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Editorial and Administrative Team
Tel: +44 (0)1223 221030
Fax: +44 (0)1223 213385

Head of content Mark Elliott
mark.elliott@europascience.com

Head of marketing Vicky Stokes
vicky.stokes@europascience.com

Group managing editor Finbarr O'Reilly
fin.oreilly@europascience.com

Group news and market editor Matthew Dale
matthew.dale@europascience.com

Head of collaborative content Keely Portway
keely.portway@europascience.com

Corporate Team
Managing director Warren Clark
warren.clark@europascience.com

Advertising
Sales director Jon Hunt
jon.hunt@europascience.com
+44 (0)1223 221049

Senior account manager Eleanor Waters
eleanor.water@europascience.com
+44 (0)1223 221041

Senior account manager Stephen Russell
stephen.russell@europascience.com
+44 (0)1223 221044

Business development manager Matt Vann
matt.vann@europascience.com
Tel: +44 (0)1223 221 037

Production manager David Houghton
david.houghton@europascience.com
+44(0)1223 221034

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News

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Vision firms collaborate to develop 'next-generation' 3D SWIR camera

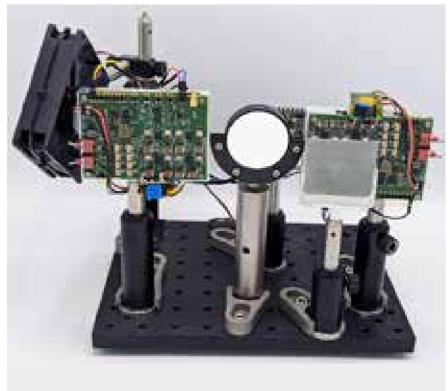
Jabil, ams Osram and Artilux are collaborating to develop a next-generation 3D camera capable of operating in both indoor and outdoor environments up to a range of 20m.

The prototype is under development at Jabil's optical design centre in Jena, Germany, where it will combine its 3D sensing architecture with ams Osram's semiconductor lasers and Artilux's germanium-silicon (GeSi) sensor arrays based on a scalable CMOS technology platform. The 3D camera will operate in the short-wavelength infrared (SWIR), at 1,130nm.

Steep growth in automation is driving performance improvements for robotic and mobile automation platforms in industrial environments. According to Jabil, the industrial robot market is forecast to grow at more than 11% compound annual growth rate, to more than $35bn by 2029. The 3D sensor data from these innovative depth cameras will improve automated functions such as obstacle identification, collision avoidance, localisation and route planning – key applications necessary for autonomous platforms.

"For too long, industry has accepted 3D sensing solutions limiting the operation of their material handling platforms to environments not impacted by the sun," said Ian Blasch, Senior Director of Business Development for Jabil's optics division. "The new SWIR camera provides a glimpse of the unbounded future of 3D sensing where sunlight no longer impinges on the utility of autonomous platforms. This new generation of 3D cameras will not only change the expected industry standard for mid-range ambient light tolerance, but will usher in a new paradigm of sensors capable of working across all lighting environments."

Dr Joerg Strauss, Senior Vice-President and General Manager at ams Osram for business line visualisation and sensing, added: "1,130nm is the first of its kind SWIR VCSEL technology from ams Osram, offering enhanced eye safety, outstanding performance in high sunlight environments, and skin detection capability, which is of critical importance for collision avoidance when, for example, humans and industrial robots interact."



Jabil

The 1,130nm SWIR 3D camera is a good fit for outdoor sensing applications

Lidar tech takes centre stage at CES 2023

With 300 vehicle tech exhibitors at this year's CES event, it's not surprising that lidar technologies were on show.

Innoviz believes the high resolution, high vertical field of view and low cost of its new Innoviz360 system could help OEMs looking to achieve Level 4-5 automation in robotaxis, shuttles, trucks, and delivery vehicles. Its design uses many hardware advances from its predecessor, the InnovizTwo, including a single laser, detector and ASIC.

Hesai debuted its new fully solid-state lidar FT120. Designed for near-range blind spot coverage for advanced driver assistance systems, the FT120 helps vehicles to accurately identify small objects while turning, passing and parking. Hesai has already received pre-orders of one million FT120 units from automotive OEMs, and will begin deliveries in H2 2023.

ZVision launched its new short-range lidar ML-30s+, which uses a non-coaxial architecture design. A MEMS mirror module is responsible for the 2D scanning of the transmitting module, while a pure solid-state receiving module is responsible for the gaze reception of large FOV.

Lumotive and Axibo jointly presented a six-axis robotic arm with 3D sensing capabilities designed for filmmakers

At the heart of SiLC Technologies' new Eyeonic Vision System is the company's fully integrated silicon photonics chip. Apart from autonomous vehicles, the system is designed for use in robotics, smart cameras and other products where manufacturers need to incorporate machine vision. It offers high resolution, high precision and long range (>1km) while being the only frequency-modulated continuous-wave (FMCW) lidar solution to offer polarisation information.

RoboSense presented its RS-LiDAR-E1, equipped with RoboSense's first in-house-developed chips designed for a flash solid-state lidar platform and its first 2D electronic scanning technology. It will be mass produced in the second half of 2023.

Not all lidar solutions were destined for vehicles. Lumotive and Axibo presented a six-axis robotic arm with 3D sensing capabilities that combines Lumotive's Light Control Metasurface (LCM) beam steering chips with Axibo's Precision eJib.

Enabled by Lumotive's M30 lidar reference design, Axibo's demonstration showcased advanced object tracking combined with automatic focus of a large, manual lens for enhanced filmmaking.

Photonic integrated circuits could close 'terahertz gap' for imaging apps

Researchers have developed an extremely thin chip with an integrated photonic circuit that could be used to exploit the so-called 'terahertz gap' for spectroscopy and imaging.

This gap, between 0.3-30THz, is currently something of a technological dead zone, describing frequencies that are too fast for today's electronics and telecommunications devices, but too slow for optics and imaging applications. However, the scientists' new chip now enables them to produce terahertz waves with tailored frequency, wavelength, amplitude and phase.

The work, conducted between EPFL, ETH Zurich and the University of Harvard, has been published in *Nature Communications*. Cristina Benea-Chelmus, who led the research in the Laboratory of Hybrid Photonics (HYLAB) at EPFL's School of Engineering, said her lab's use of the photonic circuit, made from lithium niobate, was more streamlined than the traditional bulk crystal approach.

She sees particular potential for miniaturised lithium niobate chips in spectroscopy and imaging. In addition to being non-ionising, terahertz waves are much lower-energy than many other types of waves (such as X-rays): "You could imagine sending terahertz radiation through a material you are interested in and analysing it to measure the response of the material, depending on its molecular structure. All this from a device smaller than a match head."

Accenture invests in 3D holography firm to provide Metaverse experiences

Accenture, a global IT service provider with revenues exceeding $60bn, has invested in Forma Vision, a provider of live-streamed, volumetric video technology that enables 3D holographic images of people, objects and environments to be beamed into the metaverse from any office, home or other location.

Forma Vision's live-streaming volumetric video technology enables the reproduction of people, places and things in a metaverse experience. Accenture had previously used the technology to conduct meetings and training sessions.

Growing consumer and business interest in the metaverse is expected to fuel a $1tn commerce opportunity by the end of 2025, according to Accenture findings released in early January.

The firm formed a "Metaverse Continuum business group" in March 2022, which combines metaverse-skilled professionals with capabilities in customer experience, digital commerce, extended reality, blockchain, digital twins, artificial intelligence and computer vision to help clients design, execute and accelerate their metaverse journeys.

Forma Vision is the latest company to join Accenture Ventures' Project Spotlight, an engagement and investment programme focused on investing in companies that create or apply disruptive enterprise technologies.

News from EMVA

emva
european machine vision association

By Thomas Lübkemeier

During the past year, we have seen the return of many physical trade shows, which are so important to the vision industry. Our members tell us that physical meetings remain very important in developing productive cooperation, so the return of on-site meetings and networking events such as the 21st EMVA Business Conference from 4 - 6 May 2023 in Seville, Spain, are greatly welcomed.

The most recent market statistics collected by the EMVA and broad sentiment across the industry indicate that strong growth will not be seen in 2023, with many respondents predicting flat demand. This is in contrast to the strong growth sentiment provided by the industry in the fourth quarter of 2021, prior to the war in Ukraine. One major consequence of the pandemic has been the supply-side restrictions and component shortages, which became one of the most critical topics for many companies over the past year. Although we see signs the supply situation is improving, we expect this to remain an important topic for at least the next 12 months. Another big hurdle for growth is and increasingly will be the lack of work force. Therefore, we may see a reduction in order intake during 2023, but also a relaxing of supply-side constraints, reducing backlog and increasing pressure to generate new sales.

Several macro trends across the machine vision market will continue to provide significant opportunities. For example, the drive to digitalisation is shaping the evolution of the vision tech market. Mass digitalisation of industrial processes to create a unified product lifecycle, from design through manufacture and deployment, offers many opportunities for vision tech, such as the definition of inspection and metrology plans at design time or the use of vision to analyse manual assembly operations and bring quantitative techniques to this most complex variable application area. The increasing use of AI-based vision systems is also creating an entire technology ecosystem, with many companies developing low-code/no-code toolchains to help ease development and deployment of AI models. Many companies also understand the value of additional insights that can be extracted from automated quality measurements, such as using higher-level trend analysis to predict tool performance and support preventative maintenance. We also expect the extension to hyperspectral, SWIR, UV, 3D, and event-based technologies to continue to increase the scope of the vision tech market.

New EMVA members

Just before the end of 2022, the EMVA was joined by two new members. Firstly, Datasensing is merging Datalogic's Sensor & Safety and Machine Vision business unit with M.D. Micro Detectors. Headquartered in Italy, the company is developing, manufacturing and supplying machine vision, sensor and safety, with more than 200 product lines. Finally, we welcome Vico as the last new EMVA member in 2022! Vico products include lenses, smart cameras, illuminations, cables, controllers, digital image test solutions, and more. Outside China, Vico currently has sales outlets in South Korea and Germany.

Today's Machine Vision News: CoaXPress supports fiber BitFlow announces the Claxon-Fiber

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TKH Vision group opens new Vision Solution Center

TKH Vision, a group of machine vision companies, has opened a Vision Solution Center in Konstanz, Germany, to serve as a demonstration and experience site for its integrated turnkey vision solutions for OEMs, machine builders and system integrators.

TKH Vision consists of the companies Allied Vision, Chromasens, LMI Technologies, Mikrotron, Nerian, NET, SVS-Vistek, and Tattile. The new centre is located at Chromasens' headquarters.

The group's in-house experts develop integrated solutions from a large variety of area scan, line scan, and 3D vision technologies, supporting all spectra from UV to SWIR using highly sophisticated light and optic sub-systems, in combination with state-of-the-art software products.

"The TKH Vision Solution Center is a meeting place where prospective customers can come and see our 2D and 3D machine vision solutions in action. Here, we take care of any application requirement and provide integrated, turnkey vision solutions for machine builders and integrators," said Mark Radford, Vice President of TKH Vision and CEO of LMI Technologies.

The new centre is an extensively equipped demo and experience site that highlights the capabilities, expertise, products, and technologies of the TKH Vision group. The centre will enable the group to work directly with customers on their requirements, to sketch initial solutions on digital whiteboards, and to demonstrate initial technical approaches in instant set-ups. The test labs feature a variety of live demos from all TKH Vision companies, demonstrating the use and benefits of their products.

Multispectral satellites to monitor agriculture and oil & gas industries

Two vision-equipped satellite constellations are set to enable more sustainable practices in both agriculture and oil & gas.

EOS SAT-1, the initial satellite of what developer Dragonfly Aerospace says will be the world's first agriculture-focused satellite constellation, was launched on 3 January.

It is the first of a seven-satellite constellation planned for low Earth orbit (LEO) for customer Earth Observation System Data Analytics (EOSDA). The remaining six satellites of the constellation will be deployed over the next three years.

