Agents in Traffic Modelling – From Reactive to Social Behaviour

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Abstract. In modern societies the demand for mobility is increasing daily. One challenge to researchers dealing with 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. The social nature of traffic (e.g. coordinated decisions) seems to be a key question, not well explored. 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 that 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 associated with dynamic route guidance systems for example, lead to an increasing frequency of coordinated decisions. 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 does not deal with the classical case of route choice simulation. There, the focus is on the *individual* driver without consideration of the *interaction* caused by coordinated decisions on the system as a whole. Hence, we depart from the classical view of route choice as an individual issue, and opt to study the social aspects of the problem.

Modelling of traffic scenarios with multi–agent systems (MAS) techniques is not new. However, the focus has been mainly in logistics regarding transportation

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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 (traffic flow control). At this level, few works exist. For instance, Bazzan ([1997]) discusses a mechanism for the coordination of traffic signal. However, this paper 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, 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 (CA) models were introduced by Nagel and Schreckenberg ([1992]) to describe the vehicular motion. This is implemented by means of four rules in the CA: collision–free acceleration, interaction,randomisation, and movement. A typical application is the on–line simulation of traffic in downtown Duisburg (http://www.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 (Shell for Simulated Multi–Agent Systems), described in Klügl and Puppe ([1998]). 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

As explained above, the use of microscopic traffic simulators allows travel and/or route choices to be considered. However, it is important to notice that such choices seem not to be influenced by the same attributes as is rational optimisation. The decision–making process in human beings uses not only logical elements, but also involves some emotional components that are typically non–logical. 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.

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. This is done

BELIEFS	DESIRES
BEL (usual_route (R))	DES (min_time)
BEL (roadwork (R))	DES (on_time)
BEL (roadwork (R)) ⇒ BEL (congested (R))	DES (¬jam)
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)

Table 1. Partial Knowledge Base for Agent Ag_1.

by combining traffic messages generated by the CA–based simulation tool with a BDI formalism. The latter is based on the formalism 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 the places of interest. 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, a typical agent has a knowledge base (KB) like that shown in Table 1. Others 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. Therefore, the set of goals is not necessarily a singleton. A similar relationship 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 has 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.*

4 Conclusions

This paper discusses the need to change the modelling paradigm of a driver in an intelligent transportation system. 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, and its interpretation as a multi–agent system. However, such sub–cognitive multi–agent implementation is valid mainly at a tactical level. In order to tackle the strategical one, we have developed a more deliberative model of agents, able to deal with not completely rational decision–making. To achieve this, we have used mental states like emotions, preferences, intentions, etc. Such mental states play a key 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

1997. Bazzan, A.L.C.: An Evolutionary Game–Theoretic Approach for Coordination of Traffic Signal Agents. PhD Thesis (1997), University of Karlsruhe
1998. Klügl, F., Puppe, F.: The Multi–Agent Simulation Environment SeSAm. In: Proc. of the workshop SiWis (1998), Paderborn
1992. Nagel, K., Schreckenberg, M.: A cellular automaton model for freeway traffic. J. Phys. I France **2** (1992) 2221
1991. 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