Design of a Basic Vehicular Communication Network using Radar and Camera Sensor with Enhanced Safety Features

Chinmoy Kalita, Nupur Choudhury, Aradhana Misra and Kandarpa Kumar Sarma
Department of Electronics and Communication Engineering,Gauhati University
Guwahati, India

Received: August 26, 2021. Revised: February 11, 2022. Accepted: February 24, 2022. Published: March 11, 2022.

Abstract—**The primary goal of Vehicular Ad-hoc Network (VANET) technology's development is to increase road safety and enable Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication in order to share crucial information and prevent road accidents. VANET establishes a mobile network between moving cars by considering each vehicle as a separate entity. Safety applications in VANET are currently receiving a lot of attention from researchers as well as automobile manufacturers. This paper concentrate on simulation-based safety-critical techniques in vehicle networks employing radar and video sensors in various road styles. This paper discusses about how to create a simulation-based driving scenario environment and calculates the fluctuations in sensor detection rates depending on different driving conditions. And also created a basic Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication network. An integrated approach is also proposed to Forward Collision Warning System (FCWS) in different cases.**

Keywords— VANET, Radar sensor, Camera sensor, Vehicle to Vehicle communication, Vehicle to Infrastructure communication, FCWS.

I. INTRODUCTION

The Vehicular Ad-hoc Network (VANET) has emerged as an important study topic in wireless communication. Before delving into the intricacies of VANET, it is important to first review its history. WANET [1] is the parent field of all ad hoc networks. VANET is a MANET sister that organises its own communication system and does not rely on any other infrastructure. The military is the most popular application of MANET owing to its easy and uncomplicated communication mechanism, which is similar to data exchange between multiple computers. VANET is similar to MANET, however there are notable distinctions. VANET is a mobile ad hoc network extension that allows cars to communicate with one another and also with roadside unit.

Although the Vehicular Ad-hoc Network (VANET) is not a new concept, it continues to bring fresh research difficulties and concerns. The fundamental objective of VANET is to help a collection of vehicles build and maintain a communication network among themselves without the necessity of a central base station or controller. One of the most significant uses of VANET is in severe medical emergency circumstances when there is no infrastructure yet information must be transmitted to save human lives. However, new obstacles and issues develop alongside these positive VANET uses [2]. Due to a lack of infrastructure in VANET, cars have increased obligations. Every vehicle joins the network and maintains and controls the network's communication as well as its own communication requirements. Vehicular ad-hoc networks are in charge of communicating amongst moving vehicles in a certain area. A vehicle can connect directly with another vehicle, which is known as Vehicle-to-Vehicle (V2V) communication, or it can interact with infrastructure, such as a Road Side Unit (RSU), which is known as Vehicle-to-Infrastructure (V2I) communication [2].
One of the most important aspects of reducing road accidents is obstacle identification. Various sensors (RADAR and Camera) integrated in automobiles, roadside sensors, and GPS can be used to measure the position of objects or other front or back vehicles. A collision can be avoided if there is a safe gap between cars.
In this paper, the design of a simulation-based fundamental vehicular communication network, including vehicle-to-vehicle and vehicle-to-infrastructure communication networks, employing radar and video sensors in various road styles like straight road, cross road and curved road have been considered. It demonstrated the detection rate and false alarm rate of radar and vision sensors, as well as vehicle-to-vehicle connection in varied communication ranges and road styles. In a simulated environment, we tried this on a straight road, a cross road, and a curved road. In this paper, we have also proposed an integrated approach to Forward Collision Warning System (FCWS) in different cases.

RADAR Sensor is used to continuously scan the road for frontal, side, and rear accidents and allows safety applications to change speed and engage brakes to prevent probable collisions or danger scenarios by using radio waves to estimate the distance between objects and the sensor. If something near to the car is spotted, the program alerts the driver and immediately applies the brakes to avoid a collision.

Camera sensors are used to monitor the conductor body, position of the head and eye activity to identify abnormal, such as fatigue indications or unpredictable behaviour, and to implement night-vision assistance apps to enable drivers see more and go through these areas.

A. *Related Works*

Because there are more cars on the road, traffic congestion and transportation delays on urban arterials are rising day by day; hence there is a need for vehicles, such as ambulances, fire engines, and police vehicles, to react to emergency calls with as little delay as possible [3]. It is feasible to detect the movement and position of other cars via vehicle-to-vehicle communication [4]. Vehicles today are equipped with Global Positioning System (GPS) Technology, which allows them to know where other vehicles are and for other vehicles to know where you are in situations such as blind spots, stopped ahead on the highway but hidden from view, around a blind corner, or blocked by other vehicles. A vehicle can warn drivers instantly by anticipating and reacting to changing driving conditions [5-6].

