Vehicular Safety System: Driving Behavior Identification Based on V2V Data Exchange System

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Abstract:
Driver behavior is a determining factor in more than 90% of road accidents. Previous research regarding the relationship between speeding behavior and crashes suggests that drivers who engage in frequent and extreme speeding behavior are overinvolved in crashes. Consequently, there is a significant benefit in identifying drivers who engage in unsafe driving practices to enhance road safety. The proposed method uses continuously logged driving data to collect vehicle operation information, including vehicle speed, engine revolutions per minute (RPM), throttle position, and calculated engine load via the on-board diagnostics (OBD) interface. Then the proposed method makes use of severity stratification of acceleration to create a driving behavior classification model to determine whether the current driving behavior belongs to safe driving or not. The safe driving behavior is characterized by an acceleration value that ranges from about ±2 ms-2. The risk of collision starts from ±4 ms-2, which represents in this study the aggressive drivers. By measuring the in-vehicle accelerations, it is possible to categorize the driving behavior into four main classes based on real-time experiments: safe drivers, normal, aggressive, and dangerous drivers. Subsequently, the driver's characteristics derived from the driver model are embedded into the advanced driver assistance systems. When the vehicle is in a risk situation, the system based on nRF24L01 + power amplifier/low noise amplifier PA/LNA, global positioning system GPS, and OBD-II passes a signal to the driver using a dedicated liquid-crystal display LCD and light signal. Experimental results show the correctness of the proposed driving behavior analysis method can achieve an average of 90% accuracy rate in various driving scenarios.

Keywords:
Aggressive driving, V2V , Acceleration, Speed, GPS

1. Introduction

Exploring the literature demonstrates an observable number of research articles in the area of vehicle-to-vehicle (V2V) communication systems. Over the past years, data exchange techniques among vehicles have been developed. Moreover, traffic congestion has become an ever-increasing problem worldwide. Congestion reduces the efficiency of transportation infrastructure and increases travel time, air pollution, and fuel consumption. In Europe alone, around 40000 people die, and 1.7 million are injured annually in traffic accidents [1]. Traffic safety has become a serious problem in transportation systems. The growing number of vehicles significantly increased the level of traffic accidents. The safety of vehicles and pedestrians is threatened by traffic accidents [2]. Traffic crashes on highways not only

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induce delays, but also additional safety issues in terms of secondary crashes (SCs) [3]. The new generation of the wireless network should be designed to offer a solution with a high degree of reliability and availability in terms of data rate, latency, or other quality of service parameters [1]. With the rapid development of wireless communication technologies, V2V networks are increasingly becoming common. Such networks possess enormous potential in improving driving safety and traffic conditions by sharing road and traffic information among vehicles in real-time [4].

Data exchange in V2V communications and ranging systems enable communication and measuring between two moving vehicles at a distance [5]. Enabling vehicles and additional communication infrastructure with “smart” algorithms may solve some major safety problems in vehicular networks [6]. The perception of vehicles may be improved beyond the capabilities of traditional sensors by the exchange of location data (i.e. time, position, heading, and speed), vehicle dimensions, vehicle type, yaw rate, acceleration, and many other parameters [7, 8]. Accidents are considered one of the most detrimental aspects of the usage of automobiles. Due to the high density of vehicles, potential threats and road accidents increase [9]. Road accidents are of great importance to all humanity, and this is a challenging issue that needs to be considered [10].

Ordinarily, these accidents stem from driver errors such as speeding and aggressive driving [11]. Due to the ephemeral nature of Vehicle to Vehicle (V2V) networks, no individual vehicle can have a good view of the other vehicle's incident report behavior to reason about trustworthiness effectively. However, if one can design an effective mechanism to collect observations and experiences about individual vehicles, it would greatly facilitate the process of aggregating partial and incomplete information into meaningful intelligence [4]. Motor vehicle related to crashes occur more often in collisions between vehicles than any other type of incident, crashes of this type represented approximately half of the total with 42%, while collisions between vehicles and a fixed object were the next most common type, with nearly 27%, followed by pedestrian incidents and non-collisions such as rollovers as shown in Fig. 1 [12].

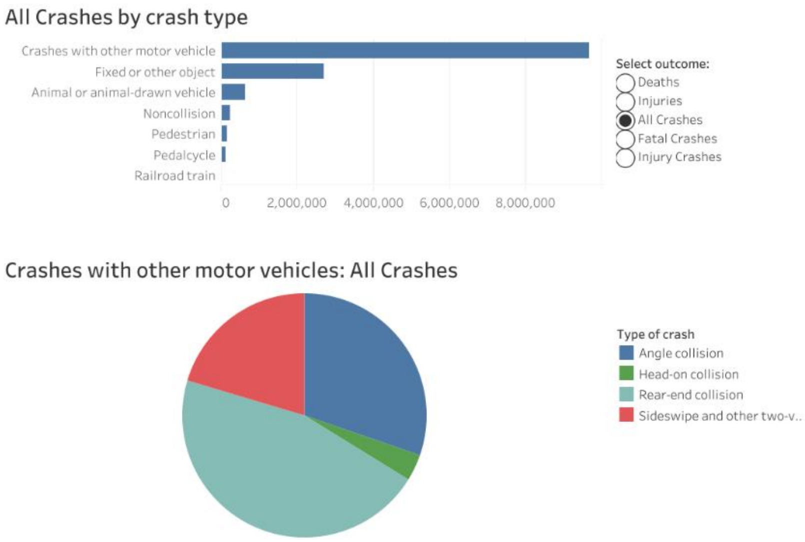


Figure 1: Accident statistics based on the type of collision [12]

A new generation of the wireless network should be designed to offer a solution with a high degree of reliability and availability, in terms of data rate, latency, and Quality of Service (QoS) [1]. Simultaneously with the worldwide increasing demand for transportation, the challenges that a driver faces every day are growing considerably. The situation analysis reports that major casualties are due to the improper driving behavior of drivers. According to the accident research statistics, 75% of fatal accidents are caused by such human factors as lack of attention, stress, loss of orientation, tiredness, medical condition, etc. In 24% of the cases the unexpected behavior is the cause of the accident and only 0.7% of accidents are due to technological failures (Fig. 2) [11, 13-15].

