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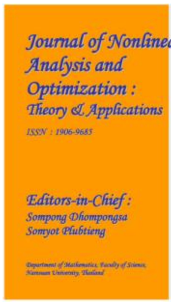

NAVIGATING THE FUTURE: A COMPREHENSIVE OVERVIEW OF AUTONOMOUS VEHICLE TECHNOLOGIES

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Abstract—
Autonomous vehicles, commonly referred to as self-driving cars, have become an innovative technological development in the transportation industry. These vehicles utilize a combination of cutting-edge technologies such as sensors, artificial intelligence, machine learning, and advanced algorithms to navigate and operate without the need for human intervention. This paper describes the technologies driving autonomous vehicles, focusing on target recognition, tracking systems, unified mapping, multisensor fusion, and accident detection. It explores how cutting-edge sensors and deep learning algorithms enable vehicles to accurately categorize objects in their surroundings, ensuring safe navigation. The integration of LiDAR and radar for tracking moving objects is examined, highlighting their role in predictive trajectories and overall road safety. Challenges of sensor fusion are discussed, emphasizing the need for seamless integration of data. Unified mapping plays a vital role, as it combines high-definition maps with real-time sensor data for precise localization, path planning, and obstacle avoidance.
Keywords—Autonomous Vehicle, Target Recognition, Tracking Systems, Multisensor Fusion, Accident Detection, Path Planning, Obstacle Avoidance, Collision Prevention, Autonomous Navigation, CVIS, V2X, YOLO.

INTRODUCTION

Autonomous vehicle is also known as a self-driving car also call it as an automatic car. These cars can be operated by itself without any direct human interaction. Self-driving cars uses many types of sensors to precising the surrounding for navigating. While depending upon a single sensor may lead to inaccuracy. In the year 2016 Tesla car misidentified an object which was laid on the road [1]. In this multi sensor fusions it combines the all the strength of sensors for accurate information. Basically, the sensor fusion was classified into three types, they are low level fusion, middle level fusion and high-level fusion [11]. The researchers are developing some new algorithm techniques for object detection such as like faster R-CNN, for reducing the time delays [16]. The main motto of the autonomous vehicles to make a safer navigation by improving the accessibility, reducing the conjunction. However, a fully automatic self-driving car was does not existed till now. Somehow these autonomous vehicles can reduce the accidents [2].
To precise the soundings the self-driving cars uses multiple number of sensors along with computer vision along with artificial intelligence to make a safer ride. These cars also provide entertainment to the passengers by playing music, movies, online games, and some features which can entertain the passengers. There are some methods are proposed such as caching, Multi Access Cloud Computing (MEC) technique [3].
There are disadvantages are while developing a system that can been communicating with vehicles is very slow due to the economic and legal challenges were facing. Emergency Breaking System [5], is an automatic braking system that can apply the brakes automatically if it is necessary whenever vehicle

detects a danger sign [13]. The self-driving cars are currently using the advanced driving assistance system which is used to apply the emergency breaking, automatic parking along with obstacle detections [7]. There are some challenges are like difficult to navigate in traffic scenarios such as unable to identify the intersections, construction zones and other [6]. While navigating these are subjected by objects well known as obstacles, to overcome from these obstacles object detection algorithms are used [10].

REATED WORK

Ze Liu proposed a method to find the distance, velocity and azimuth of the object which was detected by the self-driving car for navigating [1]. In this proposed method a Millimeter-wave radar is used, this radar is used to measure the parameters like distance, velocity, and azimuth of the object, this radar uses the electromagnetic wave to measure. As this method is accurately measures, but this method it cannot accurately measure the azimuth. For the collection of the data cameras were used because these are good enough for collecting the information, also that these are very close to human eye. In this proposed method a Mako G-192B camera was used, this camera was a monocular camera. The data which was collected by these two sensors were combined for predicting the collisions [7]. The camera was used to detect the objects and sensor was used to know the status of the object.

