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A SURVEY ON KEY TECHNOLOGY AND DECISION-MAKING IN SELF-DRIVING CARS

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***Abstract*-A self-driving car is a vehicle that does not require human intervention to operate. Instead, it employs advanced sensing technology such as lidar, sonar, GPS, radar, or odometry and inertial measurements to more establish and adapt to them, re-establishing a safe speed or distance. In this survey paper of research on self-driving cars that are capable of sensing their surroundings and driving safely, the architecture involved in this self-driving car autonomy system is typically organized into two types of systems: one is the perception system, and the other is the decision-making system. People are running from the past to the future in search of new inventions. Similarly, automakers and technology firms are racing toward the future of advanced self-driving cars. Automakers have begun their efforts to achieve this goal.**

Keywords:Lidar, Sonar, decision-making, perception, GPS, Radar

I. INTRODUCTION

Since the mid-1980s, many universities, research centers, car companies, and companies from other industries around the world have studied and developed self-driving cars, also known as autonomous cars or driver-less cars [1]. Currently, autonomous vehicles, such as self-driving cars, are on the rise in the United States, and with self-automation, conventional cars have risen in value in comparison to self-driving prototypes.

The "Winter of AI" refers to the decade-long period of inactivity that followed the collapse of artificial intelligence research, which had overreached its goals in the early 1980s. Most current approaches to the development of autonomous vehicles (AV) are centered on a lack of safety guarantees and scalability [2].

This survey was created to explain the data surrounding self-driving cars. This paper also goes into detail about the theories and applications of autonomous vehicles. Leonardo da Vinci created the first automobile in the 1500s. He designed a cart that could move on its own without being pushed or pulled. This is also known as the first robot. General Motors created the first self-driving car model in 1939. Radio-controlled electromagnetic fields were used to operate it.

Modern vehicles, as well as self-driving vehicles, rely heavily on software. In the last 20 years, the number of Electronic Control Units (ECUs) has increased from 20 to more than 100. Every 5 to 7 years, software in automobiles grows by a factor of ten. In this sense, some car manufacturers are transforming into software companies. Furthermore, self-driving vehicles will be linked to other vehicles, the manufacturers' cloud, for example, for software upgrades, Intelligent Transportation Systems (ITS), smart cities, and the Internet of Things (IoT). Self-driving vehicles will combine data from within the vehicle with data from the outside environment.[3].

II. LITERATURE REVIEW

Claudine Baduea et al. [1]proposed that the research focuses on self-driving automobiles that have been built since the DARPA challenges and are equipped with an SAE level 3 or higher autonomous system. A self-driving car's autonomous system's architecture frequently incorporates the perceptual and decision-making systems.

Shai Shalev-Shwartz, et.al. [2] extracted the major element in this race appears to be who will be the first car on the road. The purpose of this research is to add two more critical parameters to the equation. Early adoption of a safety model will allow the industry to concentrate resources on a route that will lead to autonomous car acceptance.

Tobias Holstein, et.al. [3] proposed that On the one hand, self-driving cars present new engineering challenges that are being addressed gradually; on the other hand, social and ethical issues are frequently presented as an idealised unsolvable decision-making problem, the so-called trolley dilemma, which is profoundly misleading.

Jianfeng Zhao, et.al. [4] proposed the wheeled mobile robot is a type of intelligent car that arrives at a location using data from automotive sensors, such as perception of the path environment, route information, and car control. The primary feature of a self-driving car is that it can transport people or objects to a predefined destination without the need for human intervention.

Jianjun Ni et.al. [5] proposed that obstruction detection, scene recognition, lane detection, navigation, and path planning are some of the fundamental difficulties in self-driving automobiles, and their solutions based on deep learning approaches.

Farzeen Munir, et.al. [7] proposed that many firms, including as Google, Uber, and Tesla, have invested heavily in self-driving cars, yet despite recent technological advancements, architecting the autonomous system remains an active research challenge..

Dastan Hussen Maulud et.al. [9] proposed that, from the analysis and learning to the current training results, the method would model relationships between dependent variables and independent variables. Over the last five years, an exhaustive assessment of researchers' recent and most popular methodologies in linear regression data processing, diverse statistics, and machine learning was undertaken.

