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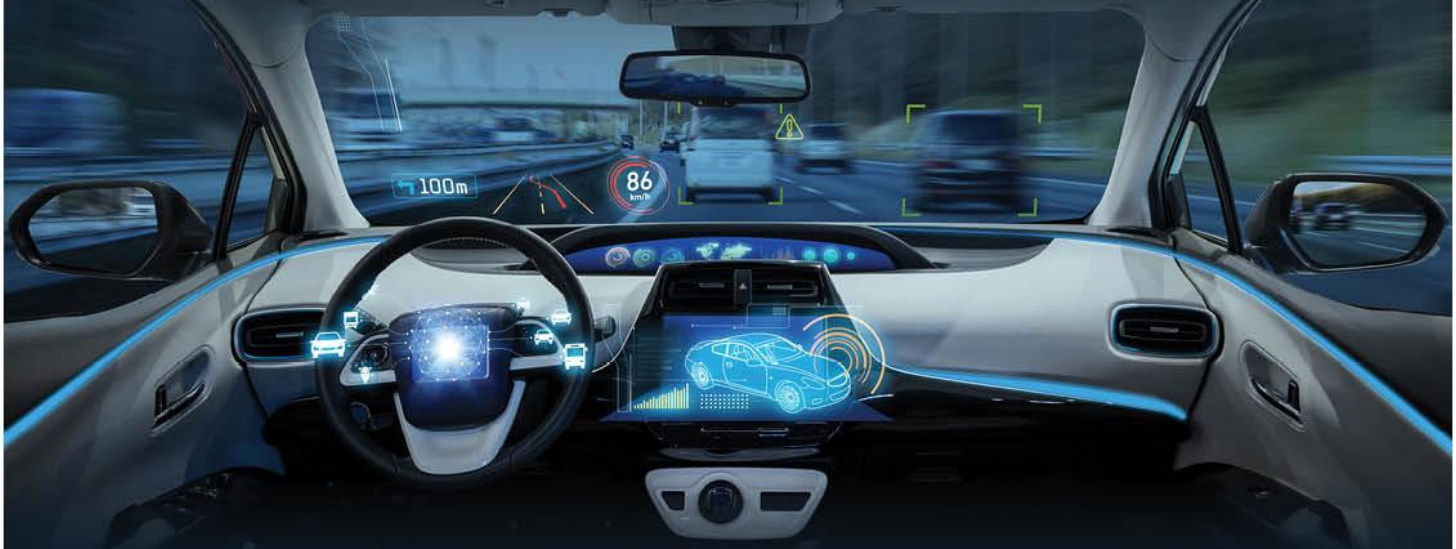

Connected and Autonomous Vehicles in Ontario: Technology Highlights

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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)** is a Government of Ontario initiative launched in November 2017 that supports Ontario's competitive advantage and reinforces its position as a North American leader in transformative automotive and mobility technologies, including transportation and infrastructure systems.

This initiative capitalizes on the economic potential of connected and autonomous vehicle (C/AV) technologies by supporting the commercialization of best-in-class, Ontario-made solutions. AVIN also helps Ontario's transportation systems and infrastructure plan for, and adapt to, these emerging technologies.

Areas of Focus

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

AVIN is delivered through the Ontario Ministry of Research, Innovation and Science (MRIS), the Ontario Ministry of Economic Development and Growth (MEDG), and the Ontario Ministry of Transportation (MTO) and administered on their behalf by Ontario Centres of Excellence (OCE).

AVIN is comprised of four distinct programs and a central hub:

- AV Research and Development Partnership Fund
- Talent Development
- Demonstration Zone
- Regional Technology Development Sites
- A central hub acting as a coordinating body for AVIN activities

AVIN has five main objectives:

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Acknowledgement

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Introduction

Autonomous vehicles (AVs) are complex systems that interact with humans using a range of computational, sensing, and control capabilities. AV systems are considered cyber-physical systems in which embedded computers monitor surrounding environments and take real-time actions to respond to different driving situations. These systems are operating in highly unpredictable and uncontrolled environments, and hence, they are required to demonstrate a highly reliable and robust behaviour when responding to environmental changes. They are also required be adaptable to system failures and unexpected situations.

Fortunately, due to major achievements in areas of computing and control technologies, AV developers have been able to overcome many of the challenges associated with the design of AV systems. Several products with some autonomy features[1] are now available in the market. Companies such as GM, Ford, Uber, Waymo, and Nissan have announced autonomous vehicle pilots to demonstrate and test these technologies. According to IHS Markit forecasts,[2] it is expected that the annual worldwide sales of AVs in 2040 will exceed 33 million units, from 51,000 in 2021.

