



Self-Driving Autonomous Car Based on Raspberry Pi.

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Abstract: This paper focuses on developing an autonomous car designed to navigate safely and intelligently, minimizing human errors. Utilizing a Raspberry Pi-based system, the car can detect obstacles and traffic signals, making real-time decisions to stop or continue based on the processed data. A cloud platform supports the system by enabling real-time training and enhancing decision-making models. The car's processor is trained to differentiate between green and red traffic signals using a large dataset. Key algorithms in perception, control, localization, and recognition are integral to the system, ensuring accurate and reliable autonomous navigation. This paper showcases significant advancements in autonomous vehicle technology, aiming to improve road safety and efficiency.

Index Terms - Lane detection, Object detection, Traffic sign, Signal detection, CNN, Imageprocessing.

1. INTRODUCTION

The rapid economic growth of developing countries like India, there has been a significant increase in the total vehicle population, rising from 55 million in 2001 to 400 million in 2023 (Source: Community Website). This surge in the number of vehicles has led to escalating issues such as a rise in the number of accidents and increasing traffic congestion. Our project aims to address these pressing challenges by introducing autonomous (driverless or self-driving) cars that are capable of sensing their environment and navigating without human intervention. These autonomous vehicles can detect traffic lights, compare them with predefined data, process this information, and make decisions accordingly. For example, the driverless car stops when it detects a red traffic signal and resumes its journey once the light turns green, ensuring compliance with traffic regulations and enhancing overall safety on the roads. The inclusion of an ultrasonic sensor further enhances the efficiency and reliability of the vehicle by allowing it to detect approaching objects and stop accordingly. Unlike human drivers, who might take time to react when a person or animal unexpectedly crosses their path, the ultrasonic sensor can immediately send data to the processor, which promptly stops the car. This rapid response helps prevent potential accidents, thereby ensuring the safety of both the driver and pedestrians.

Additionally, our work includes a remote mode selection feature along with the autonomous mode. This feature allows users to monitor and control the car's movements using a remote desktop or mobile device. This provision enables the end-user to control the car's direction with commands such as forward, back, left, right, and stop, providing an added layer of control and flexibility. This is particularly useful in scenarios where manual intervention is required or where the user wants to take direct control of the vehicle's movements.

In this research work, the Raspberry Pi will handle high-level computational tasks such as perception, decision-making, and control. Meanwhile, the Arduino will manage real-time sensor integration, actuation, and communication. The Raspberry Pi is essential for processing complex data and making informed decisions, while the Arduino ensures that sensor data is promptly and accurately processed, facilitating immediate responses to environmental changes. This complementary relationship between the Raspberry Pi and Arduino ensures that the self-driving car can effectively perceive its environment, make intelligent decisions, and execute precise actions seamlessly.

To leverage advanced technologies to address the pressing issues of traffic congestion and accidents in rapidly growing economies. By integrating autonomous driving capabilities with robust hardware and software solutions, we can create a safer, more efficient transportation system. This innovation not only promises to improve traffic management but also sets the stage for future advancements in autonomous vehicle technology, contributing to safer roads and better urban mobility.

1.1 PROBLEM STATEMENT

Human beings are not well-suited for high-speed travel, as our time and distance perception degrade with speed. Fuel wastage caused by human error is quite high. Traffic congestion is often the result of human error. Eighty percent of car crashes are caused by driver error. Often, in case of accidents, a person or animal crosses the path unexpectedly, and humans may be unable to react immediately. People who are disabled, elderly, children, or those with difficulties driving depend on others for travel. Careless and

rash driving are main causes of traffic jams, leading to wasted time and fuel, and can be fatal in emergencies. Non-autonomous vehicles have been around for years, and online surveys indicate a high ratio of accidents due to human error.

1.2 OBJECTIVE

The main objective of is to reduce road accidents, traffic jams, and fuel consumption by providing a driverless car capable of autonomous driving, detecting traffic signals to start and stop accordingly, avoiding collisions using an ultrasonic sensor, and allowing the end user to monitor and control the vehicle's movements remotely.

