AUTOMATED VEHICLES

State of Automated Vehicle Technology

brainonboard.ca

TIRF

Developments in automated vehicle technology have sparked public interest in this topic, however, research shows knowledge of automated vehicles among drivers is generally low.[1] Moreover, people tend to acquire their knowledge through media outlets and may not recognize information is often specific to limited types of technologies or features as opposed to applicable to automated vehicle technology generally. As such, consumers may lack a broader understanding of how automation is progressively being integrated into the driving experience and have the misperception vehicles could be driverless in a matter of a few years. Therefore, it is important drivers are able to distinguish between automated technologies that are currently available versus those which may be available in the future. It is equally important they understand significant challenges still exist in the development of vehicles with higher levels of automation.

This fact sheet summarizes the current state of automated vehicle technology and expands upon key technologies necessary in the development of Level 3 automation and beyond (e.g., Level 4 and 5). It also describes challenges that remain in developing higher levels of automation. This fact sheet can help drivers gain a fundamental understanding of current technology and equip them with the knowledge to critically assess future developments of automated technology as well as anticipated timelines for the availability of higher levels of automation.

Questions & Answers

What is the state of current automated vehicle technology?

In Canada, vehicles with Partial Automation or Driver Assistance, corresponding to the Society of Automotive Engineers' (SAE) Level 1 or 2, are legally permitted on public roads. These vehicles are equipped with advanced driver assistance system (ADAS) technology. This technology is designed to offer assistance to the driver but is not designed to replace an attentive and engaged driver. In these vehicles, the driver remains responsible for the safe operation of the vehicle. There is a range of ADAS functions available in vehicles for purchase, although the terms and functionality of the features may vary by manufacturer. For more information about ADAS, please see the fact sheet titled **Essential Versus Non-Essential ADAS**.

Vehicles with conditional automation, corresponding to SAE Level 3, and higher are not available for consumer purchase. They remain in testing and development as part of

Your brain is your vehicle's most important safety feature.

pilot projects in Quebec and Ontario. These vehicles are equipped with an automated driving system (ADS), which is an integrated set of automated systems operating simultaneously to perform the driving task. ADS-equipped vehicles are able to perform all aspects of the driving task, but only under defined conditions and specified road environments based on the level of automation. The ADS cannot operate if these specifications are not met. However, there remain significant technical and logistical challenges before this technology becomes available. The level of automation in vehicles will likely increase progressively, with Level 5 full automation being a longer-term goal that is decades away from being publicly deployed.

What developments in automated driving systems are underway?

Currently, multiple automotive manufacturers and technology companies are working on developing an ADS for use in vehicles with conditional automation and higher. While each company has different design concepts, all ADSs will possess similar fundamental technological building blocks, using the *sense*, *plan*, *act* model, originating from the field of robotics.[2] This model dictates how vehicles with higher levels of automation are able to observe the environment, interpret it, and produce actions quickly and accordingly. This model is described below, along with brief explanations of each stage and the supporting technology.

Stage 1 – Sense. To obtain a general representation of the surrounding environment, an ADS uses sensor technologies, such as cameras, ultrasonic sensors, RADAR, and LIDAR to see the surrounding environment. These technologies are used in combination to achieve higher levels of accuracy, as overlapping and redundant data is necessary since all sensor technologies have their own strengths and limitations.

> **Cameras:** Light rays bouncing off objects in the environment are reflected through the camera lens onto a photosensitive surface to create an image. Cameras are inexpensive and effective at perceiving and classifying objects in the environment, however, cameras can be easily affected by environmental conditions such as heavy rain, fog, snow, or glare.

