DRIVEN TO SAVE LIVES

WHITEPAPER: IMPACT OF THERMAL FIR SENSING ON AUTONOMOUS VEHICLE MARKET

TABLE OF CONTENTS

FIR IS HEATING UP IN THE AUTOMOTIVE INDUSTRY

The Far Infrared sensor (FIR) market has seen incredible growth over the past five years, with industry analysts suggesting fourfold growth for the number of units in 2017 alone. Indication from the market is that the use of FIR in automotive, especially for safety and night vision for autonomous vehicles, is taking off and could be the key to mass-market adoption of fully autonomous vehicles.

Source: Uncooled Infrared Imagers Market and Technology Trends report, Yole Développement, 2017.

Sensors have been part of ADAS systems for some time. Primarily, these have included radar, camera, and lidar sensors, all of which have their limitations in terms of detection of pedestrians, vehicles, and objects on the road, thus rendering them unsuitable as singular options to support autonomous driving. Autonomous vehicles are still not meeting key safety guidelines, because the sensor suites are not up to the task to deliver complete coverage and detection in all scenarios, weather, road and lighting conditions. For this reason, a human driver must be ready at every moment to take control of the vehicle.

However, even with a human driver present, autonomous pilot projects are still experiencing setbacks. Following several self-driving car-crash occurrences in the past year, many big OEMs have slowed down the implementation of their pilot projects and are, instead, favoring a slower approach to deployment that increases the focus on safety.

To ensure such safety across autonomous vehicle systems, the U.S. Department for Transportation's Federal Automated Vehicles Policy now requires redundancy for critical AV systems. To satisfy these requirements, most OEMs and tier-ones are using multiple sensors and other components as fail-safe measures; specifically, they have identified FIR technology as a key sensor that can help their vehicles meet the ever-rising standards for safety.

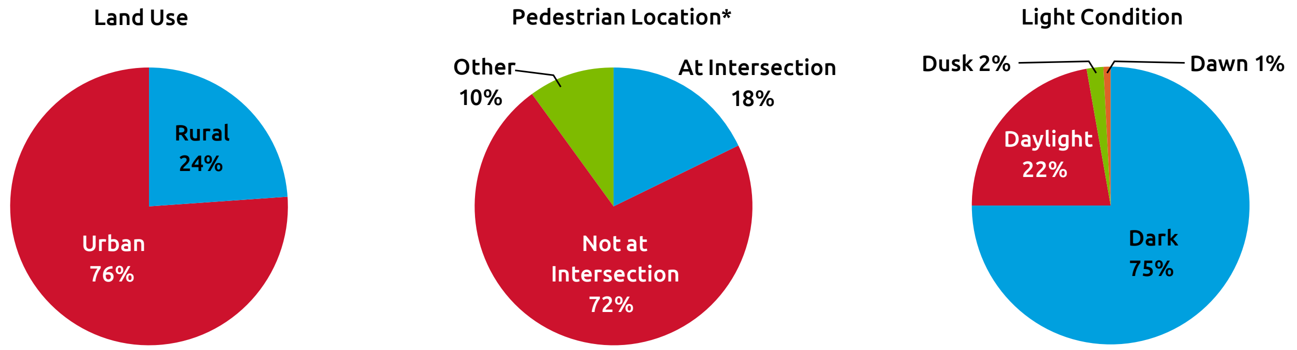
The U.S. Department of Transportation's Federal Automated Vehicles policy redundancy regulations are outlined in the recent document, Preparing for the Future of Transportation: Automated Vehicles 3.0.

There are various driving conditions in which thermal FIR sensing would increase the safety of AV systems. For example, as one of the many scenarios that plagues other sensing solutions, night-driving often poses the same challenges for autonomous vehicles as it does for human drivers. The darkness makes it difficult to see people, objects, animals, and other vehicles, because there is not enough contrast to clearly view the scene. As a result, the vehicle's sight is restricted to areas only in which the headlights shine. This proves dire for autonomous vehicles' navigation of the road, particularly when in the vicinity of pedestrians: The Insurance Institute for Highway Safety says that pedestrian deaths are rising fastest during night driving, and federal census data shows the same--three quarters of pedestrian fatalities happen at night.

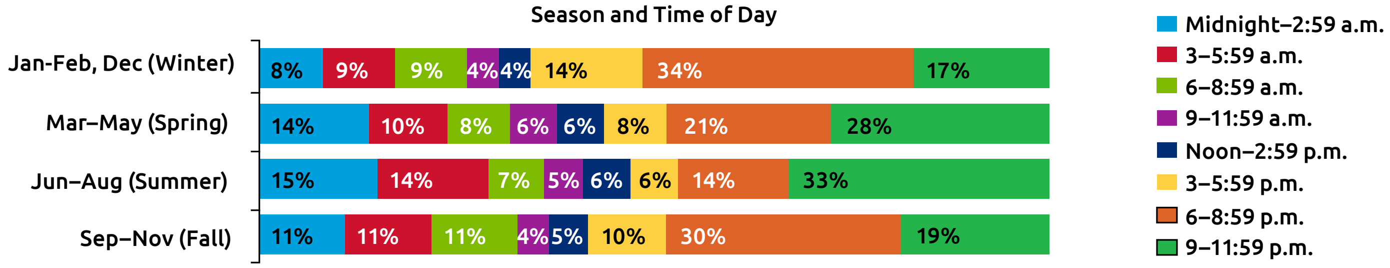
(Source 2: https://www.nhtsa.gov/press-releases/us-department-transportation-releases-preparing-future-transportation-automated)

FIGURE 1

Percentage of Pedestrian Fatalities in Relation to Land Use, Pedestrian Location, and Light Condition, and Season and Time of Day, 2016

