The Integration of Social Factors in the Development and Implementation of Autonomous Vehicles

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Autonomous Vehicles

The California Department of Motor Vehicles defines "autonomous technology" to mean "technology that has the capability to drive a vehicle without the active physical control or monitoring by a human operator" (California Department of Motor Vehicles, n.d.). Autonomous vehicles (AVs) were once envisioned a technology of the future, but have now become a concrete reality. According to the National Highway Traffic Safety Administration, "these self-driving vehicles ultimately will integrate onto U.S. roadways by progressing through six levels of driver assistance technology advancements in the coming years." The six levels of car autonomy as defined by the Society of Automotive Engineers (SAE) take values on a scale from 0 to 5. Level 0 refers to complete human driver control while level 5 is complete autonomy in any environment (National Highway Traffic Safety Administration, 2019). Today, many companies are in the process of developing a fully-autonomous car, with some promising success within the next five years. For example, Ford projects to have implemented a fully-autonomous Level 5 car by 2021 (Looking Further, n.d.). Such a car will have no steering wheel or gas pedal, thus never requiring a human driver to ever take control.

The road to a level 5 autonomous car introduces many questions that need to be answered by ongoing discussions between industry and the public. These questions involve consideration of what values to prioritize in the implementation of AVs. It is important as autonomy progresses to distinguish what those values are, how they are assessed, and how their implementation in systems are shaping society. Additionally, the transition from human driven to autonomous cars is likely to impose several implications on society. Although a new technology, historical cases of failure in autonomy have caused government policy to be enforced and public discussion to arise. AVs are changing how people think and react whether society is aware of it or not.

This paper employs several STS frameworks to explore the social influences in AVs. As both society and AVs concurrently influence one another, Social Construction of Technology (SCOT) and Technological Determinism is used for analysis. Additionally, the Wicked Problem framework is used to assess the complex network of social, economic, and political factors limiting proposed solutions for ethical decision-making in AVs. Furthermore, this paper analyzes those societal influences that have created a technologically deterministic future of AVs.

Research Questions and Methods

The research question is: how have societal demands and influences been incorporated into the development and implementation of AVs? AVs have been rapidly progressing while being modeled after human behavior and are designed for societal demands. It is crucial to assess how these demands affect the development of a state-of-the-art technology, and how that might in turn create a futuristic technological determinism of AVs as this technology has changed and continues to change human behavior. These demands set precedence in road behavior and social norms as a whole. Society must analyze what demands have shaped AV implementation and how those demands translate over into technology that changes how society thinks and behaves.

This topic is analyzed through documentary research methods, policy analysis, and historical case studies. Although AVs are a new technology, significant research has been done to theorize the social implications and dilemmas that AVs are to encounter. Furthermore, investigative research about the translation and interpretation of social practices into implementable technology is used to exhibit how AVs make decisions and what patterns they follow. This documentary research includes government publications, newspapers, and census publications to assess current guidelines in place, distinguish society's values, and inspect what factors affect decision-making. Collection of data will be centered around the decision-making processes for AVs modeled after human behavior. This data collected serves as a foundation to better understand the existing frameworks. Additionally, historical cases featuring failure in AV technology are examined to understand how policy has changed in response to transportation technology. More specifically, research is conducted with a focus on government involvement to understand the current direction of AVs, and to assess what factors are considered moving forward.

A History of AVs

In 2018, Uber released an autonomous car that hit and killed a pedestrian due to a technological failure in recognition (Lekach, 2018). Further investigation found that the driver had been streaming episodes on YouTube, Netflix, and Hulu leading up to the crash. This failure in recognition leads to the further examination of what algorithms were used to detect objects – namely, what did the algorithm lack or fail to consider that led to a critical casualty? The death of the pedestrian, Elaine Herzberg, was the "first attributed to a self-driving vehicle and prompted significant safety concerns about the nascent self-driving car industry, which is working to get vehicles into commercial use" (Shepardson, 2019). This event prompted the U.S. National Transportation Safety Board (NTSB) to investigate with the intent of issuing safety recommendations to prevent similar crashes (National Transportation Safety Board, n.d.). The crash was one of the first that instigated the incorporation of social influences such as safety into the development of AVs.