Anselme Ndikumana proposed a method about the infotainment system in self-driving car [3]. In this method, it describing about the caching content at base stations and Road Side Units (RSU). There is no deep research on caching infotainment content based on passenger's characteristics. System process to provide the information with appropriate infotainment content. By using this proposed model can leads to delays. There is another method as VANET [5], it is nothing but your cloud base vehicular ad-hoc network. A new feature that was proposed by the author, this is for the vehicle to everything communication simply known as an V2X communication this method is also useful for the catching of content through machine learning algorithms.

Michele Segata was proposed a model based on VANET's information diffusion about of the sharing the safety information from one vehicle to another [5]. While sharing the information from one to another vehicle which is very complex because vehicles are moving continuously in the all the time will affects the wireless communication. The biggest issue is about sharing the information without any clogging the network. To overcome clustering algorithms, gossiping-based protocols and schemes are used. There are many protocols that were being introduced in the vehicle for sharing the information from one to another vehicle. This approach will provide synthetic environment that can share the information by without affecting the communication. These protocols will reduce the time delays. These protocols are not for safety information sharing [22].

Inwook Shim proposed a method used for the precise the soundings and to create a unified map [6], by the self-driving car. As the autonomous vehicle must navigate through localizing its soundings initially, then it will select the route to reach its destination. As the vehicle must select the path through path planning algorithms which are introduced in the automatic driving assistance system [7]. While the autonomous vehicle in the motion must detect the objects through sensors data and camera reorganization information. Here the autonomous vehicle will detect the objects and for a point cloud map respectively. This point cloud is used to provide the accurate information of the soundings. Here unified mapping.

DAXIN TIAN proposed a method on accident detection [7], and prevention system in self-driving cars. Accident detection in self-driving car is one of the methods. There are two types for detecting the accident they are, the first method is based upon the motion of the vehicle. To know about the motion of the vehicle it uses sensors to monitor such as velocity, acceleration, and location. The second method is based upon the video feature of the accident. In this it uses the camera and machine learning algorithms for detection. The cameras are used for the recording the video and machine learning algorithms are used for detection.

Ibrar Yaqoob proposed a method describing about the architecture [10], of the self-driving car. For a self-driving vehicle, it requires some components, based upon these components the autonomous vehicle can communicate, navigate, operate, and controlled. The components require such as Robust

architecture, Fault Tollerance, Resource Management, security and Privacy, Localization and Strict latency. Each component will be inter connected with other. Based on the structure of the it the autonomous vehicle will behave according to it. Then this raw data will be processed by using the advanced algorithms such as deep learning algorithms [10].
RUI TONG proposed a method describing about sensor fusion [11], and object detection [1],[12], algorithms used in self-driving car. Multiple number of sensors were used for improving the accuracy, precision, and recall. To achieve this all the components were used in this vehicle will collectively work. The combination of the strengths of sensors are called as the data fusion. There is an algorithm is available to detect the images and provide the feature points by extracting the image. This algorithm is known as Oriented fast and Relief Brief (ORB) algorithm. This algorithm used to reduce the storage usage and reduces the response time. These detections are used to accurately detection of the objects by capturing the mages through cameras.

METHODOLOGY
A. Architecture of the Autonomous Vehicle
These cars use the cutting-edge technologies to equip itself to operate, control, navigate. The basic architecture of the autonomous vehicle has different blocks, and each block have its own significance depending upon its processing and precise the soundings. The following block diagram will explain about the basic architecture of the autonomous vehicle.
Sensor Perception: This block is responsible for collecting and processing data from the vehicle sensors. This block is used to create the 3D model of the soundings of the vehicle. This block uses a variety of machine learning algorithms to identify and track objects in the surroundings. YOLO algorithm used to identify the type of object and object tracking for track the position over time.
Data Processing: This block is used to create a compatible format by removing the noise, normalizing the data from the sensor data. This data used in machine learning model of the vehicle. This block may remove noise from the camera images by combining multiple images together. It may also normalize the data by scaling it to a specific range of values.
Localization: This block is used to determines the vehicle location in the map using the sensor data. This block plays an important role for path planning and obstacle avoidance. The localization block uses a variety of machine learning algorithms to determine the vehicle location. GPS used to determine the latitude and longitude, and it may use LiDAR data to determine the vehicle distance to nearby objects.
Path Planning: The path planning block generates a safe path for the vehicle to reach its destination. The path must consider the vehicle current location, the location of other vehicles and obstacles, and the road network. The path planning block uses a variety of machine learning algorithms to generate a safe path for the car.
Motion Control: The motion control block controls the vehicle actuators to follow the planned path. It must also consider the vehicle current state, such as its speed and heading. The motion control block uses a variety of machine learning algorithms to control the vehicle actuators.

