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AUTONOMOUS VEHICLES CHARACTERISTICS AND THEIR POTENTIAL USAGE IN THE TRANSPORT SYSTEM

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Advantages
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Application

Abstract

In the given traffic conditions, autonomous vehicles move without human involvement, detecting the environment with sensors and making decisions for their safe management. The vehicle system interprets the information and selects the appropriate trajectory, speed and analyzes the obstacles it may encounter. The paper presents the expected advantages of autonomous vehicles, but also their negative features. The way in which autonomous vehicles understand information and create an image of the environment is also explained. Some of the current achievements in the field of autonomous vehicles are presented with their characteristics as significant visions for the future of urban mobility and application in the transport system. With all the problems and challenges (legal and ethical) that these vehicles carry, it is necessary to improve them to perfection, what will be done in the future.

1. INTRODUCTION

Autonomous vehicles are vehicles capable of sensing the environment and the complete process of directing and decision making is left to the onboard computer. Thanks to the built in sensors autonomous vehicles can make a perception of the

environment on a certain but limited level. After perception, the vehicle uses complex algorithms that manage and control the behavior, so the vehicle is able to perform tasks. That is, autonomous vehicles are vehicles that can move independently and all real-time driving functions are transferred to the Vehicle Automation System [1].

The Society of Automotive Engineers (SAE) currently defines 6 levels of driving automation ranging from Level 0 to Level 5. Level 0 are full manual vehicles, no automation, where the human performs all driving tasks (steering, braking, etc.). At the next level are vehicles equipped with driving assistance. These vehicles are featured with a single automated system (e.g. monitors speed through cruise control). Level 2 are partial automation vehicles, the vehicle can perform steering and acceleration. The human still monitors all tasks and can take control at any time. At Level 3 are conditional automation vehicles. At this level vehicle can perform most driving tasks, but human override is required. Level 4 are highly automation vehicles, these vehicles are similar to full automation but they still have elements inside the car that allows human to take over the control. At the last level, Level 5, are full automation vehicles. Zero human attention or interaction is required [2, 3]. According to SAE, just vehicles from Level 3 to Level 5 are considered as autonomous vehicles.

Fully autonomous vehicles have the ability to:

- Collect data about the surrounding environment in order to create a maps;
- Detection of objects that can be of interest (people, vehicles, traffic signals etc.);
- Getting distance between two points without navigation by ground objects;
- Work for a long time without human intervention;
- Avoid situations that are harmful to a person, property or the vehicle itself;
- Self repair without external help.

As noted, all the autonomous vehicles are based on sensors and software. There is no standardized architecture for such vehicles, but there are some main sensor that allows the vehicle to operate. Those sensors are: optical (video) camera, high-frequency radar, LIDAR, ultrasonic sensors, compass, inclinometer, odometer, Global Navigation System and Inertial navigation system [4].

Video cameras are designed to recognize traffic lights, traffic signs and moving objects. Video cameras are designed not only for moving cars, but also for people and cyclists. Ordinary HD cameras are used in such vehicles and they are mounted on the windshield and on the back of the vehicle [5].

Autonomous vehicles are equipped with RADAR (Radio Detection and Ranging), designed to determine the objects height, distance, speed and direction of movement in the front and back of the vehicle. Typically, these radars are mounted in the front and rear bumpers. They work on the basis of a Doppler effect, that it sends signals and detects the characteristics of the object according to the changed frequency [6].

LIDAR (Light Detection and Ranging) is the most important part of autonomous vehicles. The main role is to provide mutual interaction between vehicle and all objects in its environment [7]. The principle of operation is similar to the operation of

traditional radar, just in the case of LIDAR the receiver is a light sensitive semiconductor device. It emits over a million laser signals per second that reflect from the target and return to the vehicle creating a very accurate 3D image of the environment. The onboard computer compares the image obtained through the LIDAR and the database, and thus the vehicle can determines what kind of vehicle (e. g. car, bike, pedestrian, ect.) is around them. Ultrasonic sensors are used as short - range measuring devices and they emit periodic short-term high-frequency sound pulses. As these are small distance devices, they usually perform the functions of parking systems and to determinate vehicle position in so called "dead spots". Ultrasonic sensors measure distance from 20mm to 10m.

