LiDAR and its Applications

By Jessica Nordlund, ECE '22

Introduction

There are many ways to measure the distance between two points, ranging from manual solutions, like using a ruler, to more technological solutions, such as employing an ultrasonic sensor. However, one of the newest and most prevalent options for distance measurement is LiDAR, or Light Detection and Ranging. LiDAR sensors emit laser beams, which can be used to calculate distance. This tech note will explore the history of this technology, its applications, and tradeoffs and considerations for the existing technology on the market.

Background

Science Behind LiDAR

The most commonly used principle in a LiDAR sensor is Time of Flight (TOF). In this case, the LiDAR sensor emits a laser on a periodic basis and records the time it takes for the light to bounce back to the sensor (Figure 1). Then, an internal calculation based on the elapsed time (time of the laser's flight) and clock pulse frequency can be used to determine the distance of the object reflecting the light (3).

Triangular ranging and phase ranging are alternative approaches to developing a LiDAR sensor, and they use similar detection and calculation principles, differing only in the fact that it is not the laser's time of flight that is measured, but the angle of deflection and phase shift of the deflected laser, respectively. These approaches are less popular, though, and the applications discussed in this tech note will be based on TOF.

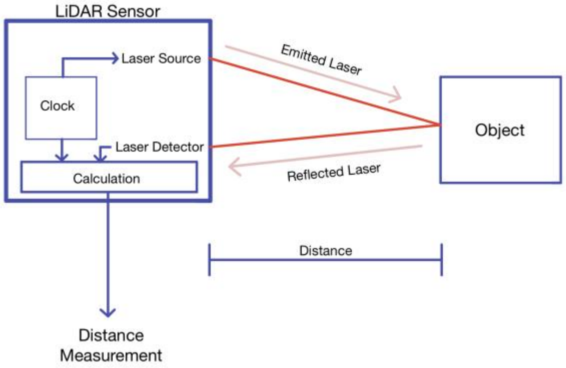

Figure 1. LiDAR Time of Flight (TOF) principle.

History of LiDAR

The principles behind LiDAR are simple, and they have been utilized since the invention of lasers in the 1960's. However, LiDAR as it is known today arose during the Apollo 15 mission in 1971 (3). Up to that point in time, SONAR (Sound Navigation and Ranging) and RADAR (Radio Detection and Ranging) had been the leading systems for mapping environments. However, as Liu et al. points out, "since laser[s] have a smaller diffraction and beam divergence angles, [they] can better identify the adjacent objects than other radar" (3). In other words, lasers offer a unique advantage when compared to sound and radio waves. Scientists discovered that they could spin the laser diodes, send out pulses in all directions, and generate a very accurate topographic map, which could then be used to analyze the moon's surface.

Since then, this technology, known as scanning LiDAR, has continued to be used for mapping, whether it be for construction projects, environmental surveys, or military surveillance (4).

Besides distance measurement, though, LiDAR has also served as a way to determine “the concentration, temperature, pressure, and velocity of molecular constituents in the atmosphere,” which has interesting applications for global warming and climate studies (2). However, there is a lack of contemporary research into this technology, and the fastest growing and dominating LiDAR application of today is, instead, self-driving cars (5).

Current Applications

Automotive Safety

Due to LiDAR’s ability to map out its environment, the technology lends itself to both obstacle detection and collision avoidance in vehicles. Most autonomous cars use a multi-line scanning LiDAR, which can measure the distance to multiple objects every laser pulse and get a 3D map of the surroundings (3). They then run the map through a machine learning algorithm to identify any potential obstacles, such as other cars, pedestrians, cyclists, or animals, which can then be used to make decisions about how the car should react. Additionally, due to the recent boom in artificial intelligence, this technology has advanced quite a bit in recent years, and many (non-autonomous) cars being sold today advertise collision avoidance. However, most of these commercial vehicles are not using the newest and most advanced LiDAR technology on the market due to the exorbitant prices of these devices. In 2018, the Velodyne HDL-64, a top-of-the-line LiDAR sensor in terms of range and resolution, was $70,000 (3). Therefore, LiDAR technology is currently dealing with the familiar tradeoff between performance and cost; a problem that is only further exacerbated by the high risk associated with performance failure in autonomous cars and the high market demand for affordable transportation.

Integration with Machine Learning

This tradeoff in LiDAR quality and price has caused many researchers to explore ways to optimize the machine learning algorithms used to interpret the LiDAR data from lower end sensors. Generally, machine learning today consists of “training” convolutional neural networks (CNNs) to make decisions based on reference data. For LiDAR, this means the distance data an autonomous car collects must be turned into a point cloud (a 3D graph of points), and the CNNs must learn to recognize different traffic patterns and obstacles based on reference LiDAR data. One way researchers have improved this process in recent years is by using multi-view color images in conjunction with the older reference point clouds to help improve the accuracy of environment recognition (5). Also, in addition to detecting scenarios and obstacles, the computer must keep track of where the car is in relation to the detected hazards using a concept called simultaneous localization and mapping (SLAM). All in all, there is a lot of information and processing that needs to occur for autonomous vehicles, especially since they are mapping such a large area, so research into how to save memory and computing resources using more efficient SLAM algorithms has been a large focus in recent years (3).

Considerations

When choosing a LiDAR sensor to work with, it is important to first decide what type of information is needed for the project. Many environmental surveys and autonomous vehicles will need a 3D map to run the machine learning algorithms they have, so a scanning LiDAR sensor or multi-line scanning LiDAR sensor would be the best choice. On the other hand, projects that simply need a single distance measurement can save money by using a stationary LiDAR sensor.

It is also important to consider other types of distance measuring technology when doing single measurements. However, as mentioned in the section Background: *History of LiDAR*, RADAR and SONAR devices tend to be less accurate due to their larger beam diffractions. Additionally, ultrasonic sensors, a common and relatively cheap type of SONAR sensor, can be a great choice for distance measurements. However, as Denysyuk et al. explains, “there is… [a] ‘blind zone’[that] occurs when the sound wave is reflected from surfaces at too large angles” (1), so consideration for whether this blind spot will affect the project is needed.

Conclusion

Overall, LiDAR is an extremely useful tool that can relay important topographical information about its surrounding environment. However, when coupled with artificial intelligence, LiDAR can be used as a quick and accurate way to see and identify real-world situations. This technology can be utilized anywhere, from space exploration to creating fully autonomous vehicles, and current research into the machine learning algorithms used in 3D mapping only provides more promise for this exciting technology.

References

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