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VEHICLE TO VEHICLE COMMUNICATION BASED COLLISION WARNING ALGORITHM FOR OVERTAKING ASSISTANCE

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ABSTRACT

Transporting people or things from one point to other became so simple and efficient by the recent developments in automobile industry and traffic systems. The increased number of vehicles and poor driving practice has lead to road accidents and deaths. Advanced Driver Assistance Systems (ADAS) are introduced in automobiles for providing increased control and enhanced driving experience. But these systems are not sufficient for tackling no line of sight situations like road curves, intersections, vehicle obstruction during overtaking and poor visibility due to bad weather. In this paper, the aim is to design and develop a driver assistance system algorithm for safe overtaking and no line of sight warning. This system takes feeds from set of sensors integrated on the vehicle and performs calculation of safe speed and distance for overtaking and avoiding collisions with other vehicles. A vehicle to vehicle communication protocol is used in this system for providing no line of sight situation awareness and warning. The algorithm is developed in Tcl script and simulated on Network Simulator 2. The proposed system also implemented on Raspberry Pi 3 for real time testing and evaluation of the algorithm.

Keywords: *Collision warning, Driver assistance system, Vehicle to vehicle communication, Overtaking*.

I. INTRODUCTION

The advancement in auto mobile industry has led to a revolution in the transportation system. From the horse driven cart to the modern machines which are powered by fossil fuels or electricity gave fastest ways to travel from one point to another. Nowadays people or goods are transported via ground, water, air and space. Among these ground based vehicles and systems are the widely used means for easy and cheap transport. This has led to the increase in vehicle count rapidly. The capacity of roads does not increases according to the increased vehicle count which accelerate road accidents. Also, bad driving habits, poor road conditions and typical human errors worsens the condition.

Advanced Driver Assistance Systems (ADAS) are intro-duced to limit the accident rates. They can provide better vehicle control by overcoming the typical human errors and misjudgements in roads. automatic breaking system, blind spot detection, cruise control are some of the examples [1]. They basically works in two aspects: they can provide situational warning or alert to the driver and/or can take over the control of vehicle if the driver fails to respond to the situation in time.

It is experimentally proven that automated machines performs repeated tasks better than human.

Accidents on roads mainly occur during overtaking and no line of sight situations like road curves, Intersections, Building or vehicle obstructions. The current ADAS is not sufficient to tackle these two situations because they basically works in the line of sight scenario. Cruise control system is not applicable at curves or intersections. Line departure warning system works only in straight roads with clear road markings. These systems uses camera which requires intensive image processing which consumes lot of time. Camera also fails under bad weather and poor lighting condition due to poor visibility. All together the ADAS in their current state are not sufficient to provide assistance during overtaking and no line of sight situations[2].

A dedicated driver assistance system for overtaking and collision warning is introduced in this paper. The system provides assistance to the driver by generating alert messages according to the activities on the road. There are sensors which are integrated to the vehicle that provide information regarding in vehicle and target vehicle dynamics like speed, position, direction, etc. The target vehicle information is obtained through Vehicle to Vehicle communication (V2V) in which the vehicles communicate each other over a radio frequency (RF) network and exchanges data related to vehicle position and dynamics in real time. This technology can overcome the limitations of current ADAS no line of sight applicability. The collected data is used to calculate safe distance between vehicles, Safe speed to be maintained for avoiding collision, possible meeting point of vehicles and overtaking feasibility. The sensors to be used are inertial measurement sensors (IMU) for gathering vehicle dynamics data and GPS for navigational data. A radio frequency communication module is to be used for sharing the data over V2V network. This network is Ad-hoc in nature since all vehicles are moving and the topology changes from time to time. The data obtained from in vehicle sensors and from V2V is used for generating alerts by a co-operative collision warning algorithm (CCW). The collected data is compared with threshold values and provide situational warning to the driver during overtaking, intersection, road curves and other no line of sight situations[3]-[5].

