Agents for Traffic Simulation

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Setting and Subject

Vehicular traffic is a classical example of a multi-agent system: Autonomous agents (i.e., the drivers) operate in a shared environment which is given by the road infrastructure. The direct correspondence becomes obvious for a microscopic modeling approach describing the motion of each individual vehicle. Although scientists had started to describe the physical propagation of traffic flows by means of dynamic models by the 1950s, the microscopic approach has grown in popularity in the last decade because of higher computational power for numerical simulations.

Contribution

The chapter will provide an overview of the state-of-the-art in traffic modeling and the implications for simulation techniques. In an introductory section, the classical subjects such as vehicle dynamics, traffic dynamics and transportation planning will be classified by typical times scales of their applicability. We will focus on the short-time dynamics of so-called car-following models which describe continuous (feedback) control tasks (acceleration and braking) and models for discrete-choice tasks (e.g., lane-changing) as a response to the surrounding traffic.

In a second section, the concept of an agent will be adopted to model the human driving behavior: The driving style of an agent is characterized by model parameters such as reaction time, desired speed, desired time gap, anticipation etc. In addition, internal state variables corresponding to the agent's "mind" are used to incorporate the past driving experiences, e.g., by means of a memory. Furthermore, the driver's behavior is externally influenced by the neighboring vehicles (speeds, gaps, etc.), and also by environmental input such as limited motorization and braking power, visibility conditions and road traffic regulations.

For matters of illustration, we will present model components for these basic tasks. The "Intelligent Driver Model" as example of a car-following model represents the operational level of driving. A "memory effect" introduces a time-dependency of some parameters to describe the frustration of drivers being in a traffic jam for a while. A general approach for dealing with discrete decision problems in the context of vehicular traffic will be introduced and applied to mandatory and discretionary lane changes. Furthermore, we will consider the decision process whether to brake or not to brake when approaching a traffic light turning from green to amber.

A third section will address the design of a microscopic traffic simulator. We will discuss the simulation core, input and output quantities, and possibilities of visualization.

In the forth section, we will demonstrate the power of the agent-based approach for handling actual research questions. By way of example, we will demonstrate how the desired individual behavior of agents to move fast forward can lead to contrary collective effects such as traffic breakdowns and stop-and-go waves. Another aspect of vehicular traffic is related to the heterogeneity of agents including characteristics of the drivers (e.g., driving "conservatively" or "aggressively") as well as features of the vehicle (such as its length, motorization, etc.).

Issues for future research

Furthermore, traffic simulation can be used to assess the impact of a percentage of vehicles equipped with advanced driver assistance systems on the traffic dynamics. The challenging question is whether it is possible to design vehicle-based control strategies aimed at improving the capacity and stability of traffic flow. Finally, we will discuss a hybrid system of coupled vehicle and information flow which can be used for developing and testing applications of upcoming inter-vehicle communication techniques.