The Ethical and Technological Challenges Facing Autonomous Driving

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Introduction to Autonomous Driving

Autonomous driving is one of the greatest modern challenges in computer science. The very idea of owning a personal vehicle that is fully autonomous raises a plethora of ethical and technological questions that must be resolved before this becomes a reality. Take the following thought experiment as an example: given the choice between killing two pedestrians or one passenger, which decision should a car make? Variations of this debate have the hypothetical car forced to decide between striking one pedestrian crossing illegally and two not or a homeless and a wealthy person. This report will give an overview of ethical choices that face autonomous driving and break down what makes this technology possible in the first place.

The Society of Automotive Engineers (SAE) classifies five different levels of autonomous vehicles (AVs) based on which driving tasks the human driver must perform. A traditional automobile performs at level 0 (Ning et al., 2021). Blindspot detection does not count as a form of autonomy because it is simply a tool to aid the driver's own perception of road hazards (Morris, 2021). In a fully autonomous – level 5 – vehicle the steering, monitoring of the road and other dynamic driving tasks are all controlled by artificial intelligence (AI) software. Then, the driver – if the occupant of the vehicle can even be called this – has absolutely no responsibility (Ning et al., 2021). Dynamic driving tasks include "lateral and longitudinal control as well as object and event detection and response" (Inagaki & Sheridan, 2018). No such vehicle currently exists. Tesla's popular Full Self-Driving Capability is actually considered just level 2 autonomy. Still, it remains the highest level of success any automaker has achieved with a commercial AV (Morris, 2021). Other companies offering level 2 vehicles include Acura, Alfa Romeo and Audi (Meier, 2021). The first consumer vehicle ever designed with a functioning level 3 autonomous driving system was the Audi A8 (Wang et al., 2018). However, the A8's

Traffic Jam Pilot never made it to market. Google subsidiary Waymo is partnered with Swedish automaker Volvo to perform research and development on a level 4 vehicle, skipping level 3 altogether (Ning et al., 2021).

Overview of Autonomous Driving Technology and its Technological Challenges

The AI systems that drive most contemporary self-driving vehicles are powered by deep learning: a type of machine learning that can choose which parameters it uses to complete a task. For example, the program itself will choose which features are important to distinguish and identify different objects on the road. Deep learning networks can do this after being fed enormous amounts of sample data and feeding this data through multiple layers to refine the resulting algorithm that it will use to make decisions.

The software designed for self-driving cars has 3 main layers: perception, planning and control (Wang et al., 2018). In the perception layer, the vehicle acquires information about the environment around it. Many cars currently use a combination of cameras, radar and LIDAR (LIght Detection And Ranging) sensors to determine the location of hazards – pedestrians or other vehicles – and read street signs. However, problems with sensors can still occur if, for example, markings on the road have worn off. A human may be able to infer that a yellow lane line should have been painted on a section of road; a camera or LIDAR sensor may not. To supplement data coming from sensors, cars also receive outside information from a GPS about their absolute location or via communication with other vehicles about traffic conditions and physical road conditions (Wang et al., 2018). After sufficient data has been gathered, the AI uses it to generate “planning instructions [that include] following, overtaking [and] accelerating”

(Wang et al., 2018). These instructions are then sent to the control layer, which executes them by manipulating the "throttle, brake and gear control" (Wang et al., 2018).

Deep learning AI also cannot extrapolate to make decisions for unknown scenarios like human drivers can; they can only make decisions based on data they have already seen. Huansheng Ning (2021), who researches different possibilities for hybrid human-AI computer architecture, believes that it is still "impossible to simulate human intelligence by data [alone]" because while one can feed the AI a lot of data, this data is often deterministic. Deterministic data refers to information that corresponds too much with the mean and has few outliers which would create an AI that is incapable of dealing with random situations (Ning et al., 2021). Thus, the planning and control stages are the hardest to program with one hundred percent effectiveness. Indeed, AV manufacturer Waymo estimates that the number of crashes involving its vehicles would have increased by approximately 50% if the human driver had not taken over (Freedman et al., 2018). So, hybrid systems in which the driver is occasionally required to take over – SAE level 4 or lower – are much more feasible than a fully autonomous vehicle based on current software and hardware capabilities.

` Hybrid human-machine driving systems bring up an entirely different and unique problem: human-machine conflict. Human-machine conflict is a cornerstone of Ning's research and must be solved to develop an ideal architecture. If a human is expected to respond to – or even take over for – an AI, a system that allows the two to seamlessly communicate must be carefully designed. Information that is presented unclearly to a human could cause confusion over what actions to take or a delay in response time. Every second is crucial when driving, so "when the deviation of two actions exceeds a threshold, the task may fail" and lead to a crash (Ning et al., 2021). To allow both the human and AI to control a vehicle together a shared control framework is applied. For instance, a driver may get an alert telling them that they need to take over control of the vehicle from the AI by using the physical steering wheel, stick shift and pedals. Different approaches to designing a framework that is as ergonomic as possible are still being studied. One promising idea involves offering "haptic feedback," such as by decreasing the stiffness – or manipulating other physical attributes that increase usability – of the steering wheel and pedals when it is more likely that the driver may need to take over (Abbink et al., 2012).

