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AUTONOMOUS VEHICLES: BASIC ISSUES

Summary. The work was dedicated to the subject of innovative autonomous vehicles on the transport market. The paper presents basic information about autonomous cars: a nomenclature characteristic of autonomous vehicles, along with the terms “automatic”, “autonomous”, “self-drive” and “driverless”. The article also presents various types of autonomous cars based on the most popular classifications in the world. The purpose of the work is to present basic issues related to autonomous vehicles.

Keywords: autonomous vehicles; autonomous vehicles nomenclature; classification of autonomous vehicles; autonomous vehicles in transport systems.

1. INTRODUCTION

Significant technological development and the increase in the importance of comfort during travelling and driving have led to the search for various types of automotive solutions. which would allow for travelling in a much more convenient way. This kind of trend has brought with it the emergence on the market of systems that can improve driving safety and thus automate it. Such solutions include adaptive cruise control (ACC), system warnings

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before running off a lane (AFIL), adaptive lights (AFL), brake assist (BAS), brake assist systems warning of a vehicle in the blind spot (BLIS), systems for monitoring driver fatigue (Driver Alert/Attention Assist) [1-4]. There are also systems supported by artificial intelligence, for example, for image analysis [5-9]. Despite equipping vehicles with various types of car support systems, no accidents or collisions caused by driver errors were avoided. At that time, the key factors in collisions or accidents were human factors related to human driving skills, mental and physical conditions or age, among others [10-13].

Due to the human unreliability during the driving process, an attempt has been made to create cars that can be driven on their own, where the role of the driver would be limited to remaining a passenger of the vehicle. These types of cars are autonomous vehicles.

Due to the fact that autonomous vehicles are the current trend in the field of motorization, many terms and divisions systematizing autonomous vehicles have been defined. The paper presents the basic issues on autonomous cars. The authors explain the definitions, the historical outline of autonomous vehicles in the world and the most popular classifications of autonomous vehicles.

2. AUTONOMOUS CARS: BASIC INFORMATION

The autonomous car (also known as a self-driving car or a driverless car) is a vehicle that is capable of sensing its environment and navigating without human input [13]. Autonomous vehicles are driven using technology such as GPS, odometry, radars, laser lights and computer vision [14-15]. Thanks to the use of these types of technology, vehicles can identify the appropriate route, existing obstacles in the way, connect with the road infrastructure and read the content of markings [14-16].

Despite the fact that, currently, autonomous cars are becoming a global trend, the first attempts to create such solutions appeared as early as 1920 [17]. These were, however, initial automation projects. Many attempts were made in the 1950s and then in 1980 [18]. The 2000s saw the gradual appearance of test vehicles from leading automotive brands [18]. Despite the construction of vehicles, testing them on public roads is not easy. This is due to the safety and necessity to adjust traffic laws for autonomous vehicles.

At the end of 2013, four US states (Florida, California, Michigan and Nevada) adopted legislation permitting autonomous cars to travel on public roads [19]. Under this legislation, state regulations have made it possible for 11 companies to test vehicles [19]. In 2015, seven major automotive brands have been tested, including Bosch, Delphi Automotive Systems, Google Auto, Nissan North America, Mercedes-Benz Research & Development North America, Tesla Motors and the Volkswagen Group of America [19].

Vehicle manufacturers emphasize that the expected period when cars can appear on roads for use by drivers is 2020-2030 [20]. In turn, the implementation of autonomous vehicles on the market will cause a transport revolution [21]. Indeed, it will be one of three revolutions that will change the face of current transport: steering automated vehicles, shared vehicles and electric vehicles [22].

Autonomous cars are supposed to bring many benefits to society. The advantages include increasing mobility, limiting congestion, improving road safety by reducing collisions and accidents, and having a positive impact on the environment [23].

3. NOMENCLATURE AND MAIN CLASSIFICATIONS OF AUTONOMOUS VEHICLES

With the emergence of test autonomous vehicles on the market, various types of nomenclature have been circulated. These cars have been referred to as autonomous as well as automatic/automated. However, they are not the same terms and the difference between them is directly related to the degree of involvement of human support in relation to the car's functioning [24]. The vehicle, which is referred to as "automatic" or "automated", is a self-acting machine, which has no intelligent systems [24]. In turn, the autonomous vehicle will be equipped with intelligent systems, based on which it will be able to make decisions, e.g., about the destination and changing the route according to its own suggestions [24]. An automatic car can only perform commands [24].