Ontario is in a unique position to play a leading role in the development of leading-edge connected and autonomous vehicle (C/AV) technologies. The province is the second largest IT region in North America after Silicon Valley, with more than 20,000 IT companies and 280K IT workers.[3] Ontario is also home to five top automakers: FCA, Ford, GM, Honda, and Toyota produce more than 2.3 million vehicles each year. More than 700 automotive parts manufacturers are based in Ontario, including top global suppliers such as Magna, Linamar, Martinrea, and Multimatic, and more than 500 tool, die and mould makers operate to produce high-quality automotive parts and components. The province also has 44 colleges and universities from which 40,000 students graduate each year in fields of science, technology, engineering, and mathematics (STEM).[4] This combination of IT companies, automotive corporations, and a highly skilled workforce results in a dynamic C/AV ecosystem within which researchers, developers, policy makers and entrepreneurs interact to create innovative C/AV products.

Despite the uncertainty associated with the deployment of autonomous vehicles technologies, the Province of Ontario has taken several steps to support developers and technology manufacturers and ensure that testing is only conducted in safe and controlled environments. Additionally, the province has adopted a regulatory framework that

33 million

Expected annual worldwide sales of AVs in 2040

Source: IHS Markit

[1] https://www.sae.org/standards/content/j3016_201609/
[2] http://news.ihsmarkit.com/press-release/automotive/autonomous-vehicle-sales-surpass-33-million-annually-2040-enabling-new-auto
[3] https://www.investinontario.com/information-technology
[4] https://www.investinontario.com/automotive

2.3 M

Vehicles produced every year

20,000

IT Companies

40,000

STEM Graduates every year

44

Colleges and Universities

700

Automotive parts Manufacturers

5

Top Automakers

Source: Ontario Investment Office

responds effectively to the needs of the industry while minimizing risks. In 2015, the province introduced a pilot project (Ontario regulation 306/15) to allow testing and demonstration of automated driving systems.[5] Proposed amendments to this pilot were announced in

[5] http://www.mto.gov.on.ca/english/vehicles/automated-vehicles.shtml

December 2017 to support new C/AV initiatives such as permitting the public use of systems that operate at the Society of Automotive Engineers (SAE) automation level 3 (a conditional automation level that requires the ability and readiness of drivers to control the car at any time);[6] testing cooperative truck platooning; and testing driverless vehicles.[7] The proposed amendments were open to public consultation to receive comments and suggestions until February 4, 2018.

Ontario's AV testing pilots are required to conform to the AV pilot regulation,[8] Highway Traffic Act,[9] and the Federal Motor Vehicles Safety Act (MVSA).[10] Current regulations mandate a driver in the driver's seat at all times to monitor the vehicle's operation. It also ensures that the vehicle has a mechanism to engage and disengage the automated driving system in case of unsafe conditions. Finally, the province requires insurance of at least $5 million to cover any damages that result from the operation of the vehicle. Ontario's expectation remains that all manufacturers continue to view the safety of Ontario's road users as a top priority when developing their products.

This report provides an overview of some of the AV technologies that Ontario companies and researchers are working on, and highlights some of their main activities and contributions. The work for this report was conducted as part of AVIN central hub activities, which aim to educate and build awareness of ongoing AV developments in Ontario. This report is the first in a series of specialized quarterly reports that discuss the activities of the connected and autonomous vehicle community in Ontario.

"The Ministry of Transportation of Ontario (MTO) announced proposed amendments to AV pilot project legislation to support new C/AV initiatives such as permitting the public use of level 3 technologies, testing truck platooning, and testing driverless vehicles."

Technology Highlights

C/AV systems are poised to improve road safety, reduce congestion, reduce transportation costs, enhance efficiency, and provide more mobility options. Achieving these goals, however, requires several technological advancements that span across different industry sectors such as automotive, technology, and telecom. It also requires a collaboration between different public and private stakeholders to mitigate any risks that may arise from the new technology. The report focuses on five main example research areas*: the development of robust and real-time operating systems*; *understanding diverse objects, environments, and situations; improving sensing technologies*; *improving urban transportation*; and *connectivity*. While selected technologies do not cover all the aspects related to the design of C/AV systems, they illustrate some of the dimensions of C/AV design problems, and they demonstrate how different products may fit into the bigger picture of future C/AV industry. It also acts as a guide for those who

[6] https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety
[7] http://www.ontariocanada.com/registry/showAttachment.do-?postingId=26147&attachmentId=36324
[8] http://www.mto.gov.on.ca/english/vehicles/automated-vehicles.shtml
[9] https://www.ontario.ca/laws/statute/90h08
[10] https://www.tc.gc.ca/eng/acts-regulations/acts-1993c16.htm

are interested in understanding the C/AV ecosystem by emphasizing core competencies.

