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Procedia Computer Science 37 (2014) 396 – 403

Procedia Computer Science

The 1st International Workshop on Information Fusion for Smart Mobility Solutions (IFSMS'14)

Organizational and Agent-based Automated Negotiation Model for Carpooling

Iftikhar Hussain[a,*], Luk Knapen[a], Stephane Galland[b], Davy Janssens[a], Tom Bellemans[a], Ansar-Ul-Haque Yasar[a] and Geert Wets[a]

[a] *Transportation Research Institute (IMOB), Hasselt University, Wetenschapspark 5 bus 6, 3590 Diepenbeek, Belgium*
[b] *Multiagent Group, IRTES-SET, Université de Technologie de Belfort-Montbéliard, 90010 Belfort cedex, France*

Abstract

In the carpooling, individuals need to communicate, negotiate and in most cases adapt their daily schedule to enable cooperation. Through negotiation, agents (individuals) can reach complex agreements in an iterative way which meet the criteria for successful negotiation. The result of the negotiation depends on "negotiation mechanism" used to match and on the behavior of the agents involved in the negotiation process. This paper presents an organizational and agent-based model for commuting by candidate carpoolers using a simple negotiation mechanism aimed at finding an acceptable agreement between agents to carpool. Initially, the agents involved in exploration process, search for their partners via some kind of Agent Communication Language (ACL); after finding potential partners, they start a negotiation to find matched partner to carpool. After having found a good match, the agents can carpool for a specified time period. The agents join the carpool group when the negotiation is successful and leave the carpool group when the agreed time period is expired. Agents can be part of several carpool groups sequentially. The first implementation used home and work locations as well as preferred trip start times and carpool periods determined by uniformly sampling given sets. Furthermore a simplistic negotiation mechanism used roughly to produce possible results for the synthetic data. An automated negotiation model is implemented and validated through simulation. The Janus multi-agent platform is used. Future research will mainly focus on the development of behaviorally sound negotiation mechanism.

Peer-review under responsibility of the Program Chairs of EUSPN-2014 and ICTH 2014.

Keywords: Negotiation; carpooling; negotiation model; agent-based social simulation; Organizational model; Agent technology; Janus platform;

* Iftikhar Hussain. Tel.: +32-11-269169; fax: +32-11- 26 91 99.
E-mail address: iftikhar.hussain@uhasselt.be

Peer-review under responsibility of the Program Chairs of EUSPN-2014 and ICTH 2014.
doi:10.1016/j.procs.2014.08.059

1. Introduction

"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"[2]. In carpooling, individuals need to coordinate, negotiate and in most cases adapt their agenda (daily schedule) to enable cooperation. Information propagation between agents can be carried out using the interaction between agents in their social group. Feedback information from social interaction can be used by the individual schedule executor to adapt the schedules. The coordination and negotiation mechanisms lead to NP-hard problems in carpooling. Each negotiation involves a small amount of participants but daily schedules can be interconnected by cooperation[1,11].

An agent-based model (ABM) is a computational model aimed at simulating the actions and interactions of autonomous agents. Agents can be both individual or collective entities such as organizations or groups with a view to evaluate their effects on the system as a whole[15]. A review of recent literature on agent-based models shows that ABMs are not limited to the computing but also are used in non-computing related scientific domains including biology, ecology and social science[16]. With agent-based social simulation (ABSS) we can explore different outcomes for phenomena, transportation, market mechanisms, cooperation and escalation and spreading of conflicts, where we might not be able to view the outcome in real life. ABSS can provide valuable information on society and on the outcome of social actions or phenomena. Currently many research areas including transportation behavior, need to analyze and model complex phenomena of interactions between different autonomous entities. While traditional modelling tools cannot handle the complexity of negotiation in carpooling, ABM is able to do so through modelling the interaction of autonomous agents[8].

