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TartanHacks25

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Wildfire damages in the US amount up to...

$894 billion/year[1]

[1]United States Joint Economic Committee

The 2025 Los Angeles fires resulted in up to...

10,000 homes lost[2]

[2]CNN

It’s only going to get worse

Coordinating search, rescue, and firefighting efforts at scale face multiple difficulties:

1) Thousands of first responders, each in different vehicles (planes, helicopters, trucks, etc.) and with different ‘skills’, are difficult to allocate strategically in a centralized manner. Humans can’t do it, and computers struggle with coordination at scale.

Coordinating search, rescue, and firefighting efforts at scale face multiple difficulties:

2) High load on communication networks during natural disasters may result in localized losses of communication. Relying on centralized coordination of first responders is not safe or optimal.

We propose a decentralized algorithm that allocates first responders without any centralized coordination, while only assuming satellite internet access.

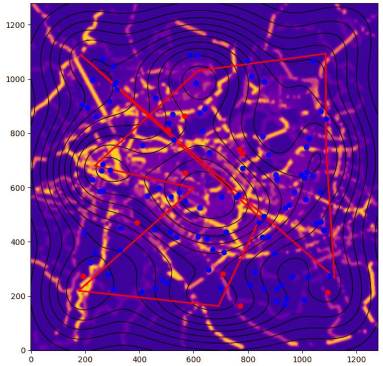
Approach:

- Use satellite imagery to build a belief state of where the fire is.
- Agents identify points of interest that need coverage based on projected fire progression.
- Each agent computes a probability of staying and continuing to assist in their current point of interest, or transitioning to an adjacent one.

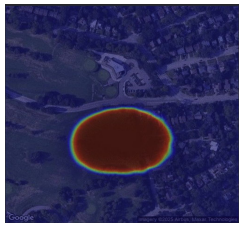
Each agent determines its behavior on its own, but this process probabilistically converges to globally proportional coverage. *The goal of the algorithm is to not only allocate agents to fight fires, but to maintain roadway arteries open as long as possible.*

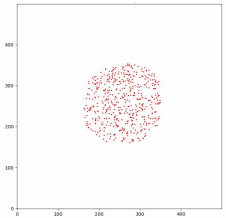
Tech Stack

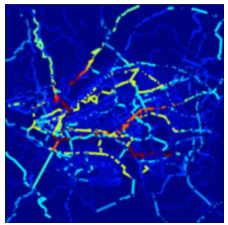
Planner for Decentralized First Responder Distribution