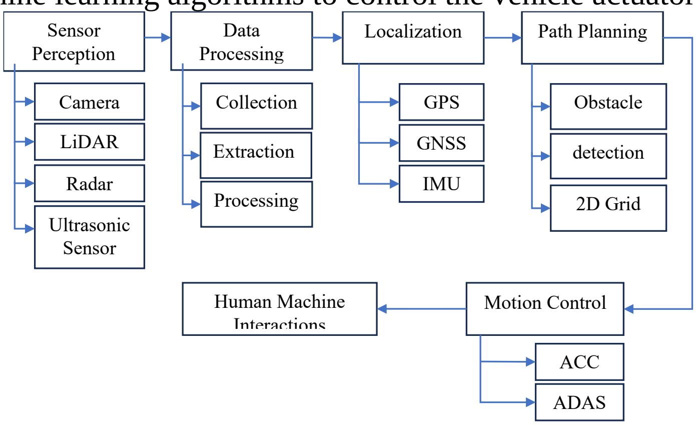


Figure 1: Architecture of the Autonomous Vehicle

Human Machine Intervention: This block allows the driver to interact with the vehicle machine learning system. The human-machine interactions block uses a variety of machine learning algorithms to understand the driver commands and to communicate with the driver.
ADAS: ADAS stands for Advanced Driver Assistance Systems. This block includes a variety of features that help the driver to safely operate the car. Such as automatic emergency braking, lane departure warning, and adaptive cruise control. The ADAS block uses a variety of machine learning algorithms to implement its features.
B. Autonomous Vehicle Driving Requirements
These are the features of the blocks which are mentioned in the architecture [10] of self-driving car. As the autonomous vehicle uses multiple number of hardware and software components in it. The following block diagram will describe about these in detail.
Data Analysis: In this data analysis block is responsible for gathering and analysing information about the driving requirements of the autonomous vehicle. This information can come from a variety of sources.
Sensors: Sensors on the vehicle can provide data about the surrounding environment, such as the position of other vehicles, pedestrians, and objects.
Maps: Maps can provide information about the road network, including traffic signs, lane markings, intersections, and speed limits.
Planning: This block is responsible for generating a plan for how the autonomous vehicle will achieve its driving requirements. This plan includes the vehicle's desired trajectory, speed, and acceleration. The planning block also considers constraints.

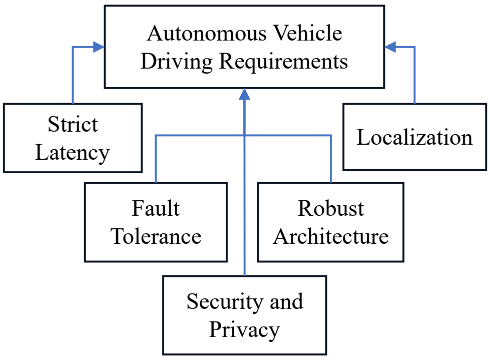


Figure 2: Autonomous Vehicle Driving Requirements
Centralized: This block can be implemented in a centralized manner. In this system, a single computer is responsible for generating the driving plan. Centralized systems are simpler to implement, but they are weaker to failures. If the central computer fails, the autonomous vehicle will not be able to drive.
Decentralized: The planning block can be implemented in a decentralized manner. multiple computers work together to generate the driving plan, they are more robust to failures. If one computer fails, the other computers can continue to generate the driving plan.
Strict Latency: The planning block must have a very low latency. If the latency is too high, the autonomous vehicle will not be able to react to changes in the driving environment quickly enough.
Robust Architecture: This means that the system must be able to handle unexpected events and conditions. The system must be able to continue to operate even if one of the sensors fails.
Security and Privacy: This means that the system must be protected from unauthorized access and modification. The system must also protect the privacy of the passenger’s data.
Fault Tolerance: This means that the system must be able to continue to operate even if one of its components fails. The system must be able to continue to operate even if one of the computers fails.
Resource Management: This system manages its resources efficiently. This means that the system must use the available computing power, memory, and energy in the most efficient way possible.

