Autonomous Vehicles & Self-Driving Cars

650046219

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Abstract

This is a literature review briefly looking at What is a driverless car, who are some of the parties leading the way in terms of automated vehicle technology as well as looking at some of the techniques used to make this possible.

The Majority of this review will look at techniques of Computer Vision based on a number of research papers found using digital libraries. Some detail is also provided on techniques of Machine Learning pertaining to Autonomous Systems

I certify that all material in this document which is not my own work has been identified.

1 Introduction

With the advancement in computer and sensor systems, autonomous vehicles is an area of research that is undergoing rapid growth and investment as it has the potential to save a lot of time and save lives. As far as the scientific principles of driverless cars are concerned, there are two main challenges to overcome: teaching the vehicle to see and to drive safely.

Some attempts to classify driverless cars have been based on how much control the system has over the vehicle and how much the input is necessary from the driver. This system is endorsed by organisations such as the national Highway Traffic Safety Administration of the USA and the Society of Automotive Engineers most modern vehicles can be described as level 1 under this paradigm as systems such as ATS breaking are handled by an on board computer to improve driver safety. Some features such as cruise control which allow other vehicles to be considered as level 2. Level 3 and up are not currently commercially available although for some functions such as parking has recently become a reality.[1][2]

2 Driverless Systems

There are many different technology and automobile companies trying to create automated vehicles. This section will briefly outline a few of them and their approaches.

2.1 Google car

The Google car is an ongoing project that consists of different car manufacturers being controlled by a system of sensors and artificial intelligence. This project is one of the most developed versions of this type of technology and was recently granted legal recognition as a driver by the US government.[3] The Google Car is also able to take advantage of other well developed software components held by the company such as Google Maps.[4]

2.2 Tesla

As an innovator in emerging technology, the Tesla Car is often considered to be the biggest rival to the Google Car. One of the main differences between the two is that Google favors the use of LIDAR technology where Tesla makes use of Camera-sensors and RADAR.[5] These technologies will be contrasted in more detail in the following section. Both companies test the vehicles with a human co-pilot for the training stages and feature other sensors such as ultrasonic and gyroscopes to better understand the vehicles whereabouts in relation to the road and other users. [4]

2.3 Other Driverless car competitors

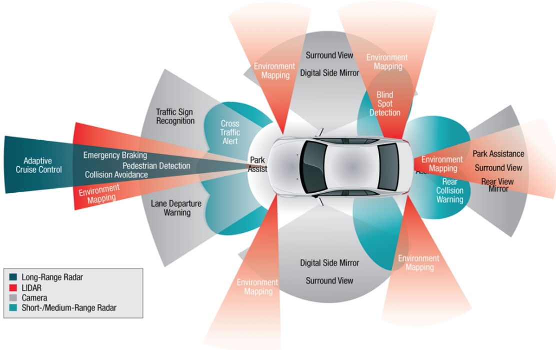
As well as Google and Tesla, many other academic institutions and car manufacturers are keen to develop working technologies that will lead to a truly driverless car system. interested parties include the University of Exeter, Berlin and Stanford and the manufacturers Toyota, BMW and Audi.[4, 6, 7]

3 Advantages and disadvantages of LIDAR and cameras.

As LIDAR emits light, it is able to map a 360 degree 3-D map in any light conditions. This poses a problem for traditional cameras as changing light conditions or reflections can be interpreted differently by the cameras sensors. These are very useful advantages in driverless car systems however one drawback of LIDAR systems is they are currently many times more expensive than camera systems and offer a much smaller resolution than a similarly priced camera. This also shows the advantage of using such systems together; as LIDAR is good at detecting all around a car but not at fine detail while a camera is better at finding the edges of objects although only where the camera is facing.

