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For suppliers, integrators and OEMs using machine vision

October/November 2021
Issue 107

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Leader
Greg Blackman

Stuttgart shines

The Vision trade fair welcomed back 5,400 visitors and 296 exhibitors in October, as the industry came together in what was a hugely successful show for most – given the circumstances. Any worries about attendance or the size of the show were quickly dispelled when the trade fair got underway, and pretty much everyone felt it was such a positive step to be back and talking with customers and competitors face to face.

Prophesee won the Vision Award for its neuromorphic imaging technology; we speak to Luca Verre, the firm's CEO, on page 12. The work with Sony on a neuromorphic sensor opens up the technology to a much wider user base – and, since Vision, Prophesee has announced a further partnership with a neuromorphic computer chip maker, SynSense, to develop edge computer vision solutions.

Deep learning was a trend topic at Vision, as it was in 2018 when the last Vision trade fair took place. So much progress has been made over the past three years, all driven by forces and markets a lot bigger than industrial imaging. On page 10 there's a report about deep learning discussions at Vision.

Elsewhere in this issue there are articles about inspecting seeds with hyperspectral imaging to see how likely they are to germinate (page 20); how infrared imaging is being used to inspect solar cells (page 16); and a 3D imaging technique used to guide a robot to pick and place shiny orthopaedic implants (page 14).

Vision is back next year to make up for lost time, before returning to a biennial cycle. With so much excitement over this show, next year's is bound to be a hit.

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Demand for vision high, VDMA reports, as Vision show reunites industry

In the first half of the year, orders for machine vision components were up by 31 per cent in Germany, according to the latest figures from the VDMA. In Europe outside of Germany, orders were up by 66 per cent.

At the opening of the Vision trade fair in Stuttgart in October, Mark Williamson, the chairman of the board of VDMA Machine Vision, said there had been a positive turnaround from 2020, when the vision sector declined by 4 per cent, but that growth will be slowed by the shortage in semiconductor components. He added that the machine vision sector is not going to contract because of chip supply.

In a statement, Williamson said: 'The demand for machine vision components and systems remains very high. However, companies are struggling to keep up with production due to the shortage of materials, especially electronic components, and therefore are having to reduce their current production plans.'

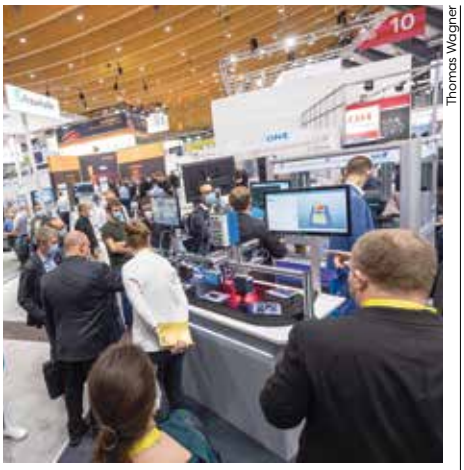
The VDMA is forecasting growth in turnover for the European vision industry at 7 per cent for this year. In Germany alone, turnover was up 21 per cent for the first half of the year, but supply bottlenecks are likely to hamper this (more on this in Anne Wendel's column on page 6).

A third of members of the European Machine Vision Association, when asked in a survey, expect the longer lead times to increase before they get better, while half expect them to be temporary.

Growth outside the factory

In 2020, the share of the European machine vision industry's turnover in sectors outside the factory floor, such as medical technology, security, agriculture, intelligent traffic systems and retail, was already 35 per cent, and turnover there grew by 9 per cent, according to the VDMA.

In addition, European machine vision firms saw 20 per cent growth in the electronics sector, the VDMA found, while turnover within the semiconductor market grew by 10 per cent. Turnover within the automotive industry fell by 13 per cent, however. Turnover within food and beverage stagnated.



Thomas Wagner

'More than 5,400 people attended Vision Stuttgart, with the trade fair hosting 296 exhibitors'

More European companies are selling into Asia, and China in particular – sales into China grew by 10 per cent in 2020, while exports to Asia increased by 3 per cent, according to the VDMA. Fifty two per cent of the turnover of the European machine vision industry was achieved in Europe in 2020, 6 per cent less than in the previous year. Exports to America increased by 5 per cent.

Busy aisles

More than 5,400 people attended Vision Stuttgart, with the trade fair hosting 296 exhibitors, about half of which came from outside of Germany.

