

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.

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AEYE iDAR Range, Scan Rate and Color Testing Validation Report

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

This testing was planned and carried out by AEye employees while reviewed and witnessed by Sara Sargent, applications engineer for VSI Labs. This testing took place at the Byron Airport in Byron, CA and AEye's offices in Pleasanton, CA on Thursday, November 8th 2018. The purpose of the testing was to determine certain specifications for AEye's iDAR system, which includes a sensor that fuses solid-state 1550nm Agile LiDAR with an HD camera to create a data type AEye refers to as "Dynamic Vixels" which integrates both color and geometry. AEye's iDAR system also enables feedback loops that enable AI-driven intelligent interrogation of a scene. The three specifications being tested were the range, scan rate and accuracy of the color fusion. 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 automated vehicles (AVs) for the purposes of object detection, classification, and tracking. A series of lasers are 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 has a distance and is called a point. 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 the AV system precision data that can be used by a number of important perception and decision-making algorithms. Current LiDAR systems are 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 an 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 AV which require maintaining safe following distances, as well as avoid objects and obstacles which may be moving or stationary but reside in the planned path of the AV.

LiDAR sensors targeting the automated vehicle market are generally bound to ranges of less than 300 meters. While this is sufficient for many applications, the ability to see further and with greater precision improves the performance and safety of the applications. This is particularly important in the commercial vehicle segment where reaction times are longer. AEye's iDAR sensor has a range of 1000 meters, more than three times that of conventional LiDAR units.

Scan rate is a key metric for temporal coverage and is another critical specification determining the usability of LiDAR data. The scan rate is a frequency 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 20 Hz to 50 Hz. AEye's iDAR sensor scan rate is 100 Hz, up to twice as fast as the current available sensors. The scan rate is important as an increase from 50 Hz to 100 Hz gives the AV perception system twice as many 3D views of the environment which is important for object classification and tracking. At speed, this allows an AV to interrogate an object every few centimeters 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 things like car, truck, bicycle, pedestrian 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.

Color is not a specification typically associated with LiDAR and instead is data that is perceived by a camera. Since the iDAR sensor couples a camera with agile LiDAR the sensor offers the ability to associate color values for all points within the point cloud. Similarly, when coupling a camera with LiDAR you now have precision depth information that can be associated with each pixel in the frame.

AEye's iDAR provides the ability to fuse each camera frame with a point cloud. It is important to note that the camera and the LiDAR share the same aperture to collect data. When coupled with computer vision in the front end (within the sensor module) you improve the accuracy of the fused data and lighten the compute load within the domain processor.

By combining camera pixels with LiDAR voxels in a scene you have what AEye calls Dynamic Vixels. Dynamic Vixels create content that is much richer than either cameras or LiDARs can produce by themselves and is better at determining how the AV system should operate in certain driving situations.



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 a semi-truck up to 1000 meters. 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 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 with a Semi-truck parked in front of the research vehicle. The iDAR-equipped vehicle started its detection while the vehicles were in close proximity of each other. The semi-truck drove from the end marked '5' to the opposite end marked '23'. The iDAR equipped research vehicle then drove in reverse to reach a distance of 1000 meters from the sensor to the semi-truck.

Validation Plan

Required Resources

Semi-Truck: 20-foot Isuzu NPR HD

Range finder: Bushnell Golf Tour V4 Slope Laser Rangefinder

Tape measure

iDAR mounted on AEye vehicle and required software

Measurements

Byron Airport runway 5/23 Pavement length: 914.4 meters, grass area length used: 100 meters

Truck length, Bumper to bumper: 8.3 meters

Procedure

A diagram can be seen below detailing the layout for the test procedure. Data must be collected for the entire duration of the test.

