A Multi-Agent Rescue Operation in a LBS Environment

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Abstract. Reduction of rescue operation time is of prime importance to minimize the risk associated with accident management in urban road traffic networks. With the ever increasing of urban traffic, rescue operation has to be improved. On the other hand, implementation of smart traffic and smart rescue operation within the framework of smart care is essential to establish a smart city. One of the most important steps for smart traffic and smart care concepts is to expedite the transfer of the injured caused by car accidents in urban traffic networks to the nearest and specialized medical centers. Traffic congestion in the urban traffic networks will decrease the efficiency of the rescue operation. This paper aims to propose a multi-agent based modeling to control traffic to expedite rescue operation. In order to achieve the aim, two solutions have been considered including the control of the traffic at road junctions for smooth movement of an ambulance as an agent and its interaction with other vehicles and traffic lights as other agents in the multi agent simulation. The second solution has been implemented as a location-based service (LBS) which leads to communicating some massages from the ambulance to the vehicles passing at the some lane to move to their nearest parking lots. This move aids the smooth passage of the ambulance in an obstacle free path. The two solutions have been simulated in Anylogic multi-agent software using three accident spots and a selected medical center in Tehran, capital of Iran. The scenario of this rescue operation is to simulate the transfer of the car accident injured from the three selected spots to Tehran Health Center based on the two solutions. In addition, the proposed methodology is tested

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using three case studies where the injured is transferred to the Tehran Health Center using the ambulance moving along with some other vehicles in the same route. The second case study consists of changing traffic lights to green based on the messages communicated to the traffic lights. The third case study considers the second one in addition to the messages which have been sent to the vehicles at the same route by the ambulance in order to guide the vehicles to their nearest parking lot. The results verified that up to 50% time reduction of the rescue operation could be achieved comparing the first and the third case studies.

Keywords. LBS, Rescue, Multi-Agent, Simulation, Smart city, Smart traffic, Smart care

1. Introduction

Emergency operation occurs anywhere at any location, at any time, and in various ways for those who are at risk. These situations require an urgent and informed response. Therefore it is very important to employ direct, fast and efficient actions to minimize the associated risks. With the increasing number of population in the metropolitan areas, the problem of traffic congestion has grown to an alarming situation. This problem has to be properly analyzed and the appropriate measures have to be taken. Even if each and every vehicle passing through the traffic has its own need, the prime importance is given to the ambulance and other emergency vehicles which should not wait in the traffic thereby decrease the probability of risk. Transfer of a patient to hospital in emergency seems very sensitive during peak urban traffic hours. Optimum utilization of the time after an accident in the golden hours of the accident management is a measure of effectiveness of an emergency response service provider system (Sangeetha et al. 2014).
Sonika et al. (2014) introduced a new vivid scheme called intelligent transportation system (ITS). The concept of this scheme was to green the traffic signal in the path of ambulance automatically with the help of radio frequency (RF) module. This will asist the ambulance to reach the accident on time and save human life. In this case, the the accident location will be introduced to the main server. The main server finds the nearest ambulance to the accident zone and sends the exact accident location to the emergency vehicle. The control unit monitors the ambulance and provides the shortest path to the ambulance at the same time to controll the traffic lights

according to the ambulance location and speed and thus arriving at the hospital safely. Bhandari Prachi et al. (2014) implemented the new system in which there is an automatic detection of accident through sensors provided in the vehicle. A main server unit has access to the database of all hospitals in the city. global positioning system (GPS) and global system for mobile communications (GSM) modules in the concerned vehicle will send the location of the accident location to the main server to call an ambulance from the nearest hospital to the accident spot. Along this there would be control of traffic light signals in the path of the ambulance using RF communication. A patient monitoring system in the ambulance will send the vital parameters of the patient to the concerned hospital. This system is fully automated, thus it finds the accident spot, controls the traffic lights, helping the ambulance to reach the hospital on time. López et al. (2008) developed a multi-agent system for coordinating ambulances for emergency medical services. The system architecture consist of some ambulance team agents and an ambulance coordinator agent. The ambulance coordinator agent collects requests for services from other external agents (including human operators). The medical service consists of reaching to the patient's location, giving the patient first aid, and transfering the patient to the appropriate medical center. Using a *winner determination algorithm*, the ambulance coordinator agent selects the ambulance to which it assigns the service. An ambulance team agent's goal is to estimate the time required to perform a service according to the ambulance current location using GPS infrastructure availability, and crew, and the traffic conditions. So, the time to get to the patient decreases.
In this article the interaction of smart traffic and rescue operations is considered as a multi-agent simulation (MAS). Intelligent transportation systems (ITS) are needed urgently to improve the road network capacity. MAS provides the actors with different abilities and goals, communicate with them in the common environment through the interaction between the accident messages delivery systems.