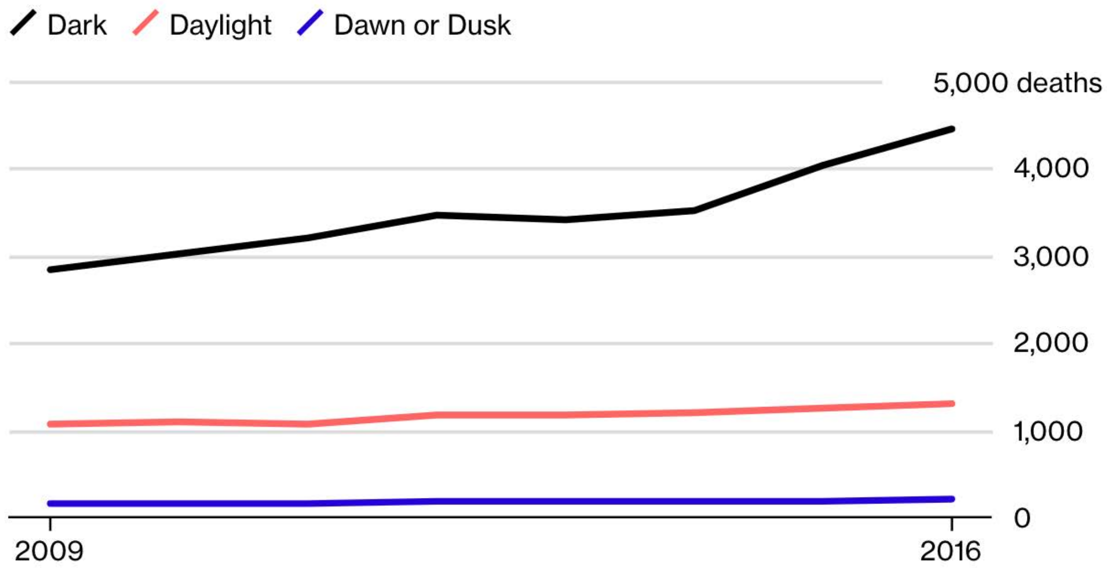


FARS 2016 ARF – Fatal Motor Vehicles Crashes Report from National Highway Traffic Safety Administration.



DEADLY DARK

Pedestrian fatalities are rising fastest during the hours when the sun is down



Insurance Institute for Highway Safety

"Human vision is already atrocious at night and we're trying to at least do as well a that and hopefully better," said Richard Wallace, an automated vehicles specialist at the Center for Automotive Research in Ann Arbor, Michigan. "Better should include night vision. Headlights are only so good and thermal infrared is a very powerful tool that the military uses." [Bloomberg, April 2018]

Unlike other sensing modalities, thermal sensors don't require any light to accurately detect, segment, and classify objects and pedestrians and are, therefore, well-suited to drastically improve AV systems' safety at night.

In addition to night driving, a key concern for OEMs is developing autonomous vehicles that can maintain adequate coverage in any lighting condition and in any kind of harsh weather. FIR can satisfy both of these use cases and has, thus, become recognized in the automotive market as a crucial sensor for Level-3 autonomous vehicles. As OEMs look ahead to the future advancement of vehicle autonomy, they also see FIR as an essential enabler for Level-4 and higher vehicle autonomy and are beginning to seriously evaluate the sensing technology in their prototypes. For example, two leading OEMs have already announced that they are using thermal-imaging cameras as part of their sensor suites for their self-driving prototypes. Other will surely follow.

To eventually achieve Level-3 and up autonomy and bring fully autonomous vehicles to the mass market, many AV developers have reached the consensus that each vehicle must be equipped with multiple sensors. Specifically, in order to enable complete detection and the most comprehensive understanding of vehicles' surroundings, automakers are favoring the use of multiple FIR sensors, as this technology can deliver the highest level of safety.

The automotive market sees FIR as the enabling sensor for full autonomy, because, in addition to its impressive sensing capabilities, the technology, now experiencing a next-generation revolution for the automotive industry, is also uniquely affordable for mass market deployment.

Its superior detection in dynamic lighting, harsh weather, and night scenes, in addition to its affordability for the mass market and its redundancy for safety are just some of the factors that are motivating OEMs to seek out FIR solutions to enable Level-3 and up driving. The market now believes that thermal sensors must be a part of autonomous vehicles' sensor suites in order to deliver the highest levels of safety and the most accurate sight and perception of surroundings.

The remaining question is: What key features of FIR sensing need to be considered when integrating the solution into a vehicle? First, OEMS need to understand the best use cases for FIR sensors; then, they must identify what key features they should look for when choosing FIR perception solutions for their applications. This paper details the technical advantages of FIR and when and where FIR and a CMOS camera can be fused for a complete sensing solution. The paper also highlights the computer-vision algorithms and features that make FIR sensors so valuable.

Advanced WDR 720p Cam

AdaSky's VIPER FIR Solution

FIR IS NOT JUST A GAP FILL

Autonomous vehicles will rely on maps, geo-positioning, and vehicle-to-vehicle communications for planning their driveable paths on roads. Unfortunately, automakers cannot rely on the above for real-time reactions and immediate scene analysis, both of which are critical for when autonomous vehicles need to assess their surroundings and make a decision within microseconds.

TECHNICAL ADVANTAGES OF FIR

FIR technology, however, gives vehicles the complete, reliable detection of the road and its surroundings. It's able to do this when other sensing solutions can't, because of its distinct technical advantages:

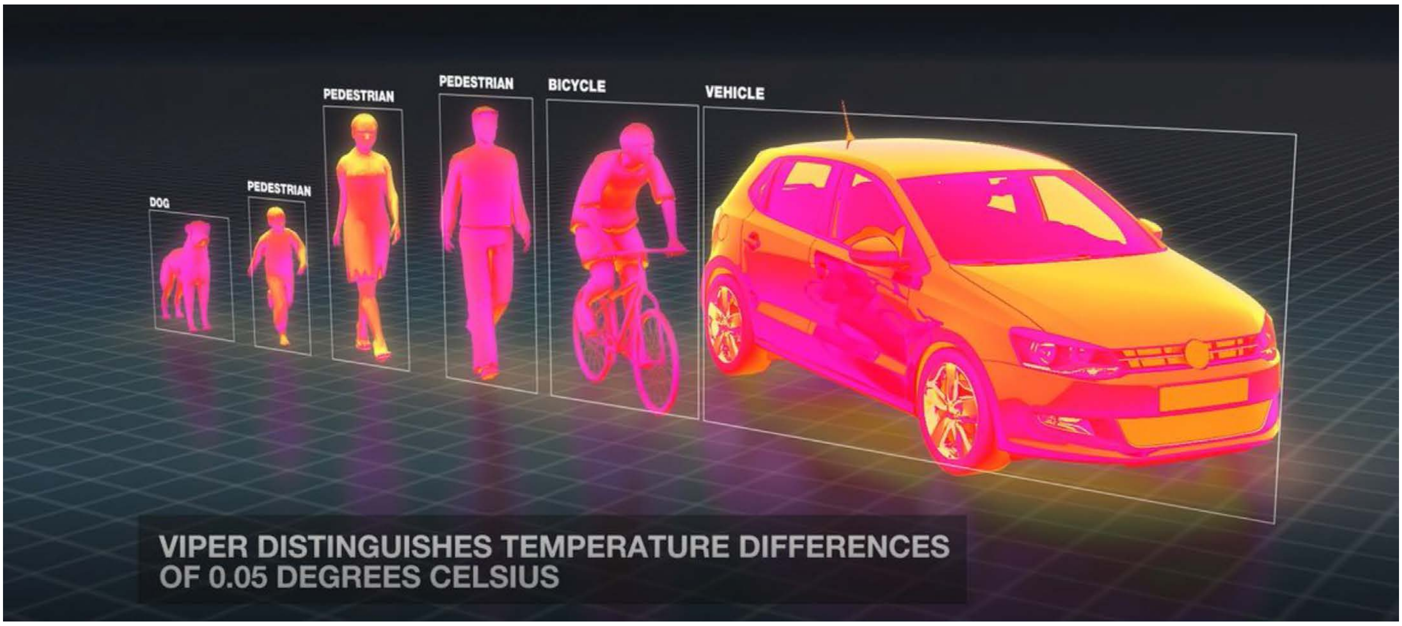
- All-weather detection
- Living and non-living object detection
- Invariant images for lighting conditions

ALL-WEATHER DETECTION

FIR sensors are capable of delivering reliable, accurate detection in real-time and in any environmental condition, because they access an additional layer of information that the other sensors don't.

