Yassine Bennani

Project advisor: Xiaoli Ma

Group Name: 1961C

Time-of-flight LiDAR sensors

Introduction

Time-of-flight, ToF, is one of the principles that is used the most in range calculation. ToF calculates the distance between a sensor and an object using signals. The sensor sends a signal toward the object and then records the signal back when it returns to the sensor due to the reflective characteristic of signals. The distance can then be calculated from the phase difference. Time-of-flight relies on either sound or light. However, light is more efficient because it combines higher speed, longer range, and does not require a material medium to travel. Time-of-flight lasers in LiDAR are the most accurate for real-time and long-range detection. This paper reviews commercial applications, technology, and implementation of ToF LiDAR sensors.

Commercial applications of time-of-flight LiDAR sensors

Throughout the years, the demand for time-of-flight sensors has increased. The most popular area that integrates ToF sensors is automation. ToF sensors are being implemented for land surveying using drones, power line inspection for maintenance, obstacle avoidance for self-driving cars and mining robots, and in the gaming industry to make 3D games more realistic [1]. These sensors are mainly used for object detection and avoidance, precise long-range distance measurements, and 3D scanning [2]. LiDAR sensors are the most recent technology to adapt ToF. They use laser light for detection and ranging. Velodyne LiDAR is one of the leading companies for this technology. Their latest product, the VLS-128, offers up to 300m range, 360° horizontal, +15° to -25° vertical FOV, and up to 9.6 million data points per second [3]. However, it is only available for high-volume sales and is estimated to be around $12,000 per unit. Furthermore, the Velodyne Puck, is another product that is available for single purchases at a price of $7,999. The Velodyne Puck has a 100m range, 360° horizontal and ±15° vertical FOV, and up to 600,00 data points per second [4]. Velodyne competitors include LeddarTech, Ibeo, QUANERGY, Continental, and Princeton Lightwave.

There are also low-cost products like the VL53L0X marketed by Adafruit for $13.95. It offers a 50 - 1200 mm range, 3 to 12% ranging accuracy, and needs to be coupled with servo motors for horizontal and vertical rotations [5].

Technology of time-of-flight LiDAR sensors

LiDAR sensors use a laser electronic, a fixed mirror, and rotating mirror. First, a timer is started when the laser fires the pulse. Then, it is reflected by both the fixed mirror and rotating mirror before it reaches the object. Once it is reached, it reflects the rotating mirror and fixed mirror before reaching back to the receiver and stopping the timer. The current technologies for the emitter are the laser diode and the light emitting diode. On the other hand, the current technologies for the receiver are the avalanche photo-diode, Geiger-mode APD, photo-diode, and silicon photomultiplier. The configuration of the emitter/receiver system depends on the aperture. It can either be biaxial, coaxial, or shared path depending on the use [6]. LiDAR sensors are required to have a wavelength between 900nm and 1500 nm so that it is safe for eyes, skin, and surrounding materials

Implementation of time-of-flight LiDAR sensors

LiDAR sensors need to be implemented using an embedded processor. This processor must have a high clock speed for real-time processing and a serial interface to communicate with the LiDAR sensor.

Most of the sensors available on the market already take care of the signal processing. Therefore, no hardware is required for denoising the data. However, this data needs to be processed to get meaningful results. For instance, when mapping a room, an array of distances would not help unless it is assembled as a point cloud. There are couple python libraries that do that. One of them is BreezySLAM, which uses SLAM algorithms to continuously update the positions of nearby objects as a LiDAR-enabled vehicle move [7]. Higher-priced products offer their own software for data processing. For example, Velodyne provides VeloView, which performs real-time visualization and processing of live captured 3D LiDAR data from Velodyne's HDL sensors.

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