**Deep Learning for Autonomous Vehicles**

*Abstract* The integration of deep learning into autonomous vehicles represents a significant advancement in modern technology, promising safer and more efficient transportation systems. This paper provides an overview of the application, development, challenges, and measures required for implementing deep learning in autonomous vehicles. By utilizing AI algorithms inspired by the human brain, autonomous vehicles can navigate and operate without human intervention, enhancing overall efficiency. The objective of this research is to analyze how deep learning contributes to the advancement of autonomous vehicle technology and to identify key challenges and opportunities within this domain. Through an examination of key research papers and statistical evaluation, this study aims to provide a deep understanding of the methodologies driving vehicle technology. By exploring recent literature and case studies, the research seeks to uncover the capabilities of deep learning algorithms in enhancing perception, decision-making, and control in autonomous vehicles. Critical analysis of the literature allows for a comprehensive understanding of the strengths and weaknesses of deep learning algorithms in autonomous driving systems, highlighting their transformative potential for society, industry, and transportation infrastructure.

# 1. Introduction

In this era, the various kinds of technological integration have helped to enhance our daily life efficiency. One remarkable technical domain is the use of deep learning to power autonomous vehicles. With the aid of AI algorithms inspired by the structure and function of the human brain, it has played a coherent role in helping vehicles to navigate and operate autonomously. Without the use of human intervention, it can easily operate everything. In order to, enhance technological advancement also to achieving safer and more efficient transportation systems it is necessary to use the application of deep learning techniques to achieve safer and more efficient transportation systems. In order to support this project and also to make a practical implication here the researcher will use Python programming language and deep learning techniques such as CNN to develop a prediction model for identification of traffic signs for autonomous vehicles.

## 1.1 Objective Statement

The purpose of this research is to give a detailed explanation of the application, development, challenges, and measures that have to be implemented for autonomous vehicles using deep learning. Through this study, deep learning methodologies currently drive the vehicle technology and it will the paper examine the key research papers results and statistically evaluate it to provide the researcher with deep understanding. Besides, the research objective is to find the most significant barriers and chances, that deep learning approaches are facing in this sphere, aiming to satisfy the demands of ethical, societal and technical aspects.

## 1.2 Research question

* How does deep learning contribute to the development of autonomous vehicle technology?
* What are the key challenges and opportunities of autonomous vehicles?

This research question is established to provide a coherent framework which can help to explore the various technological aspects of deep learning in the context of autonomous vehicles. In this project understand the deep learning techniques scope for autonomous vehicles the researcher will use the various kinds of recent published literature and also critically analyse the case studies to discover deep learning capabilities, such as underscoring which deep learning algorithms enhance perception and the ability to make correct decisions and control capabilities in autonomous vehicles 3. With the aid of critical analysis of the literature, we can understand the strengths and weaknesses of deep learning algorithms in autonomous driving systems. This analytical approach is beneficial in underscoring the ability of this transformative technology and its implications for society, industry and transportation infrastructure.

# 2. State of the Art

## 2.1 Presentation of Research Methodologies

In this phase, the developer has analysed the various kinds of methodologies which have been used for deep learning techniques for autonomous vehicles. Mainly, this approach encapsulates to underscores the innovative solution which has been delivered from the deep learning application. Here the developer utilises numerous types of methodology such as literature reviews, empirical studies, experimental setups, simulations and real-world testing.

### 2.1.1 Literature Reviews

This is a starting point for most research papers in this field because the literature review is carried out to establish the best practices, highlight gaps in current knowledge, and understand the challenges and opportunities in the domain. Literature reviews, which are an essential component of research, allow researchers to expand upon existing knowledge and contribute to other research activities. Researchers achieve novel and facts-based evidence-based knowledge by combining and analyzing previous research results, specifically regarding the functionality of the Deep Learning methods in tasks like object detection, for example, lane marking, path planning, and decision-making in self-driving cars. Also, extensive literature reviews give researchers the ability to notice the growing trends, the most updated technology and the topics for future research exploration.

