MULTI-AGENT PLANNING FOR THE ROBOCUP RESCUE SIMULATION
Applying Clustering into Task Allocation and Coordination

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Abstract: The RoboCup Rescue Simulation system provides a rich environment for developing novel techniques for multi-agent systems. The simulation provides a city map modeled as buildings and roads with civilians amongst them. A disaster scenario is simulated causing buildings to catch fire, roads to get blocked, and civilians to get injured and/or buried. The main goal is to use the available emergency services (rescue agents) to extinguish the fires, clear the roads, and rescue the civilians. This paper describes a new multi-agent planning approach applied to the RoboCup Rescue problem. The key novelty lies in the distributed approach for task allocation and coordination. It is done through clustering the map into several overlapping maps each with a different group of agents assigned to it. Our results showed that not only we could compete against the top teams in the 2011 RoboCup Rescue Agent Simulation Competition, but we ranked 3rd in this first participation of the GUC in the competition.

1 INTRODUCTION

The RoboCup Rescue project, established in 2001, aims at promoting research and development in the rescue domain at various levels including simulation and multi-agent team work coordination (Kitano and Tadokoro, 2001; Skinner and Ramchurn, 2010). The RoboCup Rescue Simulation project generates a model of an earthquake in an urban center. Student teams from different universities compete to produce efficient response techniques and policies for the simulated emergency services. The earthquake model covers building collapse, roads blocked by rubble and other debris, traffic movement, fire, and injuries to civilians and emergency services workers. Some buildings are refuges and can be used to heal injured civilians or refill fire brigades. Roads include traffic movement and blocked roads. Emergency services include fire brigades, ambulance teams, and police forces.

The goal of the simulation tool is to find the optimal online strategy that best utilizes the emergency services to save the maximum number of lives, extinguish the maximum number of buildings, and clear the maximum number of blockades. Most existing systems model the problem as a decision support system that is centralized. In this paper we show how the RoboCup Rescue Simulation can be modeled as a multi-agent planning problem and thus benefit from the strengths of distributed systems. In addition, our approach tackled the different challenges and produced competitive results based on the following additional contributions:

- Use of clustering techniques to divide the map into overlapping regions based on some density criteria, instead of a static even geographical divide. This will then allow us to distribute the agents over these regions and perform the rescue operations within them.
- A multi-agent communication model allowing the agents to exchange information and ask for help in case of necessity.

Our RoboCup Rescue Simulation tools thus defines 1) a multi-agent planning optimization problem that requires an efficient strategy for distributing up-to 30 agents over the simulated map, 2) an efficient strategy for traversing the map and discovering the unknown emergency events, and finally 3) an efficient communication component to share information among the agents. The German University in Cairo team RMAS_ArtSapience participated in the 2011 RoboCup Rescue Agent Simulation Competition in Istanbul, Turkey. This work has enabled us

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to qualify and win the third place in the competition.

1.1 Related Work

The approaches discussed in this section are all based on the team description papers that belong to the teams (excluding ours) that participated in the final round of the 2011 RoboCup Rescue Competition. They share some common elements including the even partitioning of the map and the model based on a decision support centralized system.

SEU_RedSun, Southeast University, China. Ranked first in the 2011 competition and participating since 2008. Their approach is based on accurate world modeling via multi-communication. Tasks were assigned via a centralized decision support system. The main strength lied in the ability to predict fires early and good utilization of agent communication. Their main weakness lied in not having a well defined strategy for communication-less scenarios.

Poseidon, Farazanegan High School, Iran. Ranking second in the 2011 competition and participating since 2009, Poseidon's approach depended on discovering connected and unconnected parts of the world via agent communication to build an enhanced world model. The approach is based on off-line precomputed schedules further optimized using genetic algorithms. The approach also depends on dividing the map evenly. The main strength lies in the optimized schedules and the enhanced world model.The weakness lies in dividing the map evenly without taking into consideration the map structure or distribution of buildings and in relying on the availability of communication.

IAMRescue, University of Southampton, UK. Ranking fourth in the 2011 competition and participating since 2008, IAMRescue's approach a hierarchical decision-making system supported by disaster prediction via learning fire spread. Their decision-making system also depends on agent communication for coordination. The accuracy of the decision-making system marked IAMRescue's main strength point, but similar to the previous approaches, the lack of communication-less strategies was a weakness.

2 OUR APPROACH

We choose to solve the rescue problem by modeling it as a multi-agent planning problem which differs from existing approaches in the sense that it is distributed(Weerdt et al., 2005). The main reason is the ease to divide the tasks, to define them and handled them autonomously. The nature of the presented rescue problem provides well defined tasks that can be easily divided among the different types of agents with a main goal of performing and optimizing the rescue process.The following section explain how the different phases of multi-agent planning are created and how they contribute to solve the rescue problem.

