Tele-operation of a Humanoid Robot using Haptics and Load Sensors

Master Thesis Presentation

Emílio Estrelinha

University of Aveiro - Department of Mechanical Engineering

Advisor : Prof. Doutor Vitor M. F. Santos
Co-advisor : Prof. Doutor Filipe M. T. P. da Silva

July 23, 2013

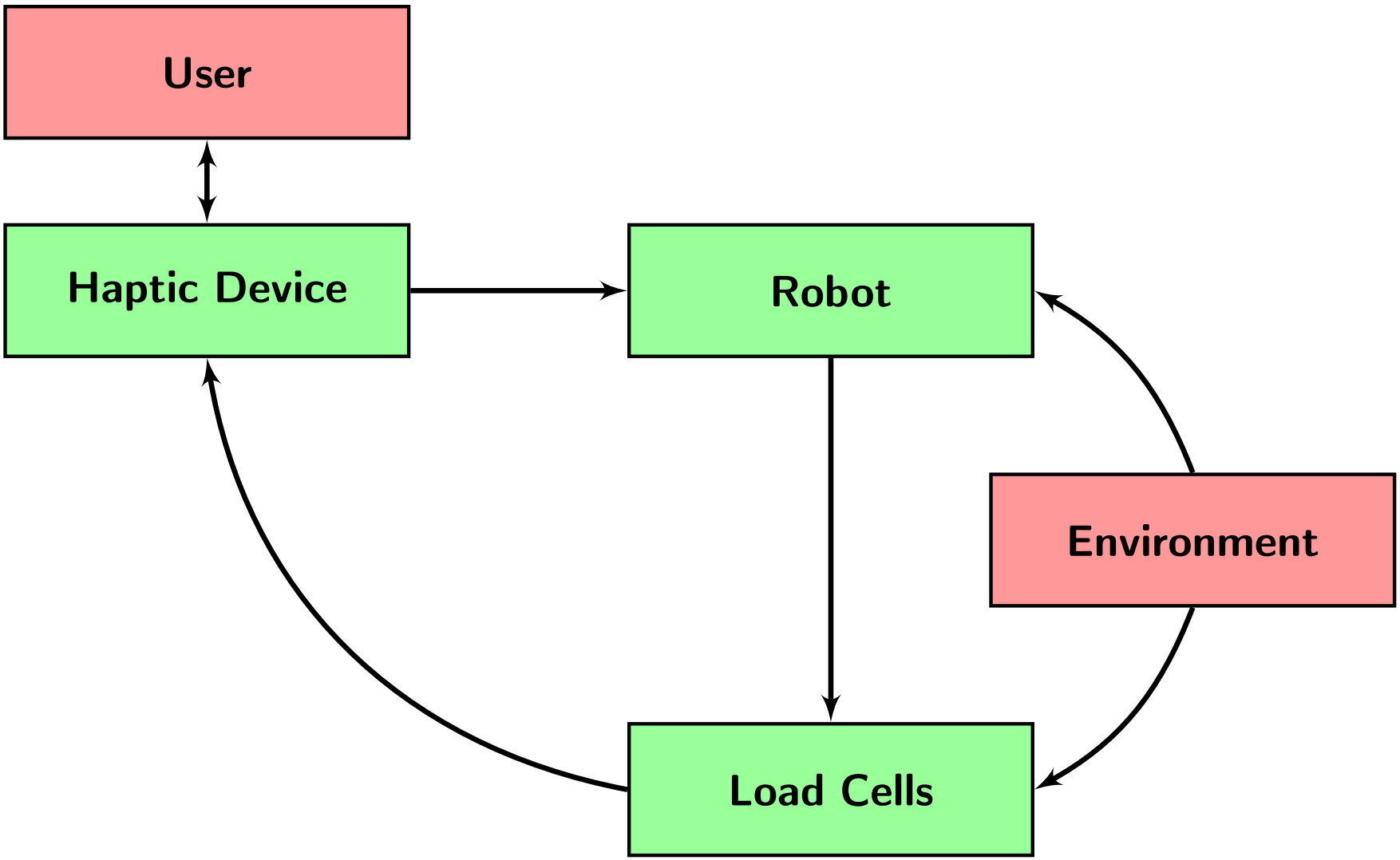
Contents

Problem:
Teach the robots how to walk and balance themselves.

Solution:
Use a haptic feedback system to sense the stability/equilibrium of the robot and use a robot learning from demonstration algorithm.

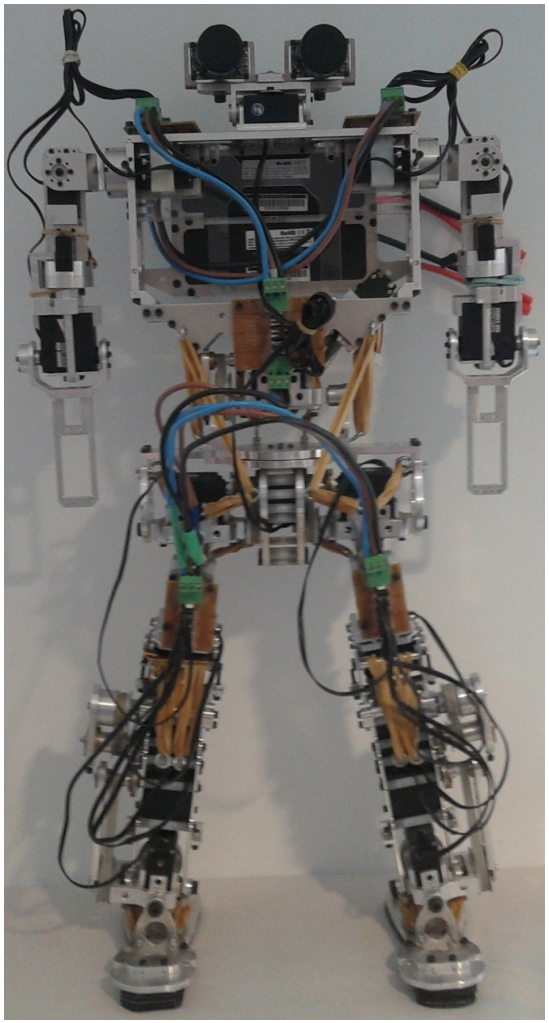
- Implement the ROS platform
- Develop a data acquisition unit for the load cells
- Link the load cells data with the haptic force feedback
- Develop a control system for the robot with haptics
- Perform balancing demonstrations
- Record all relevant data

Introduction



Framework
PHUA robot

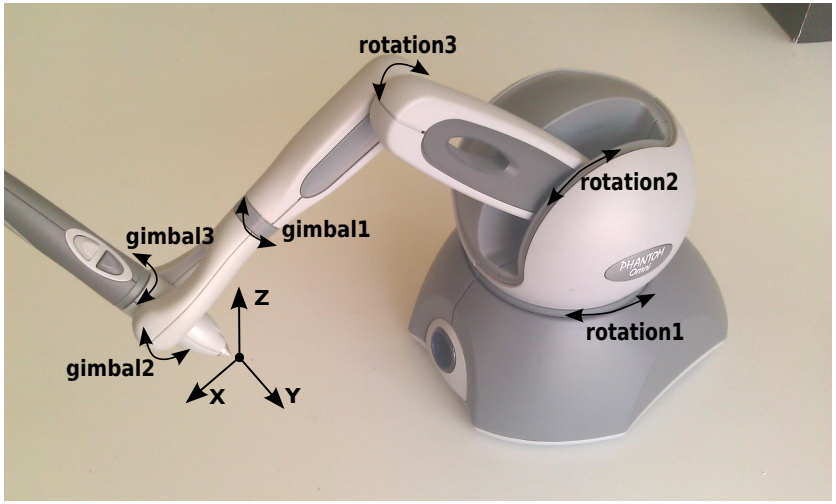
- 27 degrees of freedom
- Force sensors
- Hybrid actuation system



PHUA robot.

Framework
Haptic device

- 6 degrees of freedom
- Maximum force of $3.3\,\mathrm{N}$
- Needs a control loop of at least $1000\,\mathrm{Hz}$



PHANTOM OMNI hapic device.

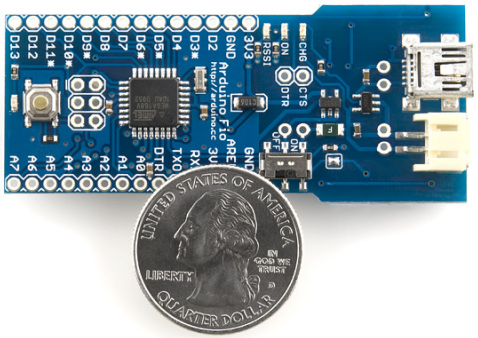
Experimental setup
Load cells

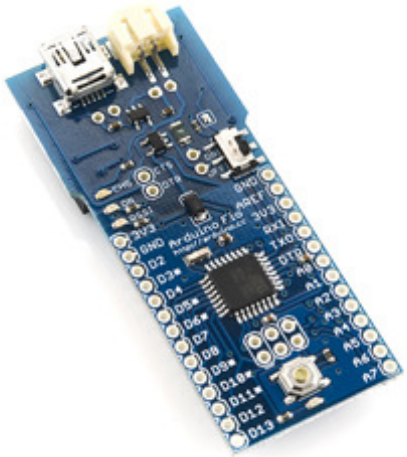
Characteristics	LBS-5	LBS-10
Nominal Load [lbs]	5	10
[N]	22,2	44,4
Safe Overload	150%	150%
Nonlinearity% FS	0,25	0,5

LBS-5 load cell.

