Coordination of Ambulance Team Agents in Rescue Simulation Using Auction Strategy with Obstinate Agents

Pooya Deldar Gohardani[1], Peyman Ardestani[1], Behrooz Masoumi[1], Mohammad Reza Meybodi[2], Siavash Mehrabi[1]

[1]Mechatronic Research Labratory, Islamic Azad University, Qazvin Branch, Qazvin, Iran
[2]Department of Computer Engineering and IT, Amirkabir University of Technology, Tehran, Iran

{Pooya.Deldar, Peyman.Ardestani, Masoumi}@Qiau.ac.ir
Siavash.Mehrabi@gmail.com
mmeybodi@aut.ac.ir

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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 goes 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.
This paper proposes an agent coordination approach based on an auction strategy for the definition of rescue team agents in disaster environment. The approach is experimented in the context of the RoboCup Rescue Simulation system and its performance is compared with other coordination methods. Finally, some simulation results are documented.

1. 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 RoboCup 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 uses obstinate agents and benefits from both centralized and decentralized approaches for better coordination of *independent* worker agents. In this paper agents don't follow the leaders bid and they make their own decisions for bidding which has better performance. The content of this article is as follows: Section 2 is a brief introduction to RoboCup Rescue Simulator. Market based task allocation is explained in section 3. Section 4 introduces the proposed algorithms. In section 5, we will evaluate the proposed algorithms in RoboCup Rescue Simulator and compare it with some other participants of RoboCup 2010 competitions (as benchmark). Finally, the Conclusion is in section 6.

2 RoboCup Rescue Simulator

RoboCup rescue simulation is a complex multi-agent system first introduced by Tadokoro [10]. Aim of the system is to simulate a part of a city to study the process of controlling a disaster using rescue agents.

Due to the disaster some buildings suffered damage caused by fire or collapse and some civilians are injured. There are three types of agents to control the disaster that are Fire Brigade Agents, Police Fore Agents and Ambulance Team Agents. Each agent has a specific responsibility; The Fire Brigades are to put off the fire, Police Force Agents clear the blocked off the roads so that other agents could pass through them and Ambulance Team Agents help injured civilians and transfer them to the refuges. You could see a simulated part of Berlin, Germany in Fig. 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; therefore 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, note that each civilian in this system have a stamina equal 10000 and health point is a number in range [0, stamina], unharmed civilians have a health point equal 10000 and if the civilian has any damage it's health point decreases every cycle based on the damage. H/H_{init}, shows the efficiency of operations, B is the summary of buildings area that are not burnt, and B_{Max} is the area of all houses.

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

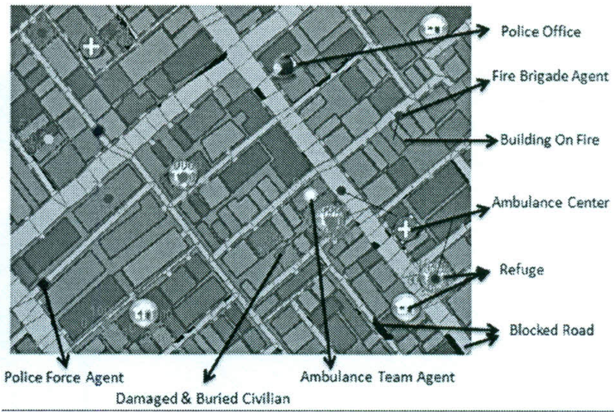

Fig. 1. A Simulated disaster environment in Rescue Simulation system

3 Market-Based Multi-agent Coordination

There is a variety of coordination methods which fall into three main categories: Centralized methods, Decentralized and Market-based methods. Market-based methods are a combination of centralized and decentralized methods which benefit 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.

4 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 with a new auction method based on obstinate agents. 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.

But the difference between this approach and other market-based approaches is the use of obstinate agents in the process of auctioning so that participant agents participate in the auction independent from leader bids as obstinate agents, this means no agents wait for leader bids to participate in the auction but if any agent needs a target, it would participate at the auction.

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 be 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 MOA (Market with Obstinate Agents), and its structure is given in more detail in Fig. 2 and Fig. 3 respectively.

