Lidar and Radar Systems
Task 1
Influence of Fog on the Sensors

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1 Introduction

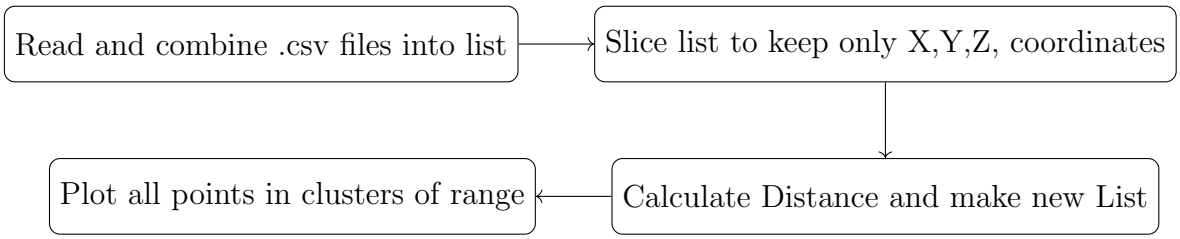
In this report, we examine point cloud data recorded under clear and foggy scenarios using three different types of sensors: A. *Velodyne Puck*, B. *Blickfeld Cube 1*, and C. *Texas Instruments radar sensor*. Our analysis aims to uncover how fog affects the perception of the surroundings from the sensor's point of view.

Firstly, we will discuss the algorithm used to analyze point cloud data, followed by the presentation of results using histograms.

2 Methodology

The programming was done in *Python* where we used standard libraries like *NumPy, Matplotlib* and *OS* to read out, combine, slice, process and plot our results.

These libraries are used with couple of nested loops which does all the work of accessing data-set for all scenarios.The flow of the code can be explained as follows...



3 Analysing Results

In this section, we will compare the results for Clear and Foggy conditions in the form of histograms and discuss the reasoning behind it.

3.1 Velodyne Puck

Comparing total number of points collected by the sensor in clear (14,069,067) and foggy scenario (11,625,977), there is a reduction of 17.4 %. This behavior can be justified as the LASER pulses from the sensor get scattered, and their intensity diminishes during the flight. The longer the flight path through fog, the more measurement points we lose. From the histogram, it can be observed that for closer ranges, i.e., 0 to 5 meters, there is only a 1% loss in the total number of points. However, as we look into farther ranges (for 20 meters and beyond), we are losing almost all of our points.