Unlike radar and lidar sensors that both transmit and receive signals, a FIR camera passively collects signals by detecting the thermal energy that radiates from objects. By sensing this infrared spectrum that's far above visible light, FIR cameras access a different band of the electromagnetic spectrum than other sensing technologies do. Most of the electromagnetic spectrum is blocked by the atmosphere, with only narrow spectral windows that can let the EM radiation through. The visible light window roughly spans 400-700 nm wavelengths; whereas, the infrared window that is commonly used in low-cost thermal imagers spans 8-14 µm wavelengths (also known as LWIR (long-wave infrared)). Thus, the FIR camera is able to generate a new layer of information, making it an all-weather solution that enables AVs to detect objects that may not otherwise be perceptible to radar, cameras, or lidar.

It's also worth noting that FIR's passivity offers another advantage to autonomous vehicles: no interference. Because lidar and radar are active, energy-emitting modalities, the lidar and/or radar installed and functioning on one vehicle may interfere with and upset that of another passing vehicle. Conversely, as a passive technology, FIR can work to detect and cover a vehicle's surroundings without ever upsetting the sensors of other vehicles.
Invariant images for lighting conditions



LIVING AND NON-LIVING OBJECT DETECTION

By accessing a different band of the electromagnetic spectrum and sensing objects' thermal energies, FIR sensors are able to seamlessly identify any living object in a vehicle's surroundings. The technology also proves itself as the best modality for non-living object detection: In addition to reading an object's thermal signature, FIR cameras also capture objects' emissivity—the rate at which an object emits heat. Emissivity is affected by each object's surface material, so every object with a different surface nature (e.g. the cracks on the road versus the sidewalk) would bear a different thermal signature. Thus, since every material has a different emissivity (and a different reflectance (i.e. the proportion of radiation striking a surface that is reflected off of it)), a FIR camera can immediately detect and classify any object—living or non-living—in its path.

"...Adasky makes a compelling argument that heat could be another way cars understand the world and determine whether or not the blob up ahead is a human in a coat or trash bag blowing into the street. Because spotting the difference is incredibly important." - ***Roberto Baldwin, Engadget 2018***

INVARIANT IMAGES FOR LIGHTING CONDITIONS

FIR further trumps other sensing modalities, as it delivers an invariant image for lighting conditions: Its image perception is not compromised by the color of an object, an object's' background, the direction of illumination, a multiplicity of light sources, specular reflections, nor many other image irregularities that may stem from variable lighting conditions in regular CMOS images. For instance, although CMOS cameras are usually quite good at detecting lanes and other road markings, they may struggle to accurately detect the drivable road area--even in daylight--due to the high variance in the visual road appearance in CMOS images. The visual road appearance in a FIR image is much less variable; it retains similar characteristics in many different lighting conditions.

Delivering an invariant image for lighting conditions is critical for autonomous vehicles to be able to see their surroundings in the highest quality necessary to understand and react to both living and non-living objects.

Besides enabling vehicles to see and understand their surroundings in any lighting condition, the invariant images produced by FIR also help support machine perception. In fact, any feature that relies on machine perception for further planning and control will benefit from the invariant images FIR delivers. Such perception-based tasks include: on-road object detection, classification, intention recognition, tracking, distance estimation, and semantic segmentation. Due to the high-quality images FIR produces, these tasks may be improved with a FIR fusion sensing solution.

Localization and mapping can also benefit from FIR imagery. The amount of detail and information that this modality can offer is rich enough to enable tasks like SLAM (Simultaneous Localization and Mapping). Moreover, landmark-based approaches for SLAM may also be easily applied on FIR data due to the high resolution that these next-generation sensors produce.
Together, all of these technical advantages enable FIR sensors to see things that other sensors miss, giving autonomous vehicles better scene detection and analysis, both of which are key requirements for achieving Level-3 or higher autonomy.

FIR FUSED WITH CMOS CREATES A COMPLETE SOLUTION

Although FIR's superior image perception enables it to successfully provide coverage in a variety of adverse weather and lighting conditions and in the midst of pedestrians and animals (as compared to CMOS sensors), the technology's proponents do not suggest that FIR replace all other sensors as the sole means of perception. Rather, they affirm that FIR be fused with a CMOS solution to deliver more comprehensive sensing capabilities needed to achieve full autonomy. Researchers from The AWARE (All Weather All Roads Enhanced vision), a French public funded project, have even confirmed long-wave infrared (or FIR) is the best wavelength band to complement CMOS for road applications.

FIR and CMOS can work in synergy on a variety of important tasks:

SIGN READING

Together, FIR and CMOS sensing solutions can help autonomous vehicles better see and understand street signs. To effectively respond to a traffic sign, a vehicle must first identify and separate the sign from the background and then read it. However, neither CMOS nor FIR can execute both of these tasks independently. Because FIR functions by assessing an object's thermal signature and emissivity, it cannot see colors in great detail (i.e. it can struggle to read the sign). CMOS, on the other hand, cannot effectively detect thermally homogenic regions and separate them from the background—something FIR accomplishes without flaw. Using these two sensors in conjunction, then (in which the FIR sensor clearly identifies the traffic sign from the background, and the CMOS solutions reads the sign), allows the autonomous vehicle to best see and understand its surroundings.

OBJECT CLASSIFICATION

FIR and CMOS can also be used in conjunction to achieve optimum object classification. Because it assesses objects' thermal signatures, a FIR sensor is currently one of the sensing solutions most easily able to immediately distinguish a living object from a non-living object. For an autonomous vehicle of Level-3 or higher, this is crucial information for control and decision making. Conversely, for general detection of non-living objects, CMOS solutions are able to offer higher resolution than FIR--but only in good lighting and weather conditions. Thus, by combining the general object detection from a CMOS solution with the thermal information from a FIR sensor, automakers are better able to achieve a comprehensive understanding of all objects—both living and non-living—in a scene.

