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AVIN Specialized Reports

Data in the Context of CAVs -

Types and Operational Opportunities

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The Autonomous Vehicle Innovation Network (AVIN) is an initiative by the Government of Ontario

About AVIN

The **Autonomous Vehicle Innovation Network (AVIN)** initiative is funded by the Government of Ontario to support Ontario's competitive advantage in the automotive sector and to reinforce its position as a North American leader in advanced automotive and mobility technologies, including transportation and infrastructure systems.

This initiative capitalizes on the economic potential of connected and autonomous vehicle (CAV) technologies by supporting the commercialization of best-in-class, made-in-Ontario solutions that create jobs, drive economic growth and enhance global competitiveness. AVIN also helps Ontario's transportation systems and infrastructure adapt to these emerging technologies.

Areas of Focus

AVIN programs focus on supporting the development and demonstration of CAV technologies in light vehicles (e.g., cars, trucks and vans), heavy-duty vehicles (commercial vehicles, trucks, buses and RVs), transportation infrastructure, intelligent transportation systems (ITS) and transit-supportive systems.

AVIN is administered on behalf of the Government of Ontario by Ontario Centres of Excellence (OCE). The initiative comprises four distinct programs and a central hub. The AVIN programs are:

- AV Research and Development Partnership Fund
- Talent Development
- Demonstration Zone
- Regional Technology Development Sites

The AVIN Central Hub is a dedicated team that supports delivery and administration of AVIN programming, and provides the following key functions:

- Connect & Coordinate - a focal point to help coordinate activities among industry, academia, research organizations and governments, and connect interested stakeholders and members of the public;
- Opportunity Identification - knowledge translation, research, data/information, trend analysis, and acting as a bridge between technology and policy; and
- Awareness & Education - promote AVIN programs and Ontario's AV testing pilot and build awareness of Ontario's growing CAV community.

AVIN has five Objectives:

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*We would like to thank the Government of Ontario
for supporting AVIN programs and activities.*

*Also, we would like to thank the partner organizations who work with OCE to deliver AVIN programs, including the Regional Technology Development Sites
and the Demonstration Zone.*

Introduction

Data is a key enabler for the operation of connected and autonomous vehicles (CAVs). These vehicles of the near future will depend on enormous amounts of diversified data collected by and disseminated to them to be able to operate safely and efficiently.

CAVs are equipped with different types of sensors to add intelligence and automation to help replace the human sense. These in-vehicle sensors are major sources of live data streams that are fed into the vehicles' artificial intelligence systems for decision making. Also, through connectivity, CAVs acquire different types of data from neighbouring CAVs, road infrastructure[1], and the Internet.

CAVs not only consume data, they are also considered major data providers with advantages of ubiquitous availability and mobility. As CAVs become well-connected to other vehicles and to infrastructure, various categories of crucial data can be gathered through and from them. Municipalities and service providers can recruit CAVs to collect on-road data that can be subsequently gathered from these vehicles either in real-time, opportunistically, or upon demand. This data can be successively processed and provided as an end service to the public or commercial subscribers. Stringent privacy practices and precautions must be taken into account in such a data access and sharing paradigm to ensure that the identity and other private traits of the data providers are not revealed or potentially predicted. Cybersecurity solutions must also be applied to ensure data is protected from cyber attacks and services are protected from disruption and misdirection.

CAVs can also report data for their own benefit and operation. Examples include live diagnostics data

[1] Autonomous Vehicle Innovation Network. (2018). Features of the Infrastructure Facilitating the Operation of CAVs. Retrieved from https://tinyurl.com/ybkbb2fr

reported to repair centres and driving behavior data reported to fleet and insurance companies.

Inspired by the noteworthy operational opportunities of these diversified streams of data coming to and out of CAVs, this report sheds light on the major sources of these data streams. The report discusses the various internal and external sources feeding data into CAVs. In addition, the report covers the different categories of data that can be gathered from CAVs. For each data category, the report sheds light on operational opportunities and applications. We conclude the discussion by providing a summary of the scopes of these operational opportunities, along with exemplary CAV data.

