NEW TECHNOLOGY ON VEHICLES - The Path Toward Autonomous Vehicles

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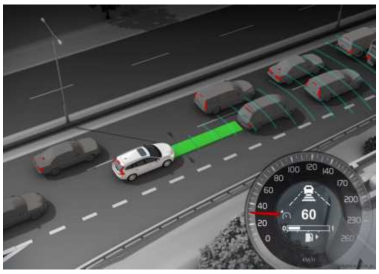
Introduction:

Whether driven by market forces, legislative ruling, or both, automotive technology has steadily evolved since the "horseless carriage" was first introduced over 100 years ago. Beginning first with improvements in comfort and reliability, followed by the addition of automated features and safety benefits, automotive technology has advanced steadily to the point where the once inconceivable is now a looming reality. The autonomous vehicle is here.

With such basic features as the automatic transmission and cruise control, both developed many years ago, to the most current production features such as Park Assist, Lane Departure Warning, and Preemptive Braking, the chronology of automotive advances makes clear that the collective of these automotive features is leading to the self-driving vehicle. A chronological review of vehicle technologies, both old and current, point the way to the autonomous vehicle. However, even the newest and best technologies can fail. As technology moves forward, those associated with the industry (automotive, insurance, legal) must have an understanding of what the technology is designed to do, how it functions as well as potential failure modes. The notes that follow are separated into four categories, Driver Assistance; Vehicle Assistance; Occupant Safety and Pedestrian Safety.

DRIVER ASSISTANCE

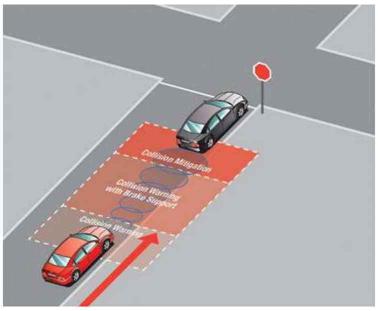
Adaptive Cruise Control (ACC)



Adaptive cruise control (ACC) allows your vehicle, through the use of forward-facing sensors, to mimic the motion of the vehicle in front of you. It will slow or accelerate your car as necessary to keep pace. This technology is referred to by a variety of names including active autonomous radar and intelligent cruise control. The user sets the cruise control to a maximum speed and, utilizing radar sensors, your car locks onto the vehicle in front of you. Then the user sets following distance according to seconds behind the lead vehicle. ACC systems are usually equipped with a pre-crash system that can alert you and, if necessary, initiate braking without your input.

This technology is a foundation for the development of self-driving vehicles. However, there are many obstacles that still need to be overcome. For example, extreme weather including fog, rain and snow decreases the effectiveness of the system, even to the point of a total system shutdown. Additionally, if the sensor becomes covered in dirt, snow or other substances, it will also result in the shutdown of the ACC system, i.e.- turning off the system. Another concern raised with regard to ACC is that current ACC does not adjust to changing speed limits. For example, if you enter a construction zone, the vehicle will not slow down for the temporary speed limit.

Forward Collision Warning or Forward Collision Alert System



Forward collision alert or crash avoidance systems utilize forward-facing sensors which oftentimes can be the same sensors used in adaptive cruise control systems. The sensors use radar, laser, or other technologies to provide data to map the area in front of the vehicle. After the data is received from the sensors, there are a variety of corrective measures a vehicle can employ. At a minimum, a vehicle equipped with forward collision alert will audibly and/or visually warn the driver of a large speed differential between their vehicle and the vehicle or obstacle in front that has been detected by the sensors. This warning may be in the form of a sound, flashing light, or vibrating steering wheel or seat. Along with a warning, the system can pre-charge the braking system. The pre-charge supplies the vehicle with more brake power the moment the driver depresses the brake pedal. More advanced systems can initiate a corrective measure such as applying the brakes and even bringing the vehicle to a complete stop. Other technologies are used in conjunction with collision avoidance systems such electronic stability control and anti-lock brake systems (ABS).

The level of safety that Forward Collision Warning technology can provide comes with minimal downsides. That said, one precaution that should be noted is that wet or slippery roads will reduce the ability of collision avoidance systems. As is the case with sensors used in other new technology applications, the Forward Collision Warning sensors, which are usually mounted behind the front bumper or grille, must remain clean for proper functionality. According to AAA Foundation for Traffic Safety, insurance data shows that the use of Forward Collision Warning has resulted in a 10-15% reduction in rear-end collisions.

