UNIVERSITY of RWANDA

Research and Postgraduate Studies (RPGS) Unit

AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS

SMART APPLICATION FOR ACCIDENT DETECTION BASED ON IOT SENSORS

UWINEZA Adeline

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ACEIoT

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SMART APPLICATION FOR ACCIDENT DETECTION BASED ON IOT SENSORS

BY

UWINEZA Adeline

214002173

A dissertation submitted in partial fulfillment of the requirements for the degree of Masters in the Internet of Things-wireless intelligent sensor networks at African Center of Excellence in the Internet of Things (ACEIoT)

In the college of Science and Technology

Supervisors: Dr. Jean Batiste MBANZABUGABO and Dr. Emmanuel MASABO

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DECLARATION

I, UWINEZA Adeline with Registration Number: 214002173, Master's student at University of Rwanda, College of Science and Technology, African center of Excellence in Internet of Things-wireless Intelligent sensor networking, hereby declare that this work is original and it was never been presented at the University of Rwanda or in any other Universities or institutions.

Student signature………………

UWINEZA Adeline

Date: 04 /08 /2021

BONAFIDE CERTIFICATE

This is to certify that the work contained in the thesis entitled "Smart application for accident detection based on IoT sensors" submitted by Adeline UWINEZA, Registration Number:214002173, for the award of the degree of masters of Science in IoT/Wireless Intelligent Sensor Networks (WISeNet), to the University of Rwanda, College of Science and Technology/ACEIoT. Adeline UWINEZA is a record of Bonafide research works carried out by her under our supervision and guidance.

We are convinced that the thesis has reached the standards and the requirements of the rules and regulations relating to the nature of a masters 'degree. The contents embodied in the thesis have not been submitted for the award of any other degree or diploma in this or any other University.

We certify that the above statements are true to the best of our knowledge.

This work has been submitted under the guidance of Dr. Jean Batiste MBANZABUGABO and

Dr. Emmanuel MASABO

Dr. Jean Batiste MBANZABUGABO **Dr. Emmanuel MASABO**

The Head of Masters and Trainings

Dr. MUKANYILIGIRA Didacienne

Signature:

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ABSTRACT

A road accident occurs unpredictably and involuntarily and often causes damage, injury, or death. The purpose of this project is to reduce the mortality rates after an accident by eliminating the time delay between the accident's occurrence and the first medical emergency. This research deploys a Machine Learning based intelligent system that can detect an accident, to notify the hospital and the police station. By using an Internet of Things system, sensors are embedding in the vehicle, such as speed sensor, gravitational force sensor, sound sensor, Nodemcu-ESP8266 with Global Positioning System (GPS). The sensors collect the data, which is then processed and analyzed using artificial neural networks. Once an accident happens, the sensors detect the accident, the sensors send the data to the Nodemcu-ESP8266, Nodemcu-ESP8266 collect data from sensors and transmit this data to the data engine. The prototype experiment results used 49 input data sensors, - with 35 accidents, -27 accidents were properly detected, while other 8 accidents were not detected; the percentage detection rate was 77.14% with this experiment. It was possible to detect the occurrence of accidents, communicate with the hospitals and police station. The GPS coordinates were provided by the GPS to identify the accident location. Based on Machine Learning with sensors can help people in an accident to get first aid on time.

KEY WORDS

1. Accident detection
2. Artificial Neural Networks
3. Sensors

LIST OF ACRONYMS

1.IoT: Internet of Things

2.VANETs: Vehicular Ad Hoc Networks

3.GPS: Global Positioning System

4.GSM: Global System for Mobile Communications

5.5G: Five Generation

6.WHO: World Health Organization.

7.AERC: Automotive Emergency response center

8.AERS: Automotive Emergency response system

9.ITU: The International Telecommunication Union

10.ICT: Information and communications technology

11.EU: European Union

12.RNP: Rwanda National Police

13.3G: Three generation

14.AI: Artificial intelligent

15.MEMS: Micro Electro Mechanical System

16.NFC: Near field communication

17.GPIO: General purpose input/output

18.ANNs: Artificial Neural Networks

LIST OF SYMBOLS

1.dB: decibel

2.Km/h: kilometer per hour

3.m s^{-2}: meter per second, squared

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

In Rwanda, 223 people missed their lives in road accidents in 2019 according to Rwanda National police[1]. According to the Association for Safe International Road Travel Nearly 1.25 million people die in road crashes each year, on average, 3,287 deaths per day, an additional 20-50 million are injured or disabled[2][3][4][5][6].

Rwanda chose to integrate smart city initiatives toward the development such as Irembo e-government portal, Kigali land, and construction one-stop-shop, Kigali smart bus project, Pollution mapping, 4G LTE rollout, Microgrids, Ndi hano, smart electricity meters, Kigali innovation city, drone delivery systems, Huza energy resource planning system [7].To contribute to existing initiatives, this research provides a Smart accident detection and alert system based on IoT sensors and machine learning that help in saving people's lives after a road accident.

1.2 Background and Motivation

The International Telecommunication Union (ITU) is responsible for studying technical, operating and tariff questions and issuing Recommendations on them to standardizing telecommunications on a worldwide basis[8].

ITU recommended the requirements and capability framework for the IoT-based automotive emergency response system. It is a technology developed by automobile industries to reduce mortality after the accident by notifying the rescue team in the time frame.

Requirements and capability framework for IoT-based automotive emergency has 5 parts:

i. The first part is composed of vehicle sensors like the accelerometer that collect data inside the vehicle.

ii. The second part is composed of internal sensors to provide information for automotive accident detection.

iii. The third part is composed of a GNSS receiver, for detecting the exact location of the vehicle based on geographic coordinate latitudes and longitudes.

iv. The fourth part, the automotive, emergency response system (AERS) reports automobile accidents to an automotive emergency response centre **(**AERC) and

v. The last part is the automotive emergency response centre **(**AERC). A center for confirming if the accident happens or not and notify the Emergency security.

Road accident in India, the period of the accident many people lose their life because medical services and police station not receiving accidental information on time, according to Planning Commission of India, during the year 2000-2015, the road accidents with an augment of 50 percent in the year 2010 as compared to the year 2000, the totality annual economic loss is 2.5% of India's GDP due to rising number of road mortality[9].

Another significant reason can be an inappropriate notification system. The survey shows that each minute that a wounded crash victim does not obtain emergency medical care can cause into fatal outcome. Most people in accidents lose their life due to such reasons. Therefore, this idea of saving lives by remedial the problem comes into survival[10].

According to WHO (world health organization), the number of road traffic deaths continues to rise, Road traffic injuries are the most important cause of death among young people aged 15-29 years.90% of the world's people fatal on the roads happen in low- and middle-income countries, still though these countries have around 54% of the world's vehicles. Nearly half of those dying on the world's roads are "in danger road users": pedestrians, cyclists, and motorcyclists. Road traffic crashes charge most countries 3% of their gross domestic product. With no sustained achievement, road traffic crashes are predicted to become the seventh top cause of fatality by 2030 [11].

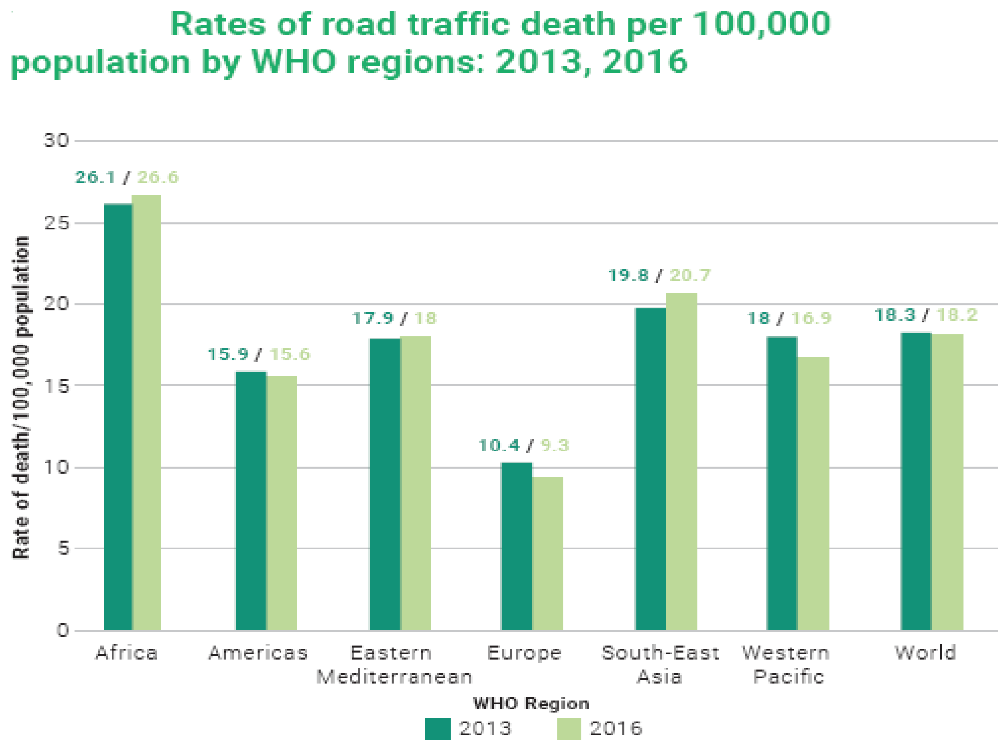

Figure 1: Rate of death [12]

As shown in the figure above, this is what WHO statistics did about the Rate of death in 2013 and 2016 on road accidents in the world; the death rate was highest in Africa compared with Europe and other continents. Road accident death constitutes the most important health and development problem in the world more than ever in the African Region. Since then, many countries have taken measures to deal with the problem, but they're still having an important amount of mortality rate. The more African countries have problems, lack of road infrastructures, lack of maintenance, and importation of old vehicles, no inspection requirement, the lack of accident detection system.

European Road Safety observatory action on vehicle safety is important for new goals and targets are to be met in Europe.EU implemented measures to reduce serious and fatal people in road accidents, EU deploys cameras on the highways. The camera films the movement of the vehicle on the roads, in case of rules violation, road incident, the information about the car is sent to the police and the EU integrated technology strategies co-operative system, airbags, seat belts in every seat position, alcohol interlocks for fleet drivers. After the accident, automatic crash notification facilitates more rapid access to emergency health responders[12].

