Modelling and Simulation of Overtaking Collision Reduction Systems

Tadesse Negesse Assefa

A Thesis Submitted to
The Department of Mechanical Engineering
School of Mechanical, Chemical and Material Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master's
In Automotive Engineering

Office of Graduate studies

Adama Science and Technology University

March, 2024

Adama, Ethiopia

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Advisor: Dr. Alemayehu Wakjira

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DECLARATION

I hereby declare that this Master Thesis entitled "Modelling and Simulation of Overtaking Collision Reduction Systems" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Tadesse Negesse Aseffa	____________________	____________
Name of student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “Modelling and simulation of overtaking collision reduction systems” prepared under my guidance by Tadesse Negesse and submitted in partial fulfillment of the requirements for the degree of Mater’s of Science in automotive engineering Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dr. Alemayehu Wakjira	___________________	___________
Major advisor	Signature	Date

APPROVAL

I, the advisors of the thesis entitled “Modelling and Simulation of Overtaking Collision Reduction System” and developed by Tadesse Negesse hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr. Alemayehu Wakjira ____________________ ____________

Major advisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by Tadesse Negesse have read and evaluated the thesis “Modelling and Simulation of Overtaking Collision Reduction System” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in automotive Engineering.

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Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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ACKNOWLEDGEMENTS

First and foremost, may the holy name of the Almighty GOD be exalted forever and ever; I thank Him for His merciful deeds in my life. I would like to acknowledge the School of Mechanical, Chemical & Materials Engineering at Adama Science & Technology University as well as the Mechanical Engineering Department for their contributions to the success of this work.

I want to express my gratitude to my advisor Dr.Alemayehu Wakjira, for his expert advice, unwavering patience during the length of my studies, and for continuing the research up till the completion of this thesis. To help me achieve my goal, a lot of people have contributed significantly. Despite the fact that your names do not appear in this, I am grateful to all the friends I have made along the journey.

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MATLAB: Matrix laboratory

OAS: Overtaking assistance system

Python: programming language

V2V: Vehicle to vehicle communication

GPS = Global Positioning System;

PCWS = Passing Collision Warning System;

PSD = passing sight distancTTC = time to collision (sec)

ABSTRACT

One of the biggest issues with two-lane highway traffic safety is passing collisions. When a driver fails to accurately analyze the situation, collisions like this happen. The framework model for a overtaking collision reduction system (OCRS), which lowers the possibility of human error and helps drivers avoid passing crashes on two-lane highways, is provided in this study. The technology makes use of sensors to determine the kind of vehicle obstructing traffic and to find vehicles that are approaching from the oncoming lane. The goals of this research are to create driving simulator trials to gather data for passing parameter calculations; and create the OCRS algorithm, which detects trucks (impeding vehicles) based on signals from camera and radar sensors. Then to create a driver handling model that explains scenarios where lane changes and maneuver interruptions require throttle linkage action and, finally to create algorithm for proteus and MATLAB simulation. The purpose of the simulation series was to validate the OCRS algorithm's efficacy. In this study, the impact of driver behavior on passing maneuvers was examined, and algorithms for a PCWS that helps drivers choose appropriate passing spacing during passing movements were developed. Several methods, including imitation and mathematical models, were improved to simulate real-world driving conditions in Simulink. The proposed OCRS uses a radar sensor placed in the passing vehicle to detect opposing vehicles travelling in the left lane and calculate their relative distance and speed in order to estimate the time to collision. Then based on the position and relative speed of oncoming vehicle the rear leading vehicle LCD display safe to overtake or not safe to overtake based on sensor data. Then the following vehicle will take text and color of LCD display of rear of leading vehicle to actuate for engaging or disengaging the acceleration pedal wire from throttle valve by model of throttle linkage. Therefore, the input from radar sensor and algorithms will be governing display of the leading vehicle. Again the leading vehicle display will govern the throttle linkage actuator.

Keywords**:** Advanced driver assistance system, overtaking assistant system, Fuzzy logic, overtaking decision making. OAS, Vehicle to Vehicle communication, collision avoidance, Microcontroller, arduino, Proteus

CHAPTER ONE

INTRODUCTION

1.1 Background

Throughout the world, cars, buses, trucks, motorcycles, pedestrians, animals, taxis and other categories of travelers, share the roadways, contributing to economic and social development in many countries. Yet each year, many vehicles are involved in crashes that are responsible for millions of deaths and injuries. Globally, every year, about 1.25 million people are killed in motor vehicle crashes and approximately 50 million more are injured. Vehicular crashes are the world's leading cause of death for individuals between the ages of one and twenty-nine. (Hamid, S., & Davoud, K. Z., 2019)

Approximately 1.25 million people lose their lives in traffic accidents each year. An estimated 20 to 50 million more individuals have non-fatal injuries each year, many of which result in a handicap (Hamid, S., & Davoud, K. Z., 2019). Accidents on public roads or streets, often known as road traffic accidents (RTAs), are among the world's most serious public health issues, particularly in developing nations. WHO estimates that 1.25 million persons worldwide have their lives cut short as a consequence of a road traffic accident each year. It suggests that more than 3000 people pass away every day as a result of traffic accidents. There are an additional 20 to 50 million people who sustain non-fatal injuries, many of whom go on to develop disabilities.

Road traffic accidents are a widespread public health issue in Ethiopia. In Ethiopia, road traffic accident is a serious problem that occurs periodically. Traffic Accident research suggested that there were more than 29,1577 accidents in the past eleven years, that include 912,956 kilometers road network and 68,100 motorized vehicles. From 2007/2008 years to 2017/2018 years, the variation of road network coverage in kilometer and motorized vehicle were estimated around 25,914 and 563,003 respectively (Deme, 2019; Deme, 2019)*)*. The objective of this thesis is to provide driver assistance systems that reduce driving errors when overtaking in order to minimize driver error and prevent potential accidents caused by overtaking. Intake manifold tube-mounted main throttle valve is virtually modeled using SOLIDWORK, and adaptive cruise control on overtaking systems is simulated using MATLAB software. On rural two-lane highways, passing maneuver accidents pose a significant risk when one car tries to pass a slower moving vehicle traveling in the same direction. When a passing vehicle is traveling in the opposing lane and there isn't adequate sight space, there is a risk.

The focus of the algorithm provided in this work has been on creating the most realistic model of overtaking on curved roads through an investigation of various overtaking strategies and driver behavior. To this end, vehicle condition with random speeds and in various times of day will be studied while passing desirable road curve, and when approaching a vehicle with lower speed, based on speed difference they will opt to pass or wait behind it. The algorithm will determine the driver's location and the start and end times of any overtakes they chose to make. The next stage will involve predicting the likelihood of a collision and investigating the presence of opposing vehicles that are approaching them while using the opposite lane of traffic. Ultimately, drivers are alerted and accidents are avoided via the use of clever speed restriction barriers and speed warning systems.

1.2 Statement of the Problem

The problem identified is the occurrence of head-on collisions during overtaking maneuvers on roadways. Overtaking is a common action taken by drivers to pass slower vehicles in front of them. However, in certain situations, head-on collisions may occur when the overtaking vehicle misjudges the distance, speed, or visibility of oncoming traffic, resulting in severe accidents and potentially fatal outcomes. This problem poses a significant risk to road safety, causing injuries, fatalities, and property damage. It is critical to understand the factors contributing to head-on collisions during overtaking maneuvers and develop effective measures to prevent such accidents, ensure the safety of road users, and reduce the overall rate of vehicular accidents.

According to the World Health Organization (WHO), head-on collisions resulting from overtaking maneuvers are a leading cause of road traffic accidents in Ethiopia. These accidents often occur due to a combination of factors such as insufficient road infrastructure, inadequate enforcement of traffic regulations, and reckless driving behavior.in addition to this problem the error made by drivers to overtake the leading vehicle has becomes the major cause of serious injuries on passengers and materials.

The World Health Organization (WHO) reported in 2013 that Ethiopia is amongst country to have the highest road accident, estimated about 4,984.3 deaths per 100,000 vehicles per year, compared to 574 across Sub-Saharan countries. In addition, the numbers of people who are victims of car crashes are about 30 times higher than of the United States (Kussia, 2017).to reduce this accident that cut off human life's and socio-economic impact in our country modifying existing overtaking collision reduction system is necessary. Research is required to reduce vehicle head on collision and its feasibility by MATLAB and proteus software.

1.3 Objectives

1.3.1 General Objective

The general objective of this thesis work is modelling and simulation of overtaking collision reduction systems.

1.3.2 Specific Objectives

The specific objectives are as follows:-

- To modify throttle linkage and build scenario for controlling throttle linkage
- To write algorithm for decision making
- To develop simulation scenarios using Simulink MATLAB to implement real-life driving

1.4 Significance of the study

The study of modeling and simulation of overtaking collision reduction systems is significant for several reasons the first one is for Safety improvement, Overtaking maneuvers on roads pose a significant risk of collision due to limited visibility and the need to cross into oncoming traffic. By studying and simulating overtaking collision reduction systems, researchers can identify potential shortcomings and improve safety measures. This can lead to the development of effective collision avoidance technologies, making overtaking maneuvers safer for driver. Secondly reduction of fatalities and injuries, overtaking collisions often result in severe injuries and fatalities. By exploring and modeling different overtaking collision reduction systems, researchers can identify ways to minimize the risk of such accidents. This can potentially save numerous lives and reduce the overall burden on healthcare systems.

1.5 Scope of study

The scope of this research is the safety issue of head-on collisions on rural two-lane highways resulting from drivers attempting to pass impeding vehicles without sufficient information regarding the relative position and speed of the opposing vehicle. In order to assure feasibility of overtaking assistance system some limitation are reduce the effectiveness of this thesis work for some reasons. Those are:-

- Evaluation of how varying road and traffic conditions, including adverse weather, road geometry, and traffic density, impact the effectiveness of overtaking collision reduction systems.
- It only applicable on head on collision to reduce accident occur during overtaking
- It is not applicable on other types of collision
- Lack of all object detection on the road including pedestrian, animal and other object to make decision

CHAPTER TWO

LITERATURE REVIEW

The examination of human variables in passing operations and the reasons for head-on crashes on two-lane roads are the main topics of this chapter. The current collision warning systems are also covered in this chapter, along with the human elements that should be considered while creating algorithms to pass collision warning systems. Also offered is a study of the current passing sight distance models, passing gap acceptance models, and driving simulator approaches.

2.1 Review of Related Literature on Human Factors and Systems for Preventing Collisions

Modern developments in digital processing, sensor, and computer technology have produced reasonably priced Collision Avoidance Systems (CAS), which can help drivers in hazardous circumstances. CAS is categorized into three groups according to the intervention's mechanism (see Figure 2.1). Advisory systems that are employed in circumstances that do not call for immediate collision avoidance action fall under the first group. Warning systems that are employed in instances where a collision is imminent and the driver must take action to prevent it fall under the second category. The automatic control intervention systems (such as automated soft braking, automated steering, and emergency braking) that deal with collision scenarios when the driver's assistance would not be enough to prevent the accident fall under the third group (Mehmood, 2010)

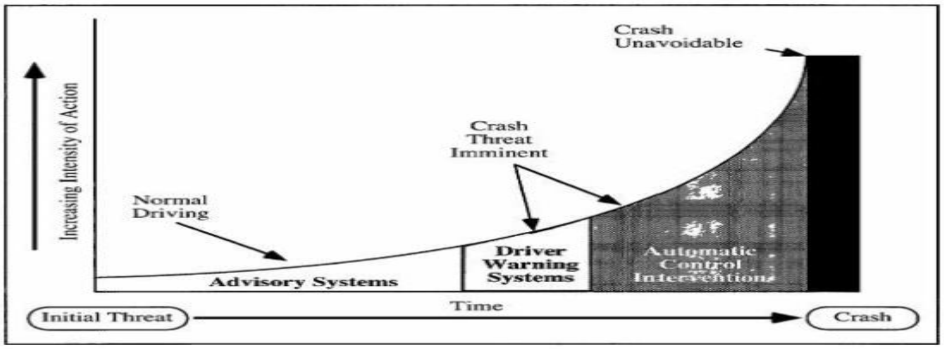


Figure2.1Categories of the Crash Avoidance System (Burgett, 2005)

The warning message technique was suggested by (Garcia-Lozano, E.; Barba, C.T.; Igartua, M.A.; Campo, C., 2013)to prevent vehicle-to-vehicle collisions by informing drivers of the status of the ongoing accident. The distance-based flooding system was employed in the proposed plan. In an effort to stop more road accidents, the author assessed the vehicle's response time following the incident. In order to attain effective bandwidth use, a warning message dissemination method has also been implemented for low priority communications. The recommended routing approach delivered the best possible high and low priority message distribution in the face of harsh weather conditions (rain, sun, etc.). In addition, the routing strategy minimized latency and made efficient use of available capacity in a variety of traffic scenarios. Nevertheless, this routing scheme's drawback is that it is ineffective in situations with a huge volume of traffic. The author's usage of the highest priority message in the basic flooding method is another flaw in this approach. Thus, less time was spent making the forwarding choice. As a result, there are scalability problems with the suggested system when it comes to sending out high priority notifications.

(Dabbour, Essam and Easa, Said M., 2014) Proposes an infrastructure-based intersection collision warning system for rural intersections. The proposed system has the objective of aiding unprotected right-turning drivers at high-speed rural intersections in selecting a proper gap for their departures. The system includes a detector (either a radar sensor or a laser scanner) that detects the nearest approaching vehicle on the rightmost lane along the major road and the system measures the positions and speeds of that nearest detected vehicle at two consecutive time intervals to determine its acceleration rate. The system’s algorithm also estimates the distance and the time needed for the right-turning vehicle to accelerate to the same speed as for the approaching vehicle.

Based on it, if the system's algorithm detects a possible conflict between the approaching and turning cars, it will alert the driver of the turning vehicle. A vehicle-presence detector (which might be another radar sensor or a simple loop detector) is used to activate the system (and start the algorithm) when a vehicle is spotted on the minor road approach. The algorithm of the suggested system takes into account how long it will take the driver of the right-turning vehicle to see the message presented by the system and respond to it (by beginning the departure). In order to evaluate the perceived reaction time required by the driver of the leaving vehicle, this research presents mathematical models.

Up to 93% of all road accidents are the result of driver mistake (Treat, J. R., Tumbas, N. S., McDonald, S .T., ShinaD.Hume, R. D. Mayer, R. E., Stanisfer, R. L and Castillan, N. J., 1977)**.** The various CAS categories are created to address various kinds of faults. For instance, an in-car advisory system that only indicates the existence of a possible danger in circumstances with proximal traffic or with a traffic control advisory display may help to avoid driver recognition mistakes. Additionally, warning systems may aid drivers in making decisions and assist them avoid making mistakes in judgment (Dabbour, E. M. S., 2009). Automated control intervention systems can deal with the drivers' inconsistent behavior. For example, a completely automated control system helps prevent collisions caused by novice drivers

The significance of human factor research in the creation of in-vehicle collision warning systems (ICWS) was highlighted by (Campbell, J. L., Carney, C., and Kantowitz, B. H., 1998) the warning system design process can make advantage of the connection between the ICWS and human factors availability. In particular, although warning systems have many advantages, their effectiveness is dependent on how well drivers adopt new in-car technologies and how well the ICWS integrates the data with driving responsibilities and capabilities.

The way in which in-vehicle collision warning systems operate is by using sensors mounted on passenger car front bumpers to search the road ahead for other cars and objects. The warning system assesses whether or not there is a risk of collision after detecting a vehicle or obstruction. The technology alerts the driver or applies the appropriate amount of brake pressure automatically if there is any chance of a crash. Through a coordinated system that transmits the vehicle speed and acceleration data via radio, the sensor system may measure the clearance distance, the relative speed, and the acceleration of the vehicle a head (Isermann, 2012)

To get over such drawbacks, researchers are starting to take into account a variety of combinations of various kinds of technologies of sensor fusions (Granet, F. Picado, R.; and Smith, L. , Longitudinal Collision Avoidance.). These systems use the time it takes for a signal to go towards and bounce back from the car in front of it to determine the distance, to the nearest few millimeters, between the two vehicles. On the other hand, the Doppler Effect and the frequency of the reflected radar beam are measured to ascertain the speed of the car ahead. The amount that the vehicle in front of it is traveling faster or slower may be calculated from the difference between the nine signals that are sent and received (ENG, 2001). A tiny digital camera tracks the lane lines by continually analyzing incoming data as it observes the road ahead. Some examples may be seen on automobiles including the Volvo, BMW, Subaru, Honda, and Mitsubishi (ENG, 2001). Every kind of vehicle has unique qualities and capabilities. The collision avoidance algorithm, which is the heart of the system, takes in data from the sensor suite, interprets it, and outputs the appropriate driver-vehicle warning response.

(Farah H. , 2009) developed a passing gap acceptance model using the data collected on two-lane highways that were collected with an interactive driving simulator. This model took into account the impact of the road geometry, traffic conditions and drivers' characteristics. However, this model did not consider drivers' motivation and desire to pass.

In order to perform a planned passing maneuver, (Farah, H., & Toledo, T, 2010)built a model that sought to capture both drivers' intention to pass and their gap acceptance judgments. The model was estimated using data gathered with a driving simulator. The impact of factors related to the various vehicles involved size of the available passing gap, speeds of the subject vehicle, the vehicle in front and the opposing vehicle, the following gap between the front vehicle and the subject and the type of the front vehicle, the road geometry, and the driver characteristics in the model were captured by using 16 different scenarios. The estimation results showed that modeling the drivers' desire to pass the vehicle in front has a statistically significant contribution in explaining their passing behavior.

With the use of video cameras set up at a permanent location next to passing sections in (Garcia-Lozano E. Barba C.T. Igartua M.A. Campo C. A, 2013)) proposed the construction of a methodology to study passing maneuvers on existing motorways. A sample of 234 moves was recorded using the approach on four passing zones. In comparison to any other model, the observed average speed differential between passing and impeded cars was substantially larger. The kind and speed of the passed vehicle as well as the length of the passing zone were the factors that had the greatest impact on the amount of time and distance spent in the opposite lane.

(Vlahogianni, 2013)Made an attempt to model the overtaking manoeuver in two-lane highways using survival analysis principles on data provided by the driving simulator. Different models were developed for describing the total overtaking duration, as well as the duration of the acceleration and back-to-lane phases. Results showed that the duration of each of the phases of overtaking considered, as well as the total overtaking duration may be best described by a log–logistic distribution. Factors influencing the overtaking duration depended on the gender, the speed difference and the speed of opposing traffic, as well as whether the driver conducts a multiple overtaking manoeuver.

(Ghods, 2013) Developed a new overtaking gap-acceptance model to simulate traffic operation and safety performance on two-lane highways. A new safety-based gap-acceptance decision variable based on the overtaking driver's perception of time-to-collision (TTC) with an opposing vehicle was introduced. The distribution of critical TTC among drivers was determined through a model calibration and validation procedure based on overtaking observational data obtained from a video-recording of a 1 km segment of a two-lane highway.

In their extensive analysis of two datasets of passing maneuvers, (Llorca, C. and Farah, H.“, 2016)used all available data. The first was based on field research, whereas the second made use of a driving simulator. The findings revealed a correlation between the passing distance and passing time of movements that were successfully executed (during the occupancy of the opposing lane). In the driving simulator, however, drivers passed more quickly while maintaining greater distances. Even though crucial gaps were discovered to be smaller in the driving simulator, gap acceptance judgments were also found to be similar as the distributions of both accepted and rejected gaps were identical. Few attempts have been made to analyze the overtaking behavior of cars on split and undivided highways in mixed traffic situations.

(Chandra, S., & Shukla, S. , 2012) Investigated the overtaking and acceleration characteristics of several types of cars. The impact of the shoulder's surface (paved and unpaved) on overtaking acceleration behavior was discussed. It was assessed how the acceleration rates and overtaking speed related. It was also determined that the overtaking time for flying overtaking correlates with the relative speeds of the overtaking and overtaken cars.

