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Using a Road Traffic Simulation for Studying City Traffic

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Kurzfassung

Die ständige Zunahme des Straßenverkehrs führt zu enormen Problemen in der Wirtschaft und in der Belastung der Umwelt. Um Phänomene des Verkehrflusses in Städten und auf Landstraßen und Autobahnen zu untersuchen, wurden zahlreiche Simulationsmodelle entwickelt. Das Simulationspaket SUMO zur Untersuchung innerstädtischer Verkehrsströme ist in der Stadt Cottbus sowohl auf eine einzelne Kreuzung als auch auf einen komplexen Trassenverlauf in Nord-Süd-Richtung angewendet worden. Einige Ergebnisse werden in dieser Arbeit präsentiert.

Abstract

The continuous growth of road traffic volumes leads to significant environmental and economical problems. To study traffic phenomena and the corresponding applications, many traffic models and simulation packages have been proposed. One model of traffic flow, which has been designed for Cottbus-City with the road traffic simulation package „SUMO“, will be presented in this paper.

1 Introduction

The increase of traffic flow intensity entails the occurrence of jams in the city-centre and, as consequence, problems connected with environmental contamination.

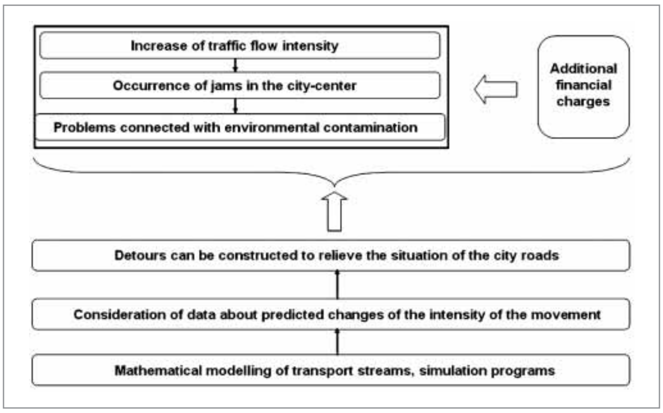

Figure 1:
Problem description

For their solution additional financial charges are required. To solve the listed detours can be constructed to relieve the situation of the city roads. For the realization of this idea it is necessary to study comprehensively existing transport streams and road systems. When a new city-highway is to be constructed, it is necessary to consider data about predicted changes of the intensity of the movement, for example, in city centre. These and a number of other problems can be solved with the help of the mathematical modelling of transport streams. The constructed mathematical models can be the basis of simulation programs. The presentation of the results of simulation modelling can help managers make decisions, which demand considerable financial investments.

2 Simulation Modelling

Simulation modelling is an increasingly popular and effective tool for analyzing a wide variety of dynamic problems which cannot be studied by other means. These problems are usually associated with complex processes which can not be described in analytical terms. Usually, these processes are characterized by the interaction of many system components or entities. Often, the behaviour of each entity and the interaction of a limited number of entities may be well understood and can be represented logically and mathematically with acceptable confidence. In general, however, the complex, simultaneous interactions of many system components cannot be adequately described in mathematical or logical forms.

All traffic simulation models describe dynamic systems, therefore why time is always the basic independent variable. Continuous simulation models describe how the elements of a system change state continuously over time in response to continuous stimuli. Discrete simulation models represent real-world systems by asserting that their states change abruptly at points in time.

Simulation models may also be classified according to the level of detail with which they represent the system to be studied: microscopic, macroscopic or mesoscopic.

A microscopic model describes both the system entities and their interactions at a high level of detail. For example, a lane-change manoeuvre at this level could invoke the car-following law for the subject vehicle with respect to its current leader, then with respect to its putative leader and its putative follower in the target lane, as well as representing other detailed driver decision processes. The duration of the lane-change manoeuvre can also be calculated.

A macroscopic model describes entities and their activities and interactions at a low level of detail. For example, the traffic stream may be represented in some aggregate manner such as a statistical histogram or by scalar values of flow rate, density and speed. Lane change manoeuvre would probably not be represented at all; the model may assert that the traffic stream is properly allocated to lanes or employ an approximation to this end.

A mesoscopic model generally represents most entities at a high level of detail but describes their activities and interactions at a much lower level of detail than would a microscopic model. For example, the lane-change manoeuvre could be represented for individual vehicles as an instantaneous event with the decision based, say, on relative lane densities, rather than detailed vehicle interactions.

3 Microscopic Modelling

I would like you to pay attention on the microscopic models as they are the basis for the simulation programs which we used for the decision of applied problems.

