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Machine Organization and Assembly Languages

Self-Driving Cars

Introduction:

Self-driving cars have been the talk of the future for many years now, however, the future may be closer than one may think. The idea of the self-driving car has been around for a very long time. Perhaps one of the earliest mentions of a self-driving car was by General Motors. In 1939, GM hosted a Futurama exhibit at the World's Fair in New York. In this exhibit, there were great visions of a future--buildings made primarily of glass or chrome, and cars running around by themselves, being dominated via radio-control. (Baker, D., Villa, L., 2017.) This was one of the first instances of self-driving cars, and since then, the image of a car that could control itself has been an idea that has stuck into the minds of many people around the world. Another instance of self-driving cars was in 1963, a Japanese cartoon displayed a self-driving car, and also the possible implications that we may deal with as a society when we have these autonomous vehicles on the road. In the cartoon, the protagonist named "Astro Boy" is involved in a self-driving car accident, which has possibly foreshadowed the legal and ethical implications of self-driving cars we may face once they are prevalent on the roadways (Marcus, G., 2018). Although back in 1939 and 1963, the idea of an autonomous vehicle may seem like something far out of reach, in today's society, we are much closer than we think. Many cars are already implementing technology that makes driving safer, and allows the driver to feel more relaxed while driving. The types of technology incorporated into these vehicles are collectively known as "Accident Avoidance Systems". This includes a collection of sensors and computers which takes in input from its surroundings in order to provide the driver of a vehicle with rear-end crash warning and control, head-on crash warning and control, passing warning, backing crash warning, lateral collision avoidance, intersection crash warning, and also to avoid collisions which may be caused by drivers who are impaired (Breed, D, DuVall W, Johnson W, 2010). Although self-driving cars are still in the relatively early stages of development, as technology is rapidly advancing, the technology in vehicles will advance with it, leading to the prevalence of more autonomous vehicles being found our roadways, which may also lead to dilemmas in terms of the transition stage from human-driven vehicles to autonomous vehicles, and also ethical and legal concerns. Although this technology is supposed to make driving safer, it may also prove to be dangerous as this new form of driving becomes the new normal.

History:

Self-driving cars were introduced in 1939 at General Motor's exhibit at the World's Fair in New York. This exhibit was appropriately named "Futurama", because it depicted images of the future. Due to the increase of cars on the roads since the beginning of the 1900s, people have been constantly looking towards ways that technology can enhance our lives in the future. The exhibit, "Futurama" was actually more of a "ride" for people to go on at the World's Fair rather than something people just walked through. They would sit in chairs that were moved along a conveyor belt, and within the chairs, there were speakers which would tell them all about the future (Turley, L., 2013). The main vision of Futurama was of "skyways", which were envisioned to be very fast roads (which today, is our highway system), and of an improved automobile that could operate under "automatic radio control". This was all envisioned many years before the creation of an interstate highway system, and before the idea of self-driving cars had ever truly entered the minds of people. Futurama had approximately 30,000 people visit the exhibit for each day the World's Fair was open, which engrained the dream of self-driving cars and a future of enhanced technology into their brains (Baker, D., Villa, L., 2017).