2.2 Systems for Collision Warning

There are two types of collision warning systems: kinematics-based and perceptual-based. The primary principles of motion are used by kinematics-based collision warning systems, which then project driver response times to trigger the alerts. When the vehicle in question is within the designated minimum distance, these devices sound the alerts. Time-to-collision (TTC) tolerance and estimated driver reaction durations are used by perceptual-based systems to trigger the alerts (Nilsson L., Alm H. and Janssen W.H., 1991). The alert algorithm is a crucial part of these systems.

A collision reduction system was created by (Dabbour, Essam and Easa, Said M., 2014)to help drivers who are turning right at rural crossroads. The system measured the incoming vehicle's position, speed, and acceleration on the main route using a radar sensor. The system's algorithm is built around acceleration profiles that were created using experimental data that was gathered with the use of a GPS data recorder device. At intervals of one second, the position and speed of several right-turning automobiles were recorded using this device.

On two-lane roads, passing crashes (also known as head-on collisions) happen when a car tries to pass a slower-moving car by going into the left lane. These crashes happen when the passing car's driver is inattentive or fails to react correctly to the circumstances. By lowering the possibility of human mistake, overtaking collision reduction system can assist drivers in avoiding passing collisions.

The architecture and design algorithm for an overtaking collision reduction system that helps unprotected drivers passing on two-lane roads are presented in this study.

2.3 Existing Passing Sight Distance Models

In order to reduce the likelihood of crashes, passing cars utilize Passing Sight Distance (PSD) to make sure they have a reasonable estimation of their distance from opposing vehicles (Harwood, D.W. & Glennon, J. C. , 1989) states that the PSD design requirements offer guidelines for designating no-passing and passing zones. The Green Book, AASHTO's Policy on the Geometric Design of Highways and Streets, (2004) has an explanation of these requirements. The FHWA Manual on Uniform Traffic Devices for Streets and Highways (MUTCD) (2003), which hasn't changed in more than 70 years, contains the operational requirements. The two sources (AASHTO and MUTCD) stated above are highly erratic and recommend various minimum PSDs under comparable circumstances.

Some models assume a uniform passing speed while occupying the left lane, despite the identification of an acceleration stage before the vehicle enters the left lane (American Association of State Highway and Transportation Officials, 2004)This model proposes an average acceleration rate of 0.62 m/s2. Other models describe the trajectories of passing vehicles using more complex kinematic equations (Hassan, Y., Easa, S. M., & Abd El Halim, A. O., 1996). These models generally suggest the existence of a critical point (point A in Figure 2.2). Once the driver reaches this point it is safer to complete the passing maneuver than to abort it. This is because the time and distance requirements are lower for the completion. According to these models, the acceleration rate of the passing vehicle is constant until the critical point is reached.

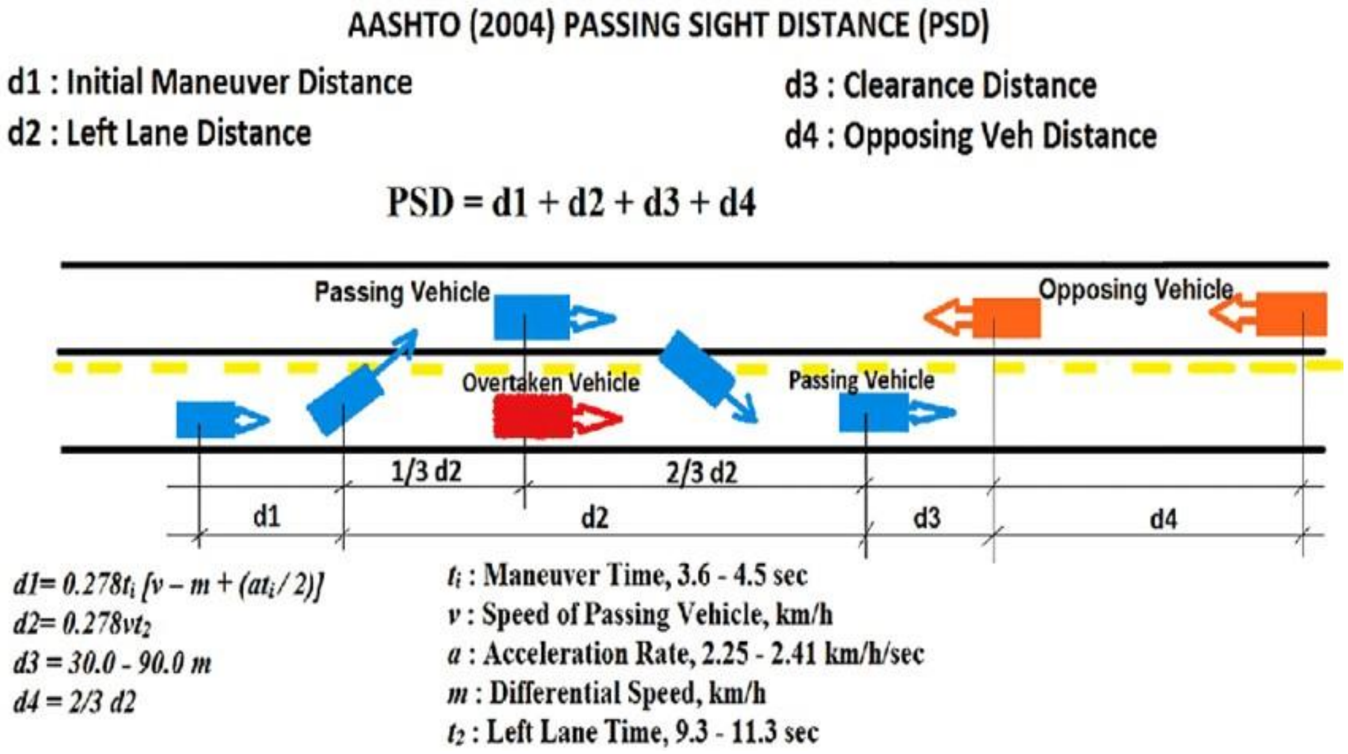


Figure 2 2 AASHTO modeling for the passing maneuver (AASHTO, 2004)

2.3.1 AASHTO Model

When designing two-lane highways, the minimum passing sight distance incorporates certain assumptions about driver behavior. The following assumptions were made by (American Association of State Highway and Transportation Officials, 2004)

1) The impeding vehicle travels at a constant speed during the passing maneuver.

2) The passing vehicle travels at a reduced speed and trails behind the impeding vehicle when entering the passing section, known as a delayed pass.

3) Once the passing section is reached, passing drivers require a short period of time to perceive that the passing section is clear and initiate acceleration.

4) Passing is done using a delayed start and a hurried return when in the opposing traffic lane. Passing vehicles accelerate during the maneuver and the average speed while occupying the left lane is 16 km/h higher than the speed of the impeding vehicle.

5) Once the passing vehicle returns to the right lane, there is an appropriate clearance length between the passing vehicle and any opposing vehicle in the other lane.

(American Association of State Highway and Transportation Officials, 2004) Developed the following model for the calculation of PSD based on field studies conducted prior to 1958:

$$PSD = d1 + d2 + d3 + d4 \qquad (2.1)$$

$$d1 = 0.278\ t1\ (v - m + a\ t12) \qquad (2.2)$$

$$d2 = 0.278\ v\ t2 \qquad (2.3)$$

Where $d1$= distance travelled by the passing vehicle during the perception-reaction times and while accelerating towards the encroachment point along the left lane (the time elapsed = $t1$, s); $d2$ =distance travelled by the passing vehicle as it occupies the left lane (the time elapsed = $t2$, s); $d3$=clearance distance between the passing vehicle and opposing vehicle at the end of the pass; $d4$=distance travelled from the opposing vehicle within two-thirds of the time a passing vehicle will occupy the left lane = 2/3 $d2$(the time elapsed = $t4$= 2/3 $t2$, s); v = average speed of the passing vehicle (km/h); a = average acceleration (km/h/s); and m = speed difference between the passing and impeding vehicles (km/h).Four PSD components are shown in Figure 2.2. This model considers the average speeds that are used to compute the design value for PSD. These speeds differ from the design speeds used for highways. The time required for the driver to abort the pass if a vehicle appears in the opposing lane is time $t1$+ (1/3) $t2$.

2.4 Passing Gaps While Overtaking

Research on overtaking (head-on) accidents is rare, even though these accidents are common and usually fairly serious. The majority of the research within the literature regarding two-lane highways involves issues such as the required sight distance (Brown, R.L., and Hummer, J.E. , 2000)the influence of the speed of both the passing and impeding vehicles on the number of passing maneuvers (Bar-Gera, 2005) the impact of impatience on the critical gap (Pollatschek, M. A., and A. Polus, (2005).) or the classification of passing maneuvers and overtaking frequency (Hegeman, 2004)Some studies have also discussed driver perception of required passing gaps.

There are several models used to compute the minimum required PSD, either for design purpose or to identify no-passing zones where drivers are informed, through lane markings and signage, that passing is not allowed due to insufficient PSD. Previous geometric design guide versions (e.g. AASHTO 2004) provided a model for PSD computation that allowed the passing driver to perceive the traffic conditions, react to them by deciding whether or not to pass, perform the passing maneuver by driving in the opposing traffic lane, and return to the original lane, while maintaining safe distances between all vehicles. Previous research studies have found that the above criteria for PSD result in two-lane highways that are generally safe for passing maneuvers (Harwood, D. W., 2007)Other research studies have found that the AASHTO (2004) criteria are too conservative (Llorca, C., and A. García, 2011)Given the rapid improvements in vehicle acceleration/deceleration capabilities and the changes in driver attitudes, if the above criteria are too conservative, some drivers may attempt to pass in non-passing zones, which could be hazardous for those drivers as well as other road users around them (Llorca, C., and A. García, 2011)

2.5 Vehicle Acceleration Profile

Since vehicles usually start a passing maneuver from a resting state, it is not realistic to assume a Constant acceleration rate for the vehicle acceleration profile (Mousa, 2002). Instead, an acceleration profile should be created for each individual case. In this study, the linear decreasing acceleration model was used in order to create the acceleration profiles. This method has been used in several other studies (Dabbour, Essam and Easa, Said M., 2014)According to his model, the acceleration rate can be computed using the following equation:

$$acc = \partial v/\partial t = \alpha - \beta v \pm Gg \qquad (2.4)$$

Where acc represents the acceleration rate for a particular speed v (m/s2);

V represents the speed (m/s);

α represents the acceleration rate at the initiation of acceleration (m/s2);

β represents the rate of decrease in acceleration with increases in the speed; G represents the grade (m/m); and g represents gravity (approximately 9.81 m/s^2). Based on the equation above, speed can be calculated as:

$$v = (\alpha \pm Gg/\ ) - ((\alpha \pm Gg)/\beta\ ) - v0))\ e - \beta t \tag{2.5}$$

Where t represents the time that has elapsed from the start of acceleration (s) and v0 represents the Initial speed of the vehicle (m/s). The distance traversed by the passing vehicle at any time is obtained using the following formula:

$$d = t\ (\alpha \pm Gg/\ ) - ((\alpha \pm Gg/\beta\ ) - v0)\ (1 - e - \beta t/\beta\ ) \tag{2.6}$$

Many different values have been suggested for the α and β parameters in the equations above. For the average passenger car, the parameter α ranged between 2.02 m/s2 (Bonneson, 1992)and the parameter β ranged between 0.0409 m/s2 (ITE, 2009) and 0.1326 m/s2 (Bonneson, 1992)It is important to note that these values represent the maximum capacity of the vehicle. Since the majority of drivers only apply the maximum acceleration power in emergency situations, these values cannot be used for road design purposes (Long, 2000).

(Farah H. , 2013)Man intelligent vehicle model was proposed to better understandings of the traffic situation and to assist overtaking behaviors analysis in traffic simulation taking into the consideration of different traffic situation. Then overtaking behavior model based on the intelligent vehicle is introduced in detail, the lane changing behavior model is analyzed. Besides, the overtaking behavior is realized by the coordination mechanism of agent-based multi-controller, which incorporates different traffic situation to explore overtaking behavioral mechanism in traffic. Presented algorithm in (Rezagholipour, K, Massoudian, N., & Eshghi, M. December)., 2016)introduces a novel method to reduce accidents caused by overtakes on curved road, via modeling this kind of accidents. In this method, to predict accidents, only presence of two vehicles in the road are assumed, one of which is vehicle attempting illegal overtake, and the second one is a vehicle in opposite direction. Using road geometrics condition and receiving momentary vehicle data via induction ring sensors, accident location will be predicted in the no-zone passing area. Then, a light and sound alarm system will warn drivers of upcoming danger. Also, in (Rezagholipour, K, Massoudian, N., & Eshghi, M. December)., 2016) intelligent barrios have been proposed in vehicles path, which after activation will cause a 5 percent speed reduction. The main problem in this paper is inaccurate overtaking modeling. In this investigation, the condition of the overtaking vehicle is analyzed only if it is occupying opposite lane of the road. Also, the third vehicle which has been overtaken is neglected in the modeling. Therefore, a vehicle which overtakes does not return to its main route. In other words, after overtake is initiated and opposite lane of the road is occupied, trespassing vehicle keeps its condition. It is obvious that accident frequency, in this case, is much more than what happens in the real case, and also there is no modeling of real overtaking.

2.6 Driving Simulators

Although simulators have been used since the early 1900s, driving simulators only began to appear in primitive form in the 1970s. The distinction between different simulators can be made according to their level (Kaptein, N.A., Theeuwes, J., and Horst, A.R.A. van der., 1996): 1) Low-level: typically consist of a PC or graphic work station, a single monitor, and a simple cap with control. 2) Mid-level: contain advanced imaging systems, a large projection display monitor, a realistic cap, and a simple motion base. 3) High-level: contain a near 360-degree field of view and a wide-range moving base. There are many possible applications for driving simulators, including human factor research, driver education, medical research, training and assessment, and vehicle design evaluation.

When it comes to research concerning traffic behavior, there are many advantages to the use of driving simulators (Kaptein, N.A., Theeuwes, J., and Horst, A.R.A. van der., 1996)Driving simulators allow researchers to test the effect of new road designs that would be too expensive to build just for research purposes;

1) Driving simulators allow researchers to investigate dangerous situations without any risk;

2) Drivers can be repeatedly challenged with events that may rarely occur in reality;

3) In some countries, field tests may be difficult because of liability problems;

4) Driving simulators allow for optimal experimental control; and

5) Driving simulators allow researchers to investigate the effects of nonexistent road elements. In spite of these advantages, there is one major disadvantage to using driving simulators: in a driving simulation the driving task is never completely realistic. Researchers must therefore question whether or not a driving simulation is sufficient for the particular area of investigation before using this method in their research study.

Because the driver simulator participants rarely need all obtainable information to perform the task, it is generally unnecessary that the information in the driving simulator be identical to what would be available in a real vehicle (Flexman, R.E. and Stark, E.A., 1987)). In some experiments, expert drivers may provide better performance in completing

2.7. Radar sensor used for overtaking assistance system

Frequency Modulated Continuous Wave, or FMCW, is the technology used by automotive radar systems. The device sends a continuous wave at a certain frequency that is modulated over a time T. This serves as a "time stamp" for the sent signal. Automotive RADARs serve as the primary speed and range sensors for a variety of driver assistance systems, including long-range adaptive cruise control (LRR), medium-range cross-traffic warning, and short-range obstacle/pedestrian detection (SRR).Radar typically consists of two parts: a transmitter and a receiver. Target is reached by the transmitter's electromagnetic waves, and the receiver picks up the target's echo. Only a portion of the sent signal is represented by this received echo signal.

2.8 Summary gap of literature review

The literature review presented several issues related to this study. First, a review of human factors, describing the ways in which humans can affect accidents, the sources of head-on collisions on two-lane highways, and the ways accidents related to human factors can be minimized. Second, a review of collision warning systems, highlighting the fact that there is currently no commercially available passing collision warning system to assist passing vehicles on two-lane highways. Third, a review of previously developed passing sight distance models, highlighting the fact that very few of the PDS models for rural two-lane highways have taken driver characteristics into account.

After reviewing the various analytical models required determining the passing sight distance along two-lane highways that is both safe and comfortable, it was discovered that these models contain assumptions that are not appropriate, leading to PSD values that are either too short or too long. Fourth, a review of earlier research on passing gaps was carried out. Fifth, an analysis of the acceleration characteristics of the vehicles was done. Finally, driving simulators were presented and a review of earlier research utilizing them was carried out.

The main problem of most paper is inaccurate and still autonomous by driver. Some investigation, the condition of the overtaking vehicle is analyzed only if it is occupying opposite lane of the road. Most of the literature concerning to this study is about warning sound that gave driver to decide so it needs further modeling to reduce the accident when passing other vehicle . In other words, after overtake is initiated and opposite lane of the road is occupied, the passing vehicle keeps its condition. It is obvious that accident frequency, in this case, is much more than what happens in the real case, and also there is no modeling of real overtaking.so I developed the modeling system that reduce the overtaking collision reduction system by modeling throttle linkage and employing throttle valve position controller. A virtual model of overtaking assistance system has done in programming language (arduino, proteus) and MATLAB for simulation.

CHAPTER THREE

MATERIAL AND METHEDOLOGY

3.1. Introduction

Together with a description of the techniques I'll employ to finish the thesis, the features and properties of the materials and software used are described in depth, and data analysis is also given. This chapter also covers algorithm and the modeling of each individual component to form the whole system. Finally, software like SOLID WORKS and MATLAB/SIMULINK is used to model the system.

3.2 Materials

Software used for the study:

MATLAB: It is used to simulate road design scenario on MATLAB app.

ARDUINO CODE-Help to code the possible logic scenario.

PROTEUS SIMULATION-used to simulate the microcontroller code and actuate
SOLIDWORKS: Helps to construct the model of throttle linkage to control throttle valve position.

3.3 Methodology

When studying the methods and methodology of an overtaking collision reduction system utilizing radar sensors, the research typically involves a comprehensive exploration of the technological, engineering, and human factors aspects. Here's an outline of the key components involved in the study:

1. Radar Sensor Technology and Data Processing: An examination of the principles, functionality, and performance of radar sensors used in overtaking collision reduction systems. This includes studying the radar's capabilities in detecting relative speed, distance, and the trajectories of surrounding vehicles.

2. Sensor Fusion Techniques: The study investigates into the integration of radar sensor data with other sensors, such as lidar and cameras, and investigates the fusion techniques employed

to achieve an accurate and comprehensive representation of the surrounding environment during overtaking maneuvers.

3. Advanced Signal Processing Algorithms: Research into the signal processing algorithms utilized to interpret radar sensor data and provide actionable insights for collision risk assessment. This involves studying algorithms for object detection, speed tracking, and collision prediction based on radar inputs.

4. Collision Risk Assessment and Decision-Making: Evaluation of the methods and algorithms used to assess collision risks during overtaking, considering the data obtained from radar sensors. The study encompasses exploring the decision-making process for triggering collision reduction actions based on radar inputs.

5. Control Strategies and Collision Prevention Actions: Investigation of the control strategies employed to mitigate collision risks using radar sensor data. This includes the study of speed adjustment, lane changing, and other proactive actions triggered by collision risk assessments based on radar inputs.

6. Human-Machine Interface Design and Evaluation: Examination of the design and evaluation of the human-machine interface aspects of the overtaking collision reduction system, focusing on how radar sensor data is presented to the driver and the effectiveness of the system's warnings and actuate on throttle linkage to engage and disengage the throttle valve.

7. Real-world Simulations and Field Testing: The study involves the development of simulation models to assess the performance of the overtaking collision reduction system based on radar sensor inputs. Additionally, it may include field testing to validate the effectiveness of the system in real-world scenarios by proteus and MATLAB

8. Implications for Road Safety and Automotive Regulations: Consideration of the broader implications of radar-based overtaking collision reduction systems for road safety practices, automotive regulations, and the potential impact on reducing overtaking-related collisions.

The method used for the entire thesis study can be summed up as the flow chart below.

