SAC Knowledge Hub

Date: 4 December 2019

Self-Driving Cars

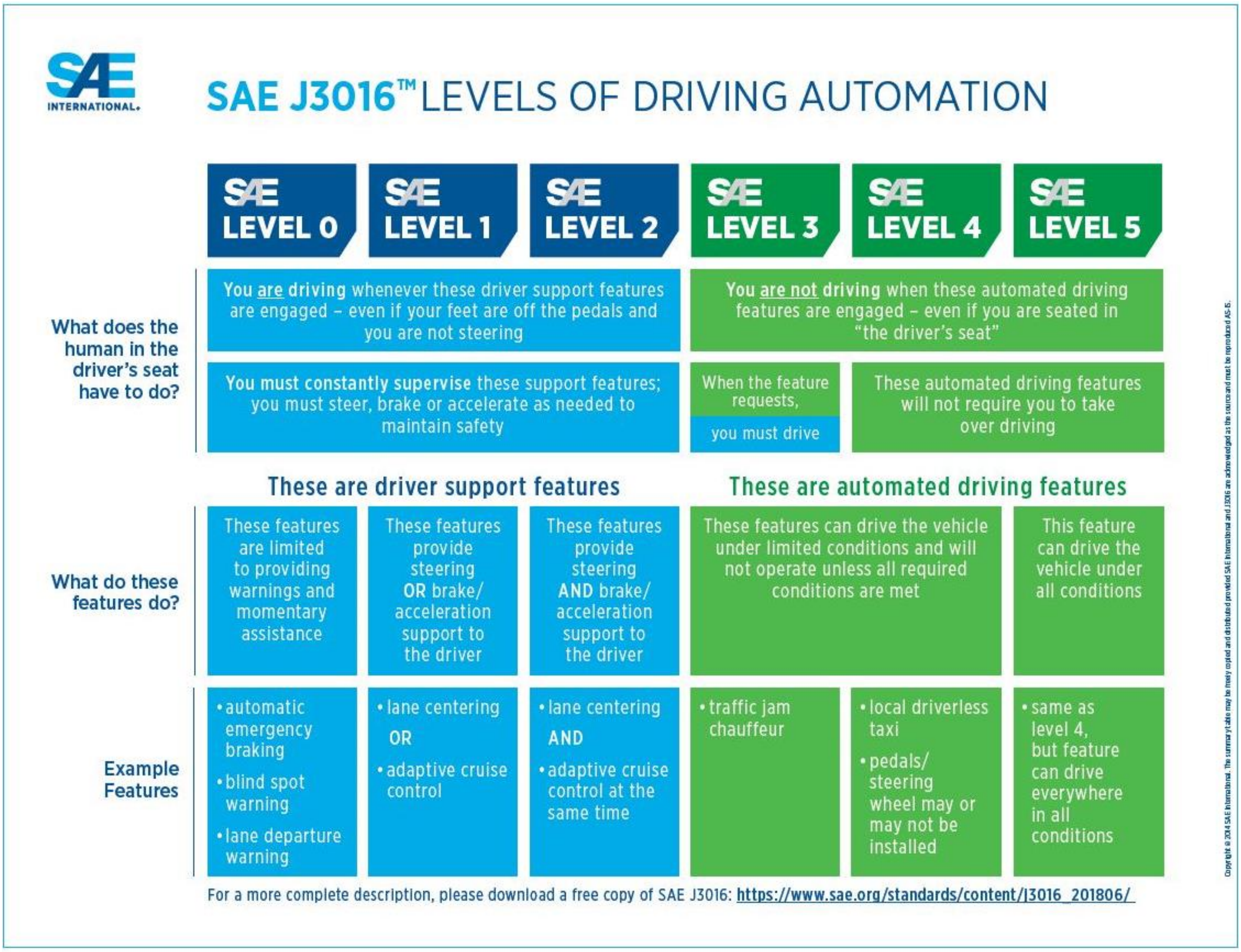
Like many of mankind's other technological dreams, the self-driving car has been a staple in numerous works of science fiction over the decades. Awe-inspiring scenes show cars being summoned remotely, and then driving to its passengers' destination as they engage in other activities. While smartphones and tablets have already found their way from the big screen into our everyday lives, self-driving car technology remains exclusive to the likes of James Bond or Batman. In this report you will be introduced to the world of self-driving cars, as we cover an overview of the technology, its game-changing applications, and how development has progressed to slowly turn fiction into fact.

