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Self-Driving Car for a Smart and Safer Environment – A Review

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Abstract

The frequent human errors while driving causes awful events ending up in significant amount of road accidents. Today's traffic forums insist drivers to pay careful attention to the traffic signals that are simultaneously notified through the different sources. The two of the major effects of reckless driving are increased traffic and fatalities. More accidents occur as a result of common errors made by people, such as talking on the phone or playing loud music while driving. Automated traffic detection and real-time monitoring may significantly enhance and assist the driving safety. The usage of automated traffic detection and real-time monitoring is more important nowadays, as technology is seeking for automation in every area. The potential of autonomous vehicles to travel on highways and roads offers people with a wide range of opportunities, from improving traffic safety to fundamentally altering the way a person gets about. Additionally, the recent increases in accidents, which have been connected to both an increase in the number of automobiles on the road and negligent driving on the part of drivers, it appears that owning a car is now necessary. Self-driving cars have the ability to sense their surroundings as it is enabled with the LiDAR, Radar, GPS, and cameras. Autonomous cars' main benefit is their decreased risk of accidents. If these vehicles are widely available and well-engineered, their reduced fuel use could help in reducing the pollution. The pre-installed features including lane identification, obstacle recognition, and traffic sign detection, enables the car to go independently from one place to another. This review article may be used as a quick guide for professionals experimenting with self-driving cars with various technologies.

Keywords: Communication, Microcontrollers, Self-Driving, Sensors, Data Acquisition, Internet of Things, Machine Learning.

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1. Introduction

The goal of the research is to create a self-driving platform utilizing a camera-based method, an Arduino Uno, and a Raspberry Pi. Three key components make up the recommended model: lane detection, obstacle detection, and traffic sign detection. A wide range of opportunities, from improving road safety to revolutionizing transportation, are made possible by the capability of cars being able to navigate roads and highways on their own. In this research, the computing power of the Raspberry Pi will be used to handle high-level tasks like perception, decision-making, and control, while the real-time processing power of the Arduino will be used to handle low-level sensor integration, actuation, and communication [1].

The purpose of this study is to develop an effective LiDAR detecting system for self-driving automobiles that can register its surroundings, navigate via a route, and arrive at its destination without human intervention. The robot establishes multiple loop closures along its route whenever it uses scan matching to identify a previously visited spot. SLAM(Simultaneous Localization and Mapping) is the process through which self-driving vehicles scan their environment. Science fiction has evolved into reality in the case of self-driving cars [2].

With the use of deep learning and CNN running on a Raspberry Pi, the research hopes to develop an autonomous car that can recognize 43 different kinds of traffic signs and lanes. In order to further integrate and separate inputs generated from the model are created; live video inputs are split into individual frames utilizing the convolutional neural network. As a result, aiding the driver with audio output based on live traffic lights may help to prevent potentially dangerous outcomes, such as bodily hurt and harm to others. By delivering live front-view streaming through a camera placed on the car and accurately detecting road signs and compliance, this function will assist the car in driving to the designated destination simply and more effectively, preventing accidents brought on by traffic infractions [3].

Self-driving car technology [14,15] has advanced significantly in recent years, and this trend is drawing in a broad spectrum of customers thanks to the advantages it offers. A few of the difficulties in designing such vehicles are localization, lane detection, and obstacle detection. Along with technological difficulties, users are worried about their privacy, cyber-attacks, and a decline in the number of driving positions. A hardware architecture that may be modified in accordance with requirements is also detailed [4].

The next 10 years might see a technological revolution brought on by self-driving automobiles, which are autonomous vehicles that can operate without any human intervention. Using simple and readily accessible technology, this research describes the creation of a low-cost prototype for a small self-driving automobile model. According to a survey from the International Road Federation (IRF), 10% of all traffic accidents worldwide occur in India, which also has the largest number of traffic fatalities and ranks #1 globally. According to research, drivers' mistakes or human error while operating a vehicle account for 78% of all accidents. The essential control for the automobile is provided by combining a number of current algorithms, including lane detection, obstacle detection, and traffic light identification. This would enable safer, simpler, more modern, and more comfortable mobility, which would represent a significant advance in the fields of automation and mobility [5-6].

