CSE475 Project Proposal

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1 Problem Statement

The objective of this project is to design a multiagent system where individual agents work together to effectively and efficiently extinguish a fire in a specific area. The area's size is $L \times L$ square units, each with its own "flammability" value, where the entire area has a total flammability value of F. There are K fires initially started in random locations, N firefighters randomly dropped into the area. Each firefighter has an initial "energy" level E, that determines their effectiveness, as well as their life.

The fire is able to spread if not attended to quickly enough, and is also capable of killing firefighters. If a firefighter is killed, any firefighters in a directly adjacent location becomes less effective at fighting the fire.

A fire can be extinguished in two ways. It can burn itself out, which is a function of time and the flammability of the space occupied. Or, it can be extinguished by one or more firefighters. Either way, a fire is considered extinguished when its strength is reduced to zero. As a fire burns, its intensity increases based on the flammability of the space it occupies. Once the flammability is sufficiently low, the intensity of the fire begins to decline due to the reduced amount of fuel it has to burn.

The simulation is ended when there are no remaining fires. If all of the firefighters in the area are killed, the fire is allowed to burn itself out, even if there are still firefighters in reserve. In order to be optimally efficient, the fire must be completely extinguished by the firefighters, and all of the firefighters must survive.

2 Agent Design Strategy

There are two types of agents, fire agents and firefighter agents. Firefighter agents are free to move about the environment one square at a time in any direction (north, south, east, west). Fire agents are not allowed to move, but can spawn new fire agents in adjacent spaces if the conditions are right. The goal of the firefighter agents is to extinguish the fire agents. This is accomplished by moving to a space adjacent to a fire and spraying water in the fire's direction.

Firefighter agents make their decisions based on the following two goals, in this order:

1. Stay alive (keep their own energy level above zero)
2. extinguish the fire (achieved by spraying a fire)
3. maximize their own energy level (achieved by spraying a fire)

In order to stay alive, a firefighter agent must keep its energy level above zero. If a firefighter's energy level reaches zero, that firefighter dies. When a firefighter dies, the energy level of any adjacent firefighters is reduced by a percentage, P, to simulate the emotional stress of losing a friend.

As a firefighter sprays a fire, the intensity of the fire is reduced, and the firefighter's energy increases. This is how the system rewards a firefighter agent, and motivates a firefighter to attempt to extinguish a fire.

If a firefighter and a fire occupy the same space, the firefighter loses energy points. This is how the system applies a cost to a firefighter's actions. A firefighter must observe the flammability of the space it occupies as well as the intensity of any adjacent fires to determine the risk of the fire spreading vs the cost that it would incur if the fire did spread. This information is used by the firefighter agent in order to decide whether spraying the fire or moving to another location would maximize its utility. This utility is:

$$U_{action} = Reward_{action} - Risk_{action}$$

Firefighter agents are able to communicate with all other firefighter agents in the same manner that real firefighters communicate with each other using two way radios. A firefighter broadcasts to the other agents when they have located a fire, or when they have extinguished a fire and there are no adjacent fires. In the latter case, the firefighter would wait a sufficient amount of time for a response and move toward the firefighter that needs the most help.

A firefighter agent bases all of its decisions solely on its own observations.

3 Desired Emergent Behavior

The desired emergent behavior is that the firefighters are able to successfully extinguish all of the fire in the environment, preserving the lives of all of the firefighters, and maintaining the highest amount of collective energy.

The flammability of a space can be modified by having a fire burning on it, or by being sprayed by a firefighter. Both methods reduce the flammability of the space. If the flammability of a space is zero, there is no chance for a fire to start there. If a fire is extinguished on a space before the flammability reaches zero, there is still opportunity for a new fire to burn in that space.

4 Hypotheses

Hypothesis 1: The effectiveness of the team of firefighter agents is proportional to $\frac{N}{K}$. However, if $N \ll K$, then the effectiveness becomes non-existent, and the fire will end up burning itself out, potentially killing all of the firefighters.

Hypothesis 2: The effectiveness of the team is directly proportional to E, but inversely proportional to P. That is, if a firefighter has more energy, it is more efficient. However, the more they are affected by being adjacent to a firefighter that dies, the less efficient they will be.

Hypothesis 3: If $L \times L \gg N$ and $K \gg N$, then the system will not achieve coherence. On the other hand, if $N \gg L \times L$ and $N \gg K$, then the system will achieve coherence quickly.

Hypothesis 4: The effectiveness of the team is inversely proportional to the $\frac{F}{L}$. That is, the higher the concentration of flammability in the environment, the faster the fire will spread, and the less efficient the team will be.

5 Experiments

Our experiments are designed to test the above hypotheses. We will run numerous simulations varying the following key parameters:

Parameter	**Range of Values**
L	100, 250, 500, 750, 1000
N	100, 500, 1000
K	100, 500, 1000
P	1%, 10%, 25%, 50%
E	100, 500, 1000
F	100, 1000, 10000

Thus, there are $5 \times 3 \times 3 \times 4 \times 3 \times 3 = 1620$ different configurations. For each configuration we will run five simulations and average the results. For each run, we will collect the number of firefighters that survive, the total amount of energy of the surviving firefighters, how many fires were extinguished, and how many fires burned themselves out. The first two values will determine the efficiency of the system, while the last two will determine the effectiveness. We will then plot the results accordingly to respond to the hypotheses posed.

If we are able to achieve coherence, we would also like to see how different flammability patterns across the area affect the outcome.