BRNO UNIVERSITY OF TECHNOLOGY

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

FAKULTA ELEKTROTECHNIKY
A KOMUNIKAČNÍCH TECHNOLOGIÍ

DEPARTMENT OF FOREIGN LANGUAGES

ÚSTAV JAZYKŮ

USE OF GPS IN THE CAR INDUSTRY ORIENTED ON SELF-DRIVING VEHICLES

VYUŽITÍ GPS V AUTOMOBILOVÉM PRŮMYSLU SE ZAMĚŘENÍM NA BEZPILOTNÍ VOZIDLA

BACHELOR'S THESIS
BAKALÁŘSKÁ PRÁCE

AUTHOR — **Marko Gróf**
AUTOR PRÁCE

SUPERVISOR — **Mgr. Magdalena Šedrlová**
VEDOUCÍ PRÁCE

BRNO 2020

BRNO UNIVERSITY OF TECHNOLOGY
FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

Bachelor's Thesis

Bachelor's study field **English in Electrical Engineering and Informatics**

Department of Foreign Languages

Student:	Marko Gróf	***ID:***	198171
Year of study:	3	***Academic year:***	2019/20

TITLE OF THESIS:

Use of GPS in the Car Industry Oriented on Self-driving Vehicles

INSTRUCTION:

Describe individual GPS types with regards to their usage in automotive industry focusing on autopilot vehicles. Discuss advantages and disadvantages.

RECOMMENDED LITERATURE:

[1] Pratap, Misra. Global Positioning System: Signals, Measurements, and Performance (Revised Second Edition). Ganga-Jamuna Press. 2010.

[2] Miucic, Radovan. Connected Vehicles: Intelligent Transportation Systems (Wireless Networks). 1st ed. Springer. 2019.

[3] McGrath, Michael. Autonomous Vehicles: Opportunities, Strategies, and Disruptions. Independently published. 2018.

[4] Lipson, Hod. Driverless (MIT Press): Intelligent Cars and the Road Ahead (The MIT Press). MIT Press. 2017.

Date of project specification: 7.2.2020 ***Deadline for submission:*** 12.6.2020

Supervisor: Mgr. Magdalena Šedrlová

doc. PhDr. Milena Krhutová, Ph.D.
Subject Council chairman

Abstract

This bachelor thesis focuses on the use of GPS in the automotive industry with a focus on unmanned vehicles. The aim was mainly to approach the GPS system but also other temporary systems, and to describe and characterize autonomous vehicles and all the hardware and software they use. The first half of the work characterizes the GPS in great detail so that the reader gets to know how the navigation system works. In the second part of this work, the reader will learn about autonomous vehicles, to which levels we divide them and which systems are used. Reader will also learn the advantages and disadvantages of these vehicles, the main differences between today's cars and autonomous cars. At the end of this work is intelligent transport and its benefits, but also a insight into the future of transport and vehicles.

Key words

GNSS, GPS, GLONASS, Galileo, Satellite, Autonomous Vehicle, Intelligent Transport, Hardware, Software

Abstrakt

Tato bakalářská práce se zabývá využitím GPS v automobilovém průmyslu se zaměřením na bezpilotní vozidla. Hlavním cílem bylo přiblížit GPS systém jako takový, jeho využití v autonomních vozidlech, vysvětlit výhody i nevýhody těchto automobilů a popsat různé hardwary a softwary, které dále využívají. První polovina práce nejprve do velkých detailů charakterizuje GPS, aby se čtenář seznámil s tím, jak navigační systém pracuje. V druhé části se čtenář dozví o autonomních vozech, do jakých úrovní jsou rozdělena, a které systémy používají. Dále jsou zde popsány výhody a nevýhody těchto vozidel a také hlavní rozdíly mezi dnešními a autonomními auty. Závěr této práce je soustředěn na benefity inteligentní dopravy, ale i na pohled do budoucnosti vozidel či celé dopravy.

Klíčové slová

GNSS, GPS, GLONASS, Galileo, Satelit ,Autonómne vozidlo, Inteligentná doprava, Hardware, Software

Gróf Marko. (2020). *Využití GPS v automobilovém průmyslu se zaměřením na bezpilotní vozidla*: Vysoké učení technické v Brně, Fakulta elektrotechniky a komunikačních technologií. 45 stran.
Vedoucí bakalářské práce: Mgr. Magdalena Šedrlová

Prohlášení

Prohlašuji, že bakalářskou práci na téma *Využití GPS v automobilovém průmyslu se zaměřením na bezpilotní vozidla* jsem vypracoval samostatně pod vedením vedoucí bakalářské práce a s použitím odborné literatury a dalších informačních zdrojů, které jsou všechny citovány v práci a uvedeny v seznamu literatury na konci práce.

Jako autor uvedené bakalářské práce dále prohlašuji, že v souvislosti s vytvořením této práce jsem neporušil autorská práva třetích osob, zejména jsem nezasáhl nedovoleným způsobem do cizích autorských práv osobnostních a/nebo majetkových a jsem si plně vědom následků porušení ustanovení § 11 a následujících zákona č. 121/2000 Sb., o právu autorském, o právech souvisejících s právem autorským a o změně některých zákonů (autorský zákon), ve znění pozdějších předpisů, včetně možných trestněprávních důsledků vyplývajících z ustanovení části druhé, hlavy VI. díl 4 Trestního zákoníku č. 40/2009 Sb.

V Brně dne ....

Marko Gróf

Acknowledgements

I wish to express my sincere gratitude to my thesis supervisor Mgr.Magdalene Šedrlovej for providing me with all the necessary consultations and for her valuable guidance and encouragement extended to me during the preparation of my bachelor’s thesis. This accomplishment would not have ever been possible without her.

Table of Contest

List of abbreviations used 8
Introduction 8
1. Global Navigation Satellite System 11
2. Multi-GNSS 12
3. GPS 12
3.1. GPS positioning 13
3.2. GPS signals 14
3.3. GPS position errors 15
3.4. GPS structure: 16
4. Trilateration 18
5. Time synchronization 19
6. DGPS 20
7. GIS 20
8. Other GNSS systems 21
8.1. GLONASS 21
8.2. Galileo 21
8.3. Local satellite navigation systems 22
9. Applications of GPS in the Automotive 23
10. Autonomous vehicle 24
11. The technology behind driverless cars 26
11.1. Vehicle to Vehicle (V2V) 27
11.2. Infrastructure vehicle (V2I) 27
11.3. Vehicle to Pedestrisn (V2P) 28
12. Autonomous car compared to the standard 29
13. The role of GNSS 31
14. Intelligent Transportation Systems 34
14.1. The use of ITS 34
14.2. Aims s of Intelligent Transport Systems Implementation 35
14.2.1. Safety 35
14.2.2. Cost reduction 36
14.2.3. Environment 36
15. Futuristic era 37
16. CONCLUSION 39

List of abbreviations used

GNSS - Global Navigation Satellite System

Global name for the global satellite navigation systems that are

GPS - Global Positioning System

GLONASS – Global'naya Navigatsivannaya Sputnikovaya Sistema

GALILEO – Navigation system created by the European Union

NAVSTAR - Navigation signal for timing and hanging

PPS - Pulse per second

GIS - Geographic Information Systems

DGPS - Differential Global Positioning System

ITS - Intelligent Transport Systems

DOP - Dilution Of Precision

AI - Artificial intelligence

Introduction

This bachelor thesis will focus on the study of the possibilities of using GNSS devices, especially GPS in autonomous cars and what a drone is, how it works. The current situation in the world is such that the technology of navigation, camera systems and other important devices in cars are advancing very fast. Its use has the origins in the military section, but today are used mainly in the transport section. The results and findings of this bachelor thesis should be beneficial in these areas in the future, also as a knowledge for general public. The first goal of this work will be to study the functional properties of GNSS.