Experimental setup
Acquisition unit

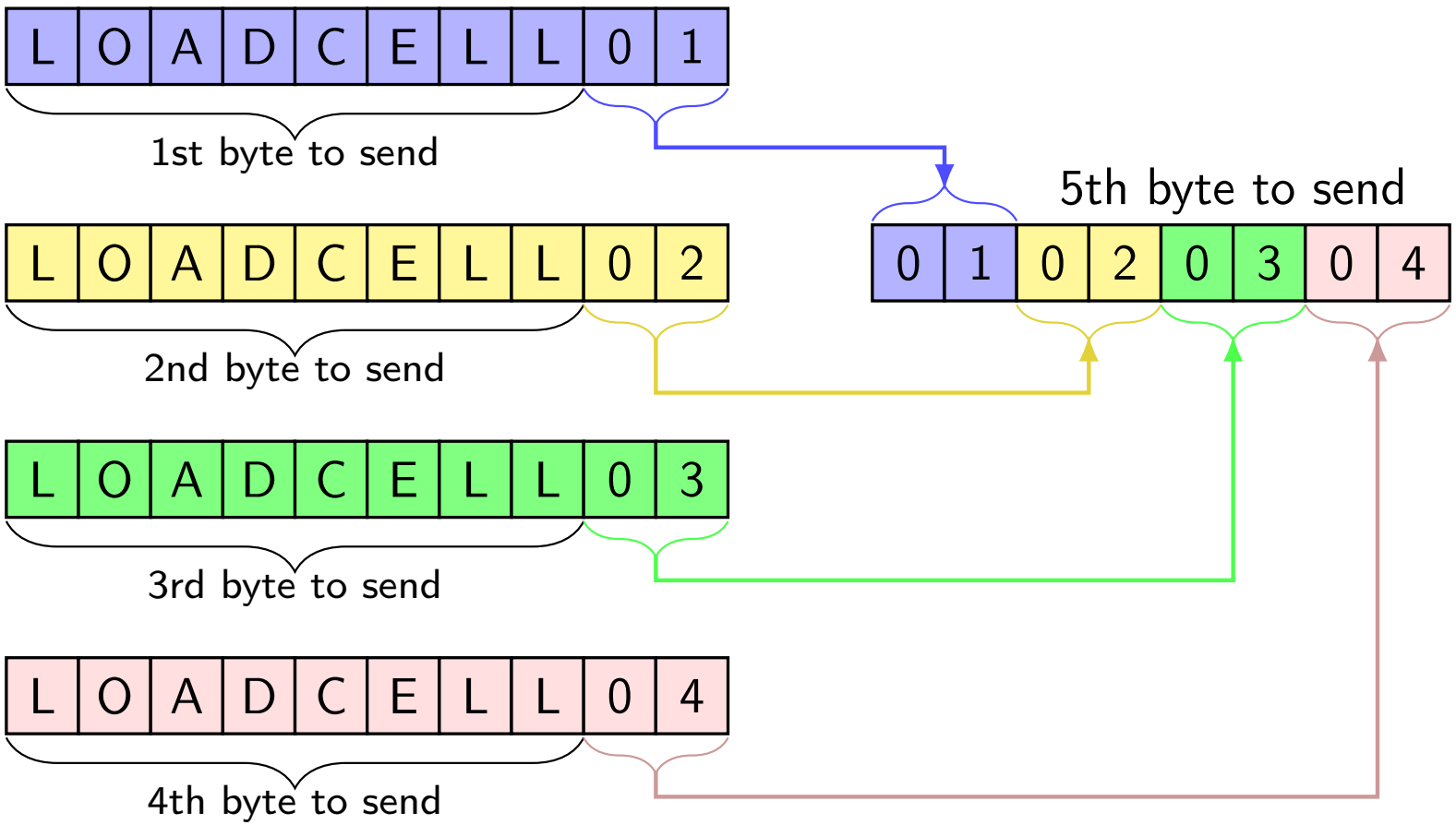
- ATmega328P microcontroller
- $8\,\mathrm{MHz}$
- 10-bit Analogue to digital converter
- $3.3\,\mathrm{V} \rightsquigarrow 5\,\mathrm{V}$





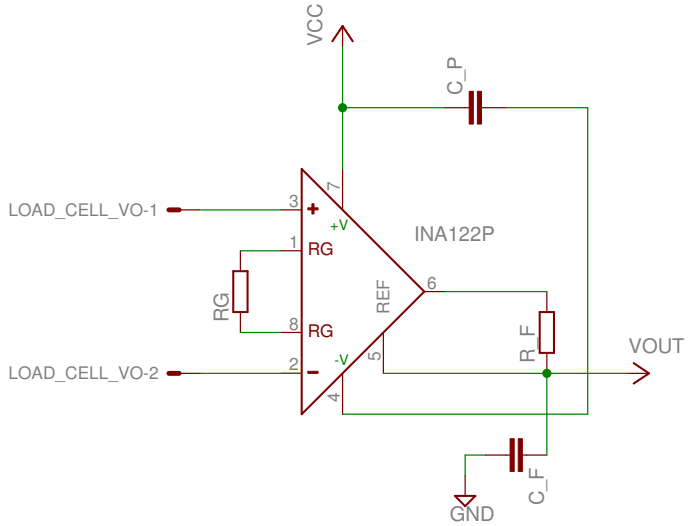
Arduino Fio.

Experimental setup
Acquisition unit

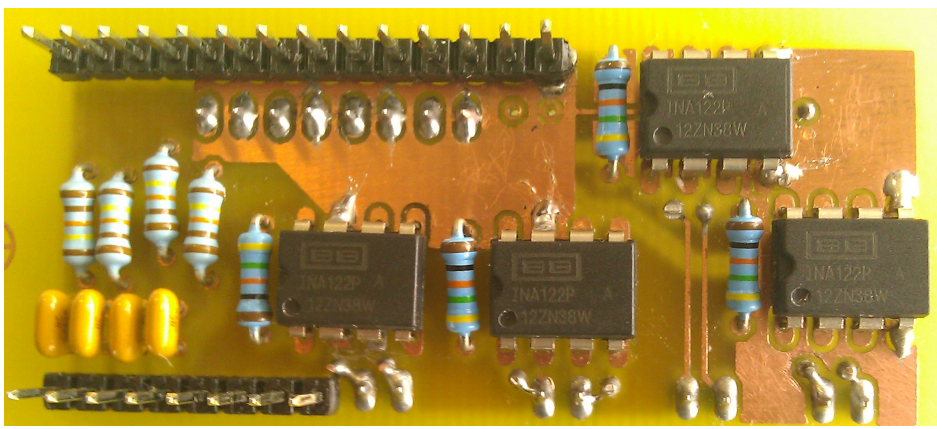


Experimental setup
Signal conditioning

- INA122P instrumentation amplifier
- Power stabilizer capacitor
- Low-pass filter at $\approx 500\,\mathrm{Hz}$
- Same footprint as Arduino Fio

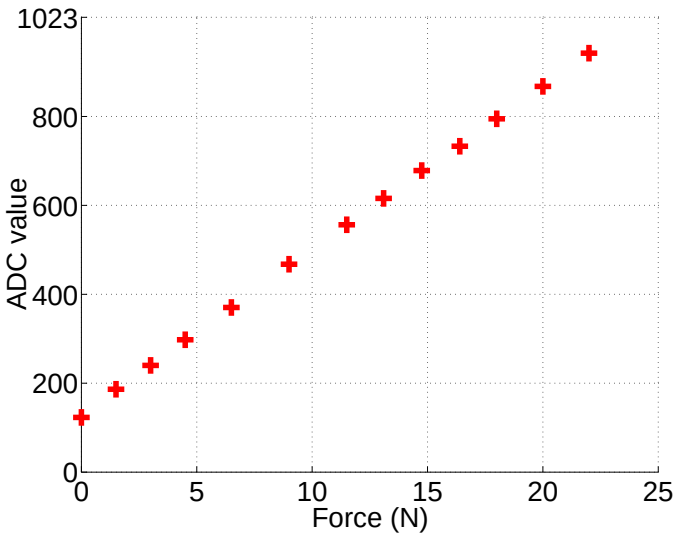


Amplification circuit.

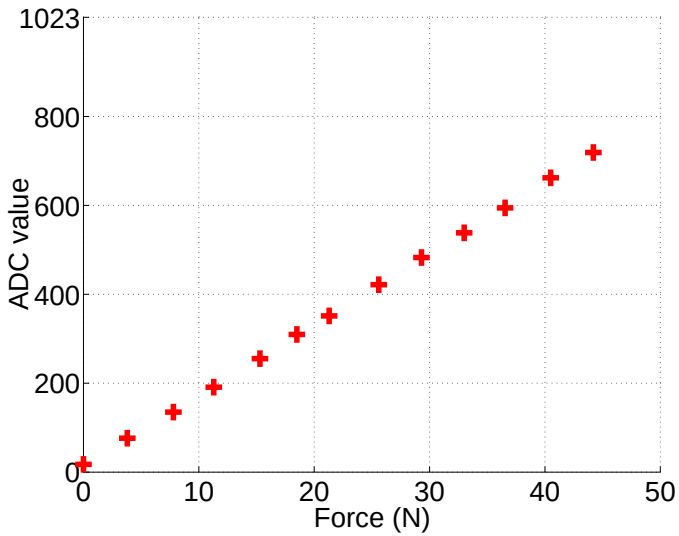


Signal conditioning board.

Experimental setup
Load cell's calibration



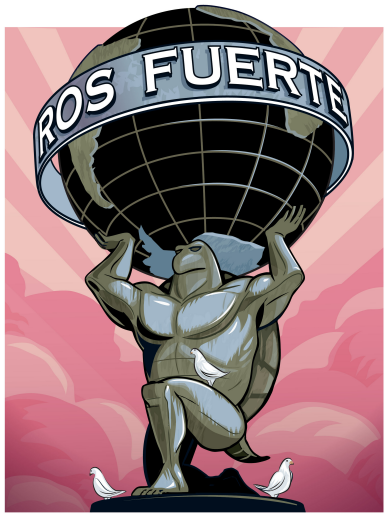
Calibration curve of a LBS-5.

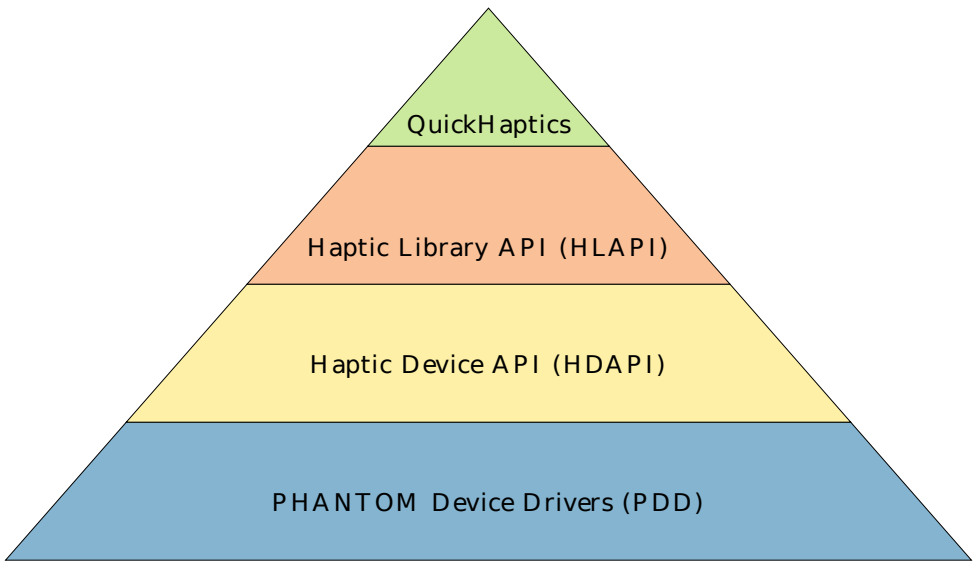


Calibration curve of a LBS-10.