The figure 2.1 shows a simple 3 car overtaking scenario. The red car E wants to overtake the car L. The oncoming traffic or vehicle in the second line is represented by car O. The overtaking is initiated when the car L moves at a lower speed compared to car E. Some safety parameters to be calculated before performing overtake. The speed and position car L and O is to be obtained beforehand and it is used to calculate safe speed, safe distance and time to perform overtake. In this case the distance d, s and the velocities vL and vO with respect to vE. It can be obtained from the RADAR calculations and/or data shared over V2V. Then the distance to overtake dover is calculated and if it is within the safe limits then overtaking is performed. This is determined by comparing the obtained values with the threshold value in the assistance system. Situational warning or alerts are given to the driver based on the calculated data in real time[5].

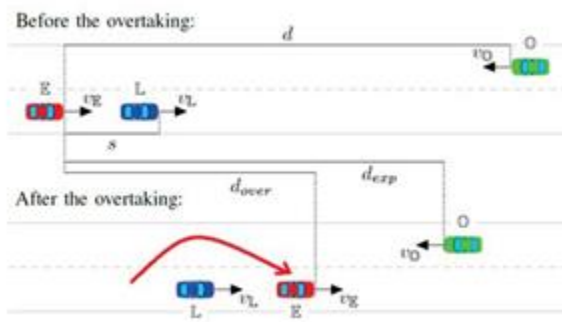

Fig. 1: An overtaking scenario of three cars on two line traffic

In this system the cars talk to each other and exchanges information like speed, position and direction. It has a huge advantage of providing no line of sight situational warning for road intersection, curves and building or vehicle obstruction where the driver cannot see the other vehicles. It also provide vision to the driver during low light and bad weather condition where conventional ADAS system fails.

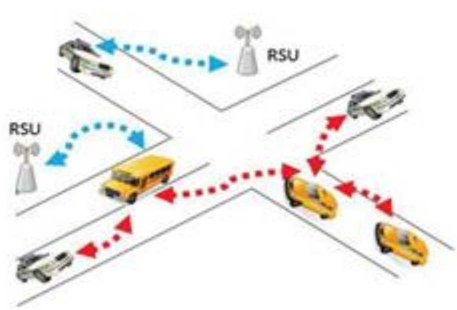

Fig. 2: A simple Vehicle to Vehicle communication scenario

The network formed for V2V communication is strictly Ad-hoc in nature since all vehicles are mobile elements and the network topology changes rapidly. So the V2V communication is also known as Vehicle Ad-hoc Network (VANET). A typical VANET configuration is shown in figure 2.2. The RSU represent the Road Side Unit which is high power wireless transmitters like cellular tower which provides a wide network coverage and also manages the data transfer between vehicles. The V2V can be formed with or without the use of RSU[6].

This paper is organized as follows: section II defines the current systems available for driver assistance and their lim-itations . In section III the vehicle to vehicle communication technology and how it is optimized for overtaking and colli-sion warning purpose is explained. section IV explains the overtaking and collision warning algorithm based on V2V, and it's observations and simulation results. And finally the conclusion is presented in section V.

II. DRIVER ASSISTANCE SYSTEMS - A REVIEW

Driver assistance systems uses sensors and controllers for improving the human driving. The vehicles are intelligent in nature by knowing their surrounding. Although the basic underlying factor of the proposed system is wireless communi-cation, there are various factors to be considered to design the driver assistance system for overtaking and collision warning. A necessary requirement of this technology is that every vehicle on road should be equipped with a communication module and a set of sensors for the system to work in co-operative manner.

A. Advanced Driver Assistance System

Advanced driver assistance systems are systems used in automobiles for over a decade. It includes adaptive cruise control, automatic breaking, collision warning, GPS naviga-tion, blind spot detection, parking assistance, etc. A set of integrated smart sensing modules and a real time electronic controller powers the ADAS. They monitor, analyse, control and co-ordinate all activities associated with the vehicle and its surrounding. They gathers data from integrated sensors, analyse it, and generate warnings or perform control actions. For example, is in some systems like Adaptive Cruise Control (ACC), the vehicle speed is adjusted automatically in accor-dance with the speed of front vehicle. It is achieved by a set of actuators which controls throttle, break and steering actions based on the data obtained from forward looking RADAR. In some other system like automatic breaking or collision avoidance, the vehicle breaks automatically when an obstruction is detected and the driver fails to respond in time[2].

