ISSN 2278-3091
Volume 12, No.3, May - June 2023
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse041232023.pdf
https://doi.org/10.30534/ijatcse/2023/041232023

FUZSLS: A Predictive Control System for Vehicular Speed Limit Application Using Fuzzy Logic

Abdulsalam Ya'u Gital[1]*, Mahmood Abdulhamid[2], Muhammed Abdulhameed[3], Mustapha Abdulrahman Lawal[1], Fatima Umar Zambuk[1], Maryam Maishanu[1]
[1]Department of Mathematical Sciences, Abubakar Tafawa Balewa University Bauchi, Nigeria
[2]Department of Electrical and Electronics Engineering, Abubakar Tafawa Balewa University Bauchi, Nigeria
[3]Department of Mathematics and Statistics, The Federal Polytechnic Bauchi, Nigeria

Received Date April 16, 2023 Accepted Date: May 19, 2023 Published Date: June 06, 2023

ABSTRACT
Tremendous effort is required for controllers in industries; the design of these controllers is a challenge for manufacturers and engineers. Proportional integral derivative (PID) controller is the most commonly used traditional controller. However, problems of stability and gained performance analysis of a discrete positive system is still an issue in the current speed limiting system. But the fuzzy logic controller can be preeminent substitute of the PID controller for its more appropriate tools in control systems as it can be replaced as the human experience. The results show that, the proposed Fuzzy Logic can address problems of stability and gained performance analysis of a discrete positive system.

Key words: Artificial Intelligence, Speed Limiter systems, MATLAB, Fuzzy logic.

1. INTRODUCTION

Over speeding is the paramount among causes of accidents which also keep an increase in the risks of injuries and crashes [1] and Nigeria as a developing country is not left out, road accidents killing a lot of people yearly due to bad roads and over speeding. Stake holders have been engaged to achieve speed limiter since 2012 in Nigeria but still await formal implementation and enforcement. Through the advancement of technology, engines and other vehicle accessories are controlled with the aid of electronic devices. The major goal of the vehicle's parts development id to reduce fuel consumption and to improve safety. Even though, cruise control has been designed to deal with large number of problems that visage problems faced by drivers and passengers like fatigue duty and traffic accident and it is only overcome, performed by or solved through velocity control [2]. AI and deep learning have made considerable amount of impact in solving complex problems [3].
Suitable vehicle speed based on conditions can achieve fuel economy and good engine condition and also can assist the drivers from averting any kind of hazard especially if the drivers manual speed control can be superseded by a cruise control system, then it will be more reliable and economically efficient. So, cruise control system and particularly the fuzzy logic to control the vehicle's speed are very paramount for the modern vehicle system. Proportional integral derivative (PID) controller is the most commonly used traditional controller. But the fuzzy logic controller can be preeminent substitute of the PID controller for its more appropriate tools in control systems as it can be replaced as the human experience. Hardware implementation of the fuzzy controller can also be carried out in variety of ways. Although some environmental factors such as temperature, humidity and some internal factors like vibration and speed deteriorates the vehicle conditions which are caused by driving engines [4].

1.1 Background of Speed Limiter System Using Fuzzy Logic

Fuzzy logic is an extension of Boolean logic introduced by Lot Zadeh in 1965, Fuzzy logic is a type many-valued logic in which truth values of variables may be any real number between 0 and 1 like the binary logic. Fuzzy logic includes 0 and 1 as extreme cases of truth or the state of matters or fact but also includes the various states of truth in middle. Also, when linguistic variables are employed, degrees may be managed by specific variables called membership functions [5, 6]. Fuzzy logic has been used to develop and implement a fuzzy controller and fuzzy fault detection for centralized chilled water system [6] by faculty of Electrical Engineering University Technology Malaysia. The paper presented the results of fuzzy logic controller and fuzzy fault detection in the framework of centralized chilled water system. They examined three operating cases through two test rooms with some parameters were set persistent throughout the simulations. Results show that the controller was able to cool the test rooms to the desired temperature values.