At the beginning of my work I focus on defining what GNSS is, what GNSS systems we know and what criteria they work with. Gradually, the reader will learn general information about the operation of GPS (Global Positioning System) and its brief history, thanks to which the reader should become familiar with the concept of GPS, but also with the risks of this system. Next, we will learn about the important technical elements that should be considered in safe unmanned vehicles. Gradually, we will go about the improved GPS system as such, especially in the accuracy of positioning, but also about how it works and how important it can be for the cars themselves. The reader will also learn about the GIS system, which records geographical data and creates 3D maps, whether it serves as an aid in various sectors of work. I also want to introduce the reader to the features of other GNNS systems, especially Russian and European, but also local navigation systems in other countries. The second half of my work begins with how a GPS device can be implemented in a car, and what uses it provides to the user. Next we will look at what an autonomous vehicle is, and we classify these vehicles in what levels and criteria on the basis of their autonomy. We will go through and explain how an autonomous vehicle works, what all systems and elements should contain, and how each system behaves. The reader will learn the basic comparison of an autonomous vehicle with an ordinary car and their advantages and disadvantages, but also whether GNSS is really necessary for the future of these vehicles, I will explain my knowledge and describe the negative aspects of this system in cars. Among other things, we will focus on intelligent transport, defining what intelligent transport means, what the goals of this transport are and what the consequences may be from an economic point of view, from an environmental point of view and, above all, safety. I want to dedicate the conclusion of my work to the reader again, based on the acquired knowledge and facts, to imagine what transport and the whole infrastructure could look like in the future.

1. Global Navigation Satellite System

According to gsa.eu, Global Navigation Satellite System (GNSS) refers to satellites that emit signals from space and then transmit position and timing information to GNSS receivers. Subsequently, these devices use obtained data to determine the object's current location. By definition, GNSS should provide global coverage. The most widespread GNSS include the NAVSTAR Global Positioning System (GPS), the European Galileo, the Russian Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS) and the Chinese navigation satellite system BeiDou, which is the least known system in our geographical location.[1,2]

GNSS reliability is assessed according to the following four criteria defined by gsa.eu:

Accuracy: „the difference between a receiver's measured and real position, speed or time"[1]

Integrity: „a system's capacity to provide a threshold of confidence and, in the event of an anomaly in the positioning data, an alarm"[1]

Continuity: „a system's ability to function without interruption"[1]

Availability: „the percentage of time a signal fulfils the above accuracy, integrity and continuity criteria"[1]

gsa.eu also mentioned that accuracy can be improved by regional satellite distribution systems (SBAS), such as the European Geostationary Navigation Overlay Service (EGNOS). This service improves the accuracy and thus the reliability of GPS data by correcting errors in signal measurement and providing information about its intact signals. [1]

2. Multi-GNSS

A multi-GNSS receiver is a system capable of calculating position, speed and time by receiving satellite signals transmitted from multiple navigation systems. Based on furuno.com previously, GPS, was the only positioning system, but as we know, other satellite navigation systems are now in operation, those will be elaborated in another chapter. Multi GNSS achieves incredible positioning accuracy with more satellites than GPS-only. The success of locating is increased by receiving significantly more satellite signals, for example in harsh environments where GPS positioning is difficult to determine. Interference immunity is also increased by using different frequency bands. Useful applications are automotive navigation, telematics systems and intelligent traffic systems for vehicle monitoring or geographic information systems such as computer simulation.[3]

3. GPS

The GPS system is one of the most famous GNSS devices in the world. Global Positioning System or NAVSTAR GPS is a satellite-based navigation system that is used to determine the exact position and also provides a very accurate time reference almost anywhere on Earth or Earth orbit.

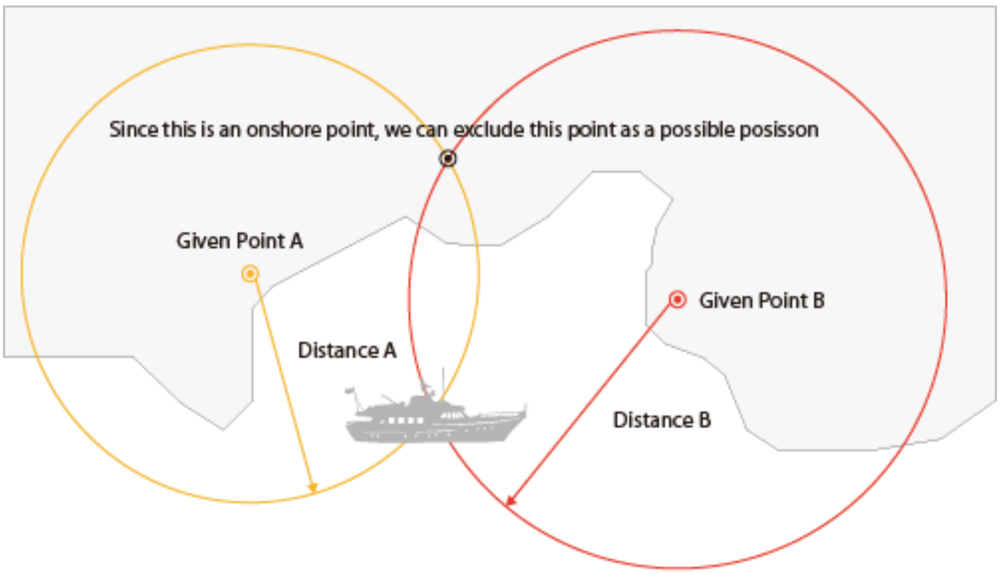
The GPS system is further used to passive satellite-length measuring and it is comprised of 24 satellites, which are placed in space approximately 19,300 kilometers above the earth's surface and evenly spread out in the orbit. Satellites circle the Earth at extremely fast pace, twice per day(11,200 kilometers per hour) [4].

The US Department of Defense initially intended to accurately determine the location, speed, and time of military units in a single reference system. It follows that the system was developed mainly for military purposes, but later the US Congress approved its use, with certain restrictions, for the civilian sector.

3.1. GPS positioning

Beginning with basics, furuno.com explains that first of all the time signal is sent from the GPS satellite at a specific point. Then, the time difference between the GPS time and the time window that the GPS receiver receives the time signal is calculated to generate the distance between the receiver and the satellite.

Very same process is performed with the another three available satellites. The position of the GPS equipped device can be calculated from the distance from the GPS receiver to three satellites. However, the position generated in this way will not be perfect, as there will certainly be an error in the calculated distance between the GPS receiver and the satellites, which arises due to the time error of the clock integrated in the GPS receiver. For a satellite, an atomic clock is included to calculate time information on site, but the time generated by the clock incorporated in the GPS receivers is not as accurate as the time generated by the atomic clock on the satellites. The fourth satellite is very important here, as the distance from this satellite to the receiver can be used to calculate the position in relation to the position data generated by the distance between the three satellites and the receiver, and thus we can alleviate positioning errors [5].



The picture from funuro.com illustrates an example of positioning by two dimensions (position acquisition by using two given points). We can compute where we are at by calculating distance from two given points, and the GPS is the system that can be illustrated by multiplying given points and replacing them with GPS satellites on this figure.

3.2. GPS signals

GPS satellites emit beams in two carrier frequencies; L1 and L2. Those that are accessible to civilians are coded in the C / A code, and rays that can only be used by the US military are coded in the P-code. The C / A code is an L1 frequency signal from GPS satellites that is phase modulated in the C / A code, which is a pseudo-random code. We also know it as the golden code. In GPS, 1,023 consecutive samples contain a sequence, and then this sequence will be repeated one after the other. The gold code code consists of the identification codes of each satellite and is transmitted together with the navigation messages[5]. The orbit data of each satellite are called ephemeris (providing the exact orbit for the satellite itself, which can be used to generate the exact position of the satellite, the information needed to calculate the position information) and the orbit data of all satellites. is called an almanac (can be considered simplified ephemeris data and contains raw data about the orbit and status of all satellites in the network. It is used to locate available satellites so that the GPS receiver generates the current position and time. Based on funuro.com It takes 12.5 minutes to receive all data from the almanac.). Navigation messages are transmitted at a rate of 50 bits per second [5]. With this GPS data collection, the receiver calculates the distance between the satellites and the receiver to generate position data. The GPS receiver needs the aforementioned 12.5 minutes to receive all the necessary data to determine its position when the power source is activated. The receiver is able to store this data, which it obtains from the internal backup battery and starts reloading the data, when the power supply is activated, it immediately begins to receive the current position. Thus, for example, in the event of a loss, a stolen vehicle and a restart, we know its current position within a few minutes. Which definitely makes it easier to find the vehicle [5].