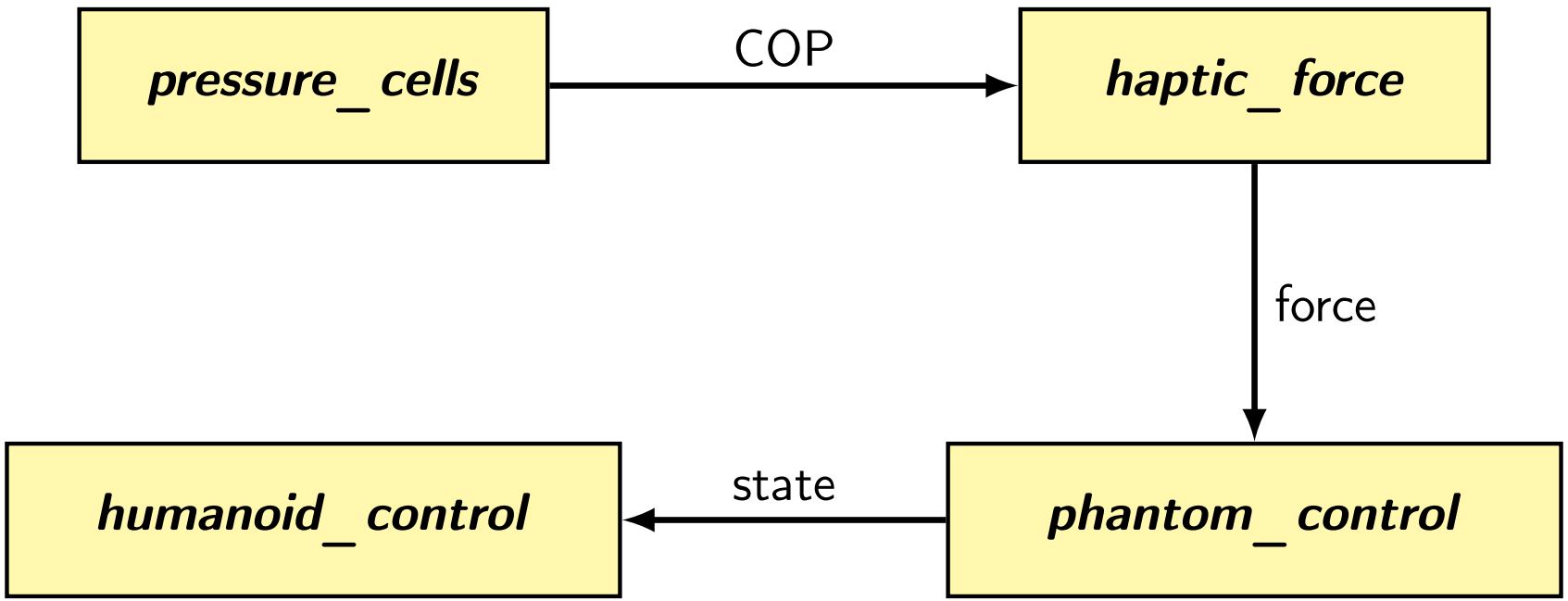
Experimental setup
Software

- ROS
  - Modular programming
  - Free and open source
- OpenHaptics toolkit
  - Low-level control API
  - High-level control API
  - Includes drivers



