ADASKY

WHITEPAPER

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HOW FAR INFRARED (FIR) TECHNOLOGY ENABLES 24/7 AUTONOMOUS DRIVING IN ANY CONDITION

ADASKY VIPER HELPS FILL THE PERCEPTION GAPS LEFT BY OTHER SENSORS.

By Doug Newcomb

Due to the rapid development of autonomous vehicle (AV) technology, the automotive industry is experiencing a seismic disruption that is predicted to affect everything from individual car ownership to the design of cities. Most major automakers and tier-one suppliers are currently investing billions into autonomous innovations, while tech companies such as Apple, Google and Uber are pouring massive financial resources into self-driving research and development.

A vital component on the road to full autonomy is the development of sophisticated sensors and software that enable AVs to "see" the world around them and to react independently and better than human drivers.

Sensing modalities, such as radar and cameras have been used for years in advanced driver assistance systems (ADAS). But with the advent of AV technology that depends on sensors to detect every possible object in its environment under all conditions, the role of sensors has intensified both in quantity and in capability. In addition, lidar (light detection and ranging) sensors on most self-driving test cars have become synonymous with AV technology and are now considered an essential – if expensive – solution for complete detection and coverage.

While still cost-prohibitive for mass market applications, more lidar sensors are now available, and prices are continuing to lower. The best lidar sensors, such as Velodyne's top-of-the-line 64-laser HDL-64E, cost around $80,000, while the company's lower-end 16-laser Puck costs around $4,000, which is still considered cost prohibitive for mass market production vehicles.

Several companies are vying to produce solid-state lidar sensor for as low as $75. But these low-resolution lidar sensors have a difficult time detecting obstacles far away compared to more expensive, high-resolution lidar sensors. The result is reduced reaction time. The cost of lidar sensors will inevitably fall, but challenges with cost vs. performance and with time to market will remain – and could slow the deployment of AVs.

CURRENT SENSOR STRENGTHS AND WEAKNESSES

Each of these sensors has its strengths and weaknesses. Radar sensors can detect objects far away but cannot identify the object. Cameras, on the other hand, can more effectively determine whether an object is, for instance, another car or a pedestrian, but only at a closer range. For this reason, radar sensors and cameras are used in conjunction for a car's forward collision warning with automatic emergency braking feature: A radar sensor detects an object down the road, and a camera provides a more detailed picture of the object as it gets closer; meanwhile, onboard image-processing and other software identify the object and decide what action to take.

Like radar, lidar sends out signals and measures the distance to an object via a reflection of those signals, but uses light waves or lasers rather than radio signals. Moreover, the best lidar sensors provide a wide field-of-view whereas radar and cameras are more directional.

Unfortunately, the effectiveness of these sensors can be hampered by weather and other environmental factors. For instance, while radar can still detect faraway objects in heavy fog or haze, at night, or in other conditions, most cameras have near-field sight limitations that constrain their ability to see in foul weather and darkness.

In addition to adverse weather conditions, sudden changes in lighting can also affect cameras and lidar, like when a vehicle enters or exits a tunnel. Just as it takes a human driver's eyes a few seconds to adjust to sudden darkness or bright lighting, these AV sensors can also be momentarily blinded in such instances.

Another challenge exists in accurate image detection. For instance, while today's cameras can detect a person or an animal, their image-processing software may not be able to accurately distinguish between a real person or an animal and a picture of person or an animal on advertisements, buildings, or buses.

Sensor fusion is used to overcome these inherent weaknesses by combining the input of several sensors. Software-processing collects data from various sensors to decide how near or far away an object is and whether it's a person, an animal, or debris on the road. The latest image-processing and deep-learning software can also ascertain whether a pedestrian ahead is stopping at a crosswalk or walking while looking down at their phone and decide whether or not to apply a car's brakes to avoid a collision.