From 1939, and onwards, designers had their eye towards self-driving cars, all thanks to Norman Bel Geddess, the designer of Futurama. In 1957, the Radio Corporation of America (RCA) decided to experiment with self-driving cars itself, to see if they could invent the future. In 1957, the RCA envisioned a "Highway of the Future". Rather than altering the car, they believed that they could alter the roadways to control the car. To do this, they created a 400 foot long test track on a public highway in Lincoln, Nebraska. They envisioned that as you arrived at this strip of highway, there would be a button in your car marked "Electronic Drive" that you would hit, that would then automatically adjust the car to the new roadway. This would then allow you to completely relax, as the car proceeds to be driven without need for human intervention. A few years later, another test track was created in Princeton, New Jersey, where a slightly different vision was created. Instead, the vehicles were being driven by themselves, but they had sensors on the front of them that detected a cable that was inside of the road. This cable told the vehicle when it should switch lanes or apply the brakes, and there was a receiver in the car that would announce information about upcoming exits (Ackerman, E. 2016). For the 1950s, it seems that the quest towards an autonomous vehicle was almost completed, since they were in a vehicle that was driving itself and able to detect its surroundings. However, as they tested out more environments, it turned out that there were scenarios where the human had to take over the vehicle because the car did not sense that the vehicle in front of it did not stop. For instance, in the case of coming around a blind curve, the autonomous vehicle only had a front sensor, and therefore did not sense the car in front of it. It seems that with this in mind, it is going to take a lot more work, and safety considerations when it comes to having an autonomous vehicle. The point of an autonomous vehicle is reliability and consistency 100% of the time--we do not want the human to have to take over, and we want to get to the point where a car may not even have to have a steering wheel within it. So, from this standpoint, we are still a long way away from a self-driving car.

Technology continued to advance in cars, when in 1962, Professor Robert Fenton at Ohio State University was able to build the first automated vehicle. This was the first car to have a computer, and within it, steering, braking, and speed were all controlled by electronics. The electronics filled the majority of the car--they could be found in the passenger seat, trunk, and the back seat. This made huge strides in the road to automation for these vehicles (Anonymous, 2016). Then, in 1986, more strides were made in the advancement of self-driving car technology as the production of the autonomous vehicle ALVINN were being created at Carnegie Mellon University. The project was completed in 1989. ALVINN (which stands for “Autonomous Land Vehicle In a Neural Network”) is a vehicle that has the capabilities to drive itself due to its abilities to capture images from a camera and from a series of lasers that produce I/O for the computers within the vehicle in order to communicate with the vehicle as to which direction is should travel in order to follow roadways. The two forms of sensory input that the computers receive are video and range information. ALVINN was used during a variety of simulations because training on actual roadways was extremely difficult. Instead, the experimenters used simulated road generators on ALVINN in order to create scenarios for the car to drive around on. The roads were randomly generated so the car would not be able to learn the roads. After 1200 simulations, the car was able to correctly travel through roads approximately 90% of the time on new road conditions.   (Pomerleau, 1989). Although 90% is not a perfect 100%, which is what is going to be needed if autonomous vehicles are going to be released on public roadways, 90% is a promising number, and seems that we will be able to close that gap within the coming years.

Working in parallel with Carnegie Mellon University, over in Munich, Germany, Professor Ernst Dickmann was also working on his own research relating to self-driving cars. He made large strides in 1986, when he was able to get a Mercedes 500 SEL to drive down the autobahn at a little less than 60 miles per hour, all on its own. This vehicle was truly seen as the first vehicle to drive autonomously, and Ernst Dickmann is seen as the inventor of the self-driving car, even though Norman Bel Geddes did originally come up with the idea. Great strides were made in self-driving cars on this day, yet there are still many steps that need to be taken in terms of self-driving cars in order to ensure that they can be safely implemented into our society and in our roadways (Delcker, J., 2018).

Current State and Limitations:

Self-driving cars have been highly anticipated for a long time. Ever since 1939, they have been something that is of a futuristic world, yet here we are, so close to that goal. Another reason that autonomous vehicles are highly anticipated is that once they are on the roads, they are supposed to make the road ways much safer. From data collected by the National Motor Vehicle Crash Causation Survey, it was estimated that in 94% of crashes, the cause of the crash can be attributed to driver-error (Singh, S.,2015). With that statistic in mind, if autonomous vehicles are on the road, this allows the possibility of eliminating 94% of accidents. This is because an autonomous vehicle is a vehicle that requires no human intervention, it is a vehicle that is fully capable of driving itself.

