Simon Fraser University

Steering The Future:
The Evolution, Technology, and Ethical Challenges of Autonomous Vehicles in Canada

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Introduction

Among the most inventive developments in modern transportation, are autonomous vehicles (AVs). As CMPT 105W students, we are aware that artificial intelligence (AI) and machine learning in general are influencing many facets of technology. By allowing such technological advancement, AVs hold a promise for improving safety on roads, reducing congestion on highways, and lowering emissions of greenhouse gases. Design and ethical complexities surrounding the creation of AVs may be less familiar. This paper will introduce the history of AV development, and its current state in Canada while exploring both technological trends and the ethical issues it poses. This paper will be able to provide a comprehensive understanding of AVs, especially focusing on their challenges and future prospects within Canada.

History of Autonomous Vehicles

The idea of AVs originated in the mid-20th century, but early experiments concentrated on much simpler automation. Only during the 1980s and 1990s, better robotics, AI, and more powerful computing allowed more ambitious schemes to be visualised [1]. Some early systems, such as advanced driver-assistance systems, provided features such as lane-keeping, adaptive cruise control, and automatic braking [2].

In the Canadian context, the road to AV development gained momentum in 2016, when Ontario became the first province in the country to present a regulatory framework for AV testing [3]. The first appearance of this regulatory framework launched a 10-year pilot project for Ontario, allowing Level 3 to Level 5 autonomous vehicles onto public roads. Level 3 vehicles provide for conditional automation, where most driving tasks are performed by the vehicle itself, but a human driver should be ready to assume full control if required. Level 5 involves fully automated vehicles needing no intervention from a human being to function and can drive in any environment under whatever conditions prevail. The rules have also allowed companies like Uber and Waymo to continue testing AVs as long as public safety was guaranteed [3].

Quebec followed suit in March 2018, thus setting a similar regulatory platform. Quebec focused its efforts on pilot projects, especially testing self-driving shuttles in more controlled environments, such as university campuses and industrial parks [3]. The idea of such projects was to collect safety data and other crucial information regarding the efficiency and feasibility of deploying AVs in particular use cases.

As the development of AVs continues to evolve, other provinces such as Alberta and Nova Scotia also take a look at their regulatory approach, though they remain less advanced. [3]

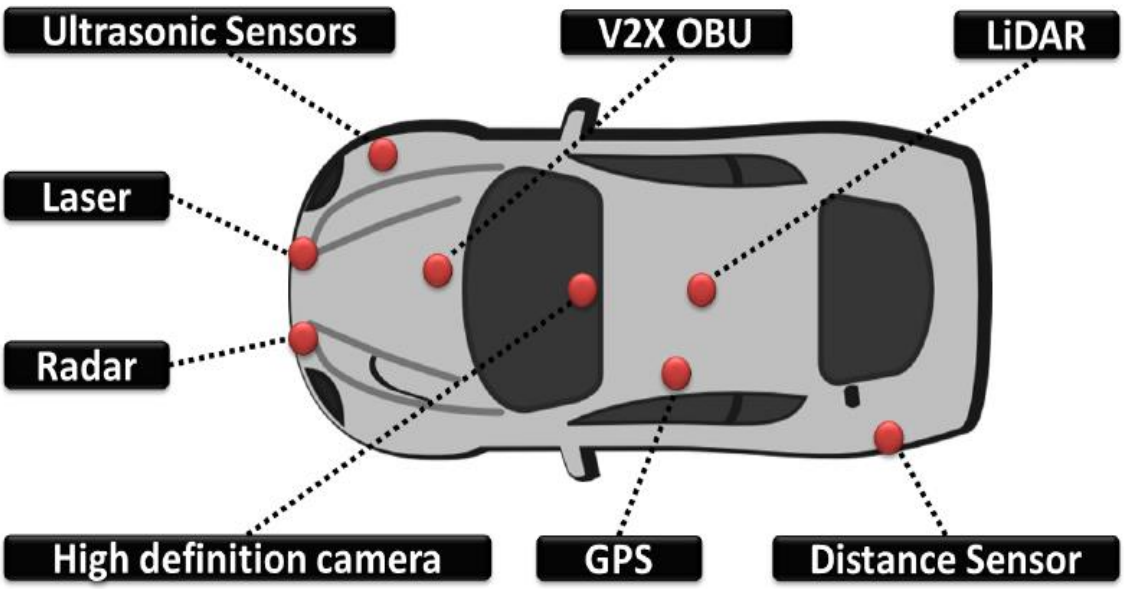
Current State of Autonomous Vehicles in Canada

Despite developments, testing of AVs in Canada remains largely restricted to various pilot programs. Ontario and Quebec remain the front-runners, but this progression towards full deployment is gradual [3]. The Ontario 10-year pilot project keeps on evolving by making further advances enabling sophisticated testing of highly automated vehicles (HAVs). On the other hand, Quebec is focusing highly on the use of AVs for public transportation, particularly self-driving shuttles [3].

One of the serious impediments to AVs deployment is Canada's extreme weather. It greatly impinges on AV technology, with snow and ice during winter and freezing temperatures. AVs have to make out such hazards as icy roads and poor visibility and safely navigate through them [14]. The researchers are working on developing weather-resistant AV systems that can work under such conditions. For instance, while the development of AI and sensor technologies is crucial for the expansion of vehicle performance in winter conditions, it may take several years before the AVs are reliably capable in Canadian winters [14].