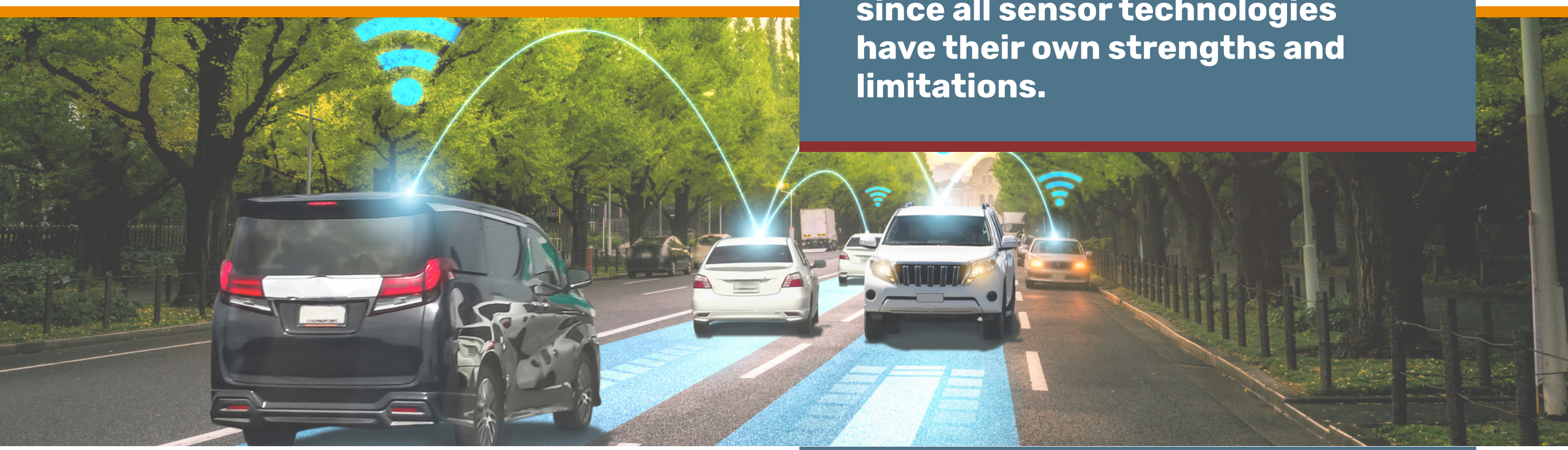
> **Ultrasonic sensors:** Releases sounds at a frequency that is too high for humans to hear and estimates the distance of objects by measuring how long it takes the sound to bounce back to the sensor. Limitations of ultrasonic sensors include a limited detection range and low accuracy when objects are at certain angles.

> **Radio detection and ranging (RADAR):** Emits radio waves to sense surrounding objects by reflecting these waves off surrounding objects and measuring how long they take to bounce back. Radar is extremely effective at determining the speed of objects however, it is not effective at recognizing what the object is.

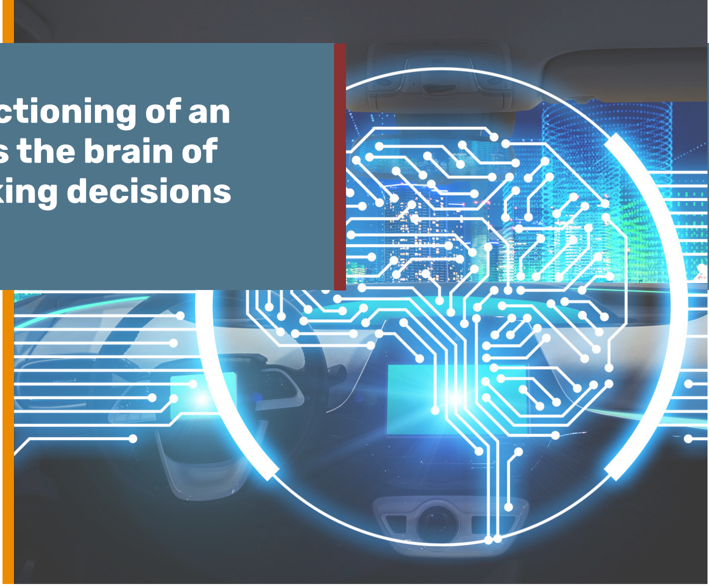
> **Light detection and ranging (LIDAR):** Emits millions of pulses of light per second to estimate the distance of objects by measuring how long these signals take to bounce back. Signals are then compiled into an extremely detailed three-dimensional map of the surrounding environment. Lidar is very accurate however, it can be affected by inclement weather. It also requires extensive processing power and is extremely costly.

> **Global navigation satellite systems (GNSS):** Receives data from satellites about the global positioning of the vehicle to provide location information used to navigate towards a given destination. This data may also be complemented with high definition (HD)

Sensor technologies are used in combination to achieve higher levels of accuracy, as overlapping and redundant data is necessary since all sensor technologies have their own strengths and limitations.



Path planning is crucial to the safe functioning of an Automated Driving System. It serves as the brain of the entire process, responsible for making decisions about the vehicle's control.



maps, which provide a high level of detail. The limitations of GNSS data include the risk of malicious interference and the lack of available GNSS data in certain locations. Also, HD maps require significant effort to create and maintain current information.

The information from these sensors is combined using sensor fusion. This process aims to use the most reliable source of each type of sensor data to form a complete picture of the driving environment, for example, cameras are most reliable for detecting road signs, whereas Radars are most effective at judging speed. All these different sources of sensor data are then fused using complex algorithms, which allow the system to understand the environment, including estimating the surrounding obstacles and how fast they are moving. Now that the ADS is aware of its surrounding environment, it also needs information on where it is located within this environment. Despite having GNSS data, an ADS cannot solely rely on this to provide information about location, as it can be inaccurate by up to approximately 30 feet.[3] Therefore, algorithms and machine learning can be applied to provide the ADS with more precise information about its position in the surrounding environment.