There are six different levels to autonomy that car manufacturers have been striving towards. Level zero is known as “No Automation”. This is many of the cars on the road today, or some of the “older” cars. These are cars where the driver of the vehicle will perform all of the operations themselves with no assistance. The next level of autonomy is level one, known as “Driver Assistance”. This level incorporates a little bit of assistance, however, the vehicle is still controlled by the driver. The main difference between level zero and level one is that in level one, the vehicle contains some driver assist features. These features may include steering or adaptive cruise control. The next level of autonomy is level two. This level is known as “Partial Automation”, where the vehicle has some automated functions such as steering and acceleration, however, the driver is still required to be fully engaged while in the vehicle and aware of their surroundings at all times. The third level of autonomy is known as “Conditional Automation”. In this level of automation, the driver is still required in the vehicle, but they do not need to constantly monitor the environment. However, the driver must be ready to take control at any moment, when the car gives notice. The fourth level of automation is known as “High Automation”. In this level of automation, the vehicle can perform all driving functions but not in all conditions, and the driver of the vehicle has the option to control the vehicle. Finally, the fifth and highest level of automation is known as “Full Automation”. In this level of automation, the vehicle can perform all driving functions under all conditions, and the driver can take control of the vehicle, however, in this state of automation, some vehicles may not even contain a steering wheel or brakes anymore. The vehicle may become so automated that the human may no longer have the option to control the vehicle (NHTSA, 2017).

Currently in the United States, we are still a few years away from the production of an autonomous car. Right now, the state of our cars are at a level two or lower. The level of autonomy of the cars on the road is not due to a technological constraint by any means--as referenced above in previous paragraphs, we were able to have autonomous vehicles way back in

1986, however, we do not have anything higher than a level two right now due to security concerns. To have autonomous vehicles on the road would be great, and the possibility of cutting down accidents by 94% would be absolutely amazing, but there are some limitations to autonomous vehicles. An autonomous car consists of multiple computers and a lot of software. This means that like any computer and any type of software or hardware based system, it is vulnerable to system malfunctions and hacking. The biggest concern for autonomous vehicles right now is that if a hacker were to obtain access to a self-driving car, they would be able to control every single function of the car. This could potentially be deadly to not only the person inside of the car, but to others. Terrorists could aim attacks this way, or attacks against specific individuals could be aimed in this way. It is vitally important that before self-driving cars become mainstream, that there is really good security on these vehicles and that hacking is an impossibility.

Many different car manufacturers are racing towards putting an autonomous vehicle out on the road--manufacturers such as Audi, Tesla, Mercedes, GM, and more are all working towards enhancing their security so they can make these vehicles a reality for many people around the world. However, it will probably not be many many more years until the level five autonomous vehicle is released onto public roadways. The reason for this is not only security concerns, but it is also due to the fact that the car needs to learn. Each autonomous vehicle will contain a GPS unit, an inertial navigation system, a range of sensors, radar, and video system. This combination of equipment will allow the car to act upon traffic data, the weather, make maps, see adjacent cars, and more. From all of this information, the car can then create an internal map to make an intelligent decision, and by using that map, it can find an optimal path to its destination that will avoid any obstacles. Although the car will be programmed to do this, the car will be thrown into some situation in which it will not necessarily “know” how to react, or may not have been programmed to react. These instances may be situations such as flying objects in the air like debris, pedestrians, heavy traffic, extreme weather, fast-approaching emergency vehicles, and more. In situations such as these ones, the car will have to learn from its environment, and may even get in an accident. All of the cars will have a cloud-computing system, so if the car had learned from a situation that was “out-of-the-norm” or unprogramed, or a situation that was in an unstructured environment, it can then send out all of that data to all of the other cars. But until it has reached that situation, the car will not have known how to react. The car will be learning as it drives, and as it is on the roadways. This is one of the reasons why autonomous vehicles may not be seen on our roadways for many years--they need a transition phase from human-driven cars to autonomous cars where these cars can learn from unstructured environments and then they can share that data across all other cars. During this time where they are introduced in our environment, and there is this transition between human-driven vehicles and autonomous vehicles, there may also be an increase in accidents. This seems counter-intuitive since self-driving cars are supposed to decrease the prevalence of accidents on the roadways. However, autonomous vehicles still have a lot to learn from their environments, and since they have not learned a lot yet, and have not been exposed to many of the unstructured conditions that include traffic, or extreme weather conditions, then they have not learned how to respond in those conditions and have not been able to pass on the data to the other vehicles yet.