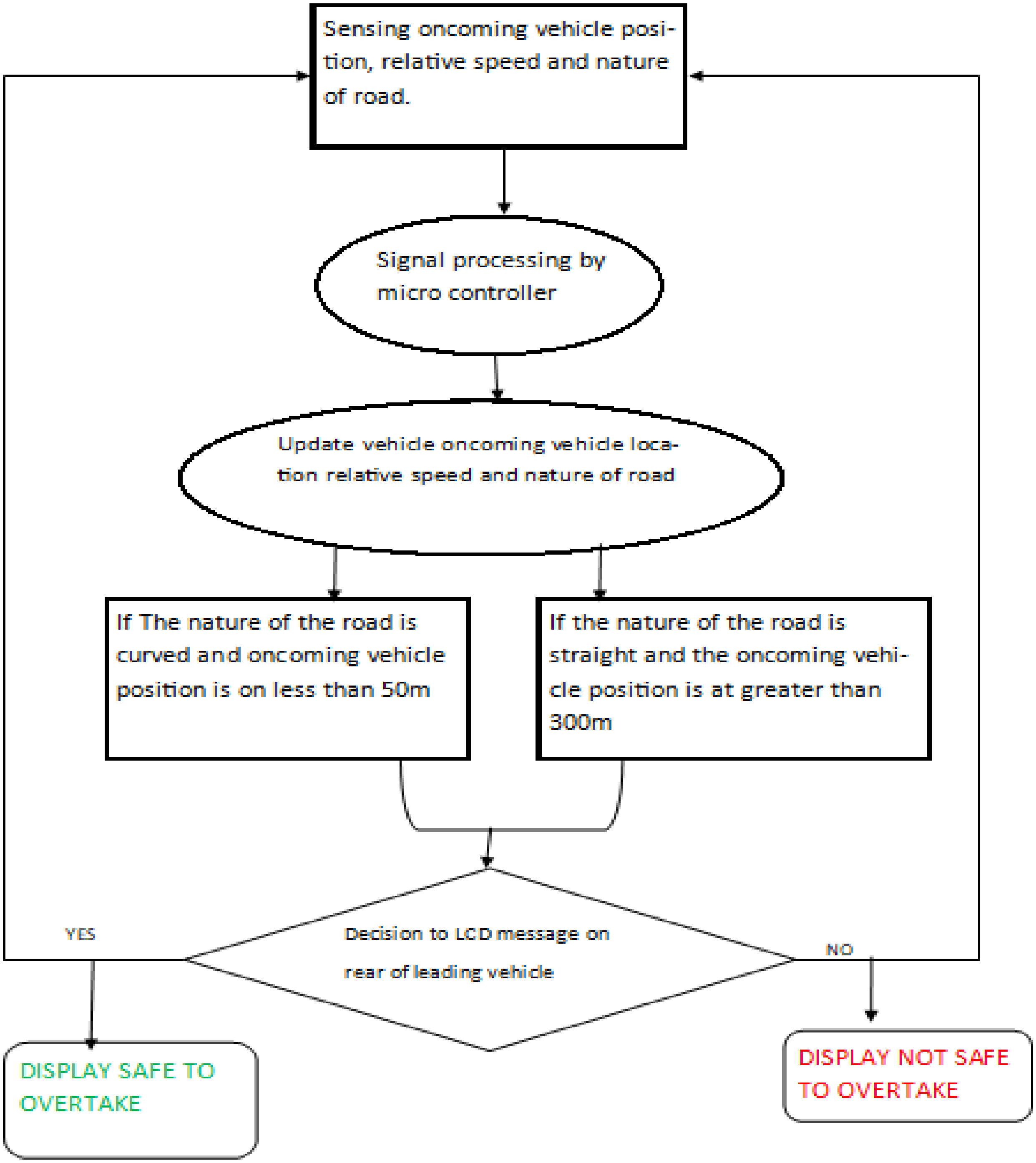


Figure 3.1 Overtaking collision reduction system chart algorithms for leading vehicle

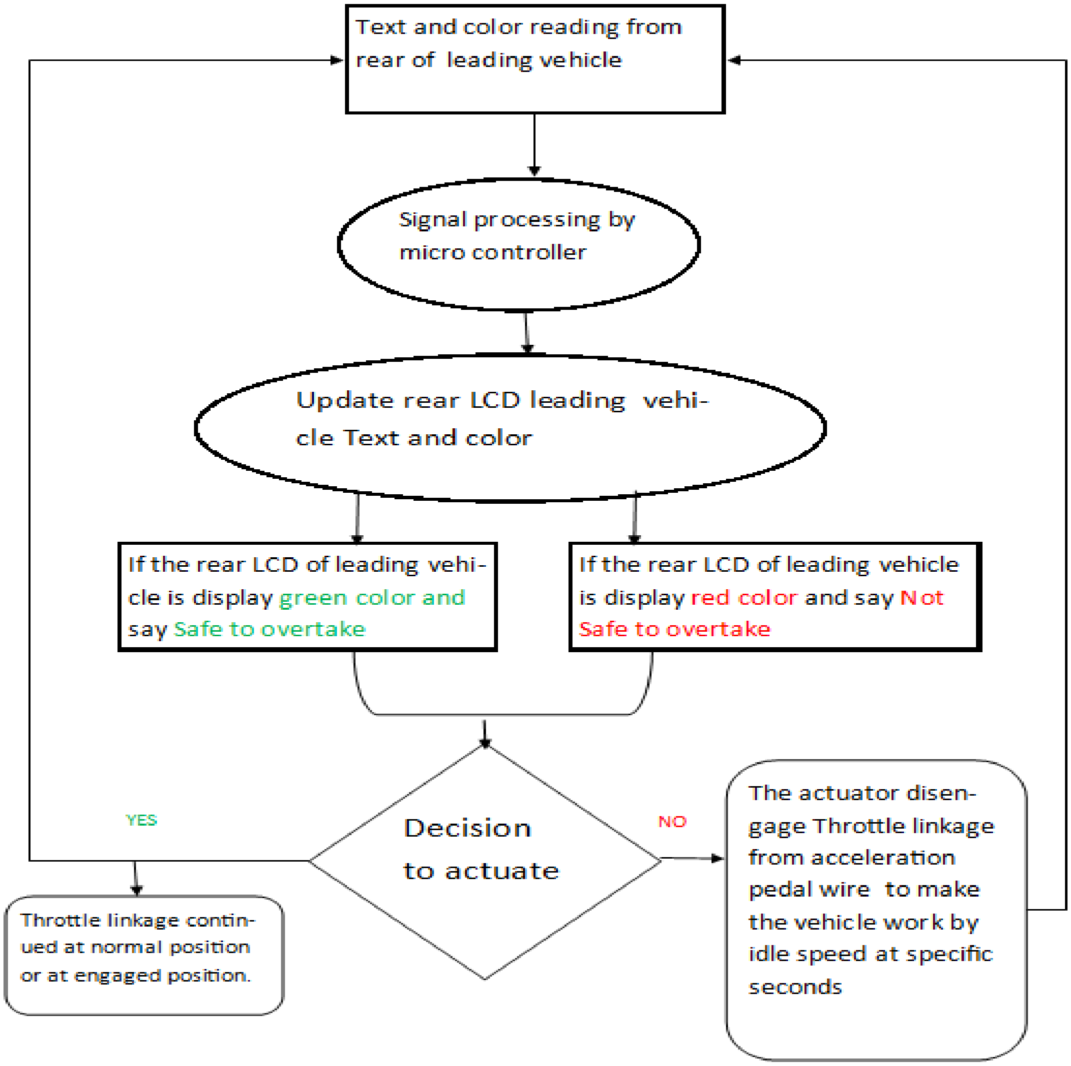


Figure 3.2Overtaking collision reduction system chart algorithms for following vehicle

3.4 General algorithm Description

1. The oncoming vehicle and nature of road characteristics are entered in the system (e.g., speed distance curved road straight road).

2. The system takes two successive measurements of both the location and speed of the nearest vehicle detected in the closest lane on the left side and the time interval between the two measurements equals the inverse of the detector's frequency.

3. Using these measurements, the system estimates the acceleration rate of the vehicle that has been detected.

4. The system then determines the time needed for the opposing vehicle to reach the safe point, to opposing.

5. This information is then used to determine the time (t passing) needed for the passing vehicle to complete the pass which is equal to the sum of t1 (the perception-reaction time and initial acceleration of the

Passing driver) and t2 (passing time), as shown in Fig. 3.2

6. The system compares times t passing, to (the sum of t opposing and t sum) where t sum represents a safety margin.

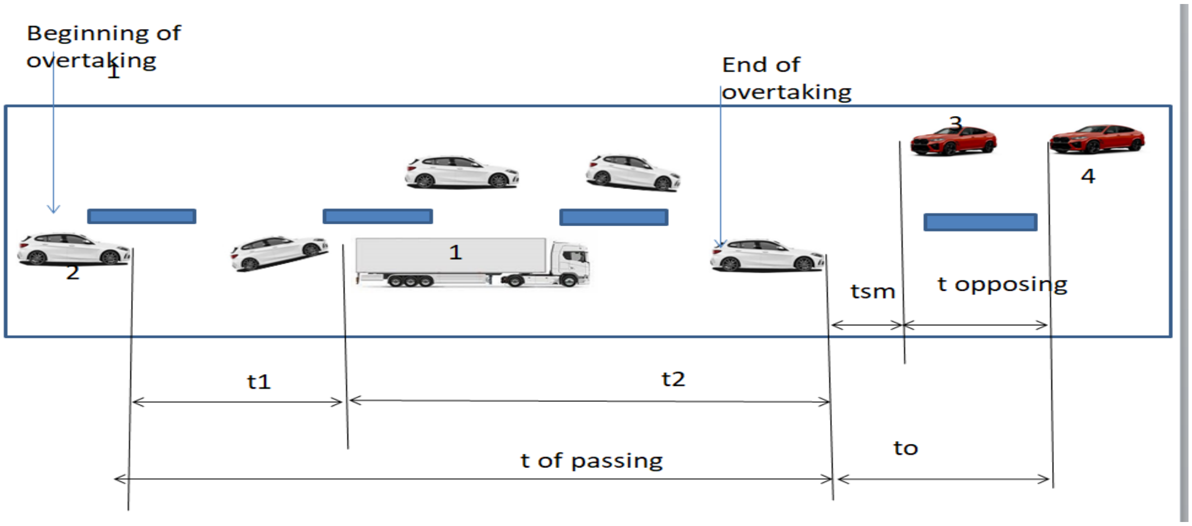


Figure 3.3 Overtaking goal and relative distance between vehicles

1. Overtaken vehicle

2. Overtaking vehicle

3. Oncoming vehicle

3. 5 proposed collision reduction system

The passing maneuver's algorithm can identify different opposing cars, and it applies the identical steps to any vehicle that is in the way. Figure 3.1 illustrates the passing collision warning algorithm's process. The ego vehicle receives a display from leading vehicle not safe passing when the system identifies a car in the opposite lane is at short distance. An arrow sign with a distinct color for each message—for example, red for "Not-safe" and green for "Safe"—or text can be used to convey the message. Until the algorithm verifies that a safe passing maneuver is possible, the notice remains shown.

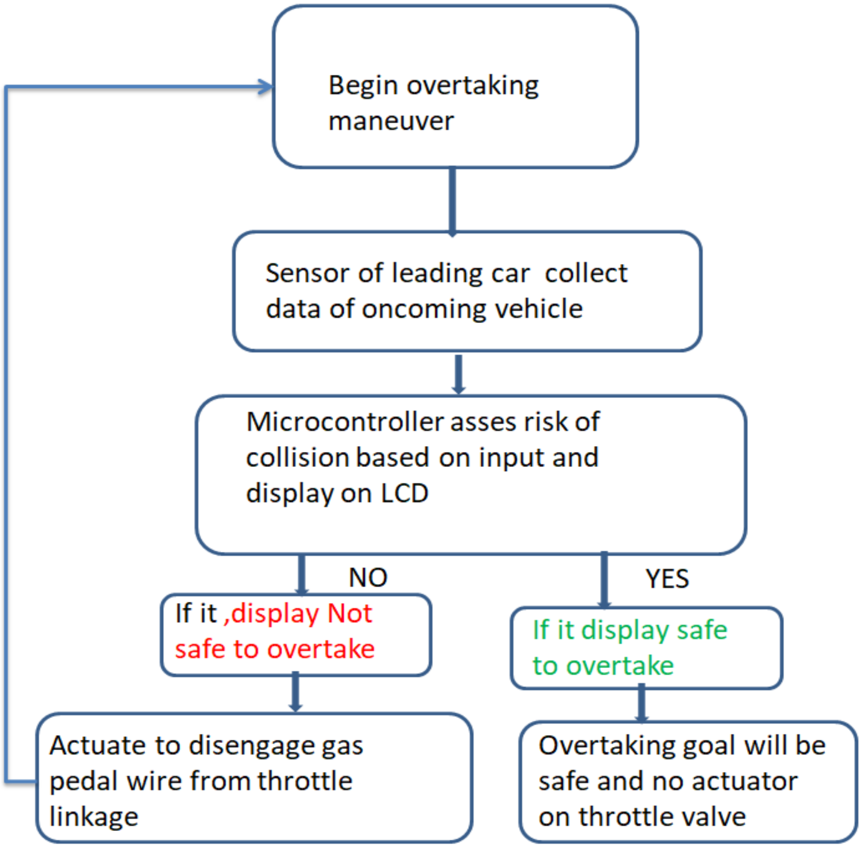


Figure 3.3 Overtaking collision reduction system chart algorithms

3.6 working principle

A vehicle overtaking assistance system can be a valuable safety feature on two-way roads. There are different approaches to designing such a system, but some common components could include:

I. Radar or Cameras sensors to detect the presence of other vehicles on the road and topography of the road.
II. An algorithm to analyze the data collected by the cameras or sensors in real-time.
III. A display system that indicate safe to overtake or not
IV. A modeling throttles linkage that actuates to assist the driver when it is not safe to overtake other vehicles.

An override system or actuating system that prevents the driver from making a dangerous move, such as overtaking when it is not safe. By utilizing these components, an effective vehicle overtaking assistance system could help reduce the risk of accidents on two-way road.

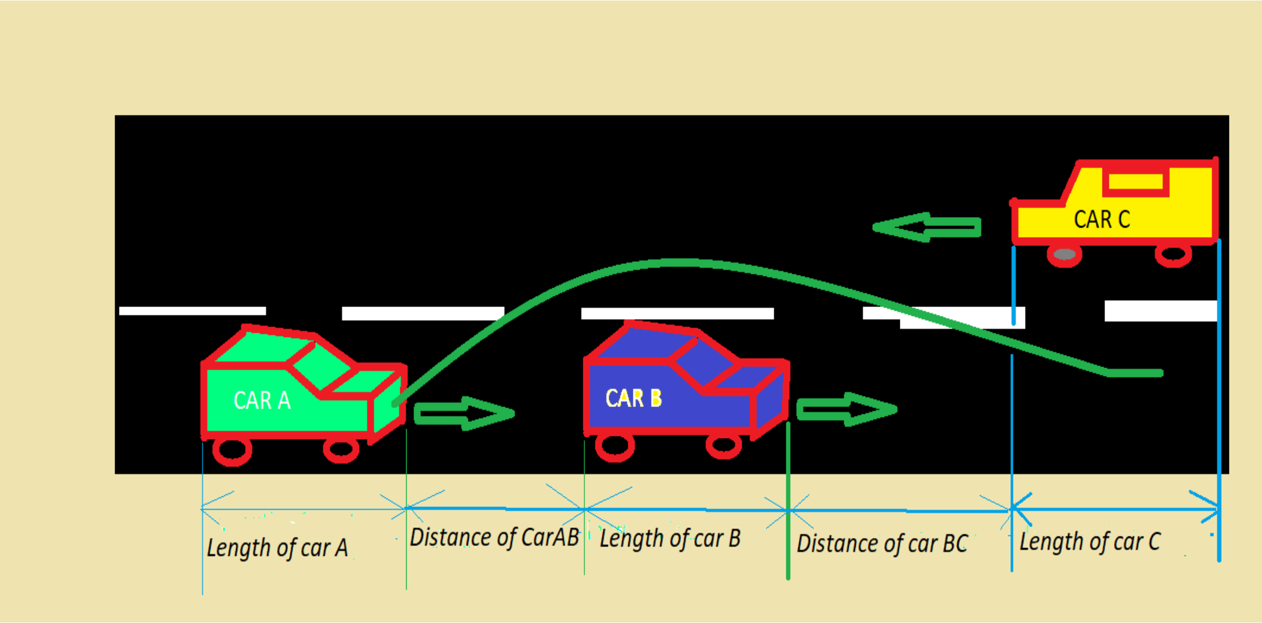


Figure 3.4Two way road overtaking attempt

The working principle of throttle linkage.

A linkage mechanism in the context of vehicle communication typically refers to systems that enable communication and coordination between vehicles. It involves several components and processes like:

1. Sensor Data Acquisition- Each vehicle in the system is equipped with sensors, such as cameras, LiDAR, radar, and GPS, to perceive its surroundings and gather relevant data about the road, traffic, and nearby vehicles. These sensors continuously collect data to provide real-time information to the vehicle's onboard systems.

2. Data Processing and Analysis- The collected sensor data is processed and analyzed by microcontroller and algorithms to extract meaningful information about the vehicle's environment, including the positions, speeds, and behaviors of nearby vehicles. This information is used to make decision ns and generate control commands for the vehicle's motion.

3. Communication Protocol- A communication protocol is established to facilitate the exchange of information between vehicles within the system. This protocol defines the format, timing, and content of messages exchanged between vehicles, ensuring consistent and reliable communication.

4. Wireless Communication- Vehicles communicate with each other wirelessly using dedicated communication technologies such as Vehicle-to-Vehicle (V2V) communication or cellular networks. These communications transmit data packets containing relevant information about the vehicle's state and intentions.

5. Information Fusion- Received information from neighboring vehicles is fused with the vehicle's own sensor data to enhance situational awareness and improve decision-making. By integrating information from multiple sources, the vehicle can better understand its surroundings and anticipate potential hazards or opportunities.

6. Decision-Making and Control- Based on the fused information, the vehicle's onboard systems make decisions about its actions, such as engaging and disengaging the throttle valve from gas pedal linkage. Control commands are then executed to implement these decisions, ensuring safe and efficient operation in coordination with other vehicles.

Overall, the linkage mechanism operates by integrating sensor data, communicating with neighboring vehicles, processing information, and making decisions to enable cooperative behavior and coordination among vehicles in the system. This collaboration enhances safety, traffic flow, and efficiency, contributing to the realization of advanced mobility concepts such as autonomous driving and connected vehicles.

3.7 Throttle linkage modification for gas pedal engagement

The throttle linkage in a vehicle is a mechanical system that connects the accelerator pedal to the throttle valve in the engine. When the driver presses the accelerator pedal, the throttle linkage system translates this mechanical input into an action that controls the engine's throttle opening, ultimately regulating the engine's power output and speed.in our case based on the input from incoming vehicle the actuator engage accelerator pedal to throttle linkage by help of stepper motor actuator. The below figure illustrate the engagement system.

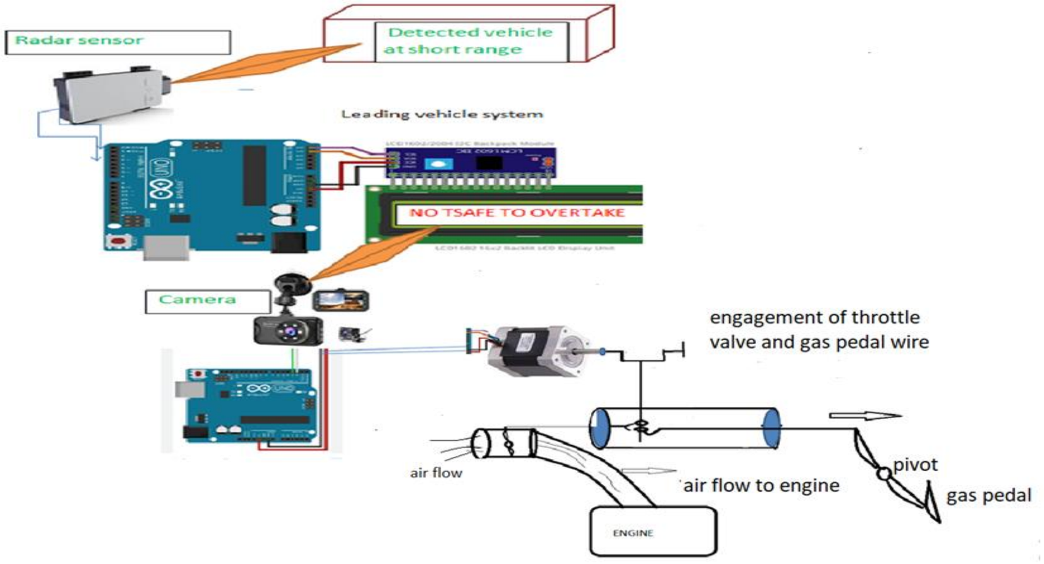


Figure 3.5 Diagram of modeling throttle linkage for engagement

3.8 Throttle linkage modification for gas pedal Disengagement

The throttle linkage in a vehicle is a mechanical system that connects the accelerator pedal to the throttle valve in the engine. When the driver presses the accelerator pedal, the throttle linkage system translates this mechanical input into an action that controls the engine's throttle opening, ultimately regulating the engine's power output and speed.in our case based on the input from incoming vehicle distance speed and leading vehicle information the actuator disengage accelerator pedal from throttle linkage by help of stepper motor actuator. The below figure illustrate the disengagement system. The below figure illustrate the disengagement system.