It has been demonstrated that a rightfully outlined direct fuzzy controller can have a superior execution than regular proportional integral derivative (PID) controllers [7]. A book that a talk about the use of fuzzy logic in building application was distributed [8]. Bose has uttered in his book about the utilization of expert system including neural system and fuzzy logic in the control of power electronics and motion devices [9]. Mamdani's fuzzy inference technique is the generally employed approach in fuzzy logic. Mamdani's approach was one of the major control frameworks constructed using fuzzy set theory. It was founded by Mamdani Ebrahim in the year 1975 in an effort to control a steam engine and heater blend through integrating an arrangement of linguistics control rules acquired from experienced administrative personnel [8].

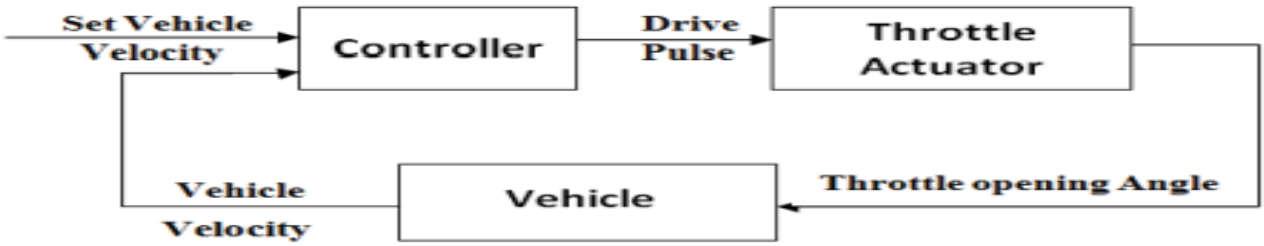

Figure 1: Overall back diagram of the system [10]

Figure 1 depict the overall back diagram of the speed limiter system. The dynamic equation of the vehicle is given below

$$\dot{v}(t) = \frac{1}{m}(-A_p u^2(t) - d + f(t)) \quad (1)$$

$$\dot{f}(t) = \frac{1}{\tau}(-f(t) + u(t)) \quad (2)$$

Here, u represents as control input, when $u > 0$ then it represents throttle input and when $u > 0$ then it represents brake input, $m = 1300kg$ represent as the vehicle mass, $A_p = 0.3\,Ns^2/m^2$ Represents the aerodynamic drag, $d = 100N$ represents as friction force in constant, driving and braking force is denoted by f and $\tau = 0.2$ is set in sec. the main goal of the research is to design a controller by fuzzy logic which can control automobile's speed to a driver-specified values [11].

1.2 Speed Controller Design Using Fuzzy Logic

There are two fuzzy controllers have been designed. One with the PI and another with the PD. Both controllers have been analyzed in the following.

1.2.1. Design of PI Fuzzy Controller

In the following a system has been considered to track a step or ramp change in the driver-specified speed value $u_d(t)$ very accurately [12]. A "PI fuzzy controller" In Figure 2, the fuzzy controller is denoted by ϕ; g_0, g_1 *and* g_2 are scaling gains and $b(t)$ is the input of the integrator.