Traffic Fatality Indicators in Africa

Country	Year[b]	Vehicles in Use	People Killed in Road Traffic Accidents
Ethiopia	2002	121,179	1,628
Rwanda	2000	26,554	401
Senegal	1999	136,471	646
Sierra Leone	1999	12,693	66
Uganda	1999	120,048	1,527
Namibia	2002	166,998	340
Swaziland	2001	85,446	255
South Africa	2002	6,549,901	12,198
Morocco	2000	1,643,978	3,627
Syrian Arab Republic	2004	669,218	1,653
Tunisia	2004	945,054	1,533
	2004[c]	585,433,946	104,501

Figure 2:Number of road accidents [13]

As can be seen in figure 2, describes the Road traffic fatality indicators in Africa for some countries between 1999-2004, the number of people killed in road traffic accidents was 104,501 in 2004 for Tunisia, on this sample Sierra Leone had the lowest number of road traffic fatality in 1999 while Tunisia had the greatest number of road traffic fatality in 2004. Rwanda had 401 road traffic fatalities in 2000.

According to Rwanda police, 465 people missed their lives to road accidents in 2018 and 223 in 2019. Despite this reduction in the number of accidents from 465 to 223, there are still major loopholes that can be looked into and closed to increase and give a better result on the roads and safety for all because the number of fatalities in 2020 was increasing. Rwanda National Police (RNP) announces that 283 people died in road accidents with 395 injuries of 678 accidents that happened in six months from March to 2nd October 2020.

Rwanda Police Statistics of 2002 – 2005 Road Traffic Accident

	2002	2003	2004	2005
Accidents	**3930**	**4210**	**4063**	**3410**
Severe	**1221**	**963**	**955**	**735**
Not severe	**2709**	**3247**	**3008**	**2675**
Day	**3045**	**3191**	**2995**	**2517**
Night	**885**	**1019**	**1078**	**893**
Injured	**3227**	**3392**	**3206**	**2856**
Dead	**416**	**385**	**323**	**267**
Total	15433	16407	15628	13353

Causes of RTA in Rwanda According to 2002 – 2005 Police data.

Cause	2002	2003	2004	2005
Overspeeding	780	749	560	447
Drunkardness	238	114	114	81
Carelessness	1920	2458	2398	1894
Wrong manoeuvres	432	408	595	648
Machanical problems	300	202	154	136
Poor roads	56	53	49	34
Rains (slipperly roads)	30	11	9	5
Lack of sign posts	12	8	2	3
Other	162	207	182	162

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Figure 3:Diagram Statistics [14]

Figure number 3 shows, Rwanda Police Statistics of 2002 – 2005 Road Traffic Accident. In the Rwanda context, the country has had lots of accidents during these past years. Ranging from, poor infrastructure in different parts of the country, poor reporting of accidents, reckless driving, poor vehicle, and many more.

There have been many attempts to curb these incidents, including deploying policemen on the roads, speed governors, safety helmets, emphasizing the regular vehicle check-up, and including the recent road awareness campaign of GERAYO AMAHORO to reduce the accidents stated by the Rwandan Police spokesperson.

This is where the research on the need and use of accident and crash detection systems is crucial to try and curb these loopholes. First and foremost is that this new technology approach is very efficient on a high level on the basis that it has direct feedback on any accident suited for its purpose. This is to say that on any impact or accident the GPS with its various accompanying technologies such as the sensors, microcontroller (Nodemcu-ESP8266), and the others[15], the cloud will be able to relay a notification to the significant authorities. These will be brought about by the direct detection system built[16].

These approaches also have the advantage that they will be able to call for help soon on impact and also will be able to send out the location-specific to the place where the accident took place with the help of the GPS also inbuilt. In conclusion, this new approach comes of vital role in the campaign for road safety awareness and with a more effective outcome to support the already put-up measures for the road safety course.

1.3 Problem statement

The majority of road accidents are caused by human mistakes, like unfocused driving, some drivers eat, drink, and use telephones when they are driving. Alcoholic and drug driving, they take alcohol and drive. The speed, the drivers exceed the speed threshold, much time they lose control.

They are road accidents caused by weather conditions like heavy rains, floods. To ignore the traffic rules like red lights, to ignore the street signs can cause accidents. Darkness driving, absence of brightness, hard to see at night if there is no street light. The sickness of the driver causes problems of accidents like heartbreaking. Adolescents driving, they don't have enough knowledge of driving, they can cause accidents. An animal passage like a monkey can cause accidents. Road construction can cause an accident for careless drivers.

The accidents have many consequences, economic backwardness, injuries, and death of people, this project will focus on the reduction of the mortality rate of people in accidents after road accidents by decreasing the time between when an accident happens and when the people in accidents get the first aid, they are some researchers who researched accident detection using Smart application like Jules White.

Jules White et al detected road accidents using Smartphone notification. The iPhone 4 builds with GPS, accelerometer, two microphones, a three-axis gyroscope, filtering system, and analysis algorithms. GPS for geographic coordinates, two microphones for sound detection, 3 axis gyroscopes in Smartphone localization, and an accelerometer for the force applied on Smartphone. The Smartphone detected the accident and send the automatic information with geographic coordinates to the central server through a 3G internet connection, the server processes the data and alerts the emergency services and authorities. This system has a weakness; all sensors are embedded in a Smartphone. If the Smartphone is down meant all systems are down, the Smartphone need more configuration system to capture all data means the Smartphone must be complex. The Smartphone can drop down, the accelerometer detects the accident pressure and, in that case, the accelerometer gives the wrong data about accidents also there is a response if the server receives the data from a Smartphone [17]. Jules wasn't the alone one who detected the road accident later Deeksha Gour detected the road accident with an AI model.

Deeksha Gour and Amit Kanskar detected road accidents and alert nearby hospitals or traffic police using an automated AI-Based Road Traffic Accident Alert System. Automated AI Based Road Traffic Accident Alert System uses artificial intelligence based on Neural networks and Deep Learning of object detection, their approach worked on images recorded videos. This system has a weakness, for the roads without cameras the road accident will not detect[18].

In the new approach, all sensors are installed in the vehicle to avoid sensors embedded in one Smartphone. The new approach will not use the image processing system; it will process the data sensors instead of images from the camera.

1.4 Study objectives

1.4.1 The main objective

To decrease the mortality rate after the road accident by implementing the system to detect the road accident based on IoT sensors, to notify the emergency assistant for giving direct help to the human suffering from the accident.

1.4.2 Specific objective:

- To localize the accident place-based geographic coordinates latitude and longitude
- To notify the accident event to the hospitals and the police station with email
- To get accident statistics based on the data recorded in a data engine and analysis of data

1.5 Hypotheses

The death rate after road accidents increases because of the lack of first aid on time.

1.6 Study scope

The general purpose of this study is to detect if the accident happens and then sends the notification to the police station and hospitals. Smart applications for accident detection based on IoT sensors will not predict the accident, the duration of the study will be 6 months.

1.7 Significance of the study

Smart applications for accident detection based on IoT sensors decrease the mortality rate of the people in the accident after a road accident. The system localizes the accident place, the system notifies the police station and hospitals, the system helps the emergency assistant to provide medical help to people in a road accident on time.

1.8 Organization of the study

- Chapter one: Introduction

The chapter for the introduction defines the background and motivation of the study, the problem statement, the general and specific objectives of the project, the study scope, significance of the study, the organization of the study finally the conclusion.

- Chapter two: Literature Review

The chapter for the literature review explains the relevant works done by other researchers to detect road accidents and sends the notification. This chapter identifies the gaps in the current research and the contribution of this project.

- Chapter three: Research Methodology

The chapter for Research Methodology describes the methodology, the tools used in the research.

- Chapter four: System Design and Analysis

The chapter for System Design and Analysis shows the simulation, the prototype, how to collect the data sensors, and how the data sensors are processed using artificial neural networks.

- Chapter Five: Results and Analysis

The chapter for Results and Analysis shows the outputs of the simulations, the prototype then the analysis methods of data.

- Chapter Six: Conclusion and Recommendation

The chapter for conclusion and recommendation concludes based on the results and recommends future researchers.

1.9 Conclusion

Information Technology and automatic systems builders are seizing the occasion of getting new original hardware components as the “Internet of Things” starts to scale up. The number of components rises day by day, more technology systems increase. The implementation of IoT in different domains like smart cities lead to smart transportation, road accident detection with IoT system combing database server for automation is one of the smart transportation systems.

CHAPTER TWO: LITERATURE REVIEW

2.1. Rationale

Smart application for accident detection based on IoT sensors, smart systems offer promising methodological solutions which can suggestively contribute to the development of quality, consistency, and financial competence of technical products. Smart system embedded analog or digital signal processing, the smart system composed with different types of systems, such as actuators, smart sensors, the unit for data processing, power electronic devices, transducers, network, and innovative manufacturing technologies.

2.2. Sensors

A sensor is a device that takes a signal or stimulus and converts it to the stimulus in the form of an electrical signal. They are different types of sensors depending on applications, some sensors are used in smart transportation, they are installed on the main road; others are fixed under the surface of the highway such as loop sensors. However, in this approach, the sensors are installed in the vehicle to sense the speed, gravitational force, and sound sensor found in the vehicle.

2.3. Internet of Things (IoT)

Smart systems and applications used the processing and combination of information into an integrated view from different technologies such as the Internet of things, social platforms. The Internet of things states to a type of network to link things with the internet connection based on advanced protocols through data sensing device to conduct data exchange and communicate for accomplishing smart recognitions, location, tracing, management, monitoring. IoT systems help users to improve their quality of life by realizing deeper analysis and automation.