A smart city is an urban development vision to integrate multiple information and communication technology (ICT) and internet of things (IOT) solutions in a secure fashion to manage a city's assets which includes local departments information systems, schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement, and other communities services[1]. Smart cities can be identified along six main elements including: smart economy, smart mobility, smart governance, smart environment, smart living and smart people (Li at al. 2013). Smart city is a combination of sensor networks (Li et al. 2013).

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[1] http://en.wikipedia.org/wiki/Smart_city

Of these, smart mobility refers to local and supra-local accessibility, availability of ICTs, modern, sustainable and safe transport systems (Vanolo 2013). Normal traffic light system operates on a timing mechanism that changes the lights after a given interval, however in the smart traffic system, drivers will not spend unnecessary time waiting for the traffic lights change.

Also, smart health is a complement to the concept of mobile health within the context of smart cities that provides a rich context-aware environment (Solanas et al. 2014). *Figure 1* shows different types of smart health in a smart city.

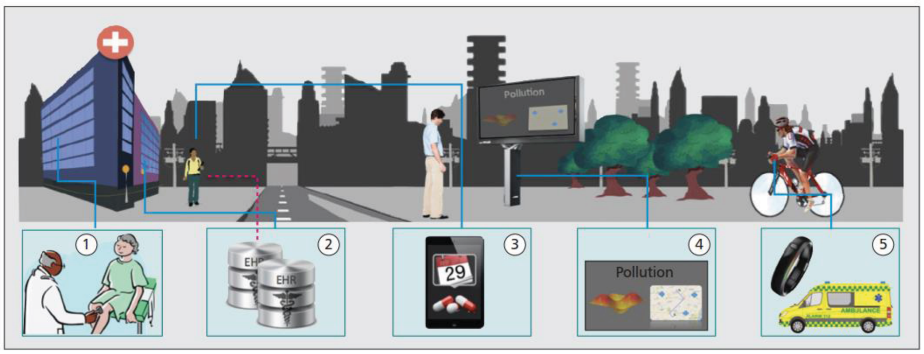

Figure 1. Examples of different kinds of health within the context of a smart city (Solanas et al. 2014)

Diffrent parts of Figure 1 are explained below:

(1) — Classical health. This is a typical health-related activity, that is, a doctor visiting a patient with traditional tools (which do not necessarily involve ICT).

(2) — E-Health. This involves the use of electronic health records (EHR) and databases that store medical information of patients.This is a subset of classical health that uses ICT.

(3) — M-Health. An example is a patient checking his/her prescriptions from his/her mobile phone to guarantee medication adherence. This is a subset of E-health since it uses mobile devices to access medical data.

(4) — S-Health. A patient gets information from an interactive information pole to check the pollution level as well as the level of pollen and dust for which he/she has allergies.Thanks to this information, the patient can avoid areas that could be dangerous for his/her health condition. The information pole informs him/her about the best route to go, and where the closest pharmacies are to buy antihistamine pills.

(5) — M-Health augmented with S-Health. A cyclist wearing a bracelet with accelerometers and vital constants monitoring capabilities has an

accident. The body sensor network detects the fall and sends an alert to the city infrastructure. When the alert is received by the system, the conditions of the traffic are analyzed, and an ambulance is dispatched through the best possible route. In addition, the traffic lights of the city are dynamically adjusted in order to reduce the time needed by the ambulance to reach the cyclist (Solanas et al.2014).

