Solution development to the challenges 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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Abstract

The ideas provided by Matthew Denecke, Timothy Tyree, Sabrina Sternberg and Prof Gorman are crucial to construct the prospectus and to turn the prospectus into the final STS research paper. This paper explores the impacts that autonomous vehicles will bring to the country. This paper also explores the engineering and social challenges of introducing autonomous vehicles and ways of facing those challenges. Frameworks of mental model, normalized deviance and trading zone were utilized in this paper for analysis.

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Introduction

A self-driving car (sometimes called an autonomous car or driverless car) is a kind of vehicle that uses a combination of sensors, cameras, radar and artificial intelligence (AI) to travel between destinations without a human operator. To qualify as fully autonomous, a vehicle must be able to navigate without human intervention to a predetermined destination over roads that have not been adapted for its use. (Rouse, 2018) The paper explains why autonomous vehicles are needed and what impact they might bring to society. Even though autonomous vehicles seem to have a bright future ahead of them, many factors are discouraging them from entering into the market. This paper explores factors that stop autonomous vehicles from being deployed, causes of those barriers, and how industries can facilitate the deployment of autonomous vehicles. The challenges are categorized into facets of engineering and social. For each challenge, either in the category of engineering or social, this paper explores the solution and what people need to be aware of by applying frameworks of normalized deviance, trading zone and mental model.

Current situation of Autonomous vehicles

The levels of Driving autonomation needs to be understood well to understand the current state of autonomous vehicles. In fact, the terms "driverless cars" and "autonomous vehicles" are inaccurate as well, at least according to SAE J 3016-2018: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. (Kelechava, 2018)
Six levels of driving automation were introduced by SAE (Society of Automotive Engineers).
Level 0 – No driving autonomation
Level 1 – Driver assistance
Level 2 – Partial Driving assistance
Level 3 – Conditional Driving autonomation
Level 4 – High level autonomation
Level 5 – Full driving autonomation

The current level of automation is level 3 – conditional driving autonomation, which only has limited autonomous features, such as Advanced driver assistance systems, Lane-keep-assist. Traffic-jam-assist. (Kelechava, 2018) Level 3 vehicles need drivers' assistance due to their limited automation system, while the term "Automotive vehicle" in the paper refers to level 5 vehicles, which refers to the vehicle capable of traveling without a human operator. The following challenges are cited from the article "Top 3 challenges to produce level 5 autonomous vehicle". (Sovani, 2018)

Why autonomous vehicles are needed and impacts

Before examining the challenges of autonomous vehicles, it is necessary to illustrate why autonomous vehicles are needed in this world. Also, what kind of impact it will bring to this world? Three sources listed below provide all anticipated impacts that will be addressed in this paper. First one is a paper "Recent perspectives on the impact of autonomous vehicles"(Hörl, S; Ciari, F; Axhausen, Kay W., September). The Second one is an article written in June 2015: Ten ways autonomous driving could redefine the automotive world.(Bertoncello, 2015) The third one is an article: The Social Implications of Driverless Cars. (Darlington, K, 2018)

Introducing autonomous vehicles increases the mobility of traffic. In the news written by Matthew Huston (2018), he gave insights into the significant impact on reducing autonomous vehicles brought by self-driving cars. The primary cause of traffic jam is the tapping on brakes. Drivers tap the brake one after the other and give a shock wave of stop-and-go reactions that can travel backward for kilometers.(Huston, 2018) The researchers used a video game-style interface to control simulated cars on made-up roadways and tested four algorithms that used reinforcement learning—a type of artificial intelligence (AI) that learns skills through trial and error. It turns out that in the first scenario of simulation, a central intersection, replacing just one of the 14 "human"-driven cars with a self-driving car doubled the average car speed. In the second case, one or several lanes of traffic merged, replacing 10% of the regular cars with self-driving cars also increased overall traffic flow, in some cases doubling the average car speed. The self-driving cars sped up traffic in part by keeping a buffer between themselves and the cars in front of them, forcing them to break less often. .(Huston, 2018)

The second impact is on city planning. The paper "Recent perspectives on the impact of autonomous vehicles" suggests that in highly congested cities, parking space is likely to vanish, and the extra space can be used for additional driving lanes to mitigate the traffic. Once the autonomous vehicle drops off the passengers, it is going to keep driving on the road until someone asks it to pick up the passengers. The vehicle will be able to find a place with the least amount of traffic and to drive around that area to dissipate the traffic pressure. However, in the other paper written by Todd Litman (2020), the author points out that most travelers will probably want their vehicles to be available within a few minutes, which will require parking within a mile or two of their destination. This may allow more off-site and shared parking, reducing but not eliminating urban parking demands. In both cases, the sideway parking will be eliminated, and the vehicles will drive around, or park in a central garage depends on the traffic condition of that area.