Although it may seem disheartening to think that self-driving cars can possibly increase accidents, in the end, if they decrease total accidents by 94%, then it may possibly be worth it. There may also be some ways to slowly introduce autonomous vehicles into the environment so they do not “overwhelm” the roadways, and cause a lot of accidents, so they can slowly learn over the years, and then slowly become safer. It will take a long time to get level five cars on the roads and make them a mainstream thing, due to security reasons such as hacking and computer malfunctions, and also due to the learning phase of the car. However, once these cars are on the road, they are expected to make our roadways much safer.

Currently, if a person were to go out and purchase a level five autonomous vehicle, they can expect to pay around $250,000. This enormous cost is due to the large amount of equipment each vehicle is required to be equipped with. This includes five LIDAR devices, which is a sensor that stands for “Light Detection and Ranging”. It is a remote sensing method that measures distances. Then, there would also be radar, a couple of cameras, GPS, an inertial measurement unit, PC, a hard drive, a graphics card,and also other hardware. All this together would total about $138,010. This is just the equipment to get the car to move autonomously--then you need to actually have the build/body of the car itself, which all together totals about $250,000. With the cost of this vehicle, once they are on the road, even though they will be available to the public, it will also take a while to have all of the human-driven cars “filtered out” and only autonomous vehicles on the road. The price of this vehicle is out of reach for many people in the world, and only those with a very generous paycheck can find this as something within their grasp. So, unless the price point comes down on the autonomous car, it will also take a very long time to see this vehicle as something that is mainstream.

Experimentation with Activity Bot:

Starting off with the activity but we had the plan of coding it with waypoint finding. Waypoint finding would allow the bot to follow a specific route that would lead it from point a to point b. This is what most current self driving cars use, waypoints on gps would show the car a general direction of where to go. The activity bot, on the other hand, did not have this capability of waypoint finding. We ended on the ping sensors which pings the distance of obstacles in front of the boy. This is similar to how self driving cars currently address lane control and obstacle detection. They use sensors that tell them the distance of obstacles and lane markers to determine the direction of the vehicle. To start we learned the basic movement of the activity bot; how to move in a trait line, how to turn 90 degrees. We caught onto these things very quickly with our previous coding experience. Next we went on to tackle the ping systems, they were pretty simple as well. There was a convenient testing code provided to us which showed the distance of objects in cm. We coded the bot to move straight until it sensed an object within 8 cm and then it would turn 90 degrees. We threw that into a loop to do the same thing up to 5 times. We then went to test it and it did not work exactly as planned. We needed to adjust the angle of the sensors to accurately detect the object. The next time we tried it it worked without a hitch.

Ethics and Legalities:

We have come so far with self-driving cars, from 1939 where the first idea of the self-driving car creeped into the minds of those in New York at the World's Fair when Norman Bel Geddes first introduced them to his seemingly "outrageous" ideas at the time, then to 1986, where inventor and professor Ernst Dickmanns was able to have a Mercedes van drive autonomously on an Autobahn in Germany at a speed of just under sixty miles an hour. Society has advanced so much, and we truly are living in the future, but as we are living in the future, this raises some major questions in regards to ethics.

