Computer Vision Systems in Autonomous Vehicles

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Abstract

This research will give a technical overview of computer vision applications in autonomous vehicles. The applications used in autonomous or self-driving cars help the driver in navigating the road, as well as avoid collision and obstacles on the road. Computer vision is used in several systems such as Advanced Driver Assist, Collision Avoidance Systems, and Lane Departure Warning System. All these systems utilize different sensory inputs from Cameras, GPS, Laser (LIDAR), and weather Radar. However, the lack of efficiency in some sensory systems in certain conditions makes computer vision systems in these vehicles a primary focus for further development. Cameras can enhance the functionality of other sensory systems by communicating visual data to increase the accuracy of vehicle tracking and object recognition. Therefore, computer vision systems in autonomous vehicles have the ability to increase the efficiency of visual mapping of navigation systems, as well as autonomous safety systems that rely on image and sensory analysis to detect obstacles and avoid collision.

Computer Vision Systems in Autonomous Vehicles

- Computer vision is an interdisciplinary field that deals with how computers can gain a high level of understanding from digital image or videos. The applications of computer vision can be used to video tracking and object recognition. This research will provide a technical introduction of the of autonomous as well as computer vision application used in driverless cars. The focus will be on navigation systems that are used to calculate the most convenient route, and safety systems such as collision avoidance and lane departure warning systems. Computer vision systems that work with sensory systems to detect obstacles as well as avoid pedestrians will be examined († & Hermanus Carel Myburgh *, 2015).

Autonomous Vehicle Navigation and Mapping System

GPS-based navigation is the standard model for a mapping system in autonomous vehicles. However, when it comes to urban domains, the accuracy of GPS drops down significantly due to unavailability of GPS signal. Hence, the system does not only relay on GPS, but to improve efficiency it uses locations information from inertial sensors. (Dhanasingaraja, 2014). Autonomous Vehicles sense their surroundings with radar, lidar, GPS, and computer vision. Advanced control systems interpret sensory information to identify appropriate navigation paths as well as obstacles. The navigation task is defined by the combination of localization and path planning:

I. Localization

Localization denotes the robot's ability to determine its own position and orientation within a global reference frame (Dhanasingaraja, 2014). The most fundumental problem to providing a mobile robot with autonomous capabilities is localization. To achieve autonomous navigation, the robot must maintain an accurate knowlede of its position and orientation. The system uses GPS and inertial sensors for localization.

II. Path Planning

Path planning defines the computation of an adequete sequence of motion commands to reach the desired destination from the current robot position. Path planning is done before motion, and followed by the robot's feedback controller that is programmed for obstacle avoidance as well as global path planning. The algorithm for navigation in autonomous cars gets the current position from GPS and destination coordinate from user input. It finds the shortest path between current position and destination and travels through it. If the vehicle senses any obstacles in the path it selects new path based on the next shortest path. This process is continued until the destination is reached. The system allows the user to view present and past positions on Google map through the internet. The system reads the current position of the object using GPS, and the data is sent via GPRS service from the GSM network to a web server to interpret the data. .

ADAS (Advanced Driver Assistant System) (Clark, 2015).

This is a technology that is used to alert the driver when there is an abrupt change of lane or to wake the driver when he or she gets drowsy. Some other ADAS technologies include the traffic light detection, collision warning, pedestrian's detection, as well as blind spot detection among others. These technologies are of great importance to the autonomous car. The technology combines Radar, LIDAR, cameras as well as sensors to make the whole technology operational. Apart from the driver assistant technologies, there has been now invented a self-driving cars that use the combination of the ADAS technology to move from coast to coast. Google has been testing their driverless car for a while but now Delphi invented the driverless car that is operating from coast to coast in the United States of America. The cars use a combination of LIDAR RADAR as well as cameras so that the car can use them to navigate (WO 2014139821 A1, 2016).

There are many prototypes for ADAS as well as Driverless car systems. All these prototypes use computer vision technology which in turn uses several cameras and it plays a major role in many applications. The technology is able to detect traffic signs, warn when there is lane departure, as well as driver drowsiness. The camera technology used is called the Bird eyes view that is used in many autonomous cars. The other implementation such as the pedestrian detection as well as collision warning is solved using Radar or Lidar or the cameras.

With the advancement of technology, computer vision will upgrade and be able to match with the Radar as well as the Lidar technologies and therefore many more camera functionalities will be implemented then. This will be a great reduction in cost since the cameras are much cheaper than the Radar and Lidar Technologies (Finnerty, 2017) .

