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Autonomous Cars: An insight to the futuristic automation

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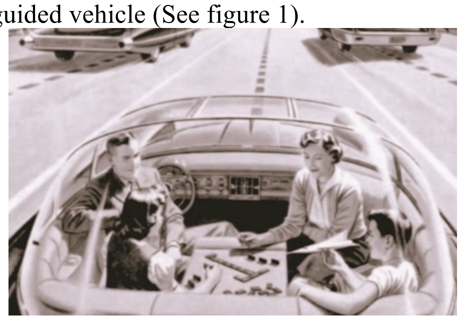
Abstract - Transportation is an integral part of our daily life. Present transportation condition mandates altering the face of motoring and delivering major assistances for road safety, social inclusion, toxic emissions and congestion. This has directed active research efforts to address these ever-growing momentous issues. Driverless vehicle technology has the potential to be a tangible propulsion amendment on the roads. The synchronized development of a combination of technologies has brought about this prospect. Developments in vehicle automation technology in the short and medium term is likely to move us closer to the ultimate scenario of automation which is completely "driverless". An illustration of autonomous technology is the production of current vehicles with adaptive cruise control and lane keeping technologies which allow the automated control of acceleration, braking and steering for periods of time in congested traffic. Advanced emergency braking systems automatically apply the brakes to help drivers avoid a collision. Self-parking systems allow a vehicle to parallel or Reverse Park completely hands free. The next step is the introduction of vehicles in which the driver can choose whether they want to drive or not. Present work, reviews the initialization in analyzing, understanding and developing a strategy to ensure to capture these potential benefits while maintaining excellent road safety record. The work documents the need and impact of an autonomous car on society through thorough evaluation of the socio-economic effect, the benefits and economic savings. Primary key controlling parameters viz., impact on safety, traffic flow, fuel economy, and professional driving culture are the important aspects discussed in this work. The results indicate that the self-driving cars presents encouraging prospective to make driving easier thus, allowing people to be more productive and offer greater mobility ever before. The technology will also help improve road safety, reduce emissions, and ease congestion. As a result, they could provide significant economic, environmental and social benefits.

Keywords - Driverless cars; sensors; embedded systems; safety, transportation.

1. INTRODUCTION

People drive their cars for multi utilities like work, to go shopping, to visit friends and to many other places. This mobility is usually taken for granted by most people and they hardly realize that transportation forms the basis of our civilization. Not having a proper transportation system costs people their safety, time and money. Statistics details that developing countries contribute a significant part of world's accident deaths owing to driver's error. As the cities grow and the population increases, more traffic is generated which results in adverse effects like complicated road systems, ill managed costs, safety, time and money. This has necessitated the need for a more feasible option with more efficient, balanced and safer transportation system. The technological development offers an appropriate solution by the implementation of autonomous transportation systems. Autonomous Transportation System mostly works on the principle of "vehicle will do the thinking for us". An automated guided vehicle system (AGVS) is essentially equipped with well-placed sensors and offers possibility of reforming ground transportation.

Most prototypes that have been built so far performed automatic steering that were based on sensing the painted lines in the road or magnetic monorails embedded in the road. An autonomous car is fundamentally defined as a passenger vehicle that drives by itself or without human control. An autonomous car is also referred to as an autopilot, driverless car, auto-drive car, or automated guided vehicle (See figure 1).



(a)

(b)

Figure 1. Schematics of basic autonomous car setup (a & b).

