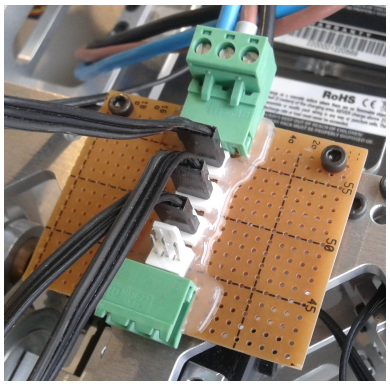
Servomotor wiring and communications

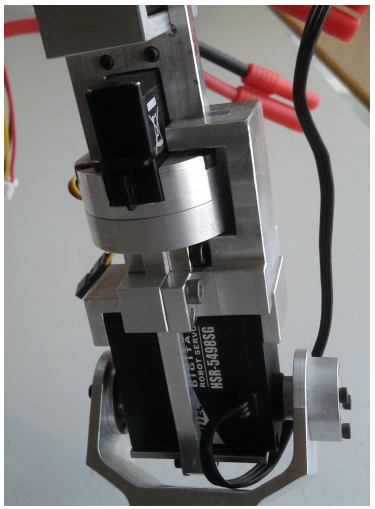
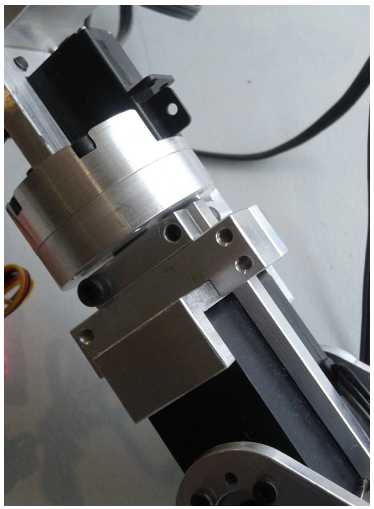
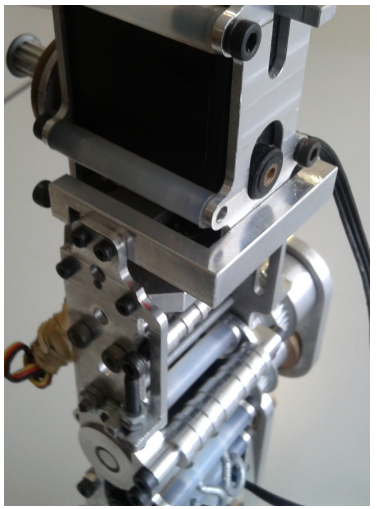
Servomotor IDs:



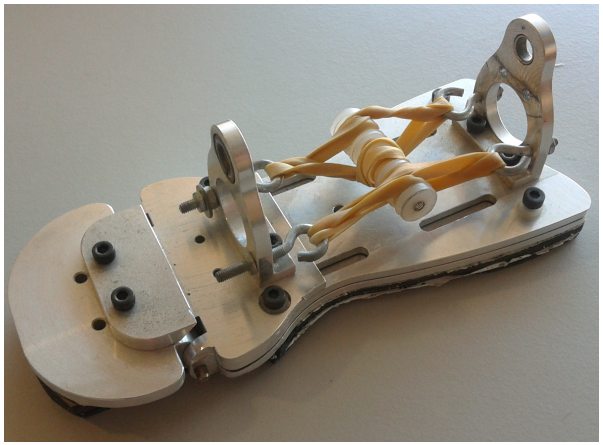
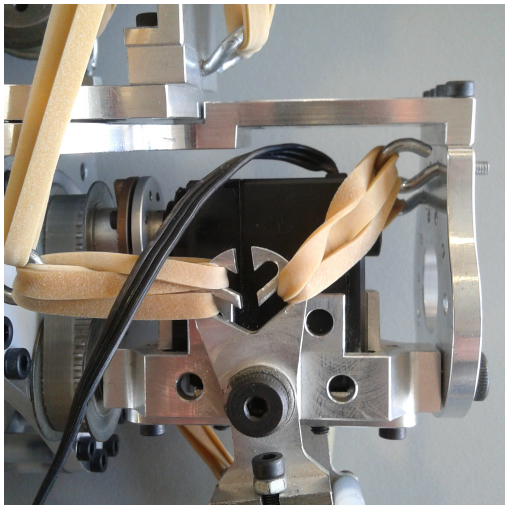
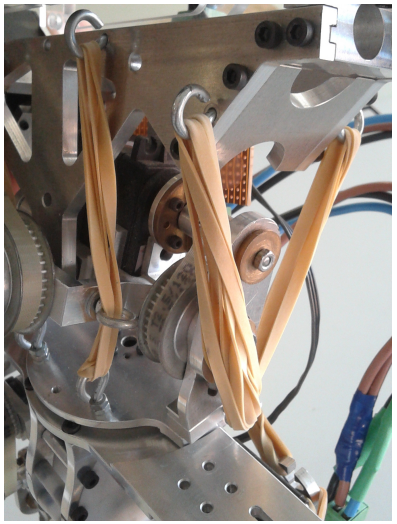
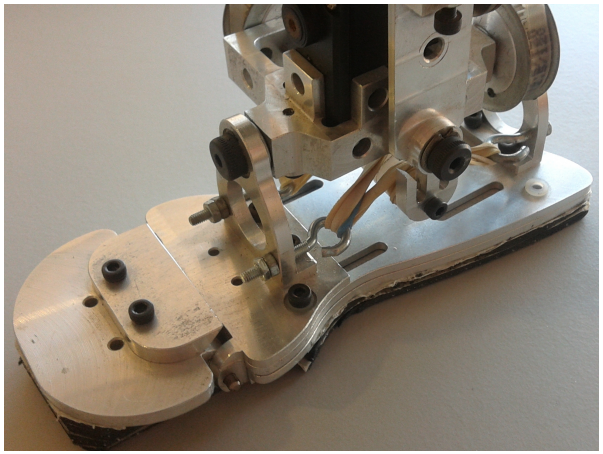
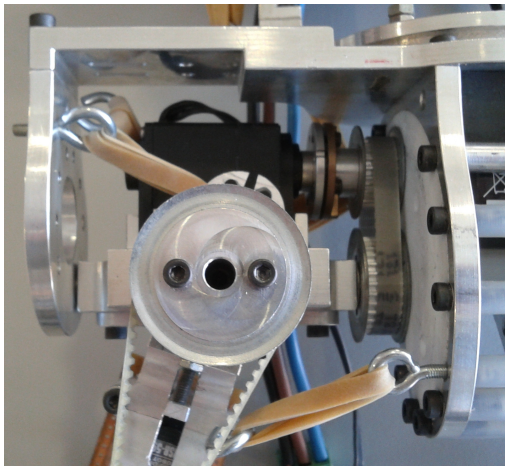
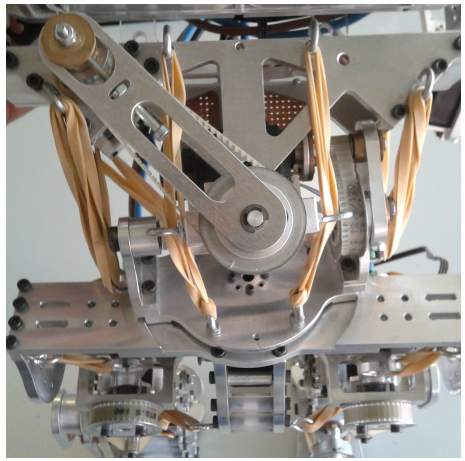
Wiring boards:

Mechanical modifications:

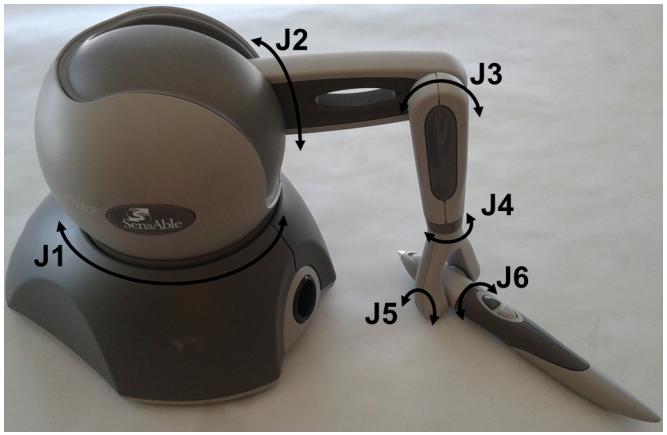




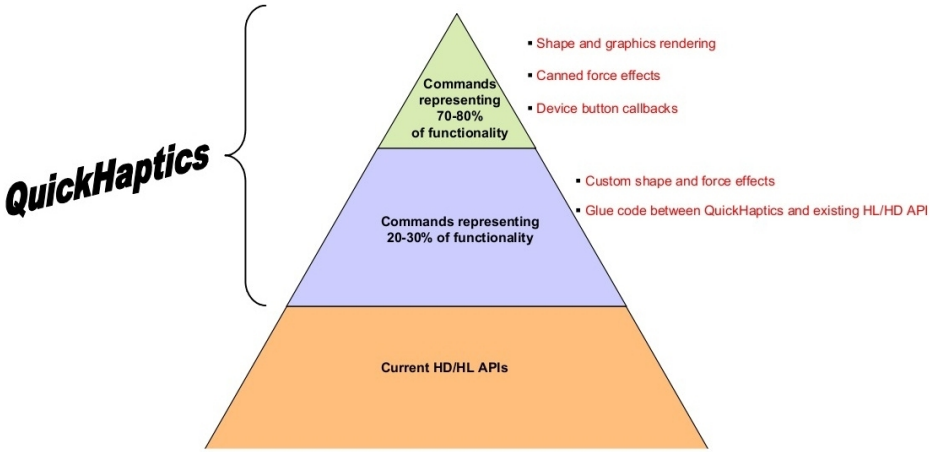
Elastic element mounting

Haptic hardware and software solutions

- Haptic Joystick
  - 6DOF SensAble PHANToM OMNI
  - 3DOF force (3.3N)
  - Wrist pivoting motion
- OpenHaptics Toolkit
  - Dedicated haptics/graphics libraries
  - Divided in APIs to ease development
- Other libraries
  - ROS
  - Armadillo
  - ...





