

Performance Evaluation of a Novel Vehicle Collision Avoidance Lane Change Algorithm

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Abstract This study, proposes a methodology to evaluate the performance of a novel emergency lane change algorithm. The algorithm, defines a number of constraints, based on the vehicle's dynamics and environmental conditions, which must be satisfied for a safe and comfortable lane change maneuver. Inclusion of the lateral position of other vehicles on the road, the tire-road friction, and real-time ability are the main advantages of the proposed algorithm. For performance evaluation of the developed algorithm, a set of driving scenarios were designed to consider different possible traffic situations that may appear in an emergency lane change maneuver. These scenarios were implemented later in IPG CarMaker, which is a vehicle's dynamics platform. Based on the designed scenarios, the efficiency of the algorithm in collision free lane change maneuver was examined.

Keywords Autonomous driving · Lane change maneuver · Decision making · Collision avoidance

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1 Introduction

Cars have a great impact on our life. They are symbols of freedom and are often used as a means of self-expression. But they can change our life to the worst. In the year 2010, 28.759 people died in the Europe [1] and 32.999 in the USA [2] because of car accidents. The lane change maneuver, is one of the serious cause of car accidents especially as a consequence of drivers' errors on accurate estimation of the distance between vehicles [3]. According to the statistics, twenty percent of highway car accidents are a result of an inappropriate lane change [4]. Also, lane change is a frequent driving maneuver and considered to be as a next step in automation of driving. In addition, it is an important part of microscopic traffic simulation and has a considerable effect on analysis results of these models [5]. Given all the aforementioned reasons, autonomous lane change is an important topic of study in automotive engineering nowadays.

Various methods have been demonstrated for lane change decision making and path planning so far. In [6], a model was developed for vehicles lane change based on the cellular automaton (CA), which mainly focused on some of the vehicle's constraints such as maximum acceleration and deceleration. The rules used in [6] were later used in another study for traffic simulation in double- and triple-lane broad highways [7]. It was demonstrated that the developed model allows realistic simulations. A soft computing method was used in this study to model driver behavior during the lane change. In order to have more comprehensive model which covers complicated scenarios, the proposed system had more than only a single input and single output (SISO) [8].

In another study, an algorithm was proposed which was able to identify the boundaries of the path, store the obtained information and design the desirable driving path using a vectorial approach [9]. In [10], the driving task was interpreted as a model predictive control which was able to control and stabilize double-lane change maneuver using fuzzy logic in accordance to the ISO standard. The aforementioned approach was also employed in another study to control vehicle velocity in addition to the lane change maneuvering [11]. The experiments conducted on a one-way two-lane road demonstrated suitable longitudinal and lateral control action of the vehicle consistent with the traffic condition of the road.

In addition to the studies about decision making, a lot of studies are focused on path planning technics. Some models where developed based on the vehicle's dynamics and the driver strategy during the lane change maneuver. The experimental evaluations during real driving conditions showed that the proposed models are superior to those using polynomial for path planning and produce more accurate paths [12, 13]. Intelligent control techniques, such as fuzzy control [14], neural networks [15] and swarm intelligence [16], were also employed for path planning. For instance, neural networks were employed in [17] to predict movements of the other vehicles in short- and long-time. Long-term predictions were used to warn the driver to do lane change or avoid it due to the possibility of collision. In addition, short-term predictions helped the driver to deal with unexpected changes in a traffic flow.

2 Algorithm

To develop the lane change decision making algorithm, first, the equations for the lateral movement of the vehicle in terms of maneuver time are produced. Then, the critical maneuvering time is calculated on the basis of the constraints. Finally, the feasibility of carrying out the maneuver is decided upon by comparing the critical times. It is assumed that, in the worst-case scenario there are three other surrounding vehicles during the maneuver, as shown in Fig. 1. Vehicle E represents the ego (lane changer) vehicle, vehicle A represents the leading vehicle at the same lane, and vehicles B and D are leading and rear vehicles at the target lane, respectively. Moreover, the dashed-line vehicle in Fig. 1 indicates the vehicle E during the maneuver. If the four conditions below are satisfied, the lane change maneuver will be possible;

1. During the maneuver, the lateral distance between the right front corner of vehicle E and right rear corner of vehicle B must be at least C_1 (Fig. 1a).