Vehicle-to-Vehicle communication technology's major goal is to aid in the prevention of vehicle accidents [7]. It proposes a communication device within the system that will interact with other cars to clear the lanes. This technology tries to communicate with vehicles in its vicinity by using their position to signal their closeness. When these cars are in close proximity, the drivers are warned through a message. In this manner, the drivers may speak with one another and act in accordance with the scenario.

Over the last decade, academics have been particularly interested in on-road obstacle detection and recognition [8–10]. On the basis of sensing data from radars, lidars, and cameras, many approaches for on-road obstacle identification and recognition have been presented. The data generated by obstacle detection and identification can be utilised to identify and categorise on-road behaviour. Millimeter-wave radar is commonly used for detecting road hazards. Vehicle-mounted radar sensors, on the other hand, cannot give a large field of view. The lidar has grown in popularity for use in on-road obstacle detection in recent years; nevertheless, it is more sensitive to weather conditions than radar and is still highly costly. The primary sensor suite for vision-based vehicle identification and recognition is one or more cameras. Cameras have a wide field of vision, allowing them to detect, recognise, and track various obstructions across several lanes.

The remainder of this paper is organized as follows. First the proposed system model is illustrated in section II; in section III we describe the Methodology; In section IV; working results of experiment model is described; finally some concluding remarks are given in section V.

II. Proposed Model

A. *Basic Simulation based Vehicular Communication Network*

A device must be aware of its own position in order to create and deliver a basic safety message (bsm) (such as via a gps antenna and receiver). Figure 1 demonstrates that once the device's position is known, it requires a computer processing unit that can take that location and integrate it with other on-board sensors (e.g., radar and camera sensor) to create the needed bsm data string. Once the bsm has been created, a device must wirelessly send it to another vehicle.

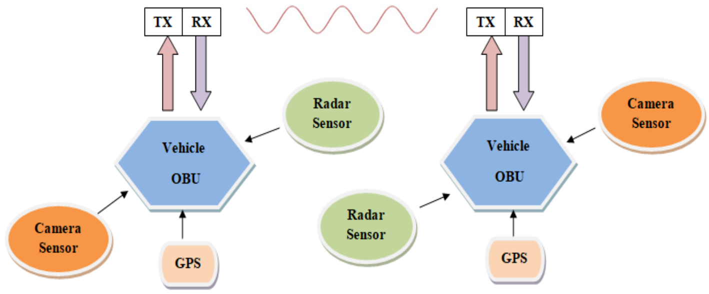

Figure 1. Block diagram of proposed model

While the on-board processor creates the bsm, a security module is analyses and prepares the security information and certificates for transmission to ensure the message's validity at the receiving vehicle. This security information must also be provided wirelessly. To receive and understand a bsm, a device must be capable of receiving the bsm broadcast from a nearby device and match the manner of bsm transmission (i.e. if the message is transmitted via rf, the receiving device must have a rf receiver). It must also have an assembly that can properly decode the bsm. To determine the relative distance between the sending and receiving devices, a GPS antenna and receiver are required. A Kalman filter based approach was employed in this work for high-level fusion of V2V communication and on-board automative sensors for remote sensing.
The initial driving scenario in our suggested model is designed in MATLAB. Then, using simulation, radar and camera sensors were connected to cars. This sensor identifies other cars and infrastructure, after which the vehicle communicates with the other vehicles and infrastructure (road side unit).

B. *Forward Collision Warning system*

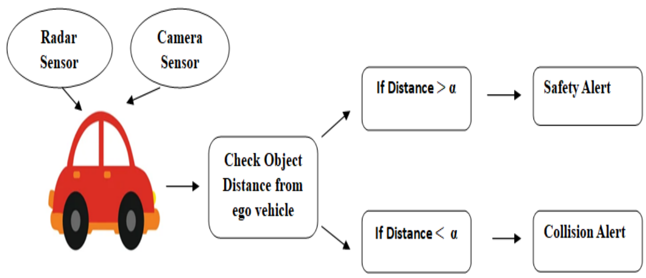

Figure 2. Block diagram of Forward Collision Warning System

Initially, the radar and camera sensors identify the car, front vehicles, and pedestrians. Following that, the coordinates of the nearest vehicle and pedestrian are retrieved using the list indexing. The distance between the coordinates of the ego vehicle (The vehicle on which the camera is mounted) and the objects identified is computed once the X and Y coordinates are retrieved from the labels list. Following that, a safe threshold distance value Alpha (α) for pedestrian and vehicle detection is established. In figure 2, it is shown that when vehicle or pedestrian comes closer than the safe threshold distance value Alpha (α), a collision alert is sent to the ego vehicle. On the other hand, if vehicle or pedestrian is above safe threshold distance value Alpha (α) then safe signal is sent to the ego vehicle. This is the mechanism of working of the forward collision warning system.