Equipped with two DragonEye electro-optical imagers, EOS SAT-1 will provide 44km swath panchromatic and multispectral imagery across 11 spectral bands at close to 1m resolution – making it one of the most capable LEO imaging satellites. Its images will deliver valuable information for harvest monitoring, application mapping, seasonal planning and assessments that analyse information such as soil moisture, yield prediction

NVIDIA

and biomass levels. This data will support growers with reducing CO_2 emissions and help them to develop sustainable agricultural methods.

The second constellation, GHOSt, is being developed by US startup Orbital Sidekick OSK for detecting gas and hydrocarbon leaks using hyperspectral imaging.

GHOSt consists of six technically identical microsatellites. It will initially be used by US pipeline operator Energy Transfer to monitor its pipelines, helping it meet compliance and regulatory obligations.

The hyperspectral data they capture, in more than 500 bands between 400-2,500nm, will be processed and analysed in real time using NVIDIA's Jetson AGX Xavier edge AI platform. Insights such as type of leak, size, urgency and location will be viewable by users of OSK's SIGMA (Spectral Intelligence Global Monitoring Application) platform.

GHOSt will perform 15 sun-synchronous orbits per day, with the captured data being processed within that orbit in real time, enabling continuous data capture.

In the US alone, 6,000 pipeline incidents between 2002-2021 resulted in more than $11bn in damages. Traditionally, such leaks have been detected using small aircraft and pilots looking out the window, which relies on a trained eye rather than sensors or other technologies.

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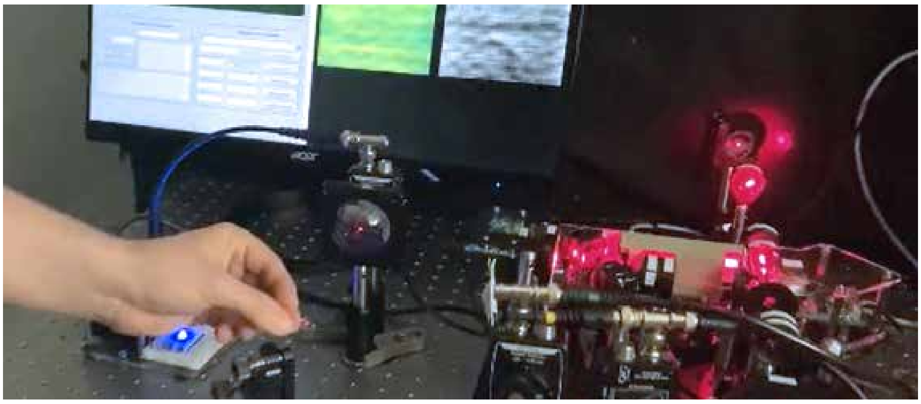
Ultrafast single-pixel camera could boost non-visible spectrum analysis

Researchers are developing a new ultrahigh-speed single-pixel camera capable of capturing video at 12,000fps. Described in *Nature Communications,* the device, dubbed 'single-pixel imaging accelerated via swept aggregate patterns' (SPI-ASAP), represents a breakthrough in ultra-high-speed single-pixel imaging, according to the scientists.

Single-pixel imaging (SPI) has emerged as a powerful technique using light modulation and a single-point detector instead of a two-dimensional sensor. However, most SPI systems are limited by the sole use of digital micromirror devices, which means the speed at which the single-pixel camera can record images is only a few tens of hertz. Other methods use fast-moving physical encoding masks for light modulation. Although fast, these masks also fix the resolution, making such systems inflexible to be adapted to different experimental parameters.

In contrast to these approaches, the new camera, developed by Patrick Kilcullen, Tsuneyuki Ozaki and Jinyang Liang at the Institut National de la Recherche Scientifique (INRS) in Quebec, Canada, combines a digital micromirror device with laser scanning for fast and reconfigurable pattern projection. This enables the system to operate at different spatial resolutions, as well as at different imaging speeds and modes. As a result, it is capable of streaming real-time video at 100fps, and up to 12,000fps offline. Another feature is that the system can be easily adapted to many configurations. It could have broad applications, especially in the non-visible spectrum, where there is a lack of ultrahigh-speed imaging technology, say the researchers. Such speeds enable the capture of transient events, such as the analysis of combustion phenomena, the detection of hazardous gases and the characterisation of semiconductor materials.

The researchers have recently patented the technique and are now seeking collaborations to commercialise it.



INRS

The new camera can stream real-time video at 100fps, and up to 12,000fps offline

Camera interfaces: making the right choice

UKIVA
UK Industrial Vision Association

By Allan Anderson, UKIVA Chairman

Interoperability is critical in the digital age. Two pieces of electronic kit should communicate seamlessly, but how often have you failed to connect an Android device with one from Apple?

The same principle applies in vision systems. When digital interfaces first emerged, many manufacturers developed their own. This inevitably led to complications when connecting to competitor devices. Happily, increased standardisation has largely solved this problem. Machine vision standards around USB, GigE and CoaXPress (CXP) boost interoperability and are aimed at particular types of application. Some interfaces are low-cost and relatively simple to use; others are more complex. Each common interface has its own advantages and limitations, so it's important to identify the best fit according to technical and budgetary requirements.

For example, USB 3 Vision is ideal for low complexity tasks and is common in vision systems. GigE Vision spans the range of cost and complexity, depending on bandwidth: interfaces of 5-10Gbps are medium-complexity and cost, while a 25 or 50Gbps interface sits at the upper end of the scale. Faster, higher resolution sensors – such as CMOS sensors – are driving development of higher bandwidths and power, longer cable lengths and lower latency communication between camera and host PC. This requires more advanced standards: CameraLink, CLHS and CXP.

Four main selection criteria dictate which interface is most suitable for an application: bandwidth; cable length; budget; and complexity. Bandwidth determines the amount of data that an interface needs to transfer. Cable length dictates whether an interface will work in an application such as remote monitoring. Budget is always critical – especially in manufacturing. And more complex systems may require some knowledge of vision technology – or the help of an expert.

The two following examples show how an interface can be selected for an application. The first is a static, offline vision inspection system with no moving parts. It does not require high speed but may need multiple cameras – in sync with each other – and cable lengths up to 10m. With a resolution of around 0.04Gbps, a standard 1GigE would be a good option – as it is scalable and has an overhead for future resolution increases.

The second is a 'driverless' vehicle, needing high resolution and speed, power over cable, and low latency, low noise imaging. Here, bandwidth needs are more than 11Gbps, making CXP a good option.

This is a basic primer on interface selection, but users should be confident that existing standards are applicable to a wide range of vision applications – allowing a camera from one vendor to 'play nicely' with software from another.

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Why you will be seeing much more from event cameras

Advances in sensors that capture images like real eyes, plus in the software and hardware to process them, are bringing a paradigm shift in imaging, finds **Andrei Mihai**

The field of neuromorphic vision, where electronic cameras mimic the biological eye, has been around for some 30 years. Neuromorphic cameras (also called event cameras) mimic the function of the retina, the part of the eye that contains light-sensitive cells. This is a fundamental change from conventional cameras – and why applications for event cameras for industry and research are also different.

Conventional cameras are built for capturing images and visually reproducing them. They take a picture at certain amounts of time, capturing the field of vision and snapping frames at predefined intervals, regardless of how the image is changing. These frame-based cameras work excellently for their purpose, but they are not optimised for sensing or machine vision. They capture a great deal of information but, from a sensing perspective, much of that information is useless, because it is not changing.

Event cameras suppress this redundancy and have fundamental benefits in terms of efficiency, speed, and dynamic range. Event-based vision sensors can achieve better speed versus power consumption trade-off by up to three orders of magnitude. By relying on a different way of acquiring information compared with a conventional camera, they also address applications in the field of machine vision and AI.

"Essentially, what we're bringing to the table is a new approach to sensing information, very different to conventional cameras that have been around for many years," says Luca Verre, CEO of Prophesee, the market leader in the field.

Whereas most commercial cameras are essentially optimised to produce attractive images, the needs of the automotive, industrial, Internet of Things (IoT) industries, and even some consumer products, often demand different performances. If you are monitoring change, for instance, as much as 90% of the scene is useless information because it does not change. Event cameras bypass that as they only monitor when light goes up or down in certain relative amounts, which produces a so-called "change event".

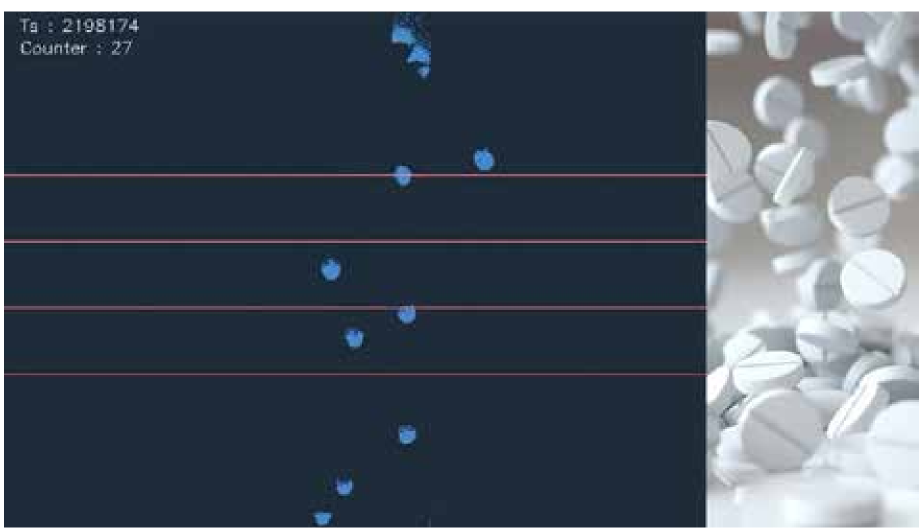
In modern neuromorphic cameras, each pixel of the sensor works independently (asynchronously) and records continuously, so there is no downtime, even when you go down to microseconds. Also, since they only monitor changing data, they do not monitor redundant data. This is one of the key aspects driving the field forward.

Innovation in neuromorphic vision

Vision sensors typically gather a lot of data, but increasingly there is a drive to use edge processing for these sensors. For many machine vision applications, edge computation has become a bottleneck. But for event cameras, it is the opposite.

"More and more, sensor cameras are used for some local processing, some edge processing, and this is where we believe we have a technology and an approach that can bring value to this application," says Verre.

