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IoT based car accident detection and prevention using Naïve Bayes Classifier

Mohammad Sanaullah Chowdhury [1,*], Mubashir Murshed[2]
Department of Computer Science and Engineering University of Chittagong, Chittagong, Bangladesh h
*Corresponding author's email: [1]s.chowdhury@cu.ac.bd , [2]mubashir.ma98@gmail.com

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Abstract: *Internet of Things (IoT) together with Machine Learning has a great impact on the new era of technology. Technological advancement and invention of smarter devices are going neck and neck in today's world. A common incident such as car accidents hampers the advancement of human life. Most common reasons for the accidents are - driver's unawareness and uncontrolled speed of vehicle. We have developed an IoT based solution to detect and prevent such incidents. This paper focuses on a smart system that alerts and controls the speed of the vehicle. It measures real-time distance between vehicles and/or obstacles in front of the vehicle using Ultrasonic sensor. It controls speed of the vehicle and alerts respective individuals if an accident occurs. The core processing unit of the proposed system is Raspberry Pi incorporating Naïve Bayes Classifier. The proposed system is implemented and the experimental results show that the system works properly in different road traffic situations.*

Keywords: *Internet of Things (IoT), Car Accidents, Ultrasonic Sensor, Raspberry Pi, Naïve Bayes Classifier.*

1. Introduction

Internet of Things (IoT) brings the human civilization one step closer to direct communication between machines. It enables devices to communicate and exchange information between them, which lead them to take decisions and perform actions [1]. IoT allows real world devices a secure connection and exchange of real-time data [2]. By using this technology, billions of smart devices such as sensors or actuators connected to the internet, collect and share real world data and information [3].

Machine Learning is a fascinating term in this modern era of advanced technology that can enrich IoT by enabling devices to take decisions on their own [4]. Emerging IoT devices apply Machine Learning technologies that capture and understand data from the environment and help in more intelligent decision [4] [5]. Sensors, actuators, etc. collect data the from environment which can be used as raw materials for the Machine Learning that help IoT devices perform more intelligently [5] [6].

As technology advances, human civilization is facing problems also. Car accidents is one of them, which is a destructive incident that interferes with civilization advancement by taking valuable lives. According to a statistic of the World Health Organization (WHO), every year about 1.25 million people die in road traffic crashes [7]. In addition to that, approximately 20-50 million become injured or disabled. According to a study, 2.2% of deaths occur due to road traffic crashes, establishing it as the 9th leading cause of death around the globe. This phenomenon cost USD $518 billion globally, which is 1-2% of annual GDP of an individual country.

The advancement of technology helps us to aid the challenge of reducing the number of road traffic accidents. IoT and Machine Learning application on vehicles can provide us a better solution to preventing road accidents and therefore increase the numbers of lives saved. A proper alert system to the responsible persons like police, ambulance, relatives can save many injured people from losing their lives.

In this paper, a smart system for vehicles is proposed which can reduce the number of accidents by controlling the vehicle speed, together with a proper alert system. One of the main focuses of this system is its speed controlling mechanism. As the vehicle speed can vary from road to road and also time to time, a light Machine Learning strategy named Naive Bayes Classifier, is used in this proposed system to update the speed control mechanism and alert the system behavior of a vehicle.

The strategy is to have a control over the brake of a vehicle along with the gear system, that is applicable for both auto and manual transmission vehicle. Also, it provides real-time alerts to the driver to control the speed of the car. An email alert is available, to accountable persons if an accident occurs. The proposed method uses Naive Bayes Classifier to learn from the environment and also provides an updated alert and speed control mechanism depending on some parameters. Ultrasonic sensors can provide the real-time distance between two vehicles. This distance data is the raw material used by the Naive Bayes Classifier to update the system mechanism in order to understand road traffic situations. The proposed system is able to control speed, focusing on the busy and regular conditions of road traffic. The gear and braking system of the vehicle is controlled by using Servo Motor. Sound and visual alert equipments such as LED, buzzer, etc. provide an alert to the driver with a graphical user interface and voice feedback.

The rest of this paper is organized as follows: section II compares the proposed system with other related proposals. Section III describes the methodology of our proposed system, while section IV discusses its implementation and results. Section V contains the conclusion.