01: The development of robust and secure real-time operating systems

A robust and secure Real-time Operating System (RTOS) is an essential component of AVs. RTOSs provide the basic functionalities required by AV processes such as timing, managing memory, networking, and managing input/output devices. For safety-critical systems such as AVs, the performance of RTOSs must be highly reliable and predictable without compromising performance. They should also employ efficient fault detection, isolation, and recovery mechanisms that respond to failures and mitigate their effects[11].

BlackBerry QNX tackles this challenge by offering the QNX OS for safety,[12] a full-featured real-time operating system for automotive solutions. The product is tested and assessed to meet various safety and security standards such as ISO 26262 and IEC 61508. It is classified to meet the requirements of Automotive Safety Integrity Level D (ASIL D), which is the highest and most stringent level of safety. Additionally, the company offers a range of AV services and products including telematics, infotainment, engine sound enhancement, and advanced driver assistance. These services are provided in collaboration with a variety of partners such as Qualcomm, Renesas, Nvidia, and ARM.[13] Blackberry QNX continues to develop, test, and demonstrate new AV products and technologies through its Autonomous Vehicle Innovation Centre (AVIC) in Ottawa, Ontario. The company has recently announced Jarvis[14], a software-as-a-service analysis tool, that allows automakers to check the quality and security of their software components.

02: Understanding diverse objects, environments, and situations

Safe driving is continuously challenged by situations in which drivers are not fully aware of their surrounding environment at all times. Drivers need to deal with different weather conditions (e.g. clear, rainy, snowy), diverse scenes and road types (e.g. highways, arterials, local roads, driveways and country roads), and different signage systems. Safe and responsible driving requires drivers to monitor other road users, including other vehicles, cyclists and pedestrians, continuously. They are also required to obey traffic rules; drive in proper lanes; be cautious in school zones; watch cautionary signs; and stop safely and properly. Therefore, understanding surrounding situations and acting autonomously is one of the critical challenges in AVs. Developers rely on a complex sensing and reasoning systems for a reliable and consistent interpretation of the surrounding environments.

Dr. Raquel Urtasun, head of Uber ATG Toronto and a Canada Research Chair in machine learning and computer vision, is one of the pioneers in the area of machine perception for self-driving cars. Dr. Urtasun's work focuses on developing and improving affordable techniques to allow autonomous vehicles to detect 3-D objects in real-

[11] D. Hildebrand, "An Architectural Overview of QNX," in USENIX Workshop on Microkernels and Other Kernel Architectures, 1992.
[12] http://blackberry.qnx.com/en/products/certified_os/safe-kernel
[13] http://blackberry.qnx.com/en/partners
[14] http://blackberry.qnx.com/en/products/jarvis

> "GM is expanding its engineering base in Ontario to reach 1,000 positions."

time and navigate road networks safely. She was part of the team that developed the KITTI Vision Benchmark,[15] which allows AV developers and researchers to test and assess the performance of their technologies in the areas of 3D object detection, object tracking, and path planning.

Another prominent research development in this area is WatCAR Autonomoose,[16] a modified Lincoln MKZ Hybrid that serves as a research platform for AV researchers. The car runs a complete autonomous driving system that is equipped with advanced sensing capabilities that utilize radar, lidar, and cameras to navigate the roads. WatCAR Autonomoose is used to enable Simultaneous Localization and Mapping (SLAM) in all driving conditions. It also aims to improve fuel efficiency, reduce emissions, and develop enhanced control systems.

Many companies in Ontario are currently working on products that improve the driving experience using machine learning techniques. GM announced a new Automotive Software Development Centre in Markham, Ontario expanding its engineering workforce to 1,000 positions. Ford Canada, announced a $500-million investment to establish a new Research and Engineering Centre in Ottawa[17], which will focus on driver-assist features. An Ontario start-up, X-matik, has introduced an add-on autopilot called LaneCruise, that uses front-facing cameras and a set of actuators to transform traditional cars into autonomous cars.[18] The system comes with three disengagement methods and assumes the full responsibility of drivers.