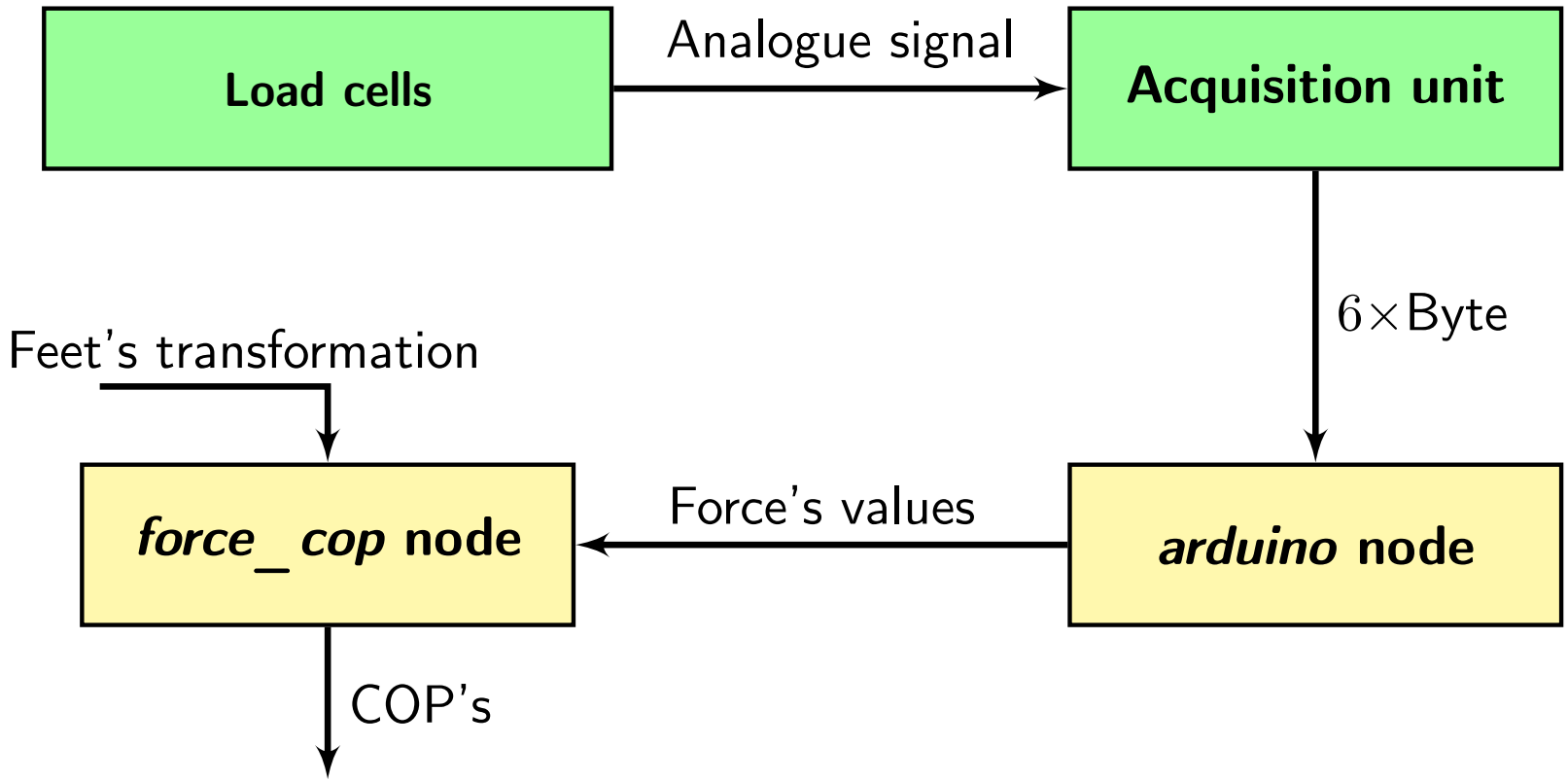


ROS modules
Structure

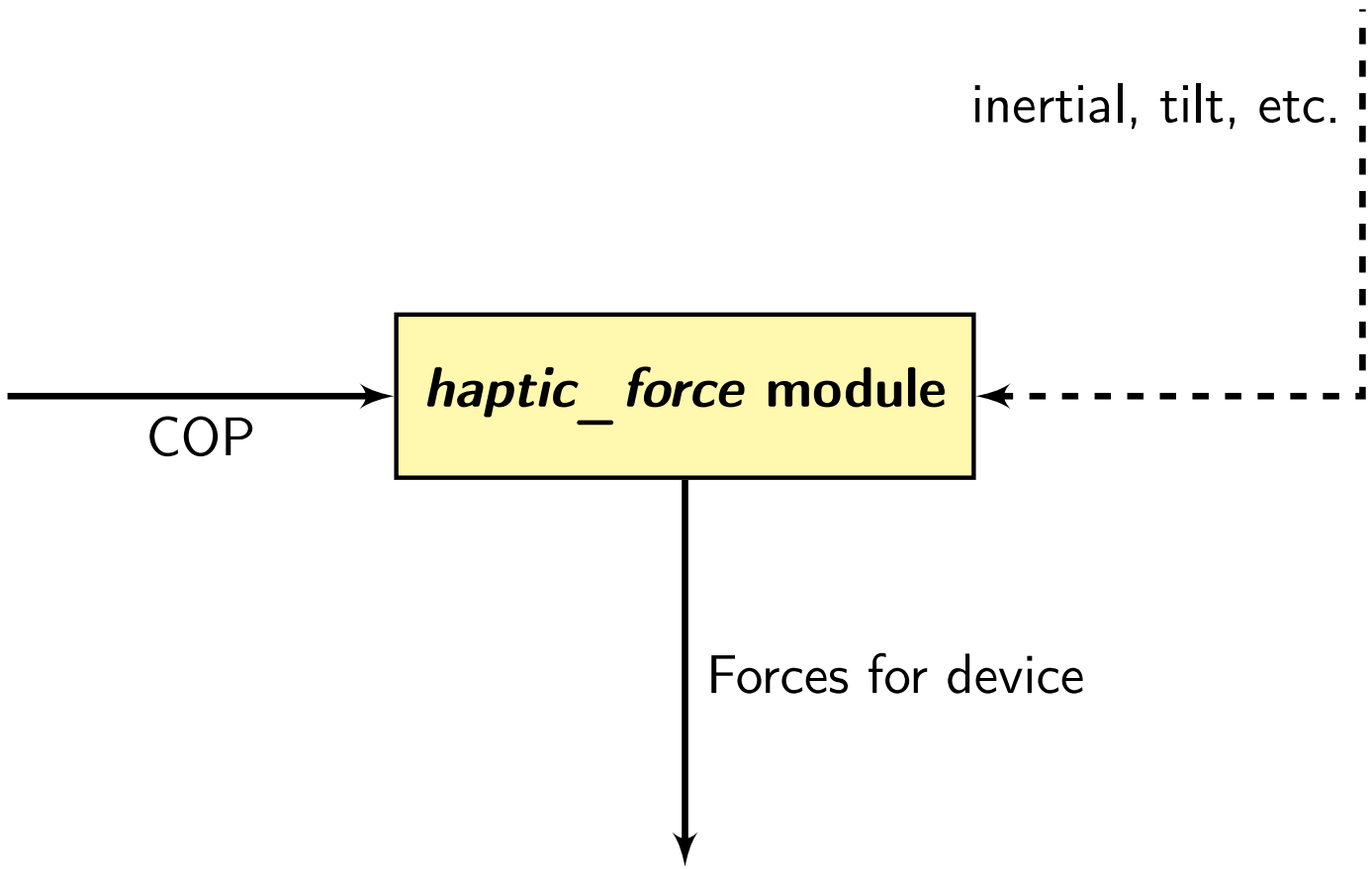


ROS modules

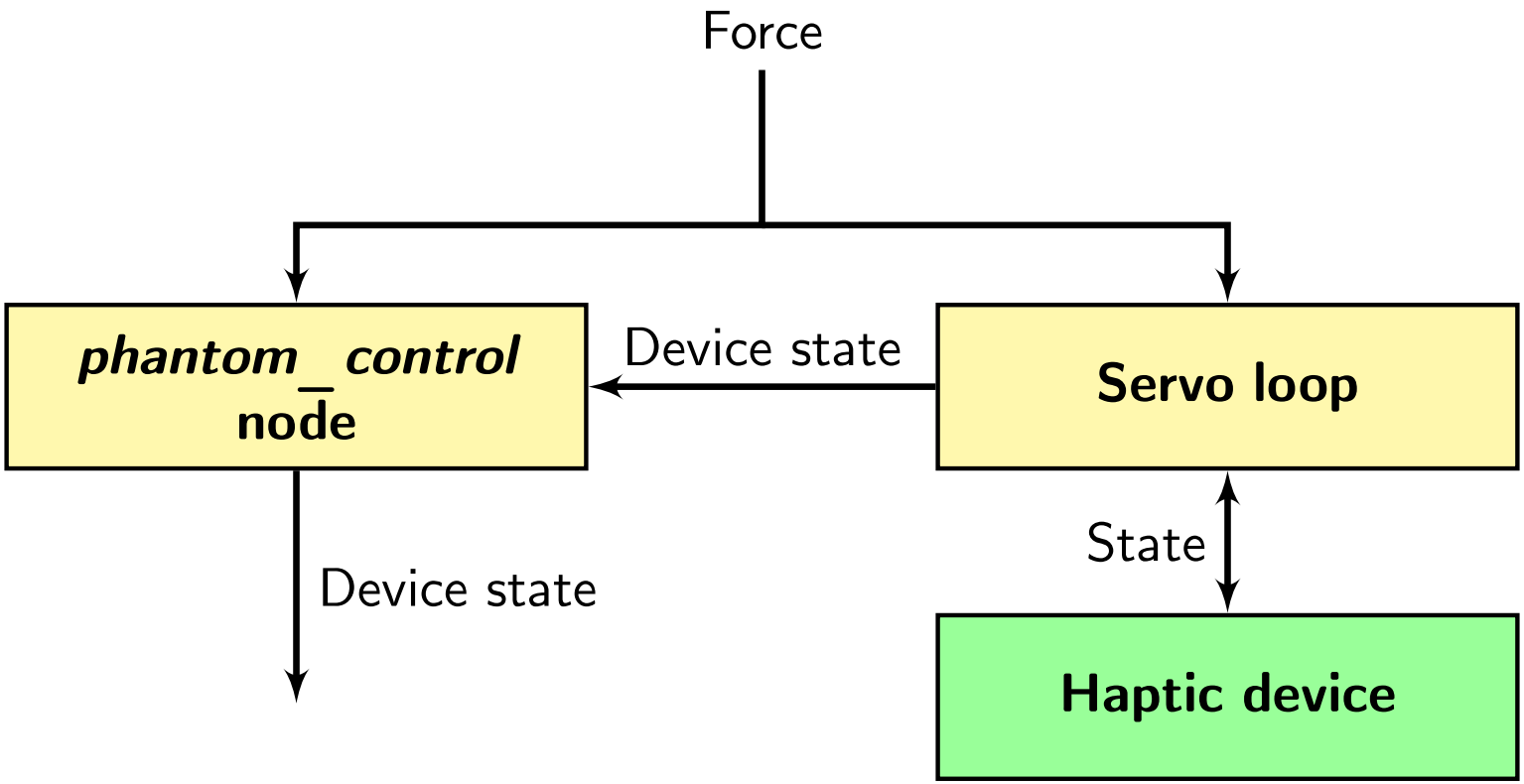
pressure_cells



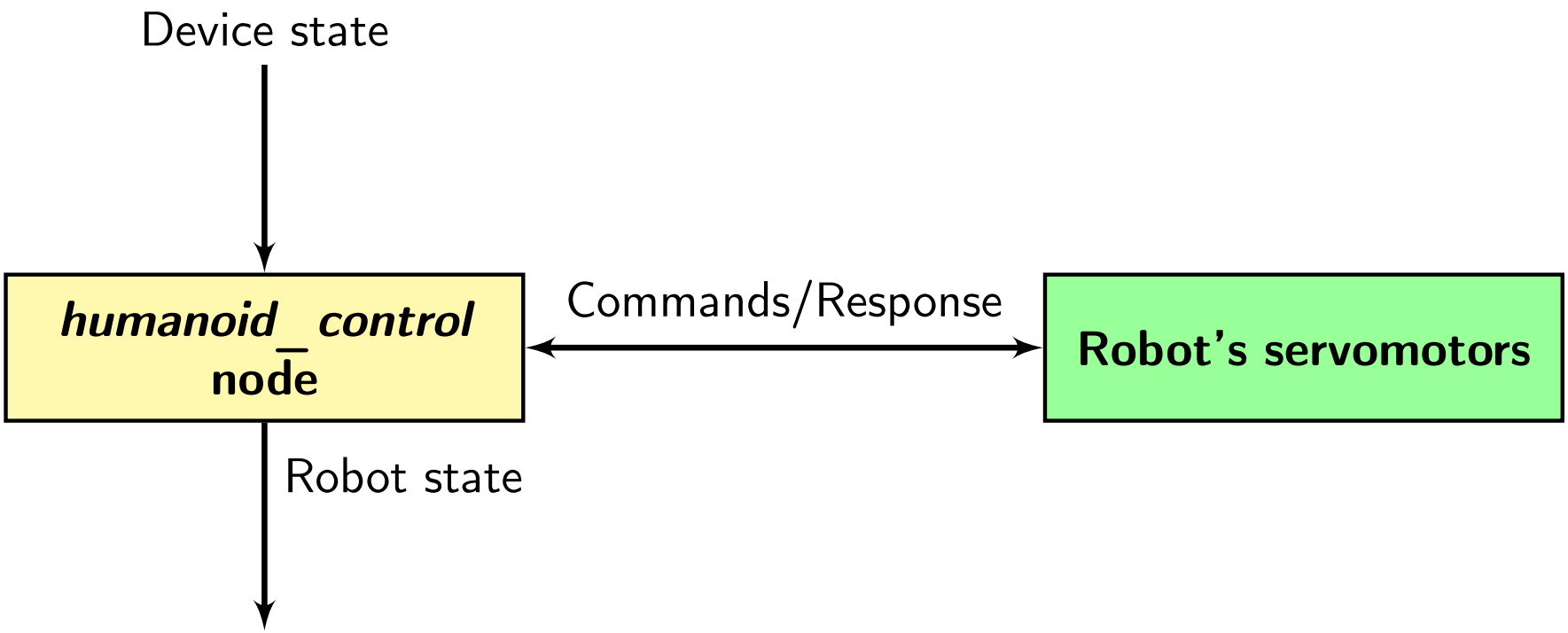
ROS modules
haptic_force



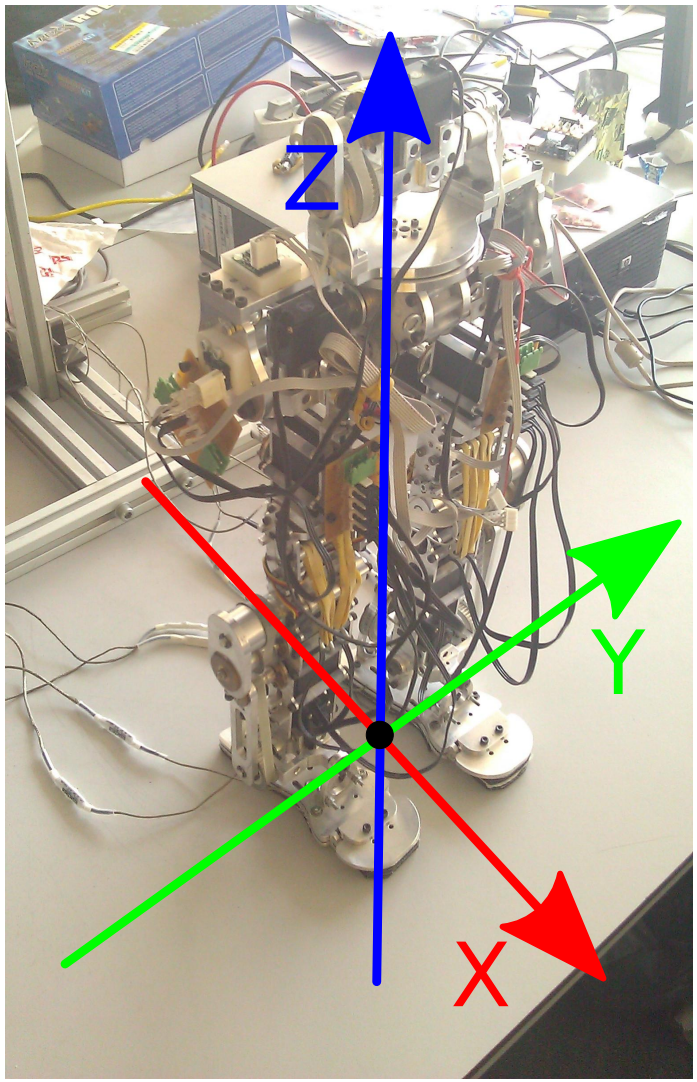
ROS modules
phantom_control



ROS modules
humanoid_control

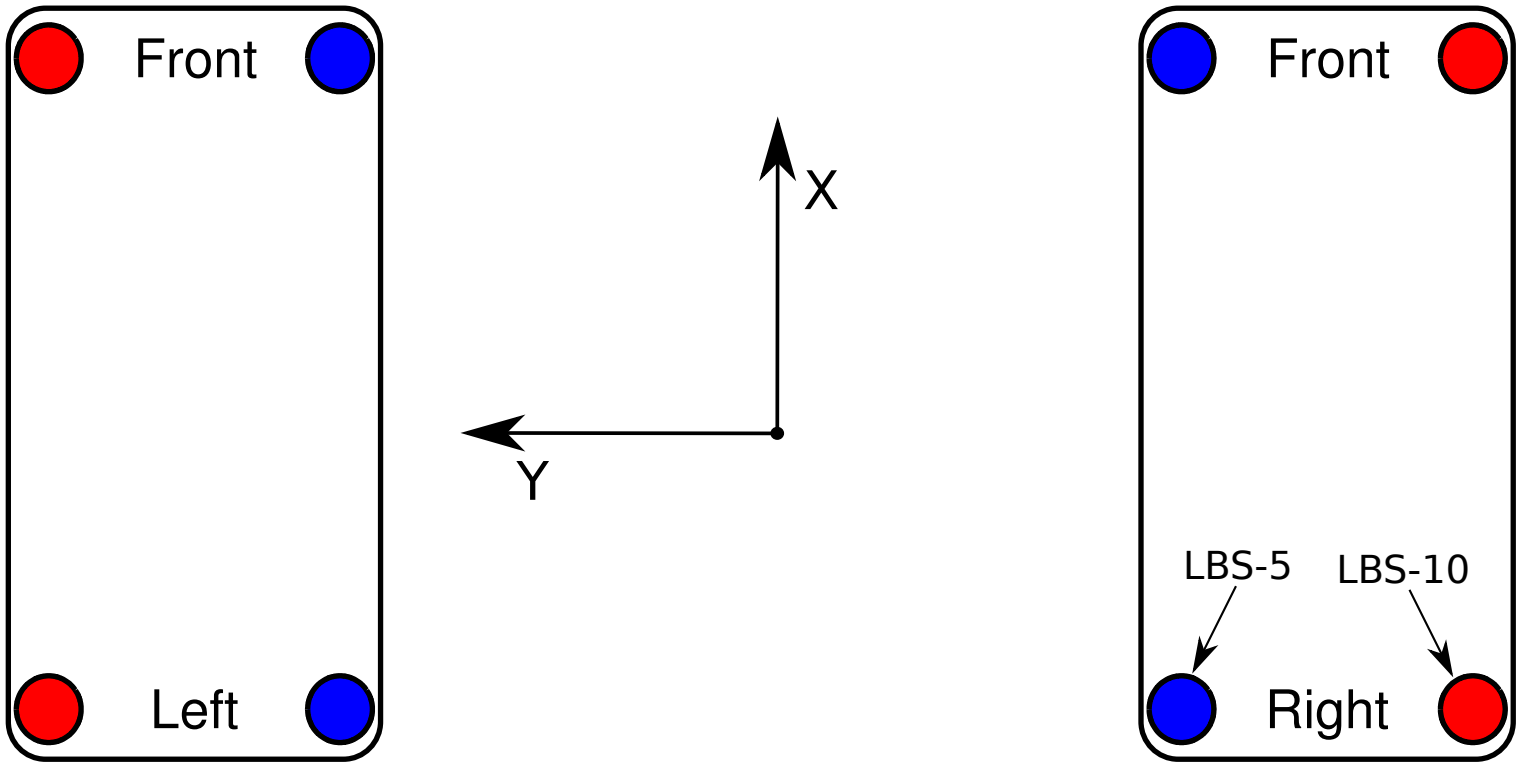


Demonstrations