State- of -the- art camera with low light sensitivity
(Featuring the sony IMX174 CMOS inage sensor)

ADASKY'S FIR solution

SIDE-BY-SIDE WITH STATE-OF-THE-ART CAMERA SENSOR AND ADASKY'S VIPER

Many decisions that are complicated for sensors are second nature for experienced human drivers. For example, we can survey a complex scene in a crowded city and anticipate the actions of other vehicles, pedestrians, and cyclists whereas, sensors and machine-learning algorithms need to be programmed to respond to such scenarios.

But sensors have the edge on human drivers in other scenarios. At 70 miles per hour, for example, it takes a driver 100 meters to come to a full stop, and the average driver's reaction time is two seconds. At this speed, if a driver detects an object 60 meters away, he or she will be unable to react and stop in time. AVs, on the other hand, have sensors with longer-range detection and can, thus, react sooner to avoid detected objects. For autonomous cars to be safer than human drivers, the ideal range for the sensors is 200 meters.

At present, long-range sensors do have some limitations, but sensors and software are continuing to become more sophisticated and better able to anticipate every scenario an AV may encounter. Once sensor capability and accuracy have been perfected, full autonomy will be achieved.

"Safe and reliable operation in adverse conditions is necessary for the mass market adoption of self-driving vehicles."

– Fred Tung, computer-vision researcher and author of The Raincouver Scene Parsing Benchmark for Self-Driving in Adverse Weather and at Night.

"How much can we ever expect the general public to buy into self-driving cars if they haven't trudged through rain, slush and snow?"

– Motherboard, December 19, 2017.