Non-Technological Challenges of Implementing Autonomous Driving

Various non-technological problems are also hindering the mass production of level 3 or higher AVs, such as the steep cost associated with each unit (Ning et al., 2021) and the legal responsibilities of the manufacturer in the event of a crash. For example, although the Audi A8's Traffic Jam Pilot was never used on the road, automobile reporter Sean Szymkowski (2020) largely blames this failure on legal worries for the company rather than any inability to engineer the technology; if the company advertises that this feature allows hands-off use of the car, the fault for any crash that occurs transfers to them instead of the driver.

The discussion around autonomy frequently involves fears that people will lose their jobs. For instance, if goods are transported across the country using autonomous trucks, thousands of truckers will be out of business. A 2018 study investigated participants' thoughts on the role of AVs in society. It found that 35% of people were at least "very concerned" about job losses in the transportation industry (Pettigrew et al., 2018). But, when asked to comment, some study participants did view this in a positive light; truckers, who work under poor conditions, may be able to move to better employment opportunities created by companies that use, design or manage autonomous vehicles (Pettigrew et al., 2018).

However, one of the largest non-technological barriers this technology faces is the numerous ethical question marks, so to speak, that come up when researchers and the public philosophize about AI. This may lead people to feel uncomfortable about putting their lives in the hands of a computer. In 2003, the Universal Theory of Usage and Acceptance of Technology was developed, which can help quantify these feelings of distrust. Charlie Hewitt and a team of researchers at Cambridge University devised a carefully worded survey that posed 26 questions to determine people's opinions on autonomous vehicles. Each question correlated to one of the 8 categories of the theory: Performance Expectancy, Effort Expectancy, Attitude Towards Technology, Social Influence, Facilitating conditions, Self-Efficacy, Anxiety and Behavioural Intention. The team also added a category for Perceived Safety. Indeed, the study showed a significant decrease in positive feelings such as perceived safety and an increase in negative feelings such as anxiety for vehicles with high or complete autonomy (Hewitt et al., 2019).

The thought experiment posed at the beginning of this report shows that AI have the power to make choices that weigh the value of human lives. This can make people very uneasy, and the technological community at large has spent years trying to tackle this problem. Some critics believe that any such debate is a waste of time, as “there are few instances in real life in which a vehicle would face a choice between striking two different types of people” (Maxmen, 2018). But, the reality is that those autonomous cars that currently exist already do make a valuation on human lives. Google's self-driving cars can choose to move to the side in order to gain more information about the road ahead, as human drivers often do. Although many people frown upon this practice, seeing it as unsafe or simply rude, Google devised and patented an algorithm that takes into account how much information will be gained by performing the maneuver and weighs it against the risk to those surrounding the car. Of course, to do this the software must inherently place some numeric value on human lives (Nelson, 2015). Therefore, these are choices that human software engineers must tackle.

An online survey called the Moral Machine asked members of the public “to choose [whom] to spare in situations that involved a mix of variables: young or old, rich or poor, more people or fewer” (Maxmen, 2018). The survey was available for 18 months and received “40 million decisions made by people from 233 countries” (Maxmen, 2018). Interestingly, respondents’ answers varied greatly by country and clearly correlated to that country’s political or economic state. For example, people from developed countries were more likely to suggest killing a person who had crossed the road illegally (Maxmen, 2018). This presents a personal dilemma for computer programmers themselves; American software engineers may find themselves forced to design software that their country unanimously disapproves of simply to get their product to sell in Columbia.

Benefits of Autonomous Driving to Society

Innovations like autonomous driving often spark not only debate and controversy, but also excitement. Autonomous vehicles could improve delivery times for goods because trucks will not have to stop for driver breaks. They could also improve public safety; one autonomous vehicle with a clear view of the road ahead can communicate the data it collects to others without this view and allow them to make better-informed decisions. It looks hopeful that AVs will decrease traffic levels because they can efficiently plan routes around each other. This would benefit any of the world's major industrialized cities, which struggle with extreme congestion in their downtown cores and sprawling suburbs. While increased traffic flow would alleviate the stressful commute times for many city-dwellers, vehicles being on the road for shorter periods would also lead to significantly reduced greenhouse gas emissions. A 2019 study by Raphael Stern et al. confirmed this theory by finding that when just one AV was added to a group of 22 driving in a circle, that car actively dampened traffic waves and decreased the velocity variation of every other vehicle. In turn, each vehicle's hydrocarbon emissions decreased by 38.4%, and their carbon dioxide emissions decreased by 31.4%.

