Impact of Interference on Time-Of-Flight LiDAR

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Abstract

A research on the interference between Light Detection And Ranging (LiDAR) was conducted. The main objective is to assess the impact its impact and behavior, since most of the self-driving vehicles rely on LiDAR technology for navigation. Two conditions were studied: the distance between the LiDARs and the voxel grid edge length used for the statistical analysis. Our findings indicate that a smaller voxel grid edge length increases slightly the magnitude of the interference, for a fixed distance. Regarding the distance, no conclusion is possible, since other factor appear to be more relevant. In a worst case scenario, one in each thousand points is expected to be interfered when two LiDARs coexist.

Figure 1: Figure of the experimental setup described on section 3, used for the data presented on this research.

1 Introduction

Since the appearance of Advanced driver-assistance systems (ADAS), consumers, experts and governments hoped that “smarter” cars would result in safer roads. Backed both by common sense and research, human error is still one of the causes of most accidents and injuries on the road [2, 9]. Despite remarkable advances in ADAS and self-driving technology, increasingly road safety awareness campaigns, laws and heavier fines, annual global road traffic deaths have reached 1.35 million in 2018, being the leading cause of death for people aged 5-29 years [9].

Several studies have been conducted on self-driving cars [2, 3, 7] and some public datasets have been made available to further the development of self-driving vehicles [4]. However, despite being a complex and broad research area, most of the current state-of-the-art for autonomous driving relies heavily on LiDAR - a device capable of measuring the depth from a scene by using laser beams.

1.1 LiDAR

LiDAR sensors create of realistic models of their surroundings, due to their capability of precisely measure depth - with a few centimeters of error, over distances that can range until 100 meters [1]. This models, commonly represented as point clouds or mesh clouds, are one of the preferred method for Simultaneous Location and Mapping (SLAM) algorithms, which allow a vehicle without previous knowledge of its surroundings to autonomous navigate them - a crucial task for self-driving cars.

The most common LiDAR sensor is a Time of Fligt (TOF) LiDAR, which acquires depth information by measuring the time elapsed between the firing of its laser and the reception of that same laser pulse. Normally, this pair of laser and receptor is assembled on a rotational device, allowing a single pair to measure in time, creating a 2D LiDAR. If multiple pairs are assembled together, with different polar angles, the LiDAR is said to be 3D, since a total revolution can produce a three dimensional map of its surroundings.

Combining the reliability of the depth measurement with the assemblage of multiple pairs of laser and receptors on a fast rotational device (typically 5 to 20 Hz) creates one of the most appealing and reliable sensors for self-driving vehicles and ADAS.

1.2 LiDAR Interference

TOF LiDARs basic principle implies that when a laser pulse is emitted, three different scenarios are possible, being the first one the only one that produces a valid measurement:

1. The laser pulse returns, due to the reflection of an obstacle;
2. The laser pulse does not return;
3. The laser pulse returns with a intensity below the noise floor.

Interference and crosstalk between the pairs of laser and receptors on a LiDAR are mitigated with different firing offsets or in the case of mutual interference between LiDAR, it is possible to synchronize their firing time using specialized clock signals [1].

However, in a society when self-driving vehicles coexist, another scenario is possible: a LiDAR A fires a laser pulse that is received, directly or indirectly, by the receptor on a LiDAR B. Since the LiDAR B measures the distance to the obstacle by measuring the time between the firing and reception of its own laser pulse, the reception of another laser pulse causes a erroneous measure with an unpredictable behavior. If this interference is significant, the reliability of the LiDAR and consequently autonomous vehicles and ADAS is seriously undermined, due to the incapability to accurately understand their environment.

This paper is organized as follows. Section one presents the introduction and motivation for this work. Section two debates the related work. The third section shows the experimental results obtained. Setup four contains the method developed for interference analysis, while the setup and the last section, Results. Section five deliberates on the paper's conclusions.

2 Related Work

To the best of the author's knowledge, despite the relevance of the topic to a society of self-driving cars, there are only available the studies conducted by Kim *et al.* [5, 6], which seek to characterize this interference; and by Retterath and Laumeyer [8], seeking to provide an apparatus for reducing the mutual interference of LiDAR sensors on the same vehicle.

Kim *et al.* research, despite using a 2D LiDAR instead of a 3D LiDAR, is the only study to use two independent LiDARs interfering with each other. Kim *et al.* results indicate that interference has spatial and temporal locality. The former states that if a particular angle is interfered, the following angles are likely to also be interfered; while the latter indicates that if a measure is interfered, on the following frame that same measure is also likely to be interfered. However, in any given time, in the setup a data point has 0.05 % of being interfered.

3 Experimental Setup

To analize the impact of LiDAR interference, two LiDARs were used. One acts as the source LiDAR, which acquires data from its surroundings and the other acts as an interference generator on the data acquired by the first.

The source LiDAR is a Velodyne VLP-16, which contains 16 laser beams and is fixed on the table. The LiDAR acting as an interference generator is a Hesai Pandar40, which has 40 lasers, and is fixed on a tripod. Both LiDARs rotate at 600 and fire their lasers at 10 Hz.

