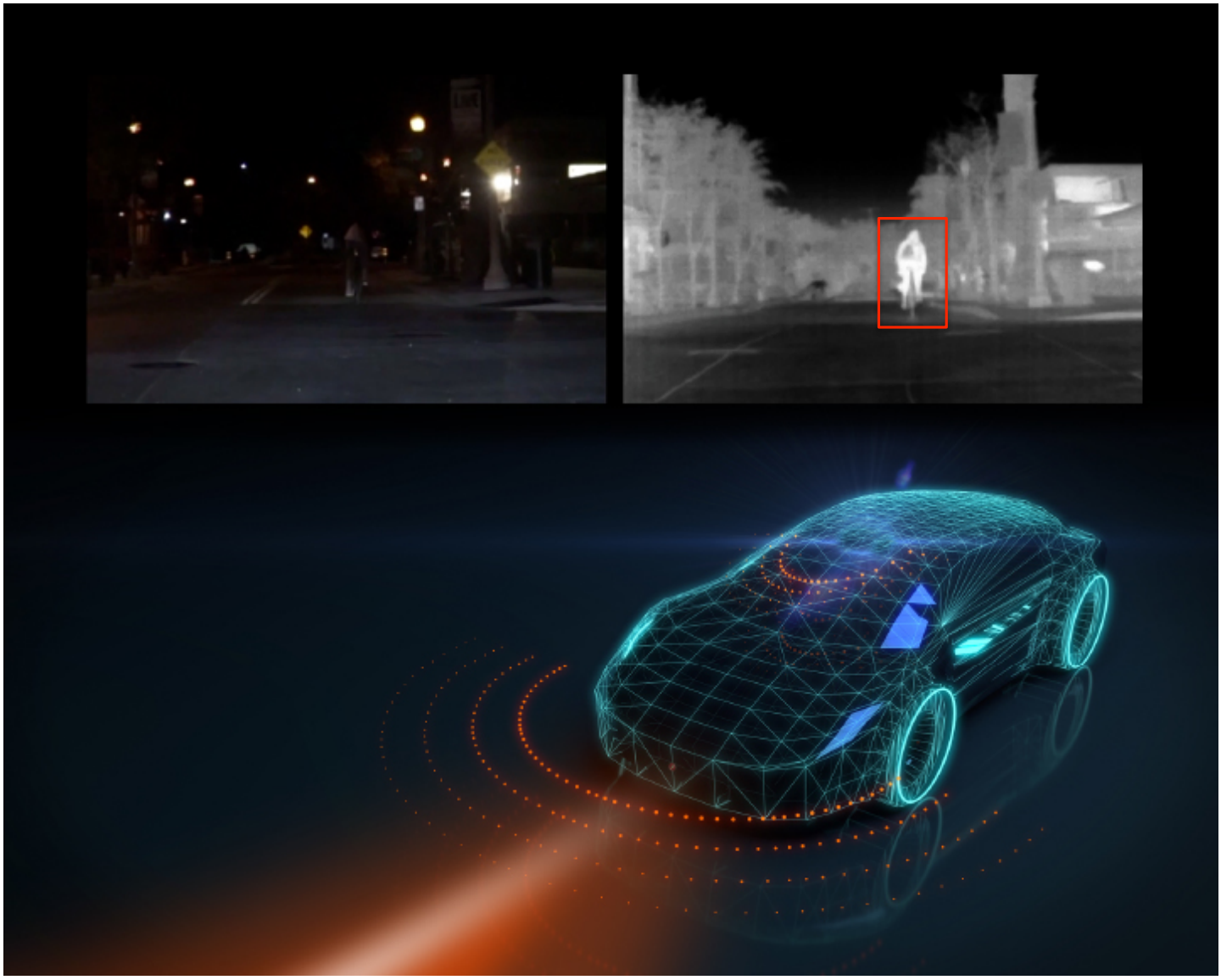

THERMAL IMAGING FOR SAFER AUTONOMOUS VEHICLES

Tim LeBeau | Seek Thermal
April 17, 2019

For the automotive industry, pedestrian safety has been a serious concern since the horseless carriage. Londoner Arthur Edsall was the first driver to strike and kill a pedestrian in 1896 at a speed of four miles per hour. It took the U.S. Congress almost seventy years to impose automotive safety standards and mandate the installation of safety equipment and another thirty years before airbags became a required safety feature. Automotive safety standards in the United States are promulgated by a process of reviewing accidents after they have occurred. In 2019, the National Transportation Safety Board ("NTSB") finally addressed this standards-promulgation process in their Most Wanted List of transportation safety improvements calling for an increase in the implementation of collision-avoidance systems in all new highway vehicles. The progression of this change in policy derived from the 2015 study (SIR-15/01) that described the benefits of forward-collision-avoidance systems and their ability to prevent thousands of accidents. After that report was published, an agreement was reached with the National Highway Traffic Safety Administration ("NHTSA") and the Insurance Institute for Highway Safety that would require compliance with the Automatic Emergency Braking standard ("AEB") on all manufactured vehicles by 2022. However, the agreement did not identify the specific technology that would enable AEB, and the question remains whether such technology is readily available and economically viable for industry-wide adoption.