With the world still gradually opening up and travel not straightforward for many, the show was always going to be smaller than in 2018 – the 2018 fair had 11,106 visitors, with almost half of those travelling from outside of Germany. This year, 39 per cent of visitors came from abroad.

But many exhibitors shared their delight that the aisles were busy and that they were able to demonstrate technology in person.

Christian Vollrath, head of computer vision at Wenglor, told Messe Stuttgart: 'Compared with trade fairs featuring a machine vision area, the discussions are deeper and more detailed. Customers have specific demands backed up by corresponding unit numbers.'

In addition, a survey by the European Machine Vision Association before the show found that 60 per cent of respondents said they were only able to partly attain their targets regarding new customer acquisitions in the last 12 months without the opportunity for personal meetings.

Messe Stuttgart found that 61 per cent of visitors surveyed at the 2021 show said that they were solely or partly responsible for purchasing decisions concerning machine vision solutions in their companies.

This year the majority of visitors came from Europe. The top 10 countries from outside Germany were Italy, Switzerland, France, Austria, the Netherlands, Belgium, Spain, Poland, the United Kingdom and Sweden.

There were also visitors from the USA, Korea, Japan and Taiwan despite the travel restrictions and quarantine regulations.

Among the highlights at the show, 15 start-ups took part in the daily start-up pitch sessions, with GrAI Matter Labs being crowned the top start-up for 2021. Meanwhile, Prophesee took home the Vision Award for its neuromorphic sensor technology.

'As far as we are concerned, Vision is and will remain the leading trade fair for machine vision. We are already looking forward to next year,' Vollrath stated.

Messe Stuttgart said that 72 per cent of the visitors surveyed are planning to attend next year's show.

Vision 2022 will be held from 4-6 October 2022, concurrently with the Motek trade fair, and thereafter again every two years.

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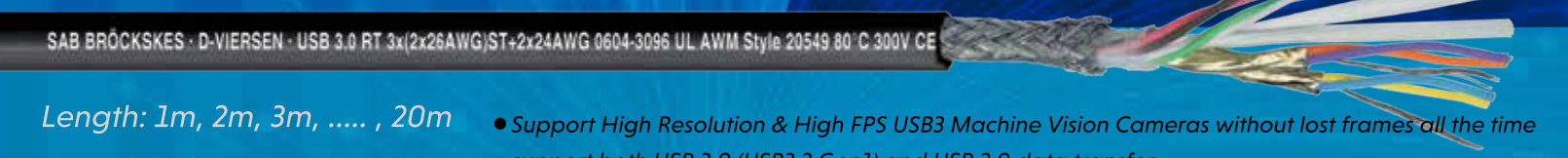

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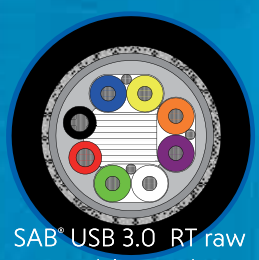

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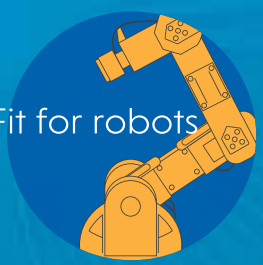

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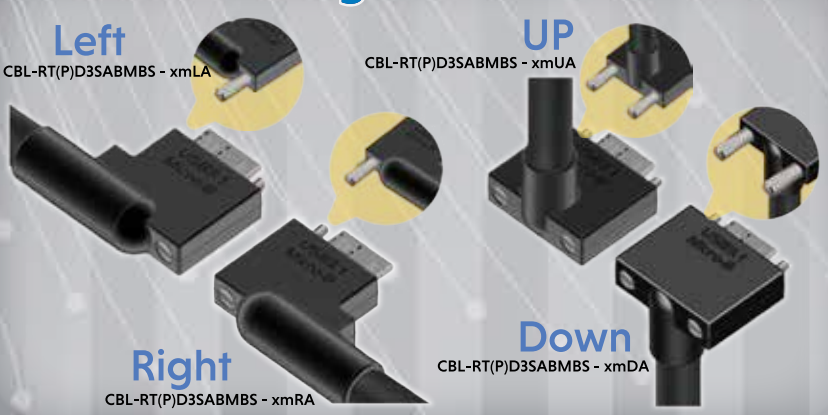

