VSI Labs

AEYE iDAR: Sensor Performance Validation Report

A report detailing VSI's oversight on the performance testing of iDAR with insight on applications for safety and autonomy.

John Cooper and Matthew Linder
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AEYE iDAR Performance Testing

A report detailing VSI's oversight on the hardware performance testing of iDAR with insight on applications for safety and autonomy.

By John Cooper and Matthew Linder

The purpose of this report is to assess the performance of AEye's iDAR™ platform, which purportedly can detect a target at a range of 1000 meters. While VSI Labs did not perform the tests, we were commissioned to examine the methodology, witness the testing, and verify the results.

The testing was planned and carried out by AEye employees while reviewed and witnessed by Matt Linder and John Cooper, engineers for VSI Labs. The testing took place at the Byron Airport in Byron California, and at AEye's offices in Dublin, California on February 3, 2021. The purpose of the testing was to determine certain specifications for AEye's iDAR platform, which combines solid-state, active LiDAR and integrated deterministic artificial intelligence to capture more intelligent information with less data.

There were 4 performance specifications being tested: Detections at 1K Range at 10Hz; Resolution as measured by Points per Degree Squared, Speed as measured by Full Frame Scan Rate, and Sensor Integration Flexibility. Details of the testing procedure and results can be found below, as well as VSI's insight, which gives context to the test results, explaining how they are relevant to the automated vehicle industry.

Sensor Specifications and Automated Vehicles

LiDAR (Light Detection and Ranging) sensors are used in Automatic Driver Assistance Systems (ADAS) and automated vehicles (AVs) for the purposes of object detection, classification, and tracking. A laser's pulse is emitted and reflected back to the sensor. LiDAR uses the 'time of flight' method to measure the distance of the object that the laser was reflected from. Each reflected beam is sensed by the LIDAR as a point with an associated distance. Current LiDAR sensors return clusters of points which are referred to as a point cloud. The point cloud gives the system an accurate 3D measurement of objects that the sensor "sees." This gives ADAS and AV systems precision data that can be used by a number of important perception and decision-making algorithms. Current LiDAR systems employ standalone modalities which require fusion of camera and other sensor data prior to analysis by the perception system.

There are a number of specifications for a LiDAR sensor that can impact the quality and usability of the resulting data. These can generally be classified into two clusters – spatial coverage and temporal coverage. Range is the distance that the LiDAR can send and receive accurate signals and is a key metric in assessing spatial coverage. Ranging for object detection in the context of ADAS and AV is critical because it determines the distance in which the vehicle can reliably detect objects that are within the field of view of the sensor. Particularly relevant are vehicles within the trajectory of the vehicle which require maintaining safe following distances, as well as avoiding objects and obstacles which may be moving or stationary but reside in the planned path of the vehicle.

Sensor Performance Metrics Tested

Range

LiDAR sensors targeting the ADAS and automated vehicle markets are generally limited to ranges of less than 300 meters. While this is sufficient for many purposes, the ability to see further and with greater precision improves the performance and safety of the applications. This is particularly important in the trucking segment where stopping distances are longer.

We observed that AEye's iDAR sensor was able to read dozens of points on an unmodified Chevy Bolt at 1,000 meters away. This detection is more than four times longer than that of conventional LiDAR units. Earlier detection with sufficient resolution enables perception systems to classify objects faster and more accurately which means the vehicle is able to make better decisions, faster – improving safety.

Resolution

The resolution of LiDAR systems is usually specified in degrees or points per degree squared. Currently, the best conventional LiDAR companies provide resolutions of 0.1°V x 0.05°H or 300 points per degree squared. In the test below, we observed that AEye's iDAR can deliver resolution of 0.025° horizontally and vertically which equates to over 1600 points per degree squared. As with range and scan rate, it is important to deliver high quality information about any object in a scene so that it can be identified, classified, and tracked as accurately and quickly as possible to increase the vehicle's response time and improve safety. Increased resolution gives improved object classification, size, and positioning information.

Speed

Scan rate is a key metric for temporal coverage and is another critical specification determining the usability of LiDAR data. The scan rate frequency is measured in Hertz, and it is more simply described as the number of times a scan is taken in one second. If the scan rate is 1 Hz, then one scan is taken each second. Current standard AV industry scan rates range from 10 Hz to 30 Hz. In the test below, we observed that AEye's iDAR full frame scan rate can be configured to exceed 200 Hz, about 10x -20x faster than typical LiDAR sensors. High speed scan rates, together with resolution and distance, draw upon any AEye's ability to give the ADAS or AV perception system a radical increase in the number of 3D views of the environment, critical for tracking and motion forecasting. At speed, this allows an AV to interrogate an object every few centimeters, or even millimeters, instead of meters or tens of meters.