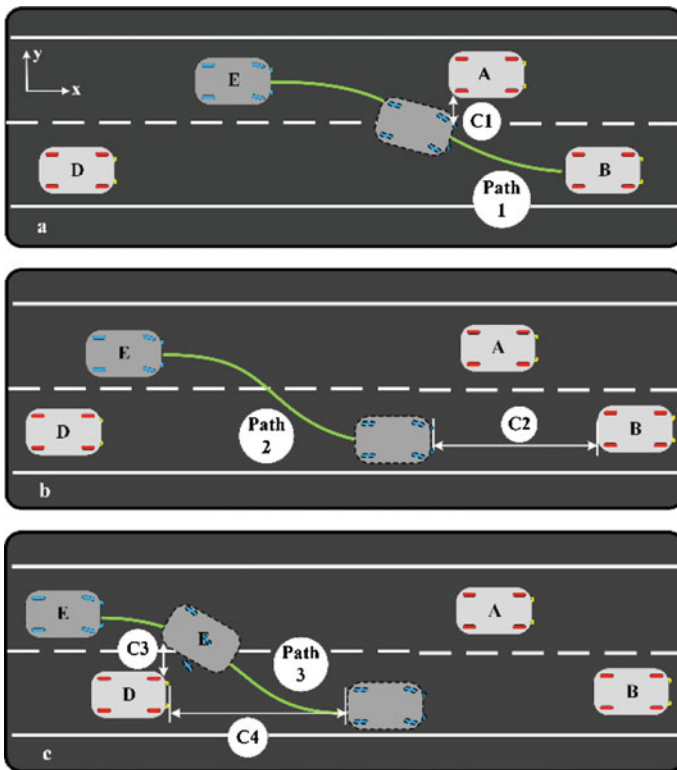


Fig. 1 Definition of constraints in lane change maneuver

2. After the maneuver and movement of vehicle E to the target lane, its distance from vehicle B must be C_2 (Fig. 1b).
3. During the maneuver, the lateral distance from right rear corner of vehicle E to the left front corner of vehicle D must be at least C_3 . Moreover, after the maneuver is done the longitudinal distance between these vehicles must be at least C_4 (Fig. 1c).
4. The generated lateral acceleration of E during the maneuver must be achievable, considering the prevailing friction potential between the road and tire.

The proposed decision-making algorithm investigates the possibility of designing a trajectory, taking all abovementioned constraints into account. It focuses on time as the main decision-making parameter. First, the lane change duration for the most critical trajectory in terms of each constraint, is derived. Then, the lane change possibility is decided upon by comparing the computed lane change durations. In the following, the methodology of calculating critical trajectories based on each of the aforementioned constraints, will be described.

2.1 Case 1: A Vehicle in Front on the Same Lane

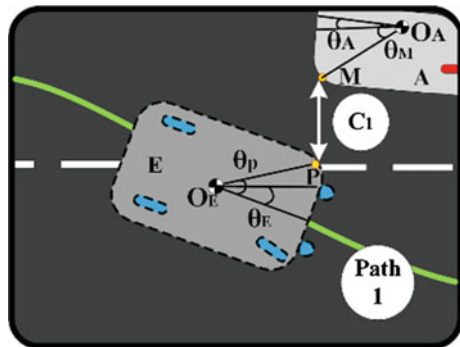
Considering Fig. 1a, during the lane change the left front corner of vehicle E (point P) will touch the right rear corner of vehicle A (point M) if C_1 is zero. Magnified illustration of this situation is shown in Fig. 2.

Considering the safe distance of C_1 between the vehicles when their longitudinal coordinates coincide, one will obtain Eq. (1).

$$y_A(t) - y_E(t) = C_1 + |O_A M| \sin(\theta_M - \theta_A(t)) + |O_E P| \sin(\theta_P - \theta_E(t)) \quad (1)$$

In Eq. (1), $y_A(t)$ and $y_E(t)$ indicate the lateral position of the center of gravity of vehicles A and E, respectively. $|O_E P|$ is the length of the imaginary line connecting vehicle E's center of gravity to point P. Similarly, parameter $|O_A M|$ indicates the length of the imaginary line between vehicle A's center of gravity and point M. θ_M is

Fig. 2 Lateral constraint between ego vehicle and vehicle in front on the same lane



the angle between $O_A M$ and longitudinal axis of the vehicle A . Parameter $\theta_A(t)$ is the angle between vehicle A 's longitudinal axis and the horizon and θ_P is the angle between $O_E P$ and longitudinal axis of the vehicle E . while $\theta_E(t)$ represents the angle between the longitudinal axis of vehicle E and the horizon at any moment. Using the numerical technique presented in [18], one can solve (1) and obtain the maneuver duration such that constraint C_1 is satisfied. This time is labelled as t_1 .

