Autonomous vehicles and their impact on road infrastructure and user safety

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Currently, many car companies have already created their own self-steering cars. However, they are still not prepared for road traffic, both urban and extra-urban. The precursor is the state of Nevada in the USA where autonomous vehicles were allowed to be tested in road conditions[5].

In Poland, the city of Jaworzno wants to become a testing ground for self-steering vehicles. First, appropriate laws must be created, then Jaworzno will be accurately metered by a special car collecting data on the road. Tests can only take place next.

Cars without a driver drive thanks to artificial intelligence and do not need to interfere with the driving process. Recognizes traffic signs, picks directions, reacts to what is happening on the road.

Science-fiction movies have made us accustomed to a variety of fantasies about autonomous cars. Can you take a nap while sitting behind the wheel in any such car? Is driving such a vehicle safe? Who is responsible for the collision of autonomous cars?

Keywords: autonomous vehicle, vehicle safety, artificial intelligence

I. AN AUTONOMOUS VEHICLE, WHAT'S THAT?

There are several degrees of autonomy of the car.

Level 0. Means a complete lack of a computer control system.

Level 1. The vehicle has individual elements to facilitate its driving, such as: cruise control, parking assistant, or indicator of the occupied traffic lane. Many ordinary cars are equipped with this type of facility, and it has to be emphasized that it does not make them autonomous. This is a kind of first step towards autonomy.

Level 2. The car is theoretically able to drive alone for a while, but the system is unreliable to such a degree that it requires continuous control from the driver. Man has the responsibility to monitor everything that happens on the road and be in full readiness to react as a driver.

Level 3. Here the driver is also obliged to constantly watch, but the control system is a bit more independent. On the longer road sections it can drive the vehicle by itself.

Level 4. The car drives by itself, without the driver's participation, but is unable to cope with all conditions (e.g. weather conditions). Sometimes it may be necessary to drive manually, therefore a driver is still required in the vehicle.

Level 5. It is only at this level that we can talk about full autonomy. Passengers can ride in the back seat or the car can be sent empty - without the risk that it can not cope with the existing road conditions[1].

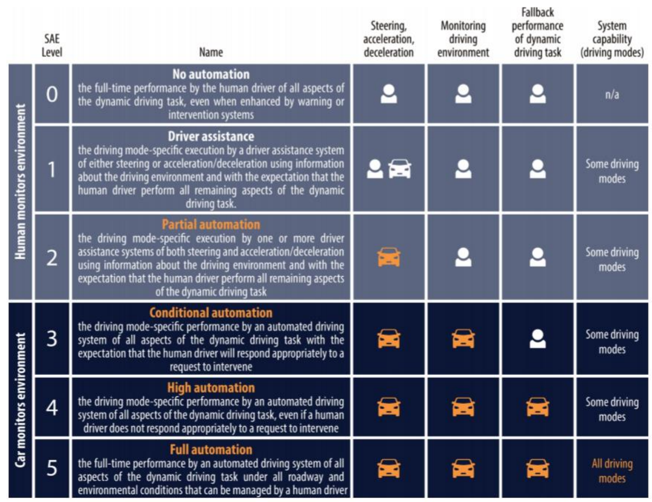

Fig.1 - Levels of driving automation [1]

II. ARTIFICAL INTELLIGENCE BEHIND THE WHEEL OR SYSTEM STRUCTURE

The transport security integration process is currently the most important aspect. Over the years, research programs were created, namely Zeus [8] and Gambit [3], whose task was to improve the safety of the road user, both using the vehicle and pedestrian. The country that was the first to implement the Vision Zero program, which assumes that the transport system does not cause traffic accidents is Sweden. "Vision zero" - this concept often appears when we mean the description of road safety in terms of its quality. Autonomous vehicles have a large share here because they exclude the most unreliable element of the system which is a human being. Replacement of the human eye's response to reliable sensors or lasers as in the case of the LiDAR system.