### 2.1.2 Empirical Studies

Empirical studies entail collecting and analyzing data from real-world experiments of simulations and experiments to confirm or put to test the accuracy and reliability of deep learning algorithms on autonomous driving. These studies could include collecting coherent data from newly developed autonomous vehicles used in controlled environments as well as public roads. After that, these pre-trained deep learning models would be employed for object detection, lane keeping and decision-making tasks, and then their effectiveness would be evaluated . The data-based studies, by all means, give us assistance in understanding the real-world obstacles which are thereby posed by autonomous vehicles such as extreme climate, being on the road alongside other vehicles and people as well as working out the GPS system in a city’s area, full of traffic signs, signs and traffic lights. Through the empirical data analysis, researchers can be able to identify the models' drawbacks in deep learning algorithms and therefore work on the models for better performance in terms of reliability.

### 2.1.3 Experimental Setups

In this project, the researcher needs to focus on the experimental setup to test the deep learning algorithms or models' capability for understanding the various driving conditions and scenarios. This setup mainly includes simulators which have replicated real-world environments. This approach has helped the researcher to configure the different traffic scenarios such as road conditions. In order to develop the experimental setup as well as make an advanced data analysis process the researcher has decided to use a secondary data collection method to collect the existing object dataset which is present on the online website. Also, to analyse the data and make a practical implication here the Python programming language and deep learning techniques such as convolutional neural network (CNN) will be used to analyse the traffic signs by autonomous vehicles. By analysisng the real-world case, we are able to make suitable decisions about its robustness, scalability and adaptability. Also, we decided to use published journal articles and research papers to underscore their experimental setups and the performance of the model in analysing real-world scenarios.

### 2.1.4 Simulations

It has been seen from the various kinds of literature that simulation is a very effective approach for testing deep learning algorithms for autonomous vehicles. Various kinds of researchers have used simulation platforms to create virtual environments. This virtual environment has helped to discover whether autonomous vehicles can identify the objects of other vehicles . This approach is a cost-effective way where we can test the algorithm in several conditions and understand whether the application is suitable for real-world settings or not. By critically analysis the literature we can define each parameter's settings as well as optimize algorithm performance. In concluding this statement we can say that the simulation is a very effective way to underscore the impact of environmental factors as well as noise off sensors and also to define the algorithmic parameters on system performance.

### 2.1.5 Real-world Testing

While on-the-road testing on public roads with the vehicles embedded with deep learning algorithms will serve as the true test of these technologies therein is an evaluation of their failure/success in real-world driving settings. The real-world testing has helped the researchers to evaluate the strength and accuracy of their models under dynamic environments and also benchmark the performance of the models against the gathered data. This data can be used further to improve the models based on real-world feedback. In addition, the physical use of autonomous vehicles in real-life situations provides various traffic patterns, road geometries and weather conditions . Real-world monitoring has helped researchers to understand the risk and usability of an automobile driving system. Also, real-world testing will offer effective insights that will aid in developing standards and principles for autonomous driving technology during the practising phase.

## 2.2 Key Papers Reviewed

### 2.2.1 End-to-End Reinforcement Learning for Self-driving Car

***“End-to-End Reinforcement Learning for Self-driving Car”*** by Rohan Chopra states that the majority of self-driving cars on the market today employ many algorithms to navigate. Furthermore, the majority of methods train a model to drive an autonomous automobile using supervised learning. This method results in the model containing human bias. We use the Deep Q-Learning algorithm to autonomously operate a virtual automobile from start to finish. Reinforcement learning, which teaches robots how to behave through interactions with their surroundings, is the foundation of the algorithm . The use of reinforcement learning in driving is quite relevant as it relies heavily on interactions with the outside world. A CNN serves as the deep Q network in our concept. The technology was tested using TORCS, an open-source automobile racing simulator. The system can function more effectively thanks to the Deep Q-learning technique.