"We are enabling fully fledged edge computing by the fact that our sensors



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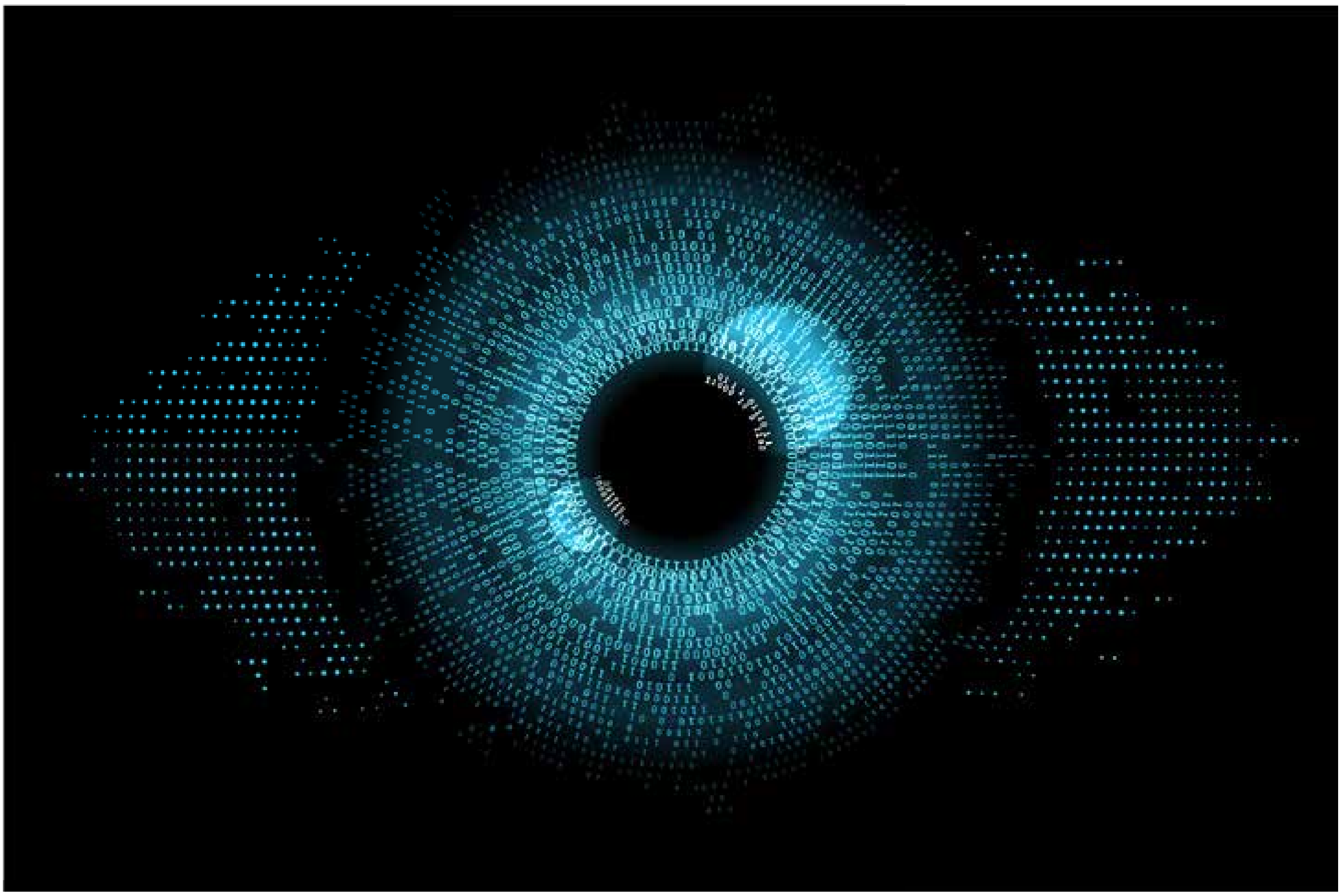
Event camera systems can quickly and efficiently monitor particle size and movement



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produce very low data volumes. So, you can afford to have a cost-reasonable, low-power system on a chip at the edge, because you can simply generate a few event data that this processor can easily interface with and process locally.

"Instead of feeding this processor with tons of frames that overload them and hinder their capability to process data in real-time, our event camera can enable them to do real-time across a scene. We believe that event cameras are finally unlocking this edge processing."

Making sensors smaller and cheaper is also a key innovation because it opens up a range of potential applications, such as in IoT sensing or smartphones. For this, Prophesee partnered with Sony, mixing its expertise in event cameras with Sony's infrastructure and experience in vision sensors to develop a smaller, more efficient, and cheaper event camera evaluation kit. Verre thinks the pricing of event cameras is at a point where they can be realistically introduced into smartphones.

Another area companies are eyeing is fusion kits – the basic idea is to mix the capability of a neuromorphic camera with another vision sensor, such as lidar or a conventional camera, into a single system.

"From both the spatial information of a frame-based camera and from the information of an event-based camera, you can actually open the door to many other applications," says Verre. "Definitely, there is potential in sensor fusion… by combining event-based sensors with some lidar technologies, for instance, in navigation, localisation, and mapping."

'There is potential in sensor fusion… by combining event-based sensors with lidar'

Neuromorphic computing progress

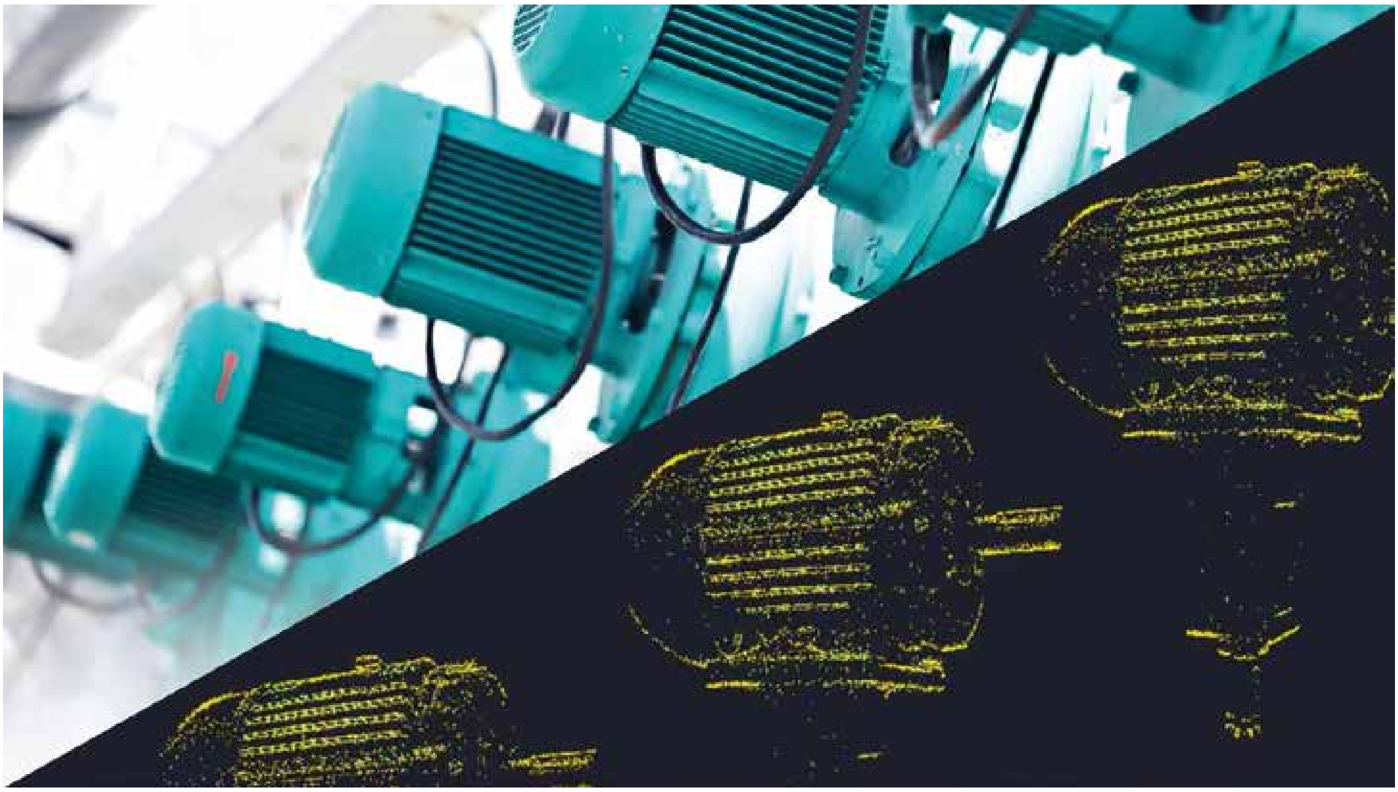
However, while neuromorphic cameras mimic the human eye, the processing chips they work with are far from mimicking the human brain. Most neuromorphic computing, including work on event camera computing, is carried out using deep learning algorithms that perform processing on CPUs of GPUs, which are not optimised for neuromorphic processing. This is where new chips such as Intel's Loihi 2 (a neuromorphic research chip) and Lava (an open-source software framework) come in.

"Our second-generation chip greatly improves the speed, programmability, and capacity of neuromorphic processing, broadening its usages in power and latency-constrained intelligent computing applications," says Mike Davies, Director of Intel's Neuromorphic Computing Lab.

BrainChip, a neuromorphic computing IP vendor, also partnered with Prophesee to deliver event-based vision systems with integrated low-power technology coupled with high AI performance.

It is not only industry accelerating the field of neuromorphic chips for vision – there is also an emerging but already active academic field. Neuromorphic systems have enormous potential, yet they are rarely used in a non-academic context. Particularly, there are no industrial employments of these bio-inspired technologies. Nevertheless, event-based solutions are already far superior to conventional algorithms in terms of latency and energy efficiency.

Working with the first iteration of the Loihi chip in 2019, Alpha Renner et al ('Event-based attention and tracking on neuromorphic hardware') developed the first set-up that interfaces an event-based camera with the spiking neuromorphic system Loihi, creating a purely event-driven sensing and processing system. The system selects a single object out of a number of moving objects and tracks it in the visual →



PROPHESEE

Event vision can trace particles or monitor vibrations with low latency, low energy consumption, and relatively low amounts of data

field, even in cases when movement stops, and the event stream is interrupted.

In 2021, Viale et al demonstrated the first spiking neuronal network (SNN) on a chip used for a neuromorphic vision-based controller solving a high-speed UAV control task. Ongoing research is looking at ways to use neuromorphic neural networks to integrate chips and event cameras for autonomous cars. Since many of these applications use the Loihi chip, newer generations, such as Loihi 2, should speed development. Other neuromorphic chips are also emerging, allowing quick learning and training of the algorithm even with a small dataset. Specialised SNN algorithms operating on neuromorphic chips can further help edge processing and general computing in event vision.

“The development of event-based cameras, inspired by the retina, enables the exploitation of an additional physical constraint – time. Due to their asynchronous course of operation, considering the precise occurrence of spikes, spiking neural networks take advantage of this constraint,” writes Lea Steffen and colleagues (‘Neuromorphic Stereo Vision: A Survey of Bio-Inspired Sensors and Algorithms’).

Lighting is another aspect the field of neuromorphic vision is increasingly looking at. An advantage of event cameras compared with frame-based cameras is their ability to deal with a range of extreme light conditions – whether high or low. But event cameras can now use light itself in a different way.

Prophesee and CIS have started work on the industry’s first evaluation kit for implementing 3D sensing based on structured light. This uses event-based vision and point cloud generation to produce an accurate 3D Point Cloud.

‘3D measurements or 3D navigation that requires high speed and time precision really benefits from this technology’

“You can then use this principle to project the light pattern in the scene and, because you know the geometry of the setting, you can compute the disparity map and then estimate the 3D and depth information,” says Verre. “We can reach this 3D Point Cloud at a refresh rate of 1kHz or above. So, any application of 3D tourism, such as 3D measurements or 3D navigation that requires high speed and time precision, really benefits from this technology. There are no comparable 3D approaches available today that can reach this time resolution.”

Industrial applications of event vision

Due to its inherent advantages, as well as progress in the field of peripherals (such as neuromorphic chips and lighting systems) and algorithms, we can expect the deployment of neuromorphic vision systems to continue – especially as systems become increasingly cost-effective.

We have mentioned some of the applications of event cameras here at *IMVE* before, from helping restore people’s vision to tracking and managing space debris. But in the near future perhaps the biggest impact will be at an industrial level.

From tracing particles or quality control to monitoring vibrations, all with low latency, low energy consumption, and relatively low amounts of data that favour edge computing, event vision is promising to become a mainstay in many industrial processes. Lowering costs through scaling production and better sensor design is opening even more doors.

Smartphones are one field where event cameras may make an unexpected entrance, but Verre says this is just the tip of the iceberg. He is looking forward to a paradigm shift and is most excited about all the applications that will soon pop up for event cameras – some of which we probably cannot yet envision.

“I see these technologies and new tech sensing modalities as a new paradigm that will create a new standard in the market. And in serving many, many applications, so we will see more event-based cameras all around us. This is so exciting.”

