Tampere University

Fundamental of Mobile Robot AUT-710

Exercise 4

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Widhi Atman

8.3.2023, 10:15 - Finish

Exercises Plan

- Exercise 4: Implementation of model + Basic Control
  - SI Go-to-goal → Proportional Control
  - SI Trajectory Tracking → Proportional + Feedforward Control
  - Unicycle Go-to-goal → Proportional Control for Orientation

10 point

Deadline: Monday 18.3.2024 at 23:59

- Exercise 5: Collision Avoidance with SI model
- Exercise 6: Control of Unicycle
- Mini Projects (optional)

20 point

20 point

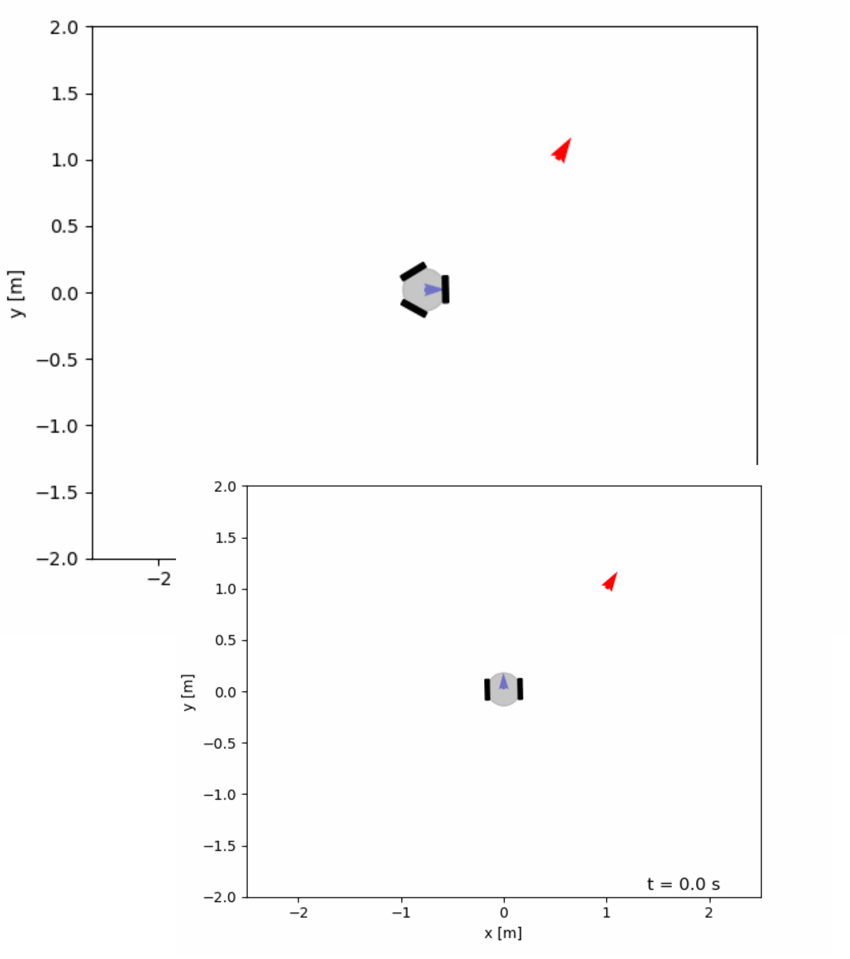
Bonus up to 20 point

Tools and Grouping

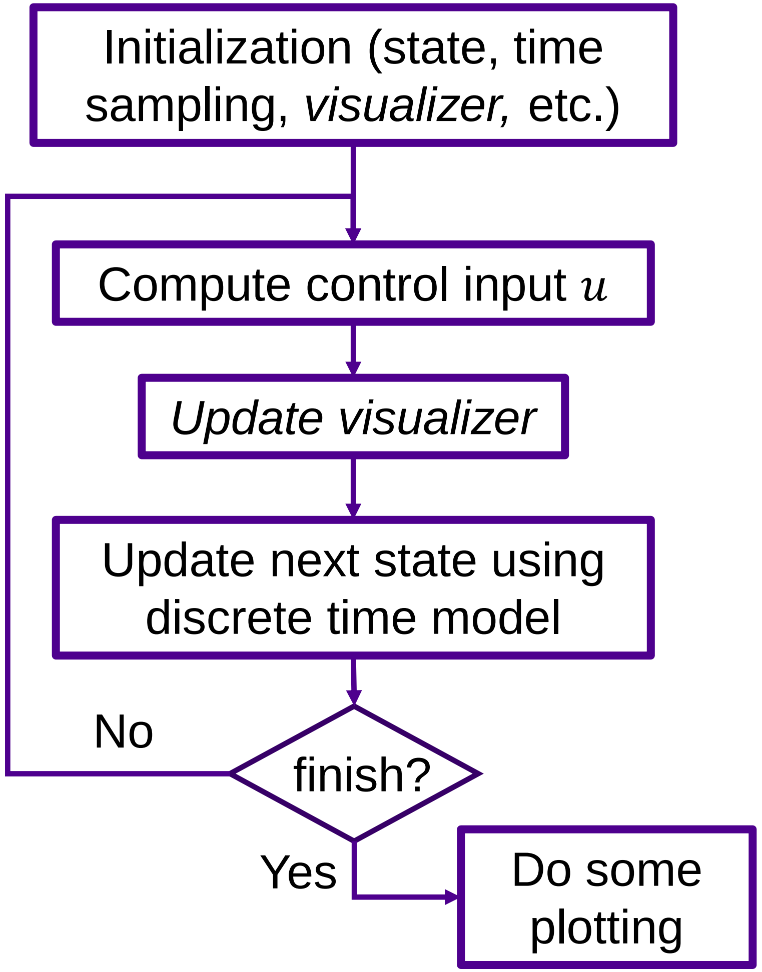
- Python: Matplotlib, Numpy, Cvxopt
  I provided scripts for the exercise setup in Python
  https://github.com/TUNI-IINES/FunMoRo_control

  but you are free to use other language or software tools that you preferred (e.g., Matlab, C++)

- Work in a group of 2 (same as before)