### 2.2.2 Dynamic Conditional Imitation Learning for Autonomous Driving

This work outlines the proposed changes in Centered Imitation Learning (CIL) for autonomous driving. The thorough occupation grid mapping method relies on carefully combining data from laser scanners and camera streams and applying the OGM technique, by which the 3-D model generalization and consistency are provided. Static blockages like traffic and alternating stops and starts are better managed and route planning improves as well dynamically . Experiments in the CARLA simulator show significant improvements such as Dash 2 has tested its autonomous driving system in four conditions against the weather and has turned out 52% more average generalization, driving success with route planning globally is 37% higher and it has 27% increase in success rate for road blockage avoidance. In addition, the model covers collision avoidance which causes one to travel 1.5 times the distance first.

### 2.2.3 Learning how to avoiding obstacles for end-to-end driving with conditional imitation learning

This research aims to solve the problem of detecting obstacles as central functionality in driverless vehicles with the help of CARLA simulator data. They humanize a Neural Network by behaviour cloning a loss function that incorporates a feature to ensure higher magnitudes of reduction of steering error. Dataset augmentation improves network learning but a handful must be set to a bid of no rewards [8]. Experiments cover three obstacle scenarios: they proved that people with varying degrees of disabilities, and other automobiles, including two-wheelers, are able to benefit from autonomous driving features. The proposed solution is tested and measured against the goal of obstacle avoidance in the challenging CARLA benchmark. A good performance is demonstrated on this task.

### 2.2.4 Deep imitation learning for autonomous vehicles based on convolutional neural networks

In this study, a convolutional neural network is assessed as the property of an influential autonomous vision system. It aims at the effect of filter number, filter area and layer count on the efficiency of the particular clothing item. Experimenting shows that amount of layers is of relatively no effect but a number of filters per layer coupled with a custom kernel size does provide an increase in quality of classification . In addition, our proposed ensemble approach implementing weighted mean squared error values is considered. Such highly targeted research shows the direction for structure optimization of networks, especially in the case of vision systems of self-driving cars.

### 2.2.5 End-to-end deep learning model for steering angle control of autonomous vehicles

Using a convolutional neural network (CNN) technique called Residual Neural Network (ResNet), this study investigates end-to-end deep learning for autonomous driving. On the UDACITY platform, training and simulation are carried on with an emphasis on track\_1 for autonomous driving. For training and validation, a collection of 11655 pictures with steering angle information is gathered and split into 80-20 groups . The ResNet CNN predicts driving elements for autonomous vehicle motion execution and decision-making by the sequential input of pictures into the network. With an 81% success accuracy and a loss value of 0.0418, the suggested model performs admirably for applications involving autonomous driving.

**3. Literature review**

In the previous discussion, the researcher has stated key papers which will be critically analysed in the literature review section. The Google Scholar online database has been used in this scenario to gather coherent literature which is related to deep learning techniques in autonomous vehicles. The researcher mainly critically analyses the literature to understand their developed methodology as well as the effectiveness of the findings. By critical analysis, we have discovered the literature gaps which is very beneficial for future enhancement. Each optimised parameter of the literature will be disclosed in this section to develop the volumetric efficiency of the project.

**3.1 Critical analysis of End-to-end reinforcement learning for self-driving car**

In this literature, the author Rohan Chopra implements a Deep Q-learning algorithm in autonomous driving systems. This agenda has been mainly utilized to define a divergence from traditional supervised learning approaches which has helped to mitigate human bias and enhance system robustness. The reinforcement learning principles have been encapsulated in this literature to allow the model to train coherent driving behaviour with the help of interactions with its environment [15]. Deep Q networks such as Convolutional Neural Networks (CNN) have been used in this literature to effectively understand complex sensory inputs and make informed decisions in real time. TORCS simulator is also used to enhance the cohesiveness of the Deep Q-Learning approach in achieving autonomous driving capabilities. Understanding the literature findings we discover that the model is showing the ability to navigate dynamic environments and handle complex driving scenarios. This supervised training method is similar to the reinforcement learning method which has analysis by its performance metrics [7]. In concluding this statement we can say that reinforcement learning offers improved efficiency and adaptability which means it has the coherent capability to accelerate autonomous driving systems. Also, further research is very beneficial to address various kinds of challenges such as scalability and real-world deployment. By enhancing the accuracy of deep Q-learning algorithms developers can enhance efficiency in autonomous vehicle technology.

