Autonomous Two-Wheeler Vehicle Built on the Arduino

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Abstract

This research explores the development and effectiveness of a two-wheeled balanced autonomous vehicle. Autonomous vehicles are capable of perceiving their environment and functioning without human intervention, gaining increasing attention due to their advanced automation capabilities. A fully autonomous system demonstrates self-awareness and independent decision-making. These vehicles utilize an array of sensors, actuators, machine learning algorithms, and high-performance processors to execute complex software tasks. The proposed two-wheeled autonomous vehicle achieves self-balancing through mechanisms such as PID or IADRC control systems and enables wireless steering via IoT connectivity using Bluetooth technology. Communication is facilitated through Java-based applications on mobile devices or personal computers. Equipped with radar sensors, the vehicle monitors nearby objects, while video cameras identify traffic lights, road signs, and pedestrians. Lidar technology aids in measuring distances, detecting road edges, and recognizing lane markings, and ultrasonic sensors ensure precise parking by identifying curbs and nearby obstacles. The innovative IADRC control system offers enhanced robustness, superior disturbance rejection, and effective obstacle avoidance. Additionally, the vehicle operates on clean energy, minimizing carbon emissions and contributing to environmental sustainability. Its potential applications include last-mile delivery services and other small-area operations, reinforcing its value as an eco-friendly and versatile solution for modern transportation challenges.

Introduction

IOT is a network of internet-connected devices and sensors that collect and share data. These devices can be basic sensors or complicated machineries and used in many ways. IoT aims to develop a network of internet-enabled devices that can collect and share data. This information can improve performance, optimize methods, and generate new services. Manufacturing, transportation, healthcare, and agriculture use IoT. In industrial plants, IoT sensors can monitor device performance, find defects, and optimize operations. In healthcare, IoT devices may remotely identify patients, collect vital signs, and provide real-time feedback to providers. [2]. Autonomous or AV automobiles need lots of data collection and processing. Driverless cars record the pre-mapped street in this case. It includes the genuine track, guests, and how to avoid obstacles. IoT automobiles communicate this data wirelessly to a cloud device for analysis and automated improvements.

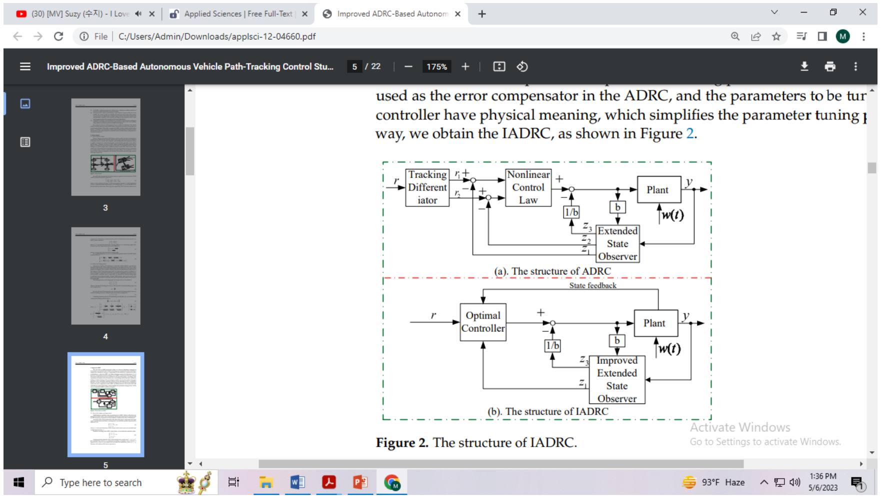
Autonomous vehicles eliminate human weaknesses including attention lapses and impaired judgement, making them a plausible answer. Self-driving automobiles can anticipate and respond to dangerous circumstances using advanced technology. They can slow down when traffic is heavy or stop at pedestrian crossings. The braking system of driverless vehicles uses ultrasonic range sensors for safety. The ultrasonic waves from these sensors bounce off obstructions, providing exact detection. The brake mechanism activates immediately when sensors detect danger, ensuring quick responses. Autonomous vehicles are becoming more popular because they reduce human error, the major cause of traffic accidents. With advanced sensors, cameras, and algorithms, these cars can sense and adjust to their surroundings with precision. Over and above safety, driverless vehicles improve traffic flow and efficiency. Self-driving automobiles can dynamically modify speeds and routes by communicating, reducing travel time and improving transportation networks.