Global navigation systems help to determine the position of the vehicle: latitude, longitude and altitude. The inertial navigation system (INS) is a navigational device that uses a computer, motion sensors and rotational sensors to continuously calculate the position, orientation and speed of a moving object without external reference. The INS measures angular velocity and linear acceleration so it can determinate its position relative to the starting point. INS is integrated into the vehicle navigation system in autonomous vehicles [8].

Inclinometer is a device used to measure the angle of inclination with respect to the Earth's gravity. The inclinometer can be used for both vertical and horizontal measurement of angles. Inclinometer is built-in with the compass on autonomous vehicles. They have a connector with an onboard computer, so data can be displayed not only visually, but also computer-processed. The compass as a navigation instrument is used for orientation, while the odometer is used to measure the distance traveled based on the wheel speed sensor.

Advanced control systems interpret the collected sensory information to identify appropriate navigation paths, as well as obstacles and relevant signals. Camera, RADAR and LIDAR are the main sensors of an autonomous vehicle, but all of the mentioned sensors provide the vehicle a clear image of the surrounding, but the vehicle has to know its position in some kind of map so it can plan the route of operation. For that purpose vehicle uses Global navigation system and Inertial navigation system [4].

This paper presents the positive and negative characteristics of autonomous vehicles and examples of their potential usage in the transportation system. It also shows how autonomous vehicles understand information and create an image of the environment.

2. ADVANTAGES AND DISADVANTAGES

Autonomous vehicles can be used for passenger traffic (e.g. car, taxi, bus) as well as cargo transportation. Table 1. shows the advantages and disadvantages of autonomous vehicles compared to conventional vehicles.

The sufficiently frequent accidents or at least emergency situations occur due to driver distraction, which is not a case with autonomous vehicles. This distortion can be caused by many factors, like: billboards, radio, self-phone, passenger presents,

noises, etc. The advantage of autonomous vehicle is reflected in the elimination of driver errors in the decision-making process while driving, which results in fewer traffic accidents. Onboard computer is programmed to adhere to strict traffic rules, so potentially dangerous situations can be avoided (e.g. drunk driving, self-phone usage, irregularly parking, exceed speed limit, etc.) [9]. Mostly autonomous vehicles are electrically powered, so they are more convenient for the environment [10].

In particular, autonomous vehicles can work under unfavorable weather conditions and at daytime. Such vehicles do not suffer from fatigue. Long sitting at the car's wheel provokes physical and psychological fatigue. Even in the most ideal road and weather conditions, even in the most comfortable cars, a person experiences fatigue over a long time running through the steering wheel. Also, such vehicles can reduce a parking space near to destination, especially in city centers. Vehicles can bring the passengers to the destination and leave to find parking spot in a different place. Passengers can easily call the vehicle back, when it is needed, by self-phone [11]. One of the main advantages of launching the autonomous vehicles is the ability to remove a person from potentially dangerous locations, such as work in areas of radioactive or chemical pollution, work with explosives, etc. [12].

Table 1. Advantages and disadvantages of autonomous vehicles

ADVANTAGES	DISADVANTAGES
The vehicle cannot be distract	Job losses
Can work under any weather conditions	Human dependency and lack of intelligence
Comfortable driving	Software abuse
Better road safety	Non-acceptance in humans
Easy maneuvering and parking	Legal issues
Ecological benefits	Ethical issues
Easy traffic control	High cost
Ability to remove a person from potentially dangerous locations.	Power and energy dependence and battery life

Usage of autonomous vehicles will come with a lot of job losses and retraining of certain qualification. Also these vehicles may be susceptible to cyber-attacks, just like home computers. If that happens it will be necessary to change certain components on all vehicles of the same series, which can be a very demanding and expensive job. Despite the fact that autonomous vehicles have a number of sensors that can identify various obstacles, that the speeds of such vehicles are not high, but the crashes happen with them. There is, also, a problem with perspective in such vehicles. For the onboard computer it is difficult to recognize and understand the pedestrian behavior (e.g. facial expression, hand signs, etc.) [9]. Sensors on autonomous vehicle can fail due to situations that could not be overviewed in the laboratory. Such failures are mostly fatal for passengers. While many of our power and energy sources have increasingly greater capacity, autonomous vehicle cannot last infinitely and are still plagued by the need to be recharged. These vehicles will

cost much more than conventional vehicles, so the price can be classified as disadvantage [12]. In addition to above disadvantages, usage of autonomous vehicles face some legal, ethical and social responsibilities.

