Fundamental of Mobile Robot
AUT-710

Exercise 4

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11.3.2022, 10:15 - Finish

General Plan for Exercises

- 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: Friday 18.3.2022 at 10:00

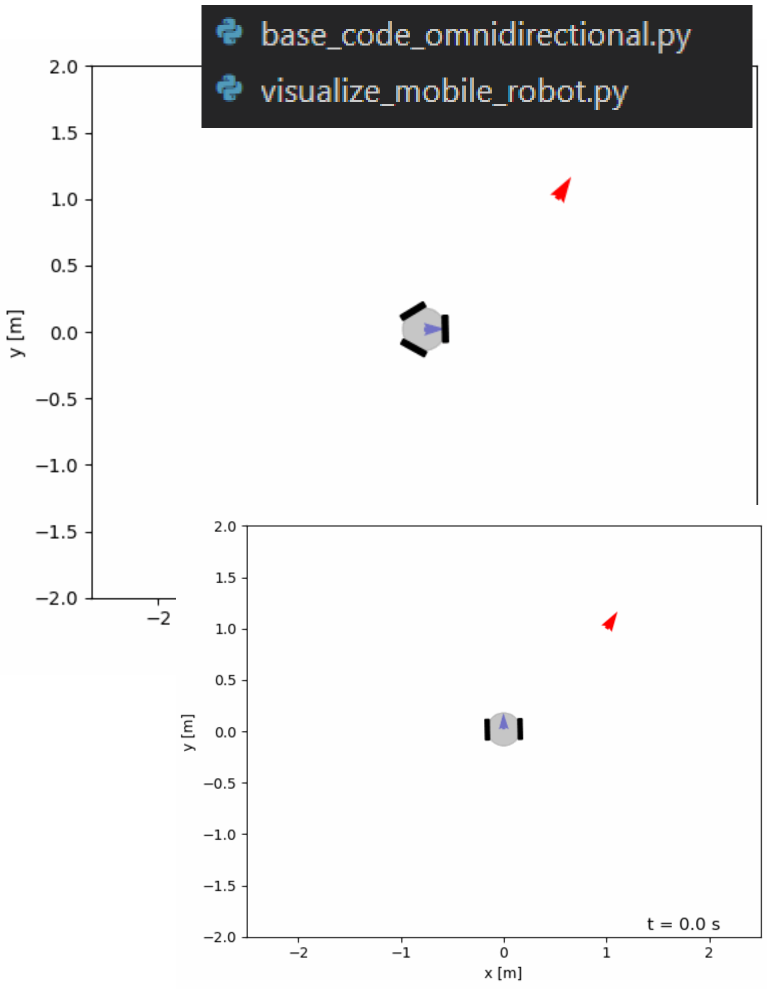
- Exercise 5: Collision Avoidance with SI model
- Exercise 6: Control of Unicycle

20 point

20 point

Tools and Grading

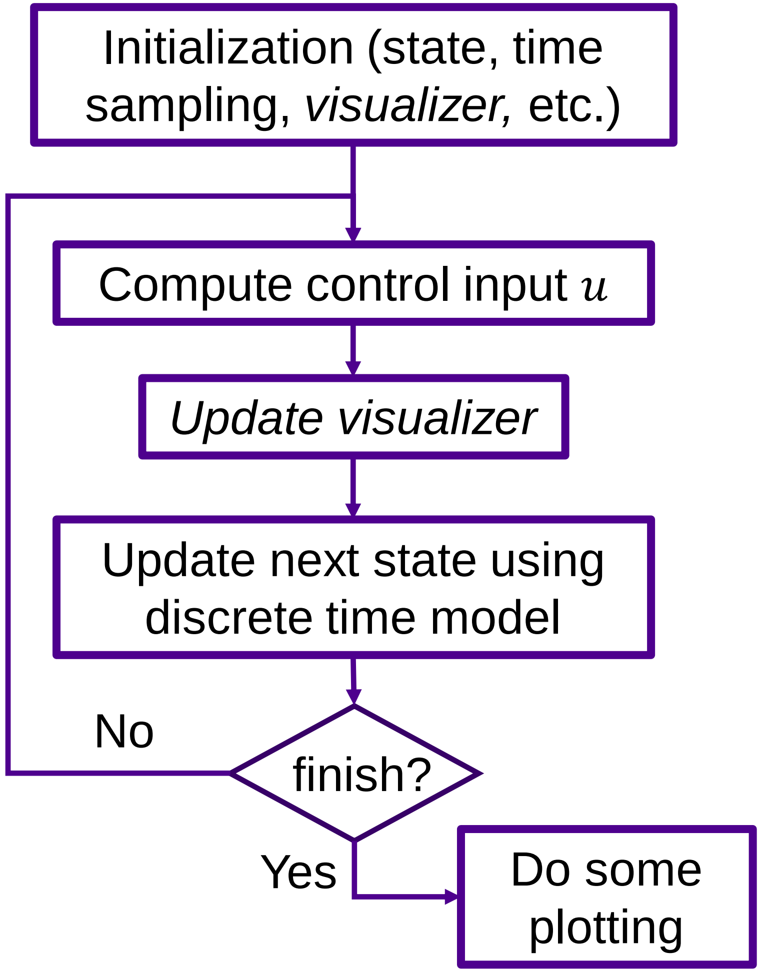
- Python: Matplotlib, Numpy, Cvxopt
  I will provide scripts for the exercise setup in Python, but you are free to use other language or software tools that you preferred (e.g., Matlab, C++)