3.3. GPS position errors

As with all modern equipment, there are negative aspects or several factors that affect the accuracy of GNSS. One of the biggest problems include the distance of satellites, the synchronization and measurement of the exact time between individual satellites and the GPS receiver or the already mentioned interference with other signals.

Company Funuro explains at its website funuro.com, for example in lonosphere - a part of the atmosphere, between the thermosphere and the exosphere. The problem is, that the propagation velocity of the GPS signal is going slower through this layer causing the propagation inaccuracy.

Secondly the troposphere, the lowest portion of Earth's atmosphere. GPS position errors can be caused, for example, by radio reflections caused by a dry atmosphere or water vapour.

Another reason for poor positioning is the fact that GPS is not resistant to reflections when it hits the ground, structures and many more surfaces. We call this phenomenon multipath[5]. But on the other hand we have the value DOP, which talks about the accuracy of GPS positioning, which can help improve the system as such in the future and move, autonomous cars to a higher level in terms of accuracy. It works on the basis of measured values. The smaller the value, the higher the positioning accuracy. However, it is dependent on the position of the GPS satellites, designed to track the location. If the tracking satellites were evenly distributed across the Earth, the positioning accuracy would increase, on the other hand, if the satellites were dispersed inaccurately, the positioning accuracy would decrease. The state of GPS reception depends on the strength of the GPS signals, and the stability of the signal itself, of course, depends on the strength of that signal [5]. The greater the force, the more stable the received signal level. However, this may be distorted e.g. by loud noise near the receiver and result in a weaker signal. For autonomous vehicles, is undoubtedly need for the strongest possible signal, especially from the point of view of passenger safety. Synchronization of a satellites, is assisted by atomic clock, which are considered by techtarget.com as the most accurate clocks in the world. It is designed to measure time based on the vibrations in atoms.

Atomic clock are used for coordination and maximum accuracy of systems such as GPS. Clocks located in various sites around the world are used to create a coordinated universal time [6]. It can be a building block for intelligent transport in the future, as a users would enjoy universal time.

3.4. GPS structure:

Although GPS is not widely understood, the structure is not as complicated as could seem at first glance. Well explained structure is presented by official US government maintained website gps.com that divides today's GPS systems into three main segments. These are the Universe segment, the control segment, and the user segment. The US Space Force is researching, maintaining, and operating space and control segments. Each GPS receiver uses signals from GPS satellites to calculate its three-dimensional position (longitude, altitude, and latitude) and current time[7]. Gps.gov defines the segments as follows:

The Universe segment: „Several GPS satellites are deployed on six orbits around the earth at the altitude of approximately 20,000 km (four GPS satellites per one orbit) and move around the earth at 12-hour-intervals." [7].

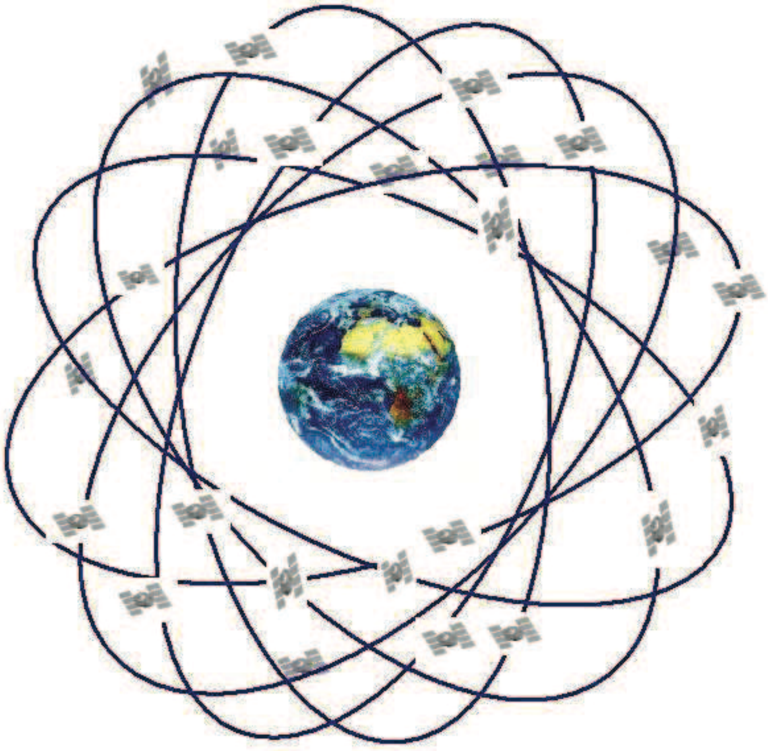
The Control Segment: „Ground control stations play roles of monitoring, controlling and maintaining satellite orbit to make sure that the deviation of the satellites from the orbit as well as GPS timing are within the tolerance level." [7].

The user segment consists of:

-„ tens of thousands of US and military troops associated with them,

which use secure GPS PPS - Precise Positioning Service,

- tens of millions of people, in the commercial or scientific field of GPS SPS - Standard Positioning Service." [7].



Picture from www.fc.up.pt/lic_eg/imagens/gps-const.jpg, showing orbits of GPS

GPS satellites emit a signal that the GPS receivers use to create a three-dimensional position (latitude, longitude and altitude) and accurate time. Each GPS provides time and location-based information to a GPS receiver, located anywhere on or near the earth surface. GPS works in all weather conditions, provided there is an unobstructed line of sight communication with 4 or more GPS satellites.A GPS operates independently of the user's internet connection or telephone signal. However, their presence increases the effectiveness of GPS positioning. GPS was initially developed by the US government for military purpose, but currently, anyone with a GPS receiver can receive radio signals from GPS satellites. Any instant of time, there are at least 4 GPS satellites in line of sight to a receiver on the earth. Each of these GPS satellites sends information about its position and the current time to the GPS receiver at fixed regular instants of time. This information is transmitted to the receiver in the form of signal which is then intercepted by the receiver devices. These signals are radio signals that travel with the speed of light. The distance between a GPS receiver and the satellite is calculated by finding the difference between the time the signal was sent from GPS satellite and the time the GPS receiver received the signal. Once the receiver receives the signal from at least three satellites, the receiver then points its location using trilateration process. A GPS requires at least 3 satellites to calculate 2-D position (latitude and longitude on a map). In this case, the GPS receiver assumes that it is located at mean sea level. However, it requires at least 4 satellites to find receivers 3-D position (latitude, longitude, and altitude) [7].

4. Trilateration

In this topic will be elaborated how trilateration works and why it will be important for the future of the car industry.

First of all, it should be emphasized that this is a mathematical technique used in GPS to determine the position, speed and altitude of a vehicle. The altitude of the vehicle may seem like nonsense, but it is very important component for flying autonomous vehicles mentioned in 14th chapter. Based on information published by lifewire.com that explains how all science works by constantly receiving and analysing radio signals from multiple GPS satellites, and using the geometry of circles, spheres, and triangles, the GPS device can calculate the exact distance or range of each satellite being monitored. It is a sophisticated version of triangulation, although it does not use angle measurement in its calculations. Information from a single satellite determines the general location of a point in a large circular area on the earth's surface. The information from the second satellite allows the GPS to refine the point by placing it down to the area where the areas of the satellite data overlap. After updating the data from the third satellite, can be located the exact position of the point on the globe. All GPS devices use three satellites to calculate the position. Information from more satellites increases the accuracy of the position, which is a big plus for the car itself. Among other things, thanks to data from several satellites are known other necessary factors, such as altitude or height from the ground when a car is flying. There are usually from four to seven satellites and use trilateration to analyse information [8].

As stated by source lifewire.com, trilateration fails when GPS receivers have insufficient data from satellites because they cannot be tracked by enough satellites. Large buildings or mountains are also obstacles that weaken a signals from satellites and prevent accurate positioning. Then the GPS device warns the user that it cannot provide the correct location information. Satellites can also fail completely or temporarily [8,9]. Signals can move very slowly from several factors in the troposphere or ionosphere. Signals can also ping off some formations and structures on Earth, which can cause a trilateration error.

