Cooperative Haptics for Humanoid Robot Teleoperation

Master Thesis Presentation

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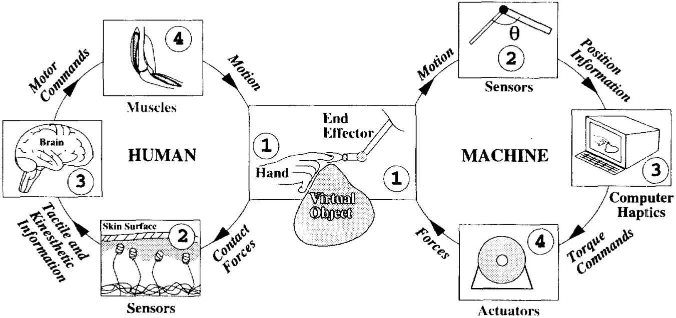
Outline

What is *haptics*?

Haptic interaction with the world refers to sensing and manipulation using our **sense of touch**. *Computer haptics* technology interfaces the user with a virtual environment via the sense of touch by applying forces, vibrations, and/or motions to the user.



PHUA project

The main goal is the development and integration of hardware and software components in a functional low-budget platform, to perform studies in balance and locomotion tasks.

- An approach for kinesthetic teaching is proposed, in which the user interactively demonstrates a specific motion task, while feeling the dynamics of the system through a haptic interface – **tele-kinesthetic teaching**.

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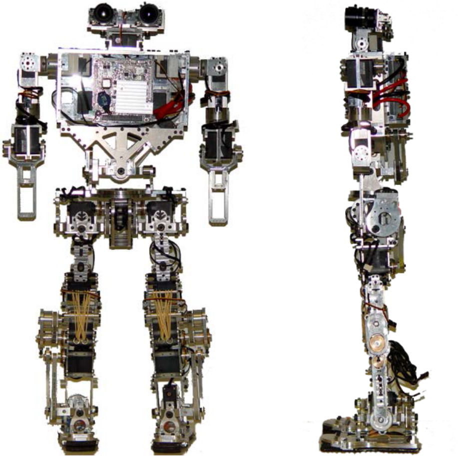
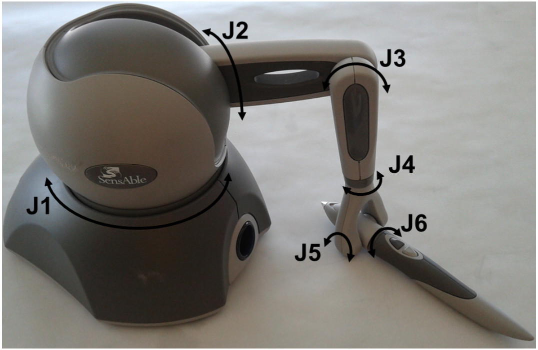
PHUA project
Robot's current form

- Anthropometrically built
- 27 degrees-of-freedom
- Hybrid actuation system
- Force sensors
- Artificial vision system
- Inertial sensors



PHUA project
PHANToM OMNI haptic device

- The haptic device used was the PHANToM OMNI, a ground-based haptic joystick.



Objectives

- Adaption/creation of a humanoid model in V-REP, and definition of its kinematic chains according to PHUA robotic platform;
- Definition of the force feedback developed towards the user;
- Setting up the communication between the two haptic devices;
- Basic teleoperation of the PHUA model in V-REP, with one joystick;
- Teleoperation of the V-REP model in more complex tasks, with two joysticks;
- Test and recording of motion parameters during the simulation of different locomotion patterns;
- Experiments in the real robot.