There were many myths around the so-called "artificial intelligence" in autonomous cars: from the unpredictability of control system decisions to the rebellion of machines. It is worth emphasizing the fact that artificial intelligence is an ordinary computer program, based on simple, well-known solutions.

We like when devices make life easier or even work for us. But do we feel justified worries when the electronic system was to drive our car? Will it be able to drive more safely than we do?

In the autonomous car control system, three groups of elements can be distinguished[6].

1. Input devices or sensors (lidar, cameras, radars), which are the "eyes" of the system. They collect information about what is happening around.

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2. Output devices, i.e. actuators. Let's call them "hands" of our system, because they affect the car directly, controlling the steering wheel, brakes, etc.

3. Control system. This is the heart, or rather the brain of the whole system, where all decisions are made, how the car is to behave. This is the so-called decision system, or in other words, a regular computer program. It was around it that many myths were created. Let's verify some of them and see how it's built.

III. ARTIFICAL HEART OF THE SYSTEM

The decision system may include the following elements:

Algorithms. This is the most common sequence of mathematical formulas. The algorithm consists of a sequence of mathematical formulas, shown as equation (1), (2),(3):

$$A = 10 \times x + 15 \quad (1)$$

$$B = 20A - 2 \times x \quad (2)$$

$$C = A + B + 5 \quad (3)$$

Input data to the algorithm are numerical values, derived directly from input devices or indirectly from other elements of the data processing system. The calculations pass successively through all elements of the algorithm. The starting information is numerical or logical values.

Fuzzy logic. This way of calculation tries to reflect a slightly more human way of thinking, related to the uncertainty of judgments. In this case, the "fuzzy" is a decision consisting in assigning numbers to specific sets, eg:

$$x \in A \; in \; 80\%,$$
$$y \in B \; in \; 60\%,$$
$$with \in C \; in \; 10\%.$$

In this calculation method, a somewhat more human way of thinking is attempted to reflect the ambiguity of judgments. Numbers can belong to individual collections to varying degrees. This allows a better description of a decision that includes many (often contradictory) factors.

Semantic data sets.

The semantic database stores pairs of information: condition + application.

$$A => B$$
$$B => D$$
$$C => B$$

It maps the sets of rules that people follow. This allows you to translate the calculation into a control system, eg: if the car's speed is higher than the speed limit, reduce the speed. Input data to the semantic database can be any information from the other elements of the control system.

Each information consists of a condition and a conclusion stemming from it. The semantic database stores information, which allows you to translate the calculations into specific reactions: if the car's speed is higher than the speed limit, reduce the speed. We use calculations e.g. from algorithms and refer them to a semantic database.

Artificial neural networks. The last element is of course the most exciting. The entire neural network can be theoretically replaced with one relatively simple mathematical formula including only addition and multiplication.

Neural is described by a mathematical formula including simple operations, shown as equation (4):

$$y = A \times x1 + B \times x2 + C \times x3 \ldots \quad (4)$$

Coefficients are selected experimentally. At the entrance to the network, we provide input data and at the same time show what values the network should respond to. The network thus "learns" the correct answers. If we repeat it many times enough, we will get a ready mathematical formula. You do not need to develop the formula in a theoretical way; you just need to have sample data.

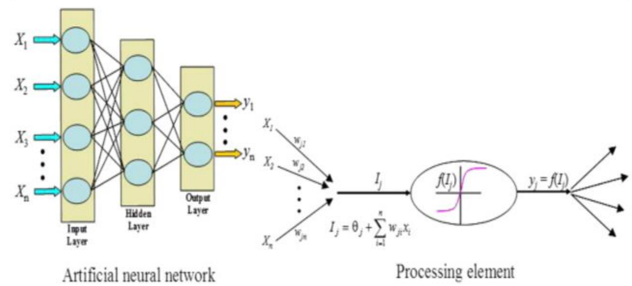

Fig. 2 Artificial neural networks [9]

Why then do artificial neural networks get used? Their advantages lie in the ease of determining the coefficients in the aforementioned formula. We do not have to calculate them based on the theoretical considerations. All we have to do is provide the network with the sample results, and the special algorithm will select the coefficients itself. At the entrance to the network, we provide input data and at the same time show what values the network should respond with. The network thus "learns" the correct answers. If we repeat it sufficiently many times, we will get a ready mathematical formula[4].

