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Research on the Track Planning of Intelligent Vehicle

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***Abstract*—Aiming at the problem of lack of adaptability of typical lane changing model, this paper analyzes the characteristics of lane changing process and compares the advantages and disadvantages of common lane changing model in the path trajectory planning. A new model of autonomous trajectory function of intelligent vehicle is proposed. Good to meet the requirements of smart cars for lane change. And the new trajectory function model is simulated by MATLAB to verify the validity and improvement of the model.**

Keywords*— *Intelligent Vehicle; Lane Change; Trajectory Planning; Model Comparison

I .INTRODUCTION

In recent years, with the intelligent traffic system (Intelligent Transport System, ITS) in China's local pilot and promotion, in the basic application of research has made great progress. It is an important way to solve the problem of urban congestion, improve the efficiency of passage and create a city of wisdom. It is necessary to develop ITS to improve the efficiency and safety of vehicle traffic and improve the traffic efficiency of the whole traffic flow. The intelligent vehicle as the most important part of intelligent transportation system, especially the current concept of intelligent network car rise, the development of intelligent vehicle put forward higher requirements. Intelligent car is a set of environmental awareness, decision-making planning and multi-level auxiliary driving and other functions in an integrated system. In the context of environmental awareness, intelligent vehicles rely on high-precision sensors, can effectively identify the surrounding obstacles and quickly obtain the current driving state; for decision-making, the intelligent vehicle simulates the human brain for the collection of effective data processing and make driving habits decision making. Analysis of the vehicle's driving process, any control state can be broken down into horizontal and vertical control[1]. In the vehicle driving, lane and overtaking is the most common driving behavior, but for overtaking can be broken down into lane and Longitudinal driving. Therefore, to achieve autonomous lane change of intelligent vehicle, the first is to be based on the current state of the vehicle movement and the surrounding environment to plan a reasonable driving track, again is the target vehicle path tracking control. Therefore, the in-depth study of the vehicle lane model is of great significance to the development of intelligent vehicles and to enhance the efficiency of the whole traffic flow[2].

Based on the analysis of the movement state of the vehicle and the analysis of the actual driving operation, the author obtains the basic constraint condition of the track track. The basic path planning function model is studied, and the model of the model is analyzed. This paper proposes a new hybrid trajectory planning model. Through the simulation analysis of the typical model and the new function model, the validity and improvement of the new model are verified.

Ⅱ. ANALYSIS ON THE TRACK PROCESS OF INTELLIGENT VEHICLE

The typical lane changing scene of the Intelligent vehicle, as shown in Figure 1. In the figure, the vehicle M is the lane vehicle, the lane is called the lane, the F1 vehicle in front of the lane is the obstacle vehicle, and R1 is the following vehicle. The adjacent lane is called the target lane, and there is a normal driving vehicle R2 and vehicle F2 on the lane. Make a change of decision, the vehicle will be drived from the lane to the target lane, lane track as shown in Figure 1 dotted line.

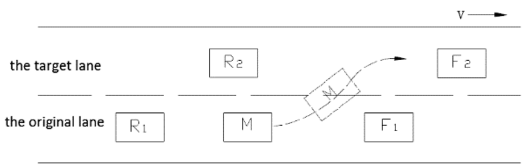

Fig.1. Typical lane changing scenes

According to the typical scenario described above, it is not difficult to see that the intelligent vehicle lane is generally divided into three stages: first, the longitudinal movement state of the lane before the lane change is located; and the second, state adjustment; third, the body into the target lane again after the adjustment of the vehicle posture stage. From the driver's point of view,it can also be divided into three steps: the vehicle was made a change in decision-making, first of all, the steering wheel was adjusted, the vehicle to the target lane deflection; second, the vehicles to be lane into the target lane, To adjust the steering wheel, to prevent the vehicle deflection over, away from the target lane; Finally, fine-tuning the steering wheel to ensure that the vehicle in the target lane straight driving. Therefore, according to the above-mentioned track trajectory process analysis and reference [3], for the lane track need to meet the following three requirements: (1) due to the vehicle in the course of the continuity of the lane change, so the track image curvature should be continuous change, (2) to consider the safety of the actual lane in the process of driving, in order to keep the lane and the surrounding vehicles and lanes have a good distance between the road line, to ensure the image curvature was zero located at the starting point and the end of the lane (3) taking into account the comfort of the vehicle lane, the implementation of the process of changing the lateral acceleration should be guaranteed within a certain range, the reference [4], generally not more than 3m / s^2.

1.1 isokinetic migration model

The model trajectory is shown in Figure 2 below. In the figure, L represents the distance between adjacent road centers and the trajectories are composed of three straight lines.