2. LITERATURE SURVEY

M. Reek et al.,[1] present an architecture for a Self-Driving car utilizing ROS2, emphasizing its robust reliability and functional safety. Through rigorous experiments conducted with an actual passenger vehicle, they validate the viability of their approach for autonomous driving in real-time settings. This demonstration underscores the practicality and effectiveness of leveraging ROS2 in developing self-driving systems capable of navigating complex environments with confidence and precision. A. K. Jain [2] article explores the creation of a vision-based autonomous driving system employing a camera module, Raspberry Pi for image processing, and a Convolutional Neural Network (CNN) for direction prediction. It stresses the necessity of amalgamating diverse sensors and AI algorithms for precise perception and decision-making in fully autonomous vehicles. By harnessing the power of computer vision and machine learning techniques, the system enhances its capability to interpret and react to the surrounding environment accurately. This holistic approach underscores the significance of integrating advanced technologies to achieve the robustness and reliability required for safe and efficient autonomous driving in real-world scenarios. H. Thadeshwar, V et al.,[3] details a monocular vision-based Self-Driving car prototype employing a deep neural network on Raspberry Pi. Trained to predict steering angles directly from raw input images, the model demonstrates effective lane-keeping performance, achieving speeds of 5-6km/h across diverse driving conditions. Additionally, it explores the application of intelligent surveillance systems for detecting potential gun-based crimes and abandoned luggage. By leveraging advanced neural network technologies and edge computing platforms like Raspberry Pi, the research contributes to the development of safer autonomous driving systems while highlighting the versatility of such systems in addressing broader societal security concerns.

W. Farag and Z. Saleh [4] presents the RT_VDT (Real-Time Vehicle Detection and Tracking) technique, aimed at accurately and quickly identifying and tracking vehicles using RGB images. This pipeline of algorithms generates boundary boxes around vehicles, demonstrating reliable performance across various conditions. However, it encounters limitations in challenging scenarios. The authors discuss potential future enhancements, particularly the integration of deep learning methods, to improve the technique's robustness and accuracy. This advancement could address the current shortcomings and further optimize vehicle detection and tracking capabilities. M. S. U. Miah, et al., [5] investigates the feasibility of implementing Self-Driving cars in Bangladesh, tackling technological limitations, safety issues, and regulatory hurdles. It endeavors to pinpoint obstacles and offer remedies, advocating for infrastructure investment, the formulation of safety regulations, and the provision of training and education. By addressing these challenges head-on, the research aims to pave the way for the integration of autonomous vehicles into Bangladesh's transportation landscape, fostering safer and more efficient mobility solutions while ensuring readiness for the future of transportation technology. T. -D. Do et al., [6] details a prototype Self-Driving car using monocular vision-based Deep Neural Networks (DNN) on a Raspberry Pi. Leveraging CNNs' superior performance in perception and control, the model maps raw input images to steering angles. Data was collected from a 1/10 scale RC car equipped with a Raspberry Pi 3 Model B and a front-facing camera, training on images paired with steering angles from manual driving. Tested on outdoor tracks, the car effectively maintained lanes and recognized traffic signs, achieving speeds of 5-6 km/h under various conditions, demonstrating the model's robustness and efficacy in autonomous driving tasks.

V. Shahane et al., [7] focuses on developing a Self-Driving car platform integrating Raspberry Pi, Arduino Uno, and a camera-based system. It aims to create a functional model by incorporating lane detection, obstacle detection, and traffic sign detection modules. Live stream images captured by a roof-mounted camera are processed by the Raspberry Pi, which distributes them to the respective modules. Lane detection utilizes Canny Edge Detection and the Hough Transform, while the Traffic Sign Detection Module employs Convolutional Neural Networks (CNN) and OpenCV-based techniques. This approach facilitates real-time analysis and decision-making, laying the foundation for autonomous navigation in various driving scenarios. J. Newman, Z. Sun and D. -J. Lee [8] The platform introduced is tailored for students and researchers to delve into Self-Driving car technology and its associated challenges. Designed to be affordable and compact, it fosters learning and experimentation. Essential technologies like computer vision and object detection are incorporated, offering a comprehensive understanding of autonomous driving principles. The abstract outlines the platform's operational overview, its comparison with industry-standard Self-Driving cars, and outlines future research pathways. This initiative serves as a foundational tool for aspiring engineers and scholars, empowering them to explore and contribute to the advancement of Self-Driving car technology.

