



Speed Adjustment for Highway Lane Change

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ABSTRACT

Freeway accidents can be ameliorated with the use of safety technology. The automotive industry is rapidly growing and the internet of Things has a major role in it. Freeway authorities have unique ways to determine speed limits for road segments. On the other hand adding an automatic optimal speed determination in the vehicle is beneficial. Taking an exit on freeway usually involves a maneuver onto a ramp, which is typically at a steep speed reduction and might involve sharp curves. We have developed a computational approach for optimal speed change upon change of lane to an exit ramp in order to complete a successful turn onto the ramp. By calculating the required forces in the required direction, we determine the optimal speed of the vehicle. This can be embedded into a vehicles intelligence to automatically reduce the speed when it recognizes an exit.

Key words: Highway driving, cruise control, Smart Vehicle

1. INTRODUCTION

The automotive industry has been overwhelmingly growing and has been solving many issues concerning safety. On a highway, it is difficult to spontaneously change lanes that may lead to accidents. The cruise control mechanism in modern vehicles has its advantages and disadvantages. When using cruise control, drivers are often oblivious to their actual speed and the change in speed required for a lane change and angles of approach. There are few precautions that must be taken while trying to maneuver on the highways:

- Know your maneuvering direction for at least a few miles ahead.
- Determine the appropriate speed for maneuvers beforehand.
- Do not needlessly accelerate.
- Pay attention to the road.

Internet of things can help the vehicle follow the precautions in many ways such as (a) prompt the driver about the speed limit during the maneuver a few miles ahead, and (b) let the driver know the lane on which she must remain. We outline related work in section 2 followed by speed change determination in section 3. Conclusions are provided in section 4.

2. RELATED WORK

When driving on a highway, at each time instance a driver must determine whether he/she should stay in the current lane or change lane either to the left or to the right. Depending on which maneuver the driver decides to execute, he/she adapts his/hers driving behavior to the surrounding vehicles in different ways. For instance, if the driver decides to stay in the current lane, he/she should adapt the vehicle's velocity to the velocity of the preceding vehicle and maintain a lateral course that will keep the vehicle in the lane. If the driver decides to change lane to the left or to the right, he/she should adapt the vehicle's velocity to both the velocity of the preceding vehicle in the current lane and the velocity of the vehicles in the adjacent lane, while performing a lateral movement into the adjacent lane. As such, which maneuver the driver intends to perform can be recognized by observing cues in both the lateral and longitudinal vehicle motion. To change lane, the driver must perform a lateral movement into the adjacent target lane. As such, lateral motion cues for lane change intention recognition include the lateral velocity, and the lateral position relative to the lane boundaries. For a left lane change, the lateral motion cues can thereby be expressed as:

$$LCLv_{qy} = v_y \geq \alpha, \quad (1a)$$

$$LCLp_{qy} = y \geq y_L - \beta w, \quad (1b)$$

$$LCRv_{qy} = v_y \leq -\alpha, \quad (2a)$$

$$LCRp_{qy} = y \leq y_R + \beta w, \quad (2b)$$

$$LCLa_{qx} = a_x \geq \kappa, \quad (3a)$$

$$LCLv_{qx} = v_{xrel} \leq \gamma, \quad (3b)$$

$$LCLTTC_{qx} = (TTC \leq \zeta) \wedge (v_{xrel} < 0), \quad (3c)$$

$$LCLTG_{qx} = TG \leq \xi, \quad (3d)$$

This paper provides a vehicle with safely speed change a lane on a freeway. we would say the trickiest part about driving on a freeway is to change lanes and take and exit as it involves multitasking like being aware of the surroundings by using the rear-view mirrors and maintaining the speed of the vehicle while performing the maneuver. After analyzing this project if a driver wants to take an exit he can successfully reach the lane where he can take it but what next? This is exactly where we prescribe speed adjustment.

3. SPEED COMPUTATION

Our model demonstrates a vehicle taking an exit on a freeway through an exit ramp. The vehicle is already on the right-most lane where it can take the exit without a legal concern. This is depicted in Figure 1 for a typical exit on a regular freeway. Basically, vehicle should be on the right-most lane in order to continue to an exit.

