# A Decentralised Multi-Agent System for Emergency Resource Allocation in Metropolitan Regions

# (Demonstration)

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Multi-Agent System; Resource Allocation; Emergency Response

## 1. INTRODUCTION OF THE APPLICATION DOMAIN

Nowadays, emergency departments in many countries still rely on human operators to allocate rescue resources to emergency events. However, with the fast growth of population in metropolitan regions, the frequency of occurrence of emergency events has risen significantly, which imposes tremendous pressure over emergency event operators. Agent and multi-agent systems (MASs) provide potential solutions to address such complicated emergency response problem due to agents ability of autonomous reasoning, adaptive decision making, complex environment modeling and collective group formulation [5]. In recent years, a number of promising agent-based emergency response and simulation systems have been developed to support rescue operations for different emergency situations. Some of the important ones include FireGrid [4], RoboCup Rescue [7], DEFACTO [10], DrillSim [2] and ALADDIN [1]. Nevertheless, most of these systems are limited to simulate and study emergency crises, which do not provide concrete solutions about how to improve the effectiveness of response operations and optimise the resource allocation results.

In this demonstration, we present a MAS for the simulation of emergency rescue response in metropolitan regions, which is implemented based on our previous work in [11]. Our MAS provides a decentralised resource allocation approach to deploy resources to multiple emergency events simultaneously on Google Maps.

## 2. PROBLEM SCENARIO DESCRIPTION

In metropolitan regions, multiple emergency events could happen concurrently at different locations, which have the five common characteristics, including that (1) these events are hard to be predicted, which makes resources per-allocation become almost impossible; (2) these events usually require multiple resources, which might be distributed over an extensive area with different usage costs, mobilities, availabilities, ownerships and functionalities. This can complicate the resource searching progress; (3) these events have strict time limits for emergency departments to response and allocate rescue resources, which increases the difficulty of finding the optimal resource allocation plan; (4) these events might require same resources at same time during the emergency response, which results in potential resource contention problems and (5) the environments around these events and the events themselves are dynamic, which may introduce many uncertain factors during the emergency resource allocation.

Due to the complexity, unpredictability, dynamic natures and potential resource contention problems among these events, human operators usually have difficulties to efficiently find out the most suitable and effective rescue solution within events' deadlines, which results in the increase of the number of casualties. Our MAS is designed to handle different types of emergency events that require the collaboration responses of multiple emergency departments. Through using a decentralised resource allocation approach, our MAS is more practical to be deployed in real world environments compared with traditional centralised systems. Besides, with the support of the domain transportation theory [9], our MAS can efficiently select the most suitable resources for multiple concurrent emergency events with the objective of minimising the total cost of resources deployment time and money expenditure. In addition to the domain transportation theory, we have also incorporated a resource coordination algorithm into our MAS to dynamically coordinate resources for resource contention events based on their attributes, such as severities and deadlines.

## 3. OVERVIEW OF THE MAS FRAMEWORK

As described in previous section, in order to maximise the system practicability and extendability, we have applied a decentralised and modular design approach for our MAS, which includes six modules in the system (see Figure 1) — a task identification module, a resource identification module, a proposal generation module, an optimal allocation module,

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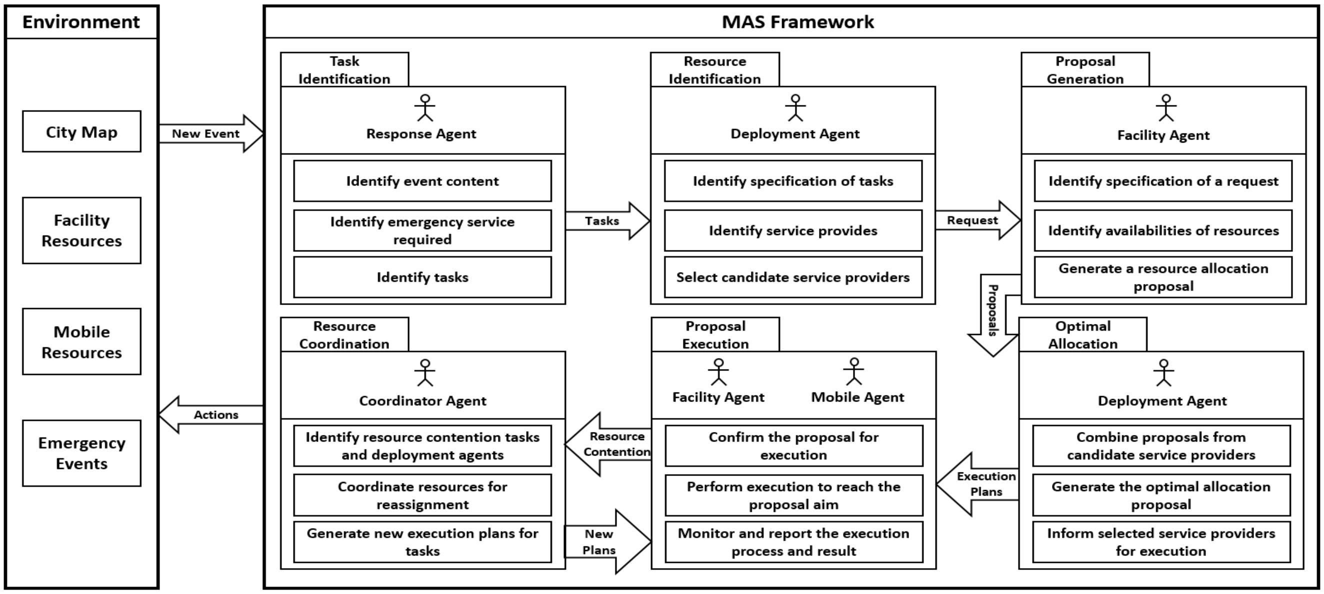


**Figure 1: MAS Framework**

a proposal execution module and a resource coordination module.