This research focuses on the simulation of the evolution of a set of candidate carpoolers. The first implementation is aimed at the setup of the framework and of a network of a carpooling candidates. It makes use of a simple negotiation model that later will be replaced by a behavioral realistic one. The model is based on an agent-based and organizational meta-model[18], in which role and organization are first class entities. In the proposed conceptual model agents are the individuals, who negotiate to reach an agreement to carpool. The daily activities of each agent is divided into different phases: exploration, negotiation and trip execution. During the exploration the agents explore their social network and send requests for carpooling. In the negotiation, agents can reach complex agreements depends on the negotiation mechanism, discussed in section 2.4, used to match partner and on the behavior of the agents involved in the negotiation process. For the trip execution, after finding matched partners, agents carpool for a specified time period. The agent behavior is encoded by state-machines. When in the *EXPLORE* state, agents explore for partners by sending *CarPoolRequest* messages. While in the *DRIVER* or *PASSENGER* states, agents play the role of driver or passenger during carpooling. The suggested model uses *CarPoolOrganization*, to model several different *CarPoolGroups*, and *NextDayOrganization*, to move all agents simultaneously to the next simulated day. The Janus[17], multi-agent based platform is used; it provides an efficient implementation of agent-based and organizational concepts.

The organization of this paper is as follows; section 2 covers the negotiation model for the carpooling application. Section 3 explains an experimental setup and some results. Section 4 briefly describes the related works on carpooling and ABM. Finally, conclusions and future work are presented in section 5.

2. Proposed Negotiation Model for Commuting of Carpoolers

Negotiation is a dialogue among parties possibly having conflicting interests and is intended to reach an acceptable agreement between partners or to collectively search for a coordinated solution to a problem. Negotiation may be bilateral or multilateral and may involve one or multiple issues in a negotiation[14].

This paper focuses on automated organizational-based and agent-based negotiation in carpooling for cooperative travelling. Long term (for multiple years) carpooling for commuting is simulated using the Janus multi-agent based platform. Agents (individuals) can interact with each other autonomously to find matching partners to carpool for multiple days and during multiple consecutive periods in different groups. The goal is to simulate how everyone is deciding to carpool, and how the carpooling process is executed. From the simulation's discussions, it is possible to understand the causes why people can adapt their daily schedule to enable cooperation in carpooling in a given area.

Figure 1 shows all the activities of an agent for specified period (e.g. number of years) in the simulation.

1. In this simulation each agent looks for other individuals to cooperate while executing its periodic trip by exploring social network. The parameter *ProbabilityToCarpool* is used in *exploration* activity to select the transportation mode (here in this case, the agent decide either he will carpool or not). If the agent decides to carpool, he will perform negotiation activity, otherwise he may travel on his own car or chose any other transportation mode.
2. There are three activities in *negotiation* activity; communication, negotiation and cooperation. The agents can communicate with each other by using agent communication language. Each agent can send and/or receive text messages to/from other agent. There are three kind of text messages used in this simulation, *CarpoolRequest*, *Accept* and *Reject* Messages. The agents who has matched home and work locations can negotiate on trip depart time and also who has driving license and vehicle to decide who will become driver. For negotiation we suggest a negotiation mechanism discussed in section 2.4. After successful negotiation (according to negotiation mechanism) the agents' may adapt their daily schedule to enable cooperation.
3. The carpooling activity corresponds to the execution of the trip. The driver controls its car (with the carpooled passengers inside) on the roads. The road network is not considered in this simulation, we assign trips only between origin and destination. All the agents in a trip must play a role in an instance of this *CarPoolOrganization*. The driver of the trip will play as *DriverRole* and the passenger will play as *PassengerRole* in *CarPoolGroup*. During trip execution the driver and passengers can receive *CarpoolRequest* messages from the other agents.