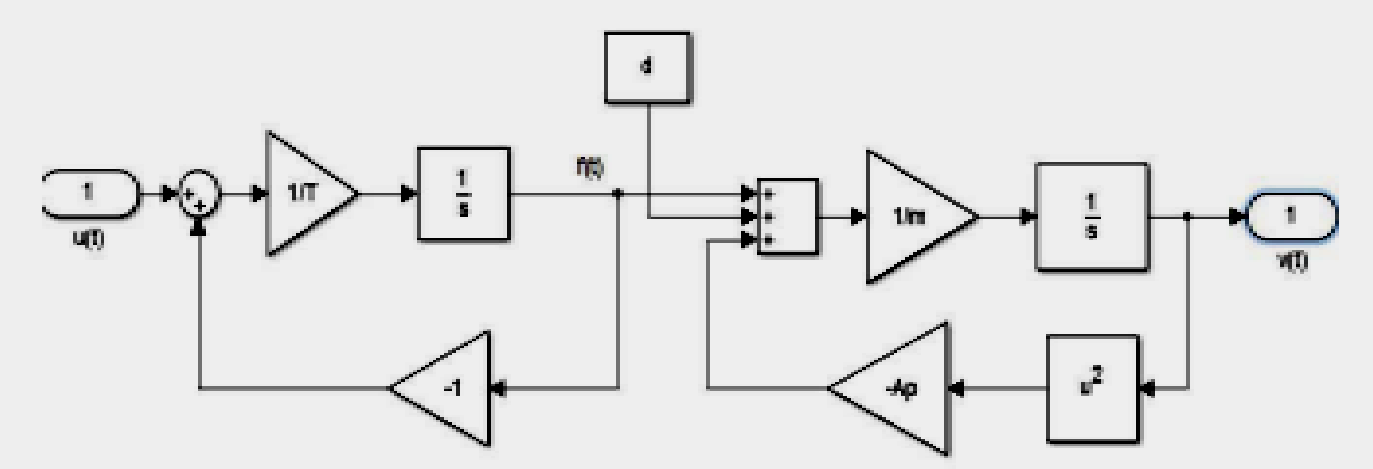

Figure 2: PI fuzzy controller design

For the reference input, three different test signals have been used [5]. Figure 2 shows the Fuzzy inference system where there are two inputs. One is speed error had other is the change in error. Each input has seven membership functions ranging from -1 to 1. This fuzzy controller has one output which is shown in figure 2. As each input has seven membership functions therefore total rules defined for this controller are 7x7 = 49. The rules are defined according to the following algorithm which has shown in table 1 [6].

2. LITERATURE REVIEW

2.1 AI approaches to Avoid Over Speeding

A lot of efforts by various researchers have been carried out to ensure accidents are reduce drastically as summarized:

They study in [1] employed IOT, Cloud computing and Open-Source Computer Vision (OpenCV) library and Python to develop a system that detects the license plate number of an over speeding vehicle with the aid of Rasberry Pi and a camera to control and manage traffic systems with the development of framework for speed detection that could report speed including violations not within the camera's line of sight and irregular traffic scenarios. However, limitations of the work include checking and testing each IoT devices and memory, processing power and bandwidth. The work can be improved by the use of advanced cameras and IoT devices, as well as deep learning for image processing and had issues with handling big data, a lot of sensors are still required to be placed to find vehicle's location and timing.

Similarly, [13], proposed an approach that automatically monitors drinking-and-driving and speeding on South Africa's roads without deploying a manual system with the aid of IOT's vehicular ad-hoc networks (VANETs), and cloud computing to introduce an innovation into the transport system but only presented a theoretical-design of the work, also more IoT devices have to be installed on all the vehicles.

Furthermore, [14], employed computer vision approach and used of an algorithm which utilizes processing of video image and an optical camera to detect vehicle speed in a précised manner with the aid of only a video camera and a computer and concurrently detect vehicle speed in different lanes with an error of less than 7%. The proposed method's result accuracy was compared with outstanding references. The proposed method solves constant threshold issue as a known existing disadvantage; the approach is more robust against misdetections and solves the problems of splitting or merging vehicles also not affected by weather changes. Yet have critical issues of caution during calibrating the camera and processes only 12 frames per second.

Also, [15] measured speed based on license plate numbers; the work uses image processing and assesses car speed with a sequence of real-time video of traffic images. The position of the cars can be tracked in different and is compared with ground truth. Nevertheless, the limitations of the work include less performance poor lightening and bad weather conditions, relied on high performance hardware for signal processing and it is difficult to distinguish the plate number of the second vehicle if two vehicles were captured in a frame moving after each other.

