A Dynamic Resource Allocation Approach for Concurrent Emergency Events in Metropolitan Regions

(Extended Abstract)

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ABSTRACT

The rescue operations for emergency events usually require multiple emergency departments to cooperate with each other to provide effective and efficient resource allocation plans within a short time limit and dynamically adjust the plans as necessary. In the paper, an agent-based resource allocation approach is proposed to automatically allocate rescue resources to concurrent emergency events by the consideration of dynamic changes in terms of event variation, task variation and resource execution variation.

Keywords

Dynamic Resource Allocation, Emergency Management, Agent Cooperation, Agent-Based Simulation

1. INTRODUCTION

Emergency resource allocation refers to the creation of plans to deploy and coordinate rescue resources to mitigate the damage caused by emergency events [3, 11]. Usually, an emergency event might require multiple rescue resources with different functionalities, which can be organised into a set of resource allocation tasks and handled by different emergency departments or services [5]. In open environments such as metropolitan regions, small-scale emergency events (i.e. urban fires, vehicle accidents) are normally hard to be predicated in advance and they could occur randomly at any possible location. The critical concerns when handling the resource allocation for these events are the dynamic features of emergency management [2, 6, 9, 10].

Generally, the dynamic features in emergency management can be classified into three levels (see Figure 1). The first level is the event variation, referring to that the occurrence of emergency events in metropolitan regions could be dynamical and unpredictable. The second level is the task variation, referring to that the total number of the resource allocation tasks and the task requirements in an emergency event could change dynamically as time passed. The third level is the execution variation, referring to that the execution plan of a rescue resource could change dynamically due to problems such as resource contention. Based on the variations of events, tasks and executions, resource allocation plans for emergency events must be adjusted timely, which is a very challenging topic in both research and applications. Currently, most of resource management approaches or systems can not provides comprehensive resource allocation mechanisms by taking the consideration of all the three levels of dynamic features in emergency management, which may lead to ineffective usage of resources and even the failure of rescue operations.

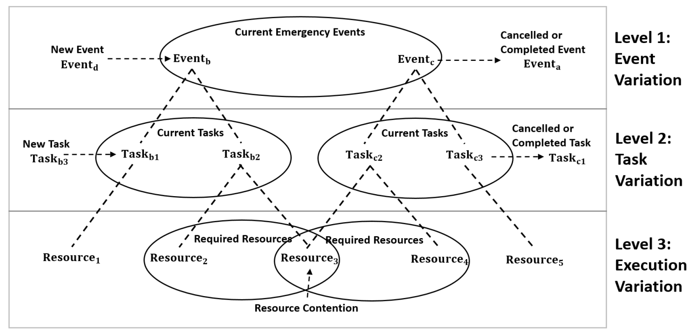

Figure 1: The Three Levels of Emergency Dynamic Features

In this paper, an agent-based resource allocation approach is proposed to allocate rescue resources to multiple emergency events simultaneously, by efficiently adjusting the resource allocation plans based on the three levels of variations that occur during the emergency rescue operations.

2. PROBLEM DESCRIPTION

In a metropolitan region, multiple emergency events $\mathbb{E}$ (i.e. $\mathbb{E}$ is a set of events) could happen concurrently at different locations. For each event $e \in \mathbb{E}$, there could exist more than one proposals with various resource combinations to fulfil the event's resource requirements. The main problem to be solved in this paper is to search for an optimal proposal p^* for each event $e \in \mathbb{E}$ to minimise the total resource allocation cost. The objective function OA for the resource allocation of all concurrent events in $\mathbb{E}$ is defined by Equation 1:

$$OA = \arg \min_{\mathbb{P}^* = \{p_1^*, \ldots, p_x^*\}} \sum_{e_x \in \mathbb{E}} CE(e_x, p_x^*) \text{ subject to } p_x^*.\mathbb{R} \in \mathbb{R}^g, \quad (1)$$

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where $\mathbb{R}^g$ represents the available resources in environment $\mathbb{G}$ and CE is a cost function for calculating the resource allocation cost of a single event based on resource money expenditure and resource allocation time.