Anthony McGregor, et.al [10] extracted that a packet header trace can be used in a variety of ways depending on its classification. This paper introduces a novel methodology for classifying packet headers, which classifies traffic into similar application kinds such as single transaction, bulk transfer, and so on. Our analysis's goal is to generate workload for simulation, but we feel the technique has a far broader application.

Awodele. O, et,al [11] proposed that when using machine learning to solve issues, several factors must be considered, including the type of training experience used, the target function to be learned, a symbol for such a function f, as well as a method for learning the target function from training images.

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III. THE KEY TECHNOLOGY IN SELF-DRIVING CARS

The self-driving car, which is the result of highly developed computer science, pattern recognition, and intelligent control technology, incorporates automatic control, architecture, artificial intelligence, computer vision, and many other technologies. In comparison to manual driving, it is the distinguishing feature of a self-driving car that uses automation equipment to replace the human driver. There are four types of self-driving cars. Some of the features include car navigation systems, path planning, environmental perception, and car control. [4].

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Table I

Levels of Automation

Level 0	Humans control all of the major systems.
Level 1	Certain systems, such as automatic braking, can be controlled by the car only once.
Level 2	The car is in charge of at least two automated functions, but it also requires human intervention for safety.
Level 3	The car will handle all functions, but the driver must be ready to take over if necessary.
Level 4	The car has been completely transformed into an autonomous vehicle.
Level 5	The vehicle is fully capable of self-driving.

A. Car Navigation System

There are two problems with self-driving cars. There is the current location of the car and how to get from thecurrent location to the car's destination. This navigation system detects by satellite using GPS

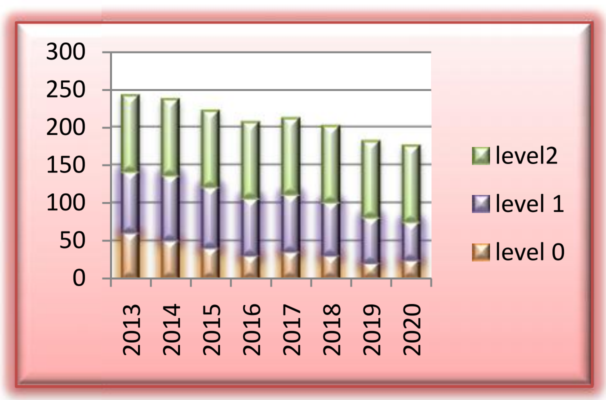

Fig.1 Cars increasingly through AV

.In human driving, the issues can be solved using human language. This data, along with road information, can be generated by a location system and a digital map database, where intelligent path planning algorithms are used toenable path planning [4].

B. Path Planning

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The path planner of the subsystem in self-driving cars computes a set of paths.

The equation, paths= P_1, P_2,..., $P_{|p|.}$ (1)

Taking into account the current root of the self-driving car's state and the internal representation of the environment, as well as traffic rules. A path is derived as, path = $P_j = P_1, P_2, P_3, P_4, ..., P_{|p|}$(2)

This is a sequence of poses such that $p_i = (x_i, y_i, i)$ which are the car positions and orientations in offline maps [1].

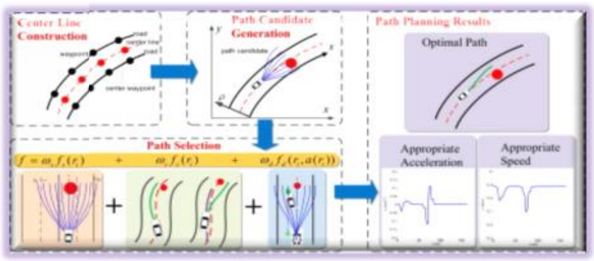

Fig.2 Path Planning

C. Deep Learning

Because of its impressive advantages in extracting features, deep learning has the potential to outperform traditional planning algorithms, and it intends to learn paths efficiently under a variety of conditions for self-driving cars[5].

