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Autonomous Vehicle Levels & Trends

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Abstract: ***This paper will deep dive into the mechanism of Autonomous Vehicles. It discusses what the different levels of autonomous Vehicles. There are five levels of autonomous vehicles: Level 0 (No Automation), where the driver controls all driving functions; Level 1 (Function - Specific Automation), with at least one function automated; Level 2 (Combined Function Automation), with at least two functions automated; Level 3 (Limited Self - Driving Automation), allowing the car to drive by itself in certain conditions, while the driver monitors safety operations; and Level 4 (Full Self - Driving Automation), enabling the car to drive without any intervention from the driver. In addition, the paper reviews the Business Trends, Advantages and Disadvantages of Autonomous vehicles in future.***

Keywords: Autonomous Vehicles, Driverless Cars, Google Car, Self - Driving, Levels of Autonomous Vehicles

1. Introduction

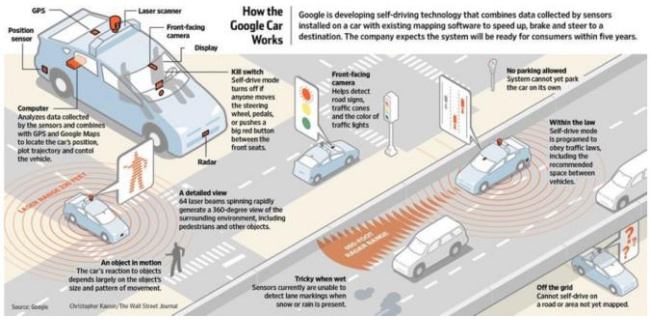
Once considered an unattainable vision, it is now evolving into a tangible reality. The Futurism of General Motors exhibit at the 1939 World's Fair had presented driverless vehicles. For decades, researchers are working to bring this dream to reality. The autonomous vehicle prototypes looked thoughtfully dull vehicles along with smart infrastructure. Guideways with magnetic or electronic built into highways would manage to control vehicles and the passenger would be relaxed with their radios. Unmet promises for so many decades left many doubtful about the concept, until the Google Car and few other autonomous cars prototypes. Yet it can be believed that with more developments on the technology front, like sensors, cameras, GPS, microprocessors, the making of autonomous cars is practical in coming age. Such cars will also involve a lot of changes in our transportation system. One easy transformation can be in infrastructure, while doing so, the infrastructure building companies will come across many challenges and opportunities too, similarly the way they faces a century ago when automobiles came into existence. Despite the safety they provide and may other benefits these infrastructure building companies neglected to invest in building technologies for autonomous cars. Auto car manufacturers also displayed a lack of interest. Instead they saw it as adding cost to the vehicle with less benefit to the customers. For decades, users saw driving as fun and exciting, hindering the development of technologies that might compromise this enjoyment. . As time passed, numerous technologies emerged in the markets, which now enable the concept of driverless cars.

Source: [1], Wired. com

The growing number of individuals using their cell phones or tablets while driving, or connecting to the internet, seek freedom from the act of driving itself, as it poses a distraction. This has led to a significant demand for driverless cars, offering a solution to save their unproductive time. Companies are now responding to these demands, giving rise to the era of autonomous cars. Various technologies that assist drivers, such as self - parking, lane - deviation correction, and collision avoidance, are already prevalent in the market. Some auto manufacturers have introduced semi - autonomous technology packages as intermediary steps towards fully autonomous cars. Additionally, there is increasing demand from sectors like the military and industries such as mining and agriculture, where operator safety is paramount. For instance, recent technologies enable trucks to operate independently, traveling just a few feet apart. Fresh market such as Google and university - affiliated research centers around the globe are working on the next steps that will yield a fully autonomous vehicles. These vehicles will be able to travel from Point 1 to Point 2 without any human intervention. Approximately 500, 000 miles are successfully travelled by google car by now, at the same time other autonomous vehicles have been tested and worked on simultaneously. Safety is big concern while building autonomous cars. Approximately 1.25 million fatal road accidents occur annually, resulting in global fatalities. It costs around $250 billion to the vehicle accidents in United States alone. The use of autonomous cars could prevent a significant number of accidents. In urban areas the capacity on the highway is not keeping pace with population growth and increasing number of vehicles on roads every year. Various efforts are underway to address these problems. One way is to have well connected and feasible public transports and public local railways. However, these issues are not significantly alleviated by current measures. Autonomous cars also offers ways to increase highway capacity problems with less amount of cost to invest. These kinds of trends are coming up together and will enforce driverless vehicles to be seen on road very soon. This process will make the consumer more productive with his work while neglecting driving time, it will also make it more efficient, bringing more safety. Meanwhile some groups like taxi drivers or bus drivers will face few forceful and uninvited problems.