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Chip shortage hampers growth

VDMA Machine Vision

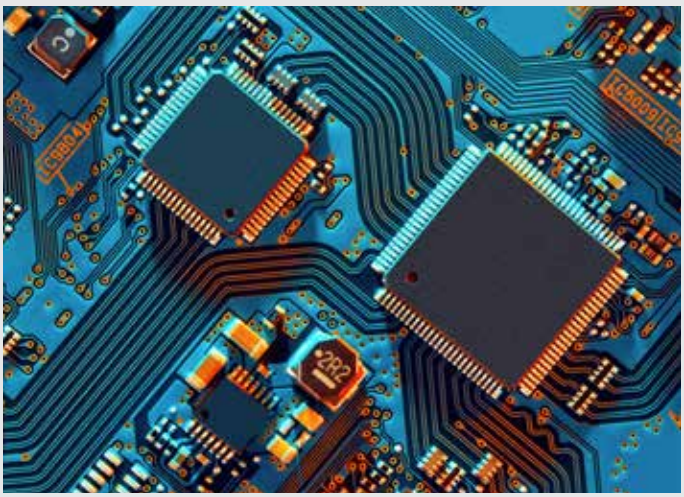
By Anne Wendel, director of VDMA Machine Vision

The latest VDMA *Machine Vision in Europe* market survey shows that the machine vision industry only suffered a 4 per cent drop in turnover in 2020. This year has got off to a very good start, as can be seen from the monthly VDMA order intake and turnover statistics.

The order books of the machine vision industry are full to the brim; demand for machine vision components and systems remains high. However, we are all concerned about the shortage of materials, especially electronic components – chips, sensors, semiconductors – which is not only hitting the machine vision industry, but the entire capital goods sector with its complex value chains. Raw materials and components are only partly procured directly. To a large extent they also flow into the company's own products via purchased components and assemblies. Therefore the risks and problems of several value chains culminate in the capital goods industry because of the complexity of mechanical engineering products.

Material shortages do not only apply to electronics, but also to steel, plastic components and much more. The VDMA has been monitoring the shortage of materials in the mechanical engineering sector for months through surveys. Many companies are struggling with increasing material and supply bottlenecks.

In the VDMA flash survey in September, 81 per cent of mechanical engineering companies from all branches mentioned noticeable or serious impairments in their supply chains. Shortages of electronic components in particular have increased dramatically. Additional membership surveys among the VDMA Machine Vision sector group show the machine vision industry is not exempt from this challenge. Virtually every company is



Wenglor

suffering in some way from the chip shortage, including component manufacturers and system integrators, with the situation worsening in the last three months and no improvement expected in the next three months.

The situation is serious and there is no relief in sight. Extended lead times are the result and, depending on the supply of materials, production plans are adjusted at short notice. Despite a shortage of materials everywhere, it is clear that the demand for image processing is not affected by this. Machine vision is in demand not only in factories around the world, but also in new areas and applications. However, these orders must first become sales. And here we are all increasingly concerned about the continuing supply bottlenecks and material shortages.

For 2021, VDMA Machine Vision is sticking to its forecast of 7 per cent growth in turnover for the European industry for the current year, and expects further growth of 7 per cent in 2022.

Integro bought by Kaman Distribution Group

Integro Technologies, the US vision systems integrator, is to become part of Kaman Distribution Group's (KDG) automation business unit following its purchase.

Based in Salisbury, North Carolina, Integro Technologies has 50 employees and 30 engineers, building automation solutions using machine vision and robotics.

Integro will support Kaman across a number of industries, including pharmaceutical, medical, automotive, aerospace, consumer products, packaging and logistics.

Kaman distributes more than six million items, including automation, motion control, electro-mechanical, bearings, power transmission and fluid power components. The company has 220 locations across the US and Puerto Rico, with approximately 2,000 employees.

'We are very excited to have Integro join KDG,' said Ben Mondics, president and CEO of Kaman Distribution. 'Integro is a leading player in machine vision inspection and we look forward to pairing their capabilities with our national scale. The founders of Integro have built a great organisation with a talented and dedicated group of associates.'

Tom Campion, founder of Integro, said: 'We are very excited to partner with KDG. Working as a team, we have always improved and evolved to accomplish far more than we could ever achieve individually. Joining forces with KDG represents an important milestone in our journey to help accelerate our growth.'