03: Improving sensing technologies

Sensing capabilities in terms of range, accuracy, and resiliency are critical for the operation of AVs. They provide the information necessary to perceive objects, navigate surrounding environments, and make accurate driving decisions. Magna International, the giant tier 1 supplier, recently announced MAX4 Autonomous Driving Platform,[19] which combines cameras, radar, LiDAR, and ultrasonic sensors to allow up to level 4 driving capabilities. Another product is Magna's ICON RADAR,[20] which was announced in January 2018, and has the ability to scan the environment in four

[15] A. Geiger, P. Lenz and R. Urtasun, "Are we ready for Autonomous Driving? The KITTI Vision Benchmark Suite," in IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2012
[16] https://uwaterloo.ca/centre-automotive-research/watcar-autonomoose
[17] https://media.ford.com/content/fordmedia/fna/ca/en/ news /2017/03/30/ford-invests-c-500-million-for-r-d-in-canada.html
[18] https://x-matik.com/
[19] https://www.magna.com/media/press-releases-news/2017/08/31/news-release---magna-unveils-max4-autonomous-driving-platform
[20] https://www.magna.com/investors/press-releases-news/news-page/2018/01/15/news-release---magna-unveils-high-definition-icon-radar---scans-environment-in-four-dimensions

dimensions: distance, height, depth, and speed with a range of 300 metres.

Neptec technologies is currently offering its OPAL 3D LiDAR scanner,[21] which provides a range of up to 100 metres, operates at temperatures between -40°C to +40°C, and is resistant to shock and vibration. Automotive sensing technologies attracted some small- and medium-sized enterprises (SMEs), such as MMSENSE, to conduct research and developments in the AV space. MMSENSE announced collaboration with the Centre for Intelligent Antenna and Radio Systems (CIARS) at the University of Waterloo to design an integrated radar module for AV applications.[22] The goal is to improve the quality and precision of radar sensors in applications such as forward collision warnings, blind spot detection, and pedestrian detection.

04: Improving Urban Transportation

Urban transportation systems face fundamental challenges the affect accessibility, equity, and quality of life in dense metropolitan areas. Challenges include increasing rates of urbanization,[23] soaring traffic congestion,[24] collisions, and Greenhouse Gas emissions. Tackling these challenges requires collaboration and partnerships among public organizations, community groups, and the private sector to create innovative solutions that address the broader mobility needs of society. Many companies and researchers are currently working to investigate how AVs can contribute to more livable and sustainable cities. Shared AVs, robo-taxis, driverless shuttles, and delivery robots are new technologies that have the potential to significantly improve the quality of life of increasingly urban residents across the province and around the world. Efforts in this area can be categorized in the following sub-domains:

Innovative Urban Design

AVs inspired urban designers and landscape architects to rethink mobility in urban areas. Sidewalk Labs and Waterfront Toronto are currently working to create a sustainable neighbourhood, Quayside, where innovative urban design and digital technologies will be leveraged to address city challenges.[25] Sidewalk Labs' vision includes autonomous waste transport, shared on-demand services, and autonomous shuttles. [26]

Adopting Shared Mobility Principles

Many ride-sharing and car-sharing providers such as Uber, Lyft, and Zipcar have realized the impact of their operations on the performance of the transportation system. They have pledged to embrace shared mobility principles for livable cities,[27] which include promoting equity, reducing emission, maximizing public safety and improving the efficiency of using vehicles. According to the principles, shared AVs are expected to play a critical role to enable efficient mobility in dense urban areas.

[21] http://www.neptectechnologies.com/products/opal/
[22] https://www.mitacs.ca/en/projects/design-and-implementation-wideband-and-low-side-lobe-level-antenna-array-ltcc-technology-0
[23] Department of Economic and Social Affairs - United Nations, "World Urbanization Prospects - The 2014 Revision," United Nations, New York, 2015
[24] City of Toronto, "Deputy Mayor's Roundtable on Gridlock and Traffic Congestion," City of Toronto, Toronto, 2014
[25] https://sidewalktoronto.ca/
[26] Sidewalk Labs, "Sidewalk Labs Vision-Sections of RFP Submission," Sidewalk Labs, Toronto, 2017
[27] https://www.sharedmobilityprinciples.org/

Intelligent Transportation Systems

Other companies focus on developing advanced smart traffic monitoring and management techniques to improve the performance of the road network. An example is Miovision,[28] which uses advanced camera-based vehicle and pedestrian detection algorithms, real-time data analysis, and connected vehicle technologies to solve traffic problems. Other companies include Fortran traffic and AUG signals.