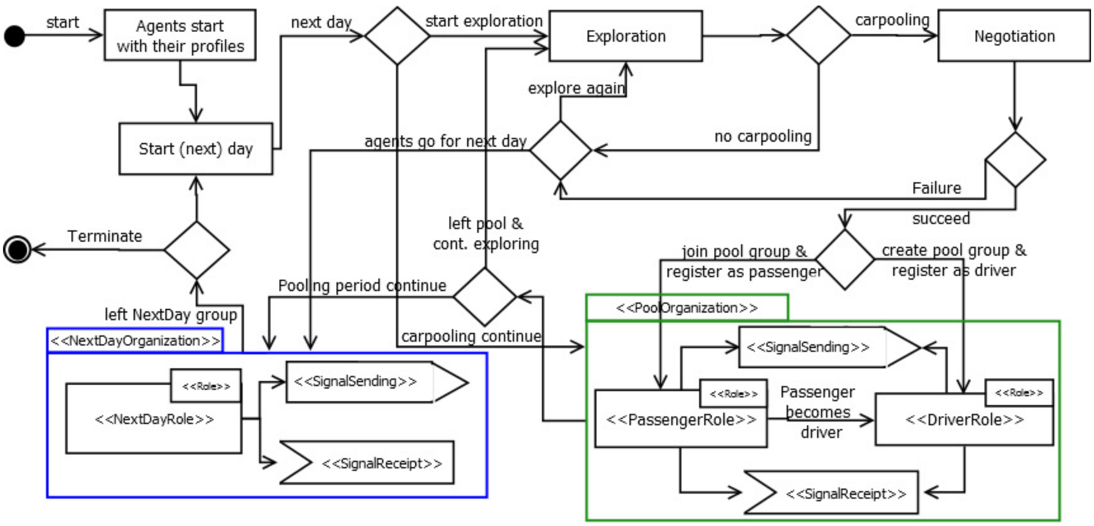

Figure 1: Activity diagram of an agent with organizations in simulation

2.1. Basic Inputs and Symbols Used

Before starting simulation, some parameters and variables need to be set; they are shown in table 1 with symbols and sample values L is the set of locations (home and work), A is the set of agents. The simulation automatically creates $10 x (|L| ^ 2)$ agents to see something happening in the simulation. The car capacity C_{cap} is constant and equal to 4. The length of simulated period is d_{simul} i.e. 3 years. For an agent, the probability to invite someone to carpool is P_{Explo}. The number of explorations per day is D_{Explo}. Furthermore D_{max} and D_{min} denote maximum and minimum carpool period durations. Δt is a time window.

When the simulation starts; each agent a_i is assigned its home location H_i (the commuting trip origin) and work location W_i (the commuting trip destination) randomly from the set L ($H_i \neq W_i$). Each agent gets a randomly selected trip start time t^w_i (between *08:00h* to *09:00h)* as well as a randomly chosen carpooling period length in the interval

[D_{max} - D_{min}] days. The effective trip start time $t^w{}_P$ of a *CarPoolGroup* is the mean value of all participating agents' start time $t^w{}_i$, and result from the negotiation mechanism discussed in section 2.4.

Table 1. Symbols and sample values.

Symbols	Meanings, default values, (units)
L	Set of all locations (origin and destination), either home or work *L* of *A*, ($L \in N$).
A	Set of all individuals, extract automatically by *10 x (|L| ^ 2)* from *L*, ($A \in N$).
a_i	Represents an individual or agent, $a_i \in A$, ($a_i \in W$)
H_i	Home location for individual a_i, $H_i \in L$.
W_i	Home location for individual a_i, $W_i \in L$.
P_{Explo}	Probability to start exploration by a non- carpooler on any given day, i.e. 0.20.
$t^w{}_i$	Start time for an individual, Select randomly (between 08:00h and 09:00h).
$t^w{}_P$	Preferred start time for pool *P* from Δt.
$t^w{}_{high}$	Higher start time for pool, 09:00h
$t^w{}_{low}$	Lower start time for a pool, 08:00h
d_{simul}	Duration of the simulation, i.e. 3 x number of working day of a year
D_{min}	Minimum duration for carpool, i.e. 60 days
D_{max}	Maximum duration for carpool, i.e. 90 days
C_{cap}	Maximum carpool size or car capacity, i.e. 4.
Δt	Maximum value for the absolute start time in order to be able to carpool
D_{Explo}	Number of explorations per day. i.e 5.