In brief

Stemmer Imaging's **Mark Williamson** has been appointed chairman of VDMA Machine Vision. **Frank Konrad**, CEO of Hahn Automation, was elected chairman of the VDMA Robotics and Automation Association, while Basler's CEO **Dr Dietmar Ley** was elected deputy chair.

Pleora Technologies is broadening its geographical scope with two distribution partnerships: Hemetek Techno Instruments for the Indian automation market and Hongke Technology for China.

Part one of the **VDI/VDE/VDMA 2632** series of standards has been published as a draft. The standard aims to support users and solution providers when implementing machine vision projects. To review the draft and submit suggestions for improvements, visit www.vdi.de/2632-1. It will be available until the end of the year.

Wenglor acquires TPL Vision for lighting tech

The automation specialist, Wenglor, has strengthened its position as a full service provider through the purchase of TPL Vision.

TPL, which manufactures LED illumination for industrial image processing, will be integrated into the Wenglor group as a division, but will continue to exist as an independent business unit.

The acquisition is Wenglor's fourth in almost 10 years. In 2012/2013, it bought AFM Sensorik and MEL Mikroelektronik in the fields of flow sensor technology and 2D/3D sensors, adding ShapeDrive, a specialist in 3D sensors, in 2017.

TPL Vision was founded in 2005. It has locations in Perth, Scotland and La Chevrolière, France, where the company moved into a new production facility this year. Both sites will remain in operation and all employees will remain part of the independent Wenglor business unit.

Wenglor managing director Rafael Baur, commented: 'The additional know-how and almost 16 years of experience of TPL in the field of industrial illumination technologies are a real advantage. Wenglor and TPL will achieve great things together!'

Wenglor

From left: Rafael Baur; TPL Vision's Daniel Huber; and Christian Vollrath

TPL Vision offers a comprehensive product range of different illumination technologies, including backlights, spot, ring, bar and dome lighting. It also has expertise in special illumination systems for the food industry and UV light.

'The wide variety of different illuminations solutions enables us to offer our customers the right combination of camera system, lighting, analysis module and software as a complete package for all types of applications,' said Christian Vollrath, head of the computer vision business unit at Wenglor.

The number of employees within the Wenglor group has grown to almost 1,000 now. To meet this growth, new development and production centres with a total floor space of 12,000m^2 will be built, both at the company headquarters in Tettnang and in Unterschleißheim, Bavaria. These will be completed over the next year.

Shows fuel desire to implement vision

UKIVA
UK Industrial Vision Association

By Neil Sandhu, UKIVA chairman

The return of live exhibitions should produce a further boost for the vision industry, based on feedback received from UKIVA members involved in the recent PPMA show in the UK and Vision in Stuttgart. A key factor that stood out was visitors to the PPMA show were arriving with a genuine desire to implement vision projects. Comments included: 'Everyone who came on to our stand had a real purpose with very specific needs'; 'There was clearly a pent-up demand to move vision projects forward'; and 'There were far fewer general interest enquiries and many more detailed requirements'. One UKIVA member offered the opinion that working from home during lockdown had allowed process engineers to step back from on-site fire fighting activities, giving them the chance to spend more time on the strategic planning of new projects that would take their businesses forward.

It was a similar story at the Vision Show in Stuttgart. UKIVA members were again impressed by the number of discussions that took place about concrete projects. At both events there was a high level of interest in 3D applications, multispectral and hyperspectral imaging solutions, and the development of AI image processing capabilities.

The impressive range of new products on display at these shows clearly illustrated the vision industry has continued to work tirelessly through the period of the pandemic to bring new capabilities to market. These new innovations further increase the ability of vision to address real-world problems, which are being further fuelled by a combination of labour and skill shortages across a diverse number of industries. While the current shortfall in some component availability may extend project implementation times, this shouldn't detract from the overall objectives of using vision systems to provide permanent manufacturing and processing solutions.

It goes without saying that manufacturers and suppliers within the vision industry are delighted to be able to re-engage on a large scale with potential customers through the medium of exhibitions, but the evidence from the PPMA and Vision shows indicates an equally strong appetite for engagement from those who need the technology. This lends even greater importance to UKIVA's next Machine Vision Conference and Exhibition (www.machinevisionconference.co.uk), which will take place on 28 April 2022 at the Marshall Arena, Milton Keynes, UK. This will be the first major live machine vision event to take place in the UK since the start of the pandemic. In addition to the opportunity for visitors to see the widest range of vision products under one roof, the comprehensive educational conference programme will once again offer valuable insights into the latest vision trends and technologies and their uses in real-life applications. Following an absence of two years, UKIVA is aiming to make this its most informative event to date.

