Expert Systems with Applications 38 (2011) 2632–2639

Contents lists available at ScienceDirect

Expert Systems with Applications

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

A container multimodal transportation scheduling approach based on immune affinity model for emergency relief

Zhi-Hua Hu *

Logistics Research Center, Shanghai Maritime University, Shanghai 200135, China

ARTICLE INFO

Keywords:
Emergency relief
Multimodal transport
Immune affinity model
Emergency management
Path selection
Supply chain

ABSTRACT

Various disasters with serious results are reported and happen around our lives. Most of them are unconventional contingency events. Emergency relief is an important activity dealing with the disasters to transfer a large number of materials to the destroyed places for casualties and reconstruction for the country, even the world. Container multimodal transportation will play an important role because of its superior characteristics. The relations in the process of supply and transportation build up the container supply chain. It is critical to schedule the multimodal transportation flow of the chain with time efficiency of higher reliability. In this study, the system of container multimodal transportation emergency relief is modeled as an affinity network inspired by the immune system. An integer linear programming model is proposed to build the path selection for container supply chain in the context of emergency relief. The simulation study shows the promising effects of the model. The study is valuable for designing the emergency logistics management system with optimal path selection and flow design of container supply chain in disaster environments.

1. Introduction

Natural disasters have brought a great impact on human beings. They are difficult to be predicted and it is too urgent to prepare for it. Emergency management has become a hot research field. Emergency relief is a very important process of emergency management. And it is a key task that we can do for the destroyed places and the wounded people when facing the disasters. Logistics support is one of the major activities in disaster response. Commodities such as food, shelter and medicine must be sent from the supply center to the affected area as quickly as possible to support rescue operation and help wounded people. This process is emergency relief. Commonly, the emergency relief is organized by the government. The components in emergency relief involve the disaster events, the destroyed places, the wounded people, the supply and transport of commodities, and the means and environments of transport, which consist of a complex system. The timely and correct decisions in this system are critical to rescue the people and reduce the effects of the disaster. For serious disasters, a large amount of commodities must be provided and transported. The range of supply and transport varies in a large extent so that container multimodal transport is an important way in emergency logistics. In this study, we try to model the system of container multimodal transport emergency relief based on immune-inspired models.

Immune system is a typical complex system. Its mechanisms and principles have been extracted to design intelligent algorithms and systems. First, the immune system is to discriminate the 'nonself' and destroy them. It is called 'Self and Non-Self Discrimination' (SNSD). Second, maintaining the stability of the body is a lifelong function expressed by the entire immune system. In order to achieve the two key functions, the components (organisms, issues, cells and other immune units) and their genotypes are organized in a dynamic network. The collaboration among them is to produce quick response to the invaders. Especially, the immune system can inherit the abilities and learn from the history and environments. These features and the underlying immune mechanisms give us inspirations to design a corresponding model of emergency relief and seek immune-inspired mechanisms for optimization.

The main contributions of the study include the following three aspects. First, a scheduling framework is proposed for the container multimodal transport emergency relief. Second, an immune-inspired affinity model is studied for emergency relief. The components are modeled by immune concepts. Affinity measures are designed to represent the complex relations among the components. Based on the affinity model, a decision process of emergency relief is proposed. Third, considering the characteristics of container multimodal transport, a multi-objective integer linear programming model is proposed for path selection and optimization. The

* Tel./fax: +86 21 58855200.
E-mail address: zhhu@shmtu.edu.cn

0957-4174/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2010.08.053

demonstration study shows the promising performance of the approach.

The remaining of this paper is organized as follows. In Section 2, we introduce the background including container multimodal transport, immune intelligence, and emergency logistics. In Section 3, the immune-inspired models for emergency relief are studied. In Section 4, the path selection and optimization of container multimodal transport are demonstrated in case. In Section 5, we conclude the paper with some remarks as well as future research directions.

2. Background

2.1. Container multimodal transportation

Container transportation plays a more and more important role in international transportation and trade. According to the summaries by WTO, in the whole world, there are more than 2 billion containers undertaking cargo transportation.

Multimodal transport (also referred to as combined transport) is the transportation of goods under a single contract but performed with at least two different means of transport, i.e. the carrier (in a legal sense) is liable for the entire carriage even though it is performed with several different means of transport (e.g. rail, road and water). The carrier, however, does not have to be in the possession of all of the means of transport and in practice usually is not. The carriage is often performed by using sub-carriers, in legal language often referred to as actual carriers. The carrier that is responsible for the entire carriage is referred to as a multimodal transport operator. The UN Multimodal Convention defines multimodal transport as follows: "International multimodal transport" means the carriage of goods by at least two different modes of transport on the basis of a multimodal transport contract from a place in one country at which the goods are taken in charge by the multimodal transport operator to a place designated for delivery situated in a different country. Therefore, there are two prominent characteristics of multimodal transport network. First, from one place to another, there may be more than one means of transport. Second, in order to transfer one means to another, the place should have additional capabilities, such as loading/unloading containers to/from transport tools of different means.

