# Paradigm change of mapping in the advent of driverless transportation

J. M. Lógó [1], Á. Barsi [2]

[1] *Dept. Photogrammetry and Geoinformatics, Budapest University of Technology and Economics, logo.janos.mate@emk.bme.hu*
[2] *Dept. Photogrammetry and Geoinformatics, Budapest University of Technology and Economics, barsi.arpad@emk.bme.hu*

## 1. Introduction

Since humanity started moving around, it has been looking for easier, faster, and more convenient transportation. In the continuous evolution of vehicles, the involvement of machines has been revolutionary. A similar revolution is the abandonment of the machine, which is autonomous or self-driving transportation.

The emergence of self-driving vehicles is the result of a long technical evolution [1]. Improvements have been made in three main areas: vehicle control, safety, and comfort. Initially, human-driven vehicles were gradually equipped with more and more helping solutions, so-called assistants [2]. The Driver Information System (DIS) provided information on the status of the vehicle and the environment. For example, a car equipped with a camera detects the speed limit indicated on traffic signs and signals this to the driver. The Tire Pressure Monitoring System (TPMS) constantly monitors the air pressure in the tires and alerts in case of deviation.

The next stage of development is Driver Assistance Systems (DAS). The main aim is to improve safety, initially by improving the braking system to deal with emergency situations. The Anti-lock Braking System (ABS) and Brake Assist (BA) improve wheel slip and thus vehicle controllability. An improved version of this is Autonomous Emergency Braking Assist (AEB). Cruise Control (CC) or tempomat is a speed-keeping assist that controls the vehicle moving at a preset speed. An advanced version can also detect the vehicle ahead and adjust the speed accordingly; this is Adaptive Cruise Control (ACC).

The Advanced Driver Assistance Systems (ADAS) is the next evolution stage. The Lane Departure Warning System (LDW), which monitors the road ahead with a camera, helps the driver to keep in lane with warnings, while the Lane Keeping Assist System (LKAS) corrects the driver by carefully steering the vehicle back into its lane. Blind Spot Monitor (BLIS) warns the driver of vehicles not visible in the rear-view mirror. Lane Change Assist (LCA) supports lane changes by monitoring blind spots and performing lane-change maneuvers. In a motorway environment, Highway Pilot is a system that can serve both speed maintenance and lane-change maneuvers.

Through the above assistants, we can see how solutions with progressively more and more functionality are helping the driver, ultimately taking over more and more activities from the driver. The Society of Automotive Engineers (SAE) International has developed a classification of vehicle maturity levels based on these factors, defining six different levels. These levels are [3]:

| Level | Name | Steering/ acceleration/ deceleration | Environment monitoring | Fallback | System capability |
|---|---|---|---|---|---|
| **Human driver monitors the driving environment** | | | | | |
| **0** | No automation | H | H | H | – |
| **1** | Driver Assistance | H/S | H | H | some driving modes |
| **2** | Partial Automation | S | H | H | some driving modes |
| **Automated driving system monitors the driving environment** | | | | | |
| **3** | Conditional Automation | S | S | H | some driving modes |
| **4** | High Automation | S | S | S | many driving modes |
| **5** | Full Automation | S | S | S | all driving modes |

**Table 1.** Automation level defined by SAE International [3]
(H – human driver, S – system)

The above table shows that full self-driving is only achieved at the top level (Level 5); for this goal, a number of intermediate levels have to be reached, i.e., the conditions have to be met (this also indicates that it is a time-consuming process, despite all promises made in advertisements!)

Autonomy means in the automotive context that the vehicle is capable to

- gain information about the environment,
- work for an extended period without human intervention,
- move throughout its operating environment without human assistance,
- avoid situations that are harmful to people, property.

The same set of conditions can be applied to robots, so a self-driving vehicle can also be considered a robot. For example, a cab with this capability is often called robotaxi.

To understand the needs of autonomous vehicles, it is worth taking a look at how they work. Figure 1 summarizes the essential components for the operational model [4]. According to the scheme, the state of the environment can be sensed by the different sensors and its objects can be detected. In addition to the information extracted, the decision mechanism can also receive input from the vehicle's communication unit and the map. The control of the vehicle is based on the decision through various interventions. The map is therefore a significant source of data for the decision process in addition to its own perception and communication.