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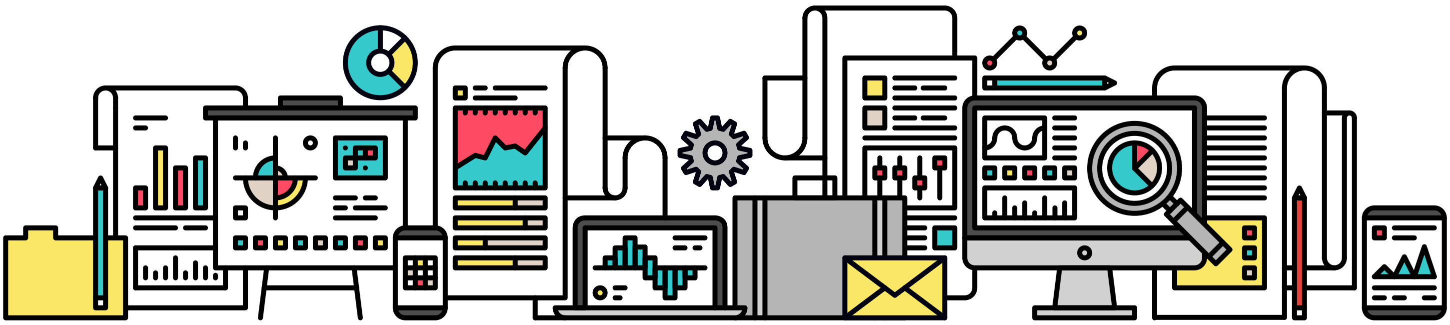

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Why optical hardware is key to hyperspectral high-res imaging

Optical accelerators are enabling a new generation of powerful hyperspectral cameras, writes **Professor Andrea Fratalocchi**, of KAUST and Pixeltra

Hardware accelerators such as graphics processing units (GPUs) and tensor processing units (TPUs) are rapidly emerging in artificial intelligence (AI) as faster processors for applications in computer vision, natural language processing and robotics.

Currently, commercial accelerators are implemented in electronics and suffer the limitation of chip architectures' processing capacity, whose processing speed lies in the hundreds of MB/s. This capacity permits the real-time processing of machine vision information limited to only a few conventional colours of red, green, and blue (RGB) channels. This problem is severe and does not allow the acquisition of important information beyond the primary colour bands, hindering new machine vision applications from emerging.

Researchers are therefore exploring alternative technologies, such as optical computation, to overcome this problem. Optical computation directly processes the information in a light beam without converting it into a digital electronic signal. This approach has several advantages over electronics:

Speed: Light information can be processed as fast as the travelling speed of photons, at the rate of hundreds of TB/s, significantly faster than electronic information could ever be.

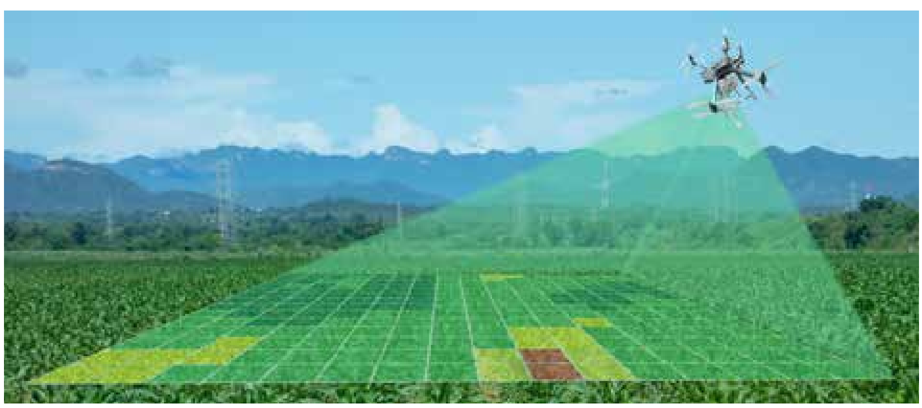
Efficiency: Optical computations require significantly less power than electronic ones. This property relies on the fact that optical signals do not generate as much heat as electronics and reach long distances with minimal energy loss.

Parallelism: Because light can travel through multiple pathways simultaneously, optical computations can perform millions of operations in parallel at practically no cost.

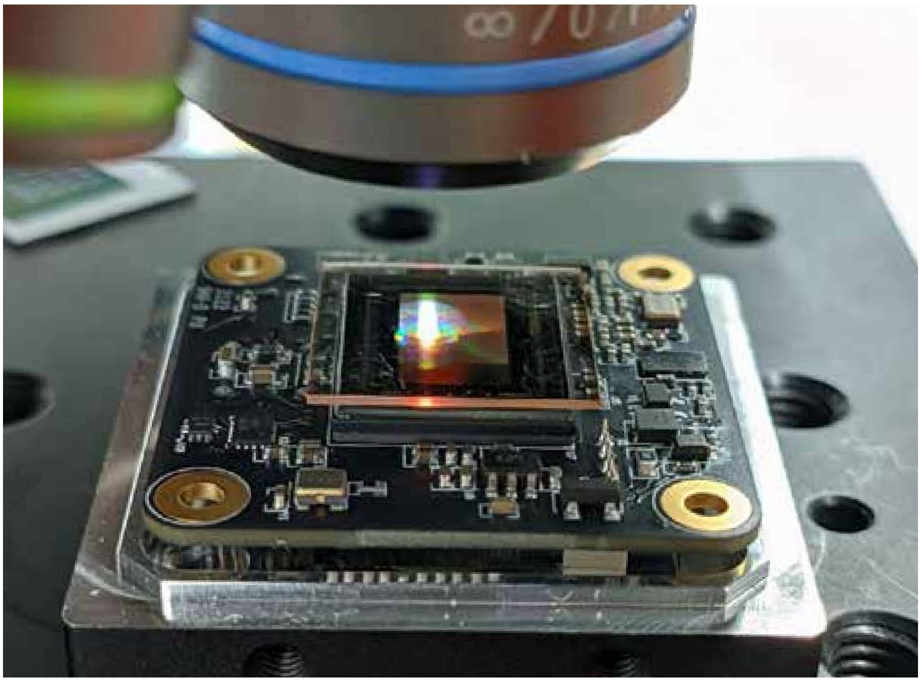
Very recently, our team of researchers of the Primalight group at Saudi Arabia's King Abdullah University of Science and Technology (KAUST) developed the first form of ultra-thin optical accelerator hardware for deep learning. This system, called Hyplex, uses light-matter interactions occurring in universal light encoders, which represent suitably engineered nanostructures with characteristic features as small as 20nm.

Hyplex technology can be integrated directly within any conventional camera and serve as a lightspeed feature extractor for spectral encoding, depth-estimation or polarisation measurement. Despite the early development of optical accelerators, Hyplex already recently demonstrated quantitative advantages in hyperspectral imaging (HSI), a field of machine vision currently attracting tremendous interest. In contrast to traditional imaging methods that only capture information in a narrow range of RGB colours, HSI acquires data across a continuous range of wavelengths. This information provides key signatures about any object's chemical and physical properties in a scene, opening key applications. In precision agriculture, HSI can detect plant stress and automatically segment and classify vegetation maps; in medicine, HSI detects and classifies various diseases, including cancer; in environmental science, HSI can monitor and detect pollution, to mention a few examples.

Currently, the best HSI available requires significant investment (in the range of $20,000-$200,000) and is affected by a slow speed of data processing (minutes). It necessitates the use of significant amounts of computational resources to post-process the large amount of data generated, while being incapable of generating high-resolution videos. The optical accelerators at the core of Hyplex enable it to address these issues. Unlike present hyperspectral systems, Hyplex does not use spectrometers or filters and can acquire and process hyperspectral videos in real time at the same rate and with the exact resolution as a modern digital camera, for example 12MP at 30fps or better. Hyplex has been validated



Hyplex is being deployed in precision agriculture using unmanned aerial vehicles to capture high-resolution hyperspectral images of crops



Hyplex technology can be integrated directly within any conventional camera

against modern spectral reconstruction and hyperspectral segmentation benchmarks. In all of these tests, it outperformed all state-of-the-art alternatives because none of these systems employ optical accelerators.

Pixeltra, a KAUST start-up with representative offices in both the UAE and Saudi Arabia, commercialises Hyplex technology. Recent developments of Hyplex are in precision agriculture using unmanned aerial vehicles (UAVs, or drones) to capture high-resolution hyperspectral images of crops. These images are analysed using machine learning software to identify diseases, pests, and nutrient deficiencies. The information can then be used to make more informed decisions about planting, fertilisation, and other management practices, ultimately increasing crop yields and reducing costs.

> ‘Optical accelerators can enable new future pathways for machine vision applications using deep learning’

Another development is DermaPlex , a new portable and non-invasive HSI device for the realtime diagnosing and classification of skin cancer. DermaPlex facilitates skin cancer diagnosis by capturing a detailed chemical profile of the tissue, analysing the texture and colour of skin lesions, and monitoring skin cancer progression over time. This system provides non-invasive imaging that eliminates the need for biopsy and when combined with AI, can drastically enhance diagnostic accuracy.

Driven by these technological achievements, we expect considerable growth in interest in HSI and video understanding for both industrial and research areas. Hyperspectral systems based on optical accelerators overcome the limitations of multispectral imaging, allowing them to tackle problems in which the information is sparse across a wide spectral range. These include remote sensing, medical diagnostic, precision agriculture, and security. The applications portfolio of optical accelerators such as Hyplex is not limited to HSI. One of the main advantages of optical accelerators is that they can perform matrix multiplications – a fundamental operation in deep learning – a few orders of magnitudes faster than electronic devices. This feature can significantly speed up the training time of neural networks and enable the training of larger and more complex models not achievable by current electronics.

Optical accelerators can be used as both standalone devices and in combination with other hardware accelerators, such as GPUs, TPUs and field-programmable gate arrays (FPGAs), to increase the performance of deep learning algorithms further. With sufficient development, optical accelerators can enable new future pathways for machine vision applications using deep learning, increasing the speed and efficiency of machine learning algorithms in more complex models that are not possible with conventional electronics today.

Professor Andrea Fratalocchi is head of the Primalight research group at KAUST, and co-founder of Pixeltra

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Machine vision drives robot farming's cutting

Camera and AI-equipped agricultural robots that can till, weed, pollinate and harvest are revolutionising farming, discovers **Benjamin Skuse**

Crop farming is not for everyone. Long hours, weeds, pests and the vagaries of the weather are just some of the challenging and often random conditions that conspire to make reaping a decent financial reward difficult.

But cutting-edge automation has already started to change this picture for tech-savvy farmers. For instance, satellite imagery and unmanned aerial vehicles (UAVs) equipped with image sensors are providing accurate crop height and health data. This data, through machine learning, can be used by farmers to estimate biomass and yield, and make important farm management decisions, such as on crop rotation. Meanwhile, vertical farms and hi-tech greenhouses that use various sensor technologies, automated environmental controls and even robotic pollination and picking are revealing a path to dealing with the combined challenges of labour shortages and increased food demands.

One company working in this agribot space is Arugga, based in Israel. Its Polly robot pollinates tomato plants in high-tech greenhouses. Tomato plants are self-pollinators, meaning each flower contains both male parts and female parts. Therefore, they only need to be shaken to induce pollination. "Greenhouses traditionally use industrial bumblebees or get workers to shake the supporting trellises or apply vibrating wands to the plants for pollination," says Arugga CTO Ariel Elbaz. "Neither method is ideal."

Polly, instead, uses four standard webcams attached to gimbals that move on two axes to image tomato plants over multiple frames and provide depth information. The robot uses a deep neural network, trained on thousands of flower examples, to detect flowers ripe for pollination and measure their approximate distance. It then sends pulses of compressed air from about 20-40cm away to pollinate the flower.

Polly has been pollinating tomatoes at Costa Group's multi-million-dollar greenhouse facility in Australia for two years, and the company has since expanded operations to other greenhouses in Australia, the US and Finland. Results so far have been encouraging, says Arugga, with Polly providing up to 15% higher yield versus manual pollination and up to 7% higher yield than bumblebees.

