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Artificial Intelligence in Autonomous Vehicles

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ABSTRACT

An autonomous vehicle is one that uses a combination of sensors, cameras, radar, and artificial intelligence (AI) to travel between destinations without a human operator. It is designed to be able to detect objects on the road, maneuver through the traffic without human intervention, and get to the destination safely. It is fitted with AI-based functional systems such as voice and speech recognition, gesture controls, eye tracking, and other driving monitoring systems. Several companies have announced their plan to get involved in autonomous or driverless and electric vehicle technology. This paper presents uses of AI technology in autonomous vehicles.

KEYWORDS: *autonomous vehicles, driverless vehicles, artificial intelligence, artificial intelligence in autonomous vehicles, Unmanned Ariel Vehicles*

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INTRODUCTION

Engineers and scientists all over the globe are struggling to make human life more comfortable. One of their most spectacular recent developments is autonomous vehicle (AV). Autonomous vehicles have been hitting the headlines lately. They usually refer to self-driving vehicles that can fulfill transportation capabilities of a traditional vehicle. They are not designed to obey the law but for the purposes of promoting safe and efficient traffic and driving from A to B [1]. They are regarded as a post-Uber disruption to public commute and transportation of goods. They are starting to become a real possibility in main economic sectors such as transportation, agriculture, and military. AV technology is regarded as a significant market disruptor for multiple industries [2].

A host of auto heavyweights are investing in autonomous R&D and developing road-going self-driving vehicles. Such companies include Amazon, Audi, Apple, Waymo, Tesla, BMW, Google, General Motors, Volkswagen, Volvo, Ford Motor, IBM, Microsoft, Mercedes-Benz, Bosch, Nissan, Alphabet, Honda Motor, and Uber Technologies. The United States is presently the largest automobile market in the world. Vehicles with crash-warning systems, lane-keeping framework, adaptive cruise control system, anti-lock braking systems, automatically activated safety mechanisms, and self-parking technology are already in use in the United States.

Autonomous vehicle (AV) is one of the key application areas of artificial intelligence (AI). In other words, AI is the most important component of autonomous and connected vehicles. This is due to the humongous amount of environmental data generated by the vehicle. AVs depend on AI to interpret the environment, understand its conditions, and make driving-related decisions. Autonomous vehicles employ numerous cameras, sensors, radars, communication systems, and AI technology to enable the vehicle to generate massive amounts of data which can be processed in fractions of a second to help the vehicle to see, hear, think and make decisions just like human drivers do. A typical autonomous vehicle is shown on Figure 1 [3].

Autonomous vehicles have been in development for almost thirty years. For a vehicle to be autonomous, it must be continuously aware of its surroundings, by perceiving and then acting on the information. SAE International has suggested the following levels of driving automation, illustrated in Figure 2 [4]:

- **Automation for driver assistance:** This is a preliminary level or starting point of car automation where the system assists the driver but does not take control of the car.
- **Partially automated driving:** The system takes partial control, but the driver is primarily responsible for the operation of the vehicle.
- **Highly automated driving:** This allows users to let the system take control of the vehicle for a longer duration of time (e.g., on the highway).
- **Fully automated driving:** The system is responsible for driving the vehicle without interference from any human. However, the human presence is still needed.

- **Completely automated car:** The vehicle can completely navigate its way through from one point to another without any assistance from a driver.

OVERVIEW ON ARTIFICIAL INTELLIGENCE

The term "artificial intelligence" (AI) was first used at a Dartmouth College conference in 1956. AI is now one of the most important global issues of the 21st century. AI is the branch of computer science that deals with designing intelligent computer systems that mimic human intelligence, e.g. visual perception, speech recognition, decision-making, and language translation. The ability of machines to process natural language, to learn, to plan makes it possible for new tasks to be performed by intelligent systems. The main purpose of AI is to mimic the cognitive function of human beings and perform activities that would typically be performed by a human being. Without being taught by humans, machines use their own experience to solve a problem.

AI is stand-alone independent electronic entity that functions much like human expert. Today, AI is integrated into our daily lives in several forms, such as personal assistants, automated mass transportation, aviation, computer gaming, facial recognition at passport control, voice recognition on virtual assistants, driverless cars, companion robots, etc. AI is not a single technology but a range of computational models and algorithms.