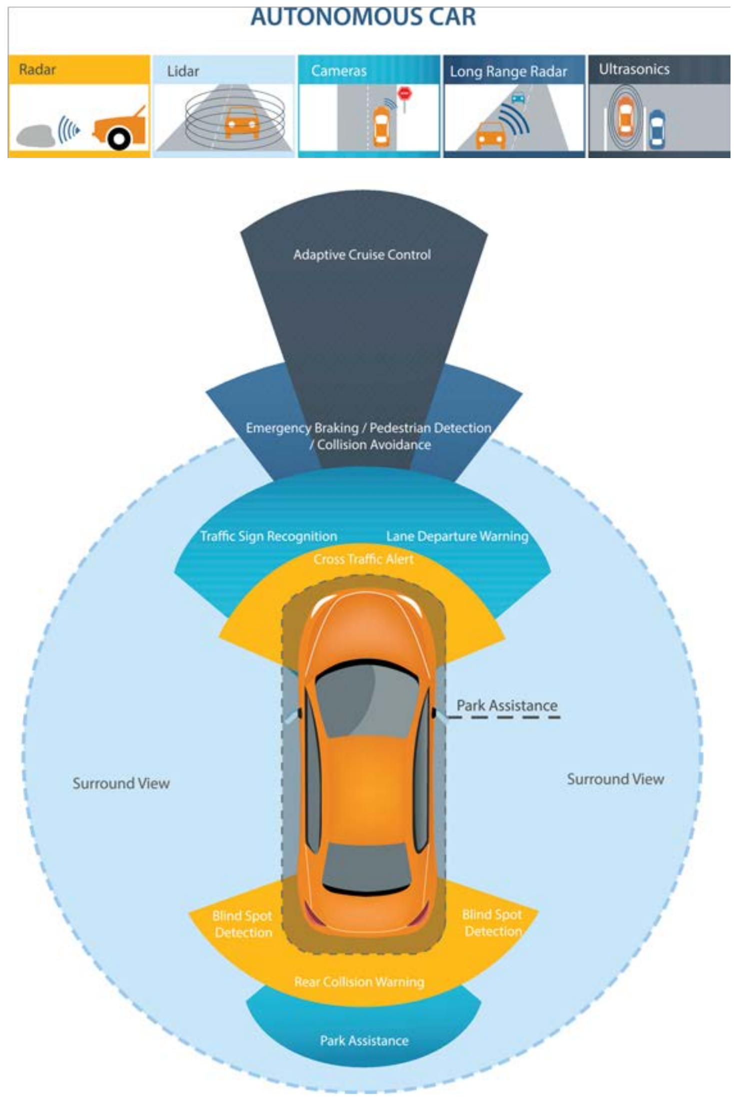
Data Collected by CAVs

Data is the fuel for CAVs. A flood of diversified data is constantly fed to CAVs to enable their operation. Some of this data is internally generated through in-vehicle sensors, and other data is externally acquired through the communication capabilities of CAVs. In the following sections, we delve into the various sources of this CAV-collected data.

1- Internal Data

A. Vehicular Data

To learn about its surroundings and driving pattern, CAVs mainly depend on the use of in-vehicle sensors.[2] These sensors and their technical data are a must for CAVs as a replacement for human sense. Currently, the average number of sensors in a CAV is 100, and this number is anticipated to increase. Some of these sensors are deployed



mainly for safety purposes. These include distance sensors such as radars, lidars, cameras, and ultrasonic sensors. These sensors are crucial for the operation of CAVs and act as their mobile eyes, detecting surrounding objects and hazards, in addition to road markings and traffic signs. Position sensors, such as the steering wheel torque sensor,

[2] Abdelhamid, S., Hassanein, H., Takahara, G. (2014) Vehicle as a Mobile Sensor. International Conference on Future Networks and Communications (FNC ‘14), Elsevier Procedia Computer Science. 34, 286-295.

are also deployed in CAVs to enable autonomous driving and steering. Night vision sensors such as infrared transmitters and receivers are deployed to provide CAVs with clear views of the road ahead. According to Intel[3], a CAV acquires around 4 terabytes of real-time data a day through its internal safety sensors. This is equivalent to the data generated daily by almost 3,000 people. This data is fed into in-vehicle artificial intelligence modules for analysis, decision making, and automation.