1.1 Google Car

For a long period, it remained undisclosed, but Google has now revealed the features and functionalities of their autonomous Google Car. It has GPS, Laser Scanner, Front Facing Camera, Radars, computer, display etc. Laser Scanner collects the information from the surrounding in three dimensions (the surrounding includes other vehicles, pedestrians, or any other objects on the road). The reaction of the cars mainly depends on these objects and their movement. The front camera helps detect the traffic lights on the roads. GPS helps cars to locate on the map and to respond accordingly. The car is also mounted with four radars on the front and rear bumper which enables the car to see far enough, so that it can deal with fast moving traffic. The car has information of traffic rules which forces her to follow the rules, which is the key feature to reduce fatal vehicle accidents. The picture below illustrates some of the key features and functions of google car:



Source: [9], [8] Google, wsj. com

1.2 Levels of Autonomous Vehicles

Implementation of Autonomous vehicles is a complex task in the real world. One practical way to tackle this is by implementing it gradually, step by step. Various levels are defined for this. These levels are from Level 0 to Level 4 in the increasing order of autonomous capabilities. National Highway Traffic Safety Association (NHTSA) is a USA government organization which administers traffic laws in the country. The agency has separated vehicles into five levels as follows which enables us to clarify the levels of automation.

a) Level 0 – No Automation

In this level, the driver controls the vehicle completely at all the time. Braking, steering, throttle, safety operations are completely dependent on the driver, vehicles have mechanical continence system in these operation but authority is held by the driver. These vehicles may have only warnings but the vehicles do not take action over it. Vehicle can still have semi - automatic operation like wiper, indicators, parking lights, headlights/ taillights. Vehicle 2 Vehicle (V2V) warning technology comes under this level.

b) Level 1 – Function - specific Automation

This level involves one or more specific control functions, which are controlled by the vehicle. These functions will carry out independent operation and won't interfere other operations. Driver is still responsible for safety operations. Limited authority can be impended on the vehicle. For example in case of adaptive cruise control. Primary controls like Electronic Stability Control (ESC), which operates automatically comes under this level. Dynamic Brake support, which can support during crash situations, falls under this level. The automated system of vehicle may assist the driver while operating functions like steering or braking etc.

c) Level 2 – Combined Function Automation

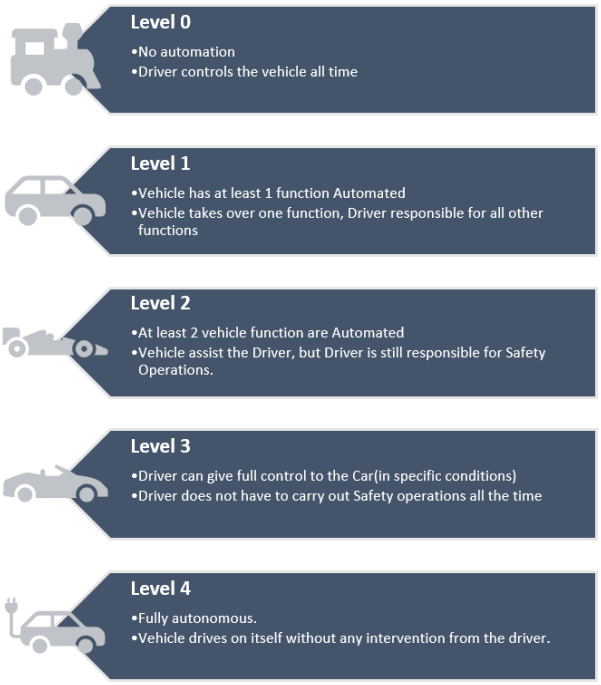
This level has automation of at least two functions which are primary works together along with driver. Driver is responsible for safety operation and monitoring roadways. Vehicle can share the authority at this level. In spite of that, driver need to monitor and carry out safety operations and is expected to be available for control on short notice. For Example, function with adaptive cruise control with lane centering. The major difference in level 2 and level 1 is that driver can physically disarm the vehicle and allow vehicle to carry out operation on its own.