Another difference in the nomenclature of autonomous vehicles concerns the terms "self-driving" and "driverless". They differ at the technological level. Self-driving is considered to refer to cars that are not as technologically advanced as the driverless type [24,25].

The most famous division of autonomous vehicles in the world is the so-called American classification, as presented by National Highway Traffic Safety Administration (NHTSA) [26]. This division includes four levels of autonomous driving and a zero level [26]. The individual levels and their description are presented in Table 1.

Table 1

Autonomous driving levels according to the NHTSA classification

Level	Description
0	The driver‘s task is to support all systems in the vehicle.
1	The vehicle is equipped with automatic versions of some systems (e.g., ESP systems, ABS, automatic braking), which can be activated spontaneously or with the help of the driver. However, the driver‘s task is to oversee system functioning.
2	The vehicle is equipped with automatic systems that release the driver from having to operate them. Such systems include the system maintaining the vehicle in the lane and an adaptive tempomat.
3	The vehicle is able to drive autonomously under specific conditions, with the driver coordinating the correct operation of the systems.
4	Full automation of the vehicle. The driver travels as a passenger without having to interfere with the operation of automatic systems.

Source: [26]

In turn, the EU distinguishes two main definitions of autonomous vehicles [27]: an autonomous vehicle and an automated vehicle. For an automated vehicle, the EU considers a vehicle equipped with technology, which allows the driver to transfer part of his/her driving duties to on-board systems [28]. In turn, an autonomous vehicle is a fully automated vehicle equipped with technologies allowing the system to perform all functions related to driving without any human intervention [28].

Another classification is the division according to the International Society of Automotive Engineers (ISAE) from 2014 [29]. This classification includes five levels of autonomous driving and a zero level. A detailed classification is presented in Table 2.

Table 2

Autonomous driving levels according to the ISAE classification

Level	Description
0	Full control of the vehicle belongs to the driver, even if the car is able to inform him/her about the hazards. The driver is responsible for monitoring the environment and must be ready to take control.
1	The vehicle is equipped with support for particular aspects of driving, e.g., steering or acceleration/braking. The driver is responsible for monitoring the environment and must be ready to take control.
2	Partial automation of the vehicle - the use of the system for both driving and speed control; the driver is responsible for the supervision and implementation of the remaining driving elements. The driver is responsible for monitoring the environment and must be ready to take control.
3	Conditional automation of the vehicle - the possibility of taking over by the car control of all aspects of driving, assuming that the driver must be ready at any time to take control of the car.
4	High level of automation of the vehicle - the car is able to take control of all aspects of driving, even if the human driver does not respond to the call to take control.
5	Full automation of the vehicle - independent driving under all conditions.

Source: [29]

The next classification comes from the German automotive industry association Verband Der Autoindustrie (VDA) [30]. The association defines five levels of autonomous driving and a zero level. A detailed classification is presented in Tab. 3.

Table 3

Autonomous driving levels according to the VDA classification

Level	Description
0	In the vehicle, there are no automated functions. The driver should control the vehicle during driving (i.e., maintaining speed, accelerating and braking) and lateral control (i.e., steering). There are active-only systems connected with car warnings and problems.
1	The vehicle is equipped with a system that is able to assume either longitudinal or lateral control of the car, during which the driver has to control all tasks in the vehicle.
2	The vehicle is particularly automated. The driver does not have to manage longitudinal and lateral control of the system in certain cases. The driver has to monitor the vehicle in traffic during a journey and be ready to resume control of the vehicle when the driver needs to.

3	The system knows the limits of its functioning and, in a situation where it encounters an obstacle, the vehicle requests the driver to resume the task of driving. The driver does not have to control and monitor the longitudinal and lateral drive but is asked to exercise special caution because, at any moment, the system may ask him/her to take control of the vehicle.
4	The vehicle is able to self-drive but only under certain conditions, for example, a specified type of road or speed range. Under these conditions, the driver can become a passenger of the car.
5	The car is fully autonomous. It is able to self-drive on all types of roads and adapt to all speed requirements. The driver acts a passenger role.

Source: [29,30]

Due to the occurrence of various types of classification, it is not an easy task to determine the current level of autonomy of individual vehicles without referring to the specific classification. Regardless of the type of the classification, the aforementioned divisions have many common points and strive to achieve a fully autonomous vehicle with the elimination of the need for human control.

