



Lane Change Path Planning in Emergency Situation Based on Skilled Driver's Performance

S. N. Minaei*, A. Ghaffari

¹Department of Mechanical Engineering, Laboratory of Advanced Vehicle Control Systems, K.N. Toosi University of Technology, Tehran, Iran

ABSTRACT: Lane Change at high speeds is a strategic maneuver to avoid the collision. In this situation, The time of an accident possibility is mainly less than two seconds. therefore, finding the proper trajectory and control of the vehicle is crucial at the lowest cost. In this paper, based on a skilled driver's performance in a similar situation, a proper path and corresponding appropriate control system was designed aiming at vehicle stability preserving and collision avoidance. To this purpose, possible paths were simulated and identified using the vehicle's seven degrees of freedom model and applying the driver's behavior. A neural network system was trained; then, the trajectory was chosen. A hybrid controller was hired for the vehicle navigation, consisting of the driver's performance pattern with a covering neural network and two proportional derivative controllers. The Novelties of this method are the simultaneous design of a stable path while maintaining geometric constraints and the low computational burden of the path planning and control system. The results show that the highest neural network error is about 11%. Also, the control system has been able to steer the vehicle and follow the trajectory with 40cm maximum lateral displacement error in the speed and road friction different conditions.

Review History:

Received: Jun. 23, 2021
Revised: Sep. 14, 2021
Accepted: Nov. 04, 2021
Available Online: Nov. 14, 2021

Keywords:

Autonomous vehicle
Collision avoidance
Skilled driver
Emergency Lane change
Path planning

1- Introduction

Today, many road accidents occur due to the driver's fault. In some cases, emergencies arise on the suburban roads which require a quick reaction of the autonomous car decision system and, if necessary, designing a proper path to collision avoidance. The sudden entry of animals into the road [1, 2] or another vehicle from the side road to the main [2] are examples of such incidents. In these cases, due to the car's high speed, the braking system cannot prevent the accident, both in terms of time and dynamic constraints [3, 4]. Besides, by studying the reaction of skilled drivers, it can be found that the use of Lane Change Maneuvers (LCM) or mouse maneuvers [5] is helpful in these situations and can avoid the accident. The approach of this study is path planning and control of an autonomous vehicle based on skilled driver's performance in an emergency LCM, with the aim of collisions avoidance, to prevent accidents at high speeds with the help of LCM.

2- Simulation of Skilled Driver's Performance

LCM at high speeds is a standard maneuver [29]. In this maneuver, a skilled driver is someone who can perform this maneuver in its standard conditions. By studying the behavioral pattern of skilled drivers in the emergency LCM at high speeds (more than 70 km/h), it can be seen that in this scenario, the driver uses only the steering actuator to perform

the maneuver and operates a quasi-sine input to the steer. In this case, according to Eq. (1), the steps of the Lane Change (LC) scenario are divided into two parts: 1. Crossing the obstacle and 2. Returning to the straight line (Fig. 1).

$$\delta = \begin{cases} \delta_f \sin\left(\frac{2\pi}{t_{arv}} t\right) & t < t_{arv} \\ -1.5(t - t_{arv}) & t > t_{arv} \text{ \& } \delta > -\delta_f \\ -\delta_f & t > t_{arv} \text{ \& } |\tan^{-1}(X/Y)| > \varepsilon \end{cases} \quad (1)$$

that δ_f is the maximum angle applied to the front wheel and t_{arv} is the time to reach the obstacle and is calculated from Equation (2).

$$t_{arv} = \frac{X_{arv}}{V_{x_0}} \quad (2)$$

To select the final path in the LCM, two geometric constraints are used for collision avoidance and exiting the road boundary. These two terms are expressed as follows and based on Fig. 1:

