Coordination of Ambulance Team Agents in Rescue Simulation Using Auction Strategy

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Abstract. RoboCup Rescue Simulation System is a large-scale, real-time and multi-agent simulation of urban disaster. The problem introduced by RoboCup Rescue brings up several research challenges that go from Intelligent Robotics to Multi-Agent Systems (MAS) research. The goal is to coordinate and control the emergency services in the city to minimize damage and injuries resulting from the disasters. In this paper a new method based on market-based method auction strategy for coordination of the ambulance team agents is proposed which can simultaneously uses the power of centralized and decentralized approaches for better coordinating of worker agents. The results of simulations show that the proposed method has better performance in comparison with the other methods coordination systems that were used in RoboCup 2010 International competitions.

Introduction

A multi-agent system (MAS) is comprised of a collection of autonomous and intelligent agents that interact with each other in an environment to optimize a performance measure [1]. RoboCup Rescue Simulation System is a large-scale, real-time and multi-agent simulation of urban disaster [2]. For robotics and multi-agent researchers, RoboCup Rescue works as a standard platform that enables easy comparison of research results. The problem introduced by RoboCup Rescue brings up several research challenges that go from Intelligent Robotics to Multi-Agent Systems (MAS) research. These research challenges include real-time flexible planning, multi-agent coordination and team formation, path planning and navigation, heterogeneous resource allocation and machine learning at the team level. In fact, the main goal in this domain is minimizing the damage by helping trapped agents, extinguishing fiery collapsed buildings, and rescuing damaged civilians. There are several studies about cooperating and coordinating agents, communication, negotiation, distributed problem solving. Coordination of the agents is one of the highly rated subjects in this field which falls into three main categories: centralized, decentralized and a combination of previous methods.

Several coordination strategies are used in Robocop Rescue Simulation challenges. For example, ResQ Freiburg [3] implements a centralized mechanism for the Fire Brigade agents which send agents current and next targets by means of a leader. Caspian [4] combines the centralized and decentralized coordination approaches and regards the partitioning strategy as a social law, applying it to all the rescue agents. S.O.S [5] divides the FireBrigade agents into several teams, each team works together to accomplish the pre-assigned tasks. SBCe_saviour2004 [6] uses centralized coordination strategy and sets up a virtual center that coordinates all the decisions made by central agents. Impossibles [7] used an auction system for decentralized task allocation amongst their fire brigade agents. Chou and Marsh [8] used a decentralized multi-agent coordination architecture based on contract net protocol.

In this paper a new method based on market-based method (auction strategy [9]) for coordination of the ambulance team agents is proposed which benefits from both centralized and decentralized approaches for better coordination of worker agents. The content of this article is as followed: After introduction, a brief description to RoboCup Rescue Simulator will be presented, then, Market based task allocation is explained, after that proposed algorithms are introduced, then, we will evaluate the proposed algorithms in RoboCup Rescue Simulator and compare them with some other participants of RoboCup 2010 competitions (as benchmark). Finally, The Conclusion is presented.

RoboCup Rescue Simulator

RoboCup Rescue simulator is a multi-agent system, first introduced in [10]. The goal of the system is to study the progress of rescue operations in a simulated part of a city (disaster space). The same as real life there are destructed buildings, burning buildings, blocked roads and injured civilians in the simulated disaster space.

There are three types of rescue agents with specific capabilities in rescue simulation system: ambulance agents are able to recover buried civilians, and transfer them to refuges where they can be tended to; fire fighter agents are able to extinguish fires, and police agents are able to clear blocked roads. An example of such simulated environment is illustrated in Figure 1.

The simulated environment is highly dynamic and Agents have to plan and decide their actions asynchronously in real-time, so single agents can make less remarkable effect on rescue processes without coordination and cooperation of other participant agents, therefor there is a real emphasis on coordinating agents to work better. There exists an evolution criterion in the simulation environment which names as score and obtained from Eq.1 [11].

$$score = (P + \frac{H}{H_{init}}) \times \sqrt{\frac{B}{B_{Max}}} \quad (1)$$

Where P is the number of civilians alive, H is the amount of health point of all agents and the ratio to the number of civilians alive initially, H/Hinit, shows the efficiency of operations, B is the area of houses that are not burnt, and BMax is the area of all houses.

As it is shown from Eq.1 the civilian health is very high on the final score, thus rescuing civilians as fast as possible with attention to their injury degree is a critical problem of this domain.