V-REP model construction - stages

1. CAD model import
2. Pure *shapes* extraction
3. Inertial parameters definition
4. *Shape* linkage (*joints* and *force sensors*);
5. Kinematic chains definition

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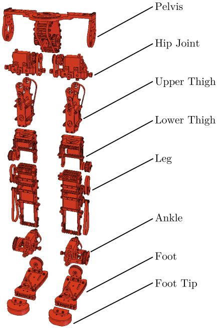
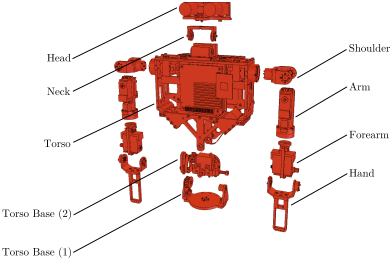
CAD model import

- CAD model parts were rearranged and redefined to match the real robot's body links and DOFs.



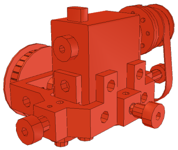
Lower limbs parts



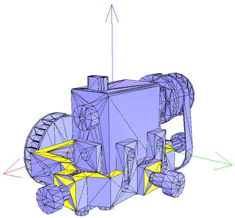
Upper body parts

Pure *shapes* extraction

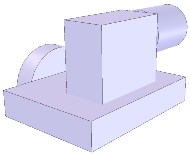
- Pure *shapes* are used for dynamic simulations.



Imported shape

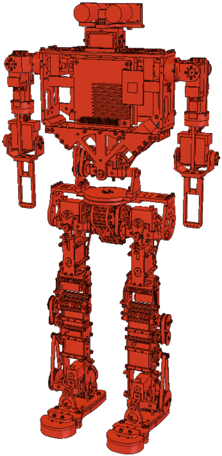


Triangle edit mode

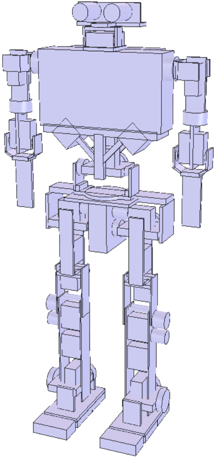


Grouped pure shapes

Approximated model for dynamic simulation

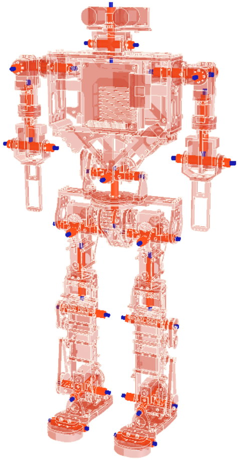


External appearance

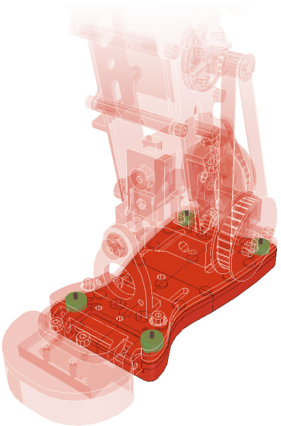


Optimized model

Joints and *force sensors*



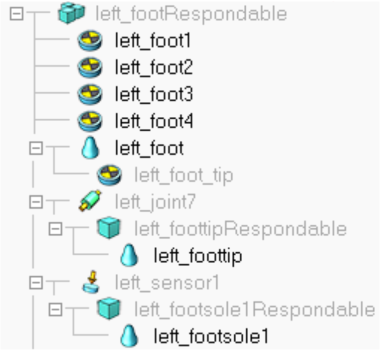
Model kinematic chains



Force sensors implementation

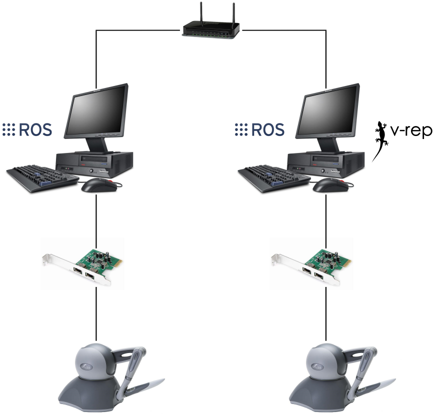
Kinematic chains definition

- All the elements of the mechanism are linked together to build the legs and arms kinematic chains.



