Preface

The increasing demand for mobility in the 21st century poses a challenge to researchers from several fields to devise more efficient traffic and transportation systems designs, including control devices, techniques to optimize the existing network, and also information systems. More than ever, interdisciplinary approaches are necessary. A successful experience has been the cross-fertilization between traffic, transportation, and artificial intelligence that dates at least from the 1980s and 1990s, when expert systems were built to help traffic experts control traffic lights. Also, information on how to combine parking and public transportation can be provided by intelligent systems, and transportation and logistics have also benefited from artificial intelligence techniques, especially those tied to optimization.

During the last decade, there has been a tremendous progress in traffic engineering based on agent technology. However, given the increasing complexity of those systems, a product of the modern way of life and new means of transportation, the individual choices must be better understood if the whole system is to become more efficient. Thus, it is not surprising that there is a growing debate about how to model transportation systems at both the individual (micro) and the society (macro) level. This may raise technical problems, as transportation systems can contain thousands of autonomous, intelligent entities that need to be simulated and/or controlled. Therefore, traffic and transportation scenarios are extraordinarily appealing for (multi-)agent technology.

Additionally, traffic scenarios became very prominent as test beds for coordination or adaptation mechanisms in multi-agent systems. Many examples of successful deployments of tools and system exist.

This book is a collection of contributions addressing topics that arose from a cross fertilization between traffic engineering and multi-agent system. Hence, this book summarizes innovative ideas for applications of different agent technologies on traffic and transportation related problems.

CHALLENGES AND APPROACHES

The second half of the last century has seen the beginning of the phenomenon of traffic congestion. This arose due to the fact that the demand for mobility in our society has increased constantly. Traffic congestion is a phenomenon caused by too many vehicles trying to use the same infrastructure at the same time. The consequences are well-known: delays, air pollution, decrease in speed, and risky manoeuvres thus reducing safety for pedestrians as well as for other drivers.

The increase in transportation demand can be met by providing additional capacity. However, this may no longer be economically or socially attainable or feasible. Thus, the emphasis has shifted to improving the existing infrastructure without increasing the overall nominal capacity, by means of an optimal utilization of the available capacity. Two complementary measures can be taken: improving the management systems by use of recent developments in the areas of communication and information
technology, and improving the management via control techniques. The set of all these measures is framed as Intelligent Transportation Systems (ITS).

Artificial intelligence and multi-agent techniques have been used in many stages of these processes. During the last decade, there has been a tremendous progress in traffic engineering based on agent technology. The approaches can be classified into three levels: integration of heterogeneous traffic management systems, traffic guidance, and traffic flow control.

The first of these levels is discussed in several papers, for example the platform called Multi-Agent Environment for Constructing Cooperative Applications - MECCA/UTS – (Haugeneder & Steiner, 1993), as well as in Ossowski et al. (2005), in Rossetti and Liu (2005), and in van Katwijk et al. (2005).

Regarding traffic guidance, it is generally believed that information-based ITS strategies are among the most cost-effective investments that a transportation agency can make. These strategies, also called Advanced Traveler Information Systems (ATIS), include highway information, broadcast via radio, variable message systems, telephone information services, Web/Internet sites, kiosks with traveler information, and personal data assistant and in-vehicle devices. Many other new technologies are available now to assist people with their travel decisions. Multi-agent techniques have been used for modeling and simulation of the effects of the use of these technologies, as well as the modeling of behavioural aspects of the drivers and their reaction to information. Details can be found in Balmer et al. (2004), Bazzan and Klügl (2005), Bazzan et al. (1999), Burmeister et al. (1997), Elhadouaj et al. (2000), Klügl and Bazzan (2004), Klügl et al. (2003), Paruchuri et al. (2002), Rigolli and Brady (2005), Rossetti et al. (2002), Tumer et al. (2008), and Wahle et al. (2002).

Regarding the third level mentioned above – traffic control – a traffic control loop was proposed by Papageorgiou (2003). It applies to any kind of traffic network if one is able to measure traffic as the number of vehicles passing on a link in a given period of time. With the current developments in communication and hardware, computer-based control is now a reality. The main goals of Advanced Transportation Management Systems (ATMS) are: to maximize the overall capacity of the network; to maximize the capacity of critical routes and intersections which represent the bottlenecks; to minimize the negative impacts of traffic on the environment and on energy consumption; to minimize travel times; and to increase traffic safety. In order to achieve these goals, devices to control the flow of vehicles (e.g. traffic lights) can be used. However other forms of control are also possible. For classical approaches please see: TRANSYT (Robertson, 1969; TRANSYT-7F, 1988), SCOOT (Split Cycle and Offset Optimization Technique) (Hunt et al., 1981), SCATS (Sydney Coordinated Adaptive Traffic System) (Lowrie, 1982), and TUC (Traffic-responsive Urban Traffic Control) (Diakaki et al., 2002). Regarding the use of multiagent systems, some work in this area can be found in Bazzan (2005), Bazzan et al. (2008), Camponegara and Kraus (2003), Dresner and Stone (2004), France and Ghorbani (2003), Nunes and Oliveira (2004), Oliveira et al. (2004), Oliveira et al. (2005), Rochner et al. (2006), Silva et al. (2006), Steingrover et al. (2005), Wiering (2000).

