Spectral Edge

Spectral Edge White paper

RGB+IR Real Time Fusion for the Security and Surveillance Industry

Cutting edge technology that solves traditional resolution and color problems associated with RGB+IR fusion for the first time

Spectral Edge RGB+IR Fusion technology provides surveillance cameras with high resolution, color accurate images, even in very low or mixed lighting conditions.

Spectral Edge Fusion ('SE Fusion') is designed for embedding into the SoCs (System on Chips) that power surveillance cameras. It is underpinned by more than five years of research, generating seven live patents and a host of academic papers[1] which can be downloaded from Spectral Edge's **website**.

SE Fusion achieves this, not by injecting 'false' color into greyscale infrared (IR) images in low light, but by intelligently-balancing Red Green Blue (RGB) and IR light to deliver high resolution, color accurate images more reliably than any other technologies currently available in the surveillance market. As such, it's the only technology on the market today that can engineer RGB and IR light fusion without introducing pixelation, artefacts or additional noise. It doesn't add colors but simply optimises the illumination that is present, even in light levels well below one lux.

The majority of surveillance cameras today feature RGB and IR sensors as standard. But these cameras limit capture to either RGB or IR data, not both simultaneously. This restricts their ability to acquire detailed information in a range of difficult conditions including low/poor light, highly variable light (e.g. bright sunshine & shadows), or misty or foggy conditions. Color accuracy and image clarity are inevitably lost, hampering object detection and identification of individuals captured on video.

The power of SE Fusion is in the way it fuses and tunes RGB and IR data, processing these light sources together within the same image. It ensures minimal loss of resolution, while delivering improved contrast, dynamic range and signal-to-noise ratio. It does this without introducing artefacts, which are common in other methods of combining RGB and IR images.

Essentially, what is lost in color as daylight fades, is made up for in additional texture of the image which IR lighting provides with SE Fusion. It also assists in providing detailed images even in foggy, misty or hazy conditions when normal RGB sensors would be unable to detect detail.

SE Fusion also delivers a build saving for camera manufacturers because only one sensor is needed for day/night cameras and no mechanical switching between sensors is required. It removes the need for an IR-cut filter, for example, further helping to minimize moving parts which wear out over time and extending surveillance cameras' Mean Time to Failure.

SE Fusion's dynamic blending of RGB and Near-IR (NIR) data, frame by frame, is particularly beneficial in mixed lighting and at dawn and dusk because it optimises the effectiveness of data captured by all camera sensors. Instead of an arbitrary switchover point between visible and IR views, surveillance cameras powered by SE Fusion provide blend of both RGB and NIR light to maximise the information captured and the resulting video quality.

[1] Finlayson, Graham D., and Alex E. Hayes. "POP Image Fusion--Derivative Domain Image Fusion without Reintegration." 2015 IEEE International Conference on Computer Vision (ICCV). IEEE, 2015.

What is color?

Visible light is a type of energy. It is a form of electromagnetic radiation which can be detected by the human eye.

Visible light is a small part of the electromagnetic spectrum (see Figure 1). Light exists in tiny energy packets called photons. Each light wave has a wavelength and corresponding frequency.

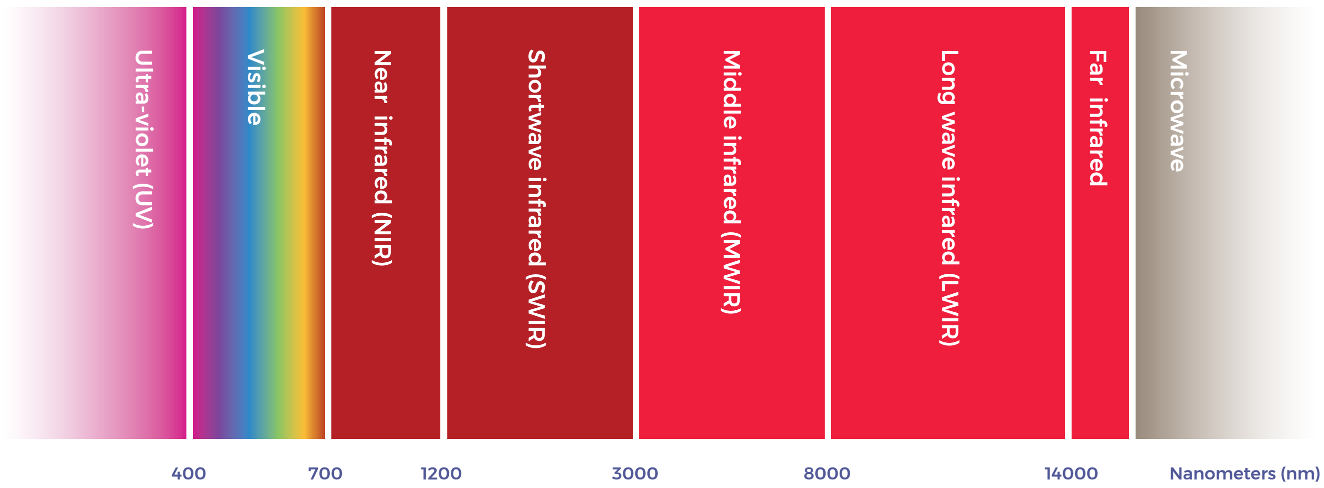
The human eye can detect photons of a wavelength between 400 nm and 760 nm (known as the visible spectrum of light). We see each wavelength as a different color. Rainbows show the entire spectrum of visible light.