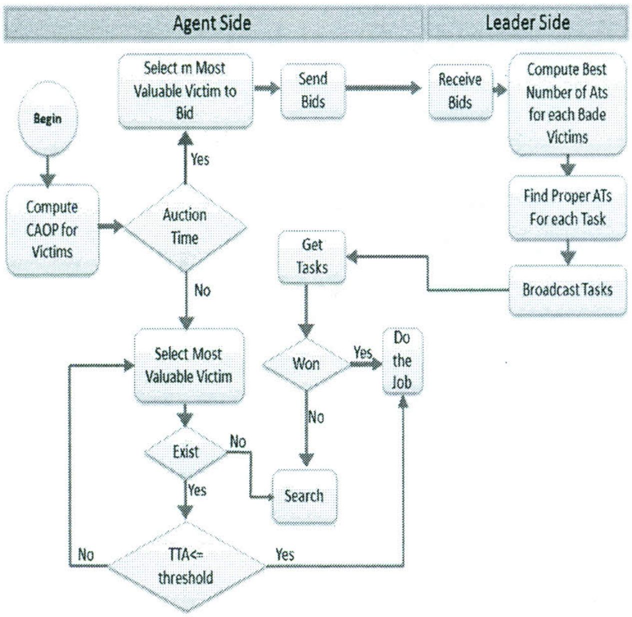

Fig. 2. *Structure of the proposed algorithm*

This proposed method is based on a simple form of market based approach which we named it as LIA(Leader Initiator Auction) which means there exist a leader agent to start the auctioning process. The main structure of LIA is shown in Fig. 3.

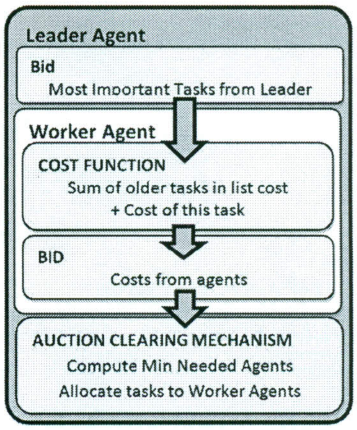

Fig. 3. *Structure of the proposed algorithm*

As Fig. 3 shows in previous approaches auctions are pre-scheduled to a specific interval, Leader puts most valued task in auction according to its own perception then workers evaluate each task using Eq.2 and Eq.3 and take part in auction by sending evaluated task values to the leader. In newly proposed method, only workers that are almost finished their task and the ones with no task, evaluate targets importance using Eq.4 take part in auction. Each agent calculates importance of the available targets using Eq.2 and sorts targets by importance, and then it sends m most important targets as its bid to leader. Leader estimates the number of agents needed to rescue each injured civilian, and then assigns task to workers by sending assignment message to them.

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

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

$$\text{UtilityFunction=f(HP,DMG,BRD,TTA)} = \frac{DMG * \alpha}{HP*BRD*TTA} \tag{4}$$

Here DMG stands for Damage (the amount of damage which effects the HP so that HP = HP – Damage every cycle), HP is health point of civilian, BRD (Buried) means the amount of collapse on a victim and TTA is the estimated time cycle remained to reach the target, and α is a normalization coefficient equal to HP maximum value.

4.3. Bidding Mechanism

In LIA method 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 tasks in agent's task list next bid will be calculated by Eq.4.

$$CostFunction = \sum_{i=1}^{m} t_{rescue}\,(Civilian_i) + \sum_{i=1}^{m} t_{move}(i\,, i+1) \tag{٥}$$

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

In new approach there is no need to estimate the time needed to finish the tasks for agent because only free agents take part in auction so system only uses Eq.4. thus it is more precise.

4.4 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 civilians, as winners of auction and assigns the target to them.

On the other 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.2 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.

5 Simulations and Results

The proposed method is implemented for ambulance team agents of MRL team [tdpIO2011][tdpRC2011]. 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 of this proposed method with test results of roboAKUT [15], RiOne [16] teams which took place in 1st, 4th in RoboCup 2010 competitions respectively [17] and a simple approach of market based method which we implemented it on Robocup rescue domain and named it LIA (Leader Initiator Auction) which means a leader exist to start the auctioning as the auctioneer.