The sensors that are used to monitor the vehicle state and its surroundings include camera, ultrasound sensor, Inertial Measurement Unit (IMU), RADAR, and GPS. The ADAS equipped with smart computation entities like microprocessors or microcontrollers. They monitor, analyse, control and co-ordinate all activities associated with the vehicle and its surrounding. The gathered data from the integrated sensors are processed and analysed to generate warning messages and to perform control actions[7].

B. Intelligent Transportation System

The advanced driver assistance systems and road side units with communicating capability forms the Intelligent Trans-portation System (ITS). It provides various safety services regarding transportation like traffic management, warning, co-operative traffic control, intersection management, etc. They are real time systems established based on various integrated technologies like wireless communication, smart computation techniques and various sensing mechanisms. Their applica-tions includes vehicle speed camera detection, Traffic light scheduling, Traffic sign recognition, collision warning, traffic updates, etc [7]. The communication between vehicles and

Fig. 3: A vehicle with Advanced Driver Assistance Systems

road infrastructure forms a network of co-operative trans-portation system. It is strictly wireless because the associated nodes are moving and the network topology changes rapidly from time to time. This dynamic behaviour made the system to be established using Dedicated Short Range Communica-tion technologies (DSRC). It consist of Wi-Fi, ZigBEE and other IEEE 802.11 standards operates on 2.4, 5.9 GHZ ISM bands. Protocols like Wi-MAX, LoRaWAN together with 5G cellular technology provides wider communication network based on higher frequency bands (eg-60GHZ) with moderate data rates and more area coverage (2-10 km). DSRC provides communication range of 50 to 1000 meters with a maximum of 200Mbps data rate. For vehicle to vehicle communication DSRC is preferred because of its short coverage, low power conception, low cost, easy to install and higher data rates. They are suitable for the requirement of rapid network topology variation of mobile nodes. For a long distance Vehicle to Infrastructure communication (V2I), protocols with higher coverage and moderate data rates are preferred. They are stable in the Ad-Hoc network requirement since the dynamic topology has lesser effect on longer distances compared to shorter ones [6].

III. VEHICLE AD-HOC NETWORK

Vehicle Ad-hoc Network is the technology used in automo-biles which allows them talk to each other. They also known as vehicle to vehicle communication since the nodes in this network are vehicles. It can provide situational awareness at intersections, road curves, building or vehicle obstruction, poor visibility of road and other no line of sight situations. They are Ad-hoc in the sense that there is no fixed network topology. They use dedicated short range communication protocols for

Fig. 4: An Intelligent Transportation System (ITS) example

implementing the network. Road side units such as cellular tower and other high power transmitters also take part in VANET to cover a wide area and to provide a efficient network management along with localised information update in real time. The vehicles and RSU shares safety related information with each other. The routing of messages according to required distance and direction are determined based on the current field status and the designer's decision. According to the configuration used in VANET, it is classified into three types. Unicast configuration, Broadcast configuration and Hybrid VANET configuration[3].

The hybrid configuration reduces the uplink and downlink load to the RSU. But it requires additional signalling within each vehicle platoon and with the RSU for selecting the cluster head. This will cause more delay in the system and it is not tolerable in real time applications. And unicast configuration which uses point to point communication required to keep and update a vehicle user profile database which requires more hardware resources and consumes time. So the best choice for establishing an ultra fast, real time communication between vehicles is the broadcast configuration. Ideally, every vehicle gathers data and broadcast the message continuously so that other vehicles within the coverage area of the broadcast network can access the data with minimum delay [3].

IV. OVERTAKING ASSISTANCE - COLLISION WARNING SYSTEM

This section explains the overtaking and collision warning algorithm and it's implementation results. Here the algorithm calculates certain distance parameters and compares it with the safety threshold for alert. The VANET shares each vehicle's speed, Direction and corresponding GPS position in real time. The three levels of warnings are: 'Safe to overtake', Overtake with caution', Cannot overtake!'. The Network simulator 2 (NS2) tool and Network Animator (NAM) is used for imple-menting the experimental set up and simulating the results. The algorithm flow chart is shown in figure 6.