After calculating the position of the receiver, other information can be easily calculated e.g. :

- Speed
- Track
- Time of sunrise and sunset
- distance to destination

5. Time synchronization

The synchronization of time is the basis for the future safe travel of autonomous cars. The receiver uses a GPS satellite to maintain timing accuracy.
With the timing of the receiver and GPS satellites maintained by the atomic clock, the receiver can calculate the exact time difference [9].
Real use on the road could anticipate e.g. during the overtaking the autonomous vehicle will be able to calculate based on the exact time, distance and speed. From that information state whether it is able to safely overtake the vehicle in advance or not. This feature could significantly reduce the number of accidents on the road. On the other hand, for such exact calculations the extraordinary accuracy of time synchronization and real-time localization will be needed.

6. DGPS

As you know it is Differential Global Positioning System. It is an improvement of the Global Positioning System (GPS) which, in according to sapos.de the best implementations, provides improved positioning accuracy over the range of operations of each system, from a nominal accuracy of 15 meters to about 1-3 cm [10].What in the future, can be a great prerequisite for successful driving and perfect control of autonomous cars.

The work of the DGPS is relatively difficult. Based on geeks.org , the GPS receiver also called as the base station must be set up at a precisely known location. The base station receiver calculates it's position based on the satellite signals and compares it's location to the known location. The difference between the two locations is applied to the data recorded by the GPS receiver. Provides position accuracy in sub-meter to cm range". The network of DGPS ground stations transmits the difference between already known positions and positions marked by GPS satellite systems. Subsequently, these stations transmit the difference, between the measured pseudo-satellite ranges and the actual ranges where they can subsequently correct it [11]. Of course, all the technical improvements, even the smallest ones, which we cannot precisely implement in cars today, can play an important role in the future in improving and safer travel.

7. GIS

Geographic information system or just GIS as another GNSS enhancement, is the system that collects data on the earth's surface. Which is of course another plus for improving transport. According to several sources such as techterms.com, we use this device to collect data and analyse the earth's surface. Subsequently, this information is used to create maps and 3D models of the earth's surface, such as mountains, trees, street buildings and everything else. This technology it is beneficial for several organizations, either today or in the future. Organizations such as the fire brigade, police, rescue service can use this data to develop emergency routes when needed [12]. Moreover in the future

GIS devices could be normal part of the autonomus car, because as we assume that the traffic situation could be alleviated during use GIS

8. Other GNSS systems

Almost everyone knows the GPS system in the developed world, but few know that it is not the only navigation system whose satellites orbit.
In short, we will mention the best known, because when using autonomous cars, it can play a significant role, where in the world the vehicle is located and thus what GNSS equipment is used

8.1. GLONASS

The technical battle between the United States and Russia has been going on for many years, and satellite navigation has not been avoided. Therefore, after the American GPS, there is a Russian satellite navigation response in the form of the GLONASS system, which was built and launched into orbit in the 80s of the last century.
GLONASS in our European latitudes should be more accurate than GPS, as GPS satellites are denser deployed just above our hemisphere and, of course, also because we are closer to Russia. The fact that it should be more accurate is a great advantage in the calculations and accuracy of factors such as, determining the exact position or the actual speed. Autonomous vehicles should currently run on the Russian GLONASS system because it is more accurate in our region than the GPS system.
Based on eetimes.com , all satellites use the cesium clock as the source of the exact frequency. in automotive industry is GLONASS used in Russia's largest carmaker Avtovaz, to develop GPS navigation units for its LADA cars [13].

8.2. Galileo

Galileo, as the third most popular GNSS device which is owned European Union, is a global navigation satellite system that provides highly accurate positioning is compatible with other global satellite navigation systems GPS and GLONASS. Galileo offers standard dual frequencies and is set to provide real-time positioning accuracy right up to the meter. According to esa.int "Galileo system consist of 24 operational satellites plus six in-orbit spares, at 23 222 km altitude above the Earth, and at an inclination of the orbital planes of 56 degrees to the equator" [14].

Base on esa.int, Galileo was launched on December 15, 2016 only as an initial version. During this year, new services will be tested and will continue to be available. If all goes according to plan, Galileo will also provide excellent coverage at latitudes up to 75 degrees north, such as the Cape of Norway. Thanks to the latest technology, the European system has a great advantage over the competition, and it obvious to see it mainly in the number of satellites. Galileo has three active replacement satellites in orbit, which provide immediate replacement in the event of the loss of one satellite and should have no visible effect [14]. These are very good prerequisites for the use of Galileo in autonomous cars that are on our continent, but this system is still in its infancy and needs to be in operation for even longer so that we can fully implement it in these vehicles.

If we want to compare Galileo with the competition, based on current information, Galileo has the highest positioning accuracy. It has higher signal coverage in the northern countries of Europe, on the other hand it is a very young project that is not as tested as the mentioned competition [14].

8.3. Local satellite navigation systems

These are navigation systems that are either under construction or are only available in the country or nearby. Due to their current uselessness in Europe, we will not analyse them in detail. But in the future those GNSS can be the more succesful, because the devices are focused on smaller area of the earth and occuracy ca be more effective

- COMPASS (BNTS) - Chinese navigation system
- QUASI-ZENITH Sat. System (QZSS) - Japanese navigation system
- Indian Regional Nav. Sat. Sys. (IRNSS) - Indian Navigation System

9. Applications of GPS in the Automotive

The navigation has never been easier than with GPS. Convenience of use is enriched by built in multi-functional screen attached to vehicle dashboard. Smart control and processing elements are built in, so car can be more less fully managed from the dashboard. Advantage of built in device in opposition to the external device is that built in device can interacts with another car components e.g. tire pressure or fuel management. Below is mentioned fraction of GPS based multi-functional stereo device functions inspired by indig.com [15].

SAFETY FEARURES

Position of the vehicle can be easily located by GPS tracker that is commonly used by car owners to determine the position of the vehicle. GPS tracker is useful in everyday situations such as finding the car at the parking lot or checking the delivery arrival. However, the exploitation range is greater as e.g. finding the stolen vehicle or tracking if the company vehicles are used for appropriate purposes.

WEATHER AND TRANSPORT

Throughout the GPS is forecasted the weather and traffic at a desired location in given time. Outcome is that user can prepare in advance to the traffic or weather situation. In general, use of GPS can prevent inconveniences connected with traffic jams or weather prediction.

ADMINISTRATION

The management of each car in a large vehicle fleet can be difficult. For instance, the effectiveness of the taxi service has increased since the use of GPS. The monitoring of a vehicles allows to send the closest driver to approach a client. Furthermore, car producers that store several hundred cars of the same kind can locate particular vehicle of fleet in the matter of seconds.

EMERGENCY USE

Driver might appear lost in middle of nowhere with a failed vehicle. In such circumstance the GPS locator provide rescue signal with exact information about the location.

Another very useful feature is to recognize the daylight on the road. A daylight recognition helps in road safety, while turning the lights on. Also, energy consumption efficiency is increased when switching between LED day lighting and night, more bright lighting.

10. Autonomous vehicle

Pursuant to GPS world, in the field of transport, the futuristic era has been entered. Companies are looking for new ways of transport, that will be more energy effective than current gas engines. The need for change has been gradually increasing over past years. As the need for change increase, the pace of new vehicles introduced to market increase simultaneously. It is very likely that in next decade will be today high-end products are to be obsolete in a blink of an eye. Also, commercial market is expected to be dramatically changed.

First concepts of autonomous vehicles came out over hundred years ago. An autonomous vehicle is a vehicle with no driver, that is able to move from point A to point B without any human intervention.

Self-driving vehicles are believed to have several advantages such as increased road safety, reduced infrastructure costs and less accident rates. Self-driving vehicle incorporate efficient fuel consumption that leads to reduced costs of transportations. Human inattention is no longer a matter as the sensors take care of road safety. Parking lots become more available as the self-driving vehicles become part of the sharing model.

There are some disadvantages linked to the implementation of self-driving vehicles into main traffic such as loss of drivers, loss of privacy as the vehicles constantly scan the environment and finally the possible misuse if the technology was hacked. Especially the last point could cause problems as consumers can become reluctant to this technology [16].