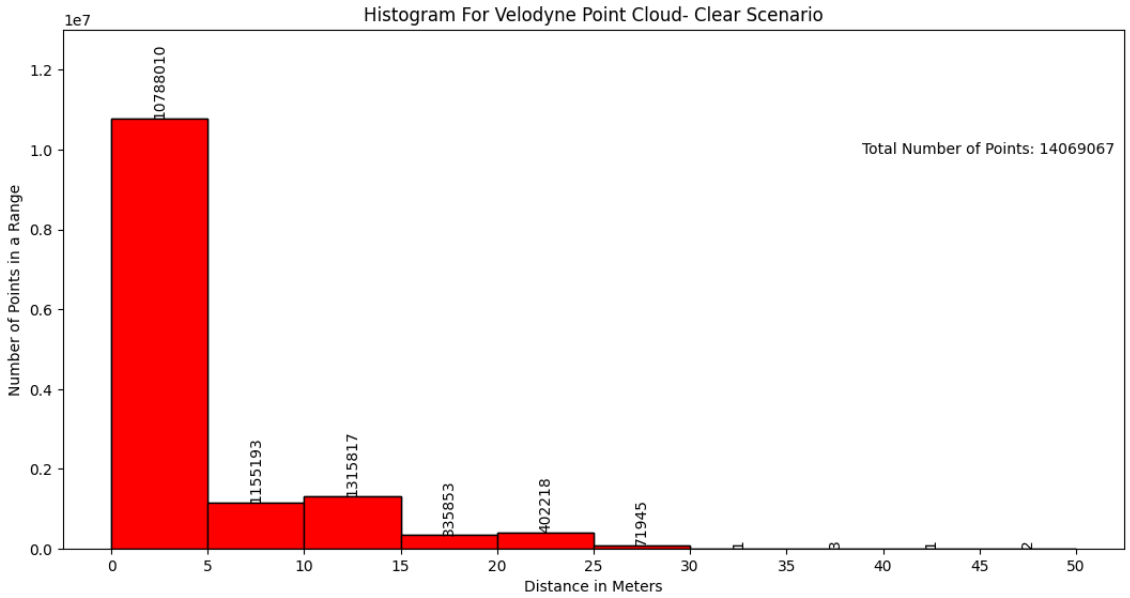


Figure 1: Velodyne-Clear Scenario

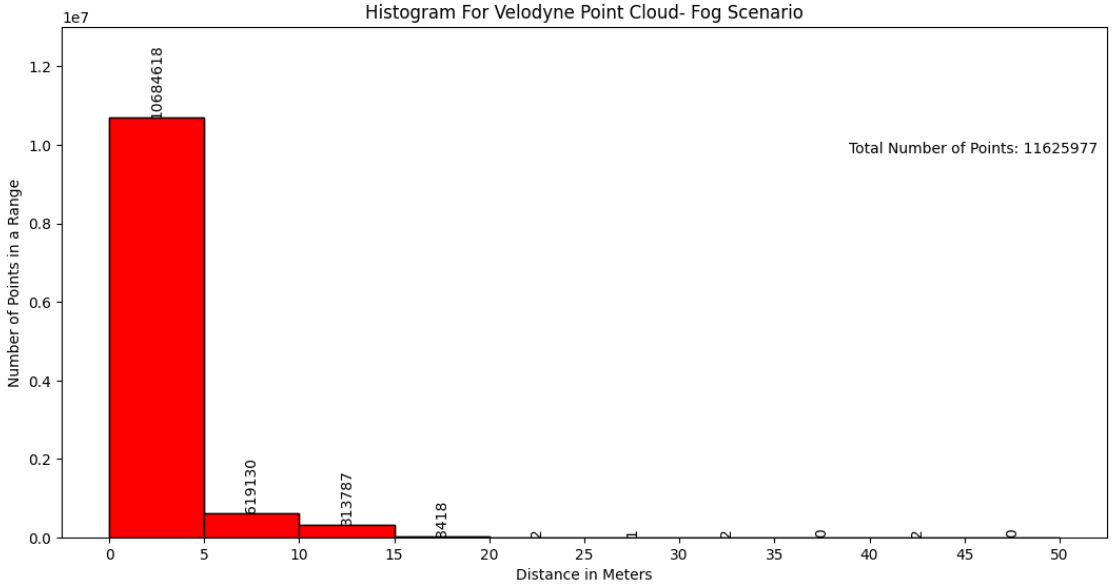


Figure 2: Velodyne-Foggy Scenario

3.2 Blickfeld Cube 1

Similar to the earlier case, a 12% decrease in point count is observed in foggy condition (less as compared to Velodyne Puck case). Scan lines for Blickfeld 1 converge near the sensor, resulting in more points near the sensor compared to the rest of the coverage area. Hence, a considerable number of points fall close to the sensor, resulting in a shorter flight path in fog and, consequently, less loss of points. We observe a 17% increase in points for the range of 0 to 5 meters. This is due to the fact that when fog scatters the LASER pulses, some of the scattered light reflects back to the sensors, resulting in 'Ghost Points.' Similar to Velodyne Puck, we observe a drastic loss of points beyond 20 meters.