As mentioned previously, the dynamic nature of emergency management might introduce many unpredictable variations during the resource allocation process for events in $\mathbb{E}$, which could cause different resource allocation problems in the three level variations.

There are two problems to consider in the level of event variation: **(1.1)** how to handle a newly arrived event and **(1.2)** how to deallocate resources for a cancelled event.

There are three problems to consider in the level of task variation: **(2.1)** how to handle a newly arrived task of an event; **(2.2)** how to deallocate resources for a cancelled task of an event; and **(2.3)** how to address the situation when a task's deadline has changed.

There are two problems to consider in the level of execution variation: **(3.1)** how to handle a resource contention problem, when a resource is requested by multiple tasks from different events at the same time and **(3.2)** how to address the situation when the estimated arrival time of a resource r has changed due to issues such as traffic jam or resource malfunction, which cause resource r can not catch its task's deadline on time.

3. THE PRINCIPLE OF AGENT-BASED DYNAMIC RESOURCE ALLOCATION

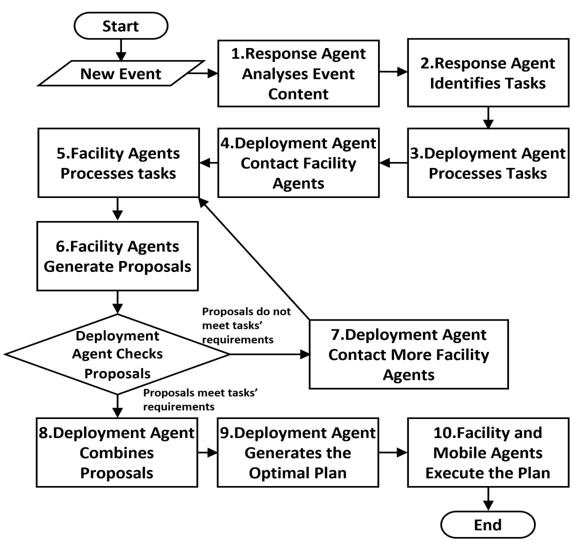

Figure 2: The Procedure of Resource Allocation for Single Event

To generate resource allocation proposals that minimise the total allocation cost of concurrent emergency events $\mathbb{E}$, the proposed approach assigns a group of agents for each event $e \in \mathbb{E}$ to generate the optimal resource allocation proposal p^* by using the domain transportation theory [7], respectively. The resource allocation process for a single event involves one response agent, one deployment agent, multiple facility agents and mobile agents, which is depicted by Figure 2.

As described in previous section, during the process of generating the optimal proposal for the each event e in $\mathbb{E}$, the event variation, task variation and execution variation could cause different dynamic resource allocation problems, which need to be handled by different dynamic resource allocation mechanisms. In general, for newly arrived events or tasks (i.e. Problems 1.1 and 2.1), their resource allocation can be handled by the single event resource allocation mechanism (i.e. Figure 2). For canceled events or tasks (i.e. Problems 1.2 and 2.2), deployment agents will inform relevant facility and mobile agents to released their resources to newly arrived events. For the problems of tasks' deadlines variation or resources arrival times variation (i.e. Problem 2.3 and 3.2), deployment agents will try to locate replace resources as necessary to ensure the succeed of the tasks. For resource contention problems between tasks (i.e Problem 3.1), a recursion algorithm will be used to dynamically re-assignment resources to appropriate tasks to minimise the total resource allocation cost.

