Guide of the Assignment 'Adaptive Impedance Control'

Authors: Xiaofeng Xiong
Email: xiaofeng.xiong83@gmail.com

Version: 2.0

Aim

The guide aims at addressing the specific aspects (see below) of the assignment 'adaptive impedance control'.

Intellectual Property (IP)

The attached files Dyna_moto.py and main.py belong to the author. However, please feel free to use them (only) for research and education. **The files may be useful, but without any warranty; without even the implied warranty of merchantability or fitness for a particular purpose.** Additionally, the papers [1-4] should be referred in your usage. The files in Dynamixel_sdk.zip are originally from Dynamixel, and more details can be seen at [5].

Hardware preparation

Please check hardware components available. There are an actuator platform, interface, power band and converter, as well as three cables (see **Fig. 1**).

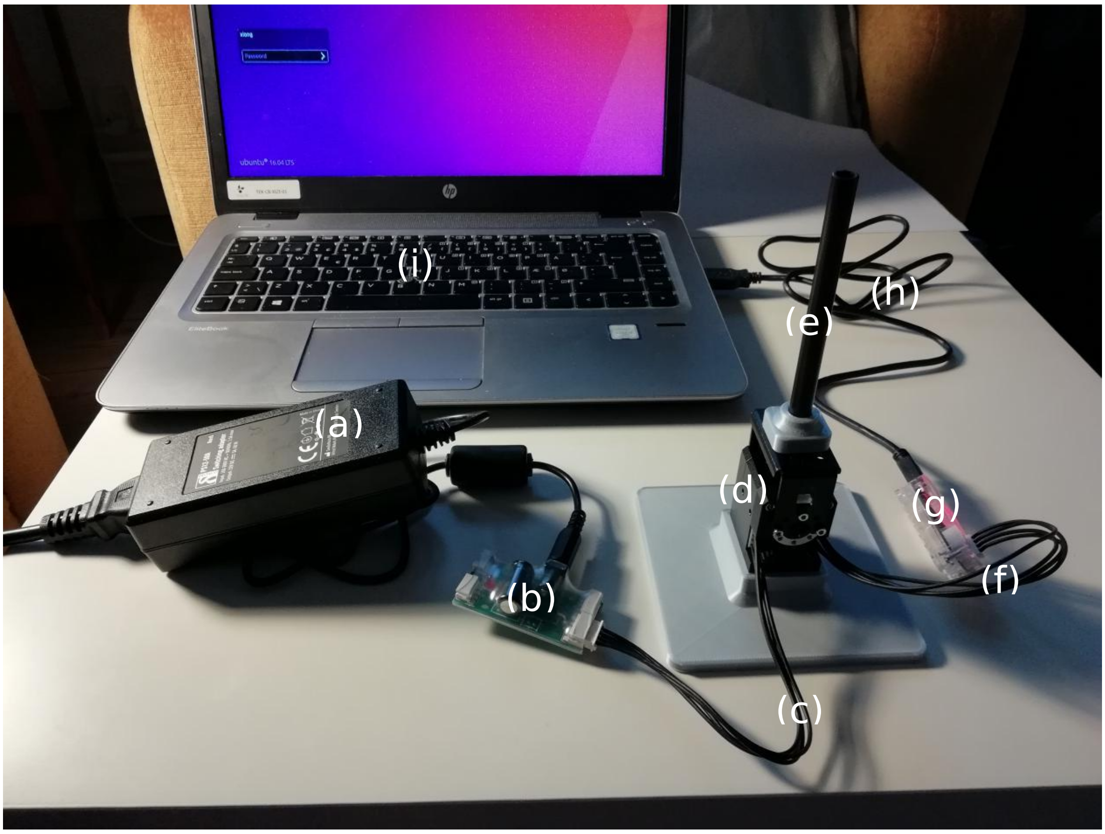

Fig. 1 Hardware setup**.** (a) Power band. (b) Power converter. (c) Beige-white headed cable. (d) Actuator. (e) Pipe. (f) White-white headed cable. (g) Interface between actuator and laptop. (h) Interface cable (i) Laptop.

Note that the 4-pin beige head is connected only to the power converter (i.e., see (b) and (c) in **Fig. 1**).

Software preparation

(1) SeiralToUSB interface **pySerial** [6] and Code editor **Sublime** [7] need to be installed. It is assumed that your had installed Ubuntu, python3, numpy, scipy, and matplotlib.