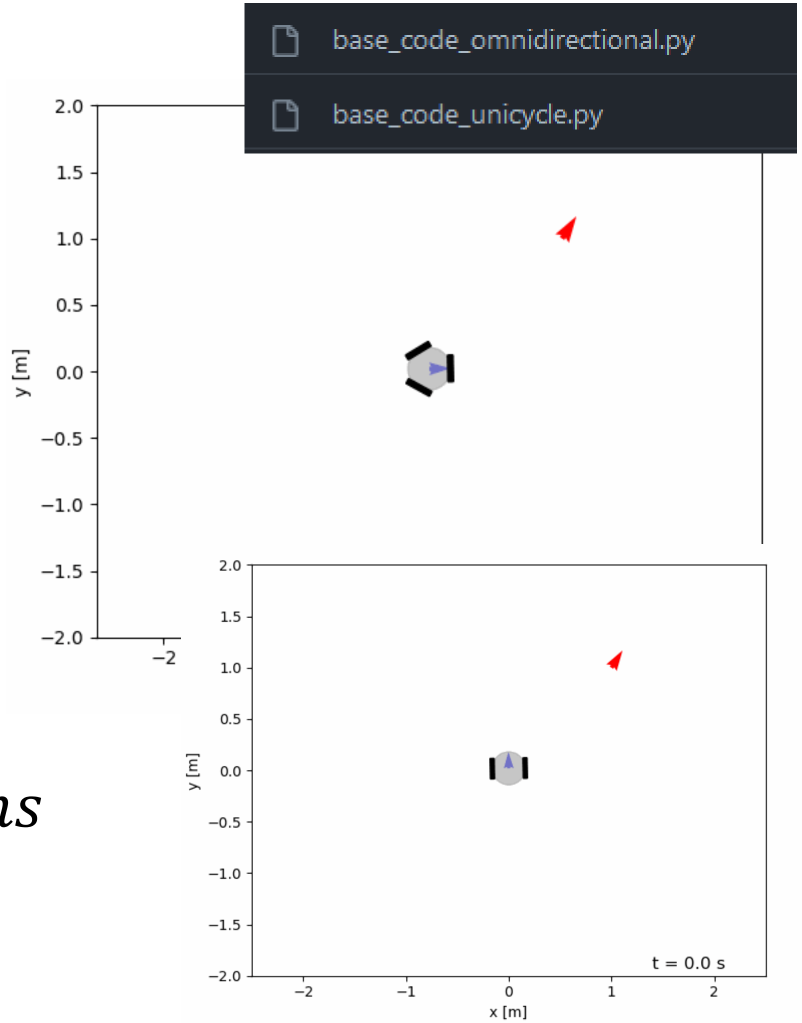
Flowchart of Simulator



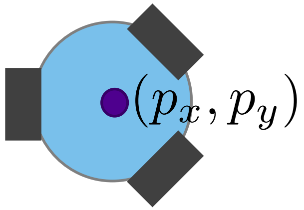
Parameter Setting
(for Exercise 4)