2.4. Related works

Different road traffic management systems develop many automatic incident detection approaches to detect and reply to traffic accidents on time. While many researchers have gone into automatic accident detection based on GPS/GSM technologies, some researchers focus on the improvement of VANET routing procedure based on sophisticated algorithms, other researchers detected the accident using a smartphone. Jorge Zaldivar et al Providing Accident Detection in Vehicle Networks Thought OBD-II Devices and Android-based Smartphone. The system is composed of smartphones with Android-based monitoring of the vehicle through a Board Diagnostics (OBD-

II) interface; the system detects the accident and sending information about the accident through e-mail or SMS to emergency services, but it has some weaknesses; the OBD-II standard is not available in all vehicles[19].

J. Maleki et al detected the road accident with the Intelligent Alarm System for Road Collision, the system had three parts, vehicle unit, GSM module, and emergency unit. A vehicle unit composed of a GPS receiver, processor and crash sensors, GSM module for the information transfer function. Intelligent Alarm System for Road Collision detected the accident and sends the information to the emergency unit, but this approach identifies the accident based on one type of sensor, crash sensors. A wrong positive accident can be detected easily[20].

A. Rajkiran1 et al M. Anusha2 detected the accident using the wireless communication system. The Wireless communication system has five components: GPS module, fire sensor, Micro Electro- Mechanical System (MEMS), infrared sensor, and vibration sensor. If the accident takes place, the sensors detected the accident and send the data to the microcontroller, the microcontroller sends the notification to the ambulance, to the police, and the parents based on the GSM network. The microcontroller also displayed the data on the LCD and the button on the buzzer, this system had some weaknesses like using GSM Module, it needs the expensive infrastructure and the license for implementation is required, it detected the accident based on three pins of MEMS and alternation in angle, this can give the positives wrong resultant. The new approach reduces the price of infrastructure based on the GSM module; this system will use Wi-Fi technology to send the data to the server[21].

Arsalan Khan et al detected road accidents with accident detection and Smart Rescue System using Android Smartphone with Real-Time Location Tracking. This system detects the accident using accelerometer sensors embedded in Smartphone and generate an emergency alert and send it to the nearest emergency responders. The weakness is that the accident was detected based on G – forces detected by the accelerometer, one type of sensor embedded in the Smartphone can increase the G forces without an accident[22].

Usman Khalil et al detected the accident based on Automatic Road Accident Detection using Ultrasonic Sensor. The approach had two ultrasonic sensors, the first one was in the front wind of the car and the second is positioned on the back windscreen of the car, once an object collides with the car, the threshold distance of the sensor is breached. The collision is detected and the processing unit turns on based on the GPS device, the system sends the geographic coordinates and sends them to rescue services through GSM. The weakness of this system is that the ultrasonic sensors sense any object approach the car means if the bird moving away from the car, a false-positive accident will be detected and it uses authentic mathematical expressions that are complex for data processing, [23].

Prof. M.B. Yelpale et al detected the accident with the Vehicle Crash Alert System, this accident alert system, its senses the accident and the condition of the accident happened after sends GPS coordinates to the precise mobile through GSM to rescue people in accidents. The system is composed of a shock sensor, GPS, and GSM systems, the weakness of this system is that no professional application for collecting and processing data from shock sensors before sending the information to a mobile/laptop [24].

Elie Nasr et al detected and reporting the accident based on IoT Approach, the IoT approach had four components, GPS, cellular IoT, shock sensor, NFC reader. Global Positioning System (GPS) is a device that provides location-based geographic coordinates, latitude, and longitude, it uses three or more GPS satellites. Cellular IoT is used for internet technology to extend the area, to send the data to the server, Shock sensor senses the shock if the accident happens, Shock sensors can be installed in various manners in the vehicle to accomplish the requirement. NFC Reader Near field communication (NFC) is a set of communication procedures that allow two electronic components like smartphones, sensors to establish communication, it links an IoT device to the database. But this system has a weakness because the accident data are collected by one sensor, a shock sensor, the system can get the positives wrong data[25].

Yu Yao et al detected the road accident using an unsupervised Traffic Accident Detection system based on visualization of images taken by cameras installed on the roads, their proposed system use alteration between present trajectories and predict trajectories, they experiment their model by evaluating the existing accidents that happen and predict the accidents, the case of vehicle deviation, their system localized the location for anomaly issues[26].

Shivan Sharma and Shoney Sebastian detected road accidents using IOT based car accident detection and notification for general road accidents, with the Internet of Things system, they detected accidents and give the notification by combining sensors with the microcontroller in the car that can detect the accident on time. Their system has other modules GPS for getting coordinates and location of the accident place, GSM sends the notification to specific numbers include ambulance[27].

WAN-JUNG CHANG et al detected the road accident using Deep learning-based Internet of vehicles system for head-on and single-vehicle deep crash, their approach has three parts, cloud with deep learning, a camera, and a sensor for detection, in case of collision, the system detects the accident and upload the information on the cloud server, an accident happens and the notification produced and sanded to emergency team. Collection of Accident collision images are used for crash prediction model for supervised system detection[28].

Nejdet Dogru et al detected the car accident, the system collects the important data from near vehicles called Vehicular Ad Hoc Networks (VANETs). The system trained the data using machine learning algorithms, machine learning processes the data using machine learning tools. Machine learning differentiates whether the condition is in abnormal performances or normal performances[29].

Prashant Kapri et al detected the accident with a smartphone, it builds with sensors, sensors in the smartphone are exceptional platforms for designing such unsupervised systems, in their approach, they used (ADAS), an unsupervised system with Accident Detection and notification system, their approach is composed of two key mechanisms, the server and the software configuration called ADAS, different sensors in the Smartphone for finding the position of the accident. The ADAS system will notify the ambulance in the instance of the accident, the ADAS system finds the location with the services of sensors within the Smartphone and alerts the medical support[30].

Jacek Oskarbski et al detected the incidence in the road with Intelligent Transport System placements in Poland, incident organization, and finding on dual-roadways and city street systems. European Union subsidized project, is to use TRISTAR discovery elements to detect incident connections fortified with road traffic signals. The system has main parts, first part offers a summary of town incident detection approaches and procedures. The second part described the TRISTAR system structure and computer software are presently used for detecting incidents on city highway sections. The approach was assumed will lead to the growth of systems for the recognition of incidents on the roads, the early outcomes of simulation training using computer software called VISSIM are obtainable in the last part, with this research, the acceleration was not considered either sound parameters when an accident occurs[31].

Amir Bahador Parsaa et al detecting traffic accidents as fast as possible, in their research, they use the Machine Learning (ML) technique to sense the existence of accidents using a group of real-time data contained road traffic, connection, demographic, terrestrial, and meteorological conditions, feature. The system detected the accident based on the average number of vehicles transitory on the junction, the system used upstream detectors and downstream detectors to calculate the average time expended by automobiles at the junction[32].

Miao M. Chong analyzes the road accident severity using the model for the harshness of injury consequential from road traffic accidents using artificial neural networks and decision trees. Data carrying is used as inputs like drivers' oldness, drivers 'gender, driver's alcohol usage, limitation system, vehicle form kind and the accident product event that is to be used as an output, injury harshness[33].

DAXIN TIAN detected the car accident based on cooperative automobile infrastructure methods and machine visualization, CAD-CVIS is comprised of different varieties of accident categories, meteorological conditions, and accident position, which can progress self-flexibility of accident detection approaches among various traffic circumstances. Next, they grow a deep neural network model YOLO-CA founded on CAD-CVIS and deep learning methods to sense accidents. The method uses Multi-Scale Feature Fusion (MSFF) and injury function with active weights to improve the performance of sensing minor objects. Lastly, their experiments showed that the performance of YOLO-CA detected car accidents[34].

CHAPTER THREE: METHODOLOGY

3.0. Introduction

This chapter discusses the technics and methodologies of this research, this approach used simulation and the prototype, by adding some functionalities and methods that can progress the existing road accident detection, Smart application for accident detection based on IoT sensors have three parts. The first part is for detecting the accident, the second part for notification, and the third for locating the system.

3.1. Data collection

Data collection is used to get information concerning speed, acceleration, sound, and location, the data collection is composed of sensors and GPS (Global Positioning System is a global triangulation satellite technic that shows the location), the sensors are input devices, they have the capabilities for sensing the physical conditions as input signal which provides an output signal. The sensors take the purpose-data information as input and send it through the network to the data engine to be processed and analyzed. This processed information is then sent to decision-making parts to make an automated activity to be appealed, the first part is composed of a speed sensor, gravitational force sensor, sound sensor, Global Positioning System -GPS and all sensors are embedded in the car.

3.1.1 Speed sensor: It keeps on measuring the speed at which the car is moving on starting from 0 to 80km/h for normal speed, from 100km/h to 120km/h is too high, for unnormal, the speed is greater than 120km/h and accident possibility is at high. The speed sensor works by converting the speed measures into electrical signals for more processing analysis, in the abnormal condition the speed can fall from a high speed to Zero, there is a big possibility that the accident has occurred and directly the other sensors value must be checked and give their immediate results to prove the existence of the accident or not.

Figure 4:LM 393Speed sensor [35]

As shown in figure 4, the speed sensor aids in determining the speed of a rotating object. The speed sensor is composed of two parts, the sensor part, and the control part. The sensor part contains an NPN Photo Transistor and Infrared LED, the control unit which is consists of an LM393 voltage comparator and some passive components.

3.1.2 Gravitational force sensor: To detect the gravitation, an accelerometer is hereby used. The gravitation varies from 0 to 5 if it exceeds the threshold of 5, there is a big possibility that the accident has occurred, and directly the other sensors value must be checked and give their immediate results to prove the existence of the accident or not, the accelerometer converts the gravitation force into an electrical signal. The gravitation force increases in accidents, the accelerator can be used to discover whether vehicles are in movement or not.

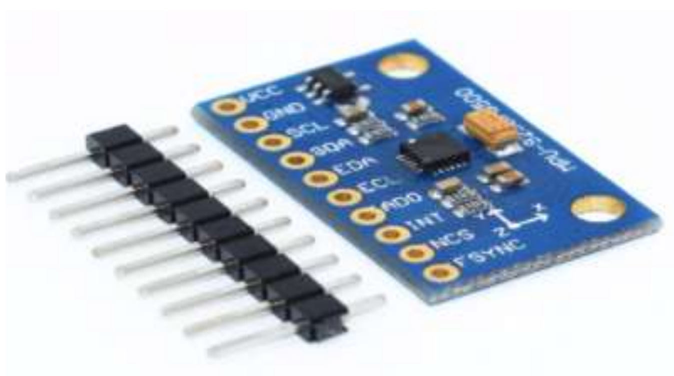

Figure 5:Accelerometer[36]

As shown in figure 5, An accelerometer is an electronic sensor that measures the acceleration force which is the change in object's velocity, the accelerometer can be used to determine the direction of gravity, the position of an object in space, and monitor object motion.