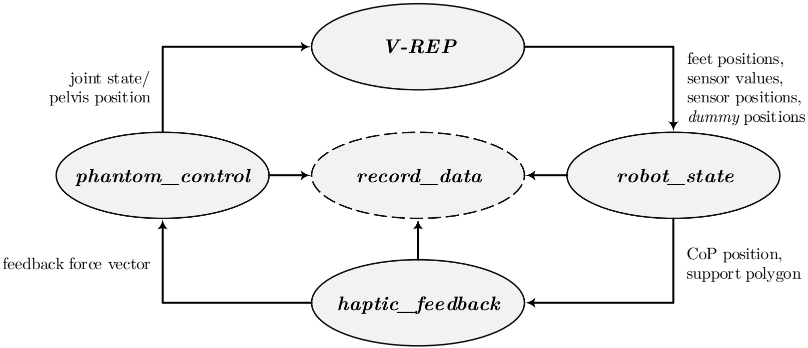
Hardware and software solutions

- ROS distributed system.



ROS modules' interaction

- V-REP operates in association with the other ROS modules.



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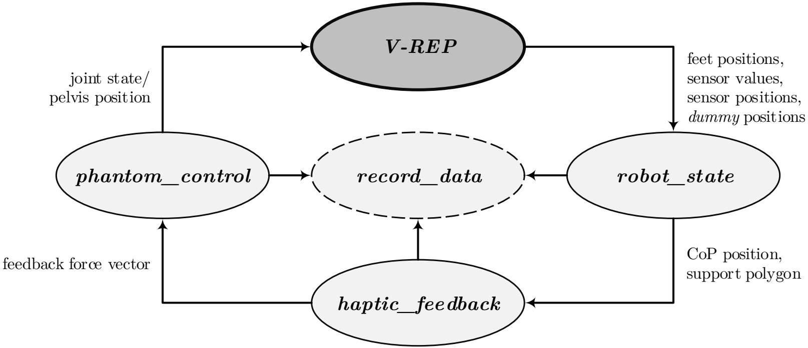

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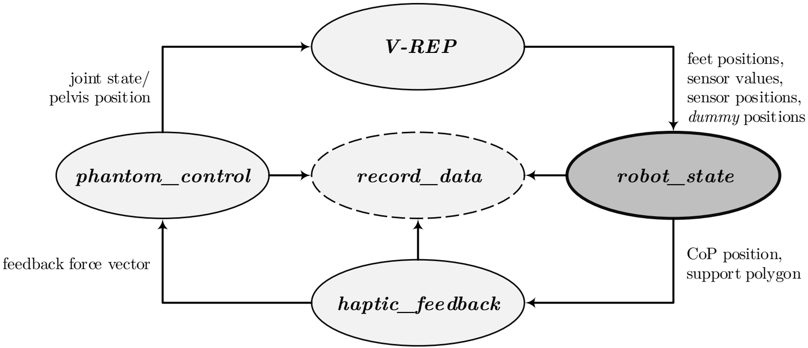

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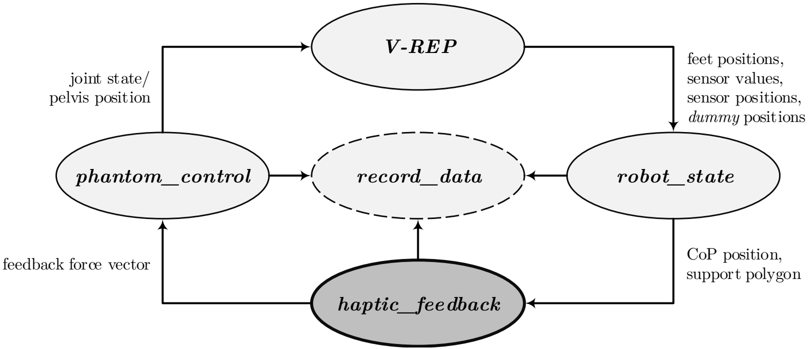