Time sampling $T = 10ms$

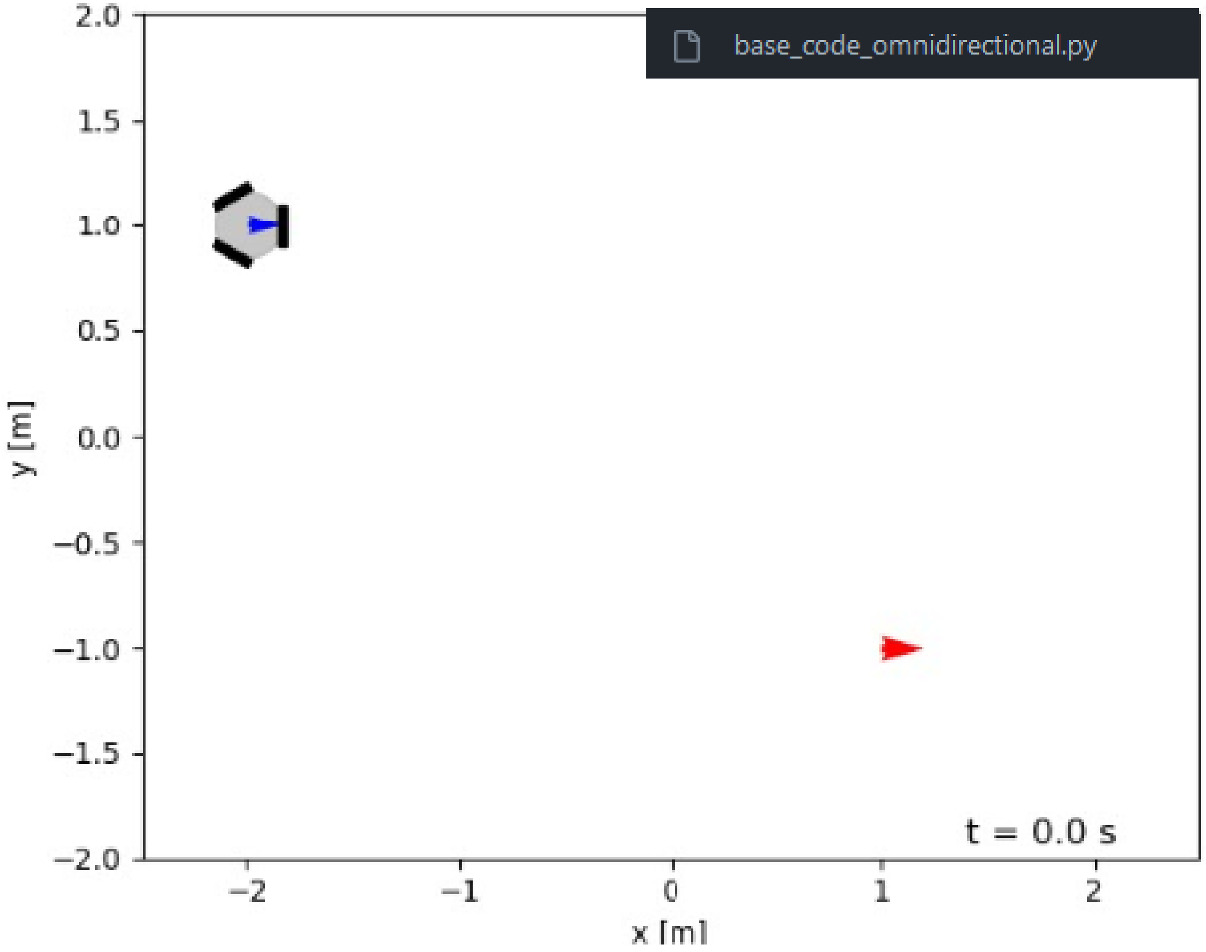
** the visualizer is optional*



Exercise 4.1 – Scenario



$$x = \begin{bmatrix} p_x \\ p_y \\ \theta \end{bmatrix} \quad u = \begin{bmatrix} v_x \\ v_y \\ \omega \end{bmatrix}$$

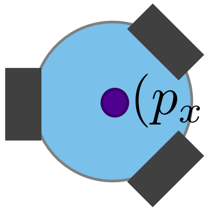


Model: omnidirectional mobile robot (**single-integrator model**)
Initial Position: $x[0] = [-2 \quad 1 \quad 0]^T$
Goal: static at $x^d = [1 \quad -1 \quad 0]^T$.

Control Objective:
- Reach the goal

Exercise 4.1

3 point



(p_x, p_y) $\quad x = \begin{bmatrix} p_x \\ p_y \\ \theta \end{bmatrix} \quad u = \begin{bmatrix} v_x \\ v_y \\ \omega \end{bmatrix}$

base_code_omnidirectional.py

With the objective to design control input u to reach the goal,