2.2. Agent Model

In this study, agents are the individuals, who negotiate to find acceptable agreement to carpool and execute their own daily schedule in order to satisfy their needs. In simulation, agent' behavior is modeled by a finite state machine. The states are; explore, wait, driver, passenger and idle as shown in Figure 2. An agent performs different activities in different states with organizations.

a. **EXPLORE**: Exploration is the act of searching, for the purpose of discovery of information, resources, or for people interested in cooperation. In the EXPLORE state, each agent (inviter) can explores for a partner (invitee) by sending *CarpoolRequest* messages to a randomly chosen other agents. Emission of an invitation, on given day, depends on the given *probabilityToInvite* parameter. As soon as an invitation has been emitted, the sender enters the WAIT state, waiting for the invitee's response. In the EXPLORE state, an agent can receive *CarpoolRequest* message from another agent; if the invitation is decent, then the agent will reply with *AcceptMessage,* and changes its state to the DRIVER state. Otherwise, it will reply with a *RejectMessage* and remains in the same state and continues exploration. The negotiation mechanism is described in section 2.5.
b. **WAIT**: In the WAIT state, if the invitee's response is an *AcceptMessage* then the inviter tries to join the *CarPoolGroup* the invitee belong to. If that succeeds, the inviter changes its state to PASSENGER. If the response is a *RejectMessage,* the inviting agent changes its state to EXPLORE again in order to try to find a partner. If the agent received a *CarpoolRequest* or other irrelevant message, then it simply replies with a *RejectMessage* and it remains in the WAIT state.
c. **DRIVER**: In DRIVER state the agent plays the *DriverRole* in *CarPoolGroup* and besides this the agent can receive *CarpoolRequest* messages and reply with either *AcceptMessage* or *RejectMessage* on the basis of inviter's profile and the car capacity. If the pool period for the driver expires, then the agent will leave its *DriverRole,* hands over the driver responsibility to the senior passenger of the same *CarPoolGroup* and change its state to EXPLORE. The Driver destroys the group when he is the only one left in the *CarPoolGroup* after all passengers have quit.

