Design of an AI Base Framework for Speed Limit Prediction and Control Using GPS Data

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ABSTRACT

Road transportation and automobile requirements are on a daily increase and are directly proportional to the frequency of accidents. Therefore, developing an intellectual automobile system and other precautionary measures to safeguard drivers have become imperative. One of the important components to deal with is the speed limit signs (SLS) for the realization of an improved advanced driver assistance system (ADAS) with fully restricted and intelligent speed limiter systems. The existing optical recognition systems involve scanning speed limit signs to recognize the acceptable speed limit in a specific location. This can restrict the use of such ISA technology to only areas with frequent speed limit signs. To address this problem, this paper explores the potential of an artificial intelligence algorithm to accurately predict the speed limit of different streets from the speed limit datasets obtained from GPS devices. The GPS data is recorded over the test track to form a comprehensive dataset for the vehicle track. The datasets are then used to train a neural network model that can predict the location's speed limit, which is then communicated to the vehicle ECU offline. In addition, the trained model can be used to provide the adjusted speed limit as input through the MCU and then apply the maximum speed restriction to control the vehicle from overspeeding. Therefore, the vehicle can set the vehicle using the predicted speed limit. Experimental result in MATLAB 2021a shows that the NN performs well in predicting the vehicle's speed limit. However, the model mean square error for the validation set was 92.33% which is the lowest when compared to the testing and training state. after achieving the research aim, the model can enhance safe driving in Nigeria.

Keyword: - *Global Positioning System, Neural Network, Prediction and Speed Limiter*

1. INTRODUCTION

An Artificial Intelligence (AI) based speed limiter system is a technology that utilizes AI algorithms to control the maximum speed of a vehicle. The system uses various sensors, such as GPS, cameras, and radar, to gather real-time data about the vehicle's speed, road conditions, and surrounding environment. Based on this information, the AI algorithm determines the appropriate speed limit for the vehicle and ensures that it does not exceed that limit [1].
The AI algorithm analyzes inputs from the sensors and processes them in real-time to make accurate decisions regarding the speed limit. It takes into account factors such as speed limits displayed on road signs, the type of road, weather conditions, traffic congestion, and other relevant data. By continuously monitoring and adjusting the vehicle's speed, the AI-based system aims to enhance safety and promote responsible driving [2].
The benefits of an AI-based speed limiter system include:
1. Safety improvement: Limiting a vehicle's speed to a safe and appropriate level reduces the risk of accidents caused by speeding.
2. Compliance with regulations: The system can help drivers comply with speed limits imposed by local authorities, reducing the likelihood of traffic violations and penalties.
3. Adaptive control: The AI algorithm can adjust the speed limit dynamically based on changing road conditions, traffic patterns, and other factors. This ensures that the vehicle operates within safe limits at all times.
4. Customization: The system can be customized to consider specific conditions and preferences, such as adjusting speed limits for different vehicle types, road zones, or driver profiles.

It is important to note that the implementation of AI-based speed limiters raises ethical considerations and potential challenges. Balancing the need for safety with individual freedom and driver discretion is a complex issue that requires careful consideration and regulation[3]. Additionally, the system must be accurate and reliable, taking into account potential sensor errors or limitations to avoid unnecessary speed restrictions or unsafe situations. Overall, an AI-based speed limiter system has the potential to contribute to road safety by using advanced algorithms and real-time data analysis to control vehicle speeds and encourage responsible driving practices [3].

One of the important components to deal with is the speed limit signs (SLS) for the realization of an improved advanced driver assistance system (ADAS) with fully restricted and intelligent speed limiter systems. The major merits derived from the speed sign recognition system is to make drivers fully concentrate on the road with less worry about the speed of their vehicles because that has been taken care of. This is a result of the system using an artificial intelligence algorithms-based detection method which recognizes speed limit signs using an image classifier. However, Optical recognition systems involve scanning speed limit signs to recognize the acceptable speed limit in a specific location. This will also restrict the use of such ISA technology to only areas that have a frequent number of speed limit signs[4]. Hence, the necessity for further research that can utilize geographical information systems in speed limiter technology.

