What are connected and autonomous vehicles (CAVs)?

Connected Vehicles (CVs) are able to gather information from and communicate with other vehicles and their surroundings (e.g. infrastructure, pedestrians/cyclists), enhancing safety and mobility. CVs can provide useful information to neighboring vehicles and infrastructure to help make safer and more informed decisions. Connectivity is achieved through vehicular communication technologies, including Dedicated Short-Range Communications (DSRC) and cellular communications. Cellular connections, commonly referred to as Cellular Vehicle-to-Everything (C-V2X), may use either 4G LTE (Fourth Generation Wireless Long -Term Evolution) or next generation 5G (Fifth Generation Wireless) networks.

Autonomous Vehicles (AVs) are equipped with onboard equipment (e.g. cameras, LiDAR, radar) to sense and monitor the surrounding environment. An AV combines data and intelligence from its equipment to automate various aspects of the dynamic driving task and navigate through the road network. The Society of Automotive Engineers (SAE) has categorized AVs into six levels of automation ranging from no automation (Level 0) to fully autonomous (Level 5).

As CV and AV technologies are complementary, it is most likely that combined CAVs will be much more prominent in the market in the future than separate CV and AV offerings.

What are the levels of vehicle automation?

The Society of Automotive Engineers (SAE) has categorized AVs into six levels of automation:

LEVEL 0 - NO AUTOMATION

A human driver is required for all aspects of the dynamic driving task. Vehicles may have assistive technology providing warnings to the driver but cannot sustain vehicle control.

LEVEL 1 - DRIVER ASSISTANCE SYSTEMS

A human driver performs most of the driving operation, with the automated system assisting with minor operations of the dynamic driving task. For example, with lane keeping assistance, the driver controls the speed, while the automated system self-corrects steering toward the centre of the lane. Another example is Adaptive Cruise Control where the automated system controls the speed, while the driver controls steering. *Level 1 automation is included in many vehicles available on the market.*

LEVEL 2 - PARTIAL AUTOMATION

An automated driving system can be in control of the dynamic driving task including steering, acceleration, and braking. However, the driver must always remain engaged in the driving task and monitor the environment. *Examples of Level 2 automation available to the public include Tesla Autopilot, General Motors (GM) Super Cruise, Mercedes-Benz DistronicPilot, and Nissan ProPilot.*

LEVEL 3 - CONDITIONAL AUTOMATION

An automated driving system is in full control of the dynamic driving task including steering, acceleration, and braking. The vehicle is able to scan its environment, react accordingly, recognize its limitations, and request intervention by a human driver. The human driver should be prepared to intervene if needed. *There are currently no vehicles with Level 3 (or above) automation available for purchase in Ontario.*

LEVEL 4 - HIGH AUTOMATION

An automated driving system is able to perform the whole dynamic driving task including steering, acceleration, and braking within a defined environment, even if a human driver does not respond to a request to intervene. The vehicle can come to a safe stop if it operates beyond the boundaries of its safe operating conditions. The human driver does not need to monitor the driving environment or be available to intervene with the driving task.

LEVEL 5 - FULL AUTOMATION

An automated driving system performs the whole dynamic driving task independently and regardless of conditions, without the need for a human driver to be present. The vehicle is truly a self-driving entity and can decide to abort a trip and come to a full stop.

How do CAVs work?

For their operation, CAVs depend on key enabling technologies:

COMMUNICATIONS

Communications enable connectivity and are key to CAV operations, providing the ability for a vehicle to communicate with other vehicles and its surroundings. Critical communication protocols and network technologies include Dedicated Short-Range Communications (DSRC), and Cellular Vehicle-to-Everything (C-V2X).

SENSING TECHNOLOGIES

Sensing Technologies are key enablers to AV operations, allowing vehicles to understand their surrounding environment. Relevant technologies include cameras and range sensors such as radars, LiDARs (Light Detection and Ranging), and ultrasonic sensors.