Autonomous vehicles also reduce emissions. Sam Abuelsamid, a principal analyst for Navigant Research and co-author of numerous studies on autonomous vehicles, told listeners that the higher-voltage electrical architectures of hybrids and battery-electric vehicles are key to the implementation of autonomy. Conventional 12V architectures used on most of today's gasoline-burning vehicles will not be sufficient to support the computing and sensing requirements of autonomous cars, he said.(Murray, 2019) A paper "Working Paper Sustainability and Innovation" suggested that emissions from electric vehicles, which are autonomous vehicles in this case, have emissions up to 43% lower than diesel vehicles. (Wietschel,M, Kühnbach,M, Rüdiger,D, 2019) As the trend of emerging electric vehicles, recharging stations will replace the current gas stations because of the electrical feature of autonomous vehicles. Meanwhile, the speed of global warming is highly likely to be mitigated. The light emission will be reduced as well, since the vehicle is more dependent on sensors, as mentioned in the engineering challenges below, but not on visualization. Electric vehicles are quieter than gas-powered vehicles, which leads to the reduction in noise emission.(Matousek, N.A) However, the quietness of autonomous vehicles may cause danger to pedestrians, who may be unaware of the approaching vehicles. Although the vehicle will need to make some kind of sound to alert the pedestrians of the oncoming vehicle, the operation noises are still significantly reduced by the electrical feature of the vehicle.

The importance of autonomous vehicles has also been revealed in the transportation service since autonomous vehicle requires no drivers. Drivers of delivery vehicles will lose jobs, and the cost of the delivery industry will reduce, which will also reduce the employment rate of the local country. Not only the drivers in package delivery service will lose jobs, but also uber drivers will be unemployed as well. The local economy will be primarily impacted by autonomous vehicles in many aspects.

Last but not least, the precision of the machine makes the emergence of autonomous vehicle unavoidable. 6 billion car accidents happen each year. 40 percent of those accidents happen due to alcohol, 30 percent of those accidents happen due to speeding and 33 percent of accidents are due to reckless driving. 23 times more likely to crash while texting and driving, and 40 percent of American teens say that they have been in a car when the driver used a cell phone in a way that put people in danger. Those accidents happen primarily due to human factors: humans are inclined to make mistakes. In a presentation to a seminar on the future of travel, Dr Dia said human error was to blame for up to 90 percent of the 1.2 million deaths that occur each year from car accidents around the world. (Swinburne ,2017) On the contrary, "By midcentury, the penetration of AVs (autonomous vehicles) and other ADAs (advanced driver-assistance system) could ultimately cause vehicle crashes in the US to fall from second to ninth place in terms of their lethality ranking among accident types," the report, from US consulting firm, McKinsey & Company, concludes. (Crew, 2015) The number of reduction in accidents results from autonomous vehicle still remain unknown. But autonomous vehicles are certainly capable of saving people's lives, either passengers' lives or pedestrians' lives.

The emergence of autonomous vehicles is highly likely to be beneficial for people. However, both engineering challenges and social challenges are barriers to autonomous vehicles. The engineering challenges are discussed in the next section of this paper,

Engineering challenges

All engineering challenges can be described with the term 'reverse salient', which refers to a component of a technological system that, due to its insufficient development, prevents the system in its entirety from achieving its development goals.(Hughes, T. P. 1983)The first reverse salient is autonomous vehicles need better sensors. Sensors of autonomous vehicles are categorized with representatives of the camera, Radar and Laser Focus. (Burke ,2019) A camera is capable of distinguishing details, like shapes of the surrounding environment, but the range of visibility of the camera is limited. Radar is an active detector that provides data on the speed and location of surrounding objects, detecting emitted radio waves. However, the data collection can be affected by other systems, like moving vehicles, since it is an active detector, which keeps the transmission of data instantly. Laser Focus gives the shapes and depth to the surrounding cars with laser light. However, Laser focus's detecting strong detecting power takes massive amounts of processing power, and the detecting range is limited. There's no best sensor for now, but the most optimal case is to have these three sensors working together, which is still insufficient for level 3 vehicles to be fully autonomous.

