Examination of Pedestrian Detection Systems: Benchmarking Thermal Camera Performance

By Matt Linder

In July of 2020 FLIR Systems, Inc. engaged VSI to test the world's first fused automatic emergency braking (AEB) sensor suite, employing a thermal longwave infrared (LWIR) camera, a radar, a visible camera, and a convolutional neural network (CNN). VSI tested the fused AEB system along with the AEB systems deployed in four 2019 vehicles. All tests were conducted at the American Center for Mobility (ACM) in Michigan and were based on Euro New Car Assessment Programme (NCAP) positive detection tests. The VSI-designed tests included driving toward a soft pedestrian target (SPT) heated to mimic a human at 25 MPH in a variety of common driving conditions, which are not currently tested as part of NCAP. This Technology Brief discusses the results of these tests:

- VSI's testing showed that the fused AEB system performed equivalently on several baseline NCAP tests and significantly improved performance in challenging, but common, real-world conditions including when sun glare is present and when a child enters the roadway from behind a parked car at night.
- Automotive testing agencies can evolve their AEB testing scenarios to be more rigorous to align with other daily driving conditions such as darkness and sun glare.
- Of the emerging sensor technologies, thermal LWIR cameras are cost effective and ready for integration today by Tier 1 suppliers and automotive manufacturers.

Current Conditions

In 2019, vehicle accidents in the United States killed more than 6,000 pedestrians, the highest annual total ever recorded, and sent more than 100,000 to hospitals with injuries. As the automotive industry moves towards autonomous vehicles (AV), the ability to sense, classify, and make split-second artificial intelligence (AI) based decisions while driving becomes increasingly necessary. Advanced driver assistance systems (ADAS), and AV systems need to get smarter and safer quickly. There is an opportunity for automotive manufacturers, Tier 1 suppliers, regulators, automotive testing agencies,

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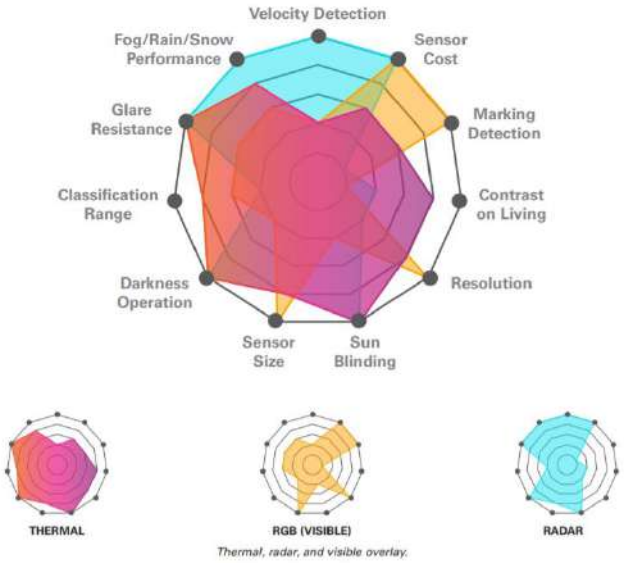
commercial vehicle operators, and consumers to demand systems that maximize safety of drivers, pedestrians, and other vulnerable road users.

A Comprehensive Sensor Suite

Based on recent findings from the AAA, the AEB systems they tested did not perform well at night. FLIR internal testing has confirmed that incorporating a thermal LWIR camera, that can see up to four times farther than typical headlights illuminate, would help enable an AEB system to perform in common nighttime driving conditions as well as other cases where visibility is poor. In addition, false positives can likely be reduced when a thermal LWIR camera is used as an orthogonal detection technology to identify real objects in the scene that give off heat, like a pedestrian. No single sensor will solve for all the variables a vehicle will encounter on the road. Many ADAS systems are built with radar and/or visible camera(s) to provide AEB capability. LiDAR is not used in these systems today due in large part to cost. FLIR proposes that a thermal LWIR camera in a fused AEB system with radar, a visible camera, and a CNN offers a comprehensive sensor suite. This fused system would improve braking and/ or impact avoidance performance in common conditions such as darkness, sun glare, fog, and corner cases not adequately addressed by methods used today. The addition of thermal LWIR sensors is achievable at a reasonable cost.



Thermal, radar, and visible overlay.

FLIR engaged VSI Labs to test a thermal fused AEB system at the ACM track alongside the four commercially available cars. The tests followed Euro NCAP standards with additional supplemental or gap tests developed by VSI. The gap tests account for common driving conditions such as darkness and sun glare, which current NCAP test protocols do not measure.

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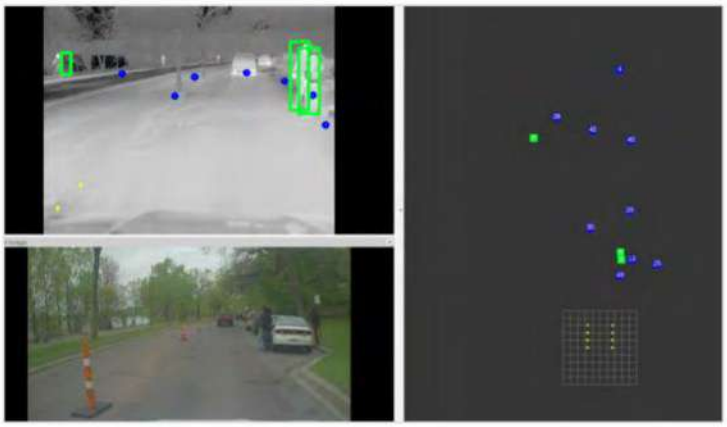
Why a Fused Sensor Suite?