More specifically, when the MAS receives an emergency event, a new system thread will be allocated to process this event. During the resource allocation, the task identification module will be activated first, in which a single response agent is used to identify resource allocation tasks for an emergency event according to the emergency service required by this event. Then, the task identification module passes the resource allocation tasks to the resource identification module, in which a deployment agent generates multiple task processing threads. Each of the task processing threads is used to identify the resource requirements specification in a task and passes this task to relevant candidate service providers (facility agents). After that, in the proposal generation module, each facility agent that has received a resource allocation task will use domain transportation theory to generate a resource allocation proposal based on all resources under its management (i.e. mobile resources). All the generated resource allocation proposals will be passed to the optimal allocation module, in which the deployment agent will combine these proposals and use domain transportation theory to generate a final optimal resource allocation plan for a task. Eventually, this final optimal allocation plan will be passed to the proposal execution module, in which relevant facility agents will confirm the detail of the resource allocation plan. During the execution of resource allocation proposals, if a facility agent finds that if one of its resources is required by two or more different proposals, a new coordination agent will be generated to coordinate the resource dynamically.

# 4. IMPLEMENTATION AND DEMONSTRATION FEATURES OF THE MAS

Our MAS is implemented as a web-based system with the Model-View-Controller (MVC) architecture [8], which can be accessed from any computer that has web browser and Internet connection. With the MVC architecture design, our system separates the presentation layer from the logic layer, thereby minimising the clutter and the system can be easily extended with new modules in the future. Besides, in order to demonstrate the system capability in solving the resource allocation problems in the real-world environment, we have integrated Google Maps into the View layer of our MAS. By doing so, real-world information regarding to emergency services, routes and live traffic can be easily accessed in our MAS. Furthermore, Java Agent Development Framework (JADE) is used for the implementation of the agents in the Controller layer [3]. The major reason of choosing JADE as the agent platform is that it provides a runtime environment for agent registration and operation, which is extremely important for deploying rescue resources to unexpected emergency events in open and dynamic environments.

With the support of JQuery and Ajax Technologies [6], our web-based MAS provides users with highly interactive demonstration. Generally, our MAS allows users to place any number of emergency events on any city around the world. Users can choose to manually configure the settings of these events or let our system to randomly generate demo settings. During the resource allocation progress, our system will use multiple animations to illustrate how agents interact and coordinate with each other to make decisions, and how rescue resources are moved dynamically on the Google Maps with the effect of live traffic. At the end of the resource allocation progress, our system also provides users with a detail resource allocation report for each event, such as the total cost of the resource allocation, average allocation time and so on.

# REFERENCES

[1] N. Adams, M. Field, E. Gelenbe, D. Hand, N. Jennings, D. S. Leslie, D. Nicholson, S. Ramchurn, S. Roberts, and A. Rogers. The aladdin project: intelligent agents for disaster management. In

*International Workshop on Robotics for Risky Interventions and Surveillance of the Environment.* International Advanced Robotics Programme, 2008.

[2] V. Balasubramanian, D. Massaguer, S. Mehrotra, and N. Venkatasubramanian. *DrillSim: a simulation framework for emergency response drills.* Springer, 2006.

[3] F. L. Bellifemine, G. Caire, and D. Greenwood. *Developing multi-agent systems with JADE*, volume 7. John Wiley & Sons, 2007.

[4] D. Berry, A. Usmani, J. L. Torero, A. Tate, S. McLaughlin, S. Potter, A. Trew, R. Baxter, M. Bull, and M. Atkinson. Firegrid: Integrated emergency response and fire safety engineering for the future built environment. UK e-Science Programme All Hands Meeting, 2005.

[5] F. Fiedrich and P. Burghardt. Agent-based systems for disaster management. *Communications of the ACM*, 50(3):41–42, 2007.

[6] C. Györödi, R. Györödi, G. Pecherle, T. Lorand, and R. Alin. Web 2.0 technologies with jquery and ajax. *Computer Technology and Computer Programming: Research and Strategies*, page 99, 2011.

[7] H. Kitano, S. Tadokoro, I. Noda, H. Matsubara, T. Takahashi, A. Shinjou, and S. Shimada. Robocup rescue: Search and rescue in large-scale disasters as a domain for autonomous agents research. In *1999 IEEE International Conference on Systems, Man, and Cybernetics*, volume 6, pages 739–743. IEEE, 1999.

[8] A. Leff and J. T. Rayfield. Web-application development using the model/view/controller design pattern. In *Enterprise Distributed Object Computing Conference, 2001. EDOC'01. Proceedings. Fifth IEEE International*, pages 118–127. IEEE, 2001.

[9] J. Liu. Regularity of monge–ampère equations in optimal transportation. *Bulletin of the Australian Mathematical Society*, 83(01):173–176, 2011.

[10] J. Marecki, N. Schurr, and M. Tambe. Agent-based simulations for disaster rescue using the defacto coordination system. In *Emergent Information Technologies and Enabling Policies for Counter-Terrorism*, pages 281–297, 2006.

[11] J. Zhang, M. Zhang, F. Ren, and J. Liu. A multiagent-based domain transportation approach for optimal resource allocation in emergency management. In *The Proceedings of the 2 nd International Workshop on Smart Simulation and Modelling for Complex Systems*, page 1.