Lane Departure Warning (LDW) or Lane-Keep Assist

A lane departure warning (LDW) system utilizes a camera mounted high in the windshield to detect road markings and to keep a vehicle centered in its lane. The camera creates a digitized image of the straight or dashed lines. Some cars, such as the Nissan Altima, include a rear camera as well. Much like Forward Collision Warning systems, this technology sends a warning to the driver when their vehicle is approaching (moving towards) the lane markings. The warning displays a visual alert, an audible sound, or a vibration (of the steering wheel or seat).

Similar to Adaptive Cruise Control, the more technologically-advanced systems will provide a corrective measure and allow the vehicle to automatically stay within its lane. Lane departure warning has limits to its effectiveness, especially during rain or snow. For the technology to be effective, a road must have visible road markings. If the particular system uses only one set of markings, it can potentially lead to false alerts. Also, most LDW systems do not operate at speeds less than approximately 30 miles per hour.
Relative to other technological advances, lane departure warning (LDW) systems are fast becoming one of the most affordable and available new types of technology found on new vehicles and through aftermarket outlets. There are now LDW systems available for approximately $1,000 that can be installed on older vehicles as

"aftermarket" equipment. Some newer GPS devices, such as the Garmin nuviCam LMTHD, have a built-in camera that is coupled with Lane Departure Warning and Forward Collision Warning alert systems.

Adaptive Headlights

Adaptive headlights, also known as Advanced Front-Lighting systems (AFS), react to multiple vehicle variables including steering, vehicle height, and speed. AFS's have the ability to turn and adjust to the angle of the headlights relative to the vehicle. When a vehicle enters a turn, adaptive headlights will illuminate the bend whereas traditional headlights will illuminate more of the shoulder. Rotation of the headlight is related to the speed at which the steering wheel is turned. A normal rotation range for an adaptive headlight is 15 degrees in each direction, for a total of 30 degrees of movement. During a study conducted by the Insurance Institute for Highway Safety (IIHS), drivers who were equipped with adaptive headlights recognized targets located inside of curves as much as a third of a second earlier, or about 15 feet sooner at 30 mph, than with regular headlights.

Adaptive headlights are not only a benefit to the vehicle operator, but also to other drivers nearby. For example, a rotated light can further indicate if a car ahead is drifting into your lane or making a turn. According to Highway Loss Data Institute research, adaptive headlights are responsible for a 10% reduction in property damage liability claims.

Backup Camera and Reverse Backup Sensors

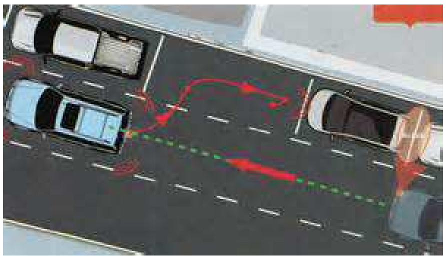
Beginning with Reverse Backup Sensors, this technology was first implemented in recognition of the dangers associated with reverse operation of a vehicle in proximity to people, particularly small children. The sensors are typically installed in the rear bumper cover and provide an audible alert that increases in frequency as objects get closer. Backup Cameras supplement this benefit by providing a direct view of the rearward scene on a display typically incorporated in the entertainment display. Many also have a visual guide that, along with the Reverse Warning Sensors, indicates the distance between the rear of the vehicle and objects behind it. Together with the vehicle mirrors, these new technological features help reduce rear blind-spots

Side View Assist/Blind-Spot Warning

Side View Assist/Blind-Spot Warning technology operates similar to the Reverse Warning Sensors but incorporates side-mounted sensors. Driver notification is typically accomplished via activation of a warning lamp located in the side-view mirror on the side of the potential hazard.

The Insurance Institute of Highway Safety (IIHS) estimated in 2010 that nearly one-third of the collisions which have occurred could have been prevented if all vehicles had forward collision warning, lane departure warning, blind spot assist, and adaptive headlights.

Parking Assist



Parking Assist Systems provide automatic, parallel parking assistance. These systems utilize the various sensors in the blind-spot mitigation systems discussed above, as well as another recent vehicle technology, Electric Steering Assistance. The Electric Steering Assistance system was first developed as a fuel-saving technology. It saves fuel by eliminating the traditional hydraulic power assist system which operates whenever the engine is running. However, Power Steering Assistance is only required at lower speeds, like low-speed turns and parking maneuvers. Electric Steering Assistance operates only when required, thus reducing fuel consumption. Electric Steering Assistance can also be programmed to self-steer. Together, with side and rear-mounted sensors, Electric Steering Assistance, and programming algorithms, Parking Assist temporarily takes control of vehicle steering, and other vehicle systems, in order to self-park the vehicle.