Nicholas Neo
nneo@saccapital.com.sg

What is a Self-Driving Car?

A self-driving car, commonly also referred to as a driverless, autonomous, or robotic car, is a vehicle that has the capability to control its own navigation without human input. Utilising an array of advanced hardware and software, a self-driving car has to be able to detect and manoeuvre around obstacles in real time, so as to arrive at its destination safely.

The self-driving capability of a vehicle is most commonly described using a standardised classification system published by the Society of Automotive Engineers ("SAE"). The scale has 6 categories, starting from non-autonomous vehicles at Level 0, with each subsequent level describing more advanced automation capabilities all the way to fully-autonomous vehicles at Level 5.



Source: SAE International

A Brief History Through the Levels

Level 0

While the long history of mechanical vehicles can be traced back to steam-powered engines as early as the 17th and 18th centuries, the Benz Patent-Motorwagen, a patent awarded to German inventor Karl Benz in 1886, is widely considered to be the world's first production automobile, thus signifying the birth of the modern car. A few decades later, Henry Ford brought the Ford Model T to the masses by bringing production costs down with his innovative moving assembly line. Cars and other land vehicles have since been more than just a means of transportation, viewed as a status symbol and giving rise to motorsports.

Innovations came aplenty too. Bigger, more powerful internal combustion engines evolved into hybrid and more recently fully-electric ones. Seatbelts and airbags greatly enhanced safety when they were introduced. In 1939, General Motors unveiled the Hydra-Matic, the world's first mass-produced automatic transmission system.

Vintage Hydra-Matic Advertisement

Source: Hemmings, General Motors

Eliminating the need to operate a clutch and gear stick, automatic gearboxes were a revolutionary invention that made driving more user-friendly and is present on the vast majority of vehicles today. Further safety enhancements emerged in the form of lane departure or blind-spot warning systems. Under SAE's standards though, with the driver in full control of acceleration, braking and steering, these features are still classified under Level 0.

Level 1

Since as early as the 1920s, there has been considerable research and development done to demonstrate proofs of concept of the self-driving car. Early tests were mainly done under highly controlled environments such as pre-marked test routes and at very low speeds. One such test was the DARPA Grand Challenge, a competition funded by the Defense Advanced Research Projects Agency in which autonomous vehicles raced on a course for millions of dollars.

Tartan Racing's "Boss", winner of the 2007 DARPA Grand Challenge, is a retrofitted Chevrolet Tahoe

Source: Carnegie Mellon Tartan Racing

The first steps towards putting self-driving capabilities into the hands of the general consumer only came in the 1990s. With adaptive cruise control, the vehicle gains the capability to automatically adjust its speed to maintain a safe distance from other vehicles in front or behind it. The driver is thus relieved of one responsibility while driving, although he or she is still required to be in control of steering and be ready to intervene at any time. By assisting with one aspect of driving, this marked the emergence of Level 1 self-driving vehicles, and adaptive cruise control is present in many vehicles on the road today.

Level 2

By introducing a second aspect of driving assistance, a Level 1 autonomous vehicle ascends to Level 2, and the car is able to simultaneously control acceleration, braking and steering under certain scenarios. At this level, it is still necessary for the driver to have eyes on the road, hands on the steering wheel, and remain alert while the car is driving automatically, ready to take full control at any time even if not prompted by the vehicle.

The early 2000s saw the introduction of lane departure warning systems which alerted the driver if the vehicle was veering off its course on highways. In the 2010s this slowly evolved into lane centering systems which automatically keep the vehicle centered in the lane. Used in conjunction with adaptive cruise control, the requirements for Level 2 automation are met and most cars described as “self-driving” today fall under this category, usually available on luxury vehicles or as an optional add-on for standard vehicles.

Tesla’s Model S, introduced in 2014, is one of the earliest Level 2 production cars, featuring the company’s “Autopilot” system. Autopilot is also capable of automatic lane changing, navigating intersections and automatic parking, and as such is sometimes described as being “Level 2.5”.

Tesla Model S

Source: Tesla

Level 3

At Level 3, the human driver may take his or her mind off the driving and engage in other tasks, such as watching a movie. SAE describes Level 3 as the start of automated driving, while previous levels are referred to as driver support features. However, the self-driving capability may not be available for all types of driving conditions and scenarios, and so human intervention could still be called for at any time. A key difference from Level 2 is that the vehicle is now expected to request for the human driver to take over whenever necessary, unlike in Level 2 where the driver may have to manually resume control if required.