3. POTENTIAL USAGE IN TRANSPORT SYSTEM

Autonomous vehicles require a base map to successfully drive on some territory. Those maps should contain basic information of the streets position as well as traffic signs position. Based on characteristics of autonomous vehicles the best application would be in the urban passenger transport system, because all the vehicles in urban passenger transport use the same transportation route so it would be easy to make a base map for autonomous vehicles [13]. However, these vehicles can transport passengers to and from work during the day, deliver goods and collect waste during the night [14]. Nowadays, a number of companies are working on the development of autonomous vehicles like: Google, Scania, Tesla Motors, Amazon, Nissan, Toyota, Volkswagen/Audi, Mercedes-Benz, Delphi Automotive and Bosch [10].

Application of autonomous vehicles leads to several challenges. One of the biggest is who is responsible when it comes to accidents. There is also an ethical character question, if we want to create an ethical robotic system, it is unclear what ethical theory to use as a model, as ethical principles depend on every individual differently [15]. Table 2. shows the current situation of autonomous vehicles and their characteristics.

Table 2.Autonomous vehicles and their characteristics

	**Scania AXL autonomous truck [16,17]** • no cabine • bio-dizel • usage in the large closed construction sites and mines • tested in 2021 on the E4 motorway between Södertälje and Jönköping • 4th degree of automation (a person can take control in a critical situation)
	**Scania NXT autonomous bus [18]** • carrying passengers (during the day), and waste (during the night) • intended for 2030 • 8m long,162 kWh battery pack, range of 245 km • 55 passengers, 20 seats, weight of 8 tonne • for extra power use solar panels at the rooftop. • infrared heating system • small turning radius (10,5 m) • easy mounting stand

Amazon Zoox autonomous taxi vehicle [19,20]

- carry ut to 4 passengers
- all the sensors are inbuilt
- same speed in both direction
- 3,63m long, electric vehicle, 133kw battery pack
- 16 hours of continuous driving
- two motors (front and back) for energy efficient
- tested in cities: San Francisco and Las Vegasa
- speed around 130 km/h and view field around 270 degree

The main problem of autonomous vehicles are errors. Errors can be physical (sensor or actuator error, control, power and communication systems, etc.) and human made (programing and design). Actuators fail most often due to mud getting into the gears. A common error is a failure of the onboard computer and control unit. As a result, the vehicle does not respond to commands and in some situations a sudden increase in speed.The loss of communication is due to the wrong choice of communication system. The problem with the sensors occurs due to inadequate placement of sensors, less often there is a malfunction on them. There are the least problems with the power supply, since they are electric vehicles [13].

4. CONCLUSION

Autonomous vehicles, called robotic vehicles, are those vehicles that move independently and where all real-time driving functions are transferred to the Vehicle Automation System. Autonomous vehicles use sensors to create an image of the environment at a certain but limited level. After perception, the vehicle uses control algorithms to perform certain tasks: chooses routes and appropriate speeds, avoids obstacles, etc.

There are divided opinions regarding the acceptance and non-acceptance of autonomous vehicles. The public claims that autonomous vehicles provide greater autonomy to people with disabilities, improve safety and reduce emissions, while opponents of this technology believe it is less safe and insufficiently tested in a real traffic environment [3]. The use of these vehicles in everyday life can lead to the loss of a significant number of jobs. Traffic safety can not be an excuse for autonomous vehicle application, because application of such vehicles require huge amounts of money that can be transferred to more efficient measures in traffic safety, like driver education.

Significant development of autonomous vehicles started twenty years ago as a result of numerous projects. However, it is necessary to improve the system of autonomous vehicles to perfection, their constant testing and especially in real driving conditions where there is human influence and compliance with legal and ethical issues.

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