Amy Fritz
Project Proposal
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Time of Flight Imaging with Single Photon Counting

Motivation

The holy grail in LIDAR technologies is a cheap, portable unit that costs less than $200 and works in full sunlight. This could be used for self-driving cars and robots, to help them map the world around them. Current LIDAR technologies, used by Google self-driving cars, and others, are scanning LIDAR units. The moving parts make these systems more apt to break, and the scanning method limits the data acquisition rate of these systems. We would like to create a flash LIDAR system, which illuminates the whole scene and uses a lens to map each point of space illuminated to a pixel on the detector. The use of Single Photon Avalanche Photodiodes (SPADs) allows us to capture data on the single photon level, which greatly reduces the signal to noise ratio needed to acquire an accurate signal.

Related Work

In 2010, an Italian group showed proof of concept of a time-of-flight ranging system using a SPAD array to collect single photons [1]. A group at MIT has also extensively investigated the signal processing of time-of-flight imaging using single photon counting arrays [2]. Our experiment continues these studies. After successfully building a time-of-flight imaging system with this experiment, we hope to carry out further studies that would expand upon these previous works. For example, the Italian group had limited success with objects further than 10m and in bright sunlight, which are problems we hope to address in future work.

People have taken many different approaches to creating better LIDAR. One alternative approach is using 1550nm light and an InGaAs detector [3]. The longer wavelength has lower eye safety standards, meaning you can send out a more intense pulse of light. The downside of this approach is that the InGaAs detectors have large dark count rates, and the technology is not as advanced as SPADs, meaning it is hard to create compact arrays. Other groups are working on making non-moving LIDAR using phased arrays [4]. These phased arrays use metallic nanoantennas to actively control the direction of the illumination light, which effectively creates scanning LIDAR without moving parts.

Project Overview

We currently have a small, portable, single pixel LIDAR system (LIDAR-Lite from PulsedLight3D). We also have a state-of-the-art 1D SPAD array (LinoSPAD from FastTree3D in Switzerland). The goal of this project is to get both of these systems running and compare their outputs. The LIDAR-Lite contains a 500ns pulsed laser diode, which we will use to illuminate the scene. The LIDAR-Lite connects to an arduino, which then connects to a computer for programming and data collection. The LinoSPAD also connects to the computer and can be programmed through a Xilinx FPGA. This first test of the system will be done indoors with objects within 10 meters, since that is the space we have in the optics lab. We will find the the resolution and number of acquisition runs needed to achieve that resolution.

Time Line

The first priority is for me to learn how to program arduinos. I have several friends willing to help me with this endeavor. The second task is for me to get the laser timing signal off the LIDAR-Lite system, so that I can also use that timing signal for the LinoSPAD array. According to documentation, there is a pin on the LIDAR-Lite that carries the timing signal, so I should be able to connect a wire between the two boards to create a synchronous timing signal for both. Another task is to understand the cryptic software that came with the LinoSPAD array. Unfortunately, there is no documentation about the software and how to read the string of numbers written to a file when you run an acquisition. I have been in contact with the company, and they told me to read through the code to understand exactly what it is doing. Finally, after these pieces have been figured out, I can attempt a time-of-flight imaging measurement in the lab.

2/20/16-2/25/16 Program arduino, understand LinoSPAD array software, and wire timing signal
2/25/16-3/4/16 Attempt to capture data and analyze it
3/4/16-3/8/16 Organize results, make poster and write paper
3/9/16 Poster Presentation
3/14/16 Paper Due

References

[1] S. Bellisai, et. al. Single Photon 3D Ranging Based on SPAD Imagers. *23Rd Meeting of the IEEE Photonics Society*, 2010.
[2] D. Shin, et. al. Photon-Efficient Computational 3D and Reflectivity Imaging with Single-Photon Detectors. *IEEE Transactions on Computational Imaging*, Vol. 1, No. 2, June 2015.
[3] Z. Li, et. al. Photon-Counting Chirped Amplitude Modulation Lidar With 1.5-GHz Gated InGaAs/InP APD. *IEEE Photonics Technology Letters*, Vol. 27, No. 6, March 15, 2015.
[4] C. T. DeRose, et. al. Electronically Controlled Optical Beam-Steering by an Active Phase Array of Metallic Nanoantennas. *Optics Express*, Vol. 21, No. 4, February 25, 2013.