Final Project Status Update: Who Stopped the Fire? Validating a Pair of Fire-Detecting, Dec-POMDP Agents

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1. Reintroduction

In safety-critical, fire-detecting scenarios, drones must quickly and reliably detect the location of a fire within a forest area [2; 4]. Myself and two students attempted to model this problem as a Final Project for Stanford University's course AA228: Decision Making Under Uncertainty [3; 1]. My current project goal is to estimate the probability of each possible modeled failure mode, which includes the budget running out ($\hat{p}_{\text{no budget}} = \mathbb{E}(\psi_{cost} \notin \Box_{[0,t_f]}(J(t) < J_{max}))$), time running out ($\hat{p}_{\text{no time}} = \mathbb{E}(\psi_{time} \notin \Diamond_{[0,t_f]}(s_t \in \mathcal{S}))$), and the drone(s) getting stuck ($\hat{p}_{\text{stuck}} = \mathbb{E}(\psi_{active} \notin \Box_{[0,t_f]}(\Diamond_{\tau \in [1,10]}(s_{t+\tau} \neq s_t)))$).

2. Progress

When I revisited the model, I found that it lacked the stochasticity that would make validation fruitful. Thus, I have spent time adding disturbances to the model and implementing a random baseline with 10000 trials. The random baseline estimates $\hat{p}_{\text{no budget}} = 7.73\%$, $\hat{p}_{\text{no time}} = 21.8\%$, $\hat{p}_{\text{stuck}} = 34.0\%$. The remainder of the project will focus on implementing importance sampling ($\hat{p}_{\text{fail}} = \frac{1}{m_{\text{steps}}} \sum_{i=1}^{m_{\text{steps}}} \frac{p(\tau_i)}{q_{\text{fuzz}}(\tau_i)} \mathbb{1}\{\tau_i \notin \psi\}$) by fuzzing the initial distributions of each model's subpart to then calculate the estimated likelihood of each failure mode. The model's environment, agent, and sensor can be described as such:

Environment The environment is an $n \times n$ grid-world with a random starting fire location and wind that can move drones in some direction with some probability p_{wind}. The initial distribution includes an initial fire location $s_{\text{fire}} \sim \mathcal{U}(0, n \times n)$ and a random initial wind direction $\theta_{\text{wind}} \sim \mathcal{U}(0, 2\pi)$. During the simulation, the wind direction can be disturbed with a 25% chance of randomly changing every 10 time steps.

Agent The agents are drones with a 3×3 observation window centered at their respective locations. Each drone has its own POMDP which makes up an overall Dec-POMDP system. They have six possible actions to take: 0: stay, 1: move up, 2: move down, 3: move left, 4: move right, 5: communicate, 6: extinguish the fire. The initial location can be described as $s_{Ai} \sim \mathcal{U}(0, n \times n) \mid s_{Ai} \neq s_{\text{fire}}$ for Drone A and $s_{Bi} \sim \mathcal{U}(0, n \times n) \mid s_{Ai} \neq s_{Bi} \neq s_{\text{fire}}$ for Drone B. During the simulation, the wind may disturb the location of the drone by one space according to, $p_{\text{wind speed}} = 0.25$ every 10 time steps. The communication action, which syncs each agent's history of explored states, is lossless and deterministic.

Sensor The drones use a "sensor" to observe whether a fire is within their observation window. This sensor is an ideal sensor, guaranteed to give the correct reading to the drone.

3. Timeline

The expected workload on the project is: Week 8 - Implement Fuzzing, Week 9 - Implement Importance Sampling, Week 10 - Revise Importance Sampling and Write Final Report.

4. Sketches of Solution

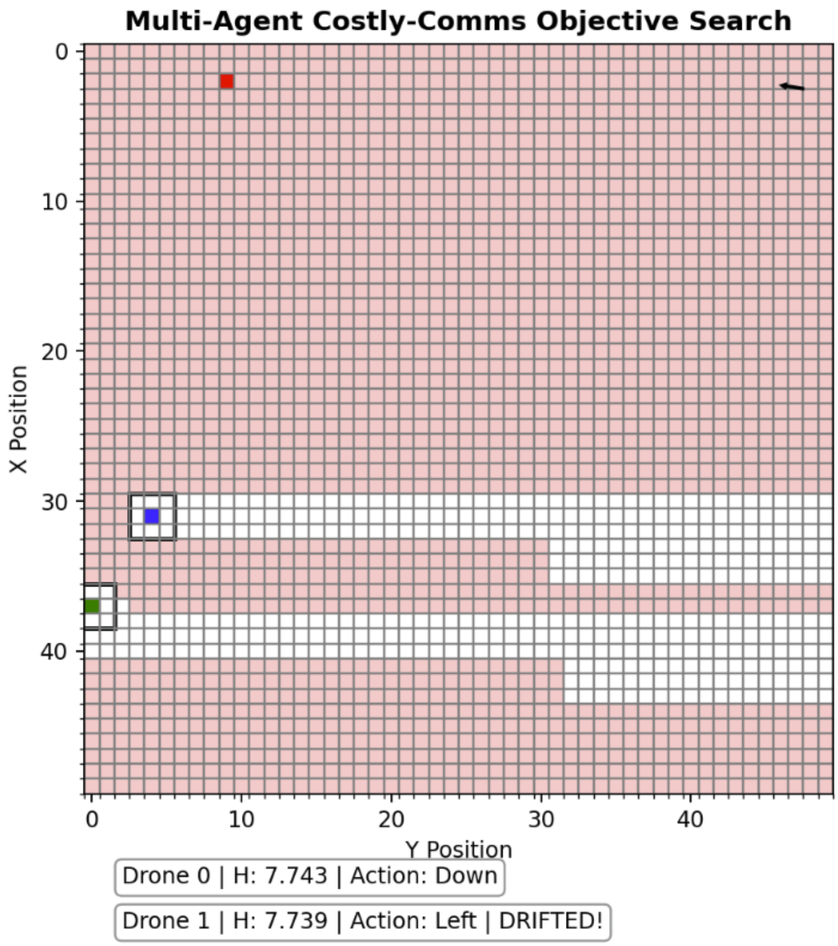

Figure 1: Screenshot of the drones (blue and green) in the grid-world searching for a fire (red). The arrow in the upper right corner is the direction of wind.

Click Me! I am a .gif file!

References

[1] Mahdi Al-Husseini, Kevin H. Wray, and Mykel J. Kochenderfer. Hierarchical framework for optimizing wildfire surveillance and suppression using human-autonomous teaming. *Journal of Aerospace Information Systems*, 21(10):790–811, 2024. doi: 10.2514/1.I011368. URL https://doi.org/10.2514/1.I011368.

[2] Calum X. Cunningham, Grant J. Williamson, and David M. J. S. Bowman. Increasing frequency and intensity of the most extreme wildfires on earth. *Nature Ecology & Evolution*, 8(8):1420–1425, aug 2024. ISSN 2397-334X. doi: 10.1038/s41559-024-02452-2. URL https://doi.org/10.1038/s41559-024-02452-2.

[3] Mykel J. Kochenderfer, Tim A. Wheeler, and Kyle H. Wray. *Algorithms for Decision Making*. MIT Press, 2022.

[4] Mongabay. Drone swarms and AI take aim at stopping wildfires in 10 minutes, jul 2025. URL https://news.mongabay.com/short-article/2025/07/drone-swarms-and-ai-take-aim-at-stopping-wildfires-in-10-minutes/. Accessed: 2026-01-20.