The idea of microscopic modelling of traffic flow is to describe the dynamics of each individual vehicle as a function of the positions and velocities of the neighbouring vehicles. In general, the two dynamical processes of car–following and lane–changing have to be considered. Since there are much more sophisticated methods for describing car–following than lane changes, we will start with a description of car–following models, assuming a road with only one lane. Positions and velocities of all vehicles are denoted by x_i and v_i respectively, where the index i rises in downstream direction.

Deriving a car following theory can obviously always start from the quite reasonable assumption that a change of the velocity is only performed, if the momentary velocity does not coincide with some desired velocity V_{des}, which is determined by safety considerations, legal restrictions and so on. The simplest dynamics that describes how a driver tries to approach the desired velocity is that of a relaxation on some time scale τ

$$\frac{dv_i(t)}{dt} = \frac{V_{des} - v_i}{\tau} \tag{1}$$

Almost all car following theories are based on the assumption that the motion of vehicle i is governed exclusively by the motion of the preceding vehicle i+1. Since a steady state obviously requires the velocity of all vehicles to be equal (otherwise they would collide), it seems natural to assume that the desired velocity of a car is equal to the velocity of the car it is following, which would mean

$$\frac{dv_i(t)}{dt} = \frac{V_{i+1}(t) - v_i(t)}{\tau} \tag{2}$$

This dynamical equation was first proposed by Pipes. This model is called classical car-following model. In the literature you can meet various updating of this model.

4 Stefan Krauss's Car-Following Model

Stefan Krauss has offered the updating of the microscopic model supposing multilane traffic. Now we shall consider the main parameters, the made assumptions and the equations of this model.

The model developed by Krauss (KRAUSS et al., 1997) is a microscopic, space-continuous, car-following model based on the safe speed – paradigm: a driver tries to stay away from the driver in his front at a distance and a safe speed that allows him to adapt this leader's deceleration.

The model assumes the driver to have a reaction time τ of about one second. The model uses the following parameter:

a – the maximum acceleration of the vehicle (in m/s^2),
b – the maximum deceleration of the vehicle (in m/s^2),
v_{max} – the maximum velocity of the vehicle (in m/s),
l – the length of the vehicle (in m),
ε – the driver's imperfection in holding the wished speed (between 0 and 1).

This safe velocity is computed using the following equation:

$$v_{safe} = v_l(t) + \frac{g(t) - v_l(t)\tau}{\bar{v}/b(\bar{v}) + \tau} \tag{3}$$

where

$v_l(t)$ – speed of the leading vehicle at the time t,
g(t) – gap to the leading vehicle at the time t,
τ – the driver's reaction time (usually 1s).

As v_{safe} may be larger than the maximum speed allowed on the road he uses or larger than the vehicle is capable to reach until the next step due to his acceleration capabilities, the minimum of these values is computed as next. The resulting speed is called the „desired" or „wished" speed

$$v_{des} = \min\left[v_{max}, v + at, v_{safe}\right] \tag{4}$$

Assuming the driver is not able to perfectly adapt the desired velocity, the „driver's imperfection" value multiplied with the car's acceleration ability and a random number is subtracted from the desired velocity. Finally, one must assure, the vehicle is not driving backwards. Due to this, the last of the model's equation is

$$v(t) = \max\left[0, \mathrm{rand}\left(v_{des} - \varepsilon at, v_{des}\right)\right] \tag{5}$$

The velocity, multiplied with the simulation step duration, which is constantly equal to one second, here, is added to the vehicle's current position to achieve the position for the next time step.

So far only single lane traffic has been modelled. In reality, however, this situation is hardly ever found on highways. Instead, a road generally is made up of two or more lanes, which allow vehicles to pass. Stefan Krauss has generalized the model to multilane traffic. The model formulation had been based on a few very simple assumptions:

- A lane change is performed, if it is favourable and safe.
- Passing on the right side is allowed only under congested conditions.
- There is a small probability p_{change} that a safe lane change is performed, even if it is not favourable.

After the generalization the time update will consist of three steps. In the first step lane changes are performed in the way specified below, in the second step the velocities are adjusted as specified in the single lane model, and in the third step the vehicles are moved according to their new velocity.

5 Modelling of the New Road Ring In Cottbus

The problem which we solve within the research project consists of studying the consequences of the construction of a new road ring in the Cottbus-City.

Today the basic stream of transport crosses all central parts of the city from north to south. Detours exist, but the quality and the hardware do not allow their full use. The administration of the city undertakes attempts to decrease transport in the centre to improve the condition of the environment and to raise the quality of life of the people living and working in this area. With this purpose it is planned to construct an additional detour. A part of this way will run on city streets, on which now traffic is not intensive. It will demand their reorganization. Our problem consisted of modelling a transport stream on an old and new transport way, their comparison and the analysis of distinctions.

