ARTIFICIAL INTELLIGENCE USED IN AN AUTONOMOUS CAR: A REVIEW

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Abstract : In this paper we have completed a substantial survey on Self Driving Cars and the technologies used in them. This article deals with the involvement of Artificial Intelligence in Autonomous cars and the general benefits acquired by the usage of Machine Learning and Artificial Intelligence in Autonomous Vehicles. Furthermore, we have also reviewed some issues that designers and developers come across in the process of implementation of an autonomous vehicle. The modern society is being revolutionized by the use of Artificial Intelligence and especially in the field of Automotive Industry wherein researchers and developers, for the purpose of autonomous driving have been actively pushing the scope of Artificial Intelligence. We have also discussed primary issues which are faced during the real-time implementation of autonomous cars such as Validation and testing, Safety and reliability, Security and hacking threats, Data Management, Accuracy in object detection and Decision making.

***Index Terms* – Artificial Intelligence, Machine Learning, Cognitive Capabilities, Machine Vision, Deep Learning.**

I. INTRODUCTION

An Autonomous car, also known as a Self-Driving car is a vehicle which is capable of analyzing its environment and is operates with little or no human support. Autonomous cars combine a variety of sensors to perceive their surroundings, this includes radar, computer vision, Lidar, sonar, GPS, odometry and inertial measurement units. An autonomous vehicle grasps information extracted from the inertial navigation system- a device that accumulates errors over time-and the GPS to determine where it is located and then uses the sensor data to further refine its position. Self-Driving cars are expected to make independent decisions to obey traffic laws, optimize fuel consumption, reduce pollution and above all protect the safety of the driver, passengers and the pedestrians. The development of Autonomous driving systems, which is an eminent application of Artificial Intelligence (AI) and Machine Learning (ML) techniques is currently a cynosure of research. Although not yet commercially available on a large scale, Driverless cars, including Google's autonomous car design- Waymo One and Tesla's various vehicles featuring their infamous Autopilot technology have logged thousands of hours on American roads. Driverless cars, also an epitome of vehicular intelligence, a notion embedding autonomy, Machine Learning, Artificial Intelligence and Adaptability that enables the car to learn by experiencing continuously the improvements, eventually outshining human driving skills.

II. LITERATURE REVIEW

Rasheed Hussain and Sherali Zeadally published a paper on **'Autonomous Cars: Research Results, Issues and Future Challenges'.[1]** This paper deals with the different technologies, Sensors and Research involved in the manufacture of a self-driving car. A number of design and implementation issues such as cost of materials, software complexity is also discussed in this paper. This would assist a specific group of individuals: researchers who look forward to collect information about the latest research results related to autonomous cars and students in order to gain knowledge about the growing field of driverless cars. We plan on using this data to address a number of issues that are discussed in this paper related to the real-time implementation and production of self-driving vehicles.

Syed Owais Ali Chishti, Sana Riaz, Muhammad Bilal Zaib and Mohammad Nauman published a paper on **'Self-Driving Cars Using CNN and Q-learning'. [2]** A simulation of real world scenarios such as roads, obstacles and lanes were built to address the plan of this paper. A book sized Raspberry Pi based car was built to be tested around in the custom built environment. The custom made environment consisted of map tracks, turns and dead ends. Road signs such as the Stop signs, direction markers and Traffic lights along with other similar signs were added to the custom environment too. The Raspberry Pi based car was made to drive around this custom built environment and learn the surroundings using the Deep Q Learning algorithm. Once the car was trained using the custom environment, it could then be used in any other environment using a real car. We plan on using the approach of this paper in order to define the Deep Q Learning techniques that are used in the training of a self-driving car with maximum efficiency.

Mochamad Vicky Ghani Aziz, Ary Setijadi Prihatmanto and Hilwadi Hindersah published a paper on **'Implementation of Lane Detection Algorithm for Self-Driving Car on Toll Road Cipularang using Python'. [3]** This paper discusses the results obtained on implementation of the lane detection algorithm on a normal double laned road. Python 3 is used as the language for image processing of the data collected by the cameras and a collection of methods such as Canny Edge Detection, Hough Transform, colour region and line selection are used to detect the lanes accurately. We have used the basic plan of this paper in order to explain important technologies such as Machine Vision which is the primary component of any lane detecting algorithm.

