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RECENT DEVELOPMENTS IN THE AUTOMATION OF CARS- A REVIEW

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***Abstract*— Vehicular automation can be defined as the use of technology in a vehicle in such a way that it can assist the driver in the best possible way by reducing his/her mental stresses. The present world is accepting the rapid changes in the technology and trying to apply it in the real world. Hence, the automobile industry is keenly interested in improvising with the dynamic features of a vehicle by using the new technology. Modern day cars such as Mercedes Benz S-class, BMW 7 series etc. are equipped with such automated systems. Vehicles at present are semi-automated: fully automated vehicles are under development and testing and will take time to be available commercially. Passengers comfort and wellbeing, increased safety and increased highway capacity are among the most important initiatives counted for automation. Adaptive cruise control, intelligent parking assist system, automatic parking etc. are systems which are embedded in the cars to assist the drivers while advanced automatic collision notification, pre-crash systems, automatic night vision with pedestrian detection etc. are the systems which are being used to safeguard the people in vehicle and on road. The following paper is a review which takes into account the various automated systems which are being used in the modern cars and shows how the automobiles have evolved with technology.**

***Index Terms*— Automation, Cars.**

I. INTRODUCTION

The efficient movement of goods and people is very crucial for modern world's operation. Modernization led to many changes including increase in the number of automobiles on road. More numbers of automobiles means more traffic, pollution (air and noise) and enhanced chances of accidents and fatal injuries. For example- rear end collisions account for approximately 1.8 million crashes annually i.e. 28% of all crashes [1]. While a report says that in 2012, human drivers killed 1,754 people in Britain [2]. Automation started in 1930, in the late 1980s and the 1990s, state and private funded programs started more focused research in the United States, Europe and Japan to bring the virtual idea of automation or the intelligence systems into the real world [3]. During this period the focus was mainly on the advanced highways which latter gave opportunities to think and work on the automation systems.

Until recently, automotive safety focused on reduction in the damaged caused by the collision but now, the scenario is changing, mitigation is simply not enough. The car industry has now become software oriented and the advanced driver assistance systems (ADAS) are engineered to eliminate the physical as well as the psychological after-effects of a collision by eliminating the possibilities of causing the collision. In the 21st century, various automobile companies are focusing on applying the newly advanced intelligent systems in their cars, in order to assist the drivers while driving as well as to safeguard the passengers travelling in the cars, systems such as adaptive cruise control, advanced automatic collision notification, intelligent parking assistant system, automatic parking, precrash system, traffic sign recognition, distance control assist, dead man's switch, anti-lock braking system(ABS) and many more. These are based on the intelligent sensor technology which constantly monitors the vehicles surroundings as well as the driving behaviour to detect potential dangerous situations at early stages. In critical driving situations, these systems warn and actively support the driver and if necessary, intervene automatically in effort to avoid a collision or to mitigate the consequences of the accidents. The National Highway Traffic Safety Administration (NHTSA) has classified the vehicular automation into five levels which are as follows:-

a) Level 0:- It is also termed as no-automation level in which the driver/user is in full control of the systems of the vehicle.
b) Level 1:- This type of automaton includes the control over a specific function i.e. one of the automated systems is being controlled by the technology while others by the user. For e.g. Cruise control, pre-crash system etc.
c) Level 2:- This involves the automation over two primary functions of the vehicle which work simultaneously. For e.g. Adaptive cruise control working in combination with lane centering.
d) Level 3:- It is a limited self-driving automation system in which the driver is not expected to monitor continuously and has the authority to give up the primary controls in certain conditions only.
e) Level 4:- It is the fully automated system in which the driver does not have to take control throughout the ride. The vehicles performs all the safety-critical driving functions. Driverless cars are being recognized under this level. Example, Third generation Google car.

This paper provides a review of the most advanced automation systems fitted in the passenger cars with their impact on the comfort, safety and highway capacity. The advantages and the limitations of each system are explained under respective topics.

II. AUTOMATED SYSTEMS

a). Pre-Crash System

It has been observed that most of the crashes occur due to unawareness of the driver while driving and inadequate safety precautions. Insufficient attention to the road ahead and inadequate safety precautions account for as much as 54% of frontal crashes [4]. Furthermore , traffic accidents analysis results also indicates cases where no accident avoiding manoeuvres such as braking and steering are performed at the time of accident account for approximately 40% of the frontal crashes [4]. Therefore a system must be developed which would assist the drivers and help in reducing the accidents.