ADVANCED ANALYTICS / ARTIFICIAL INTELLIGENCE (AI) / MACHINE LEARNING (ML)

Advanced analytics and artificial intelligence (AI), including machine learning (ML), are key enabling technologies and techniques at the core of many parts of CAV systems. They are responsible for analyzing sensor data, visualizing the surrounding environment, predicting behaviours, and guiding vehicle movements.

Advanced analytics refer to a wide range of analytic tools and techniques, and cover a wide range of analytics, including descriptive, diagnostic, predictive, and prescriptive.

AI is a subset of advanced analytics that simulates human intelligence and aims to replicate the ability of humans to analyze data, draw conclusions, and interact with humans in a human-like way.

ML is a category of AI, where the system is able to automatically learn, improve, and optimize through experience. By being able to learn and adapt on its own, ML allows predictions to be made at a scale and speed not possible for human analysts to achieve.

EMBEDDED SOFTWARE

With innovations in vehicular communications and sensing technologies, as well as AI and data analytics, embedded software is a critical enabler to the successful development of CAVs. In vehicles, the embedded software is rugged in nature and written for the specific hardware of the vehicle, and is used for a variety of purposes, such as safety management, engine control, networking, and infotainment.

What are regulations on CAVs in Ontario?

Ontario was the first Canadian jurisdiction to regulate testing of automated vehicles on public roads, and through Ontario Regulation 306/15: Pilot Project – Automated Vehicles, Ontario has established an environment of regulatory openness that is globally competitive. The regulation supports private sector AV driving pilots and testing, and provides an attractive region for industry and academia CAV-related pursuits by facilitating operational testing of new technologies and solutions.

The Cooperative Truck Platooning Pilot Program leverages Ontario's openness for AV testing and provides direction for vehicular communication testing for truck platoon pilots on specific stretches of provincial highways. Similar testing is ongoing in other countries, such as the U.S., the Netherlands, Singapore, and Sweden.

Ontario's Ministry of Transportation (MTO) and a number of large municipalities have begun developing strategies and plans to prepare for greater adoption of CAVs.

Are CAVs safe?

Safety is a paramount driving force for connectivity and automation, particularly given the fact that the vast majority of the serious crashes are due to human error. CAVs have the potential to reduce injuries and save lives. CVs can communicate and share information with neighboring vehicles and infrastructure to help make safer and more informed decisions. The U.S. National Highway Traffic Safety Administration (NHTSA) estimates that automated driving can reduce traffic fatalities by 94% by eliminating the root cause of road collisions; human error.

How will mobility be impacted by CAVs?

CAVs can increase the efficiency of mobility by decreasing traffic congestion and can deliver economic benefits by increasing productivity and providing new avenues for mobility options. Similar to how laptops and mobile phones have augmented human capabilities, CAVs strive to create a more enabled, convenient, and integrated mobility experience.

What are the benefits of CAVs?

CAVs are designed with capabilities and features that have the potential to provide increased safety, satisfaction, comfort, and convenience. To reduce the number of road fatalities and augment safety on roads, CVs have been introduced to the automotive market. Through the exchange of safety alerts, CVs can have better awareness of their surroundings, resulting in avoided collisions and fewer fatalities on roads. Furthermore, through the exchange of traffic condition messages, CVs can alleviate congestion and avoid undesirable road events, resulting in better driving experiences and environmental impacts. With their features and in-vehicle resources, CVs have been also attracting remarkable use cases beyond safe and convenient transportation including mobile sensing, data muling, cloud computing, localization, and e-commerce.

The U.S. National Highway Traffic Safety Administration (NHTSA) estimates that automated driving can reduce traffic fatalities by 94% by eliminating the root cause of road collisions; human error. Automated driving not only ensures higher safety levels on roads by, but also promotes comfort and frees up valuable time for commuters to pursue other activities. Automated driving is also poised to reduce congestion and transportation costs and provide more mobility options. Since the use of vehicles is linked to other vital sectors, the level of opportunities and disruption of the adoption of AVs will be much broader. AVs are anticipated to bring transformative opportunities to the health care, media and advertising, urban planning, delivery, and auto insurance sectors.