Scientists are developing fresh concepts for self-driving automobiles as a result of the fast advancement in technology. These vehicles are self-driving and can travel without assistance from a person. The research's goal is to demonstrate a monocular vision self-driving automobile model prototype utilizing the most recent OpenCV2 and machine learning technologies. Autonomous vehicles that need little or no human interaction would reduce the likelihood of accidents and provide safer, more pleasant transportation. It receives input from a constant stream of images through the Raspberry Pi Cam2. This input is sent through local host to the processing algorithm. The output that is given to the Arduino UNO, which in turn controls the motor drivers, is evaluated using computer vision and machine learning. Convolutional neural networks (CNNs), a particular deep learning technique that is important for categorizing and identifying objects, such as roadblocks, have been explored in this study report. In order to estimate the performance of the automobile, A basic self-driving car powered by a Raspberry Pi was build and tested in an area with the least amount of traffic complexity. [7-8].

Because computers operate more quickly and intelligently than human brains do, self-driving cars are entirely scientific and behave just as clever computers do. The computers are also free from distractions and emotions. The system is made up of many sensors, cameras coupled to the Raspberry Pi, which serves as the primary processing unit for the algorithms, and other components. The Arduino, which controls the vehicle motors and their movements, is another crucial part of the system. In order to put this into action, the following hardware components are used: a Raspberry Pi 3 model B+, a Pi camera version 2.1, an Arduino UNO, a Bluetooth receiver, a Sonar sensor, two wheels, two motors, and one motor driver. Softwarerelated work is done using Open-CV, Python, and Arduino. In order to operate, the automobile has been using an image processing technology called RGB to HSV conversion [9-11].

Artificial intelligence (AI) is developing quickly in the modern day. Self-driving has got a lot of interest by using AI technologies. One of the most practical uses for a self-driving automobile is vehicle LiDAR, which implies mobile LiDAR and is carried by the vehicle on top of the vehicle. In a short amount of time, it can swiftly scan 360 degrees horizontally and 40 degrees vertically. use the KITTI and PASCAL VOC datasets, which are two different forms of publically accessible data. YOLOv4 neural network's object identification algorithm was trained using the PASCAL VOC dataset [12].

The main objective of this review article is to;

- Examine the many technological advancements recently employed in the field of self-driving automobiles and the real-time utilization of different hardware components.
- Compare and assess the effectiveness, mistakes, and usefulness of finished goods. To provide a remark on the best technique used.

2. Methodology

This section has been divided into three parts to clarify and evaluate the various operational concepts. One may rapidly understand the importance and choose the best method to carry out their assignment by segmenting according to many categories.

