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DEVELOPMENT OF FEED FORWARD NEURAL NETWORK-BASED VEHICLE ACCIDENT PREVENTION SYSTEM

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ABSTRACT

This paper addresses a pressing issue in Nigeria's transportation landscape and proposes an innovative solution using artificial intelligence. The ban on motorcycles due to high crime rates has led to a significant shift towards tricycle transportation, creating new challenges in accident prevention. The absence of existing accident prevention systems tailored to tricycles underscores the need for a specialized approach. The use of a Feed Forward Neural Network (FFNN) for tricycle detection is a promising method, leveraging machine learning to identify these vehicles on the road. Additionally, the incorporation of rule-based systems for accident detection and control ensures adherence to safe distance standards prescribed by the Federal Road Safety Corp (FRSC). By combining these approaches, the proposed system aims to mitigate collisions between tricycles and other vehicles effectively. The evaluation metrics, including Mean Square Error (MSE), Receiver Operator Characteristics (ROC) curve, and confusion matrix, demonstrate the efficacy of the developed model. With a low MSE, high accuracy, and a robust ROC curve, the system shows promise in accurately detecting and preventing accidents involving tricycles. The implementation of this system using Simulink provides a practical framework for deployment, offering real-world applicability. By addressing a critical gap in existing safety measures, this research contributes significantly to enhancing road safety in Nigeria, particularly in the context of the evolving transportation landscape dominated by tricycles.

Tricycle; Accident Prevention; Feed Forward Neural Network; Artificial Intelligence; Rule Based, FRSC, MSE

1. INTRODUCTION

Road Accidents is a very serious and high priority public health concern as the statics shows more than 1.25 million people die each year as a result of road crashes. Different risk factors such as Speeding, Drunk drive, No safety equipment, Distracted driving, Unsafe Vehicle, Law enforcement and more importantly Inadequate post-crash emergency care. Any delay in detecting and providing emergency care can leads to the increase severity of the accident. With the advancement in the fields of Artificial Intelligence, Machine learning and Deep learning we are able to make our device smarter and smarter. Traffic surveillance cameras are already installed in almost every part of the city. This paper is motivated with the idea of implementing statistical method of machine learning to detect any kind of collision in a live feed with the application of convolution neural network (Marco et al., 2014).

Today in Nigeria, the major problem has remained insecurity which has affected all part of the country. In many occasions, these insurgents move using motorcycles which are coincidentally a major means of transport in both the rural and urban areas. Having tried, various solutions to combat this problem with no avail, the government simply bans motorcycles as a means of transport in many areas today. However, this decision has affected numerous innocent citizens which equally employed these machines as a means of transport to move people from one place to another (Ullah et al., 2015).

To this end, many of these citizens have turn to the tricycles as an alternative transport means and as a result, these means of transportation has dominated both the local and high ways. But unfortunately, in the country, there is no standard, regulation, or administrative provision made to ensure that drivers of these tricycles are qualified and fit for driving, thus resulting to both the fit and unfit to have access to the system and drive. This has remained a major problem over the years as virtually on daily basis, there are events of accident involving other vehicles and tricycle (Ting et al, 2018).

Traditional traffic monitoring system in designed only to monitor traffic or to control the traffic, but it does not provide any solution to decrease the fatal accidental human damages rate which occur due to lack of medical aid in real time. Consider a scenario where an accident occurred but no one was there to report this accident, the victim is critical and every second counts, any delay can result in disability or death. We cannot root out accidents totally but we can improve in providing post accidental care just-in-time (Kanjee et al., 2015). There are lots of sensor-based systems available in the market as well but that require vehicle owners to install those sensors in their vehicles. The working of these systems is based on any damage being sensed by the sensors installed; these signals from the sensors will trigger a system that will alert nearby medical assistance or an emergency contact number. But what if the accident happened of a vehicle which is not equipped with such sensor-based system (Bokaba et al., 2022). There is need for an advance Artificial intelligence-based surveillance system which not only can detect occurrence of accident but also can alert to nearby hospitals/ambulance or Traffic policemen in real-time (Deeksha and Amit, 2019).