Stage 2 – Plan. Now that the ADS has information about the obstacles and where it is located in relation to them, it must develop a plan to navigate the environment. This stage, also known as path planning, is crucial to the safe functioning of an ADS. It serves as the brain of the entire process, responsible for making decisions about the vehicle's control. Using various algorithms, the ADS predicts the potential movement patterns of obstacles, decides on the movements required to navigate them, and chooses an optimal trajectory to reach its destination. For example, an automated vehicle with the goal of getting from point A to B must estimate all different ways that a cyclist might move, while establishing every pattern of motion it might perform to navigate around the cyclist, ensuring it chooses the safest and most efficient trajectory. Path planning is a crucial step in the automation of vehicles, and it continues to be the focus of much of the ongoing research. However, it remains under development and it will be years before it can be optimized for use in an ADS on public roads.

Stage 3 – Act. Now that a plan has been established, detailed instructions are generated and sent to the actuators which are responsible for the steering wheel, accelerator pedal and brake pedal. For example, this might include instructions to turn the steering wheel to a 30-degree angle or to accelerate by 5%. This allows the plan to be implemented safely and accurately, producing the desired vehicle actions (e.g., acceleration required to make a lane change, steering to maintain the trajectory of the vehicle, braking to come to a stop at an intersection). However, the extreme computer processing power required to perform these increasingly complex actions remains a significant limitation.[4]

Conclusion

In conclusion, the technology required to develop a vehicle with an ADS that can reliably and accurately perform automated driving functions is still in development and faces critical challenges before being integrated into vehicles for use by consumers. As such, mass market deployment of Level 3 vehicles, the first of which are only now launching in limited quantities and in specific markets for real world evaluation, is still several years off. In the meantime, governments are working to create a regulatory framework for these vehicles to operate within (i.e., how to assign fault in a collision under a variety of scenarios). Level 4 or 5 personal vehicles are likely a decade or more into the future.

References

Anderson, J.M., Kalra, N., Stanley, K.D., Sorensen, P., Samaras, C., Oluwatola, O. (2014). Autonomous Vehicle Technology: A Guide for Policymakers. RAND Corporation, RR-443-1-RC.

Cohen, J. (2018). Self-Driving Cars and Localization. Towards Data Science, Medium Publishing.

Murray, C. (2019). Autonomous Cars Look to Sensor Advancements in 2019. Design News. Retrieved from: **https://www.designnews.com/electronics-test/autonomous-cars-look-sensor-advancements-2019/95504860759958**

Robertson, R. D., Woods-Fry, H., Hing, M. M., & Vanlaar, W. G. (2019). Senior drivers and automated vehicles: Knowledge, attitudes and practices. Traffic Injury Research Foundation.

Sanbonmatsu, D. M., Strayer, D. L., Yu, Z., Biondi, F., & Cooper, J. M. (2018). Cognitive underpinnings of beliefs and confidence in beliefs about fully automated vehicles. Transportation research part F: traffic psychology and behaviour, 55, 114-122.

van Dijk L. (2017). Future Vehicle Networks and ECUs: Architecture and Technology considerations. NXP Semiconductors. Retrieved from **https://www.nxp.com/docs/en/white-paper/FVNECUA4WP. pdf**

[1] Robertson et al. 2018; Sanbonmatsu et al. 2018
[2] Anderson et al. 2014
[3] Cohen 2018
[4] van Dijk 2017; Murray 2017

Want to learn more?

Visit **brainonboard.ca** to learn more about automated vehicles.

Traffic Injury Research Foundation

The vision of the Traffic Injury Research Foundation (TIRF) is to ensure people using roads make it home safely every day by eliminating road deaths, serious injuries and their social costs. TIRF's mission is to be the knowledge source for safer road users and a world leader in research, program and policy development, evaluation, and knowledge transfer. TIRF is a registered charity and depends on grants, awards, and donations to provide services for the public. Visit **www.tirf.ca**.

Traffic Injury Research Foundation (TIRF)
171 Nepean Street, Suite 200, Ottawa, ON K2P 0B4
Email: tirf@tirf.ca ISBN: 978-1-989766-78-1

Acknowledgements

Production of this fact sheet was made possible with sponsorship from Desjardins and technical expertise from Greg Overwater & Andrew McKinnon, Global Automakers of Canada.

Desjardins

Global Automakers of Canada

Your brain is your vehicle's most important safety feature.