Optimism prevails towards end of year

By Thomas Lübkemeier

The overall confidence at Vision in Stuttgart at the beginning of October promises a golden autumn for the machine vision industry. This is confirmed by a quick survey conducted by the EMVA in September. Eighty per cent of the respondents expect industry growth by the end of the year, and 46 per cent of them expect an increase of more than 10 per cent.

Spotlight series
During the kick-off event of the new EMVA Spotlight series, the spotlight was set on the topic of inline metrology at Volkswagen. For the next virtual Spotlight event on 18 November, a keynote speaker from market research firm, Yole Développement, will present figures and trends around the machine vision industry. Participation is free of charge: www.spotlight-series-emva.org.

Standardisation remains important
The significance of standardisation for the machine vision industry was showcased during Vision 2021 at EMVA's International Vision Standards booth. Furthermore, at a press event during the trade show EMVA president Chris Yates provided information on the status of the new evaluation group, initiated together with the US-based Khronos Group. The initiative aims to explore the potential of a new embedded camera API, which has received plenty of support in the machine vision industry and beyond. The plan is to finalise a performance specification by the end of the year. In addition, the EMVA has adopted new guidelines for standards development to give an up-to-date framework for the future development of machine vision standards.

New members
We warmly welcome Optotune as a new member. Founded in Switzerland in 2008, the company's core technology is focus tunable lenses, inspired by the working principle of the human eye. Laser speckle reducers, 2D mirrors, tunable prisms and beam shifters are further additions to Optotune's product lines. Thanks to its understanding of optics and mechanics, Optotune can help solve challenges where conventional optics fail.

The association's second new member is headquartered in Taiwan: Enli Technology provides testing solutions for optical sensors. The corporation's four main product markets include image sensor testing solutions, advanced photoelectric detector testing systems, quantum efficiency test solutions, and various light simulators. Welcome both to the EMVA community!

SWIR Vision Systems raises $5m for quantum dot sensors

SWIR Vision Systems has closed a $5m financing round to grow its quantum dot shortwave infrared sensor business.

The round included participation from a number of existing and new investors, including: Keiretsu Forum, RTI International, Blue Sky Capital (the strategic investment partner of Samtec), AAC Technologies, Carolina Angel Network, WaterStar Capital, and Oval Park Capital.

The company's Acuros extended SWIR camera reaches 2.1-megapixel resolution out to 2,000nm wavelengths. The cameras are based on a quantum-dot photodiode sensor design, and are already in use inspecting high-volume production semiconductor chips.

SWIR Vision plans to use the funding to advance the company's colloidal quantum dot sensor solutions, to grow the company's SWIR camera business in global industrial and defence markets, and to engage strategic customers in the consumer electronics, automotive and advanced sensor markets.

George Wildeman, CEO of SWIR Vision Systems, commented: 'We are appreciative of this strong vote of investor confidence in our team and our technology. The reception we've encountered in the industry has been extraordinary. We look forward to expanding our business in the industrial imaging market, while working with the world's top automotive and consumer electronics companies to explore applications of our fully scalable, CMOS-based SWIR sensor solutions.'

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Strides made in AI, but challenges remain

Greg Blackman reports on the deep learning discussions at Vision in Stuttgart

Both the award winners at this year's Vision show in Stuttgart – Prophesee for the Vision Award and GrAI Matter Labs for best start-up – were AI devices. In fact, of the 15 young companies pitching for best start-up, 10 mentioned AI.

Neural networks have become a phenomenon and the solutions addressing industrial imaging and the pain points associated with production lines – the lack of pictures of defects and the challenges of annotating data – are multiplying.

Before announcing the Vision Award winner, Martin Wäny of the judging panel picked out a few past winners, including AnaLogic, which won in 2003 for a neural network processing chip. Wäny said: 'Back then it was debatable whether neural networks were suitable or usable for industrial vision and factory automation. Well, if you walk around this show it's hard not to find a booth that doesn't mention AI.'