We had a map of city streets, data on their hardware and a marking, data about participants and the traffic regulation on a considered site as initial data. In some sections there are automobiles and lorries, buses and trams. The average length, parameters of acceleration and braking are set for typical representatives. Buses move basically on roads on which there is no rail. In areas of crossroads buses can move on the lanes of the trams. Municipal transportation is in ring movement. The quantity of involved units of transport on each route of municipal transportation and the frequency of passage of buses and trams on routes at various times are known.

The movement of transport through crossroads is described by statistical data about the quantity of passing cars in various directions in known time intervals. Results of modelling and the analysis should evidently represent the scheme of movement and possible problems which can arise when values of operating parameters are changed: for example, switching-off traffic lights on crossroads.

Proceeding from available data we have decided to take advantage of the software package SUMO. SUMO is a traffic simulation tool (KRAJZEWICZ et al., 2002). It was primarily designed for urban street networks, but it may also be used for highway traffic simulations. In the near future it will be extended to model other transit modes simultaneously with ordinary car traffic. SUMO consists of several parts. To take advantage of a simulator, it is necessary to code data of cartography and the description of parameters of movement in XML files of the set structure. These files are broadcast by the service programs creating new structures of data which will be used at simulation. The graphic interface of a simulator is simple for acquaintance and convenient for use.

The model of one crossroads has been developed, to test opportunities of the software package SUMO (see Fig. 2). As initial data we have used information about the movement of vehicles and trams where two transport highways of Cottbus-City meet. With this model we have made a series of experiments investigating the influence of various operating parameters (for example, street marking and time of day, etc.) to test how quickly jams occur.

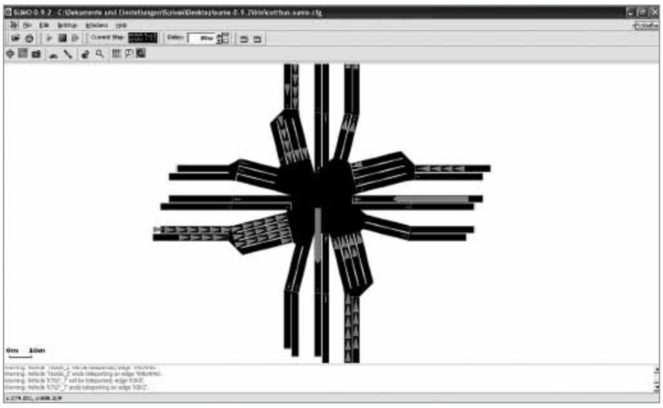

Figure 2:
Simple model of a crossroad

The verification of this simple model has allowed drawing a conclusion regarding opportunities of SUMO for modelling and researching an investigated trajectory (see Fig. 3). The set of initial data in this case was of course incomplete. Statistical data about transport movement on a new part of the city ring have been replaced with the parameters received by experts as a result of forecasting. The data describing the actual and the planned system of streets have been prepared and transformed. Experiments with various parameter values of transport movement were carried out. It has been recognized that the results of modelling correspond to the real distribution of the transport stream. They have allowed observing possible changes of traffic flow intensity in comparison with the real situation.

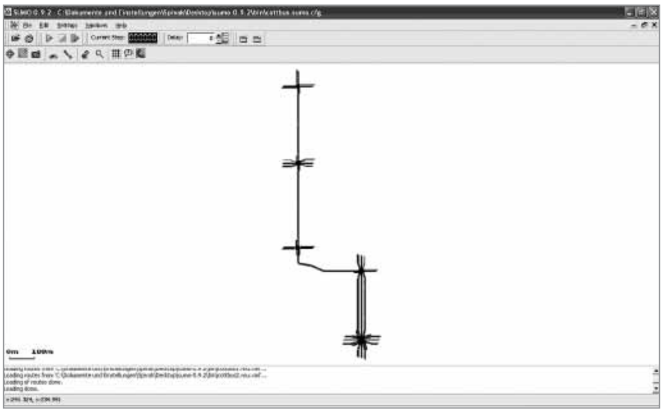

Figure 3:
Middle ring model

Conclusion

The aim of this investigation was the development of a traffic management system. The results of the transport simulation on crossroads have been shown to the administration of the city. It has been recognized that they correspond to the real distribution of the transport stream.

The existing model can be used to design new roads in Cottbus. It can be supplemented by the description of new roads and crossroads. Special emphasis is placed on the development of new modules, allowing the operation and control of traffic lights along an investigated trajectory.

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