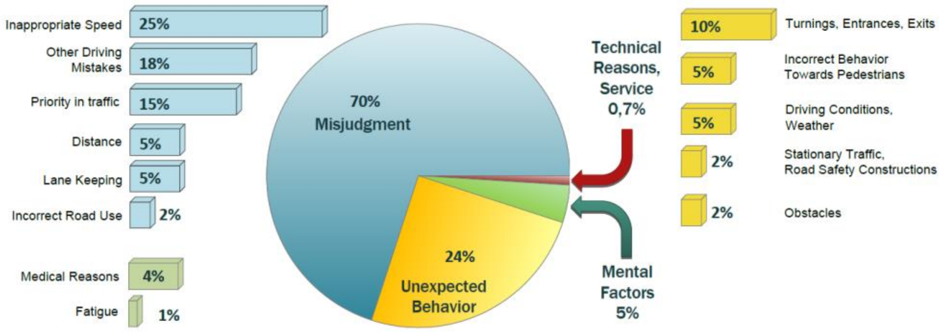


Figure 2: Accident causes, adapted from [15]

The Intersection collision avoidance application combined with driver assistance systems may aid in crucial circumstances by taking a closer look around the corner effect, even in high obstructed channel conditions, according to safety-based V2V applications [10, 16, 17]. In case of an accident, and to cover an adequately wide area, the module must resend the relevant accident message periodically and propagate them to make other vehicles aware of the accident. They can reroute accordingly [18]. Pre-collision systems are a key aspect of these systems. Whether or not the collision is avoidable because it determines the vehicle type of action should automatically take [19]. The next step is to develop systems capable of warning the driver to avoid a potential collision [20]. Road users must be notified of potentially dangerous situations to react on time and appropriately. The V2V communication technology aims to ensure that vehicles are warned of a potentially dangerous situation [21]. Driver behavior modeling is essential for comprehending the driver's involvement in the traffic system and understanding traffic flow. In terms of time and space, the relations between the main components of vehicular traffic can be interpreted as a traditional human-machine framework [22, 23]. Aggressive driving behavior is an essential factor that quickly leads to dangerous driving [14]. To understand safe behavior, that is critical to define unsafe or at-risk behavior. Previous research suggests drivers who engage in frequent and extreme speeding behavior are over-involved in crashes [22].

Furthermore, as far as searching was feasible, it was found a rare work that addresses V2V warning system based on the identification of aggressively driving on real-time data collection and analysis using different devices in a near real-time manner as it is proposed in this work. In our research, we have addressed a more flexible method for detecting driving behavior and then presented a solution using the instantaneous reading from the OBD-II adapter to maintain the string stability among the vehicles. The problem statement configuration is illustrated in Fig.3.

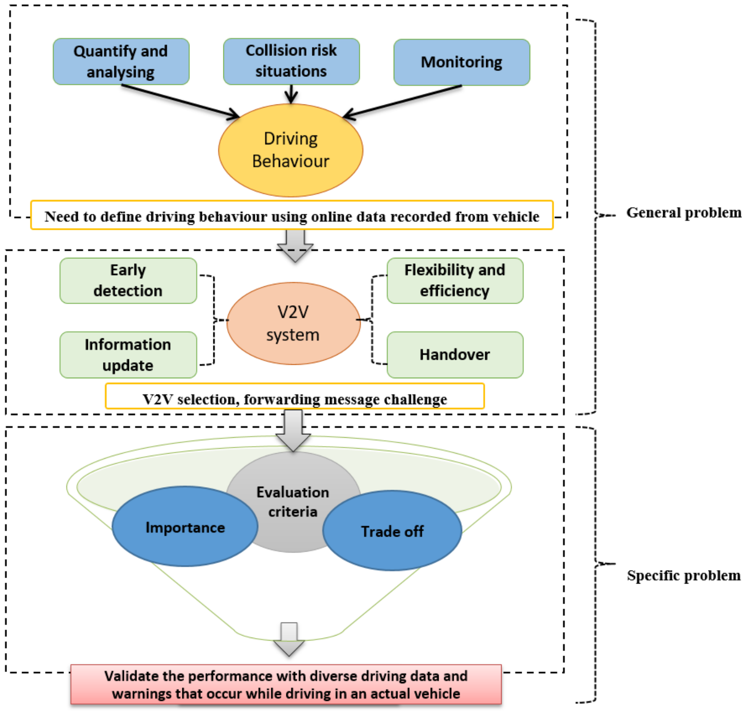


Figure 3: Problem statement configurations

In this study, two main groups were identified from previous works according to the evaluation method used: real-time and simulations. A deep analysis of the accuracy of both sections is conducted in [24] focused on the data exchange from previous articles to define the gap in future directions that target data exchange in the V2V system. In addition to that, using different types of scenarios, vehicles speed, vehicles number to provide a system that can be used in exchanging information between moving vehicles based on the driving behavior to build a collision warning system, which achieved a higher accuracy rate than the other methods used as shown in Fig. 4.

It is important to identify risky or at-risk activity to comprehend safe behavior. In this article, we attempt to use an online data collection approach for modeling drivers' acceleration to measure and analyze individual driving behavior using data collected from instrumented vehicles using various data collection techniques. Graphs and analysis were used to show the findings of the tests for a variety of aspects. The following are the main contributions of this work:

(i) To investigate the existing technologies of V2V communication systems within driving behavior applications.

(ii) To design the methodology of the V2V warning system based on driving behavior to quantify safe or at-risk behavior.

(iii) To develop hardware-based warning systems in vehicles using V2V technology context based on driving behaviors.

(iv) To evaluate the performance of the proposed system against multiple V2V scenarios.

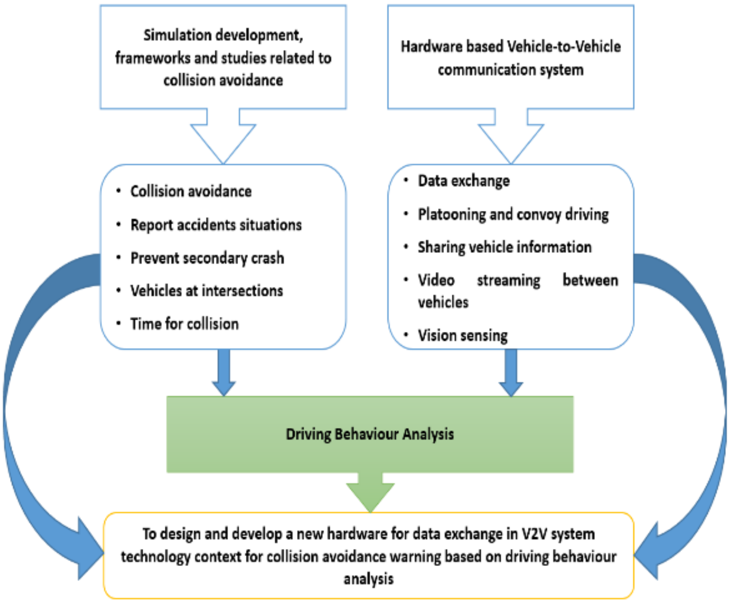


Figure 4: Study of the gap from several articles related to data exchange in V2V system and driving behavior

