A Review on Road Traffic Models for Intelligent Transportation System (ITS)

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Abstract— Traffic flow models seek to describe the interaction of vehicles with their drivers and the infrastructure. Almost all the models directly or indirectly characterize the relationship among the traffic variables: the position, the speed, the flow, and the density of vehicles. These relationships can be based on either the behavior of individual vehicles in a traffic network in relation to the dynamics of other vehicles, the overall characteristics of the flow of vehicles in a traffic network, or a combination of the behavior of individual vehicles in a traffic network and the overall traffic flow characteristics. This paper describes the different models for automatic Traffic control system.

Key words: Microscopic, Mesoscopic, Macroscopic, Dispersion, Gaussian, METANET models

I. INTRODUCTION

The nature of traffic flow models can be different in terms of their application area, in terms of their level of detail, in terms of the time domain used to describe them (as discrete-time or continuous time models), and in terms of their stochastic or deterministic nature in the description of the traffic variables [1]. Based on their level of detail, they can be categorized as macroscopic, microscopic, and mesoscopic traffic flow models. Traffic flow models that treat and model the behavior of individual vehicles in a traffic network fall in the category of microscopic traffic flow models. Macroscopic traffic models describe the collective vehicle dynamics in terms of the spatial vehicle density, the average flow, and average speed. Mesoscopic models describe the behavior of small groups of vehicles of a specific user-class classified by their position, velocity, and desired velocity at an instant of time [1].

II. BASIC TRAFFIC MODELS

A. *Macroscopic Traffic Flow Model*

Since in the microscopic traffic models each car is described by its equations of motion, the computer time and memory requirements of corresponding traffic simulations grow as the number of simulated cars increases [1,2]. Therefore, these kinds of models are mainly suitable for off-line traffic simulations, detailed studies (such as on-ramps or lane merging), or numerical evaluation of collective quantities like the density-dependent velocity distribution, the distribution of headway distances, etc., and other quantities that are difficult to determine empirically [2]. For these reasons, coarse fast micro simulation models have been developed for the simulation of large freeways or freeway networks [4, 5]. However, although they reproduce the main effects of traffic flow, they are not very suitable for detailed predictions because of their coarse-grained description [2]. Therefore, many authors prefer macroscopic traffic flow models to microscopic flow models [6]. Macroscopic traffic flow models deal with traffic flow in terms of aggregate variables (such as average speed, flow, and density). These aggregate variables, which describe the behavior of the drivers or vehicles, are assumed to depend on the traffic conditions in the drivers' (or vehicles') direct environments [1]. Macroscopic traffic models do not distinguish the behavior of individual vehicles in a traffic stream. So, in macroscopic models the simulation time and memory requirements mainly depend on the size of patio-temporal discretization, but not on the number of cars [1,2,3]. The independent variable of a continuous macroscopic traffic flow model is location x and time instant t. Most macroscopic traffic flow models describe the dynamics of the density=ρ(x,t), the average speed v=v(x,t); and the relationship of these variables. Virtually all macroscopic traffic models are based on continuity equation [6]

$$\frac{\partial \rho(x,t)}{\partial t} + \frac{\partial(\rho(x,t)v(x,t))}{\partial x} = v(x,t) \qquad (3.1)$$

for the source term v(x,t) denoting the rate of vehicles entering the freeway at on-ramp section or rate of vehicles leaving the freeway at off ramp section. Moreover in addition to equation 3.1 most macroscopic models define the relationship between the density ρ(x,t) , the flow q(x,t) and the average speed v(x,t) as

$$q(x,t) = \rho(x,t)\ v(x,t) \qquad (3.2)$$

Where the density ρ(x,t) is per single lane

B. *Microscopic Traffic Flow Model*

Microscopic traffic flow models describe the physics of individual vehicles as they interact with the driver and the infrastructure. In such modeling techniques lane changes, the inter vehicle distance, and the effect of neighboring vehicles to a vehicle are described. The main advantage of microscopic traffic flow models is that the behavior of the drivers and vehicles are described in detail. Therefore, they can provide relatively more information regarding the characteristics of the traffic flow (e.g., headway time or distance; position, speed, and acceleration of individual vehicles; heterogeneity of vehicles; and the like) than other types of models.

