Potential Field Path Planner

This project involves the design, build, testing, and optimization of a 3D potential field path planner for robotics applications. The planner navigates a robot from a start position to a goal position while avoiding obstacles using attractive and repulsive forces. This project showcases my engineering and programming skills and reflects my passion for robotics and learning.

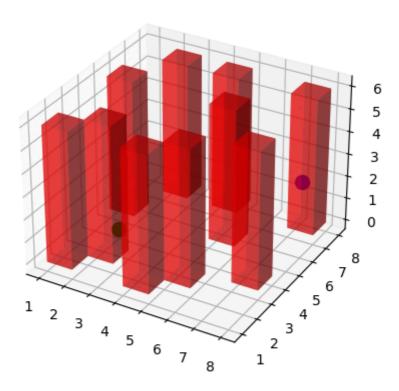
Features

- Attractive Force: Guides the robot towards the goal.
- **Repulsive Force**: Keeps the robot away from obstacles.
- Path Planning: Generates a path from start to goal while avoiding obstacles.
- Visualization: 3D visualization of the path and obstacles.
- Parameter Optimization: Finds the best attractive and repulsive gains for the planner.

Screenshot

PROFESSEUR: M.DA ROS

The following is the result of the potential field path planner navigating an agent from a start position to a goal position while avoiding obstacles.



Please excuse the fact that the path is obscured by the obstacles in the saved visualization. If I have time, I will fix this issue.

Installation

Ensure you have Python and the required libraries installed:

```
pip install numpy matplotlib
```

Usage

Example Code

```
import numpy as np
import matplotlib.pyplot as plt
from mpl toolkits.mplot3d import Axes3D
from matplotlib.animation import FuncAnimation
# Define the PotentialFieldPathPlanner class and other functions here
# Example usage
obstacles = [
    (2, 2, 0, 1, 1, 6),
    (5, 2, 0, 1, 1, 6),
    (1, 5, 0, 1, 1, 6),
    (5, 5, 0, 1, 1, 6),
    (2, 7, 0, 1, 1, 6),
    (7, 3, 0, 1, 1, 6),
    (4, 1, 0, 1, 1, 6),
    (1, 1, 0, 1, 1, 6),
    (4, 7, 0, 1, 1, 6),
    (7, 7, 0, 1, 1, 6)
1
start = (2, 4, 0)
goals = [(8, 6, 3), (1, 8, 0), (3, 1, 0)]
attractive_gains = np.linspace(1.0, 2.0, 5)
repulsive_gains = np.linspace(0.1, 2.0, 5)
best_gains, best_fitness = find_best_gains(obstacles, start, goals,
attractive_gains, repulsive_gains)
print(f"Best gains: Attractive Gain = {best_gains[0]}, Repulsive Gain =
{best_gains[1]}")
print(f"Best MSE Cost: {best_fitness}")
# Visualize the path for the best gains and the first goal
planner = PotentialFieldPathPlanner(obstacles, start, goals[0], best_gains[0],
best_gains[1])
path, cost = planner.plan_path()
visualize_path(obstacles, path, start, goals[0])
```

```
# Visualize the path for the best gains and each goal
for goal in goals:
    planner = PotentialFieldPathPlanner(obstacles, start, goal, best_gains[0],
best_gains[1])
    path, cost = planner.plan_path()
    visualize_path(obstacles, path, start, goal)
```

Visualization

The visualize_path function provides a 3D visualization of the path planned by the robot, including the start and goal positions and the obstacles.

Mathematical Concepts

Attractive Force

The attractive force \$\mathbf{F}{att}\$ pulls the robot towards the goal. It is typically modeled as a linear function of the distance to the goal:

 $$\mathrm{f}_{F}_{att} = k_{att} \cdot (\mathrm{f}_{g}_{goal} - \mathrm{f}_{g})$

where:

- \$k_{att}\$ is the attractive gain.
- \$\mathbf{q}_{goal}\$ is the position of the goal.
- \$\mathbf{q}\$ is the current position of the robot.

Repulsive Force

The repulsive force \$\mathbf{F}_{rep}\$ pushes the robot away from obstacles. It is usually modeled to have an effect only within a certain distance \$d_0\$ from the obstacle:

where:

- \$k_{rep}\$ is the repulsive gain.
- \$\mathbf{q}_{obs}\$ is the position of the obstacle.
- \$d_0\$ is the influence distance of the obstacle.

Total Force

The total force \$\mathbf{F}\\$ acting on the robot is the sum of the attractive and repulsive forces:

 $\$\mathrm{F}_{F} = \mathrm{F}_{att} + \mathrm{F}_{F}_{rep}$

Path Planning

The robot's movement is determined by the total force. At each time step, the robot's position is updated based on the force:

 $\$ \mathbf{q}_{new} = \mathbf{q} + \Delta t \cdot \mathbf{F}\$\$

where \$\Delta t\$ is the time step.

Optimization

To find the best gains \$k_{att}\$ and \$k_{rep}\$, we minimize a cost function, typically the Mean Squared Error (MSE) between the planned path and the desired path:

 $\star MSE = \frac{1}{N} \sum_{i=1}^{N} |\mathcal{G}_{i} - \mathcal{G}_{g}(g)|^2$

where \$N\$ is the number of steps in the path.

Skills Demonstrated

- **Programming**: Proficient use of Python, including libraries such as NumPy and Matplotlib.
- **Robotics Engineering**: Implementation of potential field path planning, a fundamental concept in robotics navigation.
- **Optimization**: Finding the best parameters for the path planner to minimize the cost function.
- 3D Visualization: Using Matplotlib to visualize the robot's path and obstacles in a 3D space.

Contributing

Contributions are welcome! If you have suggestions for improvements or new features, please open an issue or submit a pull request.

Contact

For any questions or inquiries, please contact ronen.g.aniti@gmail.com.