- Work in a group of 2 (same as before)
- Grading based on the report*
  Plot, discussion, derivation of equation

* The code is required for submission
but will only be checked if the report is unclear.

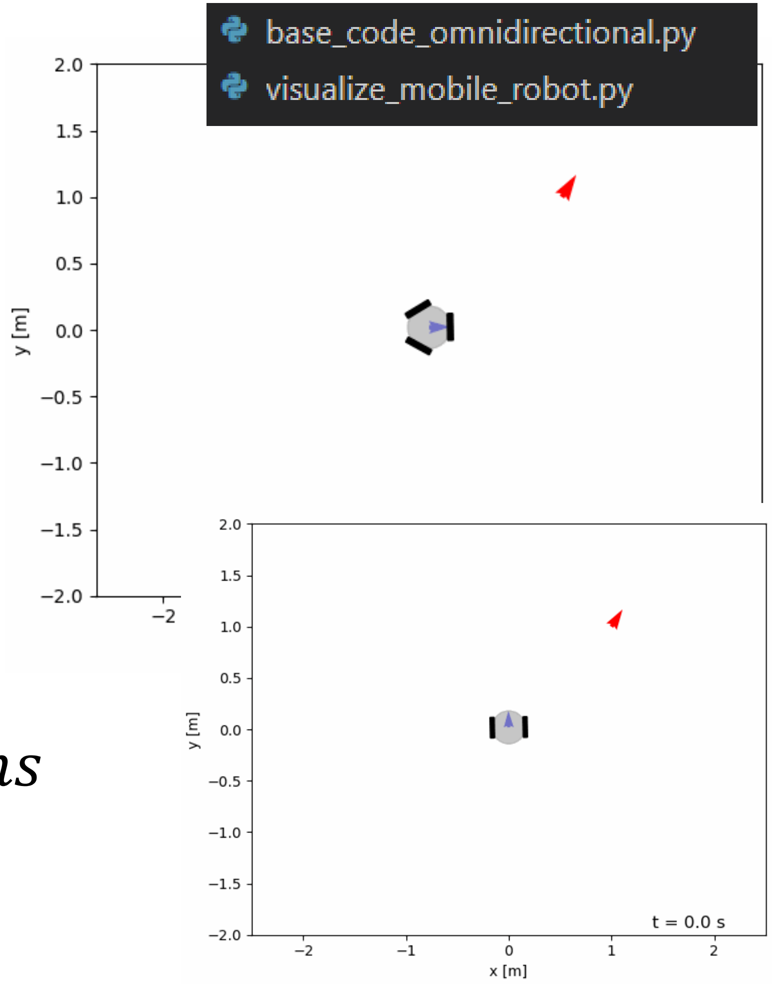
Flowchart of Simulator



Parameter Setting
(for Exercise 4)

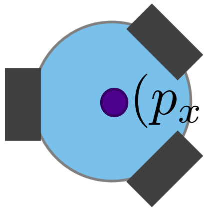
Time sampling $T = 10ms$

** the visualizer is optional*



Exercise 4.1

3 point



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

Consider an omnidirectional mobile robot (**single-integrator model**)
with initial position at $x[0] = [0 \quad 0 \quad 0]^T$ and **a static goal** at $x^d = [2 \quad 2 \quad 0]^T$.

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.