Some forms of AI that are most commonly used in different applications include the following [5,6]:

- **Expert systems:** They solve problems with an inference engine that draws from a knowledge base equipped with information about a specialized domain, mainly in the form of if-then rules. Expert systems are the earliest, most extensive, the most active, and most fruitful area.
- **Fuzzy logic:** This makes it possible to create rules for how machines respond to inputs that account for a continuum of possible conditions, rather than straightforward binary.
- **Neural networks:** These are specific types of machine learning systems that consist of artificial synapses designed to imitate the structure and function of brains. They are similar to the human brain. They are made up of artificial neurons, take in multiple inputs, and produce a single output. The network observes and learns as the synapses transmit data to one another, processing information as it passes through multiple layers.
- **Machine learning:** This includes a broad range of algorithms and statistical models that make it possible for systems to find patterns, draw inferences, and learn to perform tasks without specific instructions. Machine learning is a process that involves the application of AI to automatically perform a specific task without explicitly programming it. ML techniques may result in data insights that increase production efficiency. Today, artificial intelligence is narrow and mainly based on machine learning.
- **Deep learning:** This is a form of machine learning based on artificial neural networks. Deep learning architectures are able to process hierarchies of increasingly abstract features, making them especially useful for purposes like speech and image recognition and natural language processing. Deep learning networks can deal with complex non-linear problems. Deep learning is expected to be the largest and the fastest-growing technology in the automotive AI market.\
- **Natural Language Processors:** For AI to be useful to us humans, it needs to be able to communicate with us in our language. Human language is complex, but AI can be trained to slowly pick up the language. Computer programs can translate or interpret language as it is spoken by normal people.
- **Robots:** These are computer-based programmable machines that have physical manipulators and sensors. Sensors can monitor temperature, humidity, pressure, time, record data, and make critical decisions in some cases. Robots have moved from science fiction to your local hospital. In jobs with repetitive and monotonous functions they might even completely replace humans. Robotics and autonomous systems are regarded as the fourth industrial revolution.

These AI tools are illustrated in Figure 3 [7]. Each AI tool has its own advantages. Using a combination of these models, rather than a single model, is recommended. AI systems are designed to make decisions using real-time data. They have the ability to learn and adapt as they make decisions.

AI IN AUTONOMOUS VEHICLES

Artificial intelligence (AI) is a branch of computer science that deals anything related to making machines smart. AI uses data and algorithms to replicate human decision or thinking ability. AI performs several tasks in a self-driving automobile. One of the main tasks is path planning, which involves the navigation system of the vehicle. Path planning is needed to optimize the trajectory of the vehicle and to lead to better traffic patterns. AI helps vehicles to navigate through the traffic and handle complex situations. AI can respond quickly to data points generated from hundreds of different sensors. Sensors provide information for the road, other vehicles on the road, and other impediments.

AI in the auto industry can be classified into four segments [8]:

- **Autonomous driving:** Autonomous or self-driving vehicles are becoming more and more desirable. Autonomous vehicles can bring safety because they are much more alert and will not be overcome by distractions.
- **Connected vehicles:** Vehicles are quickly transforming into connected devices. Cars now use cellular and Wi-Fi connections to upload and download entertainment, navigation, and operational data. AI is an essential technology for connected vehicles.
- **Mobility as a service:** Mobility is the lifeblood of any city. It is what makes a city livable and an attractive place to live. Car companies are becoming mobility companies to address changing consumer demand. Car ownership in urban areas may decline in favor of various forms of public transportation and ride sharing.
- **Smart manufacturing:** Industrial Internet of Things (IIoT) and Industry 4.0 technologies can be used to automate and optimize manufacturing processes. The use of AI in vehicles helps reduce manufacturing costs while ensuring safer and more innovative vehicle production. Car manufacturers are using AI tools in every aspect of the car-making process.