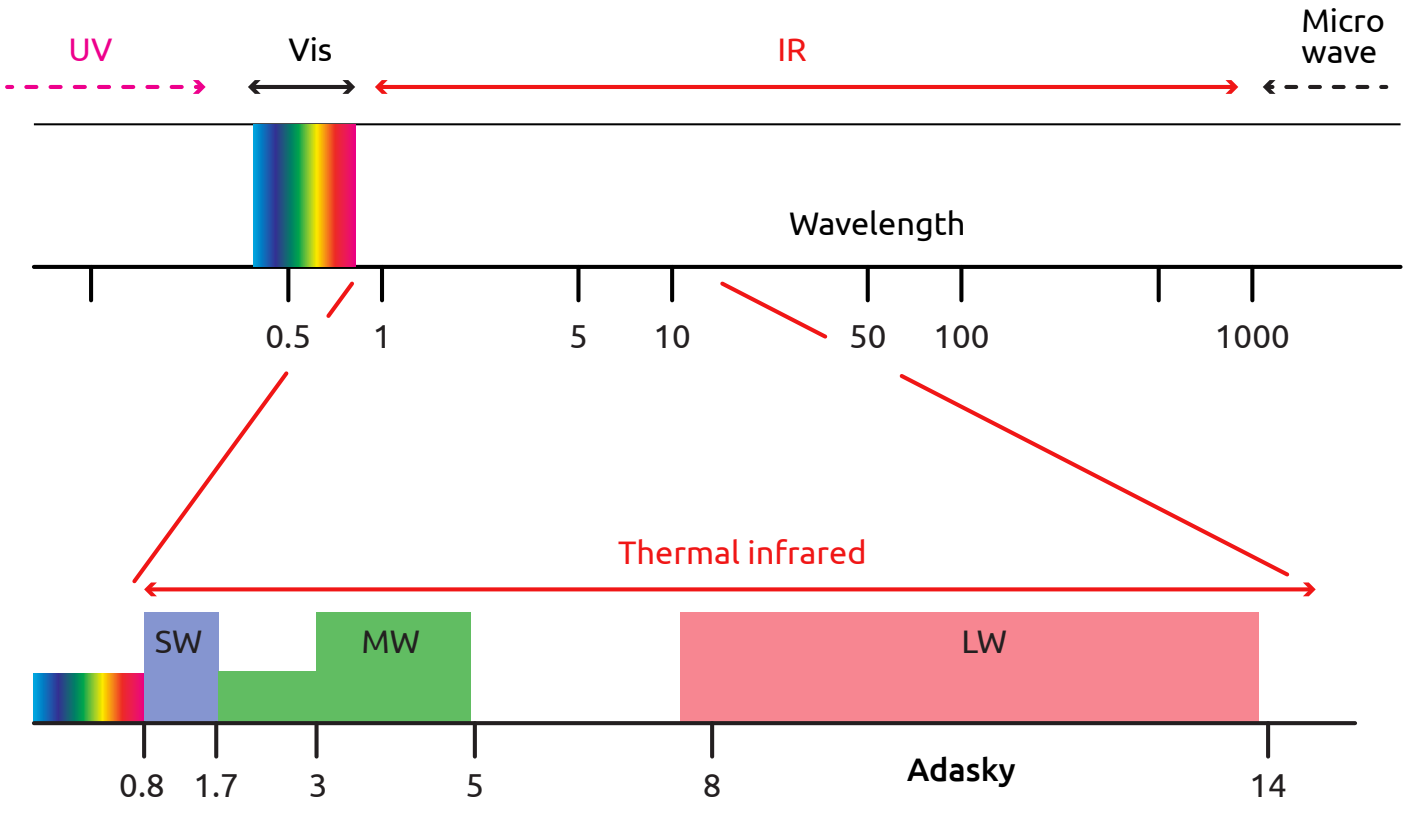
FIR FILLS THE GAPS

Numerous automakers and AV developers have announced plans to deploy fully autonomous vehicles on public roads by the beginning of the next decade, and most have started public testing in certain areas. But, before these deadline can be met and before anything over SAE Level 2 automation can be achieved, AV developers need to eliminate existing vision and perception weaknesses to ensure that vehicles can sense their surroundings 24/7, in any environment and in any condition.

Because current sensing technologies have inherent perception problems, a human driver still needs to be ready to take control of the car at any moment. This will decrease the use and efficiency of AVs and will impact the revenues of transportation network companies, fleet management firms, commercial trucks, and others who will rely on this technology. According to disengagement reports from car manufacturers testing AVs, one of the main reasons that human drivers have to take control in autonomous vehicle testing is due to adverse weather conditions.

Fortunately, a new type of sensor that employs far infrared (FIR) technology can fill the reliability gaps left by other AV sensors. FIR has been used for decades in defense, security, firefighting, and construction, making it a mature and proven technology. AdaSky, an Israeli startup, is making FIR technology available for demanding AV applications.

A FIR-based camera uses far infrared light waves to detect differences in heat (thermal radiation) naturally emitted by objects and converts this data into an image. Unlike the more common optical sensors used on cars that capture images perceptible to the human eye, FIR cameras scan the infrared spectrum just above visible light and can, thus, detect objects that may not otherwise be perceptible to a camera, radar, or lidar.



INTRODUCING A NEW MODALITY OF SENSING

PASSIVE TECHNOLOGY

EASILY SEGMENTS LIVING HUMANS AND ANIMALS FROM OBJECTS

NOT SENSITIVE TO DIRECT LIGHT

SUPERIOR SIGHT AND PERCEPTION IN ANY LIGHTING OR HARSH WEATHER CONDITIONS

PROVEN TECHNOLOGY FROM OTHER MARKETS

FEATURES OF ADASKY'S VIPER TO ENABLE A SAFER DRIVING EXPERIENCE:

- Fast detection, classification, and segmentation
- Sensitive to temp differences of 0.05 degrees C
- Superior image quality
- Compact design
- Deep-learning
- Advanced machine vision
- Large FIR data sets
- Simple integration
- Long range - 3X farther than car headlights
- No moving parts, shutterless
- Scalable for mass market
- Dedicated ASIC
- Tailored mature technology for automotive
- Meets quality and safety standards (ISO 26262 ASIL-B Ready)

Unlike sensors like radar and lidar that need to transmit and receive signals to be functional, a FIR thermal camera only collects signals and is, therefore, "passive." With no moving parts, AdaSky's initial FIR product, Viper, simply senses signals from objects radiating heat. Most importantly, a FIR thermal camera allows AVs to see and understand the road ahead in almost any lighting or weather condition and can distinguish between living and nonliving objects and between vehicles, road surfaces, traffic signs, and roadside vegetation.