In the US are autonomous vehicles working well so far, however in Europe is harder to achieve the same level of success mainly due to road conditions, and mentioned by a number of satellites.

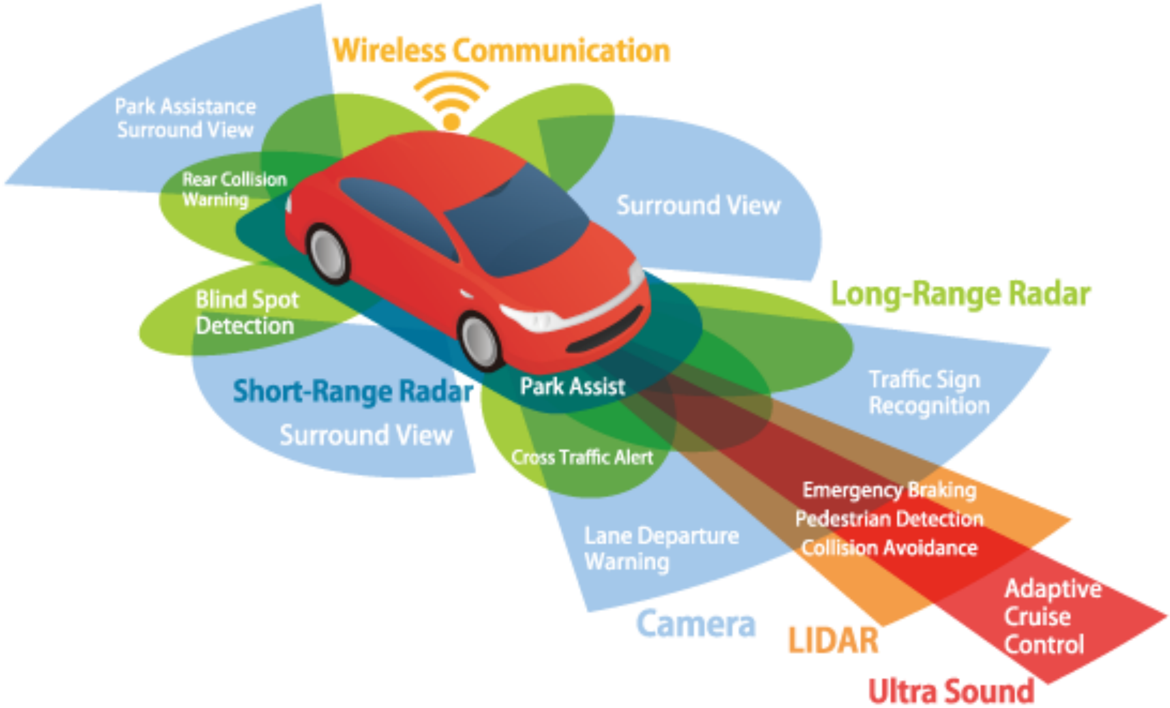
Following table shows five levels to achieve the fully autonomous vehicle based on synopsys.com

- Level 0 refers to an automated system that can warn and partially interfere with steering, but has no control of the vehicle.
- Level 1 (hands on) is an automated system with shared control of the vehicle. An example could be the adaptive cruise control ACC, where the driver controls the steering wheel and car speed. Another example is automatic parking.
- Level 2 (hands off) is an automated system that takes full control of the vehicle, including adding, braking and cornering. The driver must monitor the ride and intervene immediately if necessary.
- Level 3 (eyes off) is a system that allows the driver not to monitor the operation of the car. For example, a driver can watch a movie or make a phone call while driving. The vehicle can make an emergency stop, but the driver must be ready to intervene within a certain time.
- Level 4 (mind off) is the same as level 3, except that the driver does not have to watch the car at all, which means he can sleep or leave his seat. However, autonomous control is limited to the environment, such as during traffic delays. The vehicle may at any time cancel the autonomous steering.
- Level 5 (steering wheel optional) is a fully robotic car without the need for human intervention. [17].

Some cars use cameras, radars and sensors for autonomous control. Other vehicles have a professional environmental scanning system. All autonomous vehicles also rely on the accuracy of GPS technology and also on artificial intelligence that can assess the potential risks.

11. The technology behind driverless cars

The Self driving vehicles grabs lots of attention and for a good reason. While a decade ago it was only music of future, nowdays it is more about making neccessary steps in changing the infrastructure to driverless cars-friendly. This chapter presents the technology behind the autonomous vehicles, the envirnment and benefits that are brought. There are plenty of safety features that helps the driver such as automatic braking, collision warning and so on. Yet autonomous vehicles brings the benefits to another level as there is no need for the driver.



Picture from landmarkdividend.com shows the necessary systems in an autonomous car

Autonomous vehicles require several technologies such as radar, cameras, ultrasound and radio antenas in order to make the driverless journey possible. All those technologies are integrated inside the vehicle and collaborate together. Each component has the own, quite simple function. More difficult part is to evaluate information received from all devices combined. Based on landmarkdividend.com tesla's 'autopilot' technology uses eight cameras to provide full 360° vision around a vehicle. Twelve ultrasonic sensors and radar in the front of vehicle scans the environment for possible dangers. A key element that could bring safety to the higher level is implementation of a 5G network instead of 4G. Main purpose is communication between devices. Both of them work basically in same way, however 5G is much faster.

Again according to landmarkdividend.com, the maximum operating frequency of 5G network is 1000% faster than 4G LTE, causing the connection to be as large as high latency and long response times. This type of connection will allow communication between individual vehicles, but the most exciting part is that vehicles can communicate with every connected device in the network e.g. traffic lights can be connected to the same network and provide the information about operation directly to any vehicle in network [18].

11.1. Vehicle to Vehicle (V2V)

No delay communication between vehicles allows autonomous vehicles to share exact information about the current location at given time, but also route and dangers ahead on the particular route. For example if one car detects danger ahead with its sensors, second car driving behind it will be informed. So, second car can start the braking manoeuvrer even before its own sensors detect the danger. Third car can be more distant, and in case of significant slowdown can be route adjusted to the faster one in matter of seconds. On larger scale will be 5G network able to maintain constant flow of traffic, or at least more convenient flow [18].

11.2. Infrastructure vehicle (V2I)

Besides route conditions, autonomous vehicles using 5G network will be able to scan another infrastructure segments such as parking lots. Example of use: Autonomous vehicle A is parking at the car park, recognizing number of free parking lots. Findings are uploaded to the cloud and incoming vehicles will are informed about it. If is the car park to become full, incoming vehicle could either reserve parking place in advance or will be redirected to another car park. This V2I feature provide maximal efficiency when planning the route, and provide exact time of arrival not only to the desired location, but will work out the time of arrival with parking included [18].

11.3. Vehicle to Pedestrisn (V2P)

Communication between vehicles and infrastructure are great feature for route efficiency and safety but do not cope fully with pedestrian safety related issues. Autonomous vehicles and its current sensors can pretty accurately determine pedestrians, but there are cases where it is difficult even for humans.
There are very few people who leave their homes without any device that is not connected to the internet. Most of these devices have built-in GPS that determines its exact location. If those devices were connected also to the 5G network, then autonomous vehicles could recognize pedestrians and another public areas from location retreived from smart phones and related personal devices. Awareness of the pedestrians from network along with present sensors will raise overall safety of the teavellers by foot [18].

In addition to the above, there are other systems in the vehicle. Such as a cameras,lidar,machine learning or radars. According to wired.com cameras should be very useful hardware when seeing things around the car, such as traffic signs, traffic lights or even traffic jams. Some developers say that with even better vision, they could use cameras to identify everything and then orient themselves even more accurately. The Next common hardware that are installed in cars without a driver is definitely lidar, it is light detection. Lidar constantly emits millions of laser beams, measures the time needed to bounce, and then uses this information to create a 3D map that is much more accurate than what the radar offers, and the system understands them more easily than usual 2D maps. The next equipment can be machine learning. This artificial intelligence device is used to train computers so that they can recognize lanes of cyclists by showing them many real objects. As road traffic is so complicated that there is no way for us to come up with a rule for every possible scenario, so it is important to have cars that are able to learn from existing experiences. We cant forget on radars, they have been a part of the car until the early 90s of the last century, radars work on the reflection of radio waves and thus on the detection of the environment [19]. They recognize large metal objects such as other cars most accurately. Their advantage is that they are not obstructed by rain, fog or snow and are affordable. We know long and short range radars. Short radar is a device that helps detect hazards in the immediate vicinity of the vehicle and avoid them. But on the other hand hend Long radar is a device to improve spatial detection, such as road boundaries. The sensor is usually mounted at the front of the vehicle [20].