IV. HUMAN SENSES AND THE SENSES OF MACHINE, I.E. THE MATTER OF SAFETY

The danger of a car being driven by a computer is completely different from the dangers of human driving. We are afraid that the computer program will not include all events that may occur on the road. What will happen if a truck appears in front of us, whose colour blends with the colour of clouds in the background. Will the computer program recognize its contour?

It must be stressed, however, that driving by a man is also not free from dangers. The ability to test the operation of the system under any conditions definitely tilts the safety scales in favour of autonomous cars.

On the driving license course, one learns the basics of driving a vehicle. As a result, he can behave in many standard situations that can happen in practice. One can not predict how he will behave in an emergency situation, and it is these situations that carry the greatest danger of an accident. Despite this, we entrust the driver with the task of driving a car. The situation is quite different in the case of a computer control system. In fact, it is not a simple matter to prepare a program that will be able to control the vehicle. But when it is ready, we do not entrust him with driving yet. Now we can check how it will behave in a variety of situations that ordinary drivers have not even dreamed of.

We have this freedom of testing because the control system operates on a computer, so on the computer we can also simulate individual dangerous situations. We can make a simulation and see how the decision system behaves. To be sure, let's check it out for 20 million cases, including various lighting, lacquer shades and other factors. It will take a few seconds for the computer and we will know exactly what to expect from the tested program. We can simulate millions of dangerous situations and even breakdowns of the car and adjust our control program in such a way that it can faultlessly handle the vehicle in all conditions. These possibilities are impossible even for long-term professional drivers. Artificial control system can be safer than the best human driver, which is influenced by various factors, including fatigue, stress, distraction or bravado. These factors are completely alien to the control systems.

V. RESPONSIBILITY OF MAN OR MACHINE?

Who then drives an autonomous car? The correct answer may sound a bit perverse, but it is a man and only him. The computer only performs the simple tasks to which it was prepared, but it is the human mind that must program it. In this way man manages the vehicle indirectly - through the program he develops.

Autonomous cars will be as safe as well-educated are the specialists who build them. That is why investing in the research is so important. Before us is a long and incredibly interesting road to develop machines that will relieve us of many mundane activities of everyday life.

Communication between vehicles on the road is the foundation of safety. V2V (Vehicle To Vehicle) and V2I (Vehicle To Infrastructure) systems provide improved road traffic, driving conditions as well as mobility and safety. V2V warns of the danger of cullet, violent braking of the car ahead of us or changing the lane by a car moving in parallel. The relays of vehicles equipped with V2V technology (vehicle-to-vehicle) send information about location, direction of travel and speed, while other vehicles automatically analyze this data and inform drivers about the risk of collision. The system can also inform about traffic, which in turn significantly translates into increased driving fluidity, reduced fuel consumption and exhaust emissions[2].

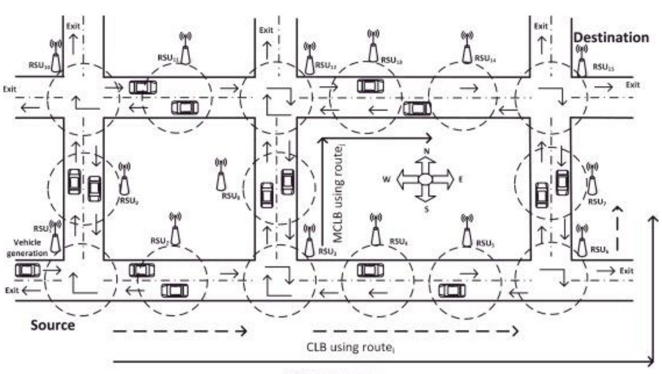

Fig.3Vehicle to vehicle [10]

Example of operation of V2V technology:

The system warns the driver about a car that has stopped on his driving lane as a result of a breakdown. Even if the vehicle is not in the lane of the car and does not pose a direct threat, the system informs the driver of the appropriate symbols even before making eye contact, so that he knows about a potentially dangerous situation and is sensitive to, for example, the presence of pedestrians on the roadside.