ROS.org

Armadillo
C++ linear algebra library

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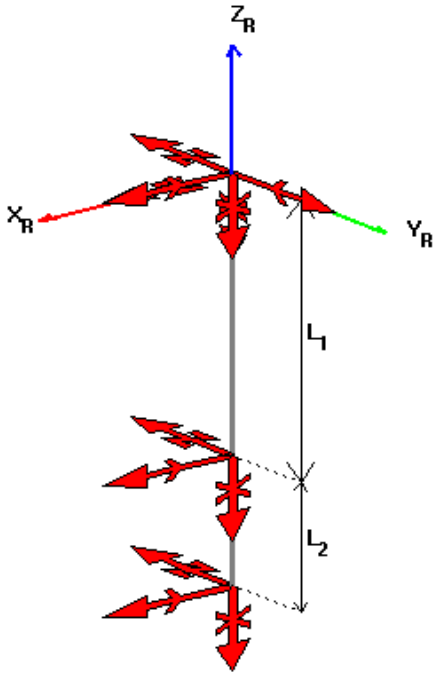
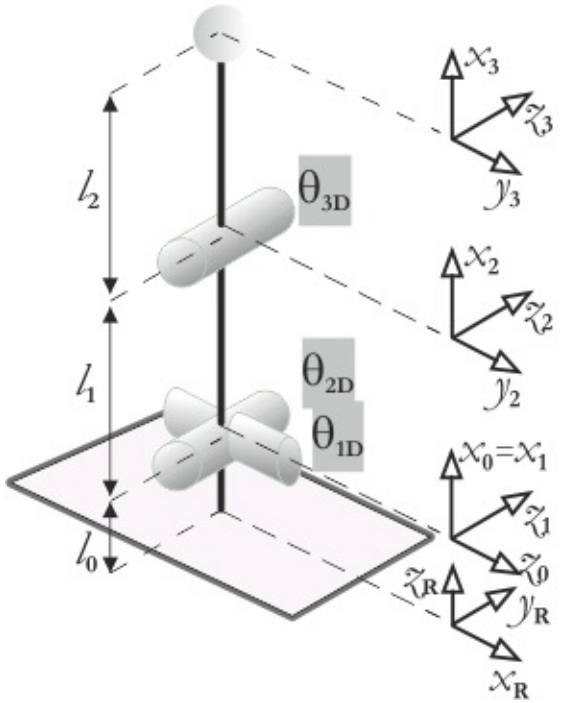
Forward/Inverse/Differential kinematics

3DOF Arm



Link	l	d	θ	α
1	0	0	θ_1	$-\pi/2$
2	L_1	0	θ_2	$\pi/2$
3	L_2	0	θ_3	0

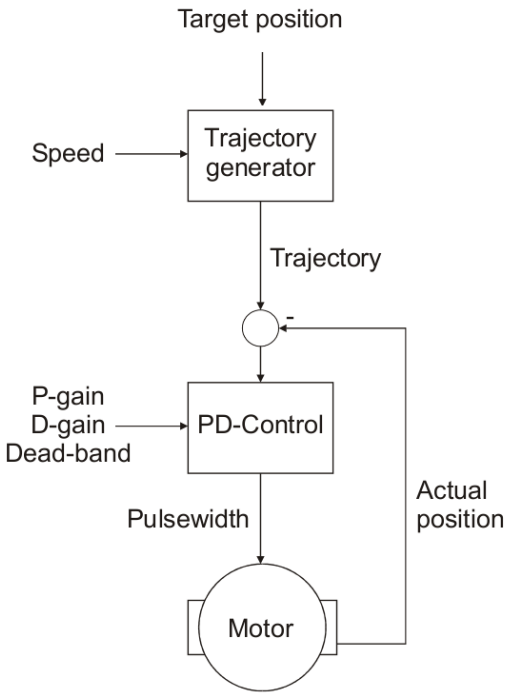
3DOF Detached Leg



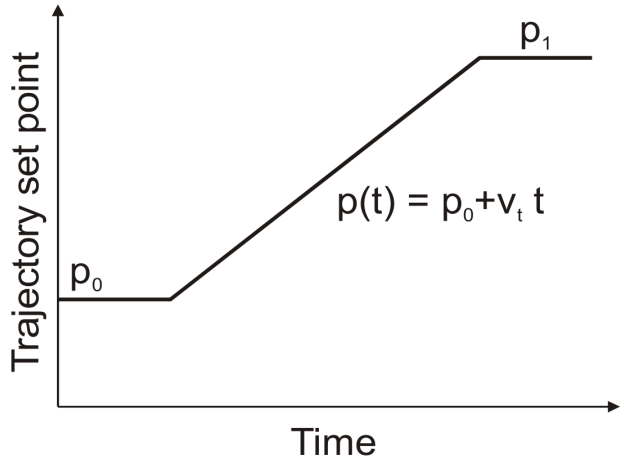
Link	l	d	θ	α
1	0	0	θ_1	$\pm\pi/2$
2	L_1	0	θ_2	0
3	L_2	0	θ_3	0