Thus, this paper designs an AI base speed limiter framework. The paper explores the potential of an artificial intelligence algorithm to accurately predict the speed limit of different streets from the speed limit datasets obtained from GPS devices. In addition, the trained model can be used to provide the adjusted speed limit as input through the MCU and then apply the maximum speed restriction to control the vehicle from overspeeding (Anand et al., 2020) This research can enable the research community to have an insight of next-generation vehicles.

The remainder of this paper is as follows. Section 2. Presents the review of related work. Section 3 discuss the methodology and section 4 presents the results and discuss the performance of the AI-Base algorithms, finally, section 5 concludes the research and proffers future opportunities with regard to the design of AI base speed limiter systems.

2. RELATED WORK

Road transportation and automobile requirements are on a daily increase and ultimately, are directly proportional to the frequency of accidents occurrences. Therefore, developing an intellectual automobile system and other precautionary measures to safeguard driver have become imperative. Many approaches have been proposed in the literature, for example, [5] creating an onboard speed regulation module for vehicles which can monitor as well as control their instantaneous speed in comparison with the maximum permissible speed of that location. The location is obtained using position tracking technology of GPS and GSM system,

Similarly, [6] proposed adaptive vehicle speed monitoring and control using GPS. GPS has been used to achieve speed determination and speed control based on the current vehicle location. Additionally, [7] proposed automatic vehicle speed control system designed to control the speed of the vehicle in specific zones to avoid the accidents in the low-speed areas.

Furthermore, [8] proposed GPS enabled speed control embedded system. The embedded system automatically controls the speed of a motor vehicle based on its location determined by a GPS device.

In 2018, [9] proposed speed detecting and reporting system using GPS/GPRS and GSM. Also, [10] proposed GPS and GSM enabled embedded vehicle speed limiting device. Based on the obtained GPS values the speed of the vehicle is controlled. More recently,

All the previous studies utilized real time GPS communication technology to update the vehicle speed limit system. However, there is need for offline model that can learn intelligently from the previous GPS data that has been recorded and train to form an intelligent speed limiter that can predict the speed of the vehicles using neural network technology. Hence, in this research, the GPS data is recorded over the test track to form a comprehensive dataset for the vehicle track. The dataset is then used to train a neural network model that can predict the speed limit of the location which is then communicated to the vehicle ECU offline. Therefore, the vehicle can set the vehicle using the predicted speed limit.

3. MATERIAL AND METHOD

The goal of this project is to provide a simple and effective solution to control the vehicle speed using an AI base framework. Adapting the speed of the vehicle to its location will substantially reduce excessive speeding and thus the chances of fatal crashes. An important use of the ISA can be in developing countries that are yet to have an effective highway patrol. A speed limiter can be used to reduce the number of speed-related crashes without spending any additional funds on highway speed supervision. Moreover, the project can be a part of the

development of autonomous cars. The ISA technology currently in use is limited to a few specific vehicle manufacturers. Also, the existing optical recognition systems involve scanning speed limit signs to recognize the acceptable speed limit in a specific location. This can restrict the use of such ISA technology to only areas that have a frequent number of speed limit signs. However, this project uses inexpensive and effective AI base speed detection algorithms using GPS data as a solution that can be easily embeddable in different vehicles as shown in Fig. 1