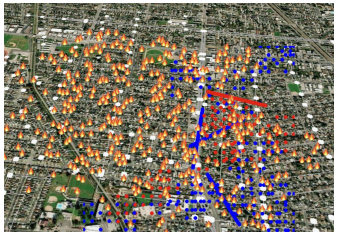
Graph Construction





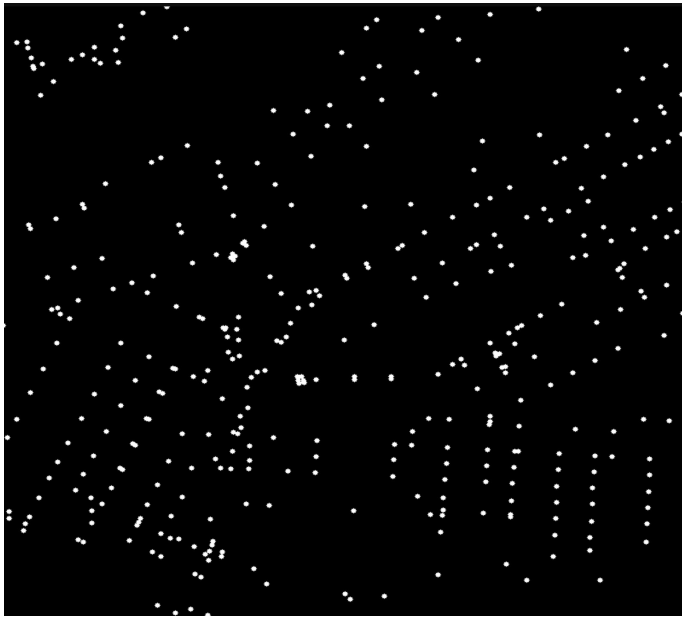


Fire Progression Modeling



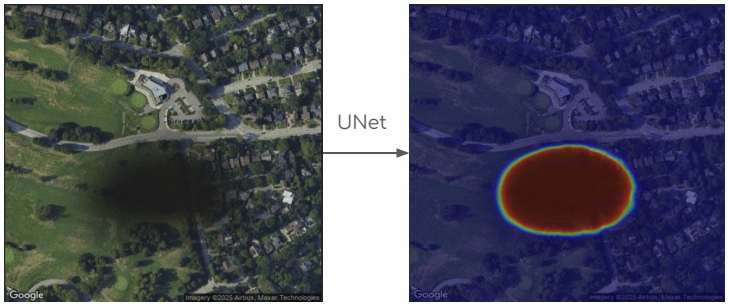
UI

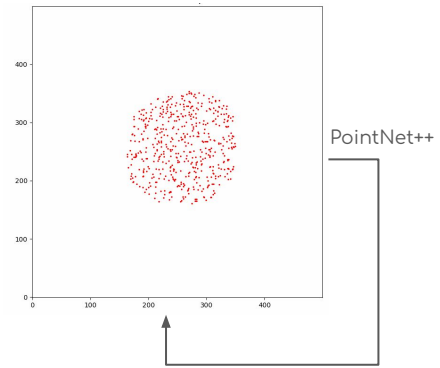
Localizing Roadway Arteries

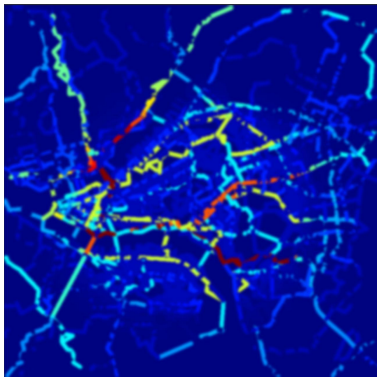


Left: reachable road networks, found by graph reachability **Right:** extracted intersections using Harris corner detector

Learning-based Particle Filter for Fire Prediction







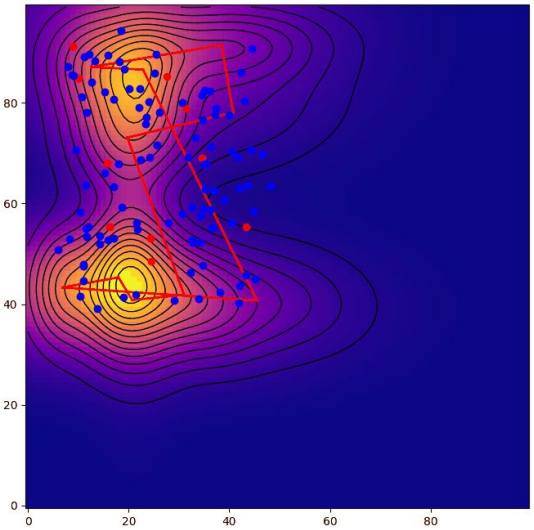
Sensor Model: $p(x_t|z_t)$

Motion Model: $p(x_{t+1}|p_{1:t}, w_{1:t})$

$\overline{\text{Bel}}(x_{t+horizon})$

Particle filter defining belief state of fire, assisted by UNet sensor model trained on synthetic satellite imagery and Transformer motion model trained in simulation on wildfire data. Propagating particles through a horizon estimates future distribution.