Servomotor controller and communication protocol

Internal Controller



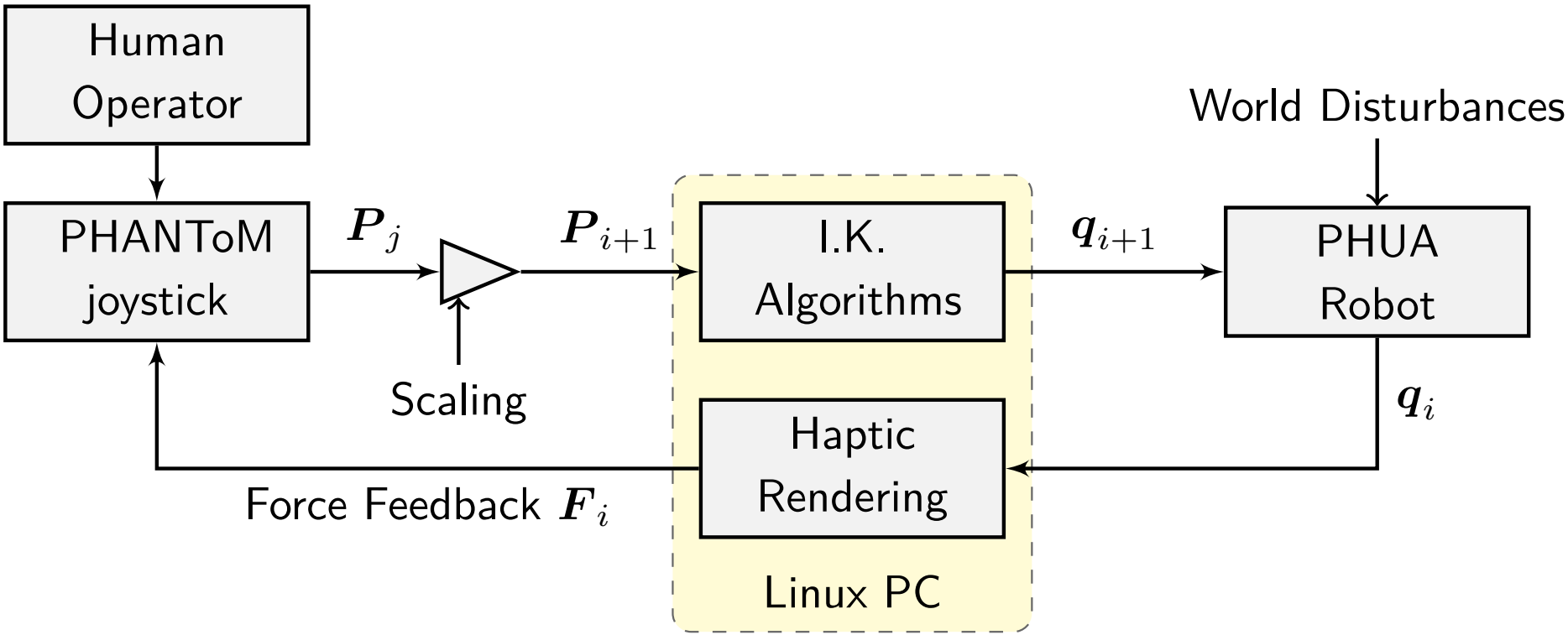
Trajectory Planner



Bidirectional Serial Interface

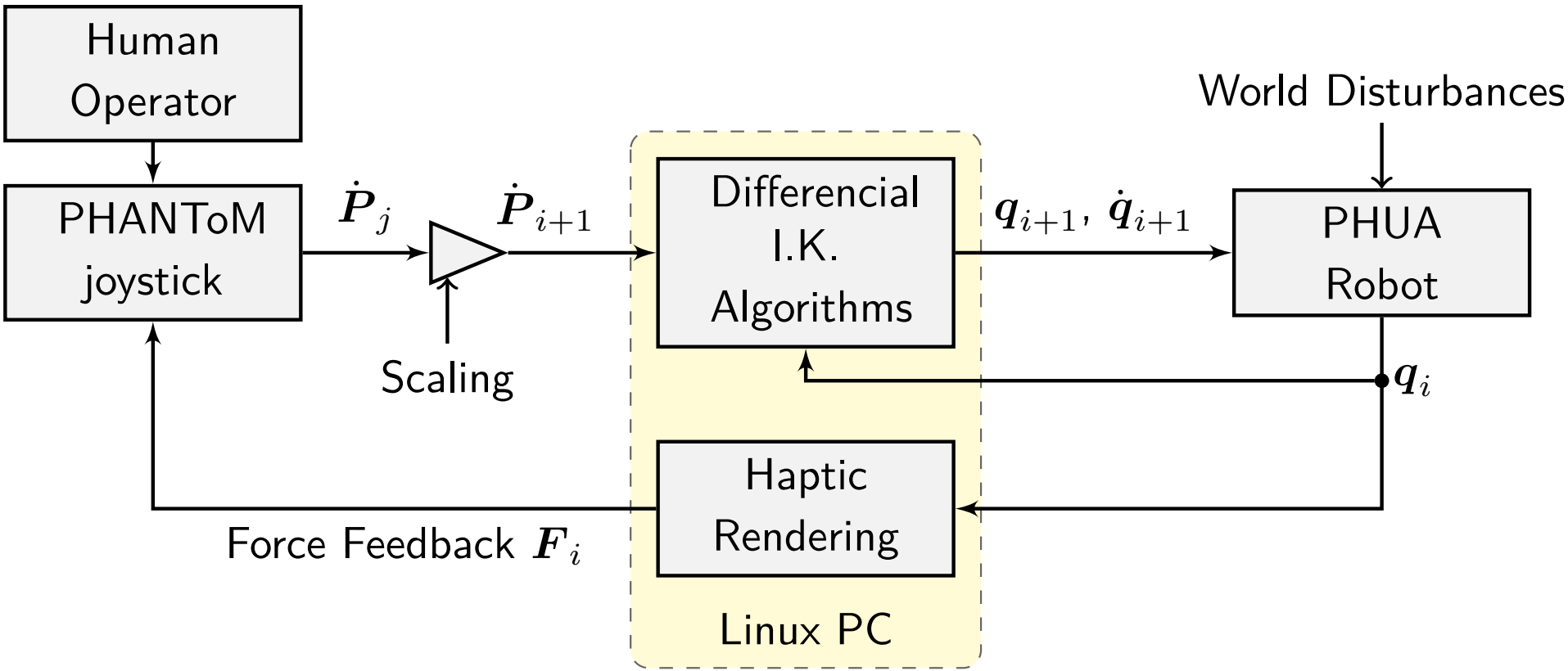
byte	1	2	3	4	5	6	7
Controller	Startbyte	Command	Param1	Param2	Checksum	0x00	0x00
Servomotor	High-Impedance					Return1	Return2

Command methodologies: Position



- Closed loop between the PHANToM and the robot end-effector. The coordinate mapping between the robot's end-effector and the joystick position is relative.

Command methodologies: Velocity



- Uses the PHANToM Cartesian velocity vector instead of position. There is no direct coordinate mapping between the robot's end-effector and the joystick position.