For easier parking was developed parking assistant, which based on guce.com the parking assistant was first introduced and implemented in vehicles in 2007 [21]. The main task is to help drivers park their cars in a small space. The first devices worked on the principle of contactless sensors or with the help of a reversing camera. If an unknown object is in the rear or front of the vehicle, an audible warning sounds to the driver or to the visual display. However, this older model also hides shortcomings in the form of blind spots or a very early audible warning. However, omniview technology can eliminate these shortcomings. The system contains four cameras, one in the front and rear of the car, and one in the right and left rearview mirrors, respectively. These cameras monitor the surroundings of the vehicle with great accuracy. The next very usseful system that should prevent the car or reduce the risk of collision with another object is called collision avoid system. Based on sadercar.gov the system basically records the speed of the vehicle, but also the speed of the car in front of it and their distance, and then warns the driver if these vehicles are close to each other to avoid collisions [22]. Among the last system which can protect the collisions is blind spot monitor. According to tricityinsurancenews.com, it is a sensor device that detects other cars in other lanes, just when we can't see them in the rearview mirror, this moment is called the blind spot. Warnings can be visually, for example, by illuminating the squadron on the rearview mirror, or even audible or vibrating way [23].

12. Autonomous car compared to the standard

What an autonomous vehicle must actually have beyond a normal car. However, this question is key to understanding why the arrival of autonomous vehicles is so unstoppably approaching. So let me satisfy this very thing on this very topic. In addition to a normal car, it is therefore necessary to have the following for autonomous driving:
By mocnedata.sk the primary premise is that the car will be able to replicate our senses. So it needs sensors to see (at least as much) what a person sees. However, since human

vision senses everything else, and thus instead of isolating visual perceptions, the reservation for driving directly from simulated vision, autonomous vehicles have decided to secure several different systems which we already mentioned to replace vision.

Unlike man, it is not enough to see the machine, because the machine must still be identified with some real object. If, for example, a box lies on the road, one immediately sees whether it is safe or not and can arrange or risk a sharp evasive maneuver accordingly or simply ignore the object. He also has to recognize that the shiny part of the road is actually water. In addition to vision sensors, autonomous control also needs software to recognize objects along the way and along the way.

In addition, of course, the car must know where it is and where it is going, so the system must include very precise location. Being half a meter somewhere else than I thought could have fatal consequences. In addition, the on-board computer must have the map data at its disposal and be able to react even in situations where optical vision signals that they are out of date. (for example, one lane of the road recently collapsed due to soil erosion, although on the map the road is beautifully two-lane).

Since autonomous control is not a set of hard-coded behavior patterns, but must be able to evaluate a situation that has not yet been encountered, the on-board unit must contain a decision module, probably based on a neural network. In addition, this decision module, which must be continuously verified (from an external environment), would not learn some bad habits. For this purpose, the results of the decision are likely to be sent continuously to a central center, which will look for system imperfections in real time and actively correct them in all other cars of the same brand.

Once the decision module has decided what to do in a given situation, there must be some physical model that translates the decision into a set of instructions for driving the car itself (down one step, throw the turn signal, lean in the opposite direction and add sharply to avoid slower car in front of you). The task of this model will always be to choose the most suitable combination of possible actions.

Performing some of the above tasks requires the presence of special hardware (stand-alone processor, memory chip for data storage), which, in addition, must manage security so that it is not directly attackable. This is why many think that the arrival of autonomous cars is far away, because most cars today do not have such hardware. But the opposite is true, but in reality it is a matter of relatively small dimensions, on which the assembly in the bodies of today's cars is enough space. So, if such facilities need to be there, there will definitely be a place for them.

Last but not least, there must be another layer of the system that pays attention to the interplay of all the above-mentioned elements. For example, she must be able to recognize that the signals sent by the sensor are "strange" and therefore it is possible that it is dirty or damaged and not mislead the whole car. It is also a unit that notifies a person when a car is unable to drive a car and must either stop or hand over control to the person [24].

13. The role of GNSS

In this topic, I will talk about the role that GNSS plays in automotive and whether it is really as irreplaceable as we think.

First of all, it must be said that GNSS systems will not be what the car will control, but it is just a device that is likely to help increase travel safety in autonomous vehicles. Based on gpsworld.com, when creating a database of visual maps that, in conjunction with cameras, radars and people on the vehicle and processed artificial intelligence (AI) algorithms, allow you to drive without a driver the way people drive. In-vehicle pattern recognition processing allows it to "read" street signs and recognize landmarks and record its location on a map. This is how people travel at the moment, in their city, where they always know their location and simply don't need GNSS. Processing AI with access to a wide range of map information, for example via local storage or a network connection, will always be in a familiar home environment: it constantly knows its own location and is correctly oriented to navigation.

Based on this knowledge, do you think GNSS would become pointless in the cars of the future? From my point of view and from point gpsworld.com definitely not

Although the navigation method is not one hundred percent reliable, but GNSS equipment is our primary method of in-car navigation today, and it must be said that for the current purposes it is also very accurate and efficient in real time and their availability improves very quickly but is not still ready for us to fully trust her and risk our lives.

Secondly, why we think GNSS is very important is the fact that not just the vehicle itself, it needs to know its exact position, but he also needs to know the position of other vehicles in the road for various tasks while driving. For example, the popular Uber application works on this principle, which shares the position of the vehicle and makes it relatively easy to order a car directly to your current location. GNSS also runs other applications than insurance applications, toll charging or various parking applications in cities. Therefore, the GNSS receiver will most likely remain in the vehicle.

The GNSS device is not only about pros but also about negatives, let's mention that one of the weaknesses of GNSS is the open unencrypted format. It is easier to falsify these signals every day. As gpsworld.com says „car sharing, usage-based insurance and dynamic toll applications create a monetary incentive for fraud that can be implemented using a spoofer “ [25]. Let's say a car connected to a location-sharing network reports a fake location in a protected area, the owner thinks the vehicle is safely parked, but in fact may have been stolen a long time ago. Just guess that all connections are secure. Which is a good assumption even though in the latter we have cases of traffic accidents over unsecured remote connections. SSL encryption, which is used to enter sensitive credit card information, works well, but according to gpsworld.com, „we now have the knowledge and technology to prevent the recurrence of such defeats. However, even if the communication links are secure, the GNSS spoofer in the car can trick the GNSS receiver into reporting a false "safe" position as soon as it is stolen. The same applies to insurance or toll applications. And fraud does not have to be sophisticated. A simple, inexpensive jammer can deny the right position long enough for the skirt to pay. A safe positioning method is needed.“ [25].

After sensors Integration, components like radar, Lidar and cameras are used to provide the distance to objects that surround the vehicle. If the exact location of the surrounding objects is known, this technology can provide the absolute vehicle location with assistance from a high amount of map data. When integrated with complimentary technology such as: ultrasonic, inertial motion, digital maps, radar/LiDAR and cameras, GNSS acts as the sixth sense to deliver the positioning performance required by autonomous vehicles.

In my opinion, and opinion from gpsworld.com[18] what would be the ideal signal for locating an autonomous vehicle?

first, it must be significantly stronger than the GNSS system to avoid freezing. second, it must certainly be encrypted and available everywhere in the world, third affordable for the necessary applications in the large market.