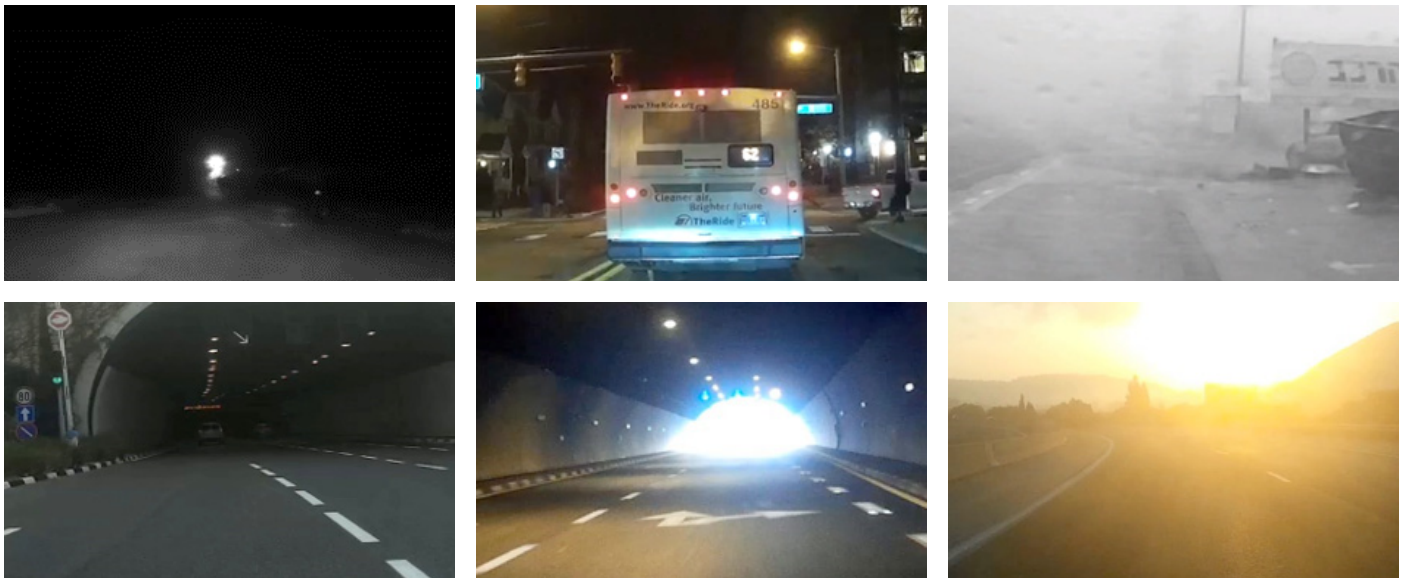
Moreover, a FIR camera can capture not only the thermal radiation or temperature of an object or material, but also its emissivity – how effectively it emits heat. Since each material has a different emissivity, a FIR camera can sense every object in its path. The camera then uses this information to create a visual painting of a roadway, including, not only other cars, pedestrians, animals, and other objects, but, also, potholes, debris, traffic signs, and more.

PERCEPTION EVEN IN HARSH CONDITIONS

AdaSky Viper is a high-resolution thermal camera that works together with state-of-the-art machine-vision algorithms and can be added to any autonomous vehicle and ADAS solution to enable better sensing and analyzing of its surroundings. AdaSky Viper passively collects the FIR signal that radiates from objects and materials and converts it to VGA video. It then applies proprietary deep-learning computer-vision algorithms to provide accurate object detection, classification, and scene analysis.

With a sensitivity of 0.05 Centigrade that allows for high-contrast imaging, AdaSky Viper can precisely detect vehicles, pedestrians, cyclists, animals, debris, and other objects more than 200 meters away, allowing more distance for an AV can react. AdaSky Viper is ideally suited for use cases in which other vehicle sensors have perception issues and enables awareness of a car's surroundings as well as detection of living and general objects in harsh conditions, such as rain, snow, fog, haze, and complete darkness.

Can you understand the scene?



And now?