Thermal LWIR cameras effectively 'see the heat' given off by objects in the environment. These cameras perform equally well in daylight, darkness, and through most fog, allowing the AEB systems to detect and classify pedestrians in many challenging driving conditions.



Fused thermal and radar (top left), visible (bottom left), fused radar and thermal (right).

Test Overview

Vehicles Tested

VSI Lab's Ford Fusion includes a fused AEB system, with a thermal LWIR camera, radar, visible camera and CNN. Five tests were conducted in a variety of conditions to compare the VSI Lab's thermal enhanced Ford Fusion to four 2019 production vehicles with AEB systems: Tesla Model 3, Subaru Forester, BMW X7, and Toyota Corolla. All four models were equipped with their most current safety features, for that model year, to avoid pedestrian collisions.

	VSI - Ford Fusion	2019 Tesla Model 3	2019 Toyota Corolla	2019 Subaru Forester	2019 BMW X7
Thermal LWIR Camera	✓ FLIR ADK with Boson® (75° FOV)	✗	✗	✗	✗
Visible Camera	✓ FLIR Blackfly (75° FOV)	✓ 3 cameras (50°, 35°, 150° FOV)	✓ 1 camera (forward facing)	✓ 2 cameras (stereoscopic 25° FOV)	✓ 3 cameras (52°, 28°, 150° FOV)
Radar	✓ Delphi ESR	✓	✓	✗	✓

Five vehicles tested. Visible cameras noted in the chart account for the Forward Camera Modules (FCM) only.

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Five test cases were developed by VSI based on Euro NCAP testing protocols. They included modified scenarios not included in standard AEB positive detection tests and identified as potentially challenging cases for standard AEB systems.

Test Setup

Five test cases were developed by VSI based on Euro NCAP testing protocols. They included modified scenarios not included in standard AEB positive detection tests and identified as potentially challenging cases for standard AEB systems.

Day Tests: In daylight, dry conditions at intersection

- Crossing adult SPT in white clothing that blends in with a light background
- Crossing adult SPT in dark oversized clothing

Night Tests: In dark, dry conditions at intersection

- Crossing child SPT emerging from behind a parked car
- Crossing adult SPT emerging from behind a parked car in dark oversized clothing

Sun Glare Tests: Vehicle emerging from a dark tunnel to sunrise glare in dry conditions

- Crossing adult SPT

The purpose of the tests was to evaluate the AEB systems in certain everyday driving situations not tested by NCAP. While automotive manufacturers and Tier 1 suppliers are making progress developing reliable AEB systems, FLIR believes that without a thermal LWIR camera, radar and/or visible cameras will not perform well in many common driving conditions that are not currently tested. Regulators have an opportunity to update testing protocols to be more representative of common driving conditions.

Test Results

Each test was repeated until the vehicle struck the SPT twice or a maximum of 5 runs. This was done to reduce potential damage to the SPT and the vehicle. The fused thermal AEB system ran through entire test plan with five tests for each test case and was successful in 25 of 25 tests at preventing pedestrian injury with only two instances where the vehicle contacted, but did not knock down the SPT. The four commercially available AEB systems had positive performance in daytime tests (42 pass out of 50 tests) but did not perform well in the nighttime tests, striking the SPT in all but two test cases.

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The sunrise glare and nighttime test cases were stopped after two SPT strikes in eleven of the twelve tests. The sunrise glare tests began with the VSI's test vehicle at 7:15 AM with a solar elevation angle of approximately 12 degrees. As testing proceeded with the Tesla, Toyota, Subaru, and BMW, respectively the solar elevation angle increased, providing less and less glare and improved AEB performance by the vehicle under test. The BMW tests started at 10:05 AM with a solar elevation of approximately 40 degrees and very little glare. Solar elevation angle and reduced glare conditions should be considered in the BMW test results.

** Sunrise glare tests started at 7:15 AM with VSI's test vehicle. Tests were run on the Tesla, Toyota, Subaru and BMW respectively. AEB performance improved as glare decreased. Glare had decreased significantly by 10:05 AM when the BMW tests started.*

*** The BMW X7 is available with an optional thermal camera Night Vision system for pedestrian and animal detection, this warning display is not connected to the AEB system.*

Conclusion

As the tests results show, the AEB system with the added thermal LWIR camera performed significantly better than existing commercial AEB systems in several real-world scenarios.

The thermal-enhanced AEB system improves the AEB functionality in the most dangerous situations, including low-light conditions, darkness, and when exposed to

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blinding conditions such as emerging from a dark tunnel into bright light. Additional positive detection gap tests scenarios are under consideration including headlight glare and more.

Preliminary false positive testing is in process and will continue in 2021. Developing AEB systems with thermal LWIR camera technology will reduce human injuries and deaths significantly. FLIR is currently working with several top AV developers, auto manufacturers and Tier 1 suppliers to continue the advancement of thermal cameras in ADAS and AV system design with the goal of improved safety.

To see the full results, visit FLIR's website.

About VSI Labs

Established in 2014 by Phil Magney, VSI Labs is one of the industry's top advisors on AV technologies, supporting major automotive companies and suppliers worldwide. VSI's research and lab activities have fostered a comprehensive breakdown of the AV ecosystem through hands-on development of its own automated vehicle platform. VSI also conducts functional validation of critical enablers including sensors, domain controllers, and AV software development kits. Learn more about VSI Labs at https://vsi-labs.com/.

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