Widely considered to be the first commercially available Level 3 system, Audi’s 2019 iteration of its A8L luxury sedan features Traffic Jam Pilot, which automates driving in traffic jams up to 60 km/h. However, due to regulatory issues, the feature is only available in Europe at the moment.

2019 Audi A8L

Source: Audi

Level 4

A Level 4 self-driving car is described to be fully autonomous, and the driver may even go to sleep. However, the self-driving capability may be restricted to certain conditions, such as to only within a highly mapped urban area. If the car needs to travel beyond its designated self-driving zone, the human driver's intervention would be required. However if there is no response, the car would need to safely and automatically park itself until further instructions are given. Due to safety concerns that people may not maintain alertness while in a Level 3 vehicle, many developers have opted to skip it altogether and jump straight to Level 4, with most expectations for a production-ready vehicle by 2022-2025.

Today, the forerunner of Level 4 technology is widely considered to be Google's Waymo, which has been operating a limited autonomous taxi service (but with human drivers just in case) in Arizona, USA since 2017.

Waymo's self-driving Chrysler Pacifica Hybrid minivan on public roads

Source: Waymo

Level 5

Finally, at Level 5, the vehicle is fully autonomous under all conditions and locations, never ever requiring the intervention of a human driver. Such a vehicle may not even have a steering wheel and pedals, and would be able to operate unmanned. Achieving Level 5 does not mean the end of development though, as incremental improvements can still be made to increase operating efficiency, safety features, emergency response and more.

Automatic Parking

Automatic parking functionality has been available for many years now, frequently offered as an add-on option. As navigating around stationary objects at a low speed is incomparably simpler than driving on a highway, automatic parking on its own has advanced at a much faster pace than self-driving in general. Mercedes-Benz, in partnership with Bosch, has achieved and received approval for Level 4 automated valet parking, albeit restricted to its Mercedes-Benz Museum parking garage in Stuttgart, Germany.

Automated Valet Parking system at the Mercedes-Benz Museum

Source: Bosch

Underlying Technology and Challenges

Self-driving technology is made possible through a complex system of hardware and software that work in tandem to give instructions to the vehicle.

Navigation

The already mature Global Positioning System, commonly known as GPS, is a network of over 30 satellites which orbit the Earth, each of which is continuously broadcasting a signal which specifies its position and time of broadcast. By receiving the signals from multiple GPS satellites, a GPS navigation device is able to pinpoint its location via triangulation. Originally developed by the US military in the 1970s, GPS is widely used today by drivers and pedestrians alike. In conjunction with updated maps and traffic data, the navigation software built into GPS navigation devices is able to plan an optimised route for its user. Similarly, self-driving cars utilise the same system for route planning purposes.

GPS III satellite

Source: US Air Force, GPS.gov

Sensors

While GPS is an amazing innovation that made street directories obsolete, its 30cm to 5m accuracy is nowhere near precise nor responsive enough to be used for navigating around moving obstacles on a road. Instead, self-driving cars utilise a variety of sensors to visualise its surroundings in more detail. Today, there are four main types of sensors, namely ultrasonic, RADAR, cameras, and LiDAR.

Ultrasonic sensors, as the name suggests, relies on sending out ultrasound pulses and measuring the echoes to detect obstacles, similar to how bats detect their prey. Ultrasound refers to sound frequencies higher pitched than 20 kHz, beyond the upper-limit of human hearing. The main drawback is its very short range of only a few metres, but the low cost and reliability in all light and weather conditions make them ideal for applications such as automatic parking, where the vehicle has to manoeuvre around tight spaces.

RADAR, which is short for RAdio Detection And Ranging, bounces radio waves off surrounding objects to determine their position and speed. It is a mature technology with origins in the late 19th century, and was first developed and used during World War II to detect enemy vehicles, ships and aircraft. While it is unable to make out any details, this shortcoming is made up through high range and reliability even in poor weather conditions, and is commonly used for automatic emergency braking systems and the aforementioned adaptive cruise control technology.

LiDAR, which stands for Light Detection and Ranging, operates on the same principles as RADAR but utilises laser light as opposed to radio waves. These lasers are typically in the near-infrared spectrum of light which has shorter wavelengths than radio waves, hence this technology can generate a more detailed and precise 3D image as compared to RADAR. However, LiDAR hardware is much more expensive, less reliable in snow and rain, and has a shorter range.