The VDMA and Messe Stuttgart organised a panel session on the topic of deep learning at the show. Dr Dietmar Ley, CEO of Basler, said during the discussion: 'We've made great strides in making deep learning more usable and more practical over the course of the last three years [since the last Vision show].'

He said: 'Three years ago it was difficult to find the right tools and components to do deep learning properly, and at a reasonable cost point. We believe this has greatly changed.'

He went on to note the abundance of processors now available for running neural networks, and not just GPUs, but processors dedicated for deep learning. As Dr Olaf Munkelt, managing director of MVTec Software, said: 'Giants like Intel have built special neural network cores in their hardware. The hope is that this becomes

'Take images, take a lot of them, store them, learn how to organise them'

more cost-effective for our customers.'

The winner of the start-up award, GrAI Matter Labs, has done just that. It plans to release an AI processor that it says is 20 times more efficient in terms of inferences per second per Watt than a Google Edge TPU or an Nvidia Jetson NX.

The Life-Ready AI chip is a vision inference processor that lowers energy consumption by only processing changes happening in the images rather than every single pixel. In this way it can optimise the compute inside the network. The sparsity-driven AI system-on-chip delivers Resnet-50 inferences at 1ms speed.

Both Framos and Adlink have built solutions based on the chip, with Framos showing a 3D imaging platform running Life-Ready AI with a D435e depth camera in Stuttgart.

GrAI Matter Labs is only one of nine AI chip makers in Europe, compared to 32 firms building AI chips in China and 64 in the US, Christian Verbrugge, GrAI Matter Labs' senior director of business development Europe, pointed out during his pitch to the start-up award judges.

The disparity in the levels of activity around using AI for image processing in different regions was picked up on by Ley during the panel discussion. He said that there's big potential behind the technology and it should be considered on its merits. 'What we see, especially in the Chinese market, is that there are a lot of people experimenting with it, and going through the learning curve now... From a regional perspective, Europeans should get into this technology sooner rather than later, to make sure they are not left behind. There are engineers in other territories that are jumping on this.'

Ley said the majority of deep learning projects involving machine vision are custom projects at the moment. He said the expectation is for large IT companies like Amazon Web Services to release toolchains in the future that make deep learning easy

'Europeans should get into this technology sooner rather than later'

to use and which might work for a couple of standard applications, but this is 'some time down the road.'

Donato Montanari, vice president and general manager, machine vision at Zebra Technologies, said a lot of the challenges organisations face are around how to start using deep learning. Zebra Technologies has recently entered the industrial vision space with a range of smart cameras, alongside acquiring software provider Adaptive Vision. Ley also noted that many of Basler's customers don't have sufficient competence yet when using the technology.

The first suggestion for companies wanting to start using deep learning is to save images, Montanari advised. 'Take images, take a lot of them, store them, learn how to organise them,' he said.

The next step is learning how to annotate the images, which is where a lot of deployments fail, Montanari continued. He said the best way to annotate images is to be on the factory floor together with the quality expert.

Some of the start-ups pitching as part of the start-up award were offering services to help make data annotation easier and more effective – companies like HodooAI, which offers a cloud service for data labelling. Services in data annotation are growing because it's such a critical part to get right – Andrew Ng of Landing AI, speaking at the Association for Advancing Automation's Automate Forward show earlier in the year, said that 80 per cent of the time invested in a deep learning vision project is in dealing with data.

Ultimately, as Munkelt said during the Vision panel discussion, there have to be toolchains developed for the entire process, from labelling data to the choice of algorithm, so that the customer can quickly find out what works and what doesn't.

Processing power

Inference can be run on a CPU, but training a network typically needs a GPU, Montanari said. There's also the option of training a network in the cloud and then deploying it to edge devices.

Stephen Walsh at Neurala Europe, one of the start-ups, noted during his pitch that GPUs are expensive and are in short supply at the moment. He said Neurala is aiming to reduce the cost of deploying deep learning and to make it more accessible. The company has partnered with Flir to offer Neurala tools and run a Neurala VIA model on Flir's Firefly DL camera.

Walsh said it's important to accept the fact there aren't many images of defects available in industrial inspection, and that 'we have to be able to train with that.'

Jens Hülsmann, of Isra Vision, said deep learning is 'clearly a future technology.' He said it's another tool in the tool box that can solve tasks that were difficult with classic imaging processing methods.