Having a car that drives itself is beyond something we as a society are used to by any means. As of right now, on our roadways, all vehicles are driven by a human being--all cars have a steering wheel, they have brakes, all vehicles have equipment within them that are meant for a human to have control over the car. However, if technology does advance to level five of autonomy, which is “Full Driving Automation”, that means that the car is making all of the decisions about where to go, when to stop, when to change lanes, when to exit, what speed to go, etc. If the car is in complete control of the vehicle, and the human is not, how does one address this in the time of a crash? Although self-driving cars are supposed to make the roadways much safer, and there are supposed to be fewer accidents with them on the road, there is still the probability of autonomous vehicles getting into accidents, especially when there is the transition phase between human-driven vehicles and autonomous vehicles. Another thing to point out is that an autonomous vehicle is going to consist of many different sensors, computers, and lasers, and this vehicle must be able to operate absolutely perfectly in any and all weather conditions. However, certain weather conditions such as extreme heat, rain, snow, or fog may result in some of these computers overheating, or maybe the cameras and sensors may not be able to detect everything perfectly. In instances like these, there will be a higher probability of an accident occurring on the road. Although self-driving cars are supposed to make roadways safer because it limits human error out of the equation, we will still have to deal with the hardware and software issues, which will be impossible to completely eliminate, and in instances like these, we will have to come up with a solution as to how to deal with crashes. Will the owner of the car be responsible for any damages incurred? Will the car manufacturer? Will people even have to carry car insurance if they are not the ones driving the cars?

The questions in the previous paragraph have been answered already by certain car manufacturers. Companies such as Volvo and Audi have already promised their customers that when their self-driving cars are prevalent on the roadways, they will be responsible for any crashes that may occur (Nyholm, S., 2018). With a promise as large as this one, clearly these two companies expect that their cars are going to be extremely safe and that the prevalence of accidents is going to be few and far between, otherwise they could be risking a lot by promising this to their consumers. With a promise like this one, this could also be an explanation as to why it is taking us so long to get self-driving cars onto our roadways. We have the technology for self-driivng cars, and we were able to get a vehicle to drive autonomously way back in 1986, which was 34 years ago. However, the ability to absolutely ensure that the vehicle will be 100% safe, 100% of the time is the hardest thing to guarantee.

There are some very large ethical dilemmas that occur when thinking about self-driving cars. As mentioned above, a vehicle that is at level five of autonomy does not even need to have any components inside of it required for human intervention--meaning it does not need to have a steering wheel, brakes, mirrors, etc. However, there is a very famous philosophical problem proposed in 1967 by Phillipa Foot called *The Trolley Problem.* The basic idea of the Trolley Problem is essentially there is a runaway trolley that is speeding down the tracks, and it is heading towards a switch in the tracks. At the switch, on one side, there are five people who are "tied-down" to the tracks, and on the other side, there is one person who is "tied-down" to the tracks. The driver of the trolley then has to make the moral decision of whether to kill the five people on the tracks (which is the way the driver is already headed), or to switch tracks and just kill the one person (Hacker-Wright, J., 2018).

The trolley problem seems to have a pretty easy answer--most people would say to switch tracks and to kill the one person, and save five. It makes sense since, afterall, you are minimizing the overall amount of pain and suffering in the world. However, in the case of self-driving cars, the trolley problem is not so easy. Programmers of self-driving cars cannot easily program something like the trolley problem into the cars, they cannot say to simply "kill less people", or tell the cars to take a Utilitarian point-of-view, because the trolley problem gets more and more complex. What if, as there is a runaway trolley on the tracks, the trolley is heading towards a group of five people on one side, and on the other side, there is again one person. However, that one person on the other side is a family member or loved one of yours? Then, the answer is not as clear for many people as they try to figure out what to do. Although in the first instance of the trolley problem, it made sense to kill one and save five in order to minimize pain. However, in this second instance, now the one that you are killing is your family member, someone who you hold near and dear to your heart, whereas if you were to kill the five other people, you do not even know them. Then, there is yet another instance of the trolley problem that needs to be taken into account: what if the five people on the track were track workers, who had already signed a waiver, and very well knew the risks of being on the track, whereas the one person on the track was a person who was unaware of the dangers of the track and had just been crossing it at a very unfortunate time?