2.2 Case 2: A Vehicle in Front and on the Target Lane

Various studies have addressed the issue of the minimum safe longitudinal distance between two vehicles and several formulations have been developed for this distance, e.g. [19, 20]. In this study, the method proposed by Juala et al. [21] is employed. In this conservative method, it is assumed that the velocity of the front vehicle suddenly becomes zero in case of collision with an obstacle. In this circumstance, the safety distance is obtained as,

$$C_2 = s_0 + v_{xE}t_d + (v_{xE}^2/2a_{Eb}) \quad (2)$$

In (2), s_0 is the safe stopping distance, while a_{Eb} is the maximum deceleration of vehicle E . In addition, t_d is the reaction time of the driver which depends on various factors such as physical and mental condition of the driver as well as road conditions and usually varies between 0.67 and 1.11 [22]. By substituting all required parameters in (2), C_2 and hence the maneuver time, labeled as t_2 , can be obtained. Hence, at the specified time instant, the longitudinal and lateral position of two vehicle are governed by (3) and (4);

$$x_B(t) - x_E(t) = s_0 + v_{xE}t_d + (v_{xE}^2/2a_{Eb}) + l_{Ef} + l_{Br} \quad (3)$$

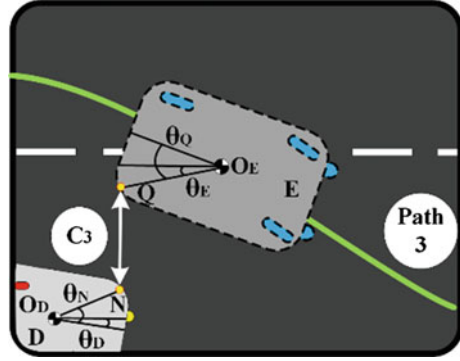
$$y_B(t) = y_E(t) \quad (4)$$

where, $x_B(t)$ and $y_B(t)$ indicate the longitudinal and lateral positions of the center of gravity of vehicle B respectively, and l_{Br} indicates the longitudinal distance from vehicle B 's center of gravity to the vehicle's rear. Obviously, this constraint designates all trajectories in which the longitudinal distance between centers of gravity of vehicles E and B at the end of the maneuver is greater than the value obtained in (3), as a candidate for a safe trajectory.

2.3 Case 3: A Vehicle Behind and on the Target Lane

This case is a combination of the first two cases. A larger illustration of the vehicles condition in this case, is shown in Fig. 3.

Fig. 3 Lateral constraint between ego vehicle and vehicle behind on the target lane



To obtain the lane change duration, firstly the appropriate maneuver time is computed based on the safe lateral distance using (5). Then, the suitable maneuver time is obtained using the safe longitudinal distance at the end of the maneuver using (6). As the behavior of vehicle D is controlled by the automatic system, the possibility of sudden velocity change is almost negligible and hence a two-second law [23] is used instead of the conservative method in case two. Finally, the larger value among the two obtained values are introduced as t_3 .

$$y_E(t) - y_D(t) = C_3 + |O_D N| \sin(\theta_N - \theta_D(t)) + |O_E Q| \sin(\theta_E(t)) \quad (5)$$

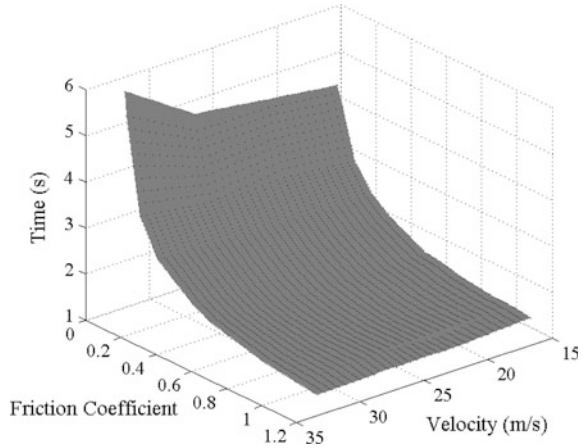
$$x_E(t) - x_D(t) = 2v_{x,D} + l_{E_r} + l_{D_f} \quad (6)$$