APPLICATIONS OF AI IN AUTONOMOUS VEHICLES

AI is revolutionizing the transportation sector. Successful applications of AV technologies could fundamentally transform various industries such as automotive, transportation, energy, agriculture, battlefield, space, the deep sea, and other dangerous environments. Autonomous vehicles include deep space probes, spacecraft, unmanned aerial vehicles (UAV), unmanned ground vehicles (UGV), unmanned sea/surface vehicles (USV), and unmanned underwater vehicles (UUV) [9].

- **Autonomous cars and other highway vehicles:** The automotive industry is focusing on the integration of AI in autonomous cars, while other application areas include R&D, procurement, supply chain management, manufacturing, mobility services, and customer experience. Cars are at the top of the list of autonomous vehicles. Figure 4 illustrates a man in an autonomous vehicle [10]. In 2015, Amazon filed for a patent for a system that helps autonomous cars navigate roadways. Traditionally, automotive manufacturing was dominated by internal combustion engine. Today, car manufacturers are implementing a range of AI technologies to mimic, augment, and support actions of humans, including voice controls, telematics, interior-facing cameras, touch-sensitive surfaces, and personalized platforms. Autonomous trucks have been tested in the U.S. and Europe to enable drivers to use autopilot over long distances.
- **Autonomous flight vehicle:** The integration of AI with the aircraft that could automate the task of manual flight and navigation would be considered a milestone in the field of aeronautics. The idea of autonomous flight vehicle incorporating AI on a large scale involves the commercial and military aircrafts and drones autonomously operating with little or no harm interaction. Such autonomous vehicles will execute shortest and fastest flight routes with more efficient path planning, which in turn will reduce the fuel consumption [11]. Large aircraft have been using automatic landing systems for several years.
- **Autonomous undcrsea vehicle:** They have also been called autonomous surface craft. As global positioning systems (GPS) have become more compact, effective, and affordable, AUVs have become more capable.
- **Autonomous agricultural vehicles:** These are characterized as the autonomous guidance system for agricultural vehicles including navigation sensors (GPS, machine vision, sensors, etc.), computational methods for features and fuse extraction, navigation planners to supply control algorithms, and steering controllers. Artificial intelligence (AI) and robotic technology will be key tools for such vehicles [12].

Other applications of AI in the automotive industry include predictive maintenance and driver assistance.

BENEFITS

Autonomous vehicles promise to reduce traffic congestion and collisions, reduce accident and pollution problems, improve traffic flow, mobility, relieve individuals from driving, decrease fuel consumption, and facilitate transportation and businesses operations. Based on the data collected over time, AI can speculate and provide preferences such as seat position adjustment, screen adjustment, controls air input, and songs to be played.

Other benefits include [13]:

- **Safety and privacy:** Security and privacy are always being the major issue associated with the electronic systems. The main benefit of autonomous vehicle is safety. Autonomous vehicles are fully capable of sensing the surrounding environment to enhance roadway safety. AVs are designed to choose the course of action that causes the less damage to everybody. Autonomous cars can remove risk factors from the equation and significantly reduce the number of accidents or crashes. AI techniques are also being implemented in vehicles to provide more safety by simply removing the need of a human driver. To ensure safety, automakers are introducing many exciting features such as automatic emergency braking, lane crossing alerts, driver and passenger monitoring, blind spot elimination, side collision warning, and optional self-driving capabilities. Risk of cyber attack will increase since the AVs are a moving computer.
- **Consumer behavior:** To be successful, AVs has to cope with individual idiosyncrasies and variation in needs. Deployment of autonomous vehicles on public roads requires understanding the intent of human drivers and adapting to their driving styles. Interacting with human drivers is a major challenge of autonomous driving. Changes in consumer behavior and technology are disrupting traditional modes of operation. AI and perception technologies promise to provide a safer and more deterministic behavior which will lead to benefits such as fuel efficiency, comfort, and convenience.
- **Smart mobility:** Autonomous vehicles are an essential part of smart mobility in smart cities. They will increase the mobility of individuals who do not drive as a result of age or disability. AI promotes advanced driving so that people can experience easy navigation. AI can help provide customized entertainment while the vehicle is traveling.
- **Ease of claim:** Data from the vehicle can be used for faster processing of claims in case of accidents. This can contribute to decrease in prices for insurance, since the safety is more deterministic and guaranteed.
- **Less equipment failure:** If a machine fails unexpectedly on an automotive assembly line, the costs can be catastrophic. AI-based algorithms can digest masses of data from sources, detect anomalies, separate errors from background noise, diagnose the problem, and predict if a breakdown is likely or imminent.
- **Quality control:** Once the parts are put into production, it is necessary to carefully control their quality. Sensor-based AI can assess the quality of every part on the production line and detect defects more accurately than humans.
- **Leaner supply chain:** Automotive supply chains are complex networks. AI-powered supply chains are being used to analyze a massive amount of data to be able to forecast accurately. AI-powered supply chains will allow fully automated self-adjusting systems to make supply-chain management decisions autonomously, adjusting routes and volumes to meet predicted demand spikes.
- **Predictive maintenance:** Predictive analytics is one of the strongest capabilities of AI and machine learning. The essence of predictive maintenance is that the