a. Self-Driving Car based on Image Processing and Machine Learning

Engineers and academics from all over the globe have been enthralled by the idea of self-driving automobiles in recent years. This module gives the self-driving automobile the ability to remain inside the lane lines. The platform can recognize lane markers, ascertain the location of the vehicle with respect to them, and make appropriate corrections to preserve proper lane alignment. It does this by using computer vision algorithms and image processing methods. This module equips the self-driving automobile with the ability to see and comprehend traffic signs on the road by using machine learning and image recognition techniques. To help with obstacle identification, OpenCV offers a broad variety of image processing and computer vision tools. To do tasks like edge detection, colour filtering, and object identification, the following procedures are utilized. Background subtraction, contour detection, and template matching are examples of approaches that may be used to identify obstacles [1]. The pre-processing prepares the dataset and the complete dataset is imported. Prior to being equalized the lighting in a picture may be standardized using segmentation, the input image is first delivered to the Open CV library function to convert the coloured image to grey scale. The subsequent feature extraction from the video frame allows for the detection of shape. The zoom, shear, and rotation parameters of the images are then modified further. The constructed model has additional filters like pooling, dense, and dropout included [3]. Through the CSI connector, this Raspberry Pi Camera is attached to the Raspberry Pi module. The processing algorithm receives this information through the local host. The output that is provided to the Arduino UNO is evaluated in this case using computer vision and machine learning. Figure 1 shows the block diagram of this work. [7]. The goal is to determine the route using edge detection or colour detection and then get the curve using a histogram, which is the total of pixels in the y direction. A support vector machine (SVM) technique with a Radial Basis Function (RBF) kernel approach is used to retrieve the data and classify it after pre-processing [9]. The suggested model has employed methods for HSV colour conversion to recognize white lanes. It has been discovered via several tests that switching from the BGR colour model to the HSV colour model is effective for lane detection. Figure 2 depicts the algorithm used for implementing Lane detection from captured images (videos) [11]. The suggested concept uses a Pi cam that is mounted to a Raspberry Pi and captures pictures of the road. The Raspberry Pi transmits the picture that was collected and is used as the input image by the Convolutional Neural Network when the Raspberry Pi and the laptop are both connected to the same network. Prior to being sent to the neural network, the picture is gray scaled. After making a forecast, the model outputs one of four options: left, right, forward, or stop [12].

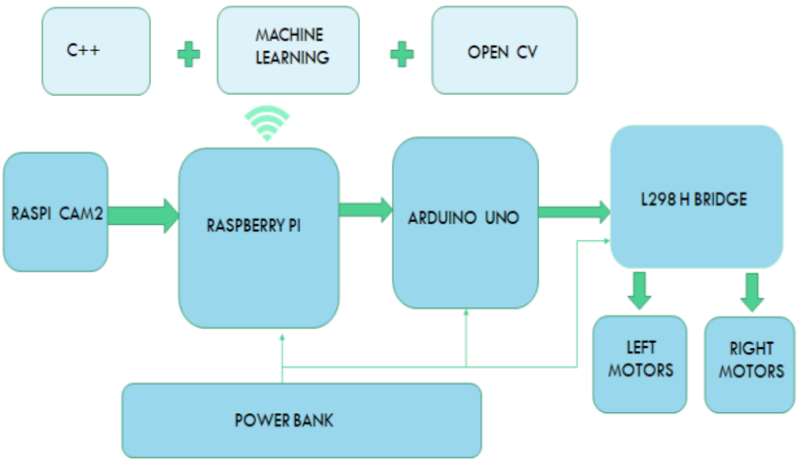

Figure 1. Flowchart for Data Acquisition and Image Processing on Raspberry Pi [7].