A pre-crash system is designed which is responsible to detect any object in front with the help of radar and avoid the collision by notifying the driver to take appropriate actions. When the pre-crash sensor detects any obstacle in the front, it determines whether the collision is unavoidable or not on the basis of three factors i.e. location, speed and course. If it is unavoidable, the pre-crash belts ejects out before crashing using a motor to protect the passengers. A test was conducted in which a car was headed on fixed barrier at a speed of 55 km/h and the chest displacement of the occupants was recorded considering that the occupants wore the seat belts and it was compared with a case in which pre-crash belt was not used. The result stated that the displacement reduction effect of approximately 40mm can be achieved [5].While the pre-crash brake assist applies the pressure on the brake pedal to improve the braking performance.

One of the earliest uses of accident detection was Mercedes-Benz pre-safe system in 2003 S-class sedan which can sense a collision few seconds before and take pre-crash protective measures. Development of these types systems needs to be fine-tuned as any malfunctioning in the system may distract driver's attention and can cause accident. BMW in 2012(7series), Cadillac in 2012, Ford 2009(Taurus), Honda 2003(Inspire and Acura) etc. implemented this technology.

b). Adaptive Cruise Control

Cruise control was invented by a blind but a creative inventor Mr.Ralph Teetor in 1945 which has now become the most important system and is accepted globally. The system was first introduced in 1958 with Chrysler models such as Imperial, New York and Windsor and by 1960 all Cadillac were offered with cruise control. Today many automobile companies like Mahindra & Mahindra, BMW, Mercedes Benz, Audi etc. are providing this feature in their cars as a mean of safety. Cruise control is a system which is used to maintain the speed of the vehicle according to the speed set by the driver. When the driver activates the cruise control, certain systems take the control over the throttle valve as well as the brakes to control the speeds. The system gets disabled once the brake or clutch pedal is pressed.

Adaptive cruise control (ACC) is the advanced form of the cruise control in which the vehicle adjusts its speed depending upon various factors affecting it. Suppose a vehicle equipped with ACC is moving with a speed of 100 Kmph and an another vehicle is moving with a speed lower than the ACC equipped vehicle, then it will slow down its speed so as to maintain a safe distance and vice versa. This system uses either the laser or radar sensor to slow down the vehicle approaching the leading vehicle and again accelerate to preseted speed by tracking the speed and distance of the leading vehicle. . The advance system can measure up to 150m ahead of a car and reduces the cars speed if an obstacle appears. Around 17% of European built cars are likely to have ACC fitted as standard [6]. Various automobile giants are using this technology in their cars for example BMW {5series (2007+), 7series (2009+), X5 (2011+) etc.}, Audi {A8, A7 (2010+), A6 (2011+)}, Mercedes-Benz {S (2006+), B, E, CLS, CL (2009+), A etc.} and many more.

The advantages and disadvantages of ACC are as follows:-

Advantages:-

1. The driver is relieved from the task of careful acceleration, deceleration and braking in a congested traffic.
2. A highly responsive traffic system that adjusts itself to avoid accidents can be developed.
3. It helps in increasing the fuel efficiency of the vehicle.

Disadvantages:-

1. It encourages the drivers to be careless and hence lead to accidents if the system starts malfunctioning.
2. It is costly.
3. The ACC systems yet evolved enable vehicles to cooperate with the other vehicles and hence do not respond directly to the traffic signals.

c). Dead-Man's Switch

A dead-man's switch is a safety device which is used to stop a machine or bring it in a safe mode when the operator becomes unfit due to death, loss of consciousness or by leaving the controls forcefully. It comes into the action automatically whenever a vehicle has suffered from an accident or malfunctioning. It is not only used in cars but also used in aircraft refuelling freight elevators, lawn movers, tractors, chainsaws, snow blowers, tread machines etc. It brings down the machine into control by either bringing the throttle to the idle position or by applying the brakes.

Dead-man's switch concept was first introduced with the launching of electric street cars in US but came into existence after the launching of PCC street car which had a left pedal operated dead-man's pedal in conjunction with the right foot operated brake and power pedals. There are many ways in

which the dead-man's switch can be styled. The operator must maintain the pressure on the handle grip to operate the machine. If the operator expires or does not feels ill, he/she releases the pressure and therefore the dead-man's switch comes into the play by turning the machine off by applying the brakes or bring the machine into the normal state by doing the same. This helps in preventing the loss of life and the property as well.

