Expert Systems with Applications 41 (2014) 2947–2956

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Greedy-search-based multi-objective genetic algorithm for emergency logistics scheduling

Fu-Sheng Chang [a], Jain-Shing Wu [a], Chung-Nan Lee [a,*], Hung-Che Shen [b]

[a] Department of Computer Science and Engineering, National Sun Yat-sen University, Kaohsiung 80424, Taiwan
[b] Institute of Computer and Information Engineering, I-Shou University, Kaohsiung 840, Taiwan

ARTICLE INFO

Keywords:
Logistics
Split delivery
Emergency logistics distribution
Multi-objective optimization
Dynamic traffic assignment

ABSTRACT

To enable the immediate and efficient dispatch of relief to victims of disaster, this study proposes a greedy-search-based, multi-objective, genetic algorithm capable of regulating the distribution of available resources and automatically generating a variety of feasible emergency logistics schedules for decision-makers. The proposed algorithm dynamically adjusts distribution schedules from various supply points according to the requirements at demand points in order to minimize unsatisfied demand for resources, time to delivery, and transportation costs. The proposed algorithm was applied to the case of the Chi–Chi earthquake in Taiwan to verify its performance. Simulation results demonstrate that under conditions of a limited/unlimited number of available vehicles, the proposed algorithm outperforms the MOGA and standard greedy algorithm in 'time to delivery' by an average of 63.57% and 46.15%, respectively, based on 10,000 iterations.

1. Introduction

The emergency logistics scheduling problem (ELSP) deals with the need to identify, inventory, dispatch, mobilize, transport, recover, demobilize, and accurately track human and material resources in the event of a disaster. Rapid response is the most critical concern in emergency logistics. Despite the wealth of research in this area, relief efforts in the northeast area of Japan devastated by the 311 earthquake were delayed by 10 days. The main problem was a lack of planning in accordance with existing road conditions and the distribution of available resources.

Most previous studies have adopted integer and linear programming to solve such problems, using a single objective or a weighted sum of objectives. However, this approach tends to be limited in real-world situations, which typically presents multiple conflicting objectives. Furthermore, this approach tends not to provide detailed routing schedules. This paper proposes a novel greedy-search-based multi-objective genetic algorithm (GSMOGA) focusing on two requirements: (1) dispatching relief resources sufficient to satisfy the requirements at all demand points; (2) the transport of relief resources with minimum delay and transportation costs. GSMOGA is far more effective than typical local search methods, such as Tabu, thanks to its incorporation of a greedy search protocol followed by the encoding sequence of chromosomes using MOGA. The resulting output is a diverse selection of routing schedules without the need for a time-consuming local search process. GSMOGA is a hybrid method combining the advantages of greedy search with those of MOGA.

The remainder of the paper is organized as follows. In Section 2, we review the literature related to emergency logistics planning. The definition of the ELSP and its essential objective functions is described in Section 3. In Section 4, we propose the algorithm used to map out optimal transport routes and maximize the delivery of resources in the minimum time at the minimum cost. Experimental results depicting two scenarios are presented in Section 5. Conclusions and considerations for future work are presented in Section 6.

2. Literature review

Solutions to the ELSP differ according to environment, population distribution, transportation networks, relief requirements, and geographic situation. In addition, the services required for the provision of food, facilities, human resources, and transportation must be taken into consideration in the design of a dispatch schedule. A number of algorithms have been proposed to overcome the difficulties associated with ELSP: Dynamic integer linear programming (Sheu, 2007), goal programming (Vitoriano, Ortuño, Tirado, & Montero, 2010), Dijkstra algorithm (Yuan & Wang, 2009; Zografos, Androutsopoulos, & Vasilakis, 2002), metaheuristic algorithms (Peng, Xu, & Yang, 2009; Yang, Jones, & Yang, 2007; cYi & Kumar, 2007; Yuan & Wang, 2009), immune intelligence (Hu, 2011), greedy method (Özdamar & Wei, 2008), game theory

* Corresponding author. Tel.: +886 7 525 2000x4313; fax: +886 7 525 4301.
E-mail address: cnlee@cse.nsysu.edu.tw (C.-N. Lee).

