SC627 - Assignment 3

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1 Velocity Obstacles

1.1 The Simulation Setup

The simulation setup and the overall objective are as follows,

- The initial pose of the robot is $\begin{bmatrix} 0 & 0 & 0 \end{bmatrix}$ and the objective is to drive the robot to the point $\begin{bmatrix} 5 & 0 \end{bmatrix}$
- Moving Obstacle 1 moves to and fro between $y = +1$ and $y = -1$ on a fixed $x = 2$, with a velocity of 0.1 units/second.
- Moving Obstacle 2 moves to and fro between $y = +1$ and $y = -1$ on a fixed $x = 3$, with a velocity of 0.1 units/second.
- Stationary Obstacle 3 is at $(x, y) = (4, 0)$.
- The robot and the obstacles are considered to be circular with a diameter of 0.15 units.

1.2 Control Strategy

The given constraint on the set of reachable avoidance velocities is that, the direction of the robot's velocity (θ), can be changed only to $\theta \pm \theta_m$ in a unit time step ($\theta_m = 10°$). Furthermore, the magnitude of the robot's velocity is capped at 0.1 units/second (V_m).

To achieve the given objective subject to the given constraints, the **TG strategy** is applied as follows.

- The primary idea of the TG strategy is that the velocity vector of the robot should be chosen such that it lies in the direction of the line ($\vec{L}_{goal}$) joining the robot's present position to the the final goal point.
- This heuristic cannot be directly applied if this $\vec{L}_{goal}$ does not lie in the set of reachable avoidance velocities of the robot. Furthermore, if this $\vec{L}_{goal}$ lies entirely within an velocity obstacle in the environment, there would exist no solution in which case this strategy would fail.
- Therefore, the implementation of the TG strategy is as follows. The set of reachable avoidance velocities is represented as RAV.
  - The ideal velocity vector computed by the TG strategy is $V_m \hat{L}_{goal}$. ($\hat{L}_{goal}$ - Unit vector from the robot's current position to the final goal-point and V_m- maximum permissible robot velocity)
  - The commanded velocity $\vec{v}$ that is given to the robot is computed as follows,

$$\begin{aligned} \underset{\vec{v}}{\text{maximize}} \quad & \vec{v} \cdot (V_m \hat{L}_{goal}) \\ \text{subject to} \quad & \vec{v} \in RAV \end{aligned} \tag{1}$$

- The characteristic of $\vec{v}$ obtained from the above strategy is that the commanded velocity $\vec{v} = V_m \hat{L}_{goal}$ (Ideal TG velocity) whenever $V_m \hat{L}_{goal} \in RAV$. In any another scenario, the commanded velocity vector that is chosen is closest to $V_m \hat{L}_{goal}$ among the permissible velocities in RAV.

1.3 Computation Details - Commanded Robot Velocity

The candidate reachable velocities are computed by radial and angular discretizations of the given reachable velocity set as follows. (The finite set of reachable velocities is represented as RV)

- Uniform discrete angular intervals (40 intervals) are chosen in the range of $\theta \pm 10°$.
- Uniform discrete radial intervals (10 intervals) are chosen in the range of $0 \rightarrow 0.1$.

The Geometric condition to check if a candidate velocity vector in the set of reachable velocities lies in the set of reachable avoidance velocities is as follows,

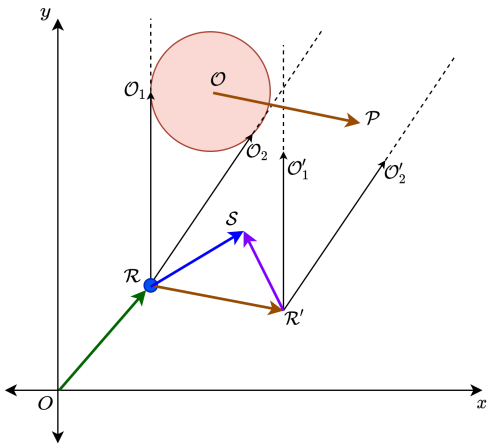

Figure 1: Collision Condition (The Robot is represented as a point object $\mathcal{R}$ and the Obstacle $\mathcal{O}$ is enlarged by the radius of the robot $\mathcal{R}$.)