Recently, [16] published another method that extracts data from CCTV and uses headlight detection to examine a moving vehicle and with the aid of pinhole and Euclidian distance techniques to calculate the vehicle speed. Also, vehicle detection algorithm was compared with vehicle counting-speed measurement. Normalized cross-correlation has given better detection accuracy than the area-centroid-difference method. However, the method has flaw if two vehicles become visible in the same frame as detecting the rear vehicle happen to be hard as some captured objects detected are given low ID and not counted, also the approach works with headlight, so it is affected by lightning and weather conditions. A genetic programming technique for detecting vehicle speed was also anticipated by certain draw back.

2.2 Application of Fuzzy Logic in SLS

Various work has been carried out to ensure Fuzzy logic have been employed in implementing varieties of techniques are employed to develop speed limiter systems to ensure accidents are been reduced to the minimum. For example, [17] projected a new flux-weakening control scheme to operate the PMSM in the maximum torque per volt (MTPV). The proposed controlled method notably improves stability, increased speed range and uphold maximum possible capability of torque. However, the proposed control system does not have the ability to adjust the command value in a larger disruption.

Similarly, [18] offered an enhanced flux weakening (FW) control for permanent magnet synchronous motors (PMSM) that focused on electric vehicle applications. Simulation and experimental results attest reliability and effectiveness of the anticipated algorithm. But the cruise controller does not work in bad weather.

Additionally, [19] planned FW control approach of infinite-speed surface mounted permanent magnet synchronous machines (SPMSMs) here, the inverter nonlinearity and winding resistance voltage are measured and the weakening current response through reduction of the d-axis current consumption in the infinite constant power speed range. So, the proposed method has efficiency and power factor in the FW region has been improved. Still, the SPMSM are not auto starting and are too expensive.

Furthermore, [20] utilizes a FW control scheme for the segmented interior permanent magnet synchronous motor (IPMSM) that includes the maximum torque per ampere (MTPA) control, the voltage reference regulated control and the maximum torque per voltage (MTPV) control, and the dynamic six-step over modulation. The proposed models attain horizontal transitions within all speed regions and fully exploit the inverter output voltage capacity. The proposed model could also attain a wider constant torque region and higher power output. But the motor used as prototype could only move via one direction.

3 METHODOLOGY

Mamdani's Fuzzy logic was used for the design and analysis of the speed limiter, distance and speed were taken as the variables and the brake served as the output as demonstrated in figure 3 and figure 4 displays the membership function that was used to create rules for the speed limiter system to follow.