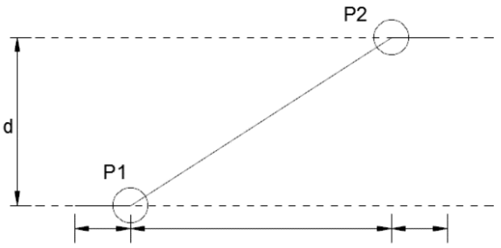

Fig.2. Isokinetic migration model

Although the model is divided into three parts by the lane changing process, it can better meet the second requirement in the above-mentioned changing request, and the comfort performance of the vehicle is well satisfied during the lane changing process. But at point P1 and P2, the direction of movement of the vehicle has changed, which is not allowed in the actual driving process.

1.2 arc lane change model

The model trajectory is shown in Figure 3 below. The trajectory is also composed of three sections, different from the model 1.1, the first part and the third part are composed of arc, the middle by a straight line connection.

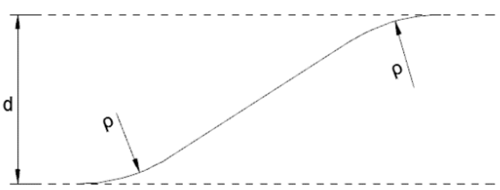

Fig.3. Arc lane change model

Although the model relieves the mutation at the connection point, it is fundamentally unresolved. This is due to the radius of curvature of the arc ρ is subject to the lateral acceleration of the road when the acceleration: lateral acceleration is too large, affecting the road comfort; too small, increase the lane time, so that the security is very unfavorable.

1.3 trapezoidal lateral acceleration lane change model

Different from the model 1.1 and 1.3, the model from the point of view of the lateral acceleration of the road, that the process of changing the vehicle lateral acceleration to meet the two congruent trapezoid of a point symmetry. The model trajectory is shown in Figure 4 below.

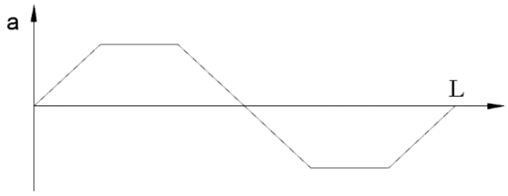

Fig.4. Trapezoidal lateral acceleration lane change model

Although this model is better to meet the three requirements of the lane, but only applies to the typical road conditions, and in the unstructured road on the poor adaptability. Therefore, do not have good flexibility.

1.4 Cosine function model

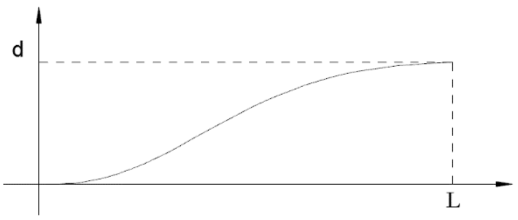

Fig.5. Cosine function model

The model trajectory is shown in Figure 5 above. Compared with the above function model, the trajectory model has good first and second order continuity, which shows a good smoothness and is simpler to calculate. However, the reference [5] shows that the maximum curvature of the model appears at the beginning and the end of the lane change, and therefore does not satisfy the second requirement of the above track path.

Ⅲ. MIXED FUNCTION MODEL

By comparing the above four basic lane function models, it is found that the curvature of model 1.1 at the beginning and end of the lane is always zero, and the model 1.4 is founded to have excellent smoothness. Based on the advantages of the two models, we can better meet the previous section of the three lane requirements.

The mixed function model combines the primary function of the constant velocity migration model with the cosine function model. The initial model is as follows:

$$f(x) = x + \cos x \quad (1)$$

According to the cosine function model in the literature [6], the following mixed function model is obtained by adjusting the model according to the requirements of changing conditions.

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$$f(x)=\frac{d}{l}x+\frac{d}{2\pi}\sin(\frac{2\pi}{l}*(x-\frac{l}{2}))x\epsilon(0,l) \quad (2)$$

In the formula (2),

x: the longitudinal displacement of the roadway in the road line, in units of: m;

d： distance between adjacent lane center lines, in units of: m;

l： The longitudinal displacement of the road during the entire lane change, in units of: m.

The derivative of the variable x in formula (2) is derived once and two times:

$$f(\dot{x})=\frac{d}{l}+\frac{d}{l}\cos(\frac{2\pi}{l}*(x-\frac{l}{2})) \quad (3)$$

$$f(\ddot{x})=-\frac{2\pi d}{l^2}\sin(\frac{2\pi}{l}*(x-\frac{l}{2})) \quad (4)$$

The curvature formula of vehicle lane change is as follows:

$$\mathrm{K}=\frac{|f(\ddot{x})|}{\sqrt[3]{[1+(f(\dot{x}))^2]^2}} \quad (5)$$

It is not difficult to find that when x is *0* or *l*, that is, at the beginning and the end of the lane, the lane curvature of the vehicle is zero. In addition, the mixed function model has good continuity. Therefore, the first two conditions for the lane change trajectory requirements are met.