III. METHODOLOGY

First, we created a simulated version of the driving situation for the design model. The MATLAB driving scenario designer software is used to design the simulation portion of the driving scenario. The driving scenario designer software allows us to create simulated driving scenarios for testing my self-driving systems.

The steps involved in driving scenario design is given below:

A. Create a road condition

To design a simulated driving scenario, the first step is to create a road condition. MATLAB provides flexibility to design any kind of roads. Here, we have designed three types of road style viz. straight, crossed and curved roads which are shown in figure 3, 4 and 5 respectively.

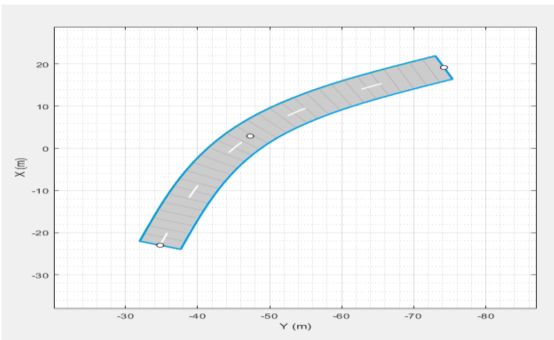

Figure 3. Straight Road Design

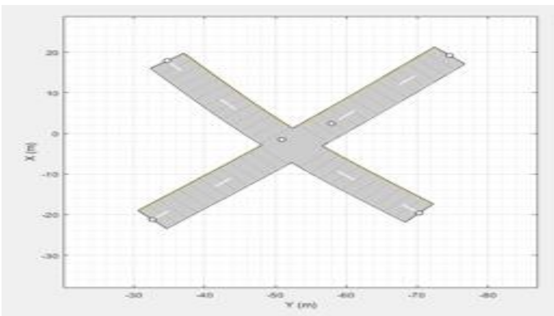

Figure 4. Cross Road Design

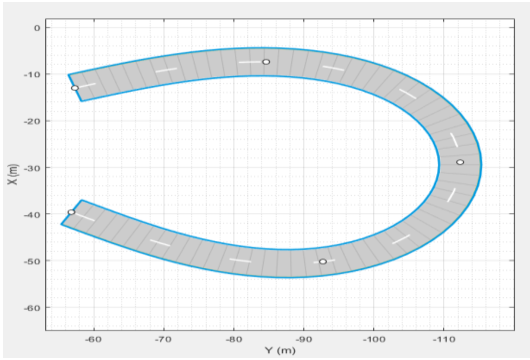

Figure 5. Curved Road Design

B. Adding vehicles in road

Figure 6 shows two vehicles on the two roads of a crossraod, one moving along the red line and another moving along the blue line.

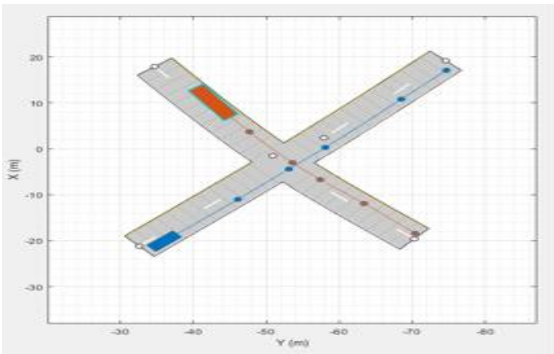

Figure 6. Adding vehicles in road

C. Adding camera and road sensors in vehicles

In this step, we added camera and radar sensor in vehicles which is shown in Figure 7. Here, camera sensor is placed in middle and front of the vehicle and radar sensor is placed in two side in front view of the vehicle. As shown in the figure, the blue part is the camera sensor placed and red parts are the radar sensor placed.

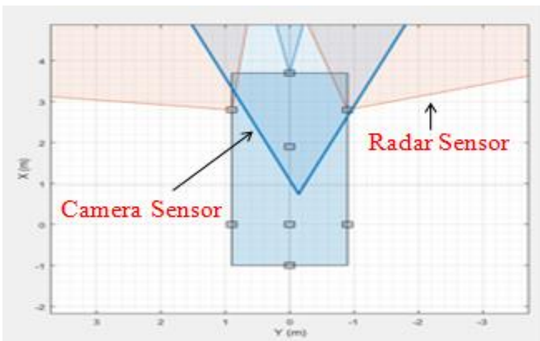

Figure 7. Adding camera and road sensors in vehicles

D. Implementation

For high-level integration of V2V communications with on-board car sensors for remote sensing, this work used a Kalman filter-based technique. Given past information of the state and current measurements, Kalman filtering [17-18] is a recursive method that maintains track of the state estimate as well as the uncertainty of the estimate. Kalman filtering reduces measurement noise and allows for the calculation of errors associated with each predicted state unit. We used position, speed, heading, yaw rate, and size information from V2V communications, range and azimuth information from both radar and lidar, and relative longitudinal and lateral distance information from the camera to detect the current locations of the remote targets and predict their future trajectories. Furthermore, the relative position and heading to the target with respect to the host vehicle were computed using the host vehicle's location and heading readings.