2. Systematic Review Protocol and Analysis

The most important keyword in this work is 'vehicle-to-vehicle (V2V) communications.' This keyword excludes any non-V2V communications, such as in vehicle-to-infrastructure or vehicle-to-pedestrian systems, and limited the scope to English literature but considered all data exchanges in V2V communications in all scenarios. Three digital databases were explored to search for target articles. (1) IEEE Xplore is a scholarly research database that provides the most reliable and wide-ranging articles in the fields of computer science, electronic technologies, and electrical engineering. (2) Web of Science (WoS) offers indexing of cross-disciplinary research in sciences, electronic technologies, social sciences, arts, and humanities. (3) ScienceDirect is a large database of scientific techniques and medical research. These three databases sufficiently cover V2V and all communication types in this area and provide a broad view of existing research in a wide but relevant range of disciplines. Study selection involved the search for literature sources and three iterations of screening and filtering. In the first iteration of screening and filtering, all unrelated articles were removed. In the second iteration, duplicates and irrelevant articles were removed by scanning the titles and abstracts. In the last iteration, the full-text articles screened from the second iteration were carefully reviewed. All iteration steps applied the same eligibility criteria followed by the authors. The search was conducted in January 2018 and used the search boxes of ScienceDirect, IEEE Xplore, and WoS. To identify the studies related to this area, the query comprises mixed keywords and includes 'vehicle-to-vehicle, 'V2V', 'car-to-car, 'C2C' in different variations and combined by the operator 'OR'; and 'information exchange', 'exchanging information', 'data exchange', 'exchanging data', 'data integration', 'information integration' in different variations and combined by the operator 'AND'. The query text is shown in Fig. 5.

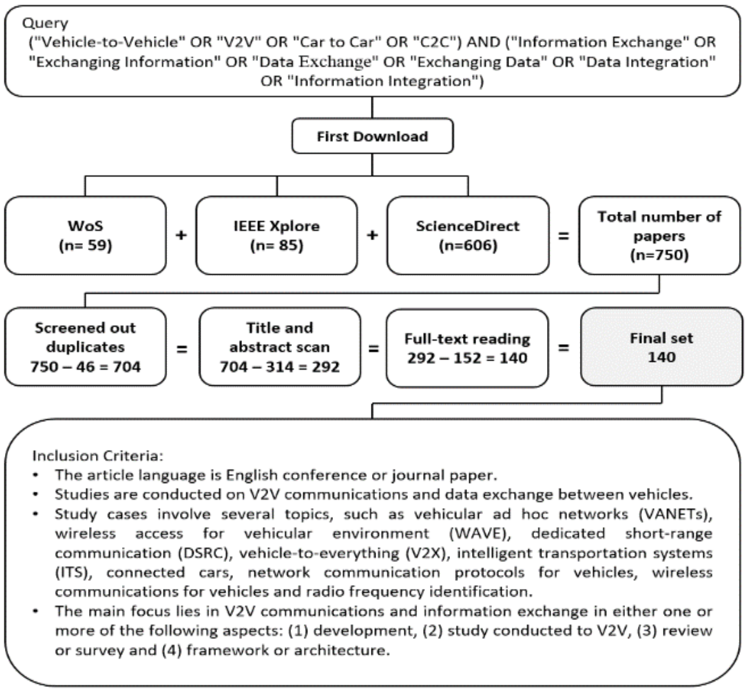


Figure 5: Selection of studies, search query, and inclusion criteria

2.1 Result of Literature Taxonomy

The initial query resulted in 750 papers (59, 606, and 85 from the WoS, ScienceDirect, and IEEE Explore databases, respectively). We filtered articles published from 2008 to 2018 and grouped them into three categories. In the three databases, 46 out of 750 papers were duplicates. After scanning the titles and abstracts, 314 papers were excluded further, which narrowed down the total to 292 papers. The final full-text review excluded 152 papers, and only 140 papers made the final set. All these papers are related to V2V technology through different topics. The taxonomy presented in Fig. 6 was used to review the main streams of research focusing on data exchange in V2V communications systems. This taxonomy shows the comprehensive development of various studies and applications. The classification suggests different classes and subclasses. The first class includes a review and survey articles related to data exchange in V2V communications systems (18/140 papers). The second class includes studies with actual attempts to develop V2V communication systems using real-time or simulation or both (51/140 papers). The third class includes studies conducted using V2V communication systems (53/140 papers). The final class comprises framework proposals and architectures related to V2V communications (18/140 papers). The observed categories are listed in the following sections for statistical analysis.

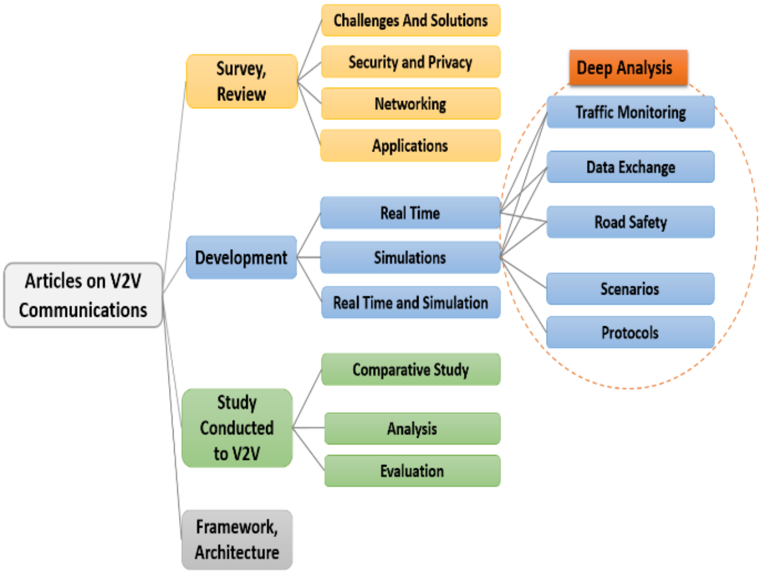


Figure 6: Taxonomy of research literature on V2V communications

2.2 Motivations

The use of V2V communications in VANETs has numerous benefits. Fig. 7 lists a few of the advantages reported in the literature, which are grouped into categories depending on the similarities. The corresponding references are cited for further discussion.