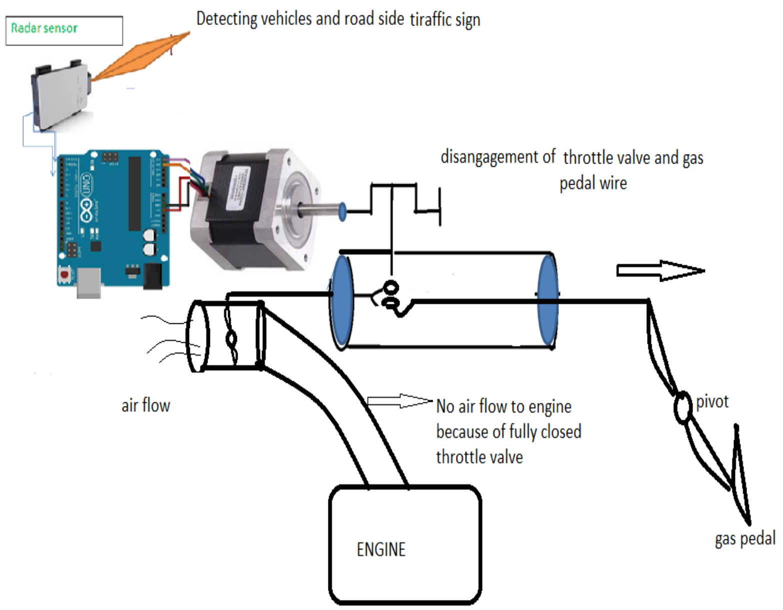


Figure 3. 6 Diagram of modeling throttle linkage for disengagement

3.9 Passing (overtaking) Vehicle Location

The sum of the following determines how long it takes a passing car's driver to finish the pass, or t passing:

1. The perception-reaction time (t1) of the driver and the first acceleration (t1), which is the amount of time the driver has to detect the "safe" signal before acting (turning on the throttle); and
2. The vehicle's travel time (t2), which is the time needed to accelerate the vehicle and clear the path for the oncoming vehicle. This involves the time needed to cross the offset distance between the passing and opposing vehicles, along with the length of the passing vehicle itself. Finally, the total time required for the passing vehicle to complete the pass, t passing, is calculated using the following formula:

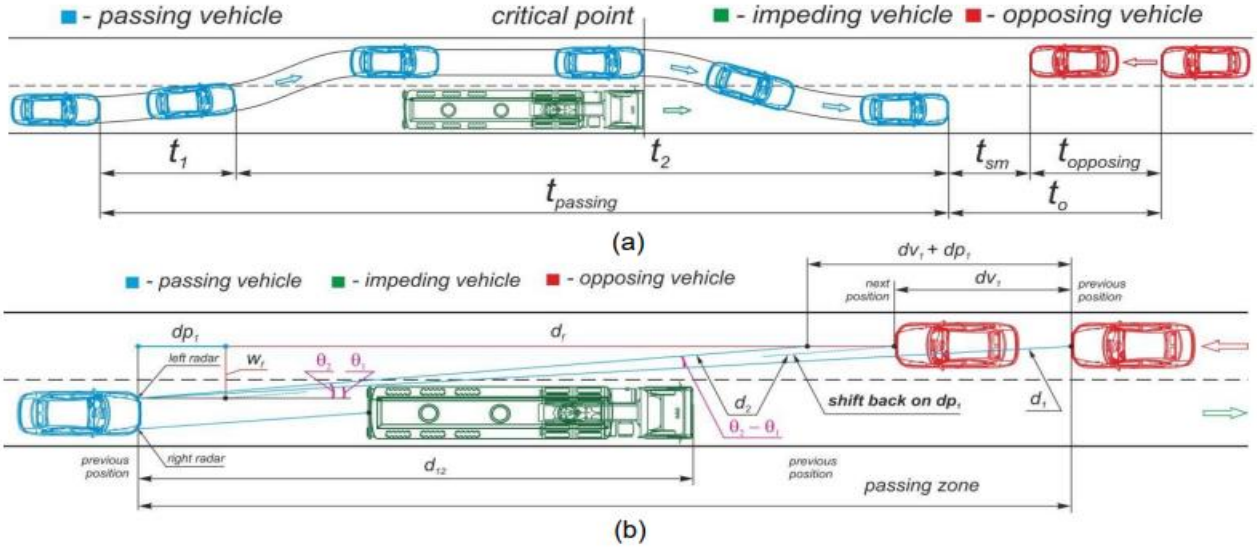


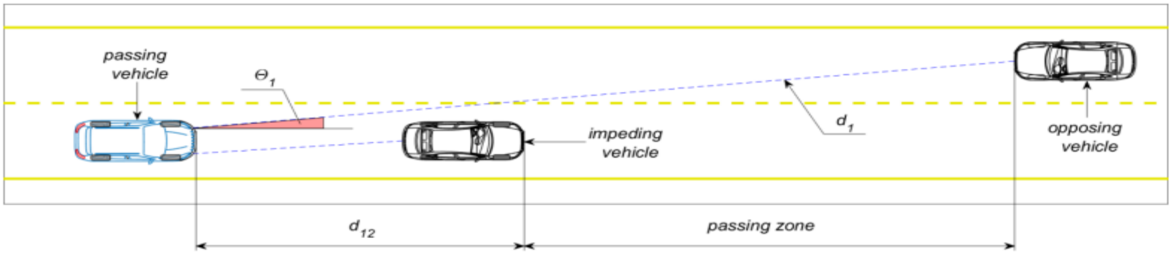
Figure 3.7 Time indication and speed indication (AASHTO, 2011)

At each time interval Δt, the opposing vehicle's v1 and v2 speeds are likewise recorded. The "Safe" message is shown and the algorithm deduces that the object (such as a tree or post) is stationary if d1 and d2 are equal (v1 and v2 are both zero). The program deduces that the item is traveling away from it and displays a "Safe" message if d2 is larger than d1. The vehicle's distance traveled during the time interval at time T+Δt (dv1), if d2 is less than d1, is found using:

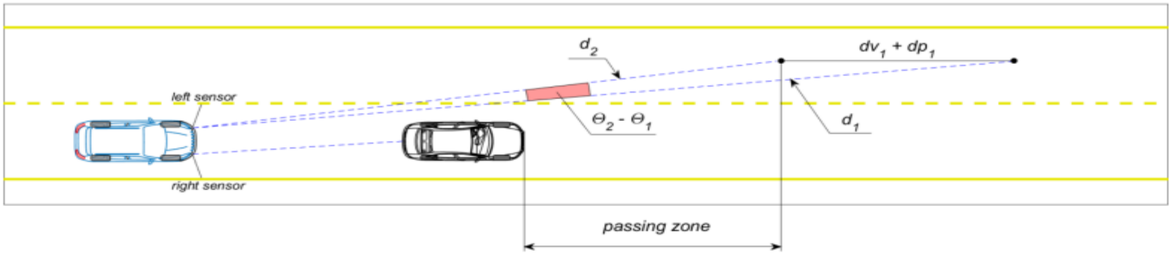
dv1=square root of (d1^2+d2^2-2d1d2cos (θ2-θ1)-dp1) (3.1)

A third radar signal is produced at time T+2Δt and records the information for vehicle A at distance d3 and azimuth angle θ3. The distance that is crossed by the vehicle in the second time interval, dv2, can be calculated in a similar way as dv1 using the following formula:

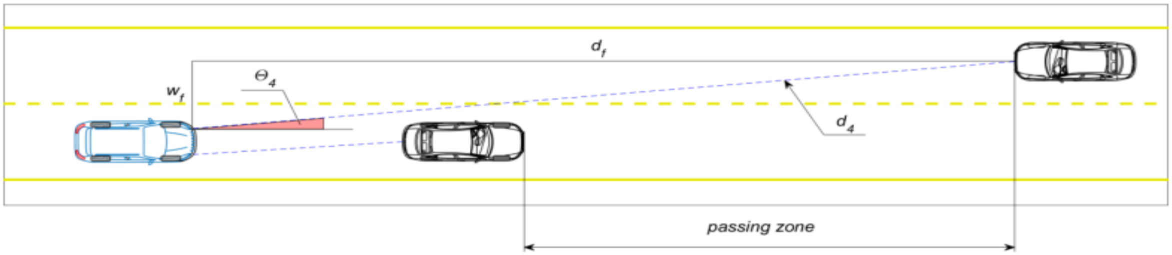
Dv2=square root of (d2^2+d3^2-(2d2d3cos (θ3-θ2)-dp2) (3.2)



(a) : Calculating the distance and angle at time T



(b) : Calculating the distance traversed by the opposing vehicle



(c) : Calculating the distance at time T + 3t

Figure3.8Calculating the distance and angle at each time interval

3.10. Radar Sensor Technology and Data Processing

Selecting a radar sensor for an overtaking collision reduction system involves carefully considering the sensor's technical specifications, performance capabilities, and suitability for the specific application. Here's an explanation of radar sensor technology and the key factors to consider when selecting a radar sensor for an overtaking collision reduction system.

Radar sensors use radio waves to detect the presence, distance, speed, and angle of surrounding objects. They operate by emitting radio frequency signals and then analyzing the reflected signals to obtain information about objects in the sensor's field of view. Here are some key aspects of radar sensor technology:

a) Frequency Bands: Radar sensors operate across various frequency bands, each offering different performance characteristics. Common frequency bands include 24 GHz, 77-81 GHz, and 24-29 GHz, with higher frequencies often providing higher resolution and accuracy.

b) Range and Resolution: Radar sensors have a specified maximum detection range and resolution, indicating their ability to detect objects at varying distances and discern between closely-spaced objects.

c) Detection Coverage: The radar sensor's field of view, azimuth angle, and elevation angle determine its coverage area, affecting its ability to provide comprehensive coverage for overtaking scenarios.

d) Doppler and Range Measurement: Radar sensors utilize Doppler processing for velocity measurement and provide range information to assess the distance to surrounding vehicles.

3.10.1. Radar Selection Considerations for Overtaking Collision Reduction

When selecting a radar sensor for an overtaking collision reduction system, several critical factors come into play:

A) Distance and Velocity Measurement Accuracy: The sensor's accuracy in measuring the distance and velocity of oncoming and surrounding vehicles is crucial for assessing overtaking safety.

B) Resolution: Higher resolution radar sensors can differentiate between closely spaced objects, supporting precise assessment of safe overtaking opportunities

C) Field of View: The sensor's coverage area and detection pattern must align with overtaking requirements, encompassing adequate forward and lateral coverage

D) Frequency Band: Choice of frequency band influences resolution, accuracy, and environmental robustness, with higher frequencies typically providing finer detail and accuracy in detection.

E) Environmental Considerations: The sensor's ability to operate in varying weather conditions, such as rain, fog, and snow, is crucial for reliable overtaking safety assessment.

F) Integration and Interface Flexibility: Consideration of how the sensor interfaces with the vehicle's control systems, decision logic, and HMI, ensuring seamless integration for safe overtaking maneuver execution

G) Safety-Critical Specifications: Compliance with automotive safety standards and regulations, including functional safety considerations as per industry standards such as ISO 26262, is paramount for ensuring safe and reliable operation.

3.10.2 Types of Radar sensor

1. (24 GHz Medium-Range Radar Sensor): Provides reliable detection with versatile angle coverage, particularly suitable for lateral vehicle detection during overtaking.

2. (77-81 GHz Long-Range Radar Sensor): Offers precise distance and velocity measurement with wide-angle coverage, suitable for real-time risk assessment during overtaking scenarios.

The long range radar sensor are used for cross traffic alarm systems, calculating the distance to and speed of other cars, and identifying things in a broader range of vision. Directive antennas with a better resolution within a smaller scanning range are required for long-range applications. Ranges between 80 and 200 meters or more are offered by long-range radar (LRR) systems.

For my work I used long range radar sensor for its wide angle coverage and capability of object detection at long range.

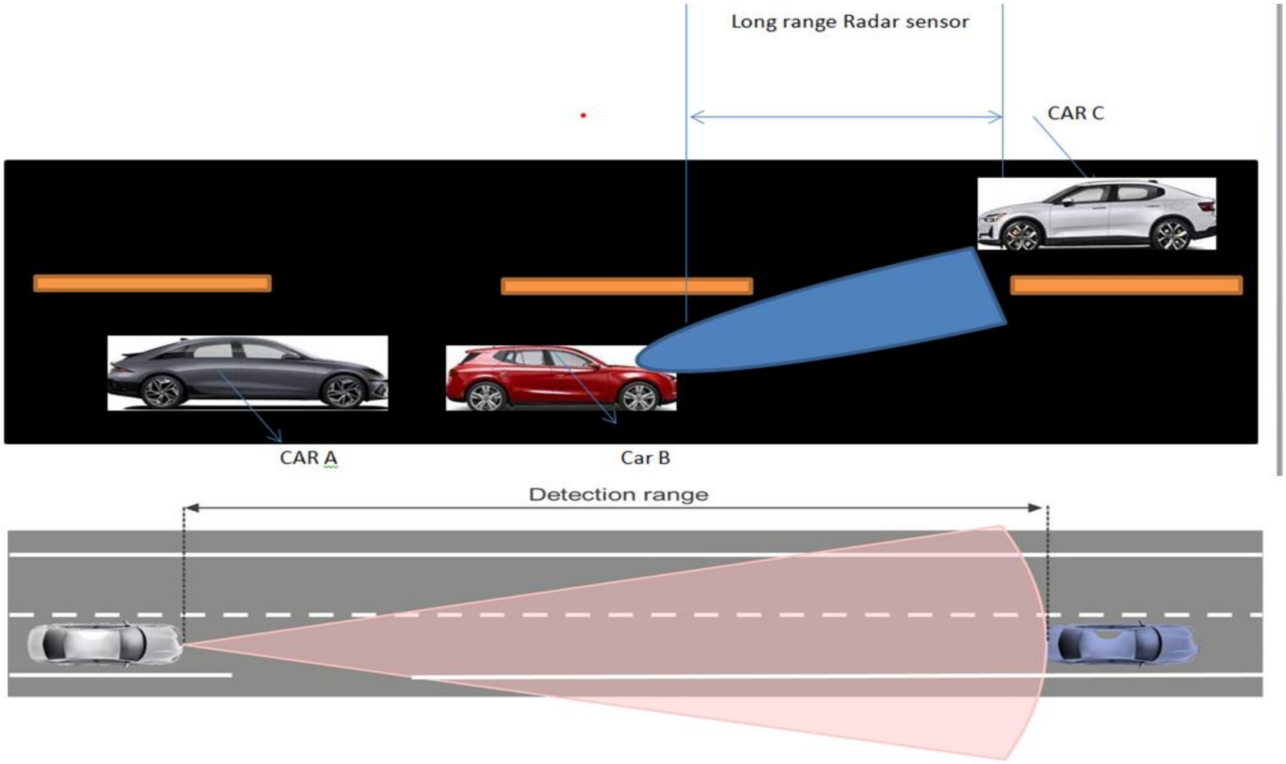


Figure3.9Long range Radar detection

3.11 Microcontroller

A microcontroller is a small integrated circuit that serves as the central nervous system of an automobile's electronic systems. It is essential for processing data, managing several operations, and enabling inters component communication. In particular, microcontrollers are in charge of handling the interpretation of radar sensor data, carrying out collision avoidance algorithms, and organizing reactions in radar technology for automotive applications.

a) Processing Power: Microcontrollers need to have sufficient processing power to handle complex algorithms involved in radar signal processing, sensor fusion, and collision avoidance strategies.

b) Peripheral Interfaces**:** Interfaces like SPI (Serial Peripheral Interface), I2C (Inter-Integrated Circuit), and UART (Universal Asynchronous Receiver-Transmitter) are crucial for connecting and communicating with radar sensors and other components in the system.

c) Real-Time Capabilities**:** Real-time processing capabilities are essential for automotive radar systems to make timely decisions based on rapidly changing sensor data, ensuring quick responses to potential collision risks.

d) Communication Protocols**:** Compatibility with communication protocols used in automotive networks, such as Controller Area Network (CAN), is vital for seamless integration into the vehicle's communication infrastructure.

e) Analog-to-Digital Converters (ADC): Microcontrollers often include ADCs to convert analog signals from radar sensors into digital data that can be processed and analyzed.

f) Low Power Modes**:** Automotive microcontrollers should support low-power modes to optimize energy consumption, especially in scenarios where the vehicle is in standby or idle states.

3.11.1 Types of microcontrollers

For an automobile radar system, selecting the best microcontroller requires taking into account a number of variables, including as processing speed, communication interfaces, safety features, and real-time capabilities. For certain needs and criteria, different microcontrollers could be appropriate. The following are some popular microcontroller choices for automobile radar systems:

A) NXP S32R Series**:** The NXP S32R microcontrollers are specifically designed for radar applications in automotive systems. They feature powerful Arm Cortex-R processors, high-speed ADCs, and support for radar signal processing. NXP S32R devices are known for their real-time capabilities and safety features.

B) Infineon AURIX™ TC2xx Series**:** The AURIX™ TC2xx series from Infineon is designed for safety-critical applications in automotive systems. These microcontrollers feature multiple cores, high-speed ADCs, and dedicated safety architecture. They are suitable for radar applications requiring high performance and safety standards.

C) STMicroelectronics SPC5 Series**:** STMicroelectronics offers the SPC5 series of microcontrollers, which are designed for automotive applications, including radar systems. These microcontrollers feature Power Architecture cores, multiple communication interfaces, and real-time capabilities. They are suitable for applications demanding high performance and reliability.

Figure 3.10 Microcontroller

3.11.2. Text Recognition

The process of displayed text recognition consists of four main stages: the first is the LCD display text (Region-of-Interest) Extraction; the second, Pre-processing of the extracted regions (ROIs); the third, Character Segmentation; and finally, Recognition of the characters on the LCD display.

I have employed a pre-trained Haar Cascade Classifier for license plate extraction. The Haar Cascade Classifier is an object identification method that is useful for identifying faces and objects in pictures and movies. The concept of features is the main focus. It forms the basis of all object detection algorithms that use the Haar-like features technique. The cascade classifier is trained using a vast number of positive and negative images using the Haar cascade approach. Therefore the LCD display of text will work same with plate number recognition.

3.11.3 LCD display

A flat-panel display or other electronically controlled optical device that makes use of polarizers and the light-modulating capabilities of liquid crystals is known as a liquid-crystal display (LCD).In this instance, the LCD is installed on the back car close to the license plate number to provide information to the vehicle in front.