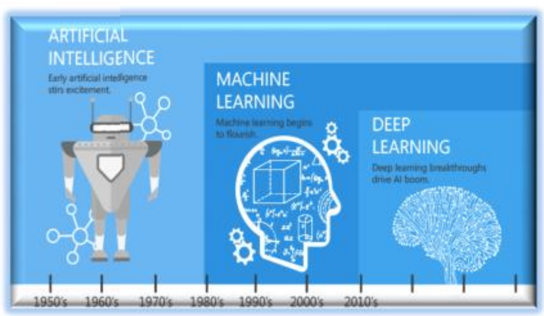

Fig.3 Deep learning

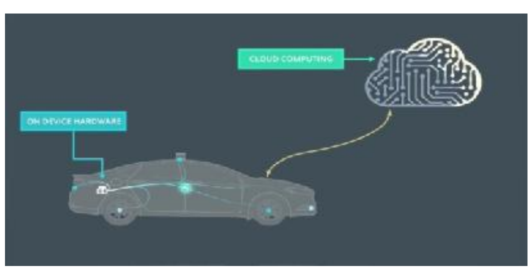

Fig.4 Cloud computing

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D. Traffic Sign And Light Recognition

Traffic sign and light recognition is a critical task in the self-driving system. It can provide some useful information in traffic light recognition for navigation and safe driving. Self-driving cars must be able to perceive intersections and crosswalks in traffic lights. It abides by traffic laws and aids in the prevention of fatal accidents.

Fig.5 Accidents preventing self-driving cars

IV. ENVIRONMENT PERCEPTION

The reliable environment perception in self-driving cars is probably the first and most important part of the automated vehicles. To correct the interpret of the sensor measurement, the vehicle must first know its current pose. This is commonly referred to as localization. The vehicles should also be able to sense their surroundings and provide robust detection. All environment perception is set to the previously mentioned tasks. These are carried out using information from perception devices such as a camera, radar, or lidar [6].

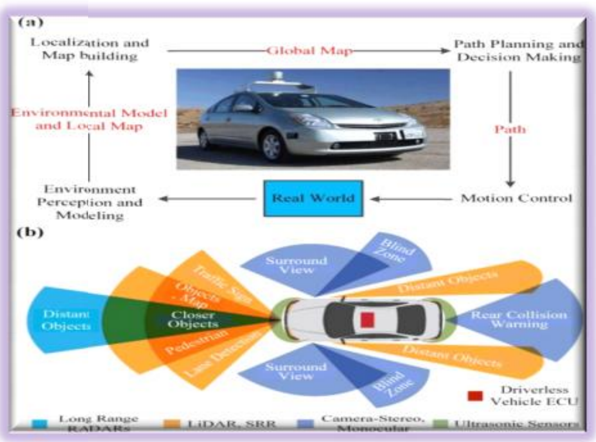

Fig.6 Environment Perception through camera and radar

V. CAR CONTROL

The controller subsystem receives the trajectory generated by the motion planner subsystem, which is then modified by the obstacle avoided subsystem, and computes and sends Effort commands to the actuators of the self-driving

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car's guidance wheel, throttle, and brakes in order to make the auto execute the trajectory as well as the physical world [1].

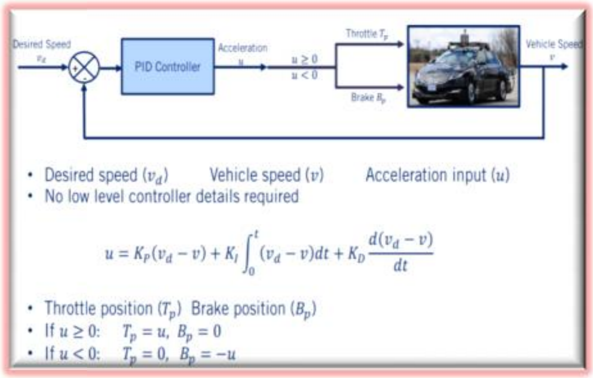

Fig.7 Car control by PID Controller

Speed controls and emergency braking are standard features in modern vehicles. This is classified as driver assistance technology.

VI. SYSTEM ARCHITECTURE

A regular vehicle that can be converted into an autonomous vehicle by changing some of its features, such as sensors that allow the vehicle to make its own decisions based on sensing, is referred to as a system architecture for autonomous vehicles.

