

000 Impact of Interference on Time-Of-Flight LiDAR

002 Pedro Martins¹

003 martinspedro@ua.pt

004 António Neves¹

005 an@ua.pt

006 Miguel Drummond²

007 mvd@av.it.pt

008 André Albuquerque³

009 Andre.Albuquerque@pt.bosch.com

¹ University of Aveiro

Campus Universitário de Santiago

Dpt. Electronics, Telecommunications and Informatics
Aveiro, Portugal

² Instituto de Telecomunicações

Campus Universitário de Santiago,

Aveiro, Portugal

³ Bosch Car Multimédia Portugal, S.A

Braga, Portugal

013 Abstract

014 A research on the interference between Light Detection And Ranging (Li-
015 DAR) was conducted. The main objective is to assess its impact and be-
016 havior, since most of the self-driving vehicles rely on LiDAR technology
017 for navigation. Two conditions were studied: the distance between the Li-
018 DARs and the length of the voxel grid edges used for the statistical anal-
019 ysis. Our findings indicate that a smaller length of the voxel grid edges
020 increases slightly the magnitude of the interference, for a fixed distance.
021 Regarding the distance, no conclusion is possible, since other factor ap-
022 pear to be more relevant. In a worst case scenario, we conclude that one
023 in each thousand points is expected to be interfered when two LiDARs
024 coexist.

026 1 Introduction

027 Backed both by common sense and research, human error is still one of
028 the causes of most accidents and injuries on the road [2, 10]. Despite in-
029 creasingly road safety awareness campaigns, laws and heavier fines, annual
030 global road traffic deaths have reached 1.35 million in 2018, being
031 the leading cause of death for people aged 5-29 years [10].

032 Several studies have been conducted on self-driving technology and
033 Advanced Driver-Assistance Systems (ADAS) [2, 3, 7], which appears
034 has one of the most promising solutions to mitigate road accidents. Along
035 with some public datasets that have been made available to further the de-
036 velopment of self-driving vehicles [4], ADAS is becoming more relevant,
037 mainly due to the maturation of LiDAR technology [9].

038 LiDAR sensors map their surroundings thanks to their capability of
039 precisely measure depth - with a few centimeters of error, over distances
040 that can range until 100 meters [1, 9]. Time of Flight (TOF) LiDAR, the
041 most common type, acquires depth information by measuring the time
042 elapsed between the emission and reception of a laser pulse reflected from
043 a surrounding target [9]. To scan a single line, a single pair of laser and
044 photodetector are assembled on a rotational device, creating a 2D LiDAR.
045 If multiple pairs are assembled together, on a rotational device, with dif-
046 ferent polar angles, the LiDAR is said to be a 3D LiDAR.

047 These maps, commonly represented as point clouds or mesh clouds,
048 are one of the preferred method for Simultaneous Location and Map-
049 ping (SLAM) algorithms, which allow a vehicle without previous knowl-
050 edge of its surroundings to autonomously navigate them - a crucial task for
051 ADAS on self-driving vehicles.

051 1.1 LiDAR Interference

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

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

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

However, in a society when self-driving vehicles coexist, another sce-
nario is possible: a LiDAR “A” fires a laser pulse that is received, directly
or indirectly, by the photodetector on a LiDAR “B”. Since LiDAR “B”
measures the distance to an obstacle by measuring the time between the
firing and reception of its own laser pulse, the reception of another laser
pulse causes an 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 in-
capability to accurately mapping their surroundings.

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 interfer-
ence; and by Retterath and Laumeier [8], seeking to provide an apparatus
for reducing the mutual interference of LiDAR sensors on the same vehi-
cle.

Kim *et al.* research is the only study to use two independent 2D Li-
DARs interfering with each other. Kim *et al.* results indicate that interfer-
ence has spatial and temporal locality [5] and in any given time, in Kim’s
setup, a data point has 0.05 % probability of being interfered [5].

052 1.2 Proposed Work

This research intends to understand the impact of the interference between
3D LiDAR, whose reliability is crucial for self-driving vehicles, conse-
quently expanding Kim’s research. Our proposal consists on assessing the
interference behavior with the relative distance between LiDARs and
the length of the voxel¹ grid used to quantify this interference.

This paper is organized as follows. Section 1 presents the introduc-
tion and motivation for this work. Section 2 debates the related work. The
third section shows the experimental results obtained. Section 4 contains
the method developed for interference analysis. The results and their dis-
cussion is presented on Section 5. Section 6 deliberates on the paper’s
conclusions.

053 2 Experimental Setup

To analyze 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 Rotations Per Minute (RPM).

To capture, manage and analyze the datasets, software was 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.

054 3 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 pro-

¹ A voxel is an element of a 3D grid that is equally spaced, representing a single point.