2. RELATED WORKS

In this section, related works regarding our proposed system is described in detail. Here, we focus on works done in the field of IoT. We proposed a straightforward approach of the alert and speed control mechanism without the application of Machine Learning in [8]. This system is designed to alert the driver. It does so by depending on certain criteria such as measuring a safe distance for suggesting a driver either to slow down or push brakes of the vehicle. When the distance between two vehicles becomes critical, the system will put the brake or change the gear by using Servo Motor to slow down the vehicle. There is also an email alert service for when an accident occurs. Limitation of this system is that it does not work with real time traffic.
In paper [9], the authors developed a system that detects car accidents. In their system, a vibration sensor detects accidents by a micro electro mechanical system and sends it to the microcontroller. GPS location address of the accident spot is provided to a police control room or a rescue team via the GPS modem. But this system carried no accident prevention mechanisms such as speed control or an alert system to control the speed before an accident takes place.

In [10], a system is proposed which is used for monitoring the eye closure ratio of the driver and detects the drowsiness of the driver by using Pi camera. If the eye closure ratio is less than the standard ratio, the driver gets an alert from a buzzer. This paper focuses on building an alert system to mitigate drowsiness of a driver. There is no speed control mechanism of the system. The authors in [11] proposed a system that detects accidents using vibration sensors, accelerometers and the accident location is detected by using a GPS and GSM module that informs nearby persons and hospitals through a text message. It also checks the driver drowsiness or unstable state using eye blink monitoring system, alcohol detection sensor, etc. This system has limitations, one of which is that the driver has to wear glasses at all times to be connected to the system. It can be quite uneasy for a person to wear glasses. Also, there is no speed control mechanism in this system. In [12], the authors proposed a system which has both accident prevention and detection mechanisms. This is done by using IR sensors that can detect accidents. SMS alert is available to the predefined numbers with location address using GSM module. Accident prevention is carried out by IR sensors by warning the driver when the distance between vehicles is close. This system still lacks a speed controlling mechanism and no machine learning approach is applied to make it smarter. The reference [13] proposed an alert system either for an accident or theft by providing the accident location using microcontrollers, embedded sensors and cloud services. It also has no mechanism to prevent accident from happening.

To the best of our knowledge, there exists no system that detects and prevents accidents for the real time traffic scenario as described. Therefore, we propose an IoT based car accident detection and prevention system using machine learning in this paper.

3. METHODOLOGY

This section describes the methodology of our proposed system in detail. In this paper, a smart system is proposed which helps to prevent car accidents, alerts the driver from time to time to control the speed of that car, and controls the speed of the car by the system when necessary, based on real-time captured data from the environment. It also alerts responsible persons when an accident has occurred for any uncertain situation. This smart system is easily applicable for both existing and new vehicles.

A. Proposed System Overview

Our proposed system is composed of a few components that perform operations individually to run the overall system. An ultrasonic sensor is placed in front of the vehicle which always measures the distance between vehicles or obstacles in front of the vehicle. This measurement data is preserved to update the Naive Bayes Classifier's dataset which is used to predict the behavioral performance of our proposed system. The alert and speed control systems work differently for busy and idle periods of road traffic, which is predicted using criteria such as time, location, etc. Servo Motor is used to control the braking mechanism as well as for controlling the gear system of a vehicle. Sound and visual alert equipment like Buzzer, LED, etc. are used to provide an alert in different situations. A Graphical User Interface (GUI) is placed in front of the driver which provides alerts with real-time distance between vehicles in order to concern the driver. An email alert system is available for any uncertainty. Raspberry Pi is the main processing unit of our proposed system to control and process the whole operation. The block diagram of our proposed system is shown in Figure 1.

B. Processing Unit

The processing unit of our proposed system is Raspberry Pi [14], which is a single-board computer with BCM43438 wireless LAN and Bluetooth Low Energy (BLE), GPIO, USB and HDMI Port. It is a low-cost device with a relatively high processing unit of 1.4GHz and a 64bit quad-core processor. The main features of Raspberry Pi are: it is portable, easily programmable and interfaceable to a large number of hardwares and sensors. Raspberry Pi consumes low power as well, and can perform operations with real-time sensor data. This is suitable for our proposed system to perform the desired operations efficiently.