In the conventional accident detection and control system developed in (Noorishta and Akheela, 2019; Deeksha and Amit, 2019; Nancy et al., 2020; Bharath et al., 2019; Boutheina, 2018; Maaloul et al., 2017; Chen et al., 2016; Chen et al., 2017) achieved a good level of success, but despite the success, none of the solution considered the operation of tricycles and this has remained problem. This research proposes to address these issues using machine learning technique.

2. RESEARCH METHODOLOGY

The research methodology used is the simulation method, while the software design methodology used is the agile model. The method employed are data collection from the ministry of transportation, Enugu state Nigeria, data extraction, Modelling of the inter-vehicle classification algorithm, modelling of the accident prevention and control system, and then implementation with high level programming language.

2.1 Data collection

Data of tricycles were collected from the federal ministry of transportation. The sample size of data collected is 21,300 samples of tricycles and was stored in the system image repository to create the training dataset. The samples of the data collected were presented in the figure 1;

Figure 1: Samples of data collection

2.2 Data extraction

Having collected the data in image format, it was converted into statistical features using the Histogram of Feature Gradient (Sadek et al., 2010). The reason this feature extraction technique was adopted was due to its ability to correctly extract the rich features in an image and then convert into statistical equivalent for training purpose (Saxe and Berlin, 2015).

3. THE INTER-VEHICLE COLLISION DETECTION MODEL

To develop the inter-vehicle collision detection model, Feed Forward Neural Network (FFNN) was adopted from Nancy et al. (2020) and then used to develop the classification model. The model of the FFNN was presented using the figure 2;

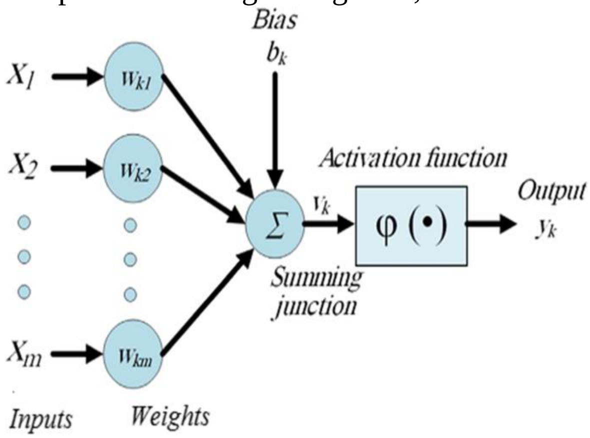

Figure 2: Architectural model of the FNN

The figure 2 presented a simple model of FFNN where x is he input neurons, w is the weights, b is the bias function, vk is the summation function, φ is the activation unction an yk is the output function. This FFNN was loaded with the data collected to configure the new FFNN as shown in the figure 3;

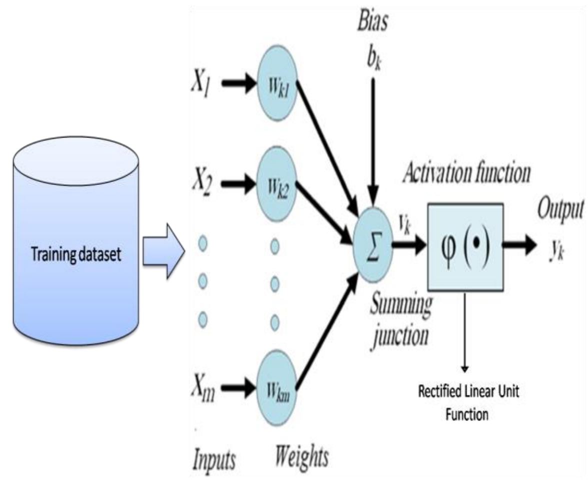

Figure 3: The system configuration of the FFNN with training data

The FFNN model was loaded with the training dataset to configure the FFNN for training using back propagation algorithm as shown in the Figure 4;