The goal of this research is to lay the groundwork for a self-sufficient vehicle that can find its destination and get there autonomously, taking into account all relevant factors such as the most efficient and secure route. It's far expected that these automobiles will operate primarily based on smooth power, so carbon and greenhouse fuel emissions could be almost zero we can also call it sustainable cars.

Literature Review

There are two ways to steer the wheel. ADRC and PID are two types of control. PID is based on feedback, and comments are used to calculate output mistakes, which adjust the auto's action to fix the mistake. Even though the PID controller is well-designed, it has a low strength compared to the robust controller when the system confronts multiple obstacles like temperature, weather, energy surge etc in the perceived environment. The comment's direction is PID controller's worst shortcoming. The controller's robustness prevents it from performing well in the best control. Noise sensitivity is another downside of the controller's linear device and spinoff element. The PID is noise-sensitive, therefore any disturbance in the operational perceived environment can change the navigation output greatly. [3]. The feedback line has the PID controller. The controller is strong but inefficient for optimal control. Noise sensitivity is another shortcoming of linear systems and the resulting controller. ADRC means Active Disturbance Rejection Control. Engineering uses it to control systems and eliminate disruptions that could impair performance. The ADRC technique is based on the idea that a device can be modelled as a combination of its internal dynamics and external disturbances. In ADRC, an extended state observer (ESO) estimates and corrects for external disturbances on the system. The ESO is a mathematical procedure that estimates the gadget's inner kingdom and outside disturbances using input and output data. The projected values are used to create a compensating control signal to offset the disturbance and maintain the machine's preferred performance. Control structures including robotics, strength structures, and commercial approaches use ADRC. Its advantages are resilience, simplicity, and device uncertainty and nonlinearity handling. For the identical input and output signals in the physical process, the ADRC recovers more information, especially noise information, than PID [4]. The middle idea of ADRC is to treat machine disturbance as a prolonged country variable and design an extended state observer (ESO) to estimate the disturbance and compensate in the comments to mitigate its impact [5,6]. The partial characteristic f al in ADRC has a discontinuous by-product at factors via parts. Enjoy and evaluation can cause segment jitter in noise estimation, adding phase jitter to the manipulate entry variable. This article introduces a new non-stop nonlinear characteristic with a continuous derivative to tackle the problem. The LQR manage technique is utilised as an errors compensator in ADRC to optimise parameter setting. The LQR controller's parameters have physical meaning, simplifying system parameter setting. This yields the IADRC (figure 1).

The new and promising International Positioning system (GPS) calculates longitude, latitude, speed, and subject from real-time location data from numerous GPS satellites to aid car navigation. The GPS receiver measures the signal's transit time from the satellite to the receiver to compute distance. After measuring the distance to at least four satellites, the receiver can use trilateration to pinpoint the user's location. Every satellite transmits GPS indicators worldwide, including company network waves, digital codes, and navigation messages. Satellite distance from receivers based on community agency frequency and codes. The navigation message comprises satellite area and clock compensation. [7] Cell phone will receive the information from the car. The car waits till the user (cell phone) responds. Mobile users can set and change destinations. In direction, the system calculates distance and draws a hypothetical line between two places. After this, the tiny controller calculates and adjusts the car angle using the integrated area. It will progress towards



the destination after the destination links are calculated. A tiny controller controls motor alignment and speed. [8] Develop a "GPS-based Autonomous Vehicle Prototype" with an ATMega2560

Figure 1: The structure of IADRC

microcontroller to improve navigation and control autonomous AV behaviour. The GPS sends the needed data to a vehicle-plugged phone over Bluetooth in this trial. The controller continuously determines the vehicle's location and destination using the GPS sensor. This research navigation system collects and analyses data. The GPS will detect the automobile and send the location data to the phone when it turns on. [9]