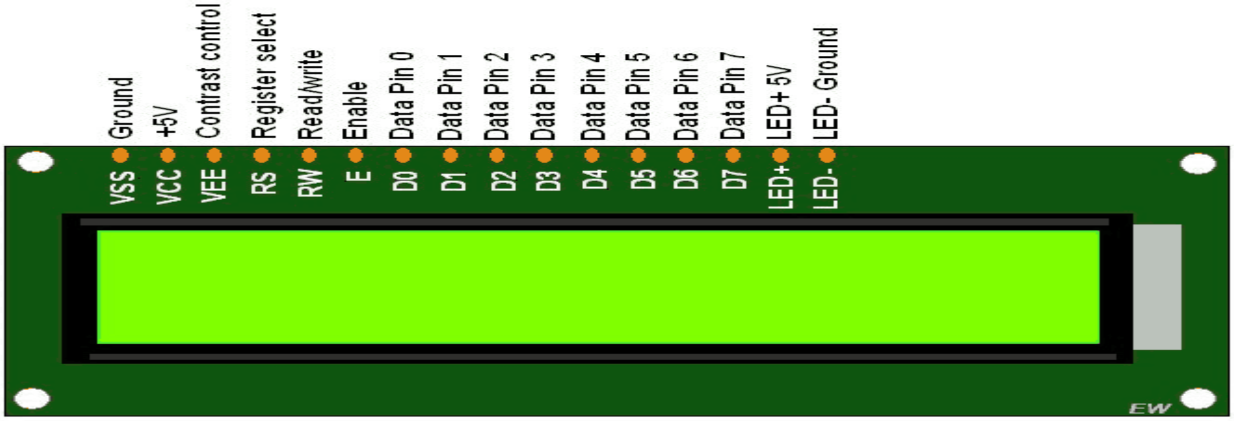


Figure3.11 LCD display

3.11.4 Solid work part and working principle of throttle valve

The designed electronic throttle Valve system comprises of a throttle plate equipped with a preloaded spring and is driven by an electronic-controlled dc motor to regulate airflow in the intake manifold. The throttle plate rotate 90 degree clock wise to fully close the tube and rotate 90 degree anti-clock wise by help of dc motor that controlled by microcontroller based on input data.

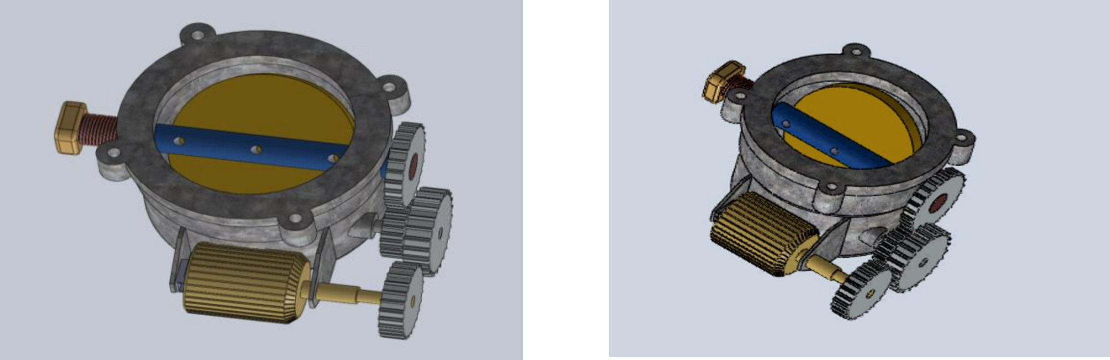


Figure3.12 3D part of fully closed throttle valve 3D part of fully open throttle valve

3.12 software part and fuzzy logic scenario

3.11.1 Overtaking assistance system algorithm

Here are the methods to build scenario and put algorithm to avoid collision due to overtaking.

- Define the problem
- Gather data
- Pre-processing
- Feature extraction
- Safety rules
- Decision-making process
- Electronic throttle valve control

Step 1: Define the problem Determine whether it is safe to overtake another vehicle on the road

Step 2: Gather data Sensor and camera provide information

Step 3: Pre-processing Data collected from sensor and camera may need to be preprocessed

Step 4: Feature extraction Extract relevant features from the data

Step 5: Safety rules Define safety rules for overtaking

Step 6: Decision-making process based on extracted features and safety rules, decide whether to overtake or not.

Step 7: Electronic throttle valve control the electronic throttle valve to achieve the desired speed and power output for overtaking.

3.13 Modeling approach

In order to be able to carry out a successful simulation of overtaking Assistance Systems (OAS), a software called MATLAB (for graphics) and PROTEUS (for algorithm) has been chosen. From previous information, (OAS) technology permits the detection of objects during driving and, simultaneously, alerts the driver to dangerous road conditions and, in my case, for overtaking maneuvers when a close vehicle is detected, to reduce speed or stop the vehicle. In order to develop the model, several steps have been elaborated, and a set of parameters has been established as a framework for the scenario. Therefore, the simulation includes a two lane rural way, each lane containing actors or vehicle. Thus, of the three vehicles (designed A,B,C) equipped with a system called overtaking Assistance Systems (OAS) .vehicle (A) will be act as ego vehicle ,Vehicle B is a leading vehicles and Vehicle C as incoming vehicle. The leading vehicle (Vehicle B) gives a head road environment and incoming vehicles for following Vehicle (vehicle A) in the form LCD display. Thus, the final objective in this simulation is for the vehicle (A) to achieve the overtaking goals for the vehicle (B), called the leading vehicle. For further explanation of the simulation, the following section explains the process and the features simulation.

3.14 Simulation process

The development of the method consists of a simulation process that involves a subdivision that presents the argument in detail. Each subdivision also includes a description of the characteristics that the scenario needs to fulfill in order to simulate the overtaking maneuver. Fig.3.1 shows a general graphic representation of several steps or subdivisions used in MATLAB and Proteus. In total, 4 steps are identified, such as (1) Build the scenario, (2) Model the sensor systems, (3) Add the control system, and (4) Execute the experiment.. The following sections explain the 4 steps of the simulation process in detail when performing an overtaking scenario with OAS.

Table 3.1 Different scenario of warning and actuating system

Scenario Participant	Warning message	Actuator
1 straight road and no oncoming vehicle	Safe to overtake	engage
2 straight road and long range and low speed of oncoming vehicle	safe to overtake	engage
3 straight road and short range of oncoming vehicle	Not safe to overtake	Disengage throttle linkage
4 curved road	Not safe to overtake	Disengage throttle linkage

Method of simulation and scenario.

Figure3.13Graphic illustrations of 4 steps of simulation

3.14.1 Simulation of overtaking scenario

Table 3.2Overtaking conditions

Simulation condition	1.Two lane rural road ✓ Straight road ✓ Curved road 2.Three vehicle ✓ Vehicle A, ✓ Vehicle B, ✓ Vehicle C 3.vehicle A is faster than vehicle B, Vehicle C is incoming vehicle 4.Vehicle A would safely overtake Vehicle B if it only fulfill the possible criteria:- ✓ Road condition (straight or curved road) ✓ Range and speed of incoming vehicle ✓ Speed of leading vehicle
Result	Vehicle overtake safely Vehicle B and And go back to its first lane

3.14.2 Overtaking scenario 1 on straight road with no incoming vehicle

On this scenario the road is straight and there is no incoming vehicle on overtaking lane. Therefore if the speed of vehicle A is faster than leading vehicle (Vehicle B) , then Vehicle A can easily overtake Vehicle B since there is no obstacle in the road.

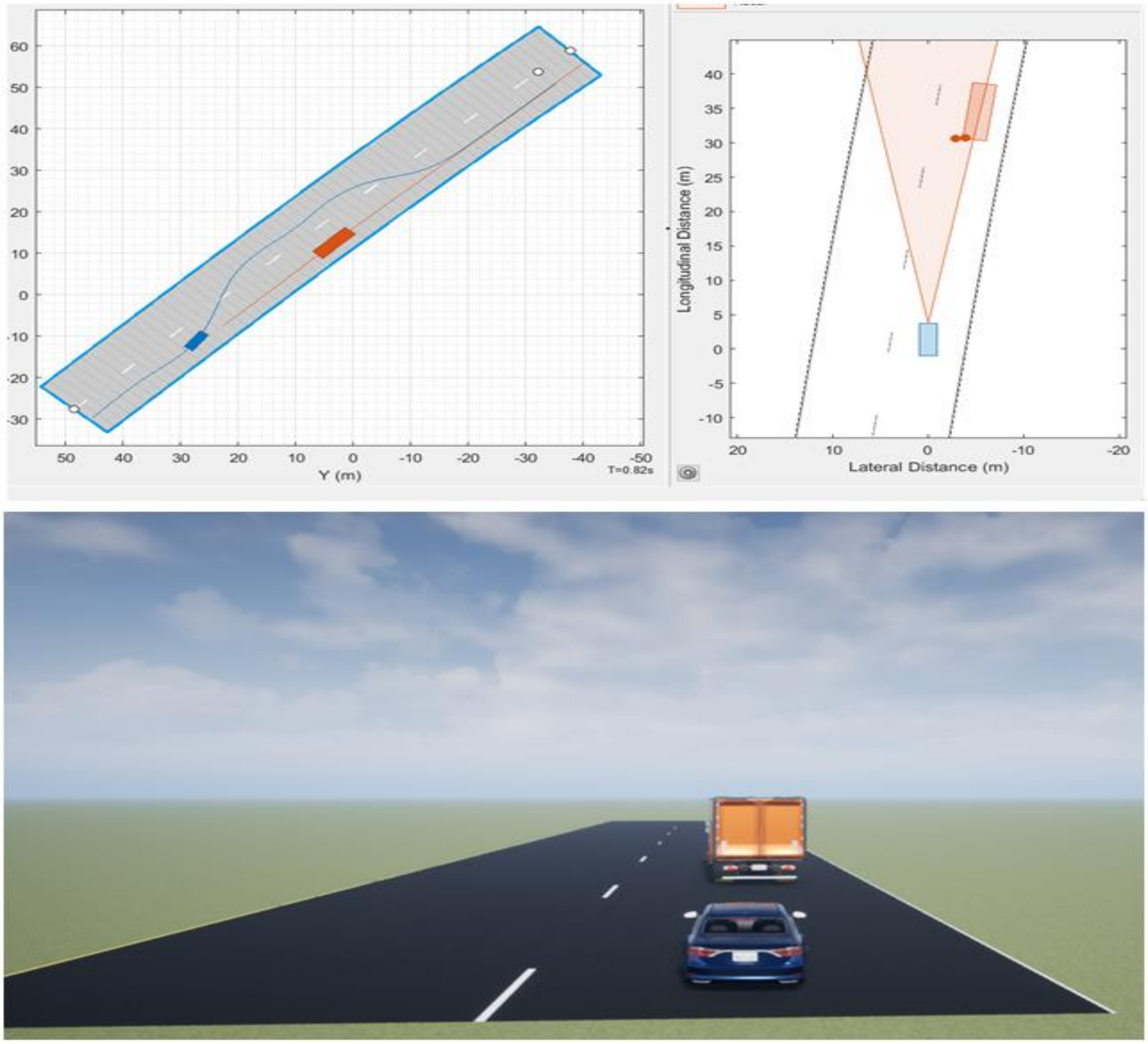


Figure3.14Overtaking safe scenarios on straight road with no obstacle

3.14.3 Overtaking scenario 2 on straight road with long range (>150m) incoming vehicle

On this scenario the road is straight and there is incoming vehicle on overtaking lane at long range. Therefore if the speed of vehicle A is faster than leading vehicle (Vehicle B) ,since the incoming vehicle on overtaking lane is at long range then Vehicle B Would display to vehicle A it is safe to overtake by computing and analyzing possible collision free.Then vehicle A Overtake Vehicle Safely within specific time of period.

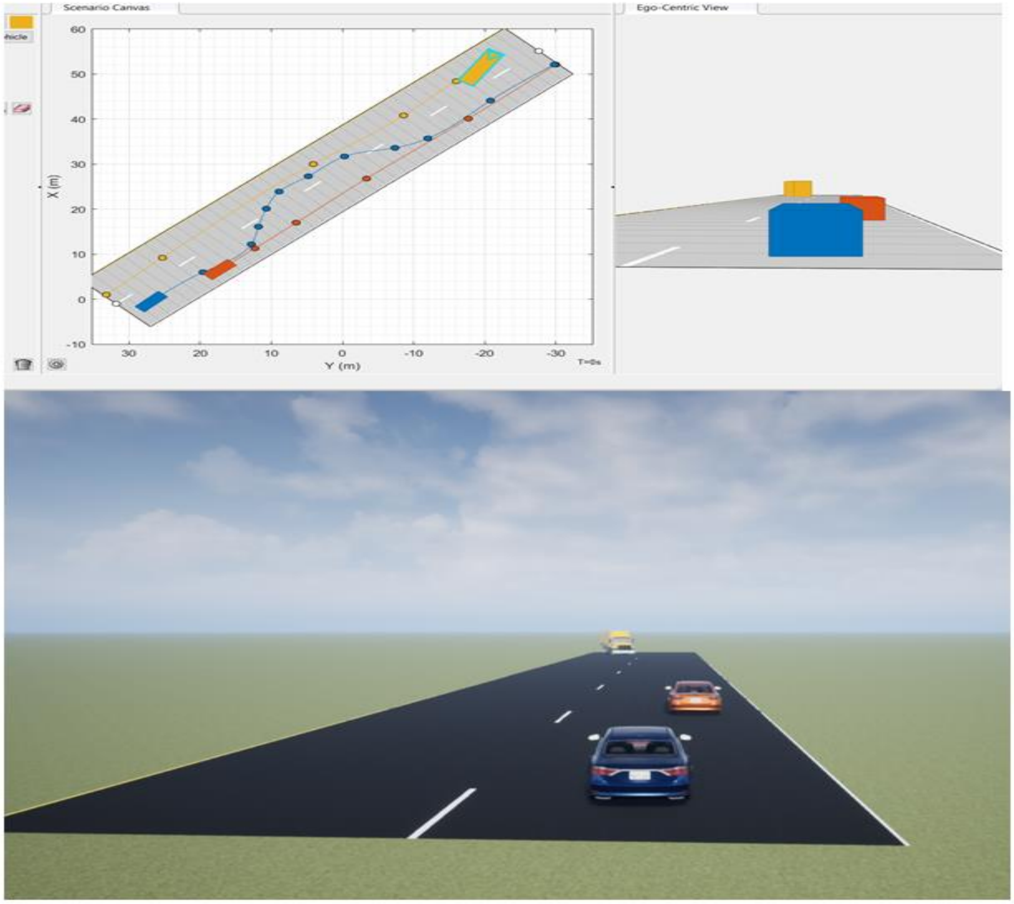


Figure3.15Overtaking safe scenarios on straight road at long range of incoming vehicle

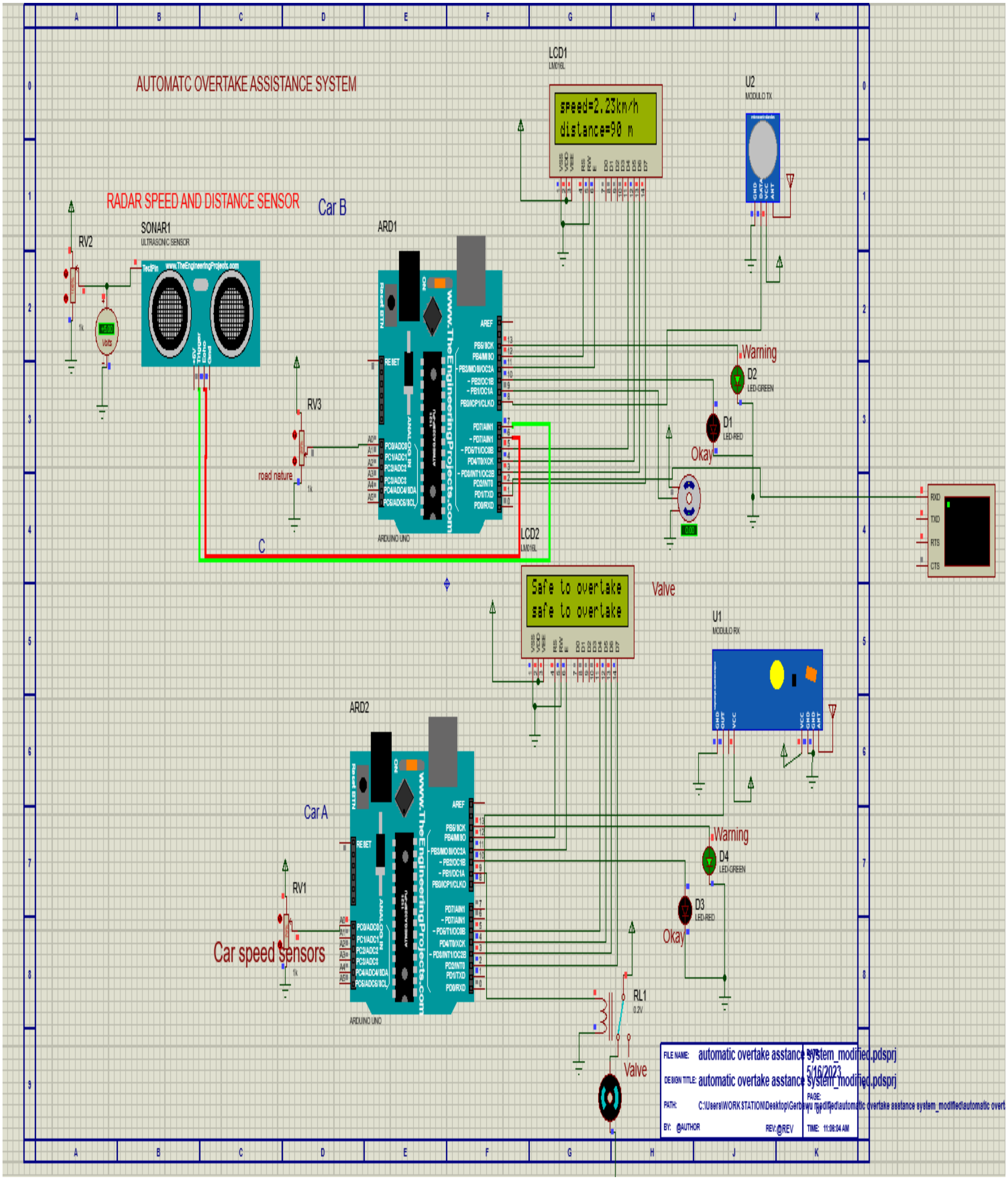


Figure 3.16 Overtaking safe scenario on straight road at long range of incoming vehicle

3.14.4 Overtaking scenario 3 on straight road with short Range (<50m) at incoming vehicle

On this scenario the road is straight and there is incoming vehicle on overtaking lane at short range. Therefore even if speed of vehicle A is faster than leading vehicle (Vehicle B) ,since there is incoming vehicle on overtaking lane is at short range then Vehicle B LCD fitted on it rear Would display to vehicle A it is not safe to overtake by computing and analyzing possible collision. Then vehicle A actuator close the designed throttle valve by help of microcontroller and actuator. Therefore the system not permits the driver to overtake for specific time of period.