The main limitation of microscopic models is that they require a large memory size and they are very slow when used for large traffic networks [4, 7]. Moreover, microscopic models most often require large number of parameters, which are most often difficult to calibrate. So microscopic traffic flow models are not feasible for online prediction and optimization of traffic control systems. These models are mostly useful for local traffic studies.

Microscopic simulation traffic flow models are computer models where the driver behavior is modeled with extensive production (if-then) rules. These models describe both car following and lane-changing behavior of individual vehicles [1]. AIMSUN2 and FOSIM [7] are two examples of micro simulation traffic models. Submicroscopic simulation models are similar to the microscopic simulation models except that they have additional non time-space features [1].

C. Mesoscopic Traffic Flow Model

The mesoscopic traffic flow models describe the traffic flow in lesser detail than the microscopic models and in greater detail than the macroscopic models. In such models the vehicle or the driver behavior is not described individually, but in more aggregate terms. For example the same probability distribution functions can be used to categorize or describe the behavior of a vehicle or a driver [1] in some range of time or distance. So mesoscopic traffic flow models describe the dynamics of individual or small groups of vehicles using aggregate variables, such as the velocity distribution at a specific location and time instant.

III. ADVANCE TRAFFIC MODELS

Traffic control approaches utilize traffic models to design the traffic control measures in such a way that the desired control objectives can be attained. Therefore, it is required to make a selection of models that are suitable for the envisaged traffic control approaches.

A. Dispersion Model

Reduction of emitted gases of the traffic flow can improve the overall traffic network emissions. However, since dispersion of these emissions is dependent on the wind, temperature, rainfall, and topography of the freeway neighborhood, the dispersion of the emissions can be distributed unevenly. This means that certain areas can face higher emission levels than other areas. The dispersion of emissions from urban traffic is affected by the canyons of the urban streets and the dispersion distance of interest is short. However, the dispersion of emissions in freeways is less obstructed than the dispersion of the urban emissions.

B. Car Flow Model

The car-following models, which are also called follow-the-leader models, describe the interaction of a vehicle with its predecessor. Most generally, car-following refers to a situation in which a vehicle’s speed and longitudinal position are influenced by the vehicle immediately ahead of it in the same lane. Car–following is characterized by the headway (time or distance between vehicles) and the degree to which the following vehicle tracks the velocity changes of the leading vehicle. Car-following behavior is influenced by the driving goals, road curvature, relative velocity, stream speed, whether car-following is chosen or imposed, and the duration in the interaction (or coupled) state [8]. Car-following is one of the main processes in all microscopic simulation models and in modern traffic flow theory. It attempts to explain the interplay between the phenomena at the individual driver level and global behavior on a more macroscopic scale.

C. Fuel Consumption Model

Traffic control approaches based on on-line optimization require fast and accurate integrated traffic flow and fuel consumption models. Traffic emissions and fuel consumption models are models of any form (graphs, tables, mathematical expressions, computer algorithms, etc.), that calculate (or provide information about) emissions and fuel consumption rates for different traffic conditions. In other words, these models provide the emissions released or fuel consumed by a vehicle or a group of vehicles based on the operating conditions and status of the vehicle(s). The operating conditions refer to variables such as speed, acceleration, engine speed, engine power demand, air-to-fuel ratio, and so on. The status of a vehicle refers to its physical conditions related to its age, technology, and maintenance level.

In a broader sense, emissions and fuel consumption models can be either technology based engineering emissions and fuel consumption models or traffic emissions and fuel consumption models. The main difference between these modeling approaches is their level of detail and their intended applications. Technology-based engineering models are models for a specific engine type and size. The main inputs for such models are the speed, acceleration, engine load, and the specification of the vehicle (or engine).