The eye has two types of light detectors: rods and cones. The cones provide color vision, but they need fairly strong light to see anything at all. However, the rods can detect very low levels of light but cannot distinguish between wavelengths and thus provide no color information.

This is why humans lose color vision in low light conditions. Put simply, the cones pick up no color in these conditions, while the rods continue to provide 'color-less' viewing. Visible light levels can be photometrically calculated as illuminance or luminous flux per unit area. It's measured in lux, with one lux equalling one lumen per square metre, roughly equal to the light of one candle.

Separate colors, from longest to shortest wavelength, are usually listed as red, orange, yellow, green, blue, indigo and violet. Wavelengths longer than red (i.e. 700nm) are called IR and colors with wavelengths shorter than violet (i.e. 400nm) are called ultraviolet (UV).

Figure 1: The electromagnetic spectrum



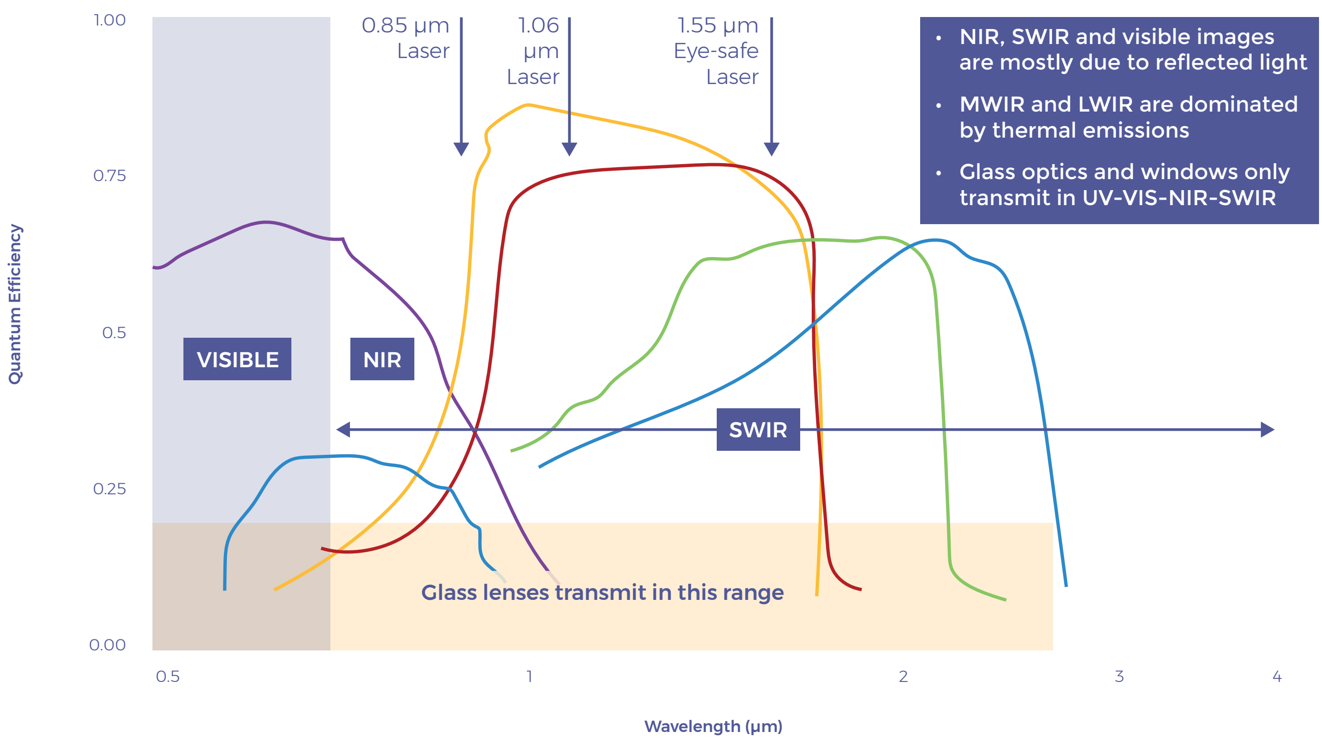
Selecting the best infrared imagery to enhance colors