The lidar sensor helps the AV understand its environment. Simply put, lidar counts events based on the brightness of the light sensed. Lidar imaging measures depth by calculating the delays between light pulses emitted by a source using time of flight (TOF). Lidar is a non-contact active rangefinder that illuminates a target and detects the reflected or backscattered signal. Data and processing to compute distance can build a 3D point cloud of a section of the unified environment. Therefore, the round-trip delay of the light wave going to the target is utilized to compute R, or target distance. Due to the short frequency modulation ambiguity distance, accuracy comparable to the pulse approach can be reached at modest distances. Because the emission is continuous, the signal reflected from distant objects is likewise weaker than pulses because the amplitude is constantly below the safe limit for the eyes. Additionally, digitizing back reflection intensity is challenging at long distances. In the third approach, frequency modulated continuous wave (FMCW) techniques directly modulate and demodulate signals in the frequency domain, allowing the superposition of produced and observed waves to be detected. FMCW provides two major advantages over other methods. Its primary advantage is to obtain velocity measurements at the same time to make the data gap by Doppler effect, but its distance measurement resolution is 150 m with an accuracy of 1 m over long distances [10].

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Figure 2. Pulsed time-of-flight (TOF) measurement principle

We can regulate an autonomous vehicle's braking system with ultrasonic sensors to avoid accidents. Ultrasonic sensors can help autonomous vehicles brake when they encounter obstacles. It goes like this: Ultrasonic sensors face outward on the car's front and back. Sensors emit high-frequency sound waves and listen for echoes from nearby objects. Sound waves' travel time and return time define a sensor's distance from an object. The car's autonomous driving system can brake to slow or stop if an obstruction is within a certain range. We try to prevent tragic accidents with supersonic. Our major goal is to compute car-obstacle distances. See figure 3. Used HC-SR04 modules have a 50-cm range. The sensor has an ultrasonic transmitter, receiver, and management circuit. It has four pins: 5v VCC, input trigger pulse, output feedback pulse, and ground. Ultrasonic sensor electrical parameters: It operates at 5 V DC and 40 kHz. It requests the 10us TTL pulse indication. Simply said, ultrasonic sensors use piezoelectricity. After a 10 us rapid pulse, the module sends an audio beam of eight ultrasonic cycles at 40 kHz. The receiver and microcontroller will analyse the reflected wave (echo) after an impediment is detected. The microcontroller will warn the driver if the distance exceeds the limit. The period is the next trigger pulse transmitted once the received echo is minimised. No less than 50 milliseconds for HC-SR04 cycle time. [11].

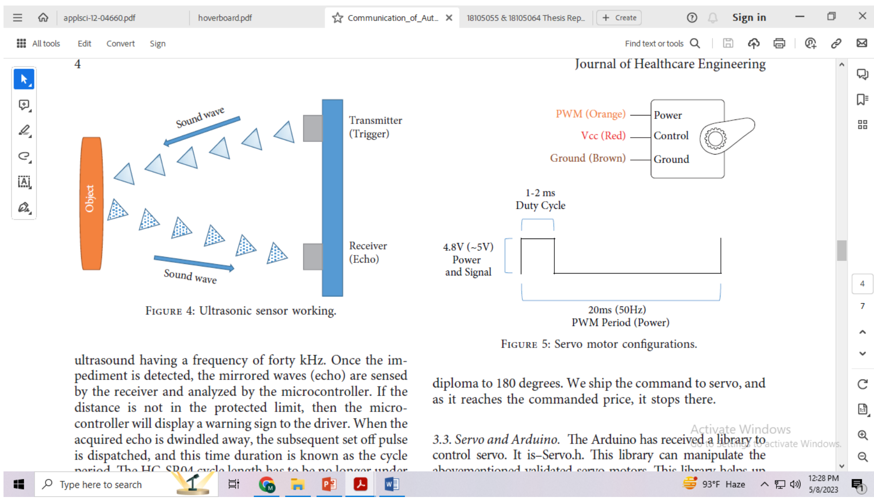


Figure3: Ultrasonic sensor working

Real-time road optimisation is crucial to preventing this car from crashing. The driverless vehicle uses GPS and navigation to find the best route to its destination. Autonomous vehicles interact with other vehicles and the traffic management infrastructure to pick vehicles based on real-time road conditions and traffic echoes. Select a path. Priority will be given to protecting passengers and pedestrians on the road. Unlike autonomous automobiles, self-driving cars will not subsidise traffic management but will improve safety and reduce accidents, saving lives.

