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An application oriented multi-agent based approach to dynamic load/truck planning

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ABSTRACT

Truck operations decisions for transportation logistics pose challenges especially when loads are less-than-truckload (LTL). Within a dynamic business environment load planners should consider effective utilization of resources and profitability of their operations. Multi-agent based system provides effective mechanisms for the management of dynamic operations in transportation. The algorithms for transportation domain that are available in the literature are generally focusing on generation of effective solutions for planning/scheduling problems without considering real transportation systems dynamics. Multi-agent based design of the load/truck planning problems is supposed to be helpful for integration of algorithms with real-time logistics controlling systems. The cooperative structure of the multi-agent based approach is motivated by real-world third party logistics (3PL) company operations. Negotiation mechanism among the agents is used to handle the dynamic events. The proposed approach is tested via simulation by using LTL data from a 3PL logistics company. The approach generates feasible and profitable decisions under dynamic circumstances by using negotiation/bidding mechanisms. Proposed approach is implemented by using JACK™, an agent development framework. A multi-agent based dynamic load/truck control system (MABDLCS) is also developed along with this approach. MABDLCS could be used for both testing some transportation scenarios and for real time vehicle/load control purposes. The solutions obtained by using the proposed approach demonstrated that MAS is contributing on problem solution quality while generating real-time schedules.

1. Introduction

Around the world, regions, both geographic and economic, have different strengths and weakness (Chen, Wang, & Xu, 2005). It necessitates the transportation of goods which are produced in different regions. Transportation is an important domain of human activity, and it is an important economic indicator of a nation (Mesa-Arango & Ukkusuri, 2013). It supports and makes possible most other social and economic activities and exchanges (Crainic, 2003). Successful management of flow of materials between different parts of the world is crucial for both economical and ecological reasons.

In today's world it is easy to build partnership between international companies with the advent of high technology in telecommunication. Due to the increased partnership between the firms, transportation has become more and more important than ever. Partnership could be seen even among firms and users (Nourinejad & Roorda, 2014). Nevertheless, as the partnership increased the type of the loads and freight rates changed proportionally. As the freight rates are negotiable among the manufacturers and carriers, there are numerous different types of freight rates for the truckloads (TL) and less-than-truckloads (LTL) shipments (Jackson, 1981). As a result of the high number of freight rates, the number of transportation service types which are provided by the logistics companies is increased. As international competition increased, improving information systems has forced logistics companies to use new business management techniques (Baykasoğlu & Kaplanoğlu, 2006).

In the planning stage, excessive installations and unbalanced spatial distribution of service facilities obviously incur a waste of investment and resources (Li, 2013). Therefore it results in high transportation cost for 3PL companies. In order to reduce the cost of transportation, manufacturers, logistics agencies and shippers are all in contact with each other. It is resulting in cooperation, joint transportation and load consolidation. All parties try to increase coordination among them in order to consolidate the loads, and reduce the cost of transportation (Baykasoglu & Kaplanoglu, 2011). There are many new technologies which

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support to increase coordination within and among the parties. Satellite monitoring systems, geographic information systems, mobile communication systems and navigation systems are some technologies which could be used in order to increase coordination of transportation operations. Although abundance of transportation types and available technologies reduces the transportation costs, the business complexity of transportation companies increases proportionally.

Logistics system managers are generally making the decision of transportation with a fleet of vehicles on their hand. While making this decision they try to find an answer to the question; "what is the cost of the transportation?". Dispatch officers who make these decisions take into consideration all the dynamics of their logistics system to answer operational questions. Previously accepted orders, geographical positions of the vehicles, physical capacities of the containers, governmental regulations, updated road information, traffic jam and driver schedules are some examples of data that shape the decision of the dispatch officers.

In this study, transportation order arrangement and vehicle operations management are modeled and solved with a multi-agent paradigm. Multi-agent based systems, a newly maturing area of distributed artificial intelligence, provide some effective mechanisms for the management of such dynamic operations. The proposed multi-agent based model works under a dynamic environment, and generates feasible load/truck planning decisions using negotiation/bidding mechanisms between agent types.