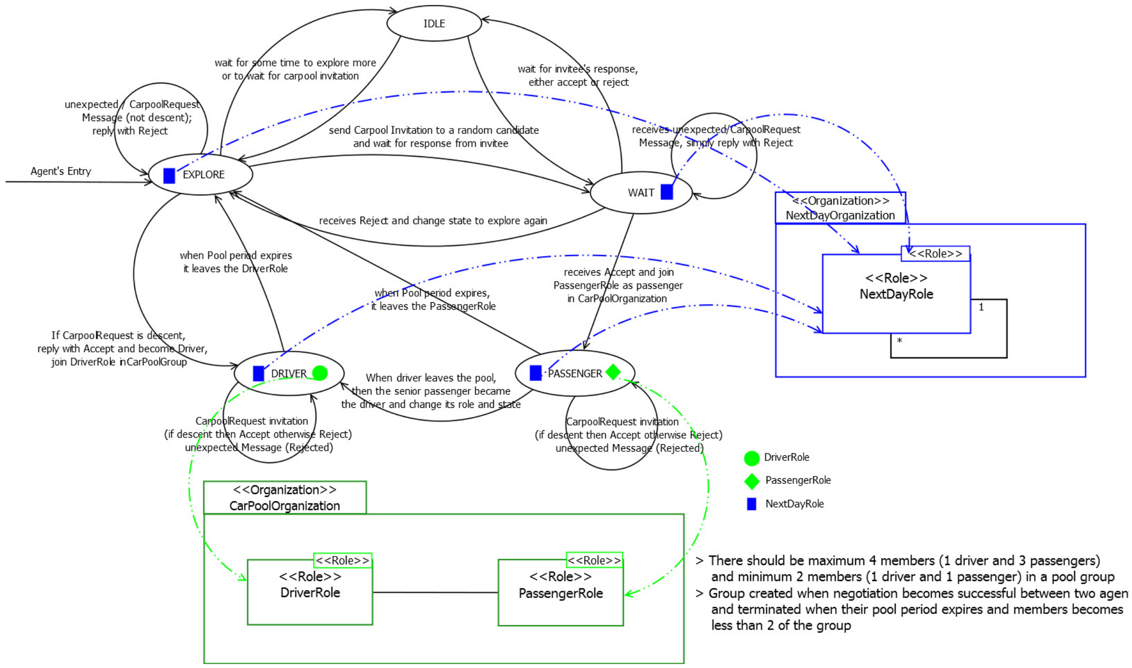

Figure 2: State-transition and organizational diagram of an agent in the simulation.

d. **PASSENGER**: In PASSENGER state the agent continues to play the *PassengerRole* in the *CarPoolGroup* until the pool period for the passenger expires. While being a passenger, the agent can also receive *CarpoolRequest* messages from inviters and can reply with either *AcceptMessage* or *RejectMessage* on the basis of the inviter's profile and the car capacity. The Passenger can also destroy the group when he is the only one left in the carpool group.
e. **IDLE**: After finishing the daily activities, the agent will transit to the IDLE state and will wait for other agents to finish their daily activities. All agents need to move to the next day simultaneously because of the conjunction of following reasons: (1) individuals carpool for a well-defined individual-specific period that is determined at the moment negotiation and (2) individuals can be member of carpools only sequentially and (3) neither carpools nor individuals keep track of a carpool calendar and (4) new individuals can join a carpool on any day.

2.3. Organizations, Groups and Roles in Conceptual Simulation

According to the CRIO (Capacity, Role, Interaction and Organization) meta-model[18], an organization is defined by a collection of roles that take part in organized institutionalized patterns of interactions with other roles in a common context. A group, used for partitioning organizations, is an organizational entity in which all members are able to interact according to predefined interaction definitions and protocols. A role is an expected behaviour, a set of role tasks ordered by a plan, and a set of rights and obligations in the organization context. The goal of each Role is to contribute to the fulfilment of, a part of, the requirements of the organization within which it is defined[17]. Every agent is able to play a role inside the group of an organization.

The simulation model consists of *PoolGroupOrganization* and *NextDayOrganization* as Figure 2 shows with agent's states.

a. **CarPoolOrganization**: Agents that are member of a group implementing the *PoolGroupOrganization* constitute a closed community for communication. Each time a non-carpooling agent receives a carpooling invitation, it creates a *CarPoolGroup* in which it becomes the driver and starts playing as the *DriverRole*.

Then it replies invitor to the inviter with an *AcceptMessage*. This allows the inviter to join the group and to start playing the *PassengerRole*. If the pool period of any agent of *CarPoolGroup* expires, then the agent simply leaves the role.

b. **NextDayOrganization**: When the agent finished the daily activities, it will play the *NextDayRole* in *NextDayGroup* represented by *NextDayOrganization* and waits for other agents to finish their daily activities. In this case the organization concept is used solely for synchronization in simulated time. As soon as the last agent joins the *NextDayGroup*, it will signal all other agents to leave the group and itself then also immediately leaves the *NextDayGroup* to start the next day activities. Remember that one group is created for each day only. The first agent, who finished the day activities, is responsible to create the group and the following agents will join the existing group.

