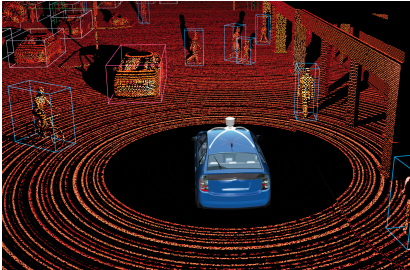
OBJECT DETECTION IN AUTONOMOUS VEHICLES

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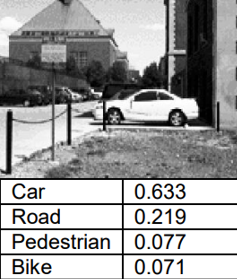
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In 1918 when the concept of vehicles that require no manual navigation and instead drive themselves first came about [5] autonomous vehicles must have sounded like science fiction. A hundred years later we are on the brink of that science fiction becoming a reality as multiple companies are currently testing fully autonomous vehicles [6]. One of the most critical functions in autonomous vehicle guidance and navigation is accurate object recognition. In order to act and function independently, a vehicle’s systems must be able to identify a variety of objects in real time and function with the utmost degree of accuracy in a variety of conditions. There has been significant progress in this field and this paper seeks to summarize the basic concepts related to object detection and classification. There are many methods related to obtaining, combining, and interpreting the data related to object detection in autonomous vehicles.

 While there are many different types of objects and approaches to obtaining the raw data related to the surrounding environment, one of the most important advances in object detection and perhaps the foundation of all autonomous vehicle navigation is the development of light detection and ranging devices [4]. Often referred to as LIDAR, this technique relies on sending pulses of light through lasers to create three dimensional models or maps of the environment surrounding the vehicle. The figure to the side shows an example of the “ideal detection results from a 3D LIDAR with all moving objects detected” [4]. While LIDAR is foundational to most autonomous vehicle object detection systems, there are other methods as well. Pre-mapping certain objects can greatly improve the accuracy in system detection. One such approach [3] uses pre-existing information about the location of traffic lights and then in real time updates the locations of the traffic lights and their current state using a histogram filter. Autonomous vehicles may also have devices designed specifically for a particular type of object. One developer used a laser-based generic sign detector with the ability to specifically differentiate stop signs from non-stop signs with a precision of rate of 89% [3]. Sometimes it may be helpful to create an artificial landmark “designed with a specific pattern or color in consideration of its detection algorithm” such as “a landmark that has a bar code or a specific shape pattern such as the sine waves” [2].

Given that there are multiple methods for object detection and object processing, it was only a matter of time before the concept of sensor fusion came to fruition. “Multi-sensor data fusion is the process of combining several observations from different sensor inputs to provide a more complete, robust and precise representation of the environment of interest” [1]. Autonomous vehicles have a variety of sensors such as LIDAR, motion sensors, sonar, radar, GPS, and camera. Alone each sensor can perhaps provide specific data sufficient to identify certain objects, but clearly combining the advantages of the sensors through fusion can provide more complete information and data about detected objects. Object detection must be able help autonomous vehicles navigate accidents, construction zones, and other irregular vehicular situations including unanticipated situations that often occur in real-world environmental conditions. “[A] single tracking method cannot deal with all the different tasks and situations presented in it” [2]. The technology and process of fusing data is a recent development and “current fusion mechanisms are still in a preliminary stage and notable to fully make use of all the information” [4]. Fusion of incoming data and then processing that data is certainly the future of object recognition in autonomous vehicles.

Regardless of the method used to gather environmental data, at some point this data must be processed in order to detect objects. “[N]ormally two steps are involved: segmentation and classification. Some may include a third step, time integration, to improve the accuracy and consistency” [4]. Segmentation is the process of segmenting out objects from the original data and is crucial in the process of object recognition. For one research group, “failures of segmentation and tracking components are currently the primary limitations of the objects recognition system” [3]. Since image segmentation is such a critical function in object detection, there are multiple categories and methods for image segmentation. Edge based segmentation is effective on objects with strong edge features such as curbs. Region based segmentation depends heavily on “seed points” that then cluster other points based on the initial seed. Model segmentation is often used to assume a flat ground surface and to therefore remove the ground plane from the image processing. Graph segmentation makes each point a node and connects to other nodes using graph edges. Often these different segmentation categories are used together to achieve better results. For example, in one approach [3] researchers used model segmentation to remove the ground plane and connected comments, and then clustered the remaining points into a 2D grid for processing efficiency.

 After objects have been segmented out from the data the next step is to process the segments. Again, there are a variety of methods: estimation, classification, inference, and even artificial intelligence. A common way to process this data is through an object processor that has been “trained” with image datasets to recognize or classify specific images. In general, as mentioned above, issues tend to arise with segmentation rather than classification. If objects are appropriately segmented out then classifiers are able to return the identification of those objects with high degrees of accuracy. For example, even in this black and white image where it would be easy to confuse a white car with a white road, the classifier returns that this object is a car with 63% certainty as opposed to identifying the object as a road, pedestrian or bike [1].

Autonomous vehicles are an attractive innovation whose commercial application is just on the horizon. With current developments in image processing, object detection and the advent of deep learning technology, it is only a matter of time before this vision made over 100 years ago becomes a reality. Particularly, advances in image segmentation algorithms, fusion of sensor data, and classification algorithms make autonomous vehicles an inevitability.

**References**

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