In Eqs. (5) and (6), $x_D(t)$ and $y_D(t)$ represent the longitudinal and lateral position of the vehicle D 's center of gravity. Moreover, $v_{x,D}$ and l_{D_f} indicate the longitudinal velocity of vehicle D and the longitudinal distance from vehicle D 's center of gravity to the vehicle's back respectively. $|O_E Q|$ is the length of the imaginary line between vehicle E 's center of gravity and right rear corner of the vehicle, i.e. point Q . Similarly, $|O_D N|$ in (5) show the length of the imaginary line from the gravity center of vehicle D and its left front corner (Point N). l_{E_r} is the longitudinal distance between vehicle E 's center of gravity and its rear and θ_N indicates the angle between this line and longitudinal axis of the vehicle.

2.4 Case 4: The Most Aggressive Lane Change

The designed lane change trajectory for the vehicle must be feasible with respect to vehicle dynamics. In other words, in addition to continuity and differentiability of the trajectory, the dynamic constraints of the vehicle must be satisfied. In particular, it must be ensured that the generated lateral acceleration during the maneuver must be attainable, considering road-tire friction, and maintain vehicle stability. The dynamic vehicle simulation tool, IPG CarMaker, is used for the analyses. Figure 4

Fig. 4 Diagram of the maneuver time in terms of weight, velocity and road-tire friction



shows the 3-D diagram of the maneuver time in terms of mass, velocity and tire-road friction. The illustrated surface divides the space into two parts. The volume above the surface indicates acceptable maneuver time.

The results of the different simulations are approximated by (7), where the minimum maneuver time t_m is expressed in terms of road-tire friction μ and vehicle velocity v_x .

$$t_m(\mu, v_x) = (\mu(8 + 0.5v_x) + 5)/10\mu. \tag{7}$$

2.5 Decision-Making Strategy

In this paper, the value of the required parameters to obtain t_1 , t_2 and t_3 based on the aforementioned equations, are presented in Table 1.

By calculation and comparison of these times, the decision can be made. Table 2 presents the possible lane change cases along with the acceptable time or time interval for the maneuver. Obviously, if the comparison of the computed time does not correspond to any of the cases presented in Table 2, the lane change maneuver is not allowed. If any of the three vehicles A , B and D does not exist on the path, its corresponding time is eliminated from calculations.

3 Scenario Design

Comprehensive scenarios including all different possible traffic situations are designed to evaluate the performance of the developed decision making algorithm. As mentioned earlier, the algorithm is designed to bring the target vehicle to the

Table 1 Value of the parameters

Parameter	Value	Parameter	Value
C_1	1 (m)	w_A	1.65 (m)
l_{Er}	1.9 (m)	l_{Df}	1.7 (m)
w_E	1.56 (m)	S_0	2 (m)
t_d	0.5 (s)	a_{Eb}	0.7 g (m/s ²)
l_{Ef}	1.6 (m)	l_{Br}	1.8 (m)

Table 2 Decision making table

No.	Case	Time	No.	Case	Time
1	$t_1 > t_2 > t_4 > t_3$	$[t_2 \ t_4]$	8	$t_2 > t_1 = t_3 > t_4$	t_1
2	$t_1 > t_2 > t_3 > t_4$	$[t_2 \ t_3]$	9	$t_1 > t_2 = t_4 > t_3$	t_2
3	$t_2 > t_1 > t_4 > t_3$	$[t_1 \ t_4]$	10	$t_1 > t_2 = t_3 > t_4$	t_2
4	$t_2 > t_1 > t_3 > t_4$	$[t_1 \ t_3]$	11	$t_2 > t_1 > t_4 = t_3$	$[t_1 \ t_3]$
5	$t_1 = t_2 > t_4 > t_3$	$[t_1 \ t_4]$	12	$t_1 > t_2 > t_4 = t_3$	$[t_2 \ t_3]$
6	$t_1 = t_2 > t_3 > t_4$	$[t_1 \ t_3]$	13	$t_1 = t_2 = t_3 > t_4$	$[t_1 \ t_3]$
7	$t_2 > t_1 = t_4 > t_3$	t_1	14	$t_1 = t_2 = t_3 = t_4$	t_1

right line of the road only if the driver is not able to control the vehicle. So, the lane change direction will always be to the right.