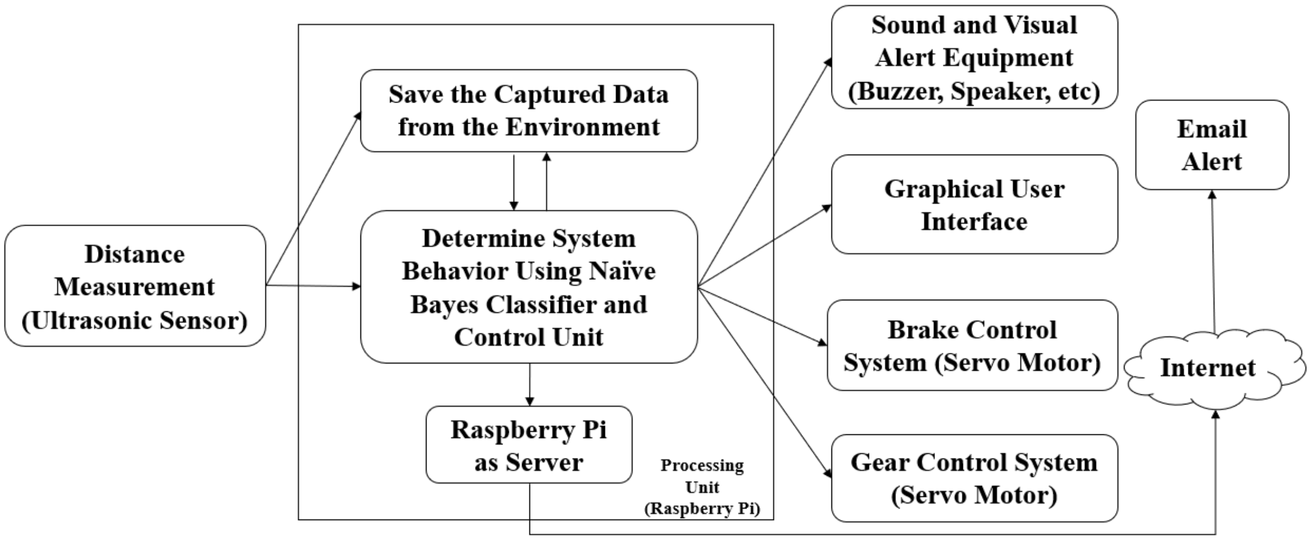

Figure 1. Block diagram of the proposed system

C. Distance Measurement

In our proposed system, in order to measure the distance between two vehicles or to measure the distance between the vehicle and an object in front, an Ultrasonic Sensor is used. This sensor uses sound waves to measure the distance. It does so by calculating the emission and reception time of the sound wave. This sensor can measure a large distance which is enough for road side data and has a desirable accuracy rate which is not affected by the accumulation of dust or dirt. The performance of the Ultrasonic Sensor is adaptable for road side real-time distance data, because its initialization time of measuring distance is a few microseconds.

The HC-SR04 Ultrasonic Sensor was used for building the prototype of our proposed system. It can initialize its measuring operation within 10 micro seconds of time.

D. System Behavior Determination using Naïve Bayes Classifier

The system behavior of our proposed system varies depending on road traffic situations. During a busy traffic period, its alert and speed control mechanism work on a closer distance than regular road traffic conditions. The system behavior can be determined by using some parameters/predictors, such as time, day, location, last 15 minutes of average speed of the vehicle, etc. If we look at the situation of roads, traffic in a commercial area is heavier than a residential area and traffic is also higher during peak hour. Tourist spots are busier in holidays. We have used Naive Bayes Classifier to determine the behavioral approach of this system.

a) Naïve Bayes Classifier

Naive Bayes is a classification technique based on Bayes Theorem, which can assume predictors independently, that is all the predictors have an equal effect on the outcome [15] [16] [17]. The mathematical expression [15] [16] of Bayes theorem is stated in equation no. 1,

$$P(y|X) = \frac{P(X|y)P(y)}{P(X)} \quad (1)$$

The variable y is the class variable (busy, normal, free condition of a road), variable X represent the parameters that helps to predict the class, shown in equation no 2,

$$X = x_1, x_2, x_3, \ldots, x_n \quad (2)$$

Here x_1, x_2, x_3,… x_n represent the predictors, i.e. they are mapped to location, day, time and last 15 minutes of average speed of the vehicle. By substituting for X and expanding using the chain rule, we arrive at the result of y, such as busy, normal, free. The equation is shown in equation no. 3,

$$P(y|x_1, \ldots, x_n) = \frac{P(x_1|y)\, P(x_2|y) \ldots P(x_n|y) P(y)}{P(x_1)\, P(x_2) \ldots P(x_n)} \quad (3)$$

As we are using Raspberry Pi as the main processor of our proposed system, we need a light Machine Learning technique to cope with the low processing unit. Naive Bayes is faster and easier to implement with less data and it does not require an extra training period to train the dataset, which helps to have a higher performance rate on the Raspberry Pi board.

Additionally, it can also be maintained by addition or removal of parameters, which is useful for predicting in any road around the whole world. Another notable feature of the Naïve Bayes Classifier is that it is not reliant on any fixed dataset, so it is not required to monitor the accuracy of any trained model or dataset. Our proposed system can predict the class (free, normal, busy) in a real-time manner by capturing data from the environment.

b)Dataset

Our proposed system uses a dataset that is captured and learned from the environment. A vehicle runs faster on a highway and sometimes there is a speed limit. During festive season, highways can be busier than on regular days. Also, a commercial area is busier during office hours than others. Our system can understand road traffic conditions by using distance data provided by Ultrasonic Sensor.
As road traffic condition varies, we cannot use a fixed Machine Learning model. Our proposed system learns from the environment and captures location, day, time, last 15 minutes of speed of the vehicle which are used for the dataset. Using these data, system behavior is determined and the dataset is updated for certain conditions/situations.

