Comparison Review on LiDAR vs Camera in Autonomous Vehicle

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Abstract - *Innovations in automation make life simpler. In the auto sector, the newly designed and planned cars require sensors to get the data and analyze it to make decisions. Tesla and Waymo have racked up the most miles and are trying to produce an autonomous vehicle without using LiDAR (light detection and ranging). Cameras are subject to the issue of change in lighting conditions.one viable solution to LiDAR versus camera debate for autonomous cars is to combining the technology. Sensor fusion in the cars fuses the data from the surrounding environment and from the sensors like radar and LiDAR to augment their perception. Undoubtedly, sensors used by self-driving vehicles will continue to progress and move past human perception. While computer vision can power self-driving cars, other sensors will keep going to the perception stack to aid with increased environmental sensing over time. This paper presents a comparison review of using LiDAR, camera and sensor fusion in autonomous cars.)*

Key Words: LiDAR, camera, computer vision, sensor fusion, autonomous vehicles.

1. INTRODUCTION

Automotive have devised easy moving anywhere without any soreness. Humans have been running cars from its origin. As the new world wants to be autonomous in every field, so it just made a way in the automotive industry. The innovation shift is in the 4th phase and wants to be in the 5th phase of fully autonomous. In the 4th phase and the upcoming phases, the usage of sensors is enormous. The dilemma at this level is about using lidar or camera for the betterment of automation.

Lidar is a top-notch sensor in accuracy, but it lags in recognizing like a camera and its price is also high. Using the camera is a good option but it still makes the same mistake as humans do when light strikes. These may result in accidents if both were used individually at any circumstances.

An autonomous vehicle must be very aware of those situations that cause accidents. So, fusing the lidar and camera will be the utmost measure that can be taken to stop those mishaps. The fusion of sensors can be done with machine learning as it is deciding in ECU of an autonomous car.

2 LiDAR in autonomous vehicles

LiDAR technology has been a part of most of the industries with and the major one's being construction and automotive. This is because of its accurate data collection , it has become one of the world's best companion in sensing technology. LiDAR comes with a lot of advantages yet there are some limitations of LiDAR which makes it difficult to use. Here have highlighted some of the advantages and disadvantages of using LiDAR.

2.1 Working process of LiDAR

2.1.1 Basic Principle of LiDAR

LiDAR sensing is a basic remote sensing technology which emits laser light beam with already defined focus and intensity, and measures the reflected beam arrival time detected by the photodiodes which are within the sensor. It consists a transmitter and a receiver which uses laser and photodiode respectively. This information data is processed to identify angular or horizontal distance to object. In this manner , LiDAR is analogous to radar , but expect that it is based on discrete pulses of laser light emitted from LiDAR.

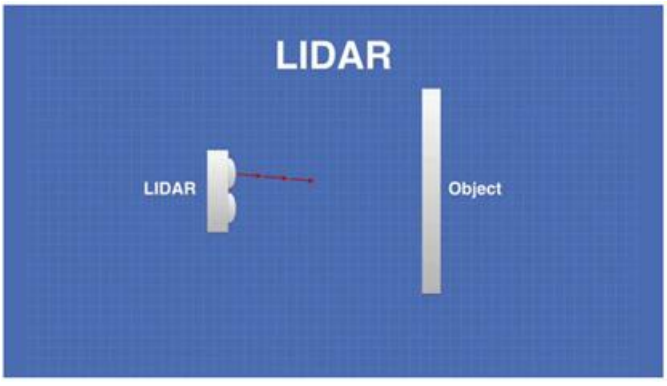

Fig -1: LiDAR working

The 3-D coordinates (x, y, z) or latitude, longitude, and elevation of the environment is computed by algorithms which considers the following

(a) the difference between the time, laser pulse being emitted and returned
(b) the angle at which the pulse was shot
(c) the accurate location of the sensor on or above the surface Unlike passive system, LiDAR is considered as active systems due to light emission and detection arrangement.

2.1.2 Collecting point clouds

As the LiDAR sensor spins on top of the vehicle the digital data are collected in the form of point clouds which corresponds to the environment . The points come from individual emitter-detector pair over flat ground appears as a continuous circle. The 3D construction of image are recorded with HDL-64E and there are no breaks in the circular data around the car in any of the point clouds. This indicates that the laser pulse repetition rate and upper block to lower block duty cycles are configured correctly for the sensor. If the repetition rate is too slow it would result in each of the circles and would appear as dotted lines. The only areas of blanking, are where there is no data, are between the point clouds, where a target is in the optical transmit path.