3.1.3 Sound sensor: This sensor detects the sound; the value of the sound varies from 0 to 140 dB for normal conditions, the threshold is 140dB. If the value exceeds the threshold, there is a big possibility that the accident has occurred, and directly the other sensors' value must be checked and give their immediate results to prove the existence of the accident or not, the microphone converts the sound into electrical signals.

Figure 6:Sound sensor [37]

3.1.4. Nodemcu-ESP8266: Node MCU-ESP 8266 is a microcontroller-based firmware build with Wi-Fi. As shown in the figure below, the NodeMCU-ESP8266 has the following main parts, ten-bit Analog to digital converter the channel, UART interface – UART interface is used to load code serially, PWM outputs – PWM pins for dimming LEDs, SPI, I2C & I2S interface – SPI and I2C interface to hook up all sorts of sensors and peripherals.

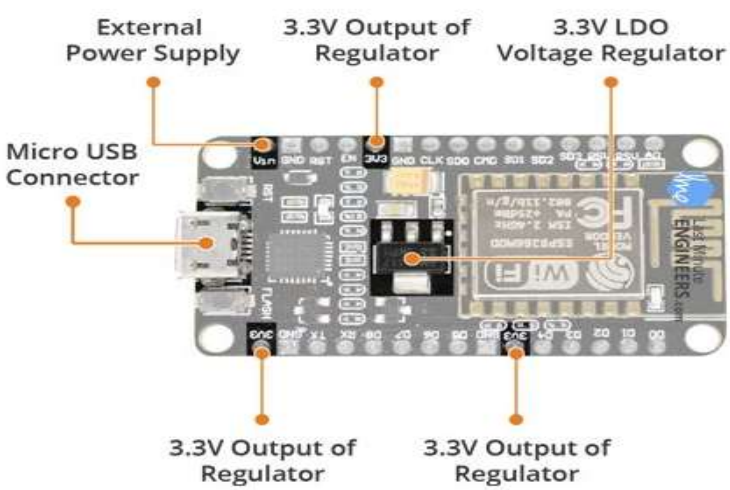

Figure 7:ESP8266[38]

3.2. Data processing

3.2.1. Prototype

The data processed with Artificial Neural networks (ANN), Artificial neural networks are a type of tool used in machine learning, ANN tool from MATLAB uses the value R which is the correlation coefficient to measure the relationship strength between two variables. The correlation coefficient *R* is used together with a minimum mean square error (MSE) to check the performance of the system using performance indexes of the ANN. The *R* values are the range of -1 and +1, then, if the *R* value is near to +1, means a better correlation performance.

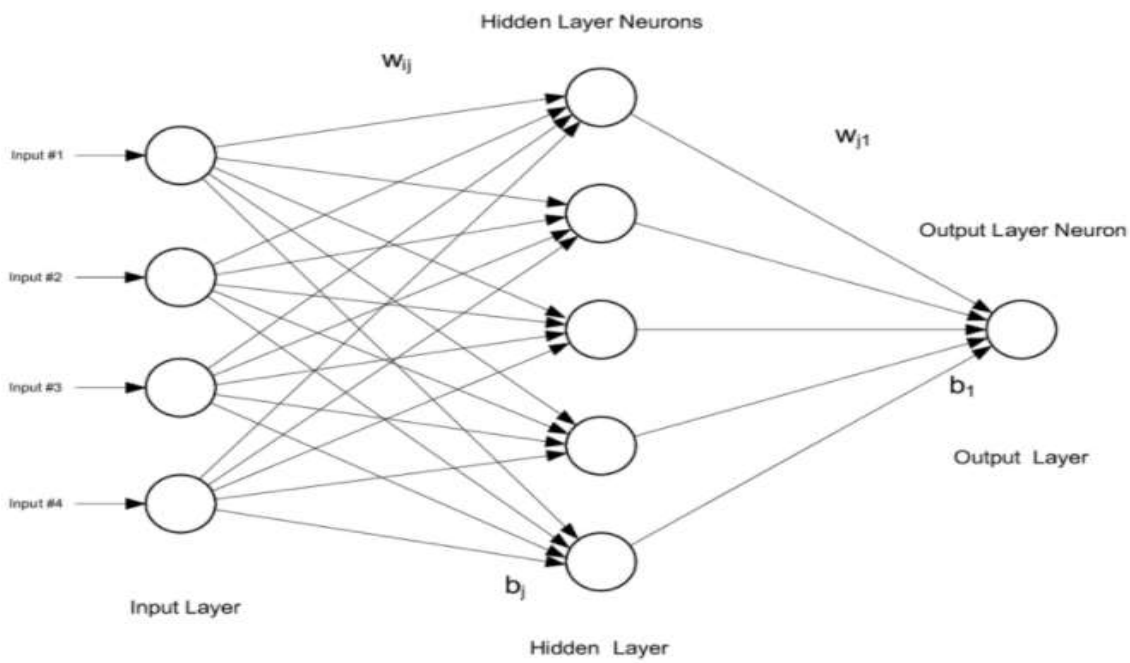

Figure 8:Artificial neural networks [39]

As discussed in figure 7, Neural networks are composed of main parts, input layer, hidden layer, and output layer, the input layer in our case is composed of data sensors, the hidden layer having the units that process the input into somewhat that the output layer can usage. They are many types of artificial neural networks, the most popular named a feedforward neural network, in which the data travels from the input layer to the output layer.

3.2.2. Simulation part.

Simulation, the electronic embedded car is used, an embedded system is an electronic or computer system implemented to control electronics-based systems. The vehicle manufacture places the embedded system in the vehicle for different functions like an anti-lock braking system, embedded cars have different sensors for a special application, why for simulation, we use the embedded car.

Table 1:The range of data sensors 1

Abnormal condition for Accident detection				
Speed sensor	**Sound Sensor**	**Acceleration sensor**		
		X	Y	Z
Speed<=0km/h	Sound>140dB	X>5 G	0 to 5G	0 to 5G
Speed>=120km/h	Sound>140dB	0 to 5G	Y>5 G	0 to 5G
Speed drop from high speed to 0km/h	Sound drops from high noise level to 0 dB	0 to 5G	0 to 5G	Z>5 G

As the table above shows, the range of data sensors in an abnormal condition, considering the vehicle in movements, the sound and acceleration can be higher than the threshold and the speed drops directly to zero, another abnormal condition is that the acceleration can be higher than the threshold at least in one direction with high speed and increase of sound, for any change of one sensor value other sensors' values must be checked.

3.3. Locating system

GPS (Global Positioning System): This is a satellite-founded navigation system used to relocate the place of an object or a person, the GPS has three parts, Satellite system, receivers, and ground stations. The satellite system consists of more than 24satellites in space at 12000 miles above the Earth, receivers get the signals from the satellites and use trilateration to determine the location of a user, in our system the user will keep the GPS receiver in their car lastly the ground station is the control system, the ground station controls the satellites if they work accurately.

Figure 9:GPS[40]

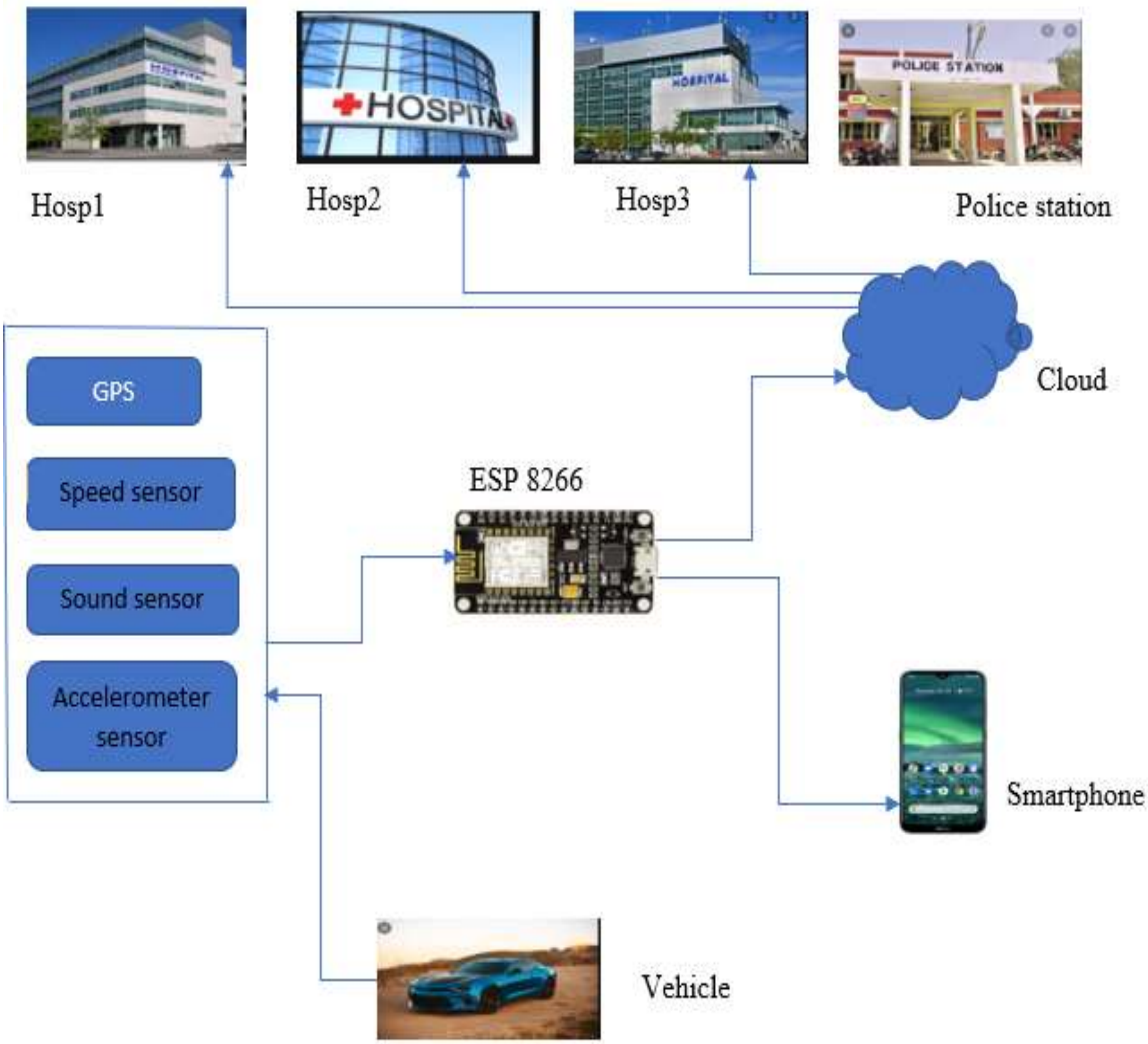

Figure 10: Project diagram approach

The figure above describes the project approach, the sensors are installed in the vehicle and collect the data and the ESP8266 receives the data sensors and send it to the cloud for data processing and makes the decision if an accident happens, the hospitals and police station get the notification email.