Infrared radiation is emitted by any object that has a temperature (i.e. radiates heat).

SE Fusion combines RGB with NIR (which has a wavelength range of 780 to 1400 nm), so that much more detail can be seen in near darkness. In daylight, detail which would otherwise be lost in foggy, misty or hazy conditions, can be retained by using SE Fusion technology.

By intelligently fusing RGB light with NIR light, it's possible to extend color accuracy, texture, detail and depth of field into near 'pitch darkness' – well below the level of light offered by a single candle. The effectiveness of NIR light on different materials is highly variable.

Figure 2: Infrared spectrum



Save money by using only one sensor for two spectra

There is also a cost advantage associated with using NIR because it can be included on the same semiconductor process as an RGB sensor. This means NIR can be combined on the same sensor chip as RGB, with no extra cost at all, if some of the pixels which sense visible light are replaced with pixels sensitive to NIR.

As a result, sensors which support both RGB and NIR wavelength are already in mass production[2], and are popular in many industries. Surveillance cameras, for example, already make use of such sensors to generate separate RGB and IR video feeds, providing there is IR illumination present.

By contrast, SWIR, MWIR and LWIR all require a separate sensor and lens which at least doubles build cost and introduces a major new technical problem called 'registration': aligning images from two or more separate sensors which are not in exactly the same place. This takes orders of magnitude more mathematics and processing, which is eliminated if one sensor is used for both visible and NIR spectra.

Thermal imaging, i.e. LWIR, can detect whether people are alive in collapsed buildings or on a battlefield at night, for example. Although there is some merit in combining information from thermal images with visible images for some applications, this will not produce images which look natural to the human observer and may not be very useful for identification and recognition tasks.

[2] The OnSemiconductor AR0237, Omnivision OV4682 and OV4686 and HiMax HM2143 all have IR pixels in their Bayer pattern. The Sony IMX488 and Fairchild CIS2521A have monochrome pixels which are sensitive to IR.

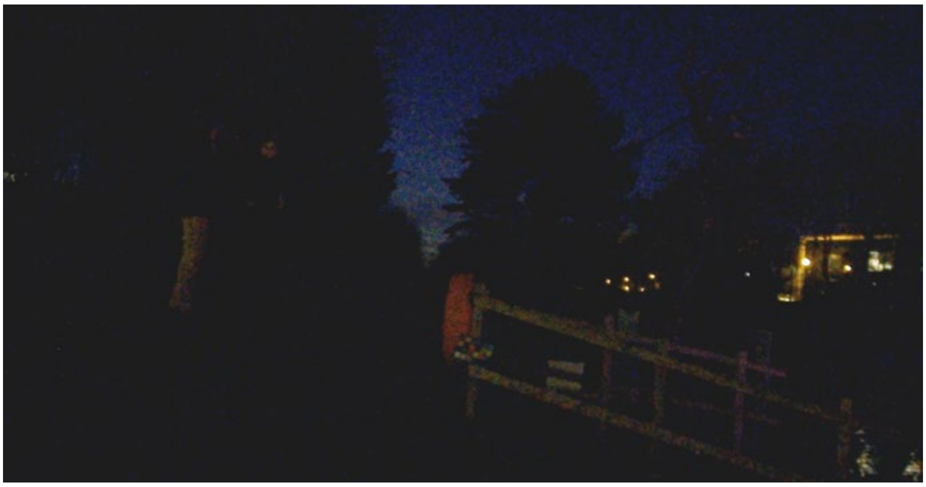
Embedding SE Fusion in your pipeline

SE Fusion takes four channels - Red, Green, Blue and NIR light - and reduces these to three channels by fusing the NIR data into the RGB image, creating very smooth transitions as natural light levels fall below levels where fine detail would ordinarily be lost.