In 2016 alone, the U.S. National Highway Traffic Safety Administration tracked a total of 37,461 lives were lost in crashes on U.S. roads that year. Driver error (of the human variety) is involved in 90 percent of accidents (National Highway Traffic Safety Administration, 2017). One of the greatest challenges in AVs is that they can never encounter all possible traffic situations, but cars can learn from their mistake and crashes (Lekach, 2018b). In acknowledgement of the recent fatal AV crashes, development of AVs continues to integrate more features that handles task of driving users do not want to or cannot do for themselves. What started as simpler features, like cruise control and antilock brakes, have evolved into blind spot detection and advanced driver assistance components, such as self-park (National Highway Traffic Safety Administration, 2019). AVs have the potential to remove human error from the crash equation, which will help protect drivers and passengers, as well as bicyclists and pedestrians. Safety is just one of the social influences being integrated into autonomous systems.

> On the other hand, recent advancements toward partly/fully automated vehicles are poised to revolutionize the perception and utilization of travel time in cars, and are further blurring the role of travel as a crisp transition between location-based activities (Malokin, 2019).

Society's desire to evolve driving from a mundane, repetitive task to an opportunity for productivity has changed how AVs are designed and what features are to be added. The progression has changed how society views travel time and driving in general. This view has evolved from its earlier motivations to lessen the amount of decisions a user has to make such as cruise control. Now, AV applications have expanded to eliminating driver fatigue the key factor in the 4,000 deaths caused by truck accidents each year (Protiviti, 2017). The U.S. Congress is already pushing for stricter trucking regulation in 2016 that will limit operating times for truckers (Lardner, 2019). This demand for ease has propelled advancement in AV technology and increased pressure to produce a Level 5 vehicle, or a car that is able to drive itself in any situation and condition: a fully autonomous car. Level 5 drastically differs from Level 0, meaning no vehicle automation with the driver fully in control (National Highway Traffic Safety Administration, 2019).

> University of Virginia professor Madhur Behl, a computer science professor who researches high-performance autonomous racing cars that are a tenth the size of a normal car, is confident in the cars' abilities to be agile and safe. "Overall, these cars will prove to be safer than human counterparts," Behl said. (Lekach, 2018).

Increasing societal demands concerning safety, ease, and efficiency are being met as AVs approach SAE's Level 5 categorization. Moreover, these present-day societal demands have created a technologically deterministic future of autonomous vehicles. Once a decision-making footprint is set, it will difficult to change and converge that logic to be ubiquitous among manufacturers of AVs.

STS Frameworks

Autonomy is both directly and indirectly modeled after human behavior. How humans act in differing environments is one of the many behaviors autonomy attempts to emulate. Society and its values play a large role in the decision-making process for autonomous vehicles. Elements of social determinism are showcased in the idea of using social norms and human emotions to improve the collision avoidance of AVs. For example, Netlogo, a social agent-based collision avoidance strategy, was found to be 78.52% more efficient than Random walk-based collision avoidance strategies (Riaz, 2018). In addition to showcasing elements of Social Construction of Technology, this incorporation of social influences shows the benefits of modeling autonomy after humans. The emulation of collision avoidance in humans have been proven to show better performance than sheer randomness.

Vinkhuyzen and Cefkin of the Nissan Research Center acknowledged the movement of cars on the road inherently involve social action, and led research for the development of AVs that engage with pedestrians, bicyclists, and other cars in a socially acceptable manner. Their challenge: "How do we translate what are observably social practices into implementable algorithms when road use practices are so often contingent on the particulars of a situation, and these situations defy easy categorization and generalization?" (Vinkhuyzen & Cefkin, 2016). They were able to distinguish and implement certain behavior patterns into decision logic. Such patterns include "piggybacking": a common pattern at four-way stops which achieves better overall traffic flow by providing an implementable way in AVs to queue order. This pattern was readily accepted and adopted to be programmed into AVs. In addition to other observed behaviors, the Nissan Research Center defined decision logic that would be able to smoothly integrate in to the flow of traffic by emulating human response, a feat that evidences SCOT values.

However, those responses must be "pre-specified by its engineers who thus have the Herculean task of defining all possible situations" (Vinkhuyzen & Cefkin, 2016). These situations seem infinitely numbered and depend on several factors. Patrick Lin, an associate professor of philosophy at California Polytechnic State University states these factors can include intensity of braking, direction to swerve, condition of the vehicle, type and size of animal, kind of vehicle we're crashing into, etc. (Lin, 2013). These can be seen as players within the Actor-Network Theory. Regardless of the ability to sense these factors, programmers need to assign costs/weights to various actions/objects as best as they can. This means having value-judgement decisions which need to be wholly agreed upon by society. Lin suggests hypothetical scenarios can be used to see that reasonable ethical principles can lead to controversial results.