Viper uses a chip engineered by AdaSky that enables shutterless functionality; this means that the vehicle's vision isn't mechanically blinded, even for a millisecond. It is the first high-resolution, thermal-perception solution for AVs with minimal size and weight and no moving parts.

AdaSky Viper is specifically designed for the automotive industry and its strict quality, safety, and environmental standards. At 4.3 cm in length by 2.6 cm in diameter, Viper is significantly smaller than other automotive cameras and has very low power consumption, making it ideal for the complex autonomous vehicle system.

Unlike other FIR cameras, Viper's application-specific integrated circuit (ASIC), combined with state-of-the-art image-processing algorithms, delivers high-resolution video. Other FIR cameras are affected by physical artifacts when pointing directly into the sun, creating a shadow or ghosting effect on the image known as a "sunburn" that can take anywhere from minutes to hours to disappear. To compensate, AdaSky Viper uses an algorithm called "sunburn protection" that presents a crystal-clear image for processing.

AdaSky Viper can detect a change of less than 0.05 degrees Celsius and has refresh rates of 60 frames per second. Resolution is VGA (640x480, 307,200 pixels per frame), with two available field-of-views: 30x24 and 17x13. Viper also uses AdaSky's proprietary algorithms (running on a dedicated ISP) to turn slight differences in the temperature and emissivity of objects into a high contrast graphic output.

VIPER PLAYS WELL WITH OTHER SENSORS

Current sensors working in concert can't provide coverage of an AV's complete surroundings, nor can they provide adequate coverage in all conditions. FIR sensors, on the other hand, generate a new layer of information originating from a different band of electromagnetic spectrum, significantly increasing performance for classification, identification, and detection of objects and of vehicle surroundings, both at near and far range.

Common camera-based solutions generate images based on visible wavelengths (similar to how the human eye works) and apply computer vision to understand those images. Conversely, AdaSky's solution generates images based on an invisible wavelength which represents thermal differences. Even low-light, high-definition cameras with a much higher cost can't detect objects at night as well AdaSky Viper. But together, the different solutions complement each other instead of competing.

AdaSky's solution complements other sensing technologies to

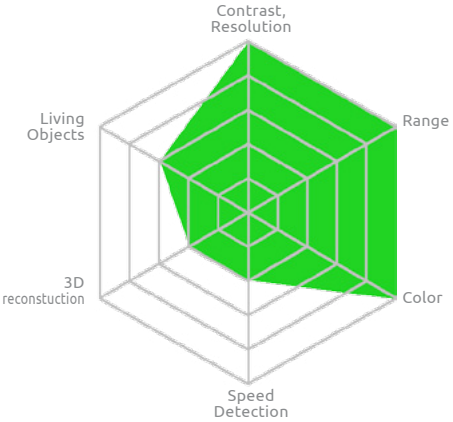
provide AVs with 24/7 perception in any weather or lighting condition while providing a crucial, additional layer of vision and brains that AVs can't get from other sensors on the market at a price point that isn't cost prohibitive for mass market production of passenger cars.

Below are examples of how each type of sensor plays a critical role in detecting objects in different scenarios, and how AdaSky Viper's FIR technology fills the gaps left by other sensors.