In lab and field tests carried out to date, SE Fusion has proved highly successful with facial recognition even in the most difficult light conditions. It's also proved to be highly effective in improving object detection, such as vehicles, by enhancing key details like number plates, thus improving detection/recognition tasks associated with security incidents. Other examples include detecting pedestrians on railway tracks or livestock on motorways. Compare the images in *Figure 3*: the latter clearly shows two people, the fencing and a color chart. In the former the fencing is barely discernible, the color chart is not identifiably and the people are undetectable.

Figure 3: RGB+IR in low light conditions (<1 Lux)

Dark outdoor scene – RGB only



Dark outdoor scene with NIR illumination and SE Fusion

This figure shows the additional detail that is available by fusing RGB and IR light using Spectral Edge Fusion technology.

A key area Spectral Edge is focusing on is power usage and chip gate usage minimisation in the course of processing and fusing RGB and IR images. This work has given the SE Fusion a favourable reception with the chip manufacturing community. This work also means SE Fusion can support mobile-driven surveillance applications including camera-carrying drones and body-worn cameras used by the emergency services and armed forces.

SE Fusion is designed to power all types of surveillance cameras, including next-generation Internet Protocol (IP) cameras. It also optimises real world video content analytics applications such as motion detection, and object, tripwire and facial recognition. SE Fusion is being integrated into a number of surveillance-ready chipsets compatible with both 2x2 and 4x4 Bayer Pattern RGB+IR First-use sensors.

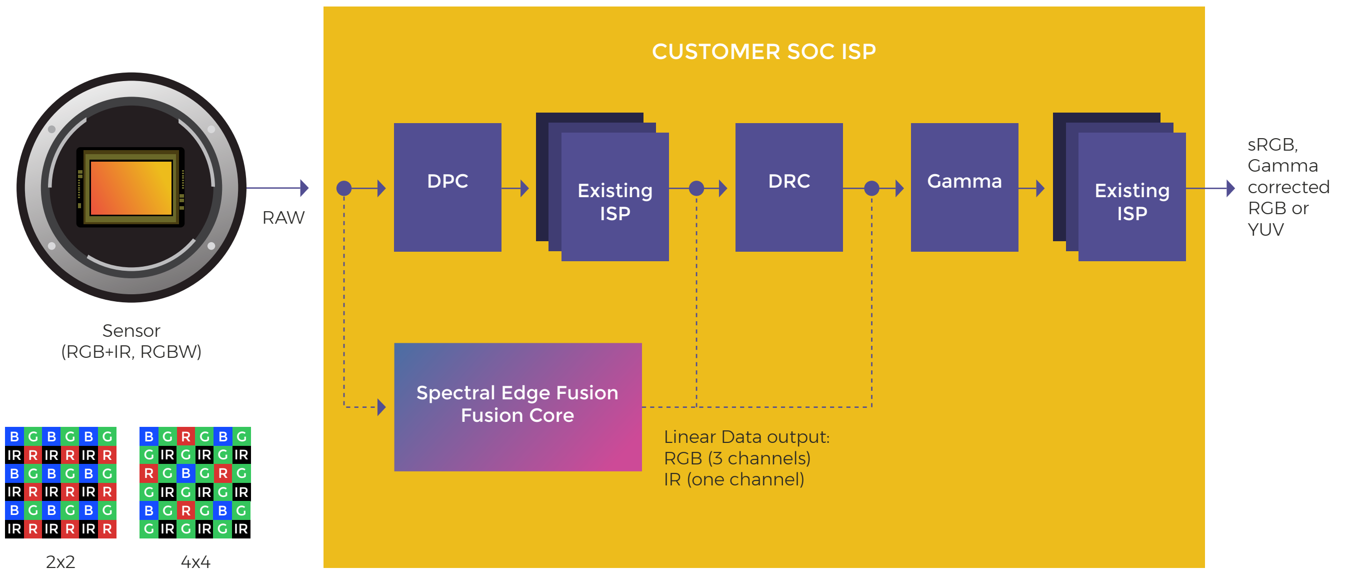
Spectral Edge has successfully tested Fusion using RGB+IR sensors from key chip manufacturers. Tests demonstrate that the lens used in Spectral Edge's lab requires a dual band pass (notch) filter instead of an IR-cut filter and the lens is IR-corrected to focus IR in the same manner as the visible light. The only other consideration is selecting the right quality and power of IR illumination appropriate to the distance between the camera and subject/objects in a scene.