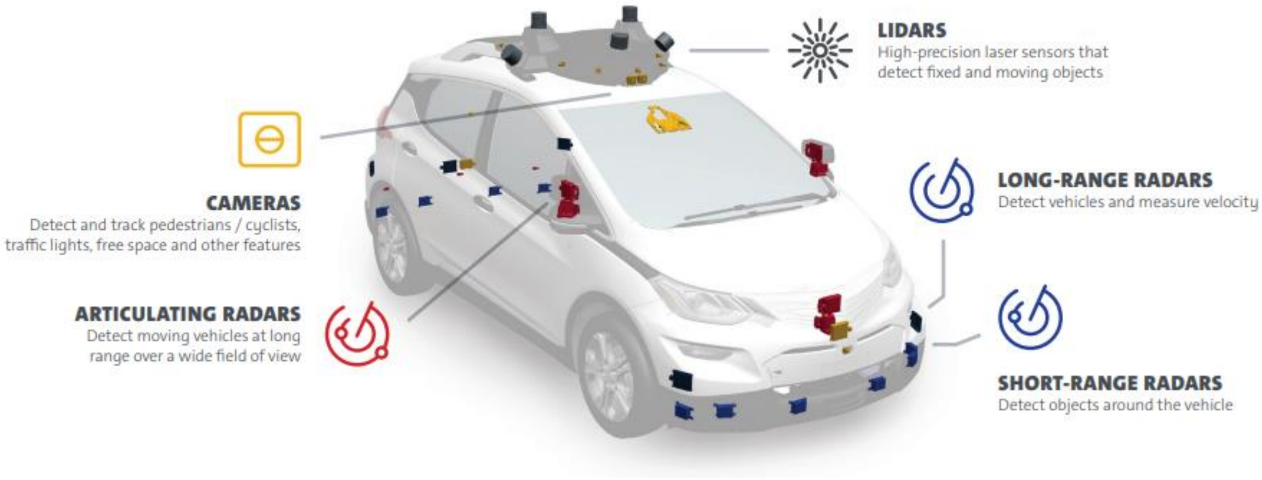
Waymo's "Laser Bear Honeycomb" LiDAR sensor installed on the car roof

Source: Waymo

Last but not least, **optical cameras** provide the same type of detailed visual data to the car's computer as a human driver would see with his or her own eyes. This enables the identification of objects, such as differentiating a car from a bicycle, or reading road signs and lane markers. The main challenge with cameras is the high amount of computational power required to achieve this reliably in real time, especially when taking into account low visibility conditions such as low light or bad weather.

Due to the different strengths and weaknesses of each type of sensor technology, most developers have opted for an array of multiple different sensors to cover all 360 degrees of visual space at varied ranges around a vehicle. This combination enables the capability to tackle different scenarios that the vehicle may face on the road, while also enhancing safety and reliability by serving as redundancy systems.

GM's Cruise AV is equipped with 5 LiDARs, 16 optical cameras and 21 RADARs



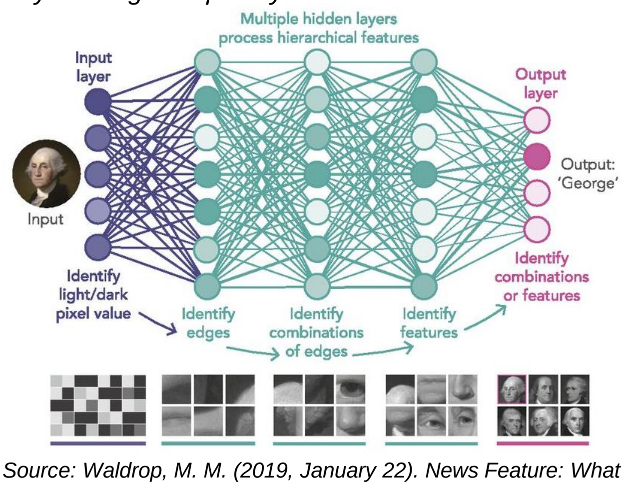
Source: General Motors: 2018 Self-Driving Safety Report

Software

A seasoned driver is able to operate a vehicle subconsciously. However, developing software to replicate this seemingly simple task is a lot more complicated and remains a key challenge. There are innumerable scenarios that may be encountered on the road, and the last thing we want happening is for the self-driving car to freeze up if it encounters a situation that it was not programmed for. As such, it is not feasible to develop self-driving software via traditional programming.