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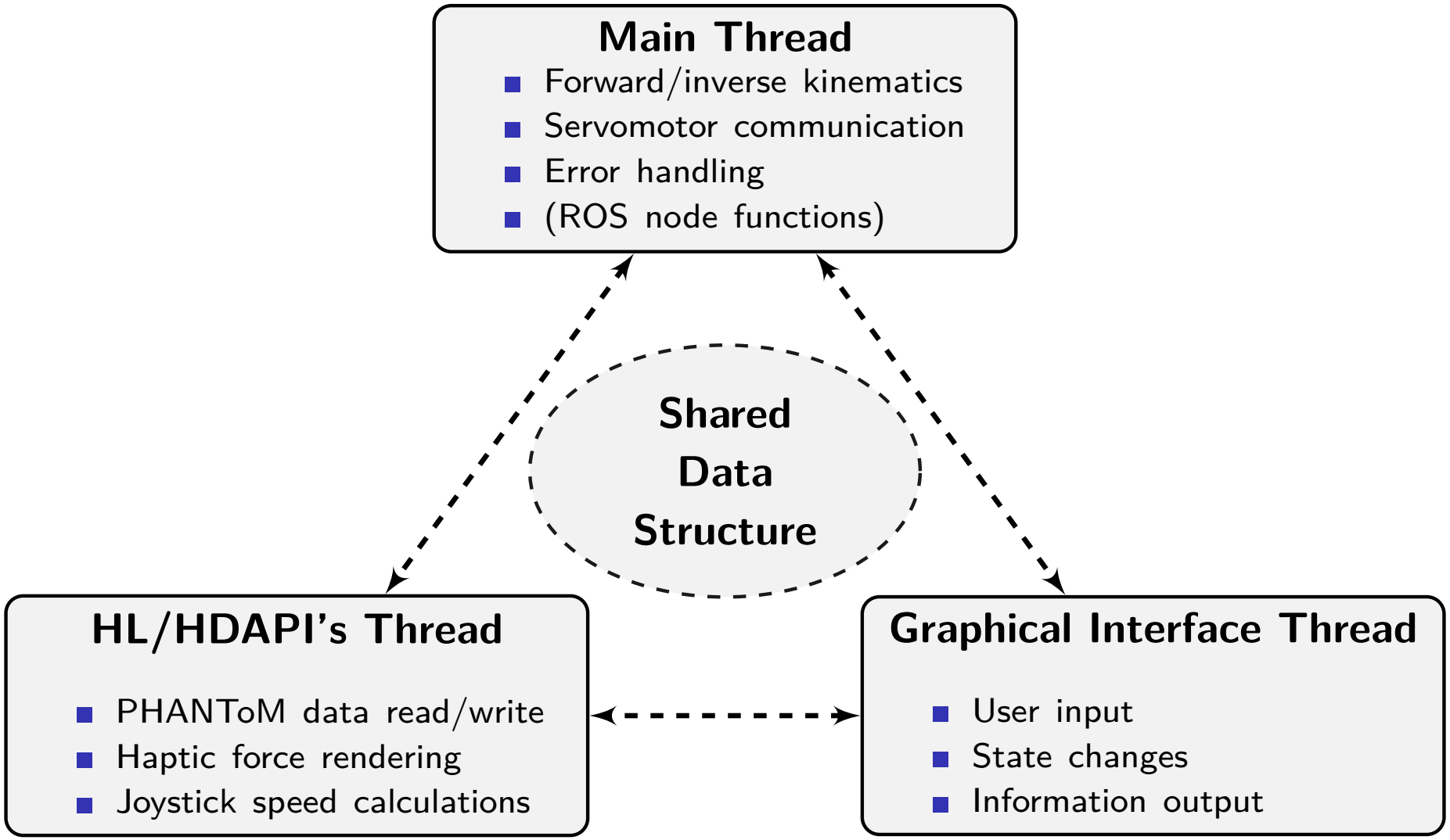
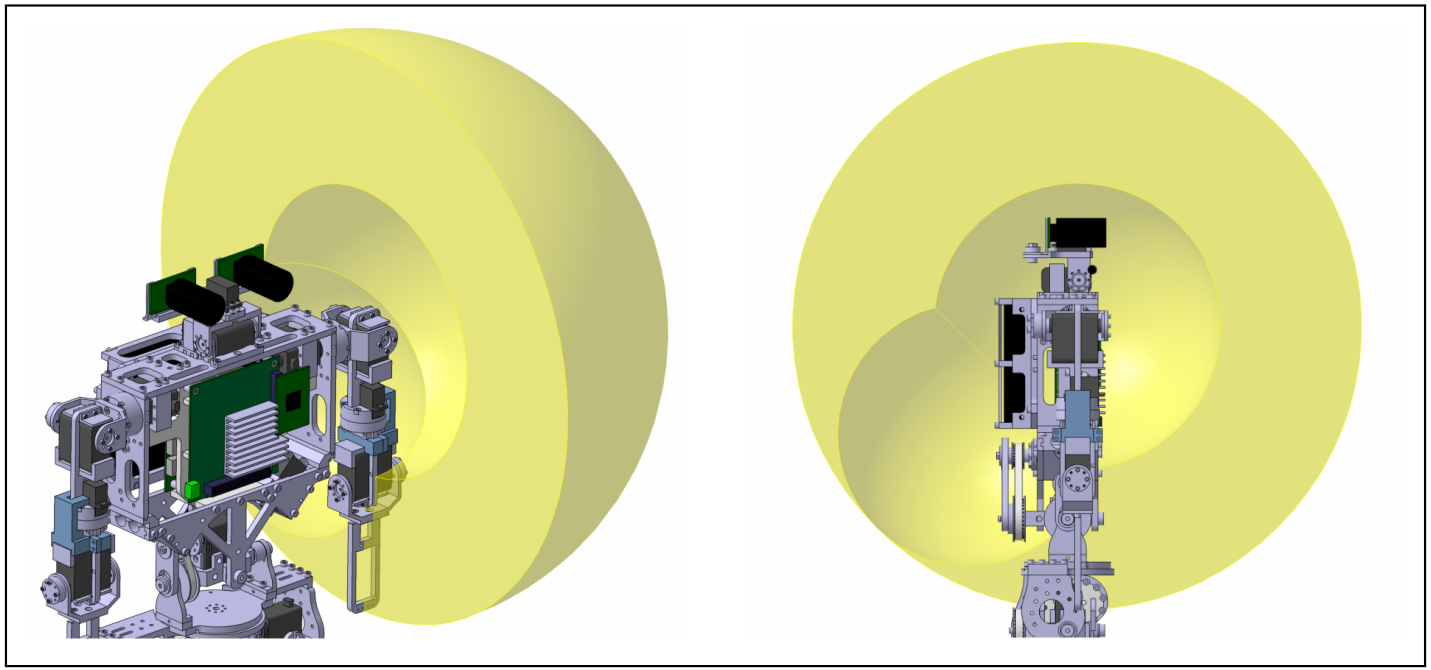
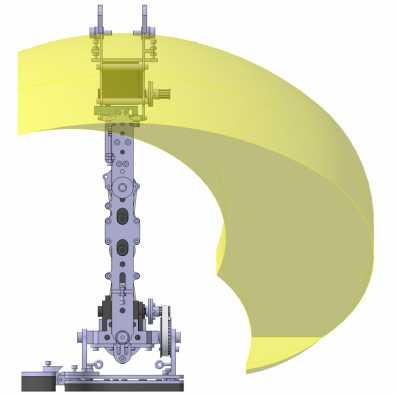
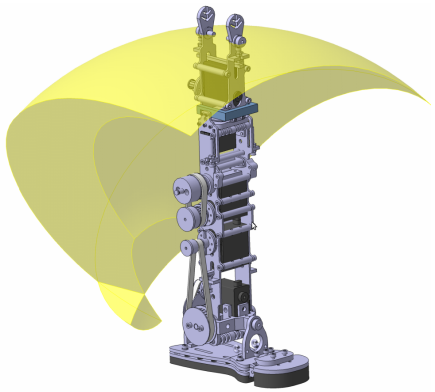
Developed application structure