d) Level 3 – Limited Self - Driving Automation

This level includes vehicles in which driver can give full control to the vehicle. Not all traffic conditions allow full control to vehicle, driver needs to take over wherever it is required. Vehicle can perform safety operation. Major transition from level 2 to level 3 is that, driver is not expected to monitor and carry out safety operations all the time. For example: Vehicle will ask driver to take over under the patches of road constructions.

e) Level 4 – Full Self - Driving Automation

In this level vehicles can perform all the operation throughout the trip. Driver need to input the destination and rest of the function will be carried out by the vehicle. Driver is not expected to take over vehicle at any moment of the trip. Monitoring and safety operations are only carried out by vehicle.



1.3 Business Trends and LAws

Automotive Business has always been a competitive market for all companies. While almost all the leading automakers are already testing and developing their autonomous vehicle, new companies are also emerging and stepping ahead into the technology development and making business into field of Autonomous Vehicle. Autonomous vehicles engineering is a broad field. It involves contribution of various technologies like software, electronic etc. integrated into the mechanical components. Therefore, it is not surprising to see Google, a software development company, enter this industry. Tesla on the other hand is a company based on alternative energy and produces electric vehicles. Tesla being very infant company, has recently announced its new model, Model D, which includes an auto - pilot feature. Along with Tesla, the automotive giants like Toyota, Audi, GM, Ford, etc. are working on this technology and testing in various conditions. In future, companies will work hard to reduce the cost of vehicles. Companies will try to commercialize the vehicle by making it affordable to most of the customer base. In this process, various affordable technologies will be developed to work efficiently. Experts say this is possible in next 10 years. The growth of Autonomous Vehicle will be step by step implementation of technology, similar to the steps that we discussed under section 'Levels of Autonomous Vehicles'. There are good chances of failure if not carried out at proper pace and time. The Tesla co - founder Elon Musk said "The problem with Google's current approach is that the sensor system is too expensive, it's better to have an optical system, basically cameras with software that is able to figure out what's going on just by looking at things. ". This indicates that companies will prioritize lowering the cost of the technologies used. Further, he also said "However, it is also possible that we do something jointly with Google. " These kinds of partnerships while sharing benefits will be seen in coming years in this business. Traffic rules and regulations will also have a huge impact on the business, which might limit the popularity of the Autonomous Vehicles. Following are few brief points regarding Laws related to Autonomous Vehicles.

When it comes to laws for Autonomous Vehicles, State of Nevada leads the discussions. Nevada started with laws for Autonomous Vehicles in June 2011. It constitutes of broad framework for regulating AVs and directed the Nevada DMV (NDMV) to produce regulations (R084 - 11), which was effective from March 1, 2012 (NDMV, 2012). Florida (Florida Statutes, 2012), California (California Vehicle Code, 2012), and Washington, D. C. (District of Columbia, 2013) followed Nevada, with legislation enacted in April 2012, September 2012, January 2013, and May 2013, respectively. Michigan also passed a law in December of 2013 that was enacted from March 27, 2014.

The clarity of these laws is frequently debated and questioned by many. Also, there are plenty of conversations among legislators, regulators and stakeholder on regulating the operators of this vehicle. The enacted laws and regulation states that the Autonomous Vehicles will be operated without interference of operator's monitoring. Vehicles inclusive of systems related to driver assist or safety are not included in this law. These systems are blind spot detection, crash avoidance, emergency braking, parking assist, lane keeping assist, lane departure warning, traffic jam assist etc. Self - Navigation was the system which was more focused while designing the laws.

Operator needs a "certificate of compliance" to use Autonomous Vehicle in the state. This certificate can be given by either manufacturer of the vehicle or from state - certified technology certification facility. The Nevada's law can state the future commercialization of Autonomous Vehicles. The "autonomous technology certification facilities" are private entities which gets endorsement from DMV, while users are required to pay $300 and surety bond of $500, 000 to operate. The user will receive special endorsement on driver's license. The regulation of Nevada's law states various requirements. One of those requirements is that users need to capture and store the data, that vehicle collects, at least 30 sec before any collision occurs between autonomous vehicles and other vehicles if the vehicle is operating in autonomous mode.