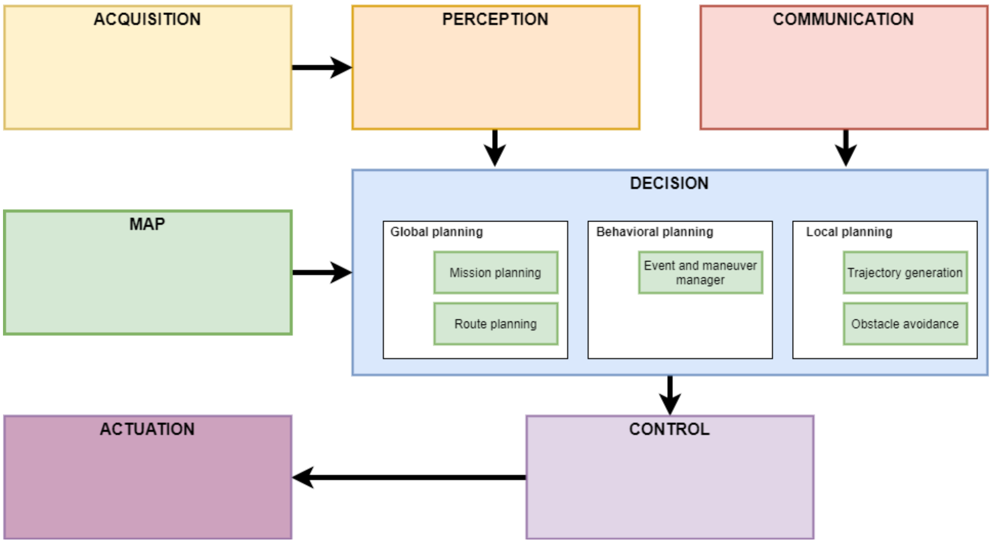


**Figure 1.** Functional component blocks in a vehicle (after Sz. Aradi)

## 2. Changes in maps

Maps have always played a central role in transportation [5]. In the beginning, paper maps, atlases, and later navigation solutions offered a variety of options to help drivers find their proper way. The availability of satellite positioning (GPS) has dramatically improved the navigation toolbox. However, self-driving vehicles require much more detail and orders of magnitude more accuracy than a human driver.

Let's briefly review the evolution of maps. There are two major parts of the process: the change in form and the change in content. In terms of map formats, the most significant improvement has been due to the digitalization of analog (paper) maps. In addition, another milestone was the replacement of the CAD-like storage model by databases.

In terms of the content, the map was initially a two-dimensional representation, which gradually became three-dimensional. There is a big difference in the content when we move from the road-level representation to the lane-level. In the latter case, a complete description of the road infrastructure is provided with all traffic lane data. A further noteworthy change is the ever-improving description of the environment: the keyed (pictographic) representation of the main environmental elements (e.g., some buildings, churches, gas stations, etc.) has been transformed into an accurate spatial geometric description of all built and natural objects: object models and three-dimensional point clouds are used. However, the map is not yet complete: the introduction of dynamic content is the most significant development. The modern map (which is now a database!) includes increasingly dynamic elements such as road closures and construction works, weather elements, the current status of traffic lights, and even the road users themselves. The EU-funded SAFESPOT project has provided the technological basis for such an approach [6].

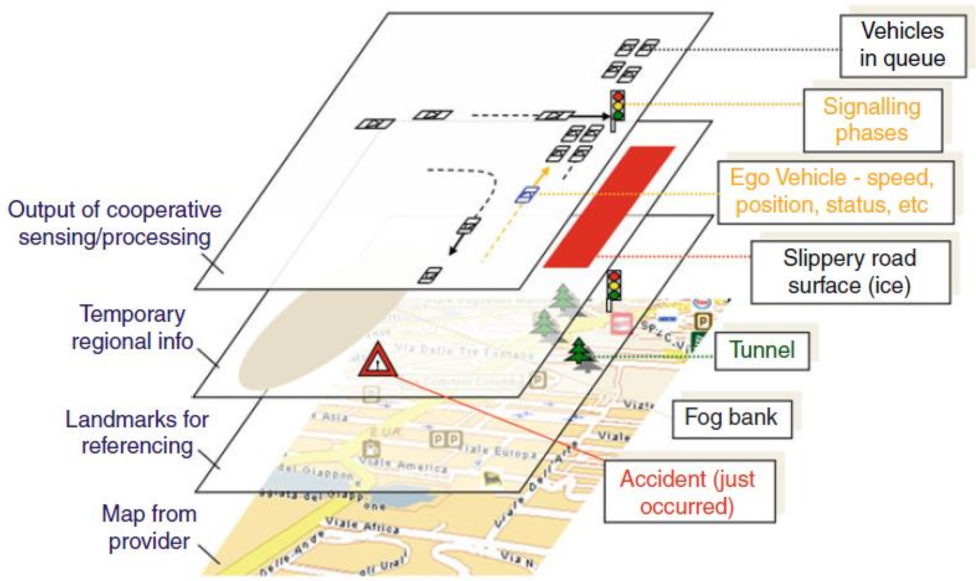


**Figure 2.** The extended layer structure of Local Dynamic Map (LDM) as proposed by SAFESPOT [6]

## 3. Mapping technologies

The technology commonly used to produce maps relies on a method of field geodesy. When measuring, the surveyor visits all the points to be measured, determines their geometric position, and records them as map points. It has the advantage of measuring only the minimum number of points needed but has the disadvantage of being extremely expensive and slow.