The company is working to make the robot fully autonomous (it currently has to be moved by an operator from row to row), faster and more accurate. "We want to get the accuracy to 100% pollination of reachable flowers and have a single robot pollinate about a hectare," says Elbaz. "Even small improvements will increase the farmer's yields and margins by much more than that." Moreover, the Arugga team aims to add new capabilities that provide further functions to growers. These include additional modules mounted alongside the pollinator, such as a plant-lowering arm which will be released later this year, and plant monitoring tools for pest and disease detection, yield prediction and crop management.

Bringing farming robots outdoors

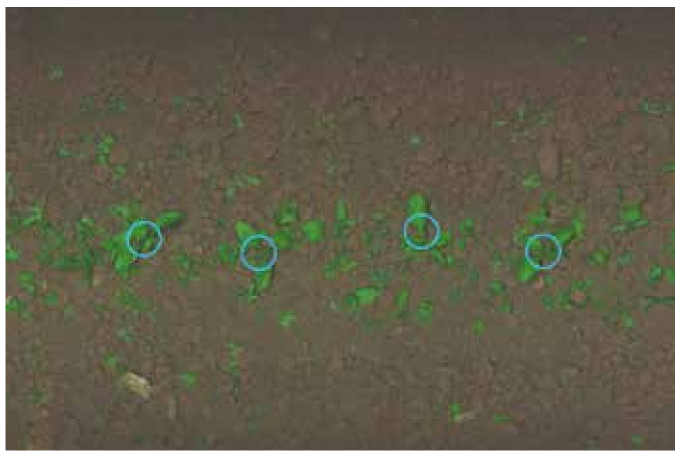
The controlled conditions in greenhouses are conducive to vision-based robotic

edge

'Advances in deep learning made it possible to recognise plants accurately and thus made it clear that a sustainable alternative to the use of chemicals for weeding was within reach'


Arugga


Farming Revolution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Above and right: Farming Revolution's Farming GT robot uses a multispectral camera to take high-res images of plants. A deep neural net identifies weeds before a rotating chopper cuts them off at the stem

Left: Arugga's Polly robot uses four standard webcams to image tomato plants over multiple frames and provide depth information. It uses a deep neural network to detect which flowers it should pollinate.

solutions such as Polly and others, including UK-based Fieldwork Robotics' raspberry-picking robot – recently deployed commercially in two locations in Portugal – and US-based Four Growers' robots that can harvest tomatoes, peppers and cucumbers.

Traditional outdoor, open-field farming is a different ball game in which unpredictable and uncontrollable factors come into play. However, the alignment of multiple technological advances, labour shortages, and public and private investment has brought robotic outdoor farming to the point where commercial solutions are starting to enter the market. These solutions are generally powered by sophisticated deep neural networks and advanced cameras and sensors, which combine with improved battery technology to provide farmers with hi-tech automated alternatives for traditional labour-intensive tasks.

For instance, Farming Revolution – a German company founded in 2020 by former Bosch roboticists and computer vision experts – focuses on weeding. "Advances in deep learning made it possible to recognise plants accurately and thus made it clear that a sustainable alternative to the use of chemicals for weeding was within reach," says co-founder and co-CEO Maurice Gohlke. The company's Farming GT robot uses a multispectral camera with an active light to take high-resolution images of plants, and then applies deep convolutional neural nets to discern between crops and weeds. From this, the robot wields its precise mechanical arms ending in a rotating chopper or blade to cut off weeds at the stem.

"The setup is able to discern more than 80 types of plants in different light conditions, and it performs well when plants are overlapping, partially occluded by other plants or earth," says Gohlke, who is currently looking to reduce component costs and simplify hardware in order to scale up the business. "Today, the robots are rented to farmers that operate them in different crops – we have 12 robots in operation, all in Europe."

At a similar level of commercialisation is the Small Robot Company (SRC), founded by a group of UK farmers, engineers, scientists and service designers in 2017. →

‘It’s automatically computing where the weed is… so that chemicals end up on the weed’

Naïo Technologies

Naïo Technologies’ tool-carrying Orio robot uses lidar to increase safety levels and work faster

“We’ve got 50 farms signed up for this year and quite a large number of customers waiting in the wings,” says Chief Marketing Officer Sarra Mander. “So the barrier is not farmer appetite, it’s stabilising the technology and seeking additional funding in order to scale up.”

SRC recently launched the latest iteration of its farming robot: Tom V4. Providing what the team calls ‘per-plant intelligence,’ Tom V4 can monitor a field in granular detail, down to individual water droplets on leaves. It achieves this with eight 6MP cameras, capturing images at a rate of 3fps mounted 95cm above the ground to give a ground sample distance of 0.28mm per pixel, among the highest resolution of any crop-scanning technology.

These images and their metadata (as well as robot location and diagnostic information) are fed into the company’s AI engine Wilma to build an ultra-high-definition map of the field. “It’s not quite as simple as a computer vision system that just looks at a bounding box around the plant and says what it is,” explains SRC Robotics Engineer Dan Rowe. “You can also look at other trends to do with location and information you already know about the field – so it’s taking an agronomist’s intuition and really catapulting it to the next level.”

Currently, farmers are using data from Tom for weed management. SRC integrates with and optimises farmers’ existing sprayer equipment so that they only treat those areas of the field where there are weeds. “It’s not highly precise at this stage because the area sprayed is greater than a single plant,” says Mander. “But it’s very much more accurate than what a farmer would otherwise be able to do.”

More exciting is SRC’s long-term plan for the technology. Tom V4 is a distributed and modular robot split into two halves, where each unit can function independently. “We can expand it and add an extra chassis, and just double the width of the robot,” says Rowe. “Or we can separate it slightly so that we can add depth and a different tool underneath.” This means the robot can handle different field sizes, different crops and can perform different farming tasks. Testing and trials are under way where the robot performs precision weeding, spraying and planting, and (with the addition of multispectral cameras) blackgrass and slug monitoring and treatment.

SRC

SRC’s Tom V4 uses eight 6MP cameras to monitor a field, down to individual water droplets on leaves

One problem facing young start-ups such as Farming Revolution, SRC and many of their competitors is that although their robots are autonomous, they cannot perform their roles unsupervised. This is because obstacle avoidance, particularly human obstacle avoidance, is a concern that is both hard to solve and a health & safety minefield.

“We have dual GPS on all of our robots and we’ve tested out a few different solutions for RTK [real-time kinematic] corrections, and that allows us to get down to a localisation accuracy, purely from GPS, of around 5mm,” Rowe says. “We also use a geofence when the robot is manoeuvring, giving it a low-definition map of the field so that when it’s navigating, it can never go outside of the field boundaries, and odometry information from the IMUs [inertial measurement units] and wheel encoders give the robot its reference location and heading – but for now we still have to have operators monitoring the robots.”

Founded by two robotics engineers after speaking with farmers in Pontonx-sur-l’Adour during the Asparagus Festival in 2011, French company Naïo Technologies has had more time to work on the obstacle avoidance problem. Naïo’s Dino and Ted robots were the first large-scale agricultural robots to be certified to work unsupervised in fields in 2022 (a few years after their appearance on the market), joining the company’s smaller farming assistant Oz, which has been working unsupervised since 2016. Their location and obstacle avoidance system is similar to those employed by Farming Revolution and SRC, based on RTK GPS signals to autoguide the robots, geofencing to ensure the robots stay within

John Deere

John Deere's 8RX feeds two NVIDIA GPUs from six pairs of cameras, inset, for obstacle detection

the bounds of the field, and sensors and mechanical bumpers; with their tool-carrying Orio robot also using lidar to increase safety levels and work faster.

"We stepped beyond testing because we focused on simple tasks where there are labour shortages, and because of solid and deep work on safety and easy-to-use specs," Marketing Content Manager Flavien Roussel explains. With this strategy, Naïo has established a distribution network in more than 25 countries, and will have 300 robots in service by early 2023.

From field robots to autonomous tractors

Though the autonomous Monarch Tractor and tractors from Yanmar, AgXeed and others were already on the market in 2022, a watershed moment for farming robots came when John Deere revealed its first fully autonomous tractor to fanfare at tech show CES 2022; the first machine ready for series production. As one would expect from the largest agricultural machinery manufacturer in the world, significant R&D went into the autonomous 8RX, which has already started to be shipped to farmers, including a highly sophisticated perception system that, among other things, tackles obstacle avoidance.

"It uses two NVIDIA GPUs, where RGBD images (colour plus distance measurements) from six pairs of cameras are fed into a deep neural network for ranging and obstacle detection around the vehicle," says Cristian Dima, Lead of Advanced Algorithms at John Deere. "It classifies each pixel about every 100 milliseconds at the moment, and then the decision is made on whether the vehicle can proceed or not." GPS-based guidance for autonomous steering and a geofence offer an extra level of safety, the result being farmers can leave the tractor to work unsupervised.

"The first autonomous solution we have introduced for the autonomous 8RX is focused on tillage," says Dima. "But tractors or combines execute some very complex operations and pull many different kinds of implements. That means that the space of problems is quite large, so it's important to pick what applications are most important and focus on those first."

Like many competitors, another key application John Deere has targeted is weed control. The company's See & Spray Ultimate system is currently available on self-propelled sprayers. Powered by NVIDIA GPUs, the system uses 36 cameras mounted on a 40m carbon-fibre boom. Trained on millions of images, it uses deep learning to classify images of the field that's being sprayed, discerning between plants and weeds. "It's automatically computing where the weed is, how quickly the sprayer is moving and exactly what is the right time at which the sprayer nozzles need to be turned on, so that chemicals end up on the weed," says Dima. "These sprayers also go fast – the top speed at which this sprayer can work is up to 20 km/h." Initial tests reveal that See & Spray saves about 66% on herbicides.

With all of these technologies from John Deere and many other agtech innovators on or coming to market soon, Dima feels computer vision and AI are on the cusp of revolutionising agriculture: "We're in a very exciting time where we have the right sensors, we have the right computing devices, and we have quite a bit of knowledge about how to actually make deep learning-based solutions and very complex computer vision systems enable farmers to be more productive and sustainable, while also minimising environmental impacts."

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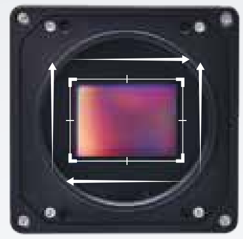

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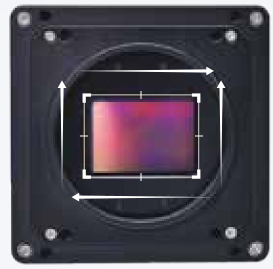

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Hyperspectral imaging: microsurgery's next big thing

Compact hyperspectral imaging cameras have huge potential once integrated into stringent clinical workflows, writes Imec's **Wouter Charle**

Surgery has evolved tremendously over the past few decades. One particularly interesting development has been the emergence of microsurgery. This development is especially meaningful due to the use of surgical microscopes to magnify the operating field and allow for higher precision. Combined with new types of cameras, they truly "make the invisible visible."

This approach is bound to revolutionise medical treatment. Imagine surgeons being able to make decisions based on real-time information about tissues' chemical composition at a molecular level, 'seeing' the oxygenation of blood flowing through arteries and vessels, or distinguishing *in vivo* (in living tissue) between healthy and anomalous tissue, such as tumour cells.

It is a glimpse at a future that is much closer than one might think. One important driver is the development of spectral imaging technology directly compatible with current medical practice.

The idea of using hyperspectral cameras in surgical practice is not new. Many studies on this topic have already been conducted, but several issues have prevented the technology from being integrated into hospitals' everyday workflows.

Hyperspectral imaging (HSI) solutions' form factor is one important hurdle. They are typically quite bulky and thus incompatible with an operating theatre's already crammed sterile field. Another limitation has been the lack of video-rate hyperspectral cameras that can acquire real-time data, which is essential to capturing the motion and dynamics in a surgical scene. Companies, such as my own, needed to respond to this.