Environmental data is collected by the sensors and sent to the framework's control module. The control block functions as the architecture's brain, generating the commands required for vehicle control based on the perception of the surroundings.Key tasks such as mapping, localization, obstacle detection and avoidance, object behavior estimation, and action planning are required for level 5 vehicle automation. [7].

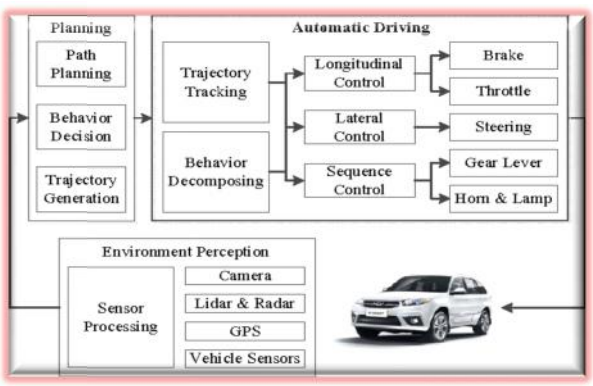

Fig.8 System architecture

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A. Localization

Localization is a critical component of self-driving cars. The self-driving car locates itself in three dimensions. The precision of localization is critical to the accuracy and reliability of autonomous driving. In self-driving cars, the NDT (Normal Distribution Transform) is used. Before approximating the normal distribution, the NDT divides the map space into voxels and assigns a set of points to each voxel. The amount of calculation required grows in direct proportion to the size of the scan data and map. The map is first created for NDT-based localization. A map of a small portion of GIST was created using lidar data for testing purposes. [7].

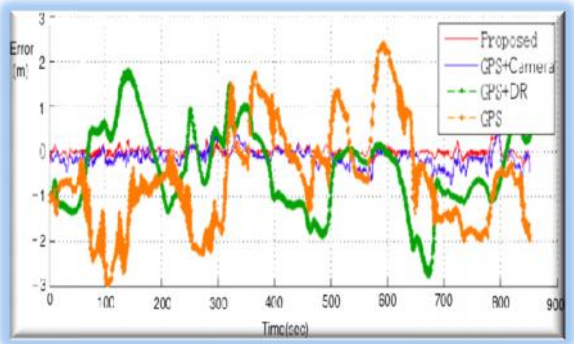

Fig.9 Localization of GPS camera

VII. DECISION MAKING IN SELF-DRIVING CARS

The self-driving car's decision-making system, which includes the route planning, behavior selection, motion planning, and control subsystems.

A. Route Planning

The Route Planner subsystem is in charge of computing a route through a road network from the initial position of the self-driving car to the finalposition defined by a user operator.

Fig.9 Route Planning

If the road network is represented by a weighted directed graph, with vertices representing way points, edges connect pairs of way points, and edge weights denoting the cost of traversing a road segment defined by two way points, then computing a route can be reduced to the problem of finding the shortest path [1].

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VIII. MACHINE LEARNING ALGORITHM

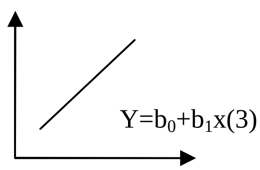
Because the surrounding environment allows for changes, machine learning is critical in self-driving cars.

Types:

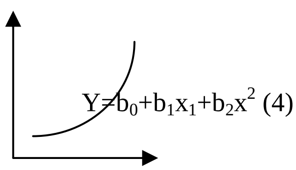
- Regression Algorithm
- Pattern Recognition
- Cluster Algorithm
- Decision Matrix Algorithm [8]

1. Regression Algorithm

Regression analyses are commonly used for forecasting and prediction, and their application overlaps significantly with machine learning. Regression analysis can be used to determine the causal relationships between independent and dependent variables in some cases [9].



