# Velocity Obstacle

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## 1 Introduction

**Velocity Obstacle** formulation is a planning algorithm that transforms dynamic obstacles to the robot's perspective and avoids them. In this report we obtain the velocity command that the robot should take in order to reach its goal and avoid obstacles.

## 2 Assumptions

For this report, we make the following assumptions:

1. Objects are circular and their **radii are known**.

2. Object **velocities are known** at every time step.

## 3 Problem formulation and solution

Our problem is to estimate a velocity vector $\mathbf{v}$ that avoids obstacles $i = 1, 2, ..., n$. The $i^{th}$ obstacle has radius $r_i^o$, velocity $\mathbf{v}_i^o$, and position $\mathbf{p}_i^o$. We begin by formulating the obstacle avoidance constraint for the $i^{th}$ obstacle. Let the position of the ego robot be $\mathbf{p}$ and its radius be $r$, we transform the dynamic obstacle to the robot's reference frame.

$$\mathbf{p}_i^r = \mathbf{p}_i^o - \mathbf{p} \tag{1}$$
$$\mathbf{v}_i^r = \mathbf{v} - \mathbf{v}_i^o \tag{2}$$
$$r^r = r + r_i^o \tag{3}$$

Here, $\mathbf{p}_i^r$ and $\mathbf{v}_i^r$ are the relative position of the obstacles and relative velocity by which the robot is approaching the obstacle respectively.