Divyajeet Bajpayee and Prof. Jitendra Mathur published a paper on **'A Comparative Study about Autonomous Vehicle'. [4]** This paper explains the different sensors, actuators and motors that are used in a self-driving car. The concept of Intelligent Transport System (ITS) is also explained in the course of this paper. A brief comparison of advantages and disadvantages of different sensors used in an autonomous car is also discussed which proves to be helpful while selecting different sensors based on their cost, range and usability. This paper also explains different feature keys in an autonomous vehicle along with their key benefits including Personal Rapid Transit (PRT), Demand Responsive Transit (DRT) and improved disaster response.

Giuseppe Lugano published a paper on **'Virtual Assistants and Self-Driving Cars: To what extent is Artificial Intelligence needed in Next-Generation Autonomous Vehicles?'. [5]** This paper deals with the concept of Human Autonomous Vehicle (HAV) Interaction and how it would play as the primary key to achieve benefits in a self-driving car. The paper also discusses the different type of virtual assistants that are both commercially available and commercially unavailable that are deployed by different consumer electronics manufacturing companies like Apple's Siri, Microsoft's Cortana, Amazon's Alexa etc. And the usage of Artificial Intelligence in these virtual assistants is also widely discussed in the course of this paper. This concept of artificial intelligence that drives these various commercial virtual assistants also drives the autonomous vehicle as these virtual assistants are being slowly integrated inside the autonomous vehicles by using different technologies that are produced by the car manufacturing companies themselves.

III. ARTIFICIAL INTELLIGENCE IN AUTONOMOUS CARS

Artificial Intelligence (AI) systems make use of data and algorithms to impersonate the cognitive functions of the human brain. The reason why Artificial Intelligence (AI) is swiftly being deployed across a number of Industries is that, it has the ability to learn and solve problems solitarily. The Automotive industry is among the industries at the front line of using AI to mimic, elevate and brace the actions of humans, while simultaneously leveraging the advanced reaction times and pinpoint precision of machine-based systems. The fundamental pillars of Artificial Intelligence that bolster the existence of Autonomous cars are: -

1. Machine Learning
2. Deep Q Learning
3. Internet of Things (IoT)
4. Machine Vision
5. Cognitive Capabilities

Following is the brief description of each fundamental pillar and further we have discussed their use in an Autonomous Vehicle:

1. **Machine Learning:** It refers to the ability of a machine to understand and learn a task and eventually improve itself to perform the same task from gaining experience without the use of explicit programming. Machine Learning algorithms are designed in such a way that on the basis of data or direct experience the machines are able to carry out a specific task and make decisions without human intervention. Machine Learning basically can be divided into two types:

Supervised Learning: Supervised Learning involves analyzing a known data set and output, the use of a particular algorithm can separate the data problem into two parts, namely: a) Regression; b) Classification. Supervised Learning algorithms are used to make predictions for a given problem statement and can also compare its output with an intended output and on the basis of errors, make suitable alterations.

Unsupervised Learning: In Unsupervised Learning specific types of data is clustered together using an algorithm. It basically finds the structure in the given set of data. It is used in case of an unclassified and unlabeled data.

One of the major jobs of a Machine Learning Algorithm in an Autonomous car is the continuous sensing of the surrounding environments and calculating the possible changes within these surroundings. These tasks are basically bifurcated as:

The Detection of an Object: Self-Driving cars have been a dream since a very long time. Knight Rider-- the fiction movie was merely based on the same theme, decades prior to when people have started serious efforts towards manufacturing an actual Self Driving car. In order to make an Automated car work in a Real-Time environment, the most important technology is Obstacle Detection. Without efficient obstacle detection, the whole system will collapse. These obstacles are divided into two types: Static and Dynamic. Examples of static objects are trees, rocks, sign boards etc. Dynamic objects are further divided into two more types: Motor Objects and Non-Motor Objects. Motor objects include all kinds of vehicles, cars, trucks etc. And the non-motor objects are pedestrians, animals, cyclists etc.