In the designed scenarios, the target vehicle is moving in a three lane highway, and in the worst case, surrounded by three other vehicles. The scenarios are designed based on the number of vehicles on the road, relative distance, velocity and acceleration of all vehicles, and road friction. For a more clear presentation of different possible traffic situations, the scenarios are defined parametric as it is demonstrated in the Table 3.

3.1 Scenario 1: No Other Vehicle on the Road

The simplest situation happens when there is no other vehicle on the road. The decision making unit defines a proper time for lane change based on the velocity of the ego vehicle and road condition. This situation is presented in Fig. 5.

Table 3 Parametric presentation of different possible traffic conditions

Vehicle	Relative Dist. (m)		Vel. (m/s)		Accel. (m/s ²)		Friction Range
	Variable	Range	Variable	Range	Variable	Range	
Ego	–	[0 60]	v_E	[0 36]	a_E	[-6 4]	[0.1 1.2]
Target 1	s_1		$v_1 = v_A$		$a_1 = a_A$		
Target 2	s_2		$v_2 = v_B$		$a_2 = a_B$		
Target 3	s_3		$v_3 = v_D$		$a_3 = a_c$		

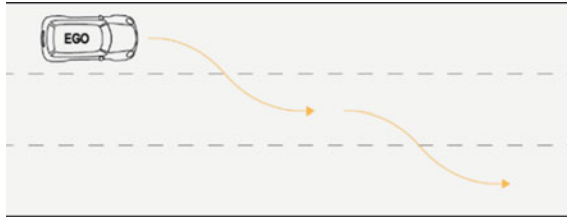


Fig. 5 The simplest possible scenario, no other vehicle on the road

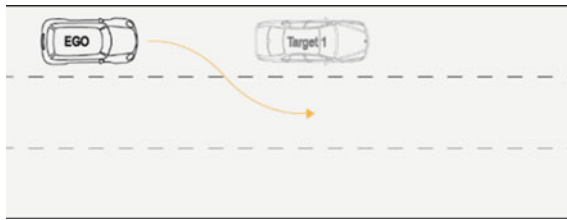


Fig. 6 One vehicle in front and on the same lane

3.2 Scenario 2: A Vehicle in Front on the Same Lane

This situation happens when there is only one vehicle in front and on the same lane. Based on vehicle A (target 1) dynamic behavior, decision making algorithm must be able to guide the ego vehicle to a safe lane change (Fig. 6).

3.3 Scenario 3: One Vehicle on the Same Lane and One on Target Lane

In this case, the decision making system should consider the situation and behavior of two other vehicles in order to prepare a safe lane change maneuver. Here, in addition to the Vehicle A which is driving on the same lane as the ego vehicle, The vehicle B (target 2) is driving on the target lane. This situation is presented in Fig. 7.

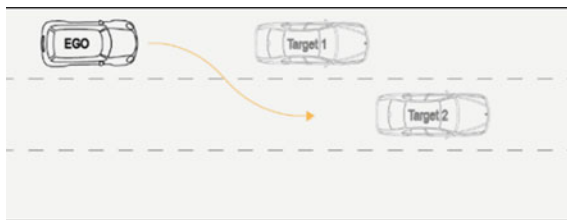


Fig. 7 One vehicle on the same lane and one on the target lane

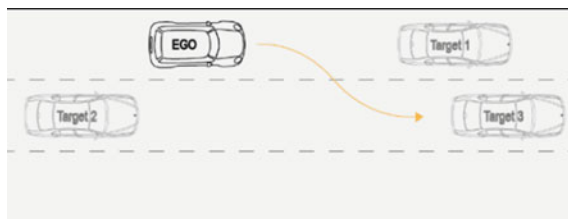


Fig. 8 One vehicle on the same lane and two on the target lane

3.4 Scenario 4: One Vehicle on the Same Lane and Two on Target Lane

This is the most complicated situation for an emergency lane change maneuver where the decision making unit should guide the ego vehicle considering three other vehicles on the road. This situation is presented in Fig. 8.

4 Implementing Scenarios in IPG CarMaker

All the aforementioned scenarios were implemented in IPG Carmaker which is a platform to simulate vehicle’s dynamics and control units. To do so, the ability of this software to communicate with MATLAB/SIMULINK was applied for better flexibility. Different constraints in decision making unit, as discussed earlier, were implemented to find out appropriate time t_1 to t_4 in each case. Based on calculated times, the possibility of performing a safe lane change and the corresponding maneuver time were reached based on decision making rules Table 2. Figure 9 shows the block diagram of final system in Simulink.