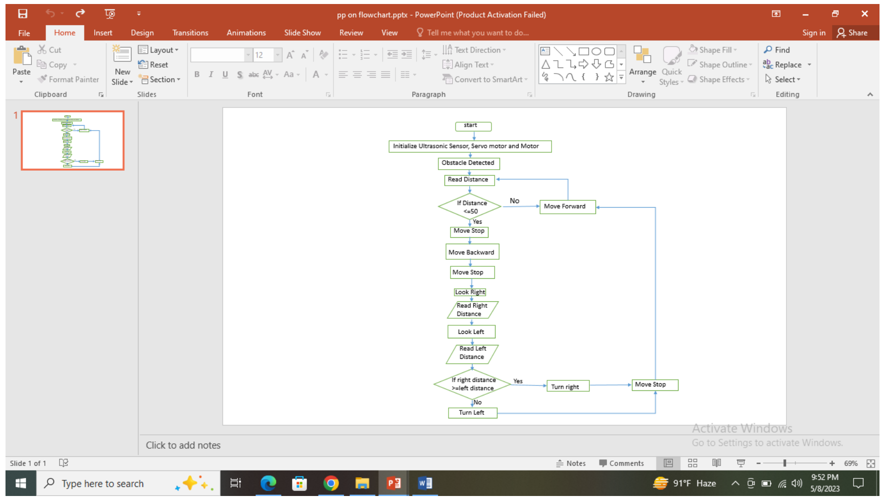
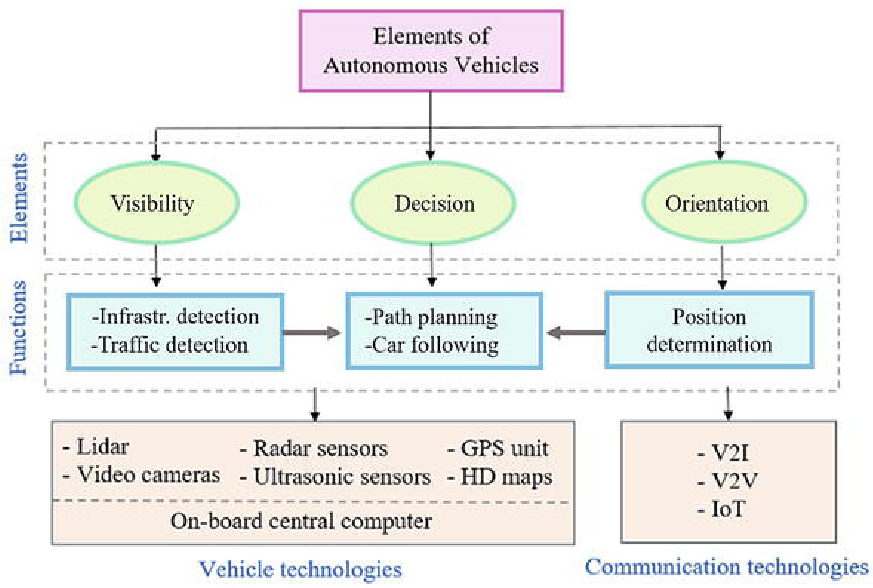
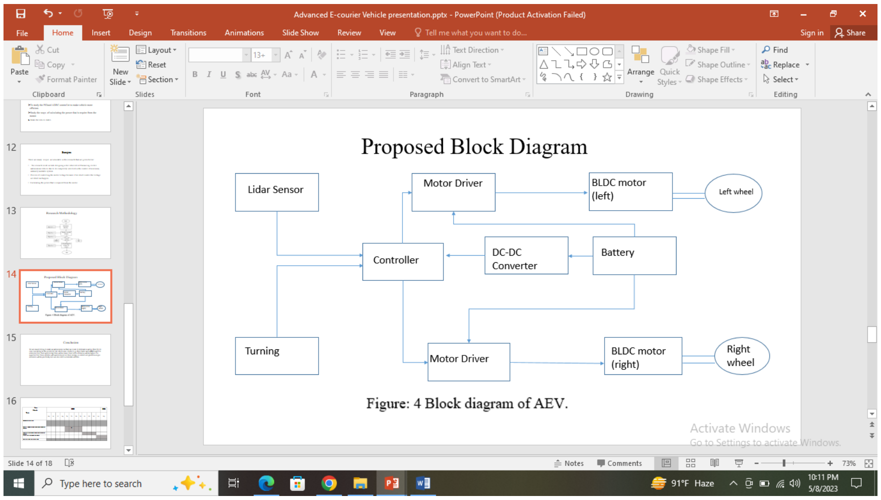