It has a great advantage that sometimes it makes the machinery very difficult to steal until and unless it is operated by some experienced operators as the thieves may find it difficult or impossible to start the machine.

d). Automotive Night Vision

According to the European Commission for automobile industry, nearly 50% of all accidents occur at night. Therefore night vision system is being designed as an optional technology which is provided in cars to assist the drivers as well as to safeguard the passengers from a crash in adverse weather conditions and at night (or low light conditions). The function of this system is to sense any vehicle or a pedestrian in front of a vehicle at a distance approximately 300 feet and display it either on the wind shield or the LCD (mounted on the dashboard) so that the driver can stop the car at a safer distance. The obstacles in the path are marked with certain warning signs (for example, red boxes). This system consists of infrared as well as thermal sensors mounted behind the grille of the vehicle. These sensors detects the IR waves or the heat to determine the distance of the object ahead. It is a fact that IR radiation cannot render human eyes, therefore it does not lead to dazzling phenomenon. Since the stopping distance of a car can easily be longer than 180 feet, it is clear that proper use of night vision can help to alert the driver to avoid certain collisions. Automotive night vision system can be combined with other safety technologies (for example, pedestrian protection system, Mercedes-Benz S-class).

Automotive night vision has been seen since 1988 but are equipped in the luxury cars only as it is quite expensive. The first automotive night vision was introduced by GM but many other automobile giants have done some tweaks to have their own versions of the system. For example, 2014 Audi A8 (instrument cluster), 2011 Audi A6 C7 (Instrument Cluster), 2005 & 2008 BMW 5series (navigation system), 2005 & 2008 BMW 7series (navigation system), 2004 Honda Legend (windshield), 2004 Mercedes-Benz S-class (C216) (instrument cluster) etc.

e). Electronic Stability Control (ESC)

Automobile manufacturers took a huge step in mid-90 in the field of vehicular safety by introducing electronic stability control (ESC). It is a system which uses several sensors to protect the vehicles from over steering, under-steering or skidding when the driver looses his/her control over the steering by either applying the brakes on of the tires or by adjusting the engine torque. It is a computer controlled technology which uses one or both of the above means to bring the vehicle back on track. The efficacy of ESC depends upon the traction between the road and tires as well as the profile of the tires (old, worn out tires) but it is independent of the environmental conditions. It is estimated that ESC will be present in 95% of the registered vehicles by 2029 (HLDA 2012). Though ESC helps in reducing or preventing the crashes but it creates complications in rebuilding the crashes for the Reconstructionist. Several studies have been presented, demonstrating the effectiveness of ESC in real life crashes. A Swedish study presented in May 2003 showed that there was a positive influence of ESC, especially in crashes on wet surface or surface covered by ice or snow. The effectiveness ranged between 20% and 40%, all being significant [7].

ESC was first introduced in 1995 by three manufacturing giants i.e. Mercedes-Benz (supplied with Bosch) in S600 Coupe, BMW (supplied by Bosch and ITT automotive) in 7series and Toyota in Toyota Crown Majesta while the other companies who started using this technology are Honda, Suzuki, Ford, Ferrari, Mitsubishi etc.

f). Blind Spot Monitoring (BSM)

Blind spot monitoring (BSM) is one of the safety adding technology which is used by almost all the automakers in their cars to warn the drivers about the presence/passing of any vehicle in their blind spot. It was invented by Platzer and incorporated into various products associated with ford motor company.

It is usually noted that a driver is not able to watch the area above as well as behind the shoulder height which is termed as blind spot. The cameras or the radar sensors are placed below the left and right rear view mirrors and inside the rear bumper. They sense the presence/passing of any vehicle from behind in the adjacent lane (in the blind spot) which try to overtake the vehicle equipped with BSM. The warning can be indicated in following three ways:-

- By beep/sound
- Light on the outside door mirrors
- Vibrations on steering wheel

The intensities of the above warnings depend upon the operation of turning lights. If the turning lights are on than the volume of the sound is louder, the frequency of blinking of light increases gradually or the intensity of vibrations increases and if the turning lights are off than the intensities of the warning signs are minimized automatically. In modern vehicles, the clear views of rear and side ends are displayed on the LCD screen of the infotainment system which provide an additional help to the driver. The use of BSM depends upon driving conditions. If the driving capabilities of the driver are excellent than BSM is of no use. But if the driver is at learning stage or get easily distracted by any means than BSM is worth it. Many automakers who are providing this technology are Volvo, Mazda, Ford, Toyota, Mitsubishi and many more.