Some of the advantages of using camera based systems for machine vision and vehicle detection is that they are able to detect colours which allows the system to potentially detect traffic lights and road signs. LIDAR is only capable of seeing in the infrared spectrum. The main disadvantage with camera based systems is that computer vision takes a lot of processing power to yield relatively simple results compared to LIDAR. [8]

Figure 1: How a driverless car senses its surroundings



4 Machine Vision

4.1 PHOGs

For a driverless system to take more control of a vehicle than maintaining speed, a better awareness of the world outside and around the vehicle is needed. One such method is Pyramid Histograms of Oriented Gradients (PHOGs).

This technique is effective at detecting the edge positions of objects by dividing an image window into smaller regions or cells and combining histograms of the change in movement. This technique is currently being used to determine between pedestrians and other vehicles on the road. As changes in the camera feeds brightness from cloud weather or reflections can be problematic for image detection, the first step in computing PHOGs is to normalize the colour and gamma from the input image. The screen is then subdivided so gradients can be calculated from each cell or group of pixels.

Once a direction is determined from overlapping blocks, this information can be referenced against a database of images to find correlations that enable the system to decide if it is viewing a vehicle, pedestrian or road sign. This technique has also been applied to infrared cameras which allow for better vision at night and hence reduce the computational steps needed in reducing color, gamma and to some degree contrast. Some systems are already fairly proficient at driving in test environments or on straight motorways, however in more urban environments traffic detection can be more difficult to predict and adapt to.[9][10]

4.2 blob detection

Another important function of driverless cars is to recognise road signs. A good driverless car system will be able to detect permanent road signs such as speed limits or other information about the roads, as well as temporary signs such as road works and diversions. One proposed system of detecting road signs uses three separate techniques: color thresholding, blob detection and contrast stretching to achieve the recognition of road signs.

In colour thresholding a baseline brightness is established. All the pixels from the image are then determined to be above or below this threshold which then allows objects to be separated from the background accordingly. A value of 1 or 0 can be applied to every pixel in an image and a binary image is created which is in a more machine readable format for the driverless system. Despite the name, this technique can be used in greyscale as well as colour images, where colour images have thresholds which include RGB values. There are also different thresholding methods including the use of histogram shapes and spatial methods[11]

Blob detection is an algorithm that takes an image and represents it as a matrix of the all the pixels where each element in the matrix indicates the pixels brightness. Each line of pixels is assessed in turn and the lighter pixels are identified and assigned a group number which is also referred to as line blobs. As each line is checked for line blobs, any line blobs that are directly below the previous lines blobs are also identified and then merged into one blob. The system will then have the coordiantes of the different blobs or objects on screen and have an ID assigned to each of them.

Blob detection is a useful technique for machine vision especially in terms of driverless cars as it has methods to allow it to detect objects even when they appear loser or further away or at angles. This could be considered the equivalent to tracking another car coming towards the driverless system around a roundabout or while changing lanes in a motorway.[1]

To ensure the images are easier to work with contrast stretching is applied on the image. This process

Figure 2: A Contrast Stretched Image of a Road Sign[1]

looks for the range of the pixels intensity from the image and then applies a linear scaling function to each pixel. If the absolute lower and upper limits of an image are the values a and b, and the lowest and highest values from in the image are c and d then the equation for calculating a contrast stretched image is given by:

Figure 3: equation for calculating a contrast stretched image

$$Pout = (Pin - C)\left(\frac{b-a}{d-c}\right) + a$$

5 K-Nearest Neighbour

The nearest neighbour algorithm is known for being a relatively simple and essential algorithm for making decisions. This was developed by Fix and Hodges in 1951. A data set is provided to the system and when a new situation is presented the data set is examined for the most similar occurrences. The K-nearest neighbour algorithm has many applications and one example in the context of driverless cars is to detect curves in the road. The main advantage is that accurate predictions can be made for situations that the vehicle has not yet encountered and when used with other machine learning algorithms is a powerful way of teaching vehicles to drive themselves. This provides a good way of implementing machine learning into a driverless Cars AI.

6 Conclusion

There are many challenges in improving the safety of driveless cars and advancements in sensor technology highlighted in this review and machine learning techniques are bringing this technology into the foreseeable future. One non-technical area of interest relates to the legality and social impact of changing commutes using state of the art technology.

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