a. Implement **proportional control with static k** within 0~3.
Plot *time series* of v_x and p_x with 3 set of different k.

$$u = k(x^d - x), \qquad k > 0$$

b. Implement **proportional control with time-varying k**
Plot *time series* of v_x and p_x with 3 pair of parameter v_0 and β .

$$k = \frac{v_0\left(1 - \bar{e}^{-\beta||\bar{e}||}\right)}{||\bar{e}||}$$

c. Discuss how the variation of k, v_0 and β affects the control input and state trajectory.
What do you think is the appropriate value of k, or v_0 and β?

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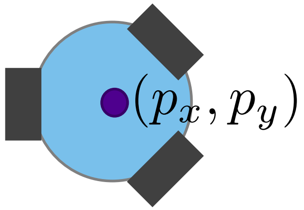
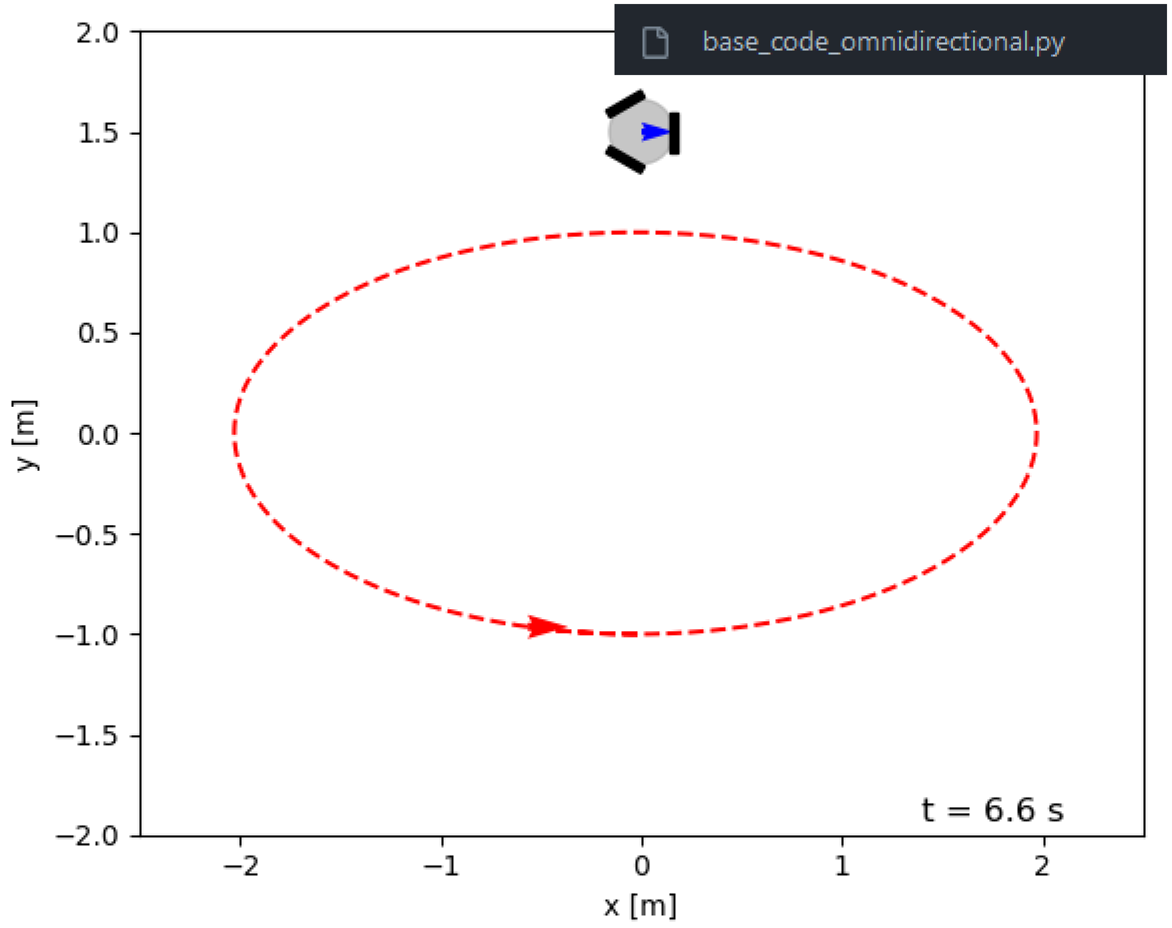
Exercise 4.2 – Scenario