These principles include consequentialism and self-sacrifice. He argues both drive the need for discussions and expectations between industry and the public.

Although development of AVs stem from safety concerns, the increased demand for ease has led to a desire for reduction in the labor force, and development of AVs have been molded to follow those demands by getting closer and closer to fully autonomous vehicles. This form of SCOT interplay with Actor-Network Theory when considering implementation of decision-making in AVs. However, due to the extensive roles and relationships in the sociotechnical environment of AVs, several limitations that impede the successful realization of societal demands are analyzed using the Wicked Problem framework.

Incorporation of Societal Demands and Influences into AVs

The social demands of safety and ease have driven the development of AVs through the translation of social practices into implementable algorithms. The desire for a vehicle with logic less error-prone than humans encourages research on human behaviors within the transportation realm. These behaviors are codified into existing and new traffic laws and regulations. Additionally, demand for ease has furthered development in fully-AVs to satisfy areas such as reduction in work force, mobilization of elderly and disabled people, and lessened congestion of parking lots. These demands drive the progress towards a Level 5 or fully-AV by ensuring no human manipulation is needed. Implementation of this decision-making involves consideration of a seemingly infinite number of situations that may arise on the road, thus driving the need for a model based on human-behaviors. Additionally, there exists a large number of factors that affect decision-making, thus providing motivation for a discussion and agreement of society's values. The excessive number of considerations in fully-automated decision-making leads to a deliberation of seemingly answer-less and impossible-to-resolve ethical dilemmas. However, this deliberation highlights the complex network of social, political, and economic factors limiting proposed solutions for ethical decision-making in AVs that in turn create a technologically deterministic future for AVs.

The desire for safety is one of the main propellants in the development of AVs. To best achieve safety, several algorithms propose a humanlike driving system to give AVs the ability to make decisions like a human (Li & Ota & Dong, 2018). AVs will share the road with cyclists, pedestrians, and human drivers. However, human drivers do not always drive according to the laws and act according to implicit social rules and subtle signals from other road users (Müller & Risto & Emmenegger, 2016). These implicit social rules facilitate safe and efficient behavior on the road. To effectively address safety, the social behavior of AVs must integrate into this complex environment by behaving and communicating in a socially acceptable manner. This requires a formation of social rules between drivers and AVs. Particularly, if AVs lack the social skills of a human, they will have to balance socially accepted behavior and the risks of anthropomorphization - the attribution of human traits, emotions, or intentions to non-human entities (Müller & Risto & Emmenegger, 2016).

Until now, AV prototypes have struggled to interpret and adapt to human behavior. In order to guarantee safety, current AV prototypes drive as carefully and leniently as possible (Richtel & Dougherty, 2015). David Friedman, the director of cars and product policy and analysis for Consumers Union, states “Human-centered automation is going to be the key to success here and that means understanding more about how people are going to interact with this technology” (Mills, 2018). As AVs progress toward human decision-making logic, AVs will have to be perceived as actors rather than just tools in a sociotechnical system.

In consideration of the sociotechnical system in which an AV exists, several factors come into play. Patrick Lin, associate professor of philosophy at California Polytechnic State University, outlines a scenario if which swerving left would kill an eight-year-old girl and swerving right would kill an eighty-year-old grandmother. If no action is taken, both are killed. Some argue striking the grandmother is the lesser of two evils. However, according to the Institute of Electrical and Electronics Engineers (IEEE), all individuals should be treated equally and are not to be discriminated against based on "race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression" (IEEE Code of Ethics, 2020). Some solutions proposed include refusing to make a swerve decision or arbitrarily choosing a path, without prejudice to either person. Both of these proposals introduce difficult dilemmas that are not easily solvable, thus pushing the need for ethics in the development of autonomous cars.

Lin states there is a daunting number of factors that must be considered when making decisions in autonomous mode: intensity of braking, direction to swerve, condition of the vehicle, type and size of animal, kind of vehicle AV is crashing into, etc. Through the lens of Actor-Network theory which investigates humans and their interactions with inanimate objects, these factors are all actors within the complex sociotechnical environment AVs reside in. Regardless of the ability to sense these factors, programmers need to assign costs/weights to various actions/objects as best as they can. Developers require definition of cost-functions – "algorithms that assign and calculate the expected costs of various possible options, selecting the one with the lowest costs—that potentially determine who gets to live and who gets to die" (Lin, 2013). Implementing powerful algorithms that discern life or death means having value-judgement decisions which need to be wholly agreed upon by society, or essentially an agreement on a choice of consequentialism. Evidently, a discussion of values and expectations between industry and public is required to safely address these issues.