Instead, self-driving technology finds itself as a part of today's broader trend of artificial intelligence ("AI") development, under the branch known as machine learning. Machine learning pioneer Arthur Samuel defined machine learning in 1959 as a "field of study that gives computers the ability to learn without being explicitly programmed". More specifically, a more advanced form of machine learning called deep learning is used. Deep learning is developed on architectures known as deep neural networks, which have the ability to process large amounts of unstructured data, making it suitable for this task. By feeding vast amounts of data from real-life driving scenarios to the neural network, it "learns" how to make sense of the inputs gathered through its sensors, make the appropriate decisions in response to what it sees, and then execute these instructions as intended. Given enough "training" the resultant AI programme can become capable of adapting and responding to any situation it may be met with in real life.

Deep neural networks mimic the way a brain works by utilising multiple layers of nodes called neurons



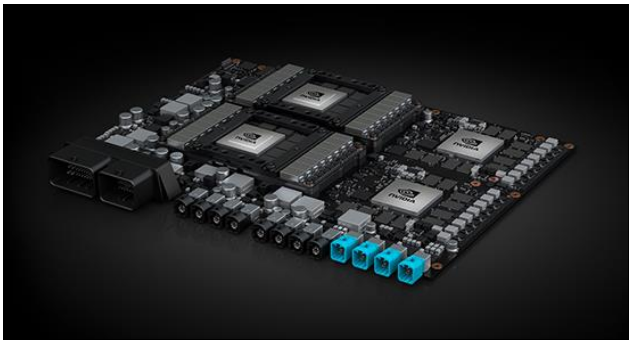
Source: Waldrop, M. M. (2019, January 22). News Feature: What are the limits of deep learning?, PNAS

Mobileye, through its EyeQ series of chips, is one of the pioneers of applying machine learning to develop commercially available driving assistance systems in the 2000s, and is still one of the leaders on this front today.

Processor

The complex software must then be run on sufficiently powerful processing hardware that can deliver fast and reliable responses in real time to ensure safety while driving. Many of the largest semiconductor companies have developed specialised chips for this purpose. One of the leaders in this space is Nvidia, who have partnered with numerous car manufacturers and research institutions with their Nvidia Drive platform.

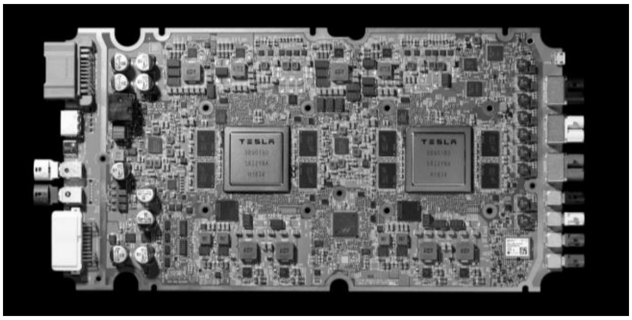
Nvidia's Drive AGX Pegasus in-vehicle computer



Source: Nvidia

At the same time, some car manufacturers have instead opted to develop their own chips. Launched in early 2019, Tesla claims that its Full Self-Driving ("FSD") Chip is capable of supporting Level 4 and 5 self-driving, and is simply waiting for the software to catch up. Powerful chips also tend to consume high amounts of power and reduce the operating range for electric vehicles, which are commonly developed in tandem with self-driving. Fortunately, energy efficiency and battery capacities continue to see good progress.

Tesla's FSD chip



Source: Tesla

Advantages and Applications

With companies and governments pouring billions of dollars into research and development, the hype behind self-driving cars has to be well-justified, and some of its key advantages are as follows.

Safety

Just like how young children today might have no idea what a cassette tape is, future generations born in a world filled with only self-driving cars may never come across the term "traffic accident". With an estimated 1.35 million road traffic deaths per year globally[1], increased safety is one of the key motivations behind the push towards self-driving cars. A self-driving car has instantaneous reaction speeds, is free from human emotions, does not tire, has no blind spots, and cannot get drunk. Over time, advancement and adoption of the technology will progressively eliminate the obstacle of human error and result in safer roads, drastically reducing the occurrence of accidents. We can also expect an advanced AI to be a skilful driver that delivers a smoother ride.

Traffic

Human drivers are quick to slow down yet slow to speed up, which may result in "phantom" traffic jams occurring in dense traffic even if there are no accidents or other obstructions ahead. In a system where most if not all vehicles on the road are self-driving, it is foreseen that traffic jams may become a thing of the past due to low occurrences of traffic accidents and narrower safety gaps between vehicles. The advent of 5G's phenomenally higher bandwidth and lower latencies makes it possible that a shared network could be used as the backbone of the self-driving infrastructure, optimising the coordinated movements of all vehicles, from route planning all the way down to lane changing. With such a system, a road junction might not even need traffic lights, with vehicles expertly passing through the gaps of the intersecting traffic. Speed limits may also be increased due to the heightened level of safety, thereby improving the efficiency of road transportation.