To capture, manage and analyze the datasets, software has developed in C++, using the Robotic Operative System (ROS) framework and the Point Cloud Library (PCL). ROS was also used for the interaction with the sensors and to allow near real-time operation on a standard laptop computer.

Figure 1 shows a picture of the described setup on one of the test scenarios, a robotic Middle Size League (MSL) soccer field.

4 Methodology

Since it is not possible to distinguish an interfered from a valid measure (from an hardware standpoint, both of them are valid measures), we propose a method to can distinguish which measures result from LiDAR interference.

The proposed method assumes a static scenario and compares the point clouds with and without interference. First, the LiDARs are positioned and the interference generator LiDAR is off. On this conditions, several point clouds are recorded and merged to create a ground truth model. Then, the LiDAR that causes the interference is turned on and several point clouds are registered.

The first data acquisition is used to generate the ground truth model of the scenario, free from interference, by stitching together the different frames using the Iterative Closest Point (ICP) algorithm. A voxel[1] grid filter is also applied to every frame, to filter out noisy points, reduce the number of points and ensure more uniform point density.

To quantify the interference, each point cloud containing interference is compared with the ground truth model. The occurrence of interference is measured relatively to the total number of voxels and represents the number of modified voxels (i.e., the number of voxels who were occupied and now are free and vice-versa) when comparing the ground truth model with the point cloud containing interference.

5 Results

For a fixed LiDAR height, direction and rotation speed, both LiDARs optical center were aligned and several point cloud were recorded while the interference generator LiDAR was active. Using the method described in section 4, the quotient of interfered vs total number of voxels was calculated for a relative distance between varying from 1 to 12 m, considering a voxel edge lengths ranging from 10 to 50 centimeters. The results presented on figure 2 on the form of a contour graph.

Analyzing the figure, one can notice that the smaller the voxel edge length (x axis), the more granularity the analysis has and therefore a higher number of voxels have been modified due to the interference. By considering a fixed voxel edge length, one can noticed that the results are prone to oscillations (that are more significantly to smaller voxel edge lengths). This results leads us to believe that despite the variation with the distance between LiDAR, there are other factors that drastically influence the interference. No further analysis was conducted to assess this factors.

The experimental results also show that on the worst case scenario, in every 1000 measurements there is an interfered measure, or 27 points per frame or 270 points per second. The best case scenario is 1 interfered point for every 100000 points, which is less than a point per second.

[1] A voxel is an element of a three dimensional grid that is equally spaced, representing a single point.

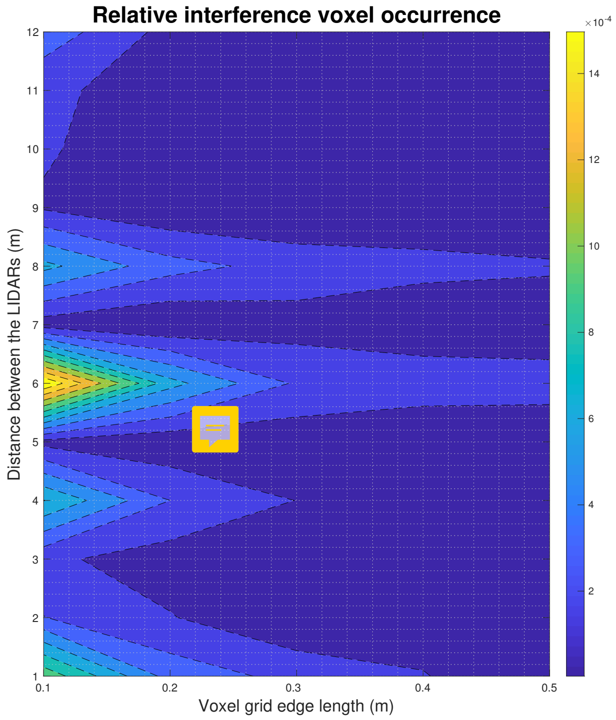

Figure 2: Figure of the experimental setup described on section 3, used for the data presented on this research.

6 Conclusion

Interference between TOF LiDAR is a research topic that is yet to receive the attention of the academy community, due to its impact on self-driving vehicles. The extensive adoption and reliance on LiDAR technology for self-driving vehicles will force the coexistent of this laser sensors on real world scenarios, which, by our findings, will resulting on mutual interference between LiDARs, causing errors on the measured data.

On this article, a study of the interference between TOF LiDARs is conducted. Previous available results have shown that on 2D LiDARs an error of 1 in 10000 points is expected [5, 6]. Our findings not only extended this study to 3D LiDARs, more common in self-driving vehicles, but also discovered that the severity of errors is highly volatile and can be one order of magnitude higher than previous findings.

Analysis were performed by varying the distance between the LiDARs and by changing the voxel grid edge size. We conclude that the lower the voxel grid edge length, the higher the effects of the interference. A trend was observed that the increasing of the distance resulted on a decrease of the modified voxels, but due to the oscillation of the results, we can only conclude that other factors significantly influence the occurrence of interference.

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