Remote target motion equations are usually provided in Cartesian coordinates. However, because automotive range sensors like radar and lidar take measurements in polar coordinates, they must be converted to Cartesian coordinates. Polar-to-Cartesian translation is a nonlinear procedure that frequently employs an extended Kalman filter (EKF). EKF is calculated using a linear approximation of a nonlinear system [17], which is only consistent for minor errors. The coordinate transformation is performed without bias by a converted measurement Kalman filter, which also computes the proper covariance for the converted data. When compared to EKF [19], this filter is virtually perfect and delivers greater accuracy. This study used the unbiased converted measurement Kalman filter technique described in.
The state vector at time step k is defined by

$$x_k = [X_k \;\; Y_k \;\; v_{x,k} \;\; v_{y,k}]^T \quad (1)$$

where X_k and Y_k describe the position of the target, and $v_{x,k}$ and $v_{y,k}$ describe the target relative velocity in longitudinal and lateral directions, respectively. The measured range and azimuth are

$$r_m = r + \omega_r \quad (2)$$

$$\theta_m = \theta + \omega_\theta \quad (3)$$

where r and θ are the true range and azimuth values. The range and azimuth measurement noises are denoted by ω_r and ω_θ, respectively, of which error standard deviations are σ_r and σ_θ. The unbiased converted measurements are

$$x_m = b_1^{-1} r_m \cos \Theta m \quad (4)$$

$$y_m = b_1^{-1} r_m \sin \Theta_m \quad (5)$$

where $b_1 = E[\cos w\theta] = e_\theta^{-\sigma 2/2}$. The unbiased converted measurement vector z_k is

$$z_k = [x_m \;\; y_m]^T \quad (6)$$

and the state $\hat{x}_{k|k-1}$ and error covariance $\hat{P}_{k|k-1}$ are predicted from time step $k-1$ to time step k by

$$\hat{x}_{k|k-1} = A\hat{x}_{k-1|k-1} \quad (7)$$

$$\hat{p}_{k|k-1} = A\,\hat{p}_{k-1|k-1}\,A^T \quad (8)$$

where the state transition matrix A is defined as

$$A = \begin{bmatrix} 1 & 0 & \Delta t & 0 \\ 0 & 1 & 0 & \Delta t \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (9)$$

The elements of the measurement error covariance R_k obtained from the unbiased conversion are given by

$$R_{11,k} = var(x_m) = (b_1^{-2} - 2) r_m^2 \cos^2 \Theta_m + \frac{1}{2}(r_m^2 + \sigma_r^2)(1 + b_2 \cos 2\Theta_m) \quad (10)$$

$$R_{22,k} = var(y_m) = (b_1^{-2} - 2) r_m^2 \sin^2 \Theta_m + \frac{1}{2}(r_m^2 + \sigma_r^2)(1 - b_2 \cos 2\Theta_m) \quad (11)$$

$$R_{12,k} = cov(x_m, y_m) = (\frac{1}{2} b_1^{-2} r_m^2 + \frac{1}{2}\frac{1}{2}(r_m^2 + \sigma_r^2) b_2 - r_m^2) \sin 2\Theta_m \quad (12)$$

Where $b_2 = E[\cos 2w\Theta] = e^{-2^{\sigma^2}\theta}$. Prior to updating the state and the error covariance, the Kalman gain K_k is computed by

$$K_k = \hat{p}_{k|k-1} H^T (H\,\hat{p}_{k|k-1} H^T + R_k) \quad (13)$$

Where the measurement function matrix H is defined as

$$H = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \quad (14)$$

Then the state $\hat{x}_{k|k}$ and the error covariance $\hat{P}_{k|k}$ are updated as

$$\hat{x}_{k|k-1} = \hat{x}_{k|k-1} + K_k(z_k - H\,\hat{x}_{k|k-1}) \quad (15)$$

$$\hat{p}_{k|k} = (1 - K_k H)\,\hat{p}_{k|k-1} \quad (16)$$

For filtering data from the vision sensor and vehicle to vehicle communication , we utilized a linear Kalman filter [18] because a polar – to -cartesian conversion was not necessary for the data we obtained from the two sources. A linear Kalman filter is similar to the filtering process described above, but without the steps for the unbiased conversion. For the purpose of combining the filtered information from multiple source, we estimated their quality scores based on the error covariance matrices. The quality score matrix $W_{j\ k|k}$ at time step k for the state obtained from the jth source is given by

$$W_{j,k|k} = [\textstyle\sum_{i=1}^{n} \hat{p}_{k|k}^{-1}]^{-1}\,\hat{p}_{k|k}^{-1} \quad (17)$$

$$\textstyle\sum_{j=1}^{n} W_{j,k|k} = 1 \quad (18)$$

where $\hat{P}_{j,k|k}$ is the updated error covariance for the jth sensor and I is an identity matrix. Finally, the weight average state $x_{k|k}$ for time step k is

$$\bar{x}_{k|k} = \sum_{j=1}^{n} W_{j,k|k}\, \hat{x}_{j,k|k} \quad (19)$$

where $\hat{x}_{j,k|k}$ is the updated state based on the information collected from the jth source.