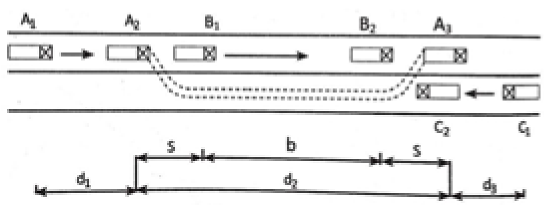

Fig. 5: Overtaking Sight Distance calculation parameters

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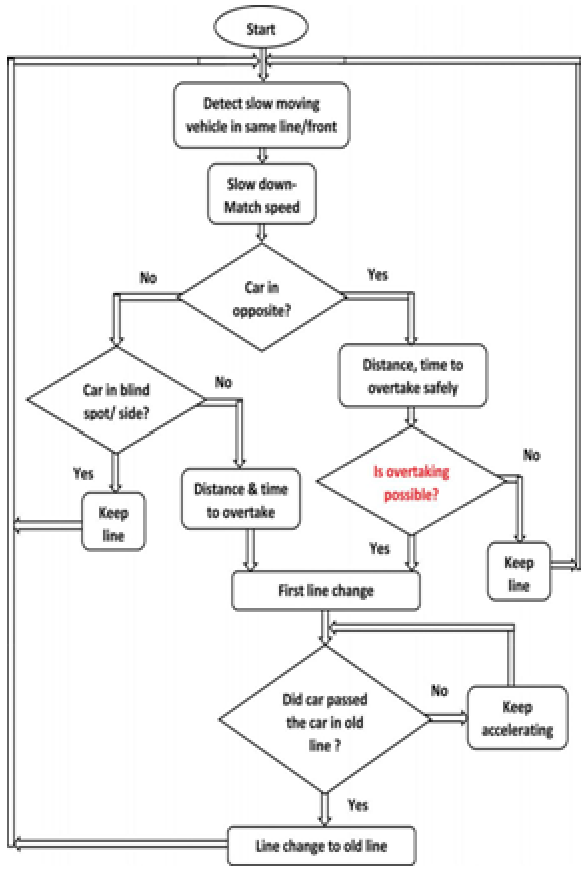

Fig. 6: Overtaking assistance - Collision warning algorithm

A. Mathematical formula

The collision warning alerts are generated based on the Overtaking Sight Distance (OSD) calculation[8]. The OSD is composed of 3 distance parameters; d1, d2, d3. Let A be the subject vehicle, B be the vehicle to be overtaken and C be the opposing traffic. To initiate the overtake the subject vehicle must match the speed with the target and should keep a minimum safe distance 'S' . Here 'd1' is the distance travelled by the subject vehicle from A1 to A2 . The distance B travelled from B1 to B2 is represented as 'b' and the total distance to complete the overtaking is b+2s . Finally the opposing traffic travel length from C1 to C2 is given as 'd3' . So OSD (in meters) is given as:

$$OSD_{min} = d_1 + d_2 + d_3 \qquad (1)$$

Since the subject vehicle matches it's speed (Va) with that of target (Vb), d1 becomes:

$$d_1 = V_b * t \qquad (2)$$

where t is the reaction time. The default value of t is set to 2 sec. The safety distance S is calculated using the empirical formula:

$$S = 0.7 * V_b + 6 \qquad (3)$$

The time to complete overtaking phase 'T' depends on the ve-locity and acceleration of subject vehicle. It can be obtained by using the Newton's second equation of motion (Displacement equation):

$$d_2 = V_b * T + 1/2 * a * T^2 \qquad (4)$$

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Equating this to b+2s gives:

$$T_{over} = \overline{(4 * s/a)} \quad (5)$$

Finally the distance covered by opposite coming vehicle with velocity Vc is:

$$d_3 = V_c * T \quad (6)$$

So, the OSD is:

$$OSD_{min} = V_b * t + V_b * T + 2 * S + V_c * T \quad (7)$$

B. Simulation results

The three car overtaking scenario is designed and imple-mented in the NS2 tool. The vehicles are represented by mobile nodes numbered 0,1,2. Node 0 is the target vehicle, node 1 is the subject vehicle and node 2 is the oncoming traffic. The wireless link between the nodes are based on User Datagram Protocol (UDP). DSDV protocol is used for Ad-Hoc routing[9]. The communication range is limited to 300 meters to avoid message overflow. 802.11 protocol based RF communication network is used in this system. The frequency of operation is 2.4 GHz The nodes transmit UDP packets in every 0.3 sec after initialisation. The various design parameters are listed in Table I.

The vehicle speed and corresponding OSD for different traffic scenario is listed in Table II. A plot of OSD verses vehicle speed is also shown. From the plot one can observe the distance required for performing safe overtake increases in proportional to the speed of target vehicle. The overtaking window closes fast depending on the opposing vehicle speed and position.

Table I: the vanet parameter values of the overtaking-collision warning algorithm

Design parameters NS2	Inference/Values
Channel type	Wireless
Antenna	Omni directional
Packet length	50
MAC type	802.11
Ad-hoc routing	DSDV
Number of nodes	3
Topography size	500*500
Packet repetition time	0.3 sec

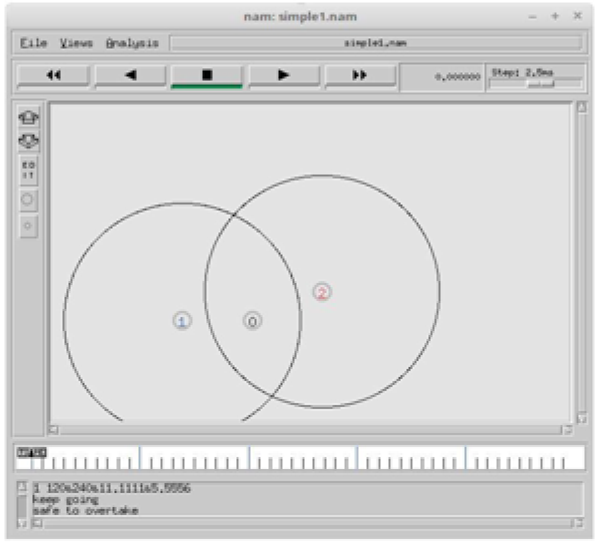

Fig. 7: NS2 simulation of three vehicle overtaking scenario

C. Hardware implementation

The algorithm for overtaking and collision warning is implemented on Raspberry Pi 3 using Python code for real time testing of the system. For the system to work in co-operative manner, every vehicle on road should have V2V communication capabilities. So each Raspberry pi board along with data collection sensors and RF module forms a single vehicle unit. The position information obtained from GPS receiver, direction information from Magnetometer and the speed is obtained from tachometer

Table II: the OSD dependency on velocity of vehicles

Velocity of Vehicle C (km/hr) (Vb=60km/hr)	OSD (m)
20	255.47
40	302.17
60	348.87
80	395.58
100	442.28
120	488.98

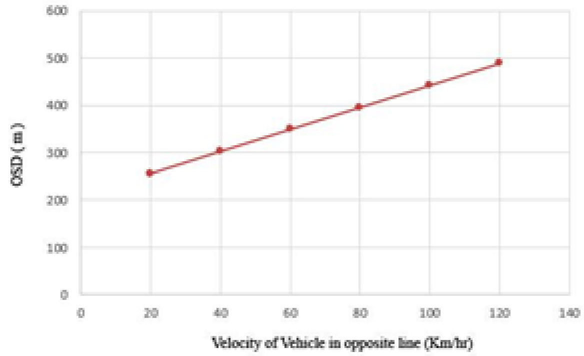

Fig. 8: OSD for different vehicle velocity: Vehicle C velocity (km/hr) Vs OSD (m)