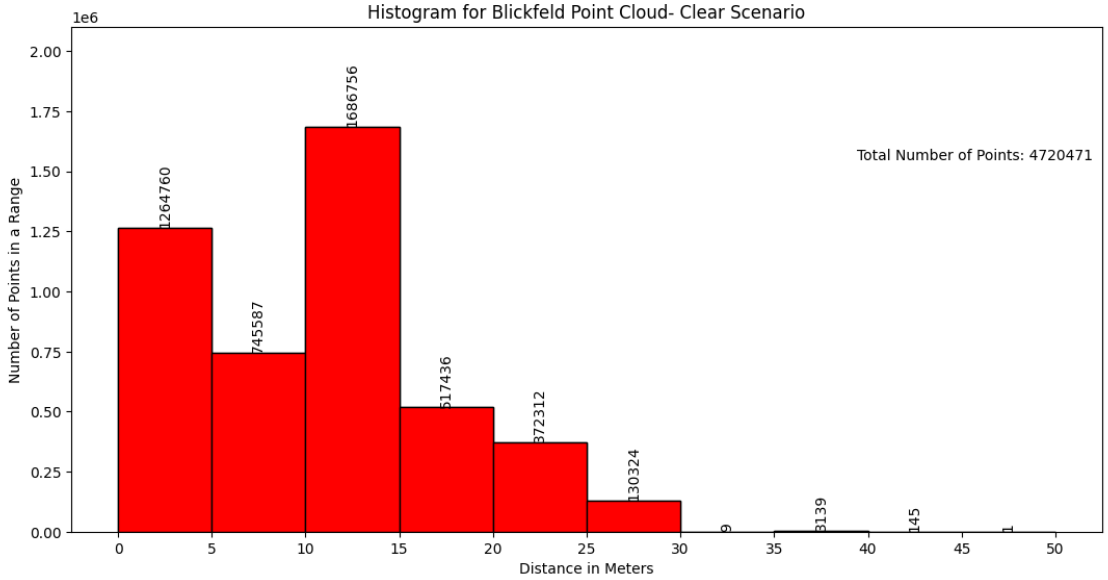


Figure 3: Blickfeld-Clear Scenario

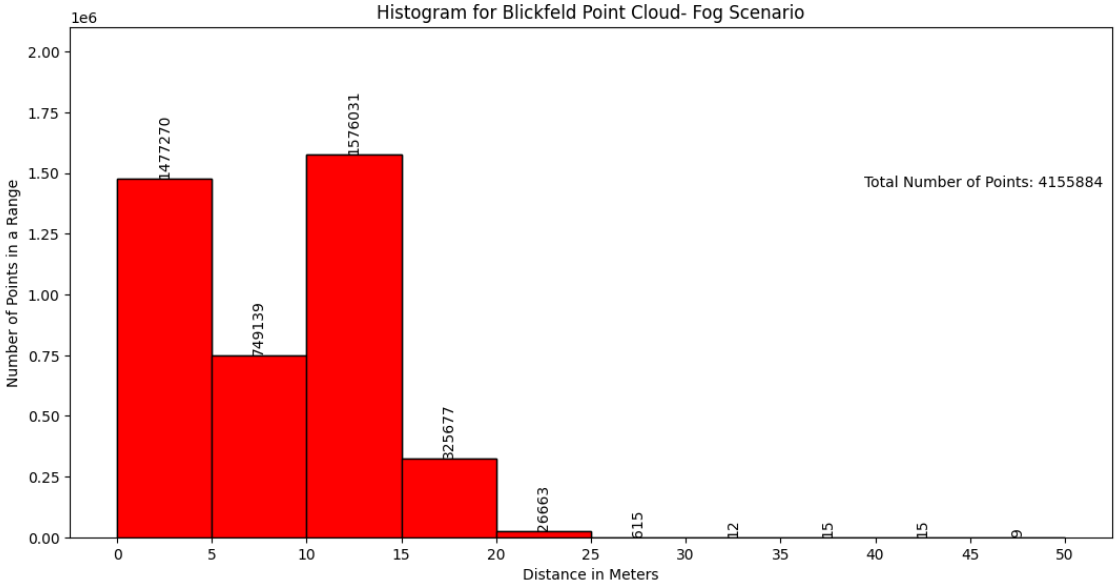


Figure 4: Blickfeld-Foggy Scenario

3.3 Texas Instruments- radar sensor

Unlike earlier Lidar sensors, the reduction in total points recorded in a foggy scenario is very minute (4%) for radar sensor. This is due to the fact that radar waves have longer wavelengths and interact less with fog aerosol particles. The Swirling Target Loss[1] associated with radar waves also plays some role in this difference as it is difficult to obtain exact same readings by recreating the scenes. However, looking at the overall histogram data for both scenarios, we can conclude that radar sensors are less likely to be affected by foggy conditions.