2.1 Defining Tasks

This phase refines the global tasks and divides them into smaller individual tasks. The rescue problem can be divided into three main tasks: extinguishing fires, saving civilians, and clearing blocked roads. These again can be further divided into several individual tasks. Figure 1 shows a how the rescue tasks are divided into individual tasks.

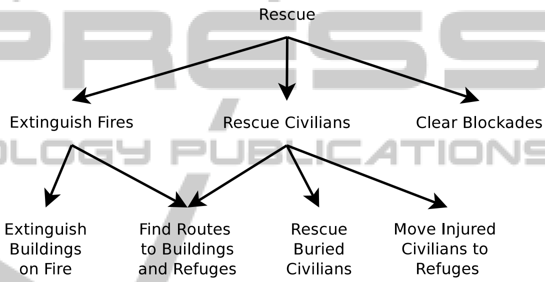

Figure 1: Rescue Tasks Tree Structure.

Finding routes to buildings and refuges will be done by all agents individually. Extinguishing buildings can only be done by fire brigades. Rescuing buried civilians and moving the injured ones can only be done by the ambulance teams. Clearing blockades can only be done by police forces.

2.2 Task Allocation

Task allocation is required to distribute and assign tasks to the agents. In our case, task definition already provided what each agent will be doing but did not specify where in the map it will carry out its action. Since it is impossible for each agent to timely traverse the whole map, the map was divided according to the number of agents available. Related works generally divided the map evenly into a grid which did not take into consideration the map structure and the distribution of the buildings in the map. In our approach, we choose to cluster the map on the buildings such that we can output regions of almost evenly distributed buildings. Each region will be assigned an agents that will traverse all of the buildings and roads in the region to search for events that require rescue actions.

This introduced a new challenge to the rescue agents due to blockades. A series of blocked roads can divide a single region into disconnected parts prohibiting, or delaying in the case of police forces, other agents from reaching some parts in the region. This challenge was solved in our approach with the use of fuzzy c-means (FCM) clustering (Bezdek, 1981; Bezdek et al., 1984). Unlike many of the clustering algorithms that produce disjoint non-empty clusters, such as K-means, FCM clustering algorithm has the ability to assign a data point to several clusters with a specific membership function. This allows some degree of overlap between the clusters.

Since FCM clustering produces intersecting clusters, the produced regions will have common buildings and roads. This will allow some of the buildings and roads within each region to be visited by at least two agents. If it happens that the area of intersection is disconnected in one cluster, it could be reachable by agents from a different cluster the area is covered by. This will increase the chance that agents will be able to visit all buildings and roads in proper time.

2.3 Coordination before Planning

Coordination is required before planning to define the rules and constraints that must be applied on planning to guarantee the satisfaction of the main goal, which is performing and optimizing the rescue process in our case. The approach we used in task allocation included coordination: 1) divide the map into regions, 2) assign agents to regions provided constraints on which agents will perform the rescue process in which region.

Another coordination challenge presented itself when it came to optimizing the rescue process. In many cases, it was noticed that blockades can cause some agents to be initially stuck and some refuges unreachable. An agent is considered to be stuck when it is surrounded by blockades from all directions and cannot move. A refuge is considered to be unreachable if all roads leading to it are blocked. The approach used in task allocation and coordination depends on dividing the map and distributing the agents on the regions. Since blockades are initially unknown, stuck agents will be considered in this distribution, which has a big negative effect on the rescue performance, especially for regions with a small number of agents. On the other hand, refuges are used for treating injured civilians and refilling fire brigade tanks and they are the only buildings that do not catch fire. Blocked refuges will prevent the rescue process from being complete and also has a big negative effect on the rescue performance.

Since police forces are the only agents capable of clearing blockades, they are the only ones that do not get stuck. Normally, police forces are assigned to regions as discussed earlier. The approach devised in this paper gives the police forces first the task of freeing all stuck agents and unreachable refuges, then of performing rescue processes in their assigned regions.

2.4 Planning

The planning phase involves the creation of the individual plans created for each agent putting in mind the global goal. In our case, planning is carried through considering the actions required to carry out the individual tasks the agents should perform and the constraints added in the coordination step. Each agent creates its own individual plan taking into consideration its type (police, fire, or ambulance agent) and the cluster the agent is assigned to. All agents will follow the routes that passes by all roads/buildings in their regions. **Ambulance teams** Ambulance teams are assigned the task of rescuing buried civilians and moving injured civilians to refuges. **Fire brigades** are required to scan all the buildings on its route and extinguish any building on fire. When it runs out water, the fire brigade will head to the nearest refuge to refill its tank. **Police forces** will execute two consecutive plans. First they will move to their assigned region for freeing all stuck agents and blocked refuges. Then they will move to their main region in which they will keep searching for blocked roads and clear them.