Productivity

The advantages of self-driving result in great potential to disrupt multiple aspects of the transportation industry. Human drivers represent a large proportion of the operating costs of running a transportation service. Apart from directly saving on paying the driver's salary, driverless vehicles further increase cost-efficiency as they have no need to take breaks and can be in operation nearly 100% of the time, only stopping for maintenance or refuelling/recharging. As an added bonus, this reduces the required amount of parking space and the freed-up land can be redirected towards other purposes. There are clear benefits of self-driving in various applications, and some of the more prominent examples are discussed here.

Public Transportation such as public or shuttle bus services with predetermined routes currently provide a good entry point to developers pursuing Level 4 self-driving. Short, less crowded routes with fewer traffic obstacles serve as a test ground that is both easy to monitor yet exposed to real-life scenarios. One of several examples in Singapore, ComfortDelGro has been testing and running a self-driving shuttle bus service within the NUS campus since May 2019.

ComfortDelGro's NUSmart shuttle

Source: Tan, C. (2019, July 29). ComfortDelGro's self-driving shuttles to start picking up passengers at NUS. The Straits Times

[1]*Source: World Health Organization: Global Status Report on Road Safety 2018*

By using a self-driving car as a taxi, we have what is commonly referred to as a robo-taxi. Due to the enormous potential for cost savings, loss-making ride-hailing giants such as Uber have been developing and testing self-driving cars of their own as a potential path to future profitability. In Singapore, NuTonomy is a spin-off from MIT that partnered with Grab to launch a robo-taxi pilot test at the One North area in 2016.

NuTonomy's modified Mitsubishi i-MiEV on Singapore's roads

Source: Abdullah, Z. (2016, August 26). World's first driverless taxi trial kicks off in Singapore. The Straits Times

Robo-taxis may make transportation so affordable through Mobility-as-a-Service subscription models that private car ownership could be substantially replaced. Tesla CEO and founder Elon Musk envisions a future where individual car owners are able to loan their self-driving car out as a ride-hailing service while not in use.

Commercial transportation would also benefit greatly from self-driving technology for similar reasons as public transportation. Some of the major players developing self-driving semi-trailer trucks today include Tesla, Waymo, Mercedes-Benz and TuSimple. These trucks predominantly drive on open roads, which is much easier to automate than driving in urban areas. Therefore, achieving Level 3 automation to cover highways alone would revolutionise the long-haul trucking industry which currently has strict regulations on working and resting hours for safety reasons.

Mercedes-Benz Future Truck 2025

Source: Daimler

Disadvantages, Issues and Challenges

Unfortunately, despite all the potential advantages, self-driving cars face their fair share of issues as well. Other than having to deal with technical challenges which are part and parcel of all advancements in technology, self-driving cars have met with some speed bumps (literally and figuratively) on its development path.

Incidents

Over the years, self-driving cars have been involved in numerous collisions, which goes to show that we are still a long way from achieving the desired near-perfect levels of safety. Most incidents have been minor and occurred under test conditions, providing developers with more valuable data to further improve their software.

Unfortunately, with Level 2 self-driving cars already out on public roads, several fatal accidents have occurred. One of the first cases took place in Florida on 7 May 2016, in which a Tesla Model S crashed into a tractor-trailer while in Autopilot mode, killing its driver. According to Tesla, "neither Autopilot nor the driver noticed the white side of the tractor-trailer against a brightly lit sky, so the brake was not applied."

Currently classified as a Level 2 system, Tesla's Autopilot requires the driver to stay alert at all times and be ready to take over driving duties if necessary. While Tesla does communicate this critical fact to customers before they are allowed to use Autopilot, the company has been criticised for introducing features to the public prematurely. Such incidents spread fears about self-driving cars and changing the public's mindset may be a significant hurdle before widespread adoption becomes a reality.

Some consumers may be too eager to be early-adopters, and there are also others who may never be comfortable letting an AI be in control of their safety, no matter how perfected the technology becomes in the future.