Axis system.

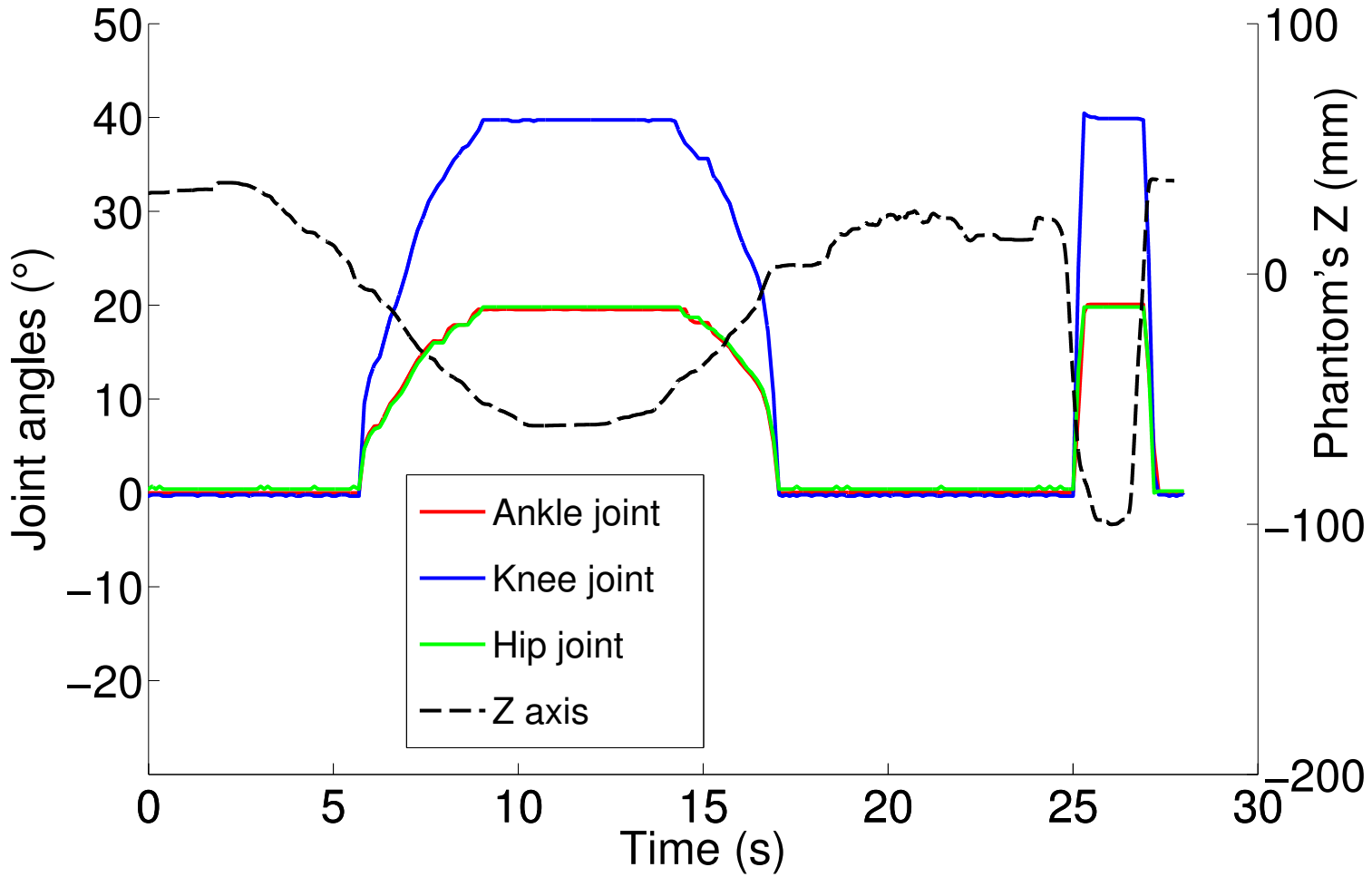
Demonstrations



Load cells placement.

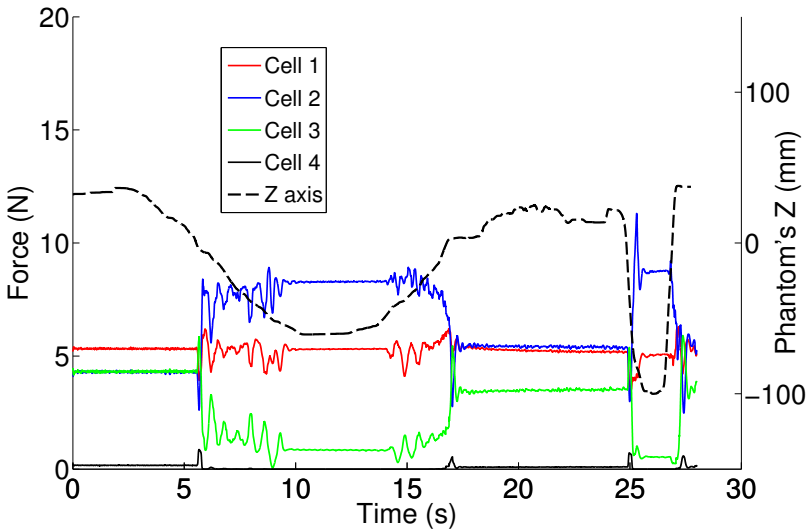
Demonstrations
Vertical movement

Demonstrations
Vertical movement

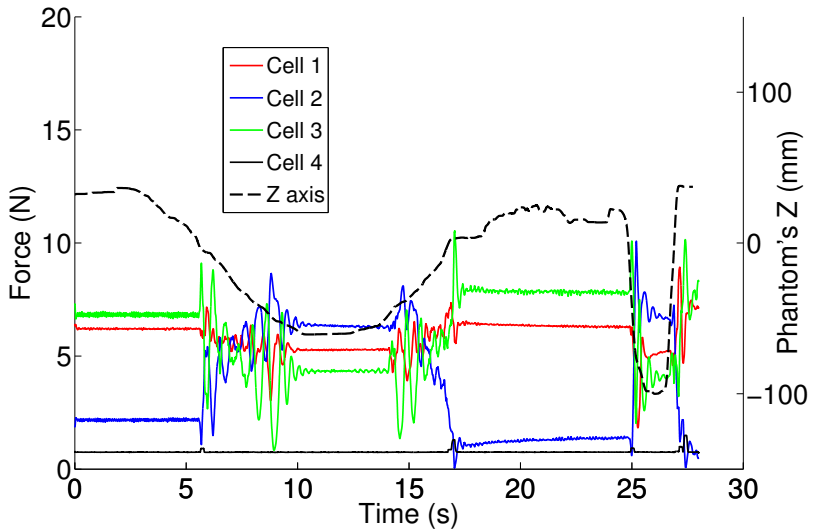


Actuated joints and Z axis of the haptic device.

Demonstrations
Vertical movement

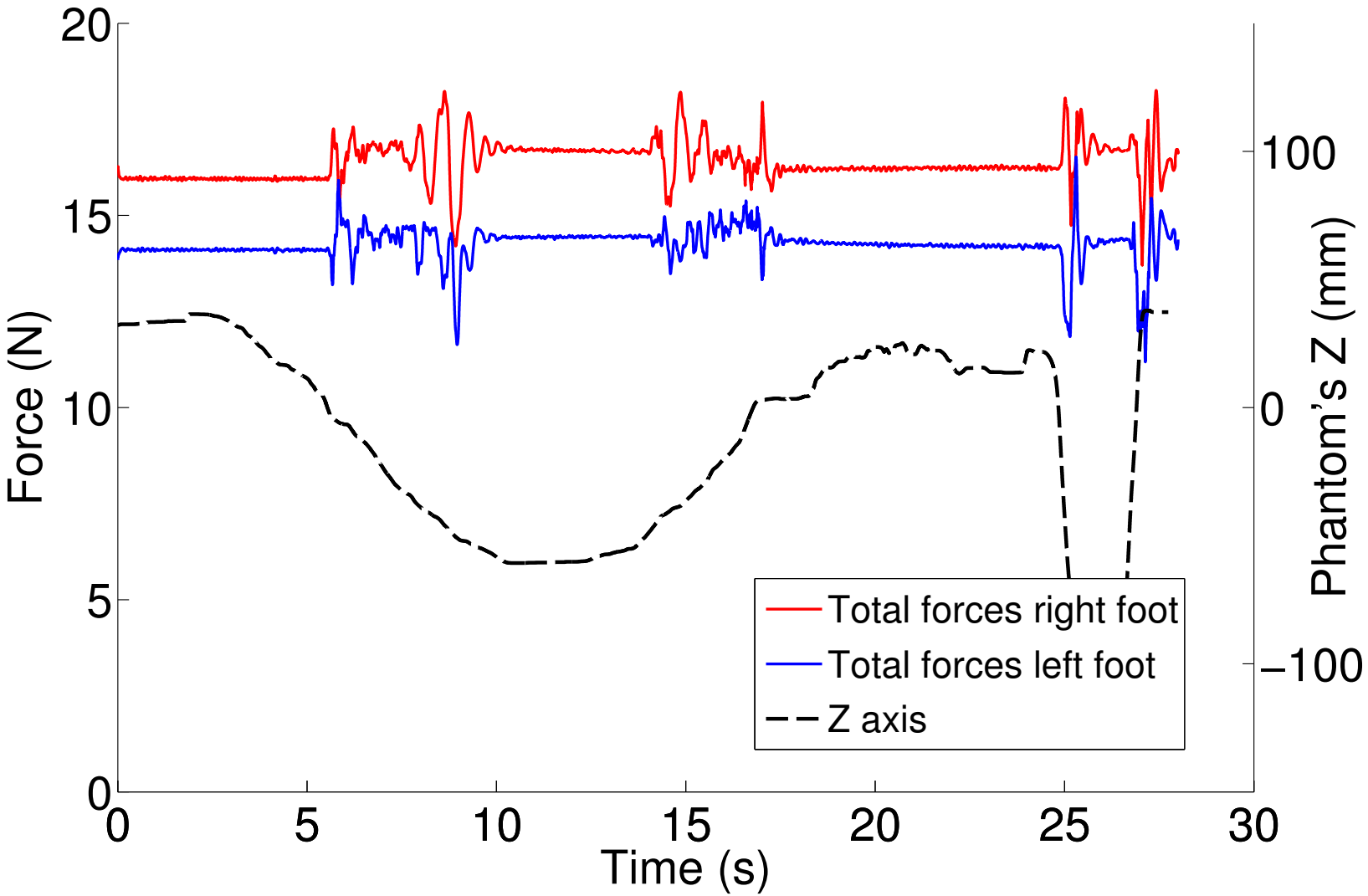


Forces on the left foot.



