A Decision-Theoretic Model for Cooperative Transportation Scheduling*

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Abstract. In this paper we analyse the domain of transportation scheduling in shipping companies from the perspective of decision theory. After giving a brief description of the application and the simulation system MARS based on the multiagent paradigm, the transportation domain is characterised according to [11]. The paper comes up with the result that it is useful to split up the class of task-oriented domains into two subclasses: cooperative and competitive task-oriented domains. The paper shows that properties like subadditivity only hold only for very specific subproblems in the transportation domain. We prove that lying may be beneficial in the transportation domain. We argue that, based on this result, it is highly desirable to have negotiation strategies for agents in the transportation domain which are robust against lying. The last section describes such a negotiation strategy.

1 Introduction

Over the past few years, the scheduling of transportation orders has been established as an important application area for multiagent systems technology both from an academic and from a practical perspective (see [10] [8] [9] [5]). It offers interesting complexity properties, an inherent distribution of knowledge and control, natural possibilities to study coordination and cooperation, and finally, there is a considerable economic interest in obtaining good solutions for these kinds of problems1.

The MARS (Modeling a Multi-Agent Scenario for Shipping Companies) system [4] [5] constitutes a multi-agent approach to these problems: a scenario of transportation companies is described. The companies have to carry out transportation orders which arrive asynchronously and dynamically. For this purpose, they have a set of trucks at their disposal. Trucks are agents that maintain local plans. Interaction between a company and its trucks is implemented by contract-net–like auction protocols [4].

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1 For a comprehensive overview of related work in the areas of Operations research and AI, see [5].
This paper provides a decision-theoretic analysis of the domain. It investigates in how far the results achieved by Rosenschein and Zlotkin [7] can be applied to the transportation domain. We come up with the result that it is useful to divide the class of task-oriented domains into two subclasses: cooperative and competitive task-oriented domains. The transportation domain provides examples for both categories of task-oriented domains. The cooperative setting characterises the situation within one shipping company where the main problem is to optimally allocate orders to a set of trucks, which is a complex scheduling problem. Results from an analysis of this setting have been published in [5]. The focus of this paper is on the competitive setting, which describes the situation in negotiation processes among shipping companies. Furthermore, we show that properties like subadditivity hold only in very specific subdomains of the transportation domain. The fact that the results of Zlotkin and Rosenschein only partially map to the transportation domain enforces us to prove separately certain properties of the domain: In Section 4, we show that lying may be beneficial also in the transportation domain. These results justify the need for negotiation strategies for the transportation domain which do not give agents an incentive to lie. We present preliminary work on a negotiation strategy that fulfils these requirements.

2 The Transportation Domain

The domain of application of the MARS system is the planning and scheduling of transportation orders which is done in everyday life by human dispatchers in transportation companies. Many of the problems which must be solved in this area, such as the Travelling Salesman and related scheduling problems, are known to be NP-hard. Moreover, not only since just-in-time production has come up, planning must be performed under a high degree of uncertainty and incompleteness, and it is highly dynamic. In reality these problems are far from being solved.

Cooperation and coordination seem to be two very important processes that may help to overcome the problems sketched above. Indeed, they are of increasing importance even in the highly competitive transportation business of today. Using the MARS system, several patterns of cooperation such as the announcement of unbooked legs, order brokering, and different strategies for information exchanges have been experimentally evaluated [3].

Corresponding to the physical entities in the domain, there are two basic types of agents in MARS: transportation companies and trucks. Companies can communicate with their trucks and among each other. The user may dynamically dedicate transportation orders to specific companies. Looking upon trucks as agents allows us to delegate problem-solving skills to them (such as route-planning and local plan optimisation). The shipping company agent has to allocate orders to its trucks, while trying to satisfy the constraints provided by the user as well as local optimality criteria (costs). A company also may decide to cooperate with another company instead of having an order executed