Contrary to conventional methods of building a hyperspectral camera, Imec's approach does not use precision optics between the lens and the image sensor to select and diffract the light. Instead, it leverages thin-film spectral filters deposited directly on top of image sensors. This translates into robust yet compact devices, very similar to standard machine vision chips and cameras. And since they build on the same wafer-level CMOS process used to create microchips, they are mass-manufacturable, cost-efficient, and highly customisable to specific customer and application needs.

'So far, underlying complexity has prevented industry from building a fully functional multi-sensor hyperspectral camera'

Imec has an extensive track record in the domain of HSI research and prototyping – with a portfolio that comes in two flavours, depending on spectral filters' patterns.

A striped pattern on top of each row of pixels enables high-resolution hyperspectral imaging, comparable to classic line-scanning push-broom cameras – yet more compact, faster, and easier to use. They make up Imec's 'snapscan' series of hyperspectral sensors.

A mosaic pattern on top of a group of 3x3, 4x4, or 5x5 pixels comes with a somewhat lower resolution but enables video-rate spectral imaging for real-time data acquisition – even in motion. Dubbed 'snapshot,' the cameras come in several flavours. Each variant covers a specific spectral resolution and range – from the visual (VIS), over the near-infrared (NIR), to the short-wave infrared (SWIR) ranges.

Making it easier to experiment with hyperspectral imaging technology

A growing number of users are investigating how hyperspectral imaging technology can enhance their product and/or service offerings – or how it can be used in (surgical) practice. For some, it is clear from the start which spectral range best suits their needs. For others, however, it is a journey that involves testing several camera options. While these camera options are available, fusing their data into one dataset from which conclusions can be drawn is a proven challenge.

This is why Imec recently expanded its snapshot portfolio with a multi-sensor system that covers both the VIS and RedNIR ranges, complemented with a high-resolution RGB sensor. It is specifically aimed at companies and research groups engaging in HSI application development.

Imec's new hyperspectral camera comes with three sensors, integrated into a single housing, and equipped with a standard F-mount lens. It will allow partners to flexibly assess the pros and cons of different spectral resolutions and ranges without needing to invest in a myriad of devices or duplicate experiments.

Inside the camera, the light is directed to three channels. Two of them are equipped with an Imec off-the-shelf two-megapixel sensor – covering the VIS and RedNIR spectral ranges. A third channel sports a high-resolution RGB sensor. As such, the device covers 30 bands in the 460 to 870nm range, complemented by a true-colour, five-megapixel image – all working in sync at video rate speed for real-time data acquisition (even of dynamic scenes).

The new camera particularly lends itself to supporting use cases that involve an uncontrollably dynamic scene. Examples include assisted (micro) surgery, environmental

Imec hyperspectral sensors, with spectral filters deposited directly on top of image sensors

With a small form factor and compatibile with standard C-mount optics, Imec's snapscan can easily be mounted on a standard surgical microscope

Case study: Using HSI for the in vivo identification of low-grade gliomas

Low-grade gliomas are a diverse group of slow-growing brain tumours that often arise in young, otherwise healthy patients. While typically benign in origin, studies have shown that low-grade gliomas can expand by 4 to 5mm a year and come with the risk of malignant transformation. Early surgical resection is thus a much-favoured treatment option – although *in vivo* detection of low-grade gliomas and retrieving their exact demarcations is extremely hard, even with the aid of surgical microscopes.

Giving surgeons the proper tools to detect these tumours *in vivo* would make for an important breakthrough. Hyperspectral imaging technology shows potential to do just that – as demonstrated in a recent research project featuring Imec's snapscan VNIR 150 hyperspectral camera.

Thanks to its small form factor (10 x 7 x 6.5cm, and weighing 645g), and its compatibility with standard C-mount optics, Imec's snapscan can easily be mounted on a standard surgical microscope. It makes for a compact set-up that can be incorporated smoothly into hospitals' stringent clinical workflows, contrary to the bulky systems used in previous studies.

What's more, the set-up generates accurate clinical data that can be fed into a deep learning neural network. This can convert the data into actionable knowledge, allowing surgeons to discriminate between healthy and anomalous tissue. As such, it is an important first step to accommodating the *in vivo* detection of intrinsic brain tumours – such as low-grade gliomas.

While intraoperative use of the set-up is premature, the approach has so far been validated using a clinical dataset of six patients at Belgium's Leuven University Hospital. Imec aims to further this project by integrating its snapshot technology, which accommodates video-rate spectral imaging. This would allow researchers to explore the real-time detection of low-grade gliomas in surgical practice.

monitoring, anomaly detection, automotive vision, precision agriculture, and crop inspection – just to name a few.

So far, the underlying complexity has prevented the industry from building a fully functional multi-sensor hyperspectral camera. Imec believes this is where its expertise is most valuable, exploring and prototyping the required components and helping the industry overcome all related hurdles. Thanks to the system's flexibility and the software that comes with it, experimenting with hyperspectral imaging technology has never been easier. It allows partners that are still in doubt about which sensor best suits their needs to focus on their core business, that is in application discovery and development.

Imec's VIS & RedNIR spectral camera system is complemented with hi-res RGB imaging for data acquisition at video rate

As a next step, Imec plans to share its learnings and a complete development kit with camera builders and systems companies to support the system's further commercialisation.

Wouter Charle is the Program Manager of Imec's spectral imaging on-chip activities. He has a physics and software engineering background and started his career in the domain of 3D machine vision. Charle joined Imec in 2014.

Bringing AI and AR to automated manual inspection

Integrating AI and augmented reality into imaging and machine vision for automated inspection tasks paves the way for faster, more efficient manufacturing, finds **Abigail Williams**


Pleora Technologies

Trialling visual inspection tools at a distillery, as both a visual learning tool for new employees so they can learn required brand elements, and as a pass/fail QC check to verify all elements are on a bottle

Automated manual inspection refers to the automation of a task performed by operators. In a manual process, human operators follow a standard operating procedure to visually inspect parts, and vision systems can be used to automate the manual tasks. Machine vision systems used in such processes vary, but are generally based on a configuration of technologies such as sensors, cameras, and lighting to aid the inspection and measurement of different components. For example, typical systems can be 1D (line scan inspection), 2D (image analysis) and 3D (time of flight, depth mapping).

According to Narcisa Pinzariu, Technical Lead for Computer Vision at the University of Sheffield Advanced Manufacturing Research Centre (AMRC), demand for automation and quality inspection has been rising in recent years – and vision-guided robotic systems, which use cameras and sensors to better understand their environment, are "used more and more to increase productivity for manufacturers of all sizes".

"Machine vision aids manual assembly, [and] the errors that arise in these operations can be reduced or prevented by using a vision system to assist the human operator. This is something the AMRC has experience with – developing an entire process that allows the operator to follow a set of instructions displayed on a screen. The inspection takes place in real time and checks if the operation has been carried out correctly, ensuring the operator does the relevant checks and cannot move on to the next task before correction," she says.

Reduced cycle times

The AMRC also recently worked with a customer that wanted to improve its current process, by reducing the cycle time of analysing the dimensions of a part. It was decided to use a vision system on a gantry robot. An algorithm was developed to compare the scans with computer aided design (CAD) drawings of ideal parts to check if the manufactured part is within tolerances. The project focused not only on the development of the machine vision solution, but also on the communication between different software packages and the development of a graphical user interface (GUI) that an operator could use. As Pinzariu explains, the GUI would also output a report that highlighted the measurements needed and the overall decision to aid the operator in their inspection.

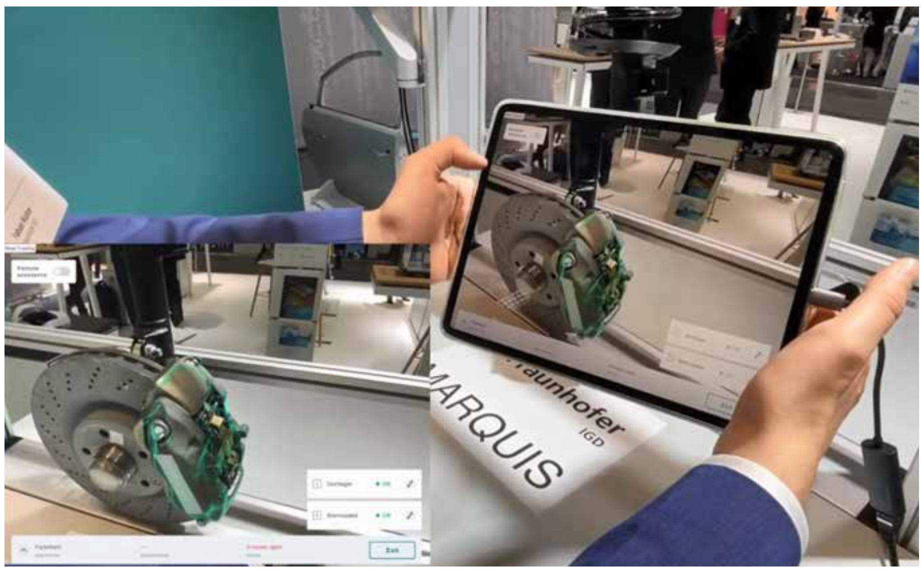
"This initial stage of the project showed that a considerable reduction in the cycle time can be achieved by using the method proposed by the AMRC," she says.

Pinzariu also cites an AMRC project that focused on aiding an operator in the detection and classification of defects on complex components. Here, the cell that was built uses a robot to position the components in front of a camera that takes images from different positions. The images are then analysed using traditional machine vision, with algorithms such as edge detection to detect any defects.

"Additionally, we developed other approaches using AI to classify the defects into their categories. The solution proposed offers a reduction in cycle time," says Pinzariu.

Different paths

Manufacturers interested in automating manual inspection can take a few different paths. According to Ed Goffin, Senior Marketing Manager at Pleora Technologies, the first, and perhaps most complex, is automating a process to "fully remove the human" by integrating cameras, real-time imaging and processing, and often robotics. Although there is a market for this type of approach, especially in "dull, dirty and



Top: Is the component in the correct position? If not, the AI-based MARQUIS software superimposes the relevant element in red. Above: Using augmented reality, the inspection engineer is able to see on the tablet that the structure is free of defects. The component is now overlaid in green.

dangerous tasks, where it's best to try and remove the human from the process", Goffin more often finds that manufacturers are not necessarily looking at replacing humans altogether. This is largely because, in many cases, the cost of fully automating a process is too high – for example in lower-run manufacturing, or for products with a high degree of customisation.

"Instead, they would like to use technologies to help ensure humans make the same consistent, reliable, and trackable decisions in these manual processes," he says.

A common example of such an application is camera-based visual inspection, where a manufacturer can use a combination of machine vision and AI to help an operator spot product differences. Here, basic image comparison is used first to highlight differences between a known good product and the product to be inspected. As the operator accepts or rejects highlighted differences, says Goffin, "behind the scenes, they are transparently training an AI model."

"After a few inspections, AI will start providing decision guidance to the operator. One of the key markets for this type of technology is electronics, where a human operator is verifying the components on a board and that the correct assembly steps are complete," he adds.

'After a few inspections, AI will start providing decision guidance to the operator. One of the key markets is electronics, where a human operator is verifying the components on a board'

Data gathering

Goffin points to a few examples of manufacturers using new technologies to add decision-support for manual processes. For example, in the electronics market, one Pleora customer uses machine vision to provide a "second set of eyes" for the human inspector to help them identify missing or damaged components. Some of the most common issues are missing labelling, component alignment, and soldering defects.

"These may be issues missed by an automated inspection, or for short-run products because it's too time-consuming and expensive to set up the system. The system is also used to visually train new employees on the inspection line, so they can more easily distinguish between good and bad products," he says.