The pace of technology over the last thirty years has been astronomical, yet technology to make driving safer has not kept pace. A computer that not too long ago was the size of a garage now fits into the palm of your hand. Today driving should be safer than ever, but the reality is that without the implantation of available modern technologies, the uncertainties of the road will always be with us. According to the NHTSA, there were 37,461 traffic fatalities in 2016 in the United States. In 2015, there were a total of 6,243,000 passenger car accidents.[1] Globally, there is a fatality every twenty-five seconds and an injury every 1.25 seconds. In the United States there is a fatality every thirteen minutes and an injury every thirteen seconds. These statistics are mind blowing. Compared to recent events affecting the aviation industry, two Boeing 737 MAX 8 airplanes crashed killing 346 people, the same number of people that die as a result of automobile accidents every 144 minutes, and all Boeing 737 MAX 8 airplanes were grounded.

The cost for automotive accidents is high. According to the national safety counsel, in the United States, the annual cost of health care resulting from cigarette smoking is approximately $300 billion whereas the annual cost of health care for injuries arising from automobile accidents is roughly $415 billion.

Technology to protect automobile occupants has reduced the number of driver and passenger fatalities. However, the number of people who die as a result of an accident outside the automobile continue to climb at an alarming rate. Pedestrians are at the greatest risk, especially after dark. The NHTSA reports that in 2018, 6,227 pedestrians were killed in United States traffic accidents, with seventy-eight percent of pedestrian deaths occurring at dusk, dawn, or night.[2] In the United States, pedestrian fatalities have increased forty-one percent since 2008. Solutions to address pedestrian fatalities are needed to meet the standards by 2022.

[1] https://www.bts.gov/content/highway-traffic-fatalities-and-fatality-rates

[2] https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812375

Technology In The Driver's Seat

Ultimately, it is safer cars and safer drivers that make driving safer, and automotive designers need to deploy every possible technological tool to improve driver awareness and make cars more automatically responsive to impending risks. Today's safest cars can be equipped with a multitude of cameras and sensors to make them hyper-sensitive to the world around them and intelligent enough to take safe evasive action as needed. Microprocessors can process images and identify subject matter 1,000,000 times faster than a human being.

Advanced Driver Assist Systems ("ADAS") are becoming the norm, spotting potential problems ahead of the automobile making auto travel safer for drivers, passengers, and pedestrians, not to mention the more than one million 'reported' animals struck by automobiles in the United States annually resulting in $4.2 billion in insurance claims each year. The advances we have seen so far are the first steps to evolving towards a future of truly autonomous vehicles that will revolutionize both personal and commercial transportation.

Drivers need no longer rely on eyes alone to maintain situational awareness. Early generations of vision-assisting cameras were innovative, but they were not particularly intelligent and could do little to perceive the environment around the car and communicate information that could be used for driver decision-making.

Today, with tools such as radar, light detection and ranging ("LIDAR"), cameras, and ultrasound installed, a car knows much more about the environment than the driver does and can control the vehicle faster and safer than the human driver. Risky driving conditions such as rain, fog, snow, and glare, are less hazardous when a driver is assisted by additional onboard sensors and data processors.

One of the most advanced automotive sensors is a thermal sensor that allows a driver and the automobile to perceive the heat signature of anything ahead of the driver. Previously used mainly for military and commercial applications, early forms of night vision first came to the mainstream automotive market in the 2000 Cadillac DeVille, albeit as a cost-prohibitive accessory priced at almost at a cost approaching $3,000. Since then, thermal cameras and sensors have become smaller, lighter, faster and cheaper. After years of exclusive availability in luxury models, thermal sensors are now ready to take their place among other automotive sensors to provide a first line of driving defense that reaches far beyond the reach of headlights in all vehicles, regardless of the cost of the vehicle.

Improving Safety Today

Like all other automotive sensory systems, the goal of thermal imaging is simple: to give drivers and ADAS computers information about their surroundings and assist a quick reaction to road hazards, sometimes automatically. It joins other sophisticated systems such as long and medium-range radar, which are responsible for a hugely beneficial set of safety features including lane-change assistance, blind-spot detection, cross-traffic alerts, brake assistance and collision avoidance, adaptive cruise control and parking assistance.

What makes thermal imaging so compelling is its ability to help drivers and ADAS computers make split-second decisions at high speeds and in all driving conditions. Unlike conventional cameras, thermal cameras can identify the heat signatures of pedestrians and animals during any lighting conditions. While a driver's view may be obscured by darkness, glare, smoke, fog, or oncoming high-beam headlights, thermal imaging can penetrate these obstructions. With thermal imaging, a driver and ADAS computers can identify a car before it appears in the headlights.