0957-4174/$ - see front matter
http://dx.doi.org/10.1016/j.eswa.2013.10.026

(Reyes, 2005), amoeboid organism model (Zhang, Zhang, Zhang, Wei, & Deng, 2013), and fuzzy multi-objective programming (Sheu, 2007; Sheu, 2010; Yang et al., 2007). These algorithms provide either a single solution or combine several objectives into a single objective. Existing algorithms for logistics planning can be divided into two categories: the preparation and dispatch of relief. Chang, Tseng, and Chen (2007) sought to identify the ideal station for the storage of relief resources in the vicinity of disaster areas through the adoption of sample average approximation to obtain the availability and distribution of rescue equipment. Sheu (2007), Sheu (2010) grouped affected areas using the fuzzy method in order to predict demand using dynamic linear programming (DLP). Liberatore, Ortuño, Tirado, Vitoriano, and Scaparra (2014) attempted to repair a broken transportation network for the distribution of relief. In (Sheu, 2007; Özdamar & Demir, 2012; Özdamar, Ekinci, & Küçükyazici, 2004), clusters of demand points were identified to determine the best routing path options for the distribution of relief and the evacuation of the wounded. Zhang et al. (2013) designed a system of weighted arcs linking nodes in disaster situations by applying the amoeboid organism method to identify the shortest routing path capable of satisfying the objectives of travel time and path length. However, they considered only a single depot and single optimal path. Zhang, Li, and Liu (2012) proposed a mixed integer programming method for application in primary and secondary disasters. They also combined a heuristic local search method for the dispatch of emergency resources with the minimum delay.

In contrast with these solutions, other researchers (Hu, 2011; Yuan & Wang, 2009; Zhang et al., 2013; Özdamar & Demir, 2012) focused on the amount of relief being distributed or global routing plans. In a review of studies related to logistic planning (Zhou, Huang, & Zhang, 2011) listed five factors critical to the success of emergency management: (1) clear organizational structure and delegation of responsibilities (2) effective sharing of emergency information (3) united leadership for planning and coordination (4) application of modern logistics technology, and (5) continuous improvement of emergency management systems. The proposed algorithm combines the factors identified in items (3) (4), and (5) for the generation of multiple rescue routing plans that can be grasped easily and implemented in accordance with the availability and distribution of resources. The resulting rescue routing plans are meant to maximize the distribution of relief resources, while maintaining a reasonable balance between the operational costs and travel time required for each type of vehicle. Decision-makers presented with these routing alternatives could then verify the parameters before implementing a given schedule.

Table 1 presents a comparison between existing algorithms and the proposed GSMOGA for the problems associated with the planning of logistics.

The attributes in Table 1 are key elements in the algorithms used in these studies: "Core" and "Benchmark" are self-designed benchmarks; "Repair scheme", "Evacuation", and "Logistics" refer to the field of rescue; "Multi-objective", "Multi-commodity", and "Multi-depot" refer to parameters; and "Binding with CPLEX" refers to the use of CPLEX to solve the problem. This integer programming-based tool is too time-consuming for most situations and only returns a final value for each variable without a suggested routing sequence.

This paper designed a benchmark based on Sheu (2007), using multiple objectives to generate a detailed schedule for the routing of multiple vehicles. We first generated a variety of routing schedules for each vehicle to provide candidate solutions, which could be implemented immediately after confirmation from decision-makers. To ensure that the proposed system is capable of responding to aftershocks, we adopted the dynamic allocation and rescheduling features found in previous studies. Thus, this study approached the problem of ELSP from a tactical point of view.

Compared with the existing literature, most of these studies adopted the weighted sum method to combine multiple objectives into a single objective. Nonetheless, selecting appropriate parameter weightings can be difficult. Thus, this study adopted a multi-objective method based on the NSGA II to generate a series of solutions that progressively move towards the Pareto front. Furthermore, we focused on the distribution of last-mile disaster relief to obtain a series of routing sequence schedules for a number of vehicles departing from multiple depots. Most previous methods prioritized the distribution of relief based on a single depot and output only a single routing schedule. The proposed algorithm is capable of generating specific routing schedules for each form of transport in accordance with the distribution and demand for

Table 1
Comparisons of the logistics planning algorithms.

Year	2013	Zhang et al. (2013)	Liberatore et al. (2014)	Sheu (2010)	Yan and Shih (2009)	Yuan and Wang (2009)	Yi and Kumar (2007)
Attributes	Author						
	The proposed algorithm	Zhang et al.	Liberatore et al.	Sheu	Yan and Shih	Yuan and Wang	Yi and Kumar
Core	Integration of MOGA and the greedy algorithm with the NSGAII ranking method	Amoeboid organism shortest path finding method	Two stages method of hierarchical cluster and route procedure	Forecast relief demand , fuzzy clustering affected area, multi-criteria decision priority of groups	Multi-objective mixed-integer multiple commodity network flow problem with CPLEX	Modified the Dijkstra algorithm and the ant colony optimization algorithm	Ant colony optimization and successive maximum flow
Benchmark	2 random benchmark and the Chichi earthquake in Nantou of 29 nodes	1 random problem with 20 nodes	15 random problems with nodes between [100,500]	Chichi earthquake	12 random benchmark similar to Chichi earthquake	1 random problem with 20 nodes	28 random problems with nodes between [20,80]
Repair scheme					✓		
Evacuation		✓	✓				✓
Logistics	✓	✓	✓	✓	✓	✓	✓
Routing sequence	✓		✓				
Multi-objective	✓	✓(into single)	✓(into single)		✓(into single)	✓(into single)	✓(into single)
Multi-commodity	✓	✓	✓	✓			✓
Multi-depot	✓		✓				✓
Binding with CPLEX			✓	✓	✓		✓