Object classification simply means that the AV can determine what type of object is being detected. Usually, these classifications are objects like cars, trucks, bicycles, pedestrians and traffic signs. Scan rate is an important feature for estimating behavior and movement of an object. By enhancing the performance of both spatial and temporal coverage, pre-classification can occur in the sensor. More accurate and reliable classification data should enable the motion planning system to make decisions faster.

Sensor Integration Flexibility

The ability to place the sensor behind first surfaces, such as windshield, with minimal performance impact gives OEMs complete flexibility in implementing sensors within their designs without compromising aesthetics or changing the aerodynamics of the vehicle. We observed that AEye's sensors, when mounted behind first surfaces, including the windshield, has less than 10% observable degradation in performance.

Test Procedure and Results

Range Test

Objective

The objective of this test was to determine the distance at which the iDAR sensor can detect the back of an unmodified compact passenger vehicle and a delivery van and maintain a 10 Hz Scan Rate. VSI Labs was selected to monitor the test procedure to validate the testing protocol and the resulting data.

Test Summary

This test took place at the Byron Airport in California during normal sunny daytime operating conditions. The iDAR sensor was mounted to the top of AEye's research vehicle. The vehicle was parked at one end of the runway, while the Chevy Bolt and a Mercedes-Benz Sprinter delivery van were placed at the other end 1,018 meters away.

Figure 1: Bird's eye image of Byron runway 5/23 with blue line representing the length of the runway, the distance driven in reverse by the AEye research vehicle (with mounted iDAR sensor). The orange dot represents the Chevy Bolt and Mercedes-Benz Sprinter delivery van.

Resulting Data and Observations

At 1018 meters, the Bolt and Sprinter van are detected within a full field of view at 10 Hz. At this distance, AEye was able to detect greater than 50 points on the van, and 39 points on the Bolt at a 10Hz scan rate.

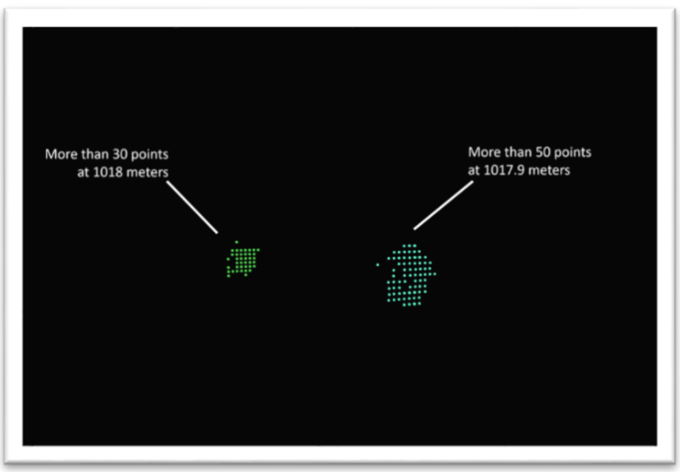

Figure 2: LiDAR imager of the Chevy Bolt with over 30 points at a distance of 1018 meters (left) and the Sprinter van with over 50 points at a distance of 1017.9 meters (right).

Conclusion

VSI Labs determined that this was a valid test and the objective was reached. The sensor was able to detect the targets with a substantial number of points at a distance exceeding 1,000 meters without compromising frame rate.

VSI Take

The classification algorithms AEye is developing were not tested, but the visualized data demonstrated that the target has enough point returns to perform meaningful and accurate classification. While most OEMs require a range greater than 200m, AEye's iDAR demonstrated point density suggests that perception algorithms should be able to differentiate discrete objects and vehicles at a 1,000m range. Using a target with worst case 5% Lambertian reflectance, (i.e. tires etc.) most LiDARs can only detect these objects at < 150 meters.

Resolution Test – Points Per Degree Squared

Objective

To verify iDAR's stated capacity to achieve 0.025° resolution by measuring points per degree squared.

Test Summary

At 0.025° resolution this equates to 1,600 points per degree. In order to test this specification a 18% calibrated 100cm x 100cm (1m x 1m) target was placed at 200meters and the number of detections were counted. With 0.025° spacing on a target placed 200 meters away this equates to a laser beam every 8.6cm vertically and horizontally on the target. This equates to 11.6 predicted rows and columns on the target (100cm / 8.6cm). Therefore, on a one-meter square target, we should then expect to see at least 11.6 points both vertically and horizontally – or 135 points in total.

