The Evaluation of The Use of a MultiAgent System Coordination Mechanism to Support Emergency Operations *

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Abstract. *This short-paper presents an initial overview of a research work that deals with emergency operations in urban cities using MultiAgent System Coordination mechanism. We presented first the emergency scenario in the state of Santa Catarina in Brazil, citing some main challenges encountered in such cases, and thus showing how it is important to find solutions to cope with emergencies. Following, we analysed some works in the literature that present some solution for emergency cases, and show some issues in such works that need more studies. Lastly, we list the likely steps of the solution method to be implemented in future works, as a potential solution that can manage emergency operations considering the observations presented in the state of the art.*

1. Introduction

Urban areas are becoming increasingly dense and interconnected which makes them vulnerable to some types of emergencies such as vehicles accidents, building fires, gas leaks, and unexpected health crisis situations [Monares et al. 2012], requiring fast and effective responses from emergency teams such as: firefighters, medical personnel, and police officers [Borges et al. 2010]. The Brazilian Mobile Emergency Care (SAMU) that is one of emergency responder teams, registered 832,965 emergency calls from January to November 2014 in the State of Santa Catarina, from which 149,934 (18%) needed ambulance intervention. From cases registered as death, 70% occurred before the team arrives, 27% during the care, and 3% during the transportation to an healthcare point [SAM].

There are various challenges to overcome in emergency operations from which we can mention at least four: the difficulty of emergency responders to reach either the incident local (I), or healthcare points (II), due to the environment chaos, traffic congestions, as well as uncertainties and uncontrollable events that can occur. Such challenges may be seen as a classic traffic control problem, but adding to this the presence of an hostile environment and uncertainties. The cooperation between several services involved into the incident and the coordination of interdependencies between their activities in order to increase the efficiency of the rescue operation may be the main challenge in disaster management (III). Such challenges involve emergency teams interacting according to a cooperation and coordination mechanism with the aim of rescuing people and recovering infrastructures. The last challenge we may cite is to improve the security of the area and people around (IV).

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Regarding challenges I and II that may refer basically to traffic control, a considerable number of advanced solutions have been proposed in order to cope with traffic control problems such as: optimization, control and automation. Nevertheless, such approaches do not seem to be sufficient to solve the presented problem, since most of researches in classical traffic control generally focus on the task of optimizing the traffic in congestion or similar situations, due to rush hours, some event, or even traffic accidents or another incident that may be considered as an emergency case, whereas the traffic control involved during a disaster management is affected by unfamiliar and hazardous events, therefore require various services working together, that is, a kind of cooperation between such services and coordination of their activities in order to reach the overall goal established.

This work aims to present an overview of the likely steps of a method that evaluate the use of a MultyAgent System (MAS), and its cooperation and coordination mechanisms, as an instrument that manage inter-dependencies between urban services activities in order to control the traffic and improve the efficiency of emergency operations in urban cities, as well as minimize the traffic chaos that such management policies could cause. To reach such aim, we need first to create an emergency scenario as well as define and implement a MAS, endowed with a cooperation and coordination mechanism, that can achieve some objectives which consist in overcoming some of the four emergency operation challenges described in the section 1, and listed below:

1. Control the traffic in order to facilitate the displacement of emergency responders to the local of incident;
2. Control the traffic in order to facilitate the displacement of victims to healthcare points;
3. Promote and improve the emergency responders cooperation in order to take care of a maximum number of life;
4. Assess and adjust, if necessary, the traffic management policies in order to minimize the traffic chaos that such policies could cause.

2. State of The Art

The scenario being studied in this work: *Traffic Management Under Emergency Situations*, is part of studies in at least two mature topics in the literature which are: *Traffic Management* and *Emergency Responses*, which are usually studied separately. Numerous researches have been realized in both fields among which we can cite: [Papageorgiou et al. 2003], [Wu 2002], [Jin et al. 2007], [He et al. 2007], and [McKenney and White 2013] for traffic Management. Solutions proposed in these works derived from areas such as: Adaptive Control, Optimization, MultiAgent System, and Artificial Intelligence. Most of these researches focus more on the congestion problem, traffic flow optimization and similar situations. Regarding emergency responses, we can cite as examples: [Abramson et al. 2008], [Adams et al. 2008], [Stranders et al. 2010], citefilippoupolitis:etal:2008b, and [Hawe et al. 2012], where most of solutions proposed derived from AI and MAS.

Even though the traffic management under emergency situations topic have solutions from several areas, we focus our analysis on solution that use Agent and MAS theory as means, since our aim is to evaluate the use of MAS coordination mechanism in order to cope with such situations. However we also comment quickly on some works cited at the first paragraph that propose some solutions in different areas than MAS. We used Google Scholar, IEEE Explorer, and Mendeley as reference managers and academic social networks in order to find such works, searching by key words such as: -*Traffic management*, *Emergency*, *Coordination*. Finally, we summarized the results in Table 1, separated by *title* and *reference*, *specific scenario* and *solution field* that is the domain from where the solution method or feature used in the publication derived.