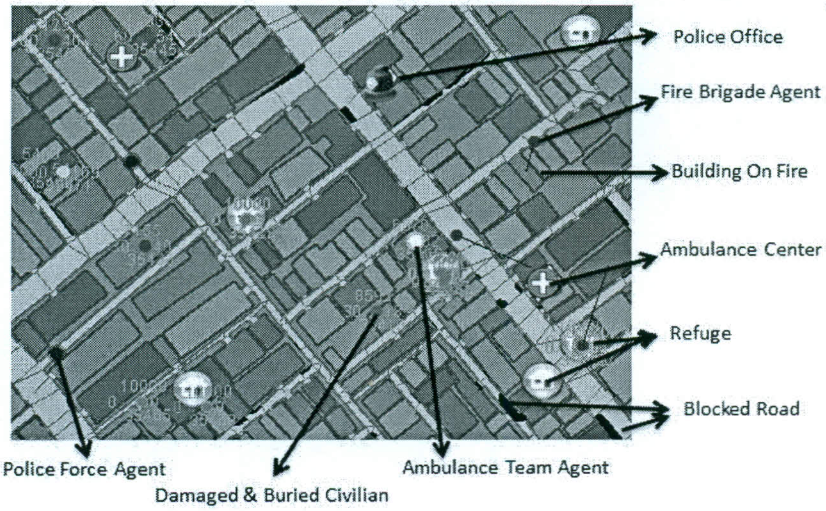

Fig.1. A Simulated disaster environment in Rescue Simulation system

Market-Based Multi-agent Coordination

There is a variety of coordination methods which falls into three main categories: Centralized methods, Decentralized and Market-based methods. Market-based methods are a combination of centralized and decentralized methods which benefits from both centralized and decentralized methods advantages [12].

As mentioned above, the principles of a market economy can be applied to multi-agent coordination. In this virtual economy, the agents are traders, tasks and resources are traded commodities, and virtual money acts as currency. Agents compete to win tasks and resources by participating in auctions that produce efficient distributions based on specified preferences. When the system is appropriately designed, each agent acts to maximize its individual profit and simultaneously improves the efficiency of the team.

Abstractly, an auction takes place between an agent known as the auctioneer and a collection of agents known as the bidders and the goal of the auction is for the auctioneer to allocate the good to one of the bidders [13].

There exist several protocols for auction settings which have differences in some dimensions as winner determination, bid awareness, and bidding mechanism [14]. As an example there could be an auction setting which uses first-price or second-price auctions for winner determination, open cry or sealed-bid methods as to different methods of knowledge awareness and one shot or ascending auctions as its bidding mechanism.

The Proposed Method for Ambulance Team Agents

In this section, we introduce the proposed method based on the concept of marketing to enhance the ambulance team agents' coordination. In this method, an auction takes place between the ambulance team agents. The goal of the auction is for the auctioneer to allocate an optimum number of ambulance team agents to an injured civilian so that the number of living civilians is maximized and minimizing the number of perished civilians at the end of the simulation. For implementing the auction model, it is assumed that two types of agents are defined: Leader agents and Worker agents. Leaders are auctioneers and workers are bidders that perform the tasks which are assigned to them. It should be mentions that a leader could act as a worker as well.

Considering the definition of a market-based method and as will introduced in next sections; in proposed method, first-price method is used for winner determination, one shot method is used for bidding mechanism and open cry method is used for their bidding awareness. The proposed algorithm, called Algorithm 1, and its structure and its pseudo code are given in more detail in Figure 2 and Figure 3 respectively.

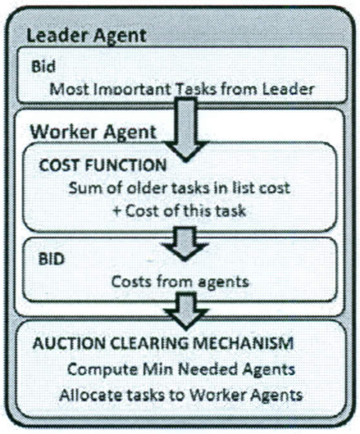

Fig. 2. Structure of the proposed algorithm

Auction Setup. In proposed method there is a constant, pre-defined schedule for beginning auctions that are called Auction Time.In each auction time there is only one agent (Leader) as the auctioneer. The Leader selects m most important (Level of importance is measured by a variable named Time to Death (TTD) which defines the remaining time cycle for a specific civilian to die, from the perspective of system or a mixture of some other parameters (Eq.1 and Eq.2)) injured civilians for auction and runs the auction. In another word Leader sends a list of m civilians and informs other agents to send their bid for an incoming auction. Workers take part in started auctions as bidders and submit their bids for every m civilian in auction considering the situation and status of themselves and status of target civilian.