Many approaches are used to detect obstacles for example: GPS (Global Positioning System) and LIDAR (Light Detection and Ranging Device) in combination with sensors like camera. However, cameras are not suitable for low illumination so LIDAR is the better approach. LIDAR detects obstacles by emitting light and then calculating distance of vehicle from that obstacle. Another approach of detecting obstacles is extracting raw images and then feature extraction is done by sending data into classifier. Convolution Neural Network (CNN) is used for this approach along with back propagation algorithm. Multiple object tracking and detection is done by Co-Fusion process, which uses SLAM (Simultaneous Localization and Mapping) system.

LIDAR gives better results a camera as it provides an in-depth information of an image and not affected by weather conditions and distance. While in case of standalone cameras, the image gets distorted because of distance because of which estimation and tracking cannot be done with precision. It also eliminates the effect of phantom obstacles.

Another approach is the Co-Fusion method in which enabling a system to make 3D models for segmented objects is used by separating background from foreground.

The Identification of an Object or recognition object classification: Object classification is an important issue in order to bring autonomous vehicles into reality. Robust perception is an important factor for creating an environmental model around the vehicle. For doing so, object classification techniques must be implemented for object identification and path planning. LIDAR is an important sensor which captures 3D point cloud from all directions. Clustering methods are applied to extract a set of points and group them as individual objects. The entire process of Object Classification can be summarized as follows:

Feature extraction: Features such as size, shape, intensity and velocity are classified. All the features are computed at large speed in order to satisfy Real-time applications. Object's features are calculated from 3D coordinates and reflectivity of point clouds.

Classification: The Classifier outputs the score of each class. Classification of the objects is done using the Real AdaBoost classifier Algorithm. The Real AdaBoost algorithm has some advantages over the trivial methods, the classifier delivers a better performance, is easily implementable and also has a very low processing time. This algorithm is divided into two parts: Weak Classifier and Strong Classifier. The weak classifier generally creates a 1D probability distribution using a single feature of all the objects. The strong classifier is then created by combining a set of weak classifiers. A better method to classify objects using LIDAR sensor is to use a 2D probability density distribution function which is more distinguishable as it is a result of the consideration of multiple features. The learning time is not long as the number of features to be sensed are limited.

Probability Calculation: The scores are then converted into probability for using logistic regression analysis. Even though human drivers necessarily do not think in terms of probabilities, we still do observe ourselves making certain decisions based upon a predictive analysis conducted involuntarily by the drivers while driving a car. A driver will never calculate the probability of a certain vehicle attempting a sudden break while driving on a highway, but the driver, through similar situations experienced in the past, makes the best guess and takes a decision accordingly. Autonomous cars, similar to the humans will take decisions based on the probability analysis but as a result of various processes. The main motive behind the calculation of Probability in a self-driving car is safety. There are two main components to achieve safety, first, accurate data should be collected by the computer and second, correct conclusions should be drawn considering the model's data by the reasoning system.

The localization of an Object and Movement Prediction: Prediction in an autonomous vehicle is all about predicting the trajectory of another vehicle in such a way that allows both the vehicles to travel on the same road, simultaneously without getting involved in a collision.

2. **Deep Learning:** Deep Learning, Machine Learning and Artificial Intelligence based technologies are vital for Autonomous cars. The unpredictable behaviour of the surrounding objects and the environment is the main reason for the significance of these techniques in today's era. In traditional software, the operational logic is written down manually and then tested over a series of test cases whereas in the case of DNN (Deep Neural Networks) based software, the software learns and adapts to certain situations with the help of large data sets. Deep learning is a solution to more intuitive and complex problems that cannot be easily solved by using classical methods. Deep Learning tends to eliminate the requirement of a human driver and enables the driverless car to learn by itself the changes occurring in its surroundings from time to time. Deep Learning techniques have been persistently used by the automotive industry for the development of advanced driver system functions and has also been recently expanded to the production of Autonomous Vehicles. The favoured Deep Learning models used in autonomous car technology include End-To-End Learning, CNN (Convolutional Neural Network), Deep CNN, FCN (Fully Conventional Network), DNN (Deep Neural Networks), Belief Networks, Deep Reinforcement Learning, DBM (Deep Boltzmann Machines) and Deep Autoencoders.