(a) Simple linear model



(b) Polynomial linear model

2. Pattern Recognition

Pattern recognition is the recognition of patterns through machine learning. Pattern recognition is used in signal processing, as it is in automotive radars

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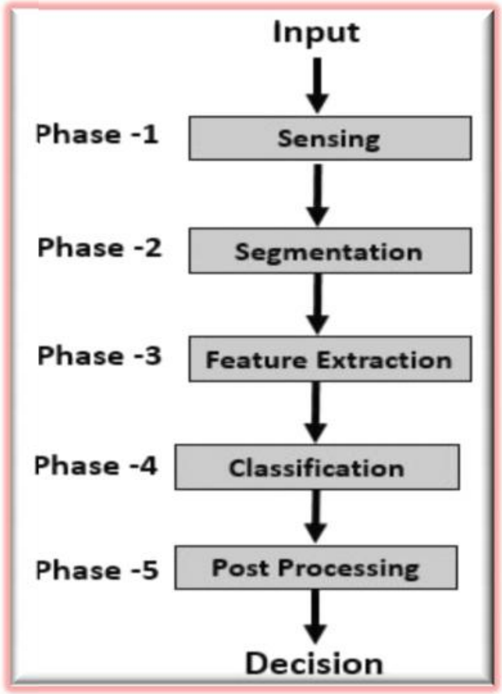

Fig.9 Flowchart of pattern recognition

3. *Cluster Algorithm*

Machine learning is used to cluster the data flows and then create a classification based on the clusters. This is a multi-step procedure. As previously described, the data is first divided into flows. Each flow extracts a variety of attributes [10].

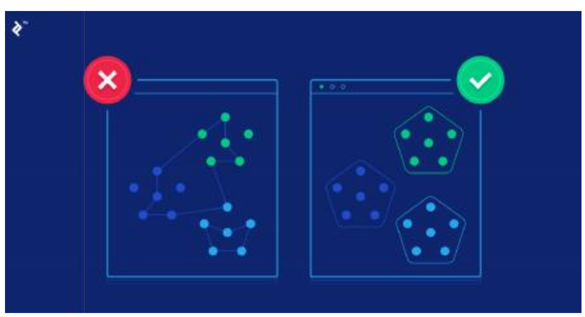

Fig.10 Cluster algorithm

4. *Decision Matrix Algorithm*

A decision matrix is an m n matrix for each element Aij expressing the n-th attribute value of the m-th substitute. That is, Aij denotes the performance rating of the m-th substitute about relation to the n-th element.

$X_1, X_2, ..., X_m$ ⟶ alternatives that are feasible.

$Y_1, Y_2, ..., Y_n$ ⟶ characteristics (criteria).

The relative performance weights of the decision criteria have been defined by Hn. As a result, the matrix given is,[11]

$X = \{a_i \mid i = 1, 2, 3, \ldots n\}$ (5)

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$Y = \{c_j \mid j = 1, 2, 3, \ldots.. m\}$ (6)

$H = \{h_1, h_2, h_3, \ldots.., h_n\}$ (7)

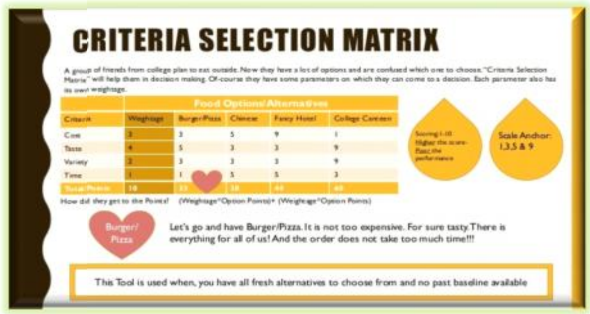

Fig.11 Decision - matrix algorithm

IX. AUTONOMMOUS VEHICLES IN 2022

- Tesla
- Pony.ai
- Waymo
- Apple
- Ford
- Audi
- Huawei

X. SENSOR TECHONOLOGY

Different types of sensors, each with its own set of properties, can be used to detect the location, geometry, type, and motion of things. Camera systems come into play when it comes to image identification. This technique is a low-cost method of identifying objects, however the sensing quality is highly dependent on ambient factors such as weather and light reflection.

Fig.12 Sensor technology in self-driving cars

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The sensor technologies discussed above are employed in their respective applications and integrated with global positioning systems (GPS). Real-time object recognition and interpretation play an important role. The aforementioned sensor data are analysed in this context to build geometric models of environment and traffic-related objects [12].