The experiments to make an autonomous vehicle initiated as early as 1920. Significant experimental, computational, analytical and theoretical work had been done in the past which has contributed to the development of an autonomous guided vehicle. The reviews can be found in [1]-[8]. In 1953, Radio Corporation of America Labs successfully built a miniature car that was guided and controlled by wires. In 1977, the first known worthy attempt to build an autonomous vehicle was carried out by Tsukuba Mechanical Engineering Laboratory in Japan. The car functioned by following white street markers and was able to reach speeds of up to 20 mph on a dedicated test course. Following the appreciable advancement, the breakthrough in the development autonomous vehicles came in the 1980.The first self-sufficient and truly autonomous cars was introduced as vision guided Mercedes-Benz robotic van which achieved a speed of 39 miles per hour (63 km/h) on streets without traffic. In the same year, Ernst Dickmanns and his team build an autonomous prototype at Bundeswehr Universität München which was able to achieve 60 miles per hour on the roads without traffic. From 1987-1995, a Pan-European project entitled 'PROMETHEUS' was headed and the prototype car achieved speeds exceeding 110 miles per hour. Another important milestone in the history of autonomous vehicles was AHS's (Automated Highway System) revolutionary demonstration made in 1997 that included more than 20 fully automated cars. The demonstration was carried out on a California highway and completed without a glitch. This event stands as gaining the most media coverage of any Intelligent Transportation System activity in US. During the 1990s, the basic capability for car automation systems was demonstrated in Europe, Japan and the United States respectively by the PROMETHEUS program, AHSRA (Advanced Cruise-Assist Highway System Research Association) and AHS (Automated Highway System) program. The European projects were completely based on vehicle intelligence, while the Japanese developed systems that were highly vehicle-highway cooperative. The U.S. projects made use of both techniques in their autonomous vehicle systems. The 1990's projects were very immense and unique as the ASH program of US resulted in the mighty Demo'97 (figure 2). The project was abandoned after this demonstration because of being too long in scope of time. Around 2000 smaller and more private attempts emerged. These smaller projects were mostly shorts-coped, and more safety based. Before 2000 most car manufacturers seemed uninterested in building a fully autonomous car because the projects seemed to be very long scoped. In the last decade (2000-2003), advancement came in the form of sensor module for obstacle detection (vision system, medium and short-range radar, laser scanner, lasers) and a processing module for crash prediction (control unit). In 2011, GM created the EN-V (short for Electric Networked Vehicle), an autonomous electric urban vehicle followed by the "Temporary Auto Pilot" (TAP) system by Volkswagen that allow a car to drive itself up to 80 mph. In 2013, Toyota demonstrated a partially self-driving car with numerous sensors and communication systems. In 2015, Delphi Automotive car became the first automated vehicle to complete a coast-to-coast journey across North America [4-8].

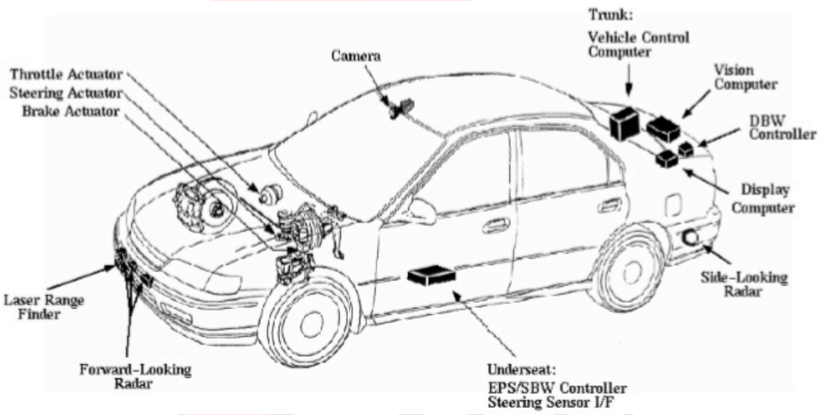


Figure 2: Placement of the test hardware in one of the cars used in AHS Demo'97.

All the big autonomous vehicle projects done in the 1980's and 1990's had been mainly funded by the governments of technologically leading countries such as USA, Germany and Japan. Now, the private sector is more involved in this area. Almost every car manufacturer has an autonomous car project or sponsors external projects. In the future, automated systems will help to avoid accidents and reduce congestion. The future vehicles will be capable of determining the best route and warn each other about the conditions ahead. Many companies and institutions are working together in countless projects in order to implement the intelligent vehicles and transportation networks of the future. Presently, researchers are using sensors and advanced software together with other custom-made hardware in order to assemble driverless cars. Most hardware used appears to be doing well in terms of reliability, response time and accuracy. It would be fair to say that the future of the autonomous cars mostly depends on the development of better artificial intelligence software. Although the prototypes seem to be very successful, a fully autonomous car that is reliable enough to be on the streets has not been constructed yet. The work is motivated by the need to have efficient, safer and reliable transportation. The specific issues in the present work are:

1. Difficulties involved in controlling a vehicle in the unpredictable traffic conditions.
2. Significant overdependence and important limitations of the artificial intelligence side of the research.