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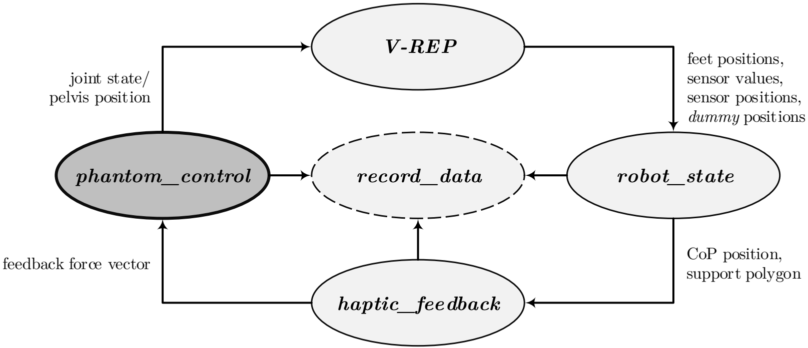

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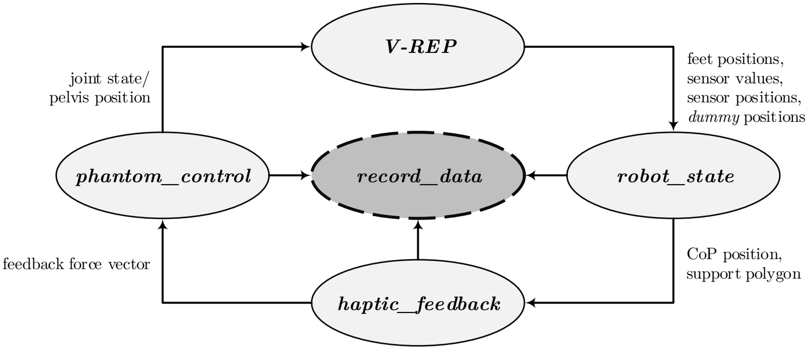
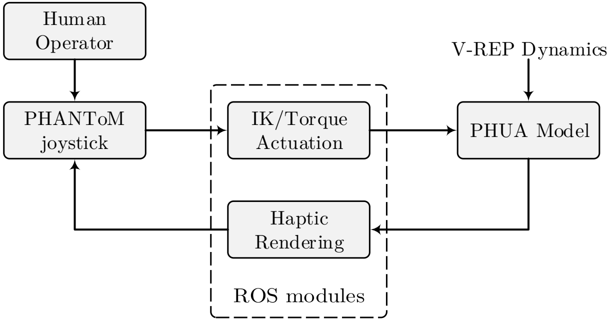


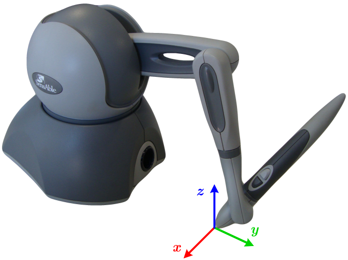
Haptic control loop

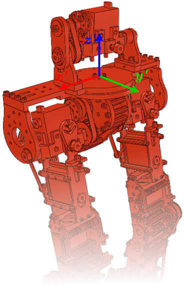
- The **position command** defines a closed loop between the V-REP model and the PHANToM device(s).



Inverse kinematics correspondence

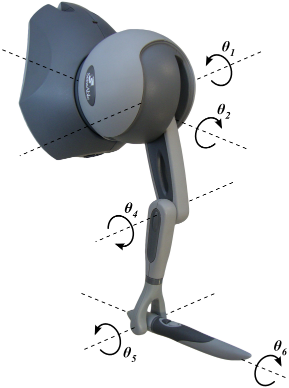
- The robot's end-effector will follow the joystick position.