For Goffin, one of the interesting by-products of adding automated decision-support to manual processes lies in its ability to enable manufacturers to start accurately →

→ gathering data. For example, automated and customisable reporting tools help manufacturers gain data on visual inspection and manual manufacturing steps.

"Often, visual inspection is a bit of a data 'black hole' for manufacturers, which makes it both difficult to ensure end-to-end quality and time-consuming to resolve issues when errors occur," he says.

"In the case of this manufacturer, they save images of every manually inspected part, as well as operator notes, to their manufacturing resource planning system. This is primarily used to help speed up root cause analysis and resolution if there in an in-field product issue," he adds.

For Goffin, a key benefit of using vision technology to automate manual inspection for this manufacturer is that it enables it to ensure "consistent, reliable and traceable human decision-making for incoming, in-process, and outgoing inspection steps across different operators". It also detects defects commonly missed by automated optical inspection (AOI) and "gathers actionable data on manual steps to help ensure end-to-end quality and speed issue resolution".

"We have also worked with a distillery that is trialling visual inspection tools, as both a visual learning tool for new employees so they can learn required brand elements, and as a pass/fail QC check to verify all elements are on a bottle before its packaged," he says.

"The system helps the distillery increase production and reduces costs by avoiding rework and downtime – if they find an error on a bottle, they report it and it takes about five minutes to correct. Since they produce around 1,500 bottles per day it reduces the risk that a poorly labelled product reaches store shelves. It also eliminates subjective, stressful and time-consuming decision-making for employees," he adds.

Augmented reality

There are a growing number of examples of automated manual inspection systems featuring AI and AR technologies. In these processes, a predefined program of inspection tasks on a complex product structure is carried out and automatically evaluated, with inspection characteristics being classified and displayed to the inspection engineer via AR. As Holger Graf, Head of Virtual and Augmented Reality at the Fraunhofer Institute for Computer Graphics Research IGD, explains, the overlay of the physical objects with their digital representations in such systems facilitates a simultaneous target-actual comparison with the given CAD specification and "shows the test engineer any deviations in position or attitude directly superimposed on the object itself."

"The training of the AI is purely 'synthetic.' Newly simulated training images are derived

AMRC

Computer vision-based solutions are set to become more affordable, says AMRC's Narcisa Pinzariu

'Finding defective parts already proved that it could improve cycle time, and it will continue to be used to aid the operators in their tasks and meet the increasing demand'

from the CAD model data and receive automated annotations and positional information of components, without the need for time-consuming photo-shooting campaigns and manual annotations. The inspection system is then able to perform object recognition, classification, and positional estimation without ever having seen the actual assembly and product configuration 'live' before," he says.

Graf cites several examples where such technologies are used, for example, in sorting processes, where specific sorting tasks of objects are displayed to human operators in colour-coded form.

"They are also used in automated quality inspections, as well as at AR-supported assembly workstations, where recording is done by means of multi-camera arrays and where deviations from predefined CAD or assembly specifications must be detected and verification must take place simultaneously," he says.

It is also possible to support virtual sampling tasks, where potential collisions between components can be detected and directly displayed to operators before product assembly begins.

"Solutions developed by Fraunhofer IGD are especially supportive in mechanical and plant engineering, as well as in the automotive sector, where they serve to reduce errors and consequently cut costs," says Graf.

"A further interesting example is incoming goods inspection with our MARQUIS software package, where every single component can be checked for defects at variance with the CAD data. We are also currently working on the further development of an AR-supported assembly workbench, which we will present at the Hannover Messe in 2023. This will support employees working on complex product assembly lines, showing them which element is to be picked next and where it fits into the overall configuration," he adds.

Future trends

Goffin believes there are several steps in a manual manufacturing process where an operator could potentially use image-based analysis to ensure accurate decisions and streamline processes. One example is for work checklists or job travellers, where an operator is tasked with completing multiple production or verification steps. By digitising this process, Goffin says they could visually compare their work against known good samples.

"The system can help make decision-suggestions around quality. Users can also capture and save images to verify they have completed work properly, and save and share notes or alerts as they spot issues," he says.

Goffin also points out that vision technologies and AI can be used for digital learning applications. Since most humans "learn best visually", he says image-based systems and AI decision-support tools "can help show a new operator how to properly complete a task or spot potential quality

When inspecting items such as such as electronics boards, AI can begin to offer decision guidance to the operator after just a few inspections

issues". Another trend is focused on making these types of technologies easier to use on a manufacturing floor.

"Whether it's a machine vision, AI, or AR tool, it needs to be simple for an operator to train and use. The other, maybe more immediate trend, is technologies that can help manufacturers deal with labour shortages. It's getting hard to find people for these manufacturing roles, and there's definitely a place to use vision-based tools to help train new employees, and take away some of the stressful decisions that lead to burnout," he says.

"Digitising some of these decisions and processes also makes it easier and faster to onboard new employees – you can have more assurance that your new employees are making the same decisions as your long-time employees," he adds.

Deep learning

As far as augmented reality output units are concerned, Graf says looking into the future is "always a bit like reading the coffee grounds", but suggests there is a lot of momentum in novel eyewear developments, with "small but positive advances that currently facilitate a continuum of perceptual realities" known as eXtended Reality (xR), ranging from pure AR environments to mixed virtual/real setups and ultimately fully immersive virtual reality.

"What xR glasses will look like in 2035 depends on further developments in hardware, sensor technology and integrated software solutions. Already today, novel AI models on resource-efficient chips can be used to run object recognition processes. Neuromorphic chips, which enable energy-efficient AI-based image processing, are also becoming increasingly important," he says.

"We are working on the assumption that xR glasses of the future will already have their own recognition and classification processes 'built in', enabling them to understand their surroundings independently and intelligently and to superimpose additional virtual information with correct positioning," he says.

Meanwhile, Pinzariu reports that there has been an increase in the adoption of machine vision technology in recent years, due to an increased demand for automation, with manufacturers adopting automated solutions to "keep operations running more efficiently, deal with labour shortages and an increase in production targets."

"Machine vision was used extensively in recent years, and there will be continued growth in this market. Automation of quality assurance processes in the manufacturing industry has [also] seen an increase in demand, with the use of robots and collaborative robots," she says.

Pinzariu also observes that solutions including object recognition, such as personal protective equipment detection, part measurement, presence detection, location tracking, and defect detection are also increasingly being developed.

"Finding defective parts already proved that it could improve cycle time, and it will continue to be used to aid the operators in their tasks and meet the increasing demand," she says.

Other contributory factors to higher demand for vision systems are recent advances in deep learning technology, especially as algorithms become more capable of processing many images. Broadly speaking, Pinzariu says AI offers the advantages of traditional rule-based machine vision systems, enabling the judgement that human operators bring, but in a semi- or fully automated fashion.

"Deep learning is a great tool to be used, where subjective decisions need to be made, like human inspection, where the identification of features is difficult, due to the complexity or variability of the image. Computer vision-based solutions are expected to become more affordable, with the development of low-power AI chips that process neural networks. Low-power AI processing will continue to shift to edge devices, making it more accessible, affordable, and easier to implement," she says.

"There will also be an increase in the use of AR in computer vision. The solutions developed will increase in complexity, such as extracting information from the whole scene and not just image classification-based. Other applications would be anomaly detection [and] assembling components using instructions in AR," she adds.

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Imaging aids forensic findings

Keely Portway discovers how a new automated approach is helping engineers in vision technology and forensics to identify rare traces, which can be essential in solving a crime

Forensic science applies scientific techniques and methods to gather, preserve, and analyse evidence in criminal investigations and trials. The goal is to use scientific evidence to provide impartial facts that can help to establish the truth.

The field covers a wide range of areas, including criminalistics, digital forensics, and forensic biology. The techniques are wide-ranging, from the analysis of DNA, fingerprints, and blood stain patterns, to the examination of firearms, ballistics and tool marks. Then there is serology, toxicology, hair and fibre analysis, entomology, anthropology, odontology, pathology, epidemiology, footwear and tire tread analysis, drug chemistry, paint and glass analysis, digital audio, video and photo analysis – the list goes on.

Imaging has a crucial role to play in forensic science. It is used to provide visual evidence that can support or refute various aspects of an investigation. It has use cases ranging from crime scene photography or video surveillance to the use of techniques such as X-rays and CT scans to examine human bones. Forensic imaging software can also be used to compare images of a suspect to existing records, such as mugshots or passport photos, to accurately identify an individual. In digital forensics, imaging tools are used to create an exact copy of a digital device's storage medium in order to analyse and uncover any hidden or deleted data.

As imaging technology advances, it opens up more powerful tools to assist forensic scientists. One particular challenge it can help to overcome is identifying "rare trace" evidence. This can be problematic for a number of reasons, such as an insufficient sample size, contamination or interference, and analytical technique limitations. Trace evidence, such as hair or fibre, may also not be unique to an individual and can therefore be difficult to link to a specific source. Then there is the securing of trace material at a crime scene, ready for examination. Transparent adhesive foils are generally used for this task. However, the analysis of materials on these foils can be a time-consuming, manual and error-prone process.

Overcoming obstacles

Challenges like these can make it difficult to obtain accurate results when identifying rare trace evidence, which can have potentially serious implications in a criminal investigation. To overcome these obstacles, forensic scientists can use a combination of specialised techniques, such as advanced imaging and analytical methods, to ensure reliability and accuracy. Arthur Stauder, Product Manager at Qioptiq Photonics, explains: "Future-oriented and innovative technology can significantly improve trace analysis in the field of forensics. What's more, these methods and components can also be used in other areas of machine vision and recognition, resulting in new possibilities in the areas of production and quality assurance."

A recent advancement in this area comes from a Horizon 2020 project financed by the European Commission (EC). The project was led by the Shuttle Consortium, which consists of six forensics laboratories from France, Greece, Netherlands, Lithuania, Portugal and Israel, alongside commercial contractor partners including Aura Optik. The aim was to develop a toolkit to facilitate the analysis of micro-traces collected at crime scenes.

Two product prototypes were produced, a high-throughput screening microscope; and the AG Shuttle Toolkit Jena, which uses a new approach: imaging the material of a trace carrier completely, with the required optical resolution and in all required spectral modes. The resulting images can be analysed and organised by the Toolkit program. Image stacks are evaluated and classified by means of artificial intelligence (AI), while images and classification results are stored in an enterprise content management system (ECM) database. This approach also provides the advantage that all alleged traces are digitally recorded.

High-resolution optics

In terms of the technology, the AG Shuttle Toolkit Jena provides complete image capture with a 150MP sensor and corresponding high-quality optics, which can record an area of 53.4 x 40 mm² for the required S- and P-images (LoRes) and 17.8 x 13.3 mm² for M- and F-images (HiRes). The achievable optical resolutions are 10µm and 3µm, respectively. The quality of these optics was critical in achieving both optical and spectral detection of traces to enable high-quality images in the critical wavelength – between 320nm and 720nm – required by forensic scientists. Happily, when Aura Optik and the consortium were searching for these very high-resolution optics, they found a reliable partner in Excelitas.

Stauder reveals: "Innovative optics in connection with constantly increasing sensor densities as well as the possibility to process ever larger amounts of data enable many solutions in the field of machine vision and robotics. Excelitas is the right partner for high-tech components and systems in the field of photonics. In the field of optical inspection and systems, we offer state-of-the-art individual components from simple lenses to extremely high-resolution lenses and microscope systems for large sensors to complex subsystems with integrated lighting, motorisation and more. Our R&D, technology department and production, all located in Germany, is constantly working on innovative and efficient improvements in order to be able to offer top optical products in the high-tech area for special challenges in the future."

In order to generate large amounts of data quickly, an extremely large, high-resolution sensor was chosen for the toolkit, and as Stauder explains, finding a suitable lens for this is not always easy. "At the same time," he says, "it must have a large aperture so that the cycle times can be shortened and the diffraction limit pushed up. Another challenge was the large wavelength range to be covered in order to make the invisible visible and detectable. However, we quickly found what we were looking for in our Linos premium lens series with the d.fine HR and Inspec.x and the results speak for themselves."