C. Path Planning of Autonomous Vehicle

Whenever the autonomous vehicle wanted to reach the destination from its current location then autonomous vehicle must select the path. To reach its destination initially the autonomous vehicle has to precise the sounding then a point cloud will be generated through sensor and camera data. The following block diagram (figure 3) describes about the autonomous vehicle path planning [6].

LiDAR: This sensor stands for the light detection and ranging. This sensor used to detect the objects which are sounding to the vehicle. This sensor will capture the light from the objects.

CAMERAS: Cameras are another important sensor for autonomous vehicles. They can be used for obstacle detection, image recognition, and path planning. Cameras are also relatively inexpensive and widely available.

S-Net: S-Net is a communication network that allows vehicle to communicate with each other. This can be used for tasks such as cooperative flight and coordination. One of the challenges of using S-Net in autonomous vehicle is that it can be difficult to design a communication protocol that is both reliable and efficient.

Obstacle Detection: The obstacle detection block uses the data from the LIDARS and cameras to detect obstacles in the path. This is a critical task, as they need to be able to avoid obstacles to avoid collisions. Algorithms rely on simple geometric techniques, while others use more sophisticated machine learning techniques.

Image Detection: The image detection block uses the data from the cameras to identify objects in the surroundings. This can be used for tasks such as tracking objects. Image detection algorithms are typically based on machine learning techniques. These algorithms are trained on a large dataset of images of different objects. Once the algorithm is trained, it can be used to identify objects in new images.

D-Net: D-Net is a neural network that is used to process the data from the obstacle detection and image detection blocks. It outputs a 2D grid map of the surroundings, which is used for path planning.

2D Grid Map: The 2D grid map is a representation of the surroundings in a grid format. Each cell in the grid represents a small area of space, and the value of the cell indicates whether there is an obstacle in that area.

IMU: The IMU (Inertial Measurement Unit) is a sensor that measures the orientation and acceleration. This information is used to control the motion of the vehicle.

D. Autonomous Vehicle Target Sequence for Decision Making

If any obstacles are detected by vehicle, then vehicle must take the specific task with respect to instructions which are given in algorithm. The following block diagram (figure 4) will describe about how the vehicle can make decision to overcome from those obstacles by using the combination of radar and camera target sequences [1]. Each stage in the given block diagram has its own specifications.