system analyzes the equipment, compares its specs with industry and safety standards. The essence of reactive maintenance is to replace a critical part before it crashes the production system.

CHALLENGES

There are still several aspects of autonomous vehicles that are presenting significant challenges and some of the challenges are due to the intrinsic nature of AI. This section presents specific challenges for developing, testing, and deploying AI technologies in the autonomous vehicle. Some serious obstacles such as adequate regulations and international standards for digital infrastructure remain.

Other challenges include [14]:

- **Complexity:** Autonomous driving systems are becoming increasingly complex and must be tested effectively before deployment. This necessitates long and numerous rounds of testing. Intensive AI algorithms consume more power, especially for electric vehicles. Accidents with testing vehicles often happen because the simulation environment is different from the real world conditions.
- **Cost:** Manufacturers of autonomous vehicles have spent heavily in building those vehicles. For example, Google paid about $80,000 for the AV module which is way out of a normal man's reach. It is hoped that in the future, the prices of AVs will come close to the cost of traditrional vehicles.
- **No regulation and standard:** There are no clear regulations on data collection and governing the new methods of autonomous transportation. Lawmakers and regulators are yet to determine who is liable when an autonomous vehicle is involved in an accident. AV technology presents a huge challenge to standardization and legal bodies.
- **No user's trust:** Automakers are facing the need of gaining the user's trust. The willingness of people to trust AI is increasing at a very slow rate. Modern users want a car to be functional, comfortable, and safe.
- **Amount of data:** AI techniques need to interact with numerous sensors and use data in real time. This is related to achieving safety while driving the vehicle. Great amount of data and expertise is required to build and leverage simulators. To mimic human behaviors is difficult. The autonomous driving task as a whole becomes hugely complex due the massive amount of data involved.
- **Social dilemma:** Autonomous vehicles are meant to reduce traffic accidents, but they will sometimes have to choose between two evils, such as running over pedestrians or sacrificing themselves and their passenger to save the pedestrians. Developing the AI algorithms that will help AVs to handle this social dilemma is formidable.

All of these challenges explain the slower adoption of AI the automotive industry.

THE FUTURE OF AI IN AUTONOMOUS VEHICLES

Cars are being manufactured all over the world, with each manufacturer in intense competition with one another to produce the best vehicle. Autonomous cars are the future smart cars which are expected to be driverless, efficient, crash avoiding, and ideal urban car of the future. Some are working tirelessly to create their very own self-driving vehicle from scratch. Car manufacturers around the globe are using AI in just about every facet of the car manufacturing process. AI is changing the way cars are manufactured globally. Due to the various challenges of AI in autonomous vehicles, barriers to widespread adoption remain. In the near future, AI will enable autonomous vehicles to become mainstream. Technology companies are at the forefront, leveraging their AI experience to capture the autonomous vehicle market.

Connected and automated vehicle has become the focal point of current transportation studies (covering topics like automation, car visions systems, and AI) and has a crucial role to play in the future of transportation. The demand and the need for autonomous vehicle technology is almost there. As the autonomous vehicle technology matures, personal and public transportation will be greatly transformed. A day is fast approaching when you can commute to work with driverless car, without needing to watch the road.

Figure 5 shows seven trends shaping the automotive industry by 2030 [15].