The related researches of container transport can be classified into two categories. One is to design the transport network (Lingaitiene, 2008; Oduwole, 1995; Qu, Chen, & Mu, 2008; Schönharting, Schmidt, Frank, & Bremer, 2003; Yamada, Russ, Castro, & Taniguchi, 2009) and another is to optimize the route selection for a specific task (Li, Huang, Lam, & Wong, 2007; Oduwole, 1995). The application of container multimodal transport is seldom seen in the literature.

2.2. Immune intelligence

Artificial immune system is a computational intelligence paradigm, which has found applications in data mine (Bereta & Burczynski, 2009), scheduling (Luh & Chueh, 2009), control (Kalinli & Karaboga, 2005), machine learning (Timmis, Hone, Stibor, & Clark, 2008), security (Swimmer, 2007), optimization (Hu, Ding, & Shao, 2009), and many other fields (Timmis et al., 2008). However, most studies are limited within several immune principles and models, including clonal selection, negative selection, immune network, and danger model, which are utilized independently. Moreover, these studies focus on the immune algorithms to improve other algorithms or to serve specific problems.

In the biological view, the components and principles in immune system do not operate in isolation, but act as a whole by delicate organization. The cytokine network is an important way to support coordination among immune components. Based on these principles, a few studies have captured some systematical requirements and proposed some models and frameworks for security of information systems or networks. For example, a distributed defense system is studied inspired by the danger model of immune system (Swimmer, 2007). In our previous study, the evolutionary features in these frameworks were studied and applied in the researches on multi-objective optimization (Hu, 2009), distributed computing systems (Ding, Hu, & Sun, 2008; Hu & Ding, 2009) and co-evolutionary design (Hu, Ding, Zhang, & Yan, 2008). There are many models, principles and concepts in the immune system. They can be employed to build models or design intelligent mechanisms for complex systems.

2.3. Emergent logistics

Emergency logistics management has emerged as a hot research field as artificial or natural disasters may occur anytime around the world with enormous serious consequences. Such disasters need quick-responsive emergency logistics systems for efficient emergency relief supply and recovery. Although emergency logistics is vital, it has also raised numerous challenging issues, which may not be addressed as easily as in business logistics (Sheu, 2007a). Some researchers have devoted to the field and published some important achievements. In the following, the research literatures are summarized.

In emergency logistics management, there are many game relations among contingency events, response strategies, and departments of various levels. Decision support platform and mechanisms (Parsa & Parand, 2007; Wang & Liao, 1997; Yeh & Chang, 2009) are effective approaches to coordinate the relations. Game theory (Radmacher & Thomas, 2008) and improvisation decision technology (Mendonça, 2007; Mendonça, Beroggi, & Wallace, 2001) are two prominent theories for emergency decision. Logistics is the main support tool for emergency management, especially for emergency relief. Emergency logistics has become a hot field in emergency management research.

In the research of design theory of emergency logistics network, a hierarchical network for the time-definite express common carriers is proposed in Lin and Chen (2004). An emergency response model is studied for military or non-military in Pettit and Beresford (2005). In Li and Tang (2008), an artificial emergency logistics planning system is proposed for severe disasters. In Yi and Ozdamar (2007), the dynamic logistics coordination model is proposed to support emergency relief. These achievements focus on the path scheduling problems for different logistics network and emergency constraints. Commonly, only the single transport means is considered. In Chang, Tseng, and Chen (2007), a scenario planning approach is proposed under the uncertainty environments for flood emergency logistics. In Yi and Kumar (2007), the optimization approach based on ant algorithm is studied to reduce the disaster effects. In Sheu (2007b), the hybrid fuzzy clustering optimization approach is proposed for coordination in logistics distribution under urgent demands. In Yan and Shih (2009), the time–space network model in emergency response is proposed for roadway repair and subsequent relief distribution. In Özdamar, Ekinci, and Küçükyazici (2004), the emergency logistics planning model is proposed for natural disasters. In the proposed logistics planning model for decision support system, in the determined time range of plan, when new suppliers or transport means are available, or there are new requests for relief resources, the model is built to optimize the vehicle routing problem and the loading/unloading problem so that the time-dependent dynamical transport problem is solved. In scheduling optimization of emergency logistics system, the present research focuses on the efficiency improvement.