2. TECHNOLOGY IN AUTONOMOUS CARS

There is a wide range of technologies being used to implement autonomous vehicles. The most available are low autonomy systems that require some driver interaction. Sensors and equipment used in these low autonomy systems are steps toward a fully autonomous package for vehicles. Figure 3 shows the schematic of the control mechanism of an autonomous car consisting of three main blocks. The fundamental aspects are vehicle hardware viz., (SENSORS, LIDAR, RADAR OPTICS, GPS), Detection & Navigation, Motion Planning (Traffic), Actuation (Operates the mechanics of vehicle) and Autonomous Technology (figure 4).

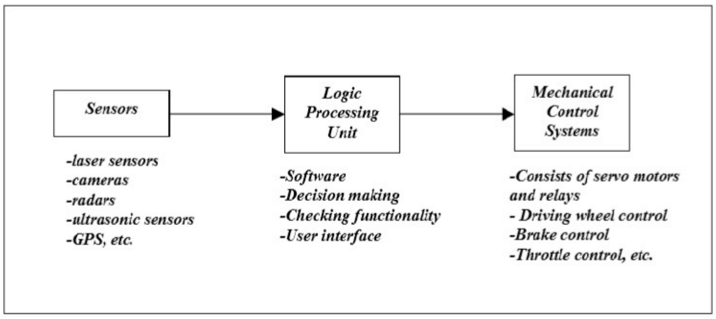
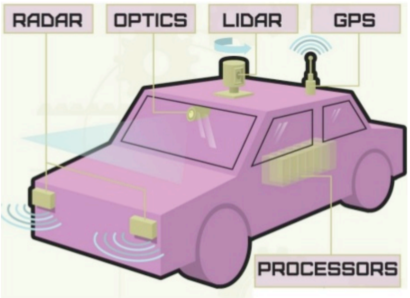


Figure 3. Basic block diagram.



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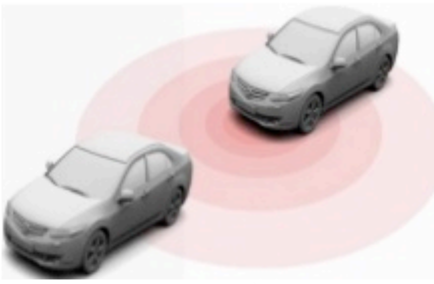

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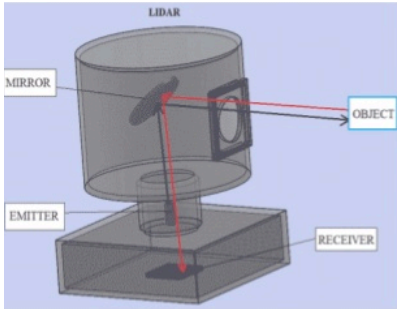

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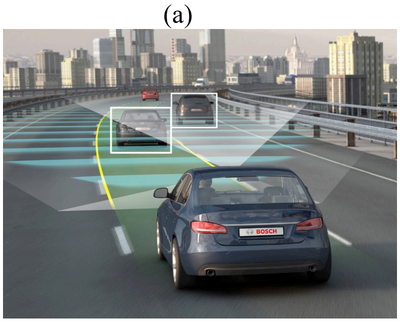

(d)

(e)

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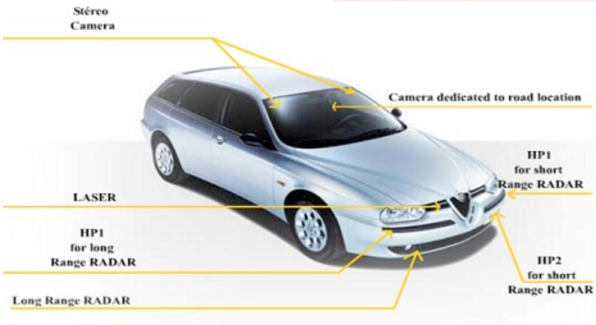
Figure 4. (a) Autonomous car sensons systems, (b) Radar, (c) Lidar, (d) external vehicle detection 'actinometer', (e) GPS, (f) wheel speed sensor.



