LTI Agent Rescue Team Description

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***Abstract*— In this paper we introduce an approach that takes advantage of the existence of local and global information in the RoboCup Rescue simulation in order to improve the coordination among the rescue agents. This approach allows the platoon agents to act independently from a central coordination, but they may benefit from a global view when necessary. Thus, the coordination centers do not directly coordinate the platoon agents, but they concentrate and constantly process global information about fire focuses and victims, and hence can provide optimized information to platoon agents when needed.**

I. Introduction

Disaster management is a critical issue which involves very large number of heterogeneous agents in an hostile environment. The RoboCup Rescue Agent Simulation [1] is a competition with the aim of promoting research and development of efficient response policies to disaster scenarios. The competition involves scoring competing multi-agent teams coordination in rescuing civilians and extinguishing fires in a city where an earthquake has just happened.

The RoboCup Rescue is comprised of simulators that create and control some environmental components like roads, nodes, buildings, civilians and rescue agents. The rescue agents are split into platoon agents and center agents that represent, respectively, mobile emergency services (Ambulance Teams, Fire Brigades and Police Forces) and their corresponding fixed control center (Ambulance Center, Fire Station and Police Office).

In this paper, we present an approach that considers and handles the existence of local and global information. The platoon agents keep only local information about the environment, while the center agents keep its global view. The platoon agents prefer to act using their local information and they request information to their center only when they are idle. Our idea is that the centers should not directly coordinate the platoon agents, but should take advantage of the global view to help in directing the actions of platoon agents when needed.

This paper is organized in five other sections. Section II presents the initialization process performed by the platoon and center agents. The agents' communication and coordination strategy is presented in section III. In section IV, we describe each of the agents' strategy. Then, we briefly describe in section V the path planning algorithm used in our team. Finally, we present our conclusions in section VI.

II. Initialization Phase

In the initialization phase, the simulator supplies to all the agents the layout of the simulated map which is composed of roads, nodes and buildings. In order to improve the speed of their future decisions, the platoon and center agents can pre-process the data provided and extract some information, for example, the shortest path between objects and the buildings vulnerability.

In this paper, we are primarily concerned with calculating the buildings vulnerability, since pre-calculated shortest paths can eventually become invalid during the simulation when the roads become blocked.

The building vulnerability may be defined as a function of the building's properties, and it is part of a decision mechanism which determines the selection order to extinguish fire when several buildings are burning at the same time.

Buildings have a size and a material type, which determines the amount of burnable material and, consequently, how fast the buildings burn. Since the fire can spread to other buildings within a certain neighborhood radius, the distance, material type and size of the neighbor buildings must be considered when determining the building vulnerability.

By collecting and pre-calculating the building vulnerability during the initialization phase, the agents can estimate more quickly the importance to extinguish the fire in each of the burning buildings.

III. Agent Coordination and Communication

The agent coordination and communication strategy employed is important to improve the results in the RoboCup Rescue Agent Simulation competition.

Initially, our strategy considers that platoon agents can act independently from their centers, nonetheless they are limited to act based solely on their own local information or on information received from other close agents. This primary strategy was defined to handle situations in which either the platoon agents cannot contact their centers or the centers are not available at the simulation. In these situations, the platoon agents behavior is to walk randomly through the environment looking for victims, burning buildings or blockages. When they find any of these situation, they may act (if they have the required ability) or keep the information in their memory (situation type and location) in order to provide this information to another agent when they meet in the near future.

However, since in most situations the communication to the centers is available, our other communication strategy emphasizes the information flow concerning victims, burning buildings and blockages from platoon agents to their center and vice-versa.
In such scenario, in the beginning of the simulation the platoon agents walk randomly in order to provide information about the environment to their centers. If they do not find any interesting situation to act upon after a short period, they request information from their centers. If the centers do not have any information to provide, the agents continue to walk randomly for another short period; however, if the centers provide an information, then they try to discover the shortest path to the target, they move to the location and start to act on the situation. When the action is finished, they update their centers with the current information. In the sequence, if the platoon agents cannot sense any other situation to act, they request again information to their centers and the cycle restarts.
Even if the centers cannot directly coordinate the platoon agents, they can perform a sort of coordination when providing information to them. Our strategy considers that the centers will receive all information provided by the platoon agents, and based on these information, the centers can determine the priority of actions to be taken by the platoon agents and, in this way, coordinate the platoon agents' work. The Ambulance Center agent, for instance, can use the information about the remaining life of the victims, the damage and distance to determine the priority for Ambulance Teams rescue. On the other hand, the Police Office Center agent can consider the rescue agent types to determine the clearing blockage priority. In our case, the priority sequence is (1) Ambulance Teams with victims, (2) Ambulance Teams without victims and (3) Fire Brigade. Finally, the Fire Station Center agent continuously determines the fire clusters based on the fire focuses information received from the platoon agents and redirects more Fire Brigades to the fire cluster that has more possible victims and higher sum of buildings vulnerability. Moreover, when new fire clusters are detected, it informs the Police Office Center agent so that this latter can assign a Police Force to that fire cluster.
In the next section, each agent type strategy is described in more detail.