CONCLUSION

Artificial intelligence is making inroads in the automotive industry. It is the backbone of self-driving, autonomous or connected vehicles. It is being harnessed to bring autonomous driving from in reality. AVs must be installed on a mobile platform. Leading automakers use the AI technologies in their operations from design development to the sale of a car. To stay on top of the developments in AI in autonomous vehicles, one should consult the books in [16-21] and two related journals: *Artificial Intelligence Review* and *Artificial Intelligence and Law.*

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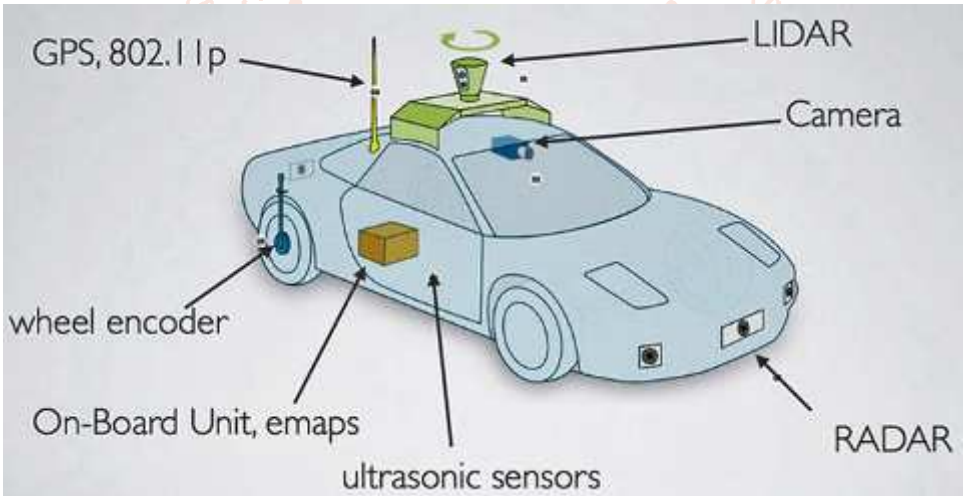

Figure 1 Autonomous/connected vehicle [3].

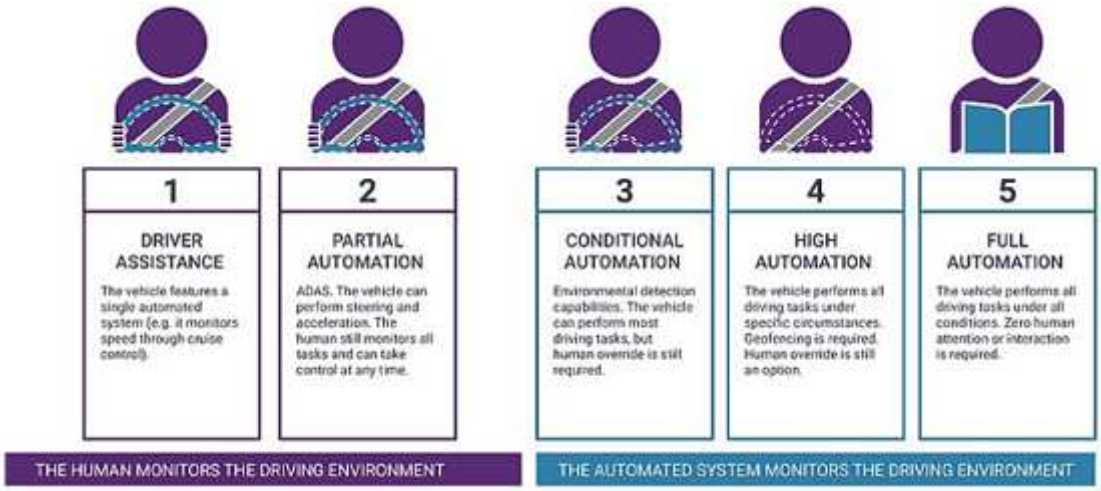

Figure 2 The levels of vehicle autonomy [4].