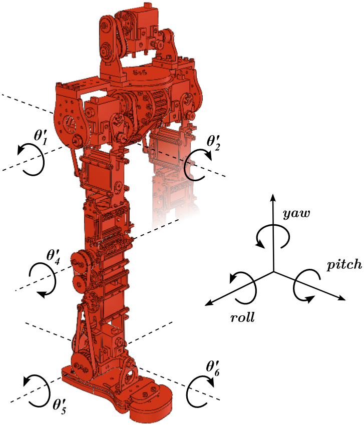




Joint space correspondence

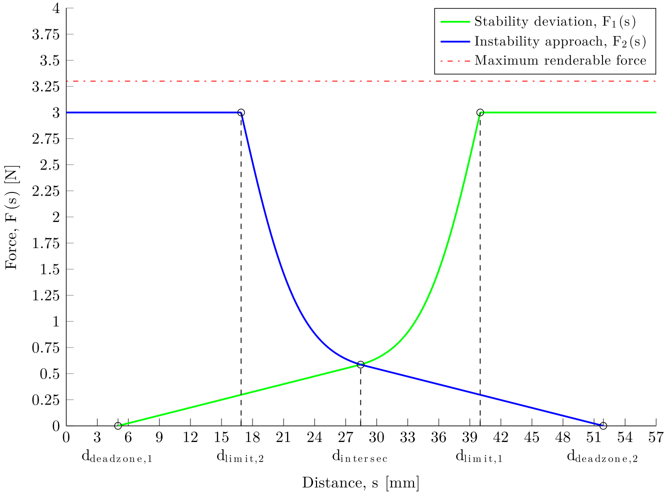
- A *joint-by-joint* control is implemented between the joysticks and the robot legs.





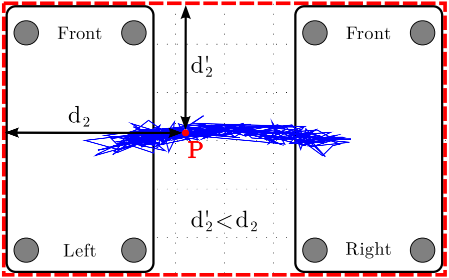
Force feedback formulation

Stability deviation and instability approach



Force feedback formulation

Force components weighting



$$\boldsymbol{F_R} = \frac{1}{\eta+1} \cdot \boldsymbol{F_1} + \frac{\eta}{\eta+1} \cdot \boldsymbol{F_2} \quad (N)$$

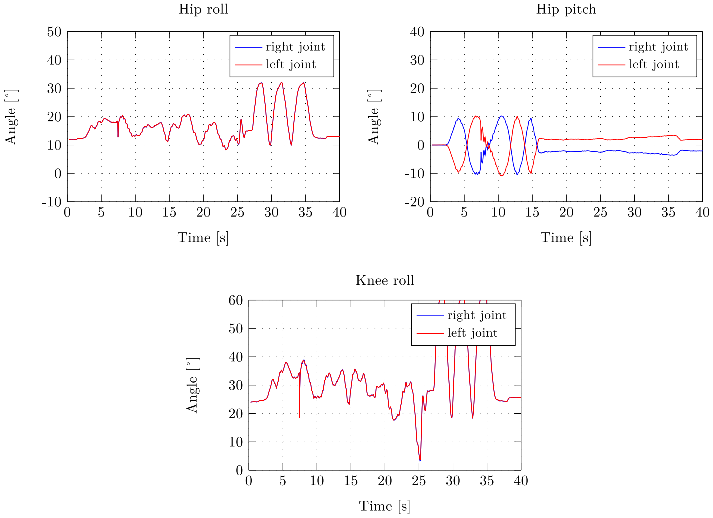
$$\boldsymbol{F} = F(s) \cdot \frac{\boldsymbol{COP}}{\|\boldsymbol{COP}\|} \quad (N)$$

$$\eta = \left| \frac{\Delta \boldsymbol{F_2}}{\Delta \boldsymbol{F_1}} \right|$$