Another important category of vehicular data is the one generated for diagnostics purposes. Sensors are also deployed in vehicles to monitor engine, chassis and body. When a malfunction is detected, actuators are triggered to provide immediate actions before severe consequences occur. For example, temperature sensors detecting overheating in the engine can trigger cooling equipment and provide a warning to the driver to stop the vehicle until issue is resolved. Another example is the data generated by the tire-pressure monitoring sensors. This data is collected and analyzed in real-time, and warnings are issued when needed. This diagnostics data can be consumed only by its generating vehicle or reported as well to an auto repair centre for vehicle health tracking and repair automation, as discussed later.

B. Personal Data

To bring ultimate personalization and convenience to CAVs, personal data about vehicle passengers is collected and utilized for corresponding decision making and enhanced user experience. Some of this data can be collected from in-vehicle sensors, and others can be obtained from the passengers' profiles registered in the on-board infotainment device. For example, driver navigation preferences such as desire to follow scenic roads and/or toll-free highways can be collected and utilized to provide a personalized route for each driver. Multimedia preferences such as singers/music can also be collected to provide personalized playlists. Passengers' preferred stores and brands can be retrieved, and corresponding promotional items can be displayed to these passengers through their vehicles' infotainment device on the go.

Some personal data can be collected in real-time for safety purposes. For example, a driver-facing camera can be used to monitor the driver's attention and warn the driver when necessary. Another example is the data collected by weight sensors deployed one in each seat to detect the weight of its passenger and adjust the airbag inflation pressure accordingly.

2- External Data

In addition to the internally generated data, data from external sources are also disseminated to and collected by CAVs. These sources include neighbouring CAVs and road-side infrastructure, and remote data providers reached through broadband connectivity. This external data can be used for different purposes as discussed below.

A. Safety Beacons and Alerts

Through their vehicle-to-vehicle (V2V) communication capabilities, neighbouring CAVs periodically exchange beacon messages that carry data about the vehicle identifier, position, speed, and heading. This beacon data is mainly used to enhance safety on roads by making CAVs aware of

[3] Krzanich, B. (2016). Data is the New Oil in the Future of Automated Driving. Retrieved from https://newsroom.intel.com/editorials/krzanich-the-future-of-automated-driving/

the position and intent of their neighbouring vehicles to avoid crashing with them.

CAVs also periodically receive beacon messages from neighboring road-side units (RSUs). These infrastructure-to-vehicle (I2V) messages carry data about existing road events and hazards to be avoided by vehicles. RSUs at intersections can also disseminate data about vehicles approaching the intersection from its different branching road segments. This helps expand the road view of recipient vehicles beyond their direct view field and/or communication range.

In addition to the periodic beacons, other safety alerts can be received by CAVs from neighbouring vehicles and/or road infrastructure upon detecting safety hazards. For instance, when a CAV detects an accident or a road hazard ahead, it disseminates data about such a hazard to neighbouring vehicles to take avoidance actions. Likewise, sensors deployed at crosswalks to detect crossing pedestrians can send alerts to approaching vehicles when a pedestrian is detected.

These safety beacons and alerts are crucial for futuristic vehicles to enhance the reliability of their sensing-based detection and identification mechanisms.

B. Navigation Data and Traffic Conditions

Maps and geodata are crucial for the operation of CAVs. These maps are not static. They have to be dynamically updated to reflect real-time traffic conditions. For efficient and safe autonomy, maps also have to be very detailed, down to the centimetre level. CAVs can access these dynamic maps through their on-board infotainment units. Maps can be automatically updated through vehicular broadband connections to the Internet and/or I2V updates from neighbouring road infrastructure.

Real-time traffic conditions can also be received by CAVs from neighbouring vehicles. For example, when traffic congestion is detected by a CAV, representing data can be disseminated by this detecting vehicle to its succeeding vehicles to take detouring actions if possible, or slow down to a safe speed.

Traffic conditions can also be crowdsourced through the Internet. Waze[4] is a popular example of such navigation applications that mainly depend on live crowdsourced traffic data reported by its users.

C. Road Conditions

Potholes, bumps, and slippery roads are often the cause of major vehicle damage as well as collisions involving other cars and pedestrians. Therefore, they are crucial pieces of data to be collected and utilized by CAVs. These road anomalies can be detected by in-vehicle sensors, such as accelerometers and cameras[5], and disseminated by the detecting vehicle to other CAVs and/or connected road infrastructure. Other vehicles can access these reported anomalies either through direct V2V/I2V communications, or through web applications offered by municipalities or commercial service providers.