Some default rules are inbuilt, such as alert for when the distance reaches 30 meters between two vehicle and the speed control mechanism performs within 5m distance etc. The dataset gets updated even if a certain location cannot provide a good prediction using the captured data or due to unavailability of internet to identify any location along with other uncertain situations. An example of a dataset in Chittagong City of Bangladesh is shown in Table 1.
The GPS location is captured by using the GPS module that is interfaced with the Raspberry Pi board. The latitude and longitude, which is acquired by using the GPS module, is converted to a textual form of the location's name to perform operation for predicting a class in discrete manner. Date and time can easily be acquired from the OS using simple Python programming. The speedometer of the vehicle provides the last 15 minutes of speed, which is further processed by Raspberry Pi.

c) System Behavior Determination by using Real-Time Captured Data

Ultrasonic Sensor provides real-time distance data between vehicles. The alert and the speed control mechanism operate based on the distance data between vehicles or object in front of the vehicle. The parameters/features of the dataset are used to predict a certain class. In our proposed system. three classes have been used for operating on busy (class 3), normal (class 2), free (class 1) road traffic situations (shown in the dataset in Table no 1).

In Chittagong city of Bangladesh, there is a rush hour in the evening on the GEC Road. A car where our system has been installed, has a dataset including GPS location, day, time and last 15 minutes of speed. It also has an Ultrasonic Sensor which provides data of the nearest object distance in front of the car. By using all of these data, Naive Bayes Classifier predicts class 3, which means the vehicle will alert or control the speed within a short distance as the road seems busy.

E. Speed Control Mechanism

In this paper, our proposed method focuses on prevention of accident. A vehicle should have speed control system of its own when the driver doesn't respond or failed to control the speed at a critical distance from another vehicle or object. Here, we propose a smart system which is workable for both Automatic and Manual Transmission Vehicle/Car.

a) Manual Transmission Car

In a manual transmission car, to control the speed of a vehicle i.e. slowing down a car needs control over the brake and clutch with the shifting of gear [18] [20]. Reduction in gearing is a proper way to slow down a car engine that run at high speeds. The gearbox which provides a selection of gears to control the car speed in different situations. The lower gear turns the car wheels slower, with comparison to the engine speed. The clutch system can stop a car without killing the engine [18]. The clutch can smoothly perform the operation of engaging a spinning engine to a non-spinning engine.

Servo Motor which is a rotary or linear actuator that allows for precise control of angular or linear position, is also suitable to use in a closed-loop control system [19]. As we see the clutch and the gear control mechanism, they can be controlled by using the Servo Motor working principle.

A Servo Motor has to be placed on the gearbox, near the fork of the gear. This motor can change the gear by performing its angular movement. Another is placed beside the clutch and the brake paddle in order to press on them. The Servo Motor is able to return to its previous position by angular movements [19]. This explains how the speed control system is able to be back in the initial position after each operation. Figure 2 shows the block diagram of the gearbox with Servo Motor in the proposed position and Figure 3 shows the block diagram of the clutch system with the Servo Motor.