Figure 1: Experimental setup described on section 2, used for the data presented on this research.

pose a method to 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 these conditions, several point clouds are recorded and merged to create a ground truth model. Then, the LiDAR that causes the interference is switched 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 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 were freed and vice-versa) when comparing the ground truth model with the point cloud containing interference.

4 Results

For a fixed LiDAR height, direction and rotation speed, both LiDARs optical center were aligned and several point clouds were recorded while the interference generator LiDAR was active. Using the method described in Section 3, the quotient of interfered vs total number of voxels was calculated for a relative distance varying meter by meter from 1 to 12 m and considering voxel edge lengths ranging from 10 to 50 centimeters, with steps of 10 cm. The results are presented on figure 2, on the form of a contour graph.

The smaller the voxel edge length (horizontal axis), the higher the number of voxels per point cloud. Analyzing figure 2 concludes that the number of voxels affected by interference increases with the decrease of the voxel edge length. If a fixed voxel edge length is considered, one can noticed that the results are more prone to variations with the distance, being this variation more significantly at smaller voxel edge lengths.

These results lead us to believe that despite the variation with the distance between the LiDAR, there are other factors that drastically influence the interference. Such analysis is yet to be conducted and it is left for future work.

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

5 Conclusion

Interference between TOF LiDAR is a research topic that is yet to receive the attention of the academic community, due to its impact on self-driving

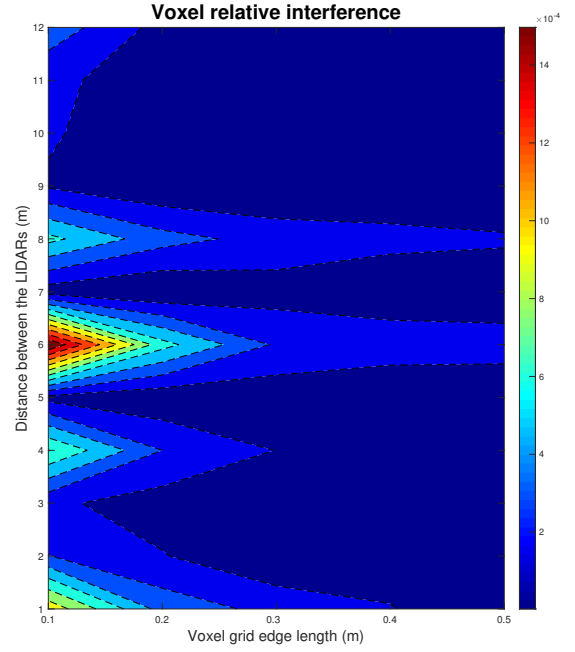


Figure 2: Contour graph of the results. On the horizontal axis the voxel edge length is varied between 0.1 and 0.5 m with steps of 0.1 m. On the vertical axis, the relative distance (keeping the LiDAR orientation with zero azimuthal angle) is varied meter by meter between 1 and 12 meters.

vehicles. The extensive adoption and reliance on LiDAR technology for self-driving vehicles will force the coexistent of these 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. Increasing the distance between the LiDAR resulted on a behaviour that has no obvious correlation with the distance. Therefore further investigations are required to identify the main factors influencing mutual interference between LiDARs and to quantify their severity in object detection and recognition.

References

- [1] VLP-16 User Manual. Technical report, Velodyne LiDAR, Inc., 2019.
- [2] K Bimbrw. Autonomous Cars : Past , Present and Future - A Review of the Developments in the Last Century , the Present ... *ICINCO-2015*.
- [3] Lex Fridman and et. al. MIT Autonomous Vehicle Technology Study: Large-Scale Deep Learning Based Analysis of Driver Behavior and Interaction with Automation. 2017.
- [4] Andreas Geiger, Philip Lenz, and Raquel Urtasun. Are we ready for autonomous driving? the KITTI vision benchmark suite. *Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition*.
- [5] Gunzung Kim, Jeongsook Eom, and Yongwan Park. An Experiment of Mutual Interference between Automotive LIDAR Scanners. In *2015 12th International Conference on Information Technology - New Generations*. IEEE, .
- [6] Gunzung Kim, Jeongsook Eom, and Yongwan Park. Mutual Interference on Mobile Pulsed Scanning LIDAR. *IEMEK 2017*, .
- [7] R. Okuda, Y. Kajiwara, and K. Terashima. A survey of technical trend of adas and autonomous driving. In *Technical Papers of 2014 International Symposium on VLSI Design, Automation and Test*.
- [8] Jamie E. Retterath and Robert A. Laumeyer. Methods and Apparatus for Array Based Lidar Systems with Reduced Interference.
- [9] Frost & Sullivan. LiDAR: Driving the Future of Autonomous Navigation. 2016.
- [10] World Health Organization (WHO) et al. Global status report on road safety 2018.