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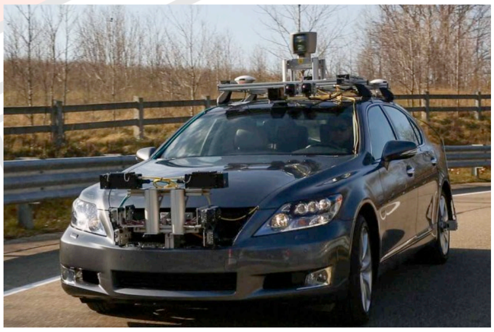
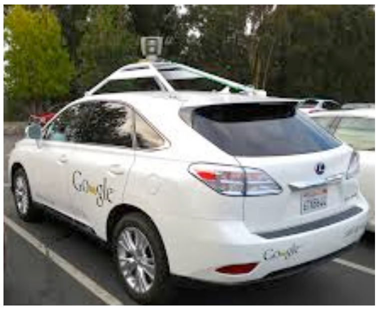


(b)

Figure 5. (a) An autonomous car prototype (b) A tested autonomous car.

A good automated guided car would need to implement a system that would enable vehicle to work fully-automated at lower speeds but with more complex driving tasks. These tasks include situations in dense traffic environments in and around urban areas that have traffic jams, tight curves, traffic signs, crossings and ancillary traffic participants such as motorbikes, bicycles or pedestrians.

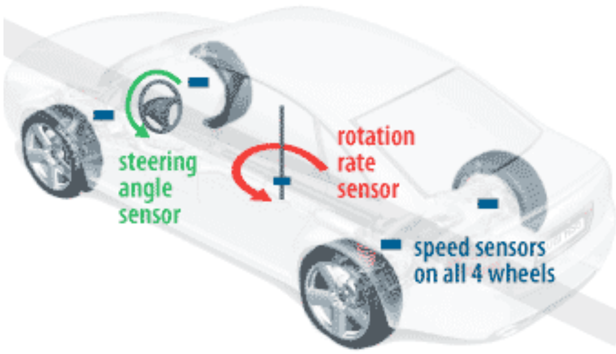
This type of a system is referred as a "Low Speed Automation" (LSU) system which take over the full control of the vehicle in congested stop-and-go traffic. A variety of sensors are used in order to increase accuracy which included short and long-range radars, laser telemeters, as well as vision and stereo vision devices. Figure 5 (a&b) shows an autonomous car prototypes with the sensors and their positions.

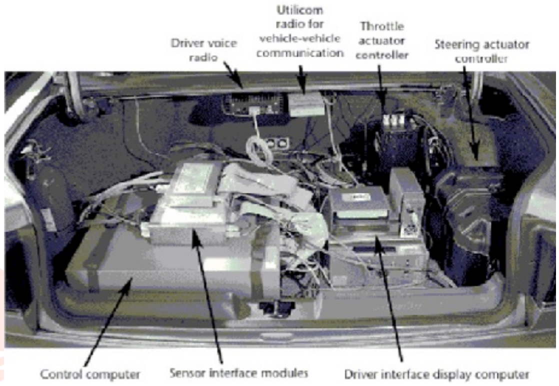


(a) (b)

Figure 6. (a) An embedded automated car (b) Google autonomous car.

Figure 6 (a&b) shows technological embedded and tested autonomous cars. An ECU (Electronic stability control) unit is utilized to gather sensor signal for decision making using a software code. Based on the information, ECU gives signal to the actuators, which in turn control the vehicle. Real time information of the surroundings is output to the user interface located inside the vehicle. ECU comprises of Wheel-speed sensors, Steering-angle sensors, Rotational-speed sensor and primarily contributes largely in improving vehicle stability by detecting and minimizing skids (figure 7).





(a) (b)

Figure 7. (a) Schematic of Electronic control unit, (b) Pictorial representation of ECU.

2.1 Mechanical Control Systems:

Designated control systems and sensors are used to control autonomous actions of the vehicle. The methods used for controlling the vehicle are broken down into lateral control and longitudinal control. The lateral controls focus on the steering, while the longitudinal controls help with the speed control.