How is thermal imaging different than long and medium-range radar? Radar detects objects but cannot identify them without the aid of a visual camera. Radar knows how far away an object is and how soon a driver will collide with it, but radar is currently deployed in low-resolution solutions limiting its viability as an independent solution. In fact, that is why auto manufacturers typically install separate radar systems for separate tasks, one for adaptive cruise control and one for emergency braking, for example.

A Clear View Ahead

Thermal imaging not only sees better, it sees further, much further. At night, for example, headlights typically illuminate road conditions up to 450 feet away. Thermal sensing can detect human-sized objects up to five times further, up to four tenths of a mile, which gives both ADAS and drivers much more time to react, a full twenty-four seconds of reaction time when driving at 60 mph.

It is this ability to detect and classify objects that makes thermal imaging effective. Is the object at the side of the road a human, a horse, or a haystack? Is it moving towards the vehicles intended path? Processing the heat signature through an algorithm gives an instant read on the situation in a way that no visual camera or radar system could accomplish on its own, especially on winding secondary and tertiary roads where frontal visibility lessens and the risk of unexpected obstacles increases.

Soon, Seek Thermal's high-resolution thermal imaging cameras will be available to everyone as an integrated or aftermarket automotive solution. Inside a hermetically sealed housing, a next-generation infrared thermal imaging sensor helps drivers instantly identify pedestrians, animals, and nearby vehicles, even in complete darkness. In the time that it takes for a human to identify and label an image, an AI algorithm can classify one million images. Its 320 x 240 high-resolution thermal sensor delivers 76,800 temperature data points for maximum image clarity and sensitivity. Its twenty-four-degree field of view dual-element chalcogenide lens is optimized for detecting potential hazards down the road.

Autonomy Requires Thermal Imaging

As advanced as ADAS are today, they will become exponentially more critical once they are used for driverless transportation as automobile companies transition to a Robotics as a Service (RaaS) business model. Naturally, there are safety concerns around the idea of minimizing human control in driving, but rapidly increasing power and perception of sensors of all kinds is

slowly but surely alleviating these concerns.

There is no doubt that government regulations will require all sorts of system redundancies before autonomous cars can safely take to the roadways. Thermal imaging is crucial to support critical decision-making processes to avoid hazards on the road. The reduction in the pricing of thermal imaging solutions also benefits the adoption of the technology. Visible cameras, radar, and ultrasound have plunged in price over the years, making them nearly ubiquitous in new cars today. Thermal imaging is riding that price curve to mass deployment as well.

Thermal imaging has a huge role to play in bringing autonomous cars on the road as soon as possible. Human-equivalent (or better) perception can only be achieved if multiple sensors work in concert redundantly. Forward-facing radar or cameras, for example, are only as useful as the depth of their vision. Should they fail or become blinded, autonomous driving suddenly becomes unsafe. By pairing these sensors with the extended vision of thermal imaging, an autonomous vehicle can more accurately identify and classify the obstacle ahead and alert the driver or trigger the vehicle's braking system. With these features, autonomous vehicles can drive as safely, or even more safely, than humans can. Working together in both daytime and nighttime conditions, thermal imaging combined with radar, LIDAR, and visible cameras can address nearly every type of visibility scenario.

The Path Forward

The need for redundant sensors is critical. There continues to be a theory in the transportation industry to use as few sensors as possible. This is a very dangerous point of view. To prove this position, all you need to do is review the 2018 Toyota Camry's owners' manual that states:

> "Some pedestrians such as the following may not be detected by the radar sensors and camera sensor, preventing the system from operating properly. Some of the situations that they refer to include: Groups of pedestrians which are close together; Pedestrians who are wearing white and look extremely bright; Pedestrians who are walking fast; Pedestrians in the dark, such as at night or while in a tunnel; Pedestrians who are pushing a stroller, wheelchair, bicycle or other vehicle. Etc…

Autonomous cars have taken human life. When drivers kill people there is a standard process for civil recovery, and some times, criminal penalties. It has yet to be decided who will be liable for the actions or inactions of an autonomous automobile, and the answers are forthcoming. Automobile manufacturers and operators may not meet the standard of care in the production and operation of vehicles that are unsafe in certain driving conditions. The adoption of thermal imaging should be a mandatory requirement for all vehicles given the additional capabilities it offers ADAS and drivers, and the technology is readily available and economically viable. Without its adoption, manufacturers and operators will likely face liability in circumstances where thermal imaging could result in the avoidance of an accident.

About Seek Thermal

Seek Thermal engineers and manufactures low-cost, high-resolution thermal imaging cameras and OEM thermal cores. Founded by industry pioneers who spent 40 years advancing the state of military and professional-grade thermal technologies, Seek Thermal has developed a breakthrough line of products at disruptive price points making this technology more accessible to end users. The company's products serve the firefighting, law enforcement, commercial, and automotive markets under its own brand and OEM offering.

Thermal Imaging cameras detect infrared light (heat) and display it as an image otherwise invisible to the naked eye. The technology aids in visual perception and awareness to help first responders save lives, building professionals work more efficiently, and drivers operate vehicles safer.