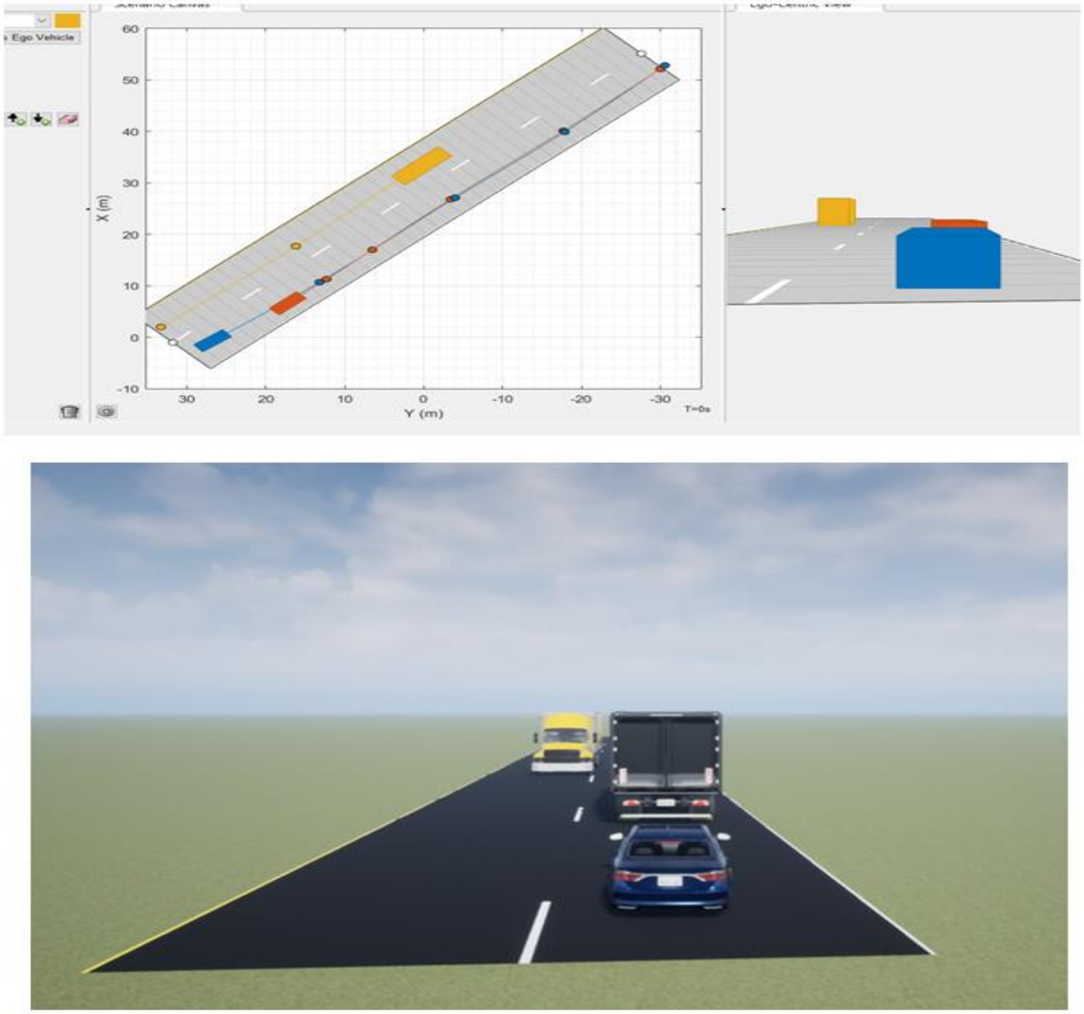


Figure3.17Overtaking not safe scenario on straight road at short range of incoming vehicle

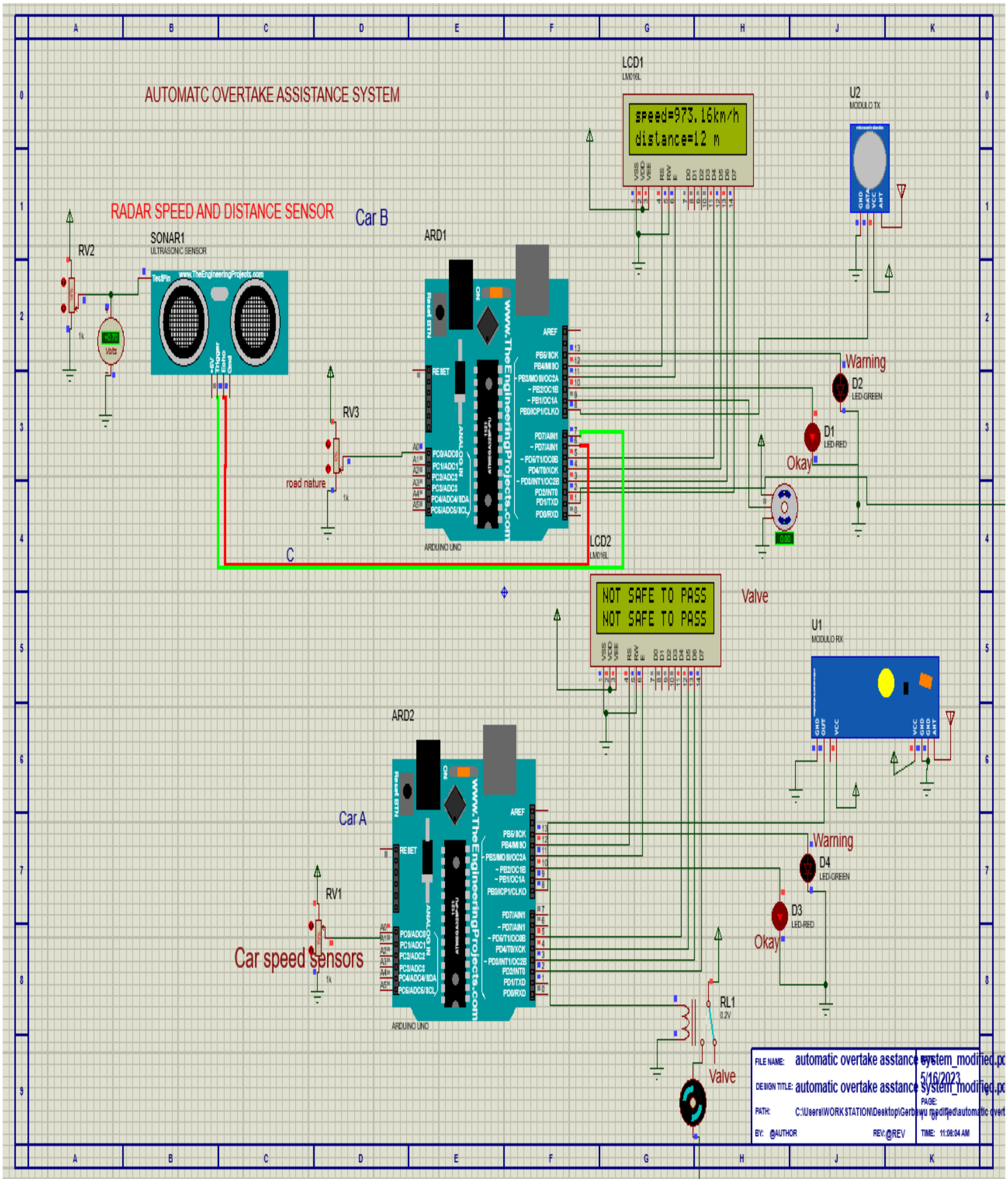


Figure3.18Overtaking not safe codes on straight road at short range of incoming vehicle

3.14.5 Overtaking scenario 4 on curved road

Detecting curved roads using radar sensors involves the use of radar technology to sense and interpret the geometry of the road ahead. This capability is crucial for a wide range of applications, including advanced driver assistance systems (ADAS), autonomous vehicles, and road safety systems. Here's an overview of how radar sensors can be employed to detect curved roads:-

1. Radar Sensor Operation: Radar sensors emit radio frequency signals and analyze the reflected signals to detect objects and surfaces within their field of view. They measure the time delay and Doppler shift of the reflected signals to determine the distance, relative velocity, and angle of detected objects.

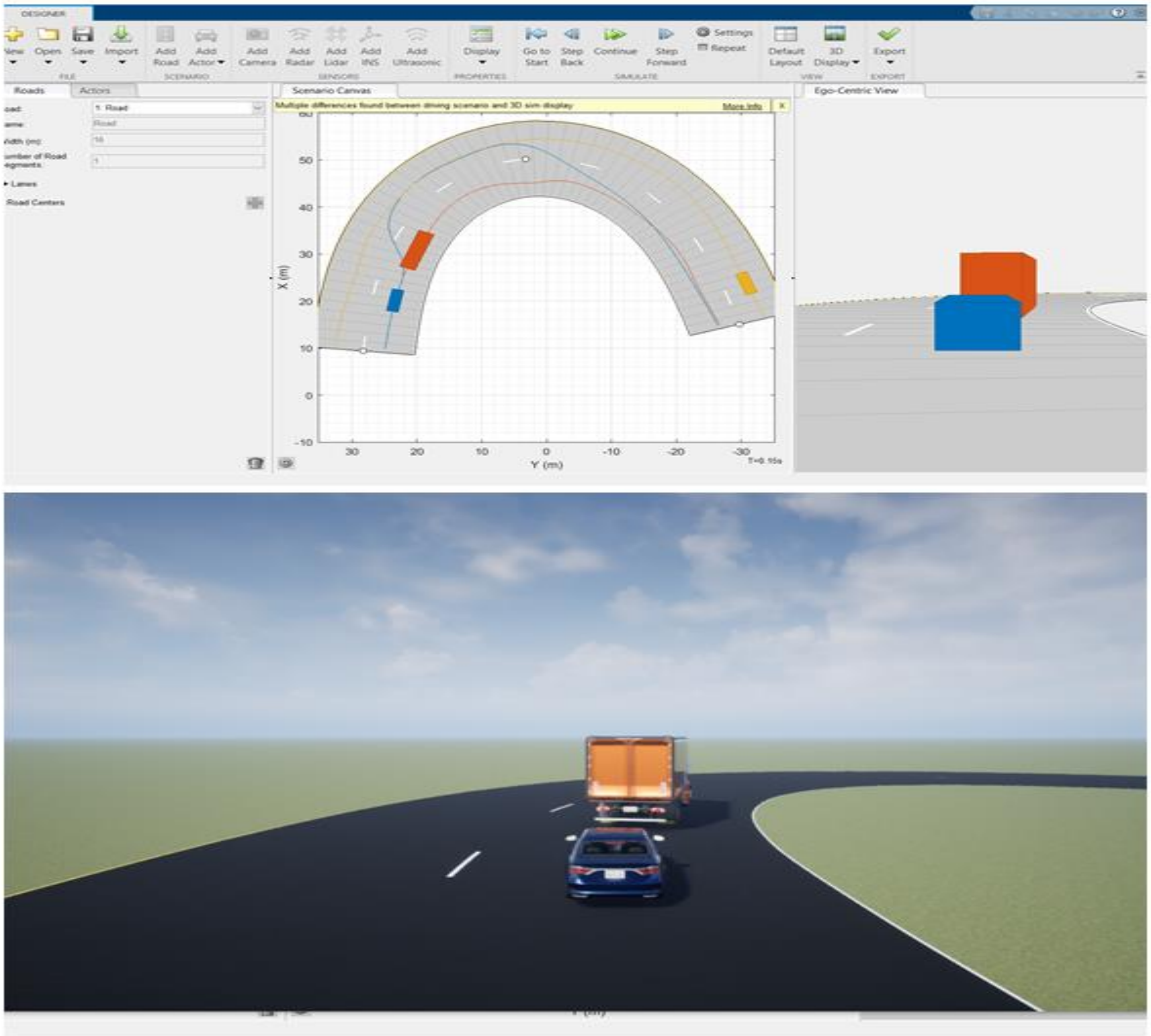
2. Signal Processing for Road Detection: Radar signal processing techniques are employed to interpret the reflections from the road surface and surrounding objects. By analyzing the received signals, radar sensors can identify the presence of a road surface and distinguish it from other objects and terrain.

3. Reflection Characteristics: Radar sensors are sensitive to the reflective properties of different surfaces. The interaction between the emitted radar signal and the road surface offers distinct characteristics that can be utilized for road detection, even on curved surfaces.

4. Angle of Arrival Estimation: Radar sensors can estimate the angle of arrival of the reflected signals. By analyzing the angular distribution of reflected radar energy, the sensor can infer the curvature of the road ahead.

Figure3.19Detecting road side sign for curved road (S H Supangkat 2018)

On this scenario the road is curved and it’s out of sight of sensors angle to know whether there is incoming vehicle or not. Therefore the leading vehicle Display Not safe to overtake for following vehicle since the its out of the sight of sensors. Therefore even if speed of vehicle A is faster than leading vehicle (Vehicle B) Vehicle B LCD Would display to vehicle A it is not safe to overtake by because of nature of road. Then vehicle actuator closes the designed throttle valve by help of microcontroller and actuator. Therefore the system doesn’t permit the driver to overtake for specific time of period.



Multiple differences found between driving scenario and 3D sim display More Info

Road: 1: Road

Name: Road

Width (m): 16

Number of Road Segments: 1

Figure3.20 Overtaking scenarios not safe on curved road

Analysis on overtaking Car speed vs. distance/curve and Optimum distance for a given velocity of each car recommend during overtake.

The distance required to overtake a vehicle depends on the speed at which both vehicles are traveling. The safest distance to overtake is one that allows sufficient time to complete the pass without creating a dangerous situation for oncoming traffic or the vehicle being overtaken. The calculation of this distance requires several variables, including the current speed of the vehicle being overtaken, the desired speed while overtaking, and the acceleration and deceleration factors of the vehicle performing the overtaking.

Assuming that the overtaking vehicle is traveling at a constant speed of V, and the vehicle being overtaken is traveling at a constant speed of U, the safe distance, D, required to complete the overtake can be estimated using the following equation:

$$D = \frac{2 * V}{V + U} * \sqrt{V^2 - U^2}$$

This equation can be broken down as follows:

D = (2 * V) / (V + U) represents the time required to overtake the reaction time. This typically ranges from 1 to 2 seconds depending on various factors such as driver alertness, road conditions, etc. (2 seconds divided by the sum of the overtaking vehicle's speed and the vehicle being overtaking’s speed).

(V^2 - U^2)^0.5 is the distance covered by the over taker during the overtaking time (V^2 - U^2) raised to the power of 0.5.If the speed of the overtaken vehicle is known, the optimum distance during the overtaking can be calculated using the following formula:

Optimum Distance = (0.5 * Speed of Overtake) / (Speed of over taker - Speed of Overtaken)

$$Do = \frac{v}{2} * (v - u)$$

The first part of the equation, 0.5 * Speed of overtake, represents the distance that the overtake travels in the time it takes to overtake the Overtaken vehicle. The second part of the equation, Speed of overtake - Speed of Overtaken, represents the time it takes for the overtaking to overtake the Overtaken vehicle.

CHAPTER FOUR

RESULT AND DISCUTION

4.1 Result

Simulations were performed with different threshold settings, that is, the minimum gap recommended by the system as an overtaking opportunity, including 8, 9.5, 11, 12.5 and 14 s and 30, 50, 80,100km/hr. Low-Speed Overtake (30-50 km/h)in this speed the optimum safe distance could be around 50-100 meters, providing ample time for the overtaking maneuver without endangering others. Medium-Speed Overtake (50-80 km/h) Maintaining a distance of about 100-150 meters for a safe overtake at moderate speeds. And finally the high-Speed Overtake (80+ km/h) for high-speed overtakes; consider distances of 150-300 meters or more, accounting for the increased speed and potential reaction times.

The overtaking distance ranges from 50m to 300m. Safety is determined based on a threshold distance is 150. Overtaking is considered safe if the distance is below the threshold. Figure 4.1 is created with overtaking distance on the x-axis and the safety of overtaking (Safe: 1, Not Safe: 0) on the y-axis. The graph will show areas where overtaking is safe and not safe based on the defined criteria as overtaking distances change over time.

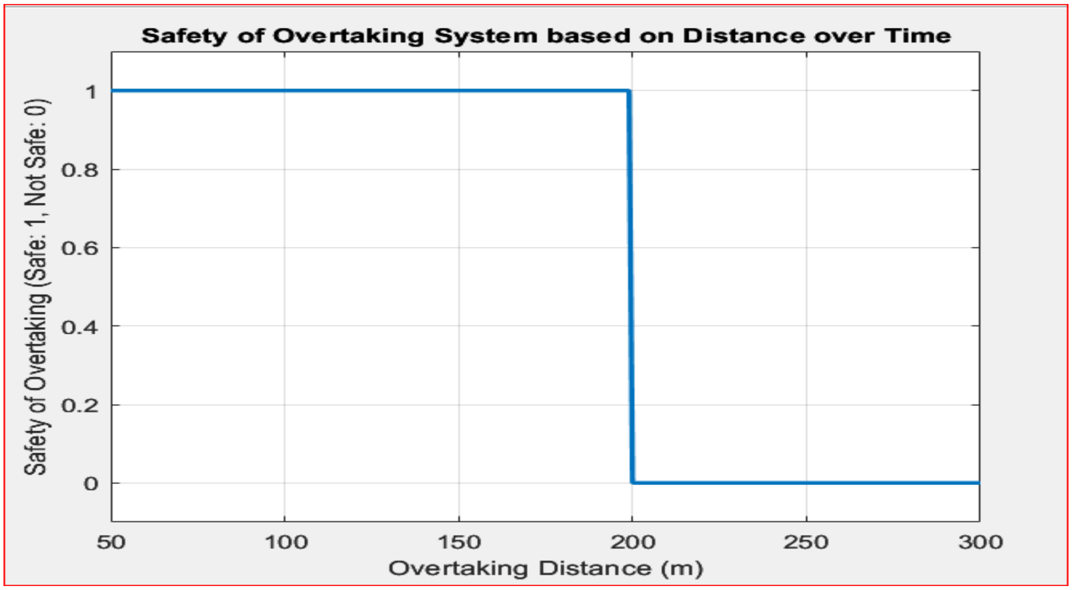


Figure 4 1Safety overtaking based on distance over time

The overtaking speed ranges from 30 km/hr. to 120 km/hr. Safety is determined based on a threshold speed (80 km/hr. in this example). Overtaking is considered safe if the speed is below the threshold. A plot is created with overtaking speed on the x-axis and the safety of overtaking (Safe: 1, Not Safe: 0) on the y-axis. The graph will show areas where overtaking is safe and not safe based on the defined criteria.

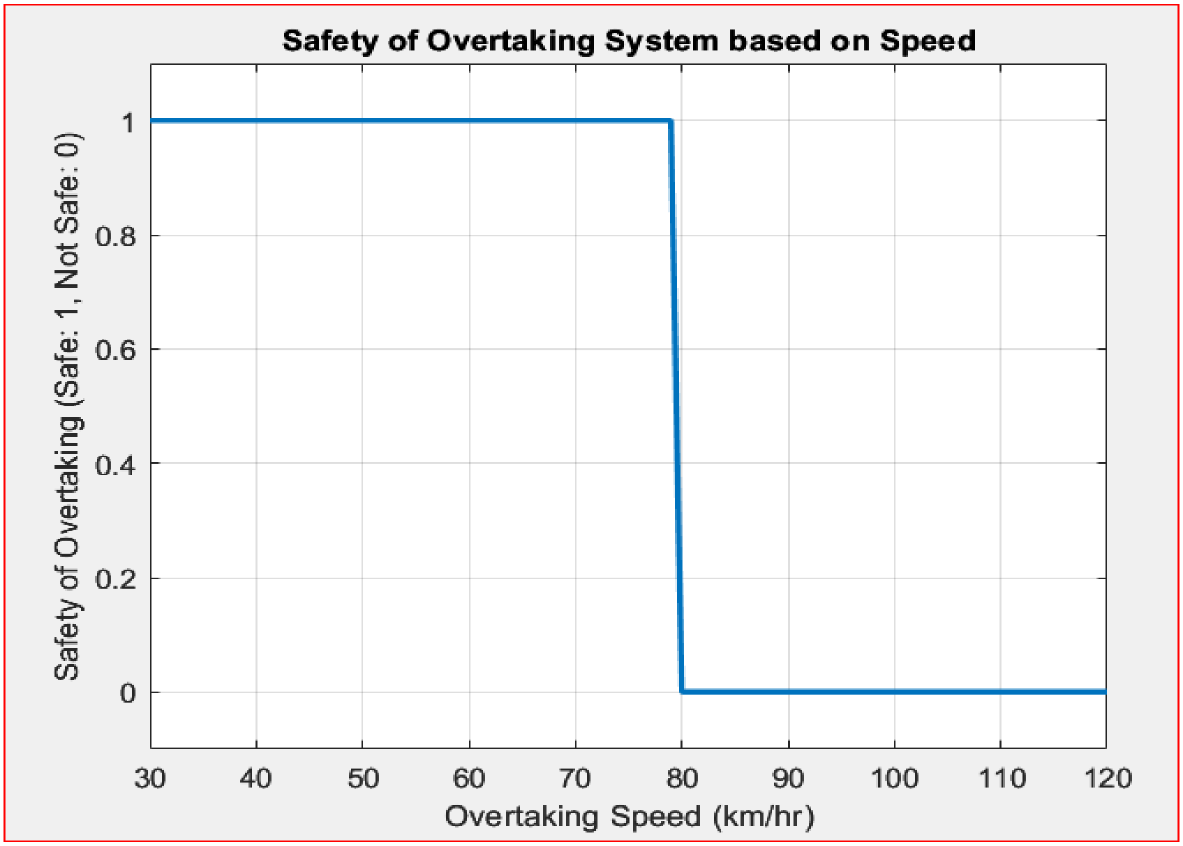


Figure 4 2 Safety overtaking system based speed

4.1.1Analysis on overtaking Car speed vs. distance/curve

The graph of the equation

$$D = \frac{2 * V}{V + U} * \sqrt{V^2 - U^2}$$

Was plotted with a constant value of \(U = 40\) m/s and \(V\) ranging from 41 m/s to 100 m/s.