All three instances of the trolley problem are extremely different situations, and unfortunately, they take contemplation and the ability to evaluate ethical and moral decisions in order to figure out what to do. No matter how complex a self-driving car can be, or how advanced the programming can get, it will never be able to truly respond in a situation like this. A programmer will not be able to take into account all of the possible situations and program into a computer moral reasoning and thought, that a human might have. If this is the case with self-driving cars, then what are we expected to do?

There are a few ideas as to what to do in a situation, such as an upcoming accident where injury or possibly death is likely to occur. One of these ideas is to transfer control to the driver of the vehicle. If this were the case, then the components for a human to drive the car would still need to remain in the car. It may seem like a good idea to transfer control to a human, since they can make certain ethical and moral decisions that a computer may not be able to, however, on further contemplation, this may also not be the best idea. Humans have relatively slow reaction time, and if the car is already autonomous, the human may not even be paying attention to their surroundings--for all we know, they could be sleeping in the car at the time, so to hand control over to a sleeping person or a person who is not paying attention would not be helpful at all. Therefore, it would most likely be a good idea to leave control with the car when it comes to a crash, and keep the human out of the decision making process. There are several advantages to allowing the car to "make decisions" during the time of an accident. A car is composed of many computers, which means that it is not a human--it is a machine. This means it will not get panicky or emotional or flustered, the car can calculate the best possible choices at a very fast rate as to how to get out of an accident or minimize the damage in an accident due to all of the input received by its sensors.

Since it has been determined to leave control to the car, there are still some considerations that need to be taken. One is whose safety should the car prioritize? For example, say there is an impaired driver that is heading towards you at high speed and you have multiple people in your autonomous vehicle. If the out-of-control car hits you, everybody in your car will die. The other option you have is to swerve out of your lane, onto the side of the road, where there is a single pedestrian. In a situation such as this one (which is very similar to the trolley problem above), should the autonomous car prioritize the life of the innocent pedestrian, or the life of the many passengers inside of the car? Although this has not been decided yet, when it comes to programming these cars, something to keep in mind is that these decisions will not be made by a single "master programmer". When a person is experiencing an accident, they are put in the position of making potentially life or death decisions--that is all on them, nobody else is there to help them with the moral and ethical decision making. However, when it comes to autonomous vehicles, the car itself is not making the moral and ethical decisions. It is going to be people who programmed the car, and these people are going to be a large group of people, a collection of ordinary citizens, programmers, philosophers, actuaries, ethicists, lawyers, engineers, and more who will collectively be able to say where the car should go and why. This way, the decision does not fall on the shoulders of one individual during the time of an accident, and the car can make the best choice possible to avoid the maximum amount of pain and suffering (Nyholm, S., Smids, J., 2016).

Future of Self-Driving Cars:

Going forward self driving cars are beginning to get to the point of hitting level 3. The Honda legend and the Audi AG are hitting the market in Japan in 2021 which will be the first set of level 3 cars on the market. The race to introduce automated vehicles to consumers is based on the promise that they will be safer than vehicles level 2 and below. That race is occupied by a large, and global collection of companies combining the traditional automotive and technology sectors, including new and established competitors. Companies have focused on their own innovations in the quest to be the most successful. But the industry, policymaking community, and public can benefit from better ways to understand and discuss the safety implications of autonomous vehicle technology. These vehicles are composed of features consistent with Level 4 in the Society for Automotive Engineers taxonomy system accepted by industry and government. As with other levels of automated driving systems, the development and testing of vehicles at Level 4 has involved a safety driver in the vehicle, available remotely, or in the vehicle. Safety drivers are meant to act as a backup to the computer-based systems that are known to have some flaws, especially during early development. At the top end of vehicle automation, developers identify Level 4 AVs with an operational design domain (ODD) where the vehicle can operate safely. The ODD may be interpreted by geography, time of day, weather, or other factors. Individual