In order to facilitate the study, assuming that the lane is running at the same speed during the whole lane change, there are: x = v * t, adjust to (2):

$$f(t)=\frac{d}{l}v*t+\frac{d}{2\pi}\sin(\frac{2\pi}{l}*(v*t-\frac{l}{2})) \quad (6)$$

For the formula (6) on the time t once and second derivative, respectively:

$$f(\dot{t})=\frac{d}{l}v+\frac{dv}{l}\cos(\frac{2\pi}{l}(vt-\frac{l}{2})) \quad (7)$$

$$f(\ddot{t})=-2\pi d\frac{v^2}{l^2}\sin(\frac{2\pi}{l}(vt-\frac{l}{2})) \quad (8)$$

In order to ensure that the track, the vehicle has a better comfort, therefore, require the need for lateral acceleration of the road within a certain acceleration value, namely:

$$2\pi d\frac{v^2}{l^2}\le a_{max} \quad (9)$$

According to equation (9), it is necessary to satisfy the requirement of lateral acceleration when changing the longitudinal displacement of the intelligent vehicle($l\ge\sqrt{\frac{2\pi d v^2}{a_{max}}}$), can satisfy the requirement of lateral acceleration lane, namely the third requirements of the lane changing trajectory in the last part.

IV. SIMULATION

In this section, the mixed function model is simulated by Matlab and compared with model 1.4. Simulation parameters d according to the national highway standard to take 3.75m, refer to the relevant information, the entire road during the longitudinal travel displacement l = 150m. As shown in Figure 6:

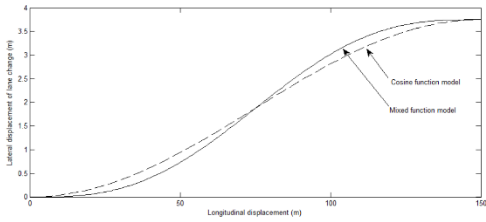

Fig.6. Mixed function model and cosine function model trajectory

The mixed-function trajectory model and the cosine function trajectory model are characterized by the solid line and the dotted line in the graph. It is founded that the mixed function model is more gentle in the track start time and the end time, and it is verified by the above formula the curvature is zero at both moments. In addition, from the overall trajectory, the hybrid function model is more smooth, more in line with the track trajectory characteristics.

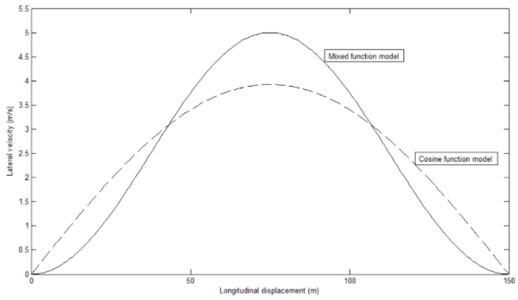

Fig.7. Expected lateral velocity change

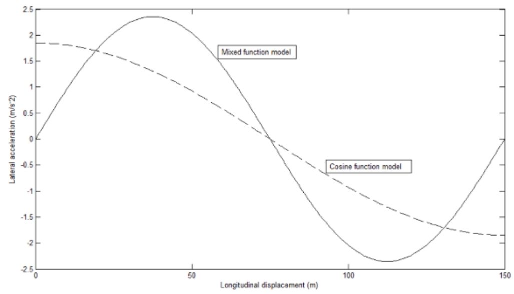

Fig.8. Expected lateral acceleration changes

Figure 7 shows the variation of the lateral velocity of the lane during the whole lane change. Figure 8 shows the variation of the lateral acceleration of the lane. Figure 7 in the mixed function model of the lateral velocity change at the beginning of the road is more gentle, is conducive to enhance the safety of the of lane changing. In Figure 8, the acceleration function of the mixed function model is better adapted to the accelerated lane changing condition, and the lateral acceleration extremum is also better to meet the requirements of the roadway comfort. Therefore, the mixed function model is more in line with the characteristics of the movement state of the intelligent vehicle during the lane changing process.

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Ⅴ. CONCLUSION

A new function trajectory planning model is proposed. The model is based on the combination of typical isokinetic offset model and cosine function model, and inherits the advantages of the two function models. Through the verification and analysis, it proves the correctness and advantages of the model. However, the adaptability of the model needs to be further explored and validated for the intelligent vehicle lane changing in the atypical lane scene.

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