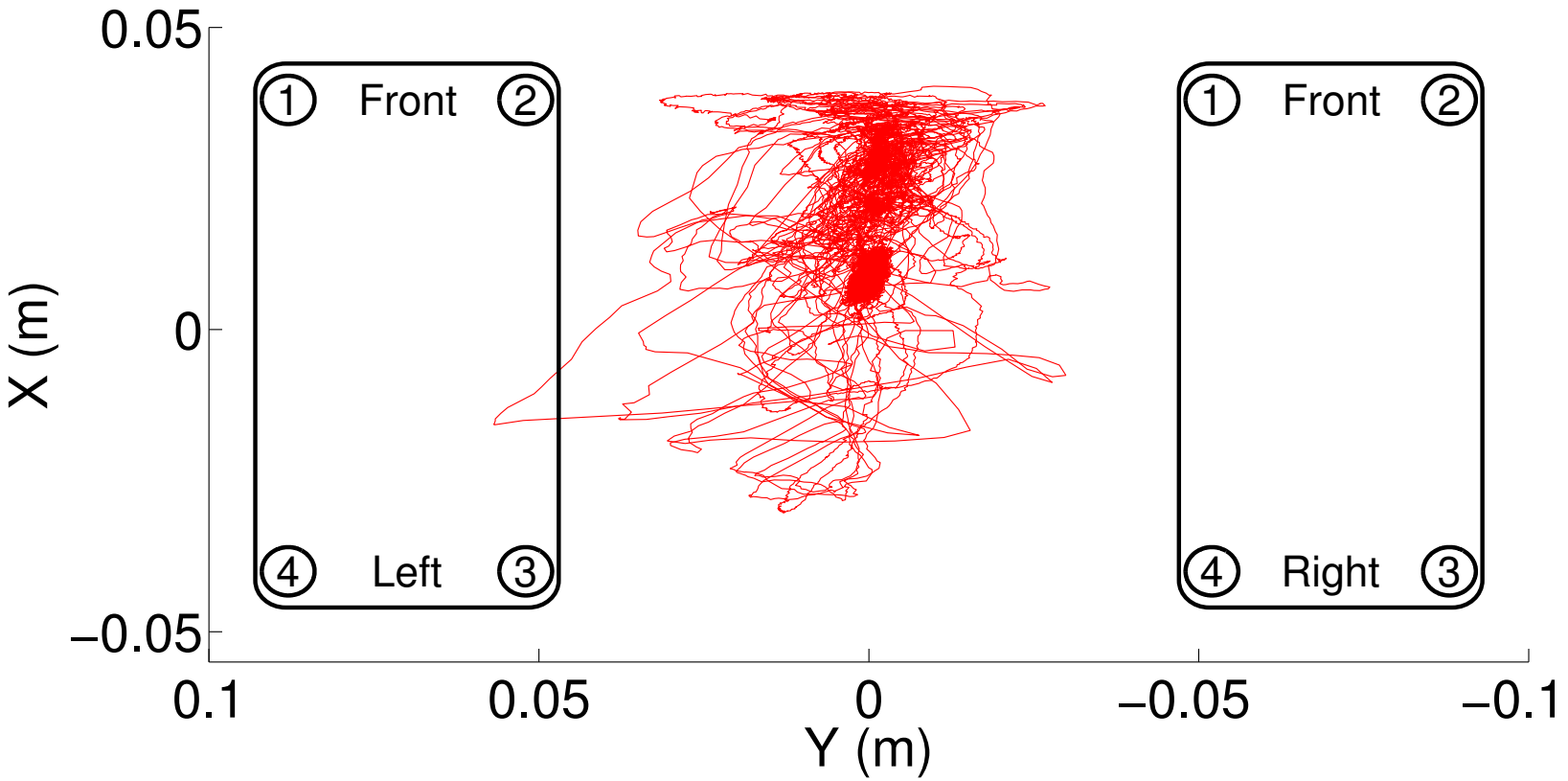
Forces on the right foot.

Demonstrations
Vertical movement



Sum of forces.

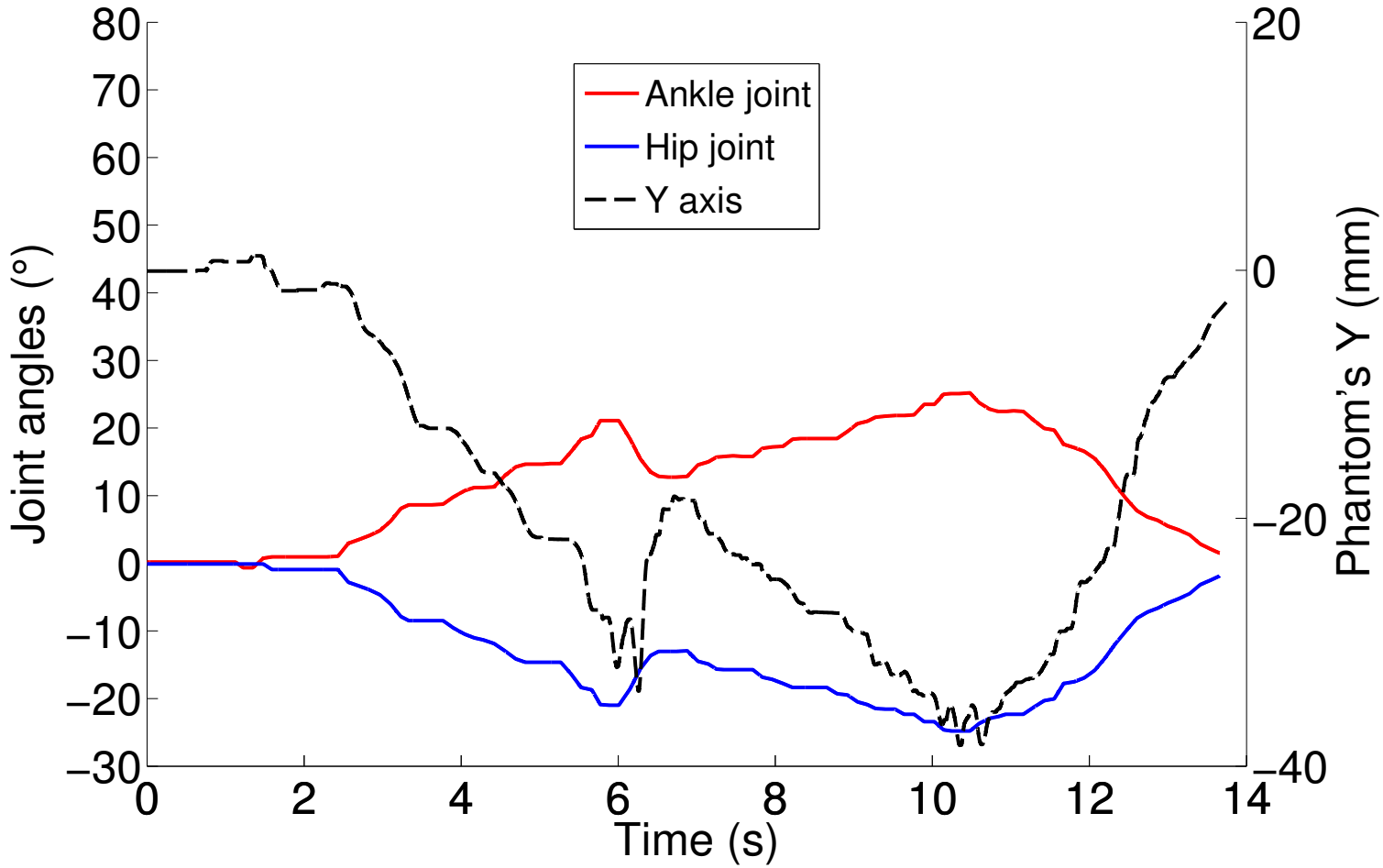
Demonstrations
Vertical movement



Complete COP.

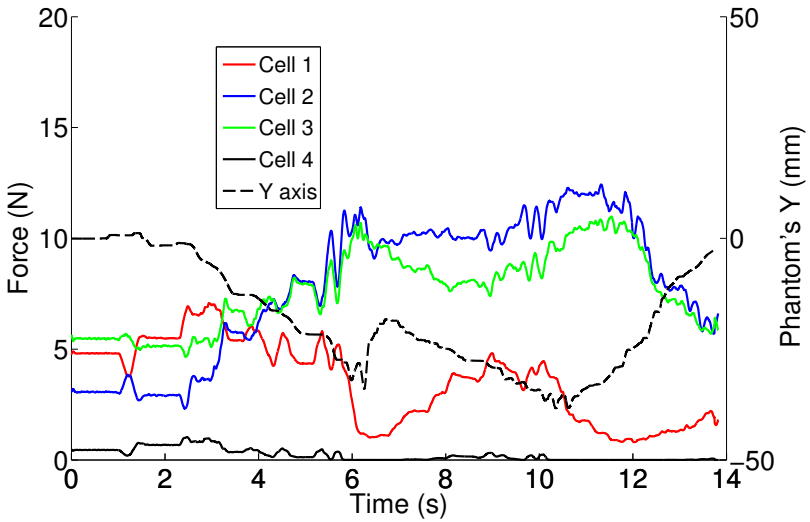
Demonstrations
Lateral movement

Demonstrations
Lateral movement

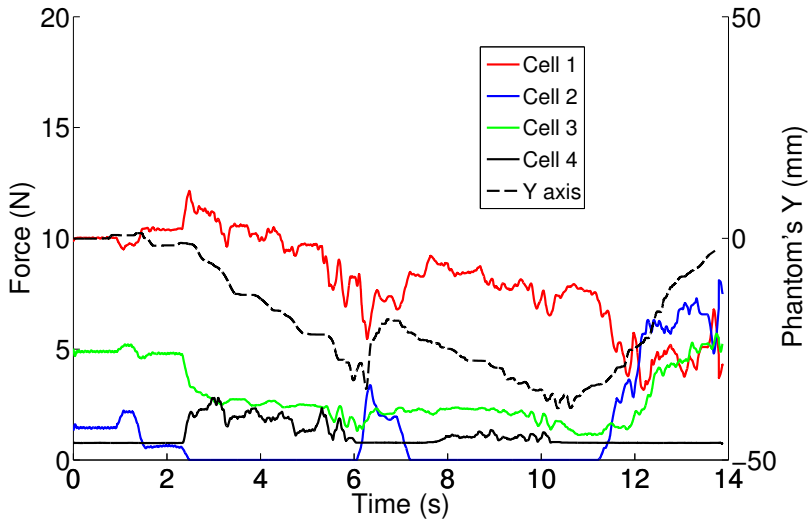


Actuated joints and Y axis of the haptic device.