g). Advanced Automatic Collision Notification

Advanced automatic collision notification (AACN) is the successor to the automatic collision notification (ACN). The automatic notification system was initiated in October 1995 with the first installations of ACN in vehicles starting in June 1997 [8]. The system helps to determine if the motorist needs care at a trauma centre after an accident or collision and also determines the severity of the accident. OnStar a subsidiary of General Motors is among the few AACN systems. Systems in the past used the cell phones Bluetooth connectivity to place a call to the operator/advisor after crash but the advanced present system like OnStar is embedded with the infotainment system of the car and doesn't need any cellular connectivity. The earlier AACN system was actuated after the air bag had deployed in a crash thus was not very reliable. The present AACN systems make use of various sensors situated all over the vehicle and calculate the crash severity, change in velocity of vehicle during crash, the direction of impact force and its magnitude, whether the vehicle suffered multiple impacts or had roll over. It also senses whether the passengers wore seat belts during the collision. Whenever a crash occurs, AACN sends telemetry data to the telematics service provider answering point. The data consists of information about the type of vehicle, the collision and the location of the vehicle (located by GPS). The severity of the crash is then found and immediate help is provided on site as soon as possible. The data helps to quickly determine the appropriate combination of emergency personnel, equipment, medical facilities etc. needed. A connection is set up between the advisor and the vehicle after crash where the advisor can talk to the victim and if no response is recorded from the victim side the data can be sent to the public safety answering point (PSAP) and further help is provided. The accuracy of the data regarding the injuries and its severity can be improved if the sex and age of the passengers are known.

h). Intelligent Lighting System

Lighting system is used in cars to provide light whenever needed. The Headlights and taillights are important lighting systems incorporated in cars. Headlights illuminates the road ahead of vehicle during night, fog etc. and taillights warn the driver of the vehicles ahead of him and help him to understand how far the vehicle is and whether it is stopping. It is required that whenever a vehicle is driven at night the headlights must illuminate the road ahead at a sufficient distance and the light must be of high intensity. Whenever another vehicle approaches in the opposite direction with high beam the drivers experience glare which may reduce the ability to see the road and in turn may lead to accidents.

To reduce the above stated effects intelligent lighting system is used in cars. In intelligent lighting system the car may detect the headlights and taillights of the traffic and may automatically switch between high beam and low beam. Sometimes the light from the headlamps may be redirected in accordance with the steering angle and vehicle speed (e.g.: Intelligent Adaptive Front lighting system). Sometimes the cars are fitted with cameras that detect the oncoming traffic. Whenever a vehicle is detected the car automatically adjusts its lights and darkens the area that the coming vehicle is in, also it detects the speed of the oncoming vehicle and the system remains in action till the vehicle passes by. This reduces the glare on the driver eyes and thus reduces chances of accidents promoting enhanced vision during night. The system may also detect pedestrians and the road signs and illuminates them from a safer distance so that the driver can notice them. In 2010 the first all LED headlamps with adaptive high beam and intelligent lighting system was used on Mercedes Benz CLS Class. Mercedes Benz uses multibeam intelligent lighting system in their cars namely S Class and Audi uses technology called the Matrix Lighting system.

i). Intelligent Parking Assist System

Intelligent parking assist system (IPAS) or advanced parking guidance system (APGS) was developed by Toyota motor corporation in 1999 for hybrid Prius and Lexus models. It is a driver assisting technology in which a vehicle can park itself by calculating the required steering angles according to the available space with little input from the user. Initially, the system was equipped in Prius hybrid in japan in 2003 (commercially). Then an upgraded version of the system with a new system of automatic parking was introduced.

The first version of the system assisted in reversed parallel parking which didn't require the involvement of driver. The cameras are located at the front and rear ends helps to calculate the size of the available space for parking and sends the information to an on board computer and thus the vehicle gets park on its own when the driver presses the 'SET BUTTON'. It had some drawbacks such as difficulty in detecting pedestrians, baby prams, cats etc. and problem in parking the vehicle in smaller spaces. This gave birth to a new version of the system which consisted of sonar park sensors placed on the front side fenders while the multiple sensors on front and rear bumpers responsible for detecting the objects. These sensors are connected to a central computer with a backup camera to provide sufficient information to the driver. As soon as the vehicle is shifted to reverse gear, these sensors come into action and allows the driver to activate the system through the LCD screen. When the system is activated the processor gains full control over the steering by calculating required steering angles so as to park the vehicle in the selected space. In order to warn the driver, red lines are indicated with the warning sounds otherwise the green boxes are indicated if everything goes right according to the calculation.

Hence, this system helps people to park their vehicle conveniently and intelligently by saving time and reducing the stresses. Many manufacturing giants are providing this system such as Toyota, Mahindra, Lexus, and Jaguar etc.

j). Traffic Sign Recognition System (TSR**)**

Traffic sign recognition system is a warning and alerting system for the driver. It is equipped in cars to recognize the traffic signs such as speed limit, U-turn, no entry, stop etc.