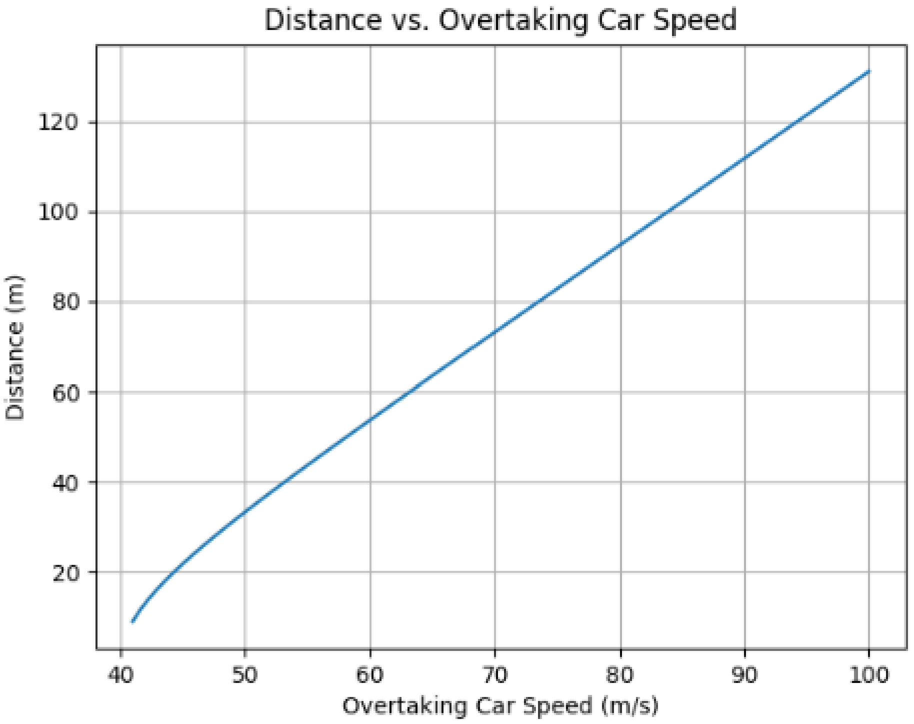


Figure 4 3Distance vs. overtaking car speed graph

As shown in the graph, the distance required for overtaking D increases as the speed of the overtaking car V increases. This is consistent with the expected behavior, as higher speeds require more time and distance to safely overtake another vehicle. Additionally, the curve exhibits a smooth and continuous increase, indicating a proportional relationship between overtaking car speed and the distance required for overtaking. The results obtained from the graph provide valuable insights for understanding the relationship between car speeds and overtaking distances on roads where overtaking maneuvers are common. This information can be utilized by traffic engineers, policymakers, and road safety advocates to develop strategies for optimizing road design, speed limits, and traffic management practices to enhance overall safety on the roads. Further analysis and interpretation of the graph can offer deeper insights into specific scenarios and conditions affecting overtaking maneuvers, such as road curvature, visibility, traffic density, and driver behavior. These factors should be considered when designing interventions and policies aimed at improving road safety and efficiency.

4.2 Discussion

The majority of research on autonomous overtaking has been conducted on multi-lane roads, treating it as a static or moving obstacle avoidance problem without taking into account any opposite vehicles. However, single-lane overtaking is a regular scenario in the real world in which a vehicle must cross the opposite lane, and overtaking becomes more difficult and dangerous when a fast approaching vehicle is present. Furthermore, prior research has primarily focused on overtaking on straight roads, with no guarantee that it will work on a curved road. As a promising solution to this problem, we develop in this paper a novel optimal trajectory generation scheme for autonomous overtaking in a smooth and safe manner on a single-lane road. We consider different road constraints, opposite vehicles, and slow or stopped preceding vehicles in the optimization process. Moreover, we obtain the optimal overtaking costs for various states of the surrounding traffic. The proposed scheme has some limitations, e.g., it requires perfect information of surrounding traffic, and traffic flow uncertainties or randomness are not considered in the optimization process. Although the scheme can generate optimal trajectories in critical cases, any risky overtaking in an uncertain situation with the opposite vehicle should be made by an extra safety margin. Overtaking in such an uncertain situation can be handled efficiently by adequately tuning the parameters associated with the scheme based on the types and levels of uncertainty. If the associated vehicles are connected–automated, V2V communication can be employed to have precise information instead of onboard sensors to overcome traffic uncertainty and randomness.

CHAPTER FIVE

CONCULUSION AND RECOMMENDATION

5.1 Conclusion

In this paper, we have developed model of throttle linkage to control the acceleration of overtaking vehicle to avoid different moving obstacles or vehicles in order to ensure driving safety and efficiency. The proposed scheme is based on solving an optimal prediction problem with the goal of minimizing driving costs while eliminating collision risks in the presence of any opposite vehicle on the overtaking lane. The simulation is applicable to both straight and curved roadways, and can be implemented in real-time. The scheme is tested on a real single-lane curved road, with stopped and slow vehicles in the lane, as well as the presence or absence of a vehicle in the opposite lane. The findings show that the proposed scheme is effective at both lane keeping and changing lanes successfully while overtaking. The optimal overtaking trajectories determined for various conditions of the associated vehicles show that the best overtaking state to initiate an overtaking maneuver in the course of driving can be identified from the obtained cost characteristics. In contrast to the existing overtaking schemes found in the recent literature, the proposed overtaking scheme can be incorporated with any driving system for providing smooth and safe overtaking trajectories over the opposite lane despite road curves and the presence of the opposite vehicle according to the illustrated simulation results. The proposed system can be employed on advanced driver assistance system (ADAS). In the perspective of the forthcoming automotive revolution on connected–automated driving, the proposed scheme can be further enhanced to develop a cooperative driving scheme. The proposed optimal overtaking scheme is expected to play an essential role in enhancing transportation sustainability by smoothing traffic flows and alleviating the adverse effects of traffic bottlenecks in challenging driving scenarios addressed in this study. In future work, the scheme will be extended for cooperative overtaking maneuver in a dense traffic conditions using inter-vehicle communication technology. The system has the potential to significantly reduce number of accidents caused by overtaking on the roads. The thesis likely involved a detailed analysis of the causes of overtaking collisions, as well as the development of a system that uses sensors and algorithms to detect potential collisions and alert drivers in real-time. The system was effective in preventing collisions in simulated scenarios, and that it has potential to be implemented in vehicles in the future to enhance road safety. Additionally it has advantage for transportation industry and society as a whole. Therefore implementing the overtaking collision prevention system in vehicle will improve the road safety. Finding a solution to the problem of head-on accidents on rural two-lane highways caused by unprotected drivers trying to pass obstructed cars without having enough information about the relative location and speed of the opposing vehicle was the aim of this research effort. By lowering the possibility of human mistake, the overtaking collision reduction system framework for two-lane roads created in this study can assist drivers in avoiding passing collisions.

The objectives of this study were to: (1) review the literature on current passing sight distance models and collision warning systems; (2) gather data on passing maneuvers through field and driving simulator studies; (3) create deterministic and reliable-based models for passing sight distance (PSD) that take driver characteristics into account; (4) create an in-vehicle overtaking collision reduction system that takes driver characteristics into account; and (5) use Simulink to simulate real-world driving scenarios.

The aim of this thesis was to design an overtaking collision prevention system that can detect and prevent collisions when a vehicle is attempting to overtake another vehicle on the road. The system was designed to use a combination of sensors, including radar and cameras, to detect other vehicles and assess the risk of a collision in real-time. The simulation result of the study is a fully functional overtaking collision prevention system that was successfully tested. The system uses a combination of MATLAB algorithms and image processing techniques to accurately detect other vehicles and assess the risk of a collision. When a collision risk is detected, the system automatically takes action to prevent the collision, such as alerting the driver to take evasive action, slowing the vehicle down, or steering the vehicle to avoid the threat. The system designed to able to accurately detect and respond to oncoming vehicles, cyclists, and pedestrians, and could automatically adjust its response based on the speed and position of the threat. Overall, the overtaking collision prevention system is useful in preventing collisions and enhancing the safety of the driver and passengers. Future work could include enhancing the system's performance in adverse weather conditions or in situations where other vehicles are not present in the same lane.

5.2 Recommendation

Conduct further research on the impact of the system on driver behavior and road safety to ensure its effectiveness in real-world scenarios. Use data analytics and machine learning to improve the system’s accuracy and performance over time. Collaborate with car manufacturers to integrate with the system into new vehicle as a standard safety feature. Develop a communication protocol between the overtaking collision prevention system and other safety features in the vehicle, such as lane departure warning and forward collision warnings, to create a comprehensive safety system. Conduct further testing and refinement of the system to ensure its effectiveness in preventing overtaking collisions and false alarms. Work with transport authorities to raise awareness of the importance of overtaking safety and promote the use of this system

REFERENCE

American Association of State Highway and Transportation Officials. (2004). *A Policy on Geometric Design for Highways and Streets. AASHTO, Washington, D. C.*

Bar-Gera, H. &. (2005). *The tendency of drivers to pass other vehicles. Transportation Research Part F: Traffic Psychology and Behaviour, 8(6), 429-439.*

Bonneson, J. (1992). *Modeling queued driver behavior at signalized junctions. Transportation.*

Brown, R.L., and Hummer, J.E. . (2000). *Determining the best method for measuring no-passing zones. Transportation* . Research Record 1701.

Burgett, A. (2005). .*Methodologies for Evaluating the Impact on Safety of Intelligent Vehicle.* MUNICH.

Campbell, J. L., Carney, C., and Kantowitz, B. H. (1998). . *Human factors design guidelines for advanced traveler information systems (ATIS) and commercial vehicle operations (CVO).* DC: Federal Highway Administration, Washington.

Chandra, S., & Shukla, S. . (2012). *Overtaking behavior on divided highways under mixed traffic conditions. Procedia-Social and Behavioral Science.*

Dabbour, E. M. S. (2009). *Development of in-vehicle collision warning system for intersections* .

Dabbour, Essam and Easa, Said M. (2014). *"Proposed collision warning system for right-turning.*

Dabbour, Essam and Easa, Said M. (2014). Proposed collision warning system for right-turning vehicles at two-way stop-controlled rural intersections", Elsevier Journal for Transportation Research, P. *Proposed collision warning system for right-turning vehicles at two-way stop-controlled rural intersections", Elsevier Journal for Transportation Research, Part C 42. Vol. 121-131.*, pp. art C 42. Vol. 121-131.

Dawson, J. D., Uc, E. Y., Anderson, S. W., Dastrup, E., Johnson, A. M., & Rizzo, M. (. (2009). *Ascertainment of on-road safety errors based on video review. In Proceedings of the... International Driving Symposium on Human Factors in Driver Asse.* NIH public access.

Deme, D. (2019). *Review on factors causes road traffic accident in Africa.* Journal of Civil Engineering Research & Technology.

Farah, H. (2009). *Development of Models to Evaluate Safety of Two-Lane Highways Based on Infrastructure, Traffic Characteristics and Drivers' Behavior.*

Farah, H. (2013). *Modeling drivers' passing duration and distance in a virtual environment.* . IATSS research.

Farah, H., & Toledo, T. (2010). *Passing behavior on two-lane highways.* .

Flexman, R.E. and Stark, E.A. (1987). *Training simulators. Handbook of Human Factors.*

Garcia-Lozano E. Barba C.T. Igartua M.A. Campo C. A. (2013). *smart communication in network technologies.* Paris France: Saconet.

Garcia-Lozano, E.; Barba, C.T.; Igartua, M.A.; Campo, C. (2013). *A distributed, bandwidth-efficient accident prevention system for interurban VANETs.* International Conference on Smart Communications in Network Technologies (SaCoNeT).

Ghods, A. H. (2013). *Microscopic overtaking model to simulate two-lane highway traffic operation and safety performance.*

Granet, F. Picado, R.; and Smith, L. . (Longitudinal Collision Avoidance.). *2003.* USA: Institute of transportation studies at university of california.

Hamid, S., & Davoud, K. Z. (2019). *Road traffic injuries measures in the Eastern Mediterranean Region: findings from the Global Status Report on Road Safety.* Journal of injury and violence research,.

Harwood, D. W. (2007). *Passing Sight Distance Criteria.* Washington, D.C: Transportation Research Board of the National Academies.

Harwood, D.W. & Glennon, J. C. . (1989). *“ Passing sight distance design for passenger cars .*

Hassan, Y., Easa, S. M., & Abd El Halim, A. O. (1996). *Passing sight distance on two-lane highways.*

Hegeman, G. (2004). *Overtaking frequency and advanced driver assistance systems.* . In IEEE Intelligent Vehicles Symposium,.

Isermann, R. M. (2012). *Collision-avoidance systems PRORETA: Situation analysis and intervention control.* Control Engineering Practice,.

Kaptein, N.A., Theeuwes, J., and Horst, A.R.A. van der. (1996). *Driving simulator validity:.*

Khajehpour, B. ((2013)). *crisis on the roads.* Iran's : Al-Monitor.

Kussia, A. (2017). *Trends, Causes, and Costs of Road Traffic Accidents in.* Addis Ababa Ethiopia: journal of road safety.

Llorca, C. and Farah, H.". (2016). *Passing Behavior on Two-Lane Roads in A Real and in A.*

Llorca, C., & García, A. . (2011). *Evaluation of passing process on two-lane rural highways in Spain with new methodology based on video data.* Transportation research record,.

Llorca, C., and A. García. (2011). *"Evaluation of Passing Process on Two-Lane Rural Highways.*

Long, G. (2000). *Acceleration characteristics of starting vehicles.* . Transportation Research Record.

Mehmood, A. (2010). *Development of framework for in-vehicle rear-end collision warning system considering driver characteristics.*

Mousa, R. (2002). *Analysis and modeling of measured delays at isolated signalized.*

Nilsson L., Alm H. and Janssen W.H. (1991). *"Collision avoidance systems: Effects of different levels of task allocation on driver behaviour." Driver Project V1041 Haren.* Driver Project V1041 .

Pollatschek, M. A., and A. Polus. ((2005).). *"Modeling Impatience of Drivers in Passing Maneuvers.".*

Rezagholipour, K, Massoudian, N., & Eshghi, M. December). (2016). *Modeling and reducing overtaking accidents on two-lane curved road. In 2016 2nd International Conference of Signal Processing and Intelligent Systems (ICSPIS) (pp. 1-5). IEEE.*

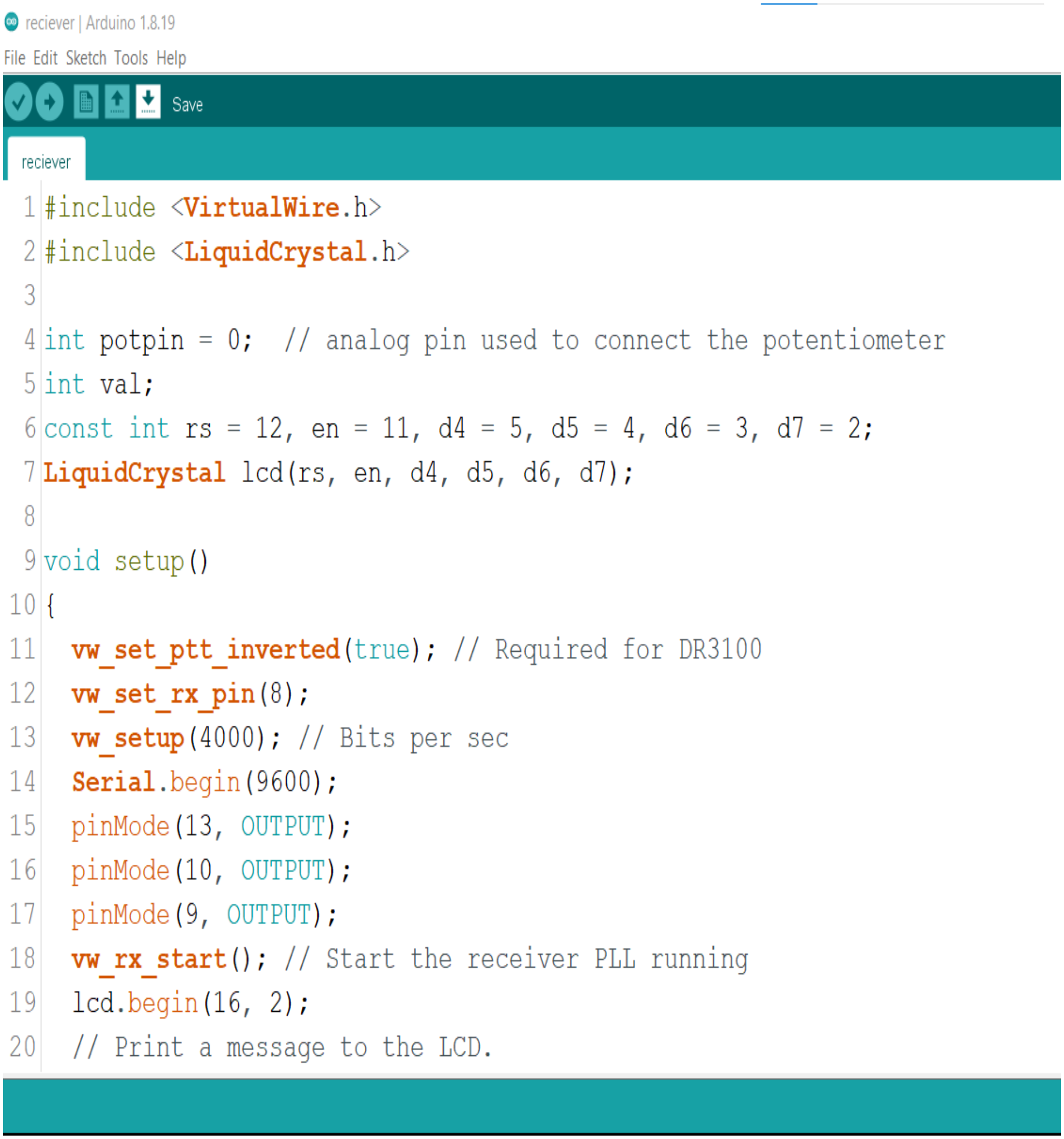
S.Jeon, B.Kim. (2016). *V2V-Based Evaluation of Overtaking A Risk in Curved Road Conditions* . International Journal of Applied Engineering Research.

Treat, J. R., Tumbas, N. S., McDonald, S .T., ShinaD.Hume, R. D. Mayer, R. E., Stanisfer, R. L and Castillan, N. J. (1977). *Tri-level study of the causes of traffic accidents.* Indiana University.