*Corresponding author's email: .n.minaee@email.kntu.ac.ir



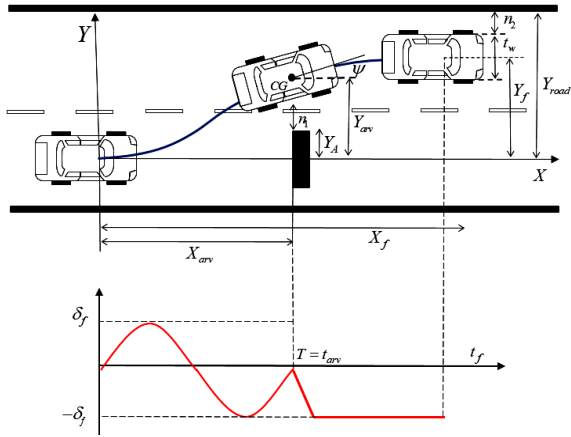


Fig. 1. Geometric schematic of the car trajectory for the front wheel angle input during the LCM

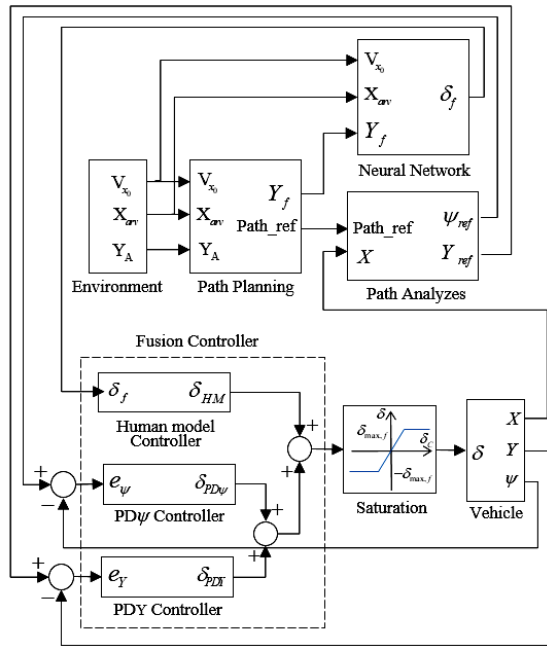


Fig. 2. Path planning and control system block diagram of the LCM based on skilled driver's Performance in the emergency situations

The corner distance of the car when crossing the obstacle is n_1 . Therefore, the center lateral distance of the car must be greater than $Y_{arv} > Y_A + t_w / 2 + n_1$ at this point. Also, Y_A is the obstacle length, t_w is the car width, and the necessary safety factor when the car crosses the obstacle.

The safe distance of the car from the road boundary is n_2 . so, Equation $Y_{crit} = Y_{road} - (t_w / 2 + n_2) > Y_f$ is required for collision avoidance with the boundary road. Also, Y_{crit} is the maximum lateral displacement of the car without exiting the road boundary and Y_f is the final lateral displacement of the car.

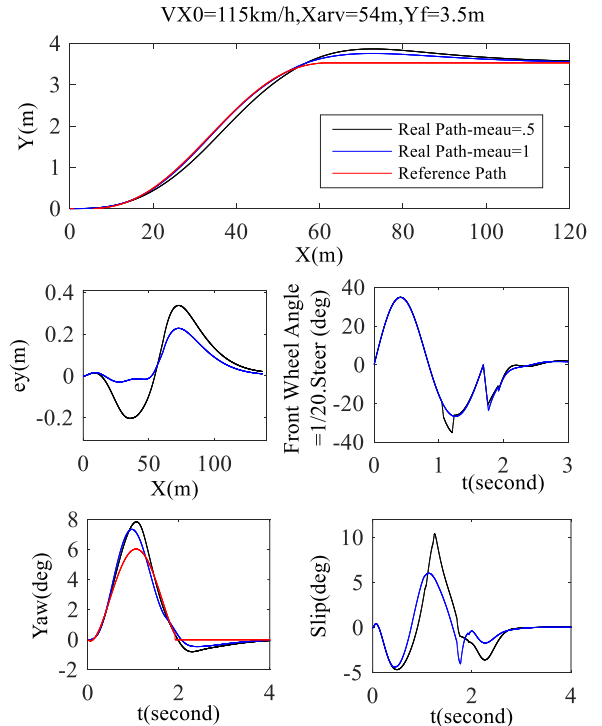


Fig. 3. Controller performance simulation with the Carsim software in the two dry and wet road modes for $V_{x0} = 115$ km/h, and $X_{arv} = 54$ m.