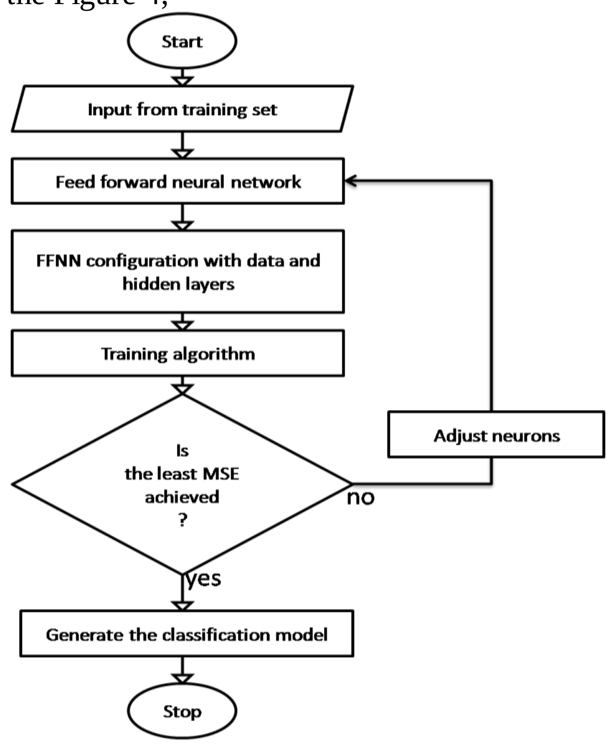

Figure 4: flow chat of the classification model with FFNN

The figure 4 presented the model of the classification system developed with the data collection and FFNN. This classification model was used to develop the inter-vehicle collision detection model as shown in the flow chart of figure 5;