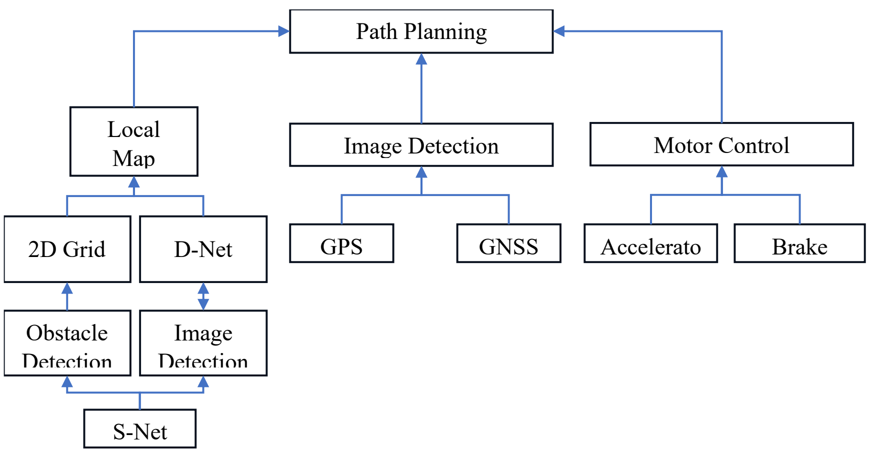


Figure 3: Path Planning of Autonomous Vehicle

Camera Target Sequence: This block takes the input from a camera and generates a sequence of target detections. The camera target sequence block takes the input from a camera and generates a sequence of target detections. The camera target detections can be generated using a variety of methods, such as object detection algorithms, tracking algorithms.
Observation Matching: This block matches the camera target detections with the radar target detections. The observation matching block matches the camera target detections with the radar target detections. This is done by comparing the features of the camera and radar detections, such as the position, size, and velocity of the targets.
Data Fusion: This block combines the camera and radar target detections to generate a more accurate and complete picture of the target environment. The data fusion block combines the camera and radar target detections to generate a more accurate and complete picture of the target environment. This is done by considering the strengths and weaknesses of each sensor.

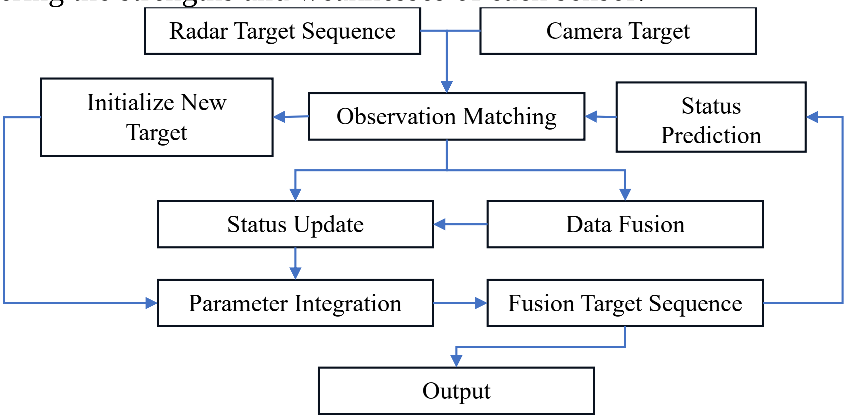


Figure 4: Autonomous Vehicle Target Sequence for Decision Making

Initialize New Target: This block initializes a new target path for each new target that is detected.
Status Prediction: This block predicts the future state of each target. The initialize new target block initializes a new target path for each new target that is detected. This involves setting the initial state of the target path, such as the position, velocity, and acceleration of the target.
Status Update: This block updates the state of each target track based on the latest radar and camera measurements. The status update block updates the state of each target track based on the latest radar and camera measurements.
Parameter Integration: This block integrates the target path parameters from the radar and camera measurements. The parameter integration block integrates the target path parameters from the radar and camera measurements for accuracy.
Fusion Target Sequence: This block is acting as like an output block. In this stage it will improve the accuracy through filtering, then it will drive to output block.
Output: Final stage of the flow while the vehicle navigating and operating in target path to overcome from the path.
E. Bezier Curve
When an obstacle that was detected by the self-driving car then it must select a path which is suitable to pass the obstacle. In the following figure describe about the Bezier curve [4].

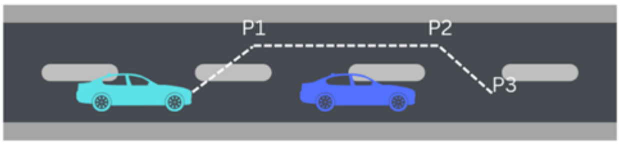


Figure 5: Bezier Curve

A Bezier curve is a mathematical curve that is defined by a set of control points. The curve passes through the first and last control points, and its shape is determined by the other control points. In the above picture it describing that, in front of a self-driving car there is an obstacle. Then it has to overtake this obstacle, the P1, P2 and P3 through these points the vehicle will move. As for the detection of the objects the sensors and cameras were been used. These sensors can be utilized when the obstacle is

near by the range to vehicle. The following table will describe about the range of sensor, camera to detect the objects, and also the time taken to make a decision by the vehicle.
Route planning is the process of finding a path from the vehicle's current location to its destination. This is done by considering factors such as the road network, traffic conditions, and the vehicle's capabilities.
Prediction is the process of forecasting the future state of the vehicle's environment. This includes predicting the positions and movements of other vehicles, pedestrians, and cyclists.