IV. Experimental Results

This section describes the results obtained from the experiment using simulated driving scenario environment. The results show sensor detection rate in different road conditions and also used some simulation parameter such as, Vehicle Speed, S-min=50 miles/hour, S-max= 70 miles/hour, Road Traffic Volume = 40 vehicles/hour/lane, vehicle arrival/departure rate = 0.833, Road Traffic Density= 10-20 vehicles/lane.

A. Performance of sensors

For VANETS , sensors play a vital role for communication. Sensors capture the surrounding view of vehicles and this data is sent to the vehicle OBU from where it is again transmitted to the other vehicles radar and camera sensor have been used in a vehicle simulation environment. Certain performance parameters of these type of sensors like detection rate, false alarm rate have been evaluated and compared in this section for different road styles..

Figure 8 shows the Bird's eye plot, which is a 2D driving scenario of moving vehicles. In this figure it is seen that, when vehicles move then bird's eye plot shown the coverage of camera and radar sensors and also shows the detecting vehicles and lanes in this sensors coverage region.

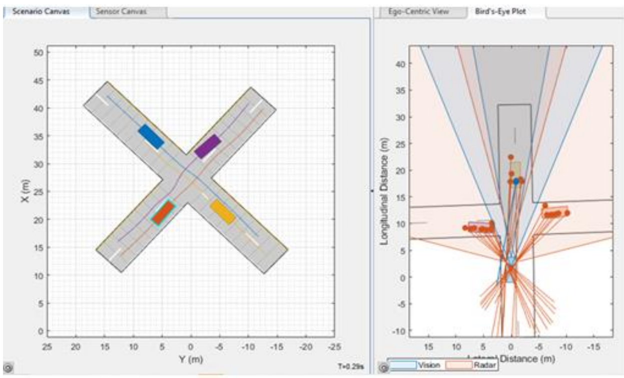

Figure 8. Birds' eye plot of driving scenario

In Table 1 , sensor average detection rate and false alarm rate in different detection ranges such as 50 m and 100 m are shown, in different road styles. This data shows that sensors in straight road has higher detection rate , compared to curved or cross roads. Also when the detection range of the sensor is increased, the detection rate also gets increased but at the same time the rate of false alarm also sees a narrow increase in value. This occurs due to the increase in traffic density when the detection range is increased.

Table 1. Sensors average Detection rate and False alarm rate.

Road Style	**Detection Range (50 m)**		**Detection Range (100 m)**	
	Detection Rate (%)	**False Alarm Rate (%)**	**Detection Rate (%)**	**False Alarm Rate (%)**
STRAIGHT	**85**	**4**	**87**	**5**
CURVED	**80**	**3**	**83**	**4**
CROSS	**76**	**3**	**79**	**3**

B. Vehicle to Infrastructure (V2I) communication

Vehicle-to-Infrastructure (V2I) communication allows cars to communicate with fixed units (i.e. roadside units) installed on the sides of the road at a defined distance. This kind of communication is advantageous for cars that are not connected to the internet, as no internet connection is necessary.

In simulation environment, we have drawn three connected roads and placed 2 RSUs along the path. The vehicle moves along the path and if the distance from any RSU is less than 100m, it establishes a connection. The red part of the road indicates path with no connection and the green part indicates connection which is shown in Figure 9. In this figure, vehicle connectivity with RSU1 and RSU2 has been shown to be established when the vehicle comes in the communication range of the respective roadside units.

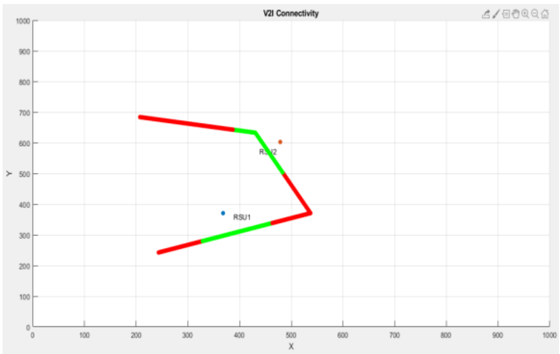

Figure 9. Vehicle to Infrastructure Communication

C. Vehicle to Vehicle (V2V) Communication

V2V communication allows sharing information about the traffic environment among moving vehicles. Firstly, we have drawn two intersecting roads and three vehicles start moving with random speeds towards the intersection as shown in Figure 10. Then a connection is established if the distance between the vehicles is less than 100m. The connection is shown by the green dashed line. Connection is established between all the three vehicles when they are close to the intersection. And that's how simulation based vehicle to vehicle (V2V) communication network is tested.