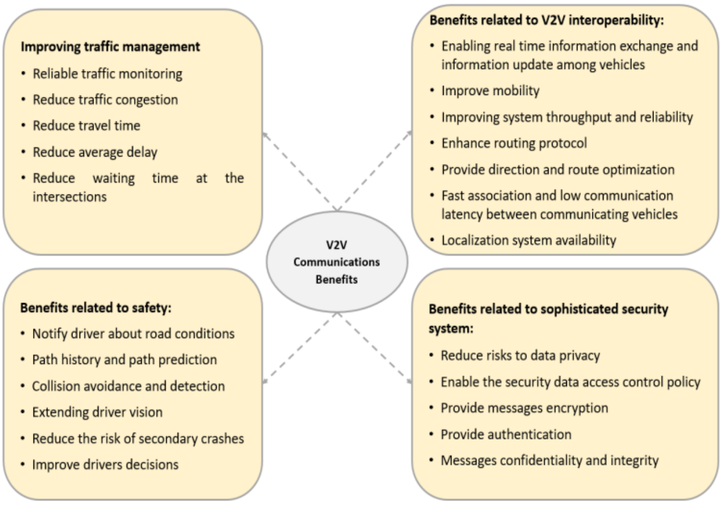


Figure 7: Categories of benefits of V2V communication system

2.3 Issues and Challenges to V2V Communications

Although V2V communications offer numerous benefits, these technologies are not the perfect solution in communication network delivery. The surveyed works indicate that researchers are concerned about the challenges associated with V2V applications and their communications systems. The main challenges in adopting V2V communications are classified according to their nature along with citations for further discussion, as shown in Fig. 8.

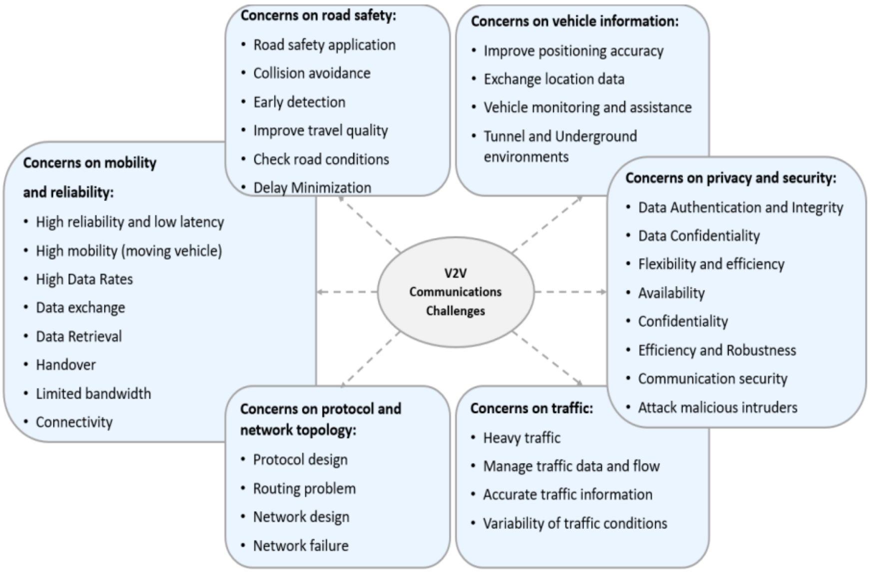


Figure 8: Categories of benefits of V2V communication systems

2.4 Recommendation

This section summarises the most important recommendations in the literature to mitigate the challenges and facilitate the safe and effective use of data exchanging in V2V communications systems, as shown in Fig. 9.

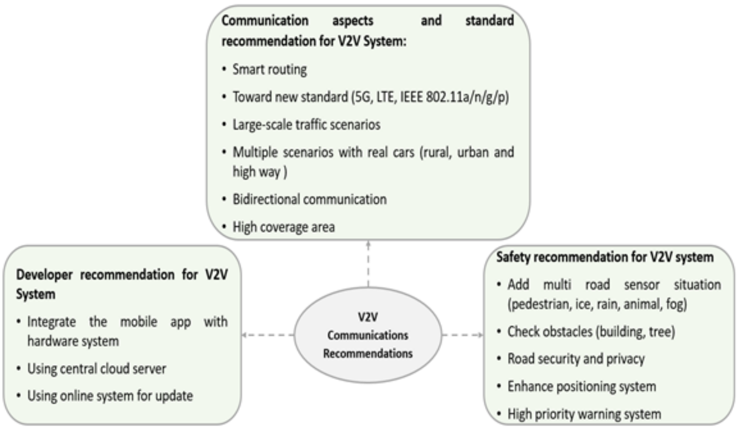


Figure 9: Categories of recommendations for V2V communication systems

3. Methodology

This section presents the number of phases that are used to explain the research methodology. Five main phases are used to get the objectives of the proposed system. The first phase (preliminary study) dealt with identifying and describing the research problem. The second phase (study and analysis) identifies the requirement and criteria for the V2V collision warning system and driving behavior to define a method and observational schemes to monitor drivers and quantify safe, unsafe, or risky behavior. The third phase (hardware design) involves designing and developing a real-time hardware-based V2V warning system based on driving behavior. The final phase (usability testing) validates the performance of the proposed methodology. Fig. 10 depicted the stages of V2V evaluation. Based on these stages, several experiments are designed and developed.