The second reverse salient is that autonomous vehicles need perceptive artificial intelligence (AI). Once sensors give the data of objects on the road, the data needs to be processed. It is not hard for AI to recognize a stop sign on the road. However, it is hard for them to distinguish running people on the road at present. Moreover, those data need to be processed instantly to ensure the vehicle make proper adjustments on time. Since the algorithm is not developed yet, the validity of AI can not be proved.

Last but not least, autonomous vehicles need to be capable of making safe decisions in the future. There are thousands of parameters that need to be considered, including but not limited to traffic conditions, pedestrian conditions and weather conditions. Many conditions that unlikely to happen should also be included. The only way to be comprehensive enough is to use virtual world simulation. As a result, an AI needs to be developed to include responses of the vehicle to all these scenarios.

The solution to these engineering challenges of autonomous vehicles is to have institutes or corporations putting efforts into those technology developments, such as developing better sensors and better AI. However, It is highly likely for engineers to make mistakes at the developmental phase of new technology. There's one kind of mistake can be described with the term "normalized deviance", which will also be used in the section of social challenges. The normalization of deviance is defined as: "The gradual process through which unacceptable practice or standards become acceptable. As the deviant behavior is repeated without catastrophic results, it becomes the social norm for the organization." (Boe, 2013) The main reason for the occurrence of normalized deviance is the limitation of the people to realize deviance. The case of Challenger failure happens on 26 Jan 1986 is a good representation of occurrence of normalized deviance while developing new technology. (Dalal, N.A)The cause of the disaster was traced to an O-ring, a circular gasket that sealed the right rocket booster. This had failed due to the low temperature (31°F / -0.5°C) at launch time – a risk that several engineers noted, but that NASA management dismissed. NASA's own pre-launch estimates were that there was a 1 in 100,000 chance of shuttle failure for any given launch – and poor statistical reasoning was a key reason the launch went through. The launching day temperature of Challenger is 36F, which is much lower than any previous launched rockets, in Florida. Nasa normalized the temperature deviance advocated by several engineers, which is the ultimate cause of this tragedy. Similar normalization can happen in the autonomous vehicle industry, and it may cause safety issues as well. The industry can not afford the consequence of risking people's lives in a false autonomous vehicle system. For example, when engineers are making engineering developments in the autonomous vehicle industry, they need to consider every condition where their products will be deployed. Not only the algorithm mentioned above need to consider every traffic condition, but also the sensors need to consider every whether condition, like foggy days and raining days. Engineers can not bring their personal assumptions into the development of technology. Their engineering knowledge is valuable to develop the autonomous vehicle, and engineers should discuss with each other to ensure the resulting vehicle performs optimally. However, It is still possible that the engineering group of autonomous vehicles is not diverse enough to include all conditions the vehicle need to encounter in the vehicle system and autonomous vehicles may not be capable of handling all road conditions as a result. Virtual reality simulation (VR) can be crucial to prevent the autonomous vehicle engineers from bringing their personal assumption into the vehicle development. With the use of VR, all kinds of driving conditions can be taken into consideration to help the engineers to include as many cases of road conditions as possible. Incidents are less likely to occur with the help of VR, which is capable of anticipating various road conditions.

Social challenges

The first social challenge is the uncertainty of the ethical standard, which is illustrated well by taking the example of trolley problem. Imagining there is a runaway trolley barreling down the railway tracks. Ahead, on the tracks, there are five people tied up and unable to move. The trolley is headed straight for them. You are standing some distance off in the train yard, next to a lever. If you pull this lever, the trolley will switch to a different set of tracks. However, you notice that there is one person on the sidetrack. You have two options:

1. Do nothing and allow the trolley to kill the five people on the main track.

2. Pull the lever, diverting the trolley onto the side track where it will kill one person. Which is the more ethical option? Or, more simply: What is the right thing to do? (Foot, 1967) A similar dilemma could occur in the case of autonomous vehicles. Assuming someone suddenly appears in front of a high-speed autonomous vehicle, and the only thing the vehicle can do is to turn and hit the light pole or to hit the walker since everything happens so instantly. In the first case, the passenger is hurt. A question comes to mind: does the passenger has the right to decide on their lives? Whatever decision the engineers program the vehicle to make, it is not the will of the passenger. Do passengers make the "right" decision if they have the right to make the vehicle behave to their will? What is the middle ground decision, the most ethical one, in this case, and how should that decision be made?