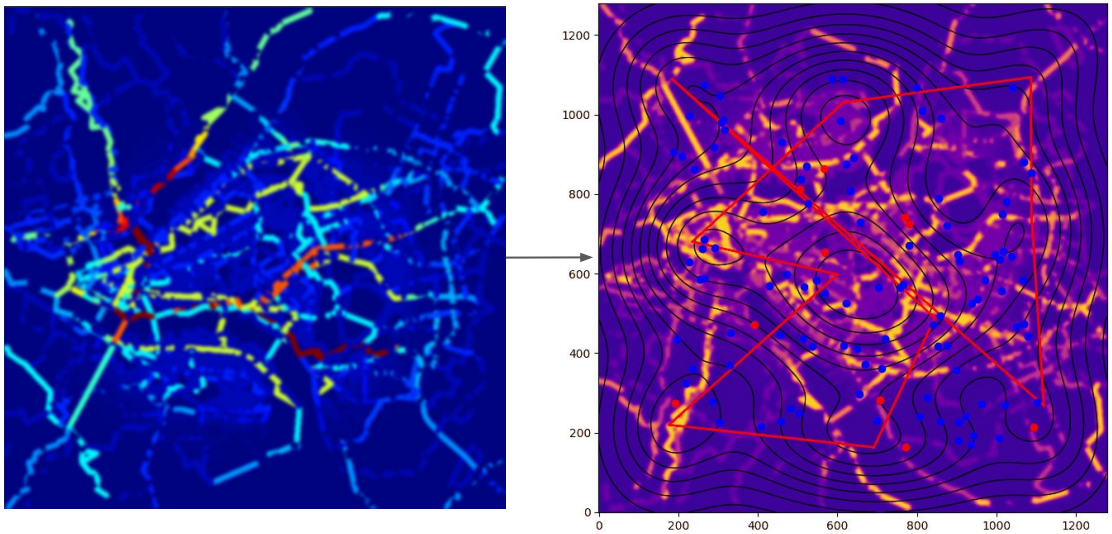
Coverage with Heterogeneous Agent Teams



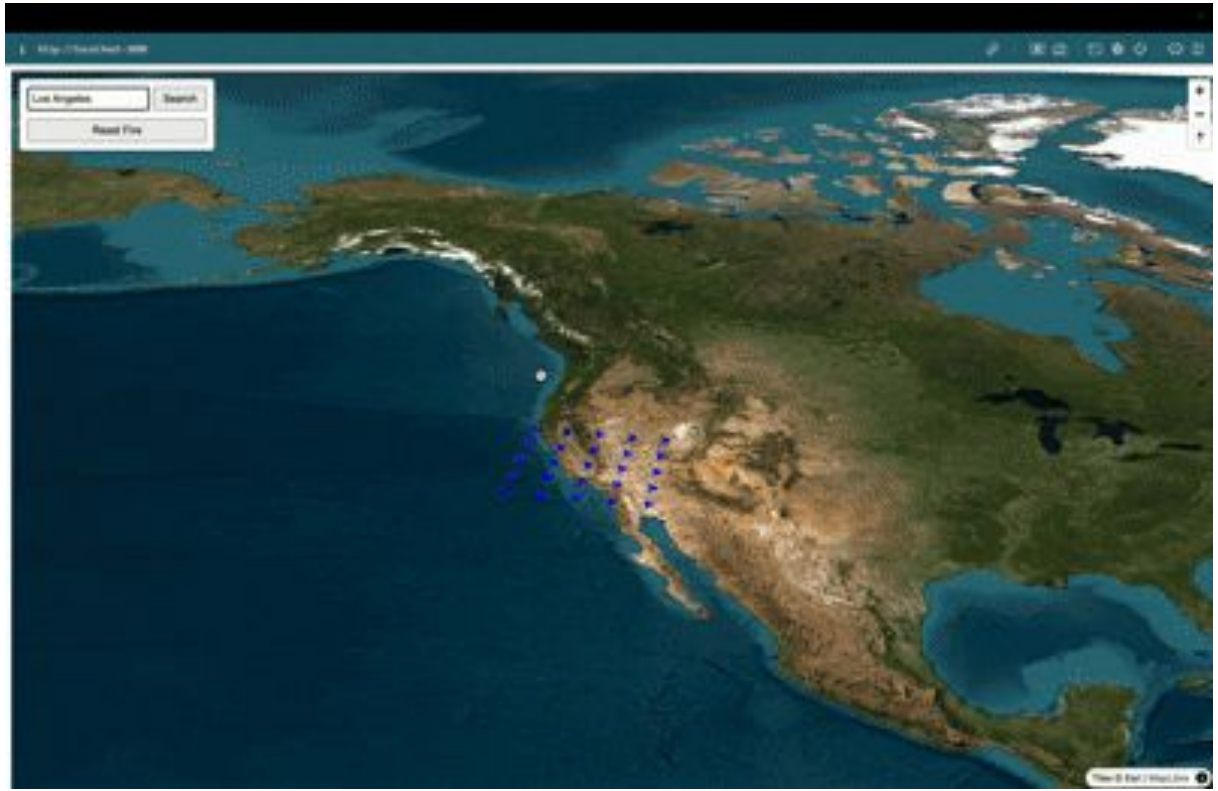
SPAGHETTI: Spectral-based Planning And Global Heterogeneous Ergodic Team Task Implementation, on a sample map with 2 agent types

