Research of Driver Decision Making Behavior Modeling and Simulation

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***Abstract*—With the increasing amount of vehicles and traffic accidents, the current situation of transport safety is pessimistic. The research of drivers' actions is hot spot. It introduces the basic contents of driver's decision and the utility theory. Dividing the driver's decision into four layers and using utility theory method to modeling the strategic layer o driver decision. It proposes the formation of safety, efficiency and easy maneuverability to evaluate the plans. It runs the model in the simulation which proves the feasibility of model.**

Keywords-Driver decision making, Utility theory, Strategic layer, Method layer

I. INTRODUCTION

With the increasing number of automobiles in our country, traffic accidents frequently occur and traffic safety situation is very stern. Driver is the main role of traffic accidents, the related behavior research also becomes the focus. It will be helpful for establishing more reasonable traffic regulations and designing more intelligent driving navigation system to decrease the traffic accidents and raise traffic efficiency by going deep into the driving behavior of driver. Analyzing from the viewpoint of cognitive science , driving behavior is formed by perception, decision and controlling. In driving course, driver carries out perception of traffic environment. At the same time, drivers make decisions on the foundation of perception information according to the decision goal and realize the decision by specific driving operations. The decision course of driver is also affected by psychological characteristic and the personlity of driver. The decision behavior of driver is the important content of driver behavior modeling and simulation research [1].

II. THE RELATED WORK

In the field of public transportation, the decision making behavior research is important for vehicle designing and traffic safety. Domestic and international researchers have put forward plenty of theories and techniques. In the aspect of the direction control models of vehicle it contain three parts: compensating track model, previewing tracking model and intelligent controlling model dividing by development of control theory [2]. In the aspect of speed control of vehicle, stimulus and reaction following model, safety distance based following model, reaction point following model, fuzzy logic based on following model and so on. On the combinition control model of direction and speed, track planing and fuzzy neural network are also applied [3].

III. DRIVER DECISION MAKING BEHAVIOR MODELING BASED ON LAYERS

The driving behavior framework is shown in figure 1.

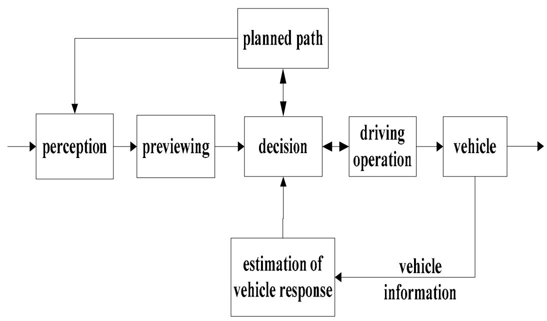

Figure 1. Driver's behavior framework

A. Basic Assumption

For driver decision behavior modeling and simulation, it needs the following assumptions:

(1) In driving virtual driver does not consider route planning and travel in the planed road;

(2)Virtual driver can percept the road, vehicle and other traffic information. The perception is close to the perception of true driver.

B. Decision Making Behavior Modeling Method Based on Layer

Decision is a basic psychological activity of human which is the process that solves contradiction. Generally speaking, in decision analysis there is 3 basic essential factors: alternative plans, constraints and utility function.

Driver's decision making behavior can divide into four layers: strategic layer, method layer, operation layer and vehicle control layer. Strategic layer is the overall planning and updating route. Method layer is driver's specific decision that is for realizing current goal in driving course such as changing lane, following or overtaking other vehicles and so on. Operation layer denotes the specific operation goal and plan based on decision of method layer such as determining the acceleration, distance between vehicles. Vehicle control layer deals with those specific control operations and directly cause the change of vehicle moving state such as increasing gas, changing gear. The four layers decisions have different abstract level and the requirement of real time which is shown in figure 2.

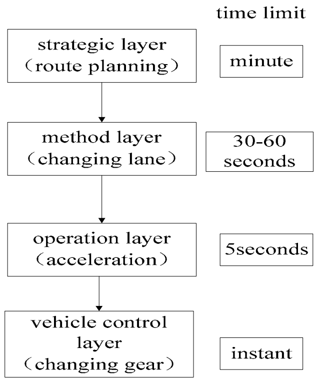

Figure 2. Driver's layered decision making

C. *Decision Making Behavior Modeling in Method Layer*

The method layer decision modeling and simulation adopts theory of expected utility. The calculation of expected utility values of alternative plans is the key of decision behavior which has embodied decision rules and decision restraint's effects on driver's decision making behavior. The calculation of expected utility values of alternative plans for driver controlling behavior is synthesizing the cost that one plan pays out , the vehicle state change caused as well as the effectiveness brought by. In specific decision course driver needs to calculate the three kinds of expected utility values of alternative plans: safety utility, effectiveness utility and easy maneuverability utility.

The three kinds of utility values need to carry out normalization. Normalization denotes the pretreatment of different dimension data before handling. Only after unifying their dimension, it guarantees the correctness of mathematics and this is also the prerequisites of multi-goal decision making.

For driving safety, the value of evaluation index is safe distance. Through the calculation of sigmoid function, the biggest and minimum values are the two critical points of the gain in oppose degree which unifies the dimension as the pretreatment of normalization.

For driving effectiveness, its value is the expected speed of vehicle, this kind of evaluation index based on speed is different from the evaluation index based on distance. In establishment of evaluation index, the biggest speed and minimum speed are respectively corresponding to the two critical points of the gain in oppose degree which puts all the effectiveness points in the predicted track in the area between the high gain and low gain[4].

Easy maneuverability is the appraisement index of driver's control burden. For driver easy maneuverability is from the operating the vehicle steering wheel, gas and brake pedal and so on. Easy maneuverability is the direct embodiment of the psychological and physiological burden in driving. Therefore the establishment of evaluation index uses the acceleration as evaluating value.