1. Start with iDAR mounted on AEye's test vehicle. The vehicle should be parked with the rear tires at the end of the pavement on the side of the runway marked '5' facing in the direction of the end of the runway marked '23'.
2. The semi-truck should be parked directly in front of the AEye vehicle, facing down the runway towards the end marked '23'.
3. The semi-truck must drive down the length of the runway, seen below in blue, toward the '23' until it reaches the end of the pavement.
4. Once the semi-truck has stopped at the end of the pavement, represented in orange below, the AEye vehicle must drive in reverse in a straight line onto the grassy area 100 meters from the end of the pavement, seen in yellow below.



Figure 1: Bird's eye image of Byron runway 5/23 with the yellow line representing the distance driven in reverse by the AEye vehicle, the semi-truck represented in orange and the entire length of the represented in blue.



Resulting Data and Observations

As the semi-truck drove away from the mounted iDAR sensor the resolution did become lower as expected but even at 600 meters the resolution was enough that the object had more than several points and its movement was easily detectable on the visualization. In the bird's eye view image below, captured from the iDAR visualizer, the AEye car is shown in white at the bottom center of the image and the truck is shown in green at the top center of the image. The distance between blue lines is 100 meters. There was an airport vehicle parked near the runway which is also visible in the image below as yellow dots to the left of the semi-truck.