A multi-agent simulation for modeling of reduction of arrival time of ambulance in an accident is used in this article. According to the heterogeneity of the involved fields, there is no common agreement about a definition of the term agent (Sengupta and sieber 2007). An agent can be anything, such as a robot that perceives its environment through sensors and acts upon it through its effectors (Russell et al. 2003). This definition is shown in *Figure 2*.

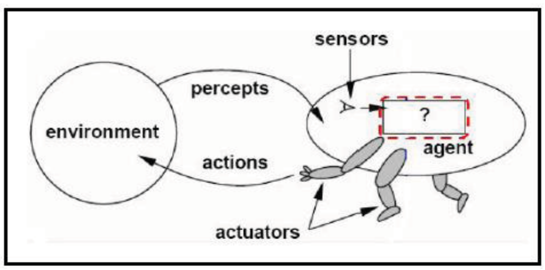

Figure 2. An agent in its environment (Russell et al. 2003)

Agents are autonomous entities or objects which act independently of one another, although they may act in concert, depending upon various conditions which are displayed by other agents or the system in which they exist (Batty and jiang 1999). Franklin and Graesser (1996) formalise the definition of an autonomous agent as "a system situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to effect what it senses in the future". Agents are endowed with behaviours that are usually proscribed in a series of rules that are activated under different conditions. This is in the manner of stimulus and response (or push and pull, or some such reactive logic), and in this sense, agents always engender change (Batty et al. 2012).

Multi-agent systems (MAS) depict systems as a combination of multiple autonomous and independent agents and are therefore well suited to simulate collaboration of different actors (Sokhansefat et al. 2012). A multi-agent system consists of several agents working in cooperation within a single environment, towards a universal goal (Roozemond 2001).

Adapting the definition of Ferber (1999), the term multi-agent system refers to a system consisting of the following parts:
• The environment, E , consisting of the following elements:
- A set of objects O: Objects can be perceived, created, destroyed and modified by agents.
- A set of agents A: Agents are a subset of objects ($A \subseteq O$) capable of performing actions (the active entities of the system).
- A set of locations L determining the possible position of the objects (from the set O) in space.
• An assembly of relations, R ,which link objects and also agents to each other.
• A set of operations ,Op, enabling the possibility for agents to perceive, manipulate, create, destroy objects of O, in particular representing the agents' actions.
• A set of operators U with the task of representing the application of the operations from Op and the reactions of the world to modification. The operators from U are called the laws of the universe.

Rescue operation has been focused especially in urban environment due to the ever-increasing traffic in urban road networks. In terms of rescue operation, in addition to selecting the optimal route from different perspective, control and management of traffic for ambulance movement facilities, is an important factor. On the other hand, interaction and coordination among the ambulances and other vehicles on the road, is of prime importance for a proper rescue operation.

In order to have enough space for the passage of ambulance in a collision free path, some free paths should be allocated. In that case, the ambulance travel times is reduced. This arrangement can make a significant contribution to smart traffic which is an essential element for the creation of smart city.
Therefore, it is recommended to consider intelligent approaches such as Multi-Agent Rescue Operation.
In this article, we are faced with the question that, how do we accelerate rescue operation by ambulance, in a smart city and using its concerned elements and modeling of the multi-agent system by using a location based service? So, the hypothesis of this article is that selecting an optimal route, traffic control and interaction with vehicles and ambulance could accelerate rescue operation and the movement of ambulances. Also equipped ambulances by a GPS navigation system for smart city is supposed.
In this article, the allocation of the hospital to the accident site is not investigated. So, it is assumed that the selected hospital in this article is the best hospital allocated to the accident site. It is assumed that the ambulance is connected with other vehicles in terms of alarms and messages communica-

tion. This connection can be direct or via a communications center between the ambulance and other vehicles. So that other vehicles become aware of the existence of the ambulance on their ways or ambulance can notify them of its existence.
In this article, the transfer of the wounded to the hospital by ambulance is considered. According to the mentioned problems for this rescue operation, a method for reducing the arrival time of the ambulance from the accident site to the hospital is proposed. The proposed method models the message communication the ambulance to other vehicles and traffic lights for evacuating a lane in the urban traffic network for passing the ambulance in the multi-agent simulation software.