Utilizing the Sigmoid function as the utility function, the formation of Sigmoid function is:

$$u = \frac{1}{1+e^{-B(x-A)}}$$

The values of Sigmoid function are between 0 and 1 so that there is no threshold and the function is strictly singleness. The figure of Sigmoid function is shown in figure 3. There are two parameters in the Sigmoid function: A denotes the variable value when r is 0.5, B denotes the changing trend of gain. The gains of Sigmoid vary in a non-linear way and the evaluation index will be single if properly choosing the values of A and B.

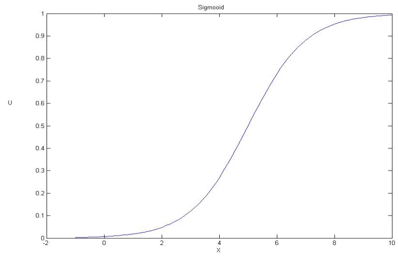

Figure 3. Sigmoid diagram

Driving safety mainly considers the possibility of vehicle collision. Vehicle collision divides into two kinds, a kind is collision with barrier and road boundary, another kind is collision with other vehicles. The calculation of collision possibility with barrier and road boundary adopts the most dangerous point method. When evaluating the alternative plan, predicting the colliding point of vehicle and the distance between the point and barrier or road boundary. For example if driver wants to turn right, the most likely collision point of vehicle is the left and back corner c4 which is shown in figure 4.

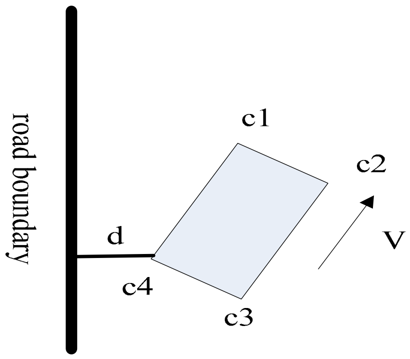

Figure 4. most dangerous point method

One feature of decision making of driver is forecast ness and the figuring out of most dangerous point is subjective. According to the driving experience, the safe distance is between 0.3 and 1 meter. For the utility function of collision with barrier and road boundary, setting 0.3 and 1 as the points whose values is 0.5 and 1 respectively. The function Us1 is as follow:

$$u_{s1}=\frac{1}{1+e^{-15(x-0.3)}}$$

The evaluation index of collision with other vehicles is distance between vehicles. The distance is calculated as:

$$d_{interval}=\frac{V_r^2}{2\cdot a}+t_l\cdot V_r+D$$

In the above form, tl is the reaction time of driver in leading or following vehicle, a is the acceleration of leading or following vehicle, D is the minimum distance between vehicles, V_r is the relative speed of two vehicles. In calculation adopting the data from experience and setting a as 2.0m/s^2, t_l as 1 second, D as 10 meters. After calculating the distance between vehicles, it sets the 10 and 20 as the point whose value is 0.1 and 0.9 respectively. The utility function of collision with other vehicles is as follow：

$$u_{s2}=\frac{1}{1+e^{-0.439(d_{interval}-15)}}$$

After figuring out the Us1 and Us2, the safety utility is calculated as：

$$u_s=(u_{s1}+u_{s2})\cdot 0.5$$

Effectiveness denotes that the driver always travel as far as possible to arrive the destination on time. The standard of appraisement index is speed. This speed is the expected speed of driver for a certain time which is subjective estimated by driver. This expected speed can get through from the estimation of vehicle feedback.

According to the specific parameters of vehicle, setting the 10km/h as the point valued 0.1 and the 90km/h as the point valued 0.9. The effectiveness utility function is shown as:

$$u_e=\frac{1}{1+e^{-0.055(x-50)}}$$

In driving driver controls the vehicle by hands and foot, frequently operation will increase the psychological and physiological burden of driver. The direct result from driver controlling the vehicle is the changes of acceleration including direction and speed accelerations which in turn alter the moving state of vehicle. The evaluation index of easy maneuverability is acceleration of vehicle. In the alternative plans the frequency and number of accelerations can change so that choosing the biggest acceleration as evaluation point for simplifying the calculation. Setting the 4m/s^2 as the point valued 0.1 and 0.5 m/s^2 as the point valued 0.9. The utility function is:

$$u_m=\frac{1}{1+e^{1.26(x-2.26)}}$$

After getting the safety utility, effectiveness utility and easy maneuverability utility of candidate plan, weighting three values and summing them together as follow:

$$u=u_s\cdot 0.6+u_e\cdot 0.3+u_m\cdot 0.1$$

After getting the total utility of candidate plan, the method layer can decide if changing lane or following the leading vehicle.

IV. Driver's Decision Making Simulation

Realizing the decision making model of driver in driving simulation system. The driving simulation system is formed by vehicle simulation program, virtual traffic environment as well as virtual driver. The simulation scene is shown in Figure 5.

Figure 5. driving scene

In the simulation, the track comparison of lane changing manipulated by real driver and virtual driver is shown in figure 6.

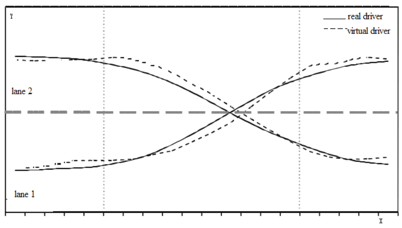

Figure 6. changing lane tracks

V. Conclusion and Future Work

Based on the features of driver decision making behavior, from the viewpoint of cognitive scientific, it divides the decision making behavior into four layers. Adopting the expected utility theory to modeling the method layer of driver decision making which has better imitated the decision behavior of true driver. The future research is to accurately mark the parameters in the model and the other three layers of decision making behavior modeling.

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