R. Kulkarni, S et al., [9] propose a deep neural network-based model leveraging transfer learning to enhance the recognition of traffic lights, crucial for the success of self-driving cars. Their approach utilizes the Faster R-CNN Inception V2 model in TensorFlow, capitalizing on GPU and cloud platform advancements. Trained on a dataset reflecting the Indian Traffic Signal system, the model addresses challenges like accurate recognition of traffic lights, signs, and pedestrians. With its potential to provide sustainable, safe, and congestion-free urban mobility, this model represents a significant step forward in autonomous vehicle technology.

3.BLOCK DIAGRAM

The autonomous vehicle system designed around a Raspberry Pi as shown in the Fig3.1, demonstrates a sophisticated approach to integrating various technologies for autonomous driving. The Raspberry Pi serves as the master device, orchestrating image processing and neural network operations, and is considered the heart of the system. It leverages the YOLO (You Only Look Once) method from the Convolutional Neural Network (CNN) algorithm for image processing and object detection tasks.

The core of the vehicle's perception system is its ability to process real-time video feeds captured by the Raspbian camera. This camera is pivotal for detecting pedestrians, other vehicles, traffic lights, and road signs.

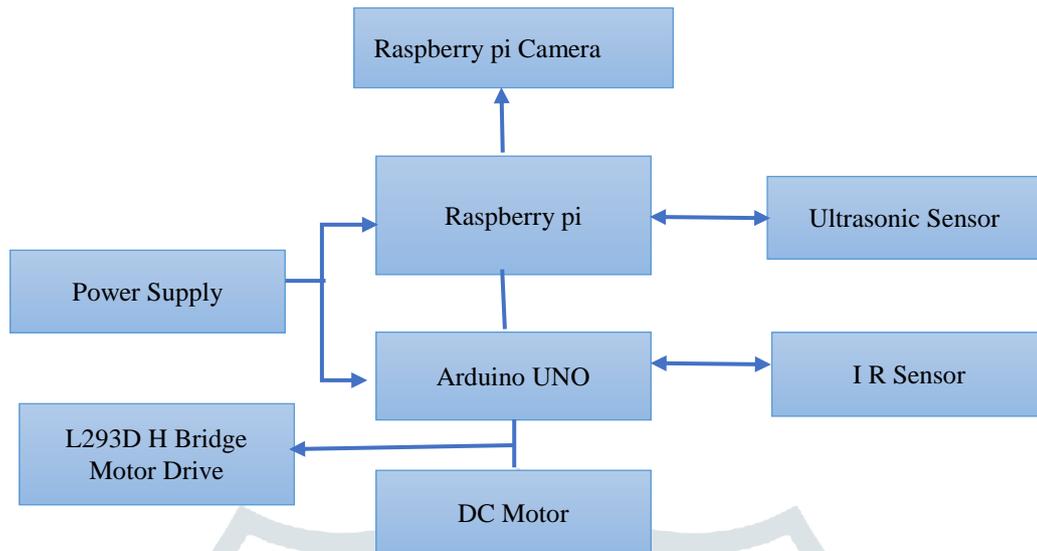


Fig.3.1:Block Diagram

The CNN algorithm processes these images to identify and classify objects within the environment swiftly and accurately. YOLO's real-time processing capabilities are crucial for maintaining the vehicle's awareness of its surroundings and ensuring timely responses to dynamic traffic situations. A significant feature of this system is its capability to recognize traffic signals and communicate the necessary actions to the vehicle.

Traffic lights are detected and interpreted, and appropriate stop signals are transmitted via the UART (Universal Asynchronous Receiver/Transmitter) protocol. This communication ensures that the vehicle complies with traffic regulations, enhancing safety. The system's connection to Wi-Fi via the IP protocol facilitates continuous data exchange, which is essential for real-time updates and remote monitoring.

The Arduino Uno microcontroller acts as a slave device within the system, primarily responsible for controlling the DC motors. It executes movement commands received from the Raspberry Pi, translating the high-level decisions made by the image processing and neural network modules into physical actions. This separation of responsibilities ensures efficient task management and reliable control over the vehicle's movements.

