Agents in Traffic Modelling - from Reactive to Social Behaviour

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Abstract. In modern societies the demand for mobility is increasing daily. Hence, one challenge to researchers dealing with traffic and transportation is to find efficient ways to model and predict traffic flow, even if the behaviour of people in traffic is not a trivial problem. Increasingly more people travel longer distances and choose more complex routes and transportation means. Thus, the social nature of traffic (e.g. coordinated decisions) seems to be a key question, not well explored. There are already systems designed to help drivers to make traffic decisions (broadcast, internet, etc.). However, such systems cannot process any feedback from the users. We aim at creating a model of drivers as social agents, thus allowing their behaviour to be predicted and considered in the simulation. This may, on its turn, improve the accuracy of the existing Advanced Travel Information Systems (ATIS).

1 Introduction

Daily traffic jams reflect the fact the capacities of the road network are satisfied or even exceeded. Thus, the modelling and prediction of traffic flow is one of science's future challenges. To be effective, such models have to make assumptions about the travel demand, and hence about travel choices and traffic behaviour. As obvious as it is, not so much attention has been paid to the social properties of traffic systems, in spite of their inherent social nature. However, the interdependence of actions leads to an increasing frequency of coordination decisions, provided by dynamic route guidance systems among others. The use of such systems has the potential to change the nature of private car travelling in a yet unknown way. One typical scenario is the broadcasting of traffic messages to commuters. It is known that they have an impact on driver's behaviour, but currently drivers' reaction is neither registered nor considered in any forecast system.

The present work thus anticipates the scenario in which drivers have to deal with the basic question of decision-making under such an amount of (possibly inconsistent) information. This is not a *classical* case of route choice simulation since in these studies the focus is on the decision made by an *individual* driver without the consideration of the *interaction* caused by such a decision on the system as a whole, as well as on the other drivers. Hence, we depart from the classical view of route choice as an individual issue, and opt to study the social aspects of the problem. The main objective of our work is the modelling of drivers from a decision-theoretic point of view, i.e. as local (though not necessarily rational) decision-makers using artificial intelligence and multi-agent tools within the existing microscopic simulation environment. A second objective is to model the feedback from drivers' reaction to the broadcast of messages in order to produce a better forecast.

Modelling of traffic scenarios with multi-agent systems (MAS) techniques is not new. However, the focus has been mainly in logistics regarding transportation scenarios, or coarse-grained level regarding traffic problems as e.g. traffic agents monitoring problem areas. The work proposed here focuses on a fine-grained level or rather traffic flow control. At this level few works exist. For instance, Bazzan 1997 discusses a mechanism for the coordination of traffic signal. However, this work deals mainly with the tactical level.

Artificial intelligence (AI) and, in particular, MAS techniques open the possibility to model the strategical level (as for instance the behaviour of drivers) in a more realistic way, at a level closer to the deliberative and social one. In the present work we focus on the use of mental states like beliefs and intentions.

2 The Tactical Layer

There are mainly two approaches to the modelling of traffic: the macroscopic and the microscopic. In the former, one basic assumption is that all drivers behave according to similar rules, so that it is not possible to individualise classes of behaviours. In microscopic approaches, each individual can be described as detailed as desired, thus permitting the model of drivers' behaviours. To meet computational constraints, one basic idea of traffic flow modelling is to describe its dynamics as simple as possible. In this spirit, cellular automaton models were introduced (Nagel and Schreckenberg 1992) to describe the vehicular motion. This is implemented by means of three rules in the CA: collision-free acceleration, interaction, movement, and randomisation. Recently, highway as well as urban traffic was successfully modelled using the Nagel-Schreckenberg cellular automaton (see e.g. Esser and Schreckenberg 1997). A typical application is the on-line simulation of traffic in downtown Duisburg (http://traffic.uni-duisburg.de/OLSIM/).

The Nagel-Schreckenberg CA can be directly interpreted as a multi-agent system with reactive agents. This was done using the multi-agent simulation environment SeSAm (<u>S</u>h<u>e</u>ll for <u>S</u>imulated Multi-<u>A</u>gent Syste<u>m</u>s), described in Klügl and Puppe (1998). Due to a declarative agent behaviour representation and a visual modelling interface it is especially apt for a development of multi-agent models above the level of traditional programming languages. In several simulation experiments we were able to show that the multi-agent model of the Nagel-Schreckenberg cellular automaton reproduces the original model's behaviour with sufficient accuracy.

3 Social Agents and the Strategical Layer

Microeconomics has provided some contributions to transportation science, especially as to what concerns the use of the concept of rationality. The question is whether rationality is an acceptable paradigm for transportation science. As explained above, the use of microscopic traffic simulators allows travel and/or route choices have to be considered. However, it is important to notice that such choices seem not to be influenced by the same attributes as is maximisation or even satisfaction. . The decision-making process in human beings uses not only logical elements, but also involves some emotional components that are typically non-logical and seem irrational. As a result, behaviour can be also explained by other approaches, which additionally consider emotion, intentions, beliefs, motives, cultural and social constraints, impulsive actions, and even simply willingness to try. Agents equipped with such mental states can thus be the nucleus of a new, necessary paradigm in transportation.

To illustrate this change in paradigm, let us tackle a common commuter‘s scenario in the near future. Dynamic route guidance systems will soon be available for a huge number of the road users. The influence of these systems on the actual traffic state cannot be modelled with the methods described above since they assume rational agents. Understanding travellers' route choice behaviour is an important consideration for the development and effectiveness of such systems. Using the CA-based simulation tool, one can calculated the actual traffic situation in large-scale networks and generate traffic messages. This is done by using a BDI formalism based on that of Rao and Georgeff (1991), i.e. based on the modalities for belief, goal, and intention.