4. EXPERIMENT

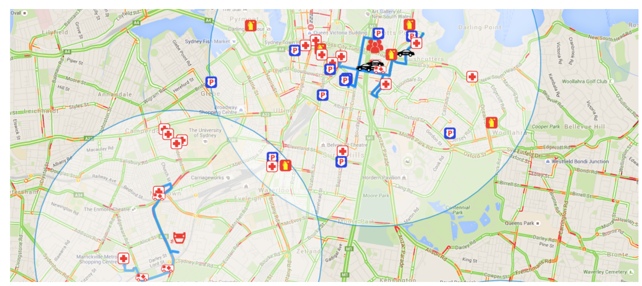

Figure 3: Agent-Based Emergency Resource Allocation Simulator

In the experiments, an agent-based emergency resource allocation simulator [13] based on GoogleMaps was implemented as the testbed (see Figure 3), which provides real world resources and environments information. The video demo can be seen at [1].

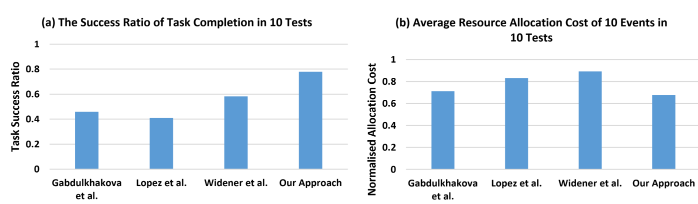

Figure 4: The Experimental Results

In our experiments, the proposed approach was tested along with other three agent-based emergency resource allocation approaches [4, 8, 12] to deploy resources to 10 concurrent emergency events. The experimental results (see Figure 4) indicates that our approach outperformed the other three test approaches in terms of the resource allocation cost and task success ration due to the capability of providing appropriate dynamic resource allocation mechanisms to address different problems caused by event variation, task variation and execution variation.

REFERENCES

[1] Aamas video demo, https://www.youtube.com/watch?v=hqfsvjy-bus.

[2] Holger Billhardt, Marin Lujak, Vicente Sánchez-Brunete, Alberto Fernández, and Sascha Ossowski. Dynamic coordination of ambulances for emergency medical assistance services. *Knowledge-Based Systems*, 70:268–280, 2014.

[3] Thomas E Drabek and Gerard J Hoetmer. *Emergency management: Principles and practice for local government*. International city management association Washington, DC, 1991.

[4] Aygul Gabdulkhakova, B Konig-Ries, and Dmitry A Rizvanov. An agent-based solution to the resource allocation problem in emergency situations. In *2011 Ninth IEEE European Conference on Web Services (ECOWS)*, pages 151–157, 2011.

[5] George Haddow, Jane Bullock, and Damon P Coppola. *Introduction to emergency management*. Butterworth-Heinemann, 2013.

[6] Athena N Johnson. Emergency relief planning and management through dynamic agent-based reallocation and tasking (dart). *Procedia Engineering*, 107:168–171, 2015.

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

[8] Beatriz López, Bianca Innocenti, and Dídac Busquets. A multiagent system for coordinating ambulances for emergency medical services. *Intelligent Systems, IEEE*, 23(5):50–57, 2008.

[9] Ruth Luscombe and Erhan Kozan. Dynamic resource allocation to improve emergency department efficiency in real time. *European Journal of Operational Research*, 2016.

[10] Sameera Ponda, Josh Redding, Han-Lim Choi, Jonathan P How, Matt Vavrina, and John Vian. Decentralized planning for complex missions with dynamic communication constraints. In *American Control Conference (ACC), 2010*, pages 3998–4003. IEEE, 2010.

[11] Claire B Rubin. *Emergency Management: The American Experience 1900-2010*. CRC Press, 2012.

[12] Michael J Widener, Mark W Horner, and Kunlei Ma. Positioning disaster relief teams given dynamic service demand: A hybrid agent-based and spatial optimization approach. *Transactions in GIS*, 19(2):279–295, 2015.

[13] Jihang Zhang, Minjie Zhang, Fenghui Ren, and Jiakun Liu. A decentralised multi-agent system for emergency resource allocation in metropolitan regions. In *Proceedings of the 2016 International Conference on Autonomous Agents & Multiagent Systems*, pages 1482–1484. International Foundation for Autonomous Agents and Multiagent Systems, 2016.