Convolutional Neural Networks: CNN makes efficient use of patterns and structural information in an image. In other Deep Learning models such as RNN, bad images are produced as a result of output dependency on previous values, while in LSTM (Long Short-Term Memory) the output tends more towards previous states as the sequence becomes too long.

Deep Reinforcement Learning: Deep Reinforcement Learning is a combination of Deep Learning and Reinforcement learning. Reinforcement learning consists of an agent having states and corresponding actions. So, to perform a task the agent learns from its experience and some previous knowledge. Hence, reinforcement models consist of different dynamics i.e. Rewards or Punishments to reinforce unparalleled types of knowledge. At any particular moment, the agent is in some feasible state. In the successive time step, this state transformed to some other state(s) by executing certain actions. This action is accompanied either by a reward or a penalty. The goal of the agent is to maximize the reward gain. The Reinforcement Learning algorithm can be depicted by the following update formula:

$$Q(s_t , a_t) \leftarrow Q(s_t , a_t) + \alpha (r_t - Q(s_t , a_t) + \gamma \, max\{a'\} \; Q(s_{t+1} , a'))$$

here $Q(s_t , a_t)$ represents the Q value of the agent in state s_t, action a_t at time t rewarded with reward r_t. α = Rate of Learning and γ = Discount factor.

3. **Internet Of Things (IoT):** The Internet of Things (IoT) provides the ability for humans and computers to learn and interact from billions of objects that include sensors, actuators services and other internet connected systems. Since the 1990s, Internet has connected Computers and Machines around the world. The Internet, as we know it became a communications infrastructure that has adopted beyond just freely connecting people. Internet of Things (IoT) contains technology that allows people to interact and connect with our natural and built environments. The Internet of Things (IoT) is a domain that provides the next most exciting technological revolution since the internet. IoT can transform manufacturing thus making it leaner and smarter.

The heart of an Autonomous car is its computing unit that executes the logic of autonomous cars in a comprehensive way in which sensors and actuators play a crucial role in the implementation of the system. The data required for the implementation of any algorithm is acquired through arrays of different sensors which combines together to form a large sensor network within the car. The environment of an autonomous car changes constantly and it is crucial to incorporate a stable mechanism that deals with the new unanticipated environments such as obstacles on the road.

The different sensors that manoeuvre an autonomous vehicle are Cameras, LIDAR, RADAR, SONAR, GPS (Global Positioning System), Inertial Measurement Unit and Wheel Odometry.

Camera: The first and the most vital sensor used in an autonomous vehicle is the Camera. Advanced vehicles have dozens of cameras mounted on them which enable literal visualization of their surroundings. Their wide availability, affordability and efficiency at classification of texture perception form the paramount reasons for their extensive use in autonomous cars. High definition cameras have the capability to produce millions of pixels per frame, with 30-60fps (Frames per Second) to develop intricate imaging which leads to multi-megabytes of data to be processed in real-time. Camera being a crucial sensor in autonomous driving, has endless applications such as perception, semantic segmentation, end-to-end autonomous driving and much more. Cameras can also be used inside of the vehicle for Human-Machine interaction.

RADAR: RADAR stands for Radio Detection and Ranging. It is a sensor integrated into an autonomous vehicle for the purpose adaptive cruise control, blind-spot warning, collision warning and collision avoidance. RADAR uses Doppler Effect to measure speed directly while other sensors measure velocity by calculating difference between two readings. In sensor fusion, Doppler Effect plays a crucial role as it gives information about velocity as an independent measure parameter and makes fusion algorithms converge much faster. Long-range RADAR is a microwave RADAR operating at 77GHz, has a low resolution but measures speed and detects vehicles and obstacles within 200m range. Short/ Medium range RADAR is mature and inexpensive operating within 24 GHz and 76 GHz bands. This sensor can detect velocity and distance, however broad beans and long wavelengths limit resolution and produce complex return signals. Even though RADAR is highly efficient, in certain situations like bad weather, RADAR has less angular accuracy and generates less data than LIDAR. RADAR does not have any heavy-data feeds to process but has lower processing speeds needed for handling data output. RADAR can be used for generating environment map seeing underneath other vehicles, spot buildings and objects. It has a wide field of view, about 150 degrees and has a low resolution, especially in vertical direction.