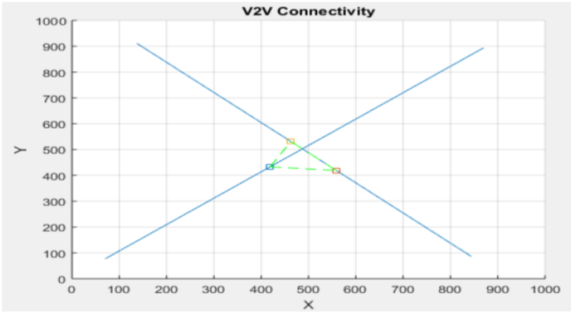

Figure 10. Vehicle to Vehicle (V2V) Communication

D. Vehicle to vehicle (V2V) Connectivity

Figure 11 shows the average number of communication nodes within 50 meters and 100 meters from the target. The number of neighbors increases as the traffic density increases since the vehicles move closer to each other due to congestion. As a result, the average V2V connectivity increases linearly in 100 meter communication range than 50 meter with traffic density. Considering 100 -500 vehicles on each lane of 5km and 50 meters communication range, when uniformly distributed, each node have connectivity with 8-40 vehicles. Our graphs give the same results.

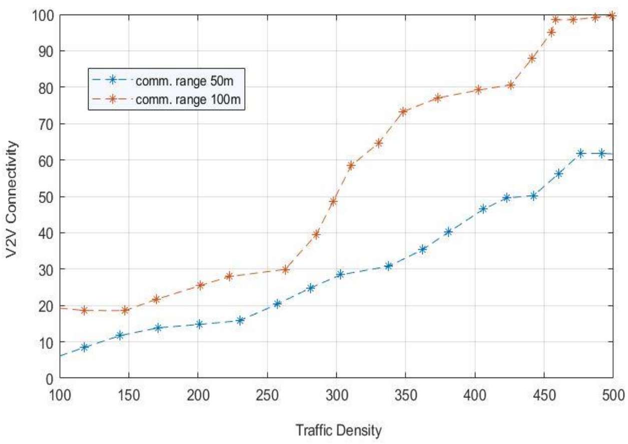

Figure 11. Average V2V Connectivity

In our experiment model, we have shown V2V Connectivity in different road type in different communication range.

Table 2. V2V connectivity in different road condition

V2V Connectivity (%)			
Communication Range		**50 m**	**100 m**
Road Type	**Straight**	**86**	**88**
	Curved	**82**	**83**
	Cross	**77**	**79**

The results in Table 2 are some various V2V simulated results in various road condition also in different range of communication. Table 2 indicates that, vehicle to vehicle connectivity is higher in straight road than other road condition like curved and cross road. The results also shows that if communication range is increases than V2V connectivity also increases.

E. Forward Collision Warning System

One important technology for intelligent cars is forward collision warning systems (FCWS). Frontal collisions account for approximately 55% of all traffic incidents involving passenger automobiles that result in deaths or serious injuries [3]. FCWS identifies the car ahead and estimates the distance between the driver and that vehicle in order to avoid such collisions. As the demand for such systems has grown, new elements of FCWS applications have emerged. A forward collision warning system, that utilizes a video stream for detection purpose.

For this forward collision system, here we used a video stream for detection purposes. In our simulation model, radar and camera sensor detects the forward vehicles and pedestrian. Then we set up a safe threshold distance value Alpha (α) for pedestrian and vehicle detection. When vehicle or pedestrian comes below safe threshold distance value Alpha (α) then alert the ego vehicle. In this project, there are different cases to which our forward collision warning system model is tested.

Using the list indexing the coordinates of the closest vehicle and the closest pedestrian is extracted. After the X and Y coordinate is extracted from the labels list, the distance between the coordinates of the ego vehicle and the objects detected is calculated by using the formula given in Equation (20)

$$\text{Calculated Distance} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (20)$$

According to the coordinate convention, the X axis is along the length of the car and the Y axis is perpendicular to the road direction. The coordinate of the ego vehicle is always set to (0,0). Thus, the equation (20) simplifies to equation (21)

$$\text{Calculated Distance} = \sqrt{(x^2 + y^2)} \quad (21)$$

Finally, the distance between the ego vehicle and any obstacle is used in a “if” condition and according to the distance different measures will be taken.

CASE I: A pedestrian was created to go in the same direction as the ego vehicle to imitate a real-life scenario. In this case, the other cars are motionless. (Figure 12 (a) and (b)).The front collision system detects both cars and pedestrians at the same time.