2.1.1 Lateral Control:

A large part of the lateral control is keeping the vehicle in its chosen lane and on the road (figure 8). Current technologies are Lane Departure Warning Systems (LDWS), Lane Keeping Assist Systems (LKA) and Parallel Parking Assist.

Figure 8. Pictorial representation of Lateral control system.

2.1.1.1 Lane Departure Warning System (LDWS):

The purpose of Lane Departure Warning System (LDWS) is "to avoid run-off-road and sideswipe crashes and to support the driver in lane-keeping." In order to do this, the vehicle must be able to sense the lane and road boundaries, and where the vehicle is positioned in the lane. There are various methods being researched to perform this task, viz., embedded magnetic markers in the roadway, highly accurate GPS and digital maps, and image processing. The magnetic markers emit a magnetic field which could then be detected by sensors on the vehicle. This gives the vehicle a path to stay in, which is in between the sets of road magnets. Implementation requires embedding magnets in all the current roads which increases integration complexities thus difficult to implement. Another approach is to combine highly accurate digital mapping of the roadway lanes with satellite positioning accuracies in the order of 0.5m or better. This method requires detailed digital maps and extremely accurate GPS to see whether the vehicle is inside the lane on the map. This small lane may cause the drivers to be very cautious and drive slow during the commute. In lately, the best way for everyday driving has been determined to be the use of image processing. This detects existing lane markers to create a virtual lane in the video camera (figure 9).

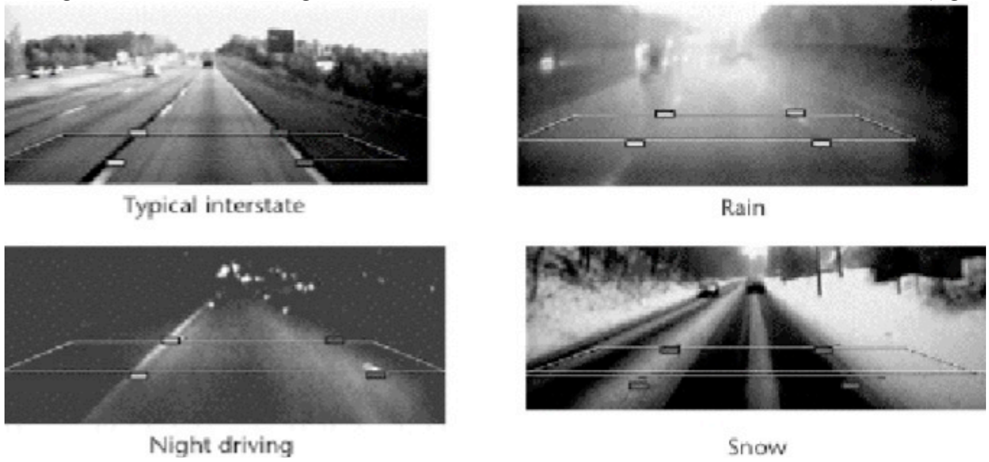


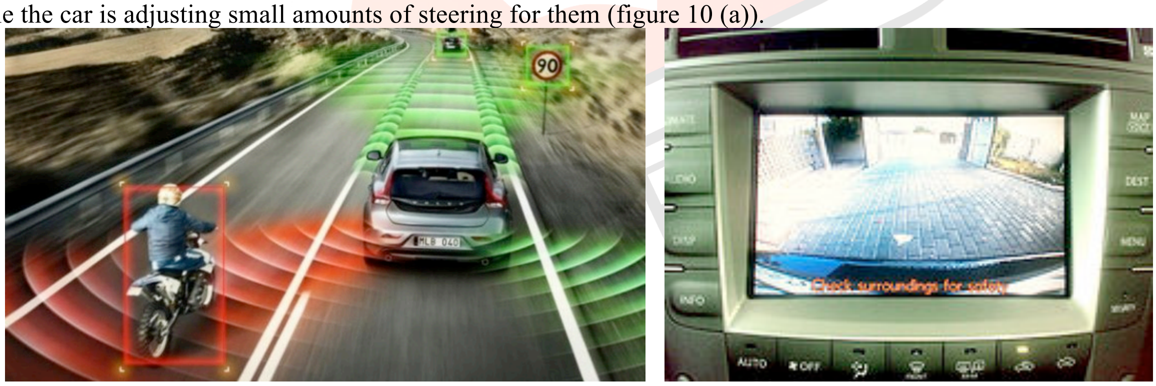
Figure 9: Views of an autonomous car in diverse conditions.