2.4. Negotiation Mechanism

Consider N agents $a_1, a_2, \ldots a_N$. Each agent a_i has a preferred trip start time t_i and a tolerance period $t_i \pm {}^{\Delta t}/_2$. Negotiation among agents $a_1, a_2, \ldots a_N \in A$ succeeds if and only if;

$$\forall_i \, a_i \in A \; : \left| t_i - \sum_{j=i,N}^{1} \frac{t_j}{N} \right| \leq \frac{\Delta t}{2} \tag{1}$$

We use ${}^{\Delta t}/_2$ +1 because the time of day is expressed in minutes as an integer.

3. Experiments and Results

The design and the implementation of a model for commuting of candidate carpoolers using a simple negotiation mechanism is based upon the Janus[17] multi-agent platform. The Janus provides an efficient implementation of agent-based and organizational-based concepts.

One of the major goals of our experimentation is to compute and possibly optimize the solution time required to compute the agent-based interactions between agents. One reason for doing this is to be able to restate reality and accurately predict carpooling negotiation outcome in order to position of a sufficient synthetic population.

Figure 3(b) shows the average computation time of the simulation for the full period (three years), in blue curve, and for one day, in dashed red curve, on an Intel ® Core ™ i5-3230M CPU@2.60GHz 2.20GHz, with 4GB RAM and Windows 7 (64 bits). The benchmark is done by taking different amounts of locations as: *2, 4, 8, 16, 32, 64* and *128*. The number of agents generated for those locations is given by 10 x (nLocations^2) to see something happening in the simulation. The simulation was run for *three* years (for working days only) and used a time window of *ten* minutes (constantly). The car capacity is *four* persons. Each non-carpooling agent has a probability *0.2* to invite someone to carpool every day. Hence the probability for not exploring to carpool after *one* working week is *0.8^5 = 0.33*.

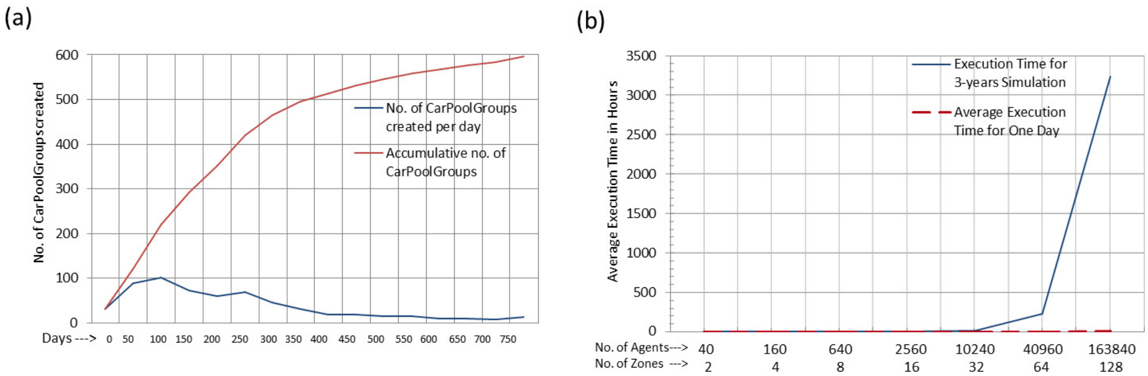

Figure 3: (a) Accumulated and per day number of *CarPoolGroups* created. (b) Average computation time for full period and per day.

In Figure 3(a), the results of 10000 agents for the period of three years; shows that in the initial days, simulation creates more *CarPoolGroups* each day than later in the simulation period. The growth of the number of carpools decreases with simulated time. Clearly a saturation effect occurs: i.e. candidates can no longer find suitable partners that fulfill the timing and spatial requirements. The maximum number of simultaneously existing carpools is approximated near the end of the simulation. The average number of persons consulting a *CarPoolGroup* is in between 2 and 3. If an agent leaves the *CarPoolGroup*, then according to logs values, it immediately (re)join or create a new *CarPoolGroup* again.