The rest of this paper is organized as follows: Section 2 explaines the details of the proposed multi-agent rescue operation, computation of optimal path for ambulance routing and the communications between the proposed agents in Anylogic software. Section 3 explaines input images, the proposed hospital, Anylogic multi-agent simulation software and 3 case studies for implementing of the proposed simulation. Finally section 4 presents results, conclusions and directions for future research.

2. Methodology

In this paper, a method for minimizing the ambulance travel time caused by traffic congestion and providing the smooth flow of emergency vehicles was proposed. According to this method, interaction of smart traffic and rescue operation is considered as a multi-agent simulation in Anylogic software. As shown in *Figure 3*, the proposed multi-agent rescue operation consists of a number of agents such as vehicles, ambulance and traffic lights which coordinate with each other and make sure that ambulance agent reaches the hospital at the shortest possible time.

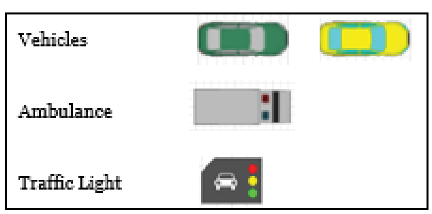

Figure 3. Illustration of the agents proposed in the multi-agent simulation in Anylogic software

Whenever an accident occurs, an ambulance of appropriate hospital is dispatched to the accident site. Selecting the optimal path through an urban traffic road network for transferring the wounded to the hospital by ambulance is an important issue in a rescue operation. The efficient management of ambulance routing from the incident site to the appropriate hospital is a vital aspect of the quality of health services offered to citizens. The routing algorithm is carried out in Anylogic software. This routing algorithm considers time, distance parameter parameters and the changes of traffic congestion for computing the optimal path. This routing algorithm is used for computing the optimal path for the ambulance routing.

The proposed multi-agent rescue operation simulation is divided in three units including the ambulance unit, the vehicle unit and the traffic unit which are explained below.

2.1. The ambulance unit

After finding the optimal path, this path is displayed by a GPS navigation system in ambulance as shown in *Figure 4*. The ambulance agent on the optimal path, sends some messages to existing vehicle agents on the same lane in addition to some messages to pedestrian traffic lights and traffic intersection lights to provide a free space for the vehicle agent crossing the lane to vacate the lane for the ambulance.

Figure 4. GPS navigation system in ambulance

2.2. The vehicle unit

Existing vehicles on the optimal path of the ambulance are received the messages from the ambulance agent and provided a free lane and assigned that lane to the ambulance. On the other hand, when the ambulance sends the messages to the existing vehicles on the streets and junctions, these vehicles updated their knowledge with the messages and withdrawn from the routes and evacuated the lane for the ambulance. The message from the ambulance to the drivers of vehicles will be announced through the GPS navigation system in vehicles as shown in *Figure 5*. In Anylogic software, some parking lots for navigating the vehicles to the side of the optimal path are considered.

Figure 5. GPS navigation system in the vehicles

2.3. The traffic unit

In this paper, intelligent traffic light system for controlling of traffic light signals in the route of the ambulance is considered. When the ambulance reaches within the specific range of the traffic intersection lights and pedestrian traffic lights, sends messages to them, then the traffic lights will change to red for other vehicles. On the other hand, the trafic light agents updated their knowledge with these messages. These traffic lights send a massage to other traffic lights in their neighborhood so they became red. Java codes is used for implementing of traffic unit in Anylogic software. The *Figure 6* shows the summary of the steps of project.