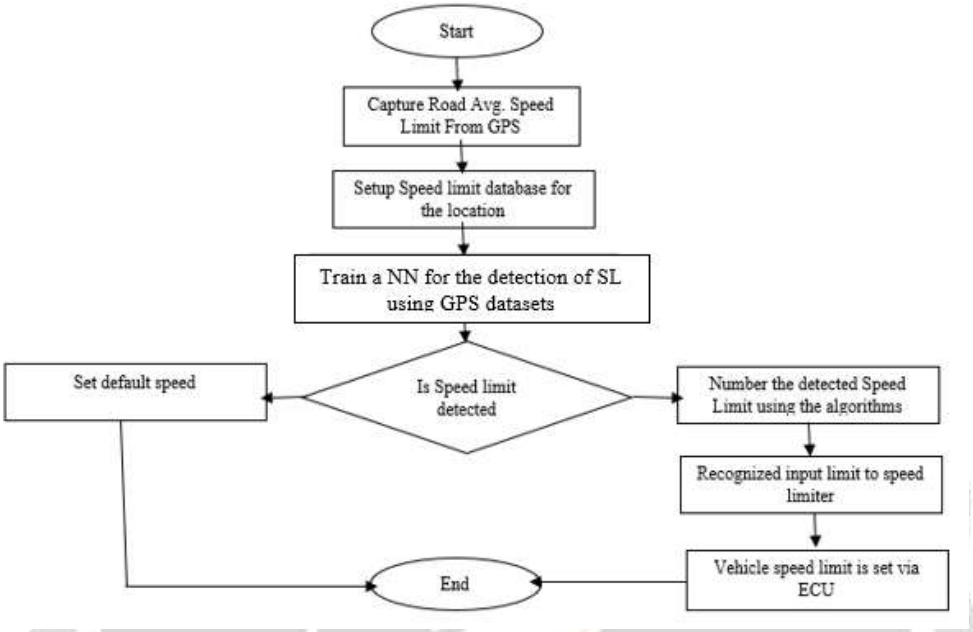

Fig. 1. Flowchart of the proposed AI base Speed Control System

For this research, we adopt the simulation approach to test the neural network. Thus, to achieved the desired objectives, first, we describe the data collection from GPS system. Secondly, we train an effective neural network algorithm for prediction of speed limit from the collected GPS speed limit database. Thirdly, we evaluate the performance of the NN model. Finally, with the help of AI base speed prediction algorithm, the speed limit of the particular area can be set. Further this limit can be provided input to the speed limiter through the car's ECU. The speed limiter then sets the maximum speed of the vehicle which restricts the vehicle to over speed. The flowchart in Figure 1 shows the complete process of the proposed AI base speed controlling framework using GPS information.

3.1 Proposed Test Location

The proposed location to test the speed control model is selected as the Wuse Zone 2. Abuja. Figure 2 shows the intended path of the vehicle. The path was chosen to be such to test the speed-limiting feature of the model at both the higher and lower end of the speed limit. The choice of this area is because it has a series of connected roads with different speed limits. The test path is divided into five regions with varying speed limits making the test datasets have eight features with varying inputs. The features of the datasets are.

i. The_ GEOM
ii. Speed Limit
iii. STREETNAME
iv. Over_ pct
v. O5mph_pct
vi. Speed_ avg
vii. Speed O_ avg
viii. Spd5O_avg