The figure 11 below presents the data processing from sensors data, Artificial Neural Networks process the data, the ANN method decides if the accident happens or not. If the accident is happening, the cloud sends the notification to the hospitals and police station

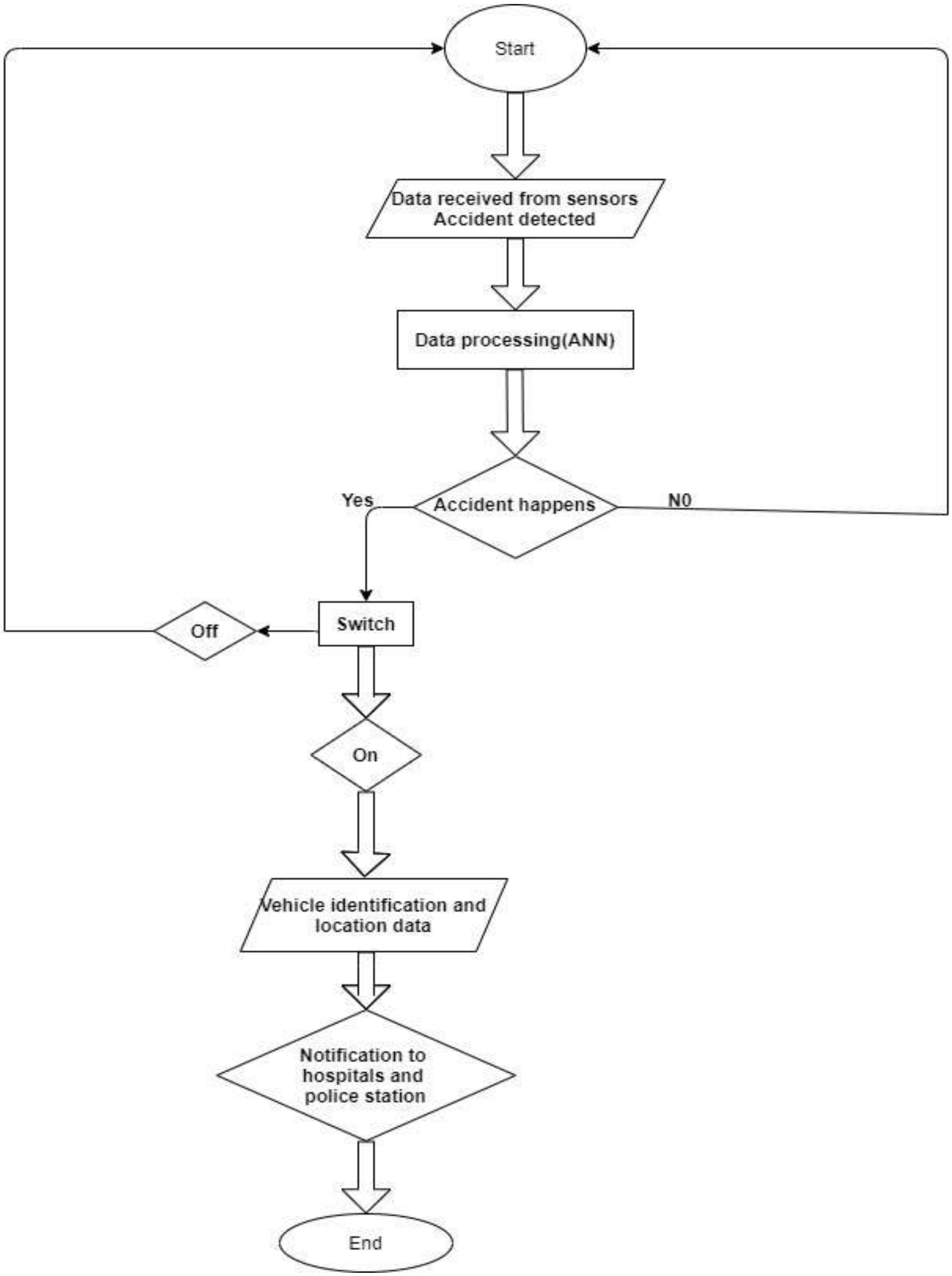

Figure 11:A software system

CHAPTER FOUR: SYSTEM ANALYSIS AND DESIGN

System analysis is the method of analyzing the data from sensors, the accident becomes one of the essential problems to be considered, to simplify the resolution of the problem for decreasing the number of death of people in the accident, the number of people in accident increase because of lack of first aid on time, the result of this analysis method is to get the notification on time in case of an accident, the new approach studied the problem and design an improved system to solve the problem. In this study, the simulation of accident detection has been used in a different condition, Node-RED is the taking to create and fix dashboard on an IoT element. An IoT component solution is really on data, data processing and deals with a serious point. The ability to create a dashboard precisely there and as soon as and on-demand is a significant time-saver and a strong benefit performs on Node-red set data immediately on gauges and charts after the dashboard is published immediately on http://node-red-instance/ui.

Table 2:The range of data sensors 2

Abnormal condition for Accident detection				
Speed sensor	**Sound Sensor**	**Acceleration sensor**		
		X	Y	Z
Speed<=0km/h	Sound>140dB	X>5 G	0 to 5G	0 to 5G
Speed>=120km/h	Sound>140dB	0 to 5G	Y>5 G	0 to 5G
Speed drop from high speed to 0km/h	Sound drops from high noise level to 0 dB	0 to 5G	0 to 5G	Z>5 G

4.1. Simulation

Considering the car in movement, when an accident happens, the data changes. As the table 3, for a high-speed sensor value greater or equal to 120, this behavior is abnormal and in case the speed is 0 means the vehicle is not in the movement. For the sound sensor, in case the vehicle meets an obstacle, the sound increases, in normal condition the sound must be less than 140dB. For acceleration, the acceleration has three directions, x, y, and z. The value of each direction must be less than 5 G in normal condition, for abnormal condition, one of all axes must be greater than five.

Table 3:Accident detection

Ranges for sensors to detect the accident					
Speed sensor	**Sound sensor**	**Acceleration sensor**			**comments**
		X	**Y**	**Z**	
120km/h	**150 dB**	**2G**	**4G**	**6G**	**Accident detected (case1)**
0km/h	**140 dB**	**4G**	**5G**	**0G**	**Accident detected (Case2)**
3.9 km/h	**40 dB**	**0 G**	**3G**	**4 G**	**No accident detected (case3)**

Figure 12:Live chart and gauge in case1

As the figure above shows, sound value and speed value are greater than thresholds. Node-Red is flow-built programming that lets the system link code blocks for realizing tasks, it can be run online means cloud, on the computer locally, on components like an ESP8266.

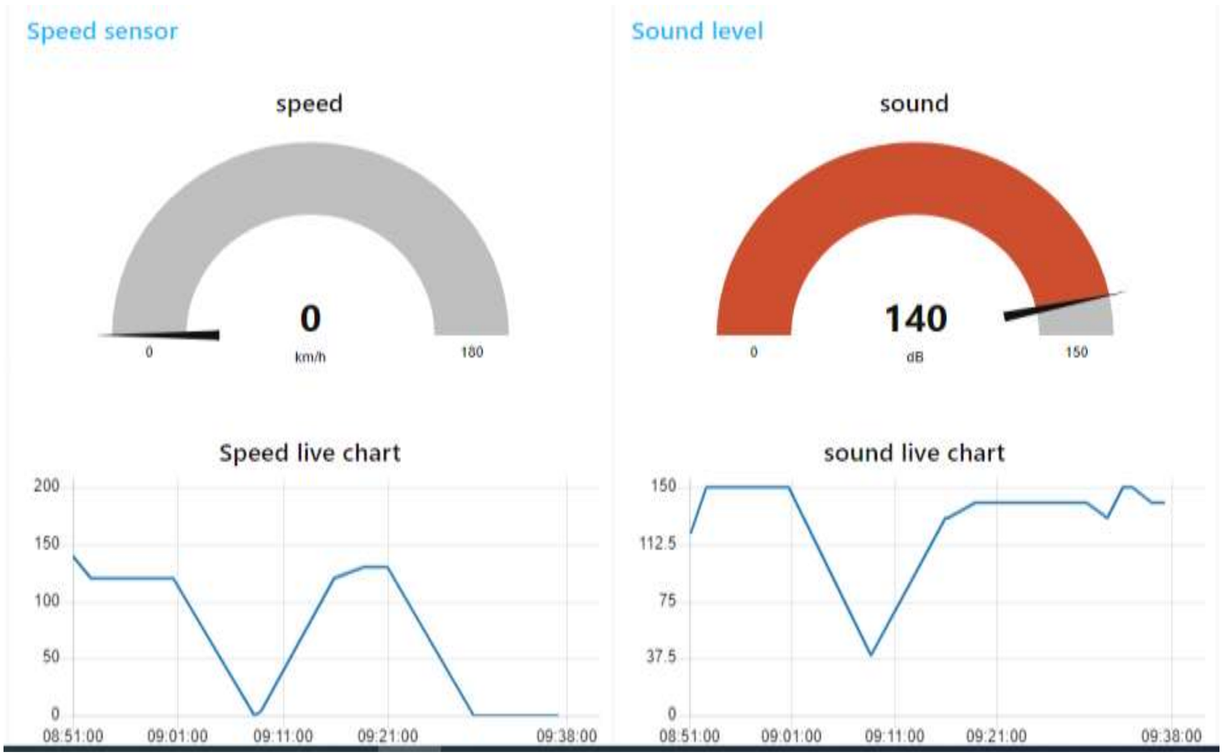

Figure 13:Live chart and gauge in case2

Figure 12 describes the Sound value and speed value which are beyond the threshold, to get the amount of data sensor, python language programming is used to simulate the process of the accident and crash detection. Using the code for JavaScript Object Notation, the sensor's values are gated then the data is displayed on an interface via an MQTT broker.

