SAFETY CHALLENGES THAT REQUIRE REAL TECHNOLOGY SOLUTIONS

Until recently, SAE automation level 2 (partial automation) and level 3 (conditional automation) vehicles that drive our roads did not include thermal or infrared (IR) imaging in the sensor suite. High-profile accidents involving both Uber and Tesla vehicles have increased the scrutiny of sensor performance and safety. Although many test vehicles perform admirably under test and ideal conditions, their actual performance must stand up to the rigors of real-life driving conditions.

Thermal sensors perform well in conditions where other technologies in the sensor suite are challenged. Developers are taking advantage of the opportunity to integrate FLIR’s automotive development kit, the FLIR ADK™, into vehicles to add thermal imaging to their sensor suite. Thermal sensors can detect and classify people and animals in darkness and through sun glare and most fog at distances greater than four times the illumination distance of typical headlights.

Figure 1. Thermal imagers use infrared energy to detect, classify, and measure temperature from a distance.

Figure 2. The FLIR ADK with VGA resolution can “see” precise details including roadway surface markings – day and night.
SENSING MINUTE DIFFERENCES IN TEMPERATURE

Thermal or longwave infrared (LWIR) energy is emitted, reflected, or transmitted by everything that would be on or near a roadway. It is well known that thermal cameras can clearly detect differences between a human body (living things), inanimate objects, and background clutter, differentiating them as an essential technology to detect pedestrians.

FLIR thermal imaging cameras are extremely sensitive to differences in temperature as small as 0.05° Celsius. With this precise sensitivity, VGA thermal cameras (640 x 512 pixels) can clearly show nearly everything in a scene, even the centerline on a roadway. Figure 2 (a screen capture of video from a FLIR recreation of the Uber accident in Tempe, Arizona) clearly shows roadway surface details such as paint while detecting and classifying the pedestrian at over twice the required “fast-reaction” stopping distance for a human driving at 43 mph\(^1\) (126 feet or 38.4 meters).

“SEEING” HEAT THROUGH FOG INSTEAD OF RELYING ON LIGHT

The 2016 AWARE (All Weather All Roads Enhanced) vision project tested a suite of cameras that could potentially enhance vision in challenging-visibility conditions, such as night, fog, rain, and snow. To identify the technologies providing the best all-weather vision, they evaluated the four different bands on the electromagnetic spectrum: visible RGB, near infrared (NIR), short-wave infrared (SWIR), and LWIR, or thermal. The project measured pedestrian detection at various fog densities (Table 1) and formulated the following three conclusions.\(^2\)

- The LWIR camera penetrated fog better than the NIR and SWIR. The visible camera had the lowest fog piercing capability.
- The LWIR camera was the only sensor that detected pedestrians in full darkness. The LWIR camera also proved more resilient to glare caused by oncoming headlamps in the fog.
- Visible RGB, SWIR, and NIR cameras sometimes missed a pedestrian because she/he was hidden by headlamp glare.

<table>
<thead>
<tr>
<th>Camera</th>
<th>Fog Density for Pedestrian Detection</th>
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<tbody>
<tr>
<td>Visible RGB</td>
<td>Moderate (visibility range = 47 ± 10 m)</td>
</tr>
<tr>
<td>Extended NIR</td>
<td>High (visibility range = 28 ± 7 m)</td>
</tr>
<tr>
<td>Extended SWIR</td>
<td>High (visibility range = 25 ± 3 m)</td>
</tr>
<tr>
<td>LWIR</td>
<td>Extreme (visibility range = 15 ± 4 m)</td>
</tr>
</tbody>
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Table 1. Fog thickness for pedestrian detection at 25 meters (glare cases not included) indicate LWIR superiority for pedestrian detection in fog.

\(^1\) http://www.brakingdistances.com

ON DETECTION, CLASSIFICATION, AND FIELDS OF VIEW

Detection and classification are key performance metrics within advanced driver assist system (ADAS) and AV sensor suites. Detection lets a system know that there is an object ahead. Classification determines the class of object (person, dog, bicycle, car, other vehicle, etc.) and indicates the classification confidence level.

In photography and thermal imagers, the field of view (FOV) is that part of a scene that is visible through the camera at a particular position and orientation in space. The narrower the FOV, the farther a camera can see. A wider FOV cannot see as far, but provides a greater angle of view. FOV impacts the distance at which a thermal camera can detect and classify an object, meaning multiple cameras may be required; a narrow FOV sensor to see far ahead of the vehicle on a rural highway, and a wide FOV sensor for optimal use in city driving.

Current artificial-intelligence-based classification systems typically require a target to fill 20 by 8 pixels to reliably (>90% confidence) classify a given object. For example, to classify a human with reliable confidence, the human needs to be approximately 20 pixels tall as shown in Figure 4. Table 2 includes classification distances for different thermal camera horizontal fields of view and indicates that a FLIR ADK can classify a 6-foot tall human at a distance greater than 600 feet (186 meters) for a narrow FOV lens configuration. Detection, which requires fewer pixels on an object, means that a 6-foot tall human can be detected at greater than 200 meters using the FLIR ADK.

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<table>
<thead>
<tr>
<th>FLIR ADK Horizontal FOV</th>
<th>Classification Distance (feet)</th>
<th>Classification Distance (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>220</td>
<td>67</td>
</tr>
<tr>
<td>32</td>
<td>344</td>
<td>105</td>
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<td>24</td>
<td>451</td>
<td>138</td>
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<tr>
<td>18</td>
<td>611</td>
<td>186</td>
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</tbody>
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 BETTER SITUATIONAL AWARENESS RESULTS IN MORE INFORMED DECISIONS

Thermal imaging technology is a highly sensitive, passive imaging technology that can be a key enabler for safer ADAS and AV platforms. Thermal sensors can detect and classify people and animals in darkness and through sun glare and most fog at distances greater than four times the distance that typical headlights illuminate and visible cameras can see. FLIR thermal cameras complement existing technologies in the sensor suite and help these systems make better, safer decisions based on improved situational awareness.

To learn more about thermal technology for ADAS and AV platforms, visit www.FLIR.com/ADAS to download the following solution briefs:

- Why ADAS and Autonomous Vehicles Need Thermal Imaging Sensors
- The Pathway to Affordable, Scalable Automotive Integration
- Overcoming Technological and Logistical Thermal Imaging Automotive Integration Challenges
For more information about thermal imaging cameras or about this application, please visit www.flir.com/adas.

The images displayed may not be representative of the actual resolution of the camera shown. Images for illustrative purposes only.