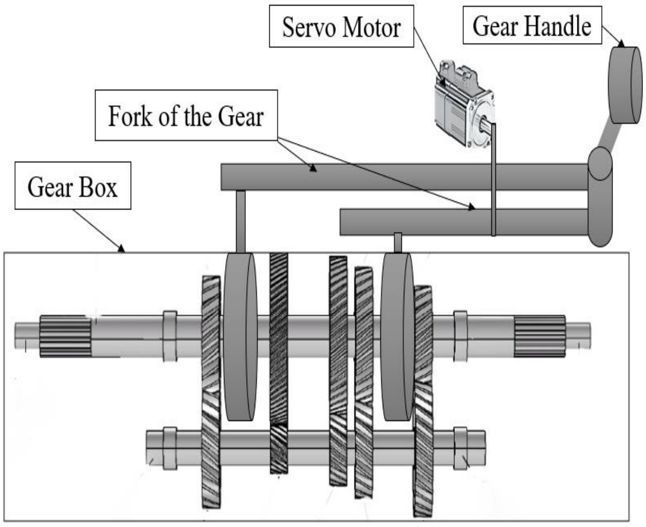

Figure 2. Block diagram of the gear control system with servo motor

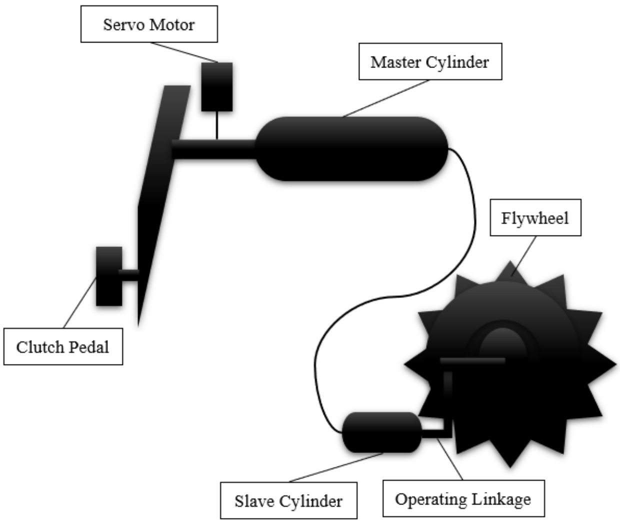

Figure 3. Block diagram of the clutch system of a car with servo motor

*b) **Auto Transmission Car***

In the current age, most modern vehicles are following the auto transmission system. They have brakes on all four wheels of the hydraulic system to control vehicle speed [21] [22]. In a hydraulic brake circuit, the fluid-filled master and slave cylinders are connected by pipes. As soon as the brake pedal is pressed, it depresses a piston in the master cylinder, forcing fluid along the pipe. The fluid travels to the slave cylinders at each wheel and fills them, forcing the pistons out to apply the brakes [20] [21] [22]. This setup allows greater force to be applied by the brakes, in the same way a lever does its work.

According to an auto transmission car braking system, we only need to press the brake pedal to have control over the car speed [21]. A Servo Motor placed beside the brake pedal can perform pressing operations with its working principle. In figure 4, the block diagram of the braking system with is shown with the Servo Motor proposed position indicated in the figure.

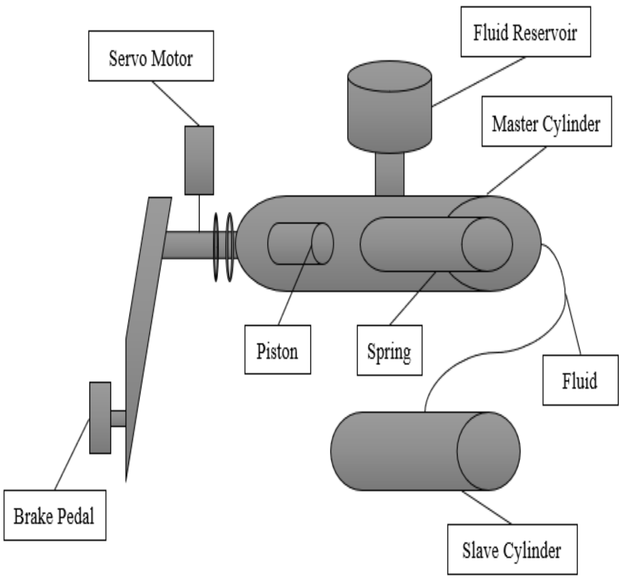

Figure 4. Block diagram of the braking system of auto transmission car with servo motor

F. System's Alert Working Principle

The proposed system provides different types of alerts depending on the road traffic condition. This alert system works for both alerting the driver and the responsible person for any uncertainty. The system sends an alert to the driver depending on the different traffic situations of a road. When two vehicles come close, an alarm in the car is placed as an initial awareness. The yellow led alert with a a Buzzer sound and voice feedback plays as a risk indication. If there comes a critical position between two vehicles, the red LED alert is shown with a Buzzer sound and voice alert. The system constantly keeps showing the distance between two vehicles on a Graphical User Interface. The calculated distance helps driver to determine actual distance between two vehicles. Our system also includes alarm to alert the driver. When the distance between two vehicles becomes critical and the driver doesn't respond, the system performs its operation of slowing down or stopping the vehicle by itself. Hypothetically, if an accident happens, the system will send an email as a rescue alert with car details and a GPS location of the accident spot to the authorities. The flow chart of our proposed system is shown in Figure 5.

4. IMPLEMENTATION AND RESULTS

The method of implementation of our proposed system is discussed in this section with results. For implementing our proposed system, we have used hardware, such as Ultrasonic Sensor, Servo Motor, Buzzer, LED, GPS module and a normal sound system for voice feedback. Raspberry Pi has been used as the main controlling unit. We programmed the system with the Python programming language which is efficient and easy to program with large numbers of library functions that deal with hardware components.

