Autonomous Air Traffic Route Planning Under Severe Weather Conditions

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Problem Motivation

- Severe weather is the #1 cause of flight delays, accounting for 69% of all delays between 2008-2013 in the U.S.
- Rerouting aircraft around storms increases stress for air traffic controllers and costs the aviation industry
- The goal of this project is to develop a smart air traffic controller that will automatically direct a plane to its destination while avoiding inclement weather and minimize time spent in the air

Modeling

- A 2D grid containing a plane object, storm object, and airport location models the world
- Plane moves at constant velocity and altitude, has control over heading
- Storm defined by a center location and severity modeled as a 2D Gaussian. Its position changes randomly at every time step according to a defined transition distribution
- Plane and storm locations do not have to be fixed to grid points

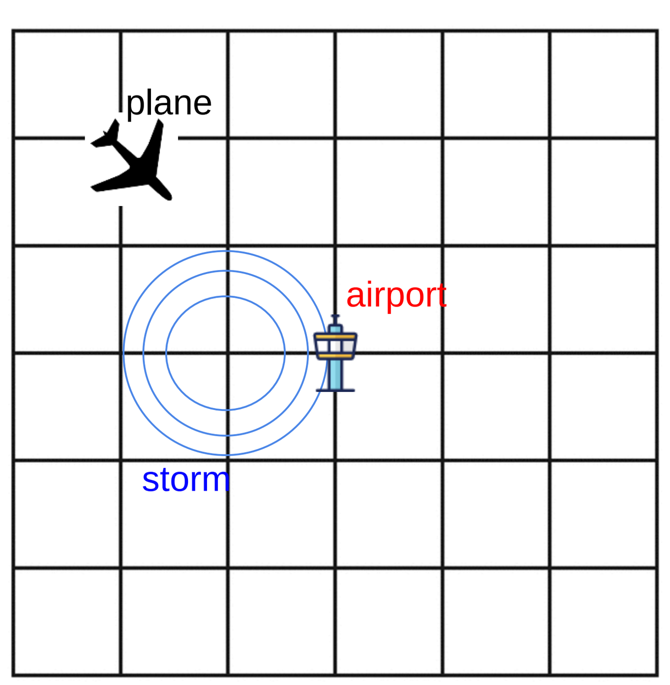

Figure 1: Visualization of the problem gridWorld

Methods

Offline Method: MDP Value Iteration

- MDP Problem:
  - States – plane x-y coordinates, storm x-y coordinates
  - Actions – choose a waypoint to fly to on the N-by-N grid
  - Transitions – defined by storm transition distribution
  - Rewards – high reward for reaching airport
    Penalize traveling through storm and total distance
- Optimal policy is precomputed with the Bellman equation for every plane-storm location pair for discrete grid points

$$V_{opt}^{(t)}(s) = max_{a \in actions(s)} \sum_{s'} T(s,a,s')[R(s,a,s') + \gamma V_{opt}^{(t-1)}(s')]$$