Validation Plan

Procedure

1. Place a one-meter square 18% target at a 200m distance from the sensor.
2. Scan the target and, using the AEye visualizer, count the number of points on the target.
3. Verify points on target exceeds 135 points.

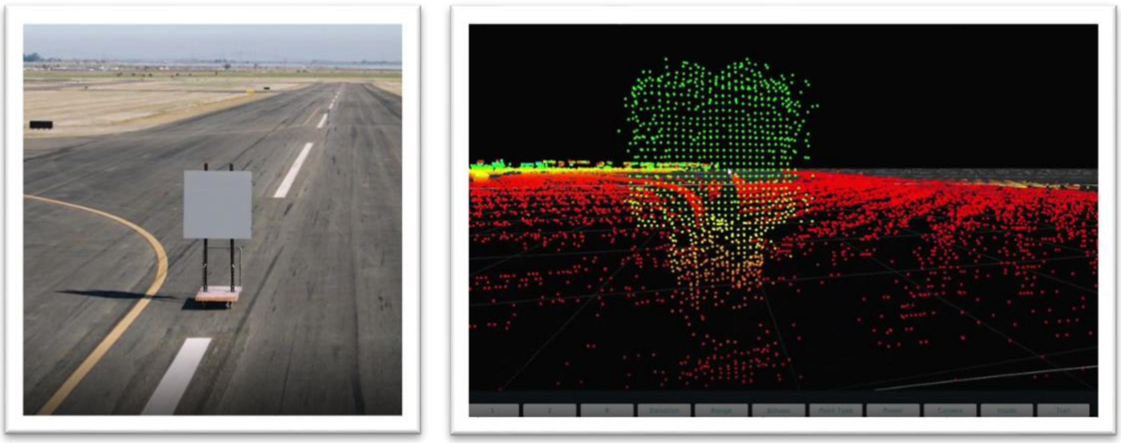

Figure 3: The one-meter square 18% target, placed at a distance of 200m from the sensor (left); point cloud image showing over 175 points on the target (right).

Resulting Data and Observations

As Figure 3 above shows, we observed 175 total points which exceeds the 135 points needed to satisfy the objective.

Conclusion

VSI Labs determined that this was a valid test and that the objective was reached. During the test at the Byron Airport, VSI was able to validate that over 175 points were on the target, achieving the metric with 1,600 points per degree squared.

VSI Take

iDAR's ability to put high density resolution where it is needed enables vehicles to quickly and accurately identify and classify threats. The 4Sight M sensor, with 5X the resolution of most other LiDAR sensors, should be able to differentiate between a balloon and a brick. According to another LiDAR leader (based on its assessment of OEM RFIs,) current OEMs requirement for max resolution is about 200 pts/deg² @10 Hz in the range of 200 meters. That other leading LiDAR company boasts 300 pts/deg² @10 Hz, while most LiDAR companies have less than 45 pts/deg² in such a range.

Speed Test

Objective
The Objective of this test was to determine whether the iDAR scan rate was at least 200 Hz for a full field of view scan.

Test Summary
For the Full Frame test, the iDAR sensor was turned on for 30 seconds. At 200 Hz, there must be 200 scans per second. Each full field of view scan was recorded as a frame. In 30 seconds, at least 6,000 frames must be captured to validate a 200 Hz scan rate.

Validation Plan
Procedure

1. Run the iDAR sensor for 30 seconds.
2. Calculate the number of recorded frames.
3. Using the formula for frequency, calculate the frequency in Hz.

Resulting Data
For the Full Frame test, there were 7235 measurements captured in 30.2465 seconds.

$$f = \frac{cycles}{time\ (s)} \qquad f = \frac{7235}{30.2465} \qquad f = 239.2Hz$$

Conclusion
VSI Labs determined that this was a valid test and that the objective was reached. In the Full Frame test, iDAR recorded 7,235 files in 30.2465 seconds, which means that the scan rate was 239.2 Hz, significantly faster than the 200 Hz objective.

VSI Take
The scan rate describes how frequently the system is receiving real-time environmental data. The faster the system can receive this data, the more accurate and up-to-date the data becomes. Scan rates are especially important for object tracking – determining and predicting where an object is going. As the human eye scans at the equivalent of 27 Hz, achieving a scan rate that is nearly 9X the ability of humans will help ensure that AVs understand the potential movements of pedestrians, bicyclists, motorcyclists and other vehicles. High scan rates will contribute greatly to addressing the most daunting edge cases (e.g. a child stepping into the street from behind a parked car, as well as cut-in moves from motorcycles, deer and vulnerable road users).

