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A Review on Simulation of Traffic Control

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Abstract

Traffic Simulation plays an important role in both today's traffic research and in many traffic applications such as traffic flow prediction, instant detection and traffic control. The term simulation is taken broadly to mean a model which tries to represent or reflect actual traffic performance and takes in equilibrium models. To some extent, models imitate stages in the development of the field but the differences are mainly attributable to different needs and applications. In this review we focus on transportation traffic models and the simulation techniques for traffic control.

***Keywords*-- Traffic control, simulation, traffic models.**

I. INTRODUCTION

Demonstration of traffic flows is an essential addition to both urban and non-urban organizations. Traffic models have received a great deal of attention from academic and other analysts. Urban traffic models have been of greatest interest, because congestion adds to the complexity (as shown in figure 1), but traffic modelling is also essential for non-urban road planning and investment. Traffic flow may be treated as a fluid, without considering the individual elements, or individual vehicles may be modelled.

TYPE

Figure 1: Traffic congestion on roads

1.1 Traffic control and Traffic congestion

Traffic congestion on roads is becoming an ever more pressing problem in countries all over the world. One approach to tackle congestion could be the construction of new roads to enlarge the capacity of the traffic infrastructure.

This approach is very costly and it is often not possible due to environmental or societal constraints. In addition, it can only be executed on the longer term. So there is a need for another, short-term solution. This short-term solution exists of controlling traffic in such a way that congestion is solved, reduced, or at least postponed. In most countries traffic operators in traffic control centers monitor the traffic situation based on video images and measurements. Especially during rush hours the interpretation by experts of information about traffic intensities, average velocities, weather conditions, incidents, on the roads leads to advice for the travelers and/or actions in order to solve, to prevent or to postpone congestion. Traffic models allow for a simulation of future traffic densities and average velocities. These predictions can help traffic operators to determine which control measures to take. Another advantage of simulation models is that they allow for a prediction of the traffic state that takes exceptional situations such as (partially) blocked roads into account.

II. HELPFUL HINTS

1.2 Objectives

One of the objectives of traffic control is to solve congestion. This objective is translated into a cost function expressed in terms of the traffic states: traffic flows, traffic densities, average speeds, As the name cost function states, the cost associated with an undesirable traffic state with congestion needs to be higher than the cost associated with a traffic state with less congestion.

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1.3 Problem of traffic control

Due to the dynamic nature of traffic on roads, the control actions need to be updated regularly to account for changing traffic situations. This leads to an adaptive control scheme. The model-based approach described above requires prediction of the future traffic situation for different control strategies followed by selection of the control strategy resulting in the lowest cost. In scope of this approach, simulation of traffic situations using traffic models shows some important advantages:

(a) Simulation of traffic models allows for fast, reproducible and cost effective experiments. Using currently available traffic models and computers it is possible to simulate some traffic situations faster than real-time. This allows for a real-time evaluation (optimization) of different alternative control strategies that would not be possible otherwise.

(b) Since the safety of the travelers cannot be compromised at any time, models are an interesting alternative for experiments in extreme traffic regimes which could lead to potentially dangerous situations and which can therefore not be invoked intentionally. e.g. traffic operation near congestion with shock waves or with large speed differences between adjacent lanes can safely be simulated and reproduced using models.

2 Traffic model Classification

A wide variety of traffic models exists. These models can be classified based on their properties. In this section we illustrate four ways to classify traffic models from the point of view of a traffic control engineer:

(a) Physical analysis

(b) Level of detail

(c) Discrete versus continuous

(d) Deterministic versus stochastic

2.1 Physical analysis

According to the theory, there are three major approaches towards modelling:

White box, black box, and grey box modelling [Ljung, 1987].White box modeling or the deductive approach. In the deductive approach physical equations describe the relationships between different states of the traffic system. This approach is used for instance to describe a mechanical system by Newton's laws and is called white box modelling.

An alternative approach is inductive, or black box, modeling where input and output data of the system are recorded and a generic parameterized model is fitted to the data. For a traffic system, the input/output data typically consist of the evolution of traffic flows, traffic densities and measured speeds over time.

Finally, we can distinguish an intermediate method between black and white box modeling, known as gray box modeling. Grey box modeling is a combination of the inductive and the deductive approach. In the deductive phase, parameterized equations between the states of the motorway system are written down. During the inductive phase, the parameters in the model are tuned by fitting the input-output relation of the traffic model to input-output measurements of the traffic system.

2.2 Level of detail

Based on the level of detail, we distinguish two types of traffic models in this paper: microscopic and macroscopic models.

Microscopic traffic models are models in which all vehicles or 'particles' in the system are described individually. A model for the behaviour of every single vehicle is defined. These vehicle models include e.g. the interaction between the vehicles or between the vehicles and the motorway.

Microscopic traffic simulators can be implemented based on different microscopic traffic models. Some microscopic simulators start from a description of the motorway network we want to simulate where the network is characterized by the speed limit, the number of lanes, overtaking prohibitions, for all motorway sections. Every vehicle in the network is characterized by some parameters describing its origin, its destination, the desired velocity, acceleration and deceleration abilities, vehicle type, driver's patience, aggressiveness and so on. During simulation, a flow of vehicles is entered into the network.