Market with Leader Initiator Auction
Leader Agent

While(simulation is not ended){
if it is Auction Time {
Find m most valuable victims;
Put selected victims to sell as leader bids;
{
if it is Time to get worker bids {
Compute needed agents for each bade victims;
Find winner/winners of each bade victim;
Broadcast winners of all bade victims;
{
Do assigned tasks based on task list;
}

Worker Agent

While(simulation is not ended){
if it Time to get leader bid/bids {
compute cost /utility for each leader bid;
send bid for each leader bid;
{
If it is Time to get winner {
if I am winner{
add won victim to task list;
}
{
Do assigned tasks based on task list;
}

Fig.3. Pseudo code of the proposed algorithm

$$\text{Importance} = F\,(\text{TTD, BRD, ATA}) \tag{2}$$

$$F\,(\text{TTD, BRD, ATA}) = w_1 \times TTD + w_2 \times BRD + w_3 \times ATA \tag{3}$$

Here BRD and ATA respectively stand for Buried property (the amount of collapse on a victim) and Ambulance Team Around (number of ambulance teams nearby the victim).

Task Management byAgents. Considering that leader put m injured civilians in each auction, there is a probability that workers win in another auction before finishing their previous task. This could happen for many times and agents need to stack up their tasks in a list. This helps to calculate bids more precisely as well.

Bidding Mechanism. Each worker agent could announce its preparation for bidding after receiving the auction schedule message considering its current status and circumstances of the simulated environment.

This bid could be as a cost of service or a profit from service. In this article, cost of service is considered for bidding in a way that with m task in agent's task list next bid will be calculated by Eq.4.

$$\text{CostFunction} = \sum_{i=1}^{m} t_{rescue}\,(Civilian_i) + \sum_{i=1}^{m} t_{move}(i\,,i+1) \tag{4}$$

In this equation t_{rescue} is the time needed for rescuing i_{th} injured civilian and t_{move} is move cost-function from an injured civilian to next injured civilian.

Task Assignment (Winner Determination). If we use the cost of service method (as considered in this article), after calculating the number of needed agents, the leader will announce the agents, with minimum cost-function to rescue the civilian, as winners of auction and assigns the target to them.In another hand if we use the profit from service method, leader will assign the task to agents with higher bids. It should be noted that phrase "Compute needed agents" in Fig. 1 that represents the number of needed ambulance team agents needed for rescuing an injured civilian which is the minimum number of agents that is needed to rescue that civilian and bring him/her to refuge alive.

Simulations and Results. The proposed method is implemented for ambulance team agents of MRL team. MRL is one of the most successful teams that take part in International RoboCup Competitions and other competitions like IranOpen. In order to measure the functionality of this method, we have compared the test results with test results of roboAKUT [15], RiOne [16] which took place in 1st, 4th in RoboCup 2010 respectively [17]. Studied parameters in this comparison are shown in table 1.

Table 1. Comparison parameters

Parameter Name	Definition
Score	Final score of simulation
Alive Civilians	Number of alive victims at the end of simulation
Dead Civilians	Number of victims which die before simulation ended
Sum Of HPs	Sum of Health Points of victims at the end of simulation
Sum Of DMGs	Sum of damages of victims at the end of simulation

Score is a standard parameter that represents the total functionality of agents in n time cycles of simulation, higher value in score is better. The higher Alive Victims and Sum of HPs show the better performance. In contrast, less Dead Victims and Sum of DMGs are better. In order to obtain comparison parameters we ran simulation on Kobe, VC, Berlin and Paris maps with listed parameters in Table 2. As it is obvious by Table 2, Berlin and Paris maps are so bigger than two other ones and have more injured civilians, so their conditions are more critical.

To get precise results, each method executed 5 times and the average of those results listed in Table 3-7.

Table 2. Map parameters in our experiments

Parameter / Map	Civilians	Ambulance Teams	Refuges	Dimensions
Kobe	169	10	5	450×350
VC	162	10	5	430×440
Berlin	199	10	4	2200×1650
Paris	196	10	5	1000×1000

Table 3.comparison of different methods in different maps in terms of Score parameter.

	Method / Map	RiOne	roboAKUT	LIA_1	LIA_2	LIA_3	LIA_4	LIA_5
Score	Kobe	63.225	67.288	69.567	77.441	72.446	74.653	75.658
	VC	40.146	41.95	41.689	53.312	49.718	49.919	50.72
	Berlin	44.093	45.339	35.686	49.115	54.125	53.938	48.533
	Paris	41.475	44.124	36.67	43.081	54.096	48.898	46.098

Table 4. Alive Civilians comparison of different methods in different maps

	Method / Map	RiOne	roboAKUT	LIA_1	LIA_2	LIA_3	LIA_4	LIA_5
Alive Civilians	Kobe	63	67	69.333	77.2	72.2	74.4	75.4
	VC	40	41.8	41.6	53.2	49.6	49.8	50.6
	Berlin	44	45.2	35.6	49	54	53.8	48.4
	Paris	41.4	44	36.6	43	54	48.8	46