DRIVEABLE AREA DETECTION

In most circumstances, a CMOS solution is sufficient to provide an autonomous vehicle with adequate lane-detection; however, it may struggle to detect a vehicle's entire driveable area accurately, as there is high variance in the visual appearance of the road in CMOS-generated RGB images--even in daylight. Moreover, a CMOS-based driveable area detection could be severely compromised in partial or complete darkness. A FIR sensing solution, on the other hand, produces a much less variant image of the road surface, i.e. the appearance of the road has similar characteristics in all environmental conditions. A fusion of FIR and CMOS sensing solutions, then, can deliver to autonomous vehicles a better system for driveable area detection and, consequently, any path-planning tasks.

WHAT MAKES FIR VALUABLE FOR AV SYSTEMS?

FIR thermal sensing technology certainly delivers improved coverage and detection on which autonomous vehicles must rely for scene analysis and decision making. But while the images produced by a FIR thermal sensor deliver a wealth of information, what makes the difference in giving autonomous vehicles better sensing capabilities is a dedicated ISP and computer-vision algorithms.

DEDICATED IMAGE SIGNAL PROCESSOR (ISP)

There are numerous advantages to using a FIR sensor with a dedicated Image Signal Processor (ISP). For one, a dedicated ISP provides much more computational power, which is necessary for the many customized applications of autonomous vehicles. Besides offering more power, a dedicated ISP also helps simplify communications OEMs and their technologists. For OEMs developing autonomous vehicles, the processes for approving new technology can be lengthy, which ultimately slows down development. However, by working with a sensor-maker who uses their own dedicated ISP, OEMs can streamline their approval processes, as they only need to communicate with the sensor-maker, instead of an independent sensor-maker and an independent chip-maker.

THE BENEFITS OF HAVING A DEDICATED ISP

More and more companies are beginning to see the benefits of using customized chip development. For example, in summer 2018, Tesla announced that it would no longer rely on NVIDIA's chip to power the autonomous features of its vehicles and would, instead, embark on developing its own technology, internally. AdaSky, too, has been one of the early adopters of this design strategy, as the startup uses a dedicated ISP to power its FIR sensor.

A dedicated ISP provides highly-optimized hardware that is designed specifically for the product's unique task and market. Compared to FPGAs (field-programmable gate arrays) or general-purpose ISPs, a dedicated ISP also provides low power consumption; this is crucial for next-generation autonomous vehicles, which many OEMs aim to make electric. Low power consumption further translates to lower heat generation (an important advantage for thermal sensors) and low latency (which, in turn, allows for a smaller-sized sensor and a longer braking distance). Finally, a dedicated ISP, in AdaSky's case, enables the sensor-maker to run its proprietary state-of-the-art thermal image-processing algorithms, including algorithmic non-uniformity correction and automotive qualification.

Even though the Israeli startup is a small company, its team has been working with FIR technology for years in other industry verticals, equipping them with the requisite knowledge to develop their own proprietary chip from the company's inception.
In other verticals (such as military, aviation, etc.), FIR technology is typically achieved with third-party processing, as size and reliability are not as crucial as they've proven to be in the automotive industry. But as a leader of the FIR revolution, AdaSky was founded with the primary focus of bringing FIR technology to the automotive market; as such, its team has always considered the specific needs of autonomous vehicles.

ALGORITHMS—WHY THEY MAKE THE DIFFERENCE

By applying algorithms to images, autonomous vehicles get a better understanding of their surroundings—and the higher quality the images, the more comprehensive is this understanding.

For instance, autonomous vehicles typically use lidar and CMOS sensing solutions to generate mapping of the road; these tasks can be further improved with the additional information provided by FIR cameras. This is because the images produced by thermal cameras contain such rich details that, when used in a fusion solution with other sensing modalities, they can power almost any computer-vision algorithm, such as those for: mapping, getting a 3D understanding of the scene, and other computer-vision tasks. Employing such a breadth of algorithms is crucial for providing the best detection, classification, and scene analysis to give vehicles the greatest perception and decision capabilities for safe autonomous driving.

COMPUTER-VISION ALGORITHMS FROM ADASKY

Israeli startup, AdaSky, is one sensor-maker that's using computer-vision algorithms to improve capabilities for autonomous vehicles with their FIR thermal sensor, Viper.

Viper passively collects the FIR signal that radiates from objects and other materials to produce a VGA video; it then applies AdaSky's proprietary deep-learning computer-vision algorithms to paint, in real time, a picture of the vehicle's immediate driveable area.

This kind of superior detection is only possible through the use of algorithms and is vital for any autonomous vehicle seeking to achieve level-3 or higher autonomy.

The computer-vision algorithms in AdaSky's FIR sensing solution, which runs on NVIDIA's Drive PX2 and Jetson Xavier platforms, enables the following capabilities:

- Multi-class detection
- Pedestrian and animal detection
- Pedestrian intention prediction
- Road detection and semantic segmentation
- Range estimation
- Sunburn detection and correction

MULTI-CLASS DETECTION

The multi-class detection feature of Viper simultaneously detects and classifies pedestrians, vehicles, buses, trucks, bicycles, and motorcycles.

PEDESTRIAN AND ANIMAL DETECTION

Based on a combination of engineered features and deep neural network models, Viper enables real-time detection of pedestrians and animals up to 120 meters away with a 30-degree field-of-view and up to 200 meters away with a 17-degree field-of-view. Moreover, this pedestrian and animal detection can be achieved irrespectively of the number of pedestrians and/or animals appearing in the scene, enabling autonomous vehicles to successfully operate even in dense urban environments. Considering Viper's field-of-view and resolution, AdaSky currently achieves the best detection rate and the lowest false-alarm rate when compared to other FIR and CMOS solutions with similar characteristics.

PEDESTRIAN INTENTION PREDICTION

In addition to detecting the presence of pedestrians and animals in the autonomous vehicle's driveable area, AdaSky's FIR sensing solution can also help to predict pedestrian intention. Viper accomplishes this similarly to CMOS sensing solutions; however, because Viper is a thermal technology, it can more easily detect objects' thermal signatures and classify them as living objects (i.e. pedestrians or animals), thus, allowing for faster and much more robust intention estimation.

ROAD DETECTION AND SEMANTIC SEGMENTATION

These detection features are based on state-of-the art deep neural network models that are optimized for each specific task, such as free-space segmentation or semantic segmentation in which there is pixel-level classification for one of five classes: road, sidewalk, road-object, sky, and side-object. These deep neural network models are trained on large amounts of pixel-level annotated data, collected and annotated in-house by AdaSky. Road detection and free-space detection are also available.

