CS684: EMBEDDED SYSTEMS

THE SUPERVISORS

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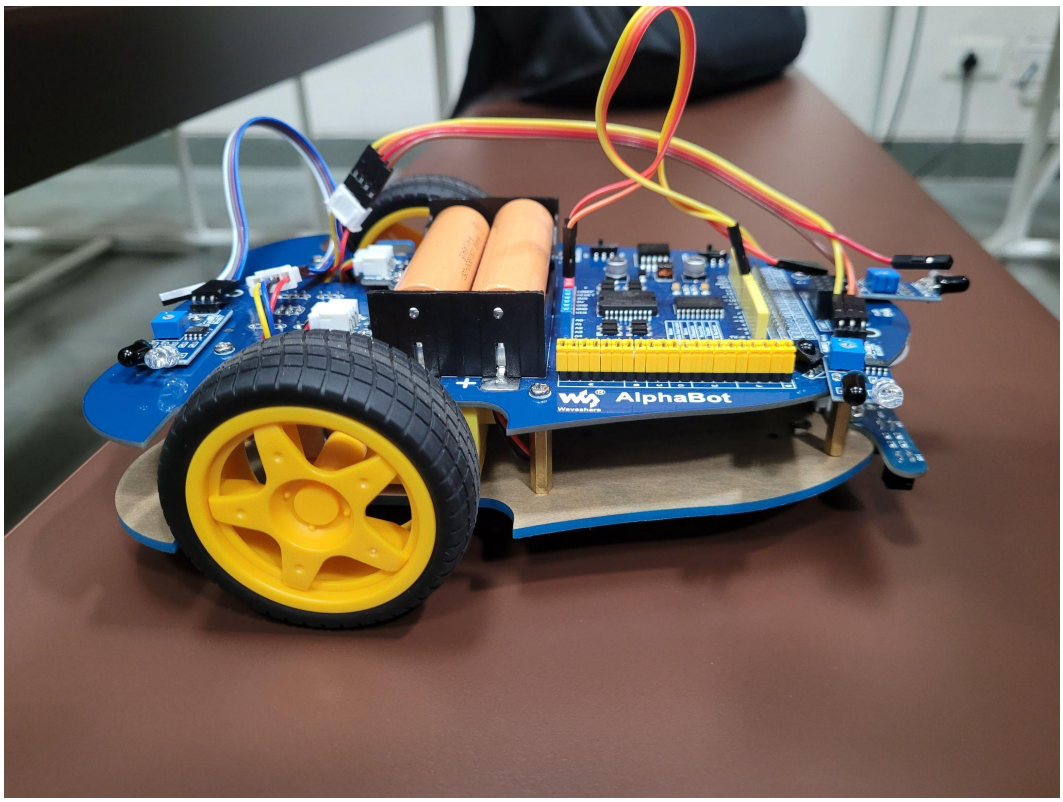
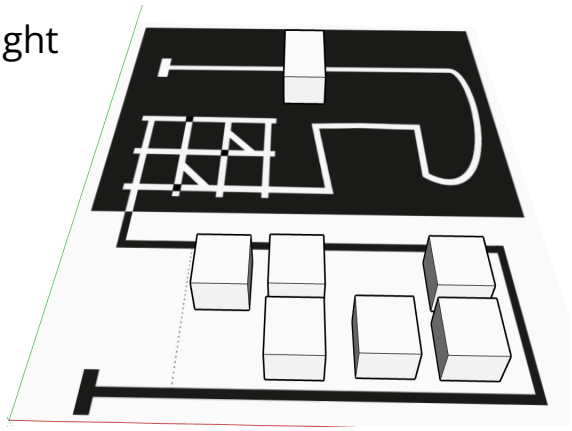


Overview

- To traverse the arena shown on the right
- Requirements:
  - Avoid the obstacle
  - The transition from white lines on a black background to black lines on white background
  - Park in a free space available, or go till the end