**3.2 Critical analysis of dynamic conditional imitation learning for autonomous driving**

The literature depicts an all-inclusive review of avenue autonomous-driving systems emphases on improving safety, reliability and generalization to capture variability in scenarios. It provides the generator that connects the conditional imitated learning process with LiDAR sensor input, with the aim of solving issues such as generalization and weather effects which affect the performance. The response model that we have developed pushes ahead relatively to the previous models, being the greatest in new domains. As the main result, the model can be seen as the one that helps the vehicles in many situations such as keeping from hitting the pedestrians and the vehicles or the static objects. It is also effective in the cases of not leaving the road or going into the opposite lane of the road [9]. The interface of a global planner being added means the route planner list becomes more accurate and does away with committable infractions. One of the salient features, which may be identified as our contribution, is using an efficient Occupancy Grid Mapping (OGM) method that improves runtime performance, memory utilization, and map accuracy. This method is actually of very great importance due to the fact that any time of the day and night the traffic situation on the road will be analyzed and changes in roads identified so that the vehicles can be automatically led to alternative routes, reducing the risk of collision. In addition, the research had highly positive findings from both real-life and simulated tests proving the model's adaptability and appropriate driving actions in different situations. It accentuates that the constant improvement of autonomous driving technology is therefore of paramount importance to maintain reliability and safety [16]. The paper comes to a conclusion by highlighting future research directions, such as evaluating the network performance of complicated road intersections, precision determination of underlying causes of the model’s failure to generalize, and the implementation of various error mitigation techniques.

**3.3 Critical analysis of the literature to understand how to avoid obstacles for end-to-end driving with conditional imitation learning**

In the literature, the problem of obstacle avoidance in autonomous driving systems, and many neglect the point which is often one of the prioritized skills of the latest end-to-end learning-based approaches is highlighted. This study carries out extensive data gathering via the CARLA simulator that incorporates different dynamics of human drivers' reactions to obstacles along various driving commands. They suggest implementing a behaviour cloning neural network architecture by modifying the loss function so that it will put front steering accuracy. It is what really matters in the avoidance of obstacles in navigation. The principle result shows the high efficiency of the used data augmentation methods in training the specified network and providing a chance for it to assume functions in uncertain circumstances [10]. Furthermore, it is stressed in the study the need to give correct settings as well as not to forget about the strategy connected with the stopping of the flow, which is needed in order to provide stable and continuous driving. Experimental results demonstrate the effectiveness of the proposed approach in three obstacle avoidance scenarios: exiting the virtual road and entering the real one, seeing other automobiles similar to those in the training data set, and two-wheeled vehicles [17]. Evaluation is the last factor that turns around in the model performance utilizing the CARLA benchmark as a toolkit for evaluation provides insights into the capability and limitations of the model. Overall, the literature is helpful in understanding the successful address of the diversities of obstacle avoidance in autonomous driving systems with data-driven approaches with additional information about the right steering behaviour and making sure the training is accurate.

**3.4 Critical analysis of deep imitation learning for autonomous vehicles based on convolutional neural networks**

The studies discussed in detail the use of Convolutional Neural Networks (CNNs) for autonomous vehicle vision systems, which bring imitation learning and ensemble methods to the forefront. Depending on the sequence of the channel filters, by the thorough comparison of 96 CNN architectures, this study will address the effect caused by the architectural parameters such as depth, filter size, and number on model performance. The findings imply that more precise networks with expansive filters in the initialization layers usually show the greatest performance, thus indicating that the architecture design component is decisive in CNNs for vision tasks [8]. Even though the study results can be a useful tool for CNN tuning and ensembles, the fact remains that artificially generated data are reliant and a lack of testing outside traditional driving environments among the limitations. The foreseeable research options in future may include fine-tuning CNN parameters through sophisticated algorithms like Genetic algorithms and testing the effectiveness of ensemble modules on various atmospheric conditions to improve the dependability and performance of practical vision systems of automated vehicles.