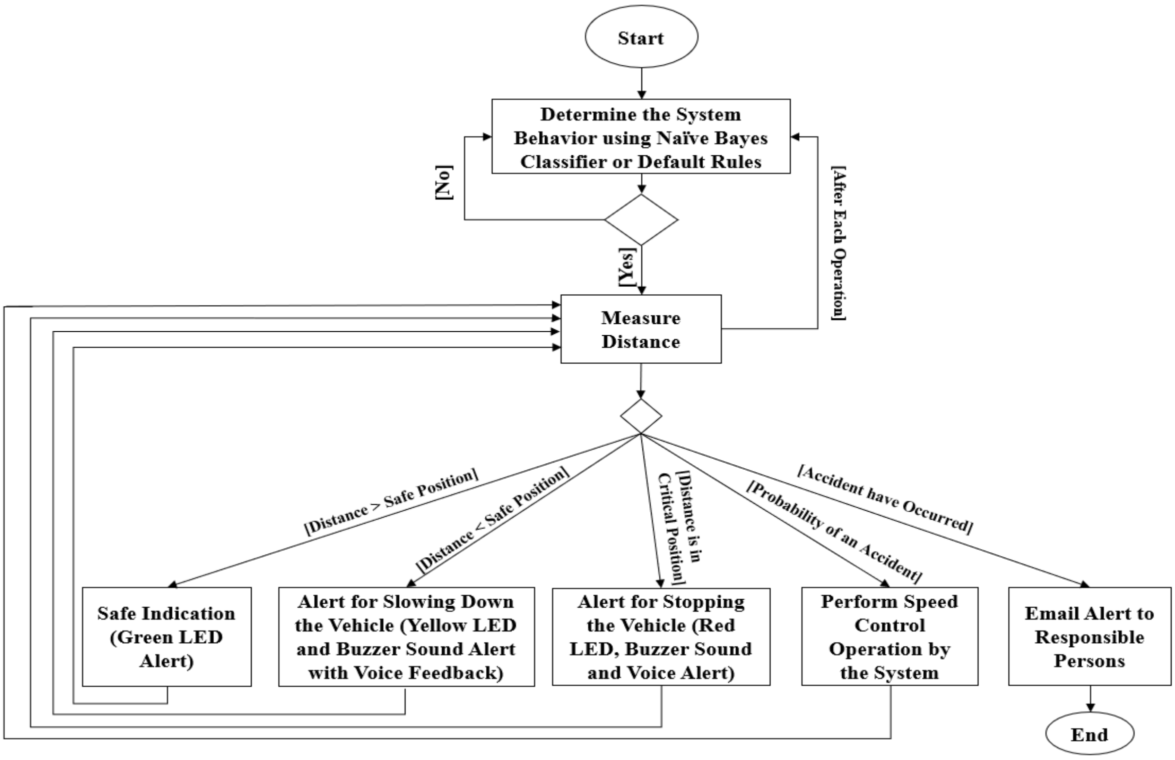

Figure 5. Flow chart of the proposed system

Ultrasonic Sensor captures real-time distance data which is shown in Figure 8 and is also saved in a text/excel file (shown in Table 1) for further processing by using simple Python programming language. This data is necessary for Naive Bayes Classifier operation handling, which is programmed by a Machine Learning tool named Scikit-Learn. GPS location address which is captured by using the GPS module on a road, will be preserved in a text/excel file that is usable for updating dataset, and for providing location address as Email alert when necessary. The GPS location address (longitude and latitude) is converted to the location name by simple Python programming for discrete class prediction by Naïve Bayes Classifier.

Table 1 shows an example of a captured dataset from an experimental environment. Our proposed system always checks the current location's dataset. When a new GPS location address is retrieved, the dataset of that location is updated for that certain city. If the system has less data or no data to perform the operation of Naive Bayes Classifier at a certain location,

Table 1. Example of a dataset

Location	Day	Time	Last 15 avg minutes speed	Class
New market road	Sat	Morning	40	1
Agrabad road	Mon	Evening	8	3
GEC road	Tue	Evening	5	3
Oxygen road	Wed	Night	50	1
GEC road	Mon	Evening	9	3
New market road	Sun	Noon	20	2
GEC road	Fri	Morning	40	3
Oxygen road	Wed	Night	45	3
2no gate road	Fri	Morning	40	3
New market road	Sun	Evening	5	1
GEC road	Fri	Evening	20	2
Oxygen road	Sun	Noon	8	1
2no gate road	Mon	Noon	5	1
GEC road	Mon	Night	40	3
New market road	Thurs	Evening	10	1

