SMITH COLLEGE

Memo

From: Jay Frothingham
To: EGR 390 class participants
Date: September 21, 2022
Subject: A Memo on Modeling LiDAR Detections of Surfaces With Differing Characteristics

Introduction

Students in the course EGR 390, a seminar on remote sensing, have been exposed to the basic technical principles of Light Detection And Ranging (LiDAR) during in-class lectures. With this background, students are equipped to understand and discuss published journal articles relating to LiDAR. The purpose of this memo is to summarize one such article, giving engineering students a more detailed understanding of advanced topics relating to LiDAR.

Paper description

Zhang et al. "Research on the detection probability curve characteristics of long-range target based on SPAD array lidar," *Infrared Physics & Technology,* Volume 126, 2022. https://doi.org/10.1016/j.infrared.2022.104325.

Single-photon avalanche diodes (SPAD) can be used in LiDAR detectors to receive reflected laser pulses. To process SPAD data, histograms counting the number of photon detections within a set pixel field-of-view are constructed for each detector pixel. This is known as the detection probability curve. For targets of uniform structural and reflection characteristics, the detection probability curve can be modeled with simple, traditional algorithms taking advantage of the detection probability curve's approximately Gaussian shape.

For targets with non-uniform distance, orientation, reflectivity, or cross-sectional area, these algorithms are not suitable. Differences in the listed characteristics distort the shape of the detection probability curve so that it is no longer well-approximated by a Gaussian distribution. This is a particular risk for long-range LiDAR surveys, as the increased distance from the target increases the field-of-view per pixel and increases the chance that a pixel's field-of-view may contain a target with non-uniform characteristics.

The research conducted by Zhang et al focused on improving models to calculate detection probabilities even with non-uniform targets. To do this, they evaluated the distortion caused by different characteristics. Distortion was quantified based on full-width-at-half-maximum (FWHM) and skew of the detection probability curve. FWHM is a measure of how much spread is present in a curve, while skew is a measure of how centered or symmetrical a curve is.

Zhang et al found that increases in the non-uniformity of target surface characteristics (such as distance from the detector and orientation) correspond to an increase in the FWHM and a decrease in skew, both according to a cubic polynomial relationship. Increases in the non-uniformity of target reflection characteristics (such as surface reflectivity and cross-sectional area) correspond to a decrease in the FWHM and an increase in skew, both according to a first-order polynomial relationship.

The article concludes that distortions in FWHM and skew can be used to identify pixels corresponding to detections of surfaces with different distances. The authors state that their research "lays the theoretical foundation for target characteristic analysis and target recognition based on SPAD array lidar." Though the researchers did not fully test models for determining targets based on distortion in the detection probability curve, their findings are a good start.

Thoughts

I chose this article out of an interest in the instrumentation used in physics and astronomy, where single-photon avalanche diodes and pixel arrays are commonly used. It seems like this research topic could be significant in a variety of applications. The statistical techniques used by the researchers are applicable for analysis of data collected in different types of LiDAR surveys as well as other instruments altogether.

In my opinion, this is a "good" article. The abstract states all the important information--motivation for the research, some methodology, and the significant findings. The figures are well-designed and well-labeled. There is a good balance of text, mathematical equations, and figures.

If I had the opportunity to go back to the Jay of this morning and pick a different paper, I would still choose this one. I found it interesting to see how some of the statistical analysis I've learned in other classes can be applied to real instruments and real situations.

Conclusions

The purpose of this memo is to explain a more advanced topic relating to LiDAR. In this memo, I have summarized a paper presenting current research on how LiDAR can potentially be utilized even at long ranges to identify different targets based on their structural and reflective characteristics. This example is valuable for showing a weakness in LiDAR and an approach to address that weakness, as well as the versatility of data collected in LiDAR. This memo enriches students' understanding of LiDAR's limitations and applications.