**3.5 Critical analysis of End-to-end deep learning model for steering angle control of autonomous vehicles**

The literature, through the investigations, describes a detailed introduction end-to-end deep learning model for steering angle control of autonomous vehicles. The research utilizes a ResNet architecture, consisting of convolutional neural networks (CNNs) that receive images from the camera as an input and their output is the steering angle. Data collection seeks to log image snapshots and corresponding tagged parameters, such as steering angle, throttle, brake, and speed, during the simulator's usage in the UDACITY platform. The dataset contains two sets of training and validation, which require cropping, normalization, and resizing processes during preprocessing [14]. The ResNet model is constituted by ELU layers and dropout regularization layer which helps mitigate overfitting. Conducting evaluations on the Udacity simulator establishes a point in the right direction, showing an MSE of 0.0418 and a training accuracy of 0.81%. A comparison of the proposed technique with the existing models clearly exhibits that this approach is effective [18]. As future works, possible extensions are to integrate more variables and to better the entire performance among other efforts.

**4. Critical evaluation**

In this phase, the researcher will discuss the coherent insights of the research paper as well as the effectiveness of deep learning in autonomous vehicles. By analysing the implications, limitations and literature gaps the developer aims to present a coherent critical evaluation.

**4.1 Implications**

The findings from the papers show RL algorithms, specifically Deep Q-Learning possibly have a great level of effectiveness and can be used for training automatic vehicles for roads with dynamic environments without human interference. Through its interaction with a given environment, the RL algorithms can be an unbiased and robust way to balance human bias and system performance. It means, therefore, a huge milestone with the help of AI inventing systems that can handle any surprising/unpredictable situations [19]. Additionally, researches on dynamic conditional imitation learning are carried out in order to make use of LiDAR sensor resources and grid mapping technologies for obstacle, passability, and route planning purposes [23]. They could improve safety, reliability and the ability to generalize improved. This will make people believe in these cars more and eventually accept the change. Furthermore, the investigation into neural networks for image input also known as steering angle control provides us with a possible architecture for convolutional neural networks to predict the driving elements overseeing the whole deep network, interweaving into smarter and more efficient self-driving systems.

**4.2 Limitations**

However, the validity of the information when using deep learning algorithms is very sensitive to the quality and size of the training set. For instance, these problems include dataset bias, the absence or limited number of representing the different countries, and data augmentation, which can make the trained models more generalized and trusted. To be more precise, the fact that CARLA offers a highly controllable testing environment for autonomous driving demonstration only creates more problems for the practical usage of this technology [20]. Factors like climate, the behaviour of unpredictable people, and the rather complex structure of the urban environment restrict the possibilities of these forms of studies and, thus, are often incomplete.

**4.3 Contradicting Viewpoints and Research Gaps**

A particular inconsistency that can be correlated with the supervised learning algorithms and reinforcement learning techniques is the fact that their contrastive nature should not get lost. Despite the advantages of RL, supervised learning has the tendency to perform best in some cases like with best-defined objectives and large amounts of labelled data. Besides that, as of right now, there exists a lack of information about how deep learning models are applied for driving autonomous vehicles on a large scale. Experiments, conducted under controlled conditions, are evident to have positive outcomes [21]. The application and performance of the techniques in varied real-world situations, however, are not apparent. The observation of the diverse viewpoints and the gaps in the research mentioned above, require thorough analysis to determine the level of scalability, robustness, and real-world suitability of deep learning algorithms in autonomous vehicles [22]. Along with them, attempts to ensure data diversity, simulation completeness, and explainability are important elements of the continual elevation of self-driving systems technology.

**5. Conclusion**

The use of deep learning in self-driving cars holds great potential for transforming transportation infrastructure. Although approaches such as imitation learning and reinforcement learning provide improvements in terms of safety and dependability, issues with data quality, practical application and relative efficacy still exist. Further research is needed to improve scalability, dependability and practical application in order to close these gaps. Even with its drawbacks, deep learning has enormous potential to transform transportation in the future—that is if further efforts are made to resolve conflicts and obstacles. Deep learning algorithms-powered autonomous cars have the potential to provide society with more dependable, safe, and efficient mobility options as they continue to progress.

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