EFFECTIVE APPROACH FOR TRAFFIC SIGNAL CONTROL USING IOT

RAVIRAJ A N, PRABODH C P

M.Tech Computer Science, Siddaganga Institute of Technology, Tumakuru, India
Assistant Professor, Computer Science, Siddaganga Institute of Technology, Tumakuru, India

ABSTRACT.

Urban road traffic management is an example of a socially relevant problem that can be modelled as a large-scale, open, distributed system, composed of many autonomous interacting agents, which need to be controlled in a decentralized manner. Most models for urban road traffic management rely on control elements that act on traffic flows. Dresdner and Stone have put forward the idea of an advanced urban road traffic infrastructure that allows for cars to individually reserve space and time at an intersection so as to be able to safely cross it. In this paper we extend Dresdner and Stone's approach to networks of intersections. For this purpose, we draw upon market-inspired control methods as a paradigm for urban road traffic management. We conceive the system as a computational economy, where driver agents trade with infrastructure agents in a virtual marketplace, purchasing reservations to cross intersections when commuting through the city. We show that in situations of similar traffic load, an increase of the infrastructure's monetary benefit usually implies a decrease of the drivers' average travel times.

Keywords: Frame extraction, Graphical User Interface, Motion Detection, Motion identification.

1. INTRODUCTION

The control of a large-scale, open, distributed system, composed of many autonomous interacting agents, with the aim of instilling some desired global properties, is not a trivial task. Being too complex for centralized decision making, the only feasible way is delegating and distributing power and control. Unfortunately, decomposing and distributing the problem generates other issues to cope with. Consider (future) traffic control systems: intelligent traffic infrastructures, provided with sensors and computing power, aiming at resolving congestions and speeding up the traffic flow; millions of drivers commuting every day from their homes to their respective workplaces and back, making autonomous decisions about route assignment and departure time selection, learning from their past experiences and influencing each other in both positive and negative ways. Here the infrastructure components are faced with a very complex problem, since they aim at controlling a system that is partially observable (e.g. a component cannot access directly the degree of satisfaction of a driver), and without "powerful actuators". In this paper we draw upon market-based control methods as a paradigm for the management of an urban road traffic system, which would otherwise be very difficult to control and maintain. We conceive the system as a computational economy, where driver agents trade with the infrastructure agents in a virtual marketplace, purchasing reservations to cross intersections when commuting through the city. We design the market rules with the aim of aligning the "global profit" (revenues from the infrastructure use)with the "social welfare" (e.g. average travel time), in a way that, in situations of similar traffic load, an increase of the infrastructures' monetary benefits usually implies a decrease of the drivers' average travel times.

The paper is structured as follows: in section 2 we discuss Basic concepts of agent and multivalent system technology the context in section 3 we see related work: section 4 Market Inspired Approach and Interaction model finally we conclude in section 5.

2 BASIC CONCEPTS OF AGENT AND MULTIAGENT SYSTEM TECHNOLOGY

One reason for the popularity of agents and multiagent systems relates to the advances in computational systems, which are increasingly more distributed, open, large, and heterogeneous. The positive side about this is visible every time we use the Internet. However, this comes at a cost: increasing complexity of both hardware and applications. Canonical examples are the current paradigm of cloud computing versus centralized, mainframe-based computation of some decades ago. Managing interactions among autonomous entities with ever increasing interdependencies has been one of the biggest motivations for distributed artificial intelligence and for multiagent systems. These aim at developing and analysing models derived from social interactions in human societies, and applying them to computational systems in order to resolve conflicts in organizational structures of various types. In particular, in the present paper we deal with agent-based techniques for modelling and simulation as well as for coordination and adaptation. As a comprehensive introduction to the various related subjects is outside the scope of this paper, we simply sketch the basic ideas. Agent-based simulation uses the metaphor of autonomous agents and multiagent systems as the basic model conceptualization. This means that a model consists of interacting agents situated in a simulated environment. Agents may correspond to cities, blocks, platoons, households, individual travellers (drivers), vehicles, sensors, traffic signals, etc. Also elements of the environment may be conceived as agents. A general introduction into the underlying concepts of agent-based simulation from the social science point of view, together with a few selected examples can be found in Epstein (2007) and Gilbert (2007) gives a practical introduction to the basic ideas, model development and its implementation; a more recent introduction to more general aspects of agent-based modelling and simulation can be found in Klu¨ gl and Bazzan (2012). In the context of simulation modelling, two concepts are particularly relevant: BDI (Belief–Desire–Intention) and layered architectures. In the particular case of traffic modelling, both are useful for combining decision making on different (e.g. temporal) levels such as high-level strategic planning (e.g.route choice) and low-level tactical action selection (e.g. actual driving).

3. RELATED WORK

In recent years, there is a growing interest in applying agent-based techniques for traffic management [1, 2]. Urban road traffic control appears to be a particularly promising application area for agent technology. To this respect, many approaches aim at optimizing the use of existing traffic infrastructures, by providing adequate coordination policies that are either designed off-line or learned at run-time. For example, in [3]intelligent traffic light agents create “green waves” in a particular direction, while in [4] the traffic lights learn in a coordinated way the best signal plans. Still, in these approaches just the intersections are modelled as agents, while drivers are only considered in so far as they are a part of the traffic flow through the road network. Other approaches conceive the drivers as the agents whose behaviour is to be modelled [5] (e.g. for simulation purposes). In this context, it is particularly interesting to study mechanisms that influence driver behaviour so as to improve their local utility (e.g. to reduce travel time) and/or to enhance the global system performance (e.g. to reduce number and size of congestions). Variable message signs and on-board driver information systems, for instance, may help agents avoid congested road sections, but may cause new problems when used by a large population of drivers. Toll-based approaches dynamically adjust the price of using certain road sections so as to achieve an adequate traffic flow distribution within the road network. However, a tight integration with the aforementioned approaches is difficult, since existing urban road traffic management infrastructures based on traffic light controlled intersection affect traffic flows, but cannot act on individual cars.