Table 1: Response Time of an Autonomous Vehicle for Action

Parameter (Action)	**Space (in meter's)**	**Time (in second's)**
Route Planning	> 100	> 60 < 3600
Prediction	> 1 < 100	> 1 < 60
Decision Making	> 10 < 100	> 1 < 60
Generation	> 10 < 100	> 1 < 60
Deformation	> 0.5 < 10	> 0.01 < 1

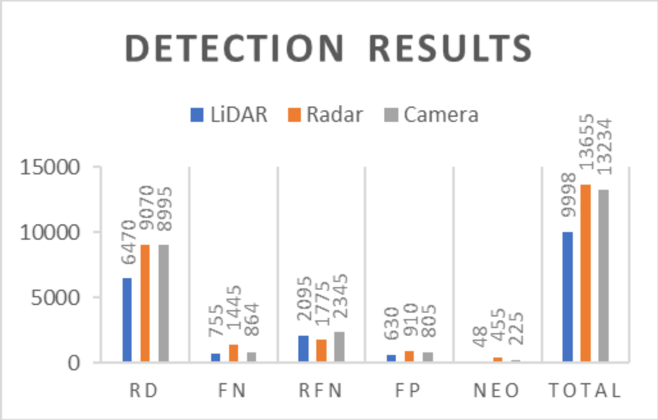
Decision Making and Generation is the process of selecting the best decision for the vehicle to take, based on the current situation and the predicted future state of the environment.
Deformation is the process of adjusting the vehicle's planned trajectory in real time to avoid obstacles and ensure safety.

RESULT

The proposed methodology performs various calculations with the real time vehicle trials conducted in the adverse atmospheric conditions such as like wet weather, snowy cases, sunset obstacle scenarios and heavy traffic situations. Under all these situations proposed model is works accurately and the calculations are measured on the stand-alone. Although this method led to the misidentification and case of unable to identify the objects.

A. Detection Results

The detection of objects is done by using the various sensors. The following bar graph will show the simulated results which are calculated by performing the trails under odd situations and conditions. The following bar graph consists of four readings which are taken by conducting the trails, they are as follow;
RD: The targets which are detected by radar sensor and then validated and refined by using camera.
FN: The targets which are detected by radar sensor but not validated and refined by using camera.
RFN: The targets which are not detected by radar sensor or detected in low precision.
FP: A noneffective obstacles were detected by radar sensor and validated by using camera.
NEO: A noneffective obstacles were detected by radar sensor but not validated by using camera.



Graph 1: Object Detection Results

The following table describes about the statistics of the algorithms which are used to detect the objects accurately.

Table 2: Sensor Detection Results

Detection Type	RD	FN	RFN	FP	NEO	Total
LiDAR	6470	755	2095	630	48	9998
Radar	9070	1445	1775	910	455	13655
Camera	8995	864	2345	805	225	13234
Accuracy (%)	66.5	83.1	16.8	6.3	1.9	100

The following table describes about the statistics of comparison between developed model and other models based on F1 score.

B. F1 Score

To know about the accuracy and efficiency of the autonomous vehicle, it means how accurately it was working. For that purpose, must know the F1 score.

Accuracy is the ration of the true predictions to total number of predictions.

Accuracy=(TP+TN)/(TP+TN+FP+FN)

Precision is the ration of the true positive predictions to sum of True Positive and False Positive predictions.

Precision=TP/(TP+FP)

Recall is the ration of the true predictions to sum of True Positive and False Negative predictions.

Recall=TP/(TP+FN)

F1 Score is the harmonic mean of Recall and Precision results.

