Drone Path Planning with Dynamic Obstacles

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Problem Statement

The goal is to create a **smart navigation system** that helps a **drone travel safely and efficiently** from its starting point to its destination, even in an environment that's always changing. This means designing an algorithm that lets the drone find its way on its own, avoiding any obstacles that might move or appear suddenly.

Note – We shall restrict this project to a drone flying in just 2-Dimensions for the sake of completing the project in the required timeline.

Note – The major difference between our project and the Homework 4 is that we do not know how many dynamic or static obstacles are present at a certain point in time on the grid.

The Uncertainties Involved

The main uncertainties in this problem are the unpredictable locations and movement patterns of obstacles in the environment, such as other drones or changes in the obstacle locations. The drone must operate with incomplete information, as it cannot fully anticipate when or where new obstacles will appear.

- **Other drones (other agents) fly in an area to reach different goals (or destinations).**
- **Some obstacles like birds (dynamic obstacles) may appear suddenly.**
- **Trees and Buildings are static obstacles.**

Why the Problem is Non-Trivial?

The problem is non-trivial because the **environment is constantly changing**, with obstacles that move unpredictably or appear suddenly and require the drone to adapt its path in real-time. Traditional search algorithms like **BFS or A*** are not well-suited for this task, as they assume a static environment and cannot respond quickly to unexpected changes.

Existing solution methods

Existing solution methods for path planning in dynamic environments include:

- **Simultaneous Location and Mapping (SLAM)**: Drones use this technique to create maps and understand their position within them. The disadvantage of using SLAM for drones is its **computational complexity**.

- **Probabilistic Roadmaps (PRM)**: A path-planning method where a graph of feasible paths is created by randomly sampling collision-free points in the environment and connecting them to form a roadmap for navigation. PRMs are less effective in highly dynamic environments since the roadmap is generated based on static samples and requires re-sampling or re-planning if obstacles move or new ones appear.

Modeling and Solving the Problem

What is the State Space, Action Space and Observations?

To model this problem, the **state space** will represent the drone's position, and environment layout, including the positions and predicted movements of obstacles. For Example - In this model, the state space includes all possible configurations of the drone and its environment on a 10x10 grid.

The **action space** will consist of possible movements the drone can make, such as changing directions. Example – For example, on a 2-Dimensional Plane, it has eight possible actions: Move Up, Down, Left, Right, Move Up-Right, Up-Left, Down-Right, Down-Left

Observations will come from the drone's sensors, capturing data at each timestep on obstacle locations (static and dynamic). At each timestep, the drone scans its surroundings to detect the position of obstacles within a certain range.

Methodology

Particle Filter for Sensing Obstacles – The particle filter is effective for tracking obstacles in environments with uncertainty, as it represents potential positions of obstacles through a set of weighted particles.

Exploration vs. Exploitation Policy and Obstacle Avoidance Policy – An Exploration vs. Exploitation Policy helps the drone balance the need to try new paths (to avoid uncertain regions with potential obstacles) with following the shortest known safe path to its destination.

D* for Dynamic Pathfinding – D* (Dynamic A*) is a pathfinding algorithm optimized for environments that change over time, making it especially useful for navigating dynamic obstacle fields.

Note – If time permits, we can also create a simple GUI for better visualization of the Drone flying whilst avoiding obstacles and reaching its goal.