To further enhance safety, the vehicle is equipped with ultrasonic sensors. These sensors are used to detect obstacles and monitor the surrounding environment to avoid collisions with other cars or objects. The sensors provide real-time distance measurements, enabling the system to make immediate adjustments to the vehicle's path to prevent accidents. The vehicle's movement is driven by DC motors, which are capable of navigating various roadways. The system uses an L298D H-bridge driver motor to control two DC motors simultaneously, providing sufficient voltage and current to drive the motors effectively. This setup allows the vehicle to move in all four directions, ensuring versatile maneuverability.

A GPS module is integrated into the system to track the vehicle's location. This module continuously sends the vehicle's coordinates, making it easy to locate the vehicle if it goes out of bounds. The GPS functionality is critical for navigation and for providing a safety net in case the vehicle strays from its intended path. The integration of these components results in a cohesive and functional autonomous vehicle system.

The Raspberry Pi's computational capabilities ensure that the image processing and neural network operations are handled efficiently. The Arduino Uno's role in motor control allows for precise and responsive movements based on the high-level commands from the Raspberry Pi. The ultrasonic sensors add an additional layer of safety, actively preventing collisions, while the GPS module ensures that the vehicle's position is always known. This multi-faceted approach to autonomous driving not only enhances the vehicle's functionality but also improves safety and reliability.

Looking ahead, future enhancements could involve upgrading the Raspberry Pi to a more powerful model or integrating additional sensors to improve environmental perception. Incorporating more advanced neural network models could enhance the system's ability to understand complex traffic scenarios and make more nuanced decisions. Additionally, developing more robust communication protocols could improve the system's responsiveness and reliability, making it even more suitable for real-world applications.

In conclusion, this autonomous vehicle system represents a significant step towards practical, low-cost autonomous driving solutions. By leveraging the capabilities of the Raspberry Pi, Arduino Uno, and various sensors, the system achieves a high level of functionality and safety, paving the way for further advancements in autonomous vehicle technology.

4. HARDWARE COMPONENTS

- Raspberry pi 4 with Camera: The central control unit responsible for processing sensor data, running machine learning algorithms, and making real-time decisions
- Arduino Uno: The companion microcontroller board for executing control tasks, interfacing with components, and enabling communication with Raspberry Pi.
- Ultra Sonic sensor: Used for front collision detection

- IR sensor: Module has built-in an IR transmitter and IR receiver that sends out infrared light and looks for reflected infrared light to detect the presence of any obstacle in front of the sensor module. It is used to find obstacles and short & medium-range communication.
- DC Motor: Drives the car's movement
- Battery: A battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, smart phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode.

5. SOFTWARE COMPONENTS

- Raspbian OS: Raspbian OS is highly optimized for the Raspberry Pi with ARM CPUs. It runs on every Raspberry Pi except the Pico microcontroller, which looks similar to many common desktops, such as mac OS and Microsoft Windows.
- Arduino IDE: The Arduino ide is used to write the computer code and upload this to the Physical board.