The development of AVs has progressed so rapidly that current traffic laws cannot keep up. The National Highway Transportation Safety Administration has issued recommendations to aid states as they make regulatory decision regarding vehicles with new technological capacities (Schreurs & Steuwer, 2015). The Wicked Problem framework outlines an approach for inherently unsolvable challenges with complex systems that prevent stakeholders from defining strict problem boundaries. These stakeholders include engineers, AV companies, and the government in addition to the aforementioned factors considered in decision-making. As such, these actors have a crucial role in the translation of social practices into implementable algorithms in AVs that fulfills society's demands for safety and ease. The Wicked Problem framework weighs the limitations of the proposed solutions in the context of complex factor asymmetries in AV decision-making. As a result, the Wicked Problem Framework helps meter the expansive implications of the research question by acknowledging factors that can impede the realization of theoretical projections. Rodney Brooks, a roboticist and artificial-intelligence researcher at the MIT Computer Science and Artificial Intelligence Laboratory, argued against the short-term viability of self-driving cars based on the sheer number of "edge cases," i.e., unusual circumstances, they'd have to handle. He also argued AVs will have "to be as intelligent as a human, in order to handle all the edge cases appropriately" (Brooks, 2017). However, due to the expansiveness and complexity of the network AVs exist in, it is difficult to assess every possible edge case.

> In the case of more revolutionary technological developments, which result in more disruptive changes to the status quo, politicians may be forced to make rapid and major

> regulatory decisions with little preparatory or learning time and with few existing experiences to draw upon (Brooks, 2017).

The rapid development of AVs causes hasty decisions to be made by political organizations. This setting of precedence can lead to dangerous case of technological momentum, the theory about the relationship between technology and society over time. The idea of technological momentum is that relationship between technology and society is reciprocal and time-dependent so that one does not determine the changes in the other but both influence each other. In the case of AVs, rapid development of AVs force unrepresentative regulatory decisions to be made. These policies create a technologically deterministic future for AVs. In particular, the commercialization of AVs may drive a wedge between social classes if not made affordable. Widespread adoption of autonomous vehicles could also displace millions of Americans employed as drivers. Additionally, AVs could negatively impact public transportation funding, and perpetuate the current transportation system's injustices (Self-Driving Cars Explained, 2017). Depending on implementation of AVs, if gas-powered, could drastically effect environment by increasing transportation-related climate emissions. If electric, could benefit environment by reducing emissions. The environmental demands of society thus create a technologically deterministic future of AVs, posing serious environmental issues in the future. Through the lens of technological determinism, these social, political, economic, and environmental implications are a result of the limitations in AVs highlighted by the Wicked Problem framework.

Under Actor Network Theory, the interactions and relations between the actors are stable, determining the place and functions of the actors within the network. AVs are considered nonsentient actors, thus making translation of social practices on the road extremely difficult. A limitation of Actor Network Theory is that all actors, human and non-human, are weighted equally which poses complications in ethics decision-making in AVs. In a sociotechnical system that introduces several actors such as humans, animals, buildings, road signs, and traffic lights, Actor Network Theory provides a limited perspective due to its simplicity. Another limitation is the sheer novelty of AVs. This novel form of transportation brings about large amounts of uncertainty such as the ethical guidelines to follow, the government policies to redact or amend, and the expectations of safety with AVs. With such a rapidly advancing technology as the AV, future research would include the most-updated information on what factors are considered in the decision-making logic in AVs. Continued research in this field is essential to being preemptive as a society, and would provide better insights on how AVs have influence society. Further research could include an analysis of social factors in AVs with a focus across different cultures or physical environments. As AVs begin to become a part of society, it will remain important to maintain a close analysis of the social, political, economic, and environmental implications that come with it.

Conclusion

Social demands of safety and ease have affected the development and implementation of AVs through modelling the technology around human decision-making. Social Construction of Technology (SCOT) framework analyzes the definition and translation of social practices concerning safety and ease into implementable algorithms in the AVs. However, due to the extensive roles and relationships in the sociotechnical environment of AVs, several limitations exist that impede the successful realization of societal demands. Through the lens of the Wicked Problem framework, it is possible to then assess the complex network of social, economic, and political factors limiting proposed solutions for ethical decision-making in AVs. The examination of these limited proposals reveals a technologically deterministic future for AVs that include social, political, economic, and environmental implications.

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