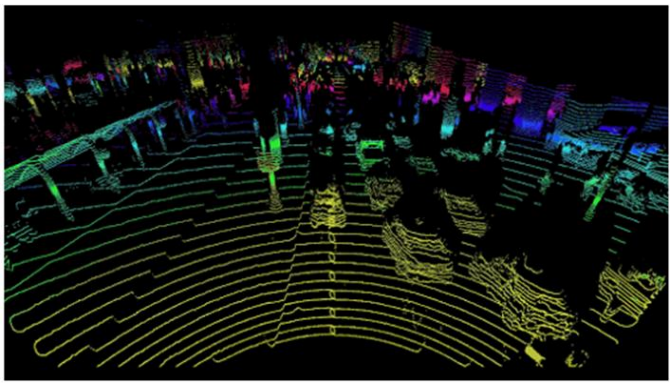

Fig -2: LiDAR points cloud corresponding to the environment.

2.2 Advantages of using LiDAR

2.2.1 Data collection with accuracy

As LiDAR is an airborne technical invention it is easier to collect data with high accuracy, thus creates an advantage for LiDAR

2.2.2 Minimum human dependence

Unlike photogrammetry, LiDAR has minimum human dependence since most of the process are automated. This makes valuable time is saved especially during the process of data collection and data analysis.

2.2.3 Day and night available

LiDAR technology can be used in day and in night. This is due to the active illumination sensor which is not affected by light variations such as brightness and darkness of light. Thus, improving its efficiency.

2.2.4 Not affected by extreme weather

LiDAR technology is not bothered by extreme weather conditions such as extreme sunlight and rain etc. Thus, data can still be collected under these conditions.

2.3 Disadvantages of LiDAR

2.3.1 High operating costs

Even though LiDAR is cheap when it is used in huge applications, it is expensive when it is applied in smaller areas for collecting data.

2.3.2 Ineffective under some conditions

LiDAR pulses can be affected by heavy rains or hanging clouds because of the effects of refraction.

2.3.3 Degraded at high sun angles and reflections

LiDAR does not work well in areas where there are high sun angles huge reflections since the laser pulses depend on the principle of reflection

2.3.4 Difficult to interpret

LiDAR collects a huge dataset that requires high level of analysis and interpretation. Thus, it takes a lot of time to analyse the data.

3. Cameras in autonomous vehicles

As we all know digital cameras are electrical devices which converts visual feeds to digital data which is stored and used as per application. For autonomous vehicles similar cameras are used for collecting visual data, these data are processed on machine learning algorithms to map the surroundings or environment to avoid obstacles and to operate the vehicle accordingly. In autonomous vehicles, cameras and computer vision are used exactly how humans process their vision to control the vehicle based on surroundings. The output feeds from the camera is processed to get the necessary results like identify or classify obstacles present in the way of the autonomous vehicle and to make decisions. And based on the result from the computer vision the vehicle is instructed by the software to navigate through space.

3.1 Working process of computer vision

The video feed is first split into still frames, and these frames are then passed into deep neural networks to extract the information's in the frames, these information's can be other vehicles, pedestrians, traffic lights, traffic symbols, lanes etc. And then by using desired algorithms on the information collected, the vehicle can be navigated in the space. In autonomous vehicles, one of the major tasks of machine learning algorithms is to continuously render the surrounding environment and to forecast the changes that are possible to these surroundings. These tasks are classified into four sub-tasks:

- Object detection,
- Object identification and recognition,
- Object Localization
- Movement prediction

The machine learning algorithms that are used in autonomous vehicles are divided into four classes: decision matrix algorithms, cluster algorithms, pattern recognition algorithms and regression algorithms. One category of the machine learning algorithms can be utilized to accomplish two or more subtasks. For example, the regression algorithms can be used for object localization as well as object detection or prediction of the movement.

For the autonomous vehicle to move in a 3d space it must have 360-degree view of space, it is not possible with normal cameras, which is a major drawback when it comes to navigate self-drive vehicles, but due to advancement in camera technology this problem is overcome by using,

Stereo cameras, where two digital cameras work together, similar to stereoscopic vision of a pair of eyes which provides depth perception of a surrounding area. The cameras capture the same scene from two different viewpoints. And by using triangulation and based on the arrangement of pixels, software compares both images and determines the depth information required for a 3D image. To get more precise in the result, structured light is added with these stereo solutions which projects geometric brightness patterns onto the scene, and based on the distortion in this pattern due to three-dimensional forms, the depth information is also obtained

Time of Flight (ToF) cameras, which determines distance based on the transit time of individual light points. Time-of-flight technology is highly effective for obtaining depth data and measuring distances. A ToF camera provides two types of data on each pixel: the intensity value as grey value and the distance of the obstacles from the camera, known as the depth of field. Now a days ToF cameras have a built in image chip which has several thousand receiving elements. This means that a scene can be captured in its entirety and with a high degree of detail in a single shot.