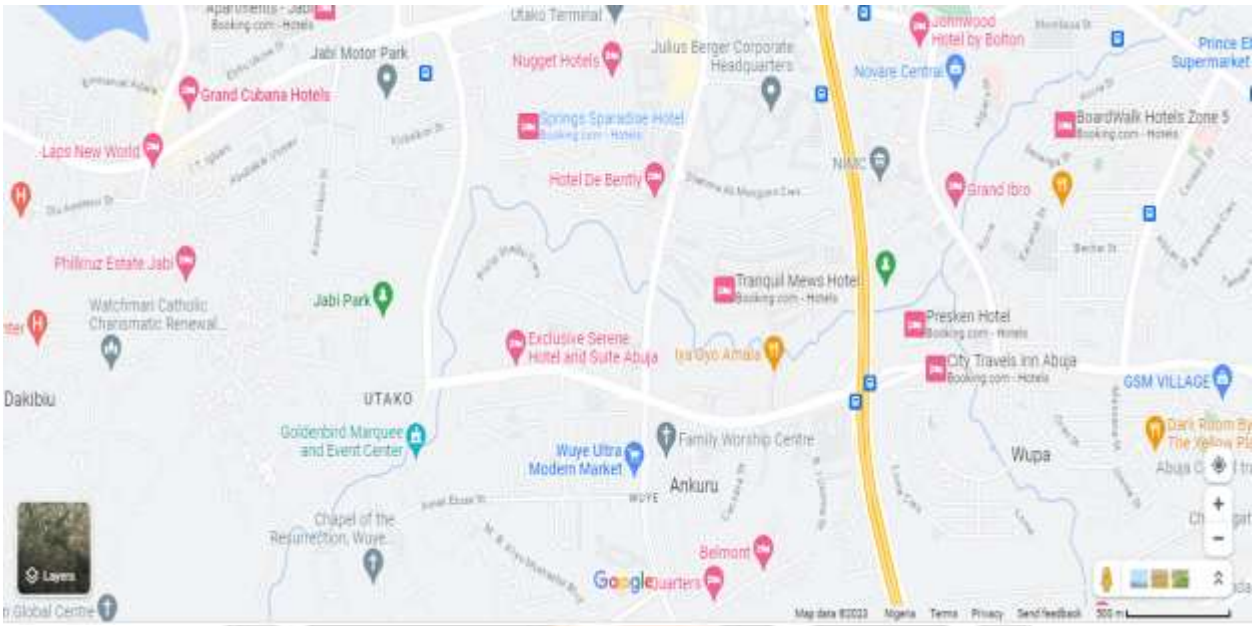

Fig. 2 Test track of Vehicle

A sample of the first five datasets used for the neural network training is depicted in table 1.

Table 1: A sample of the first five datasets used for the neural network training

The_ GEOM	Speed Limit	STREETNAME	Over_ pct	O5mph_pct	Speed_ avg	SpeedO_ avg	Spd5O_ avg
LINESTRING (-122.39031948388298 37.78813450234439, -122.39117965804613 37.787455186972764)	30	HARRISON ST	39.77	11.11	28.4	33.76	38.32
LINESTRING (-122.39117965804613 37.787455186972764, -122.39205296294394 37.78676548321337)	30	HARRISON ST	39.77	11.11	28.4	33.76	38.32
LINESTRING (-122.39961623244395 37.78079148306888, -122.40184327335723 37.77903213358389)	30	HARRISON ST	48	15	29.55	33.88	38
LINESTRING (-122.38775628064698 37.75283561191084, -122.38767895622722 37.75275271855192, -122.38757222629916 37.751639193810746, -122.38763397457048 37.7515596035663)	30	3RD ST	58.5	25.5	31.26	34.89	38.63
LINESTRING (-122.38775628064698 37.75283561191084, -122.38781677990747 37.752742975819686, -122.38771113084314 37.75164075762112, -122.38763397457048 37.7515596035663)	30	3RD ST	58.5	25.5	31.26	34.89	38.63

3.2 Working Principle of the Proposed Framework

In the framework, the device prototype is tested in the proposed region shown in Fig. 2. In order to properly test the device, a fixed procedure can be used in each speed region. After detecting the vibrations, the location (i.e., longitude and latitude) can be marked on the GPS, the data store gets information about the location via updated Maps and also the location stored in the database. The flowchart in Figure 3 shows the complete process of speed limit prediction using GPS to mark the location of potholes on the Map. In the proposed speed controlling framework, the speed-limit prediction system works in three different stages: first preprocessing of the datasets obtains from GPS, second is training and prediction of the speed limit using the train Neural Network, and the third is the adjustment of the speed limit in the vehicle ECU. Table 1 presents the performance of the training model in predicting the speed limit using the GPS data.