Figure4: Autonomous vehicle on case of accident avoidance

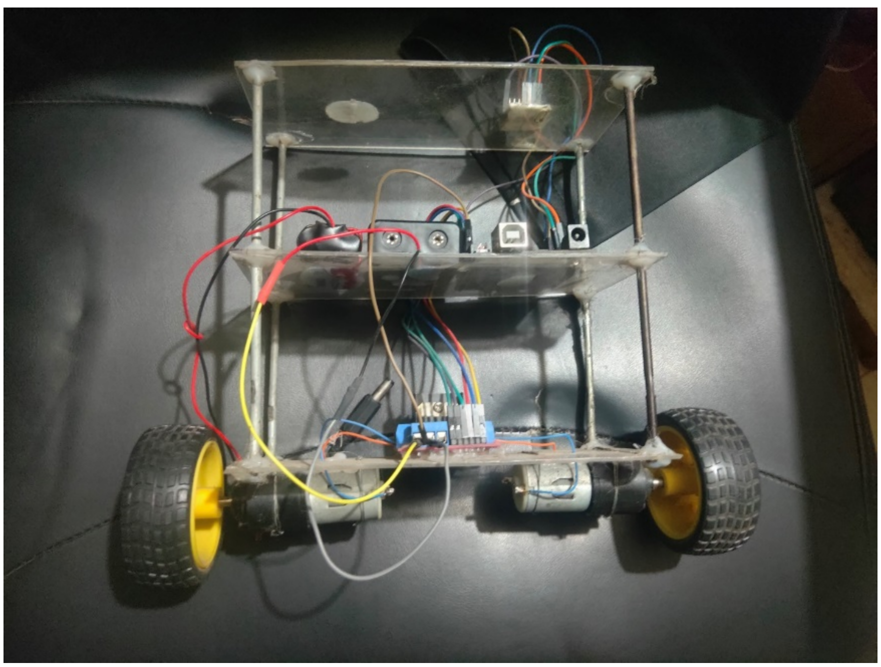
Research Methodology





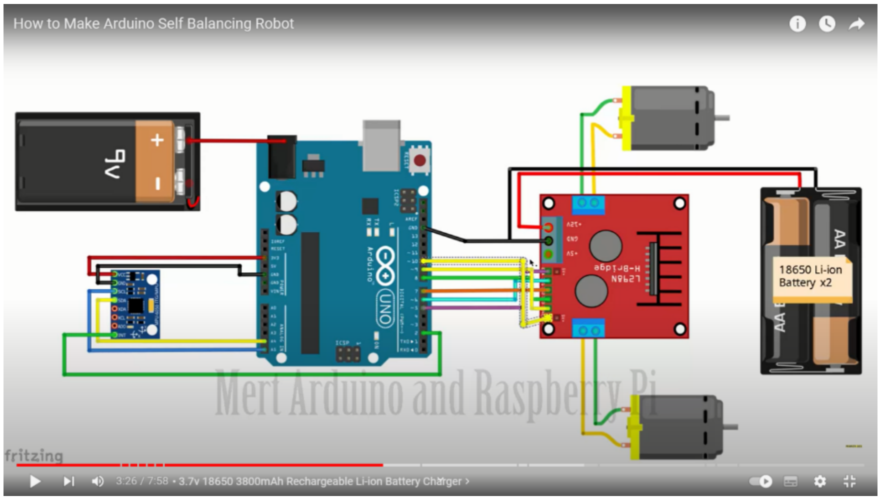
Circuit Diagram:

Figure 5: proposed circuit diagram



Implementation of the Model

Figure: 6 - Two-wheel blanching car model



Connection model of proposed car

Figure 7: Connection Model

Result and Discussion

Power required for the motor

A vehicle reference point and the moment produced by each component at that position were used to compute the centre of gravity. A 1kg component 10 cm from the reference point has a moment of 10kgcm. This is calculated for all components and divided by their total mass. Thus, centre of gravity is determined. The base, two BLDC motors, and all its components weigh about 40kg. Therefore, the motor power and torque rating calculation uses 100kg mass, assuming 60kg for the basic human. Based on chassis frontal area, drag coefficient, and tyre rolling resistance, the following were estimated. Steps to calculate motor power:

Force due to Aerodynamic drag,

= 0.5 Af*CD*v2 (1)**

= 0.5*1.202*0.09*1.3*8.332

= 4.879N

Where is the Air density, Af is the frontal area of the vehicle, CD is the aerodynamic drag coefficient and v is the velocity.

Force due to tire rolling resistance,

= μ*P (2)

= 0.013*9.8*100

= 12.74N

Ωηερε μ ις τηε φριςτιον ςοεφφιςιεντ τηατ δεπενδς ον τηε ροαδ ανδ P ις τηε ρεαςτιον φορςε αςτιον ον τηε ωηεελ (ηυβ μοτορ).

Total Force = 4.879 + 12.74

= 17.62N

Power required from motor = 17.62*8.33

= 146.77W

Torque output of motor:

The torque output of motor is,

= 17.62*0.0851 (3)

=1.5Nm

The motor requires 146.77W, according to the figures above. Vehicle grade is not considered in this computation. To allow vehicle grading, the motor rating is double the computed figure.

A vehicle with several sensors is autonomous. This research focused on sensors for an autonomous vehicle that can sense its environment and operate without human intervention. For steer the wheel, we have to analyse PID and ADRC to determine the best one for our AV. We found that IADRC is better for our AV. This paper proposes a disturbance-tolerant IADRC approach that works.The practical model we constructed there used Arduino Uno, motor driver, 18650 batteries, 9v battery, gear motor, and mpu6050. We stabilised the car by connecting all the equipment.