Privacy and Security

The cameras and other sensors of self-driving cars which constantly monitor all directions raise some concerns about privacy. It is possible for a large network of self-driving cars to be implemented as an all-seeing surveillance system, not to mention being able to collect the location data of passengers. Even if the appropriate regulations are put in place, there is still the risk of cyber-attacks being able to access the data being collected by the car and used for malicious purposes. Worse still, a hacker could take control of the vehicle, such as a 2015 case of a Jeep being carjacked remotely and driven into a ditch as part of a research experiment. There is also the potential for the escalation of terrorism as self-driving cars could enable the unmanned delivery of dangerous payloads.

Charlie Miller (left) and Chris Valasek (right) send their photo to the hacked Jeep's dashboard

Source: Greenberg, A. (2015, July 21). Hackers Remotely Kill a Jeep on the Highway – With Me in It. Wired.

Legal and Regulatory Response

With public safety at stake, governments have naturally taken action in the form of regulations. Unlike the mobile phone industry's transition to smartphones in the late 2000s, no government will give the green light for mass public adoption of self-driving cars until they are perfected. While the slow pace of legislation planning and overly conservative policies may have a limiting effect on development and deployment, many governments recognise the many benefits of self-driving cars and well-implemented regulations could help to facilitate the transition to autonomous vehicles. For example, in early 2019 Enterprise Singapore published Technical Reference 68 ("TR 68"), which comprehensively sets out standards and guidelines such as for driving behaviour, safety design and management, and cybersecurity safeguards. TR 68 was described by ST Engineering Land Systems chief robotics engineer Tan Nai Kwan to be "much welcomed by industry players as they provide developers with clear guidelines benchmarked against international standards." A joint partnership between LTA and A*STAR, the Singapore Autonomous Vehicle Initiative ("SAVI") further cements the government's support of the technology. Just recently in October 2019, the testbed for autonomous vehicle trials was expanded to over 1,000 km of public roads in Singapore, adding neighbourhoods such as Bukit Timah, Clementi and Jurong to the list of existing test sites which includes Buona Vista, Jurong Island, NTU and Sentosa.

Ethical Issues

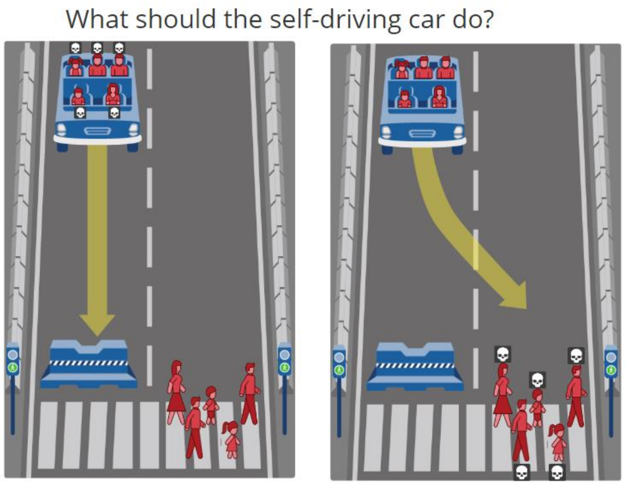
Technological Unemployment

The introduction of new innovative technologies inevitably results in the loss of jobs as machines are able to automate tasks more efficiently. Telephone switchboard operators were made obsolete by automated systems, manual labour in factories are quickly being replaced by robotic production lines today, and the case of self-driving cars will hardly be any different. When self-driving vehicles become more widespread in the future, we can expect driving-related jobs to gradually become redundant. The resulting technological unemployment is generally accepted to be a good thing in the long run due to increased productivity and the creation of new jobs, but there will inevitably be resistance from those who are losing their jobs. Lobbies by drivers' unions could deter policymaking, slowing down the development and adoption of self-driving cars.

Moral Dilemmas

A widely-discussed moral dilemma is the question of how a self-driving car should behave in an emergency situation. Picturing this scenario: a self-driving car is traveling at speed, and a pedestrian suddenly enters its trajectory. Should the self-driving car continue on the collision course with the pedestrian, or swerve into a wall, saving the pedestrian but killing its passengers? To shed some light on this issue, MIT launched an experiment called the Moral Machine, which is a website that generates moral dilemma situations involving self-driving cars. Visitors of the site are to select from one of two harmful decisions that the car should make, and with data spanning 40 million decisions from 233 countries and territories, the study provided some insight into our moral preferences. From a third-party perspective, utilitarianism seems to be the most popular moral basis, whereby the self-driving car should make whichever decision that will minimise harm, even if such a decision endangers its passengers. However, it was also unsurprisingly revealed that people would only use a self-driving car which always prioritises the lives of passengers. With these conflicting ideas, there is still no clear solution to this conundrum.