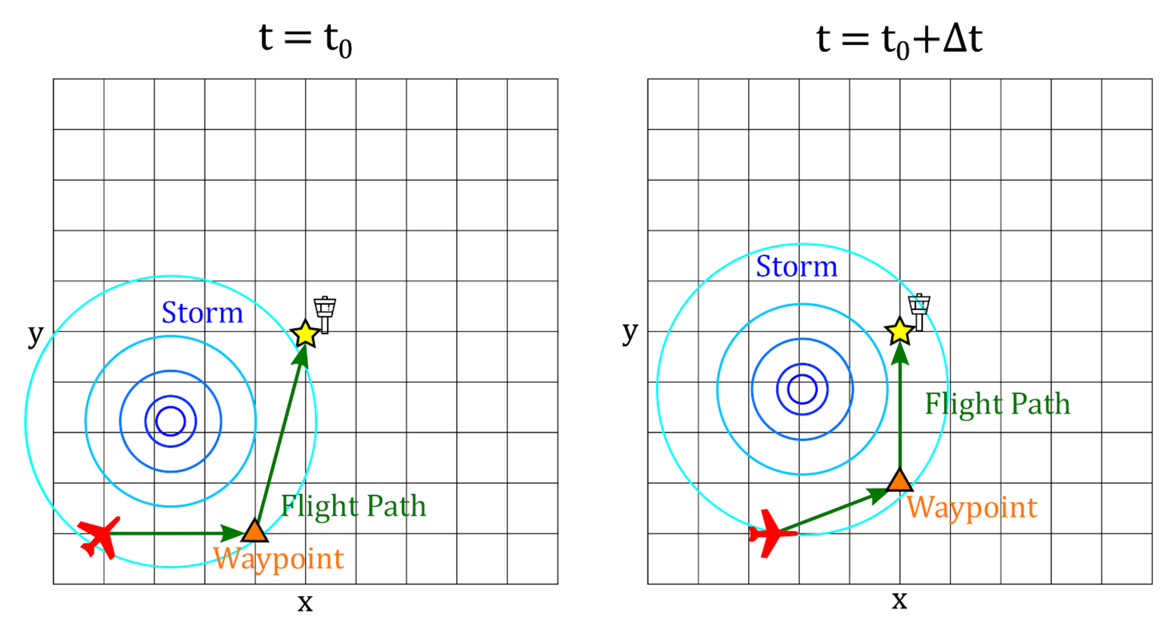

Figure 2: MDP Visualization

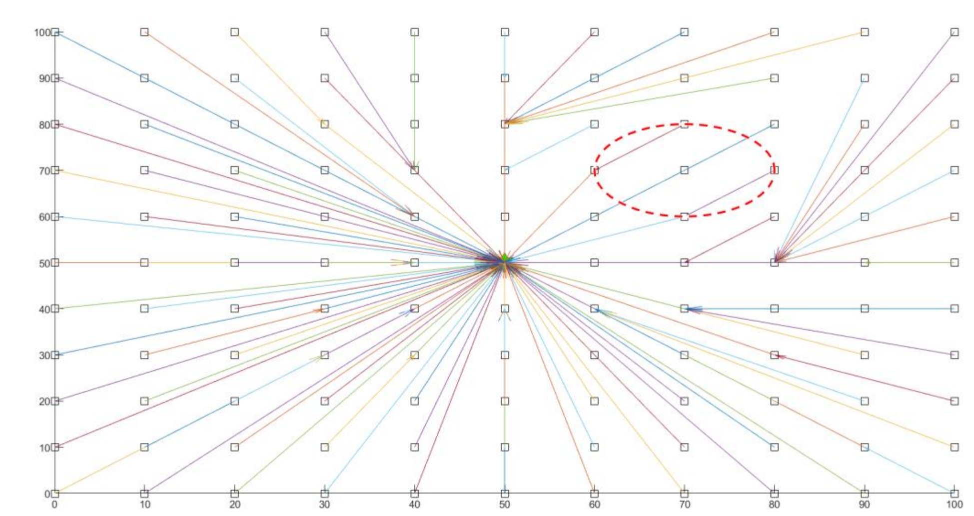

Figure 3: Optimal Policy Map

Online Method: A* Search

- At each time step (for a given plane and storm location), call A* search to get the optimal path of the plane to its destination
- Step the plane towards the first waypoint on the optimal path, move the storm
- Repeat these 2 steps until plane reaches airport

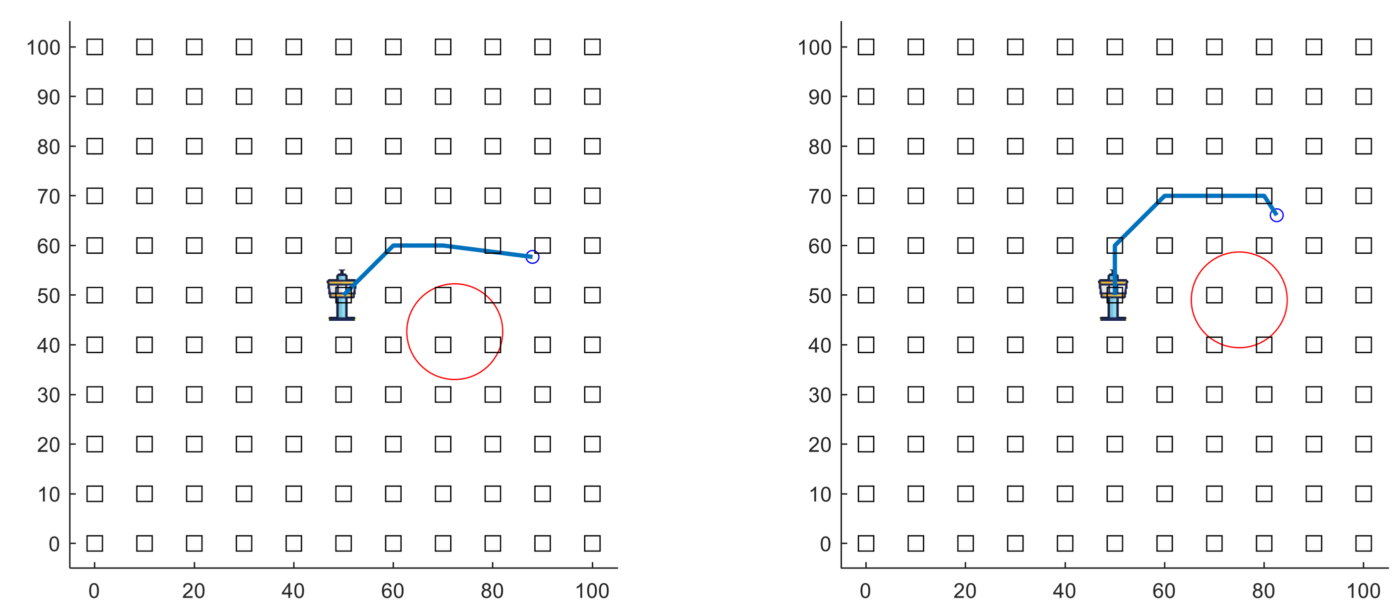

Figure 4: A at 2 successive time steps*

Evaluation

- Baseline: plane flies straight to airport without avoiding storm
- Oracle: plane flies around stationary storm
- Reward Function:

$$R(s,a,s') = 1000 \; if \; s_{plane} = airport_{x,y}$$

$$R(s,a,s') = -\left[dist(s_{plane}, a) + dist(a, airport_{x,y}) + k\int_{C} N(s_{storm}, \sigma_{storm}^2)dr + k\int_{C'} N(s_{storm}, \sigma_{storm}^2)dr\right] \; if \; s_{plane} \neq airport_{x,y}$$

C: path from plane to waypoint   C': path from waypoint to airport
k: weight hyperparameter

Experiments/Results

Average Delays from Straight Line Distance (1000 trials, random plane and storm initialization):

MDP	2.5%
A*	3.7%

Average Total Reward at End State (1000 trials, same plane and storm initialization):

MDP	774.5477
A*	743.6346
Baseline	682.6979
Oracle	758.3259