6. PROPOSED FLOW CHART

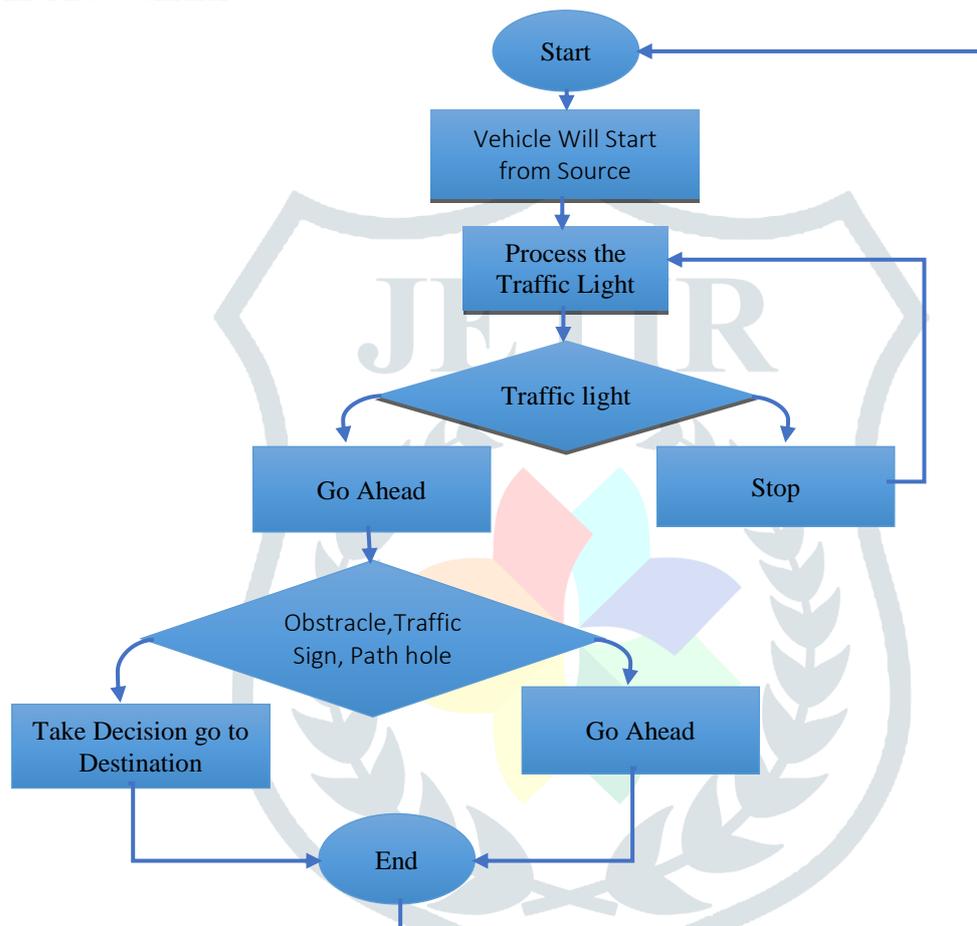


Fig.6.1: Proposed Flow chart of Autonomous Car Prototype

Description of Proposed Algorithm Fig 6.1: Car will start from source. For detection of traffic light, the camera will capture signal's image and process it. If the traffic signal is red, it will stop for some time and wait for signal to become green if, green it will be in motion. If green it will continue its path. If there is an obstacle it will detect obstacle or path hole or Traffic Sign and it will stop and change its path. If not, then it will continue its normal path and reach the destination.

The work done for this project includes the total hardware assembly, testing for the proper working of interfaces between the camera, ultrasonic sensor and the raspberry pi, installation of open CV which is required for image detection, processing and recognition Implementation of the remote mode. On the base- a power supply, a raspberry pi board, motor driver circuit, a camera for capturing images and a ultrasonic sensor for measurement of distance between the model and any obstacle, are the various components that have been mounted. Infrared sensors used for the lane detection of the road. For the remote mode different programming languages like Phyton and C were used to create different direction buttons like right, left, forward, backward and stop which will be visible to user on the domain purchased and he/she will be able to monitor on desktop/mobile as well as control the car movements using the buttons .These commands will be given to processor which is programmed using python to take the different actions to make the motors rotate and thus make the vehicle move in the user defined direction.

7. RESULT ANALYSIS

The autonomous car prototype shown in Fig 7.1 utilizing a Raspberry Pi demonstrated impressive performance in real-world scenarios, underlining the potential of low-cost, efficient solutions for autonomous driving. The system was developed with a 1/10 scale RC car, equipped with a Raspberry Pi 3 Model B and a front-facing camera, to capture road images. These images were paired with time-synchronized steering angles generated through manual driving, creating a dataset for training a

Convolutional Neural Network (CNN). The CNN was designed to directly map raw input images to predicted steering angles, capitalizing on the ability of deep learning models to learn complex patterns from large amounts of labeled data. During training, the model parameters were optimized to minimize the prediction error, ensuring accurate steering control based on visual inputs. Experimental testing was conducted on outdoor tracks, specifically designed in oval and figure-eight shapes, to evaluate the car's ability to navigate under various conditions show in the Fig 7.2. The results were notable: the car-maintained lane discipline and effectively recognized and responded to lined traffic signs and signal as shown in the Fig 7.5 and Fig 7.6, even in the absence of clear lane markings. This demonstrated the model's robustness and adaptability to different driving environments. The car achieved a top speed of approximately 5-6 km/h, which, while modest, was sufficient for the scale and scope of the prototype testing. This speed allowed for a controlled assessment of the car's ability to perform autonomous driving tasks, including lane-keeping and obstacle detection as shown in Fig 7.4. Overall, the successful deployment of the model on the Raspberry Pi underscores the feasibility of using low-cost hardware for developing autonomous vehicles. The study highlighted the efficiency of CNNs in processing visual data for real-time control tasks, setting a foundation for further enhancements. Future work could focus on scaling the model for full-sized vehicles and optimizing it for higher speeds and more complex driving scenarios, potentially incorporating additional sensors for improved perception and decision-making.