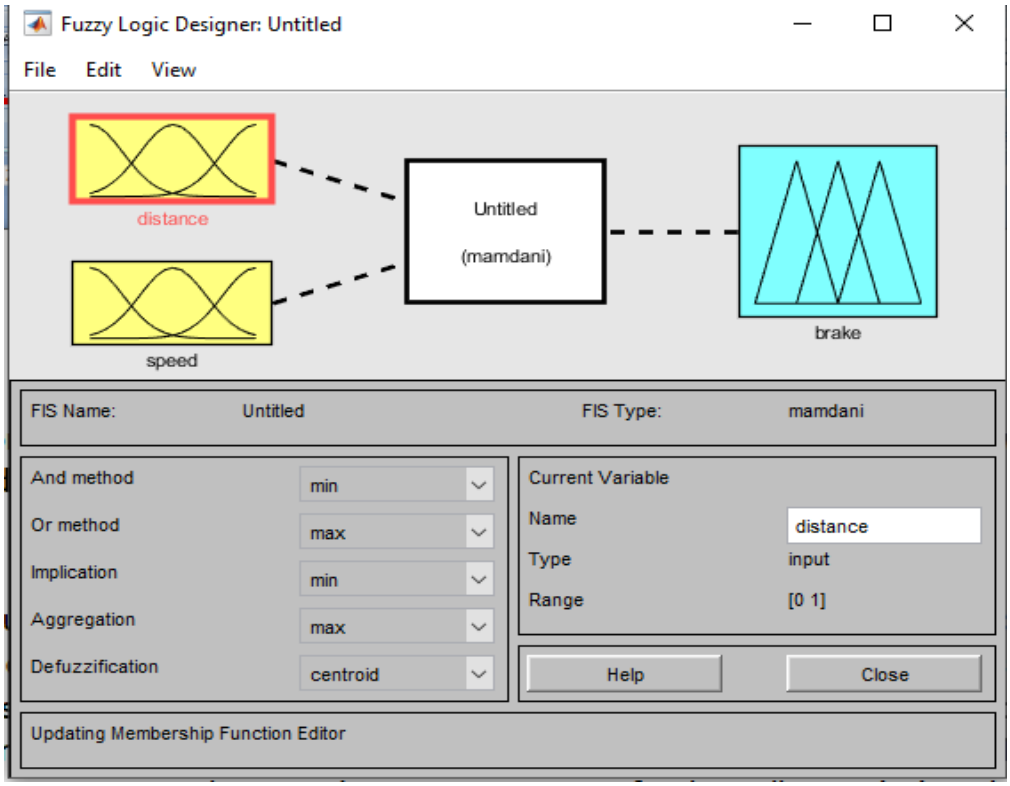

Figure 3: Fuzzy Logic Designer Interface

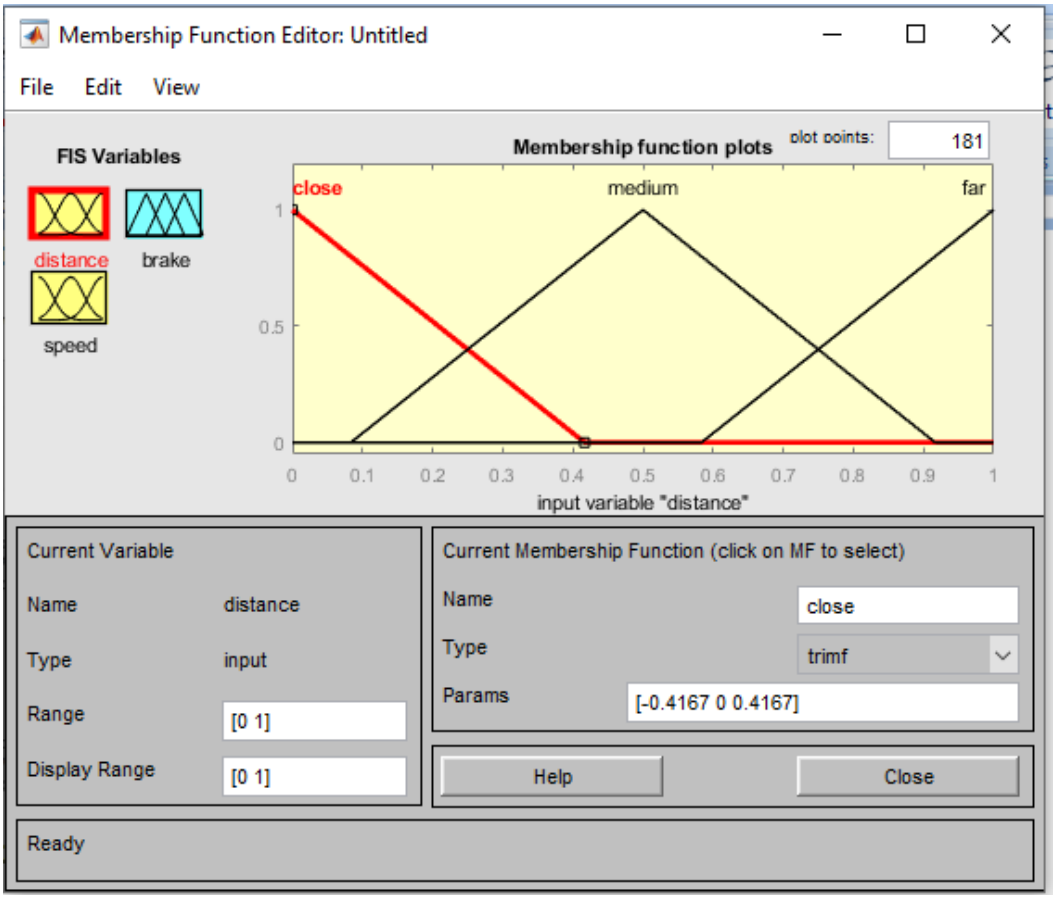

Figure 4: Fuzzy Logic membership function

4 RESULTS AND DISCUSSION

At distance 0.5 and speed equals 1 the brake output was found to be 0.859 which is where it satisfies the local minimum gratify the constraints and the optimization point as displayed in figure 5 and figure 6 displaying our surface viewer in graphical form saved as Gital.