The approach relies on the predominant use of a monochrome video camera and image processing to extract the lane and road edge markings from the image. The downside of this method is that the road markings are not always clearly displayed viz., snow, worn down, or difficult for the camera to see because of highly reflective road conditions.

This is counteracted by using special detection algorithms that can even detect tire lanes. There are still issues where the system may become confused or the ability for the camera to transition between drastically different lighting. All these systems provide a range of warnings from audible beeps to physical feedback to the driver to alert them that they are departing the lane.

2.1.1.2 Lane Keeping Assist System (LKA):

The Lane Keeping Assist System (LKA) is used as a convenience product for the driver of a vehicle. When driving on a highway, there are small adjustments that need to be made to the steering in order to stay in designated lane. The LKA helps by providing small amounts of actuation to steering to keep the driver in their lane. While driving on the highway, the amount of torque that is necessary to turn the wheel is a very small amount. Because of this, it makes it very easy for any driver to override the assistance provided by the system. There are on-board sensors that analyse different factors, such as Cross-winds, road surface geometry, detection of the current lane and curves. These sensors include radar, LIDAR (laser radar), ultrasonic range finders, and image processing with video cameras. One problem for this system is the ability for the driver to remain alert while the car is adjusting small amounts of steering for them (figure 10 (a)).



(a) (b)

Figure 10: Pictorial representation of the (a) Lane Keeping Assist System (LKA), (b) Parallel Parking Assist.

2.1.1.3 Parallel Parking Assist:

Parallel Parking Assist systems are currently available from automobile manufacturers for public use. The first system was introduced by Toyota in 2003. This incorporates the rear-view camera to help with parallel parking assist. The user pulls past the spot they wish to park in, engages reverse, and then using the dashboard screen which displays what the rear-view camera can see the driver moves a box over the spot they wish to park in (figure 10 (b)). After making confirmations, the driver must control the braking and acceleration, but the vehicle will do all the steering to back into the spot successfully. The user must then engage the drive gear again to pull forward and finish the parallel park. This system provides a convenience for users in cases where parallel parking may be difficult.

2.1.2 Longitudinal Control:

Longitudinal control encompasses the forward and reverse directions of the vehicle. It has applications to control the speed of the vehicle and assist the driver with forward and reverse driving tasks. These applications include rear sensing to assist with parking, Adaptive Cruise Control (ACC), and pre-crash break assist.

2.1.2.1 Rear Parking Assist:

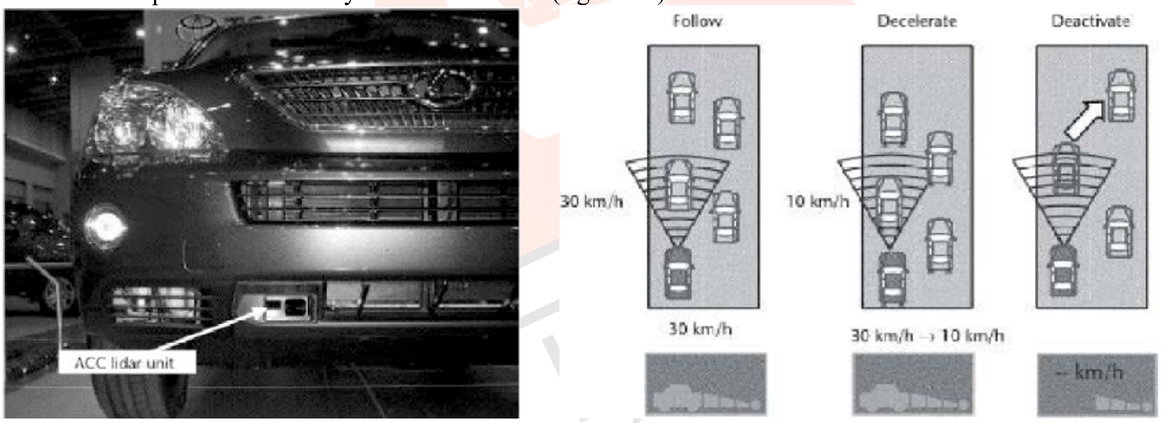
There are many systems currently available to assist the driver with parking. The most common is the use of ultrasonic range finders embedded in the rear bumper of the car that give the driver a changing audible sound as the distance decreases.