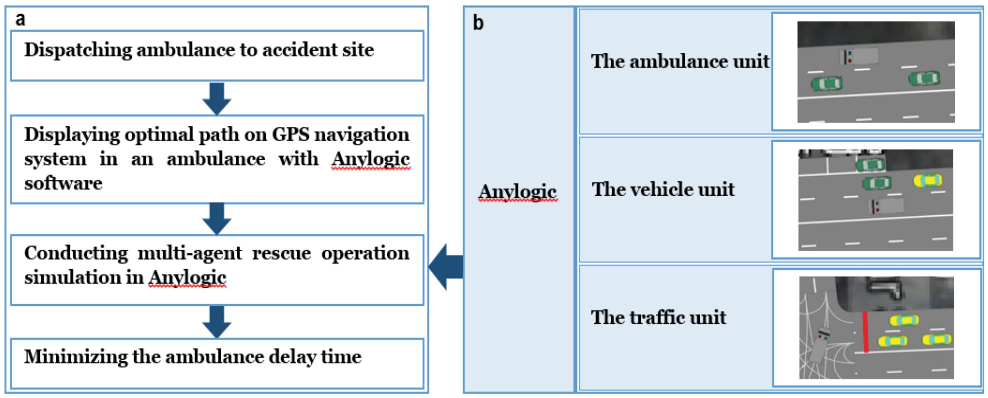

Figure 6. a) The summary of the steps of project. b) Three units of our multi-agent rescue operation simulation

3. Implementation

AnyLogic is the simulation tool that supports the most common simulation methodologies in place today including system dynamics, process-centric, and agent based modeling. Java and unified modeling language for Real Time(UML RT) are programming languages in this software. Anylogic software simulation has many benefits including reduction of the reduces cost and time of modelling, includes object libraries to provide the ability to quickly incorporate pre-built simulation elements and runs models anywhere. This multi-agent software supports both tile maps from free online providers and shapefile based map[2]. In this study, Anylogic software is considered for the multi-agent simulation. This software includes a traffic library for simulating traffic on highways and streets. This library supports detailed yet highly efficient physical level modeling of vehicle movement. Traffic library is suitable for modeling highway traffic, street traffic, on-site transportation at manufacturing sites, parking lots, or any other systems with vehicles, roads, and lanes.

The selected hospital for our simulation is Tehran Heart Center located in District No.6 of Tehran on North Kargar avenue (from 35°42'04.9"N 51°23'28.0"E to 35°44'47.9"N 51°23'20.7"E) at the west of Tehran capital of Iran. This hospital was inaugurated in 2001 having 460 inpatient's beds.

[2] http://www.anylogic.com/

This medical center is one of the best-equipped diagnostic and therapeutic cardiology centers in the region as shown in *Figure 7*.
Satellite images of Tehran Heart Center and surrounding areas provided by Google Earth. First, satellite images have been mosaiced and then these images used for the simulation in Anylogic software.
In this paper, three case studies have been considered for the proposed methodology. In these case studies, the location of the wounded has been changed. For each of the case studies, three types of multi-agent rescue operation simulations of the ambulance routing from the incident site to the Tehran Heart Center have been considered. In the first simulation, typical situation regardless of the messages from the ambulance to traffic lights and vehicles has been implemented. In the second simulation, only the messages from the ambulance to traffic lights has been implemented. The third simulation implemented the idea that messaging from the ambulance to traffic lights and other vehicles in the same lane have been considered.

Figure 7. Satellite image of Tehran Heart Center

In these case studies, traffic lights are considering 30 seconds red light and 15 seconds green light.

3.1. Case study No.1

In the first case study, it is assumed that an accident happened in intersection of Zommorrod Street and North Kargar Street as shown in *Figure 8* and the ambulance was dispatched to the accident site. As it was explained, three types of simulation of the ambulance routing from the incident site to the Tehran Heart Center have been implemented for this case study.

Figures 9, 10 and *11* have illustrated these simulations. Traffic library of Anylogic software has seven blocks for defining vehicle flow such as CarSource, CarMoveTo, CarDispose and TrafficLight. CarSource block Generates cars, puts them into the specified location inside a road network and soon. CarMoveTo block controls the car movement and CarDispose block removes the car from the model. TrafficLigth block simulates the traffic light and signalling device positioned at road intersections, pedestrian crossings, and other locations to control conflicting flows of traffic. For this case study, *Figure 12* shows ambulance agent behaviour and *Figure 13* shows vehicle agents behaviour through these blocks in road network in third simulation.