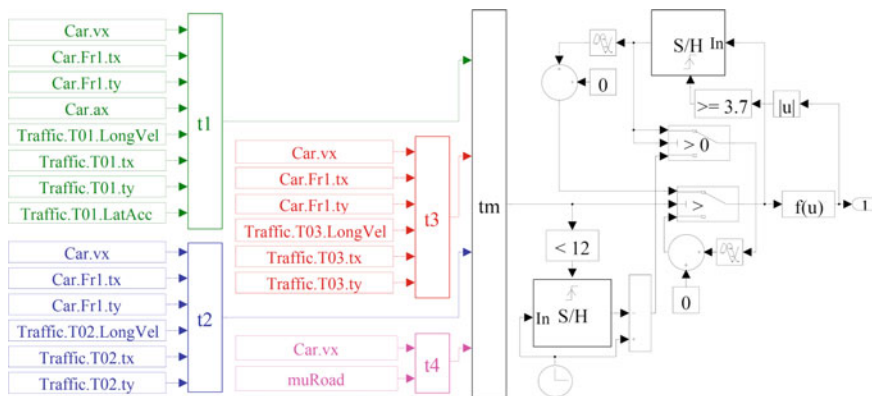


Fig. 9 The Block diagram of decision making system in MATLAB/Simulink

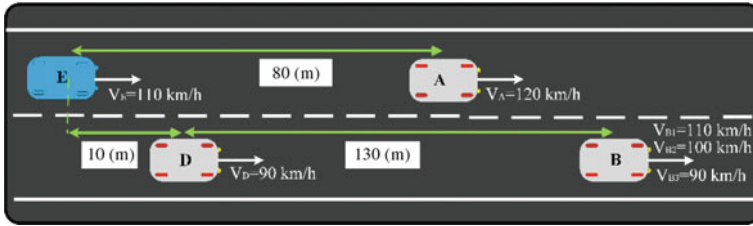


Fig. 10 Sample scenario used to evaluate lane change algorithm performance

In Fig. 9, dynamic data of the ego and target vehicles as well as tire-road friction is fed into the functions where the critical lane change times t_1 , t_2 , t_3 , and t_4 are calculated based on equations presented in Sect. 2. These times are then sent to the decision making function where the rules demonstrated in Table 2 are coded in order to find the final maneuver time (t_m) which is finally presented to the driver model via port number 1. The driver model is responsible to guide the vehicle on the lane change trajectory using Eq. (8).

$$y_E(t) = (-6h/t_m^5)t^5 + (15h/t_m^4)t^4 + (-10h/t_m^3)t^3 \tag{8}$$

In Eq. 8, h is the maximum lateral displacement of the ego vehicle at the end of the maneuver and attains the value of -3.75 which is the standard lane width. The negative sign indicates lane change to the right-side of the road.

5 Results

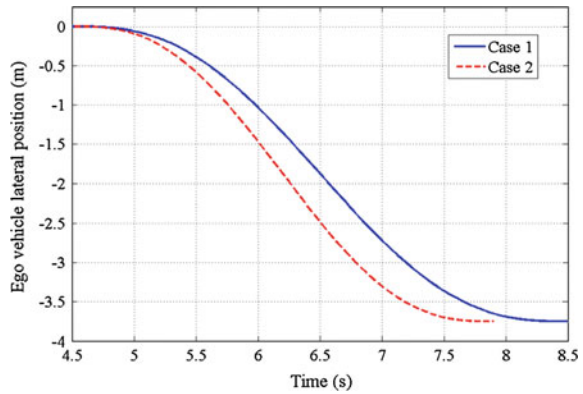
To evaluate the performance of the decision making algorithm, various tests were performed based on aforementioned scenarios in Sect. 3. In this paper, the results of three different cases are presented and discussed. In case one, the ego vehicle velocity is $v_E = 110$ (km/h) and vehicle A is driving with the speed of $v_A = 120$ (km/h) and 100 (m) away in front. Also, vehicles B and C are driving in target lane with the speed of $v_{B1} = 110$ (km/h) and $v_C = 90$ (km/h) and are located at the distances of 140 (m) and 10 (m) in front of ego vehicle, respectively. In case two and three, vehicle B is driving at the speed of $v_{B2} = 100$ and $v_{B3} = 90$ km/h respectively while all other conditions remain the same as in case one. All explained cases are presented schematically in Fig. 10. Tire-road friction is equal to 0.9 for all cases and the lane change maneuver begins 4.5 (s) after the scenario begins.