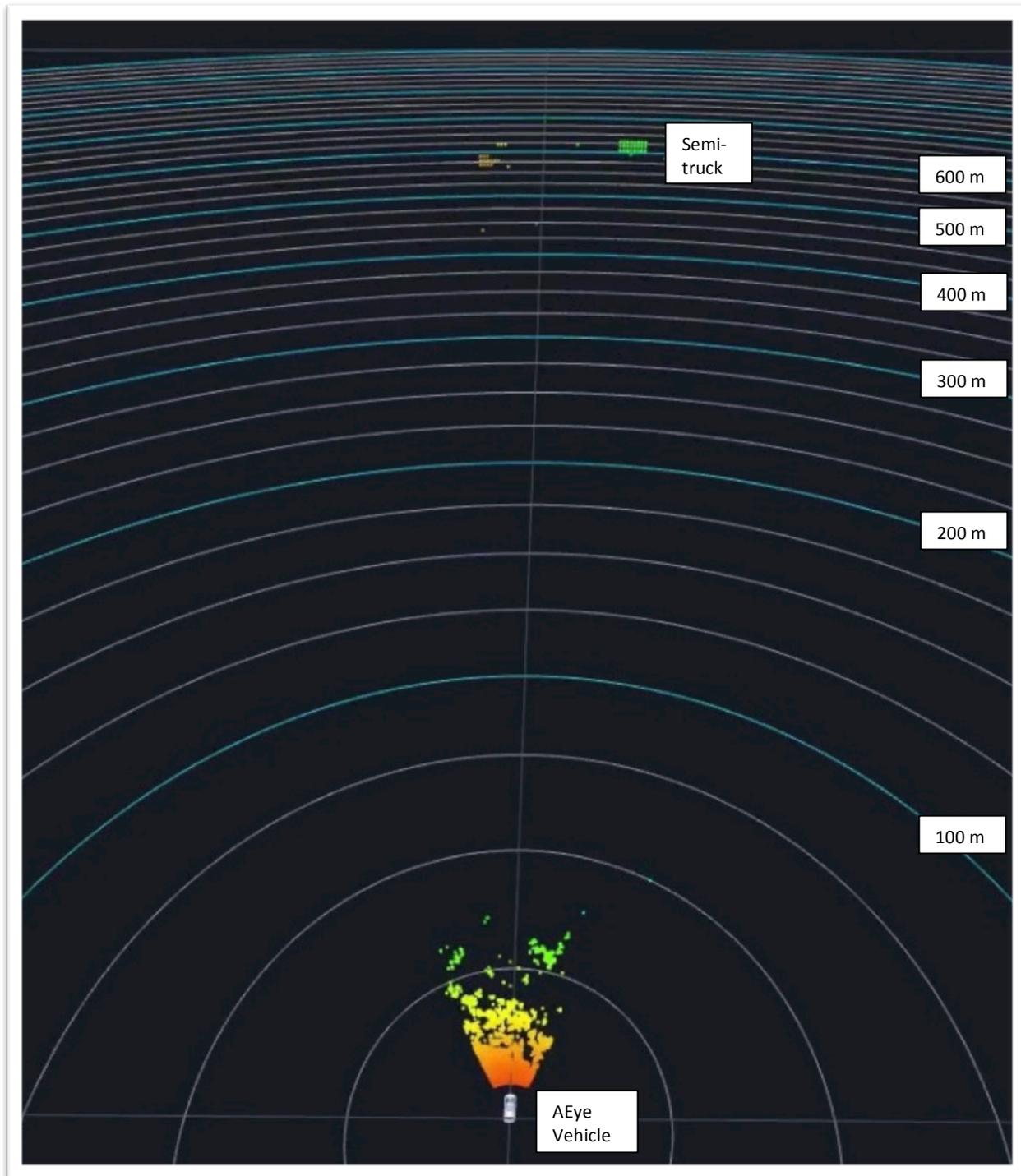
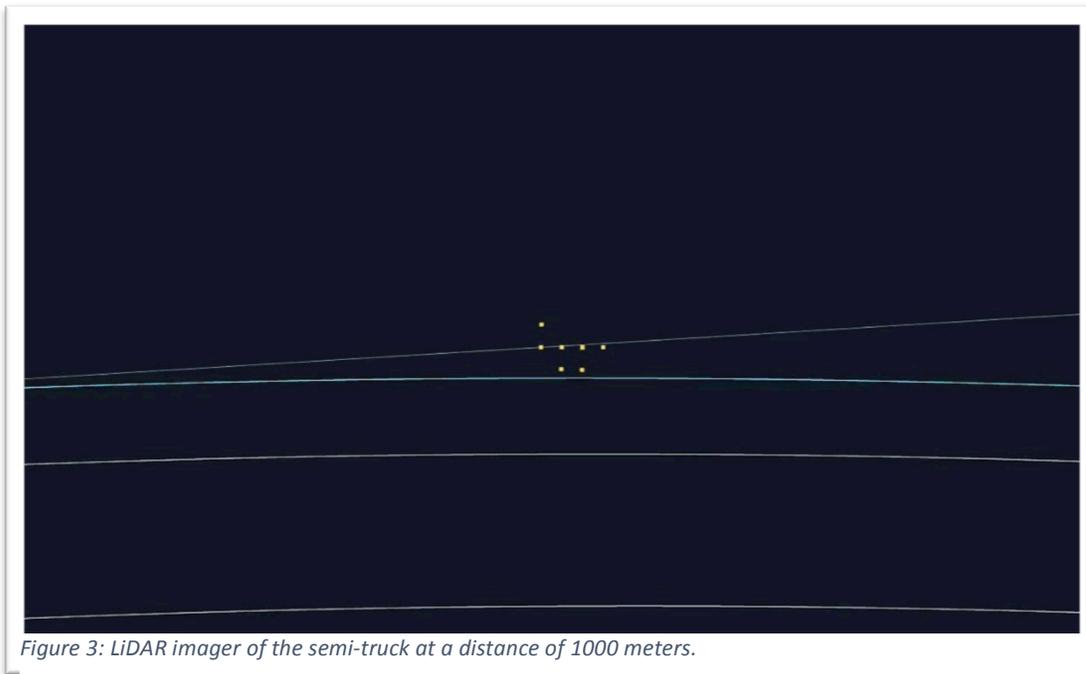


Figure 2: A bird's eye view from the iDAR imager of the LiDAR detection of the semi-truck, shown near the top in green and the mounted sensor represented by the car near the bottom. The blue lines have a spacing of 100 meters.



At 1000 meters the semi-truck is detected within a full field of view with a cluster of points as seen in the image from the visualizer below showing multiple independent (not integrated) shots creating a definable cluster. The movement of the semi-truck was also detectable. In addition to the planned testing, once at the end of the runway the semi-truck drove side to side and was easily recognized within the visualizer as a moving object. In the image below, the third line up from the bottom is the 1000-meter mark. The semi-truck was actually a few meters past the 1000-meter measurement which was as expected due the additional distance between the sensor and the back of the semi-truck.