Normalized deviance can potentially come to play a role in this case. The deviation of the ethical standard may be normalized by the engineers since engineers are the people designing and manufacturing the vehicles. The morality of engineers working in autonomous industries is undoubtedly correct, given none of them will design a vehicle that is made to kill but to serve the comunnity. However, those engineers are not capable of recognizing their mistakes. Engineers can not be the only group of people making the call under this circumstance. To prevent the normalized deviance in this case, trading zone including social experts can be helpful. Trading Zone refers to the situation where different parties with different backgrounds come together to exchange their thoughts. Introducing the trading zone helps people to discern deviant. (Galison 1997) Social experts and ethicists provide the most insightful suggestions on making ethical decisions. Social experts help the engineers to find the optimal resolution for the walker and the most acceptable result for the driver. Trading zone of engineer, social experts and ethicists, who understand the psychology of the general public, prevent engineers from making deviated and unethical design of the vehicle. Engineers, social experts and ethicists can come together to discuss what's the most ethical eay of handling each situation while the VR was stimulating various simulations that autonomous vehicle will encounter. Combing VR simulation and the trade zone of those three groups of people facilitates the process of making ethical decision for autonomous vehilces.

Besides the ethical concern of autonomous vehicles, the framework of the mental model can be utilized to analyze other social challenges. A mental model is an explanation of someone's thought process about how something works in the real world. It is a representation of the surrounding world, the relationships between its various parts and a person's intuitive perception about his or her own acts and their consequences. Mental models can help shape behaviour and set an approach to solving problems (similar to a personal algorithm) and doing tasks.("Mental model", N.A) According to the paper: "A case study on drivers' mental model of partial driving automation," three cases of studies were conducted on drivers' mental model. (Strand, N; Stave, C; Ihlstrom, J. , 2018) Even though the study focused on Partial Driving Automation (PA), the level 3 driving automation, the results are sufficient to help understanding the mental model of the level 5 driving automation. The first conclusion is that user may have the wrong assumption of autonomous vehicle through referring to their prior knowledge. The user also doesn't have enough understanding of Partial driving automation in the cases. From the response of the participant of the case studies, it is observed that engineers and users don't share the same mental models, which leads to users' suspecitablty of the validity of autonomous vehicles. In an article written by Jakob Nielson (2010), he pointed out individual users each have their own mental model. A mental model is internal to each user's brain, and different users might construct different mental models of the same user interface. Normalized deviance plays a crucial role in this case. One of usability's big dilemmas is the common gap between designers' and users' mental models. Because designers, also known as the engineers, know too much, they form wonderful mental models of their own creations, leading them to believe that each feature is easy to understand. Engineers may wrongly assume that some behaviors of autonomous vehicles, which may vary at different driving situations, are easy for passengers to understand, but the passenger may assume the vehicle drive in their habits with their personal understanding of artificial intelligence. This may bring unpleasant experience of using autonomous vehicles to passengers. The paper written by Strand (2018) proposes having an instructor to navigate users at the very first stage of driving the partial driving automation. The same strategy can be used in the case of autonomous vehicles. Trading zone of an instructor and users helps users adapt well to autonomous vehicles. Another way for engineers to solve this issue using the VR simulation to understand the mental model of drivers on driving. Observing the behaviors of vehicles on road in VR helps engineers to understand current drivers' driving pattern.

The differences in mental models between engineers and users also bring another issue: How will traditional vehicle drivers react to autonomous vehicles on the road? It is highly likely that traditional vehicle drivers don't know the driving pattern of autonomous vehicles, and some behaviors of autonomous vehicles may confuse the traditional vehicle drivers.In an article written by Kevin Desouza named" Can Self-Driving Cars Share the Road With Old-School Vehicles?", (2016) the author points out that traditional vehicles will likely need sensors to communicate information about their speed, braking, etc., to self-driving cars. Self-driving cars will also need sensors to communicate information about their speed and braking to other communities, like pedestrians and traditional vehicles. Using VR simulation can also help to tackle this dilemma by stimulating traditional vehicles' reactions to autonomous vehicles on the road. The transitional period from having traditional vehices on the road to fully autonomous may make traditional vehicle drivers uncomfortable for a while. Still, they will get more used to other self-driving vehicles as time goes.