Figure 14:Acceleration gauge

As the figure above shows the change of acceleration in three directions X, Y, Z, the color change based on acceleration value. The value of acceleration is in the normal range in the X direction, the value of acceleration is in the abnormal range in the Y direction and the value of acceleration is in the abnormal range in the Z direction.

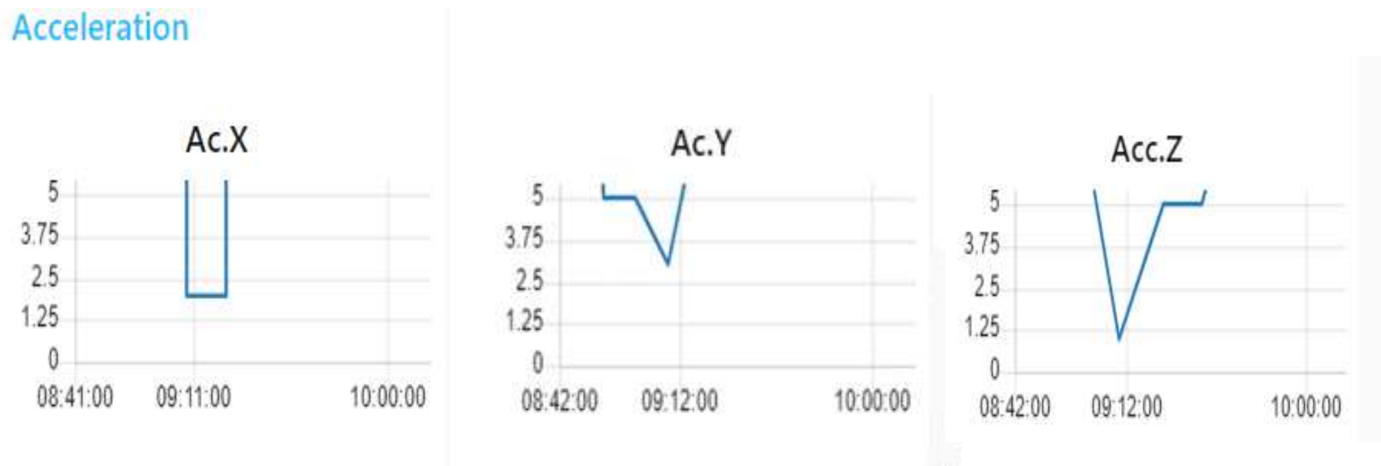

Figure 15:Acceleration flowchart

On this chart above, the acceleration varies differently in three directions. on the X direction, the acceleration reached 4, for Y direction, the acceleration exceeded the threshold means is an abnormal condition, for the Z direction, the acceleration is approaching zero, so no problem, at least the acceleration must exceed the threshold in one direction in an abnormal condition.

The email for notification in case of an accident detection

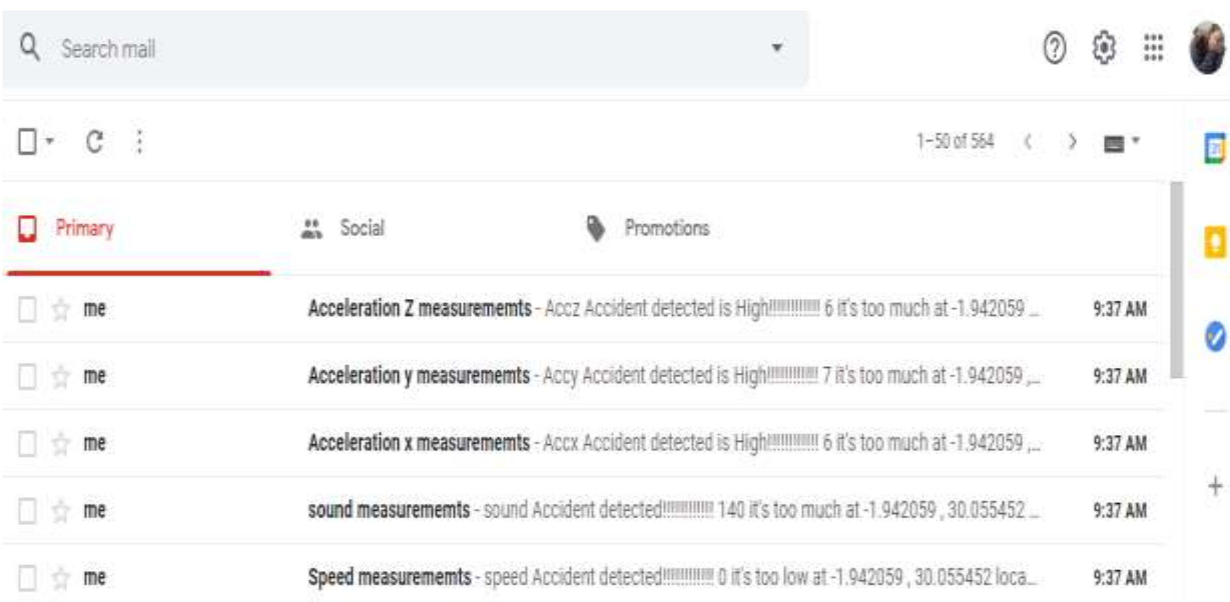

Figure 16:Notification email

As in figure above shows the notification email to alert the police and hospitals, police and hospitals get the alert message on time and give the first aid time to the people in an accident, on this figure, the values of acceleration, sound, speed exceed the threshold values why the accident is detected and the notification email is sent.

For normal condition, no accident detected on the diagram

Figure 17:Live chart in case 3

In this chart above the speed is not zero and is not exceeded 120km/h no problem, the speed is in normal condition, let see on sound, the audible sound must be below 40 dB, if it exceeds 140 dB there is a high probability that the accident happens, for exceeding the threshold other sensor values must be checked to confirm the accident event.

4.2. Prototype

Data on the serial monitor using Arduino Idle

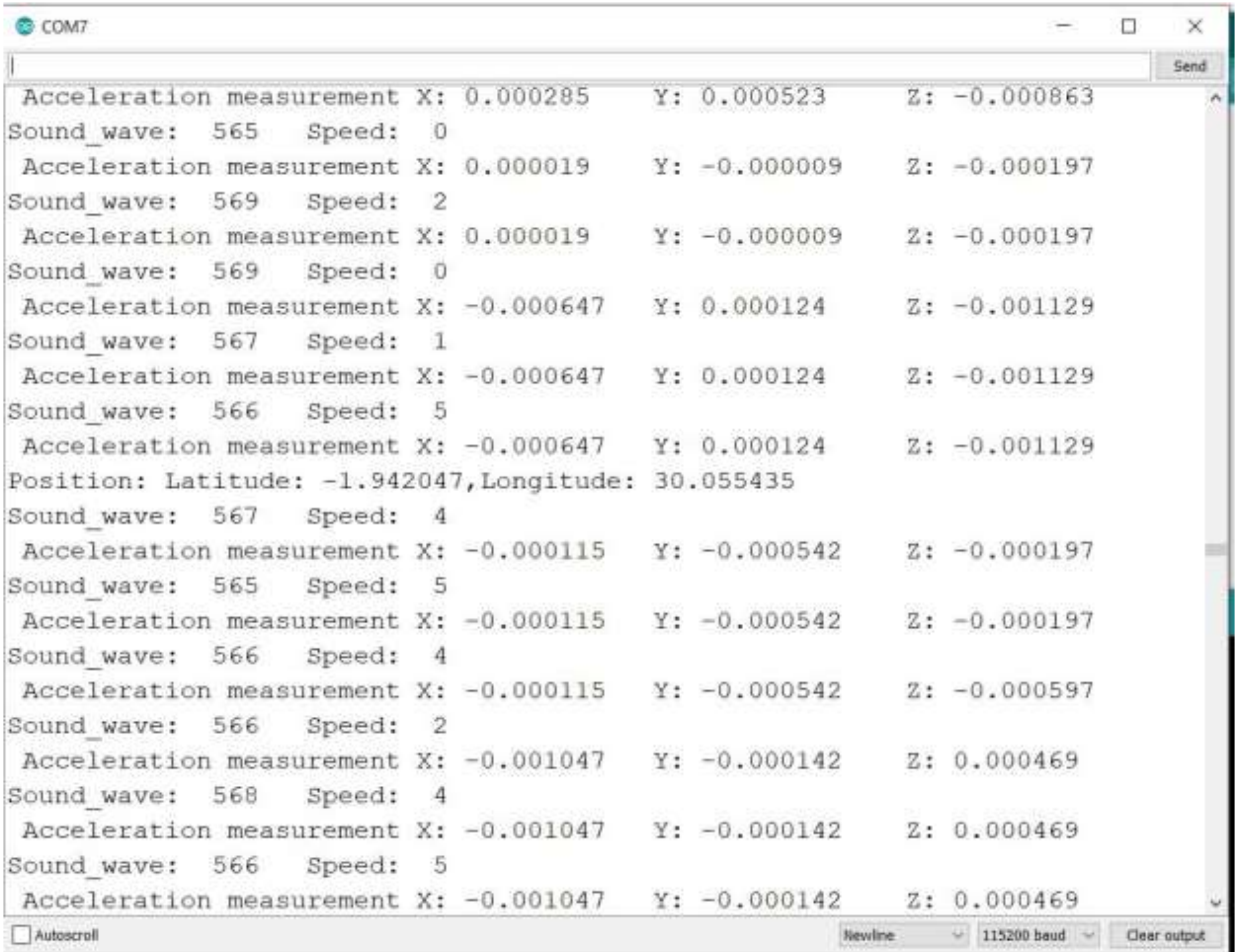

Figure 18:Arduino data 1

The figure 18 above shows that the sound signal is too high but no accident detection because the values for the Acceleration sensor and speed sensor are in normal conditions. The building of the Arduino programming language is justly simple, the Arduino IDE has two basic functions, void setup, and void loop, the Arduino programming language is compatible with ESP8266, it links sensors and other components with ESP8266.