LIDAR: LIDAR stands for Light Detection and Ranging. It is used as an Infrared laser beam determining the distance between sensor and nearby object. Most current LIDARs operate in 900 nm wavelength range, although some use longer wavelengths showing better performance in rain and fog. In recent LIDARs, a rotating swivel scans the laser beam across the field of view. The lasers are triggered and then the transmitted pulses are reflected by the objects which return a point cloud that represents these objects. LIDAR has a much higher spatial resolution as compared to RADAR because of the more focused laser beam, large number of scanned layers in a vertical direction and high density of LIDAR points per layer. These types of LIDARs cannot measure velocity of objects directly and need to rely on different position between multiple scans. LIDARs with a MEMS (Micro-Electro-Mechanical System) vibrating micromirrors have a possibility to scan the laser beams. Dividing a single laser beam into multiple waveguides, the phase relationship between waveguides can be altered and thereby the direction of the laser beam shifted. Coherent LIDARs can measure velocity directly.

An overview of different sensors used in a self-driving car is tabulated in Table. 1 shown below:

Pros and Cons of different sensors that are used in an autonomous car are discussed in the table given below.

Table. 1 Overview of Sensors used in a Self-Driving car

Sr No.	Sensor	Pros	Cons
1	**Radar**	1. Suitable in environment with reflections. 2. Accurate Distance detection. 3. Long range and short-range detection is possible. 4. Accurate Speed detection.	1. Poor lane detection. 2. Large in size. 3. Poor vehicle and pedestrian detection.
2	**LIDAR**	1. Proper obstacle detection. 2. Can detect small sized objects. 3. Good distance and speed detection.	1. Poor lane detection. 2. Poor vehicle, pedestrian detection. 3. Smaller range than Radar.
3	**Camera**	1. Usable under low-light conditions. 2. Proper lane detection.	1. Poor contrast shown by traffic signs.

4. **Machine Vision:** Machine Vision bounds all applications which is a cluster of hardware and software approaches that provide operative guidance to devices which are based on capturing and processing of images. Machine Vision is a science that allows a machine to acquire and understand images and videos and execute functions on the basis of what the computer *sees* or *recognizes*. On one hand when human vision works best for qualitative elucidation of a complex, unstructured scenario, Machine Vision is proved to be excellent at quantitative elucidation of a structured scenario because of its pace, precision and repetition. In order to mimic human-like behaviour while driving, autonomous cars must be able to *see* the road and detect any obstacles in front of it and around it. These key features along with other modules enable autonomous cars to drive along the road and respond to any situations such as stopping at traffic signals, slowing if the preceding car reduces its speed, avoid running into pedestrians and so on. Computer Vision in autonomous cars involves Object Detection, Calibration and Motion Estimation. While detecting an object, machine vision should take into account factors like shadow, identical objects, lighting conditions and so on.

Sensors such as LIDAR generate data and other RGB images are taken as input in a self-driving car and this data is represented in a 3-dimensional form. Deep Learning algorithms are applied on this 3-dimensional data for object detection. Construction of a 3D image is also considered an important feature of Computer Vision. This must be included in a self-driving car for motion planning and activation. The main aim of this construction is to acquire minute details while construction of a 3D map.