4. SUMMARY

In conclusion, despite the fact that autonomous vehicles seem to be an abstract issue for current public road users, worldwide tests of vehicles in motion predict the appearance of cars for public use in the near future. Such changes in transport will certainly mean another revolution, which is why it is important to educate the public in the field of dealing with autonomous vehicles. This education should include appropriate behaviour on roads on which the vehicles will be able to move. However, before cars are fully implemented on current transport systems, it is important to familiarize the public with the applied nomenclature and the division of vehicles due to the degree of autonomous driving. This will allow society, in a more accessible way, to become acquainted with a new way of moving, which, although it may seem abstract at the moment, represents the future of transport. It is hoped that this work will act as an introduction to learning the basic issues about autonomous vehicles.

References

1. Vahidi Ardalan, Azim Eskandarian. 2003. "Research advances in intelligent collision avoidance and adaptive cruise control". *IEEE Transactions on Intelligent Transportation Systems* 4(3): 143-153. ISSN: 1558-0016. DOI: 10.1109/TITS.2003.821292.
2. Kusano Kristofer, Gabler Hampton. 2012. "Safety benefits of forward collision warning, brake assist, and autonomous braking systems in rear-end collisions". *IEEE Transactions on Intelligent Transportation Systems Archive* 13(4): 1546-1555. ISSN: 1524-9050. DOI: 10.1109/TITS.2012.2191542.

3. Kato Shin, Sadayuki Tsugawa, Kiyohito Tokuda, Takeshi Matsui, Haruki Fujii. 2002. "Vehicle control algorithms for cooperative driving with automated vehicles and intervehicle communications". *IEEE Trans. Intelligent Transportation Systems* 3(3). ISSN: 1558-0016. DOI: 10.1109/TITS.2002.802929.
4. Schöneburg Rodolfo, Karl-Heinz Baumann., Justen Rainer. 2003. "Pre-safe - the next step in the enhancement of vehicle safety". In *18th International Technical Conference on the Enhanced Safety of Vehicles*, *Transport Research Laboratory* 1-8. ISBN: 0115511121.
5. Ogiela Lidia, Ryszard Tadeusiewicz, Marek Ogiela. 2006. "Cognitive analysis in diagnostic DSS-type IT systems". In *Eighth International Conference on Artificial Intelligence and Soft Computing*. Zakopane, Poland. 25-29 June 2006. *Artificial Intelligence and Soft Computing - ICAISC 2006*: 962-971. Book series: *Lecture Notes in Computer Science* 4029.
6. Ogiela Lidia, Ryszard Tadeusiewicz, Marek Ogiela. 2006. "Cognitive computing in intelligent medical pattern recognition systems". In Huang D.S., Li K., Irwin G.W (eds.) *International Conference on Intelligent Computing*. Kunming, P.R. China. 16-19 August 2006. *Intelligent Control and Automation*: 851-856. Book series: *Lecture Notes in Control and Information Sciences* 344.
7. Ogiela Marek, Ryszard Tadeusiewicz, Lidia Ogiela. 2005. "Intelligent semantic information retrieval in medical pattern cognitive analysis". In Gervasi O., Gavrilova M.L., Kumar V. et al. (eds.) *International Conference on Computational Science and Its Applications*. Singapore. 9-12 May 2005. *Computational Science and Its Applications - ICCSA 2005* Vol. 4: 852-857. Book series: *Lecture Notes in Computer Science* 3483.
8. Tadeusiewicz Ryszard, Lidia Ogiela, Marek Ogiela. 2008. "The automatic understanding approach to systems analysis and design". *International Journal of Information Management* 28(1): 38-48.
9. Dyakov I., O. Prentkovskis. 2008. "Optimization problems in designing automobiles". *Transport* 23(4): 316-322.
10. Dresner Kurt, Peter Stone. 2006. "Traffic intersections of the future". In *Proceedings of the 21st National Conference on Artificial Intelligence NECTAR Track* 2: 1593-1596. Palo Alto, CA: AAAI Press. Accessed: 30 June 2018. Available at: https://www.aaai.org/Papers/AAAI/2006/AAAI06-258.pdf.
11. Gehrig Stefan, Fridtjof Stein.1999. "Dead reckoning and cartography using stereo vision for an autonomous car". In *Proceedings 1999 IEEE/RSJ International Conference on Intelligent Robots and Systems. Human and Environment Friendly Robots with High Intelligence and Emotional Quotients (Cat. No.99CH36289), Kyongju,* 3: 1507-1512. ISBN: 0-7803-5184-3. DOI: 10.1109/IROS.1999.811692.
12. Wolcott Ryan, Ryan Eustice. 2014. Visual localization within LIDAR maps for automated urban driving. In *IEEE/RSJ International Conference on Intelligent Robots and Systems, Chicago*: 176-183. ISSN: 2153-0866. DOI: 10.1109/IROS.2014.6942558.
13. Kröger Fabian. 2016. "Automated driving in its social, historical and cultural contexts". In Maurer Markus, Gerdes Christian, Lenz Barbara, Winner Hermann (eds.) *Autonomous Driving. Technical, Legal and Social Aspects*. New York, NY: Springer. ISBN: 978-3-662-48845-4. DOI: 10.1007/978-3-662-48847-8.
14. Moras Julien, Cherfaoui Véronique, Bonnifait Phillipe. 2010. "A lidar perception scheme for intelligent vehicle navigation". In *11th International Conference on Control Automation Robotics & Vision*, 1809-1814. ISBN: 978-1-4244-7815-6. DOI: 10.1109/ICARCV.2010.5707962.