FOUR DIFFERENT SENSING MODALITIES

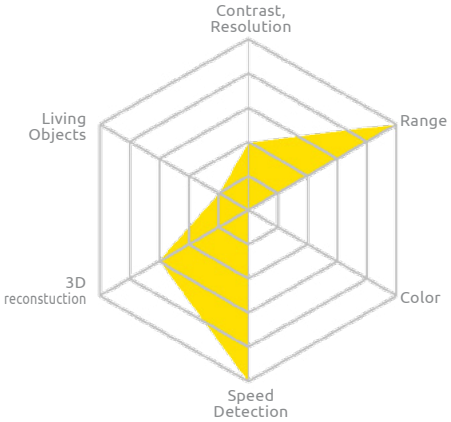
LEGACY SENSORS

CMOS camera



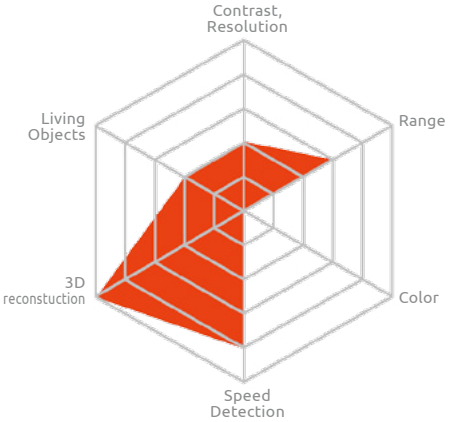
✗ Darkness, direct sun, glare, harsh weather

RADAR



✓ Works in any condition

LIDAR

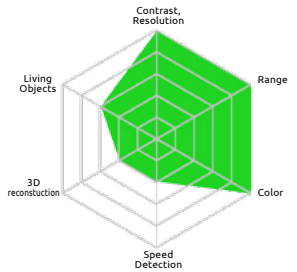


✗ Direct sun, harsh weather

Not good enough for Autonomous Driving

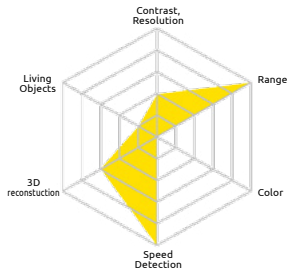
LEGACY SENSORS + ADASKY'S VIPER

CMOS camera



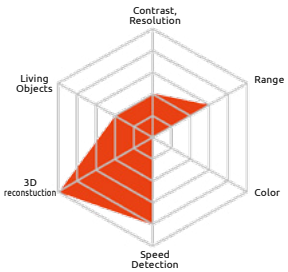
✗ Darkness Direct sun, glare Harsh weather