Edge detection is a fundamental tool in Image Processing, Machine Vision and Computer Vision, particularly in the area of feature detection and extraction. Edge Detection is a process which is applied for identifying those points in a digital image at which the image brightness changes abruptly and also has discontinuities. Such points are structured into a set of curved lines called as the edges. Discontinuities in image brightness correspond to discontinuities in depth, discontinuities in surface orientation, variation in material properties and variation in scene illumination. The edges extracted from non-trivial images are usually hampered by

fragmentation i.e. not connected edges, missing edges as well as false edges, all of which complicate the task of interpreting the image data. Edge detection is important for image processing, image analysis, image pattern recognition and computer vision techniques. The concept of feature detection implies abstraction of image information and making local decisions at every point on the image. Region Masking of the image is performed with Hough Transform to find imperfect instances of objects within the image by a voting procedure. Hough Transform deals with identification of lines and identifying the position of arbitrary objects in an image.
In the figures 4.1 and 4.2 given below, the outputs of a lane detection algorithm using Machine Vision are shown. Fig 4.1 represents a normal image that was captured by a camera on a highway before implementing the lane detecting algorithm. Whereas Fig 4.2 represents the same highway after the lane detection algorithm has been implemented. The detected lanes are represented by red lines that are sensed by the car and hence drives driverlessly.

Fig 4.1- Normal Image Before Implementing Lane Detecting Algorithm

Fig 4.2- On Implementing the Algorithm

5. **Cognitive Capabilities:** Artificial Intelligence not only depends upon the development of computers but also on their computational development. Over the years the ways and processes of human thinking have been welcomed by computational experts and has become the backbone of Artificial Intelligence. This continues with the development of cognitive science that encourages Cognitive Thinking Intelligence, a new pathway of Artificial Intelligence that can emulate human Cognitive abilities even if not 100%. Emulation of these abilities is developed based on the modelling of system interaction with the environment and information fusion, which can be used to conduct inferencing, so when it occurs repeatedly it will produce knowledge that grows. This process which is brain inspired Cognitive Intelligence is called Knowledge growing system and can be used for information extraction and effective implementation.
An important task of autonomous vehicle in increasingly complex and uncertain environment is Decision Making. As mentioned in the previous sections, the algorithms and techniques used for running an autonomous car produce results which are basically predictions with the high probability. Cognitive capabilities in an autonomous car is thus responsible for selecting the most appropriate prediction with the highest probability. Factors such as obstructions and uncertain environment affect the prediction and ultimately the decision making process. Such issues are caused by noise in sensory data, unforeseeable behaviour, limitation of sensors and most importantly the hidden state of neighbours. For the purpose of predicting the highest probability, the autonomous car system, must have detail information about its neighbours, however in some cases such information may not be available. This limitation poses serious problems in the prediction and perception modules of an autonomous car thus affecting decisions. Human behaviour impersonation in autonomous cars is extremely difficult which makes the decision making process even more challenging. Decision making is multi-dimensional and depends upon factors like the car's behaviour, perception, prediction, neighbours, sensor data processing, component calibration and so on.
Existing decision making mechanism can be divided into Machine Learning, Deep Learning, Multi-Policy decision making and Markov decision process. Although efforts have been made to make decision making decision making more reliable, there are certain issues that still need to be addressed hence a holistic approach should be considered while decision making in an autonomous car.

IV. ISSUES IN REAL-TIME IMPLEMENTATION OF SELF-DRIVING CARS

The future of Autonomous Cars depends upon their safety, robustness, fail-safe nature, hardware/software design and most importantly on consumer satisfaction. However, there are some challenges which must be addressed by various developers and manufacturers in order to enable ubiquitous deployment and full commercialization of autonomous cars. To achieve these goals, it is important to overcome certain issues as the autonomous car need to provide extreme precision, safety and reliability. In this section we have highlighted the various issues faced during the development of an autonomous car.

1. Validation and Testing:

Validation and Testing are two of the most important requirements in the development of autonomous cars. Depending on the requirement, application and degree of sophistication, the time and effort for validation and testing can vary. Several techniques exist for validation and testing. However, mission-critical and safety-critical systems require detailed comprehensive validation and testing in order to make sure that all the precise requirements are met. Any decisions made by an autonomous car will directly affect human lives and hence validation and testing is of utmost importance. Unique feature of an autonomous car is that there is no human driver and this affects the traditional validation and testing techniques. In the presence of a human driver, in spite of any critical situation human mind can still think, at least in most cases of alternate solutions. On the other hand in case of autonomous cars, there is a high degree of uncertainty of how the system responds to critical situations such as bad weather, traffic rules violation, pedestrians and so on. Since autonomous cars use sensors like LIDAR, Radar, cameras, it is mandatory that a proper testing and validation of these sensors both individually and in accordance with each other is done several times before a car is deployed on the road. Hence a proper testing is required before the complete implementation of a self-driving car.