Conclusion

VSI Labs determined that this was a valid test and the objective was reached. That sensor was able to detect the target at a distance of 1000 meters.

VSI Take

The classification algorithms that AEye is developing were not tested but the visualized data demonstrated that the target has enough point returns and when coupled with color information could perform meaningful classification.



Scan Rate Test

Objective

The Objective of this test was to determine whether the iDAR scan rate was at least 100 Hz.

Test Summary

The iDAR was turned on for 30 seconds. At 100 Hz there must be 100 scans per second. Each scan was recorded as a measurement. In 30 seconds, at least 3000 measurements must be captured to validate a 100 Hz scan rate.

Validation Plan

Procedure

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

Resulting Data

There were 3,316 measurements captured in 30 seconds.

$$f = \frac{\text{cycles}}{\text{time (s)}}$$

$$f = \frac{3316}{30}$$

$$f = 110.5 \text{ Hz}$$

Conclusion

VSI Labs determined that this was a valid test and that the objective was reached. The iDAR recorded 3316 files in 30 seconds which means the scan rate was 110.5 Hz, somewhat faster than the 100 Hz expectation.

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 27Hz, achieving a scan rate that is almost 4x the ability of humans will help ensure that AVs understand the potential movements of pedestrians, bicyclists, motorcyclists and of course other vehicles.



Dynamic Vixels Color Test

Objective

The objective of this test was to identify whether the Dynamic Vixels generated by the iDAR were an accurate representation of the colors from the camera image. Dynamic Vixels are the result of sensor fusion of an HD camera and a LiDAR. Both sensors scan the same instance and the color from the HD camera is mapped to or overlaid onto the LiDAR point cloud. The data output by the iDAR sensor is composite information, namely a LiDAR point cloud in color.

Test Summary

The iDAR visualizer was turned on and facing a shelving unit and table with a variety of object sizes and colors represented. The AEye representative showed a live feed with moving objects as well as static objects. The VSI representative compared the colors of the objects in the camera to the Dynamic Vixel visualizer and to the actual objects.

Validation Plan

Procedure

1. Select a scene to view through the iDAR visualizer.
2. Add objects with a variety of colors to the scene.
3. Run the iDAR and compare the colors from the HD camera visualizer to the iDAR, Dynamic Vixel visualizer.

Resulting Data and Observations

The colors from the camera were accurately represented by the Dynamic Vixels. An orange cone, yellow spray bottle and white table in the scene are identifiable based on the color seen in the iDAR color overlay image. Also visible is the change in color created by a shadow on the top most part of the wall in the image.

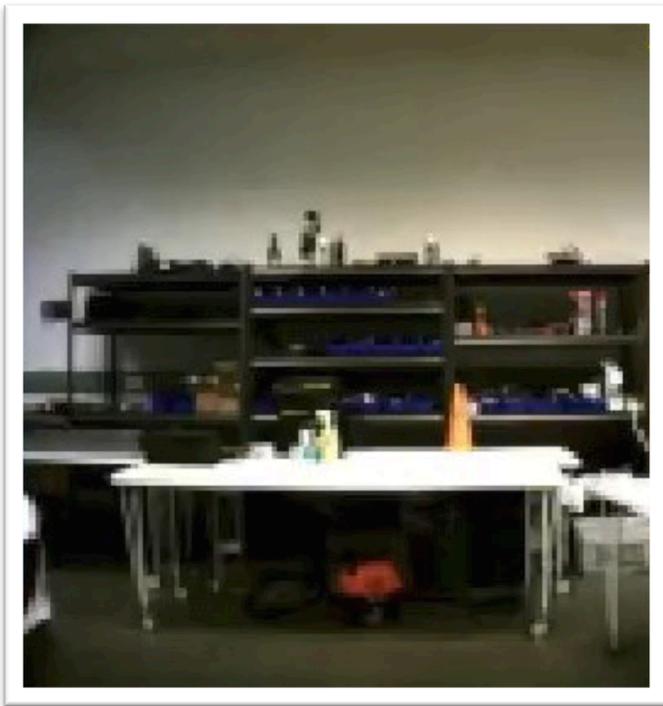


Figure 4: The HD camera image of part of the lab at AEye's headquarters. This is considered the true color control.