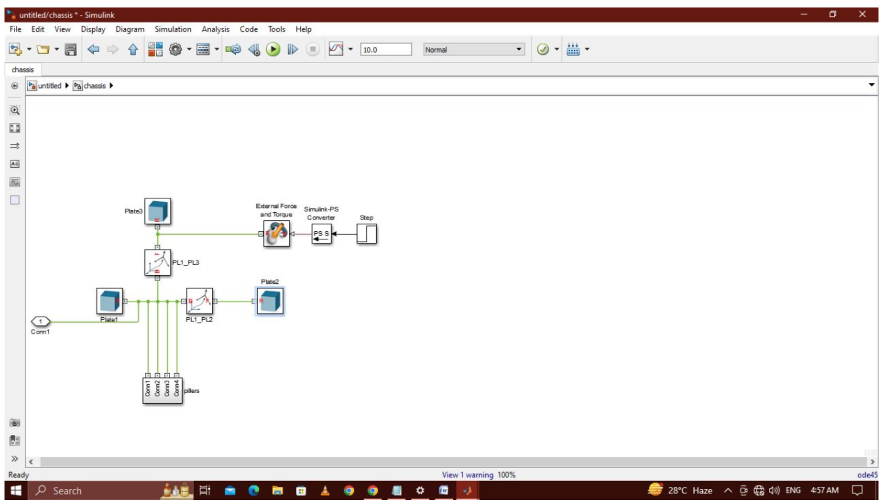


Figure 8: Simulink model of the stable two wheeled autonomous car

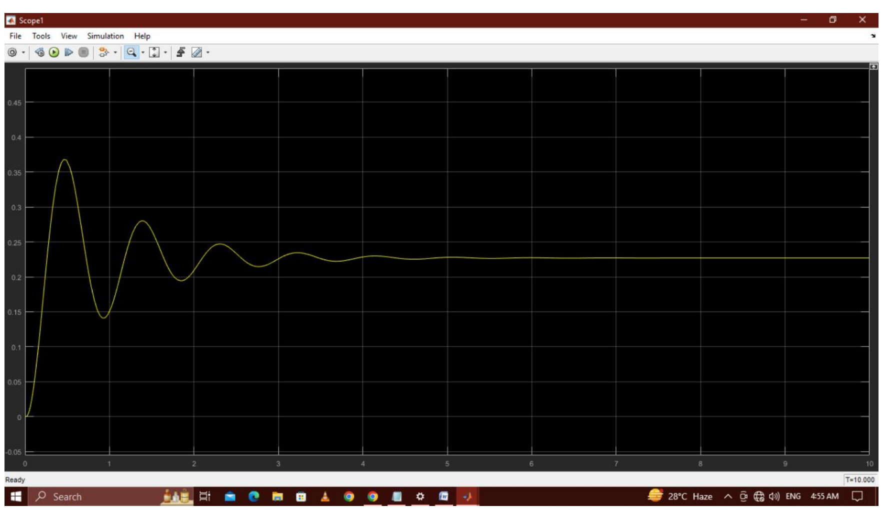


Figure 9: Simulink result of stable two wheeled autonomous car

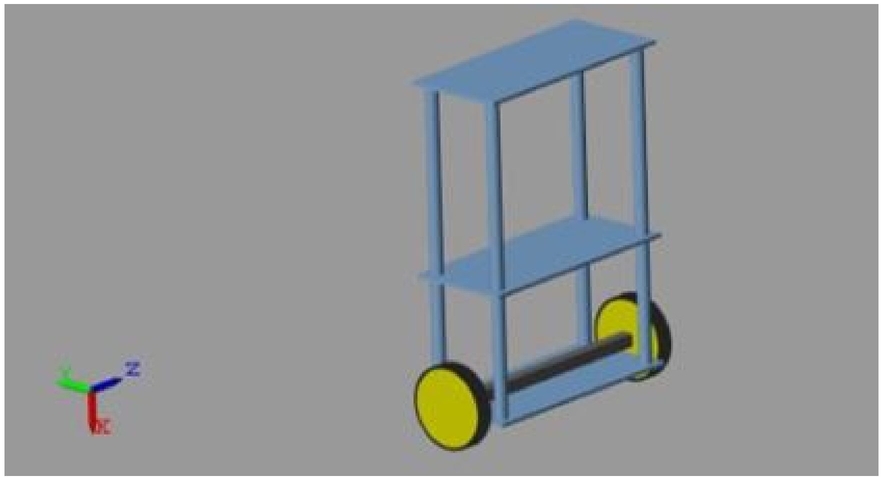


Figure 10: 3D model of the autonomous car in MATLAB

Conclusion

Autonomous system capabilities and self-balancing technologies have come a long way since the two-wheeled autonomous vehicle was developed. The vehicle's navigation, obstacle avoidance, and environmental awareness capabilities are enhanced by incorporating powerful control mechanisms such as IADRC, Internet of Things connectivity, and a suite of high-tech sensors. Its use of renewable energy sources makes it an innovative answer to the transportation problems of the contemporary day and promotes sustainable behaviours. This breakthrough, which could find use in last-mile delivery and small-area operations, is a great example of how technology advancement and environmentally sensitive design can work together to create better, more sustainable urban mobility solutions. the primary emphasis is on a fully autonomous vehicle that can find its route to its destination while taking into account all relevant factors, such as the most efficient and secure mode of transportation. Their predicted reduced speed in urban areas belies their improved traffic efficiency. We term these vehicles "sustainable" because they are designed to run on renewable energy, meaning they will produce almost no carbon or greenhouse gas emissions.