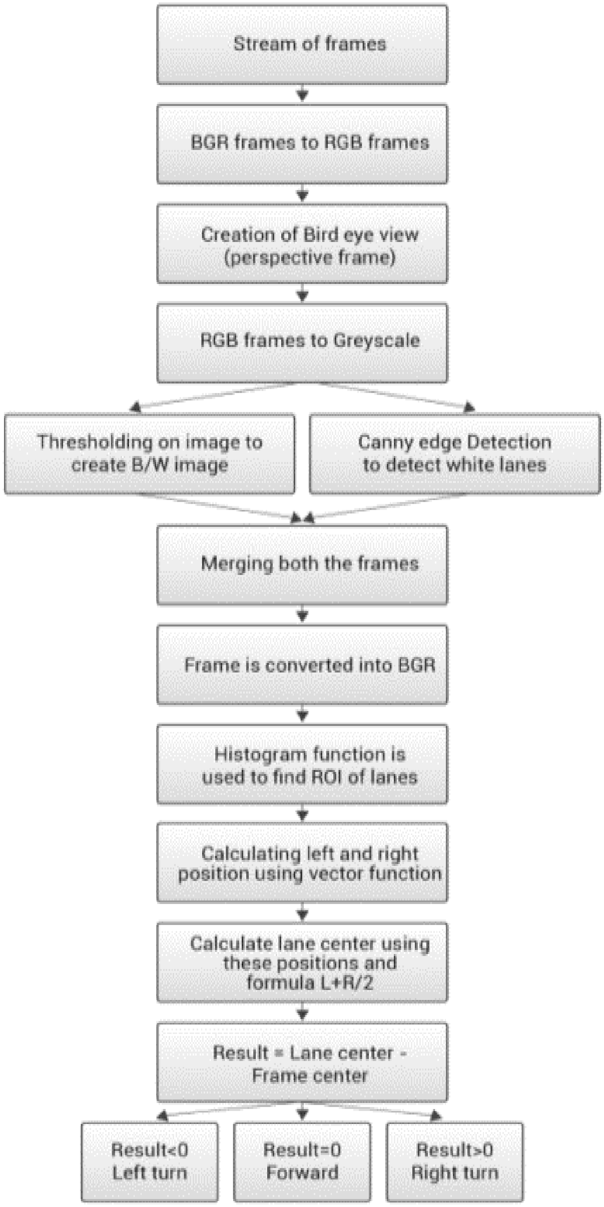

Figure 2. Image Processing Algorithm for Lane Detection from Captured Images [7].

b. Self-Driving Car using LiDAR

The purpose of this reviewed article is to create an effective LiDAR sensing system for self-driving automobiles that can map its surroundings, follow a route, and arrive at its destination without human intervention. A 360-degree LiDAR called YDLIDAR X2 is linked to the USB port on the Raspberry Pi. A probabilistic roadmap (PRM) uses a network of linked nodes to identify an obstacle-free route from a start to an end point in order to properly plan a journey across an environment. The SLAM methodology uses mapping, localization, and pose estimation techniques to simultaneously create an environment map and localize the vehicle inside it. Each LiDAR scan is independently examined by the SLAM algorithm, which then builds a pose graph connecting them to construct a map of the near surroundings. Based on loop closure data, the SLAM system modifies the map and alters the predicted robot path. The flow diagram of this model is shown in Figure 3 [2]. The LiDAR point cloud image is processed, which makes use of the KITTI dataset. The point cloud image created by this technique will have a 45° frontal perspective. The next phase is LiDAR segmentation, which involves ground extraction, hierarchical merging, and segmentation of the point cloud image shown in Figure 4. [13].