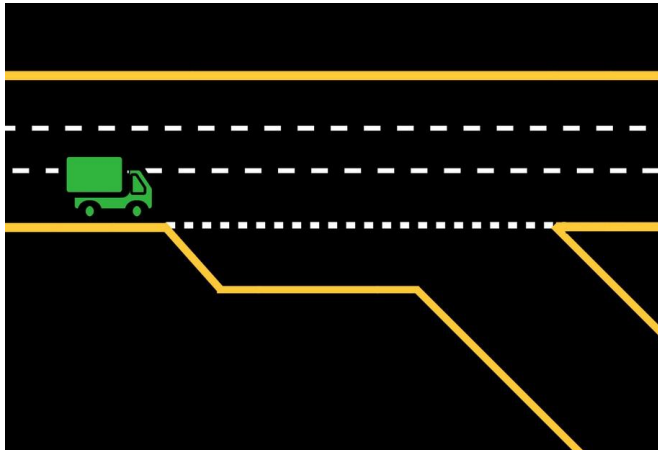


Figure 1. Lane change Illustration

To achieve this the maneuver intention recognition concept is relevant [1][2][3]. After reaching the right-most lane, the scenario looks something like shown in Figure 2.

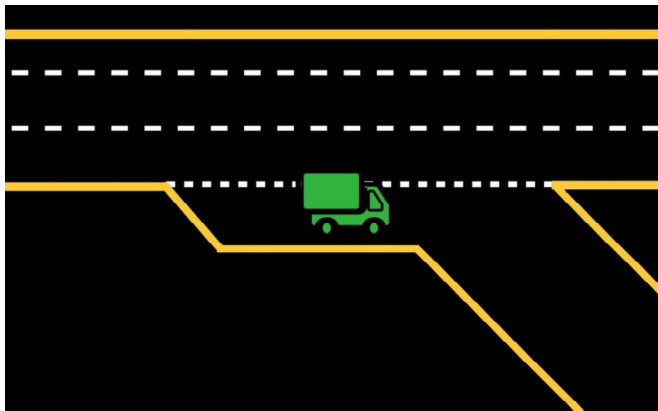


Figure 2. Committed Lane Change

During this process, the main intention is to ascertain the vehicle is not hurled towards the opposite side of the road while taking the turn from the centrifugal force. The natural and applied forces acting on the vehicle are depicted in Figure 3. These forces can vary depending the mass and acceleration of the vehicle. The resultant force is what that drives the vehicle.

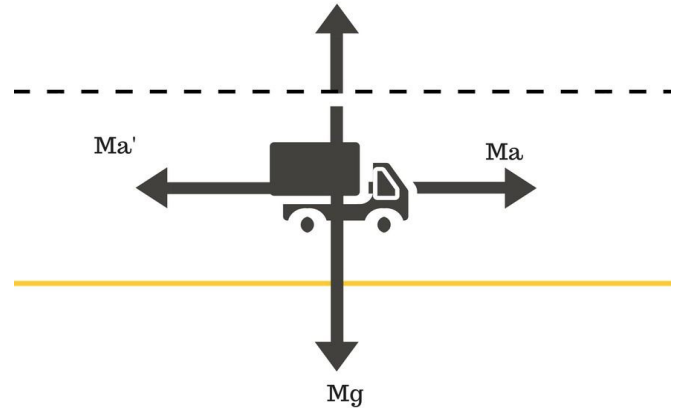


Figure 3. Forces applicable on a Vehicle

The resultant force should be the speed that ensures safety of the vehicle and the driver. It can be computed by determining basic details from the surroundings. The vector representation of the forces acting on the vehicle during the maneuver and the resultant force is shown in Figure 4. Here, the forces depicted are Ma , which is the force from the acceleration of the vehicle applied to gain speed, Ma'' is the force which has to be applied in order to change the direction of the vehicle to safely get onto the ramp. The force $M(a-a'') \times \cos\theta$, where θ is the angle between freeway and the ramp. This angle acts as the deciding factor for the resultant force.

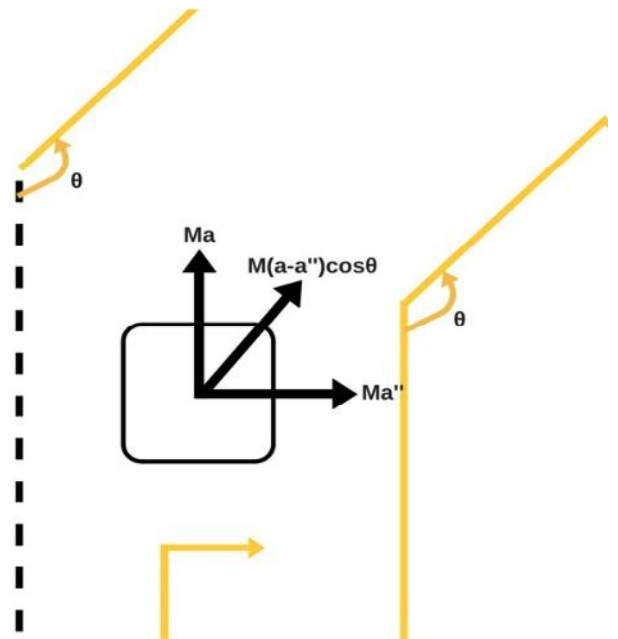


Figure 4. Force Vector Depiction

Let the force with which the Vehicle is moving be F and the force which has to be applied to turn the vehicle be F'' . As the Figure 4 shows.

$$F = M \times a \quad (1)$$

$$F'' = M \times a'' \quad (2)$$

$$\text{Resultant Force} = (F - F'') = M(a - a'') \times \cos\theta \quad (3)$$

M in the formulas 1-3 is the mass of the vehicle, which can be determined by the class of the vehicle. A simplified classification of vehicle is given by the thruway authority as shown in Table 1 [3][4]. The condition of the road i.e. the asphalt also has an effect on the vehicle’s grip and the required optimal speed.