The inbuilt Wi-Fi module (802.11) of Raspberry Pi 3 is used as the RF module for establishing the V2V at 2.4 GHz band. The range of the V2V depends on the power of RF module used. In this system the maximum range obtained is 60-70 meters between two nodes (Vehicles) since low power Wi-Fi modules are used. Since the V2V is Ad-hoc, all the nodes associated in the network together provides a total range of 150 meters. If high power RF transmitters are used, the range can be increased further. The stepper motors represent the vehicle speed and they are controlled by L298N motor driver interfaced with Raspberry Pi. The algorithm and sensor interfacing are done using Python 3 coding on Raspbian jessie. The algorithm calculates Safe distance, Time required for completing overtake and the total distance to be covered to complete the overtake. The calculated distance parameters based on OSD is compared with the GPS distances to generates alerts. The system tested on outdoor condition and obtained satisfactory results.

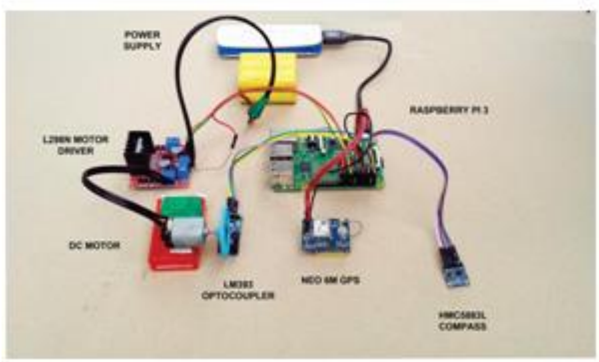

Fig. 9: Hardware implementation using Raspberry Pi 3 model

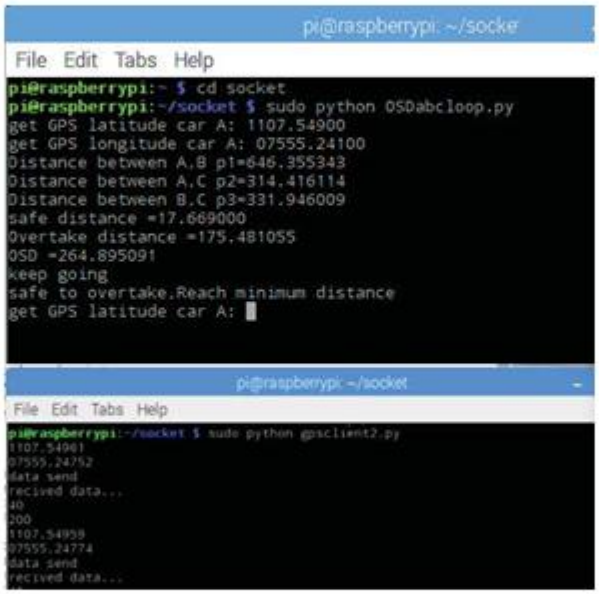

Fig. 10: Hardware test results of 3 car overtaking algorithm

V. CONCLUSION

In this work a vehicle to vehicle communication protocol based collision warning algorithm has been proposed. The algorithm provides timely warning to the driver about a potential collision which is going to happen in the future. The algorithm can be used in assistance systems for drivers during overtaking. Network simulator 2.34 was used to analyse the performance of the proposed algorithm. It was found that the distance required for overtaking a vehicle increases in proportional to the target vehicle speed. As the relative velocity increases the calculation becomes little ambiguous in nature . Existing Ad-Hoc routing protocol DSDV is used in the simulation and UDP wireless link is provided between the nodes. The results shows the requirement of new routing and communication protocols for implementing robust vehicle Ad-Hoc network for real time collision warning.

The system also implemented on Raspberry pi platform for real time evaluation. Wi-Fi based V2V network is formed at 2.4 GHz with a maximum range of 150 meters. The system collects position and speed data and shares with other units for generating collision warning. As future work more rigorous testing with multiple vehicle representing real life traffic scenarios are required. Overtaking and collision warning in multiple line highways, road curves and intersections are also needed to be implemented and tested for developing a sophisticated system. Integrating this V2V based collision warning on the current ADAS will provide a much more efficient and robust driver assistance system.

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