RADAR



✓ Works at any condition

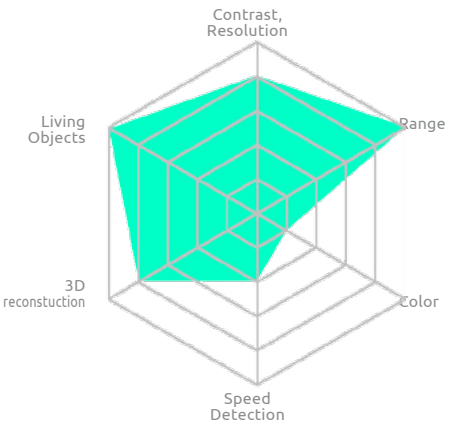
LIDAR



✗ Direct sun Harsh weather

Not good enough for Autonomous Driving

AdaSky's FIR Viper

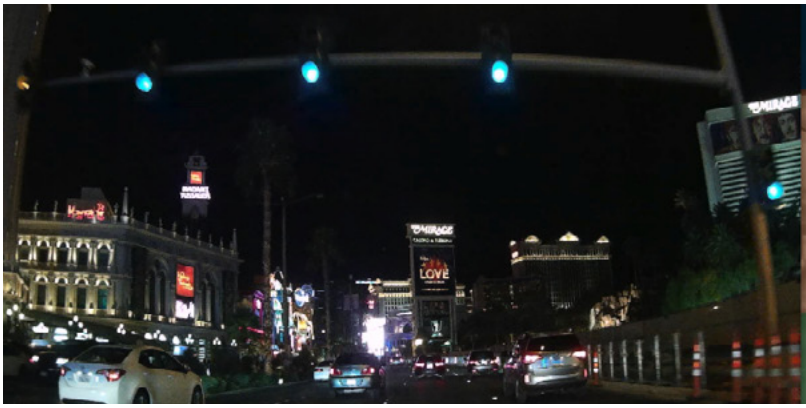


✓ **Works in Any weather and lighting condition**

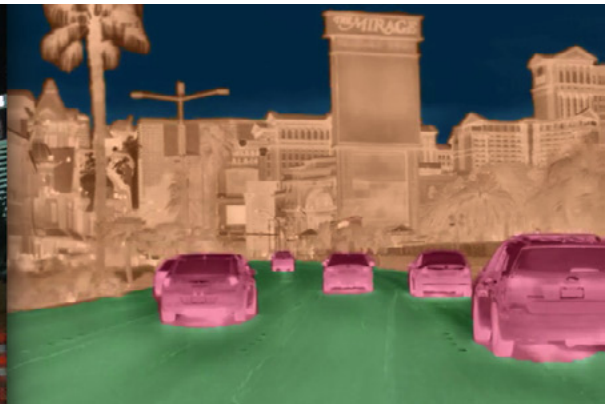
When you put all these sensing modalities together into a fusion solution that can be easily integrated, the gaps are filled to enable fully autonomous driving in all conditions.
AdaSky's computer-vision algorithms can run on a host ECU of the sensor suite or of the car, and its output can be fused with that of other sensors. When combined with other sensors, AdaSky's solution gives AVs perception of their surroundings in any condition to enable fully autonomous driving.
Using thermal images and machine learning, AdaSky Viper colors the road and all objects in the vicinity – other vehicles, pedestrians, cyclists, animals, signs, guardrails, vegetation – to allow a vehicle to know where it's allowed to drive. By creating this visual representation of the roadway in all conditions, AdaSky Viper provides the missing piece of sensor data that AVs need to be truly autonomous.

"Infrared sensors provide some visual information, as well as the 2d shape of objects, and are very useful for nighttime where vision via optical cameras fail."

– Tarek El-Gaaly, senior research scientist at Voyage, IEEE Spectrum, October 18, 2017



Advanced Full HD Dashcam



Segmentation based on VIPER FIR

WHY ADASKY?

Developing a FIR sensor and optimizing it specifically for automotive requirements demands multidisciplinary engineering capabilities and a focus on the AV market. There is an exceptionally high degree of difficulty to develop and manufacture FIR sensors for automotive use and to break the barrier of entrance into the market.

AdaSky founders' decades of experience developing thermal-imaging solutions for defense, security, firefighting and aviation industries and applications allowed the team to specifically adapt FIR technology to meet the needs of the automotive market. AdaSky is also working with SPICE® and quality standards experts Kugler Magg and functional safety experts Exida.

AdaSky is developing several SKUs of its sensing solution, each matched to the desired AV application required by customers, whether it be urban, rural, or highway driving – or a combination of all three. For example, on the highway, it's crucial to have long-range sensing so that if an object is detected, there is ample time for the vehicle to make the decision to stop – even as it travels at high speeds. In urban areas, having a wider field-of-view is prioritized in order to be able to detect pedestrians and cyclists on the sidewalk and at

crosswalks. AdaSky's solution can be adapted to specifically detect and analyze these and many other AV use cases.

AdaSky will be ready for mass production in 2018, although, due to traditional automotive product planning cycles, the target for the start of production in autonomous vehicles will be in 2020. In the short-term, AdaSky Viper will be included in Level 1 and 2 ADAS platforms, as well as in AVs that will start in low volumes but will ramp up significantly in a few years.

The company anticipates that there will be several FIR cameras in each AV to enable wide coverage and a comprehensive understanding of its surroundings. In addition to general safety needs, this is doubly important because the U.S. Department of Transportation's Federal Automated Vehicles policy requires redundancy for certain critical AV systems, and most OEM and tier-ones are gearing up to use multiple sensors and other components as fail-safe measures.