Example of operation of V2I technology:

Vehicle-to-Infrastructure (V2I) is the next generation of Intelligent Transportation Systems (ITS). V2I technologies capture vehicle-generated traffic data, wirelessly providing information such as advisories from the infrastructure to the vehicle that inform the driver of safety, mobility, or environment-related conditions. State and local agencies are likely to install V2I infrastructure alongside or integrated with existing ITS equipment. Because of this, the majority of V2I deployments may qualify for similar federal-aid programs as ITS deployments, if the deploying agency meets certain eligibility requirements.

Adjustment of road infrastructure

Autonomous vehicles are adapted to the existing road infrastructure. One of the most important is to reflect the infrastructure in the navigation device. Systems responsible for vehicle steering, using sensors and cameras are able to read road signs. However, they need detailed data about the space they are moving on to compare the existing state with the state stored in the navigation database. TomTom is the first company to start creating maps for three-dimensional navigation. They created the RoadDNA system and HAD (Highly Automated Driving) maps, which enable vehicle location, both at high speed and in difficult weather conditions. As a result, a detailed and optimized route image is provided so that the vehicle can compare it with the image from cameras and sensors[7]

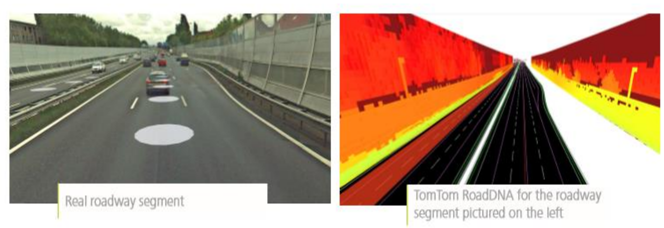

Fig. 4 Real view and view from RoadDNA map [7]

During the CES fair (Consumer Electronics Show) of the world's largest electronics trade fair and new technologies in Las Vegas, TomTom presented the latest solutions for autonomous vehicles. The first of these is TomTom AutoStream - a completely new map service that allows vehicles to build the horizon before the planned route, by streaming the latest map data from the TomTom cloud. Another new feature is TomTom MotionQ, a unique driving concept designed to ensure the comfort of passengers using self-propelled vehicles[7].

VI. SUMMARY

The rapid development of autonomous cars technology and the interest of companies and corporations in the creation of their own vehicles of this type indicates that intelligent technologies on the road are the future of transport. It is a chance to improve road safety and turn towards ecological thinking about transport. In addition, autonomous mobility improves the mobility of people with disabilities and older people. The most serious problem of common infrastructure for conventional and autonomous vehicles is to solve legal problems. This solution requires the development of common rules for self-aware vehicles for all countries, making ethical decisions, and who is at fault for causing an accident: vehicle manufacturer, system manufacturer used in the vehicle, or driver - passenger.

The commencement of cooperation at the government level in the field of road automation in Poland was announced by the Minister of Infrastructure and Construction Andrzej Adamczyk and the Minister of Energy Krzysztof Tchórzewski during the international conference "Autonomous future of the road transport". It was organized by the Motor Transport Institute in Warsaw. Over four hundred representatives of the automotive industry and the business world as well as scientists have registered to participate in the meeting. Among them are guests from Israel, the United States, Germany and Belarus.

First, the autonomous cars will appear in enclosed areas, i.e. it will be testing under special supervision. However, their full commercial use is planned for around 2025. Then all guidelines for self-steering cars will be created.

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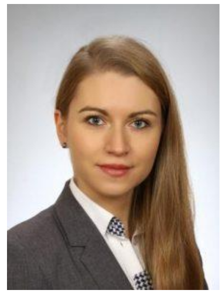

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