Table 4 shows critical maneuver times based on Eqs. 1–7 and final maneuver time based on decision making rules in Table 2. As it can be seen, for the first two cases, the decision making unit allows the lane change maneuver to be performed.

Table 4 Allowable maneuver times for each three cases

Case	v_b (m/s)	μ	t_2 (s)	t_3 (s)	t_4 (s)	t_m (s)
1	30.6	0.9	4.2	1.26	3.2	[3.2 4.2]
2	27.8	0.9	3.6	1.26	3.2	[3.2 3.6]
3	25	0.9	3	1.26	3.2	–

Fig. 11 Lateral position of ego vehicle



The maneuver time for case 1 must be in the range between 3.2 (s) and 4.2 (s) and for case 2 between 3.2 (s) and 3.6 (s). The lane change cannot be performed in case 3.

The diagrams of lateral position of ego vehicle is demonstrated in Fig. 11 for cases one and two. In addition, corresponding lateral velocity and acceleration of the ego vehicle is presented in Figs. 12 and 13. As it can be seen in both cases, the lateral acceleration value is less than $2 \text{ (m/s}^2\text{)}$ which satisfies passenger comfort condition.

Fig. 12 Lateral velocity of ego vehicle

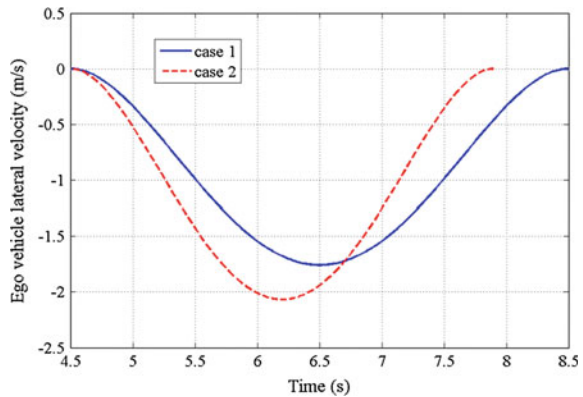
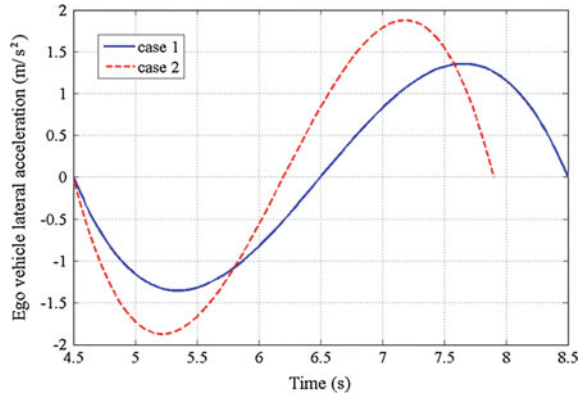


Fig. 13 Lateral acceleration of ego vehicle



6 Conclusion

This study, proposed a methodology to evaluate the performance of a novel emergency lane change algorithm. Inclusion of the lateral position of other vehicles on the road, the tire-road friction, and real-time ability are the main advantages of this novel algorithm. For performance evaluation of the developed algorithm, a set of driving scenarios were designed to consider different possible traffic situations that may appear in an emergency lane change maneuver. These scenarios were implemented later in IPG CarMaker, which is a vehicle's dynamics platform. The result of three different cases were presented and discussed. The results show an acceptable performance of the algorithm.

