Basic Control Experiments

1 Objective

In order to become familiar and autonomous with both control and experiments, several basic control strategies will be tested, first in simulation then experimentally. These control strategies include direct-drive and impedance control on three basic motions:

- static
- knee sinusoidal motion
- knee and hip sinusoidal motions

These motions trajectories will first be manually implemented, then by using the TSID framework.

2 Main code

Two main codes were produced during this work :

- `main_simu_solo8_tsid_control.py`, the main code for simulation
- `main_solo8_tsid_control.py`, the main code for experiments

The experimental code requires a mandatory string argument `-i`, which defines the interface used to connect to the robot. This interface can be found using the `ifconfig` command.

Both codes take a mandatory argument `-exp`, which takes as an input an integer used to choose the controller used in the simulation. These controllers go from number 1 to 20, and are detailed in the next part.

Both codes take an optional boolean argument `-rc`, which adds a low-pass filter to the velocity measurement or estimation. This filter's goal is to remove or lower the cyclic noise created during the experiments.

Finally, the experimental code takes an optional boolean argument `-mc`. When True, starts motion capture for the experiment.

Examples:

```
main_simu_solo8_tsid_control.py -exp 5 -rc False
main_solo8_tsid_control.py -i interface0 -exp 2 -rc True -mc False
```

3 Control

3.1 Control strategies

Three distinct control strategies are implemented:

1. Impedance control, without Feedforward torque;
2. Impedance control, with Feedforward torque;
3. Direct-Drive control.

3.1.1 Impedance control

Scheme:

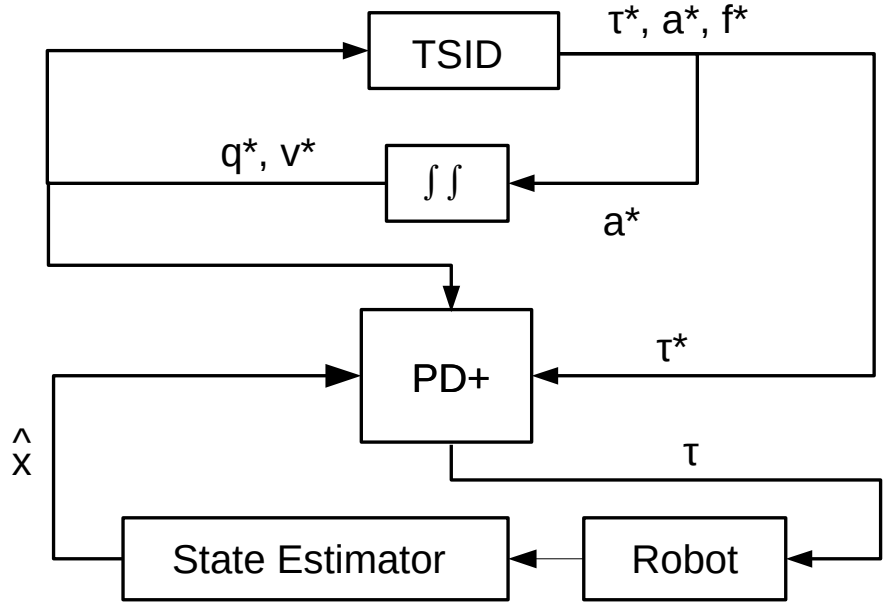

Figure 1: Impedance Control Scheme

Without Feedforward

Torque calculation:

$$\tau = Kp(q - qmes) + Kd(v - vmes) \tag{1}$$

With Feedforward

Torque calculation:

$$\tau = Kp(q - qmes) + Kd(v - vmes) + \tau_{FF} \tag{2}$$

with

$$\tau_{FF} = \begin{cases} \texttt{pinocchio.rnea(model, data, q, v, dv)} & \text{if the motion is manually generated} \\ \texttt{tsid.getActuatorForces(sol)} & \text{if the motion is generated by TSID} \end{cases} \tag{3}$$

3.1.2 Direct-drive control

Schematic:

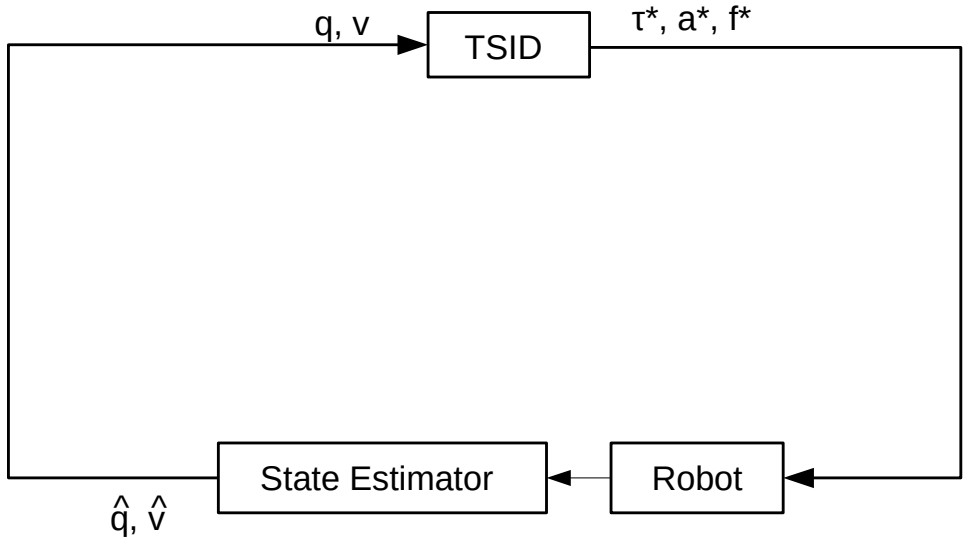

Figure 2: Direct-Drive Control Scheme

3.2 Motions

In order to test these control strategies, four motions are studied:

1. the robot remaining static,
2. a sinusoidal motion of the front left knee,
3. a small sinusoidal motion of the front left hip and knee,
4. a wide sinusoidal motion of the front left hip and knee.

These motions can either be generated manually, or generated by inverse dynamics calculations with TSID, by creating posture tasks.

3.3 Controllers

These controllers from 1 to 20 are detailed in the following sections.

3.3.1 Controller 1

Control Strategy: Impedance control without feedforward
Type of motion: Static
Motion generation: Manual
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 1`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 1`

3.3.2 Controller 2

Control Strategy: Impedance control without feedforward
Type of motion: Sinusoidal knee motion
Motion generation: Manual
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 2`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 2`

3.3.3 Controller 3

Control Strategy: Impedance control without feedforward
Type of motion: Small sinusoidal hip and knee motions
Motion generation: Manual
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 3`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 3`

3.3.4 Controller 4

Control Strategy: Impedance control without feedforward
Type of motion: Wide sinusoidal hip and knee motions
Motion generation: Manual
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 4`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 4`

3.3.5 Controller 5

Control Strategy: Impedance control with feedforward
Type of motion: Static
Motion generation: Manual
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 5`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 5`

3.3.6 Controller 6

Control Strategy: Impedance control with feedforward
Type of motion: Sinusoidal knee motion
Motion generation: Manual
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 6`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 6`

3.3.7 Controller 7

Control Strategy: Impedance control with feedforward
Type of motion: Small sinusoidal hip and knee motions
Motion generation: Manual
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 7`

Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 7`

3.3.8 Controller 8

Control Strategy: Impedance control with feedforward
Type of motion: Wide sinusoidal hip and knee motions
Motion generation: Manual
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 8`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 8`

3.3.9 Controller 9

Control Strategy: Impedance control without feedforward
Type of motion: Static
Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 9`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 9`

3.3.10 Controller 10

Control Strategy: Impedance control without feedforward
Type of motion: Sinusoidal knee motion
Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 10`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 10`

3.3.11 Controller 11

Control Strategy: Impedance control without feedforward
Type of motion: Small sinusoidal hip and knee motions
Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 11`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 11`

3.3.12 Controller 12

Control Strategy: Impedance control without feedforward
Type of motion: Wide sinusoidal hip and knee motions
Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 12`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 12`

3.3.13 Controller 13

Control Strategy: Impedance control with feedforward
Type of motion: Static

Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 13`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 13`

3.3.14 Controller 14

Control Strategy: Impedance control with feedforward
Type of motion: Sinusoidal knee motion
Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 14`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 14`

3.3.15 Controller 15

Control Strategy: Impedance control with feedforward
Type of motion: Small sinusoidal hip and knee motions
Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 15`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 15`

3.3.16 Controller 16

Control Strategy: Impedance control with feedforward
Type of motion: Wide sinusoidal hip and knee motions
Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 16`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 16`

3.3.17 Controller 17

Control Strategy: Direct-drive control
Type of motion: Static
Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 17`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 17`

3.3.18 Controller 18

Control Strategy: Direct-drive control
Type of motion: Sinusoidal knee motion
Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 18`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 18`

3.3.19 Controller 19

Control Strategy: Direct-drive control
Type of motion: Small sinusoidal hip and knee motions
Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 19`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 19`

3.3.20 Controller 20

Control Strategy: Direct-drive control
Type of motion: Wide sinusoidal hip and knee motions
Motion generation: TSID
Simulation: `python3 main_simu_solo8_tsid_control.py -exp 20`
Experiment: `sudo -E python3 main_solo8_tsid_control.py -i interface_name -exp 20`

3.3.21 Recap

Controller	PD	PD+	Direct-Drive	Motion	Manual	TSID
1	X			Static	X	
2	X			Knee	X	
3	X			Hip + Knee (Small)	X	
4	X			Hip + Knee (Wide)	X	
5		X		Static	X	
6		X		Knee	X	
7		X		Hip + Knee (Small)	X	
8		X		Hip + Knee (Wide)	X	
9	X			Static		X
10	X			Knee		X
11	X			Hip + Knee (Small)		X
12	X			Hip + Knee (Wide)		X
13		X		Static		X
14		X		Knee		X
15		X		Hip + Knee (Small)		X
16		X		Hip + Knee (Wide)		X
17			X	Static		X
18			X	Knee		X
19			X	Hip + Knee (Small)		X
20			X	Hip + Knee (Wide)		X

Table 1: Controllers recap