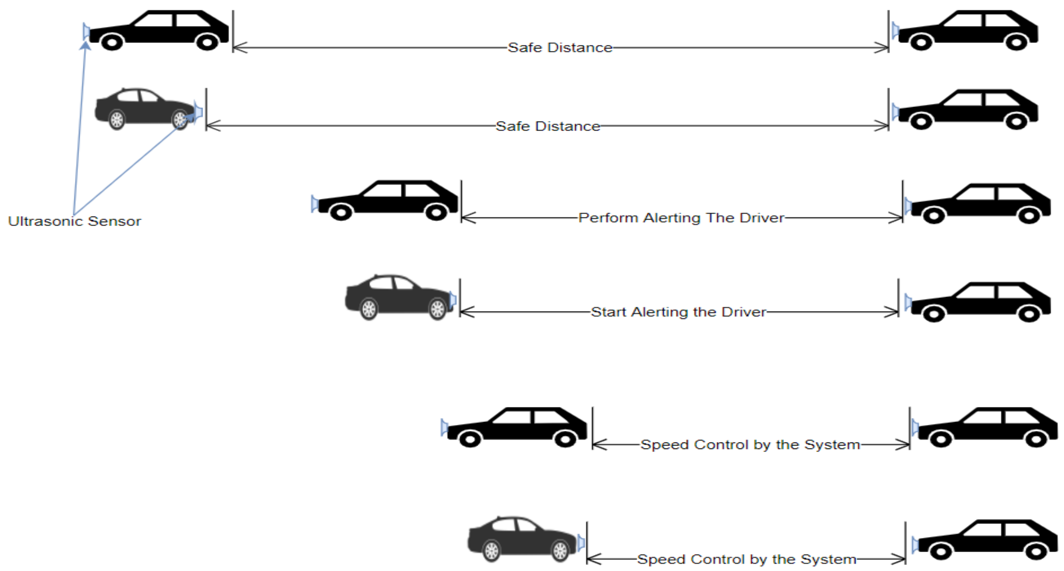

Figure 6. Some experimental scenarios of the proposed system

or it does not have a probability greater than the threshold value for any class, it applies the default rules and updates datasets for later processing. This system gathers knowledge about traffic conditions of a road by analyzing distance data which is captured by Ultrasonic Sensor. It always checks the last 15 minutes of average speed of a vehicle, and then compares it with the distance data in order to analyze the situation of traffic on a road for certain periods of time. We have used location, day, time and the last 15 minutes of speed of the car as the parameters for the Naive Bayes Classifier. There are three classes (busy, normal, free) to determine the road traffic situation. Our prototype used a threshold of 0.4 to select a class. If Naive Bayes Classifier provides a class probability greater than 0.4, that class will be selected for determining system behavior. If a situation arises where no class has a probability greater than the threshold, the proposed system performs its default rules to select the system behavior on that location. It also updates the dataset of that location for future operation. The threshold of our prototype was selected at 0.4 to cope with four parameters efficiently, and to maintain a large range of probability values of a class, in comparison with others, when selected as the system behavior.