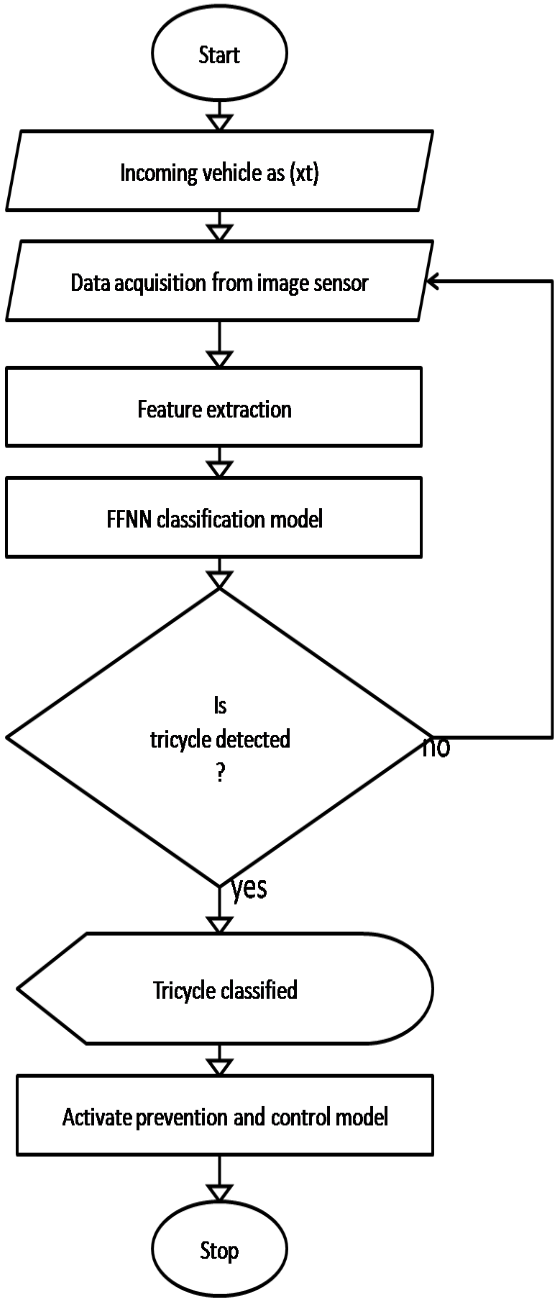

Figure 5: Flow chart of inter-vehicle collision detection model

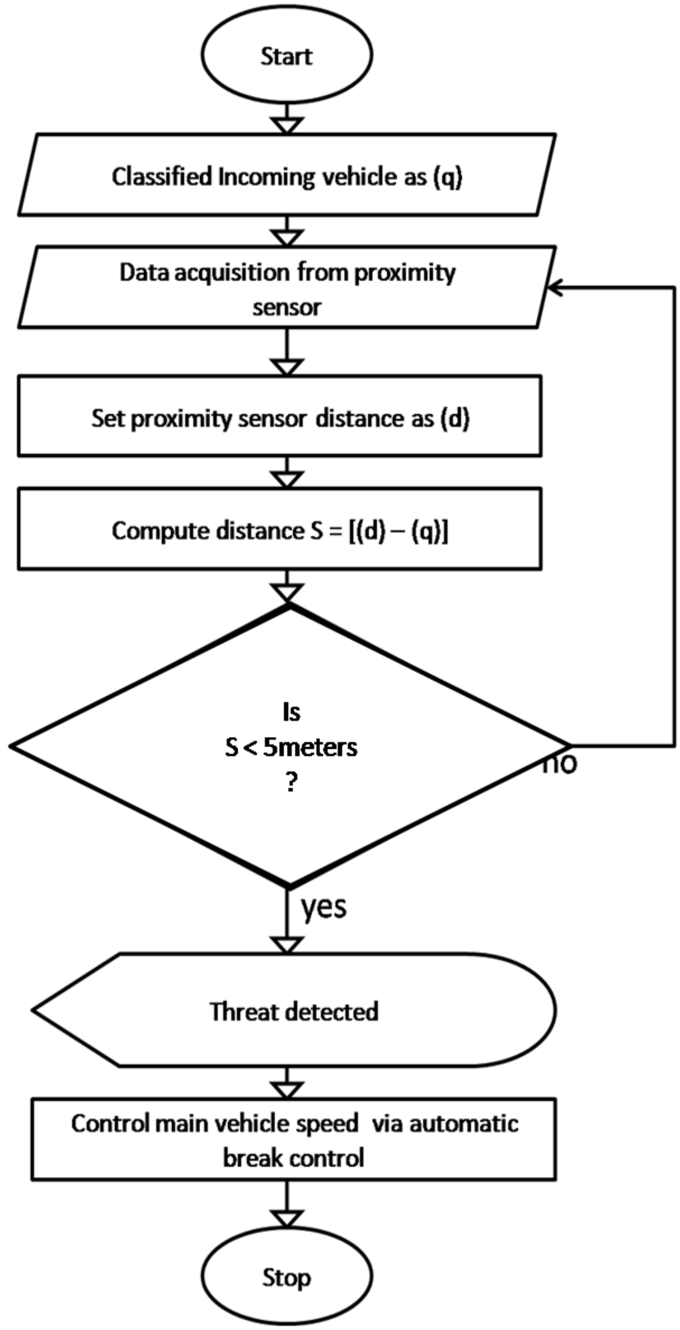

Figure 6: The accident prevention and control flowchart

4. THE ACCIDENT PREVENTION AND CONTROL MODEL

The model was developed using rule-based optimization approach based on the incoming from proximity sensor and then classified output from the model in figure 5 to develop a flow chart which showed the workflow for the prevention of accident.

The figure 6 presented the flow chart used in modelling the accident prevention and control system. The complete system flow chart which showed the workflow of the entire system operation was presented in the figure 7.