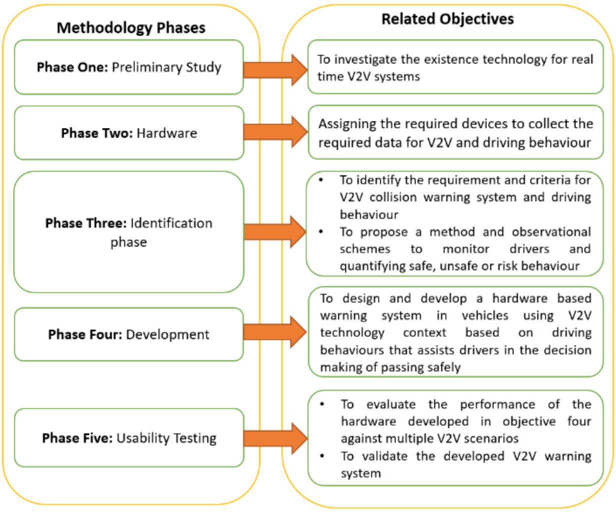


Figure 10: Relation between methodology phases

The collision warning system intends to alert drivers about the existence of unexpected or unseen vehicles using real-time driving behavior data. In producing an effective product, the system should provide a reliable real-time warning system capable of warning the driver and giving the driver time to react. In doing so, the system should pass through several phases, as shown in Fig. 11, which in the first phase, the system must detect vehicles and capture all data needed for collision prediction in real-time. The sensing functionality used should have the ability to differentiate between signals coming from the vehicle and extraneous noise. During the second phase, acquired telematics data filtered together with driving behavior data then placed into input queues for analysis. The use of a transceiver is required. If the final phase analysis results in a high probability of collision, a warning system is activated to alert drivers of a possible collision.

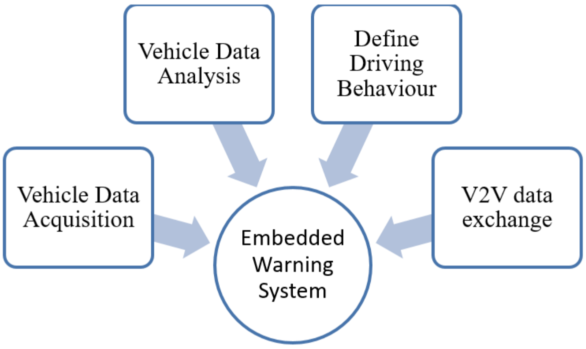


Figure 11: V2V warning system main self-content

3.1 Proposed Algorithm

Vehicular networks have two distinct classes of applications, which are driver assistance and vehicle safety. These classes require different QoS characteristics due to their different communication patterns. Applications for vehicle safety and driver assistance are intended for vehicles that exchange messages among themselves to identify dangerous situations or events that may occur in the vicinity. When a safety alert is received, the vehicle warns the driver through sound or light indications, giving enough time to react and avoid an accident. After the calculation of all evaluation attributes, data was formed for each attribute. The final decision was completed and structured by combining the data from all attributes together. The reason behind this process is its ability to simultaneously consider various procedures for the assigned priority to each attribute. Moreover, the trade-off and conflict among the PKL, PDR, throughput, latency, acceleration and vehicle location criteria are reflected in the V2V data exchange selection process. The complete proposed system presented in Fig. 12, consists of three components, which become the main contribution of this project. These three components are the OBU deployed on the vehicle for driver behavior model analysis, pre-processor system inside the vehicle for potential collision identifier, and V2V data exchange system.

Vehicle-to-vehicle communication is employed, in this case, to provide inputs for intelligent driving algorithms to maintain the distance, speed, and trajectory according to those defined by the leader. Those applications are characterized by small messages intended for vehicles that are close to the sender and must be received as soon as possible to avoid an accident. Thus, those communications will occur among vehicles through a transport protocol based on datagrams. Such applications do not require large bandwidth, instead of depending on low latency, jitter, and loss rates. Meanwhile, the innovative applications of the proposed V2V are applications related to driver assistance and safety. Those applications should not rely on 3G/4G networks since they should operate even in situations where there is little to no network coverage due to the lack of pre-existent communication infrastructure. Further, to reduce the end-to-end delay, those messages should be exchanged from vehicle to vehicle without being required to pass through fixed infrastructure. Thus, new communication standards intended for the V2V system were developed. OBU is designed for the interconnection of the various subsystems. Vehicle information can be collected by connecting the OBD interface and GPS. Surrounding vehicles' information can be collected through the nRF24L01 system. With information from the OBU, they can provide collision forewarning for the drivers. Besides, the LCD screen can demonstrate driving information. The onboard equipment monitors engine start date and time, second-by-second vehicle position (latitude and longitude), heading, and speed. The number of satellites and GPS signal quality indicators are also collected and used in the proposed system. The equipment also provides up to ten engine and emissions-related parameters from the onboard diagnostics system directly connected to the OBD-II engine computer port.

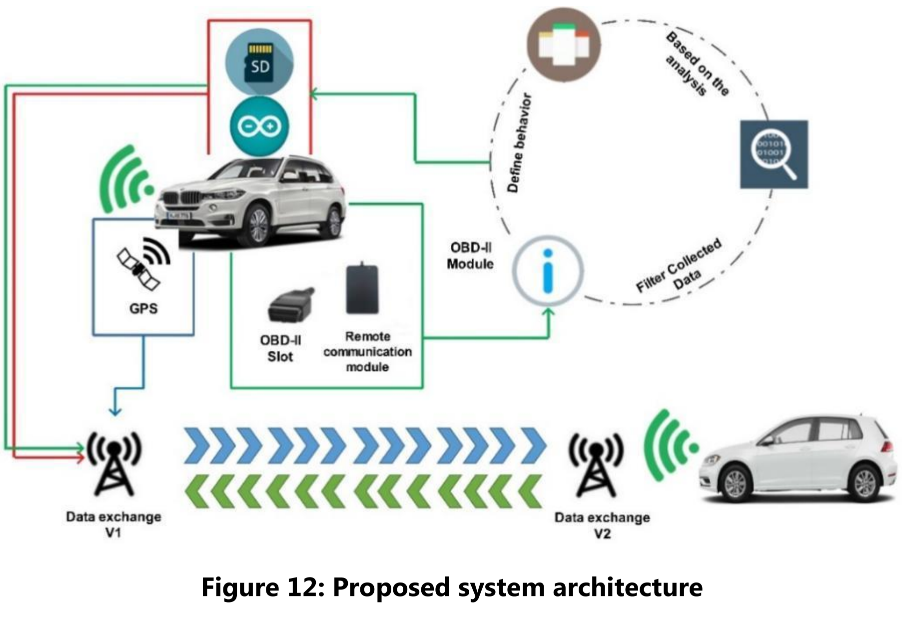


Figure 12: Proposed system architecture

The performances of all the alternatives (vehicles, driving data) are evaluated according to these attributes. This section presents the evaluation of the proposed system for providing a V2V warning system based on driving behaviors, packet loss (PKL), Packet Delivery Ratio (PDR), Throughput, Latency, the distance between vehicles, and Speed and acceleration. The following subsection will provide a brief desecration for each attribute. The first evaluation attribute to be measured is the number of packets loose during the communication between the moving vehicles. The number of packet losses (PKL) is calculated by using Equation (1).