[4] Waze Mobile (2018). Free Driving Directions, Traffic Reports & GPS Navigation App by Waze. Retrieved from https://www.waze.com/

[5] Bello-Salau, H. et al. (2018) New road anomaly detection and characterization algorithm for autonomous vehicles. Applied Computing and Informatics. Retrieved from https://doi.org/10.1016/j.aci.2018.05.002

D. OEM Data

Original equipment manufacturer (OEM) data, such as software updates, is also an example of critical data that is fed to CAVs upon an update release. These updates can be downloaded remotely or at service centres. For safety, in cases of remote download, the vehicle owner should ensure the vehicle is not in operation while its software system is being updated.

E. Web Infotainment Data

Facilitated through on-board connectivity, information and entertainment (combined as infotainment) traffic is a major data stream accessed by CAVs. In addition to the external data traffic collected through V2V and I2V communications, infotainment traffic accessed through the Internet is one of the major sources of data for CAVs. Examples include e-mail, voice over IP (VoIP), and social media traffic accessed through the on-board infotainment device. Multimedia traffic such as music and video streaming is also a major part of this web data traffic.

This infotainment data may also include some personal data that should be handled with the highest privacy practices ensuring that this data is only accessed by authorized users. Passengers' navigation and multimedia preferences retrieved from social media profiles are examples of this personal infotainment data.

Data Gathered from CAVs

In this section, we focus on the various types of data gathered from CAVs by remote third parties such as municipalities and service providers. Data gathered from CAVs can be classified into four main categories as discussed below.

1- Environmental Data

CAVs can collect and report data about their surrounding environment. This can facilitate provisioning many location-based information services. For instance, data about road anomalies can be reported to municipalities, or the provincial government, to take repair actions and share the locations of these anomalies with other residents through a web portal or mobile application.

As mentioned earlier, traffic data can also be crowdsourced from CAVs and shared with the public either through mobile applications such as Waze, or through radio news, and/or electronic traffic signs on roadways.

Through equipping CAVs with related sensors, weather conditions such as temperature, humidity, and ambient pressure, can be collected by vehicles and reported on the fly. Mobility of vehicles brings an advantage to such data collection through the ability to cover wide areas using a single mobile sensor instead of deploying multiple scattered fixed sensors. Following a similar data collection paradigm, road pollution and noise levels can also be collected through CAVs.

As a common feature, all environmental data should be geotagged with the location obtained from the on-board positioning system such as GPS.

2- Driving Data

Companies running fleets of vehicles, such as taxi cab companies, may need to collect data about the driving habits of their fleet drivers. Fleet companies may collect such driving data to monitor the safety of drivers, carried goods, and the vehicles themselves. Companies may also use this data to monitor the working hours of their on-road employees. Fleet companies can also collect the trip start and end times of their vehicles to track and bill their service accordingly.

Some auto insurance companies monitor their customers' driving behaviour for adopting using-based insurance (UBI) programs, also known as pay how you drive (PHYD) and pay as you drive (PAYD) insurance. With UBI, a telematics device installed in the vehicle reports the user's driving behaviour back to the insurer. The driving behaviour metrics include acceleration, braking, and speeding habits. Based on the reported behaviours, low-risk drivers qualify for a discount on their auto insurance premiums.[6]

3- Vehicle Diagnostics Data

Data collected from in-vehicle diagnostics sensors can be reported to repair centres to keep track of the vehicle's health status. Remote automation and repair can also be applied to the vehicle when feasible. This diagnostics data can include the status of the engine, transmission, stability, and emission systems. It can also include the oil quality and amount of pressure in each tire.

Some vehicle makers provide their customers with on-board capabilities for remote diagnostics. GM OnStar[7] and Hyundai BlueLink[8] are popular examples of such diagnostics systems. These proprietary systems run regular remote checks on the vehicle's key systems and provide customers with a detailed monthly diagnostics report. Customers can also trigger on-demand checks when on-board emergencies happen and get live assistance from a technical advisor.

Vehicles that do not come with such diagnostics capabilities pre-installed can still get the service through an on-board diagnostic (OBD) dongle plugged into the vehicle's OBD port[9] and equipped with a communication capability for reporting the data.