An example question on the Moral Machine website



Source: http://moralmachine.mit.edu/

Concluding Thoughts

We are fortunate to live in such exciting times, with the Internet of Things and artificial intelligence ushering in a new era of technology. Self-driving cars are just one small part of this broader tech revolution, but they are certainly among the most fascinating technologies we can look forward to, awe-inspiring from both a practical and technical standpoint. Despite numerous challenges, the global development race rages on, and our very own Batmobiles may be just around the corner.

DISCLAIMERS AND DISCLOSURES

This report has been prepared and distributed by SAC Capital Private Limited ("**SAC Capital**") which is a holder of a capital markets services licence and an exempt financial adviser in Singapore.

This report has been prepared for the purpose of general circulation. We have not had regard to the specific investment objectives, financial situation, tax position or unique needs and constraints of any individual person or any specific group of persons and does not purport to be comprehensive or contain all necessary information which a prospective investor may require in arriving at an investment decision. Any prospective purchaser should make his own investigation of the securities and all information provided. Advice should be sought from a financial adviser regarding suitability, taking into account the specific investment objectives, financial situation or particular needs of the person in receipt of the recommendation, before a commitment to purchase is entered into.

This report does not constitute or form part of any offer or solicitation of any offer to buy or sell any securities.

This report is confidential and the information in this report shall not be copied or reproduced in part or in whole, and save for the recipient of this report, shall not be disclosed to any other person without the prior written consent of SAC Capital. The distribution of this report outside the jurisdiction of Singapore is also strictly prohibited.

Whereas SAC Capital has not independently verified all the information set out in this report, all reasonable care and effort has been taken to ensure that the facts stated herein are accurate, this report may contain certain forward looking statements and forward looking financial information which are based on certain assumptions and involve known and unknown risks, uncertainties and other factors which may cause the actual results or performance of the subject companies to be materially different from those expressed herein. Predictions, projections or forecasts of the economy or market trends are not indicative of the future performance of the subject companies. The inclusion of such statements and information should not be regarded as a representation, warranty or prediction with respect to the accuracy of the underlying assumptions of the subject company or that the forecast results will or are likely to be achieved.

Our opinion and facts set out in this report are based on the market, economic, industry and other applicable conditions prevailing as at the date of the preparation of this report. Such conditions may change significantly over a relatively short period of time and we assume no responsibility to update, revise or reaffirm our opinion in light of any development subsequent to the publication of this report, that may or may not have affected our opinion contained herein.

This report contains forward-looking statements which are based on assumptions or forecasts and are subject to uncertainties which may result in the actual result or performance to be materially different from the opinion or facts set out herein. Caution should be exercised in placing undue reliance on such statements. such assumptions or forecasts may change over a relatively short period of time and we assume no responsibility to update, revise or reaffirm our opinion in light of any development subsequent to the publication of this report.

No representation or warranty, expressed or implied, is made and no responsibility is accepted by the companies, SAC Capital, or any of their affiliates, advisers or representatives as to the fairness, accuracy, completeness or adequacy of such information or facts, in this report or any other written or oral information made available to any interested party or its advisers and any liability therefore is hereby expressly disclaimed.

SAC Capital and its associates, directors, and/or employees may have positions in the securities or securities of the companies covered in the report and may also perform or seek to perform other corporate finance related services for the companies whose securities are covered in the report. SAC Capital and its related companies may from time to time perform advisory services, or solicit such advisory services from the entities mentioned in this report ("**Other Services**"). This report is therefore classified as a non-independent report. However, the research professionals involved in the preparation of this report have not and will not participate in the solicitation of such business.

ANALYST CERTIFICATION/REGULATION ACT

As noted above, research analyst(s) of SAC Capital who produced this report hereby certify that

(i) The views expressed in this report accurately reflect his/her personal views about the subject/subject corporation(s);

(ii) The report was produced independently by him/her;

(iii) He/she does not on behalf of SAC Capital or any other person carry out Other Services involving any of the subject/subject corporation(s) or securities referred to in this report; and

(iv) He/she has not received and will not receive any compensation directly or indirectly related to the recommendations or views expressed in this report or to any sales, trading, dealing or corporate finance advisory services or transaction in respect of the securities in this report. He/she has not and will not receive any compensation directly or indirectly linked to the performance of the securities of the subject corporation(s) from the time of the publication of this report either.