- $\mathcal{OP}$ is the obstacle velocity vector.
- $\mathcal{RS}$ is the robot velocity vector.
- The points $\mathcal{O}_1$ and $\mathcal{O}_2$ are the point of tangents on the circular obstacle $\mathcal{O}$ from an external point $\mathcal{R}$.
- $\mathcal{O}'_1\mathcal{R}'\mathcal{O}'_2$ is an unbounded cone representing the velocity obstacle. Here, the apex of the velocity obstacle is obtained by translating the apex of the cone $\mathcal{O}_1\mathcal{R}\mathcal{O}_2$ by $\mathcal{RR}' = \mathcal{OP}$ units.

The geometric condition employed to check if a candidate reachable velocity lies in the velocity obstacle is as follows,

- The vector $\mathcal{R}'\mathcal{S} = \mathcal{RS} - \mathcal{RR}'$
- Defining $C_1 = \mathcal{R}'\mathcal{S} \times \mathcal{R}'\mathcal{O}'_1$ and $C_2 = \mathcal{R}'\mathcal{S} \times \mathcal{R}'\mathcal{O}'_2$
- Only if the signs of the z- components of C_1, C_2 are the same and not equal to zero, then the candidate reachable velocity $\mathcal{RS}$ lies in the set of reachable avoidance velocities (RAV).

To determine the commanded the velocity vector, firstly, the candidate reachable velocities from the set RV are filtered using the above geometric condition to obtain the set of reachable avoidance velocities RAV.

Now, once the set of RAV is obtained, the commanded velocity is obtained as the solution to the TG optimization problem in the previous subsection by exhaustively searching through the finite set of RAV.

1.4 Simulation

Also, please find the Simulation Video in the Assignment 3 folder.

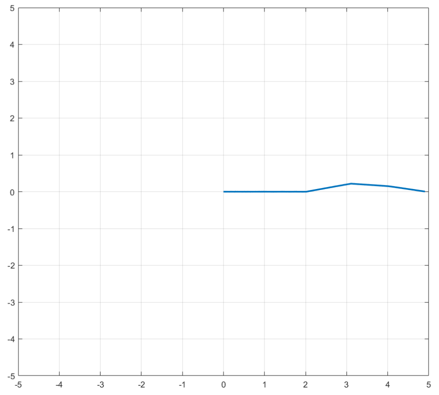

Figure 2: Robot's Path Simulation

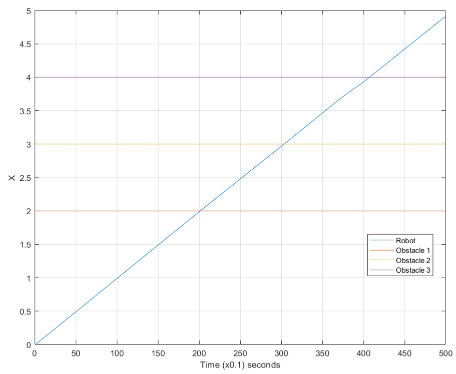

Figure 3: Robot X vs Time

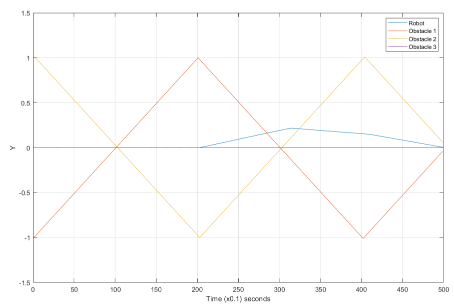

Figure 4: Robot Y vs Time