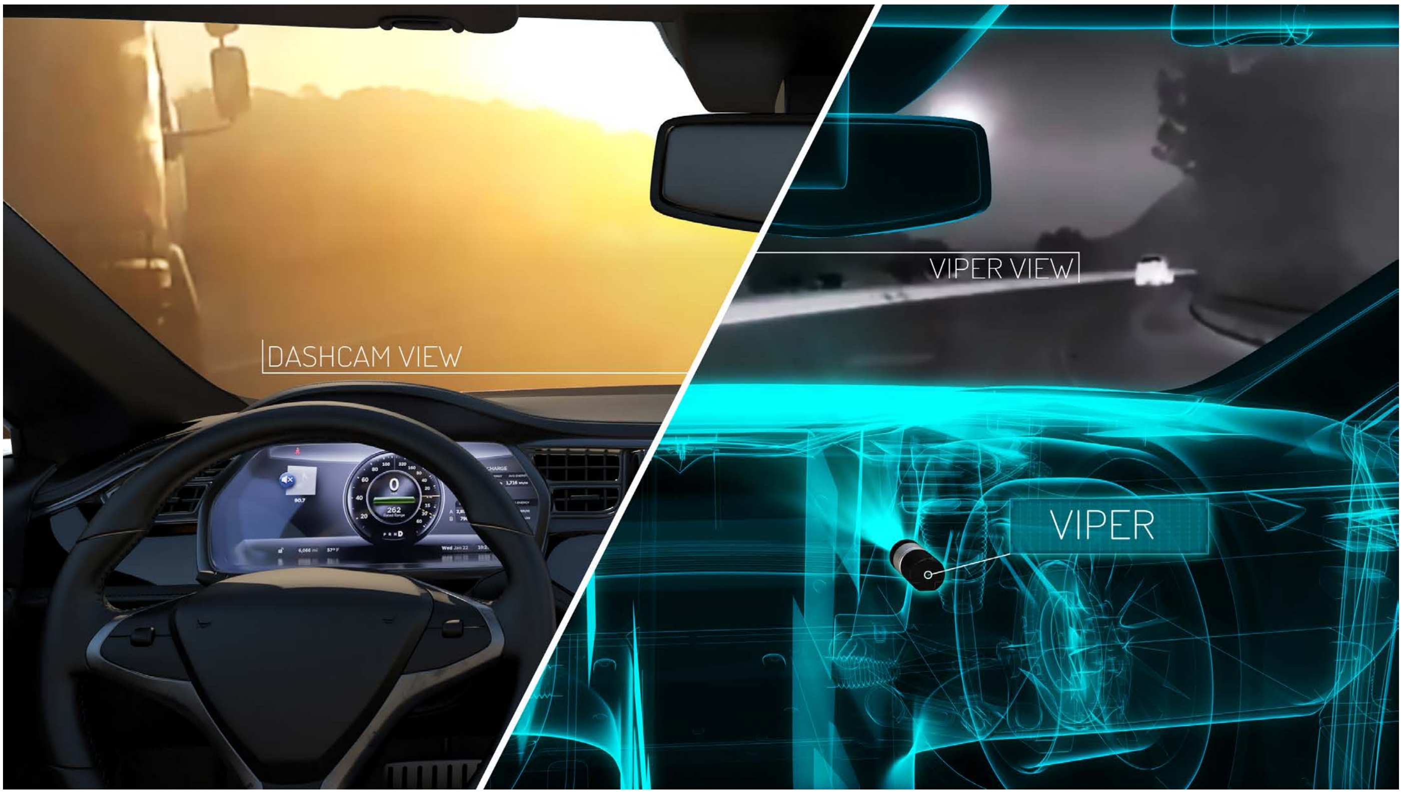
RANGE ESTIMATION

Range estimation is done in a monocular setting, currently on classified objects using scene semantic information and per-object class statistics.

SUNBURN DETECTION AND CORRECTION

Most shutterless FIR sensors becomes compromised when exposed to direct sunlight, as the lack of a mechanical shutter often results in a shadow or ghosting effect, known as a "sunburn," cast over the image. Although only temporary, this impaired vision threatens the visibility and, consequently, accuracy and safety of the autonomous vehicle. To combat this, AdaSky implemented a hardware solution with a unique algorithm that detects and corrects the areas of the image affected by the sun, presenting a final, crystal-clear image for algorithmic processing.

Delivering accurate, real-time, and reliable detection of the road, pedestrians, and animals is a must-have feature for any automaker who wishes to achieve Level-3 or higher autonomy—and these features are achievable only through the use of sophisticated computer-vision algorithms, such as those possessed by AdaSky. Besides enabling the most important high-level features of an autonomous vehicle (e.g. collision avoidance and automatic braking), AdaSky's sensing solution and computer-vision algorithms can also be fused with the lane detection of a CMOS solution to enable even more high-level functionalities, such as lane-keeping and lane-changing.



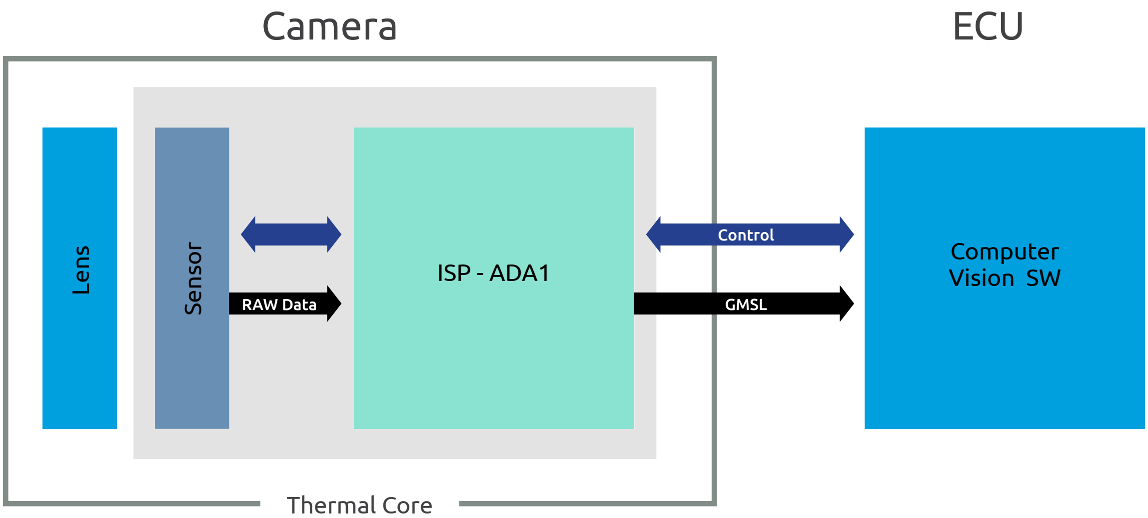
IT'S ALL ABOUT THE DATA

Curating a rich pool of data is vitally important for the development of autonomous vehicles, as it is with this data that the computer-vision algorithms are trained. First, when developing any machine-learning or computer-vision algorithm, large quantities of data must be harvested and collected--often one of the most expensive parts of the process--before they are then manually annotated by a team of data scientists.