Figure 11: Autonomous car with rear parking assist.

Innovative devices include rear facing video cameras that display what is seen from the rear of the vehicle when the driver shifts into reverse. Along with the video processing, there is an overlay of guide lines that guide the driver into the spot and tells them when to stop. Also, the use of radar in similar systems is being developed (figure 11). It is more accurate than the ultrasonic range finders and allows for greater application. The downside to these devices is that they only work in very short range, that of only a few meters.

2.1.2.2 Adaptive Cruise Control (ACC):

Adaptive cruise control is used to aid the driver in driving by controlling the speed at which the vehicle moves relative to the vehicles in front of it. There are a variety of ACC systems such as high-speed ACC, low speed ACC, and full ACC. Different sensors can be used to provide an ACC system to the driver (figure 12).



(a) (b)

Figure 12: Pictorial representation of the (a) ACC Sensor Location, (b) Schematic of the Low Speed ACC.

Full ACC is a combination of high and low speed ACC and step toward autonomous speed control. The system could be activated and adjusts between high speed highway driving and low speed traffic or city driving. This allows the driver more freedom to concentrate on steering and conditions around the vehicle. Pre-crash brake assist uses ACC to detect possible collisions by calculating the speed at which a driver is closing in on an oncoming object. If the rate is high enough, the system will pre-arm the brakes so optimum braking can be achieved. This helps to reduce stopping distance and speed of impact.

2.2 Full Autonomous Systems:

In order to achieve a fully autonomous passenger vehicle, there must be seamless integration of both lateral and longitudinal control systems. They must be developed to the point that the community can trust the systems to be reliable. Automated public transportation is currently available using rail systems such as subways, streetcars, or trains. The initial fully autonomous system in production is a low speed version which is a combination of low speed ACC and lane keeping assistance. The system is efficient for use in highly congested traffic as it provides the vehicle with information about the road ahead such as safety alerts or traffic details. In the development of autonomously driven vehicles for public transportation, ultrasonic sensors are used to detect any objects around the perimeter of the vehicle.

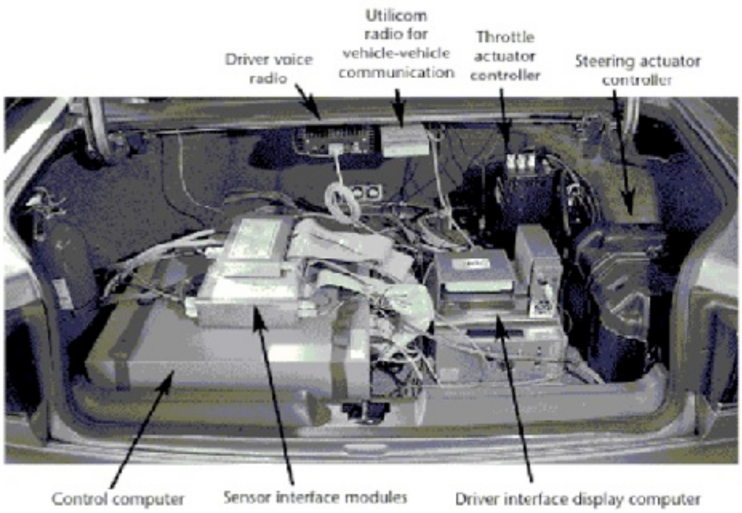


Figure 13: Equipment for Autonomous Operation.

3. IMPLICATIONS OF DRIVERLESS CAR

The review of the automated guided vehicle technology and its considerations, one can import useful insight about the futuristic role of autonomous technology in transportation. Modern transportation is a very fast evolving sector, which is highly associated with new technologies and has a very important role in the world. Autonomous vehicle systems are one of the research areas in the transportation sector that shows great potential for development. There is no doubt that vehicles are getting smarter every day. In present time, the technology is changing so fast that it is hard for people to adapt to it. Making educated guesses about the future developments and determining their possible outcomes helps people understand and prepare for these changes. Therefore, it is important to determine possible outcomes of the implementation of autonomous vehicle technologies. The investigation of the possible impacts of the implementation of autonomous vehicles on the society can be stated in terms of substantial rewards and shortcomings.