**ORGANIZATION OF THE BOOK**

The book is organized into three parts. The first is a collection of chapters that focus on agent-based simulation of transportation and traffic scenarios for traffic reproduction, both for vehicular traffic and pedestrian traffic. A second section is a compilation about traffic control and management, mainly using traffic lights. A third part deals with agent-based approaches for related themes such as air traffic management and logistics.

A brief description of each of the chapters follows, starting with those in Section I.
In Chapter I, Takama discusses congestion and adaptation by means of a multi-agent system (MAS) aiming to analyse real transport and traffic problems. The chapter contribution is both a methodological discussion and an empirical case study. The latter is based on real stated-preference data to analyse the effect of a real road-user charge policy and a complimentary park and ride scheme at the Upper Derwent Valley in the Peak District National Park, England.

Han and colleagues (Chapter II) discuss an agent-based modeling approach focusing on the dynamic formation of (location) choice sets. Individual travellers learn through their experiences with the transport systems, changes in the environments and from their social network, based on reinforcement learning, Bayesian learning, and social comparison theories.

Chapter III tackles micro-simulation by discussing design and implementation issues of MATSim, as well as an experiment in which this simulator is used to study daily traffic in Switzerland.

Continuing the discussion around microscopic simulation, in Chapter IV, the TRASS simulation framework, a multi-layer architecture, is presented and evaluated in the context of several application scenarios.

In Chapter V, a multi-agent model is proposed aiming to cope with the complexity associated with microscopic traffic simulation modelling. Using a prototype with some of the features introduced, the authors discuss scenarios using car-following and lane-changing behaviours.

Schadschneider and colleagues investigate the behaviour of pedestrians and human crowds, focusing on aspects related to physical movement. Chapter VI thus starts with a review of methods and approaches, and continue with a discussion around validation issues, aiming at reducing the gap between the multi-agent and pedestrian dynamics communities.

Chapter VII discusses the “Social Potential” model for implementing multi-agent movement in simulations by representing behaviours, goals, and motivations as artificial social forces.

In Chapter VIII, Sabine Timpf presents a vision for simulating human navigation within the context of public, multi-modal transport, showing that cognitive agents require the provision of a rich spatial environment. She introduces spatial representations and the basics of wayfinding as key components in the model. She illustrates her ideas by a case study that deals with multi-modal public transport.

Chapters IX to XV compose Section II of this book and have in common the focus on traffic control.

Chapter IX presents two extensions of a system for managing autonomous vehicles at intersections. In the first, it is demonstrated that for intersections with moderate to low amounts of traffic, a completely decentralized, peer-to-peer intersection management system can reap many of the benefits of a centralized system without the need for special infrastructure at the intersection. In the second extension, it is shown that the proposed intersection control mechanism can mitigate the effects of catastrophic physical malfunctions in autonomous vehicles.

Providing services and infrastructure for autonomous vehicles at intersections is also the topic of Chapter X in which the authors describe an agent-based valuation-aware traffic control system for intersections. Their approach combines valuation-aware intersection-control mechanisms with driver-assistance features such as adaptive cruise and crossing control.

Collaborative driving is the focus of Chapter XI. The authors describe an agent-based cooperative architecture that aims at controlling and coordinating vehicles, also showing that reinforcement learning can be used for this purpose.

Tumer, Welch, and Agogino (Chapter XII) tackle the issue of how road users can learn to coordinate their actions with those of other agents in a scenario without communication. Further, the authors explore the impacts of agent reward functions on two traffic related problems (selection of departure time and selection of lane).
In Chapter XIII, the authors discuss multi-agent learning in the context of a coordination mechanism where teams of agents coordinate their velocities when approaching the intersection in a decentralised way, improving the intersection efficiency.

Yamashita and Kuramatami (Chapter XIV) propose a cooperative car navigation system with route information sharing, based on multi-agent simulation. They use a scenario from Tokyo in which drivers can share information about their route choices. Results have confirmed that the mechanism has reduced the average travel time of drivers sharing information and that the network structure influenced the effectiveness of the mechanism.

Exchange of information is also tackled in the Chapter XV, this time by traffic signal agents. The authors show that these agents can learn better than independent ones, by sharing information about their environment.

Section III (chapters XVI to XVIII) of the book brings a collection of topics that are related to transportation and focus on different agent technologies such as agent-based simulation.

In Chapter XVI the authors apply agent-based solutions to handle job arrival uncertainty in a real-world scenario. This approach is compared to an on-line optimization approach across four scenarios, with the results indicating that the agent-based approach is competitive.

Chapter XVII deals with the use of agent-based simulation for modelling the organisational structure and mechanisms in the context of regional transport corridors.

Collaborative air traffic flow management is the topic of Chapter XVIII. This chapter describes the design and methodology of a multi-agent simulation for this problem. This is then used to evaluate several policies for the management of air traffic flow.

REFERENCES


Ana L. C. Bazzan
Instituto de Informática, UFRGS, Brazil

Franziska Klügl
Örebro University, Sweden