How do autonomous cars perceive and interact with their environment?

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# Introduction

This report was written as research for competing in the Self Driving Challenge. The goal of this is to make an autonomous car which has to complete a set of challenges along a circuit, like stopping for traffic lights, letting pedestrians cross and drive below the speed limit on speed signs.

For this challenge our group of Applied Computer science worked together with Mechanical Engineering and Automotive. Their part was to build a cart and we worked on making the cart drive autonomously.

The importance of self-driving vehicles, in particular the technology, is to reduce car accidents due to human behaviour or mistakes. This is relevant for all traffic users.

This leads to the main research question: "How do autonomous cars perceive and interact with their environment?". To answer this question some sub questions are defined below:

* What sensors are used in autonomous cars to perceive their environment?
* How do these sensors work to collect data about the environment?
* How is the collected data processed and interpreted by autonomous cars to make decisions?
* What are the challenges and limitations in the current technology for environmental perception and interaction?

# Methods

For this literature research I’ve gathered information from various scientific articles on Google Scholar. The articles were found by searching about autonomous car sensors, cameras, technology, how to stay between lines and image processing.

# Results

Autonomous vehicles need to perceive their surroundings to be able to navigate through it. This is done with various sensors. In the following paragraphs will explain the most commonly used sensors and how they work.

**Camera**

Cameras are the most commonly used sensor for perceiving the environment. They produce images of their surroundings by using a camera lens. A photosensitive surface behind the lens will detect light emitted from the environment. The low price makes it also popular equipment. Cameras are able to detect moving and stationary objects and can produce high resolution photographs. [1]

**LiDAR**

LiDAR, which stands for light detection and ranging, is a sensor that sends out lasers of light in all directions. These lasers reflect off of objects and then get detected by the LiDAR again. The time it takes before a laser returns is used to determine the distance to the object it hit. All this data is put in a point cloud, which is like a 3d map of the surroundings. Furthermore, the object intensity data is received which describes the strength of the laser pulse. One downside is that Lidar is more expensive, although cheaper versions are being developed that are more suitable for large-scale development. [1],[2]

**Radar**

Radar sensors can measure the distance and velocity of objects by sending out radio waves. They are mainly used in the range of 50-100 meters. One of their strengths is their robustness in different conditions. They are commonly used in Advanced Driver Assistance systems (ADAS). The focus of this device is to interact with cruise control functions and collision detection. They are also able to detect the relative motion of objects. Pricewise they are cheaper than LiDAR. [2]

**Data processing**

Before that autonomous vehicles can make decisions on the data from the sensors, the data needs to be processed first. This is because data like pictures and point clouds is unstructured, which means that it needs interpretation and has to be translated to structured data.

There are multiple parts of the environment an autonomous vehicle has to perceive, such as road lines, traffic signs and pedestrians. These are detected with sensors by using AI-based algorithms. Machine learning and artificial intelligence play a significant role in analysing the data from the sensors. Technology companies use machine learning algorithms to build predictive models, automate tasks, and extract insights from complex data. Deep learning enables advanced capabilities like image recognition, natural language processing, and speech recognition.

**Limitations and challenges**

Self-driving cars can be costly as it requires a large investment in technology and infrastructure. The maintenance and updates required to keep the systems running can also increase the expenses. This can make the car less accessible for consumers.

Data breaches and hacking is a danger that should not be underestimated. By the data collecting of the self-driving cars big amounts of data can be stolen by cyberattacks. The privacy and personal information of the car’s passengers is at risk.

The complexity of self-driving cars can make it difficult to diagnose and fix problems when they arise. It even can result in errors and malfunctions of the car’s operation. The complexity can also result in a lack of transparency on how the technology is used in self-driving cars.

The self-driving cars are heavily relying on data so when data is not available or inaccurate this can lead to a unreliable driving experiences.

# Conclusion

The future of cars is that they drive autonomously and will interact with their environment. To be able to do this we need to know which kind of sensors and technologies are needed to perceive the environment. How do they make decisions and what kind of challenges and limitations are still ahead of us?

For autonomous vehicles several sensors have to be used. Cameras, LiDAR and radar all have different advantages, so the best option is to use them in combination.

To make autonomous vehicles on a larger scale the cost can be reduced so the cars become more accessible for consumers.

The security of the car must be ensured so it will not be able for hackers to access the data and the privacy of the driver must be guaranteed.

The events while driving should be logged and be traceable for further analysis for when problems occur. Emergency systems should be in place so the driver can take over when needed.

A strong infrastructure needs to be in place so cars can access the needed data.

To summarise the conclusions, unstructured data needs to be interpreted from sensors and several software techniques are needed to create models that can distinguish different traffic situations.

# References

[1] [An overview of sensors in Autonomous Vehicles - ScienceDirect](https://www.sciencedirect.com/science/article/pii/S1877050921025540)

[2] [Sensor Technology in Autonomous Vehicles : A review | IEEE Conference Publication | IEEE Xplore](https://ieeexplore.ieee.org/abstract/document/8585340)