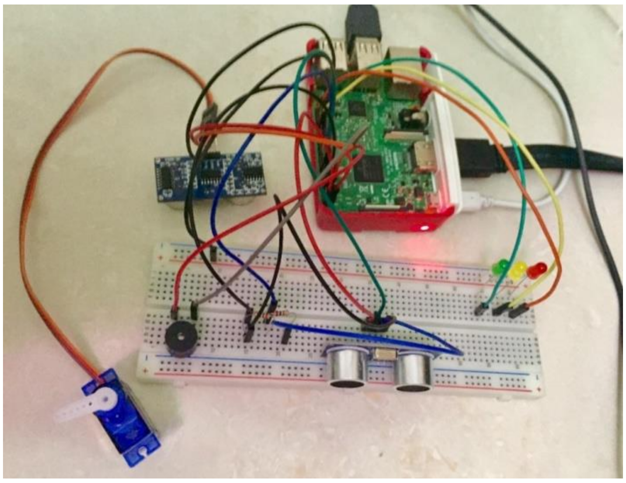

Figure 7. Experimental setup of the proposed system

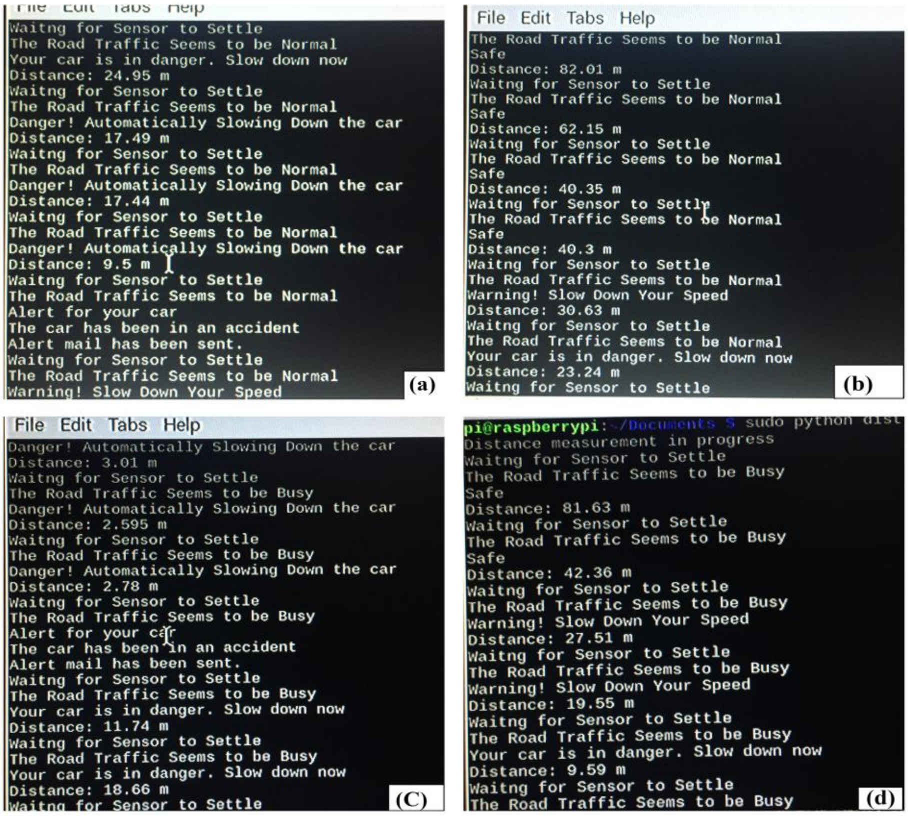

Figure 8: Awareness text produced for the driver

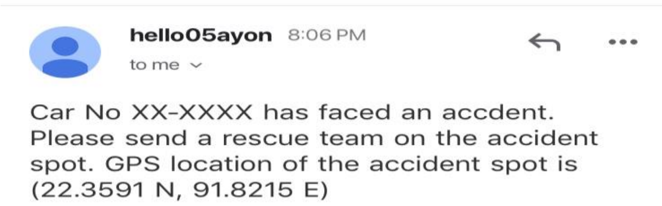

Figure 9: Email alert to the responsible person

The predicted result of Naïve Bayes Classifier is always between the ranges of 0 to1. Hence, we consider a certain value in between this range effective for predicting a class. We focus on a threshold for our proposed system. The dataset always gets updated according to the different traffic condition depending on time and place. Therefore a fixed dataset or model cannot be applied and we should not deal with a pre-trained model in order to maintain accuracy for determining system behavior in a real time manner.

Some experimental scenarios of our proposed system on the road is shown in Figure 6. Our proposed system is implemented as shown in Figure 7. The results are shown in Figure 8 and Figure 9.

Figure 8 shows the Graphical User Interface that will be placed in front of the driver's seat. It displays the various road traffic situations and how the system acts. Figures 8(a) and 8(b) show the system behavior for regular traffic on a road, and Figures 8(c) and 8(d) show a busy road traffic condition. The proposed system predicts busy traffic conditions on the road, in which case the system performs its operation on a closer distance than regular road traffic situations. In this proposed system, Email Alert service is implemented by using Python library and Gmail Server which is free. Others email servers can also be used. Figure 9 shows the Email Alert system which will be available to responsible persons if an accident occurs.

5. CONCLUSION

We have introduced a low cost, reliable, reusable and easily maintainable system, focusing on the detection and prevention of car accidents. We have implemented a smart IoT based system, which can control the speed of a vehicle automatically whenever there is a risk of an accidental incident. The experimental results show that it works with real-time data from the environment which is processed by Naïve Bayes Classifier efficiently. One of the most useful traits of Naïve Bayes classifier is that it can work with low processing units (in our case, Raspberry Pi). Our proposed system predicts and determines the system behavior by considering the threshold value for the real-time captured dataset. As a result, the system performs well. The results show that the integration of IoT and Naïve Bayes Classifier yields detection and prevention of car accidents in real time traffic.
The proposed system fulfills most of the necessities of a smart system with minimal effort and maximum gain. Our proposed system works in an efficient manner on roads with a 4G/high speed internet connection.
Moreover, the location provided by the GPS module used in this system helps in rescuing victims by providing prompt email alerts.
The motivation behind designing this system is the desire to reduce car accidents and reach increased system performance overall. The future works of this system may include concentrating on integrating new features with technological advancements.

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