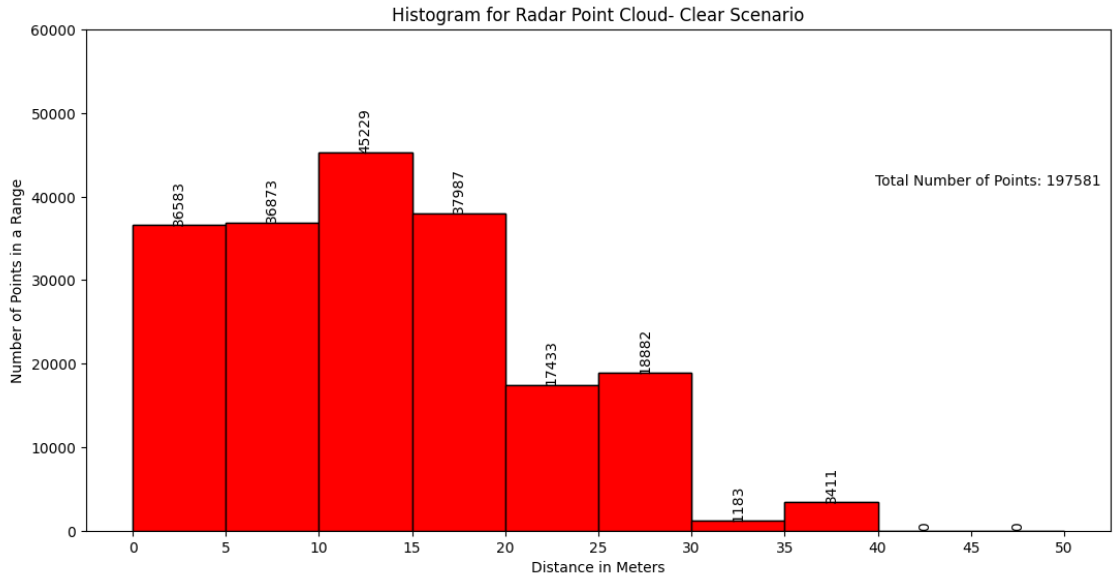


Figure 5: Radar-Clear Scenario

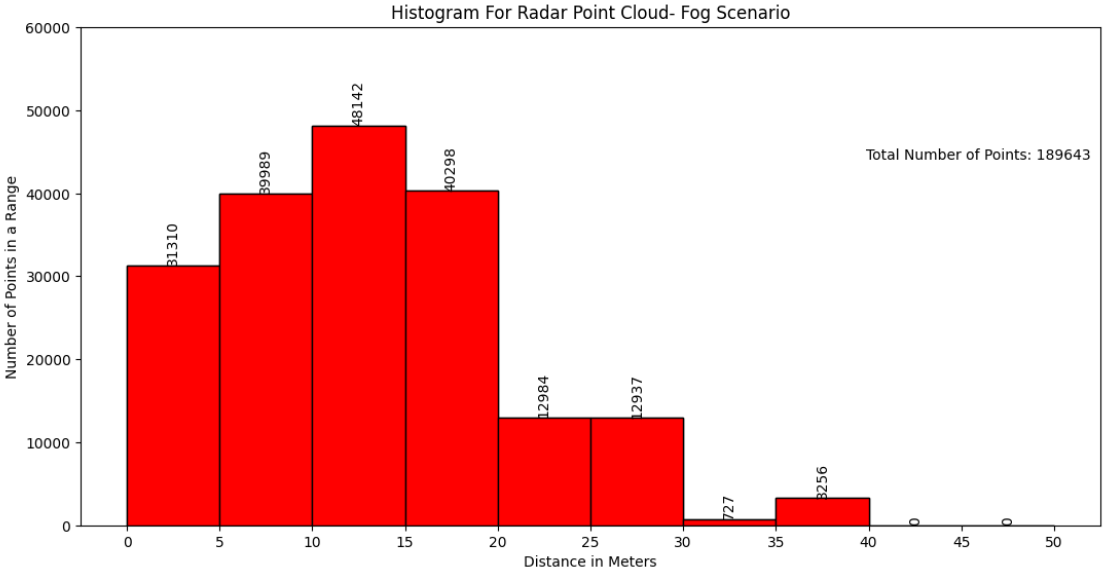


Figure 6: Radar-Foggy Scenario

4 Further Scope of Analysis

We have not observed the Ghost Particle Phenomenon in the case of Velodyne Puck, as we did in Blickfeld. To reason this, we may have to look into aspects such as the wavelength and intensity of laser pulses, scan pattern, and other parameters, which do not fall under the scope of analysis for the moment.

References

[1] Prof. Dr. Stefan Elser *LIDAR AND RADAR SYSTEMS,CHAPTER 04:RADAR RANGE EQUATION, DEPENDENCIES AND LOSSES, page 72-77.*