- Planner uses SPAGHETTI: a novel decentralized planner for Ergodic search.
- SPAGHETTI matches agents with regions of interest, identified through fitting a Dirichlet Process Gaussian Mixture Model to the information map, by matching agents' sensing footprints with the spectral properties of regions of interest.
- SPAGHETTI is decentralized, relying on agents stochastically transitioning to neighboring regions based on locally available information.

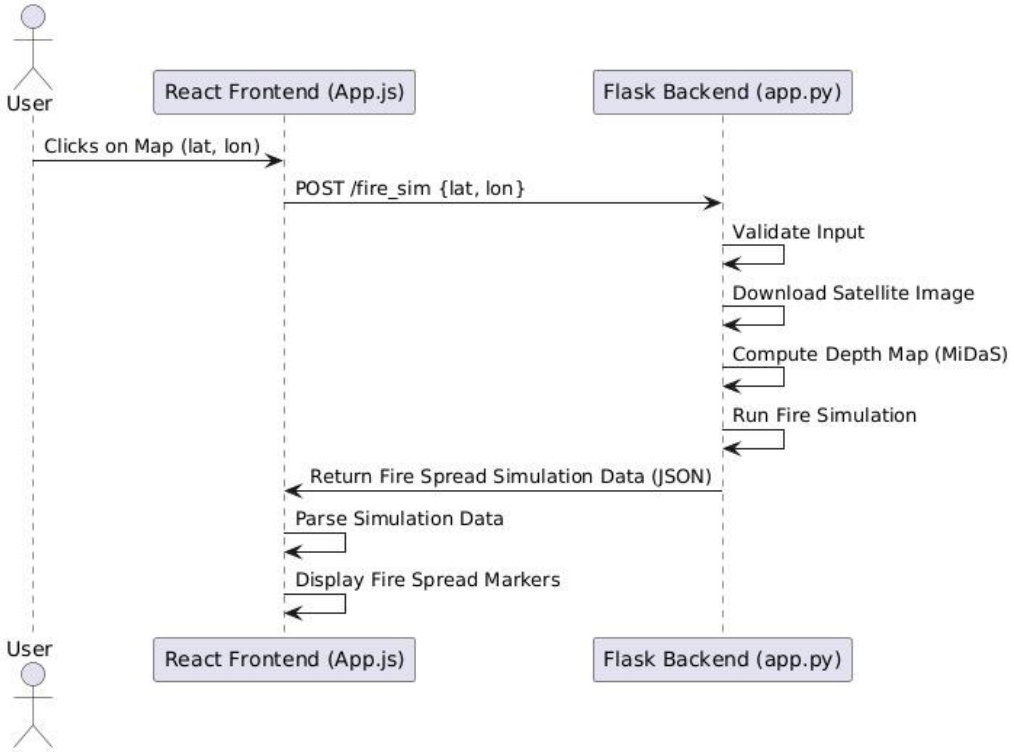
Coverage with Heterogeneous Agent Teams



Prototype User Interface



Web Infrastructure



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