Terrestrial laser scanning (TLS) captures millions of points per second, making it a much faster, more efficient method. Part of the work is done in the field, while the other, larger part is executed in the office (unlike geodesy, where the bulk of the work happens in the field). TLS, therefore, has the advantage of increased measurement performance, while the disadvantage is that it requires expertise and powerful hardware support for data processing.

Aerial photographs are taken from aircraft, which can be evaluated to produce maps of larger areas with homogeneous accuracy. This method – called photogrammetry – also has the advantage of being cost-effective but has the disadvantage of being highly dependent on weather conditions, requiring a high level of expertise, and being quite expensive for the whole project.

Images can also be purchased from remote sensing imagery providers. Satellite images can be used for mapping over an even larger area than aerial imagery. Still, they require particular attention to cloud cover and are much less detailed than aerial solutions. Expertise is an indispensable requirement for this technology.

Drones (unmanned aerial vehicles – UAVs) are all the rage these days, also suit great for mapping tasks. Easy-to-obtain devices make it easy to collect pictures of the earth's surface and process them in various applications. The advantage of the UAV method is that it is easy to use and quick to set up, but the disadvantage is the small survey area and the variable accuracy of the resulting product.

Mobile mapping is the best solution in terms of detail, geometric accuracy, and processing methodology. In this methodology, the measuring instruments are mounted on a mobile platform, such as a van, together with a positioning unit, and a detailed survey of the roads and their surroundings is carried out. Mobile mapping primarily uses cameras and laser scanners to acquire data. The technology can be used to survey a large network of roads in a cost-effective way, but the equipment itself is expensive to purchase. The evaluation of the results is the main part of the work, which is also done in an office environment. From a quality point of view, this method seems the best one in supporting self-driving. A typical mobile mapping system is shown in the following figure.

**Figure 3.** A Leica Pegasus Two mobile mapping system mounted on top of a car

## 4. Conclusion

Future road transportation has been dreamed with driverless, i.e., self-driving vehicles. These cars, trucks, and buses are equipped with environmental sensor systems (cameras, laser scanners, radars, and similar devices). The captured data must be processed in an acceptable time frame, where the onboard computers and the corresponding communication platforms have extreme importance. The behavior of these vehicles depends then highly on the extracted information about the moving and non-moving objects in the vicinity. The decision-making procedure here considers the influencing environment. Still, it guides the vehicle to the desired goal, keeping in mind the safety (ego and the environment) and the effectiveness (concerning fuel, time, costs, etc.).

The above efforts are realized by complex vehicular systems, which also contain the capability to handle map information. Maps of these vehicles store significantly more information; road and lane focus, but other infrastructure objects also: buildings, bridges, tunnels, trees and vegetation, water bodies, railways, traffic signs, and signals – the list can be continued for a long time. Self-driving vehicle maps must therefore be compiled in a different way; unfortunately, the well-known technologies have to be replaced with more appropriate ones. Modern technologies like artificial intelligence, big data analyses, effective computing algorithms should be encapsulated into the map-making workflow. Up-to-date maps have fresh and valid content, which requires a suitable update mechanism. Vehicle control can accept only methodologies that are constantly reliable, so all the necessary methods undergo a serious quality check and validation test series. The map content is – at the very end – not only geometrically but topologically correct and consistent, while the attributes are also verified. Static map disappears, and a dynamic map database penetrates the automotive location description progress.

## Acknowledgements

The authors are grateful for the financial support received from the joint grant of the Hungarian and the Polish Academy of Sciences and the Hungarian Ministry of Human Resources (ÚNKP-21-3-II-BME-26) as well as from the project “Development of regional network on autonomous systems for structural health monitoring” financed by the Visegrad Fund.

## References

[1] Árpád Barsi, András Csepinszky, János Máté Lógó, Nikol Krausz, and Vivien Potó, “Az önvezetés térképi támogatása,” *Geodézia és Kartográfia*, vol. 72, no. 2, pp. 10–15, 2020, doi: 10.30921/GK.72.2020.2.2.

[2] Hermann Winner, Stephan Hakuli, Felix Lotz, and Christina Singer, Eds., *Handbuch Fahrerassistenzsysteme*, 3. Springer Fachmedien Wiesbaden, 2015.

[3] "J3016B: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles - SAE International." https://www.sae.org/standards/content/j3016_201806/ (accessed Jul. 21, 2020).

[4] Richard Matthaei and Markus Maurer, "Autonomous driving - A top-down-approach," *At-Automatisierungstechnik*, vol. 63, no. 3, pp. 155–167, 2015, doi: 10.1515/auto-2014-1136.

[5] Nikol Krausz, András Csepinszky, Vivien Potó, and Árpád Barsi, “Az autós térképtől az önvezetésig: a járműnavigáció története,” *Geodézia És Kartográfia*, vol. LXXI, no. 1, pp. 14–18, 2019, doi: 10.30921/GK.71.2019.1.1.

[6] Azim Eskandarian, *Handbook of intelligent vehicles*, vol. 1–2. Springer London, 2012.