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Declarative Representation and Solution of Vehicle Routing with Pickup and Delivery Problem

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Abstract

Recently we have proposed a multi-agent system that provides an intelligent logistics brokerage service focusing on the transport activity for the efficient allocation of transport resources (vehicles or trucks) to the transport applications. The freight broker agent has a major role to coordinate transportation arrangements of transport customers (usually shippers and consignees) with transport resource providers or carriers, following the freight broker business model. We focus on the fundamental function of this business that aims to find available trucks and to define their feasible routes for transporting requested customer loads. The main contribution of this paper is on formulating our scheduling problem as a special type of vehicle routing with pickup and delivery problem. We propose a new set partitioning model of our specific problem. Vehicle routes are defined on the graph of cities, rather than on the graph of customer orders, as typically proposed by set partitioning formulations. This approach is particularly useful when a large number of customer orders sharing a significantly lower number of pickup and delivery points must be scheduled. Our achievement is the declarative representation and solution of the model using ECLiPSe state-of-the-art constraint logic programming system.

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Keywords: constraint logic programming, vehicle routing, pickup and delivery problem

1 Introduction

The research reported in this paper is motivated by a project involving the application of intelligent agent-based computational technologies to freight brokering. Recently we have proposed an agent based architecture of a freight brokering system [8]. We have identified the major role of the freight broker agent in matchmaking of provided transport resources with requested transportation orders such that various transportation constraints are met. We proposed a solution for the broker agent that integrates agent and service technologies [7]. The broker agent

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uses a mathematical optimization service to compute an optimal transportation schedule that fulfils the customer requirements.

Our main contribution is to formulate the freight broker function as a special vehicle routing with pickup and delivery problem [10]. There are many types, models, solution methods, and applications of vehicle routing. Our specific case involves many customer orders representing a set of requested freight deliveries. Each order specifies the source or pickup point, the destination or delivery point, as well as the transported capacity (for example the freight weight). Sources and destinations represent towns or cities of a geographical region. Pickup and delivery points (also known as transportation hops) can be arbitrarily shared by the orders, so the total number of hops specified by the orders can be different, actually lower, than the total number of orders. Note that hops can represent towns, cities, or even different regions or areas in a certain, usually large, city, depending on the modeling decision taken by the model engineer.

Mathematical models of vehicle routing typically fall into one of two categories: vehicle flow and respectively set partitioning [10]. Our new proposed model can be described as belonging to the class of set partitioning. Nevertheless, vehicle routes are defined on the graph of hops, rather than on the graph of customer orders, as typically proposed by set partitioning formulations. This approach is particularly useful when a large number of orders sharing a significantly lower number of pickup and delivery points must be scheduled.

Our main achievement is the formulation of the declarative model of the problem. We also propose the model representation and solution using ECLiPSe state-of-the-art constraint logic programming [3] system.

There are three major directions of developing declarative languages for the specification and solution of constraint satisfaction problems: constraint logic programming (or CLP hereafter) [4], answer set programming (ASP hereafter) [5] and satisfiability checking (SAT hereafter) [6]. An experimental comparison of CLP with finite domains and ASP for solving combinatorial NP-complete problems is presented in [2]. Our proposal belongs to the CLP approach.

There are also approaches of combining constraint satisfaction with evolutionary algorithms. An optimization method by hybridizing genetic algorithms with CLP is proposed in [1]. The method uses constraint satisfaction to search feasible solutions on a subspace of the search space, and genetic algorithms to efficiently explore the space of subspaces for optimal solutions.

2 Mathematical Model

2.1 Background

Recently we proposed a multi-agent system that provides an intelligent logistics brokerage service focusing on the transport activity for the efficient allocation of transport resources (vehicles or trucks) to the transport applications. The goal is to create optimal transport routes or policies such that a vehicle does not move without cargo or at least, that the movement without cargo is kept at a minimum, on the road segments between two loading and/or unloading points.

In our system a freight broker agent coordinates arrangements between transport customers (shippers and consignees) and transport resource providers or carriers, following the freight broker business model. We focus on the fundamental function of this business that aims to find available trucks and to define their feasible routes for transporting requested customer loads.

In what follows we assume that customer orders are accumulated over a period of time, before shipping. Available trucks are also recorded into the system, as soon as they become ready for serving new transport requests. The freight broker agent maintains this information and applies mathematical optimization methods for the freight brokerage industry [13].