XI. IMAGE RECOGNITION

Camera-based systems can provide detailed information on traffic circumstances, such as objects on or alongside roadways, traffic signs, road markings, and road conditions, as well as surrounding objects, such as buildings. In this sense, picture recognition is crucial for traffic situation modelling because the machine can view the situation in the same way that a human driver does [12].

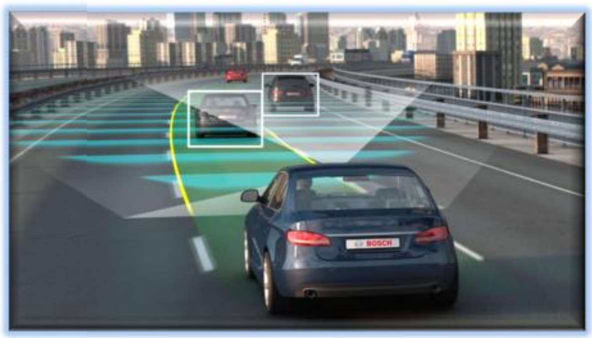

Fig.13 Image recognition

XII. BLIND SPOT DETECTION

The BSD system will be divided into two modules. The first module will use sensors to identify any object in the vehicle's blind spot. The second module will employ machine learning techniques to determine the vehicle's relative speed. Object is the initial module. The detector module is the first module, while the second module is the Assistance Module. The DC can be assisted based on the speed estimations. If the thing in the blind spot is moving at roughly the same speed as our DC, it must alter its speed so that the object is no longer in the blind spot area [13].

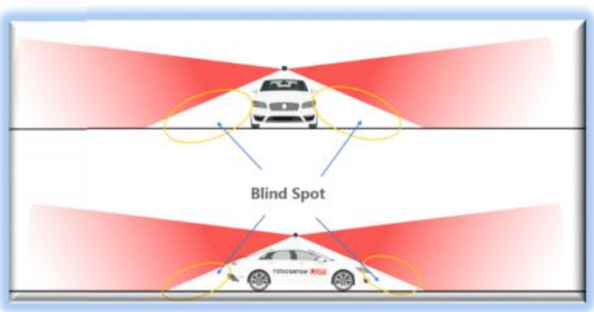

Fig.14 Blind spot detection

XIII. MOVING OBJECTS TRACKING

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The Moving Objects Tracker subsystem, also known as the Detector and Tracker of Moving Obstacles, detects and tracks the pose of moving obstacles in the environment around the self-driving automobile. This subsystem is critical for self-driving cars to make decisions about how to behave in order to prevent collisions with potentially dangerous objects. objects in motion For instance, other vehicles and people [1].

A. Stereo VIsionin MOT

For recognising and tracking moving impediments in the environment, stereo vision-based approaches rely on colour and depth information provided by stereo pairs of images. They use a hypothesise and verify technique for fitting a collection of trajectories to potentially observed obstacles, such that these trajectories have a high posterior probability when combined.

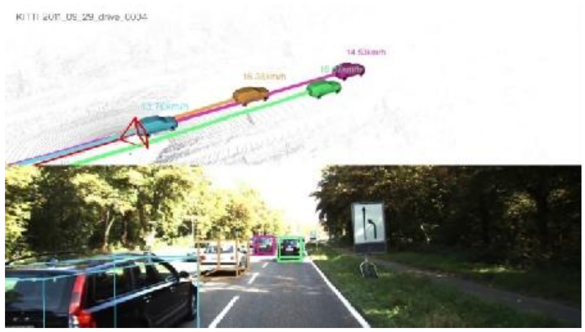

Fig.15 Stereo vision in MOT

B. Sensor Fusion in MOT

Sensor fusion methods combine data from many types of sensors. LIDAR, RADAR, and cameras, for example, investigate their specific properties and improve environment perception. The sensor layer gathers information from sensor input to characterize a moving obstacle hypothesis using either a point model or a box model. The sensor layer also attempts to correlate features with the fusion layer's present projected hypotheses.