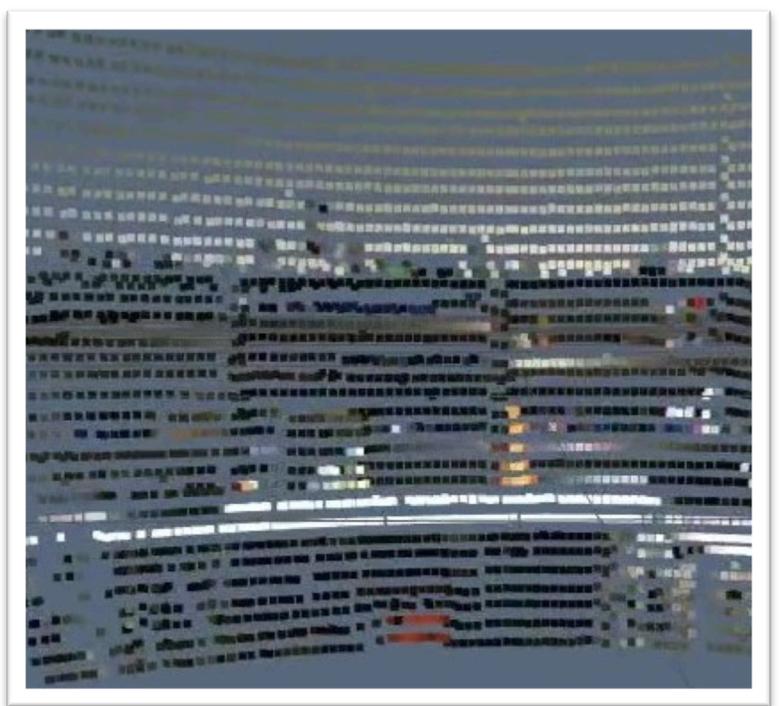


Figure 5: The iDAR visualizer showing the Dynamic Vixels created for color comparison to figure 4.

Conclusion

VSI Labs determined that this was a valid test and that the objective was reached. The real-time color fusion of Dynamic Vixels accurately represented the colors of the objects whether they be moving or stationary. The color was well represented whether it was a bright, dark or neutral color and whether the size of the object was large or small relative to the other objects in frame.

VSI Take

Color is an important feature during classification of objects— determining what an object is. A stop sign is red, if a system identifies a sign that has a similar shape to a stop sign but it is not red, it can conclude that the sign is not a stop sign. In a larger application color could be used to aid in identifying an object as a fire truck or a school bus. Both are vehicles that the AV may need to react to in different ways than another large truck – requiring the AV to brake sooner and leave a greater distance and have an awareness of a higher amount of smaller, unpredictable pedestrians.

VSI Take

The range test of AEye’s iDAR delivered impressive results, achieving a range more than twice that of most devices currently on the market. This data can be used by the automated vehicle to see further and make decisions about its trajectory at a greater distance or at a higher velocity.

The scan rate is impressive as well for the purposes of object tracking. The Dynamic Vixel color overlay provides accurate colors assigned to each LiDAR point in such a way that the data is a rich resource for the AV to use for object classification.

The iDAR sensor from AEye is a unique device because it couples an HD camera and LiDAR within the sensor hardware. AEye calls their combined frames Dynamic Vixels which includes the properties of computer vision with the depth information associated with the LiDAR point cloud.

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. Furthermore, coupling the two sensors at the front end eliminates the compute intensive sensor fusion within a domain controller from using discrete 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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