2. Safety and Reliability:

Safety and Reliability in an autonomous car is a critical issue. Any autonomous car must conduct test drives equal to hundreds and millions of miles before this technology is commercialized. Non-Critical statistical analysis which includes a large amount of data helps in determining the reliability of a system. This data is nothing but the distance travelled by the car. It is assumed that an autonomous car must drive itself around 291 million miles without fatality to guarantee 95% confidence in resemblance to a human driver. This critical requirement impedes the success of this emerging technology. Hence new methods for testing the safety and reliability are required. In recent years multiple major automobile companies have started developing their autonomous cars and conducting test drives in order to ensure the complete safety of the driver, passengers travelling in those cars and also the pedestrians present on the roads.

However, it is important to know that none of the 2578 disengagements that these companies experienced while road testing their autonomous vehicles in 2016 resulted in an accident. Therefore, in order to ensure the safety offered by a fully autonomous vehicle requires an interdisciplinary approach across all levels of functional hierarchy, from hardware fault tolerance to flexible machine learning, validating systems for operation in highly unstructured environments, to cooperating with humans driving conventional vehicles, to appropriate regulatory approaches.

The table given below represents the number of autonomous miles driven by the autonomous cars of different companies and the disengagements they came across during this testing.

Table. 2 Disengagements faced during the testing of Autonomous Cars

Company	Autonomous Miles	Disengagements
Google	635868	124
Cruise	10015	284
Nissan	4099	28
Delphi	3125	178
Bosch	983	1442
Mercedes	673	336
BMW	638	1
Ford	590	3
Tesla	550	182
Volkswagen	0	0

3. Security and Hacking Threats:

Security has always been an important issue in autonomous cars. Security and privacy have always been the major factors impeding the deployment of connected car technology. In this technology data is shared among vehicles and with the infrastructure for various purposes which makes ensuring the quality of data very important. Also, data must not be accessed by any unauthorized entities. It is mandatory for the user and location information to be secure during all communications. The existing threat mitigation leverage both traditional, cryptographic and non-cryptographic mechanisms to provide security and privacy. The internal architecture of the autonomous car is a complex network with multiple elements often connected through the CAN (Controlled Area Network) Bus which is susceptible to hacking. A fully automated system would be a favourite target to selfish users, hackers, discontented employees or terrorist organizations. Researchers at multiple universities like China's Zhejiang University, University of South Carolina and Chinese security firm Qihoo 360 demonstrated that it is possible to jam various sensors on a Tesla Model S which causes the failure of its navigation system as the object becomes invisible to the system. Security experts are constantly exploring new defense mechanisms for autonomous vehicles. However, as security mechanisms evolve, so does the threat model which means in a truly autonomous environment security issues are likely to happen. An Autonomous car hosts a network of multiple sensors and other communication devices which support the decision making process and drives the autonomous car. The traditional security threats to these devices include hacking into an in-car network, injection of malicious code into different sensors and other units, external signal spoofing during communication, packet sniffing, packet fuzzing, jamming and so on. Security is thus a key component which must be considered while designing an autonomous car. An autonomous car must be full proof and tamper-resistant and to achieve these goals more research is needed in the field of security with respect to autonomous cars to identify real-world threats in addition to the traditional existing security challenges for an autonomous car.

4. Data Management:

Autonomous cars have multiple sensors which together generate large amount of data in real-time. Multiple components of an autonomous car use this data for proper functioning. However, the data generated is too much to be handled by the algorithms used in the car. This is a significant challenge to the efficiency of the car. Other challenges related to the data include redundancy, coarseness, anomaly and so on. Thus, efficient and Real-time data management is of utmost importance. A fundamental requirement in an autonomous car is achieving response in mere seconds. And for acquiring such rapid results, it is important to have a good metadata which helps in the management of complexity. To meet this challenge proper indexing of the metadata and query management is required. Current data processing algorithms experience high computation and communication overheads. Hence crowdsourcing and crowdsensing play a vital role in the future of autonomous cars. So, to put it differently, instead of having a large array of sensors, having an optimal number of sensors and sharing data among the neighbours are likely to produce better results. This perspective seems favourable but the mobility of autonomous vehicles and their interaction with each other and the environment will pose many other challenges which need to be addressed. Some other challenges include number of sensors, cost of sensors and the overhead that they incur on the data processing and decision making system.