Though accuracy is always important, the signal used for localization does not have to be as accurate as GNSS is today. Accuracy to 10s of meters is sufficient for all these applications needing fraud protection since it would not be used for steering the car, but rather, only localization. It can also be used in tandem with GNSS to authenticate a reported position when a GNSS signal is available. Such a signal is available today, worldwide: STL (Satellite Time and Location). Carried on the Iridium satellites, it is a special purpose signal that is more than 30 dB stronger than GNSS and encrypted for anti-spoof protection. Decoding of this signal is available via a subscription model to users. Here’s how it would work using a car-sharing example. A group of people subscribe to a car-sharing service that provides X number of cars to serve Y number of people, where X is less than Y. The service optimally schedules people when and where a car will be available. The service provider needs to know the whereabouts of the cars at all times to maximize utilization of the fleet, so every car has a GNSS receiver in it. But to ensure the authenticity of these reports, they also have a secure localization receiver. This receiver is assigned a unique ID that is authorized to decode the encrypted signal. (Eventually, we expect this receiver and GNSS to converge into one device much the way multi-GNSS receivers operate today) [25].

14. Intelligent Transportation Systems

In this chapter, will be generally described Intelligent Transport Systems (ITS). Main focus is on where ITS are currently being used, what technologies they use and what are the benefits of using them. At the end of the chapter is outlined what could be improved on the ITS in the future and what other functions the ITS could fulfill.

14.1. The use of ITS

Intelligent transport systems are used in many areas of life, and often people do not even know about its use. ITS are present on road, rail, sea and air. This part is focused on road transport.

Most common areas where intelligent transport systems are present:

- Phase-optimized intersection phasing optimization.
- CCTV (Closed Circuit Television) traffic monitoring systems.
- Meteorological stations - cooperation with traffic reports.
- Traffic Control on Ramp Meters.
- Electronic toll.
- Support for parking systems.
- Provision of security and rescue services.
- Driving support.
- Provision of travel information.
- Logistics and distribution systems.
- Transport and transport databases.
- Freight and public transport management.

Above is mentioned only fraction from all application of ITS. This sector is on the rise and in next decade will penetrate in another areas.

14.2. Aims s of Intelligent Transport Systems Implementation

Miucic Radovan (2019) describes a ITS as "Intelligent transport systems integrate the means of transport, transport infrastructure, information and communication technologies, services, problem-solving methods and people involved in the operation of such systems "[26].

The use of new technologies and integration into present world is the key to the current transport problems. The ITS undertake certain objectives that can be according to the Cluster Competitiveness divided into three main groups. Those are: safety, cost reduction and environment.

14.2.1.Safety

More then 25,000 people die annually on European roads [27], and accidents cost the European economy many billion. While safety systems inside cars have recently been greatly improved to increase the chance of an accident surviving, more attention today needs to be given to systems that will even help prevent an accident. Intelligent transport systems can make travel safer, save lives, save time and money.

The main points in the area of security are:

• Helping drivers of cars and trucks, bus drivers to avoid an accident or not get out of the way. IDSs will help maintain a safe distance between vehicles or speed when approaching a dangerous point.

• Provide information on road areas, congestion, road conditions and other potential hazards.

• Assistance to emergency services. Detecting an accident, selecting the nearest and most appropriate rescue unit, adjusting the traffic lights so that the rescue unit arrives at its destination as quickly as possible.

• Help in preventing and responding to various disasters. Whether natural, caused by human error or terrorist attacks.

• Providing protection to people using public transport.

• Monitoring the transport of hazardous materials.

• Determining the escape route when evacuating people at risk.

14.2.2.Cost reduction

IDSs can help the ordinary driver or operator of a transport company the most by reducing transport costs, thus increasing transport efficiency. That is why governments, logistics, freight and distribution companies, as well as ordinary citizens, turn to IDS to help them save time and money. The main points in reducing costs are:

• Quickly provide accurate and complete information to travelers to make it easier to decide where to start their journey and what means of transport to use.
• Helping drivers choose an efficient and safe way to their destination.
• Toll payment without stopping.
• Helping freight to move swiftly and reliably. Choosing the right one
a combination of road, rail, ship and air transport.
• Allowing cargo tracking, estimating the time it takes to reach the destination
destination.
• Helping people working in transport with management, trip planning and management critical processes.

14.2.3.Environment

Since the use of ITS can increase the efficiency of transporting people and cargo and reduce the time spent in congestion, it also means that the burden on the environment is also proportionately reduced.

Benefits for the environment:

• Smooth driving without unnecessary stops will reduce fuel consumption and emissions.
• Making public transport more attractive by making it more reliable, efficient and safer.

Of course, IDS cannot do wonders in this respect, and change can only come from a change in people's thinking.

15. Futuristic era

For the general population, autonomous vehicles are the future of the automotive industry. Mankind will rely gradually more on computers, which are already performing our daily duties. It means that people will be less and less in control of their lives and will rely on technology. But is that really what men would like? People who love to drive a car, or people who work as professional drivers, what would they do? Although many of us believe that engineers are only a few years away from the full exploitation of these cars, the opposite may be true and all that is in media can only be science fiction. In order to be able to say where autonomous cars are heading, we need to look at where we are now, what technology already exists, and what ideas about the future have the largest autonomous vehicle companies such as Tesla or Google.

Where are we now?

There are thousands autonomous vehicles in use, but how far are we really? In the last half century, as a human beings, we have had an enormous number of tests around the world, but in the last 8 to 10 years, we have seen perhaps the greatest technical progress in the development and testing of these technologies. Not only drivers without a driver were tested, but a large number of elements became part of traffic life. One of the popular autonomous elements that is used even today is the self-parking of the vehicle companies such as Waymo, Google or BMW test their vehicles on public roads or even in a virtual world in which they simulate various traffic situations. The vast majority of cars are currently between the second and third stages. Although it all looks fantastic, a study by RAND Corp. in 2016, states that automotive companies would need millions to billions of test kilometers to truly prove the reliability of this type of car. Let us recall the death of a 49-year-old woman who was hit by an autonomous car. To this day, it is not clear why the accident occurred, why the car did not stop, or why the so-called safety driver did not intervene. Despite the tragic incident, testing for many other car companies continues, especially in the UK, as the English are building large-scale infrastructure to attract these partners.

What is next?

We need to look to the future and in addition to classic autonomous cars, we can also expect flying autonomous cars that would be hybrid (traveling classically on the road but also in the air). Currently, the so-called Aeromobil vehicle is being completed right on our territory, which should be commercially introduced and available this year. This is the first ever flying car with a lot of autonomous elements such as autopilot, and many other useful systems that are mentioned in this thesis. In the distant future, this car could bring not only unmanned drivers, but also flying, which would significantly reduce the number of cars on the ground, but of course would increase air traffic. But now imagine a situation that is not unrealistic at all, and is that the number of these cars will only increase. Would long-term traffic regulations also change? Probably yes, as much as we would have give way from the top or the bottom. But what would the infrastructure look like if there were more and more of these cars available today? I will leave this dreaming to the reader to make the picture of the future autonomous transport himself

16. CONCLUSION

In this bachelor's thesis, all assignment points were met. We studied the functional properties of GNSS systems, especially GPS, which we discussed in detail, but also other global navigation systems. In the second half of my bachelor's thesis, we learned what possibilities the GPS system has in cars, we gained knowledge about what an autonomous vehicle is, what levels they are divided into and what principle this car works on. We have also discussed many other systems that make an autonomous vehicle autonomous. We compared an autonomous vehicle with a normal vehicle of today's type, where we found very interesting findings. We went through intelligent transport, where facts were mentioned that the reader may not have known about and how it would make life easier for us in the future. However, from the acquired knowledge, I believe that the arrival of full-fledged autonomous cars of level 4 to 5 is not yet as close as we think, although car companies would certainly not like to confirm my statement. I mainly assumed that we are currently only at level 3 and at level 5 we still need a lot of money, which will be difficult to find at the moment during this crisis. Another reason why I think it will take a long time is that we do not have a complete infrastructure for the arrival of these cars, especially in Europe, apart from Britain, and only construction will take many years. Another reason is the testing itself, as I mentioned in my work, it is necessary to drive millions of test kilometers, which will also take a long time. On the other hand, I am very pleased, because autonomous cars are a step forward, we would reduce road accidents, we would lighten the environment and many other benefits. However, I do not think it is as close as it is presented.

Rozšířený abstrakt

Tato bakalářská práce se zabýva využitím GPS v automobilovém průmyslu se zaměřením na bezpilotního vozidla. Hned na začátku jsme čtenářům vysvětlili lze pro něj neznámí pojem GNSS, a hlavně uzrozumili, že GPS není jediný navigační systém na světě.