2.5 Coordination after Planning and Execution

Coordination after planning was carried out dynamically during the execution of the agents' plans. It mainly consists of utilizing multi-agent communication and adding a criteria to have agents change it's region.

Communication. Communication is mainly used to exchange information on the rescue events that require attention. Communication messages are divided into informative and query messages. Informative messages inform other agents of sensed fires, blockades, and buried civilians.They are sent by agents that detect events they cannot act up on. On the other hand, query messages ask for help from agents of the same type as the sender. They are sent when an agent realizes that it cannot perform a rescue action on it's own.

Changing Region. An agent can change its assigned region during execution. Changing regions is only allowed in one of two cases: 1)changing region temporarily in response to a communication message informing of an event in a different region the returning to the original region, 2) and when an agent does not find any rescue events in its region. In the second case, the agent will change its region if there are no more events that it can handle in its region. If some regions are overloaded with rescue events, none of its agents will change regions. On the other hand, agents in other regions that are either event free or with handled events will keep changing regions until they reach the overloaded region. This will accumulate all free agents in the overloaded regions.

3 EVALUATION

The main performance measure used to judge the efficiency of the implemented approach was the final simulation score of the rescue simulation. The score is automatically calculated by the simulation kernel. The full detailed scores of the 2011 competition can found on the RoboCup Rescue Simulation (`http://roborescue.sourceforge.net/`).

3.1 Results and Ranking

Our team, `RMAS_ArtSapience` reached the final round of the 2011 competition and ranked third after tying on the 2nd place in total ranking but lost to score difference. Our evaluation is based on two types of maps: maps with communication enabled and communication-less maps.

Map with Communication The maps with agent communication enabled are designed to test the ability of the agents to detect the fires early in the simulation and coordinate with other agents through communication to extinguish the fires and clear the blocked roads around the fires. Our team ranked in most cases in the top 4 in these maps. Table 1 shows the results in some chosen samples from the 2011 competition. The main strength of our approach is the efficient agent distribution. Police forces where able to spread through the map and clear most of the blockades fast enough during the simulation.

Communication-less Maps. The communication-less maps did not allow the use of multi-agent communication. This made it hard for the agents to discover the location of fires. In addition to that, fires started randomly during the simulation, which furthermore increased the fire discovery challenge. The scenario is designed to mainly test how agents will perform in the absence of communication and how it affects their rescue actions.

Our approach was able to control the fires more efficiently than the other teams. This was due to efficient distribution of the agents over the map achieved through the use of clustering without depending on agent communication. The final scores, as seen in table 2, showed that in some cases our team achieved a significantly higher scores than all other teams competing in the map.

Table 1: Top 4 scores for thee maps with communication enabled.

Map	Paris3	Istanbul3	Berlin3
1^{st} Rank	IAMRescue	Poseidon	SEU_RedSun
Score	12.8098	66.1779	128.06
2^{nd} Rank	RoboAKUT	SEU_RedSun	RoboAKUT
Score	9.9392	60.9769	121.58
3^{rd} Rank	Poseidon	**Our Team**	MRL
Score	9.7506	59.8821	119.50
4^{th} Rank	**Our Team**	IAMRescue	**Our Team**
Score	9.2929	49.2957	112.2160

Table 2: Top 4 scores for thee maps with communication enabled.

Map	Berlin4	Paris5	Kobe4
1^{st} Rank	**Our Team**	**Our Team**	**Our Team**
Score	140.95	15.51	90.64
2^{nd} Rank	SEU_RedSun	SEU_RedSun	SEU_RedSun
Score	132.01	12.4263	80.36
3^{rd} Rank	RoboAKUT	Poseidon	Poseidon
Score	131.33	8.5938	77.76
4^{th} Rank	Poseidon	IAMRescue	IAMRescue
Score	130.46	0.9531	73.10

REFERENCES

Bezdek, J. C. (1981). *Pattern Recognition with Fuzzy Objective Function Algorithms*. Kluwer Academic Publishers, Norwell, MA, USA.

Bezdek, J. C., Ehrlich, R., and Full, W. (1984). Fcm: The fuzzy c-means clustering algorithm. *Computers & Geosciences*, 10(2-3):191–203.

Kitano, H. and Tadokoro, S. (2001). RoboCup Rescue: A Grand Challenge for Multiagent and Intelligent Systems. *AI Magazine*, 22(1).

Skinner, C. and Ramchurn, S. (2010). The RoboCup Rescue Simulation Platform. AAMAS '10, pages 1647–1648.

Weerdt, M. D., Mors, A. T., and Witteveen, C. (2005). Multi-agent planning: An introduction to planning and coordination. *In: Handouts of the European Agent Summer*.