The Linos d.fine HR 2.4/128 3.33X high-resolution inspection lens is optimised for a magnification factor of 3.33X, achieving object resolution of up to 300 lp/mm across image circle diameters as large as 82mm. It also enables dual-support for both 12k/16k line sensors and large format area sensors, providing maximum versatility. Stauder continues: "The d.fine HR 2.4/128 3.33x impresses with its extremely high resolution over the entire image circle of 82mm. It also has a very large aperture and features a diffraction-limited design."

The Linos Inspec.x L 5.6/105 lens demonstrates even contrast and resolution over an image circle up to 82mm. It is a perfect match with 5µm pixel size and has a focal length of 105mm. It offers a working distance of 100-420mm and a spectral range of 400-750nm. "Furthermore, its colour correction is excellent over a large wavelength range," says Stauder.

> 'Future-oriented and innovative technology can significantly improve trace analysis in the field of forensics'

Aura Optik and the team demonstrated the Toolkit at the 2021 Vision event in Stuttgart, Germany, and the German forensic fibre group in Erfurt, Germany. Last year it was also showcased at the European Academy of Forensic Science (EAFS) conference in Stockholm, Sweden, where feedback from potential relevant users was positive.

Looking to the future of imaging for forensic science, Stauder believes that there are still lots of potential opportunities. He says: "In my opinion, the interaction of all toolkit components with the know-how of Aura Optik and the downstream artificial intelligence and database opens up many more possibilities for forensics in terms of finding and evaluating rare traces. I am convinced that future technological developments in vision technology will continue to serve forensics and truth-finding, making the world a little better and fairer."

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Cameras

Gemini 2 and Astra 2

Orbbec introduced two of its most advanced 3D sensor cameras at CES 2023, the Gemini 2 and the Astra 2. Both cameras have been developed with Orbbec's new generation ASIC chip MX6600, which enables high-quality depth processing and supports depth/colour image registration in different resolutions. With an easy-to-use software development kit, onboard inertial measurement unit and multi-camera sync support, the two cameras introduce new possibilities in 3D for applications such as robotics, logistics, security monitoring, and other uses.

The Gemini 2 is based on active stereo IR technology and offers a sensing range of 0.12 to 10m, along with a field of view of up to 100° diagonal (89°H x 65°V, ±3°). Gemini 2 is also capable of working in indoor or outdoor environments and comes in a compact size of 90 x 25 x 30mm. It is able to provide motion, position and navigational sensing over six degrees of freedom.

The Astra 2 uses structured light and image processing to compute a 3D image of the observed environment in real time. With the latest generation ASIC, Astra 2 supports higher resolution (up to 2MP) for both depth and colour images output in real time. Compared with the original Astra Series, Astra 2 offers more stable output depth data, as well as lower motion blur. **www.orbbec3d.com**

Harrier 23x AF-Zoom IP 4K Camera

Active Silicon has combined high-resolution imaging and networking capability with the introduction of its Harrier 23x AF-Zoom IP 4K Camera.

This new addition to the Harrier series is a compact autofocus-zoom Ethernet camera with real-time 4K video output and 23x optical zoom. It features an 8.3MP Sony CMOS sensor and provides very low-latency H.265/H.264 video output.

Active Silicon is providing samples for testing by drone and ROV manufacturers, law enforcement agencies and even a company monitoring industrial gas leaks. **www.activesilicon.com**

MIPI

At Photonics West, Vision Components showcased its new MIPI camera modules and components that make the integration of embedded vision faster, easier and more cost-efficient.

The highlight was the FPGA-based hardware accelerator VC Power SoM, which completes complex image processing calculations and transfers the results directly to a processor board. The tiny, 28mm x 24mm module facilitates development of embedded vision systems. It can be directly integrated into embedded vision mainboard designs as a module or combined with an I/O board with multiple MIPI interfaces. OEMs benefit from the VC Power SoM's mature FPGA technology and comprehensive image processing functionalities.

VC also presented a sneak preview of FPGA designs for applications such as colour conversion, 1D barcode identification, epipolar correction, etc., which are currently being developed. Lastly, the firm also showcased VC MIPI camera modules with Sony Pregius S series sensors as well as new MIPI cameras for SWIR and 3D/ToF applications. **www.vision-components.com**

Mantis

LightPath Technologies' Mantis is the company's first multi-spectral infrared camera system.

Multi-spectral cameras allow users to reduce the number of cameras and lenses needed for infrared imaging. Currently, users typically use uncooled longwave cameras (LWIR), and cooled midwave cameras (MWIR), the latter having high costs and shorter lifetime due to the complex cooling requirements. The Mantis multispectral camera is capable of imaging in both the midwave and longwave ranges simultaneously without needing a complicated, heavy and expensive cooling system. With fewer lenses and cameras, the thermal imaging solution's total cost, weight, and size is reduced.

The camera uses LightPath's own Black Diamond glass materials, which enable the multi-spectral functionality and allow the firm to use its proprietary fabrication technologies and coatings to achieve the very broadband performance. **www.lightpath.com**

Cameras

Triton SWIR 1.3MP and 0.3MP

Lucid Vision Labs has introduced its new compact and cost-efficient Triton SWIR IP67-rated 1.3MP and 0.3MP cameras.

The Triton SWIR features wide-band and high-sensitivity Sony SenSWIR 1.3MP IMX990 and 0.3MP IMX991 InGaAs sensors, capable of capturing images across visible and invisible light spectrums, and with a miniaturised pixel size of 5µm. Its ability to image the short-wavelength infrared light spectrum opens a world of industrial applications, including greater precision in fruit inspection and sorting, packaging, IR microscopy, semiconductor inspection and material sorting.

Triton's Factory Tough design offers IP67 protection, Power over Ethernet (PoE) and provides protection against shock, vibration, water, dust, and electromagnetic interferences. It features Active Sensor Alignment for superior optical performance, a compact 29x44mm size, M12 Ethernet and M8 general purpose I/O connectors for a robust connection, industrial EMC immunity and a wide ambient temperature range of -20° to 50°C. The Triton SWIR does not have a TEC cooling device and can therefore be smaller and use less power.

www.thinklucid.com

Alvium with Sony IMX548

Allied Vision has integrated Sony's fourth-generation 5.1MP IMX548 global shutter sensor, with Pregius S Sensor Technology, into its Alvium camera portfolio.

With the new camera models, the Sony IMX548 sensor is now also available in Alvium cameras with either GigE Vision (Alvium G1-510, 22fps), 5GigE Vision (Alvium G5-510, 81fps), USB3 Vision (Alvium U-510, 79fps), or MIPI CSI-2 (Alvium C-510, 81fps) interface.

The IMX548 sensor provides the same pixel size (2.74µm) and resolution (5.1MP, 2,464 x 2,064) as Sony's IMX547, but comes in a smaller, more affordable sensor package which makes the cameras slightly less expensive.

www.alliedvision.com

Hawk Indigo

Raptor Photonics has launched the Hawk Indigo, using a next-generation 2/3" CMOS sensor, enabling exceptional UV sensitivity and high QE of 36% at 250nm.

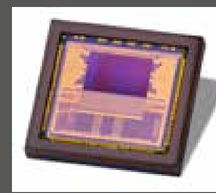
With a pixel size of 2.74µm, the camera achieves a resolution of 8.1MP and offers global shutter, progressive scan technology to enable real-time, lag-free images at 15Hz full-frame through a CameraLink interface. The Hawk Indigo is extremely rugged and can be used in harsh environments, working from -20° to +55°C, with more extreme temperatures on special request.

It is ideal for integration into industrial applications offering greater precision in hyperspectral imaging, transparent materials (plastic and PET), semiconductor, wafer and mask inspection, material sorting, combustion imaging and high-voltage technology.

www.raptorphotonics.com

Hydra3D+ ToF sensor

Teledyne e2v's new Hydra3D+ Time-of-Flight (ToF) CMOS image sensor incorporates 832 x 600 pixel resolution and is tailored for versatile 3D detection and measurement.



Hydra3D+ features a new 10µm three-tap pixel which provides very fast transfer times (starting from 10ns), and displays high sensitivity in the NIR wavelength, alongside excellent demodulation contrast. This precise combination enables the sensor to operate in real time without motion artefacts (even if there are fast-moving objects in the scene) and with excellent temporal noise at short ranges, essential in applications such as pick and place, logistics, factory automation and factory safety. An innovative on-chip multi-system management feature enables the sensor to work alongside multiple active systems without interference that can lead to false measurements.

The sensitivity of Hydra3D+ enables it to manage lighting power and handle a wide range of reflectivity. Its high resolution, with on-chip HDR, featuring an on-the-fly flexible configuration, enables the best trade-off between application-level parameters, such as distance range, object reflectivity, frame rate etc. This makes it ideal for mid, long-range distances and/or outdoor applications such as automated guided vehicles, surveillance, ITS and building construction.

The sensor has been designed for customers seeking real-time and flexible 3D detection with uncompromised 3D performance. It offers large field-of-view scenes captured in both 2D and 3D by a compact sensor, which makes the system very cost-effective.

www.imaging.teledyne-e2v.com

Embedded vision

Robust Edge AI Platform

Vecow has introduced a new Robust Edge AI Platform: ECX-3000 PEG, ECX-3000 and IVX-1000 Series, powered by the latest 13th-generation Intel Core i9/i7/i5/i3 processor.

The new platform combines performance with reliability, making it suited for IoT use cases in machine vision, robotic control, advanced driver assistance system (ADAS), mobile communication, smart manufacturing, in-vehicle computing, public security, and any edge AI applications.

Vecow says the Robust Edge AI Platform offers exceptional compute-intensive performance and real-time data synchronisation capable of TSN and TPM 2.0. Equipped with Intel UHD Graphics 770 driven by Intel Xe Graphics, the platform delivers immersive interactions with enhanced graphics and accelerated AI.

Moreover, incorporating a rugged, extended temperature package and ultrafast 10G LAN technology, the new platform provides seamless communication and can be deployed in harsh environments.

www.vecow.com

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info@automationtechnology.de
www.automationtechnology.de

Basler AG
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sales.europe@baslerweb.com
www.baslerweb.com

BitFlow, Inc.
Tel: +1 781 932 2900
sales@bitflow.com
www.bitflow.com

Chromasens GmbH
Tel: +49 (0) 7531 876-0
sales@chromasens.de
www.chromasens.com

Components Express, Inc.
Tel: +1 630-257-0605
info@componentsexpress.com
www.componentsexpress.com

Edmund Optics
Tel: +44 (0)1904 788600
sales@edmundoptics.eu
www.edmundoptics.eu

Euresys SA
Tel: +32 4 367 72 88
sales.europe@euresys.com
www.euresys.com

Excelitas PCO GmbH
Tel: +49 9441 2005-0
info@pco.de
www.pco.de

Frankfurt Laser Company
Tel. +49 (0) 6172 27978-0
sales@frlaserco.com
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JAI A/S
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JARGY CO., LTD.
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Kowa
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Laser Components (UK) Ltd
Tel: 01245 491499
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www.lasercomponents.co.uk

LUCID Vision Labs GmbH
Tel: +49 (0) 7062 97676 12
sales.emea@thinklucid.com
www.thinklucid.com

Macnica ATD Europe
Tel : + 33 (0) 1 30 15 69 70
sales@atdelectronique com
www.atdelectronique.com/macnica

MATRIX VISION GmbH
Tel: +49 7191 94320
sales@matrix-vision.com
www.matrix-vision.com

Matrox Imaging
Tel: +1 800 804 6243
imaging.info@matrox.com
www.matrox.com/imaging

Navitar
Tel: +1 585-359-4000
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Theia Technologies
Tel: +1 (503) 570-3296
info@theiatech.com
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TPL Vision
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contact@tpl-vision.co.uk
www.tpl-vision.com

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