(2) **Checking pySerial installation** (succeed or not): running **python** in terminal and executing command lines: **import serial**, **print(serial.__version__)**,

```
xiong@xiong-HP-EliteBook-840-G4:~/courses/adaptive_locomotion/ppts/uploaded_mate
rials/2$ python
Python 3.6.6 |Anaconda custom (64-bit)| (default, Oct  9 2018, 12:34:16)
[GCC 7.3.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> import serial
>>> print(serial.__version__)
3.4
>>>
```

Fig. 2 Check pySerial installation.

The version (e.g., 3.4 in **Fig. 2**) of pySerial will be printed, if the installation succeeds.

(3) Checking interface between USB and serial ports, after powering the band on and connecting the actuator to laptop (see Fig. 1). Executing command lines in terminal (see **Fig. 3**): **dmesg | grep tty** and **sudo chmod a+rw /dev/ttyUSB0**.

```
xiong@xiong-HP-EliteBook-840-G4:~/courses/adaptive_locomotion/ppts/upl
oaded_materials/2$ dmesg | grep tty
[    0.000000] console [tty0] enabled
[    4.529828] 0000:00:16.3: ttyS4 at I/O 0x3088 (irq = 19, base_baud
= 115200) is a 16550A
[    4.923212] tty tty18: hash matches
[  263.813412] usb 1-1: FTDI USB Serial Device converter now attached
to ttyUSB0
[26927.697761] ftdi_sio ttyUSB0: FTDI USB Serial Device converter now
disconnected from ttyUSB0
xiong@xiong-HP-EliteBook-840-G4:~/courses/adaptive_locomotion/ppts/upl
oaded_materials/2$ sudo chmod a+rw /dev/ttyUSB0
[sudo] password for xiong:
```

Fig. 3 Check interface between USB and serial ports

Note that ttyUSB0 is the default port ID here.

(4) Downloading the code files from SDU Blackboard (in Course Materials), zipping Dynamixel_sdk.zip (see **Fig. 4**).

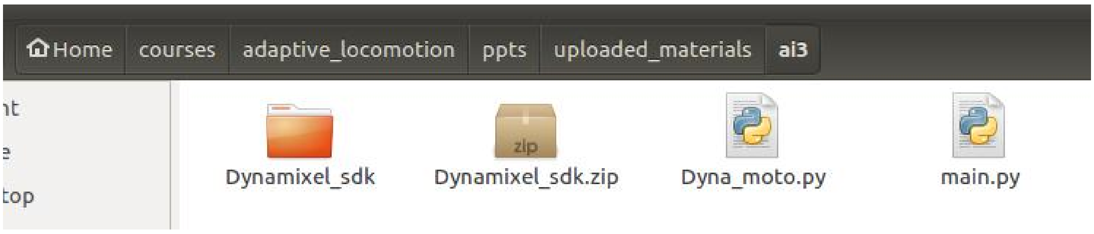

Fig. 4 Downloading and zipping files from SDU Blackboard.

Experimental safety

(1) Your hands should be out of the work space of an actuator (see the red area in **Fig. 5**).

(2) You should not push and stall the pipe too hard and long, since you may break the actuator.

(3) Your should pull the pipe back to the neutral potion (see Fig. 5), after an experiment and before a new one.

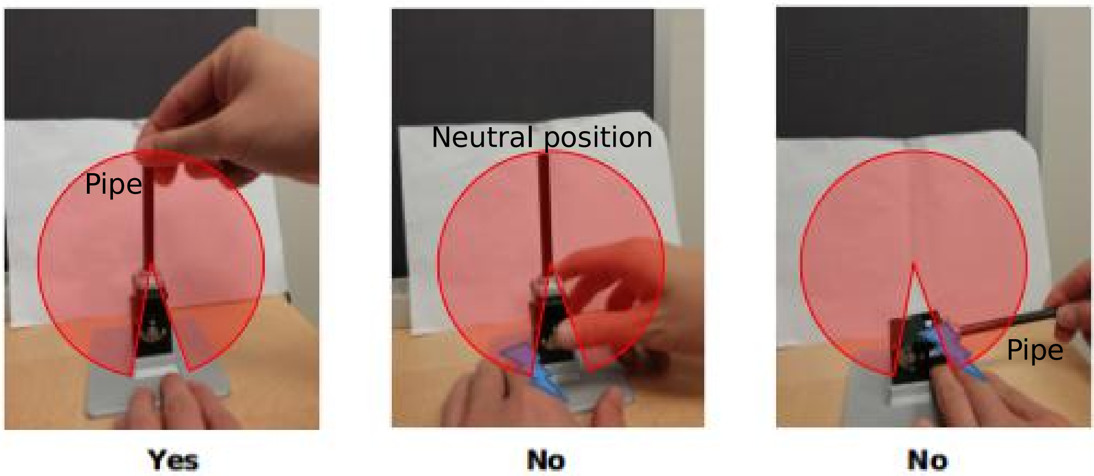

Fig. 5 Three example ways to interact with an actuator. A safe one should be adopted (e.g., see the most left one).