Vlahogianni, E. I. (2013). *Modeling duration of overtaking in two lane highways. Transportation research part F: traffic psychology and behaviour.*

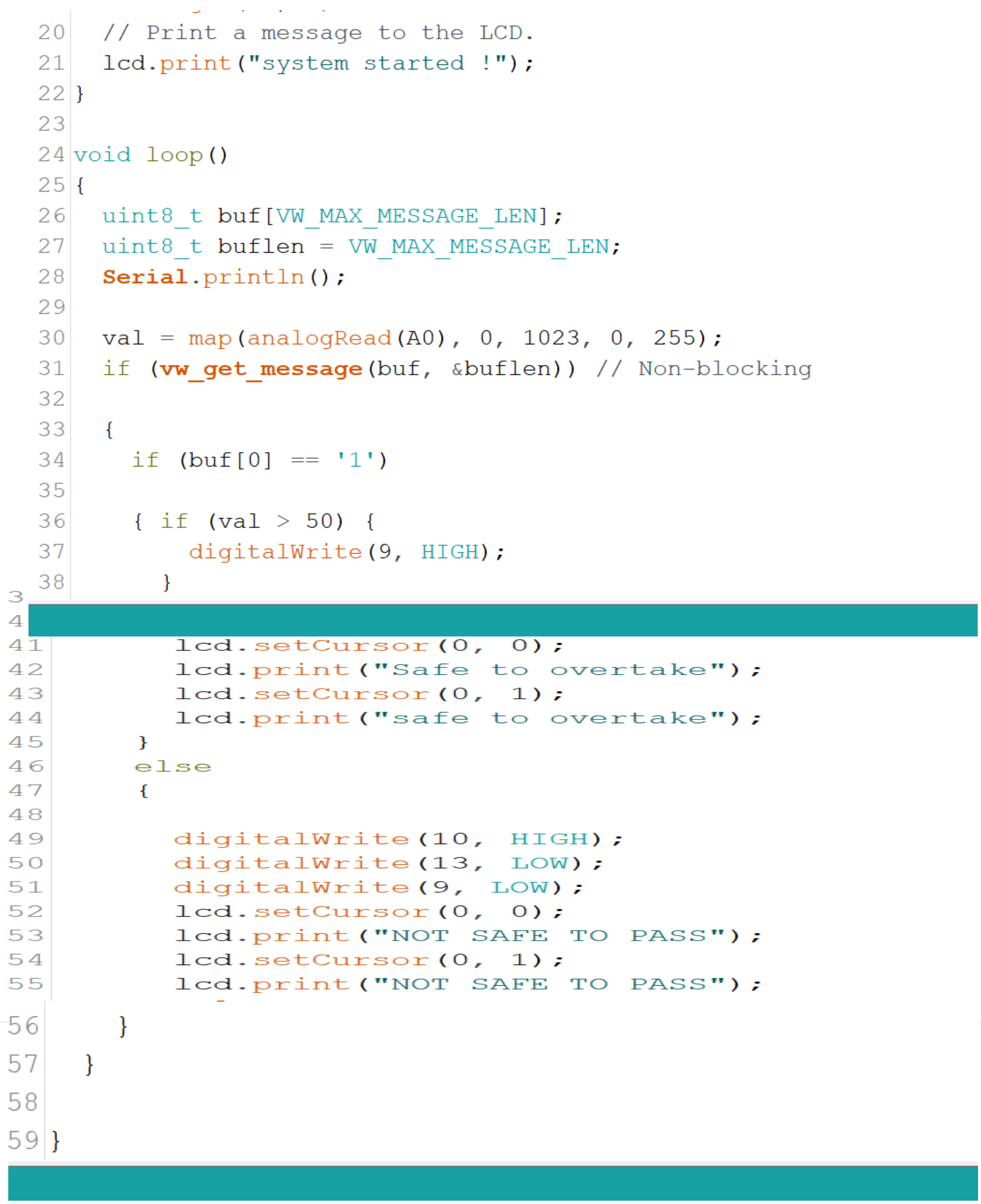
Appendix

Arduino code of receiver



```
#include <VirtualWire.h>
#include <LiquidCrystal.h>

int potpin = 0;  // analog pin used to connect the potentiometer
int val;
const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

void setup()
{
  vw_set_ptt_inverted(true); // Required for DR3100
  vw_set_rx_pin(8);
  vw_setup(4000); // Bits per sec
  Serial.begin(9600);
  pinMode(13, OUTPUT);
  pinMode(10, OUTPUT);
  pinMode(9, OUTPUT);
  vw_rx_start(); // Start the receiver PLL running
  lcd.begin(16, 2);
  // Print a message to the LCD.
```

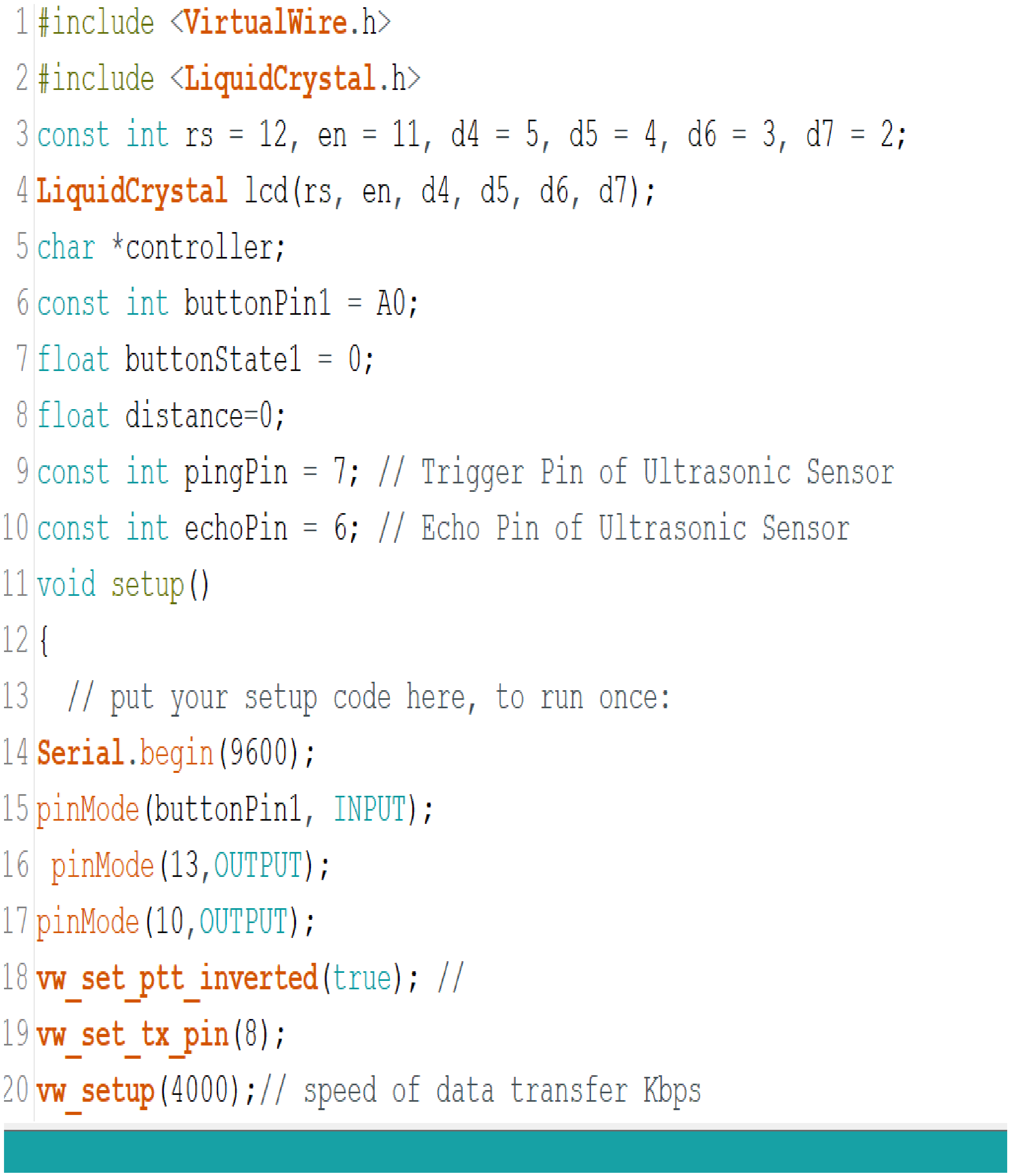
Arduino code for receiver



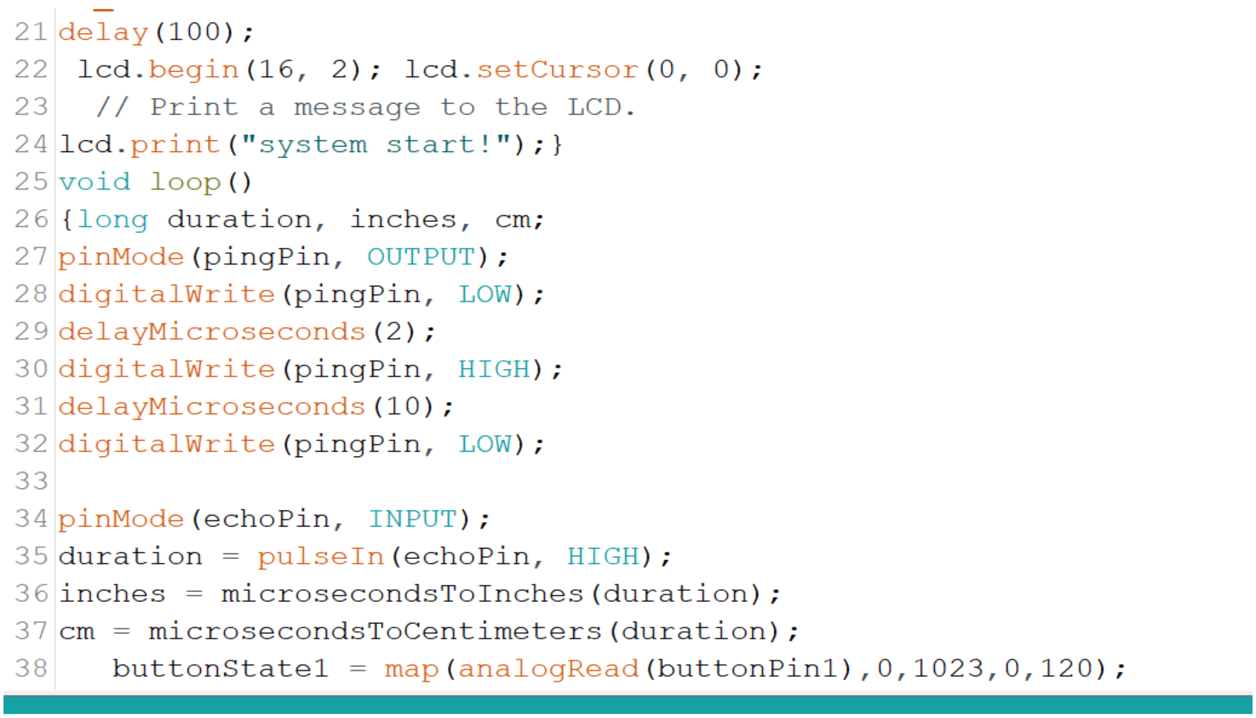
```
  // Print a message to the LCD.
  lcd.print("system started !");
}

void loop()
{
  uint8_t buf[VW_MAX_MESSAGE_LEN];
  uint8_t buflen = VW_MAX_MESSAGE_LEN;
  Serial.println();

  val = map(analogRead(A0), 0, 1023, 0, 255);
  if (vw_get_message(buf, &buflen)) // Non-blocking

  {
    if (buf[0] == '1')

    { if (val > 50) {
        digitalWrite(9, HIGH);
      }
```

```
          lcd.setCursor(0, 0);
          lcd.print("Safe to overtake");
          lcd.setCursor(0, 1);
          lcd.print("safe to overtake");
      }
      else
      {

          digitalWrite(10, HIGH);
          digitalWrite(13, LOW);
          digitalWrite(9, LOW);
          lcd.setCursor(0, 0);
          lcd.print("NOT SAFE TO PASS");
          lcd.setCursor(0, 1);
          lcd.print("NOT SAFE TO PASS");
     }
  }

}
```

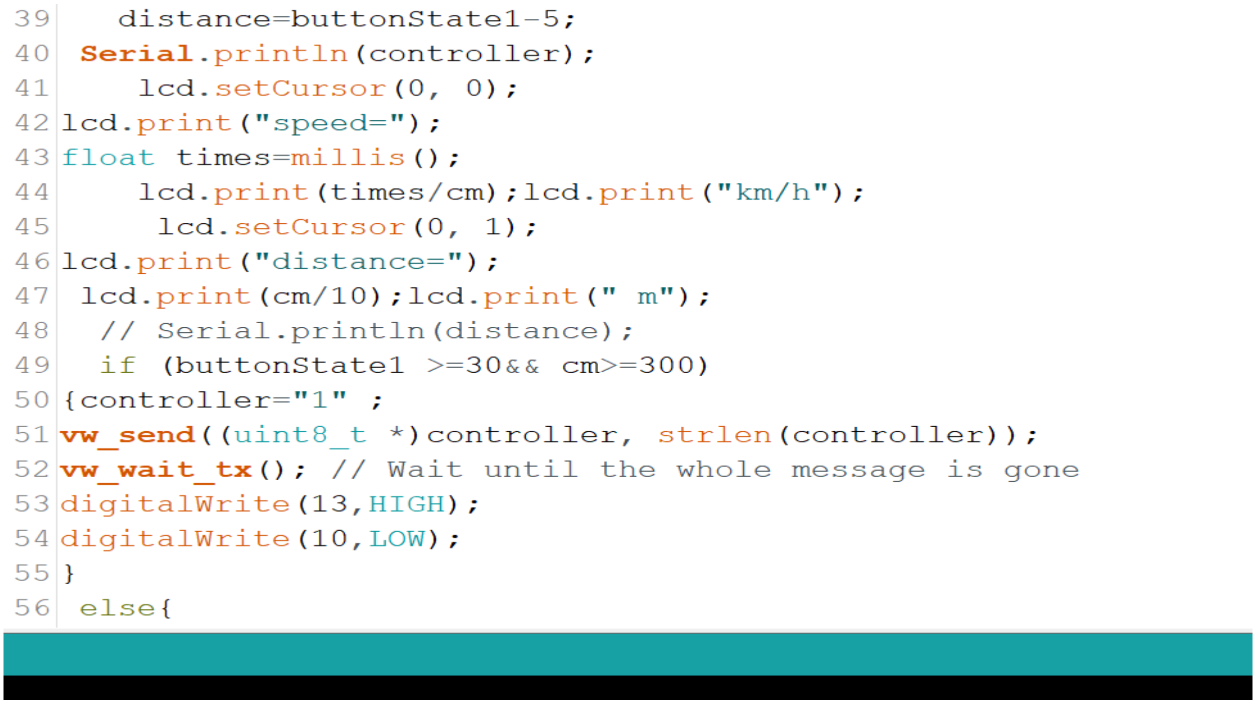
Arduino code for transmitter



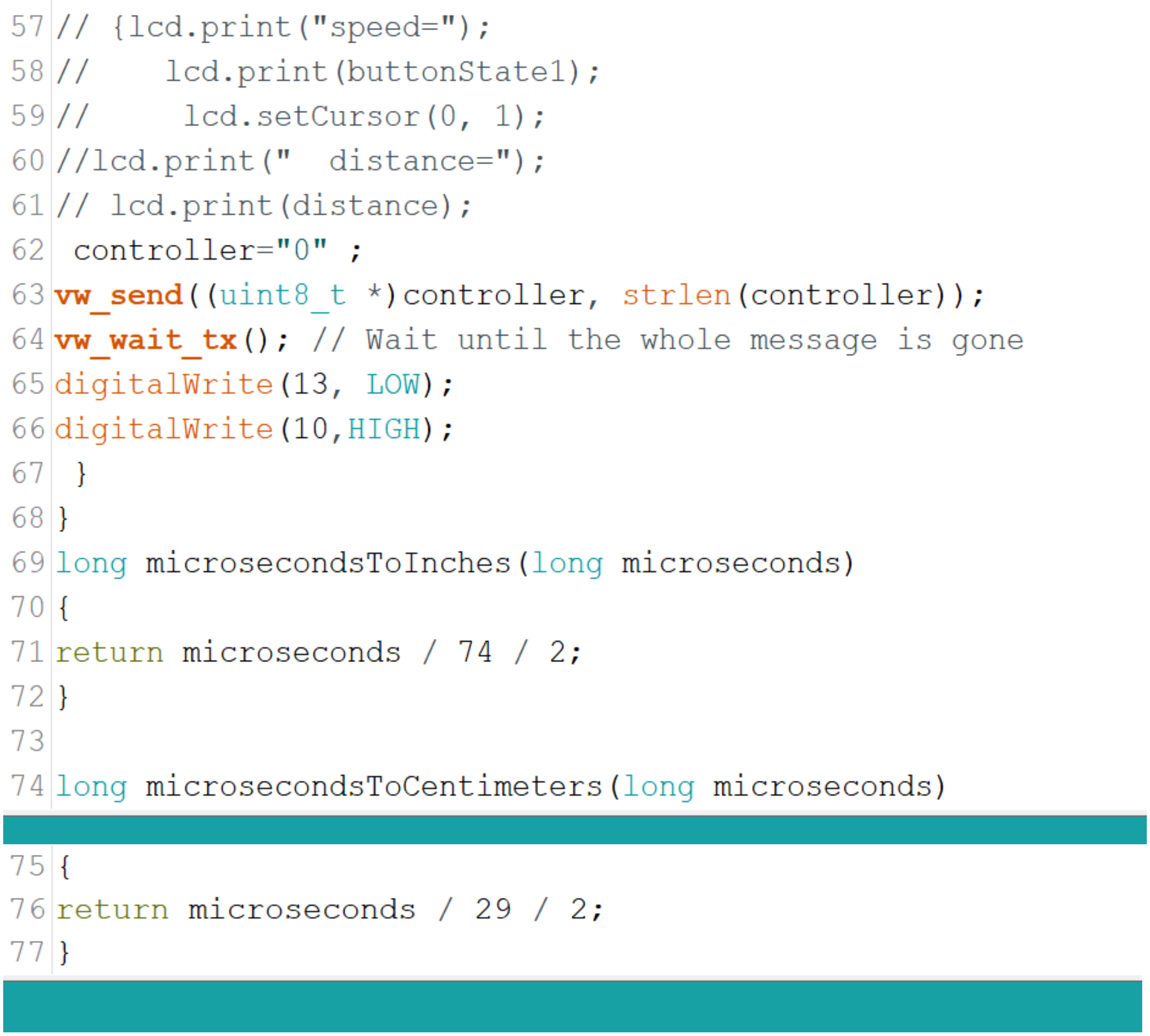
```
#include <VirtualWire.h>
#include <LiquidCrystal.h>
const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);
char *controller;
const int buttonPin1 = A0;
float buttonState1 = 0;
float distance=0;
const int pingPin = 7; // Trigger Pin of Ultrasonic Sensor
const int echoPin = 6; // Echo Pin of Ultrasonic Sensor
void setup()
{
  // put your setup code here, to run once:
Serial.begin(9600);
pinMode(buttonPin1, INPUT);
 pinMode(13,OUTPUT);
pinMode(10,OUTPUT);
vw_set_ptt_inverted(true); //
vw_set_tx_pin(8);
vw_setup(4000);// speed of data transfer Kbps
```



```
delay(100);
 lcd.begin(16, 2); lcd.setCursor(0, 0);
   // Print a message to the LCD.
lcd.print("system start!");}
void loop()
{long duration, inches, cm;
pinMode(pingPin, OUTPUT);
digitalWrite(pingPin, LOW);
delayMicroseconds(2);
digitalWrite(pingPin, HIGH);
delayMicroseconds(10);
digitalWrite(pingPin, LOW);

pinMode(echoPin, INPUT);
duration = pulseIn(echoPin, HIGH);
inches = microsecondsToInches(duration);
cm = microsecondsToCentimeters(duration);
   buttonState1 = map(analogRead(buttonPin1),0,1023,0,120);
```



```
   distance=buttonState1-5;
 Serial.println(controller);
    lcd.setCursor(0, 0);
lcd.print("speed=");
float times=millis();
    lcd.print(times/cm);lcd.print("km/h");
     lcd.setCursor(0, 1);
lcd.print("distance=");
 lcd.print(cm/10);lcd.print(" m");
  // Serial.println(distance);
  if (buttonState1 >=30&& cm>=300)
{controller="1" ;
vw_send((uint8_t *)controller, strlen(controller));
vw_wait_tx(); // Wait until the whole message is gone
digitalWrite(13,HIGH);
digitalWrite(10,LOW);
}
 else{
```



```
// {lcd.print("speed=");
//    lcd.print(buttonState1);
//     lcd.setCursor(0, 1);
//lcd.print("  distance=");
// lcd.print(distance);
 controller="0" ;
vw_send((uint8_t *)controller, strlen(controller));
vw_wait_tx(); // Wait until the whole message is gone
digitalWrite(13, LOW);
digitalWrite(10,HIGH);
 }
}
long microsecondsToInches(long microseconds)
{
return microseconds / 74 / 2;
}

long microsecondsToCentimeters(long microseconds)
{
return microseconds / 29 / 2;
}
```