研 究 速 報

Driver Model for Traffic Simulation, with Tactical Lane Changing Behavior

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1. Introduction

Microscopic traffic simulation is a useful tool for testing and evaluating infrastructure design, operation, and control policies in a virtual environment, realizing cost savings and flexibility compared to real-world testing or implementation. The motion of each vehicle is reproduced, and the mutual interactions can allow a richer, more accurate model of the overall system, compared with non-simulation based approaches.

Considering the vehicle's response to its environment, driver-vehicle behavior can be classified into three categories. In order of increasing detail, these are: strategic (route planning), tactical, and operational (accelerator / brake pedal, steering).[1] Tactical driver behavior is considered as the development, evaluation, and execution of near-term maneuvers to realize short-term goals, specifically the choice of nearby lane and path.

A particular feature of tactical driver behavior is that the "decisions we make in our vehicle are largely based on our assumptions about the behavior of other vehicles."[2]. In this research, two components of tactical driver behavior are inferred: (1) planning of sequential maneuvers, and (2) anticipation of the changing state of the self and surrounding vehicles. However, these two components are not included in many of today's traffic simulators.[4,5,6,7,8]

There are a variety of situations in which there is a potential for difference in modeling of tactical lane changing behavior between the driver model and the behavior of the real driver. Aggressive driving (cutting into small gaps) can have disproportionate impacts on the traffic stream, and the representation of the aggressive drivers gap acceptance and the maneuver planning leading to these decisions. Weaving sections are particularly important for consideration of planning and anticipation, because vehicles entering and exiting the freeway must take into account the other vehicles expected course as they plan their own path. This is especially true of vehicles entering a freeway with high-occupancy vehicle (HOV) lane system. The simulated travel time of the qualified vehicles could depend strongly on how their tactical behavior of weaving across the slower-moving middle lanes is modeled.

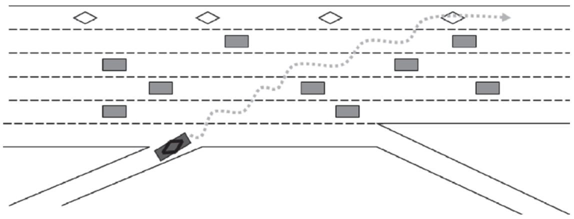

Figure 1. High-occupancy vehicle lane simulation.

In recent years, advances in traffic data surveillance technologies, computational hardware and algorithmic techniques now allow more realistic driver models to be developed and used.

In this research, an algorithm hereafter called the Tactical Lane Change Model is described for representing driver behaviors of anticipation and sequential planning of lane change maneuvers in a traffic simulator. In addition, a method of assessing the performance of lane change models is proposed. The method is used to compare the performance of the Tactical Lane Change Model to a straw man algorithm hereafter called the Basic Lane Change Model which is similar to those in today's traffic simulators which does not include driver planning for sequential lane change maneuvers or anticipation of changing conditions.

2. Basic Lane Change Model

The Basic Lane Change Model serves as a straw man, to represent models used in present-day traffic simulators, inasmuch as it does not contain planning of sequential lane change maneuvers. It uses a form of the Gipps[11] lane change model. The framework, is to first check if a lane change to the adjacent lane is feasible, that is, whether both lead and rear gaps are large enough to allow a safe completion of the lane change maneuver. If so, the second step is to check if the lane change is desirable. This is done

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by comparing the allowable safe speeds in the current lane and candidate lanes, and if the candidate lane offers a more favorable speed, within the limits of the vehicle's desired speed, then the model initiates a lane change to the candidate lane. In determining the gap safety and desired speed, the Gipps longitudinal control model is used.