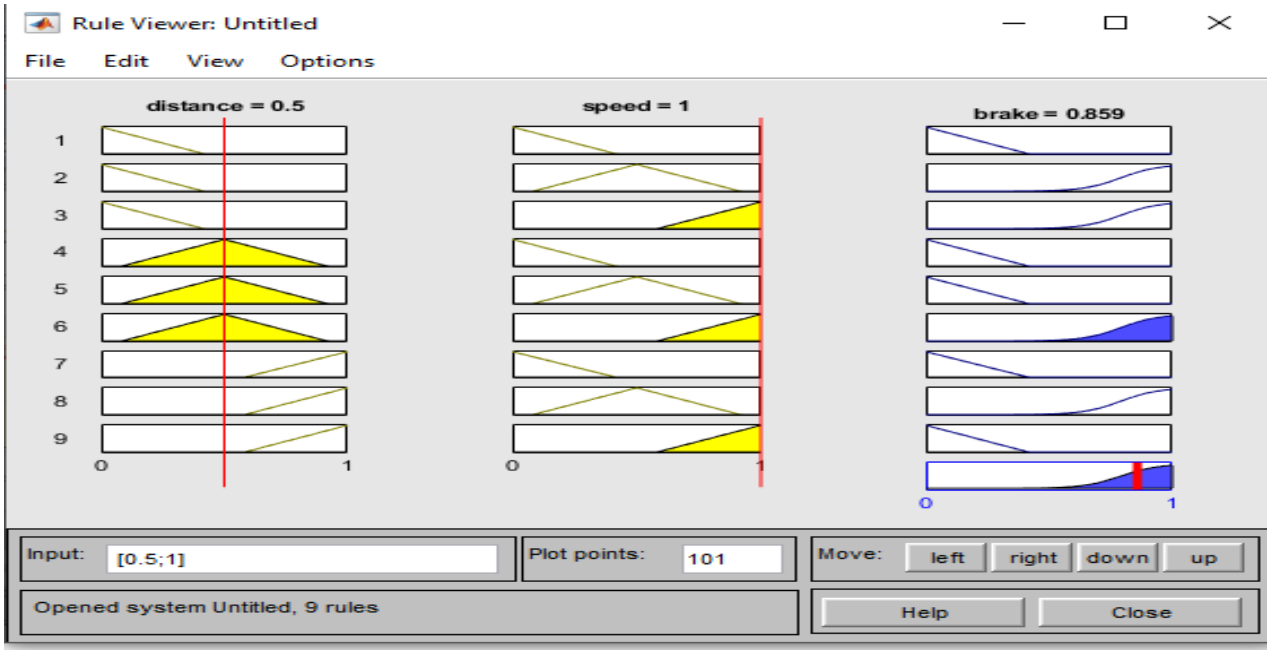

Figure 5: Rule viewer displaying results of the fuzzy logic

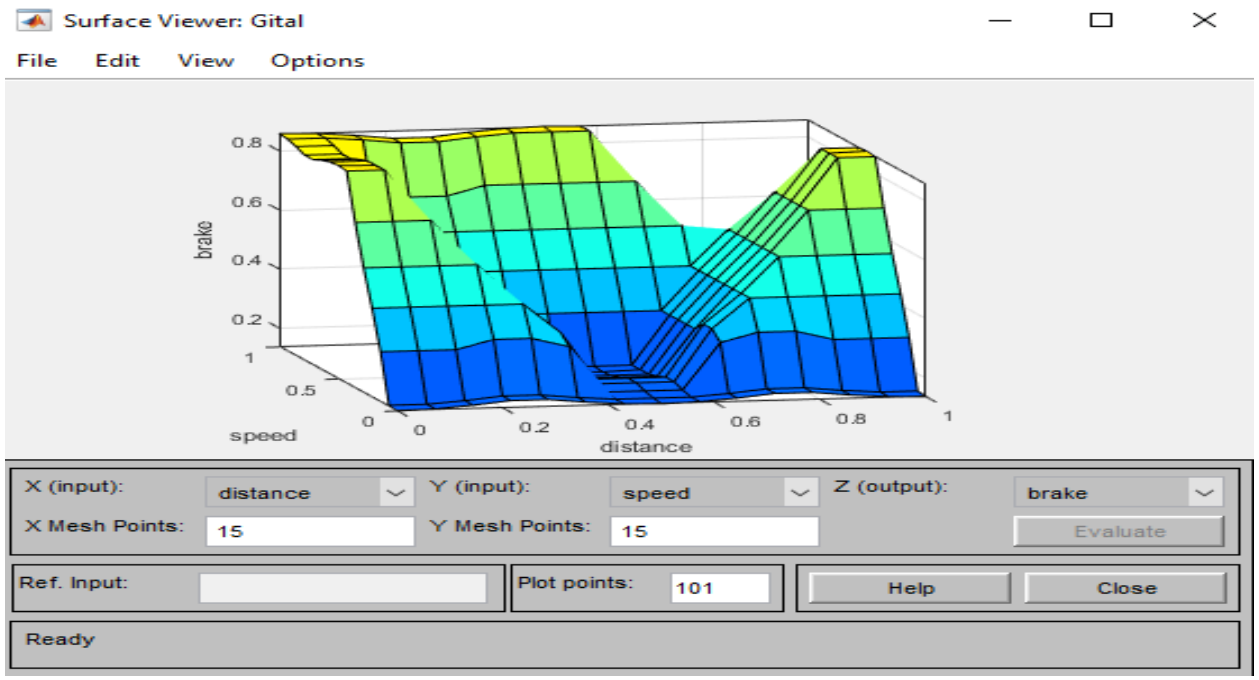

Figure 6: Surface viewer

5 CONCLUSION AND FUTURE WORK

In this paper, we provided a general survey on Speed Limiter System for reducing Vehicle Accident with Fuzzy Logic and AI Approaches towards this goal a lot of successes had been recorded with the use of varieties of AI techniques to detect over speeding vehicles and with Fuzzy Logic in achieving speed limiter systems which automatically stop vehicle's speed if it reaches certain limit. In the future, we hope to include more variable and add more rules and certain environmental factors in the fuzzy logic. Limitations stated in the reviewed literatures can be looked into by researchers working in the field to be overcome the challenges of the field.