Technology Behind Autonomous Vehicles

The technology behind AVs is much more than just AI. They integrate a host of other systems such as Light Detection and Ranging (LiDAR), radar, cameras, and advanced sensors, creating a very realistic understanding of the world around them. LiDAR sends out laser beams and measures the time it takes to return, thus determining distance, and immediately plots an accurate 3D map of what is surrounding the vehicle [7]. This enables the AV to "see" and detect objects even in conditions difficult for human drivers, such as in fog or snow- a frequent occurrence in Canadian winters. Understanding how those systems work together provides insight into the computational complexity of AV decision-making, which is a key component of machine learning models that predict and react to human behaviours. The figure below clearly depicts the key technologies required for the smooth functioning autonomous cars.



Key technologies enabling autonomous cars [11]

Other, more advanced capabilities of AV technology involve predictive modelling. Not only must AVs react to immediate obstacles, but they also must predict what other vehicles and

pedestrians are going to do. In AVs, machine learning algorithms can analyze patterns of movement and make decisions based on real-time data inputs [17]. This becomes important in urban settings when vehicles need to make their way through generally quite unpredictable environments that contain heavy traffic, pedestrians, and cyclists.

The other major technological frontier for AVs is vehicle-to-everything (V2X) communication, wherein AVs are in contact with infrastructure such as traffic lights and other vehicles. V2X technology can reduce accidents and improve traffic as it would enable anticipation of changes in traffic through real-time coordination among vehicles [5]. This communication system would be an integral part of ensuring that safety and efficiency in autonomous traffic systems, especially in complex city environments. Cities like Toronto and Montreal have just begun investing in intelligent infrastructure to support V2X technology- a key component, some might say, of future AV deployment [13].

Emerging Trends and Future Outlook

The future of AVs in Canada will be closely related to the development of Connected Autonomous Shared Electric (CASE) vehicles [18]. The CASE technology combines the advantages of autonomous driving with electric power and shared mobility models- a model promising lower emissions and reduced congestion. CASE Vehicles would potentially reduce the number of vehicles on the road by providing on-demand transportation services, hence reducing the need for personal car ownership [18]. This could therefore have one of the most significant environmental advantage in reducing the emission of greenhouse gases and dependence on fossil fuel sources within urban settings.

Canadian researchers also strive to improve the AI algorithms driving the AVs through machine learning models, analyzing large volumes of real-world driving data, developing better decision-making by AVs, and ensuring that the vehicles can handle a wide range of scenarios [14].

Considering urban settings, with all those complicated crossroads, pedestrian crossings, and heavy traffic, this research is particularly important.

The future for AVs is anything but unproblematic. Public trust and acceptance remain a huge barrier. While the advantages are numerous, there is fair skepticism among Canadians about the safety and reliability of AVs [5]. Simply put, people do not feel very safe with them, without the human element to help avert accidents or machine error. These concerns, over the long term, have to be taken care of, if AV deployment in Canada is to be successful as these will determine public perception and its wide acceptance.

Ethical and Social Controversies

One of the biggest ethical concerns with AVs is called the "trolley problem," a moral dilemma about how the AV would act in a life-threatening situation: should it protect its own passengers or protect pedestrians? The dilemma is largely theoretical, however, this does bring up some critical questions about how AVs will be programmed to make moral decisions [4][12]. Unlike human drivers, who make split-second decisions based on instinct, AVs must follow pre-determined algorithms, which has led to debates over the ethical implications of such programming,

Another major ethical concern is data privacy. AVs collect vast amounts of data, including GPS locations, camera feeds, and real-time driving patterns, which can be used to improve vehicle performance but also raise significant privacy concerns. Besides the increased application, the potential misuse of the AVs' personal information is a big challenge that needs consideration [6].

The other big issue is cybersecurity. Since more and more AVs are connected, they can be more easily accessed by hackers [19]. A successful intrusion into AVs could have disastrous

implications, including running an AV in a way that causes a crash to occur or providing access to unauthorized persons to sensitive data.

Besides privacy and security issues, AVs create societal challeneges. One of the most important concerns is the potential job displacement [10]. As the use of AVs proliferates, industries employing human drivers- for example, trucking, taxi services, and delivery firms- stand to lose upward of millions of jobs. While employment opportunities could be created by generally widespread use of AVs, it would be at the discretion of policymakers to devise plans that would retrain workers who are displaced, so that benefits from this new technology are shared relatively equitably across society.

Finally, there is social inequality. While AVs would extend transportation options for both disabled and remote residents, the benefits of the AVs may not be distributed evenly. The maximum deployment of vehicles might be witnessed in urban areas since cities will be most interested in investing in the required infrastructure, which will support large-scale availability, leaving behind the rural communities [20].

Conclusion

Full-level autonomous vehicles can change the face of transportation in Canada by improving safety, reducing emissions, and increasing access. The technology also introduces an array of highly significant challenges related to ethical decision-making, privacy, cybersecurity, and social equity. As Canada proceeds with the testing and development of AVs, it is in a position to deliver relevant regulatory frameworks that cover these issues, ensuring equitable benefits of AV technology at the societal level.

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