2. Advantages

An increase in the use of autonomous cars would make possible numerous amounts of benefits as follows:

- Fewer road accidents, as reliability and faster reaction time is better in an autonomous car when compared to human drivers.
- Improvement in highway capacity and reduced congestion of traffic as gaps needed for safety can be reduced and the system will have better ability to manage traffic flow.
- User will be relieved from driving and navigation at any turns.
- Speed limit can be set higher for autonomous cars.
- Car can be used to wide range of age groups and wide range of physical conditions. It would not matter if the

occupants were under age, over age, disabled or blind, distracted, injured or weak.
- It can be parked far away in case of parking congestion and can be called back whenever needed.
- Car can eliminate a passenger in case of trucks, taxis or car sharing services and can be called whenever required at the pickup point.
- Space reduction that is required for vehicle parking.
- It will reduce the need of insurance and traffic police.
- It will increase standardization in the time required to travel from point to point.
- Car theft will be reduced as autonomous vehicles have built - in GPS and sensors

3. Disadvantages

In spite of the various benefits to increased vehicle automation, some foreseeable challenges persist:
- Liability for damage in driverless cars raises complex legal and ethical issues.
- Resistance for individuals to forfeit control of their cars.
- As these cars are heavily controlled by software, the reliability of the software is a matter of concern to every consumer.
- Cyber Security is common problem with many software systems, same applies to autonomous vehicles.
- Establishment of government regulations for self - driving cars.
- Challenging to implement laws around autonomous vehicles.
- In the situations where autonomous functionality fails and driver is required to take over, driver can be inexperienced about handling the car.
- There will be a problems interacting with non - autonomous vehicles those are driven on the same road.
- Loss of driving - related jobs.
- Cars will need to share a good chunk of data to implement autonomous driving, this can be a threat for data privacy.
- Autonomous cars could easily be misused for criminal activities
- This can also be discouraging for the people enthusiasts about the driving vehicles, because the technology development pace will be reduced.

4. Summary

Dependency on technology is growing every day. Products are been manufactured and designed for a broader consumer base. Products are focused on requirements, such as providing freedom from driving for individuals who wish to utilize their time in better ways. Many companies and businesses are getting involved in developing Autonomous Vehicles. Autonomous Vehicle seems to have various advantages in safety front, traffic congestion etc.

One very exciting product which is gaining popularity is the new Autonomous Car developed by google. It uses GPS, Laser Scanner, Cameras, Radar, Lidar etc. to operate autonomously. Vehicle follows traffic rules which helps in reducing accidents. It is mounted with Lidar, the laser scanner, which collects surrounding information of obstacles, road, pedestrian, and reacts accordingly.

There are various levels defined by NHTSA (National Highway Traffic Safety Administration) in increasing order of autonomous capabilities. There are 5 levels for autonomous vehicle:
- Level 0 - No Automation.
- Level 1 - Function Specific Automation.
- Level 2 - Combined Function Automation.
- Level 3 - Limited self - driving Automation.
- Level 4 - Full self - driving Automation.

References

[1] Damon Lavrinc, “The Feds have no clue how to legislate Autonomous cars”, Blog, Jun.2013. [Online]. Available: http: //www.wired. com/2013/06/nhtsa - autonomous - vehicles/
[2] Thomas J. Bamonte, “Autonomous Vehicle: Drivers of change”, Article, Jul.2013. [Online]. Available: https: //www.roadsbridges. com/transportation - management/article/10645291/autonomous - vehicles - drivers - of - change
[3] Wikipedia Contributors, Self - driving car, Wikipedia Mar.2013. [Online]. Available: https: //en. wikipedia. org/wiki/Self - driving_car
[4] Tyler Cowen, “Can I see your License, Registration and C. P. U?”, Blog, May.2011. [Online]. Available: https: //www.nytimes. com/2011/05/29/business/economy/29view. html
[5] Randal O’Toole, “Gridlock: Why We're Stuck in Traffic and what to Do about it”, 1st edition, Cato Institute, Jan.2010. [Online]. Available: https: //books. google. com/books/about/Gridlock. html?id=1I8Wuv7P13AC
[6] Editorial, “Get ready for automated cars”, Article, Sep.2012. [Online]. Available: https: //www.chron. com/opinion/editorials/article/get - ready - for - automated - cars - 3857472. php
[7] Horatiu Boeriu, “BMW Remote Controlled Parking”, Blog, Oct.2010. [Online]. Available: http: //www.bmwblog. com/2010/10/10/bmw - remote - controlled - parking/
[8] Chunka Mui, “Will Driverless Cars Force A Choice Between Lives And Jobs?”, Article, Dec.2013. [Online]. Available: https: //www.forbes. com/sites/chunkamui/2013/12/19/will - the - google - car - force - a - choice - between - lives - and - jobs/?sh=1ae00c903995
[9] Amir Efrati, “Google's Driverless Car Draws Political Power”, Article, Oct.2012. [Online]. Available: http: //online. wsj. com/news/articles/SB10000872396390443493304578034822744854696
[10] “Google’s Driverless Car Draws Political Power”, Article, Oct.2012. [Online]. Available: https: //serbaysenturk. blogspot. com/2012/10/googles - driverless - car - draws - political. html
[11] Erico Guizzo, “How Google's Self - Driving Car works?”, Article, Oct.2011. [Online]. Available: https: //spectrum. ieee. org/how - google - self - driving - car - works