Fig.7.1 Raspberry Pi Autonomous Car Model



Fig.7.2: Value between <-50 and >60 indicates a straight path

Fig.7.3: Value <-50 indicates left lane

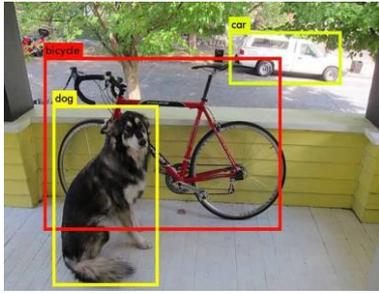


Fig:7.4 Object detection

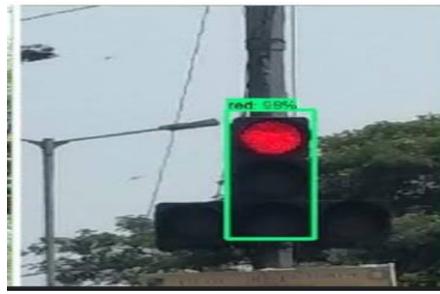


Fig:7.5 Traffic signal detection



Fig:7.6 Traffic sign detection

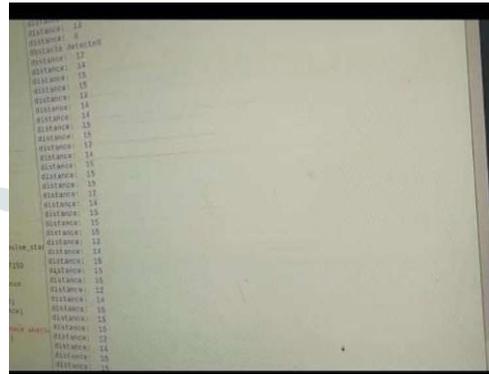


Fig.7.7:Distance of obstacle detected by ultrasonic sensor

8. CONCLUSION

The proposed model leverages convenient and affordable technology, including Raspberry Pi, ultrasonic sensors, and cameras, to provide a safe, driverless journey. It offers mode selection provisions, enhancing its safety and efficiency to address the growing traffic problems on today's streets. This system's potential for improvement through new technologies makes it suitable for both private and public sectors. Human drivers often cause stop-and-go traffic through lane changes, merges, and natural driving oscillations. Autonomous cars can mitigate these issues by controlling traffic flow and dissipating stop-and-go waves, thus preventing the oscillations typical of human-driven cars. This results in significant reductions in traffic jams and fuel consumption. Even a small percentage of autonomous vehicles on the road can drastically reduce traffic waves, decrease total fuel consumption by up to 40%, and cut braking events by up to 99%. This highlights the substantial benefits of integrating autonomous cars into the traffic system, improving overall efficiency and sustainability.

9. FUTURE SCOPE

The future scope of autonomous cars using Raspberry Pi is promising, driven by advancements in artificial intelligence, sensor technology, and edge computing. As Raspberry Pi becomes increasingly powerful and affordable, it serves as an ideal platform for prototyping and developing autonomous vehicle technologies. With the integration of machine learning algorithms, real-time data processing, and sensor fusion, Raspberry Pi-based autonomous cars can improve in navigation, object detection, and decision-making capabilities. Moreover, the open-source nature of Raspberry Pi fosters a collaborative environment for innovation, enabling researchers and hobbyists to experiment with and refine autonomous driving systems. This accessibility accelerates the development of low-cost, efficient autonomous vehicles, potentially revolutionizing transportation in urban and rural settings by making self-driving technology more accessible to a broader audience. As these systems mature, they could significantly enhance road safety, reduce traffic congestion, and provide mobility solutions for those unable to drive, thus contributing to a smarter, more efficient transportation ecosystem.

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