Hlavním cílem bylo přiblížit GPS systém jako takový, jeho využití v autonomních vozidlech, vysvětlují výhody i nevýhody těchto automobilů a popsat různé hardwary a softwary, které dále využívají.

První polovina práce Nejprve do velkých detailů charakterizuje GPS, aby se čtenář seznámit s tím, jak navigační systém pracuje, aby si věděl predtaviť složitost tohoto systému, a že autonomní vozidlo nebude jen o GPS signaloch.

V druhé části se čtenář dozví co to znamená ked se řekne autonomní vozidlo, či do jakých úrovní jsou rozděleni. Mimo jiné se čtenář dozví jaké možné systémi ať už hardwarové nebo softwarové obsahuje toto vozidlo a na jakých principech pracují. Porovnávali jsme na základě obecně známých poznatků autonomní auto s normálním autem. Určili jsme jestli má nebo nemá GNSS systém budoucnost v autonomních vozech.

A nakonec jsou zde popsány cíle a benifity inteligentní dopravní, která nás pravděpodobně nemine, ale i pohled do budoucnosti vozidel či celé dopravy.

REFERENCIE

1. *European global navigation satellite systems agency,* (2017). What is GNSS? [online]. [cit. 2020-02-10]. Retrieved from: https://www.gsa.europa.eu/european-gnss/what-gnss?fbclid=IwAR1HBhSANYLmEFIbDbyK_QRslPO4rjsSMHkkUE3q4bnzDzq3DZKeIcORLVU

2. *HEGARTY, C.J., E. CHATRE.,* (2008). Evolution of the Global Navigation SatelliteSystem (GNSS). *Proceedings of the IEEE* [online]. 96(12), 1902-1917 [cit. 2020-05-20]. DOI: 10.1109/JPROC.2008.2006090. ISSN 0018-9219. Available from: http://ieeexplore.ieee.org/document/4745647/

3. *Furuno*, (2014). Multi-GNSS (Multi-frequency GNSS) [online]. [cit. 2020-02-10]. Retrieved from: https://www.furuno.com/en/gnss/technical/tec_multi?fbclid=IwAR0HEHJKCuWjbCsJQGIO9UdHiA-DL2Ptx5VNACM4X6vRnouBI3q0QAagZq4

4. *Techterms,* (2020). GPS. [online]. [cit. 2020-02-11]. Retrieved from: https://techterms.com/definition/gps

5. *Furuno,* (2014). What is GPS? [online]. [cit. 2020-02-11]. Retrieved from: https://www.furuno.com/en/gnss/technical/tec_what_gps?fbclid=IwAR1aIiiG5LhyQkK8XclhKpE5Kgrg4qPdUGMfIf5Jz16n9Wcg9ea1uj_F804

6. *Margaret Rouse,* (2014). Atomic clock (NIST-F1) [online]. [cit. 2020-02-03]. Retrieved from: https://whatis.techtarget.com/definition/atomic-clock-NIST-F1

7. *U.S. Government*, (2020). *GPS: The Global Positioning System* [online]. [cit. 2020-02-12]. Retrieved from: https://www.gps.gov/systems/gps/

8. *Fred Zahradnik,* (2019). How GPS devices use mathematics to determine positioning [online]. [cit. 2020-02-16]. Retrieved from:

https://www.lifewire.com/trilateration-in-gps-1683341

9. *Mayank Kumar, Akanksha Rai,* (2019). How GPS works? [online]. [cit. 2020-02-25]. Retrieved from:

https://www.geeksforgeeks.org/how-gps-works/

10. *Sapos,* (2019). Dienste im Uberblick [online]. [cit. 2020-03-02]. Retrieved from:

https://www.sapos.de/dienste-im-ueberblick.html

11. *Mayank Kumar, Akanksha Rai,* (2019). How GPS works? [online]. [cit. 2020-01-20]. Retrieved from: https://www.geeksforgeeks.org/how-gps-works/

12. *TechTerms,* (2020). GIS [online]. [cit. 2020-01-04]. Retrieved from: https://techterms.com/definition/gis/

13. *Drew Wilson,* (2008). Russia to leverage GLONASS system for in-car GPS [online]. [cit. 2020-01-20]. Retrieved from: https://www.eetimes.com/russia-to-leverage-glonass-system-for-in-car-gps /

14. *ESA,* (2018). What is Galileo? [online]. [cit. 2020-03-20]. Retrieved from: http://www.esa.int/Applications/Navigation/Galileo/What_is_Galileo/

15. *Indig*, (2020). Applications of GPS use in automotive industry [online]. [cit. 2020-03-20]. Retrieved from: https://indigy.org/what-are-the-applications-of-gps-in-the-automotive-industry/

16. *Tim springer, Rolf Dach,* (2010). Multiple constellation Processing in the international GNSS Service [online]. [cit. 2020-03-22]. Retrieved from: http://www2.unb.ca/gge/Resources/gpsworld.june10.pdf

17. *Attila Albini, Dániel Tokody, Zoltán Rajnai,* (2018). Interdisciplinary Description of Complex Systems. THE CATEGORIZATION AND INFORMATION TECHNOLOGY SECURITY OF AUTOMATED VEHICLES, At Óbuda University, Doctoral School on Safety and Security Sciences Budapest, Hungary. [online] ISSN 1334-4676.

18. *Landmark Divident,* (2020). Self-driving car technology [online]. [cit. 2020-03-26]. Retrieved from: https://www.landmarkdividend.com/self-driving-car/

19. *Alex Davies,* (2018). The wired guide to self-driving cars [online]. [cit. 2020-03-26]. Retrieved from: https://www.wired.com/story/guide-self-driving-cars/

20. *Continental,* (2020). Short range radar SRR320 [online]. [cit. 2020-03-26]. Retrieved from: https://www.continental-automotive.com/en-gl/2-Wheeler/Safe-Mobility/Sensors/Short-Range-Radar-SRR320

21. *Donald Melanson,* (2007). Infinity EX35 Around View Monitor system makes windows redundant [online]. [cit. 2020-03-26]. Retrieved from: https://www.engadget.com/2007/09/17/infinitis-ex35-around-view-monitor-system-makes-windows-redunda/?guccounter=1&guce_referrer=aHR0cHM6Ly9lbi53aWtpcGVkaWEub3JnLw&guce_referrer_sig=AQAAALLdHuMTN1N7ih4_SijO4JQHrYWISkbBrn6dPu6zIiSDWpHcR2E1p0FCXvrl3oyVuwJevV92YT08BI9qUZvdM7

QNrpdr_GfJZh5kLJzW58KE27UrGwcoDBrygDjozqb-Et0Uy8l-LGuYyllo0Azs-_pAHkOcbdPGjqaAIX1rgLz4

22. *NHTSA*, (2020). Forward collision warning systems [online]. [cit. 2020-03-26]. Retrieved from: https://www.safercar.gov/Vehicle+Shoppers/Safety+Technology/fcw/

23. *Tricityinsurance*, (2006). Automobile blind Spot Monitoring System [online]. [cit. 2020-03-26]. Retrieved from: http://www.tricityinsurancenews.com/archives/automobile-blind-spot-monitoring-system/

24. *Filip Vítek,* (2018). Autonómne autá rozobrané na detail [online]. [cit. 2020-03-26]. Retrieved from: https://mocnedata.sk/extra-autonomne-auta/

25. *John Fischer,* (2018). The role of GNSS in driverless cars [online]. [cit. 2020-04-20]. Retrieved from: https://www.gpsworld.com/the-role-of-gnss-in-driverless-cars/

26. *Radovan Miucic,* (2019). Connected Vehicles. Intelligent Transportation Systems [online]. DOI 10.1007/978-3-319-94785-3. Ebook ISBN 978-3-319-94785-3. Online version available on: https://www.springer.com/gp/book/9783319947846

27. *ETSC*, (2019). Road deaths in the European Union [online]. [cit. 2020-04-20]. Retrieved from: https://etsc.eu/euroadsafetydata/

BRNO UNIVERSITY OF TECHNOLOGY

Faculty of Electrical Engineering
and Communication

BACHELOR'S THESIS

Brno, 2020 Marko Gróf