References

1. Broughton J, Brandstaetter C, Yannis G, Evgenikos P, Papantoniou P, Candappa N, Christoph M, van Duijvenvoorde K, Vis M, Pace JF, Tormo M, Sanmartín J, Haddak M, Pascal L, Amoros E, Thomas P, Kirk A, Brown L (2012) Assembly of annual statistical report and basic fact sheets. Tech. Rep. Deliverable D3.9 of the EC FP7 project DaCoTA, 2012
2. Blincoe LJ, Miller TR, Zaloshnja E, Lawrence BA (2010) The economic and societal impact of motor vehicle crashes. National Highway Traffic Safety, Washington, DC, Tech. Rep. DOT HS 812 013, 2010
3. Djenouri D, Soualhi W, Nekka E (2008) VANET's mobility models and overtaking: an overview. In: 3rd international conference on information and communication technologies: from theory to applications (ICTTA), pp 1–6
4. Wang J, Chai R, Wu G (2014) Changing lane probability estimating model based on neural network. In: 26th Chinese control and decision conference (CCDC), pp 3915–3920
5. Mathew TV (2014) Lane Changing Models. In: Transportation systems engineering anonymous, pp 15.1–15.12
6. Lee HK, Barlovic R, Schreckenberg M, Kim D (2004) Mechanical restriction versus human overreaction triggering congested traffic states. Phys Rev Lett 92:238702-1–238702-4

7. Habel L, Schreckenberg M (2014) Asymmetric lane change rules for a microscopic highway traffic model. In: 11th international conference on cellular automata for research and industry (ACRI), Krakow, pp 620–629
8. Ghaffari A, Khodayari A, Arvin S, Alimardani F (2012) Lane change trajectory model considering the driver effects based on MANFIS. *Int J Automot Eng* 2:261–275
9. Yoon J (2011) Path planning and sensor knowledge store for unmanned ground vehicles in urban area evaluated by multiple laders
10. El-Hajjaji A, Ouladsine M (2001) Modeling human vehicle driving by fuzzy logic for standardized ISO double lane change maneuver. In: 10th IEEE international workshop on robot and human interactive communication, pp 499–503
11. Nilsson J, Sjoberg J (2013) Strategic decision making for automated driving on two-lane, one way roads using model predictive control. In: IEEE intelligent vehicles symposium (IV), pp 1253–1258
12. Xu G, Liu L, Ou Y, Song Y (2012) Dynamic modeling of driver control strategy of lane-change behavior and trajectory planning for collision prediction. *IEEE Trans Intell Transp Syst* 13:1138–1155
13. Xu G, Liu L, Song Z, Ou Y (2011) Generating lane-change trajectories using the dynamic model of driving behavior. In: IEEE international conference on information and automation (ICIA), pp 464–469
14. El-Hajjaji A, Ouladsine M (2001) Modeling human vehicle driving by fuzzy logic for standardized ISO double lane change maneuver. In: 10th IEEE international workshop on robot and human interactive communication, pp 499–503
15. Engedy I, Horvath G (2009) Artificial neural network based mobile robot navigation. In IEEE international symposium on intelligent signal processing (WISP), pp 241–246
16. Doctor S, Venayagamoorthy GK (2004) Unmanned vehicle navigation using swarm intelligence. In: Proceedings of international conference on intelligent sensing and information processing, pp 249–253
17. Tomar SR, Verma S (2012) Safety of lane change maneuver through a priori prediction of trajectory using neural networks. *Netw Protoc Algorithms* 4:4–21
18. H. Jula, E. B. Kosmatopoulos and P. A. Ioannou, "Collision Avoidance Analysis for lane Changing and Merging", *IEEE Transactions on Vehicular Technology*, vol. 49, pp. 2295–2308, 2000.
19. Y. L. Chen and C. A. Wang, "Vehicle Safety Distance Warning System: A Novel Algorithm for Vehicle Safety Distance Calculating Between Moving Cars", in *IEEE 65th Vehicular Technology Conference (VTC)*, 2007, pp. 2570–2574.
20. G. Feng, W. Wang, J. Feng, H. Tan and F. Li, "Modelling and Simulation for Safe Following Distance Based on Vehicle Braking Process", in *IEEE 7th International Conference on e-Business Engineering (ICEBE)*, 2010, pp. 385–388.
21. Y. Wu, J. Xie, L. Du and Z. Hou, "Analysis on Traffic Safety Distance of Considering the Deceleration of the Current Vehicle", in *Second International Conference on Intelligent Computation Technology and Automation (ICICTA)*, 2009, pp. 491–494.
22. Y. L. Chen, S. C. Wang and C. A. Wang, "Study on Vehicle Safety Distance Warning System", in *IEEE International Conference on Industrial Technology (ICIT)*, 2008, pp. 1–6.
23. D. D. Salvucci and A. Liu, "The Time Course of a Lane Change: Driver Control and Eye-movement Behavior", *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 5, pp. 123–132, 6, 2002.