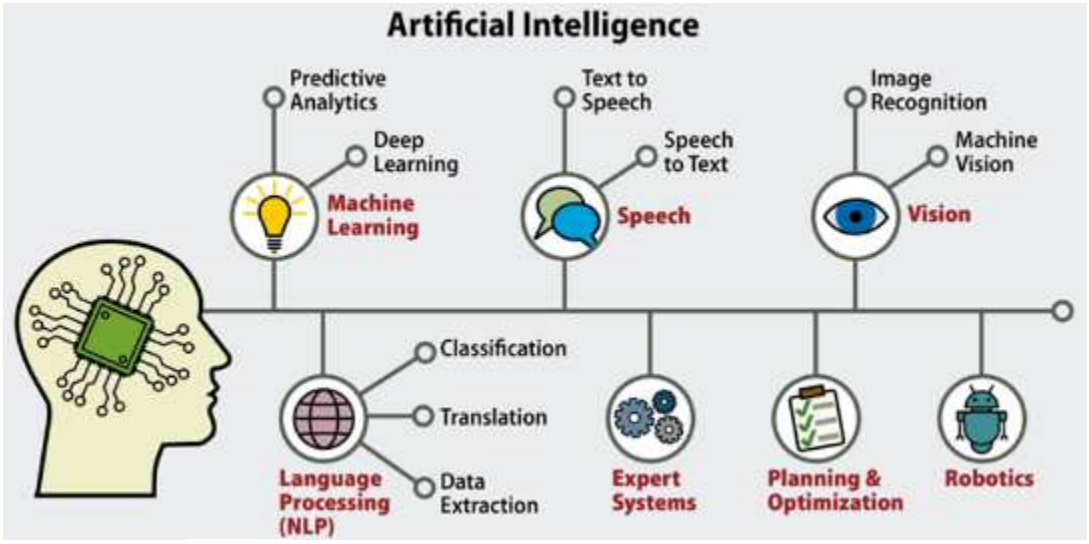

Figure 3 Different components of Artificial intelligence [7].

Figure 4 A man in an autonomous vehicle [10].

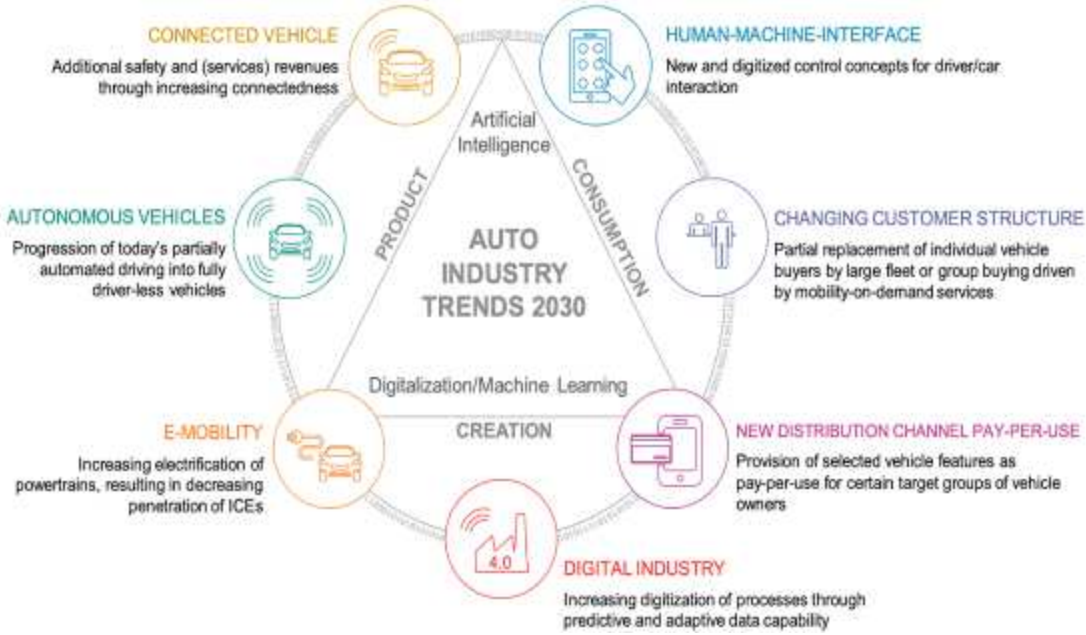

Figure 5 Seven trends shaping the automotive industry by 2030 [15]