Fig.16 Sensor fusion in MOT

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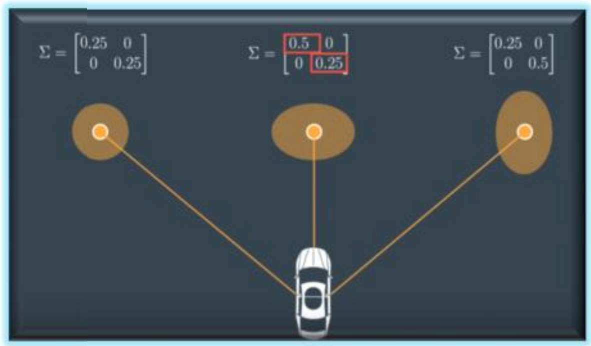


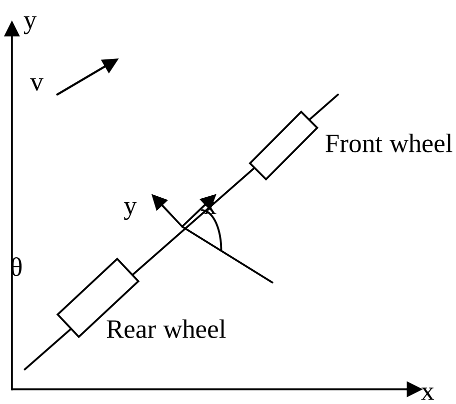
Fig.17 Kalman-filter in sensor fusion

XIV. KALMAN-FILTER

Based on the data our autonomous vehicle receives, the Kalman Filter may be used to forecast the next set of actions that the automobile in front of it will do. It is an iterative approach that employs a two-step predict and update procedure [15].

A. Particle FilterAlgorithm

The particle filter is a Monte Carlo technique capable of dealing with both Gaussian and non-Gaussian noise. Because the vertical movement of the vehicle is minor, we just consider it in a two-dimensional Cartesian space with the vehicle direction [16]. The state of the vehicle is indicated by



Vehicle state in two-dimension

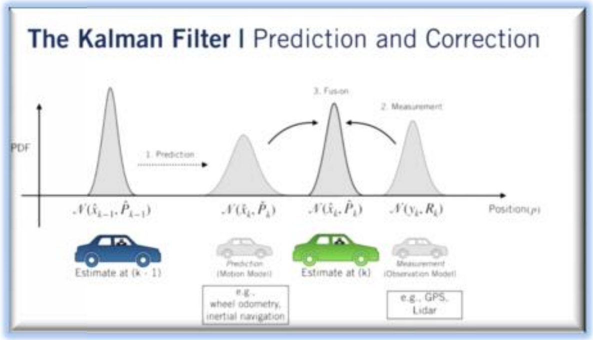


Fig.18 Prediction and correction

XV. ACHIEVEMENTS TILL 2022

Table II

Year-wise achievement in self-driving cars[14]

Year	Autonomous Vehicles
1926	"Linriccan Wonder" was the first radio-controlled car.
1926	Achen Motors' "Phantom Auto."
1939	Previous attempts at driverless cars were radio-controlled.
1940	Bel Geddes is promoting technological advancements in highway design and transportation.
1953	RCA labs created a miniature automobile.
1954	General Motors created an experiment that serves as a traffic counter.
1957	RCA labs successfully demonstrated the full-scale system.
1960	Driving the cars is permitted at the RCA lab headquarters.
1961	With his personal self-driving hovering cars, William Bertelsen was revolutionising transportation.
Mid-1970s	Experiments were halted due to over-accidents.
1980	Mercedes-Benz first robotic van.
1987	HRL lab's sensor-based autonomous navigation vehicles.
1989	Autonomous vehicles will be guided by neural networks.
1991	Demonstrate self-driving vehicles on highways.
1997	Intend to operate in both segregated traffic and as a "Free Agent." Toyota and Honda are also taking part.
1993	Han Min-Hong was involved in the development of self-driving cars. He made use of Asia Motors.
1994	The twin robotic vehicles.
1996	The vehicle was outfitted with low-cost video cameras and stereoscopic vision.
2005	Cars designed with lidar sensors and built with Velodyne LIDAR.
2008	World's first commercial autonomous vehicles.
2010	General Motors, Ford, BMW, Benz, Toyota, and Audi, among others, are testing driverless car systems.
2012	Toyota Prius modified Google's experimental dor driverless technologies and received a DMV licence.
2013	Mercedes-Benz created an S-class vehicle equipped with near-production stereo cameras and radar.
2014	The Mercedes-Benz S-class offers autonomous steering, lane keeping, acceleration/braking, parking, accident avoidance, and driver fatigue detection as options.