Planning

Ontario cities are currently investigating how C/AVs will impact the day-to-day activities of their residents. They do so by conducting research, establishing demonstration zones, and providing infrastructure support. Recently, Ottawa announced on-street testing of connected/autonomous vehicles in partnership with BlackBerry QNX and its Autonomous Vehicle Innovation Centre (AVIC). [29] A demonstration zone was announced in the City of Stratford as part of AVIN activities and in collaboration with The Automotive Parts Manufacturers' Association (APMA) and Ontario Centres of Excellence (OCE). [30] The City of Toronto is also preparing for the arrival of AVs by forming partnerships with academic institutions, professional associations, industry and other peer cities; a series of research activities regarding AV activities; integrating AV considerations in the planning process; and establishing an AV communication strategy.[31]

72.5 million

The number of connected Cars by 2023

Source: IHS Markit

05: Connectivity

Another challenge that attracted many companies and researchers is connectivity[32]. The ability of AVs to establish two-way communication channels with their surroundings allows a wide range of applications that improve road utilization and road safety. Vehicle-to-Vehicle (V2V) communications allow vehicles to exchange safety messages that help reduce and mitigate vehicle crashes such as lane changing warnings, collision warnings, blind spot warnings, etc. Vehicle-to-Infrastructure (V2I) communication allows better utilization and management of the road network by sending real-time messages about road conditions, construction zones, parking availability, etc. Many cars sold today are connected, and it is expected that total number of connected cars will reach 72.5 million units by 2023.[33] Connectivity involves many challenges that will be discussed in the upcoming reports such as cybersecurity, data accessibility, and privacy. Companies such as, Isara[34], Intelligent Mechatronic Systems (IMS)[35], and Escrypt[36] are

[28] http://miovision.com/trafficlink/
[29] https://ottawa.ca/en/news/ottawa-launches-canadas-first-street-test-autonomous-vehicle
[30] http://www.investstratford.com/en/Stratford-Apps.asp
[31] B. Gray, "Preparing the City of Toronto for Automated Vehicles," City of Toronto, Toronto, 2018
[32] https://www.its.dot.gov/cv_basics/index.htm
[33] https://ihsmarkit.com/topic/autonomous-connected-car.html
[34] https://www.isara.com/
[35] https://www.intellimec.com/about-ims
[36] https://www.escrypt.com/en

currently working to address these challenges using a broad range of technologies.

Conclusions

The design of safe and reliable autonomous driving systems requires partnerships and collaboration between many different stakeholders to ensure the new technology meets society's expectations. This report highlights different dimensions of AVs systems and how Ontario researchers and companies are working to improve safety, create livable cities, and offer better driving experiences. AV developers in Ontario are currently providing robust and predictable real-time operating systems; reliable machine learning techniques to navigate roads; advanced and accurate sensing technologies; innovative urban design and traffic management solutions; and secure connected vehicle technologies to improve the driving experience. Technologies for automation levels 1, 2, and 3, which require full attention from users, are currently available. Ongoing research and development efforts are currently taking place to bring safe and reliable level 4 and level 5 AV products to the streets of Ontario.

OCE Automotive and Mobility Team

Raed Kadri
Director, Automotive Technology and Mobility Innovation
(416) 861 1092 x9-7400
raed.kadri@oce-ontario.org

Sam Saad
Manager, Automotive and Mobility Portfolio
(416) 861 1092 x9-1097
sam.saad@oce-ontario.org

Jesika Briones
Manager, Automotive and Mobility Portfolio
(416) 861 1092 x9-1079
jesika.briones@oce-ontario.org

Martin Lord
Senior Sector Manager, Automotive and Mobility Portfolio
(905) 823 2020 x9-3236
martin.lord@oce-ontario.org

Holly Gardner
Sector Manager
Automotive and Mobility
(416) 861 1092 x9-1086
holly.gardner@oce-ontario.org

Mohamed Elshenawy
Technical Data and Global Trends Analyst
(416) 861 1092 x9-1077
mohamed.elshenawy@oce-ontario.org

Shane Daly
Automotive and Mobility Team Coordinator
(416) 861 1092 x9-5017
shane.daly@oce-ontario.org