ACKNOWLEDGMENTS

This study was supported by the Tertiary Education Trust Fund (TETFund) National Research Fund 2020 (NRF, 2020), through the directorate of Research and Innovation of Abubakar Tafawa Balewa University, Bauchi Nigeria

REFERENCES

1. Khan, S.U., et al., *IoT-Enabled Vehicle Speed Monitoring System.* Electronics, 2022. **11**(4): p. 614.
2. Bharadwaj, S.S.M. and S. Dattawadkar, *Design of autonomous cruise control unit for intelligent vehicles.* International Journal of Emerging Technology and Advanced Engineering, 2015. **5**(6).
3. Gidado, U.M., et al., *A survey on deep learning for steering angle prediction in autonomous vehicles.* IEEE Access, 2020. **8**: p. 163797-163817.
4. Voit, E., *Fuzzy logic in control systems: Fuzzy logic controller-part i.* IEEE Trans. Systems, Man. and Cybernetics, 1990. **20**(2): p. 404-418.
5. Mamdani, E. and S. Assilian, *An experiment in linguistic synthesis with a fuzzy logic controller*. International journal of human-computer studies, 1999. **51**(2): p. 135-147.
6. Sulaiman, N.A., M.F. Othman, and H. Abdullah. *Fuzzy logic control and fault detection in centralized chilled water system*. in *2015 IEEE Symposium Series on Computational Intelligence*. 2015. IEEE.
7. Lekhchine, S., T. Bahi, and Y. Soufi, *Indirect rotor field oriented control based on fuzzy logic controlled double star induction machine.* International Journal of Electrical Power & Energy Systems, 2014. **57**: p. 206-211.
8. Ross, T.J., *Fuzzy logic with engineering applications*. 2009: John Wiley & Sons.
9. Bose, B.K., *Expert system, fuzzy logic, and neural network applications in power electronics and motion control.* Proceedings of the IEEE, 1994. **82**(8): p. 1303-1323.
10. Mahmud, K. and L. Tao. *Vehicle speed control through fuzzy logic*. in *2013 IEEE Global High Tech Congress on Electronics*. 2013. IEEE.
11. Koo, E.-S., et al. *Torque control strategy for a parallel hybrid vehicle using fuzzy logic*. in *Conference Record of 1998 IEEE Industry Applications Conference. Thirty-Third IAS Annual Meeting (Cat. No. 98CH36242)*. 1998. IEEE.
12. Pusca, R., Y.A. Amirat, and A. Berthon. *Fuzzy logic speed estimator to drive a four electric wheels truck*. in *The 4th International Power Electronics and Motion Control Conference, 2004. IPEMC 2004.* 2004. IEEE.
13. Isong, B., O. Khutsoane, and N. Dladlu, *Real-time Monitoring and Detection of Drink-driving and Vehicle Over-speeding.* International Journal of Image, Graphics and Signal Processing (IJIGSP), 2017. **9**(11): p. 1-9.
14. Rad, A.G., A. Dehghani, and M.R. Karim, *Vehicle speed detection in video image sequences using CVS method.* International journal of physical sciences, 2010. **5**(17): p. 2555-2563.
15. Abbass, A., *Estimating vehicle speed using image processing.* AL-Mansour Journal, 2010. **14**(2).
16. Sina, I., et al. *Vehicle counting and speed measurement using headlight detection*. in *2013 international conference on advanced computer science and information systems (ICACSIS)*. 2013. IEEE.
17. Hu, D., L. Zhu, and L. Xu. *Maximum Torque per Volt operation and stability improvement of PMSM in deep flux-weakening Region*. in *2012 IEEE Energy Conversion Congress and Exposition (ECCE)*. 2012. IEEE.
18. Miguel-Espinar, C., et al., *Maximum torque per voltage flux-weakening strategy with speed limiter for PMSM drives.* IEEE Transactions on Industrial Electronics, 2020. **68**(10): p. 9254-9264.
19. Pothi, N. *Improvement of flux-weakening control of surface mounted permanent magnet synchronous machine considering inverter nonlinearity*. in *2017 International Electrical Engineering Congress (iEECON)*. 2017. IEEE.
20. Li, J., et al. *Deep flux weakening control with six-step overmodulation for a segmented interior permanent magnet synchronous motor*. in *2017 20th International Conference on Electrical Machines and Systems (ICEMS)*. 2017. IEEE.