EE3002 Embedded Control Systems Project
Line Follower Robot with PID Adaptive Cruise Control

The purpose of this project is to build a Line Follower Robot with PID control. Line Tracking is one of the most useful and popular behaviors of mobile robots. Line tracking is the most convenient and reliable navigation technique by which autonomous mobile robots navigate in a controlled environment. The path of the robot is demarcated with a distinguishable line or track, which the robot uses to navigate. Commonly used examples of these lines include magnetic tape on a non-magnetic surface, a void or a cut on a flat surface, reflective tape on a non-reflecting surface, and vice-versa. In most situations, the robots are mounted with Hall-Effect sensors or Photo-interrupters, which are based on Infra-Red or visible light.

Traditionally, the approach to line tracking is usually considered in the digital domain where the outputs from the digital line sensors are given to a microcontroller which is programmed to run the motors of the robot at various speeds depending on where the robot is positioned with respect to the center of the line. The motor speed settings are selected by trial and error for various sensor readings. The robot should be assigned a maximum speed setting that will allow reliable line tracking. For each setting, the best possible values for all the parameters should be chosen by iterative closed-loop tuning techniques.

In this project, you will integrate your mobile robot and write its embedded code so that it can track a given line and follow a board at a specified distance (Fig. 1). You will need a photo sensor that tracks the line on the surface and a distance sensor (infrared or ultrasonic) on the front side of the robot to measure the distance to the board. The board will be held constant or driven at different speeds on the track by a human operator for a certain time, and the robot should respond to the card motion and maintain a specified distance to the board.

Your job in this project include:

- Design and implement the wheeled robot that can track the line and maintain a specified distance to the board.
- Do a literature review.
- Draw the closed-loop block diagram of the given system.
- Implement PID (P, PD, PI, or PID) controller for controlling the robot's speed to achieve the two objectives.
- Select suitable components and draw circuit schematics.
- Write **register-based** microcontroller code.
- Simulate the system if possible.
- Test your robot until it gives satisfactory performance.
- Adjust controller gains, provide the final design, and present it on the demo day.

The test track is seen in Fig. 1. The board size will be suitable to be detected by distance sensors. The mobile robot should follow the board at the desired distance d_{des}. You will be given some time to test your code before the actual demo.

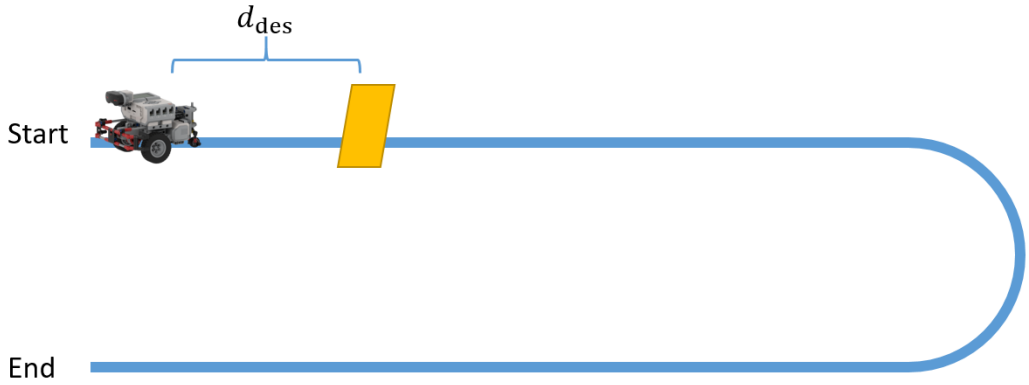

Figure 1: The test track

Here we present some suggestions for embedded design:

1. **Structured Code Design:**

    - You can break the code into modules for sensor interfacing, motor control, PID algorithm, and communication.
    - Use function-based programming for readability and debugging.

2. **Use of Interrupts:**

    - You can use hardware timers and interrupts for precise sampling of sensors and motor control to ensure consistent PID performance.

3. **Sensor Integration:**

    - Employ an array of IR sensors for precise line detection and an ultrasonic (HC-SR04) or infrared sensor (TCRT5000) for distance measurement.
    - Implement software-based noise filtering such as moving average to stabilize sensor readings.

Note that these design methods and sensors are only suggestions. If you have any other methods or hardware that you think useful for this project, feel free to try it.

Evaluation Criteria:
Maintaining the desired distance to the board (%20)
Completing the track (%15)
Code accuracy (%20)
Report (%25)
Creativity (%10)

Rules:

- Project groups can have three students.
- At the end of the semester, you have to prepare a project report and a **group demo**. However, **each member should know every detail of the project. The deadline for the report submission is the 11th of January. The demo day will be announced later according to the exam schedule.**
- You can make any modifications to your robot, such as adding a new piece, using different wheels, drivers, etc.
- It is forbidden to use an Arduino bootloader.
- You may want to do a different project. In that case, your project should contain both hardware and software parts and its difficulty level should not be less than this robotics project (The difficulty level will be evaluated by the instructors; please advise as soon as possible).