Level 4 AVs will be designed to provide varying kinds of service in different circumstances, each with its own ODD restrictions. Automated shuttles, for example, keep to basic and fixed routes and many times travel at low speeds, tend to have comparatively simple ODDs. A minimum ODD for a low-speed city shuttle service will be vastly different from a minimum ODD for a long-distance highway trucking service. Because Level 4 AVs are not expected to operate at anyplace or anytime, their ODDs and associated limitations would have to be known to owners and users. The demonstration stage is a presentation period in a way, developers demonstrate that the vehicle performs safely. It can also be a period to observe data to make the case for the safety of the automated driving network. Demonstration could be devised as a developer-declared period with some level of lapse or candidness, set at a time of the developer's choosing and in combination with the stated ODD. Although measurements obtained during a demonstration can be differentiated from those collected in development, demonstration testing could be redone throughout the development life cycle. Having a demonstration period, especially one after which safety measures are made public, allows for more scope in the development period, during which new challenges and approaches can be introduced without fear of undermining the AV's safety level. There are three categories of measures in AV safety. The first classification comprises the principles, cycles, techniques, and plan prerequisites engaged with making the AV framework equipment, programming, and vehicle segments. Cycles and norms could be innovation explicit or, comprehensive, decide in favor of being excessively wide. These come from numerous sources, including FMVSS, ISO, and SAE, each with (gradually) developing applications to AVs. Safety driver preparation could be incorporated here. Since norms, measures, methodology, and configuration are developing continually and may be estimated at lower levels of vehicle arrangement and in light of the fact that proportions of adherence relate by implication to security through capacity. The center tumbles to the second and third categories, leading and, lacking measures, as will be talked about. All things considered, this class of measure shows the approaches through which it is conceivable to follow how security is inherent, starting with plan. Adherence to industry guidelines is both industry best practice and connected with diminishing possible obligation for organizations. The second category comprises leading measures. Leading measures show performance, activity, and preinvention; lagging measures are observations of safety outcomes or harm. These measures serve as proxies for lagging measures. Leading behaviors linked with a safety outcome are not themselves and outcome, but in changing the precursory behavior, the probability or severity of outcomes are affected. The link between a proxy and an outcome should not relate to circumstances under which either occurred. Additionally, the link relates to risk of collision, not of injury, which would include other deliberation such as fragility of the road user. Because the events included in leading measures happen with larger frequency than events in lagging measures, leading measures are often achievable with statistical confidence at lower cumulative mileage than lagging measures, giving them a "canary-in-the-coal-mine" quality. Category 3 focuses on lagging measures. Lagging measures involve actual harmful crashes and their outcomes. Severitybased outcomes include any contact between the vehicle and its outside environment (e.g., other road users, animals, or property), crashes resulting in property damage over a certain cost, crashes resulting in injury, in severe injury, in death, etc. As an additional layer, outcomes can be classified by crash types or configurations. Measures that integrate across crash severities include cost, disability-adjusted life years, and quality-adjusted life years. For the most part, two different business models have dominated discussion of AVs: the first is consumer ownership and the second includes fleets (different taxi or ride-share services and institutional-support models) owned and operated by a single entity. Consumer ownership involves individuals who could vary in their abilities to maintain a vehicle's sensing, seeing, and operating systems appropriately. For example, whereas a clean exterior might be a matter of aesthetics for a conventional vehicle, it could be essential for the proper performance (and thus, safety) of an AV that depends on cameras and other external sensors. Consumer owners, and the businesses they use that focus on automotive service and repair, might require education and support in sensor and camera maintenance. Fleet owners face similar challenges, but, with a large number of vehicles to support, they will probably choose to employ dedicated maintenance professionals. AVs produce massive amounts of data, questions have been raised about who beside the companies that produce or own AVs should have access to that data. There is a small amount of data-sharing among developers, nor is there much between developers and regulators or researchers. This is largely the result of the highly proprietary nature of AV development, variation in technologies that collect and process data, and the immense value of data as an asset and competitor differentiator, combined with the lack of retail availability. Contents of California's mandatory disengagement reports show a lack of uniform reporting by developers. When crashes occur, state and federal entities undertake investigations that hinge on the willingness of developers to share and interpret data and other information not otherwise available. Uncertainty exists involving individual AV actions and reactions and in terms of AVs' broader influence on the roadway ecosystem. An AV's view of the world grows steadily but will always be incomplete. Even within an AV's ODD, there are uncertainties that should be acknowledged by policymakers and communicated to the public. And even if AVs were completely certain within their ODDs, the roadways are not static. New surroundings and road users will populate the roadway ecosystem, presenting ongoing hurdles for AVs to get past.