The earliest versions of TSR was developed in cooperation by Mobeleye and Contenintal AG which was responsible to recognize speed limit signs only. They were equipped in BMW 7series in late 2008 while for Mercedes Benz S-class in 2009.

One passes through many traffic signs on a road which cannot be recognized by human eyes rapidly due to some considerable reasons such as bad weather or due to congested traffic conditions. This issue is eliminated by TSR system. A camera is fitted in the mirror base which recognizes the various traffic signs and displays them in the instrument cluster panel. This information is sometimes gathered with the help of navigation system also. The system is equipped with an aging algorithm in which the recently detected signs appear lighter and the colour becomes darker gradually till it becomes gray and finally gets disappeared. This helps the driver to be aware of the changes in real time.

Various cars in which this system is installed are BMW 5series, Ford Focus, Honda Civic, Volvo S90, Renault Escape, Nissan Pulsar, and many more.

k). Driver Monitoring System

Driver monitoring system (DMS) or Driver attention monitor is one of the safety systems equipped in a vehicle which was first introduced by Toyota in 2006 for its and Lexus models. The system works with Pre-collision system and is responsible for monitoring the driver's attention. A recent estimate by the National Highway Traffic Administration (NHTSA) shows a 10.4% increase in US roadway fatalities in 2016. This is the result of drowsiness, fatigue, bad health or distraction. According to report, 20% of all accidents in Australia are caused by monotony and fall in the categories of fatigue and inattention [9]. In order to reduce the number of fatalities all over the world, DMS was invented which constantly monitored driver's attention through the infrared LED sensors placed just behind the steering wheel. They are capable of eye tracking. When a driver distracts and does not pays attention on the road, the software alerts the driver by either flashing lights in the in the instrument cluster panel or by certain sounds. If still the driver does not react to the warning signals than the system automatically applies the brakes and brings the vehicle at rest.

ABI research forecasts that the global market for driver monitoring system will reach 64.8 million units by the end of 2020. Many manufacturing giants have developed their own versions of DMS which are as follows:-

- Mercedes-Benz attention assist
- Ford driver alert
- GM-eye tracking
- Volvo driver alert control and driver state estimation
- Skoda fatigue detection
- Toyota driver monitoring

l). Dynamic Steering Response

Dynamic Steering Response is a safety aided as well as the driver assisted technology which helps in improving the manoeuvrability of a vehicle by providing the precise steering control by adjusting the steering ratio according to the vehicle's speed and road conditions. It was launched with SEAT Leon CupraR and thereafter many manufacturers started providing this feature in their cars.

An electric motor is placed just above the hydraulic steering gear which works 2000 times per second to harmonise the steering power. The sensors sense the movement, speed and lateral acceleration of the vehicle as well as the road conditions and sends it to the electric motor in order to make the required changes in the steering force to assist the driver.

It increases the directional stability of the vehicle. It also helps to reduce the effort of the driver to steer the vehicle at heavy loads and diminishes the effect of road disturbances. Volvo, Audi are some of the giants which are providing their own version of the system in their cars.

III. SWOT ANALYSIS

Strength

a) Reduces driving efforts and hence the stress and fatigue
b) Prevents accidents by taking over the control and reduces the Causalities
c) May help to regulate the traffic
d) Controls the vehicle systems like engine, power output etc. and thus helps in saving the fuel

Weakness

a) Increases the cost of vehicle as it is expensive
b) Less reliable at present and needs more development and research
c) The technologies are complex and hence needs high end electronics making it difficult
d) Some are dependent on satellites and network connectivity which may lead to failure in remote areas.

Opportunity

a) Once successful may change the whole automation industry
b) Is a next step towards making vehicles and travelling more safe than ever before

Threats

a) May lead the driver into overconfidence increasing the risk of accidents
b) Drivers will completely rely on software and computers neglecting the reality
c) Electronics may fail anytime and neglecting the same will increase the risk of severe causalities.

IV. CONCLUSION

Today's cars have level 3 automation in which there is no need of continuous monitoring of the car's primary controls by the driver. The above discussed technologies are embedded in cars so as to assist the drivers, make the ride safe and utilize the highway space in an efficient way. Hence efforts are being made to achieve the level 4 automation to make cars fully automated or driverless cars in the future. Few organizations like Google, ford etc. are continuously working towards making cars fully automated. Some of the tests are found to be successful yet testing is in process to make them completely reliable. Thus more research and development is needed in cars to make them level 4 automated.

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