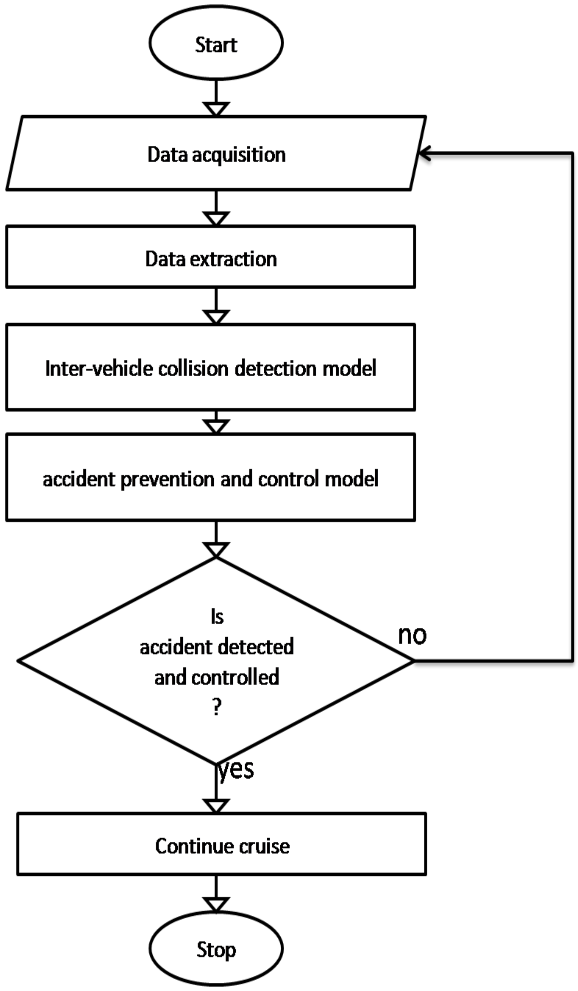

Figure 7: The complete system flow chart

The Figure 7 presented the work flow of the complete accident prevention and control system developed with machine learning. From the flow chart in figure 7, the image sensor was used to capture incoming vehicles on the road and extracted using the histogram extraction technique into the collision detection model in figure 4 and tricycle was detected from the vehicle, the distance was determined using the accident prevention and control model in figure 5 to compute the distance from the main vehicle and if it do not satisfy the 5meter inter-vehicle standard specified by the Nigerian road safety commission, then the automatic brake control system was sued to control the main vehicle speed to prevent the accident.

4.1 Use Case and Domain Analysis

Use Case Universal Modelling Languages are deployed in research to explain in details the main components of the requirement definition. They buttress the activity through which the system will satisfy the aforementioned functional requirements and would then be deployed in constructing the process model which explains the operations (user action) in a more formal manner. The process uses diagrams to document an object-based decomposition of systems showing the interaction between these objects and their dynamics. The author's objective here is to provide a common vocabulary of object-based terms and diagramming techniques that is rich enough to model any system modelling project from analysis to design.

Use case diagrams give a user point of view of the new system with different users referred to as the Actors. Here in the User Case diagrams below the actors is the main vehicle while the supporting actors include the various vehicles like tricycle, car, bus, trailer which can cause accident along the road. The figure 8 presented the use case when the actor detects accident from another car.

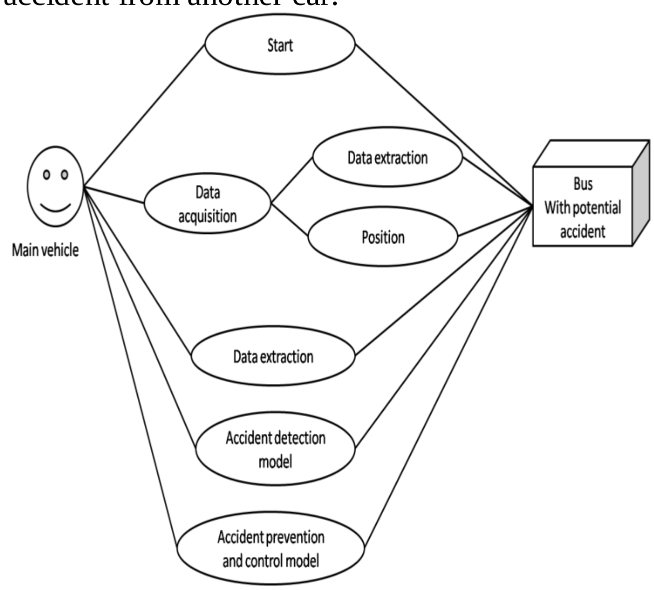

Figure 8: Use Case diagram for potential accident from another bus

Primary actors: Main vehicle

Secondary actor: Bus

Brief description of event: the modelling diagram presents the main vehicle which detected potential accident from a bus due to over speeding and then used the accident prevention and control model to avert the danger.

Pre-conditions: the main vehicle was already integrated with the new accident prevention and control system

Post-conditions: **W**hen the accident was detected, the brake was automatically applied in the main vehicle for control

Main flow of events:

1. The sensor collected data from the car
2. The data captured are extracted
3. The accident detection model was used to classify the car
4. The accident prevention and control model were used to avert the accident