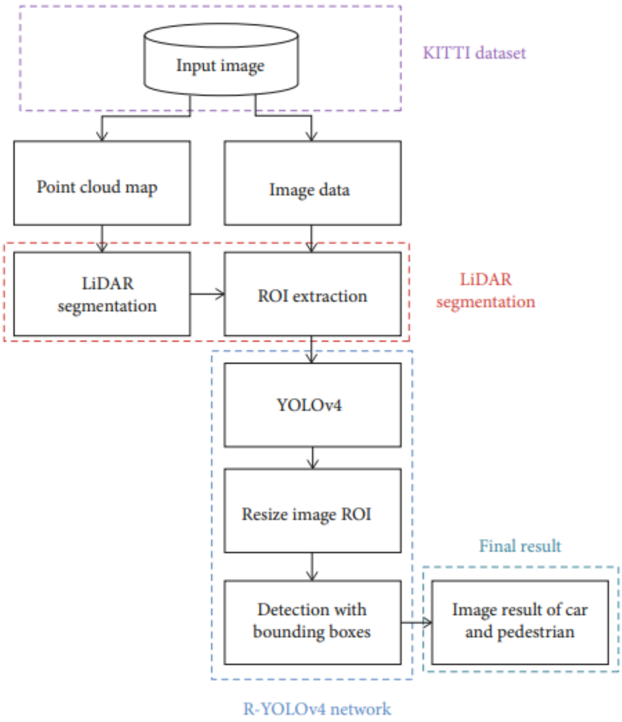

Figure 3. Flow Diagram of the Self-Driving Car using LiDAR

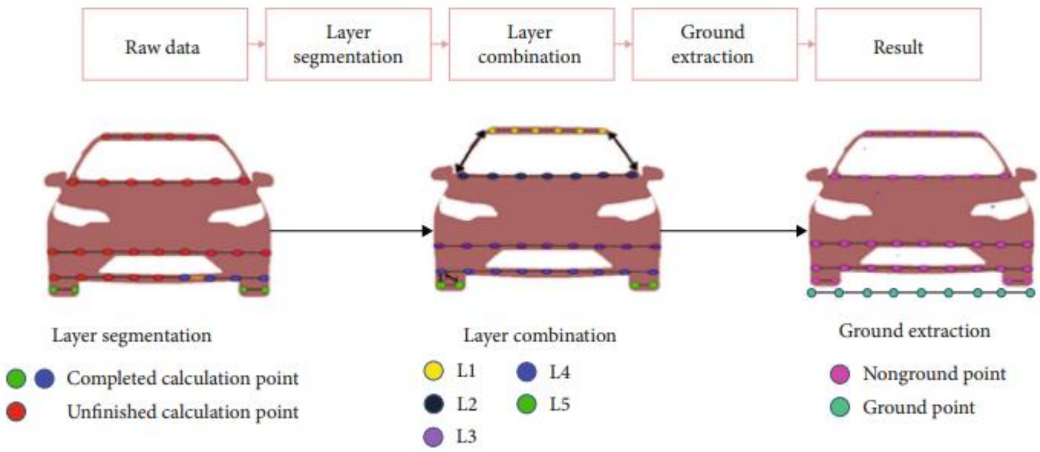

Figure 4. LiDAR Segmentation / Processing.

c. Self-Driving Car (SDC) using Ultrasonic Sensors with IoT and Arduino

The main processing unit of this vehicle is a Raspberry Pi. As well as its separation, it is in charge of detecting obstacles and objects. Along with these additional tasks, Raspberry Pi is using static IP to keep the automobile connected to a reliable Wi-Fi network. Furthermore, it interfaces with other parts, including a camera and an ultrasonic sensor. Using an ultrasonic sensor, a car's frontal obstructions may be found. information determines the distance from the automobile to the nearby item and transmits information to the Raspberry Pi. Socket programming, which combines an IP address and port number, is used for this. The ability to connect to other clients and bind to an IP address is a feature of a server [4]. Through the Raspberry Pi 3 controller's General-Purpose Input Output (GPIO) pins, a number of sensors, including an ultrasonic sensor, IR sensors, and the L293D H-bridge motor driver, are linked. The USB port on the Raspberry Pi board is where the web camera is linked. Utilizing IC MCP3008, the analog output of the accelerometer sensor is transformed to digital. GPIOs on the Raspberry Pi 3 were supplied from an analog to digital converter [5]. To distinguish traffic signs and signals from the image in front, a classifier called the HAAR cascade is utilized. The available image's area of interest from positive samples is compared to the current image by the classifier. In the instance of a traffic light, the bounding boxes are taken into account as the area of interest, and then the noise existing in it is reduced by applying a Gaussian blur. According to the brightest point in the area of interest, the red or green lights of the signal are ultimately determined. Figure 6 shows the Traffic light detection system employed in the reviewed article [6].