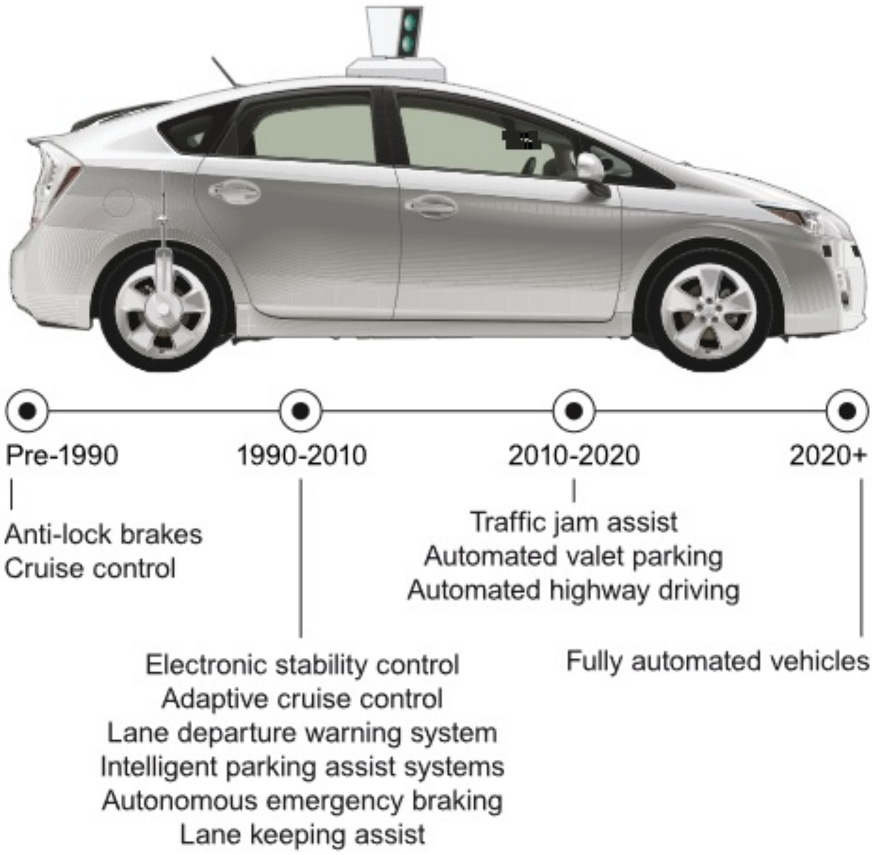
Adoption Metrics for Currently Available Driver Assist Features

Feature	*System Description*	*Adoption Rate*
Adaptive Cruise Control	Monitors distances to adjacent vehicles in the same lane, adjusting the speed with the flow of traffic	6.9M yearly installs by 2017
Lane Assist	Monitors the vehicle's position in the lane, and warns the driver when vehicle is leaving lane (or corrects for driver)	More than 10 automakers offer such feature
Parking Assist	Assists the driver in parallel parking	65 models in 2013
Blind Spot Monitoring	Detects objects in a drivers blind spot	Over 20 models in 2013
Forward Collision Monitoring	Detects objects in front of a vehicle presenting immediate collision risk, typically assists in braking for driver	All major makers

Most of the autonomous cars are not available to the public but there are many cars that are used today by the public that possesses some of the autonomous features. The autonomous functionalities in the modern cars are adaptive cruise controls, lane assist, adjusting speed with the flow of the traffic as well as parking assist. Lane assist is used for monitoring the position of the vehicle on the lane and warns when the vehicle leaves the lane while parking assist is used to assist the driver when doing parallel parking. (Jammshid, 2015)

Autonomous Sensory Systems.

The figure below shows the evolution of fully automated car from today's car:



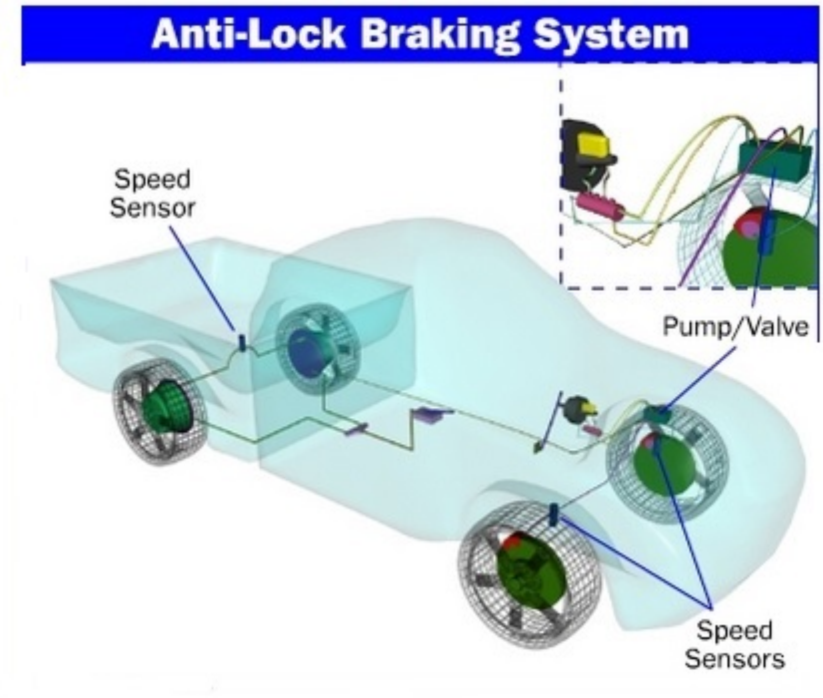
Adaptive Cruise Control:

The adaptive Cruise control, abbreviated as ACC is an intelligent type of cruise control that enables the car to slow down or speed up depending on the car in front automatically. There is a very small radar unit at the front grille or even under the bumper that measures the distance between the car and the one in front of you. In some cars, a laser is used while in others, they use an optical system that uses stereoscopic cameras. ACC is very essential in stop and goes scenarios of traffic as well as rush hour travelling that sees a drop from 60 mph to a standstill. ACC works during the day and the night but its efficiency is affected by heavy rains, snow as well as fog. ACC in driverless cars does not only monitor the car in front only but also Motors cars in the adjacent lanes in case lane change becomes necessary.

Collision avoidance system:

This is the safety mechanism enforced by the automobiles to reduce the effect of a collision on the vehicle. It uses radar as well as laser and camera. Camera and laser sensors are important in the case of bad weather. These systems are used to detect a forthcoming crash. When the detection is done the detection system sends an alert to the driver or just take action autonomously without any drivers input to avoid the detected collision. There are two actions that a car can take when avoiding the collision, either braking or steering or even both actions. The avoidance by braking is ideal for vehicles moving at a slow speed while avoidance by steering is ideal for vehicles moving at high speed.

Anti-lock brakes system (ABS):



Anti-lock brakes, a standard feature in most cars, are a basic form of driverless technology.

These brakes are a technology that is used for driverless cars. The anti- clockwise brakes need the driver to technically step on the pedal for it to work but they are used to do what the drivers used to themselves. Anti-clockwise brakes are important especially when the car is braking hard because it avoids wheels lock up as well as out of control skid

With anti-lock brakes, the system does the propelling on your behalf and it does it better as well as much faster than you ever could, thanks to speed sensors in the wheels of the car

Electronic stability control (ESC):

This system is also called the electronic stability program and it is the computerised technology that is used to improve the stability of a vehicle through detecting as well as reducing the loss of grip and avoid skidding. When this technology (ESC) detects the loss of control of the steer the system responds by applying brakes and directing the steer so that it goes where the driver intends to go. The braking is only applied to the wheels separately to control the under steer and over steer. Some of the ESC systems can reduce the power of the engine until control is regained again.

Lane departure warning system:

This is a system that is used to warn the driver when the vehicle starts to move out of its lane. This warning happens only when the vehicle is moving out of the lane and there is no turn signal in front and in the direction the vehicle is moving to. The system works by minimising the causes of most accidents by avoiding the major causes of accidents on the road. The issues addressed by this here by this system are driver error, distractions as well as drowsiness.

These lane warning systems are based on:

1. Video sensors in the visual
2. Laser sensors (placed on the front of the vehicle)
3. Infrared sensors (placed either behind the windshield or under the vehicle)

There are two main types of systems used in autonomous cars;

- Systems which warn the driver (lane departure warning, LDW) if the vehicle is leaving its lane (visual, audible, and/or vibration warnings)
- Systems which warn the driver and, if no action is taken, automatically take steps to ensure the vehicle stays in its lane (lane keeping system, LKS)

Lane Keeping Assist:

This feature works with Lane departure warning system and it automatically makes sure that a vehicle stays on its lane. There are some autonomous vehicles that combine cruise control with lane keeping assist to improve the safety of the vehicle on the road. Although the combination of these features may seem like it has created an autonomous vehicle, they require in most cases the availability of the driver to take control of the vehicle while in use. This is due to the limited features that are provided by the lane keeping assist mechanism. This feature can either return a vehicle back into the lane if the vehicle had started to move out of the lane or even keep the vehicle at the centre of the lane.

Conclusion.

Computer vision systems in driverless cars are at the forefront of the modern automobile industry. With different advanced systems used to operate these vehicles autonomously, the problems related to full automation of self-driving cars relies on the reliability of the cameras and sensory system to communicate information data and make the right decision based on interpreting the available data. However, improving the efficiency of cameras in computer vision systems would help to make the technology more accessible to the public because cameras are cheaper to produce than other sensors like the radar, or LIDAR sensors. Another problem facing these systems is the reliability of GPS systems for Navigation. The signal of GPS drops when it approaches urban environment. Other systems such as the Adaptive Cruise Control, become less efficient with different weather conditions. Therefore, integrating cameras with the internet to mitigate connectivity issues is needed to increase the accuracy of sensory systems. Improving the efficiency of computer vision systems in autonomous vehicles would rely on a lot of trials and testing to ensure that the technology is reliable everywhere and in every situation. After these problems are addressed, further testing for control and consistency of these technologies is needed to standardize these technologies in every modern car. Therefore, the next step would be to examine the efficiency of communication between computer vision with other sensory systems. Computer vision systems in autonomous vehicles would make these technologies more accessible to the public by developing a system that relies on cameras to communicate with other sensory systems for a quick and reliable output of sensory data.

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