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

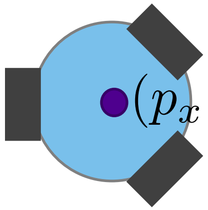
b. Implement **proportional control with time-varying *k***
   Plot *time series* of v_x and p_x with 3 pair of parameter v_0 and β .

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

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?

Exercise 4.2

2 point



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

Consider an omnidirectional mobile robot (**single-integrator model**) with initial position at $x[0] = [0 \quad 0 \quad 0]^T$ and **moving goal** $x^d[t] = [\cos(2t) \quad \sin(2t) \quad 0]^T$.

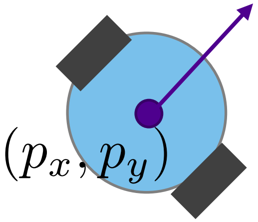
Design **proportional control with feedforward** $u = k(x^d(t) - x) + \dot{x}^d(t),\ k > 0$ to track the moving goal and show it by plotting the *time series* of:

- Control input u
- Error $(x^d - x)$
- State trajectory x vs x^d.

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

Exercise 4.3

5 point



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

Consider an **unicyle mobile robot** with initial position at $x[0] = [0 \quad 0 \quad \pi/2]^T$ and **a static goal** of $x^d = [-1 \quad -1 \quad \theta^d(t)]^T$ with $\theta^d(t)$ as the angle towards goal position.

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

** You need to implement the unicyle model and the v in the simulator*

a. Design a **proportional control for the orientation** to reach the goal position.
Describe your design approach and your observation.
Plot the *time series* of control input u, the state trajectory of x, and the state error $(x^d - x)$.

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: θ^d constantly changes as the robot moves
Hint2: remember to ensure that $e_\theta \in [-\pi, \pi]$

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General Tips for Plotting Simulation

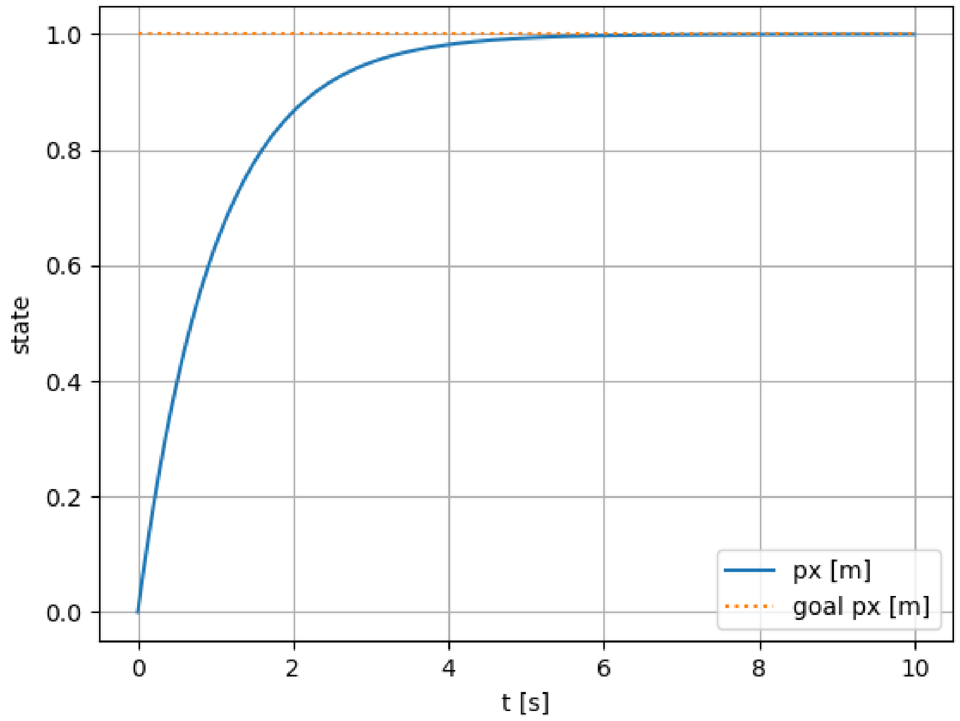

Figure 1. Trajectory of robot in x-dimension

Make your figure clear and self- explanatory.

- Use legend, axis name, and title appropriately
- Always specify the measurement unit

Choose simulation time wisely.

e.g., properly show that the state reaches goal, or the error is diminishing (close to 0)

Never leave a figure alone in your report.

- Use figure with caption in your document
- Embed the figure in your discussion, refer it using the caption number.
- Plot with appropriate dimension (e.g., text size, line width) for your document

Any Question?