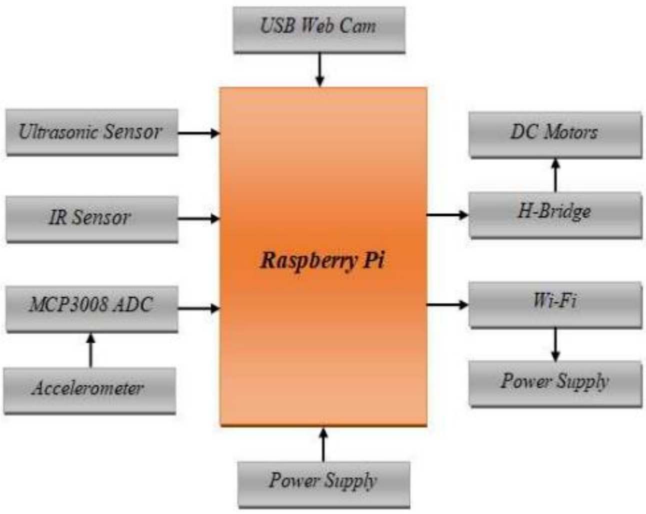

Figure 5. Block Diagram of the SDC Model [5].

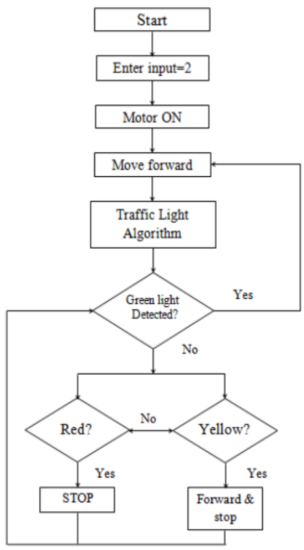

Figure 6. Flow Diagram of Traffic Light Detecting System [5].

3. Comparison of the Reviewed Articles

a. Self-Driving Car based on Image Processing and Machine Learning

The planned self-driving automobile has cutting-edge features to guarantee effective and safe road travel. The performance of three important models has been carefully examined. First of all, the lane detecting system maintains a high accuracy rate of 97% while operating at an astonishing speed of 27 frames per second. This enables the vehicle to accurately monitor and adhere to the lane lines, ensuring that it follows the intended course. Second, the technology claims to recognize traffic signs with a stunning 97% accuracy. This indicates that a variety of traffic indicators, including yield, stop, and speed limit signs, may be efficiently recognized and understood by the vehicle. It may then make wise judgments and follow traffic laws, hence enhancing overall road safety [1]. It can identify things such that collisions may be avoided, which is useful for averting mishaps in the real world. More than 200 examples of images in various lighting situations were used in its training, which helped to improve accuracy and greatly speed up detection [3]. The strategies used in the system include disparity mapping for distance measurement and anomaly identification, as well as lane recognition utilizing image filtering techniques and the Hough transform feature extraction methodology [9]. The vehicle was trained on several track configurations, including straight, curved, and mixes of straight and curved, among others. Images were taken from a total of 24 videos that were captured. There were 10868 pictures extracted. The network was trained on these images, which were scaled to 320 x 240. There were 128 input nodes in the convolutional neural network, two hidden layers with 32 nodes each, and an output layer with 4 nodes for each of the 4 outputs. [12]. Table 1 explicates the performance metrics of the works which are employed for Self-driving Car based on Image Processing and Machine Learning.

Table 1. Performance Metrics of Self-driving Car based on Image Processing and Machine Learning.

Cited Work / Parameters	**[1]**	**[3]**	**[7]**	**[9]**	**[12]**
Objective of the cited work	Lane, Traffic sign and obstacle detection	Sign detection	Lane, Traffic sign and obstacle detection	Lane detection	Lane detection
Accuracy (%)	97	98	98	98.5	80
Error rate (%)	3	2	2	1.5	20
Hardware employed	Rpi, Arduino, Camera	Rpi, Camera	Rpi, Arduino, Camera	Rpi, Camera	Rpi, Arduino, Camera
Algorithms / Software req.	OpenCV	OpenCV, CNN	OpenCV2, DNN	SVM, KNN	OpenCV
Network Connectivity	No	No	Yes	No	No