Demonstrations
Lateral movement

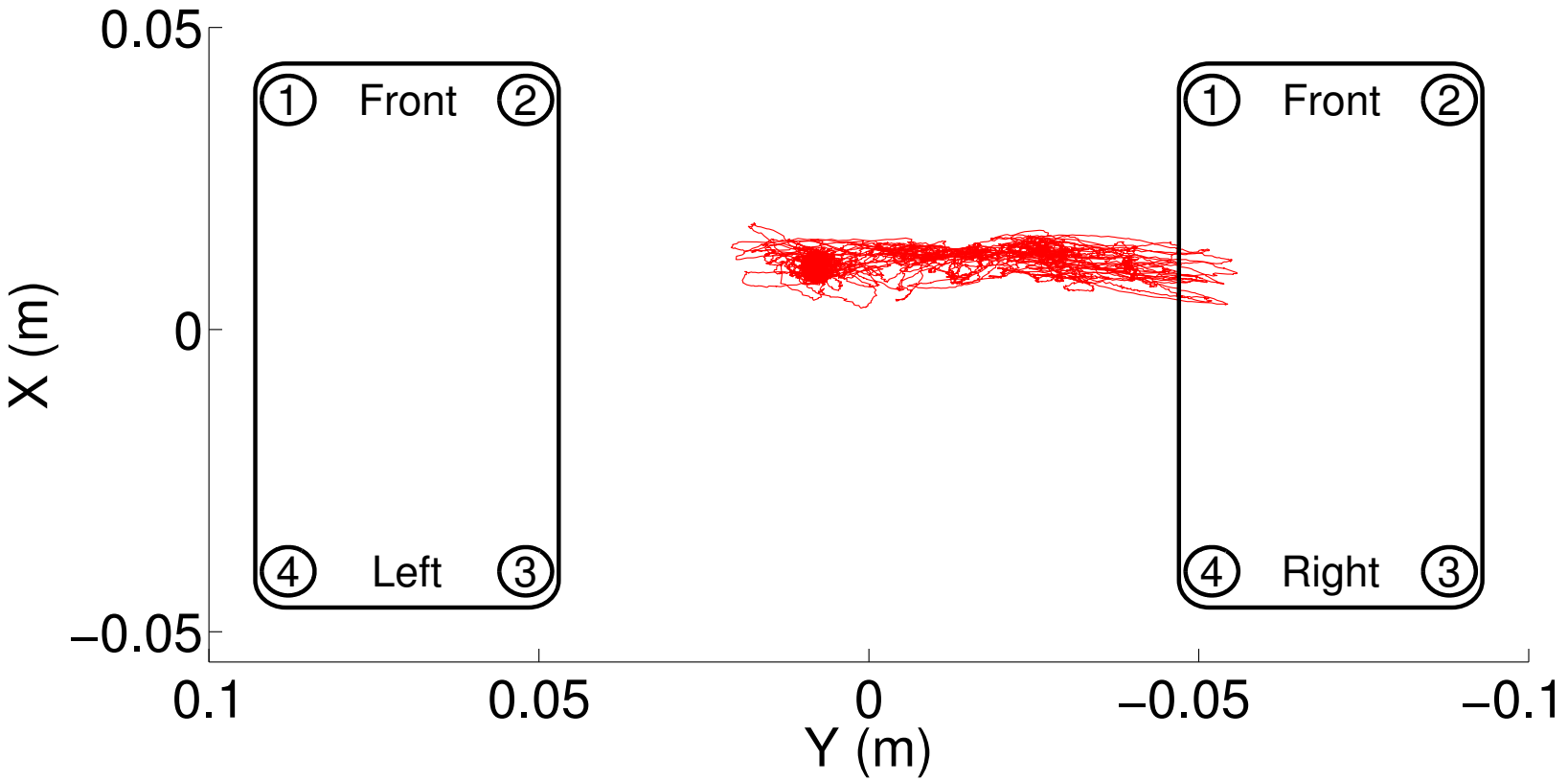


Forces on the left foot.



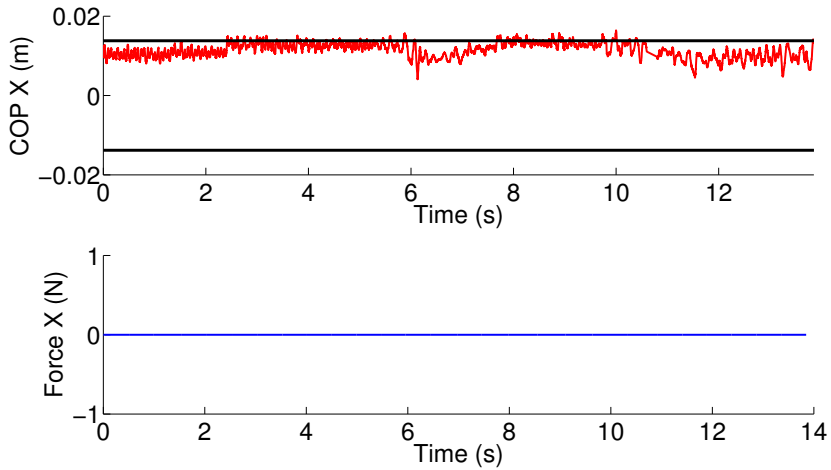
Forces on the right foot.

Demonstrations
Vertical movement

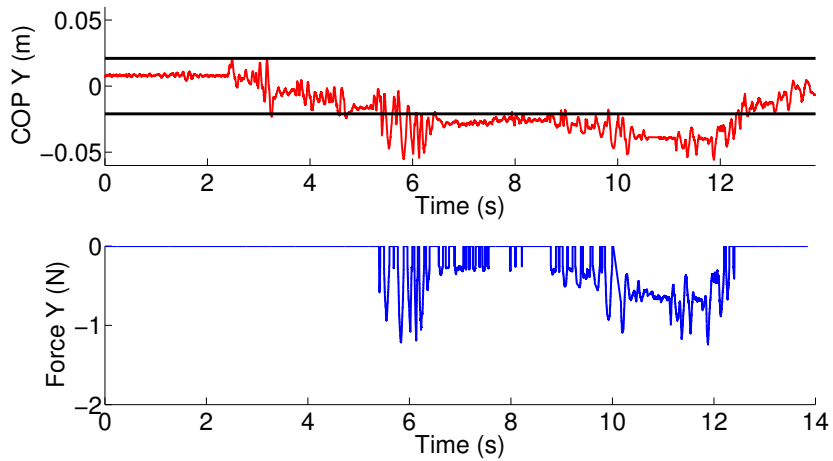


Complete COP.

Demonstrations
Lateral movement



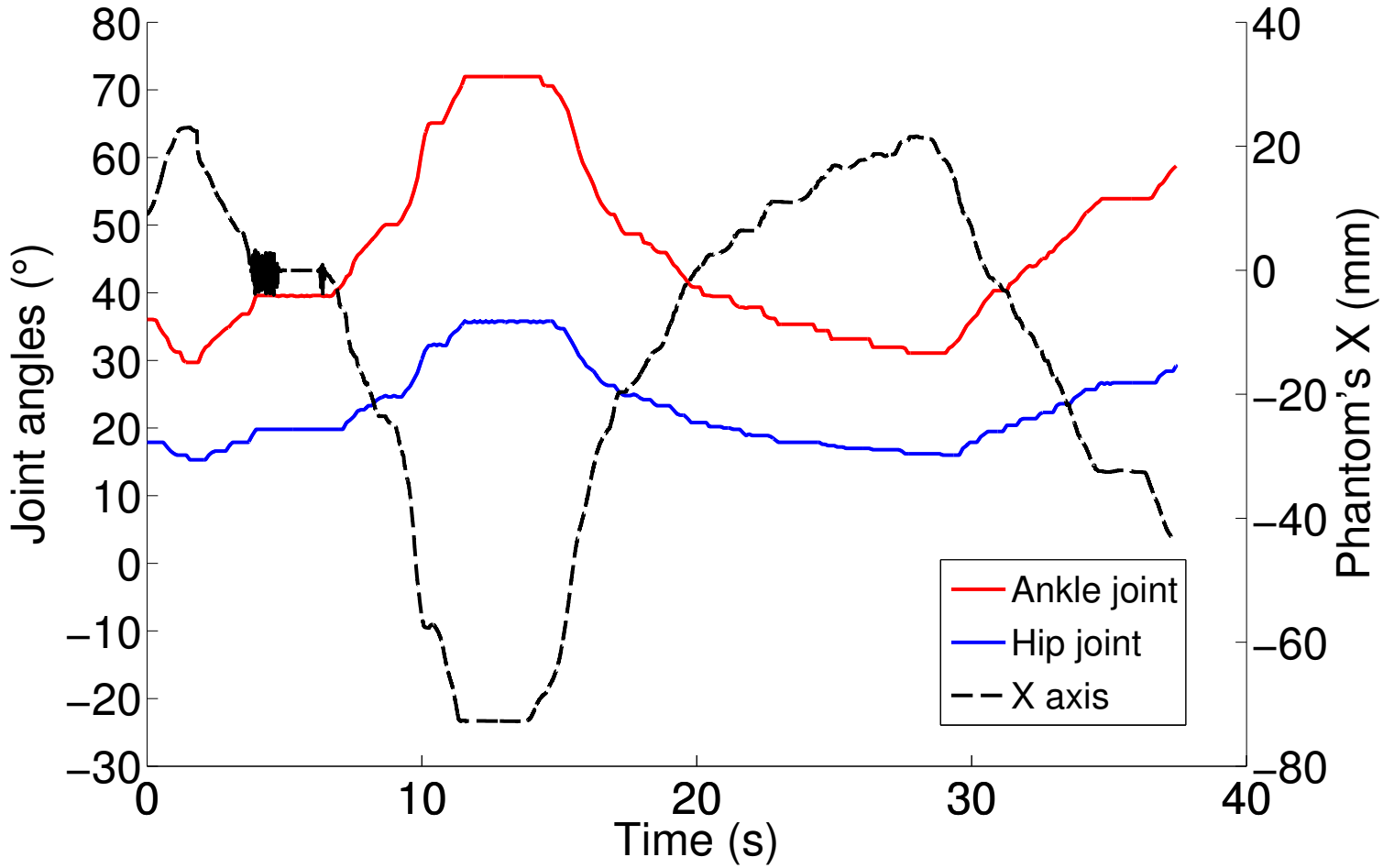
X's Components.