Experts refer to the problems posed by “edge” and “corner” cases, situations that deviate from what is expected to be the norm but need to be addressed by the engineers in the interest of safe operation. The development process involves working through anticipated and unanticipated circumstances that are encountered; there is residual uncertainty from the unanticipated and not yet encountered—the unknown unknowns. Regulation and data-sharing can help in managing that residual uncertainty. Conformance to ISO standards is intended, in part, to reduce this very issue.

Conclusion:

Although self-driving cars have been the talk of the future since 1939, now we can surely say we are “living in the future”. We have the technology that is required in order to build a self-driving car, and many people around the world have successfully completed this task. The autonomous car contains technology such as lidar, radar, an inertial navigation unit, GPS, sensors, computers, and other forms of technology needed for the car to run autonomously. The largest thing holding us back right now is the security on these vehicles. Since autonomous cars are filled with computers and software, we need to be concerned about the possibility of hackers getting into the system and taking control of the vehicle and every aspect of it.

We have come a long way as a society in the development of the autonomous car, but we still have quite a few years before these types of vehicles become mainstream on our roads. They will need to be slowly integrated into society, whether that be in smaller communities with a slower speed limit, such as senior villages, or theme parks, or in mild tempered areas or given a specific lane on the highway for autonomous vehicles. Doing this may help lower the number of accidents caused during the transition phase between human-driven cars and autonomous vehicles, as the autonomous vehicles are still learning and sharing the data they have "learned" with the other autonomous cars through cloud computing.

There have been a lot of critiques about autonomous vehicles, which include the technology within the car, the security of the cars, and also ethical and legal dilemmas of the cars. The critiques surrounding the technology are due to the possibilities of computer malfunctions or hackers being able to potentially take control of the vehicle. This is currently the main reason why autonomous vehicles are not on the road and we are still on level two for the level of autonomy. Until the security of these vehicles is firmed up and the likelihood of computer malfunctions or hacking is extremely slim to none, these cars will not be prevalent on the roadways because it will be too risky both for the drivers and the car manufacturers. When the autonomous cars are released to the public, there are already manufacturers claiming that they will take full responsibility for any accidents/incidents the car gets into, therefore, this is known that when the car does get released to the public, the manufacturers believe that these cars will be extremely safe. This also means that they believe the likelihood of an accident or other malfunction will be extremely rare, which is why they are willing to take responsibility when that would happen. Finally, there are also concerns regarding the ethics of a self-driving car. Many people have argued that since the self-driving car is programmed, it cannot go through the decision making process that a human would be able to go through during the time of an accident. However, the autonomous vehicle will be pre-programmed, most likely by a group of ethicists, lawyers, programmers, moralists, and others rather than just a single individual trying to make a decision about what is right or wrong during a panicky moment. Therefore, the self-driving car will be able to make the most ethical choice, in comparison to the human, and it will do so without experiencing the heightened emotions and feelings of shock and panic that the human will.

Overall, despite the critiques that self-driving cars are facing right now, these cars show promise as the idea of them becoming more prevalent on our roadways becomes a greater reality. Although it will probably not be many more years until we start seeing vehicles such as these, once they are mainstream, one can expect to see less accidents and greater sophistication on our roadways.

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