Therefore, technology-based engineering models are primarily meant to be used by car-manufacturing companies for the assessment of new technological developments and by government agencies for regulation purposes [9]. Since these models are very specific and very detailed, they can neither generalize the emissions and fuel consumption rate of other vehicles in the fleet nor be used for on-line estimation and prediction, and thus they are not of interest for this thesis. Traffic emissions and fuel consumption models are developed for diverse collections of vehicles grouped in homogeneous categories. These models are simpler and have relatively less details than the technology-based engineering models.

Traffic emissions and fuel consumption models mainly consider the inter-relationship of the different traffic flow variables (speed, acceleration, flow, density) with the emissions and fuel consumption of the vehicles in the fleet. Since these models generally try to relate the traffic flow variable with the fleet emissions and fuel consumption, these models are more suited for the study of the effects of traffic flow control and management strategies. Moreover, these models are more suited for on-line estimation and predictions than the technology-based engineering models. Therefore, traffic emissions and fuel consumption models are the center of attention of this paper. In the sequel, the possible applications and classifications of traffic emissions and fuel consumption models are elaborated.

D. METANET Model

The METANET model is a second-order macroscopic traffic flow model that has been proposed by Papageorgiou and his co-workers [9]. The METANET model is discredited in time and space. As it deals with macroscopic variables rather than the variables or states of individual vehicles, it is suited for on-line computational purposes. The basic METANET model consists of link equations and node equations (nodes can represent a junction or a bifurcation point).

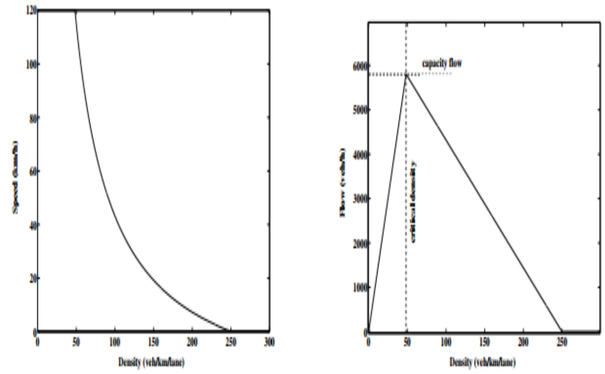

Fig. 1: Fundamental diagram for IV

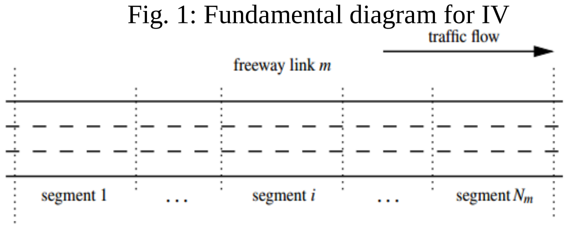

Fig. 2: Freeway link in METANET

The link model describes the behavior of the traffic in the highway stretches, and the node model describes the behavior of the traffic at the nodes in the network. The METANET model can be classified as destination-oriented or destination independent. Since we will use the METANET model for solving routing problems.

IV. CONCLUSION

As the phrase "model-based traffic control" indicates, the control approach presented in this paper requires models of the traffic system. So, in this paper an overview of the traffic flow models in general and the specific traffic models to be used have been discussed. The paper has provided the general overview of the traffic models by exploring the general applications of these models and the way they can be classified. Based on the level of details, the classification of traffic models as microscopic, macroscopic, and mesoscopic has been discussed with a special emphasis on microscopic and macroscopic models.

The general modeling concepts underling the microscopic and macroscopic models have been in particular discussed. Among the microscopic models, a brief account has been given for the car-following models, because the car-following models are the building blocks of most traffic flow models. Two of the car-following models, the GHR model and the IDM model have been discussed in detail. Since the GHR model is unable to model the traffic flow under free-flow conditions, it has been suggested to use a separate expression to model the free-flow traffic conditions if one opts to use the GHR model for the car-following situations under high to medium traffic densities. Therefore, the GHR model and the additional free-flow expression can be used to model free-flow and congested traffic conditions for both accelerating and decelerating cases of individual vehicles. The IDM model, however, is a full-fledged model that can capture the traffic scenarios the GHR model, without the additional free-flow expression, cannot. The IDM model does not require different parameters for different traffic conditions as the GHR model does.

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