HOW ADASKY'S DATA ENABLES BETTER AV TRAINING

The AdaSky team is made up of veterans from the semiconductor, thermal sensor, image-processing, and computer-vision markets who, together, have decades of experience in developing state-of-the-art firmware and hardware design, image processing, algorithms, and FIR sensing solutions—and with these years of experience comes a mass of proprietary data.

Since its inception, AdaSky has been collecting data and has now amassed nearly three million data points in their portfolio. The Israeli startup's data is much richer than many of its competitors', as the FIR-generated imagery includes greater information, such as the temperature of the scene. Moreover, by maintaining its own annotation mechanism, AdaSky is able to obtain large quantities of high-quality data that are uniquely relevant to FIR-specific tasks.

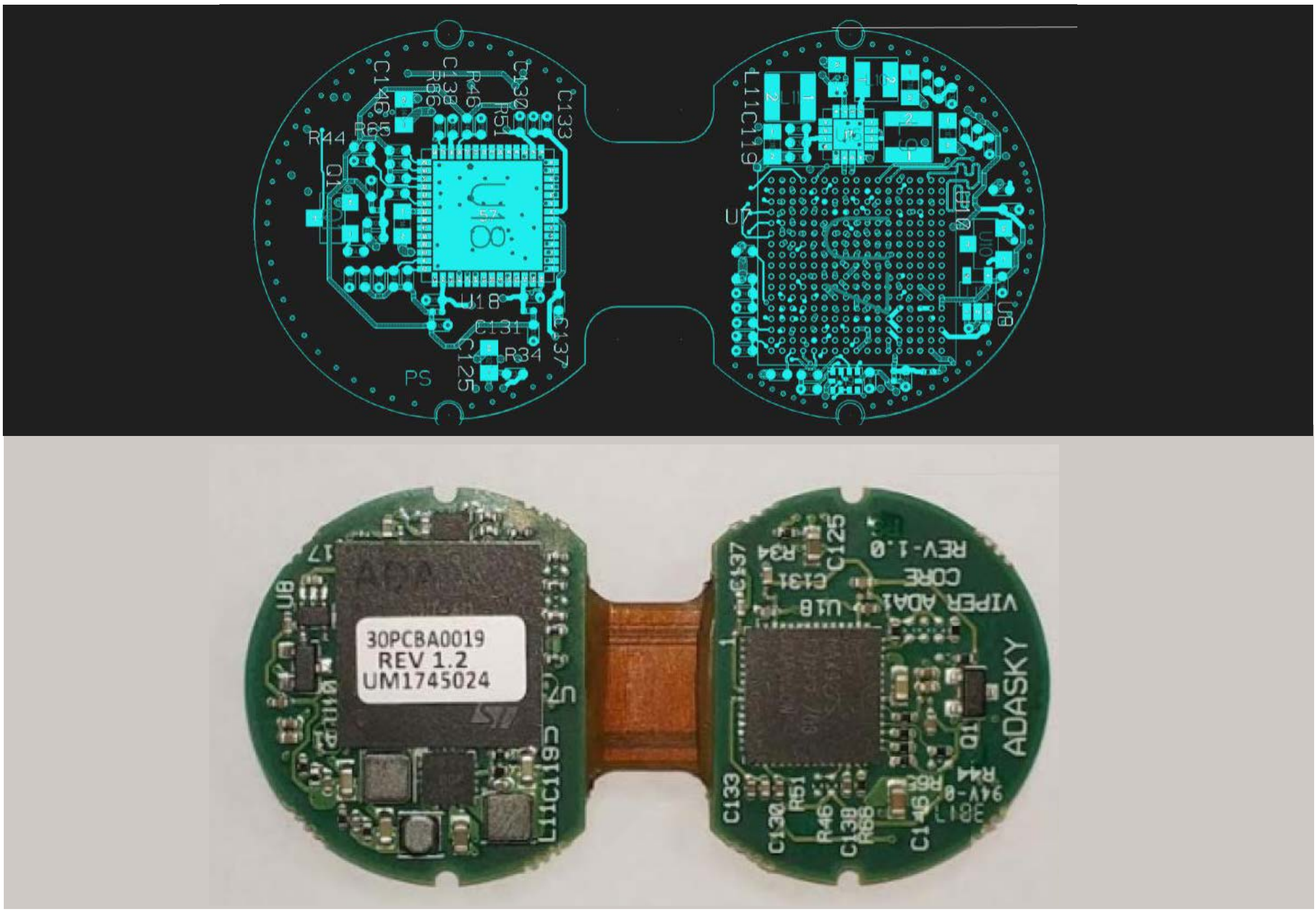


AFFORDABILITY

Historically, FIR sensors have been reserved exclusively for luxury brands, as the technology was considered too expensive for mass market use. One reason for the high development costs were the material required to develop FIR technology. Thermal cameras require lenses made from unique, transparent materials at the FIR spectrum, and the common optical materials traditionally in use, such as germanium, are very expensive and, thus, not suitable for mass production. However, newer and advanced chalcogenide glass materials and molding manufacturing technology have recently made thermal cameras affordable. Coupled with the most advanced detector fabrication techniques adopted from the semiconductor chip industry, this allows thermal imagers to have improved quality, a smaller size, and an affordable price.

HOW ADASKY IS MAKING FIR AFFORDABLE

AdaSky has been a distinct leader in the FIR revolution, as the startup has developed a FIR sensor economically suitable for mass market deployment. This has been possible due in part to the sensor's design, size, and low power consumption, as well as its advanced, proprietary thermal calibration equipment and algorithms. AdaSky's Viper is unique in that it does not require a shutter (which other FIR cameras typically do), because it uses the startup's shutterless, non-uniformity correction, and because it is the only camera to apply a dedicated system on-a-chip ISP, accompanied by one of the smallest detector pitch and wafer level packaging technologies. AdaSky is able to make Viper as small as Ø26mm and 44mm long with 30.4° FOV, enabling the startup to deliver FIR technology at a low price and in a small enough size to facilitate installation almost anywhere on a vehicle.