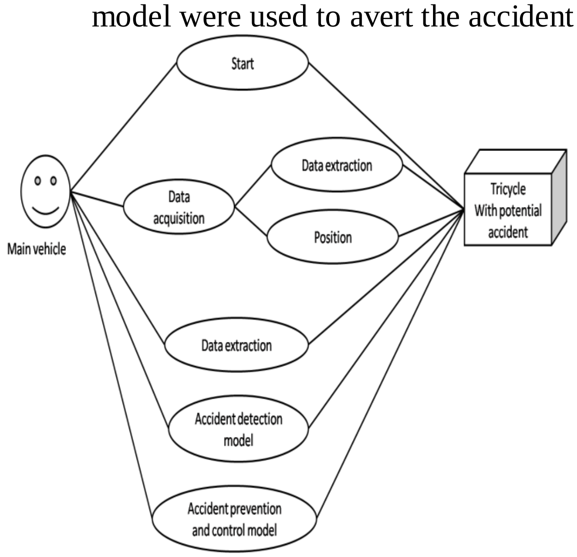

Figure 9: Use Case diagram for potential accident from a tricycle

Primary actors: Main vehicle

Secondary actor: tricycle

Brief description of event: the modelling diagram presents the main vehicle which detected potential accident from a tricycle due to over speeding and then used the accident prevention and control model to avert the danger.

Pre-conditions: the main vehicle was already integrated with the new accident prevention and control system

Post-conditions: **W**hen the accident was detected, the brake was automatically applied in the main vehicle for control

Main flow of events:

1. The sensor collected data from the tricycle
2. The data captured are extracted
3. The accident detection model was used to classify the tricycle
4. The accident prevention and control model was used to avert the accident

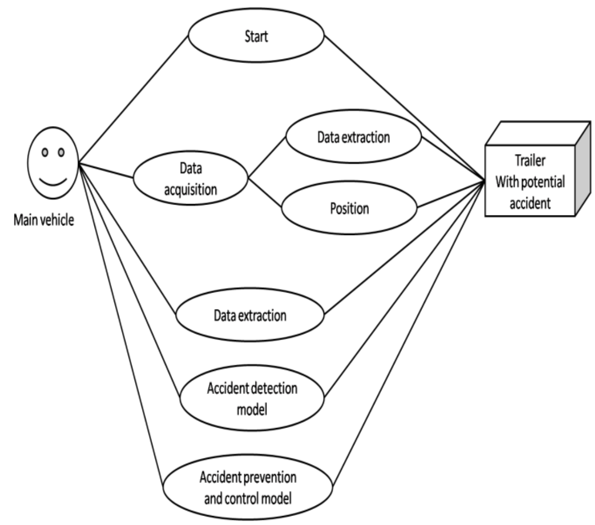

Figure 10: Use Case diagram for potential accident from a trailer

Primary actors: Main vehicle

Secondary actor: trailer

Brief description of event: the modelling diagram presents the main vehicle which detected potential accident from a trailer due to over speeding and then used the accident prevention and control model to avert the danger.

Pre-conditions: the main vehicle was already integrated with the new accident prevention and control system

Post-conditions: **W**hen the accident was detected, the brake was automatically applied in the main vehicle for control

Main flow of events:

1. **The sensor collected data from the trailer**
2. **The data captured are extracted**
3. **The accident detection model was used to classify the trailer**

4. The accident prevention and control model was used to avert the accident

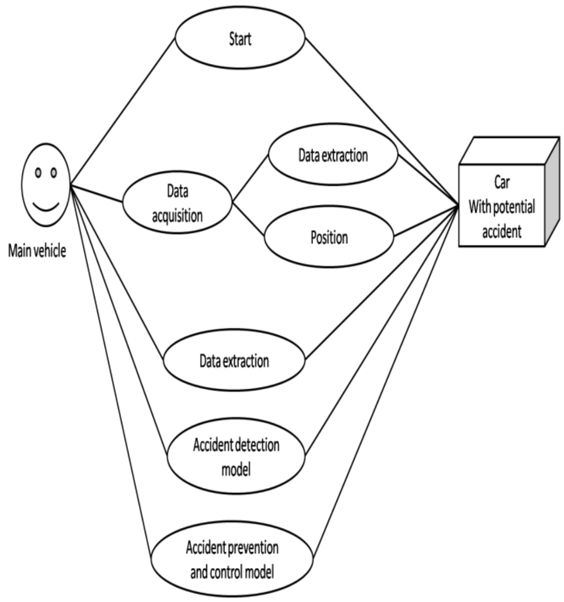

Figure 11: Use Case diagram for potential accident from a car

Primary actors: Main vehicle

Secondary actor: car

Brief description of event: the modelling diagram presents the main vehicle which detected potential accident from a car due to over speeding and then used the accident prevention and control model to avert the danger.