Figure 8. Implementation of the first case study (accident site shows with red circle)

Figure 9. The first multi-agent rescue operation simulation in the first case study (ambulance shows with red circle)

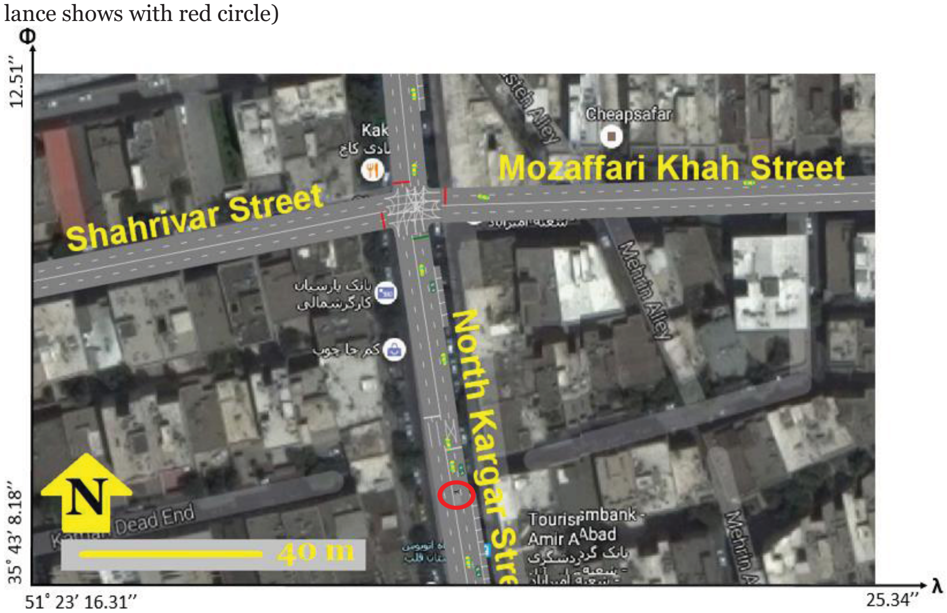

Figure 10. The second multi-agent rescue operation simulation in the first case study (ambulance has been shown with red circle)

Figure 11. The third multi-agent rescue operation simulation in the first case study (the ambulance has been shown with red circle)

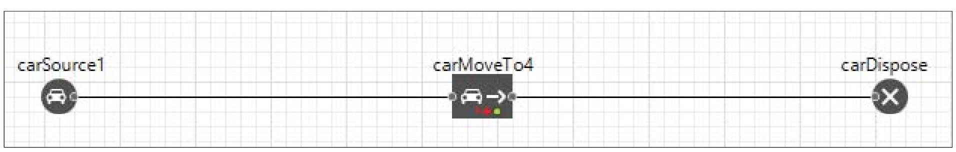

Figure 12. Blocks of traffic library for defining flow of ambulance in the road network for the third simulation of the first case study

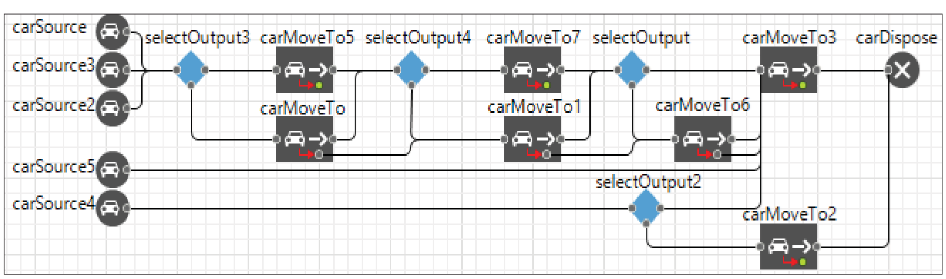

Figure 13. Blocks of traffic library for defining flow of vehicles in the road network for the third simulation of the first case study

3.2. Case study No.2

In the second case study, it is assumed that an accident happened in Mozaffari khah Street as shown in *Figure 14*. According to what was described, three multi-agent rescue operation simulations have been considered. For this case study, blocks of traffic library for determining the flow of the ambulance and the vehicles is considered.