Heads-Up Display

Drawing from aviation technology, a Heads-Up Display provides basic, but important, driver information such as vehicle speed directly on the vehicle's windshield. The benefit of this technology is that it can reduce the amount of time that the operator's eyes are not focused on the road ahead. A common complaint however, is that the information displayed on the windshield can actually be a distraction to the operator's forward view of the road. Few car manufacturers utilize this technology.

Driver Fatigue Alert

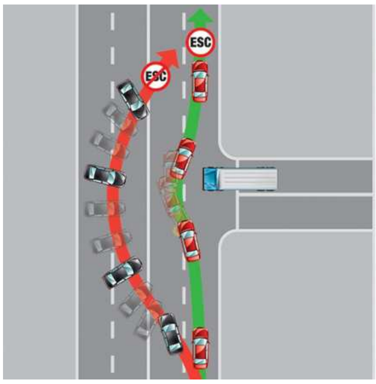
Driver Fatigue Alert is a relatively simple system that simply monitors trip duration and activates an audible and/or visual alert reminding the vehicle operator to take a break/rest. However, newer technologies can also monitor driver motion and, in particular, eye motion and position, and recognize patterns associated with driver fatigue.

VEHICLE ASSISTANCE

Anti-lock Braking System (ABS)

Anti-lock Braking Systems were, after Cruise Control Systems, among the first to temporarily assume vehicle control. The primary purpose of ABS is to help maintain directional control during periods of wheel lock during braking. Individual wheel speed sensors provide input to an electronic control module that continually compares wheel speed values during braking. Upon detecting variation, the system intervenes and individually applies and releases hydraulic pressure to restore braking balance. While the system is active, and as long as the driver continues to apply the brakes, the driver is "locked out" of the braking system. Once wheel speed balance is restored, driver input is also restored. This is why most owners' manuals instruct operators to maintain steady pedal application pressure and not "pump" the brake pedal, during ABS activation. Over time, and with increasing technology improvements, traditional antilock braking systems have evolved into Electronic Stability Control Systems.

Electronic Stability Control (ESC)



Electronic Stability Control (ESC) is a feature that detects and prevents (or recovers from) vehicular skids. ESC is designed to help prevent an operator from losing control of the vehicle on slippery roads and/or due to a sudden (panic) steering maneuver. ESC uses sensors in the vehicle (wheel speed sensors, steering wheel position sensors and yaw sensors) to determine which direction the driver wants the vehicle to travel and compares that to the direction that the vehicle is actually traveling. If the system senses that a skid is imminent or has already started (i.e., that the vehicle is not going in the intended direction), it can apply the brakes on individual wheels and reduce engine power in order to bring the car back under control. Because the system can brake individual wheels, whereas the driver can only brake all four wheels at once, ESC can recover from skids that a human driver can't. Some high-performance cars have ESC systems that are programmed to be more permissive, allowing the car to exceed its limits of traction and actually skid slightly before the system steps in and recovers from the skid. Even with ESC, it is still possible to lose control of a vehicle. Excessive speed, slick roads, and excessively worn or improperly inflated tires are all factors that can reduce ESC's effectiveness.

Different manufacturers refer to their ESC systems by their own names but the systems do essentially the same job. Other names include Electronic Stability Program (ESP); Vehicle Stability Assist (VSA); Vehicle Stability Control (VSC); Vehicle Dynamic Control (VDC); Dynamic Stability Control (DSC) and AdvanceTrac with Roll Stability Control. The Insurance Institute for Highway Safety touts the effectiveness of ESC noting that ESC reduces the risk of fatal single-vehicle collisions by 56% and fatal multiple-vehicle crashes by 32%. Because of its proven effectiveness, the US Government has mandated that all new cars manufactured by the 2012 model year be equipped with ESC.

Traction Control

A traction control system (TCS) is typically a secondary function of the ESC system that is designed to prevent loss of traction between the tires and the roadway. TCS is activated when throttle input and engine torque are mismatched to road surface conditions. When the traction control computer senses/detects one or more driven wheels spinning significantly faster than another, it invokes the anti-lock braking system to apply the brakes to the wheel(s) spinning with the lessened traction. Braking action on slipping wheel(s) will cause power transfer to wheel axle(s) *with* traction due to the mechanical action within the differential (i.e., *"transfers power from the wheels that slip, to the wheels that grip"*).

In many vehicles, traction control is provided as an additional option to Anti-Lock Braking Systems (ABS). Each wheel is equipped with a sensor which senses changes in its speed due to loss of traction. The sensed speed from the individual wheels is passed on to the electronic control unit (ECU). The ECU processes the information from the wheels and initiates braking to the affected wheels via a cable connected to an automatic traction control (ATC) valve. In all vehicles, traction control is automatically started when the sensors detect loss of traction at any of the wheels.

