New Performance Metrics for Lidar

by Indu Vijayan

Frame-rate measurement is so yesterday. Object-revisit rate and instantaneous resolution are more relevant metrics, and indicative of what a lidar system can and should do, argues a revolutionary in the artificial-perception space.

How do you measure the effectiveness of an intelligent, lidar-based perception system for autonomous vehicles? Conventional evaluation metrics favor frame rate and resolution as the ideal criteria. However, experts at Pleasanton, Calif.-based artificial perception company AEye believe that these criteria are inadequate for measuring the unique capabilities of more advanced lidar systems, nor do they explicitly address real-world problems facing autonomous driving, such as hazard detection and tracking.

“Makers of automotive lidar systems are frequently asked about their frame rate, and whether or not their technology has the ability to detect objects with 10% reflectivity at a specified range, frame rate and resolution,” said the company’s co-founder and senior VP of engineering, Dr. Barry Behnken. “These metrics were established back in 2004 during the first DARPA Grand Challenge and haven’t been altered since. Unfortunately, they fail to adequately rate a perception system’s ability to perform safely on public roads, as the AVs back then were not being built for widespread use.”

As perception technology improves and more real-world challenges present themselves (such as the false-positive detection of other vehicles and traffic signals that plague conventional systems), AEye experts believe new metrics must be established to assess the performance of lidar-based perception systems. The company is recommending revised metrics that it believes are not only more advantageous for AV development but will oblige more robust safety standards across the industry. But what are the new metrics?

From frame rate to object-revisit rate

As opposed to the conventional metric of “frame rate of xx Hz,” AEye proposes a new measurement of object revisit rate. This is the time between two shots at the same point or set of points.

“Defining single-point detection range alone is insufficient because a single interrogation point, or shot, rarely delivers enough confidence to ascertain a hazard—it is only suggestive,” explained AEye chief scientist and former DARPA chief scientist, Dr. Allan Steinhardt. “Therefore, we need multiple interrogations at the same point to validate or comprehend an object or scene.”

But the time it takes to validate an object is dependent on many variables, including distance, interrogation pattern and resolution, reflectivity, and the shape of the objects being interrogated. AEye experts believe what is missing from the conventional metric is a more fine-tuned definition of time.

“The time between the first detection of an object and the second is critical, as shorter object revisit rates can keep processing times low for advanced algorithms...
that need to correlate between multiple moving objects in a scene,” noted Dr. Steinhardt. “Too long of an object revisit rate at fast velocities could be the difference between detecting an object in a timely manner and the loss of life.”

Having an accelerated revisit rate increases the likelihood of hitting the same target with a subsequent shot, due to the decreased likelihood that the target has moved significantly in the time between shots. This helps solve the “correspondence problem” (determining which parts of one “snapshot” of a dynamic scene correspond to which parts of another snapshot of the same scene), while simultaneously enabling the quick build of statistical measures of confidence, generating aggregate information that downstream processors might require (such as object velocity and acceleration).

“While the correspondence problem will always be a challenge for autonomous systems, the ability to increase revisit rate on points of interest can significantly aid higher level inferencing algorithms, allowing path-planning systems to more quickly determine correct movements,” said Dr. Steinhardt.

When you’re driving, the world can change dramatically in a tenth of a second. In fact, two cars closing at a mutual speed of 124 mph (200 kph) are 18 feet closer after 0.1 seconds. That is why AEye was determined to expedite the process. The achievable object revisit rate of AEye’s iDAR system for points of interest currently is microseconds to a few milliseconds; this compares to many tens or hundreds of milliseconds between visits with conventional lidar systems.

Using revisit rate as a standard metric for automotive lidar performance would compel the industry to cut down on latency, ultimately making all perception systems much safer, AEye experts believe.

**On to instantaneous resolution**

In contrast to the conventional metric of fixed (angular) resolution over a fixed Field of View, AEye’s proposed second metric, instantaneous (angular) resolution, provides insight into the driving force behind iDAR: more information, less data.

“The assumption behind the use of resolution as a conventional metric is that it is assumed the Field of View will be scanned with a constant pattern. This makes perfect sense for less intelligent, more ‘traditional’ sensors that have limited or no ability to adapt their collection capabilities,” Dr. Behnken stated. “Also, the conventional metric assumes that salient information within the scene is uniform in space and time, which we know is not true.”

Because of these assumptions, conventional lidar systems indiscriminately collect gigabytes of data from a vehicle’s surroundings, sending those inputs to the CPU for decimation and interpretation, where an estimated 70-90% of this data is found to be useless or redundant, and thrown out. “It’s an incredibly inefficient process,” observed Dr. Behnken.

AEye’s iDAR technology was developed to break these assumptions and inefficiencies. The AEye team believes that intelligent and agile scanning provides greater safety through faster response times and higher
quality information. Additionally, agile lidar, which enables faster object revisit rates, enables dynamic foveation. Foveation is where the target of a gaze is allotted a higher concentration of retinal cones, allowing objects to be seen more vividly.

Humans do this naturally. We don’t “take in” everything around us equally. Rather, our visual cortex filters out irrelevant information (such as an airplane flying overhead) while simultaneously focusing the eyes on a particular point of interest such as a pedestrian crossing the road. This allows other, less important objects to be pushed to the periphery. Enabling dynamic foveation in artificial perception can change the instantaneous resolution throughout the Field of View, allowing for the targeted collection of the most relevant data.

**iDAR’s actionable data**

AEye argues that object revisit rate is a more meaningful metric than frame rate alone, as the time between object detections cannot be ignored at the cost of vehicle reaction time to hazards. This is tantamount to ignoring safety. Because multiple detects at the same point are required to fully comprehend an object or scene, measuring object revisit rate is a more useful and critical metric for automotive lidar than static frame rate. Additionally, quantifying fixed (angular) resolution is not enough. It is more important to measure instantaneous resolution because intelligent and agile resolution in scanning is more efficient and provides greater safety through faster response times.

However, the sum of these two metrics (and the way in which AEye has combined them) is greater than the two parts alone. Object revisit rate and instantaneous resolution, are not only more relevant and indicative of what a lidar perception system can and should do, but they are also synergistic in combination, allowing the industry to define new constructs, such as Special Regions of Interest.

For example, when points or objects of interest have been identified, AEye can “foveate” its system in space and/or time to gather more useful information about it. Let’s say the system encounters a jaywalking pedestrian directly in the path of the vehicle. Because the path is lateral, current radars and coherent lidars will have trouble recognizing the threat (e.g. lateral velocity vs radial velocity vector). However, because iDAR enables a dynamic change in temporal sampling density and spatial sampling density within a Special Region of Interest, it can focus more of its attention on this jaywalker—and less on irrelevant information, such as parked vehicles along the side of the road. Ultimately, this allows iDAR to more quickly, efficiently, and accurately identify critical information about the jaywalker.

“iDAR swiftly provides the most useful, actionable data to the domain controller to help determine the best timely course of action,” said Dr. Behnken. “This unique ability is critical to the development and universal adoption of autonomous vehicles.”

As more AVs are tested on public roads, it’s imperative that technologists help automakers maintain the highest standard of safety. Modernized metrics for assessing the performance of lidar-based perception systems is a valuable start.

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