Figure 14. Implementation of the second case study (accident site shows with red circle)

3.3. Case study No.3

An accident was happened in Salehi Street before Salehi and Majd streets intersection for the third case study as shown in *Figure 15*. According to the previous case studies, three multi-agent rescue operation simulations have been implemented and blocks of traffic library for determinig the flow of the ambulance and the vehicles is considered.

The arrival time of the ambulance from the accident site to Tehran Heart Center is measured in the three types of simulations in the form of the three case studies as shown in *Table 1*. According to the results of *Table 1*, the proposed idea of this paper led to significant reduction of the an ambulance delay time from the accident sites to Tehran Heart Center.

Figure 15. Implementation of the third case study (the accident site has been shown with red circle)

Case studies No.	Simulation 1	Simulation 2	Simulation 3
1	72.4	47.9	29.1
2	81.5	47.8	36.9
3	113.7	70.9	62.0

Table 1. Travel times of the ambulance to Tehran Heart Center in different scenarios (Seconds)

As the results suggest, accidents happen everywhere, if no solution is expected to reduce path traffic for ambulance, rescue operation may be done in a long time. In the next step, if the intersection traffic lights are always green for an ambulance, time relief 30%-40% can be reduced. In the final step, if in some way the communication between ambulances and other vehicles occur, For example, through special sensors as vehicles are aware of the arrival of the ambulance, the rescue time can be reduced by 18%-35%. Therefore, the combination of the second and third causes, time relief has been decreased by 48%- 61%. The rescue time depends on the traffic volume and the number of lanes. If the path length and traffic volume are high and the number of lanes is low, the coordination with the vehicles to change their lane significantly reduced.

4. Conclusion

Along with population growth, the number of vehicles on the road is increased. Therefore the problem of traffic management arises specially for emergency vehicles. In this paper, a novel idea is proposed for reducing the delay time caused by traffic congestion and providing the smooth flow of emergency vehicles by the multi-agent rescue operation simulation. The proposed idea was implemented in Anylogic software.In Anylogic software, the algorithm for computing optimal route for passing the ambulance considered time, distance parameters and the changes of traffic congestion. The multi-agent rescue operation simulation was divided in to the ambulance unit, the vehicle unit and the traffic unit. An ambulance sends messages to existing vehicles on the path, pedestrian traffic lights and traffic intersection lights to assign the free lane to the ambulance. Optimal route is displayed by the GPS navigation system in ambulance and the massages from ambulances to vehicles displayed by the GPS navigation system in the vehicles.

Tehran Heart Center was selected for the proposed simulation. Three case studies were considered for this multi-agent rescue operation that location of the wounded is different in these case studies. For each case study, three simulations were considered. In the first simulation, typical situation regardless of the proposed idea has been implemented and in the second simulation, only messages from the ambulance to traffic lights has been implemented. The proposed idea has been implemented in the third simulation.

According to the results of *Table 1*, the ambulance delay time in the second simulation to the first simulation has been reduced by 37.6% and during the third simulation compared to the first simulation,the delay time has been reduced by 53.3%. Also, the ambulance delay time in third simulation compared to the second one had 24.83% improvement. On the other hand, our idea was improved the ambulance delay time approximately 24.83% to previous ideas that only control traffic lights in the path of ambulance is cosidered. These results verify that our idea can accelerate rescue operation by the ambulance, in a smart city using smart care and smart traffic elements and modeling of the multi-agent system.

In our future work, we test the idea on another hospitals, road networks and accident sites to achieve more reliable results. If the allocation of the wounded to hospitals to be considered in the proposed simulation, the results of simulation become more closer to reality. For a more realistic simulation, dynamic modelling of streets and roads due to obstruction of roads and uncertainty in location of accidents and arrival time of ambulance can be considered. There may be some inconsistencie in messages between agents, so data fusion algorithms can be used to solve this inconsistencie.

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