Gross Vehicle Weight Rating (lbs)	Federal Highway Administration	
	Vehicle Class	GVWR Category
<6,000	Class 1: <6,000 lbs	Light Duty <10,000 lbs
10,000	Class 2: 6,001–10,000lbs	
14,000	Class 3: 10,001–14,000 lbs	Medium Duty 10,001–26,000 lbs
16,000	Class 4: 14,001–16,000 lbs	
19,500	Class 5: 16,001–19,500 lbs	
26,000	Class 6: 19,501–26,000 lbs	
33,000	Class 7: 26,001–33,000 lbs	Heavy Duty >26,001 lbs
>33,000	Class 8: >33,001 lbs	

Table 1. Mass for common vehicle classes

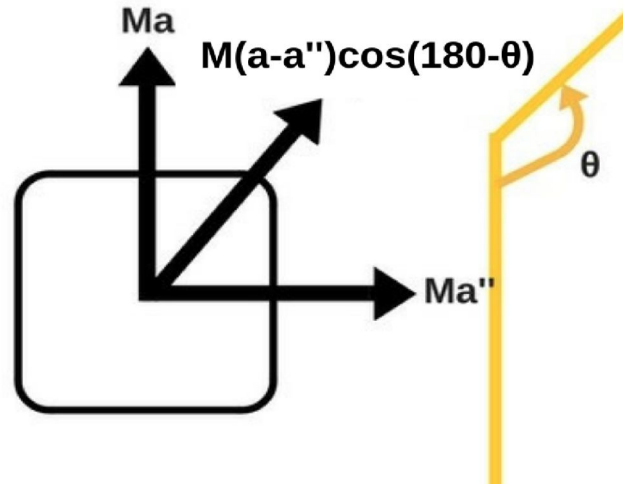


Figure 5. Applicable Force Vectors

The mathematical computation of optimal speed requires various inputs from the vehicle; these inputs are obtained by various programmable detectors, which are present inside a vehicle such as speedometer, lane sensors, etc. Initially, the forces which are acting in the direction of the turn are considered. These forces are usually applied by the driver using the acceleration pedal and the steering wheel; i.e. by accelerating and steering. They are depicted in Figure 5. The upward arrow is diagrammatically showing the forward force applied by the driver that is mathematically the resultant force of the forward applied force and the backward friction. The mathematical representation of forward force is force due to acceleration: $F' = M \times a'$, where M is the mass of the vehicle and a' is the current acceleration.

Force due to Friction: $F'' = M \times f$, where M is the mass of the vehicle and f is the friction from the wheels.

The resultant force i.e. $F' - F'' = M (a' - f) = M \times a$, where a is the resultant acceleration. Next, the force which is required to achieve a safe turn should be applied perpendicular to the forward force in the direction of the turn, in this case, to the right. Shown in Fig. 5. This is mathematically represented as Force required: $F = M \times a''$, where M is the mass of the vehicle and a'' is the optimum acceleration which is to be calculated. As force is a vector quantity it has

to be calculated in the by keeping the direction in mind.

Here the direction of the force can be shown with the help of the angle the exit is making with the freeway. So, the cosecant value of that angle can give us the vector quantity for calculation. The formula for resultant force would be:

$$M(a - a'') \times \cos(180 - \theta).$$

The optimum speed calculation requires various inputs from the vehicle such as the angle from the lane recognition tech and the mass of the vehicle from Tale.1.

4. CONCLUSIONS

In this project, we formulated computation of the optimum speed for a vehicle to exit a freeway. The reason behind the speed calculator even though there are speed limits on the freeway is that, the moment you are taking an exit your speed is equal to the speed limit of the freeway and not the exit ramp, which is obviously of a much lower speed limit. To successfully complete the maneuver until the driver notices the speed limit, this is the optimum speed. The next stage for this project would be to install this computation into the cruise control mechanism of the vehicle so that the vehicle automatically reduces the speed to the optimum value during the maneuver. Our approach is scalable for any lane change and our presentation has been an illustration for the specific case of an exit lane.

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