To illustrate its use, we discuss a well-known scenario: the day-to-day travel choice of commuters. For simplicity, we assume that there are two possible routes, namely R and A, connecting those places. Route R is shorter than alternative A but a heavy roadwork is announced for R. In this scenario, there is no optimal solution to the problem. If a significant number of commuters follow the recommendation and use alternative A, route R might be still faster. On the other hand, many drivers think the same way and stay with their typical choice.

To implement such a scenario using the BDI formalism, each agent has a knowledge base (KB) like that shown in Table 2. Other agents have similar KB's.

The beliefs set is represented by formulae describing the world. Desires are all possible states that the agent can achieve. Notice that they can be conflicting, like *DES (on_time)* and *DES (leave_later)*, or nearly unachievable as e.g. *DES (¬stop)*. Goals are desires that are consistent with the beliefs, not conflicting, and believed to be achievable. The set of goals is therefore not necessarily a singleton.

A similar relationship between desires and goals also exists between plans and intentions. Hence, an agent can have many plans, each to achieve a given state, but only plans believed to be achievable will form intentions. Besides, intentions must be mutually consistent.

Table 1 shows part of an agent KB. For the sake of simplicity, the identification of the agents is omitted from the logical declarations. This states that the agent Ag_1 believes that R is its usual route in this commuting scenario. The sixth line of the beliefs column states that if it is believed that A is an alternative route (to R), then it is believed that the agent will have to drive along a road with many traffic lights.

Ag_1 have a set of desires, not all consistent with the beliefs. As it is believed that there is a roadwork on R, the usual route, R is believed to be congested, and an alternative route A should be chosen. These beliefs are definitively not consistent with the six last desires. As for *DES(min_time)* and *DES(on_time)*, these are consistent as long as no broadcast over route A means that A is not congested. Hence Ag_1 can still be on time and the journey will take the minimum time *for that route*.

Table 1: Partial Knowledge Base for Agent Ag_1

BELIEFS	DESIRES	GOALS	INTENTIONS	PLANS
BEL (usual_route (R))	DES (min_time)	GOAL (min_time)	INT (min_time)	Plan1
BEL (roadwork (R))	DES (on_time)	GOAL (on_time)	INT (on_time)	Plan2
BEL (roadwork (R)) ⇒ BEL (congested (R))	DES (¬jam)			Plan3
BEL (alt_route (A))	DES (few_lights)			
BEL (congested (R)) ⇒ BEL (choose (A))	DES (via_highway)			
BEL (alt_route (A)) ⇒ BEL (many_lights (A))	DES (¬stop)			
BEL (broadcast (R, 'jam')) ⇒ BEL (congested (R))	DES (¬roadwork (R) ∧ usual_route (R))			
BEL (¬broadcast (R) , 'any') ⇒ BEL(¬congested (R))	DES (choose (R) ∧ usual_route (R))			
BEL (leave_later) ⇒ BEL (¬on_time)	DES (leave_later)			

4 Conclusions

This paper discusses the need to change the modelling paradigm of a driver in an intelligent transportation system. Dynamic route guidance systems will supply users with such an amount of information that they will demand decision under uncertainty and time pressure. However, no traffic forecast system is currently able to represent drivers as more than rational decision-makers who merely perceive small parts of their environment and react according to pre-established rules. Hence, this work extends the existing systems first by modelling a driver as a social agent based on multi-agent systems techniques, and second by generating a feedback to the simulation tool from such a model.

We have started with an existing microscopic traffic simulation tool, the CA-based Nagel-Schreckenberg model. The rules embodied in this model were directly interpreted as a multi-agent system where the driver-vehicle unit perceives its environment. In several simulation experiments we were able to show that the multi-agent model reproduces the original model's behaviour. However, such sub-cognitive multi-agent implementation are valid mainly at a tactical level. In order to tackle the strategical one, we developed a more deliberative model of agents, able to deal with not completely rational decision-making.

The BDI logic has already been successfully used to model decision-making process in human beings when involving emotions, preferences, intentions, etc. At the strategical level, such mental states play a big role especially in a commuting-like scenario, since the actions tend to be repeated and the knowledge of the driver accumulates with time. Another important characteristic of this scenario, to which the BDI formalism fits very well, is its social nature. The individual decision has no optimal solution. If a significant number of commuters follow the route recommendation broadcasted, there is no guarantee that the recommended route will be a better choice.

In short, we have present two possible layers of a multi-agent system designed to simulate traffic flow and to model drivers. While the former can be tackled by a tactical level (where sub-cognition is enough to make drivers act), in the latter it is essential to embed not only cognition but also more sophisticated forms of decision-making involving the mental states mentioned above. The next challenge of the work is to integrate both tools and environments.

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References

Bazzan, A.L.C.: An Evolutionary Game-Theoretic Approach for Coordination of Traffic Signal Agents. *PhD Thesis* (1997), University of Karlsruhe

Esser, J., Schreckenberg, M.: Microscopic online simulations of urban traffic flow. *Int. J. of Mod. Phys*. **8 (**1997) 1025

Klügl, F., Puppe, F.: The Multi-Agent Simulation Environment SeSAm. In: *Proc. of the workshop SiWis* (1998), Paderborn

Nagel, K., Schreckenberg, M.: A cellular automaton model for freeway traffic *J. Phys. I France* **2** (1992) 2221

Rao, A.S., Georgeff, M. P.: Modelling Rational Agents within a BDI architecture. In: Proc. of the Int. Conf. on Knowledge Representation and Reasoning (1991) 473-484, San Mateo, CA, Morgan Kaufmann