3- Path Planning and Control

The path planning algorithm is such that first, with the help of an initial neural network, the traversable range of the path is determined with a focus on maintaining the vehicle's stability constraints and non-collision with the obstacle. After identifying this range, the 5th-degree curve coefficients of the final path are calculated by using a secondary neural network.

The designed control process consists of two parts. The first part is inspired by the behavior pattern of a skilled driver in an LCM that has the main load of car control in this maneuver (Eq. (1)). The second part consists of two proportional-derivative controllers whose output is added to the first controller output and its main task is to correct the output of the human model controller designed to follow the path more accurately.

4- Results and Discussion

With Carsim simulator software, the performance of the path planning neural network and control system is evaluated for the condition that $V_{x0} = 115$ km/h, $X_{arv} = 54$ m, and $Y_A = 2$ m.

The maneuvering time, in this case, is about 2s and the time to reach the obstacle is 1.6s. In Fig. 3, in the lateral error diagram, the error rate is zero at the car arrival point to the obstacle. Therefore, considering the safety factor of the passing moment, the controller has been able to show appropriate performance on both dry and wet roads and

avoid the collision. Also, after crossing the obstacle, the controller, in addition to preventing the car from leaving the road boundary, prevented the increase of the vehicle's lateral displacement error and reduced it to zero.

The red line in the yaw diagram is the designed trajectory slope by the neural network. The controller has been able to track this angle to a reasonable extent in both dry and wet road conditions, although its performance on the dry road is better than the wet road. Also, the variation domain is in the appropriate range in the sliding angle diagram, and the car has maintained its stable condition.

5- Conclusions

In this paper, a path planning algorithm of the LCM is designed to prevent collisions in emergency situations at high speeds by inspiring a skilled driver's performance. The most important features of this study are:

The path planning process is such that each designed trajectory certainly be stable. Also, Because The path planning calculations are algebraic, the decision speed is appropriate in the situation of the accident Probability.

The highest error of the path planning neural network is

about 11%. Also, the designed control system was able to steer the car in the designed direction,

References

- [1] J.A. Decker, S.H. Haus, R. Sherony, Potential benefits of animal-detecting automatic emergency braking systems based on U.S. driving data, *Journal of the Transportation Research Board*, 2675(10) (2021) 678-688.
- [2] IIHS HLDI, Collisions with Fixed Objects and Animals. Insurance Institute for Highway Safety, *Fatality Facts*, (2019).
- [3] S. Sadeghi Namaghi, M. Moavenian, An adaptive modified fuzzy-sliding mode longitudinal control design and simulation for vehicles equipped with ABS system, *Int. Journal of Automotive Engineering*, 9(1) (2019) 2895-2907.
- [4] J. Lenarda, A. Badea-Romero, Russell danton, typical pedestrian accident scenarios for the development of autonomous emergency braking test protocols, *Accident Analysis and Prevention*, 73 (2014) 73–80.
- [5] <https://www.toyotaofnorthcharlotte.com/blog/so-what-exactly-is-the-moose-test/>

HOW TO CITE THIS ARTICLE

S. N. Minaei, A. Ghaffari, *Lane Change Path Planning in Emergency Situation Based on Skilled Driver's Performance*, *Amirkabir J. Mech. Eng.*, 54(2) (2022) 53-56.

DOI: [10.22060/mej.2021.20198.7191](https://doi.org/10.22060/mej.2021.20198.7191)