References

[**1**] T. Liu, N. Zheng, Li Zhao, and H. Cheng, "Learning based symmetric features selection forvehicle detection," in Proceedings of the Intelligent Vehicles Symposium, Dearborn,Michigan, USA, July 2005. May 28, 2022.

[**2**] O. Vermesan, P. Friess, P. Guillemin, S. Gusmeroli, H. Sundmaeker, A. Bassi, I. S. Jubert, M. Mazura, M. Harrison, M. Eisenhauer, and P. Doody, "Internet of Things strategic research roadmap," in *Internet of Things: Global Technological and Societal Trends* , vol. 1,O. Vermesan, P. Friess, P. Guillemin, S. Gusmeroli, H. Sundmaeker, and A. Bassi, Eds. Gistrup, Denmark: River Publishers, 2011, pp. 9_52.May 28,2022.

[**3**] Robust Navigational Control of a Two-Wheeled Self-Balancing Robot in a Sensed Environment CELESTINE IWENDI 1, (Senior Member, IEEE), MOHAMMED A. ALQARNI 2, JOSEPH HENRY ANAJEMBA 3, AHMED S. ALFAKEEH4, ZHIYONG ZHANG1, (Member, IEEE). 30 May,2022.

[**4**] Zhejiang Gao, "On Disturbance Rejection Paradigm in Control Engineering," in *Proceedings of the 29th Chinese Control Conference* , July 29-31, 2010, Beijing, China, pp. 6071-6076. 30 May,2022.

[**5**] Han, J.Q. Auto Disturbances Rejection Controller and its Applications. Control. Decis. 1998, 13, 19–23. (In Chinese). 15 July, 2022.

[**6**] Han, J. From PID to active Disturbance Rejection Control. IEEE Trans. Ind. Electron. 2009, 56, 900–906. 20 September,2022.

[**7**] F. Pin, and Y. Watanabe," Driving A Car Using Reflexive Fuzzy Behaviors", in IEEE International Conference on Fuzzy Systems, vol. 2, pp. 1425-1430, 2020.20 September,2022.

[**8**] Asher Rahman, Muhammad Farhan Aslam, Hassan Ejaz "GPS based Navigation and Collision Avoidance System using Ultrasonic Sensors and Image Processing for Autonomous Vehicle". 15 January,2023.

[**9**] Datasheets of Arduino mega 2560, GPS SIM28M Module, HC-05 Bluetooth module, HMC5883L, Motor Controller L293 and ultrasonic sensor.15 January,2023.

[**10**] Behroozpour, B.; Sandborn, P.A.; Wu, M.C.; Boser, B.E. Lidar system architectures and circuits. IEEE Commun. Mag.**2017** , 55, 135–142.10 January,2023.

[**11**] Communication of Autonomous Vehicles in Road Accidents for Emergency Help in Healthcare Industries by D. Prem Raja and V. Vasudevan Department of Information Technology, Kalasalingam Academy of Research and Education, Virudhunagar, India.30 May 2022.

[12] Mehra, A., Ma, W., Berg, F., Tabuada, P., Grizzle, J. W., & Ames, A. D. (2015). Adaptive cruise control: Experimental validation of advanced controllers on scale-model cars. 2022 American Control Conference (ACC), 1411–1418. https://doi.org/10.1109/acc.2015.7170931.

[13] Guo, G., & Yue, W. (2012). Autonomous platoon control allowing Range-Limited sensors. IEEE Transactions on Vehicular Technology, 61(7), 2901–2912. https://doi.org/10.1109/tvt.2012.2203362

[14] Oltean, S. (2019). Mobile Robot Platform with Arduino Uno and Raspberry Pi for Autonomous Navigation. Procedia Manufacturing, 32, 572–577. https://doi.org/10.1016/j.promfg.2019.02.254

[15] Rahiman, W., & Zainal, Z. (2013). An overview of development GPS navigation for autonomous car. 2022 IEEE 17th Conference on Industrial Electronics and Applications (ICIEA), 1112–1118. https://doi.org/10.1109/iciea.2013.6566533