Rollover Prevention/Mitigation Systems

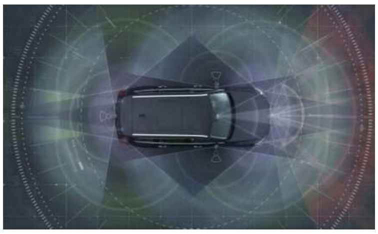
A rollover prevention system is an "intelligent" method that is intended to detect conditions that could lead to a vehicle rollover, and also ultimately prevent the rollover. Typically the systems have an accelerator that defines the vehicle speed and lateral "G"-force acting on the vehicle. A processor computes the center of mass of the vehicle relative to the lateral "G"-force produced while the vehicle is turning. If the "critical" speed of the vehicle during that turn is exceeded or if the turn radius is reduced beyond safety limits (indicating a potential rollover situation), an alert is produced. Then, using the various ABS, ESC, and other systems discussed above, the rollover prevention system activates any, or all of the systems as needed to control wheel speed, engine power, and wheel torque to prevent rollover.

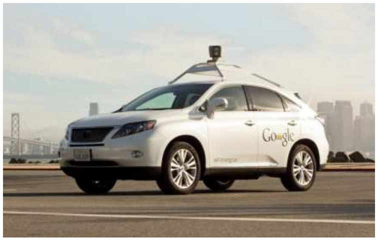
Automatic Crash Notification

Automatic Crash Notification utilizes built-in cellular technology, along with the occupant restraint system, and calls a monitoring center upon airbag deployment. Systems such as On-Star for General Motors and M-BRACE for Mercedes-Benz will attempt to communicate directly with the vehicle occupants while simultaneously notifying local first-responders. A key element to this technology is the capability to communicate the collision severity to first-responders so that they can respond with appropriate equipment and personnel.

Autonomous Vehicles:

Autonomous vehicles are vehicles that can take over the task of driving by maneuvering on roadways without human intervention. Technology which allows cars to drive themselves includes radar, lidar, cameras, ultrasonic, and infrared sensors. In addition, Global Positioning Systems (GPS) and inertial navigation systems (INS) can be used for localization. By using a combination of the various sensors and positioning technology, an autonomous vehicle senses the surrounding environment, plans its next movement, and acts accordingly.





In theory, autonomous vehicles will be able to detect any obstacles in the roadway (i.e., other vehicles, pedestrians, cyclists, debris, etc.) and then respond with the appropriate action to avoid a collision and reach the desired destination as efficiently as possible. Google’s fully autonomous vehicles (Lexus RX 450h SUV with autonomous driving technology added on) have logged over one million miles on U.S. public roads, with only about a dozen minor incidents (which appear to be the fault of other human drivers). Delphi engineers completed a cross-country trip using a 2014 Audi SQ5 equipped with a windshield-mounted camera to identify lane lines, road signs, and traffic lights, midrange radars on the front, back, and corners of the vehicle, two long range radars on the front and back, and two front corner lidars.

Potential obstacles for the autonomous vehicle include (but clearly are not limited to) dirt, rain, snow and ice which sometimes can prevent the sensors from gathering the appropriate data; sun or glare which sometimes can affect the sensors ability to discern the color of a traffic signal; the fact that the sensors detect objects as a pixilated shape thereby being unable to differentiate a human being on the roadway from a random piece of trash on the roadway; and, the fact that not all roadways have the appropriate lane striping and other markings necessary for the vehicle to safely traverse the area.

Fully autonomous vehicles are expected to be mainstream by 2040, with various automotive manufacturers planning on producing these vehicles in the next 5-10 years. Moreover, while fully autonomous vehicles are still being perfected and tested, many semi-autonomous technologies have been available for years (as noted in the preceding paragraphs). However, the biggest challenges that autonomous vehicles may face are public acceptance, cost of production, implementation, and liability.

OCCUPANT SAFETY FEATURES

Active Head Restraints

An active head restraint moves forward and upward in a rear-end collision to decrease the space between the restraint and the occupant's head. By doing so, the dynamic restraint reduces the degree to which the head accelerates before making contact. By reducing the acceleration, the potential of occupant injury is decreased. Active head restraints are devices typically applied to a vehicle's front seats, but can also be found in rear seats as well.