Workspace limits

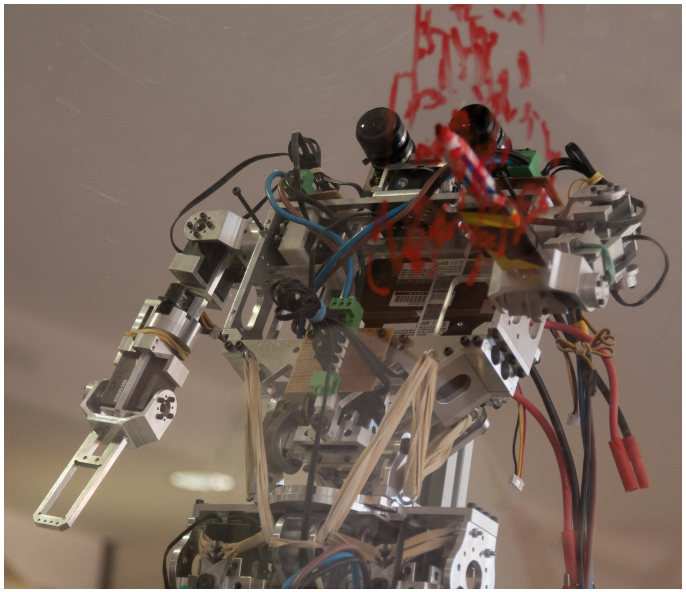






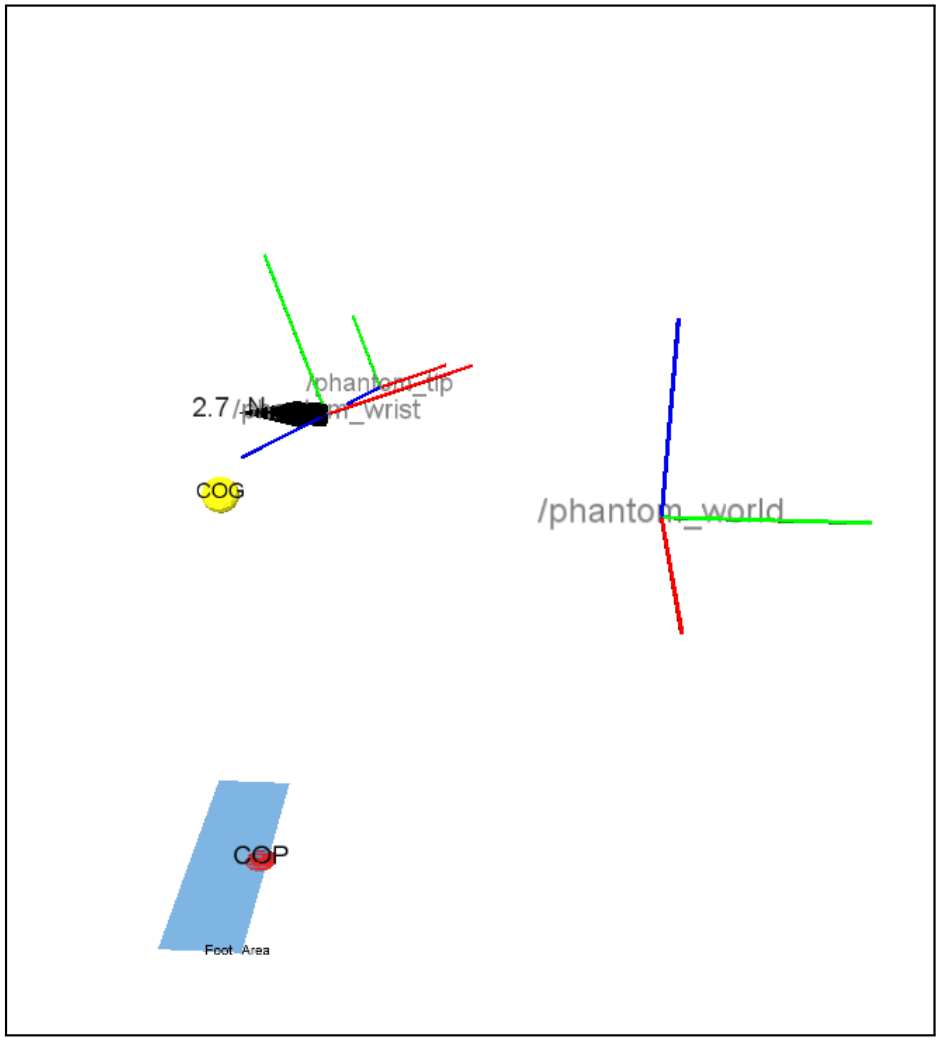
Workspace limitations demonstration

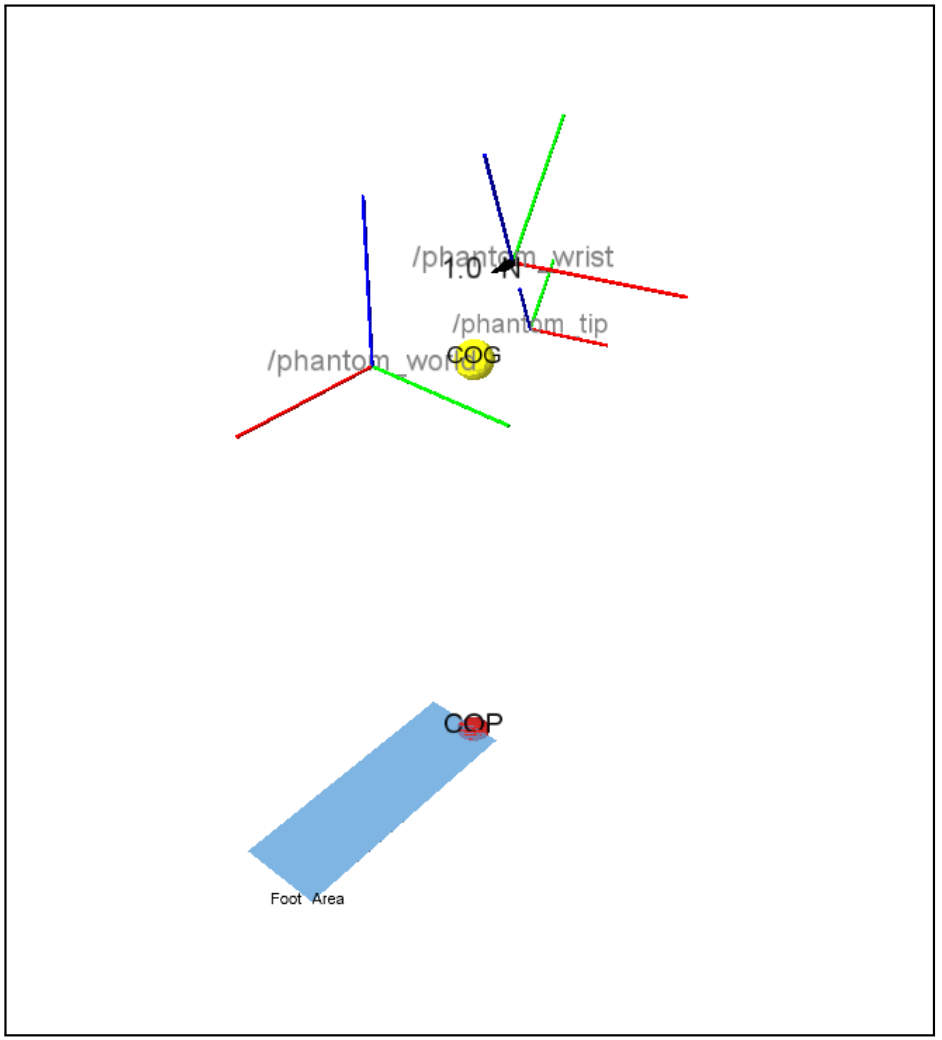
Plane drawing (UA Summer Academy)



Plane drawing (haptic object interaction)

Balancing the detached support leg





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- Future Work

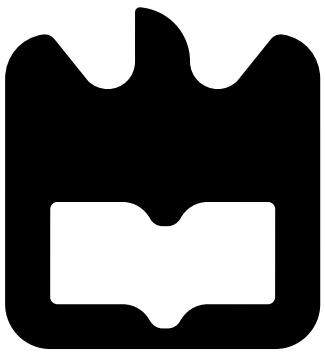
Conclusions

- SimMechanics model was successful on determining torque requirements for complex motions.
  - However, its limitations with elastic elements must not be overlooked.
- The position command strategy was the first choice among the inexperienced operators.
- Haptic systems can effectively bridge together the robot teleoperation and kinesthetic teaching fields.
  - Workspace limitations haptics are intuitive while teleoperating and critical for enriched data logging.
  - Telerobotic physical interaction with world objects is possible using haptics.
  - Haptic signals for balance applications are possible but must not interfere with the control.

Relevant future work suggestions

- Human Interface:
  - Test overall user-friendliness.
  - Test buzzing, force kicking, etc...
- Software:
  - V-REP.
  - ROS.
  - OpenHaptics, H3DAPI, etc...
- Hardware:
  - Timing belts.
  - Conditioning of the elastic elements.
  - Tabletop power supply.

Thank you!



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