Transportation Research Part C 45 (2014) 83–98

Contents lists available at ScienceDirect

Transportation Research Part C

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

Multi-agent simulation of individual mobility behavior in carpooling

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ARTICLE INFO

Article history:
Received 14 May 2013
Received in revised form 8 November 2013
Accepted 31 December 2013
Available online 22 January 2014

Keywords:
Carpooling problem
Multi-agent simulation
Organizational model
Janus platform
JaSim environment model
FEATHERS

ABSTRACT

Carpooling is an emerging alternative transportation mode that is eco-friendly and sustainable as it enables commuters to save time, travel resource, reduce emission and traffic congestion. The procedure of carpooling consists of a number of steps namely; (i) create a motive to carpool, (ii) communicate this motive with other agents, (iii) negotiate a plan with the interested agents, (iv) execute the agreed plans, and (v) provide a feedback to all concerned agents. In this paper, we present a conceptual design of an agent-based model (ABM) for the carpooling a that serves as a proof of concept. Our model for the carpooling application is a computational model that is used for simulating the interactions of autonomous agents and to analyze the effects of change in factors related to the infrastructure, behavior and cost. In our carpooling application, we use agent profiles and social networks to initiate our agent communication model and then employ a route matching algorithm, and a utility function to trigger the negotiation process between agents. We developed a prototype of our agent-based carpooling application based on the work presented in this paper and carried out a validation study of our results with real data collected in Flanders, Belgium.

1. Introduction

Nowadays, carpooling is an emerging transportation mode that is eco-friendly and sustainable as it enables commuters not only to save the travel cost, such as fuel, toll and parking costs, of the carpooling participants, but also to reduce emissions and traffic congestions. Carpooling, known as ride-sharing, is the sharing of a car between people (agents) from a certain origin to a specific destination. Thus, in order to study the carpooling concept, we should take into account the interactions of two or more agents throughout the carpooling process. The procedure of carpooling consists of a number of steps, namely: (i) create a motive to carpool, (ii) communicate this motive to other agents, (iii) negotiate a plan with the interested agents, (iv) execute the agreed plans, and (v) provide a feedback to all concerned agents. Creating a motive means that a traveler (agent) may choose to carpool because of the availability of travel resources, time, monetary and route cost constraints.

Moreover, change in some socio-economic factors such as the increase in fuel price, in parking costs, or in the implementation of a new traffic policy, may trigger the initiative to carpool. Once to the decision has been made to carpool, the traveler

[1] http://www.multiagent.fr.
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http://dx.doi.org/10.1016/j.trc.2013.12.012

(agent) will try to find one or more potential partners (agents). First, each individual looks in its social network to find carpooling companions. If none can be found, global web-based matching advisors can be used. When a company plans to deploy such matching advisor software, it shall perform thorough testing because a failing service and wrong advice provision will cause customer loss. Furthermore, the company will be interested to study the transient effects occurring during the initial deployment stage. Neither this evaluation nor the testing can be performed with the help of real users. Hence, a virtual agent community is built. The agent-based model is used to evaluate the global carpooling advisory software.

The carpool initiating agent will send a request to other interested agents in its vicinity. If one or more agents who receive this request are willing to carpool, then they begin the negotiation phase. In this phase, these agents will negotiate about sharing their travel resources and optimizing total costs and daily schedules. After reaching a compromise, these agents can do carpooling. Meanwhile, an agent can appraise its partners according to their degrees of faithfulness to the carpooling. We call this degree of faithfulness the agent reputation. This reputation factor can serve as a criterion for the selection of a potential partner for carpooling. An agent-based model (ABM) is a class of computational models for simulating the actions and interactions of autonomous agents with a view to assessing their effects on the systems as a whole (Ferber, 1999; Niazi and Hussain, 2011). ABM is now widely used for modeling increasingly complex systems (Macal and North, 2005; Cossentino et al., 2010). Application of ABM is not only limited to the computer science domain. Currently, many research areas such as transportation behavior modeling, need to analyze and understand the complex phenomenon of interactions between different entities. While traditional modeling tools cannot catch the complexity, ABM can do it through modeling the interaction of autonomous agents and deducing the rules for such a system. We, therefore, in this paper propose an agent-based interaction model for the carpooling application.

This paper briefly describes a conceptual design of the carpooling application, initially proposed by Cho et al. (2012), Bellemans et al. (2012), and Galland et al. (2013). It uses an agent-based model on the Janus platform[3] (Galland et al., 2010). A simulation model needs to be created to support the individual behaviors of the participants. The contribution of this paper is the design and the implementation of an agent-based model upon the Janus multi-agent platform. This platform permits to individuals to (i) select the best transport mode according to their characteristics; (ii) maintain a social network; (iii) negotiate for carpooling; and (iv) carpool the driver and the passengers of a car.

Section 2 presents some related work to the carpooling concept and ABM. Section 3 explains our ABM for the carpooling application with details of the activities and the roles of the agents, and of the environment. Section 4 gives several implementation notes and experimental results. Section 5 is dedicated to our concluding thoughts and ideas for future work.

2. Background

Research on the carpooling concept is largely separated into two parts: (i) technical studies and (ii) empirical studies. The first ones focus on the development of carpooling support systems with techniques of travel route matching (DeLoach and Tiemann, 2012; Massaro et al., 2009). In the second part, the overall trend of carpooling – or of the interrelationship between willingness-to-carpool and the socio-economic attributes of the carpooling participants – is treated in general (Kamar and Horvitz, 2009; Horvitz et al., 2005). The previously mentioned studies are limited, and they do not consider the potential agent (participants) interactions to perform carpooling.

Most transportation-related applications of ABM are related to vehicle routing, pedestrian-flow simulation or demand modeling efforts (Bernhardt, 2007). Among these applications two of the more widely known are the ABM simulation platforms TRANSIMS and MATSIM. TRANSIMS, developed by Los Alamos Lab, is designed to supply transportation planners with more delicate information about traffic impacts, energy consumption, land-use planning and emergency evacuation (Smith et al., 1995). MATSIM is also a large-scale agent-based simulator similar to TRANSIMS, but it is different using of XML and quickly run simulation, due to a simplified traffic simulator (Waraich et al., 2009). Those applications only consider the whole effect of each agent's action on a system, and cannot handle a detailed agent-to-agent or agent-to-environment coordination, communication and negotiation.

According to Odell et al. (2002), "the environment provides the conditions under which an entity (agent or object) exists." The author distinguishes between the *physical environment* and the *communication environment*. The physical environment provides the laws, rules, constraints and policies that govern and support the physical existence of agents and entities. The communication environment provides (i) the principles and processes that govern and support exchanges of ideas, knowledge and information, and (ii) the functions and structures that are commonly deployed to exchange communication, such as roles, groups and interactions protocols between roles and groups.

Odell et al. (2002) define an agent's social environment as "a communication environment in which the agents interact in a coordinated manner." This approach is shared by Ferber et al. (2006), Cossentino et al. (2010), and Galland et al. (2009), who proposed to integrate the environment with organizational models. The Janus platform (Gaud et al., 2008; Galland et al., 2010) provides an implementation of the agent-based concepts, and of the Capacity–Role–Interaction–Organization metamodel (Cossentino et al., 2010). The JaSim library[4] (Galland et al., 2009) provides a model of the physical environment upon the janus platform. In the rest of this paper, the graphical notation is inspired by Cossentino et al. (2010).

[3] http://www.janus-project.org.
[4] http://www.multiagent.fr/Jasim_Platform.