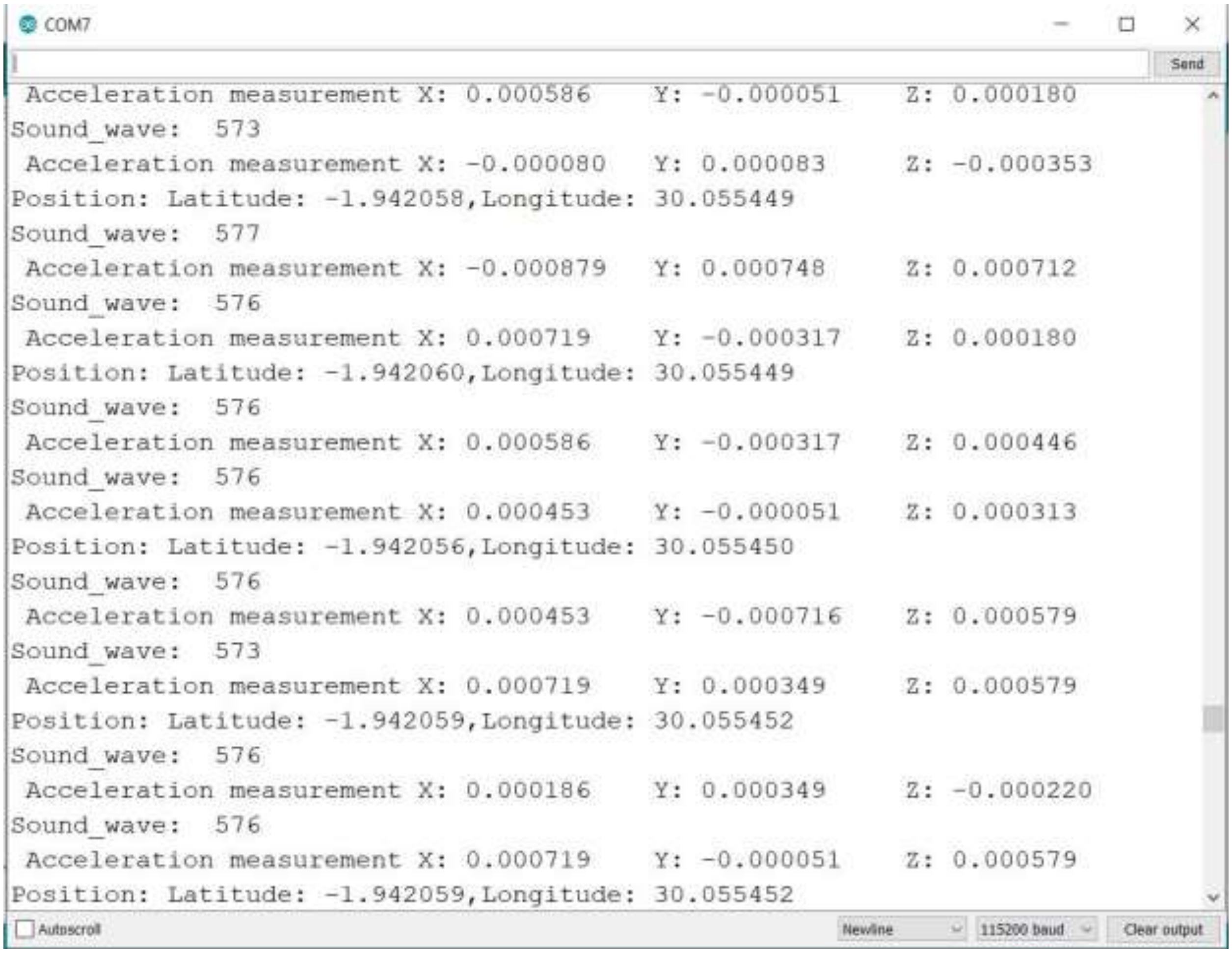

Figure 19:Arduino data 2

Figure 18 shows a serial monitor of Arduino. The data are sent from ESP8266 to the computer using a connection cable called a USB cable, on this figure, the sent data are displayed on the serial monitor of the Arduino (IDE), the data can be delivered to the data processing unit. This serial monitor shows the analog sound values, acceleration, latitude, and longitude. The acceleration has three directions X, Y, Z with latitude, and longitude to show the location of the vehicle accident. Based on the data received, there is no accident detection because the only sound is exceeding the threshold but other sensors 'values are in normal condition.

CHAPTER FIVE: RESULTS AND ANALYSIS

This chapter describes the results obtained after data processing using Artificial Neural Networks (ANN), it has three figures, the first shows the system without data training, the second shows the system after data processing but no accident detected and the last shows the system after data processing and accident detection. They are three layers in ANN named input layer, hidden layer, and output layer. Input layer received the input, hidden layer which processed the data finally the output layer shows the final results. In this project, the sensors data collected are the inputs of the network, are processed, and the output are given which showed by the number R.

Artificial neural networks (ANN) give machines the capability to process data like to the human brain and make decisions based on the data received, ANNs support machines to complete and learn from the tasks they perform. Artificial neural networks are the main part of machine learning, ANNs are used to classify, to clustering and make estimations from data to detect fraud. ANNs have many advantages like the capability to learn by themselves and give the output, ANNs stored the input data in itself networks and they can accomplish multiple tasks at the same time without disturbing the system performance, Artificial neural network has many applications, forecasting, speech recognition, image processing, language processing and translation, route detection.

Without data training

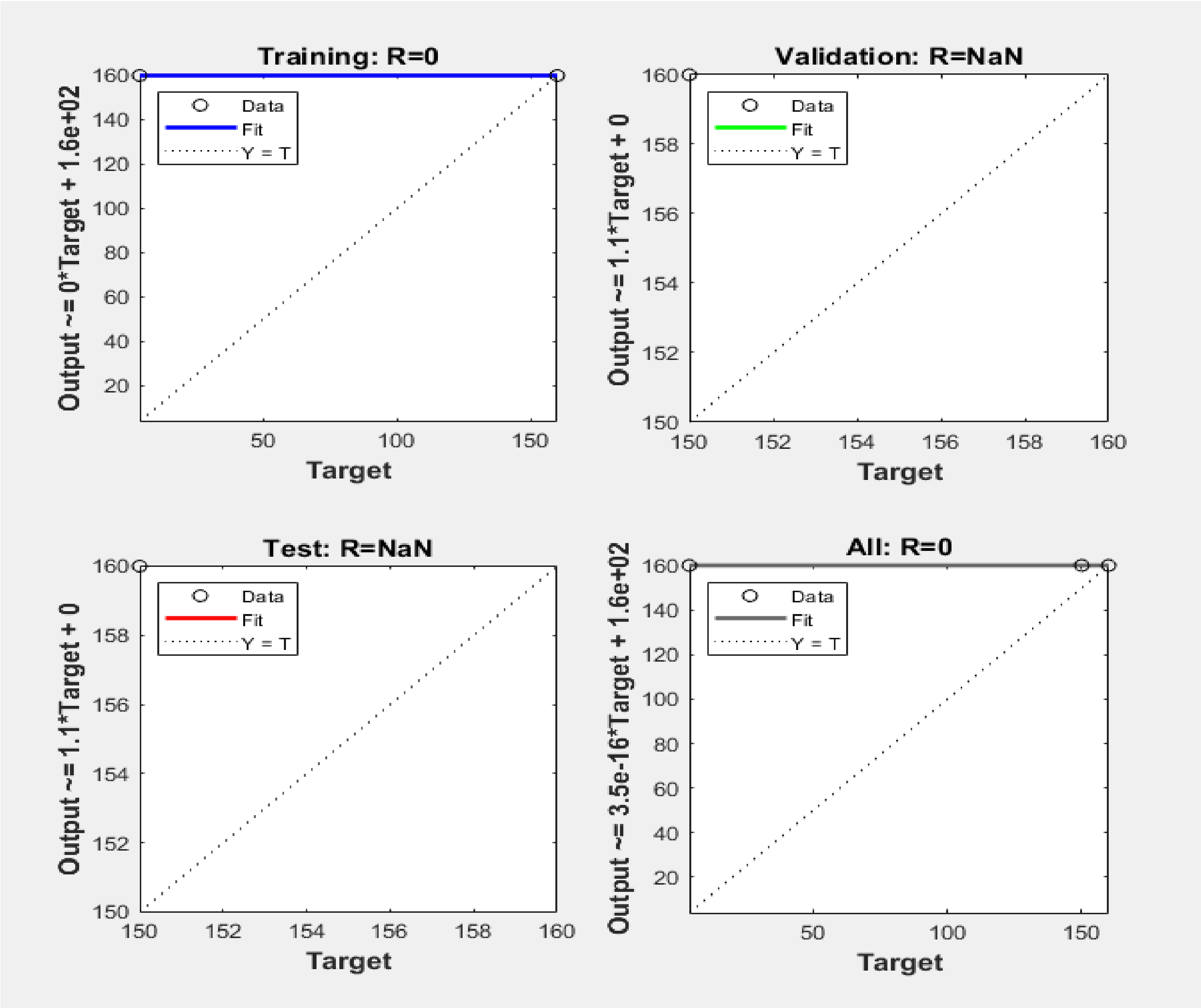

Figure 20:ANN case1

The figure 20 above presents an Artificial Neural Networks (ANN) with regression models, it has three main parts to get the output: training, validation, and testing. The data is divided into three groups, a training group, a validation group, and a test group. Training a neural network is the procedure of discovering the values for the weights and biases. During the training data set, the training algorithm trains the data to match the prediction data from the network with the desired output, validation set; a set used to set the parameters like the number of hidden layers in a neural network, test set; a set used to check the performance of a training system.

