UAV-based surveilance system for fire prevention

Project Proposal

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ABSTRACT

In this paper, a multi agent system related to unmanned aerial vehicles (UAVs) is proposed. The domain in focus is fire surveillance. How can UAVs help with fire surveillance? Can they predict the areas with increased risk of fire? Can they patrol those areas?

KEYWORDS

UAVs; Forest Fires; Fire Surveillance; Artificial Intelligence; Multi agent systems

1 INTRODUCTION

The importance of forests is indisputable and yet the threat of fires keeps on getting higher due to global warming. As such, fire prevention and surveillance is a rising topic in the scientific community. The advent of AI (artificial intelligence) has brought more tools to tackle problems in non-conventional ways. This group is set to combine these technologies in the domain of fire prevention and surveillance.

This group proposes an intelligent system composed by autonomous agents which will be UAVs.

2 PROBLEM DEFINITION, RELEVANCE AND REQUIREMENTS

The objective of the project is to design a multi-agent system composed by UAVs that surveil a forest. The system would be composed of agents, UAVs, and an environment, a forest. The forest will be represented as a heat map with different colors representing different fire threats. The agents must have the ability to optimize a utility function which related to the target patrolled area. Meaning, the agents would receive a greater utility value with the surveillance of areas which represent an increased fire threat (again, denoted with the color scheme of the heat map representation). As a multi-agent system the agents should have the ability to communicate with each other in order to optimize their goal.

Forests are vast and abandoned areas that play a vital role in the Earth's ecosystem, the ecological balance of the earth depends upon the forests. Most of the time when fires are observed they have already been burning for quite some time, making them more challenging to stop than what they might otherwise have been. There are many possible ways that can make a fire gigantic, for example, weather changes. Despite that, the lack of an early response is what creates fires with unmanageable dimensions. Jobs related to forest vigilance are also disappearing making the surveillance almost impossible without the use of new technologies.

In Portugal, the situation is dramatic during the summer. Every year, hundreds of firefighters spend their days battling wildfires in the center of Portugal. Portugal is a warm country with strong winds from the Atlantic. As rural populations have died or, migrated to the city, many of these privately owned lands have been neglected. The increased amounts of brushes and detritus, compound fuel for the flames. These facts make Portugal a ticking bomb.

Employing technological advances in the aerial surveillance of forests would not only make sense, but would also enable us to setup a safety monitoring system making proactive surveillance of forests. This would be specially important to give firefighters a faster and more agile response to the ignition of a fire. To create that sort of system, UAVs would have to work as a team to cover the area of the forest. That is the problem we are set to address. How to optimize the work of the UAV swarm in the area of operation with a peer to peer communication and the employment of AI related technologies to track the spots that are more likely to serve a fire ignition.

3 PROPOSAL OF THE INTELLIGENT SYSTEM

There will only be one type of agents, the UAVs and, they will be in an environment represented as a grid world. The objective is for the agent is to perceive forest blocks with respect to their current fire threat. The effectiveness of the agents should be perceived by paying attention to the number of fires that have actually ignited in the environment. Once an agent checks a forest cell (element of the grid world), its fire threat resets to green (assuming a scale from green to red) since it was already perceived by the agent. In order to assure each UAV is ready to operate under the terms that were set, they should be equipped with internal tools to track:

- Number of detected blocks (`blocks_counter`)
- Remaining battery (`batt`)
- If a fire is detected, has a notification been sent to alert to it? (`has_fire_been_published`)
- Patrolling boundaries to know where to operate (`patrolling_bounds`)

The interaction between the agents is performed towards finding the optimal strategy to patrol a region (probably large), as such, they should share data such as battery capacity (which may differ from UAV to UAV) and current patrolling boundaries (if they exist). Agents should try to reach a consensus that makes their patrolling region smaller in order to reach a greater accuracy and, specially, efficiency.

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In order to evaluate the performance of the presented solution, a plethora of metrics shall be used. As list is presented below accompanied by a brief explanation of each one of the metrics.

- How many fire ignitions have been triggered? – Displays the accuracy of the overall system, combining the results of all UAVs.
- Given a single fire instance, how many agents detected it? – Shows if the agents are doing the same thing, or not. Can be a measure of redundancy or task negotiation.
- What is the coverage of the environment at any given time? – Are the negotiations between UAVs effective in obtaining a higher supervision?
- Number of squares patrolled by each UAV? – Are the UAVs overwhelmed with too much area to surveil?
- Average time steps needed to detect a fire – How efficient is the system?
- Average time steps between recharges – How long are the UAVs "dead"?; During that time does the accuracy drop?

These metrics are relevant at any given time step, however, to have a greater insight towards the system, critical analysis should be carried after a long session, e.g. 1000-time steps.

4 AGENT PROPERTIES

There is only one type of agents in this solution: UAVs. They will operate in a swarm, giving this system the multi-agent characteristic. The UAVs should surveil a specific area, negotiated with the other members of the swarm. As such, there is a need to establish agent communication in order to, at least, negotiate those patrolling areas. The properties of the UAVs are organized in four (4) categories: architecture, sensors, actuators and negotiation/communication.

4.1 Architecture

These properties will be used to characterize the agent:

- Adaptability: The agent should be **adaptable**, The UAVs will learn to interact with the environment and will get better overtime.
- Autonomy: The agent should be **autonomous**, UAVs are ready to autonomously negotiate their patrolling targets.
- Rationality: The agent should be **rational**, the UAVs quickly react to changes in the environment and, always chooses to perform the action with the optimal expected outcome.
- Collaboration: The agent should be **collaborative**, they negotiate the terms of patrolling, are collaborating towards a common goal: signal new fire instances as fast as possible.
- Proactivity/Reactivity: The agent should be **proactive**. It tries to check the forest according to the fire threat before the fires actually ignite.

4.2 Sensors

A sensor is what detects or measures a physical property and records, indicates or otherwise responds to it. The sensors could be:

- Number of UAVs available?
- Is it fire?
- What is the fire threat colour?
- How much battery is left?
- Has end of terrain borders?
- Has terrain irregularity?

4.3 Actuators

An actuator is what causes a machine to operate. As actuators for this project we could have **Move**, **Perceive** and **Rotate**.

4.4 Negotiation/ Communication

On a "real-life" system, this communication could be carried over WiFi or LoRa. Since we are dealing with a simulation of that system, the focus will shift entirely to the content of those communications, rather than on the architecture used to create the messaging channels. Since the flying mechanics and controls should be local, there is no need to share this type of data. So, telemetry will remain private to each UAV.

5 ENVIRONMENT PROPERTIES

The environment for this project will be represented as an grid world where each square should have a different colour representing the threat of fire in that location (green, yellow and red), representing a heat map. There will be squares represented as other things that we find in a forest biome, for example, brushes or grass. Terrain irregularities, like mountains, can also be represented to limit the capability of observation of the UAV. About the environment properties:

- Accessibility: The environment should be **accessible**, the agent can obtain accurate and complete data about the environment state.
- Determinism: The environment should be **deterministic**. an action has a single guaranteed effect.
- Dynamism: The environment should be **dynamic**, it changes while the agent is deliberating.
- Continuity: The environment should be **discrete**, there is a finite number of possible actions and perceptions.
- Memory: The environment should be **non-episodic**, what happens in one episode has influence on the others for example, when agents negotiate with each other they decide which areas to patrol and that negotiation makes a change in behaviour between episodes.