Or **by combining vision from multiple cameras around the vehicle**. 3D cameras that have to function in varying lighting conditions are hindered by large pixels and therefore lower resolution. To overcome this, work is under way to develop a piece of software which can fuse together 3D camera images with those of a high-resolution 2D camera. This will enable high-resolution 3D data to be obtained, which can then be further processed with the help of machine learning: because of these high-resolution images, the detected objects can be classified with high accuracy, and it is safe to say that a person will not be mistaken for a trash bin. Other methods are also using colour cameras to enable classification to be made according to colour as well as shape.

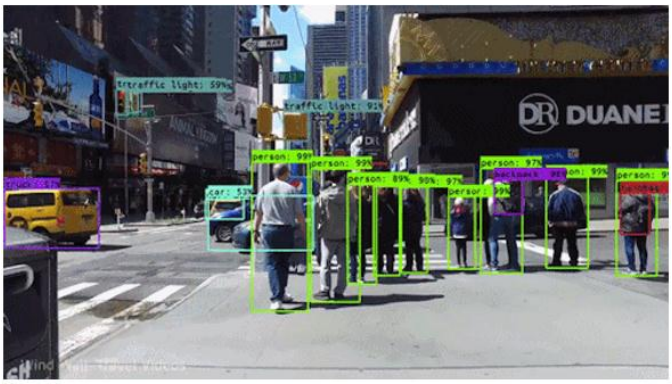

Fig -2: Classifying objects from camera output

3.2 Advantages of using camera over LiDAR

3.2.1 Can support other applications

Addition to application of mapping the environment, visual data can be used for various other applications like classifying objects or obstacles, recognition of traffic lights, traffic symbols and words, determining road and weather conditions etc. Which is not possible with the lidar data where even color is not distinguished

3.2.2 Versatility

Versatility in camera technologies that can be used based on application.

3.2.3 Can be used in low lighting conditions

Various types of cameras like infrared or night vision cameras can be used in low light situations, but with some limitations.

3.2.4 Low operating cost

Because cameras have various other applications and are popular, many manufacturers offer them at low price and processing of their data does not require any special equipment's hence low processing cost.

3.2.5 Low power consumption and no interference

It is not emitting any kind of rays which helps in less power consumption and has no interference.

3.2.6 Advancement in the area

Advancement in computer vision and machine learning algorithm which uses visual data promises high level autonomy for vehicles in future.

3.3 Disadvantages of using camera over LiDAR

3.3.1 Change in lighting condition

Cameras have the same issues as the humans in changing lighting and weather conditions.

3.3.2 Low depth accuracy

The depth data which is computed using algorithms may not be as accurate as lidar data.

4. Sensor fusion

One of the viable solutions to the LiDAR versus camera debate for autonomous vehicle is to combine the technology. The autonomous vehicle uses a large number of sensors to understand its environment, these sensors send different kinds of data based on the environment to the computer, but by fusing these data from all the sensors and providing simpler data which corresponds environment the computer can process it with ease. By fusing sensors, we can get the all the advantages of individual sensors and eliminate the disadvantage, for instance by combining both camera and LiDAR data of the environment both image quality and depth can be obtained with high accuracy and precision. Today most of the automobile companies which offers some kind of autonomy relays on this sensor fusion process.

4.1 Benefits of Sensor fusion

The main aspiration of fusing the sensor is predicting the displacement and distance with the data of both sensors. The technique of fusing the sensors have made a significant rise in 3D marking by testing it on a real road. The upshot of the technique was the object depth is evaluated more accurately and precisely. The major lead in blending the sensors is the calibration outcome of camera and camera projection matrix and distortion co-efficient from its intrinsic traits. The determination of 6DOF transformation criterion was very successful with the detection of circle markers by both sensors. The perfect determination of distance from object were done by taking account of aspects like vehicle speed and operational frequency of both sensors.

5. CONCLUSION

From this it is clear that using LiDAR and camera separately have their own demerits and this may lead to accidents. Instead of relying on single sensor, we are using multiple sensors which consists of LiDAR, radar and camera combines to form a single model. LiDAR and radar are active remote sensing where the time delay between emission and reflection is measured. And the camera used here acts as human eye which is sensitive to light. Upon these three LiDAR exhibits high performance. The combination these three, collect information from various sources and it produces the accurate result to perform task. This combination sensors are also called as sensor fusion. Thus, we are concluding that sensor fusion is used for autonomous vehicles which is a viable and more efficient solution than any other systems used so far.

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