With data training but no accident detection

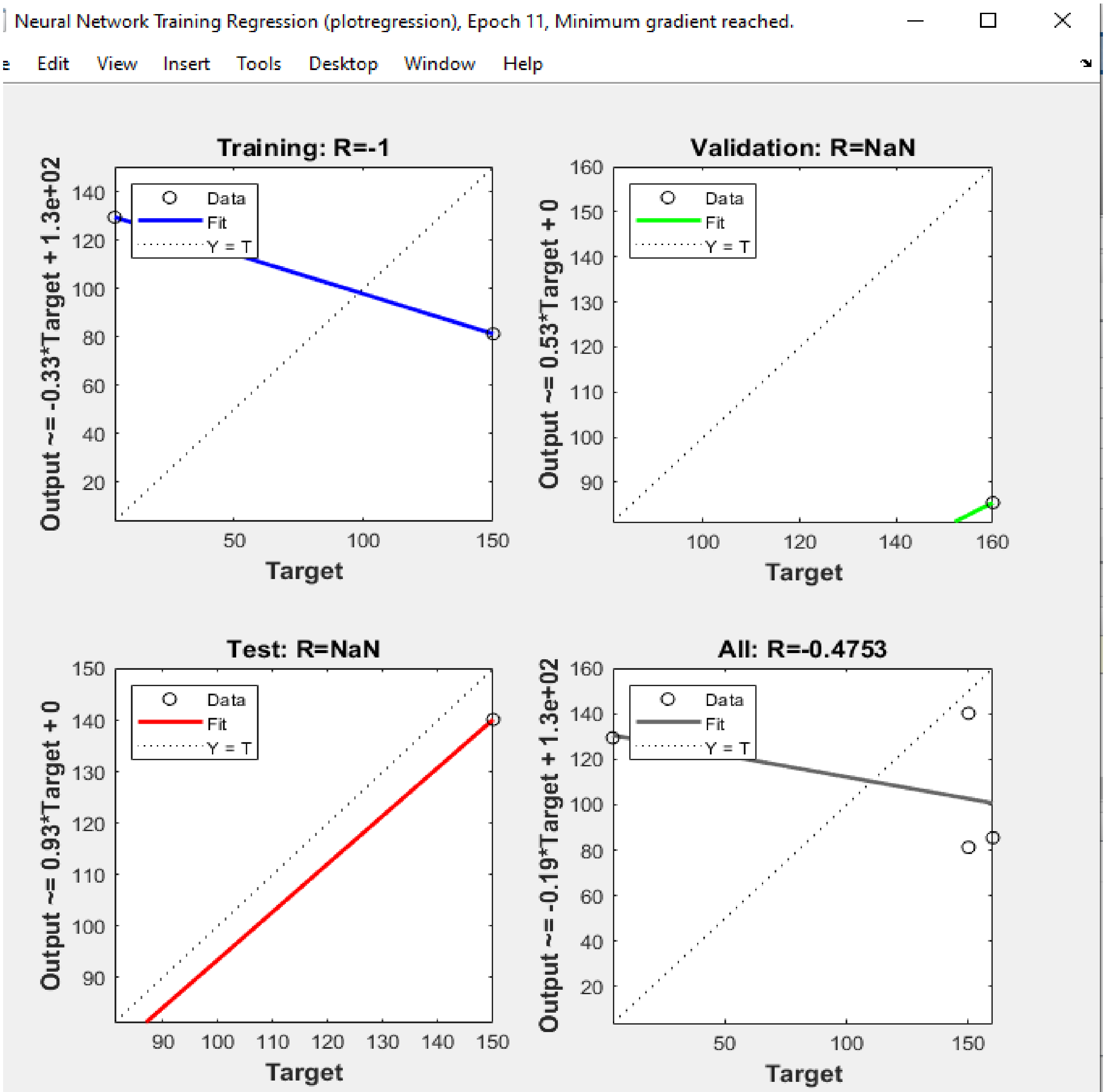

Figure 21:ANN case2

Figure 20 describes the data training but no accident detected. The R is equal to 0.4753, I trained the neural network with a linear regression model – 11 epochs, during training, the test data is not used at all. After training completes the accuracy of the resulting neural network model's weights and biases are applied just once to the test data. The accuracy of the model on the test data gives a very rough estimate of how accurate the model will be when presented with new data.

With data training and accident detection

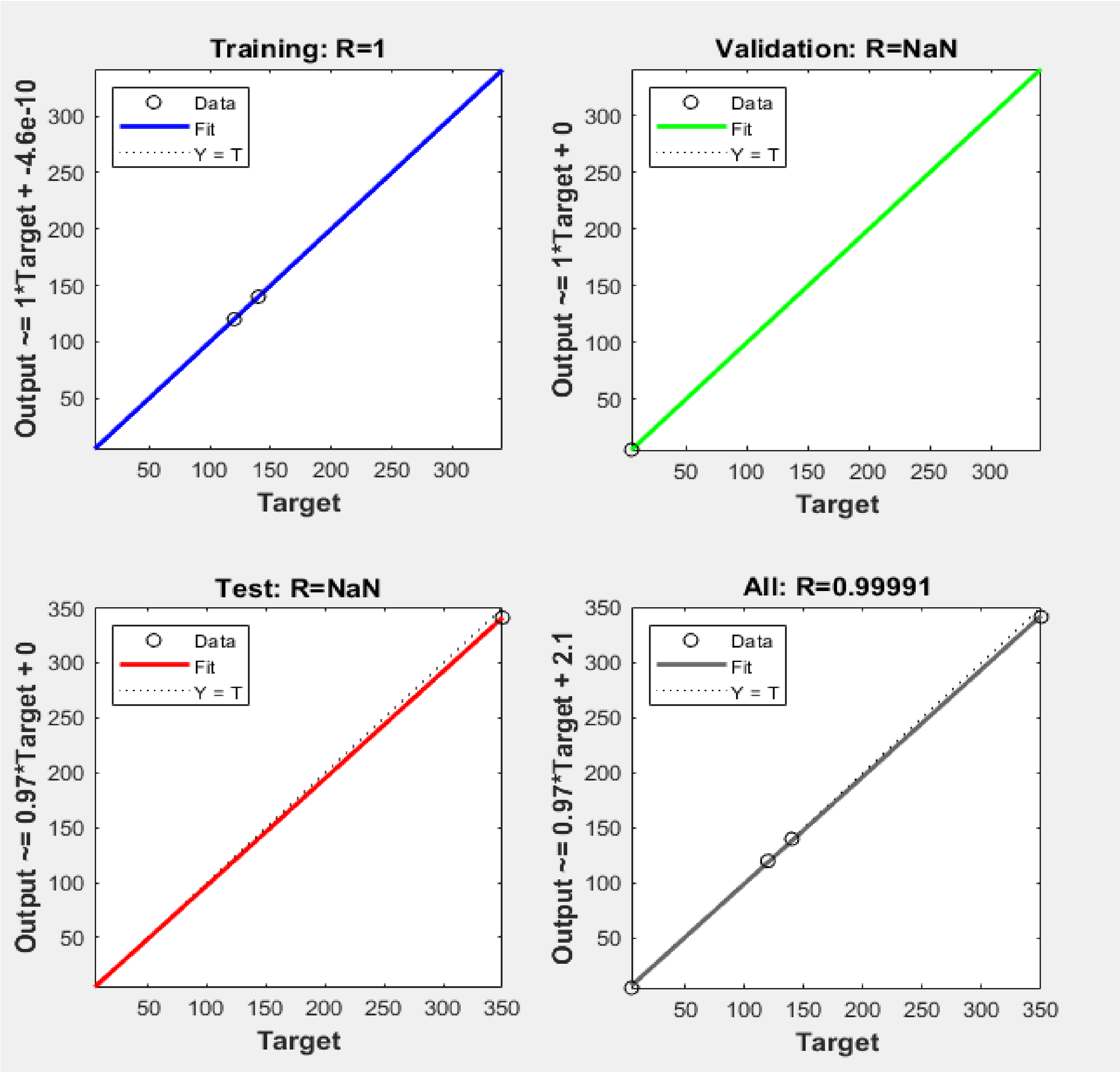

Figure 22:ANN case 3

Figure 21 shows the results of data training with accident detected, the R is equal to 0.99991, the R is near 1. The system used a feed-forward neural network model with 10 hidden layers was built. There are (49, 10, 1) the inputs, hidden, and output layer, correspondingly. At the input layer, the number of processing elements corresponds to the number of data sensors obtained in the circulation of a vehicle and accident condition. The main contribution of this work is to detect the road accident and send the notification.

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1. Conclusion

Smart application for accident detection based on IoT sensors is very important in smart transportation, the approach will decrease the mortality rate of people in the accident by getting medical help on time, the approach can help police to clear the roads in case of an accident to avoid jams. The experiment results showed that 49 inputs data sensors with 35 accidents, 27 were properly detected, then 8 accidents were not detected; the percentage detection rate was 77.14% with this test it is possible to detect the occurrence of accidents and communicate with the hospitals and police station in 5 minutes after accident event by sending an alert email. Considering the present road accident methods have proposed by other searchers, these methods characteristically use images from cameras which difficult to get cameras on all roads and take a long time for data processing, GSM which is expensive in infrastructures, sophisticated models for data processing which heavy for storage, compared with this approach. The simulation results and prototype results showed that the objectives were achieved.

6.2. Recommendation

In this research, I have detected the accident based on IOT sensors, I recommend the intervention of the Ministry of health in Rwanda and Rwanda national police for future enhancement and a real implementation of this project. Additional research is needed to increase the percentage of accident detection which is 77.14%. Using the sensors for high sensitivity and high accuracy, the system can be able to detect all road accidents, I recommend the people who want to decrease the number of fatalities in road accidents to implement a Smart application for accident detection based on IoT sensors.

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