15. Howard Andrew. 2008. “Real-time stereo visual odometry for autonomous ground vehicles”. In *IEEE/RSJ International Conference on Intelligent Robots and Systems*, 3946-3952. ISSN: 2153-0866. DOI: 10.1109/IROS.2008.4651147.
16. Yuchao Sun, Doina Olaru, Brett Smith, Stephen Greaves, Andrew Collins. 2017. “Road to autonomous vehicles in Australia: an exploratory literature review”. *Road & Transport Research: A Journal of Australian and New Zealand Research and Practice* 26(1). ISSN: 1037-5783.
17. John W. 2014. *Driverless Car: Autonomous Future in Your Garage*. Scotts Valley, CA: CreateSpace Independent Publishing Platform. ISBN: 978-1503287907.
18. Wadhawa Vivek, Alex Salkever. 2017. *The driver in the driverless car. how our technology choices will create the future*, USA: Berrett-Koehler Publishers. ISBN-13: 978-1626569713.
19. Glassbrook Alex. 2017. *The law of driverless cars: an introduction*, USA: Law Brief Publishing. ISBN-13: 978-1911035282.
20. Sudha Jamthe. 2017. *2030 The Driverless World: Business Transformation from Autonomous Vehicles*, Stanford: CreateSpace Independent Publishing Platform. ISBN-13: 978-1973753674.
21. Hermann Andreas, Walter Brenner, Rupert, Stadler. 2018. *Autonomous Driving: How the Driverless Revolution Will Change the World*. Somerville, MA: Emerald Publishing Limited. ISBN: 1787148343.
22. Sperling Daniel. 2018. *Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future*. Washington, DC: Island Press. ISBN: 9781610919050.
23. Zanchin Betina, Rodrigo Adamshuk Silva, Max Mauro Santos, Max Mauro, Kathya Linares. 2017. “On the instrumentation and classification of autonomous cars”. In *IEEE International Conference on Systems, Man, and Cybernetics*, 2631-2636, DOI: 10.1109/SMC.2017.8123022.
24. Levinson David. 2017. “On the differences between autonomous, automated, self-driving, and driverless cars”. Available at: https://transportist.org/2017/06/29/on-the-differences-between-autonomous-automated-self-driving-and-driverless-cars/.
25. Bargelis A., A. Baltrušaitis. 2013. “Applications of virtual reality technologies in design and development of engineering products and processes”. *Mechanika* 19(4): 673-676. DOI: http://dx.doi.org/10.5755/j01.mech.19.4.5057.
26. National Highway Traffic Safety Administration (NHTSA). “Automated vehicles for safety”. Available at: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety.
27. European Union. *Briefing: Automated Vehicles in the EU*. Available at: http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/573902/EPRS_BRI(2016)573902_EN.pdf.
28. International Society of Automotive Engineers. *Automated Driving*. Available at: https://www.sae.org/misc/pdfs/automated_driving.pdf.
29. Verband der automobilindustrie (VDA). “Automation from driver assistance systems to automated driving”. Available at: https://webcache.googleusercontent.com/search?q=cache:rB5YVdzyLdwJ:https://www.vda.de/en/topics/innovation-and-technology/automated-driving/automated-driving.html+&cd=2&hl=pl&ct=clnk&gl=pl.

30. Samociuk W., Z. Krzysiak, G. Bartnik, A. Skic, S. Kocira, B. Rachwal, H. Bakowski, S. Wierzbicki, L. Krzywonos. 2017. "Analysis of explosion hazard on propane-butane liquid gas distribution stations during self tankage of vehicles". *Przemysl Chemiczny* 96(4): 874-879. DOI: 10.15199/62.2017.4.29.

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