2.3 Deterministic versus stochastic

In a deterministic traffic model there is a deterministic relation between the input, the states and the output of the model. If we simulate a traffic situation twice, starting from the same initial conditions and with the same inputs and boundary conditions, the outputs of the model will be the same. Payne's macroscopic traffic simulation model, discussed later on, is an example of a deterministic traffic model.

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A stochastic traffic model contains at least one stochastic variable. This implies that two simulations of the same model starting from the same initial conditions, the same boundary conditions and the same inputs may give different results, depending on the value of the stochastic variable during each simulation. The stochastic variable is characterized by a distribution function or a histogram.

III. Traffic Simulation Techniques

Extensive studies have been performed to evaluate different traffic simulation packages and their ability to adequately simulate various test networks and transportation system configurations. Studies of the capabilities of specific packages as well as previous studies are reviewed in the following sections.

3.1. CORSIM

CORSIM has been studied extensively and is well documented in the literature. Some key papers are summarized in the following section. In particular, they focused on its ability to model special circumstances such as HOV facilities and real-time adaptive traffic control systems. The authors concluded that CORSIM is a quality model, but cannot possibly model all potential transportation system improvements. Nonetheless, the usefulness of CORSIM as a traffic engineering tool has been demonstrated repeatedly. It can be used for operational analyses. For example, Kim et al. (2003) evaluated the HCM-based level-of service thresholds for rural freeway facilities using CORSIM. Chien et al. (2002) used CORSIM to simulate delays associated with work zone traffic control. With respect to access management treatments, CORSIM has been used extensively to examine traffic control operations and to evaluate bus arrival times predicted by two artificial neural networks they developed.

3.2. SimTraffic

There were numerous examples in the literature of applications of SimTraffic. An introduction to SimTraffic and its applications was presented by Sorenson and Collins (2000). It showcased the unique abilities of the SimTraffic model to analyze intersections. In this study the software was used to compare the operation MOEs (e.g., delay) of roundabouts with that of stop-controlled and signalized intersections serving the same traffic. SimTraffic was used to generate traffic MOEs to compare with computed crash rates.

As with CORSIM, there are numerous examples of SimTraffic being used to analyze traffic operations. Although it does not explicitly treat transit, SimTraffic creatively examined impacts to vehicular traffic from light rail transit crossings.

3.3. AIMSUN

Barcelo (2003) describes the AIMSUN model and its potential applications. Barcleo presents a detailed description of the dynamic assignment capabilities of AIMSUN. Within the discussion, a description of the car-following and lane changing algorithms in AIMSUN and their relation to past methodologies is presented. AIMSUN was applied to traffic-responsive signal control analyses. In addition to examining traffic-responsive control and its advantages in saturated traffic conditions, the work also examined priority control for transit vehicles in a coordinated urban traffic control system. In particular, the articles focused on the dynamic route assignment capabilities of AIMSUN. The concept of alternate routing within traffic management architecture is developed in all three papers. Finally, Barceló provides a case study showcasing the use of AIMSUN in analyzing ITS strategies such as ramp metering and advanced traffic information systems (referred to as vehicle guidance systems in the paper).

IV. Model Calibration And Validation

As discussed in the previous section, these models use a wide range of user-defined parameters to model driver behaviour and vehicle performance. Each of these parameters is assigned a default value by the software, but in order to generate meaningful outputs from a simulation model it is important that each model be validated and calibrated to local conditions. Validation is the process whereby model outputs are compared to actual field data to determine how well the model replicates real-world conditions. Calibration is the process in which model parameters are adjusted to reflect the unique driving conditions associated with the network being modelled, and thereby generate a model that more closely reflects real-world conditions. After the initial comparison of outputs described in the previous section, each network was validated and calibrated for observed field conditions. Primary validation parameters were traffic volumes; speeds; travel times; and observed queues.

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These validation measures were selected largely for their ease of collection in the field. The models were calibrated based on appropriate parameters, including but not limited to headway factors, lane changing variables, driver familiarity, and free flow speeds.

There were no major differences in the types or amounts of input data required among the three models. Any significant differences were related primarily to different capabilities and features among the models. For instance, the Synchro input program used to develop SimTraffic networks can generate optimized signal timings as part of its analysis, obviating the need to use a separate piece of software to optimize timings for different scenarios. Likewise, CORSIM and AIMSUN can model transit operations thus requiring more data collection if transit is to be included. For basic arterial and freeway segments, however, the generic data types are similar for all three models.

V. Conclusions

In this paper we have presented a brief overview of traffic flow models and the simulation techniques commonly used for their support. These models can be used to develop traffic controllers using model-based control system design procedures. Some model classifications have been provided based on the following properties: physical analysis of the model, level of detail, discrete or continuous models, and deterministic versus stochastic models. For these models we have given an intuitive interpretation of the simulation packages that describe the model.

It was found found that SimTraffic, CORSIM, and AIMSUN can all provide reasonable results for typical simulation applications. So in this paper we have given an overview of traffic models, which are a basic ingredient of model-based control design procedures for traffic flow control and a combination of simulation packages for suitable planning of the traffic flow.

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