F1 Score=(2*Recall*Precision)/(Recall+Precision)

Table 3: Comparison of F1 Score with Proposed Model

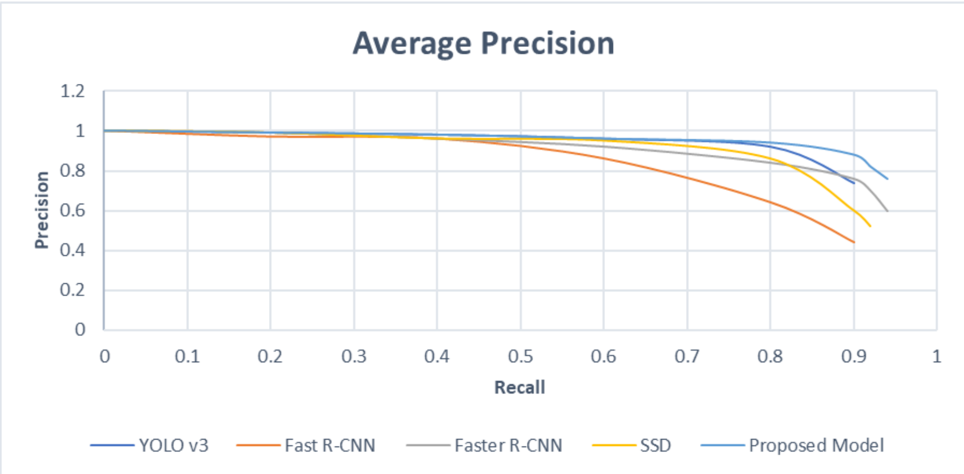
Model Name	Layers	Recall Factor	Precision Rate	F1 Score
ZF-Net	7	0.785	0.841	0.812
YOLOv3	64	0.842	0.827	0.834
VGG	16	0.859	0.845	0.851
SSD	16	0.851	0.872	0.856
Faster R-CNN	17	0.878	0.858	0.867

Proposed Model	28	0.879	0.887	0.882

From the above data represents that the proposed model is more accurate while comparing with other algorithms.

C. Average Precision

The performance of the object detection algorithms can be identified by using average precision (AP). The AP will be determining how accurately the algorithms are working to identify the objects. The average precision can be calculated by using the values of Precision and Recall by plotting a graph between these values. The area under the Precision-Recall curve is known as an AP. Higher in the value of AP means higher in the performance of algorithm to detect the objects. The following graph shows the comparison of AP between different algorithms by comparing with proposed model. The graph consists of algorithms like YOLO v3, Fast R-CNN, Faster R-CNN, and SSD along with proposed model.



Graph 2: Average Precision Results

From the above data represents that the proposed model is more accurate while comparing with other algorithms, here the YOLO v3 algorithm having of 86.2% of AP, Fast R-CNN with 77.65% of AP, Faster R-CNN with 82.02% of AP, SSD with 83.4% of AP and proposed model with 87.89% of AP. From the data it clearly shows that our model works more accurate than other algorithms for detection of objects.

D. Dataset

In the dataset consists of frames for every image. Then vehicle will do the necessary instruction. The following images will show the objects which are detected by the proposed model. The following images are taken from the dataset of object detection. The following images are detecting objects such as traffic light, animal, people, and traffic logos.

Detection of Traffic Lights:

Detection of Traffic Logos:

Detection of people:

Detection of obstacles:

CONCLUSION

This paper provided the brief explanation of cutting-edge technologies which are used for developing this self-driving vehicle model. This paper described about how the self-driving car can combine the technologies for precising the soundings, navigating, operating, and controlling. The object detection technologies with advances algorithms were proposed. The object detection, tracking system, Unified mapping and obstacle avoidance systems were implemented in the proposed model. Also explained about how the self-driving car works, the principles involved in it and the requirements for navigation, localization. Then the proposed model was tested under all the diverse and adverse weather conditions and their outcomes are calculated each time. Then a statistics tables and graphs are plotted by comparing with different technologies and algorithms which are already implemented. The proposed model is working more efficient and accurate by comparing with other algorithms based on the F1 score. Some dataset images are shown which are detected by the model during navigation and operating.

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