IV. Agents' Strategy

The agents in the RoboCup Rescue Agent Simulation are divided in two main types: rescue agents and victims (civilians). The rescue agents are classified into moving (platoon) agents and fixed (center) agents. The platoon agents are responsible for performing some actions in the environment like clearing roads, rescuing victims and extinguishing fires. They are subdivided into three kinds: Ambulance Teams, Fire Brigades and Police Forces.
Table I presents their available capabilities; it may be noticed that civilians do not have any special abilities.

TABLE I
AGENTS' CAPABILITIES

Type	Capabilities
Civilian	Sense, Hear, Move, Say
Ambulance Team	Sense, Hear, Move, Say, Tell, Rescue, Load, Unload
Fire Brigade	Sense, Hear, Move, Say, Tell, Extinguish
Police Force	Sense, Hear, Move, Say, Tell, Clear
Center	Hear, Say, Tell

The Ambulance Teams are capable of rescuing victims (Rescue), loading them into the ambulance (Load) and unloading them at the refuges (Unload). Fire Brigades have the ability to extinguish fires (Extinguish), while Police Forces are able to clear blocked roads (Clear). There is one important difference between Police Forces, Fire Brigades and Ambulance Teams: while it makes no difference to have more than one Police Force to clear the same blocked road, this is not the case for the other two types of agents. A fire will be extinguished faster if more Fire Brigades are acting on it, and victims are going to be rescued faster as well if more Ambulance Teams are allocated to their rescue. The only limitation of the Ambulance Team is that it can not carry more than one victim simultaneously.
Reliable information about the simulated environment is vital for efficient action planning. The information mentioned are those related to blocked roads, victims and buildings on fire. In order to keep the agents well informed, updated and reliable information must be available for them and the best information sources in this scenario are the agents themselves. However, since the agents have limited sensing and communication capabilities, information sharing becomes much easier if it is centralized and then redistributed to the agents. Our idea is to hold a global and centralized information repository where all relevant data sensed by the agents are kept. This information is provided by the agents themselves, and then processed and redistributed to all the other agents. A better description of the agents' coordination and communication was provided on section III.
The following subsection provides a brief description of each type of platoon agent available in the simulation.

A. Fire Brigade Agent

Fire Brigades are the agents responsible for extinguishing fires. Their amount of water available in the tank is an important property, since when they are run out of water they need to go to refuges to refill it.
Fires may become stronger and spread to the neighboring buildings if they are not extinguished, so efficiency is fundamental in order to control fire focuses and keep them from spreading to other buildings.
At the beginning of the simulation, before the simulation really starts, the Fire Brigades perform the pre-calculations in order to determine the buildings vulnerability as described in section II.
When the simulation really starts, the Fire Brigades seek for fire focuses randomly and if they do not find one in a certain amount of time they may request such information

to the Fire Station. After finding or being informed of a fire focus, they move to that location to extinguish the fire. Once they start to extinguish a fire, they do not stop unless the fire is extinguished or the water tank is empty, when they seek the closest refuge to refill.
After extinguishing a fire or filling the tank of water, the Fire Brigades look for a burning building close to them. If there is more than one in such condition, they determine the priority order based on the buildings vulnerabilities and other available properties. If there is none, they request the information to the Fire Station. Once determined a new fire focus location, they move to this location and the process described is repeated.

B. Police Force Agent

Police Forces are the agents responsible for clearing blocked roads. If a road is blocked, agents cannot cross it, may get stuck or may need to take a much longer route to get to their destination. Efficient path clearing is an important issue to allow a better and faster flow of agents across the city.
The Police Forces walk randomly looking for some blocked road. However, they may be notified by another agent about the existence of a blockage; in this case, they move to the blockage location and start to clear the road. When finished, they restart to walk randomly. In certain more critical situations, the Police Office may be assigned to help in clearing the routes close to a fire cluster. When this happens, the Police Forces start to clear the route between the fire cluster centroid and the closest refuge. After this job is finished, they continue to move around the cluster's centroid to clear the roads close to it. The Police Forces which were not assigned to any cluster will be available to fulfill tasks of clearing other paths assigned by the Police Office or by other agents.