b. Self-Driving Car using LiDAR

SLAM and the PRM algorithm have been used to model an effective LiDAR sensing system for self-driving cars. According to the experimental findings, a 9% error rate is achievable when using LiDAR to estimate distances between 0.12 and 8 meters. In order to cover a significant section of the free space, PRM creates a single roadmap. Then, to move along the roadmap, a shortest route planning method may be used. Robotics Operating systems are effective tools for gathering and processing data from Laser Scans via the ROS Network [2]. The findings are much superior than those of the YOLO algorithm in comparison to the LS-R-YOLOv4 identification rate, identify the pedestrian and automobiles. With 97.7% accuracy, the method offers a substantial advantage in terms of the recognition rate of computations for object recognition [13].

Table 2 explicates the performance metrics of the work employed for Self-driving car using LiDAR.

Table 2. Performance Metrics of Self-driving Car using LiDAR.

Cited Work / Parameters	**[2]**	**[13]**
Objective of the cited work	Path Mapping, Shortest distance mapping	Obstacle detection, Path mapping
Accuracy (%)	91	97.7
Error rate (%)	9	2.3
Hardware employed	LiDAR, Rpi	LiDAR, Camera
Algorithms / Software req.	SLAM, PRM, ROS	YOLOv4
Network Connectivity	No	No

c. Self-Driving Car (SDC) using Ultrasonic Sensors with IoT and Arduino

Ultrasound Sensors convert ultrasound waves into electrical signals or the other way around. The time it takes for a sound to return from an item is used by an ultrasonic distance sensor to calculate the distance to that object. A sensor's component that creates sound also captures the echo that is reflected [4]. Traffic signals are successfully detected by the self-driving automobile, which then responds as follows: The automobile stops for red, yellow, and green lights; it continues ahead for yellow but stops for red. It is shown that the self-driving automobile identifies and avoids nearby impediments, stops after seeing real-time objects, and estimates distance [5]. The HAAR cascade is a classifier that is used to recognize traffic signs and signals from the front-facing perspective. The classifier compares the current image with the area of interest from the available images from positive samples. For a traffic light, the bounding boxes represent the area of interest, and to lessen the noise existing in it, the Gaussian blur is used. Ultimately, based on the brightest point in the area of interest, the red or green lights of the signal are determined [6]. The quick development and debugging of the robotic vehicle's motion algorithms were made possible by the usage of the Arduino Mega 2560 platform. Robotic vehicles now have their most basic motion patterns. Decision algorithms will be developed for the automated system's future evolution based on these modalities [10]. Table 3 explicates the performance metrics of self-driving car (SDC) using ultrasonic sensors with IoT and Arduino.

Table 3. Performance Metrics of Self-Driving Car (SDC) using Ultrasonic Sensors with IoT and Arduino.

Cited Work / Parameters	**[4]**	**[5]**	**[6]**	**[10]**
Objective of the cited work	Passive object detection	Lane, Object, Traffic light detection and Accident alert system	Lane detection	Obstacle detection
Accuracy (%)	80	83	85	70
Error rate (%)	20	17	15	30
Hardware employed	Arduino, Rpi, Camera, HC-SR04	ultrasonic sensor, IR sensors, Rpi, Camera, Accelerometer	Rpi, Camera, Ultrasonic sensor	Arduino, GPS, Ultrasonic sensor
Algorithms / Software req.	OpenCV	OpenCV, DNN	OpenCV	-
Network Connectivity	No	Yes	No	No

4. Discussions

This section discusses the tactics that were looked at along with the advantages and disadvantages of different works. A quick comparison of the most current studies is provided in Table 4.

Table 4. Pros and Cons of Reviewed Articles.