AdaSky's dedicated system-on-a-chip ISP

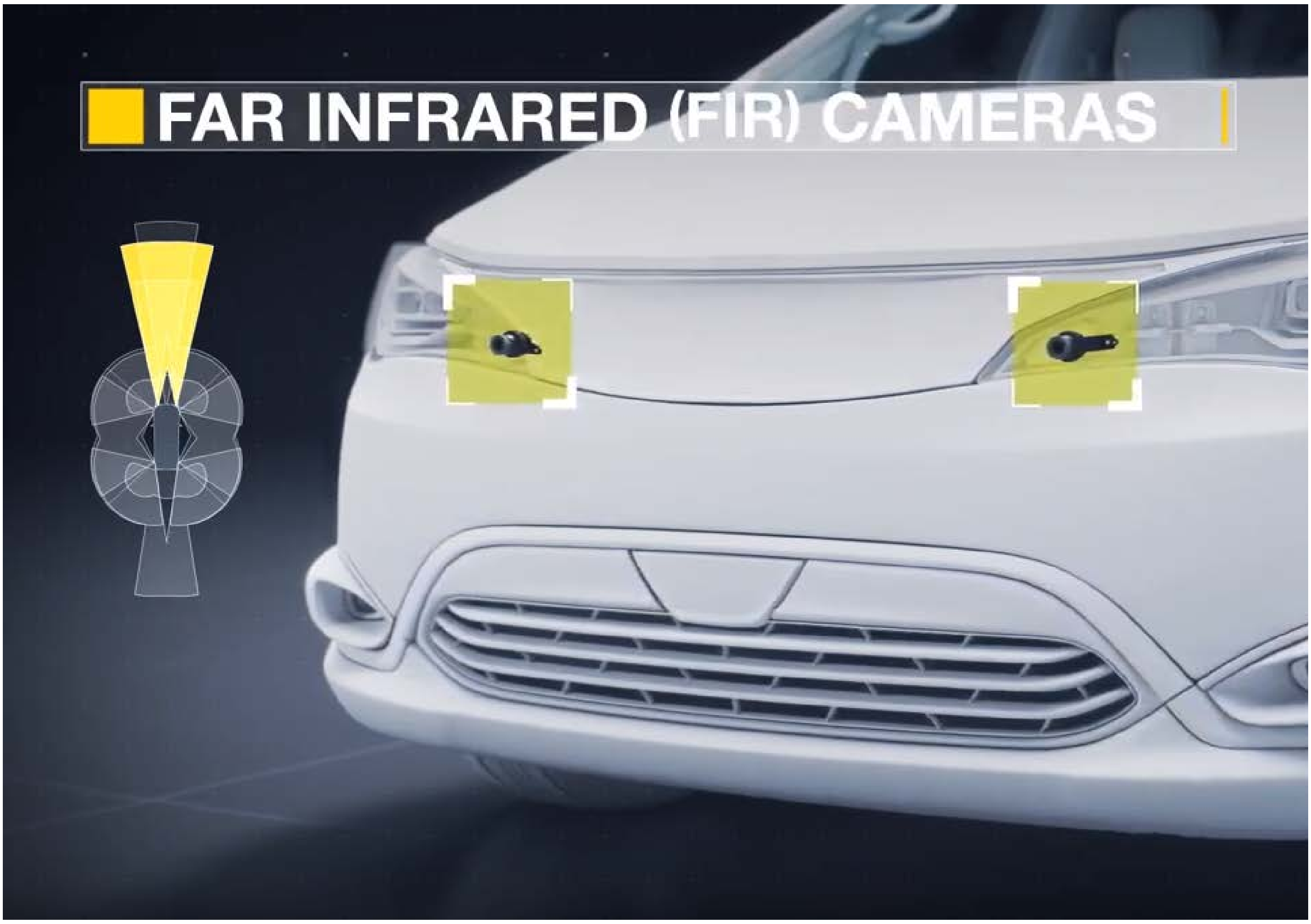
HOW WILL FIR BE INTEGRATED?

Research and development versions of autonomous vehicles have rapidly become abound, and the industry is edging ever closer to producing these vehicles for mass consumer use. To meet this end, it is clear that OEMs will require a FIR integration that is aesthetically pleasing, expertly advised, and suitable for a variety of use cases.