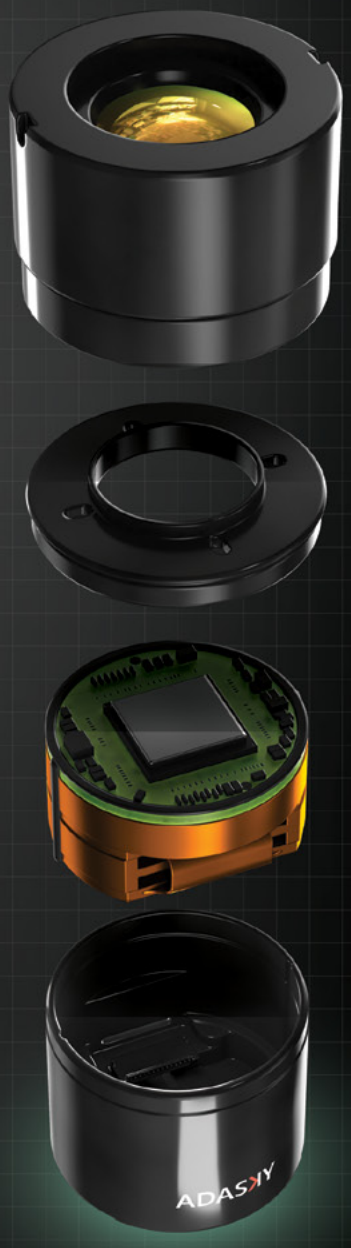
An important goal of AdaSky is to enable mass market pricing by offering a complete FIR solution and by designing and choosing components that are based on scalable technology. Pricing of sensors is significantly affected by volume, and at large volumes Viper will be priced competitively with other sensors on the market.

FIR technology has been used in vehicles primarily for night-vision systems that are expensive and only available in luxury vehicles. AdaSky has created a scalable solution and expects the price to go down significantly as volume increases. AdaSky aims to disrupt the autonomous vehicle market with a FIR solution priced for mass market that is built to meet the specific and demanding requirements of autonomous vehicles.

Two other large companies offer a FIR-based solution for automotive use, but AdaSky Viper does not use any moving parts (Shutterless), is more comprehensive and has better image quality and computer-vision performance, higher resolution, and is available at a lower cost. AdaSky is also the first to specifically adapt high-resolution FIR sensors and imaging for the automotive industry in terms of the safety and performance needs for AVs, and it is the first to make the technology scalable beyond luxury vehicles to support mainstream adoption of AVs.

"Far infrared technology has been around for decades in night vision goggles and security cameras, but its automotive applications have been limited to date. One only company, autoliv, currently offers an infrared camera for cars, which is sold as a pricey (us $2,000+) option on a few luxury models from audi, bmw, cadillac, mercedes-benz and rolls royce."

– IEEE Spectrum, October 18, 2017



REALIZING THE GOAL OF FULLY AUTONOMOUS DRIVING

As OEMs and others seek a solution to bridge the gap in AV perception, AdaSky Viper allows the goal of fully autonomous driving (Level 3-5) to be realized much faster. AdaSky adapted this mature technology specifically for autonomous vehicles to create a solution that complements other sensing technology, while providing an extra layer of perception for AVs regardless of the surroundings or conditions.

While FIR technology has been used in several markets for decades, AdaSky has optimized the cost structure, safety features, system architecture and performance, image-processing algorithms, and computer-vision solution to match the unique needs of the automotive market. AdaSky believes that FIR cameras will be one of the most important sensors in AVs and an essential part of a sensor suite for full autonomy.

"The race towards the first fully-autonomous vehicle has begun. Prototypes are already being tested worldwide, and leading car manufacturers and technology leaders are well on the way to developing their own vehicles for commercialization. To achieve full autonomy, vehicles need a fail-safe perception solution to enable sight and understanding of the road with complete accuracy, in all weather and lighting conditions. This remains a challenge to this day. The market needs a new solution to unlock the potential of the autonomous vehicle. A fir solution, such as adasky's, may be a solution to bridge the gap and expedite deployment of l3, l4 or l5 cars."

– Angelos Lakrintis, Strategy Analytics, Industry Analyst For The Autonomous Vehicles Service (Avs)

ABOUT ADASKY

AdaSky is a quick-moving start-up comprised of an experienced team that combines image-processing industry veterans from the Israeli high-tech market, automotive experts and machine-learning and computer-vision specialists. AdaSky was founded with the core vision of advancing autonomous vehicle technology with a bold new perception solution that increases safety and performance but at a mass-market price. The company was founded in 2015, AdaSky has 55 employees and its main office and headquarters are located in Yoqneam, with a smaller office is in Ramat Gan.