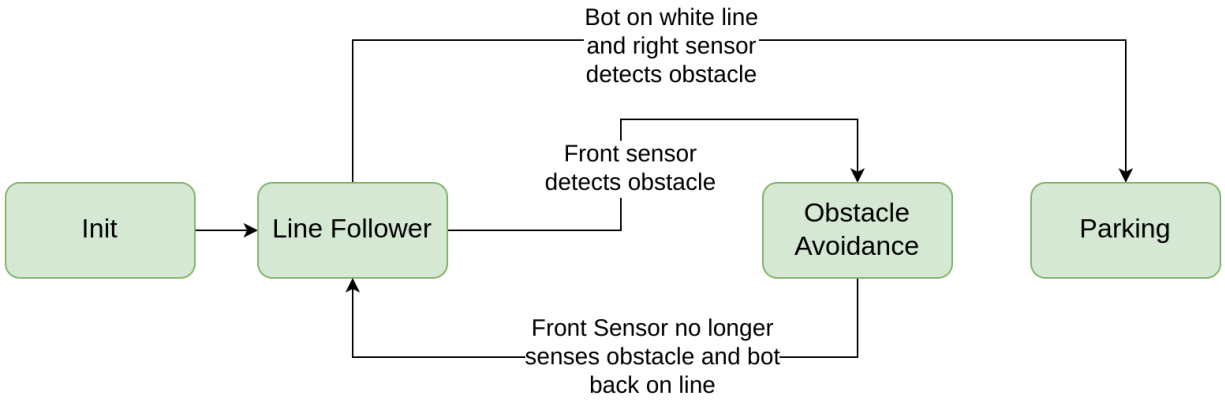


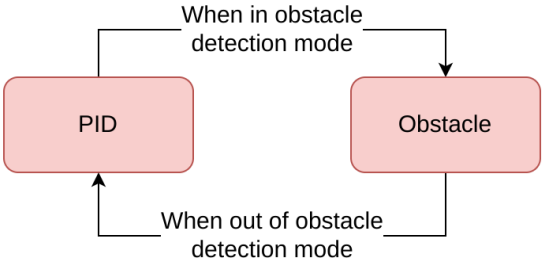
Algorithm

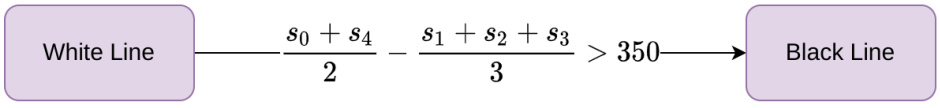
The hardware used currently for Obstacle Avoidance and Line Following are-

- IR Proximity Sensor (3): {0, 1}
- DC Motors (2)
- White Line Sensor Array (5): 0-1023

Heptagon was used for designing the bot's reactive kernel. We have used mealy machine automata for modelling the states and sub-states the bot can be in. After extracting the C code from Heptagon, we have used further modifications and integration into the C code to make it a feasible supervisor for the bot. The bot was programmed using Arduino IDE.

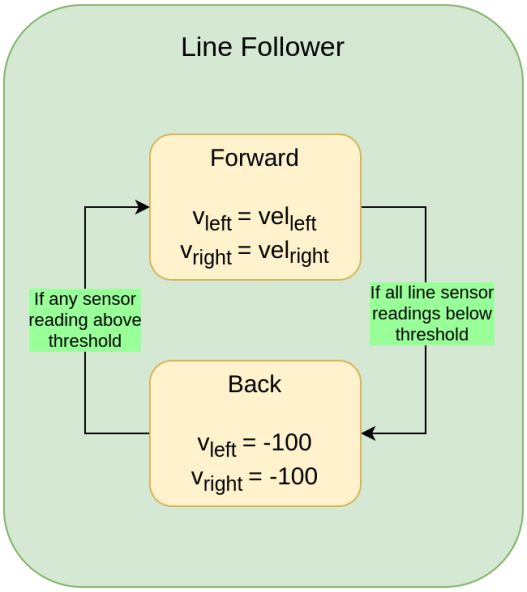






Line Follower and PID

- Basic design: two PID controllers
- Input to PID controller #1:
  - the middle tracker sensor value
  - constant
- Input to PID controller #2: weighted difference of tracker sensor values (Left-Right)
- One wheel gets the sum of the two PID outputs
- The other wheel gets the difference between the two PID outputs