Spectral Edge focuses on delivering three core elements in the RGB+IR Image Processing Pipeline (IPP): Demosiac, Color Correction blocks and Fusion. (see *Figure 4*). Spectral Edge's expertise in color science and fusion, along with its patent-protected technology has enabled it to deliver color accuracy and detail in the toughest and darkest of lighting conditions.

Spectral Edge holds a total of seven patented algorithms and it's this, together with focus on gradient domain research and development over the last five years which gives Spectral Edge a technological edge over alternative technologies.

Spectral Edge has designed its software for SoC implementation for mid-to-high volume cameras or as an encrypted Field Programmable Gate Array (FPGA) design for low volume specialist camera manufacturers. SE Fusion is designed to be integrated with all other IPP blocks which camera vendors may have built into their chipsets. Vendors can therefore use the full Spectral Edge IPP or only those blocks they believe will enhance existing in-house pipelines as shown in *Figure 4*.

Figure 4: Spectral Edge Fusion Core embedded into an ISP



Key Benefits of Fusion

1 Detecting and recognising people, objects & actions more reliably

(a) Facial Recognition: Reliable facial identification in highly variable and difficult lighting conditions

SE Fusion cannot only generate high quality images to enable reliable identification of an individual in low light conditions but also in 'mixed light', or over-exposed and under-exposed images as seen in *Figure 5*.

Figure 5: Spectral Edge RGB+IR Fusion: Mixed lighting example

Facial image with visible light from right and NIR illumination and SE Fusion

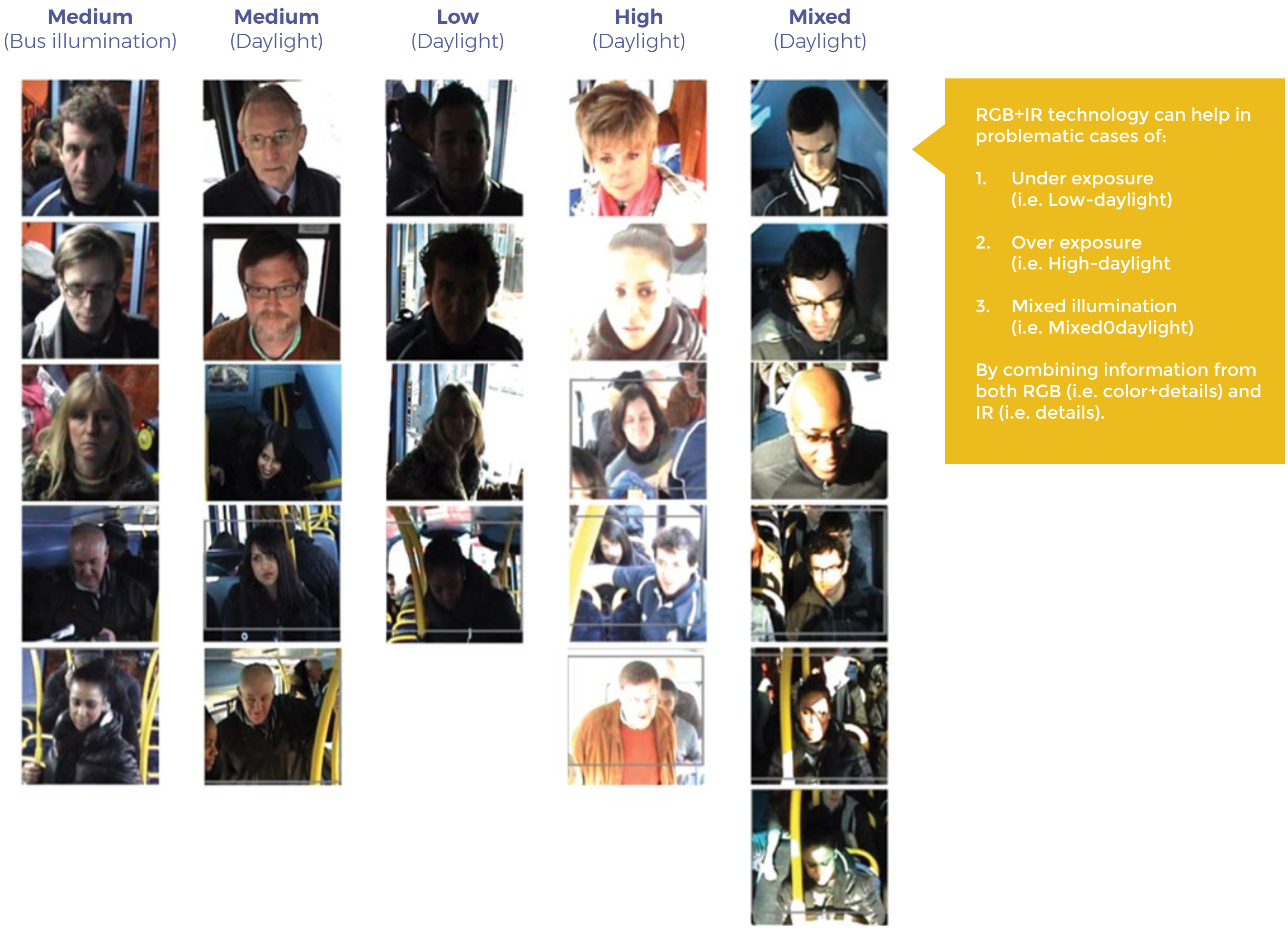
Facial recognition with strong light from the right