Title	Scenario	Solution Field
Model Reference Adaptive Control Framework for Real-Time Traffic Management under Emergency Evacuation [Liu et al. 2007]	Traffic control under emergency evacuations	Adaptive Control Theory
Traffic organization method for emergency evacuation based on information centrality [Wu et al. 2010]	Traffic control under emergency evacuations	Optimization
(Notice of Retraction) A Decision Support System of Urban Traffic Emergency Control Based on Expert System [Shumin et al. 2010]	Traffic control under emergency operations	AI (Expert Systems)
Rapid Handling of Urban Traffic Emergencies Based on Decision and Command Support System [Lu 2009]	Handling urban traffic emergency	Software engineering
A heuristic implementation of emergency traffic evacuation in urban areas [Kang et al. 2013]	Traffic control under emergency situations	Algorithms and Graphs

Table 1. Works in Traffic Management under Emergency Operations

Analysing some of Table 1 works, we can notice that [Liu et al. 2007], by example, integrate both dynamic network modelling techniques and adaptive control theory to manage the traffic at real-time during emergency evacuations. They consider that the traffic flow during emergency is full of uncertainties, therefore needs a dynamic modelling technique as well as a real time adaptive control. Although such approach shows interesting results regarding optimization of traffic evacuation, it does not include explicitly the emergency responders management into the scenario, in the sense of several services cooperating according to a coordination mechanism in order to reach a same overall goal. Which is one of important problems to consider to cope with emergency situations. Another considerable issue in the solution proposed by [Liu et al. 2007] is that the system objectives are almost handwritten by the designer, which do not match totally with the real scenario in which team responder objectives can change at real time depending on events occurring. The same two main problems observed in [Liu et al. 2007]'s approach are encountered in [Wu et al. 2010], and [Kang et al. 2013].

[Shumin et al. 2010], by example, proposed a solution that establish a decision support system of urban traffic control for emergency based on expert system. They consider that there can have a expert system that have enough knowledge of the overall problem, therefore, can be used to solve it. Such centralized problem solving approach in which one assumes that a component or agent must have the appropriate expertise to decompose the overall problem to specific ones, thus, must have knowledge of the task structure [Wooldridge 2009], is less encouraged to cope with complex problems. Since it is less sure to find a component that has a global view of the environment as well as events occurring. The same main problem observed in [Shumin et al. 2010]'s approach is also encountered in [Lu 2009], and [Kang et al. 2013].

[Rodríguez et al. 2009] proposed a solution using MAS. They focused on recalculation of route in real time to reduce the travel time between two points, using several emergency agents collaborating together into a hierarchical agents architecture. Still, one issue of such approach is that part of agents are not autonomous since they are used to pass the information observed to global agents and wait for their decisions. This cause a considerable quantity of explicit communications between agents that could be avoided if each agent was able to decide it self based on what it observed and its belief base. To illustrate such quantity, just consider a quadrant Q_1 in which IP_{1x}, an Information Panel got a message m_1 from a given local agent LA_1, and output $m1$. GA_1, the Q_1 Global Agent uses m_1 together with other messages in order to decide what to do. After deciding, GA_1 informs to the concerned Regional Agent R_{1x} the decision, and R_{1x} does the same recursively until to reach the concerned local agent(s) LA_{1Y}, etc. Let consider T the total need time for D_1 be done, t the unit explicit communication time. h, the agent hierarchical tree heigh. The value of T is given by: *T = t*h*;

Let suppose now that D_1 was a message that had to be output to another Information Panel IP_{ix}. This means that GA_{ix} would have to wait T time to evaluate and decide what to do, and such decision would take T' time to be done. So supposing that $T = T'$ and such event occurred n times, we have: *X = nT = n*(t*h) = t*(n*h)*; where X is the global time. So h could be avoided if each agent was able to decide itself based on what it perceives and knows. Such approach can be possible by using norms, for example. That means, when any agent perceive something that can be useful for farther decision, it can put it as a new norm so that others agents can perceive and act based on such norm. This lead us to one of mains coordination mechanism called: *coordination through norms and social laws*, presented by [Wooldridge 2009], that we intend to use farther as coordination mechanism.

3. Steps to Reach the aim

This section presents an initial method to reach the defined aim, addressing the observations highlighted at the state of the art. So it is fundamental to get more knowledge on MAS traffic control strategies as well as emergency operations management in order to combine and adjust both area methods. Furthermore, it also seems important to make some interviews with emergency responders about how their activities occur, so that we can find a solution that matches with the real world. This work will be developed in following steps:

1. Construct a urban traffic network using AIMSUN, an advanced traffic simulator;
2. Create an emergency incident scenario at one point of the network from step 1, that better represent the challenges defined in section 1, hence, the need of reaching all the specific objectives enumerated in section 1.
3. Define metrics that can better assess the MAS to be implemented, as well as its cooperation and coordination mechanisms, according to the specific objectives defined in section 1.

4. Implement a MAS as well as its cooperation and coordination mechanisms in order to reach the overall goal, achieving all the specific objectives, and meeting all the observations highlighted in the section 2.
    (a) Define an ontology that can better represent the scenario from step 2.
    (b) Define a protocol for the overall problem decomposition and task allocation;
    (c) Define a method that will synthesize the overall solution from sub problem results;
    (d) Define a adequate language for communication between agents;
    (e) Implement the MAS: agents, environment, and organization;
    (f) Implement a coordination mechanism that will manage inter-activities between the agents.
5. Apply the MAS from step 4 to the scenario from step 2, and evaluate the results based on the metrics from step 3.

4. Final Considerations

This short-paper just presents an initial overview of a research work that deals with emergency cases in urban cities. We presented first the emergency scenario and some main challenges encountered in emergency operations. We chose MAS as the technique to manage emergency operations because we believe and consider as hypotheses that MAS can better represent such scenario and also inherently considers cooperation and coordination mechanisms that are powerful instruments to cope with problems such as emergencies. After searching and analysing some works in the literature that also present solutions to cope with emergencies, we highlighted some observations that should need more studies, and lastly, we list the likely steps of the solution method to be implemented in future works, considering all the observations highlighted in the state of the art.

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