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2014	The Navia shuttle was the first commercially available driverless car.
2015	Tesla Motors introduced Autopilot technology for vehicles equipped with systems that enable autonomous driving.
2015	Tesla Motors has released versions 7 and 7.1 of its vehicles with Autopilot capability.
2017	The introduction of Level-3 automation technology was announced.
2019	There are fully automated vehicles on the market.
2020	GRVA established regulation on SAE Level-3.
2021	Honda is outfitted with newly approved Level-3 automated driving technology.
2021	Mercedes-Level-3 Benz's Automated Lane Keeping System has been approved in Germany.

XVI. ADAPTIVE CRUISE CONTROL

The current development and availability of ACC systems expands on previous cruise control systems, which were designed to reach and maintain a predetermined speed set by the driver. The ACC system extends its functionality to instances where driving at a consistent pace is impossible due to heavy traffic.

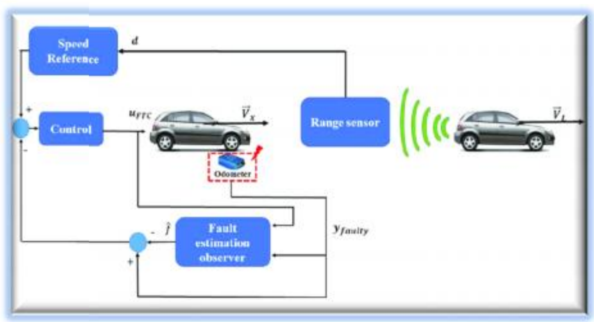

Fig.19 ACC system

Furthermore, the IDM algorithm was recently used as the foundation for an ACC implementation in a Volkswagen test car as part of the German project. This model represents ACC automobiles in the following scenarios[17].

XVII. OBSTACLE AVOIDER

In the obstacle avoider subsystem, to decrease accidents, the subsystem alters the motions planner projected path and reduces velocity as necessary. There is not much information accessible concerning how to use the obstacle avoider subsystem. If a collision is anticipated along the path, the obstacle avoider reduces the self-driving car's linear velocity in order to avoid a crash.

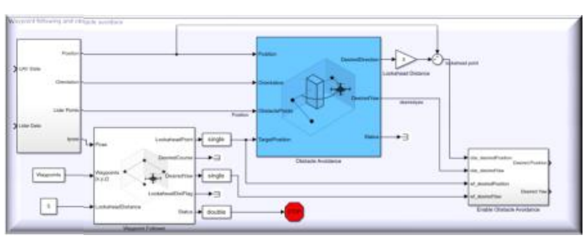

Fig.20 Obstacle Avoider Subsystem

XVIII. ADVANTAGES OF SELF-DRIVING CARS

- Machines do not tired
- Robots make less errors.
- Systems do not have feelings
- There is no danger of intoxicated driving
- Robots have the ability to maintain steady focus
- Self-driving cars obey traffic laws.
- Robots have longer attention spans.
- Mobility enhancements for persons who are unable to drive
- Possibility of cheaper insurance rates with a more convenient driving experience
- On average, it may be speedier.
- Allows you to work while driving.
- Savings on gasoline
- Reductions in automobile thefts as a result of improved air quality
- Reduced fatalities as a result of driver errors
- Economic benefits[18].

XIX. CONCLUSION

The race for commercial autonomous vehicles is well underway among major corporations and research institutions. They have the potential to drastically alter our perceptions of and use of transportation. Self-driving cars are efficient and environmentally friendly modes of transportation. It promises to improve safety and reduce traffic. Autonomous vehicles are becoming increasingly important in today's hectic world. It has the potential to reduce road accidents and driver error. When fully developed, it can have a positive impact on our safety and make us safer while driving.

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