In a Spectral Edge lab test, with uniform lux levels and increasing IR lighting intensity you can see how SE Fusion is able to dynamically rebalance the RGB and IR images. The result is a more color accurate, high resolution image suitable for use in facial recognition,

As many as 22 of the 25 images taken on a bus (*Figure 6*) would not be of high enough quality to facilitate automated positive identification using facial recognition software.

However, by combining RGB and NIR light to obtain additional detail and depth it would be possible to get a reliable, consistent image capable of identifying an individual accurately in more than 90 per cent of examples in *Figure 6*.

Figure 6: Examples of typical facial recognition use cases on a bus[3]



[3] Source: Tsifouti, A. 2016. Image usefulness of compressed surveillance footage with different scene contents

(b) Object Recognition: Reliable object detection in highly variable and difficult lighting conditions

Figure 7 has been taken using the same camera and show a test scene in Spectral Edge's lab. The first image has 50 lux of visible light, with no IR and the second scene has both 50 lux of visible light and NIR illumination. The difference in the level of detail, added by SE Fusion – particularly seen in the bottom right box is palpable.

Figure 7: Spectral Edge RGB+IR Fusion enhances object detection and recognition

High dynamic range laboratory scene without NIR illumination

(50 Lux RGB only)

High dynamic range laboratory scene with NIR illumination and SE Fusion

(50 Lux with Fusion Core)

(c) Action Recognition: More accurate color representation and higher resolution with no artefacts in mixed and low light assures much more accurate identification of people and objects on the move

Spectral Edge has seen the potential for use of its technology to improve facial recognition associated with access control systems integrated with network video systems. SE Fusion also opens up the opportunity for accurate facial expression detection so that capturing of facial expressions could trigger a security alert in an airport check-in area. Similarly, a SE Fusion-embedded in-car sensor could detect indications of tiredness in a driver's face - such as yawning or drooping eyelids.

Accurate facial recognition is also vital for enabling authorised to access a restricted area or building versus identifying a possible intruder. Again, SE Fusion would ensure facial images being captured at gates and perimeters are accurately matched with facial databases of authorised individuals and intruder false positive alerts are minimised.

Spectral Edge is looking at the benefits of its software to assist object recognition. One example is identifying different drone types crossing a restricted area like an airport or military base in low light, to establish the degree of security or safety risk posed. Another is combined vehicle/occupant identification, where the vehicle color can be accurately captured in RGB, and interior details illuminated by infra-red.

Spectral Edge

Spectral Edge is a fast-growing technology company in Cambridge, United Kingdom. A world-leader in Image Fusion technology, patents and skills, for more information see **www.spectraledge.co.uk**.

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