5. Accuracy and Efficiency in Object Detection:

The different types of sensors used in an autonomous car are LIDAR, radar, cameras. LIDAR, which is mainly used for short-range object detection, possesses the main limitation of having a short coverage range. This basically means that LIDAR is not suitable for long distances. From the perspective of an autonomous car in motion, it is important that the plan to control an autonomous car is executed incrementally as there are high chances of obstruction in the plan trajectory by unforeseen objects or unpredictable behaviour of neighbouring vehicles. In addition to this, reflectivity issues also affect the efficiency of LIDAR. As opposed to this, radar uses radio waves to measure the distance from target objects. Nevertheless, radars have their own limitations despite their advantage of possessing a long range as compared to LIDAR. Radar also suffers from reflectivity issue but only in this case it is even worst as radar can only detect metallic objects such as vehicles on the road. Pedestrians, potholes cannot be detected using radar. Therefore, only LIDAR and radar will not work on their own. The use of finite-state machines has been brought up by some researchers to address the issue of effective and runtime motion planning. These finite state machines generate sub-goals as replanning incremental strategy although the cooperation among different components including LIDAR, radar, ultrasonic, infrared, GPS and inertial position system is essential. The main drawback with LIDAR is its high cost, which has been decreasing recently and current LIDAR possess better efficiency. Infrared sensors and ultrasonic sensors are used for short range and adequately contribute to the overall functionality of the vehicle. However, intelligent analysis of each sensor and communication among sensors are needed.

6. Decision Making:

The fundamental ability of an Autonomous car is to adjust its behaviour according to the surrounding environment. However, the unpredictable nature of the decision making process and the surrounding environment poses serious challenges for the designers and the developers of an autonomous car system. In ideal situations, an autonomous car exactly replicates human behaviour. However, in a practical scenario, the best possible outcome is considered. Object Detection and Perception are two primary components of the decision making procedure of an autonomous car. Additionally, context is an equally important input parameter in the decision making process wherein a lot of research is still required. The decision making procedure of an autonomous car may be complete but may not be optimal at all times. For example, it is still a challenging task to detect errors and failures of various systems such as sensors and actuators in an autonomous car. Judgement is a primary characteristic in the decision making process of an autonomous car. Based on the information perceived by a self-driving car, the best judgement is taken into consideration. However, in real world scenarios it may not necessarily be the best judgement. Therefore, many decisions taken by an autonomous car require a human element obtained from the acquaintance with the situations and understanding of multiple consequences. This entire process will require multiple trial and errors until a fully capable system is obtained.

IV. CONCLUSION

The development of autonomous vehicles is a rapidly growing field and Artificial Intelligence is paving the way towards it. Contemporary developments in Autonomous Cars reflect the vivid features autonomous cars behold. Autonomous cars will have great impact on our lives. It will make driving safer, more convenient, less energy intensive and cheaper. Autonomous cars have multiple benefits which include safety for both passengers and pedestrians and other vehicles, improved traffic conditions, convenience, new business opportunities and much more. However, before full commercialization of autonomous cars there are certain design and implementation issues that need to be addressed. In this paper we have discussed the basic chronology leading to the development of autonomous cars. Autonomous vehicles developed from basic robotic cars to much efficient and practical vision guided vehicles. Modern development in autonomous cars reflect the vivid future that Autonomous cars behold. Multiple automobile companies have started the production and development of autonomous vehicles and also predict full deployment of autonomous vehicles in the next decade. However, it is important to address some important issues before the full deployment of autonomous cars. If not, the issues reviewed in this paper could cause serious problems to both the developer and the customer. Overall, the cardinal purpose of this review is to provide an educational insight to students and other individuals to assist them in the field of artificial intelligence and autonomous driving.

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