3. Tactical Lane Change Model

The Tactical Lane Change Model, like the Basic Lane Change Model, also follows the same two-step decision process: (1) checking the feasibility of lane change to the candidate adjacent lane feasible in terms of safe gap availability and (2) checking the desirability to change lanes. However, the Tactical Lane Change Model assesses the desirability not by considering the current conditions, but rather by predicting the resultant states of the subject and surrounding vehicles for various sequences of subject vehicle lane change maneuver choices over the planning time horizon t_h, which is a model parameter. This is shown schematically in Figure 2. The lane change action is selected as the initial lane change action (or non-lane-change action) in the maneuver sequence which allows the subject vehicle to move the greatest distance ahead over time horizon.

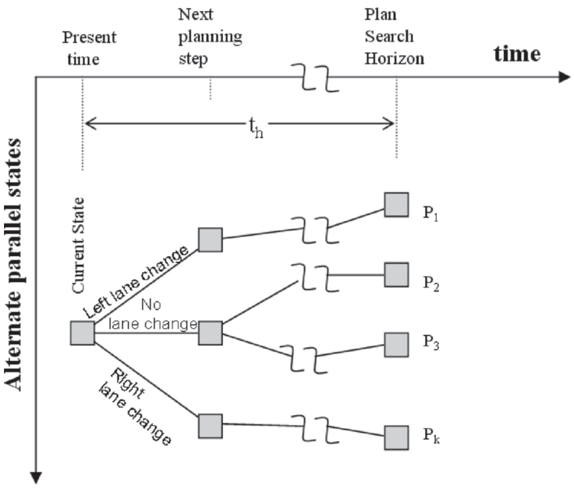

Figure 2. Forward Search Tree.

4. Performance Evaluation

Using selected vehicles from a trajectory data set, the performance of the Tactical and Basic Lane Change Models were compared. This section describes the data set, the traffic simulator which serves as the test environment for the lane change models, the performance evaluation method, and the results of the lane change model performance comparison.

4.1. Traffic Data Set

The NGSIM project[9] is a research project led by the US Department of Transportation to provide a core set of driver behavior data and algorithms for verification and validation purposes. Vehicle trajectory data from video image processing is provided free to the research community. The data set consists of a 900 m long 6-lane section of the I-80 freeway in Oakland, California. The data set was collected from 2:35 to 3:05 p.m. on April 22, 2004. The traffic conditions range from moderate to congested flow conditions. The section contains an upstream single-lane entry ramp, and a downstream single-lane exit ramp. The data has a spatial resolution within 1.0 meters, and the time resolution is 1/15 s. The time duration of the data set is approximately 30 minutes.

4.2. Traffic Simulator and Performance Test Environment

In this research, a traffic simulator was developed to serve as the testing environment. It is a time-step based simulator which is capable of representing the vehicle management, network geometry, animation, and data I/O processes. Additionally, it contains the driver behavior models for longitudinal control, and either the Basic or Tactical lane change models as specified by the user.

4.3. Performance Evaluation Method

Each lane change model is evaluated in terms of the weighted proportion of lane change actions which are the same as that performed by the real vehicle from the data trajectory set. First the longitudinal control model parameters for the vehicle are best-fit estimated through an iterative search process. The longitudinal control model is a Gipps-type model and is based on safe stopping without collisions. Two longitudinal control model parameters are best-fit estimated: reaction time lag and desired speed.

The lane change model performance function U_{LC} is computed separately for each vehicle to be analyzed, as described in this section. First, the traveled course of the real vehicle is divided into units known as gap sessions.

A gap session is a time period over which the subject vehicle has the same set of vehicles in the relative positions around it, specifically the {lead, rear, left lead, left rear, right lead, right rear} positions, and the same gap availability. The concept of gap session is illustrated in an example in Figure 3 which shows how one gap session transitions into another.

The gap session shown at the top of Figure 3 has lead vehicle D, rear vehicle C, a left gap with lead vehicle B and rear vehicle A, and right gap with lead vehicle F and rear vehicle E. The spatial size of this gap session is the length in meters from the back bumper of Vehicle D to the front bumper of Vehicle C. This gap session transitions to that shown at the bottom of Figure 3, when vehicle A in the left lane pulls alongside the subject vehicle, ending the availability of a left gap.