Table 2. Speed Limit Prediction Performance of Neural Network

Metric	Accuracy	MSE
Training	97.22	96.44
Testing	90.44	93.65
Validation	93.21	92.33

Table 2. shows that the NN performs well in predicting the speed limit of the vehicle. However, the model mean square error for the validation set was 92.33 which is the lowest when compared to the testing and training state. This elaborated graphical in Fig. 3

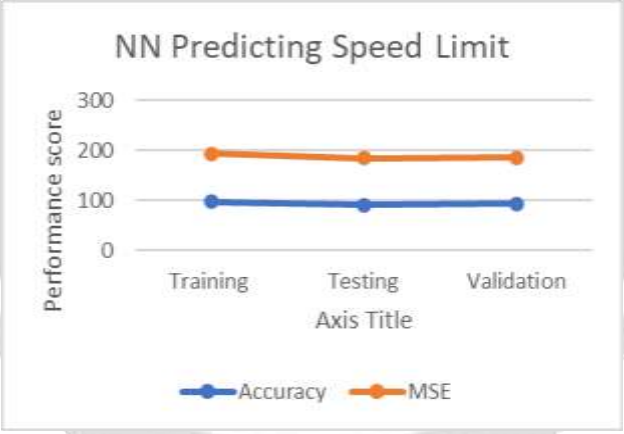

Fig.3 Prediction Performance of Neural Network

After prediction of the speed, The NN can then set the speed limit of the vehicle by changing the limit of speed limiter via providing it the limit by using raspberry pi. Thus, the vehicle maximum speed is set automatically by using the speed limit obtain from the train network and the speed limiter can be set.

5. CONCLUSIONS

Previous studies utilized real time GPS communication technology to update the vehicle speed limit system. However, there is need for offline model that can learn intelligently from the previous GPS data that has been recorded and train to form an intelligent speed limiter that can predict the speed of the vehicles using neural network technology. Hence, in this research, a framework was design in which the GPS data is recorded over the test track to form a comprehensive dataset for the vehicle track. The datasets are then used to train a neural network model that can predict the speed limit of the location which is then communicated to the vehicle ECU offline. Therefore, the

vehicle can set the vehicle using the predicted speed limit. Experimental result in MATLAB 2021a shows that the NN performs well in predicting the speed limit of the vehicle. However, the model mean square error for the validation set was 92.33% which is the lowest when compared to the testing and training state. This research has demonstrated the suitability of the proposed framework in enhancing safety driving in Nigeria. As our future work, we will embed and the test the proposed train AI base speed limiting framework using raspberry pi along the track selected for collection of the GPS speed limit database.

6. ACKNOWLEDGEMENT

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7. REFERENCES

[1] Olugbade, S., et al., A review of artificial intelligence and machine learning for incident detectors in road transport systems. Mathematical and Computational Applications, 2022. 27(5): p. 77.
[2] Gital, A.Y.u., et al. Review of GPS-GSM Based Intelligent Speed Assistance Systems: Development and Research Opportunities. in 2023 3rd International Conference on Intelligent Communication and Computational Techniques (ICCT). 2023. IEEE.
[3] Lawal, M.A., et al., A Fuzzy Logic Base Speed Limiter System for Improving Road Safety Driving in Nigeria. Available at SSRN 4214139.
[4] Jahan, A.S., I. Hoq, and D. Westerfeld, GPS Enabled Speed Control Embedded System. 2013, IEEE.
[5] Sethuramalingam, T., R.N. Devi, and K. Sangeetha, Speed Control for Motor Vehicles Using Global Positioning System. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 2014. 3(1).
[6] Rajeshwari, B., S. Chaudhary, and B. Divya, ADAPTIVE VEHICLE SPEED MONITORING AND COTROL USING GPS.
[7] Bhargave, S.S., M.V. Jadhav, and A.S. Patil, Automatic Vehicle Speed Control System. 2018 International Journal of Innovative Science and Research Technology, ijisrt, 2018.
[8] Jahan, A.S., I. Hoq, and D. Westerfeld, GPS Enabled Speed Control Embedded System. IEEE Journal of speed limiting device with display and engine control interface 2013, 2013: p. 2467-2472.
[9] Rajeshkumar, T., et al., Speed Detecting and Reporting System using Gps/Gprs and Gsm. International Journal of Pure and Applied Mathematics, 2018. 118(20): p. 73-79.
[10] Priyadarshni, V., P.G. Krishna, and K.S. Ravi, GPS and GSM enabled embedded vehicle speed limiting device. Indian Journal of Science and Technology, 2016. 9(17): p. 1-6.