VSI believes this increased scan rate would add value to vehicles in numerous situations including detecting lane cut-ins, determining object heading more quickly, and having greater confidence and accuracy in the velocity and behavior of vehicles approaching intersections for taking unprotected turns.

Windshield Placement Performance

Objective
Verify that when placed behind a windshield or other “first surface”, iDAR has minimal performance degradation.

Test Summary
AEye has a bi-static architecture that allows for flexible mounting locations. In order to demonstrate this, a windshield sample made from AGC WideEye glass was put in front of the iDAR sensor and the same scene was analyzed before and after the windshield was placed in front.

Validation Plan
Procedure

1. A one-meter square 18% Lambertian target was placed 100m in front of the sensor
2. Number of points were recorded without the windshield in front of the sensor
3. Number of points were recorded with the windshield in the front of the sensor at various angles of incidence (from 0° to 70°)
4. Recordings were compared

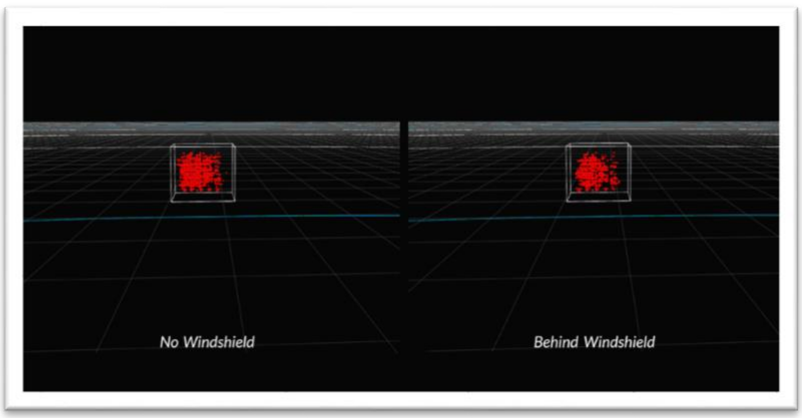

Figure 4: The point cloud with no windshield in front of the sensor (left), compared to the point cloud with the windshield in front of the sensor (right).

Resulting Data and Observations
The number of points recorded on the target without the windshield glass was 52. With the windshield glass in place, at various angles of incidence, the number of points recorded was 47. This is less than a 10% degradation in performance.

Conclusion
VSI Labs determined that this was a valid test and that the objective was reached. The iDAR sensor works effectively behind a first-surface made of windshield glass material at a nominal thickness at various angles of incidence.

VSI Take
The location and packaging of LiDAR represents one of the most difficult challenges to automotive OEMs in the application of LiDAR. OEMs certainly prefer, and some demand, complete flexibility in implementing sensors within their designs without compromising aesthetics or changing the aerodynamics of the vehicle. AEye’s bi-static architecture allows for flexible mounting locations, including the roof, grill and most significantly, behind the windshield.

Though the Robotaxi market may be unconcerned about external protuberances, for consumer-owned vehicles, aesthetics and attractiveness are a high priority for OEMs. Volvo’s protruding LiDAR (Luminar) integration or Nio’s Innovusion LiDAR integration on the roof line are bold moves in the area of styling, but also implicate major packaging issues, including: cleaning/washer liquid, power/data links, and cabin sealing – all of which can drive up cost and cause reliability issues.

VSI Take

AEye's iDAR delivered impressive results, achieving a range of more than four times, a resolution of more than five times, and scan rates of over ten times greater than LiDAR devices currently on the market. This data can be used by the automated vehicle to see further, gain more accurate information, and make decisions about its trajectory at a greater distance or at a higher velocity. The end result is a sensor that can detect and potentially classify objects with enough precision, accuracy, and distance not possible with conventional LiDAR or camera sensors.

About VSI Labs

Since 2014, VSI has been conducting applied research on the technologies used for active safety and autonomous control. Through its own test vehicles, VSI has examined major functional elements of automated vehicle systems, including by-wire control systems, sensor fusion, localization, odometry, and precision localization.

VSI Labs offers its research and advisory services through research portals which are designed to help companies at any stage in their planning or development process. VSI works with major automotive and technologies companies worldwide. For more information, please visit www.vsi-labs.com.

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