For each driver model considered, U_{LC} is computed for each

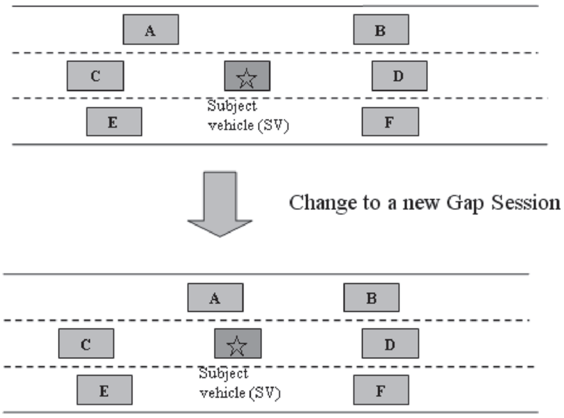

Figure 3. Transition between gap sessions.

point in the parameter search space covering lane change model parameters. The best-fit parameters are those which minimize the fitness value U_{LC}. The overall performance of the model is the minimum score obtained for U_{LC}. U_{LC} is the proportion of the lane changes for each gap session in the analyzed vehicle trajectory for which the model gave the incorrect lane change action. A value of *0* would indicate completely correct representation of the analyzed vehicle's lane change (and non-lane change) actions by the lane change model.

This weighting strategy allows gap sessions which have a bigger size and a longer duration to get a greater influence on the computation of the measure of correctness U_{LC}. This is important to prevent gap sessions which are very small or of short duration from having a disproportionate influence on the measure of correctness.

5. Results

From the trajectory data, a set of 36 vehicles was selected which performed a relatively large number of lane changes, and had an overall high travel speed in comparison to the surrounding vehicles. The performance of both the Basic and Tactical lane change models was measured for each vehicle.

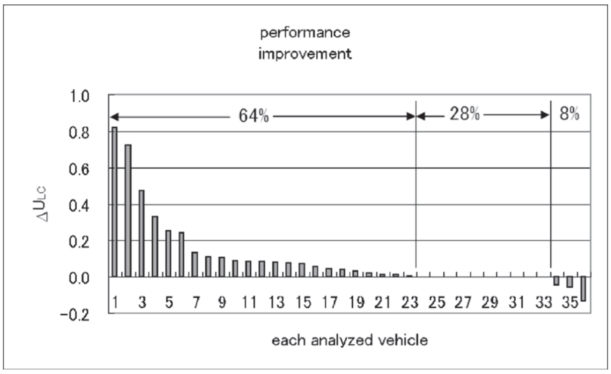

Figure 4. Comparison of performance of lane change models.

Over the set of vehicles analyzed, the overall performance of the two lane change models can be judged by the number of vehicles in which the performance was better by either model. Figure 4 shows the performance improvement (reduction in U_{LC}) due to using the Tactical Lane Change Model compared to the Basic model. It can be seen that the Tactical model gave superior performance for 68% of the analyzed vehicles.

It should be noted that although this comparison has shown a superior performance for a subset of the vehicles in the traffic stream, that these vehicles may likely exert a disproportionate effect on the traffic stream as a whole through shockwaves due to their frequent lane changes. Further, in simulation travel time studies of a subset of the traffic stream, such as the HOV vehicles entering the freeway in the example presented earlier in Figure 1, such a difference in lane change behavior will influence the travel time of this subset of the vehicles.

6. Conclusions

A Tactical Lane Change Model was proposed, and it was found to have a better performance compared to the Basic Lane Change Model. The Tactical Lane Change Model determines the current lane change action by enumerating the possible combination of sequential lane change maneuvers, whereas the Basic Lane Change Model considers only the immediate utility of the current lane change action. A method for evaluating the performance of a lane change model was introduced. In the performance evaluation, selected vehicles from a real vehicle trajectory data set from freeway traffic were examined under both lane change models. Both the Tactical and Basic models were evaluated and the Tactical Model was found to give more realistic representation of the vehicle lane change behavior in comparison to the Basic Lane Change Model.

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