Citation Number	Methodology (Dataset/Realtime)	Advantages	Disadvantages
1	Realtime	Enables Lane, Traffic sign and obstacle detection with least amount of hardware components.	Accuracy can be improved, with efficiency and upgrade in the components.
2	Realtime	Usage of LiDAR provides an edge, along with SLAM and PRM being used for higher efficiency.	Parallel processing is absent. Multiple trials needed for running in real-time.
3	Realtime	Minimal hardware used for traffic sign detection with good accuracy.	Delay in processing with lag. To improvise the concept of parallel-processing to unlock faster execution rate.
4	Realtime	The concept of Ultrasonic sensor enhances object detection.	Requires finesse in the outcome and demonstration.
5	Realtime	Satisfies the requirements of a SDC with lane, traffic sign, obstacle detection and Accident alert system with integration to IoT.	-
6	Realtime	Obstacle detection is enhanced with the concept of ultrasonic sensors along with data acquired by the camera.	The number of bins and epochs could be increased to increase the accuracy.
7	Realtime	Enables Lane, Traffic sign and obstacle detection with least amount of hardware components. Also, feature of path planning employed.	The trials need to be increased to reduce the threshold and increase the accuracy along with reduction in delay.
8	Realtime	Lane Detection with least amount of hardware.	Smaller area of interest, can be widened to deploy other parameters as well.
9	Realtime	Lane detection executed with usage of SVM with Hough transform for feature detection.	-

10	Realtime	Obstacle detection mapping using an ultrasonic sensor to map on a 2D histogram.	Narrow usage of technology, can be employed to devise a new algorithm for betterment of Self-Driving Car.

It is discovered that the majority of systems employ Image processing as the basis in Real-time combined with Machine Learning by assessing multiple strategies for various factors, functioning, depending on sensors, microcontrollers, and algorithms used. The bulk of the requirements for a self-driving automobile are met by image processing-based works, which are used to recognize lanes, identify obstacles, detect traffic signals, and identify signs. The least number of goals are being met by LiDAR-based efforts for self-driving cars. LiDAR is also highly costly, which limits its use in real-time. Few works have integrated the use of an ultrasonic sensor with image processing for improved obstacle detection and accident alarms with higher efficiency and accuracy with the least amount of delay.

5. Conclusion

A range of microcontrollers, IR sensors, ultrasonic sensors, LiDAR, cameras, and other image processing devices are used in this review research to evaluate and comment on the different technologies used in self-driving vehicles for lane detection, obstacle detection, and traffic sign identification. This work is comprised of works that have only been published in the recent years, in order to solely take into account, the most advanced and excellent work.

A self-driving automobile is one that can navigate without human intervention by detecting its surroundings. Self-driving vehicles can perceive their surroundings using a variety of technologies, including LiDAR, Radar, GPS, and cameras. Accident reduction is the primary advantage of self-driving automobiles. If such vehicles are broadly accessible and well-engineered, may lead to reduction in fuel use and pollution. The self-driving car industry has seen great growth in recent years, and this growth is drawing in a broad spectrum of customers, mostly because of the advantages it offers. To guarantee safe and effective driving on the road, the self-driving automobile includes cutting-edge capabilities. In the automation business, the autonomous automobile would undoubtedly show to be beneficial and would be preferable over many conventional ways. These vehicles could be used even for surveillance, tracking and as well as taking pictures. The autonomous vehicles will reduce the number of accidents caused by irresponsible truck drivers thus , improving the logistical flow.

Artificial intelligence holds the key to the development of smart and autonomous vehicles. Hardware restrictions are the only drawbacks faced by these technologies. It is highly intriguing and exciting to use tools like the Raspberry Pi to get this outcome. For better results and the least amount of delay, the majority of the works utilize Raspberry Pi, which can be switched out and used with Nvidia Jetson Nano.

The efforts using cameras as a sensor for the self-driving car need to be much improved. The causes for this include poor precision and distortion in low-light situations, which might lead to careless driving by the vehicle and result in accidents. LiDAR is needed in these situations to map the surroundings effectively and avoid accidents. IoT plays a significant role in today's digital age in keeping consumers and authorities informed about every surrounding aspect, which is to be considered in the future research works as IoT definitely plays a vital role in self-driving car.

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