Y's Components.

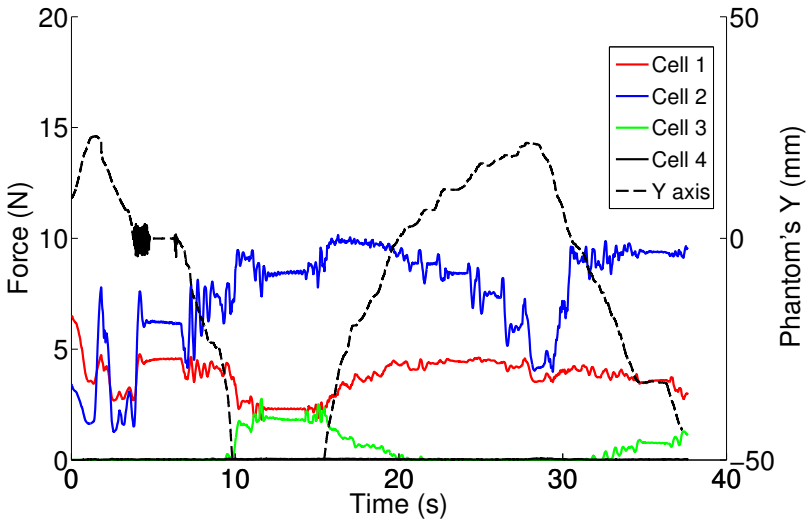
Demonstrations
Sagittal movement

Demonstrations
Sagittal movement

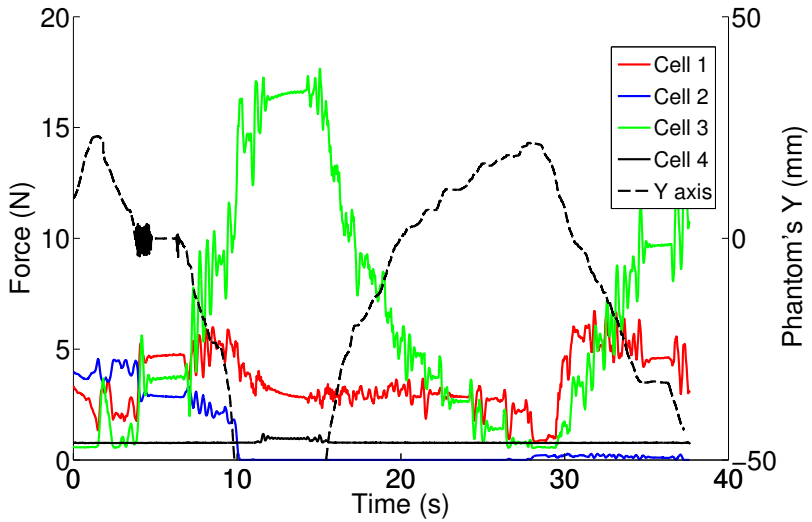


Actuated joints and X axis of the haptic device.

Demonstrations
Sagittal movement

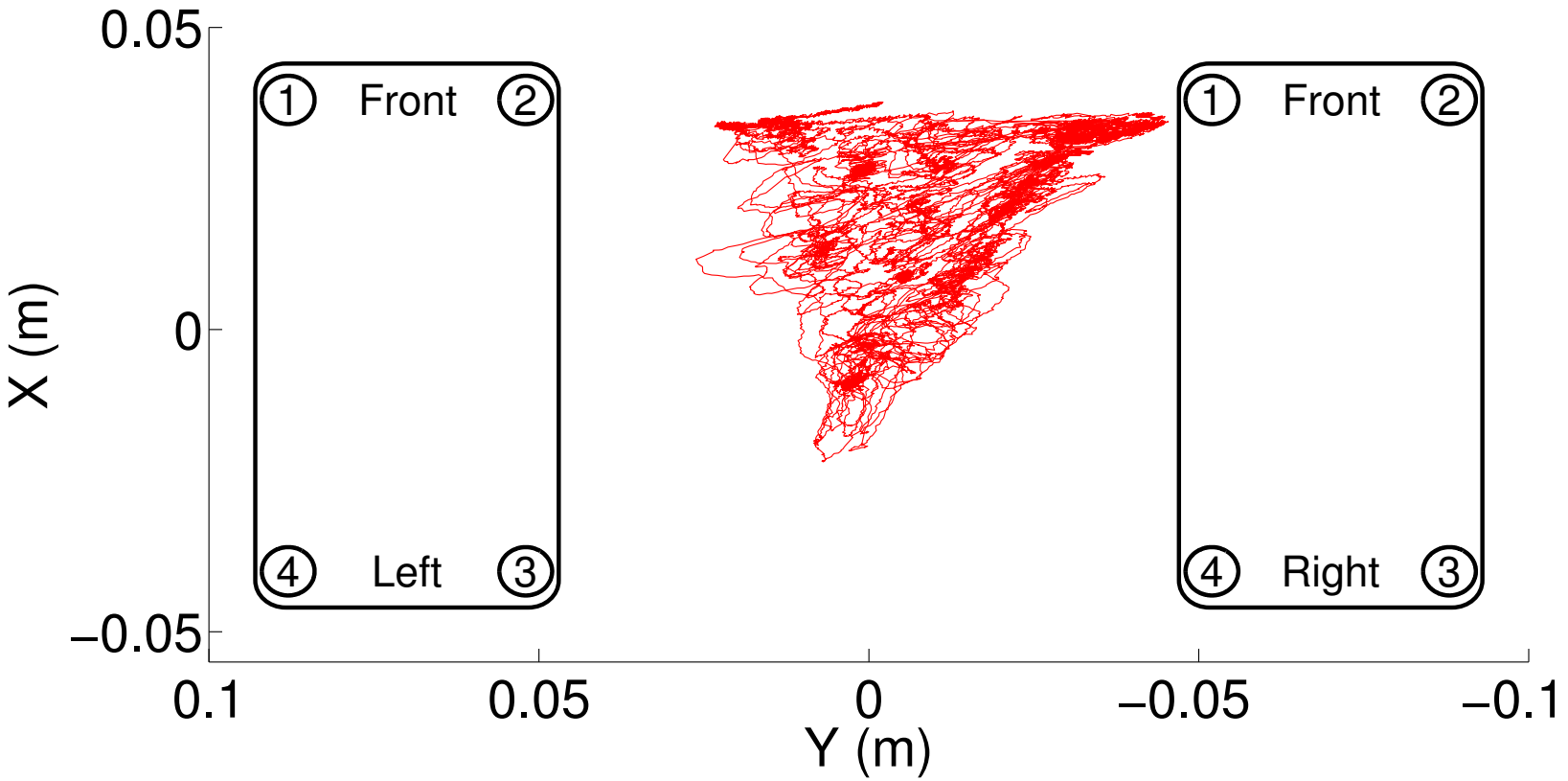


Forces on the left foot.



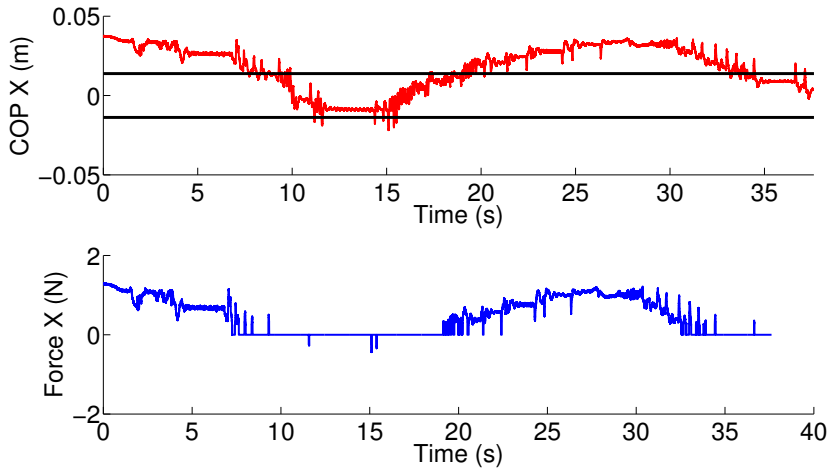
Forces on the right foot.

Demonstrations
Vertical movement

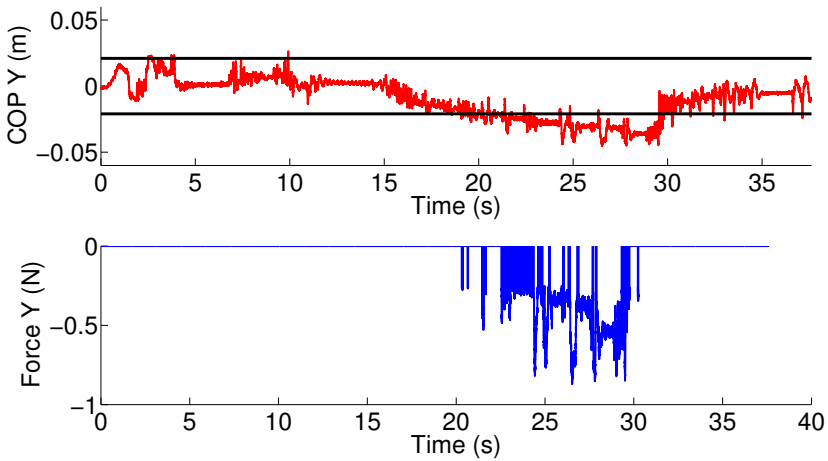


Complete COP.

Demonstrations
Lateral movement



X's Components.



Y's Components.

Conclusions and future work
Conclusions

- Implement the ROS platform ✓
- Develop a data acquisition unit for the load cells ✓
- Link the load cells data with the haptic force feedback ✓
- Develop a control system for the robot with haptics ✓
- Perform balancing demonstrations ✓
- Record all relevant data ✓

Conclusions and future work
Future work

- Velocity control
- Use of the Z component of the force
- Experiment with different formulas for force generation
- Addiction of other sensors for force generation
- Improve kinematic model
- Usage of two haptic devices

Tele-operation of a Humanoid Robot using Haptics and Load Sensors

Master Thesis Presentation

Emílio Estrelinha

University of Aveiro - Department of Mechanical Engineering

Advisor : Prof. Doutor Vitor M. F. Santos
Co-advisor : Prof. Doutor Filipe M. T. P. da Silva

July 23, 2013