Development of an Improved Traffic Cellular Automaton Model for Traffic Flows on a Highway and National Road Network

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Abstract

Realistic macroscopic and microscopic models form the core functionality of advanced traffic management systems (ATMS). We develop a flexible testbed environment based on a multi-lane traffic cellular automaton (TCA) that alleviates several classical deficiencies. Generic qualitative measurements act as testing tools to assess the validity of the developed TCA model. This model is then integrated in a road network consisting of primary highways and secondary national roads. Calibration and validation are based on real-life traffic data gathered by sensors in the network and allow us to tune the model parameters to the dynamic traffic state on the already existing road infrastructure.

Outline of the paper

Background

One of the main challenges today in traffic flow modeling, lies in the construction of macroscopic and microscopic models that lend themselves to a faithful representation of road traffic. This proves to be of tremendous importance, as these models are used in several key aspects in the control of traffic flows by means of advanced traffic management systems (ATMS).

Our approach towards the alleviation of road congestion, consists of the development of a flexible testbed environment – based on a traffic cellular automaton – that is capable of providing us with a simulation model of a real-world road network (which is, in our case, the Flemish primary highway network and its secondary national road network).

The testbed is constructed in two stages : construction of a traffic flow model and simulation of the road network.

Construction of a traffic flow model

The core of our testbed will consist of a microscopic traffic flow model, based on the cellular automata programming paradigm as a discrete dynamical system for the modeling of traffic flows. The system's state is changed through synchronous position updates of all the vehicles (i.e., the cells) [3]. This level of detail is needed in order to fully grasp the emergent effects of the dynamical processes behind traffic flows.

Our traffic cellular automaton (TCA) model will be able to handle highway traffic, thus explicitly including the car-following and lane-changing dynamics [6]. Routing is done on a higher layer (for the moment we'll assume dynamic origin-destination (OD) matrices in the sense that they only change in time to mimic the daily flow patterns).

The dynamics of the TCA will be modeled as rule-sets that reflect the rule-based behaviour of a cellular automaton evolving in time and space [1]. Our motivation is largely driven by the fact that classical TCA models (i.e., CA-184, NaSch's STCA, …) suffer from several deficiencies and are therefore more suited for theoretical studies [2]. We remedy this situation by constructing a new TCA model that alleviates the problems of the aforementioned TCA models and at the same time includes advanced traffic characteristics (such as metastability, hysteresis, time-based headways instead of space-based headways, …). Most of the already developed models either exhibit the aforementioned deficiencies, or they're not suited for large scale application in an integrated real-life road network. Our modeling efforts provide the necessary significant innovation.

Several generic qualitative measurements will also be performed. They act as testing tools to assess the validity of the developed TCA model (as well as the classical TCA models). These tests will include histograms of lead gap distributions, measuring the time needed to travel a congested section or to completely dissolve mega-jams, measuring the life-time and size of congestion waves, …

Simulation of the road network

Our developed model will form the core of a testbed of a real-life road network environment [4]. Its scope is the Flemish major road network whose physical modeling will be done by employing data available from satellite images and geographical information systems (GIS).

Calibration and validation of the system are required in order to tune the model parameters to the dynamic traffic state on the already existing road infrastructure [5]. All the data needed for real-time simulation is gathered by sensors in the road network and stored in a database by Flander's Traffic Centre. This database contains the macroscopic flow, occupancy and average speed measurements as time series (with a sampling interval of one minute).

Furthermore, constructing the fundamental diagrams from these time series, allows us to investigate the transient phenomena associated with traffic flow operations; meta-stability and hysteresis can be observed and checked for in the developed TCA model.

Conclusion

Our research allows us to have a realistic representation of the Flemish highway traffic. In addition, the developed testbed can be used to assess the impact of policy measures, traffic flow control strategies, et cetera.

Presentation format

The presentation will be held with the aid of Microsoft's PowerPoint application. In case of failure, transparencies will be used as a backup.

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