Concluding Recommendations

This report has attempted to summarize AV classification and the current market, explain the premise of current AV software and present the various challenges and benefits of rolling out AVs. Below are recommendations for the future study and implementation of this complex branch of computer science. The academic world currently appears to have a sense of optimism when it comes to clearing the technological hurdles preventing the widespread adoption of AVs. The ethical and personal concerns over AVs will be far more exigent. However, despite some of these still being up in the air, people seem to acknowledge that vehicles with greater levels of autonomy will have myriad benefits to individuals and society. Although Hewitt's study found a downward trend between a vehicle's level of automation and public opinion over it, "participants were generally positive [rather than negative] about high-level autonomy" (2019). So, further research into society's ethical preferences is well worth devoting resources to, if it means the possibility of mass-production consumer vehicles with greater than level 2 autonomy.

In his 2020 paper, Mark Ryan posed a scenario with an optimistic timeline in which over a hundred cities may be trialing the use of self-driving cars “within designated areas” by 2025. The scenario was intended to help policymakers “explore possible consequences of current trends … [and] uncover issues that might otherwise be overlooked” (Ryan, 2020). It would be an incredible opportunity for the city of Ottawa to become one of these pioneers and receive the many benefits outlined earlier in this report. But, as indicated by the Moral Machine, the choices AVs are programmed to make may end up varying from country to country (Maxmen, 2020). So, to facilitate an Ottawa rollout, research must be conducted within this country to determine what choices Canadians are comfortable with.

One topic that should be studied is the ethical decisions that human drivers currently make on the road every day. Passengers and pedestrians alike currently live comfortably knowing that no one other than another human is trusted with a car – and thus that no one else can make instinctual emergency decisions that weigh the value of human lives. So, perhaps to ease the fears of critics, AVs should make decisions that mimic those of a human driver. If rigorous studies find that human drivers tend to protect themselves over the lives of multiple others, then perhaps, unfortunately, this is what the vehicle should do. If it is found that a human driver makes the decision to strike one of two people completely at random, then AVs should be programmed to do this too. Still, some people might prefer cars that actively preserve the lives of certain types of people over others, even if these are not decisions that human drivers make. This might mean a preference for saving younger people, who supposedly have more life left to live than older people. No number of studies in the world will be able to get Canadians to agree on one of these two philosophies; there will never be one correct answer. But, there does not have to be. After all, no existing or future method of transportation can be 100% safe or ethical either.

All people need is to know that their lives are valued as fairly as possible. Surely, the world's brightest computer programmers can manage that.

References

Abbink, D., Mulder, M., & Boer, E. B. (2012). Haptic shared control: smoothly shifting control authority? *Cognition, Technology & Work, 14*(1). https://doi.org/10.1007

Freedman, I. G., Kim, E., & Muennig, P. A. (2018). Autonomous vehicles are cost-effective when used as taxis. *Injury Epidemiology*, *5*. https://doi.org/10.1186

Hewitt, C., Politis, I., Amantidis, T., & Sarkar, A. (2019). Assessing Public Perception of Self-Driving Cars: the Autonomous Vehicle Acceptance Model. 24th International Conference on Intelligent User Interfaces, 518-527.

Inagaki, T., & Sheridan, T. B. (2018). A critique of the SAE conditional driving automation definition, and analyses of options for improvement. Cognition, Technology & Work, 21(4). https://doi.org/10.1007

Maxmen, A. (2018). Self-driving car dilemmas reveal that moral choices are not universal. Nature, 562(7728). https://doi.org/10.1038

Meier, F. (2021, March 24). Which Cars Have Self-Driving Features for 2021? Cars.com. https://www.cars.com/articles/which-cars-have-self-driving-features-for-2021-433821/

Morris, J. (2021, March 13). Why Is Tesla's Full Self-Driving Only Level 2 Autonomous? Forbes. https://www.forbes.com/sites/jamesmorris/2021/03/13/why-is-teslas-full-self-driving-only-level-2-autonomous/?sh=1cf240ae6a32

Nelson, G. (2015). Self-driving cars make ethical choices. Automotive News, 89(6681).

Ning, H., Yin, R., Ullah, A., & Shi, F. (2021). A Survey on Hybrid Human-Artificial Intelligence for Autonomous Driving. IEEE. https://doi.org/10.1109

Pettigrew, S., Fritschi, L., & Norman, R. (2018). The Potential Implications of Autonomous Vehicles in and around the Workplace. *Environmental Research and Public Health*, *15*(9). https://doi.org/10.3390

Ryan, M. (2020). The Future of Transportation: Ethical, Legal, Social and Economic Impacts of Self-driving Vehicles in the Year 2025. *Science and Engineering Ethics*, *26*. https://doi.org/10.1007

Stern, R., Chen, Y., Churchill, M., Wu, F., Delle Monache, M. L., Piccoli, B., Seibold, B., Sprinkle, J., & Work, D. (2019). Quantifying air quality benefits resulting from few autonomous vehicles stabilizing traffic. *HAL Open Archives*. https://doi.org/10.1016

Szymkowski, S. (2020, April 28). Audi hangs up hopes for Level 3 partial automation system. Roadshow; CNET. https://www.cnet.com/roadshow/news/audi-a8-level-3-automation-traffic-jam-pilot-system/

Wang, J., Liu, J., & Kato, N. (2018). Networking and Communications in Autonomous Driving. IEEE. https://doi.org/10.1109