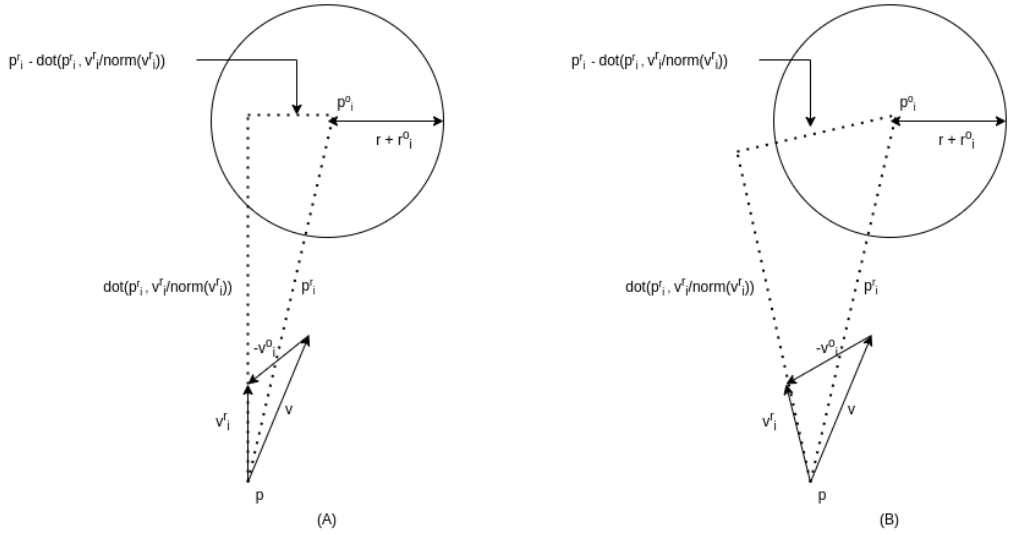



Figure 1: **Obstacle avoidance constraint**: (A) Collision (B) Avoidance

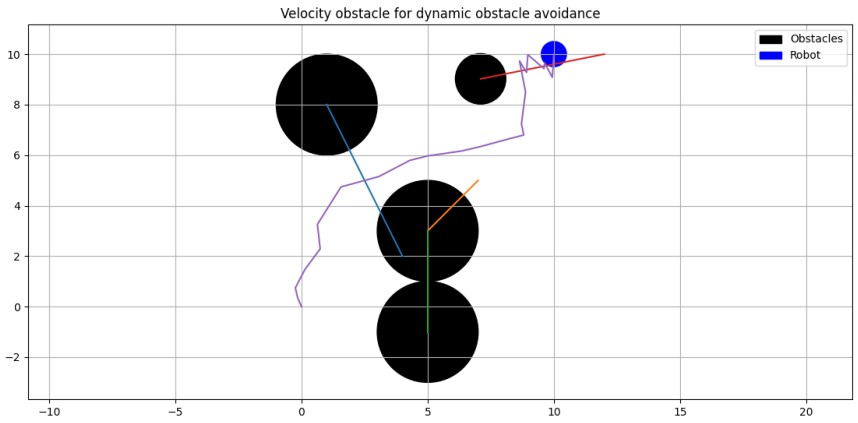
To avoid the obstacle we project $\mathbf{p}_i^r$ in the direction of $v_i^r$. If the vector subtraction of $\mathbf{p}_i^r$ and the resultant project is greater than the obstacle radius then the velocity direction avoids the obstacle. This can be visualized in figure 1 part (B).

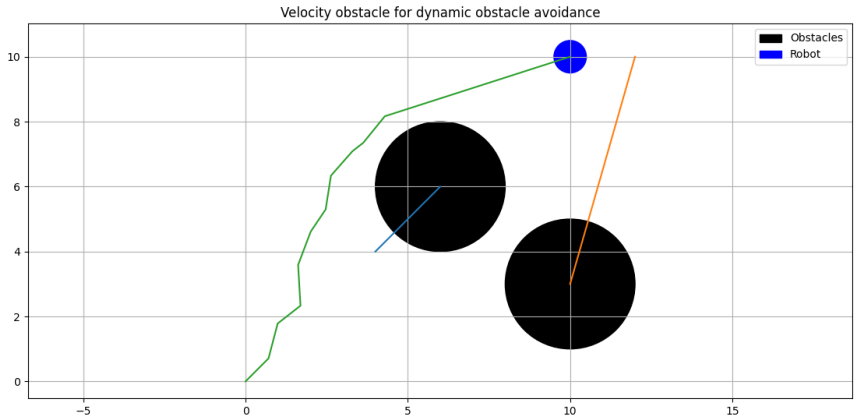
$$\mathbf{p}_i^{proj} = \mathbf{p}_i^r \cdot \frac{\mathbf{v}_i^r}{||\mathbf{v}_i^r||_2} \tag{4}$$

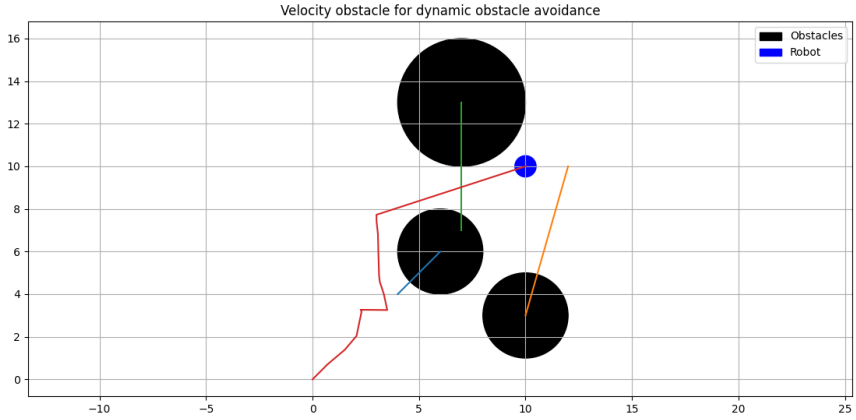
$$\mathbf{p}_i^r - \mathbf{p}_i^{proj} < r + r_i^o \qquad (Collision \quad (A)) \tag{5}$$

$$\mathbf{p}_i^r - \mathbf{p}_i^{proj} > r + r_i^o \qquad (Obstacle \quad avoidance \quad (B)) \tag{6}$$

# 4 Results






# 5 Deliverables

The code performs the dynamic obstacle avoidance by using velocity obstacle. It also provides configuration file to change the number of simulation parameters in a simple manner.

## 5.1 Running the code

Change the configuration in *config/config.yaml* and run the code.

```
python simulator.py
```

## 5.2 Contributions

Velocity obstacle, Agent, simulator, and report - Rahul Sajnani