Pre-conditions: the main vehicle was already integrated with the new accident prevention and control system

Post-conditions: **W**hen the accident was detected, the brake was automatically applied in the main vehicle for control

Main flow of events:

1. The sensor collected data from the car
2. The data captured are extracted
3. The accident detection model was used to classify the car

The accident prevention and control model were used to avert the accident

5. SYSTEM IMPLEMENTATION

The models were implemented using image acquisition toolbox, data acquisition toolbox, machine learning and statistics toolbox, neural network toolbox and Simulink. The data acquisition and image acquisition toolbox were used to drive the data capturing process. The statistics toolbox was configured with the feature extraction techniques adopted. The neural network toolbox was configured with the accident prevention and control system developed. These toolboxes were used to implement the new system in Simulink environment and the performance evaluated.

6. RESULT

The performance of the inter vehicle collision detection system was evaluated using MSE, ROC curve and confusion matrix. The MSE was sued to show the error which occurred during the training process. The ROC was used to show how the model trained was able to detect potential accident and then Confusion matrix was used to measure the accuracy of correct accident detection. The figure 12 presented the result of the MSE performance.

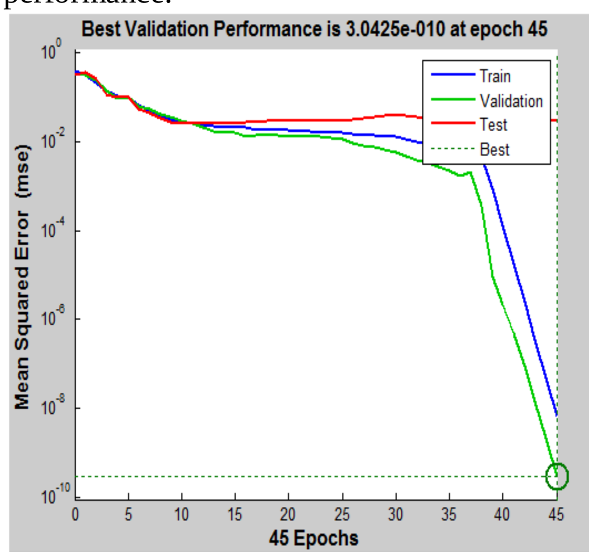

Figure 12: MSE result

The figure 12 presented the performance of the accident detection model developed with the FFNN. The result showed the performance of the neurons trained with the data collected. In the result the aim was to achieve a least MSE value of equal or approximately zero. This implied that the neurons learnt the features of the data with no overshot or tolerable error. From the result achieved, the MSE is 3.0425e-10 after epoch 45 which is good. The implication of the result showed that the training error achieved with the neurons was tolerable and showed that the neurons correctly learn the features they were trained with after 45 respective iteration epochs. The next result presented the performance of the ROC which was used to study the Correct Classification (TP), False Classification (FP), False Negative (FN) and True Negative (TN) rate of the accident detection model. The result was presented in the figure 13;

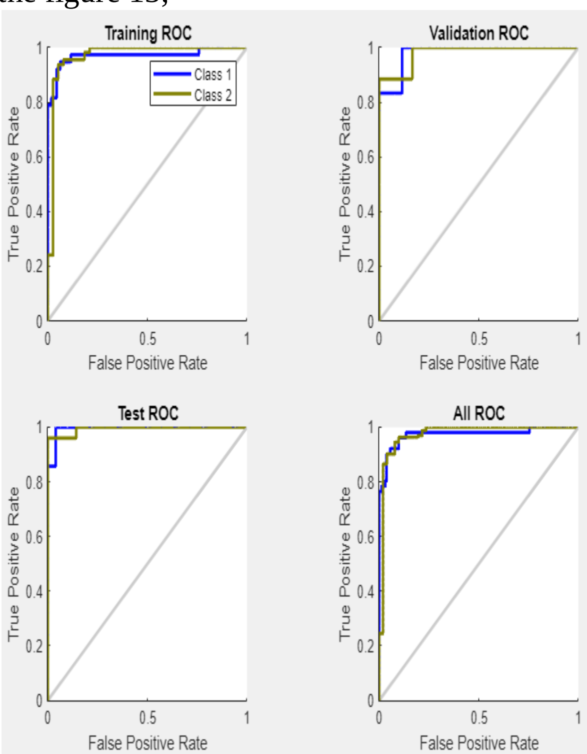

Figure 13: ROC analysis

The figure 13 presented the ROC of the training, test and validation of the accident detection model. The aim of this result was to achieve ROC value approximately or equal to one, which implied good accident detection performance. The overall ROC was achieved from the average of the training, test and validation set as 0.9831. The implication of the result showed that the neurons correctly learn the data and was able to detect accident correctly. To measure the detection accuracy of the model, the confusion matrix was used as in figure 14;