Inverse kinematics control mode

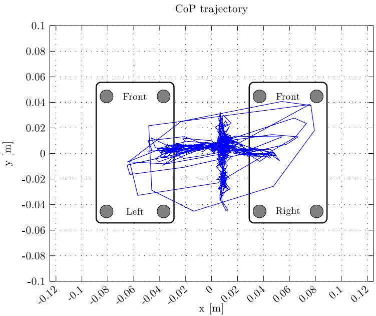
Inverse kinematics control mode

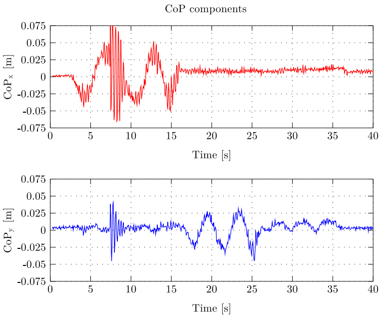
Joint state evolution



Inverse kinematics control mode

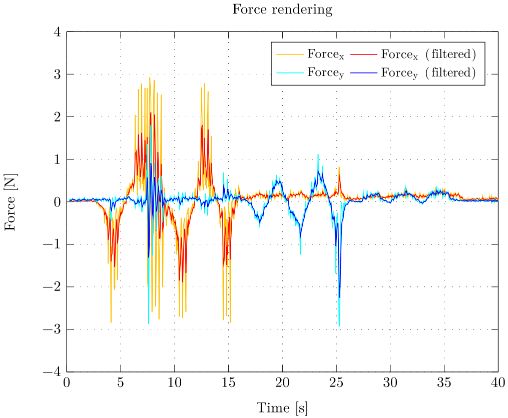
CoP variation





Inverse kinematics control mode

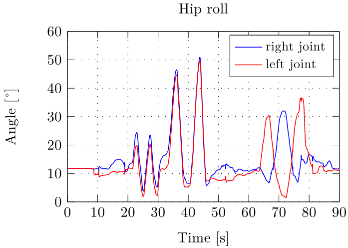
Force rendered by the haptic device

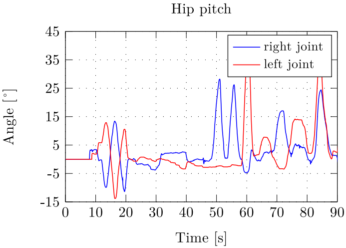


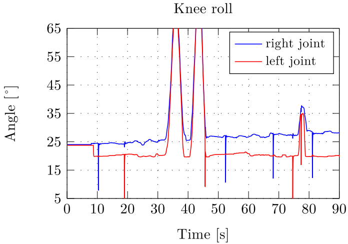
Torque control mode

Torque control mode

Joint state evolution







Conclusions

- Simulating the teleoperation scenario in a virtual environment provides many benefits to the operator;
- Dynamically-rich simulations were possible, with very satisfying results;
- Occasional glitches due to a defective contact with the ground were the main problem registered in this work;
- The dual PHANToM OMNI configuration was successfully implemented, by means of a well designed ROS framework;
- The developed force generation algorithms were successful for testing purposes, but this formulation still needs improvement, particularly in *joint-by-joint* control;
- When controlled in the dual joystick configuration, the V-REP model offers a wide range of teleoperation possibilities.

Future work suggestions

- Foot plates construction should be reviewed;
- Force generation algorithms can be further developed in terms of mathematical formulation, using extra sensory information;
- Metrics of the user's performance during the teleoperation should be defined, since they are crucial in what concerns to the learning process;
- Exploring new scenarios, as uneven terrains, and include external disturbances are within the next goals in simulation;
- Test typical gait patterns using a *path planning* strategy;
- A support bracket for the haptic joysticks should be designed, in order to truly implement, and ease the bimanual teleoperation;
- Adaption of dual joystick configuration to the real PHUA platform.

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