An active head restraint uses a lever-action mechanism built into a seat. The active restraint redirects the force of an occupant's body as it presses into the backrest to move the head restraint forward. The mechanism is designed to react proportionately to the occupant's motion. Unlike the type of pyrotechnic charge used in airbags and seat-belt pre-tensioners wherein the intensity is not governed by the individual occupant and therefore may be too high or low, the active head restraints' motion is dictated specifically by the occupant's size and weight and the severity of impact. Like frontal airbags, which normally only deploy during frontal or near frontal collision, active head retraints require rear, or near-rear collisions to activate. Also, like any occupant restraint system, a certain collision severity, or threshold, is required for activation.

Occupant-Sensitive/Multi-Stage Airbags

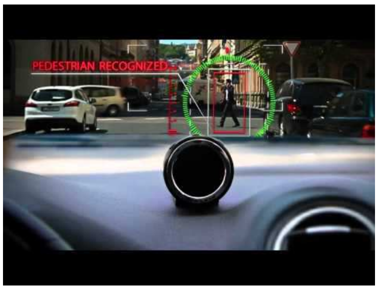
Early airbag systems had only a single level, or stage, of deployment, with each airbag having only one pyrotechnic charge. The size of that charge, and thus the force with which the airbag deployed, was chosen such that the airbags provided protection during a 35 mph barrier collision, as demanded by the Federal Safety Standards. One of the early problems however was that the deployment force was far too high for most lower speed collisions. This was particularly problematic for smaller-stature operators and passenger-side front seat occupants. Multi-stage airbags contain regulated pyrotechnic charges that deploy discriminately, depending on collision severity. For example, in the very earliest moments of a collision, the system may determine the need for airbag deployment. Once it does, it then determines if, or when, multiple airbag stages are required. The system may recognize immediately that all stages must be fired immediately. Other times, the system may deploy the first stage, then monitor the collision progression, then call for subsequent stages if needed, or simply stop at the first stage. Occupant-sensitive systems utilize weight sensors to "classify" the occupant to determine, for example, whether the passenger-side front seat occupant is a small child. Other systems utilize seat track position sensors to determine the distance between the driver and the airbag. Both systems incorporate this information into airbag deployment decisions.

Ducati Wirelessly Integrated Airbag Jacket

Ducati receives credit for the first production motorcycle to come with a wirelessly integrated airbag jacket. The Multistrada D-Air® system completes data analysis and airbag deployment inside both rider and passenger jackets in just 45 milliseconds. At 80 milliseconds, the jacket airbag is fully deployed. Although two-wheel safety has proven to be a difficult task, this technology makes significant strides towards advancing motorcycle safety. The jacket/motorcycle combo is currently only available for one model, the Multistrada 1200

PEDESTRIAN SAFETY

Pedestrian safety is enhanced by systems such as pre-emptive braking and impact force mitigation systems, such as exterior airbags. Preemptive braking utilizes frontal detection sensors and a vehicle's "brake-by-wire" system to automatically detect and respond to pedestrians. Impact force mitigation systems can detect the pedestrian impact and activate either an exterior airbag on the hood or at the base of the windshield, or elevate a portion of the hood to direct and cushion the impact force.



Many automakers are proposing/introducing Pedestrian Detection Systems. Ford's system is known as Pre-Collision Assist with Pedestrian Detection, while Honda named their system Pedestrian Collision Mitigation Steering System. These systems consist of a millimeter wave radar sensor in the grille and a monocular video camera in the windshield. These components sense the presence of pedestrians in front and alongside the vehicle. Unlike Ford's system, Honda's proposed system will also veer away from the pedestrian if the pedestrian is determined to be too close for braking alone to suffice. Volvo is viewed as one of the leaders in pedestrian detection technology. Numerous Volvo models come equipped with a pedestrian detection system, and Volvo estimates a reduction in the number of pedestrians killed by more than 20% and seriously injured by 30%.There are some cautions worth mentioning.

There are certain situations that make pedestrians less likely to be detected. For example, BMW's owner manual states that "cyclists on unconventional bicycles" are less likely to be recognized. Also, like many sensor- related technologies, snow or rain can create challenges for the system. Pedestrian detection is more effective during the daytime rather than nighttime. To address these issues, a few manufacturers such as BMW and Mercedes are currently exploring the use of infrared technology to produce a mapped view where objects are detected by the heat they emit. This method could solve the issue of nighttime and severe weather pedestrian detention.

Summary:

With a greater understanding of how and why the new technology works and not just what the technology can do (i.e. help improve the driving experience from technology that assists the vehicle in performing its required tasks, to technology that assists the driver in performing his/her required tasks, and technology that improves the safety of the occupants in the vehicle and/or pedestrian around the vehicle), industry professionals will be better suited to evaluate all aspects of the effect of this technology including but not limited to the effect of potential failures.