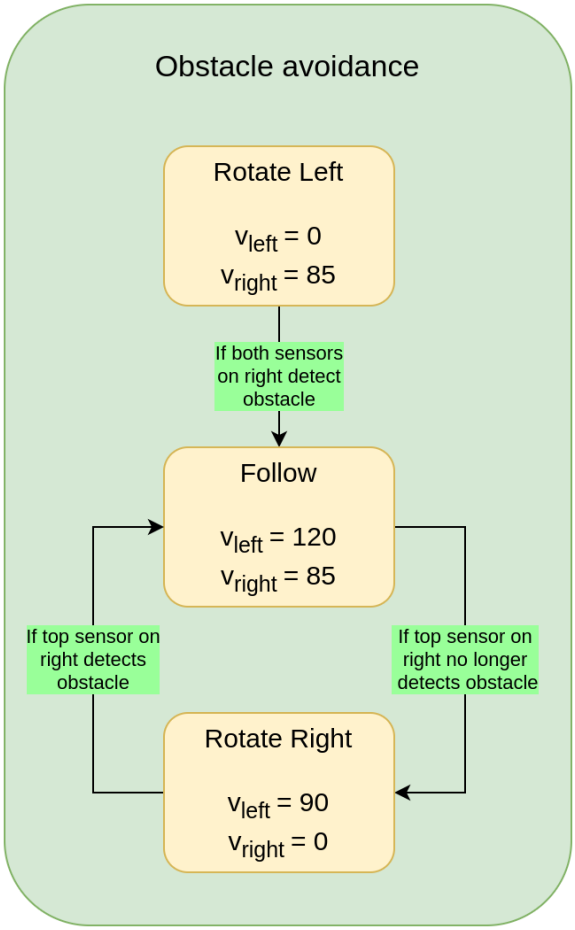
PID

$$\text{pid}_{\text{forward}} = 80$$
$$\text{pid}_{\text{left}} = 0 \rightarrow k_{p2} \cdot (s_0 - s_4) + k_{p3} \cdot (s_1 - s_3) + k_{d2} \cdot (s_0 - pre(s_0) - s_4 + pre(s_4)) + k_{d3} \cdot (s_1 - pre(s_1) - s_3 + pre(s_3))$$

$$\text{vel}_{\text{left}} = max(min(\text{pid}_{\text{forward}} - \text{pid}_{\text{left}}, 150), 55)$$
$$\text{vel}_{\text{right}} = max(min(\text{pid}_{\text{forward}} + \text{pid}_{\text{left}}, 150), 55)$$

Obstacle Avoidance

- While doing PID-based line following, if the IR sensor in the front detects an obstacle, the bot shifts to an obstacle-following mode.
- The bot turns to the left till both the sensors on the side detect the obstacle.
- Then the bot keeps turning right and going straight whenever the top sensor on the right does not detect an obstacle.
- It does this till it reaches the white line again and goes back to Line the following mode.



White to Black Transition and Parking

White to Blackline transition

- The bot transitions to a black line from the white line black background region when the mean of the extreme TR sensor values is greater than the mean of the middle three values by a certain threshold.
- After a lot of tinkering and tuning, this threshold was set to 350 for appropriate functioning

White Line $\xrightarrow{\frac{s_0 + s_4}{2} - \frac{s_1 + s_2 + s_3}{3} > 350}$ Black Line

Parking

- When in the line the following mode, the bot shifts to the parking mode if it is on a white line and also detects an obstacle to the right
- It will continue moving on the line till it no longer detects an obstacle to the right, and makes a right turn and stops, thereby parking itself

Demonstration

The video of the bot performing the Valet Parking tasks is depicted in the video below:

https://www.youtube.com/watch?v=hOUl5oRU8VU

Challenges

- As the battery discharged, the hardcoded values did not work effectively, so we had to change velocities for our implementation to work correctly continuously.
- Proximity sensors needed to be tuned multiple times to give consistent output overruns.
- The black part needed to be spray painted so our sensors could differentiate between white and black.
- Velocity values after PID had to be capped between 55 and 150 (can range from 0-255) so the bot did not unnecessarily stop or go too fast
- White and black regions needed different thresholds to get similar performance, found out through trial and error

Acknowledgements

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