$$PKL = NRpkt - NTpkt \qquad Eq.\ 1$$

Where $NRpkt$ the number of received packets by the second vehicle and $NTpkt$ is the number of transmitted packets by the first vehicle. Due to the large size of the collected data, an excel sheet was used to calculate the number of packet losses for each alternative. The second evaluation attribute to be measured is the number of packets delivery ratio during the communication between the moving vehicles. The number of packets delivery ratio (PDR) is calculated by using Equation (2).

$$PDR = \frac{NRpkt}{NTpkt} \qquad Eq.\ 2$$

Where $NRpkt$ the number of received packets by the second vehicle and $NTpkt$ is the number of transmitted packets by the first vehicle. Due to the large size of the collected data, an excel sheet was used to calculate the number of packets delivery ratio for each alternative. The third evaluation attribute to be measured is the throughput, which is expressed as the volume of data being sent successfully in unit time. Throughput is calculated by using Equation (3).

$$Throughput = \frac{Number\ of\ bytes\ sent}{Total\ transmission\ time\ (sec)} \qquad Eq.\ 3$$

Throughput of the nRF modules recorded at different bit rates and payload sizes, then plot the measurements on charts to analyze the best performance criteria. The fourth evaluation attribute to be measured is the latency which is defined as the time interval from the time of a packet generated by the sender to the time of the packet received by the receiver. A pingpair setup on the Arduino designed enclosed in an infinite loop. A pingpair setup is an experimental setup where Node A sends a message with a predefined size to Node B and Node B echoes back to Node A. After that, Node A calculated the round trip time between sending the original message and receiving the echoed message and used the mean of the delays of the successfully received packets as the average delay. The fifth evaluation attribute to be measured is speed and acceleration refers to an individual driving action using different test vehicles. The behaviors described were the typical exploit that the driver mostly has control over (speed, acceleration, accelerator pedal press). Initially, it should mention the following three concepts regarding the final design, which are speed, velocity, and acceleration, and how they affect and use in the proposed system to determine the behavior of the driver while driving. Speed refers to the distance traveled during a period. Speed is a scalar quantity and it is measured in units of distance divided by time. The commonly used formula for speed calculates average speed rather than instantaneous speed while the instantaneous speed shows the speed at any given moment of the trip as shown in the vehicle's speedometer. Therefore, in the proposed system, we will rely on the current speed. Velocity refers to the rate at which an object changes its position in a certain direction. It is calculated by the displacement of space per unit of time in a certain direction. In the short term velocity factors in direction, but speed does not. The instantaneous velocity is calculated by using Equation (4).

$$V = \frac{\Delta d}{\Delta t} = \frac{d_f - d_i}{t_f - t_i} \qquad Eq.\ 4$$

Where (Δd) represents the change in distance (final - initial) and (Δt) represents the change in time. Acceleration is a measure of how fast velocity changes. Acceleration, like velocity, is a vector quantity, so any change in the direction of a moving body is also an acceleration. An increase in the magnitude of the velocity of a moving body is named a positive acceleration; a decrease in speed is named a negative acceleration. The acceleration is calculated by using Equation (5).

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i} \qquad Eq. 5$$

Where Δv is the change of the velocity which is equal to the difference between the initial speed and the final speed over the time Δt which represents the change in time. To calculate the instant behavior of each driver different OBD-II Parameter IDs (PIDs) codes were used to request data from a vehicle to define driving style. The most common PIDs are defined in the OBD library and used in the proposed system presented in Table 1. The adapter used is directly pluggable into the vehicle's OBD-II port providing a serial data interface (UART or I2C) with a high-efficiency module and fast (up to 100Hz) access to all OBD-II PIDs available in-vehicle ECU.

Table 1: OBD-II PIDs details used in the system

Mode (Hex)	PID (Hex)	Data bytes returned	PID command	Unit	Description
01	0C	2	PID_RPM	RPM	Engine RPM
01	0D	1	PID_SPEED	Km/h	Vehicle speed
01	1F	2	PID_RUNTIME	sec	Engine run time
01	21	2	PID_DISTANCE	km	Distance travelled since engine start

The microcontroller and sensors attached to the vehicles can provide information such as the speed, location, and distance of the impeding and opposing vehicles. These sensors send a signal at every time interval, Δt, to scan the coverage area for any nearby vehicle. The time interval is 0.5 sec or 1 sec based on sensors used to extract the driver's condition. Based on these points, we note that it is not possible to calculate instantaneous acceleration or deceleration during a short time since the (Δt) will be always the same because the update interval of the system is constant so it is not possible to get a correct impression of acceleration and behaviors of the drivers. Most studies related to driving behaviors in terms of acceleration and deceleration are concluded after making an experiment trip where drivers' behavior is calculated and recognized. Last but not least, reference [25] propose driving behavior analysis method based on OBD-II information to collect vehicle operation information, including vehicle speed, engine RPM, throttle position, and calculated engine load, via OBD interface then using MATLAB to complete the data preprocessing and driving behavior modeling in offline mode. Hence, the use of wireless technology for information exchange can influence the drivers' behavior towards improving driving performance and reducing road accidents. In this system, we will focus on new factor during the development phase that is the driving behavior to address the challenges and limitation of the previous researchers.

4. Experimental and Result

One of this study's goals was to predict a driver's driving style based on an analysis of their behavior and surrounding data. Its acceleration and engine RPM determine the speed of a vehicle. These variables are also crucial in predicting a driver's actions. The analysis of instantaneous vehicle parameters recorded during real-world road tests is helpful in this regard. Because of advancements in mobile sensing technologies and these devices' technological capabilities, a variety of objective vehicle and driving style data can be obtained and used for driver style recognition using OBD-II adapters. We conducted a real-world experiment to collect data for driving activities. An Android application captured vehicle engine data while a driver performed specific driving events in these experiments. The beginning and end timestamps of the driving events were recorded to create the ground truth for the experiment. Several researchers discussed thresholds of acceleration linked to causality and a high risk of crash participation. The risk of collision start from -4.0ms-2 according to [26], while in [27, 28] similar results were obtained with a risk of accident involvement around -5.0ms-2. [23] proposed an acceleration/deceleration intensity stratification focused on numerous publications to provide an overview of the driving styles. In case of acceleration present the following parameters (dangerous (7.0 ms-2 - 12.0 ms-2), aggressive (3.5 ms-2 - 7.0 ms-2), normal (1.5 ms-2 - 3.5 ms-2) and safe (0 ms-2 - 1.5 ms-2). Considering the mentioned works, we suggest an acceleration stratification consisting of several groups to test driver acceleration and braking based on our experiments to create a driving style table to enable the V2V alert system based on driving behaviors. It is possible to categorize driving behavior into four major classes by calculating in-vehicle acceleration based on real-time experiments: safe or non-aggressive drivers, normal, aggressive, and dangerous drivers, as shown in Fig. 13.