Experimental tasks

The adaptive impedance controller is presented in **Fig. 6**. The central pattern generator (CPG) produces the desired position input to the controller.

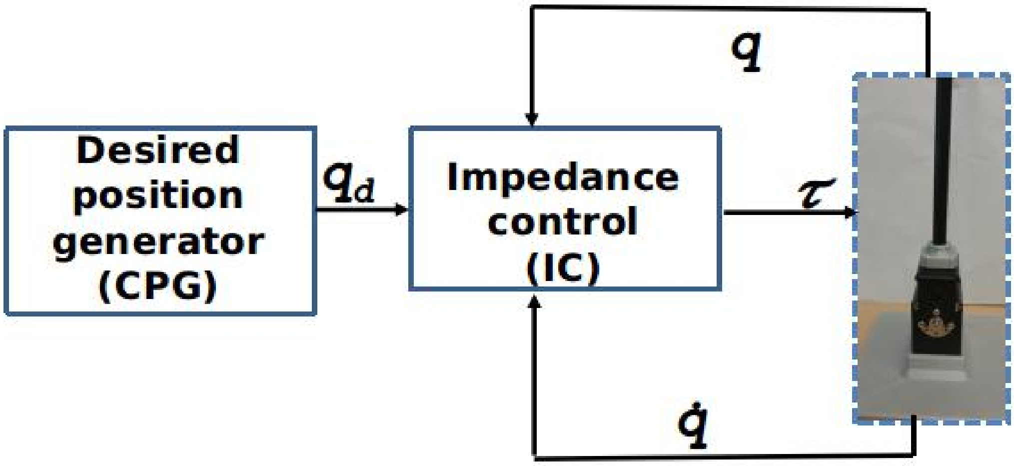

Fig. 6 Adaptive impedance controller [1]. Its implementation refers to [2, 3].

The stiffness *K*, damping *D* and bias *F* parameters are online modulated to achieve muscle-like (i.e., variable compliant) actuator control based on position and velocity errors [2, 3]. The controller is compared with a fixed compliant controller in interaction and tracking tasks (see **TABLE I**). **Note that you should not interact with the pipe when the task is tracking. The pipe has to be pulled back to the neutral potion (see Fig. 5), after an experiment and before a new one**.

TABLE I Generating the desired joint positions for different tasks.

Control\Task	Interaction	Tracking
Adaptive impedance control	$q_d = 0$	q_d = a + b*sin(c*t) (see a, b, and c values in file main.py)
Fixed compliant control		

The controller and tasks can be manually set in file main.py. For example, as **Fig. 7** illustrates, the fixed compliant control is set in the tracking task.

```
CONTROLLER = 'const_imp'#'ada_imp'#
TASK = 'track'#'post_con'#
```

Fig. 7 Manually setting the controller and task in file main.py.

Your task is to fill in blanks in file main.py (e.g., see the blanks marked by ? in **Fig. 8**). In the file, there are 10 tasks marked by T1-10 for finishing the exercise (e.g., see T9 in **Fig. 8**).

```
#T9
#self.get_?
#self.get_?
#self.get_tra_?
#self.get_?
```

Fig. 8 Fill in the blanks marked by ?.

References:

[1] X. Xiong and P. Manoonpong, “Adaptive Motor Control for Human-like Spatial-temporal Adaptation,” in IEEE International Conference on Robotics and Biomimetics, Kuala Lumpur, 2018, pp. 2107–2112.

[2] X. Xiong and P. Manoonpong, “Online adaptive resistance control of an arm exercise exoskeleton,” in Robots in Human Life-Proceedings of the 23rd International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines, CLAWAR 2020, V. G. Gradetsky, N. N. Bolotnik, M. O. Tokhi, M. Silva, and G. S.Virk, Eds. CLAWAR Association Ltd, 2020, pp. 31–38.

[3] X. Xiong and P. Manoonpong, “Resistance-as-needed (RAN) control for a wearable and soft hand exoskeleton,” Gait & Posture, vol. 81, pp. 398–399, 2020.

[4] X. Xiong and P. Manoonpong, “A Variable Soft Finger Exoskeleton for Quantifying Fatigue-induced Mechanical Impedance,” 2021 International Conference on Robotics and Automation (ICRA 2021), accepted.

[5] https://github.com/ROBOTIS-GIT/DynamixelSDK

[6]https://pyserial.readthedocs.io/en/latest/pyserial.html#installation

[7] https://www.sublimetext.com/docs/3/linux_repositories.html#apt