4. MARKET-INSPIRED APPROACH

In this paper, we set out from Dresdner and Stone’s work and assume the existence of an advanced traffic management infrastructure that allows for reservation-based intersection control. Furthermore, we draw upon ideas from toll-based systems and allow intersection managers to sell time-space slots at an intersection, thus generating incentives to prefer or to avoid routes that pass through certain intersections. In addition, we apply distributed learning techniques that have been successfully applied to the air traffic domain, so as to dynamically coordinate the intersection managers’ pricing policies. In such a setting, urban road traffic management can be conceived as a computational economy, where drivers trade with the intersection managers in a virtual market place, purchasing reservations to cross intersections when commuting through the city. As with traditional toll-based systems, we would like the “global profit” (revenues from the infrastructure use) and “social welfare” (e.g. average travel time) to be aligned:

we would like to build our market in a way that, in situations of similar traffic load, an increase of the infrastructures' monetary benefits usually implies a decrease of the drivers' average travel times. Of course, there is no way to directly influence autonomous driver behaviour for this purpose, but we can act on (parts of) the infrastructure, in particular the interaction protocol that driver and intersection managers have to comply with, as well as the agent programs of the intersection managers This section is organized as follows: we first present the general characteristics of the urban road traffic management infrastructure that we envision, and describe the protocol by which drivers can purchase reservations from intersections.

4.1 Interaction model

We assume that the agent's in the future urban road management infrastructures will have the following capabilities:

- Intersection managers are able to communicate with each other. This assumption is reasonable, e.g. already existing fibre-optic connections along certain main urban roads could be used.
- Drivers can communicate with intersection managers. Such proximity-based communication is already in use in different elements of today's traffic infrastructures. We assume that a driver is able to communicate with the forthcoming intersection on its route, and also with the neighbours of such intersection.
- Drivers can be provided with the current prices of the intersections in the network. This can be done, for instance, by a price propagation scheme through the intersection network.
- A trusted payment system is available, allowing drivers to securely transfer money to intersection managers when required. Such mechanisms are already in use in today's toll roads.

4.2 Intersection manager agent model

Intersection managers apply the simple "first-come first served" algorithm described in to honour reservation requests 3. Therefore, decision problem boils down to determining the current reservation fare, and coordinating it with the other intersection managers in the team.

Action space

The action space Zi of an intersection manager is composed of the prices that it can apply to the reservation fares that it manages. More formally:

$$Z_i = \{p_i \ 2 \ [p_{min}, p_{max}]\} \quad (1)$$

Where pmin and pmax are the minimum and maximum allowed price for a reservation fare.

Profit function

An intersection manager is characterized by its profit function Ui, defined as the difference between revenues Ri and costs Ci. More formally:

$$U_i = R_i - C_i \quad (2)$$

The revenues Ri are calculated as the money earned with the reservations that have been sold over time, rt. The cost function Ci is a function of the number of drivers that have purchased a reservation through time, dt. The cost function has a maximum if no drivers have purchased a reservation, and tends to 0 with the increase of drivers (i.e., the costs are amortized). Such profit function intends to penalize unused intersections, by a man of few revenues and high costs, as well as congested ones, since vehicles stopped at the intersection do not generate any revenue (recall that a vehicle stopped at the intersection is entitled to receive a reservation for free).

4.3 Driver agent model

The deliberation process of a driver is shaped by the fact that it must purchase the reservations to cross the intersections that it encounters during its trip. We model a driver as an individually rational utility maximizer, which aims at choosing the "best" route, accordingly with its utility function. Route choice is the fourth step in the conventional Transportation forecasting model [13]. Such utility function, Bi, is a weighted sum of two factors: travel time and costs. More formally:

$$B_i(x) = -[\sigma \cdot TT(x) + (1 - \sigma) \cdot K(x)] \quad (4)$$

Where σ is a trade-off factor that weights the relative importance of the travel time of route x, TT(x), and the costs implied by such route, K(x). The cost of a route x is the sum of the reservation fares applied by the intersection managers that govern the intersections that lay on route x. Still, special attention deserves the travel time function TT(x). Although this function is unknown in general, we use an optimistic estimation TTest(x) of the travel time, calculated as:

$$TTest(x) = ||x||/vmax \quad (5)$$

Where ||x|| is the route length and vmax is the maximum allowed speed

5. CONCLUSION

In this paper we studied the application of market-inspired mechanisms for managing future urban road traffic infrastructures, where drivers can individually reserve the necessary space-time slots to safely cross intersections. We put forward an interaction protocol between drivers and intersection managers that aims at efficiently assigning reservations to drivers, based on a pricing model, while reducing the effect of strategic manipulation. At the same time, this protocol maintains the option for drivers to navigate through the road network for free, although with increased travel times – an important characteristic to foster the acceptance of the mechanism. We have put forward a learning model for intersection manager agents, so as to coordinate their pricing policies within a team of intersection managers. A model of individually rational driver behaviour within this context has been outlined based on the notion of route choice. Finally, we have analysed the system performance with regard to different driver profiles. We showed that, in general, an increase in the global profit of the intersection manager team is aligned with reduced average travel times, and that coordinated policies of intersection managers (as part of the infrastructure) outperform significantly strategies based on the maximization of only local utility. This holds for different types of drivers populations. In summary, besides the “knowledge engineering” work of framing the problem and designing adequate “rules of the game” for a domain of potential social relevance, our contribution consists in an Innovative combination, adaptation, and integration of economically inspired and computational learning techniques for a truly open class of multivalent system.

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