Figure 12(a). Distance of pedestrians and vehicles more than alpha

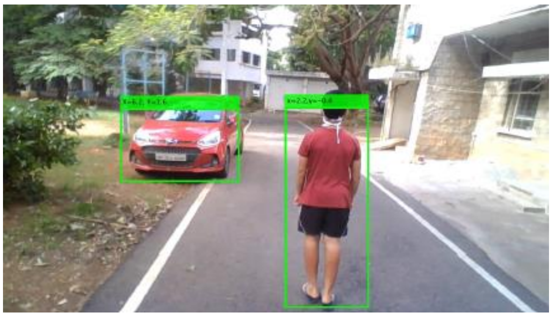

Figure 12(b). Distance of pedestrians and vehicles more than alpha.

Table 3. Ego Vehicle Status for Case I

Figure Number	Pedestrian α Value	Vehicle α Value	Actual Pedestrian Distance	Actual Vehicle Distance	Ego Vehicle Status
Figure 12 (a)	3 m	5 m	3.114 m	7.337 m	Safe
Figure 12 (b)	2 m	5 m	2.23 m	6.40 m	Safe

Table 3 shows the list with the coordinates of the detected vehicles and pedestrians. The minimum distance calculated from the coordinates in the array is compared with the value of alpha. Both the cars and the people are farther away than the alpha value specified for this example. The pedestrian alpha value is set at 5 metres, whereas the vehicle alpha value is set to 3 metres. Because the computed distance between the closest pedestrian and vehicle is more than the value of alpha specified for both, it is decided that there is no imminent collision on track.

CASE II: In the same environment the ego vehicle now moves forward, and in doing so, the distance between the ego vehicle and the pedestrian decrease in (Figure 13 (a) and (b)).

Figure 13 (a): The pedestrian, is closer to the ego vehicle than the threshold safe distance (3 meters)

Figure 13 (b): The pedestrian, is closer to the ego vehicle than the threshold safe distance (3 meters)

Table 4. Ego Vehicle Status for Case II

Figure Number	Pedestrian α Value	Vehicle α Value	Actual Pedestrian Distance	Actual Vehicle Distance	Ego Vehicle Status
Figure 13 (a)	3 m	5 m	2.86 m	7.337 m	Collision with Pedestrian
Figure 13 (b)	3 m	5 m	2.23 m	6.40 m	Collision with Pedestrian

Table 4 shows the list with the coordinates of the detected vehicles and pedestrians. As the calculated distance for the closest pedestrian is less than the value of alpha set for the pedestrian, thus it is concluded that there is imminent collision on course and that too with a pedestrian.

CASE III: In this case the scenario is that instead of a pedestrian a vehicle might move closer to the Ego vehicle, and the distance between the ego vehicle and the detected vehicle might become less than the value of alpha set, which is the safe threshold distance set (Figure 14 (a) and (b)).

Figure 14 (a): The vehicle is closer to the ego vehicle than the threshold safe distance (5 meters)

Figure 14 (b): The vehicle is closer to the ego vehicle than the threshold safe distance (4 meters)

Table 5. Ego Vehicle Status for Case III

Figure Number	Pedestrian α Value	Vehicle α Value	Actual Pedestrian Distance	Actual Vehicle Distance	Ego Vehicle Status
Figure 14(a)	2 m	5m	2.94 m	2.64 m	Collision with vehicle
Figure 14(b)	–	4 m	–	3.64 m	Collision with vehicle

Table 5 shows the list with the coordinates of the detected vehicles and pedestrians. As the calculated distance for the closest vehicle is less than the value of alpha set for the vehicle, thus it is concluded that there is imminent collision on course and that too with a vehicle.

V. Conclusion

VANETs face high customer services demand to overcome issues like traffic jam, car crash etc. In this paper, design of a simulation based driving scenario environment has been discussed., the variation of sensor detection rate in different road conditions have been discussed. Basic Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication network design has been discussed and also V2V connectivity in different situations have been shown here. This paper proposes an integrated approach to Forward Collision Warning System in different cases. The designed prototype can be enhanced by adding more features like increasing the number of sensors to visualize the surrounding environment. This will provide more safety protocols and make the driving and travelling more safe and enjoyable.

References

[1] M. R. Ghori, K. Z. Zamli, N. Quosthoni, M. Hisyam,and M. Montaser, "Vehicular Ad-hoc Network (VANET): Review", IEEE International[Conference on Innovative Research and Deve[opment (ICIRD), vol. 5, no. 2, pp. 121-127, May 2018.

[2] S. Rehman, M. A. Khan, T. A. Zia, and Lihong Zheng, "Vehicular Ad-Hoc Networks (VANETs) - An Overview and Challenges", Journal of Wireless Networking and Communications , vol. 3, no. 6, pp. 29-38, 2013.