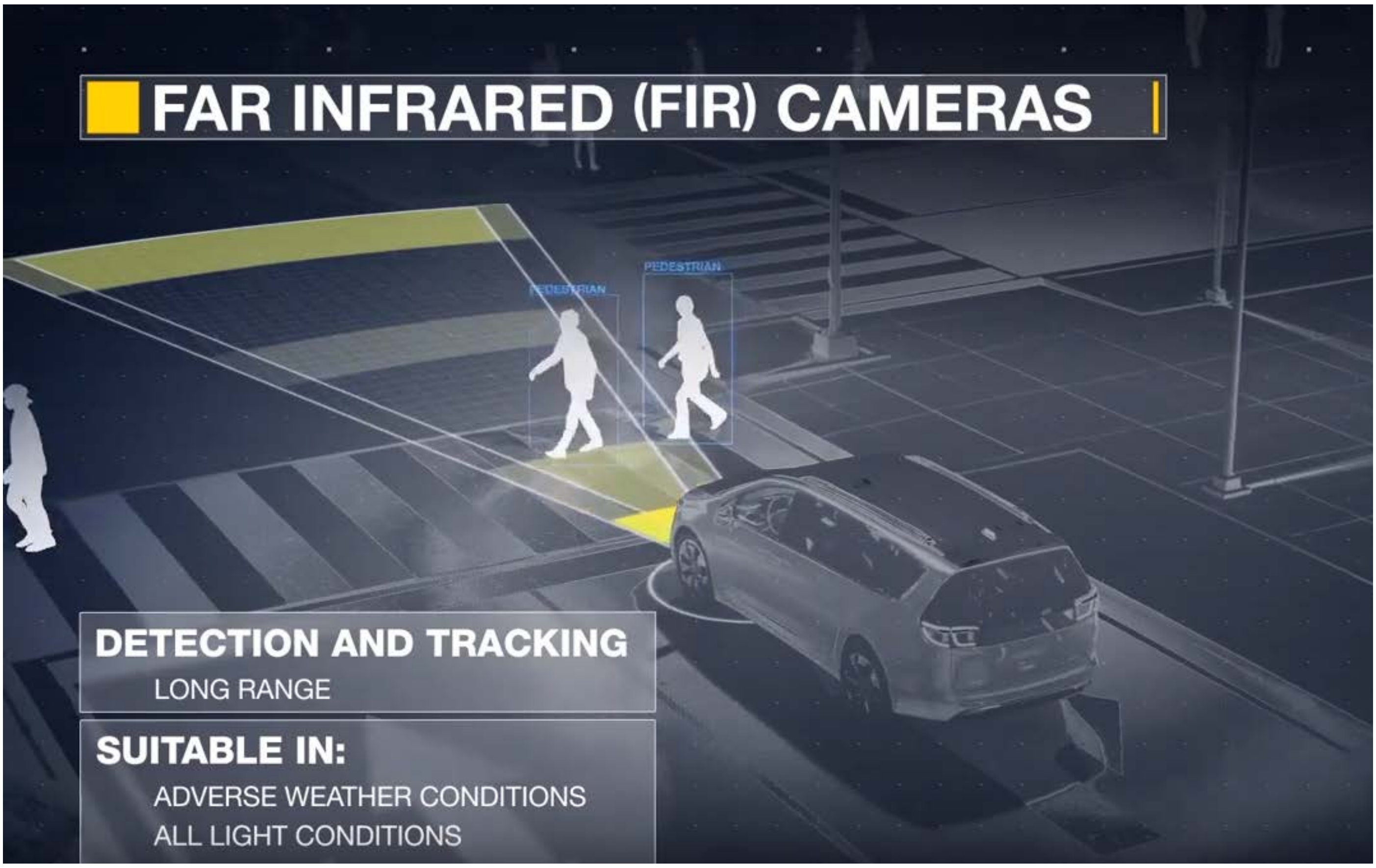
AESTHETIC INTEGRATION

While advancing in technological capabilities, the autonomous vehicles being developed and trialed today are not always given equal considerations for their style of design. For example, many of these models have massive lidar on the vehicles' roofs--an obtrusive design that OEMs will likely want to abandon if they are to bring autonomous vehicles to the greater public.

For the previous generation of FIR technology, aesthetic integration was difficult to achieve. Because the sensors were big, the only place they could be installed for both effective operation and decent appearance was a vehicle's grill. Now, however, in the FIR revolution, new sensors like AdaSky's Viper can be installed almost anywhere on the vehicle for complete detection, classification, and analysis in an aesthetically-pleasing integration.



AdaSky and Magneti Marelli integrate FIR into a vehicle's headlights for the first time



Integrated in a vehicle's headlights, FIR enables complete detection without compromising design

FIR EXPERTISE

In the race to develop autonomous vehicles, automakers have tried many different kinds of sensors, from radar to lidar to CMOS solutions and FIR. However, achieving Level-3 (or higher) vehicle autonomy is not about selecting just one sensor, but about determining the best way to fuse information across different sensing modalities together to achieve the most powerful combination of detection, classification, and analysis for autonomous vehicles.

Finding the most efficient sensor fusion method is key for automakers, as only a combination of sensors will give the highest qualitative and quantitative input to autonomous vehicle perception algorithms. As the automotive industry continues to explore sensor fusion and introduce new-generation FIR into their sensor suites, AdaSky has been developing unique expertise that can help OEMs and automakers to find the best fusion combination of the FIR technology other sensors.

DIFFERENT FIELDS-OF-VIEW FOR DIFFERENT USE CASES

Autonomous vehicles of Level-3 or higher all require accurate detection, classification, and analysis of their surroundings, but there are different driving scenarios or conditions that may require different perception capabilities. For example, FIR can be used in many applications and smart transportation solutions, such as vehicle-to-infrastructure, mapping, localization, and surround view of public transportation. For this reason, ideal FIR integration must also be adaptable for different use cases.

AdaSky's Viper currently offers a 17- to 30-degree field-of-view, which can be customized per application. Among other features, using 30-degree field-of-view images our algorithms are able to detect pedestrians and animals up to 120 meters away, while a 17-degree field-of-view detects up to 200 meters away. These use cases are mainly for forward-facing cameras that enable autonomous vehicles and ADAS safety systems to see on highways and in rural areas. The Israeli startup is also demonstrating a proof-of-concept for an even wider field-of-view, which would enable autonomous vehicles to see the full width of the road and detect objects on either side, satisfying the dire need for full detection in an urban environment. Fully autonomous vehicles will require full 360-degree view to change lanes, a crucial capability necessary for navigation and safety.

CONCLUSION

*"AdaSky is finding key opportunities to transform the autonomous vehicle arena by providing superior far infrared thermal imaging sensors and cameras that are able to capture objects in the environment that elude competing technologies, such as radar and Lidar. This capability drives opportunities for self-driving and autonomous vehicles by enabling vastly improved object detection and navigation. AdaSky has extremely strong growth prospects that can eclipse those of radar or Lidar, extending into the high double-digit range annually." - **Peter Adrian, Principal Analyst / Research Manager, Technical Insights, Frost & Sullivan***

The main use cases now being developed for FIR position Viper as the primary sensor for driving in dynamic lighting conditions, in harsh weather, and at night. Viper's value is also demonstrated in the various corner use cases in which CMOS cameras are unable to see clearly, as, unlike CMOS cameras, FIR cameras produce images that are not confused by colors, are invariant for lighting conditions, and are richly detailed despite their low pixel counts. For these reasons, among others, FIR is now regarded by the automotive market as the best sensing modality for reliable detection of living and non-living objects in all environmental conditions at day or night.

With the data it has been collecting for years, AdaSky can now develop for analysing infrastructure and objects based not only on a thermal signature, but also on the emissivity and reflected heat spectrum radiated by the environment.

The high reliability of detection from AdaSky's Viper means that new markets are on the horizon for the technology. The company is also evaluating opportunities for thermal FIR sensing in vertical industries and applications, such as:

- **Night Vision and Warning Systems (also for after market segment);**
  - Driver-assistance display and warning system
- **Commercial transportation (buses, mini-buses, trucks, delivery trucks, ride sharing);**
  - Long-range, forward-facing
  - Surround-view solution (360-degree field-of-view)
  - Localization and mapping
- **Intelligent Transportation Systems (vehicle-to-infrastructure);**
  - Sensor for smart traffic management systems

Level-3 and higher vehicle autonomy can only be realized when vehicles are reliably able to see and understand their surroundings in any environmental condition. It's become clear to automakers that these capabilities cannot be achieved by one sensor alone but, instead, necessitate the fusion of several different sensing modalities. As OEMs and tier-ones have begun trialing self-driving prototypes globally, FIR technology has become recognized as a key sensor vital to the success of vehicle autonomy.
Specifically, Viper has emerged as the only sensing solution capable of delivering the perception and coverage needed to facilitate Level-3 to Level-5 autonomy for the mass market. With proven efficiency from years serving military, aviation, and other industries, FIR has traditionally been reserved for use only among luxury brands. But now in the form of AdaSky's Viper, FIR technology has become affordable for the first time for the automotive mass market, where OEMs now regard it as the key sensor that will make safe, fully-autonomous vehicles a reality.