$$x = \begin{bmatrix} p_x \\ p_y \\ \theta \end{bmatrix} \quad u = \begin{bmatrix} v_x \\ v_y \\ \omega \end{bmatrix}$$



Model: omnidirectional mobile robot (**single-integrator model**)

Initial Position: $x[0] = [0 \quad 1.5 \quad 0]^T$

Goal: moving at

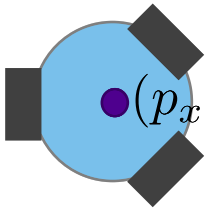
$$x^d[t] = [-2\cos(t) \quad \sin(t) \quad 0]^T$$

Control Objective:

- Track the moving goal

Exercise 4.2

2 point



$$x = \begin{bmatrix} p_x \\ p_y \\ \theta \end{bmatrix} \quad u = \begin{bmatrix} v_x \\ v_y \\ \omega \end{bmatrix}$$

base_code_omnidirectional.py

Track the moving goal
by designing **proportional control with feedforward term**

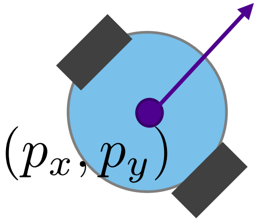
$$u = k(x^d(t) - x) + \dot{x}^d(t), \;\; k > 0$$

Describe your design process and
show the result by plotting:

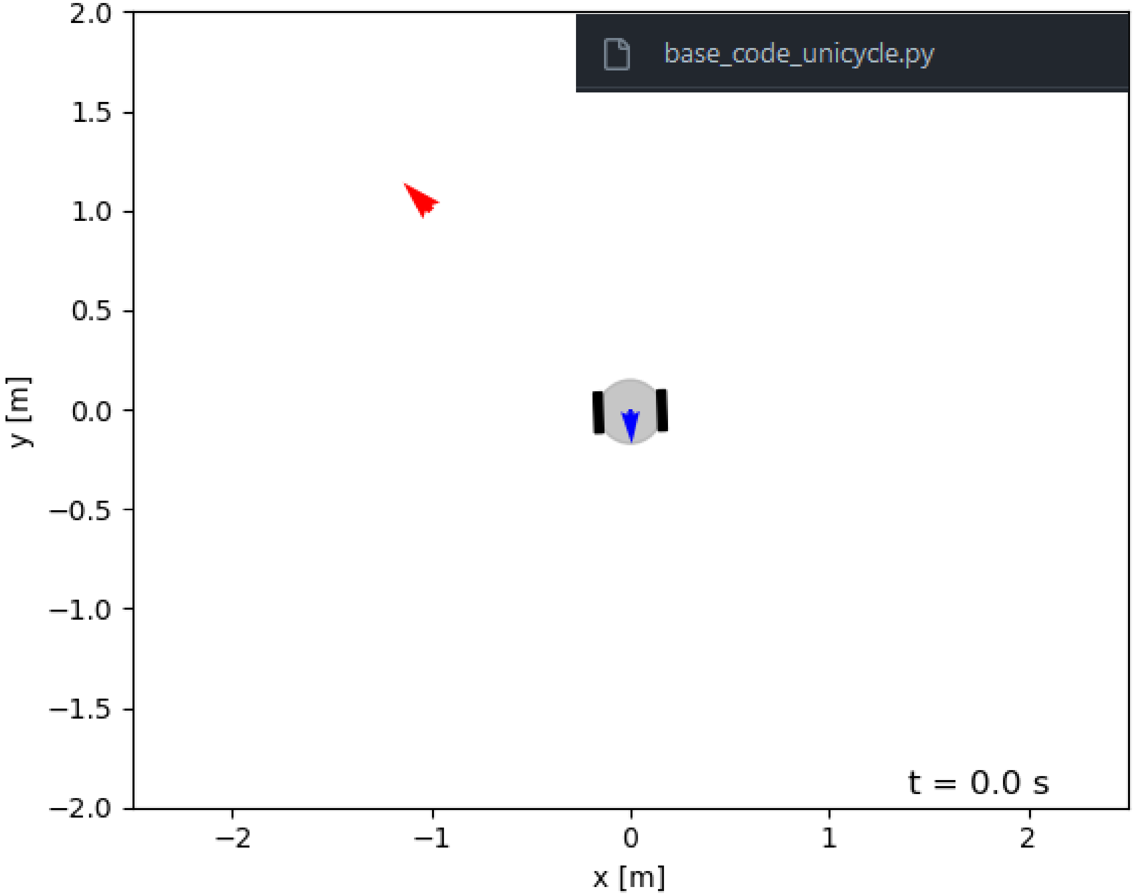
- *time series* of control input u
- *time series* of error $(x^d - x)$,
- *time series* of state trajectory x vs x^d, and
- XY **trajectory** of the robot (or final snapshot of the simulator).

** Remember to modify the x^d in the simulator.*

Exercise 4.3 – Scenario



$$x = \begin{bmatrix} p_x \\ p_y \\ \theta \end{bmatrix} \quad u = \begin{bmatrix} v \\ \omega \end{bmatrix}$$



Model: unicycle mobile robot

Initial Position: $x[0] = \begin{bmatrix} -1 & 0 & \frac{\pi}{2} \end{bmatrix}^T$

Goal: fixed position at $x^d = [-1 \quad 1 \quad *]^T$

* can be any orientation at the goal position

Control Objective:

- Reach the goal (by designing ω)

  with $v = \begin{cases} 0, & \text{if distance to goal} < 0.05m \\ 1, & \text{otherwise} \end{cases}$

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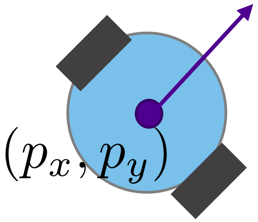
Exercise 4.3

5 point



$$x = \begin{bmatrix} p_x \\ p_y \\ \theta \end{bmatrix} \quad u = \begin{bmatrix} v \\ \omega \end{bmatrix}$$

base_code_unicycle.py

a. Design a **proportional control for the orientation** to reach the goal position.
Describe your design approach and your observation.
Show the result by plotting:
- *time series* of control input u
- *time series* of error $(x^d - x)$,
- *time series* of state trajectory x vs x^d, and
- XY **trajectory** of the robot (or final snapshot of the simulator).

b. Find the minimum k in the proportional controller that ensure the robot can reach the goal.
Describe the problem with small gain k and analyze what affects the minimum k value.

Hint1: Compute desired angle θ^d towards goal position that constantly changes as the robot moves
Hint2: remember to ensure that $e_\theta \in [-\pi, \pi]$

Question?

- Consult them via
  - Exercise sessions on 8.3.2024 and 15.3.2024
  - Teams channel