Organization of this paper is as follows: in Section 2, state of the art about agent based systems and their implementation in logistics is presented. Section 3 shows the multi-agent based dynamic load/truck planning model. Section 4 presents logistics company transportation network and the application of the model to a logistics company. Some test runs are demonstrated to show the capabilities of the proposed model. Finally, conclusions with further projections are given in Section 5.

2. State of the art for multi-agent systems in transportation domain

In this section of the paper, definition of agent and multi-agent systems are introduced first. Then relevant literature about multi-agent systems and transportation planning domain are presented. A discussion is made about current literature and unique contribution of the present paper at the end of this section.

2.1. Multi-agent systems

Agent based design and application methods are newly emerged paradigms in computer science and artificial intelligence research area. In artificial intelligence, an agent is defined as anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators (Russell & Norvig, 2010). Actually, there is no consensus on the definition of software agents in the literature because it is a fairly young research area (Padgham & Winikoff, 2004). Most of the focus in this field is based on computer software units that mimic the human intelligence. As we consider computer software agents; Wooldridge and Jennings (1995)'s definition is increasingly adopted in this field which is; "An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives". Agent is also defined as; "autonomous, computational entity that can be viewed as perceiving its environment and acting upon it" (Farahvash & Boucher, 2004). In another definition, an agent is defined as a component that can exhibit reasoning behavior under both proactive (goal directed) and reactive (event-driven) stimuli.

Agents are also considered as computer systems with two important capabilities. First, they are at least to some extent capable of autonomous action of deciding for themselves what they need to do in order to satisfy their design objectives. Second, they are capable of interacting with other agents, not simply by exchanging data, but by engaging in analogues of the kind of social activity that we all engage in every day of our lives: cooperation, coordination, negotiation, and the like (Wooldridge, 2002). Therefore, agents are also considered as social, because they cooperate with humans or other agent types in order to achieve their tasks. Additionally, agents are reactive, because they perceive their environment and respond in a timely fashion to changes that occur in the environment. In addition to that, agents are proactive, because they do not simply act in response to its environment but are able to exhibit goal-directed behavior by taking initiative (Bellifemine, Caire, & Greenwood, 2007). When an agent is instantiated, it will wait until it is given a goal to achieve or experiences an event that it must respond to Hahn, Madrigal-Mora, and Fischer (2009). All definitions agree that an agent is essentially a special software component that has autonomy that provides an interoperable interface to an arbitrary system and/or behaves like a human agent, working for some clients in pursuit of its own agenda (Bellifemine et al., 2007).

An agent system can have a single agent working within an environment and interacting with its users. When many agents operate as collaborator or competitors, it is called multi-agent systems (MAS). MAS is a collection of organized intelligent and autonomous software agents that work together or compete to find answers to problems that are complex for a single software agent to solve (Erol, Sahin, Baykasoglu, & Kaplanoglu, 2012). Most of the systems in practical usage are based on multi-agent mechanism where agents negotiate and try to find solution for particular problems. MAS can be used to model complex systems and introduce the possibility of agents having common or conflicting goals (Bellifemine et al., 2007).

When all the definitions and characteristics of the agent and/or multi-agent based systems are considered it can be figured out that transportation domain is very suitable for agent research because transportation domain is totally decentralized, distributed and dynamic. Higher organizational units like dispatchers, forwarders, carriers, consigners, consignees, stevedores, etc., as well as the loads or loading units (containers, palettes, packages, etc.) may be represented as agents (Bürckert, Fischer, & Vierke, 2000). After representing them as an agent type we can use the capabilities of agent based systems to make transportation units to compete and cooperate to find optimal (or near optimal) solutions in a dynamic way.

Multi-agent technology provides autonomous and flexible problem-solving capabilities in dynamic and adaptive environments (Zhang, Zhang, Cai, & Jian, 2015). We can state that MAS can help transportation capacity/route planning decisions. We can list the reasons for why multi-agent based systems are suitable for logistics domain as;

- The domain is inherently distributed (Fischer, Müller, & Pischel, 1996).
- There is a high degree of dynamics in the process of planning (Fischer et al., 1996).
- Human-experience (intelligence) is used for planning operations.
- High amount of environmental factors exist (traffic jams, vehicle breakdowns, etc.).
- Need for cooperation among the parties.
- Distributed and dynamic resources are used.