[6] Grzadkowska, A. (2018, Nov). What is usage-based insurance? Retrieved from https://www.insurancebusinessmag.com/ca/guides/what-is-usagebased-insurance-116605.aspx
[7] OnStar. (2018, Jan). Your Vehicle Can Tell You How It's Feeling. Retrieved from https://www.onstar.com/us/en/articles/tips/your-vehicle-can-tell-you-how-its-feeling/
[8] Hyundai Auto. (2018). BlueLink® A World of Connections. Retrieved from https://www.hyundaicanada.com/en/mobile-and-audio/blue-link
[9] Edelstein, S. (2017, July). From dongles to diagnostics, here's all you need to know about OBD/OBD II. Retrieved from https://www.digitaltrends.com/cars/everything-you-need-to-know-about-obd-obdii/

4- Biometric Data

Some services and functionalities might require collecting drivers' biometric data. For instance, fleet management companies might collect live biometric data such as drivers' voice, photo and/or fingerprints to authorize the on-board drivers before granting them access to the company's vehicles. Some biometric data might also be periodically reported to the fleet management system for monitoring purposes. Examples include periodic reporting of a driver's live photo for fatigue detection and alerting.

Conclusions

Accessing vehicular data can bring significant benefits to end-users and massive opportunities to service providers. Equipped with an abundance of sensors and communication capabilities, CAVs can be major data consumers and providers, facilitating remarkable applications for passengers of the data-providing vehicles, neighbouring drivers, and remote end-users. This report highlighted the various types of data that can be collected by CAVs for their own use, and data that can be gathered from CAVs for provisioning both private and public services. With regard to the data collected by CAVs, the report covered the internal sources that feed data into CAV systems, and external sources that disseminate data either directly or remotely to CAVs. As for the data that can be gathered from CAVs for use by third parties, the report covered the different data types classified into four major categories, namely environmental, driving, vehicle diagnostics, and biometric data. For each data category, we highlighted the operational and application opportunities. Based on our discussion, we summarize the major scopes of these opportunities and applications in the table below.

With the wide benefits that can be gained through gathering data from CAVs, monetizing this data can be a major direction for developers and researchers to investigate. Also, new business models are needed to manage incentivizing and rewarding the CAV owners for reporting data.

Although vehicular data brings enormous operational opportunities and benefits, accessing and using this data presents some challenges that need to be taken into consideration. Ensuring privacy is vital when collecting and accessing CAV data. Any collection, dissemination or use of data must comply with existing privacy legislation. Due to the critical nature of protecting privacy, solutions are actively being sought, developed and introduced by collectors of data as well as service providers and others in the marketplace. As the technology continues to develop, stakeholders should keep data privacy in the forefront and ensure that rigorous privacy practices are considered in the foundation of the design and throughout the overall data access and usage processes. Some early solutions that are proving effective include hiding the identity of reporting vehicles and drivers. Cybersecurity is another major consideration when it comes to collecting and utilizing CAV data. Since safety applications are key targets of accessing and processing such data, cyber attacks such as data alteration and service disruption are critical acts that the in-vehicle and external CAV data repositories must be protected from. Privacy and cybersecurity mechanisms and the regulatory environment around collecting and using CAV data will be further discussed in the next AVIN specialized report, along with other challenges associated with accessing vehicular data.

Scopes of Operational Opportunities and Corresponding Examples of CAV Data

Scope	Exemplary Data
Safety	▪ Data generated by in-vehicle distance, position, and night vision sensors. ▪ Beacon messages periodically broadcast by CAVs and RSUs. ▪ Event-triggered safety alerts.
Environmental Monitoring	▪ Traffic conditions. ▪ Road surface conditions. ▪ Road pollution and noise levels.
Infotainment	▪ Web data traffic. ▪ Real-time navigation data. ▪ Driver navigation and multimedia preferences. ▪ OEM Data.
Diagnostics	▪ Data generated by in-vehicle engine, chassis, and body diagnostics sensors.
Fleet Management	▪ Driving behaviour data such as driver's accelerating, braking, and speeding habits. ▪ Trip start and end times. ▪ Drivers' biometric data.
Auto Insurance	▪ Driving behaviour data such as driver's accelerating, braking, and speeding habits.

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