C. Ambulance Agent

Ambulance Team are the agents responsible for rescuing (unburying) and transporting victims. They play a major role in the post-disaster scenario, as they are the ones who should prevent civilians from dying. Their main objective is to transport hurt civilians to the refuges.
Civilians may die if not rescued fast enough, hence efficiency is vital. Therefore, the strategy adopted by Ambulance Teams has to be carefully planned. The strategy employed by our Ambulance Teams has some phases. At the beginning of the simulation, they search randomly for victims. If after some time they do not find anything, they ask the Ambulance Center for information.
When a victim is found, the Ambulance Teams move to that location and start the rescue procedure. If they notice that the victim cannot be rescued before it dies, then they request help to the Ambulance Center, which may send other Ambulance Teams to help in the rescue. After rescuing the victim, the Ambulance Team loads it, moves to the closest refuge and unloads the victim there.
Finally, after having dropped the civilian at the refuge, the Ambulance Team asks the Ambulance Center for new information regarding victims and restarts the process.

V. PATH PLANNING

An important role in the efficiency of the decisions taken by the agents is played by the path planning technique adopted. It is really essential that this technique should be as efficient as possible, since it will probably be one of the most demanding for processing during the reasoning process.
There are two famous algorithms to solve the problem of finding the shortest path between two node: Dijkstra's algorithm [2] and A* [3]. Dijkstra's algorithm can be considered a simpler A*, without the heuristics function to optimize the search. Because of this improvement, in this work the A* algorithm was used.
The main characteristics of the applied A* algorithm are the following:

- A cost of traversal is defined for each edge as:
  - 0, if the edge is a building
  - The length of the road, if the edge is a road and it is not blocked
  - The length of the road added to the cost of unblocking it, if the road is blocked and the agent is a Police Force
  - ∞, otherwise
- The $g(x)$ function is defined as the cost to get from the starting node to the current node
- An heuristic estimate $h(x)$ of the distance to the goal is created. In this case, the heuristic function is the Euclidean distance between the nodes. This means that: $h(x) = EuclideanDistance(x, goal)$
- The $f(x)$ function is defined as the sum of the cost from the starting node and the heuristic estimate to the goal. Mathematically: $f(x) = g(x) + h(x)$
- There is a $closedSet$ containing the nodes already evaluated and an $openSet$ containing the nodes to be evaluated
- The openSet orders the nodes to be evaluated according to their $f(x)$ functions, in increasing order
- At each cycle, until the goal node is chosen, the node with the smallest $f(x)$ is selected, put in the $closedSet$ and its neighbors are added to the $openSet$ if they are not already in the $closedSet$ or if their new $f(x)$ is smaller than the previous one (their distance begins as infinity)

By the end of the run, the algorithm has already discovered the shortest path, if there is one, and the agents are then capable of moving to their destination through the fastest path. The A* algorithm's pseudo-code is presented at Algorithm 1.

If a new blockage is detected by an agent when following the shortest route calculated, then the agent executes the A* algorithm again considering the information to obtain a new route.

Algorithm 1 A* algorithm's pseudo-code

```
function astar (start, goal) : path
closedSet ← empty set
openSet ← set with the initial node
g[start] ← 0
h[start] ← heuristicEstimateOfDistance(start, goal)
f[start] ← g[start] + h[start]
while openSet is not empty do
  current ← node with the lowest f(x) in openSet
  if current = goal then
    return path(start, goal)
  end if
  remove current from openSet
  add current to closedSet
  for i in current.neighbors() do
    if i in closedSet then
      continue
    end if
    tmpGScore ← g[current] + vertexCost(current, i)
    isBetter ← false
    if i not in openSet then
      add i to openSet
      isBetter ← true
    else if tmpGScore ¡ g[i] then
      isBetter ← true
    end if
    if isBetter = true then
      g[i] ← tmpGScore
      h[i] ← heuristicEstimateOfDistance(i, goal)
      f[i] ← g[i] + h[i]
    end if
  end for
end while
return null
end function
```

VI. Conclusions

We believe that our strategy to divide the control between a local one, decentralized among the platoon agents, and a more global one, played by the center agents, is a good compromise between the need of a more comprehensive and elaborated long-term strategy and a quick reactive strategy. We hope that this belief could have good results in the next Agent Rescue Competition.

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