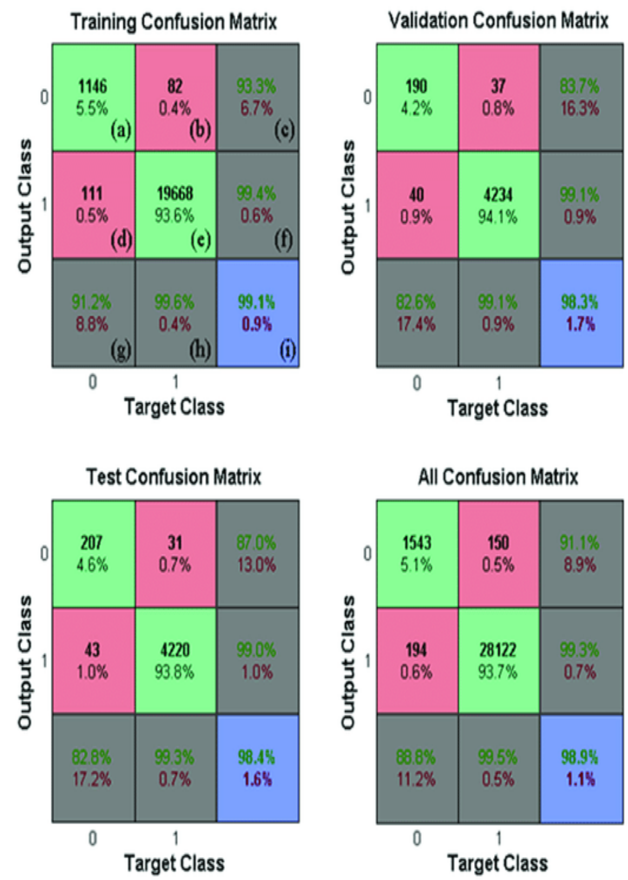

Figure 14: Confusion matrix

The figure 14 presented the confusion matrix used to evaluate the accuracy of the accident detection system. The result showed how the model developed was able to correctly detect incoming tricycle which poses threat to the main vehicle and correctly control to prevent accident. The results accident prevention accuracy was measured here and the result overall is 98.9%. The implication of the result showed that the system was able to correctly detect potential accident on the road and control.

7. CONCLUSION

The high rate of crime in Nigeria using motorcycles has resulted its ban in many areas today; however, this decision has equally affected millions which also used this means of transportation to earn a living via logics and transport services. As an alternative for survival, many of these people have shifted to the tricycle vehicle and as a result, it has dominated transport system nationwide. Secondly, to the best of my knowledge, there is no driving school for these tricycles and its increase adoption as a means of transport has greatly increased the rate of accident on both local and high ways and has resulted to social and economic problems such as loss of lives, damages of vehicles, injuries, etc. Furthermore, the conventional accident prevention systems never considered tricycles in their models and this has remained a technical problem. There is need for an accident prevention system which considered tricycle and develop a system which will help reduce its collision with other vehicles. Many works have developed accident detection and control system, but solution was never modelled which considered tricycles as a major cause of accident, even though it has dominated the means of transport and logistics in many developing countries. This study has successfully collected the data and develops a model which was used to the detection of incoming tricycle which can cause accident to the main vehicle. The detection output was identified by the control model developed with rule based which used the FRSC standard for safe vehicle distance on high way to make control decision and prevent accident. The result when tested and validated showed that the accident detection accuracy is 98.1; MSE is 3.0512e-10 and ROC is 0.9807.

7.1 Recommendation

Having developed, implemented and tested the system, the following were recommended;

i. The accident detection system should be integrated in all vehicle for accident detection and control

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