Moreover, workers in a business are highly likely to normalize the deviance caused by the business culture of their company or country. In the case of Chernobyl, one reason for the nuclear explosion is using cheap control rods. Engineers were too afraid to bring up this fact to the public, considering it's inappropriate to accuse the government of making the risky design. Besides that, the leading engineer of the Chernobyl reactor commanded his fellow engineers to raise the temperature of the reactor through increasing the power and extracting the controlling rod. This command is not following the safety protocol and is made out of the leading engineers' irresponsibility and overconfidence. Engineers with robust academic background predilect to regard their autonomous vehicle designs as unimpeachable and not accepting others' critiques. This kind of attitude unmistakably endangers the safety of autonomous vehicles. Inviting the current autonomous vehicle company comes together to discuss the designs and operations of the vehicles that can prevent the deviances in this case.

The government regulation of autonomous vehicles will also be a new story departing from traditional vehicles. The autonomous vehicle industry should also work closely with the government to ensure the vehicle is approved to run on the road with no issues. Every autonomous vehicle needs government documentation, just as what DMV is doing now. DMV representative is capable of informing the engineers whether the car is suitable for the current traffic. To optimized the autonomous vehicle, engineers need thoughts on which party should be responsible for an accident: the autonomous vehicle company or the non-autonomous vehicle driver. DMV representative has thorough insights into the traffic laws and knows which party takes response under which circumstances. Suggestions from DMV representatives reduce the loss of autonomous vehicle enterprise and perfect the vehicles.

Even though the opposition of autonomous vehicles is due to safety concerns, which results from the immaturity of the technology, the cause of people's opposition to autonomous vehilces is partially due to the "fear" of this new technology. Autonomous vehicles fall between the cultural categories of drivers and vehicles. The combination of these two categories makes people fear this technology for people to assume drivers can not be perfectly combined with vehicles, which is currently true. Another reason for this fear is that people can not take the consequence of having a flawed autonomous vehicle driving on the road. No one wants to see an vehicle with an incorrect algorithm either hit people or not functioning well and causes traffic accidents on road.

Conclusions

Autonomous vehicles are needed in this world and will bring tremendous impacts to society. The emergence of autonomous vehicles is unavoidable when people see the relative precision of the machine compared with the human being. However, many challenges still remain ahead of this future. Those challenges, either in engineering context or social context, may result in more problems, such as normalized deviance. Engineers of the autonomous vehicle industry should be alert that they may unintentionally make some mistakes, which can only be noticed by people outside that cultural norm, to confront those challenges. But usually, it is difficult for people to know they are wrong. Social experts, engineers with different cultures, and DMV representatives should come to form a trading zone, which is a good antidote to normalized deviance, to help the deployment of autonomous vehicles and prevent engineers from making mistakes. Besides utilizing trading zone, an objective technology is also helpful to discern the problem, such as VR. Autonomous vehicle engineers should always consequently seek help from appropriate party, like technology or people outside their social norm, when designing and manufacturing the vehicle.

Future research suggestions

For future research on the challenges faced by autonomous vehicles, researchers can acquire more knowledge related to algorithms and hardware of autonomous vehicles and describe what the engineering challenges in more detail are. For social challenges, researchers can look into more about the fear of people, the framework of "monster theory" proposed by Smits (2006) is really helpful in analyzing people's fear. Smits' monster theory is a constructive framework for understanding why perception towards autonomous vehicles is polarized in cultural context because this theory explains the fascination/aversion towards new technology, leaving aside 'naturalist' and 'nature-skeptic' explanations of technology ethics. The monster theory offers a point of departure for a new, pragmatic approach to controversies about new technology, the approach being named a pragmatist monster-ethics. It tells people have to reflect on and shift cultural categories as well as to adapt technologies in order to domesticate their technological' monsters.' (Smits, 2006) This paper didn't include this framework since fear is just one kind of social challenges, and this framework can only explain this kind of social challenge. This paper wants to be comprehensive when analyzing all of the social challenges.

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