Studied parameters in these comparisons 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_2	LIA_3	*MOA*
Score	Kobe	63.23	67.29	77.44	72.45	82.26
	VC	40.15	41.95	53.31	49.72	56.13
	Berlin	44.09	45.34	49.12	54.13	58.73
	Paris	41.48	44.12	43.08	54.10	52.31

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

	Method / Map	RiOne	roboAKUT	LIA_2	LIA_3	*MOA*
Alive Civilians	Kobe	63	67	77.2	72.2	82
	VC	40	41.8	53.2	49.6	56
	Berlin	44	45.2	49	54	58.6
	Paris	41.4	44	43	54	52.2

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

	Method / Map	RiOne	roboAKUT	LIA_2	LIA_3	*MOA*
Dead Civilians	Kobe	106	102	91.8	96.8	87
	VC	122	120.2	108.8	112.4	106
	Berlin	155	153.8	150	145	140.4
	Paris	154.6	152	153	142	143.8

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

	Method / Map	RiOne	roboAKUT	LIA_2	LIA_3	*MOA*
Sum Of HPs	Kobe	56.10	77.27	61.33	63.30	69.13
	VC	27.22	28.64	16.35	18.26	23.01
	Berlin	16.99	35.36	25.90	29.93	33.02
	Paris	9.52	28.69	11.85	17.83	21.14

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

	Method / Map	RiOne	roboAKUT	LIA_2	LIA_3	*MOA*
Sum Of DMGs	Kobe	58.43	59.64	52.17	55.02	50.2
	VC	73.58	71.57	64.47	65.38	63.15
	Berlin	91.93	93.85	89.98	85.10	85.37
	Paris	92.37	91.92	90.52	85.28	87.2

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 …). It is considered to show LIA_2 and LIA_3 results due to their better results between other types of LIA method.

As it is shown from Table 3-7, it is obvious that market based methods have better results than other approaches but then between these market based methods, MOA approach had better results in most scenarios. In more details, without considering the MOA method, 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 but when considers the MOA method, it says its strength by its better results.

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 previous method, simple market-based method (LIA) has some shortcomings that need solutions. Some of these shortcomings are as follows:

1. This system needs a high bandwidth for setting the auction, which is problematic in noisy and limited communication conditions.
2. 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.
3. 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. 3 section LIA_2 and LIA_3 method have better result by holding more auctions but it will demand more bandwidth due to a huge amount of messages needed for every auction.

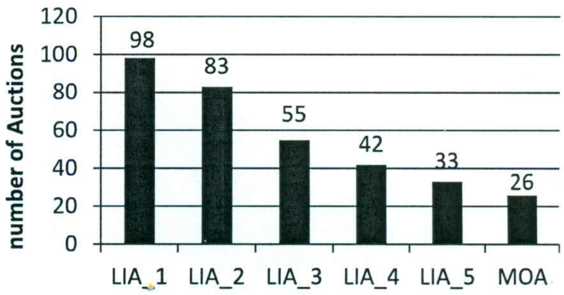

Figure 3. Comparison of Auction times in different proposed methods

4. 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.

The new approach covers some shortcomings in LIA approach; it significantly reduces the communication bandwidth needed which is one of the most important problems in LIA. In this system leader does not send the available options to workers; Workers send bids to leader when they need a new target instead. And leader will only assigns the targets. So the bidding communication over head is reduces plus each auction will take 2 cycles (Workers send bids, Leader assigns tasks) instead of 3 cycles (Leader sends available options, Workers send bids, Leader assigns tasks). In another words by avoiding excess auctions we save more time and more bandwidth. This approach also addresses the 3rd and 4th problems by root cause elimination; because there will be no task queue to manage and no need to estimate the time that agent will finish queued tasks which depends on other agents' cooperation.

6 Conclusion

This paper presented an auction-based method for coordination of ambulance team agents in RoboCup Rescue Simulation. A brief overview of market-based approaches had been presented and RoboCup rescue simulation described as a great challenge for multi-agent coordination mechanisms. After presenting a detailed discussion on proposed method, comparisons between LIA methods as simple form of market-based approaches in this area and higher statuses in RoboCup2010 had been introduced.

Results shows that market based approaches has good performance on multi-agent environments and specially in Rescue Simulation Platform, However market-based systems demand overhead on communication and process; we tried to address these problems using methods involving obstinate agents that demand less communication and help to distribute the process.

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