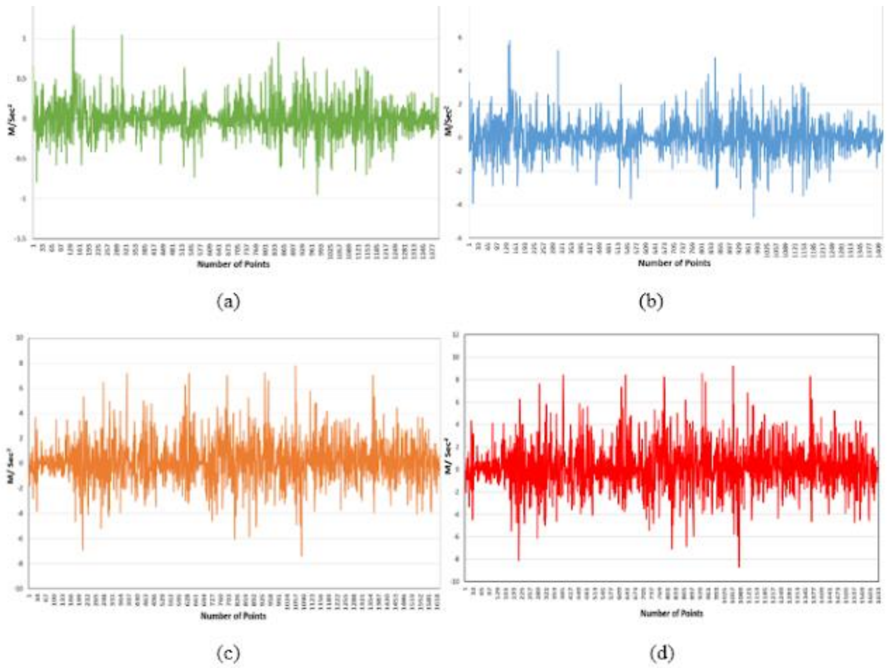
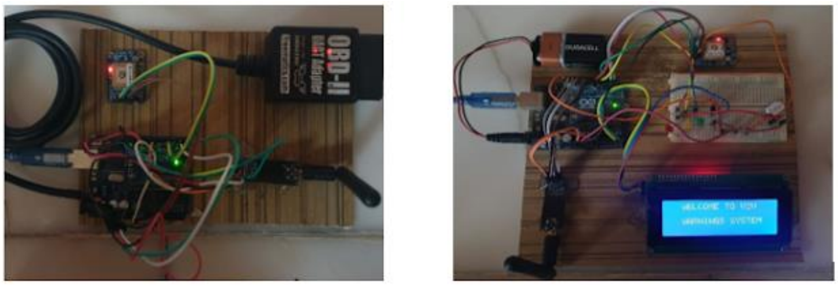


Figure 13: Driving behavior analysis based on acceleration data of (a) non-aggressive drivers; (b) normal; (c) aggressive; and (d) dangerous drivers

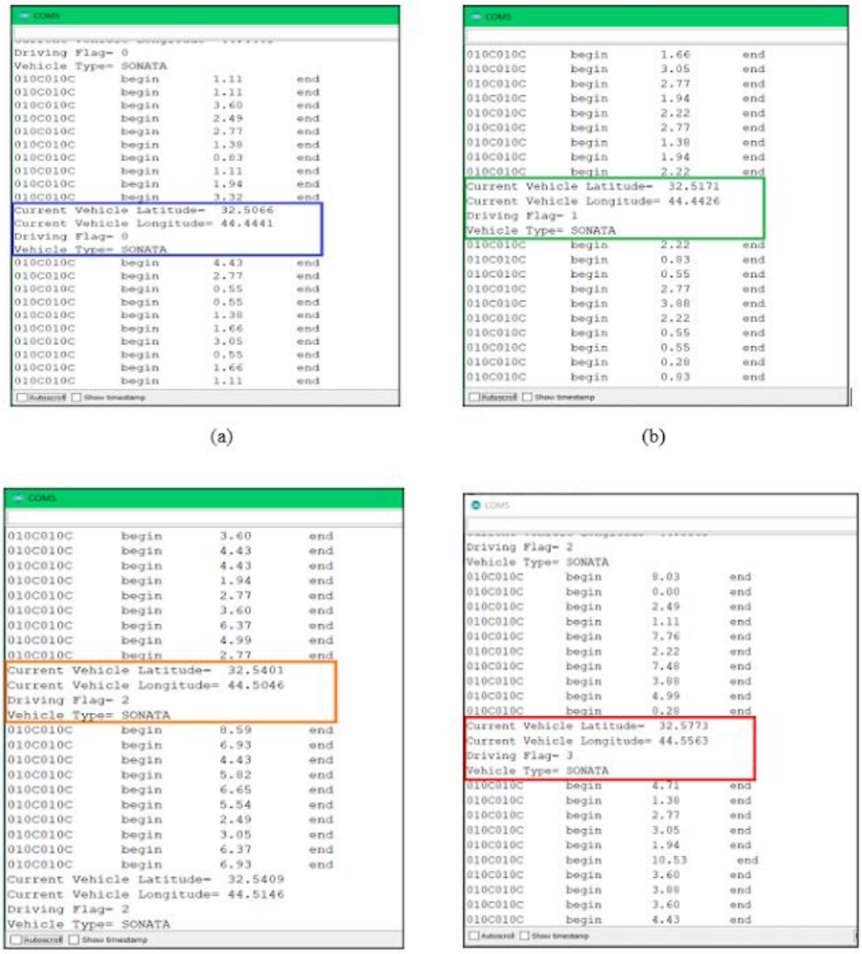
The system algorithm generates an alert message and an estimation distance for vehicles based on driver behavior within the proposed system's coverage area. Driving behavior recognition is a subjective mechanism that relies on the driver's interpretation and response to changing external pressures of time. The driving environment and behavior are well known to be based on a high degree of individual variability in experience and calculation. A high-level architectural framework that incorporates current technology and cognitive structures to build a new approach to identifying driving behavior trends is thus a critical question. The results obtained from the different experiments present accelerations data close to the values provided by previous researchers with some minor differences. These data have been injected into the proposed system to classify the driving performance, as shown in Fig. 14.