The important advantages are:

a) Savings in professional driving.
b) Enhances safety by avoiding accidents.
c) Contributes Economically in growth.
d) Better fuel economy and maintenance.
e) Efficient and well-organized management of traffic flow to increase road capacity.
f) Time saving by Relieving vehicle occupants allowing them to concentrate on other tasks
g) Automatic parking with Less space requirement.
h) Simple transportation system as no need to gain a driving license and even disable would be able to drive.
i) Easily trackable using G.P.S.

The following are the important disadvantages:

a) Over internet dependence from the hackers' point of view in some cases the vehicle can be switched off on the road.
b) Hackers can change the rout which is plotted in the system.
c) In case of failure of main and backup sensors the vehicle can create a chance of accident.
d) Likely to be extremely expensive, and therefore most people won't be able to afford them.
e) May create a wave of unemployment.

4. FUTURE OF AUTNONOMOUS CARS

a) IEEE predicts 75% of vehicles to be autonomous by 2040.
b) GOOGLE driverless car in market by 2018.
c) First fully autonomous cars by major Automobile companies TOYOTA, NISSAN and FORD by 2020.
d) TESLA announced fully Autonomous cars by 2018 and duly approved by 2021.
e) INTEL predicts autonomous cars by 2022. Hoping to equip autonomous cars.
f) JAGUAR and LAND ROVER to provide fully autonomous cars by 2024.
g) UBER expects fleets to be driverless by 2024.
h) Most Insurance Think Tanks expects Truly Autonomous cars to populate roads by 2028-2032.

5. CONCLUSIONS

Research indicates that the transition to an automated transportation structure will greatly prevent many problems caused by the traffic. Implementation of autonomous cars will allow the vehicles to be able to use the roads more efficiently, thus saving space and time. With having automated cars, narrow lanes will no longer be a problem and most traffic problems will be avoided to a great extent by the help of this new technology. The traffic patterns will be more predictable and less problematic with the integration of autonomous cars. Smooth traffic flow is at the top of the wish list for countless transportation officials. It is important to note that most government officials and scientists see the future of transportation as a fully automated structure which is much more efficient than the current configuration. All developments show that one day the intelligent

vehicles will be a part of our daily lives, but it is hard to predict when. Car manufacturers are already using various driver assist systems in their high-end models and this trend is becoming more and more common.
Since these assist systems are very similar with the systems that are used in autonomous car prototypes, they are regarded as the transition elements on the way to the implementation fully autonomous vehicles. As a result of this trend, the early co-pilot systems are expected to gradually evolve to auto-pilots. Currently, there are many different technologies available that can assist in creating autonomous vehicle systems. Items such as GPS, automated cruise control, and lane keeping assistance are available to consumers on some luxury vehicles. The combination of these technologies and other systems such as video-based lane analysis, steering and brake actuation systems, and the programs necessary to control all the components will become a fully autonomous system. The most important factor is whether the public sector will be proactive in taking advantage of this capability or not. Because of this, there must be research and testing done repeatedly to assure a near fool proof final product. The product will not be accepted instantly, but over time as the systems become more widely used people will realize the benefits of it. The implementation of autonomous vehicles will bring up the problem of replacing humans with computers that can do the work for them. There will not be an instant change in society, but it will become more apparent over time as they are integrated into society. As more and more vehicles on the road become autonomous, the effects on everyday life will be shown. It will result in an increase of the efficiency of many companies as less time is wasted in travel and less money is spent on tasks autonomous vehicles can perform where a human was previously needed. This may also cause the loss of thousands of jobs all over the world. There would have to be a plan in place before society would allow this to happen. This is an important reason behind the lack of interest and slow development of fully autonomous vehicles. As a result of the study it can be concluded that:

a) Driver less car technologies improves vehicle's stability helps to minimize loss of control.
b) Driver less cars are designed to minimize accidents by addressing the main causes of collisions: driving error, distraction and drowsiness.
c) Expected to add a new dimension to automation with maximization of benefits and minimization of losses.

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