4. Related Works

According to literature review, the agent-based models are also used in non-computing related scientific domains and can provide valuable information on society and the outcomes of social actions or phenomena. A detailed literature review on technical[12,13], focuses on the development of carpooling support systems, and empirical, interrelationships between willingness to carpool and socio-economic attributes of carpooling, is presented.

Galland et *al*.[2] presented a conceptual design of an ABM for the carpooling application, that is used for simulating the interactions of autonomous agents and to analyze the effects of change in factors of infrastructure, behavior and cost. This model used agents' profiles and social networks to initialize communication and then employ a route matching algorithm, and a utility function to trigger the negotiation process between agents. Authors showed computation time of carpoolers by taking different number of agents as input.

Knapen et *al*.[1] presents an automated, Global Car Pooling Matching Service (GCPMS), advisory service to match commuting trips by carpooling, where the candidates can register for their personal profile and a set of periodically recurring trips. The probability values are calculated through a learning mechanism, vary over time due to repetitive execution, on the bases of personal profile and trip characteristics and the negotiation feedback. As a significance, the matcher needs to deal with dynamically changing graph w.r.t. topology and edge weights. Authors[1] propose to an agent-based model simulating the customer communal in order to exercise GCPMS for testing and validation.

Knapen et *al*. [3] studied the problem of finding an optimal route for carpooling and proposes an algorithm to find the optimal solution for the join tree. Authors proposed that the home, work and parking locations are possible transferal where one can join or leave a carpool. Each individual declares the maximal time and/or distance that is acceptable to move from origin to destination. The combined route that consists of join part, join the main drivers' car at several locations and time, and fork part, successively leave the car at destination otherwise continue carpooling, respectively.

Manzini and Pareschi[5] demonstrated that the carpooling is an effective strategy to reduce transport volumes, costs and related hill externalities. The authors presented a GUI based interactive system to solve the carpool problem that can be applied to company employees. The proposed decision support system is based on hierarchical clustering models which helps the mobility manager (officer) to generate the pool and to design realistic paths for shared vehicles. A case study for a public service in the city of Bologna is presented. Experiments showed that the overall relative saving in distance and time increases with the number of participants.

Trasarti et *al*.[6] derived travel routine from sets of GPS traces and extract similar trips based on space and time of day. Authors initiated the profile matching problem to proactive carpooling services, that satisfy basic constraints obtained from the background knowledge of the application domain. In addition the resulting loss in accuracy and coverage of profile matches is measured.

Iwan and Safar[7] presented two mining algorithms to discover user link, patterns apply to similarity between the sequences of locations visited by the individuals, and location link, apply to sequences of locations, respectively. Both are relevant when trying to estimate the probability for people to be able to carpool.

Agatz et *al*.[4] focuses on dynamic non-recurring trips which are related to commuting carpooling but requires different solution concepts. Both maximal individual advantage and system wide ideal are considered.

5. Conclusion and Future Work

As agent-based models are becoming popular in the domain of transportation, the detailed information about relationship between agents is increasingly needed for a recent research. An organizational-based and agent-based framework has been setup to evaluate the evolution of a carpooling society under several conditions and it has the ability to analyze various effects of agent interaction, adaptation and behavior reproduction of agents through modeling. The first implementation used home and work locations as well as preferred trip start times and carpool periods (for long term) determined by uniformly sampling given sets. Furthermore a simplistic negotiation, the home work mechanism used roughly to produce possible results for the synthetic data. Note that simulation performance can look completely smooth for real data. Janus platform needs a lot of computing resources (e.g. processing time, memory, and data storage) because of the high number of agents to simulate, and the big data processing for each agent.

Future research will mainly focus on the development of behaviorally sound negotiation protocols. Data will be taken from a realistic synthetic population used in transportation analysis. Finally distributed solutions will be anticipated to take performance issues.

Acknowledgements

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement nr 270833.

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