Table 5. Dead Civilians comparison of different methods in different maps

	Method / Map	RiOne	roboAKUT	LIA_1	LIA_2	LIA_3	LIA_4	LIA_5
Dead Civilians	Kobe	106	102	99.667	91.8	96.8	94.6	93.6
	VC	122	120.2	120.4	108.8	112.4	112.2	111.4
	Berlin	155	153.8	163.4	150	145	145.2	150.6
	Paris	154.6	152	159.4	153	142	147.2	150

Table 6. Sum Of HPs comparison of different methods in different maps (values are changed to (value - 100000) /5000)

	Method / Map	RiOne	roboAKUT	LIA_1	LIA_2	LIA_3	LIA_4	LIA_5
Sum Of wHPs	Kobe	56.099	77.269	58.857	61.33	63.302	65.455	67.123
	VC	27.217	28.641	8.865	16.345	18.259	18.467	18.817
	Berlin	16.991	35.362	14.339	25.898	29.933	35.027	32.932
	Paris	9.524	28.694	7.408	11.851	17.826	18.283	18.578

Table 7. Sum Of DMGs comparison of different methods in different maps (values are changed to (value-140000)/200)

	Method / Map	RiOne	roboAKUT	LIA_1	LIA_2	LIA_3	LIA_4	LIA_5
Sum Of DMGs	Kobe	58.435	59.635	56.846	52.167	55.021	54.801	53.635
	VC	73.584	71.572	70.25	64.471	65.377	66.029	65.246
	Berlin	91.925	93.851	98.705	89.98	85.096	86.02	90.4
	Paris	92.365	91.92	95.522	90.52	85.274	86.631	88.833

As it is shown from Table 3-7, there are different methods in LIA that the difference is in the number of injured civilians that leader puts in auction (LIA_1 one civilian, LIA_2 two civilians …). Due to the results it is obvious that LIA methods have better results comparing to other methods but according to the map conditions, if the map is not huge like Kobe and VC, then the LIA_2 method is the best one and if the map is huge then the LIA_3 has best overall result.

Considering Table 6, it seems that roboAKUT acts better than all other methods to save more HPs, but making a glimpse at Table 7 it will be shown that it got more DMGs too, which resulted in getting less overall Score.

Alongside these positive results this method has some shortcomings that need solutions. Some of these shortcomings are as follows:

- This system needs a high bandwidth for setting the auction, which is problematic in noisy and limited communication conditions.
- Delay in assignment. Because there are only a few targets for sale at auction there is a possibility that system fails to assign agents too all targets in auction time therefore some injured civilians remain unattended and may perish before ambulance teams could rescue them.
- In case of a big number of injured civilians (m) agents have to stack up their assigned tasks; this makes the calculation of cost function more complex and less precise in every step. As mentioned these data are used as bids in auctions which directly affect the precision of leader decision making system. This works as a destructive cycle and has negative effects on overall results.

As you could see in fig. 4 according to part 2 and 3 of this section LIA_3 method has better result by holding more auctions but it will demand more bandwidth due to a huge amount of messages needed for every auction

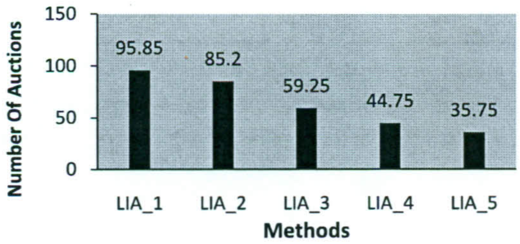

Fig.4. Comparison of Auction times in different proposed methods

There is a lot of load on the leader to hold auction, task assignment and communication with all workers; this makes the leader a bottleneck for this system due to a limited process time for each agent and may cause action timeout for leader which means the simulation kernel ignores the leader action commands and leader misses a cycle.

Conclusion

This paper presented an auction-based method for coordination of ambulance team agents in Robocop Rescue Simulation. A brief overview of market-based approaches had been presented and Robocop rescue simulation described as a great challenge for multi-agent coordination mechanisms. After presenting a detailed discussion on proposed method, comparisons between higher statuses in Robocop2010 and different methods of auctioning had been introduced. It had been shown that LIA_2 with m=2 injured civilians for each auction had best overall results in normal maps and LIA_3 with m=3 injured civilians had best overall results in huge maps.

In an overview the proposed method has the best results comparing other methods of other multi-agent coordination systems that were used in RoboCup 2010 International competitions but of course this method has its own shortcomings such as: requirement for high bandwidth communication, delay in assignment and need for a leader as a coordinator of other agents. In future works it is possible to address these problems with changing the marketing system.

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