Introduction

We are glad you want to join this workshop and hope you will learn much from it. In this document, you will find details about the workshop itself, logistics, and technical requirements.

Workshop Details

This workshop is divided into 2 phases. The first includes 5 sessions on various topics in robotics such as ROS, SLAM, modeling, etc. In the second phase, you will choose one of three tracks (preception, SLAM&planning, control); in each track, there will be three sessions. You are welcome (and encouraged) to attend sessions in tracks other than the one you choose. Throughout the sessions, there will be various projects to apply what you learn.

Common FAQs:

1. Are the sessions online or offline?

   The sessions will be offline at the university

2. Can anyone join this workshop?

   Yes, anyone can join this workshop; however, there are some technical prerequisites such as programming, problem-solving skills (coding), some math, and excellent research skills.

3. How can I join the Formula AI or Shell AI teams?

   Participants that successfully complete this workshop will be the main candidates to join the Formula AI and Shell AI teams.

4. Can I do my graduation project with the team?

   Yes; however, joining this workshop doesn't guarantee that you will be able to join the Formula AI team. However, if you join the team, your graduation project can be with us.

Technical Mission

This online test is aiming to test your ability to search and self-study in technical topics that you may know or don't know about, feel free to get help from the internet, doctors, teaching assistants, textbooks, or whatever source you find available to you (but you can't work on this mission with others that are also planning to attend this workshop)

Please read all the following questions carefully and provide your answers in a single pdf file, aid your answers with figures, graphs, or sketches if needed.

Please **don't be intimidated** if you find the questions hard, we don't expect you to solve most of them; the goal is to expose you to some of the topics that will be explained in greater depth in the workshop and measure your research skills, so do your best and (more importantly) try to learn along the way.

Submit your answers to this google form:
https://docs.google.com/forms/d/e/1FAIpQLSfym0hBhvQhWUyVDOtzhlU1o5WH97ffRgW5ALBrdoMnroVSVw/viewform

The deadline for submission is:

If you have any inquiries about the question below, send them to alsawahkareem@gmail.com

Questions

Perception

1- What is a neural network? What are its types and applications?

2- Write Python code that compiles and trains a deep neural network on the Fashion MNIST dataset. Assume and tune your parameters and hyper-parameters.

3- Write Python code that compiles and trains a deep neural network for the ImageNet dataset. Assume and tune your parameters and hyper-parameters.

4- Read the LaserNet paper used for 3D-object detection. What sensors does it require? What is the main working principle of this technique? Do you see any way to improve it?

5- What is the difference between stereo-camera and mono-camera? State mathematically how coordinates can be transformed from the 2D pixel domain of the two images of the stereo-camera to 3D world coordinates.

State Estimation

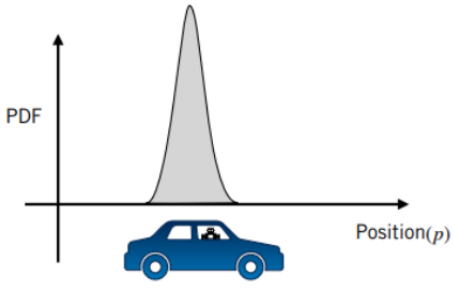
6- What are the different approaches to odometry sources and localization in self-driving cars?

7- What is known by SLAM? What are its different types?

8- Describe briefly the ICP algorithm used for localization using LIDAR point clouds. Write a pseudo-code for the algorithm

9- What are the types or variants of the Kalman filter? What are the uses and applications?

10- Write C++ code that implements the linear Kalman filter for one predict and one update step for the following problem. (Hint: You may use Eigen library)



$$\mathbf{x} = \begin{bmatrix} p \\ \frac{dp}{dt} = \dot{p} \end{bmatrix} \qquad \mathbf{u} = a = \frac{d^2p}{dt^2}$$

Motion/Process Model

$$\mathbf{x}_k = \begin{bmatrix} 1 & \Delta t \\ 0 & 1 \end{bmatrix} \mathbf{x}_{k-1} + \begin{bmatrix} 0 \\ \Delta t \end{bmatrix} \mathbf{u}_{k-1} + \mathbf{w}_{k-1}$$

Position Observation

$$y_k = [1 \quad 0]\, \mathbf{x}_k + v_k$$

Noise Densities

$$v_k \sim \mathcal{N}(0,\, 0.05) \qquad \mathbf{w}_k \sim \mathcal{N}(\mathbf{0}, (0.1)\mathbf{1}_{2\times 2})$$

Path Planning

11- What are the different path planning algorithms that are used in autonomous mobile robots?

12- Write Python code that implements BFS (Breadth First Search) or A* Algorithm - whichever you find yourself comfortable with - algorithm on a 5 x 5 occupancy grid.

Obstacles on (2,0), (2,1), (2,2)

Start on (1,1) - Goal on (4,1)

Assume the grid is a 2D NumPy array, obstacle cells have a value of 1, and free cells have a value of 0.

Navigation Control

13- What is the difference between kinematic and dynamic modeling of vehicles?

14- State different longitudinal and lateral vehicle controllers.

15- Write C++ code that implements the forward kinematics of a kinematic bicycle model.

Inputs = [v, δ] (velocity of the vehicle and steering angle)

Outputs = [x, y, θ] (The 2D pose of the bicycle, x, y, and yaw)

Assume your step-time for integration and any other missing parameters.

16- Why is modeling an important part of control (Ex: what could the bicycle model be used for in control)? What if there is no model, can you still control a system?

17- What is the MPC (model predictive control), how does it work? What are the most common issues with it?

Low-Level Control

18- Perform closed loop control on a steering wheel in a self-driving car. Define your controller, the final control element, and the process variable. (Draw the block diagram).

19- What are the hardware and actuators needed for low-level control in self-driving cars?

Good Luck