[3] V. Kodire, S. Bhaskaran, and H.N. Vishwas "GPS and ZigBee Based Traffic Signal Preemption" Amrita School of Engineering, Bengaluru, India, Publisher IEEE, vol. 11, no. 6, pp. 2129-2135, 2015.

[4] Y. S. Weng, S. F. Su, and C. S. Yu, "Modelling of Emergency Vehicle Preemption Systems Using Statecharts", Publisher IEEE , vol. 7, no. 4, pp 94-108, August 2011.

[5] H. Ito, T. Murase, K. wako, and K. Saszjma. " Crash warning for intersection and head-n car collision in Vehicle-to-Vehicle communication", International Conference on Connected Vehicle and Expo, Tokyo Institute of technology, vol. 1, no. 5, pp. 118-125, 2015.

[6] A. Thakur and R. Malekian, "Internet of Vehicles Communication Technologies for Trafc Management and Road Safety Applications", Wireless Personal Communications, Springer Nature, vol. 15, no. 8, pp. 20-28, 2019.

[7] M. J. Piran, G. R. Murthy and G. P. Babu, "Vehicular Ad Hoc And Sensor Networks; Principles And Challenges", International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC), vol. 2, no. 6, pp. 37-48, 2011.

[8] Z. Zhao and X. Cheng "IEEE 802.11p for Vehicle-to-Vehicle (V2V) Communications".School of Electronics Engineering and Computer Science, Peking University, Beijing, China, vol. 9, no. 10, pp. 541-547, March 2016.

[9] S. Zhang, Y. Wu, and Y. Wang "An Embedded Node Operating System for Real-Time Information Interaction in Vehicle-to-Vehicle Communication", 19th International Conference on Intelligent Transportation Systems (ITSC), China, IEEE, vol. 7, no. 9, pp. 1224-1229, 2016.

[10] T. Limbasiya and D. Das. "Secure Message Transmission Algorithm for Vehicle to Vehicle (V2V) Communication", Department of Computer Science & Information Systems BITS Pilani,Publisher IEEE, vol. 9, no. 4, pp. 24-27, 2016.

[11] M. A. Hossain, R. M. Noor, S. R. Azzuhri, M. R. Z'aba, K. L. A. Yau, I. Ahmedy, "Approaches in Cognitive Radio-based Vehicular Ad Hoc Networks", IEEE, vol. 9, no. 5, pp. 232-237, 2017.

[12] V. D. Nguyen, T. T. Nguyen, D. D. Nguyen, S. J. Lee, and J. W. Jeon, "A fast evolutionary algorithm for real-time vehicle detection," IEEE Trans. Veh. Tech., vol. 6, no. 6, pp. 2453–2468, Jul. 2013.

[13] G. Toulminet, M. Bertozzi, S. Mousset, A. Bensrhair, and A. Broggi, "Vehicle detection by means of stereo vision-based obstacles features extraction and monocular pattern analysis," IEEE Trans. Image Process., vol. 15, no. 8, pp. 2364–2375, Aug. 2006.

[14] F. Erbs, A. Barth, and U. Franke, "Moving vehicle detection by optimal segmentation of the dynamic stixel world," in Proc. IEEE Intell. Veh. Symp., vol. 5, no. 2, pp. 951–956, Jun. 2011. Proc. 13th Int. IEEE Conf. Intell. Transp. Syst. (ITSC), vol. 7, no. 3, pp. 439–444, Sep. 2010.

[15] C. D. Pantilie and S. Nedevschi, "Real-time obstacle detection in complex scenarios using dense stereo vision and optical flow," in Proc. 13th Int. IEEE Conf.

Intell. Transp. Syst. (IPSC), vol. 7, no.3, pp. 439-444, Sep, 2010.

[16] L. Zhenyu, P. Lin, Z. Konglin and Z. Lin, "Design and evaluation of V2X communication system for vehicle and pedestrian safety", The Journal of China Universities of Posts and Telecommunications , vol. 6, no. 11, pp. 18-26, 2015.

[17] Kalman, R.E. A new approach to linear filtering and prediction problems. Trans. ASME J. Basic Eng. 82, 35–45 1960.

[18] G. Welch and G. Bishop, "An Introduction to the Kalman Filter". In Proceedings of the SIGGRAPH, Los Angeles, CA, USA, 12–17 Course 8, 2001.

[19] S. Zang, M. Ding, D. Smith, P. Tyler, T. Rakotoarivelo and M. Kaafar, "The impact of adverse weather conditions on autonomous vehicles", IEEE Veh. Technol. Mag. Vol. 14, no. 3, pp. 103–111, 2019.

[20] J.M. Wille, F. Saust, M. Maurer, " Stadtpilot: Driving Autonomously on Braunschweig's Inner Ring Road. in Proceedings of the IEEE Intelligent Vehicles Symposium, SanDiego, CA, USA, vol. 6, no. 2, pp. 506–511, 2010.