(a) (b)

Figure 14: Network layout of point-to-point link; (a) transmitter and; (b) receiver

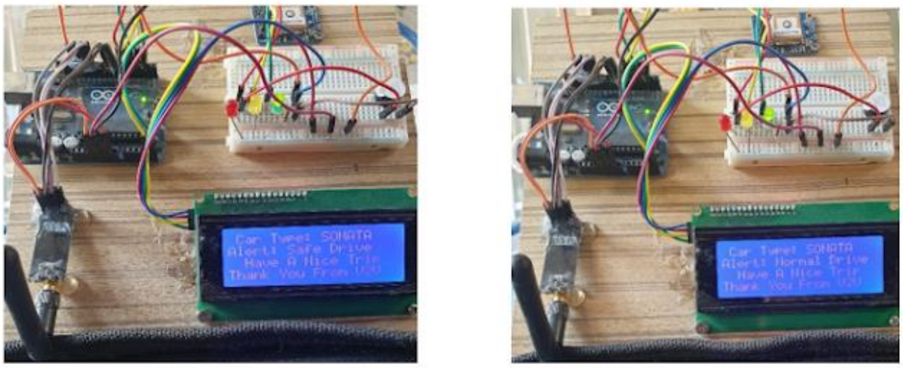
Acceleration values ranging from 2 ms^{-2} are indicative of safe driving behavior. On the other hand, normal driving may necessitate more efficient but still planned braking, resulting in acceleration rates ranging from 2 to 4 ms^{-2}. The risk of a collision begins at 4 ms^{-2}, which represents aggressive drivers in this study. According to the risk assessment, the driver uses abrupt motions in terms of speeding starting at 7 ms^{-2}. The test results are successful, where it can be seen that the driver's behaviors were displayed based on the real-time acceleration readings taken from the OBD-II device connected to the vehicles, as shown in Fig. 15.



(a) (b) (c) (d)

Figure 15: Test results of the proposed methods of; (a) safe; (b) normal; (c) aggressive and; (d) dangerous driving

First, the transmitter is placed inside the first vehicle with the OBD-II connected to the Engine Control Unit (ECU) to obtain driving behavior and consider it as a power source for the board as a whole. In the second vehicle, the receiving device is placed on the dashboard of the second vehicle. A suitable and reliable external warning system has been used to inform the drivers about the driving conditions. However, capturing the driver's attention is a complicated job because it relates to his/her psychological behavior. Humans tend to adapt and entirely down statistical regularities. One idea is to place Lighting LEDs as the visual stimulus regarding surroundings vehicles to capture drivers' attention. Using a large screen with a regular background color deployed at the dashboard would be enough to get the driver's attention. For testing, the V2V system employs a 20x4 I2C character LCD mounted on the microcontroller testing board. The display is capable of displaying four lines of twenty dot matrix characters. If normal behavior occurs, the green LED starts flickering as a simple type of additional alert for the driver. It displays normal on the board to disturb the driver inside the vehicle, especially the surrounding vehicles is normal and it does not represent any threat with no further calculation or analysis needed as shown in Fig. 16.



(a) (b)

Figure 16: (a) Safe and; (b) normal driving results

Two vehicles have been used in leading and the following position on the highway roads to check the system performance in aggressive and dangerous behavior. Data have been sent to the neighboring vehicles together with the vehicle type and the flag status through the nRF24L01. On the far side of the receiving vehicle, the system displays the transmitted flag and then uses the GPS unit mounted inside the board to measure the distance between moving vehicles. In addition, the V2V system switched on the orange LED with a continuous updating of the distance between vehicles whether the threat is approaching or drifting away as long as the sending vehicle is within the coverage range of the receiving vehicle. An example of a warning signal displayed by the LCD is shown in Fig. 17.

Figure 17: Aggressive driving results

The dangerous evaluation indicates that the driver applies sudden movements in terms of acceleration starting from 7 ms^{-2}. Based on these data, the warning system is activated using the same procedures present in aggressive behavior. In the receiving vehicle, the system displays the transmitted flag and uses the GPS unit mounted on the receiving board to measure the two moving vehicles' distance. The red LED is switched on, and the buzzer should be enough to get the driver's attention. The V2V system continuously updates the distance between two vehicles whether the vehicle is approaching or drifting away as long as the sending vehicle is within the coverage range of the receiving vehicle. An example of a warning signal displayed by the LCD is shown in Fig. 18.

Figure 18: Dangerous driving results

5. Conclusion

The V2V communication system is an emerging technology. Research efforts in this direction are still ongoing, as relevant descriptions and boundaries remain ambiguous. Obtaining understanding and insights into this research direction is important. This paper has presented a naturalistic driver method to identify driver's aggressive behavior. The method is composed of five steps capable of studying, collecting data, identifying, developing, and validating to identify aggressive behavior in near real-time response. We intended to define risky driving habits and include appropriate trip characterizations in this article. According to studies, further research and development are required to overcome these limitations, especially in terms of driving actions. This paper proposes a real-time V2V alarm framework that is focused on driving actions. It is possible to categorize driving activity into four major groups based on real-time studies by calculating in-vehicle accelerations: healthy or non-violent drivers, average, aggressive, and dangerous drivers. We suggest a stratification of acceleration consisting of various classes to test driver speed and braking based on our experiments. A severity stratification of acceleration/deceleration presented with the following parameters (dangerous (more than 7 ms^{-2}), aggressive (4 ms^{-2} – 7 ms^{-2}), normal (2 ms^{-2} – 4 ms^{-2}) and safe (0 ms^{-2} – 2 ms^{-2}). In future studies, we would like to use the obtained data sets as input values for a machine learning environment to forecast parameter values with prediction algorithms, decision trees, or time series analysis. Future studies could also use different communication modules such as Wi-Fi, Bluetooth, and ZigBee. Different data types can be used during the test scenarios, including videos and voices data.

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