[12] J. S. Abel, J. W. Chaffee, “Existence and uniqueness of GPS solutions”, IEEE, Nov.1991. doi: 10.1109/7.104271. [Online]. Available: https: //ieeexplore. ieee. org/document/104271
[13] Paul Theodosis, Lauren Wilson, SiQi Cheng, "Road Sign Detection and Distance Estimation in Autonomous Car Application", Review Paper, Aug.2014. [Online]. Available: https: //stacks. stanford. edu/file/druid: np318ty6250/Chen_Theodosis_Wilson_Stereo_Vision_in_Autonomous_Car_Application. pdf
[14] Sibel Yenikaya, Gokhan Yenikaya, Ekrem Duven, "Keeping the vehicle on the road: A survey on on - road lane detection systems", Research Paper, Jul.2013. doi: 10.1145/2522968. [Online]. Available: https: //dl. acm. org/doi/10.1145/2522968.2522970
[15] Margery Conner, “Automobile sensors may usher in self - driving cars”, Blog, May.2011. [Online]. Available: https: //www.edn. com/automobile - sensors - may - usher - in - self - driving - cars/
[16] Marc Heddebaut, Fouzia Elbahhar, Christophe Loyez, Nizar Obeid, Nathalie Rolland, Atika Rivenq, Jean - Michel Rouvaen, "Millimeter - wave communicating - radars for enhanced vehicle - to - vehicle communications", Science Direct, Jun.2009. [Online]. Available: https: //www.sciencedirect. com/science/article/abs/pii/S0968090X09000588
[17] Wikipedia Contributors, “Radar”, Wikipedia, Feb.2013. [Online]. Available: https: //en. wikipedia. org/wiki/Radar
[18] Wikipedia Contributors, “Lidar”, Wikipedia, Oct.2013. [Online]. Available: https: //en. wikipedia. org/wiki/Lidar
[19] James M. Anderson, Nidhi Kalra, Karlyn D. Stanley, Paul Sorensen, Constantine Samaras and, Tobi Oluwatola, "Autonomous Vehicle Technology: A Guide for Policymakers", Research Gate, Jan.2014. [Online]. Available: https: //www.researchgate. net/publication/296697033_Autonomous_Vehicle_Technology_A_Guide_for_Policymakers/stats
[20] KPMG's Automotive Team, "Self - Driving Cars: Are We Ready?", Research Paper, Oct.2013. [Online]. Available: https: //assets. kpmg. com/content/dam/kpmg/pdf/2013/10/self - driving - cars - are - we - ready. pdf
[21] SlashGear, Tesla Model S P85D AWD and auto - pilot demo, Youtube video, Oct.2014. [Online]. Available: https: //www.youtube. com/watch?v=7quu551ehc0
[22] Driverless cars to be affordable within 10 years thanks to new 'eyes and ears' technology, Firstpost Article, Oct.2014. [Online]. Available: https: //www.firstpost. com/tech/news - analysis/driverless - cars - to - be - affordable - within - 10 - years - thanks - to - new - ears - and - eyes - technology - 3657491. html
[23] Alan Ohnsman, Tesla CEO Talking With Google About ‘Autopilot’ Systems, Article, May.2013. [Online]. Available: https: //www.bloomberg. com/news/articles/2013 - 05 - 07/tesla - ceo - talking - with - google - about - autopilot - systems?embedded - checkout=true