Mark Williamson, of Stemmer Imaging, noted during the panel discussion there is now technology developed to make it easier to train a network with fewer defect images, and that over the last three years, deep learning has become easier to deploy with examples in industrial applications.

He said: 'Like any technology, you can be too early, you can be too late, you can be at the right time. Neural networks have been talked about since the 90s. That was too early but there was potential. We're now [beginning to see] adoption in some applications. Certainly it's got its future. Now is the moment [to adopt].'

Depth of AI products in Stuttgart

Musashi AI has worked with automotive firms to develop AI inspection for complex parts like camshafts. The software combines anomaly detection and supervised learning with object detection. It has the ability to start inspecting with 30 to 50 good parts, and use the anomaly detector to correlate what the object detector sees to identify defects. It runs on the edge. Version 2.0 also uses instance segmentation to improve the process.

EVT was showing a smart 3D triangulation camera built on a Google Coral chip for running deep learning, either for pre-processing or analysing the point cloud. The camera also contains a Xilinx Zynq dual-core processor with FPGA.

The Coral SoC for deep learning operates at 4TOPS and 4W TDP power consumption. Those developing in TensorFlow can convert their networks to TensorFlow Lite and run it onboard the camera in the Coral chip. Transfer learning can also be done on the smart camera, meaning the network can be trained on site.

Other EVT cameras are also available based on similar processing hardware, including a dual-head camera, a line scan model and a thermal camera.

Easics has developed an embedded neural network technology called NearbAI. The technology is designed for running neural networks close to the sensor on embedded hardware, typically in an application with low latency. NearbAI is platform independent and can be mapped to FPGAs, ASICs and SoMs. It can be used for tasks requiring ultra-low latency, as well as non-variable latency.

Neuromorphic pioneer wins Vision Award

Greg Blackman speaks to Prophesee's **Luca Verre** about the prospects for event-based imaging

Landesmesse Stuttgart GmbH

Luca Verre (second from left) collecting the award in Stuttgart

Vision Stuttgart has returned and with it the Vision Award, which this year went to Prophesee, recognising the potential its neuromorphic – or event-based – approach to imaging has for the machine vision sector.

Martin Wäny of the judging panel for the award called event-based vision a 'new paradigm' in imaging technology, one that's been worked on for 20 years, but is now coming to fruition through the efforts of Prophesee.

Prophesee's first Vision show was in 2016, fresh off the back of winning best start-up at the investment conference, Inpho Venture Summit, the month before.

Since then a lot has changed: recently Sony announced neuromorphic sensors based on the firm's technology, and earlier in the year Prophesee won investment from the Chinese AI venture capital firm, Sinovation – the first European company to do so – along with Xiaomi as a corporate investor, showing the technology has scope for use in mobile devices.

Prophesee's CEO Luca Verre explained that machine vision remains an important market segment for the company. Prophesee began by targeting machine vision for the first three iterations of its sensor, in part because the form factor of those sensors was too large for consumer devices but a fit for machine vision. Now, its fourth-generation sensor, which has just been released with Sony, has an optical form factor that can fit easily into consumer devices, even mobile, Verre said.

Nevertheless, machine vision is still a key market, as the high-speed, real-time performance of neuromorphic sensing lends itself to machine vision tasks. Unlike conventional imaging, where all the information in the scene is captured for each frame, event-based imaging records changes – or events – in the scene, similar to how the human eye records and interprets visual input. This gives specific advantages: the sensor can run at microsecond time resolution, or greater than 10,000 images per second time resolution equivalent. It is therefore ideal for applications like high-speed counting – counting and measuring the size of particles or objects moving at up to 500,000 pixels per second – or monitoring vibrations in manufacturing equipment at 10kHz for predictive maintenance.

Because the sensor is only capturing changes in the scene, it generates 10 times to 1,000 times less data than frame-based approaches; it offers 120dB dynamic range, imaging in light levels down to 0.08 lx, and power efficiency of 26mW at the sensor level.

The sensor developed with Sony uses Sony's 3D stacking technology and Cu-Cu interconnects to shrink the pixel to 4.86µm with 80 per cent fill factor; the previous generation of the sensor, Gen 3, based on a 180nm CIS process, has 15µm pixels with 25 per cent fill factor. The two Sony sensors have a dynamic range of 86dB, and resolutions of 1,280 x 720 pixels (IMX636) and 640 x 512 pixels (IMX637).

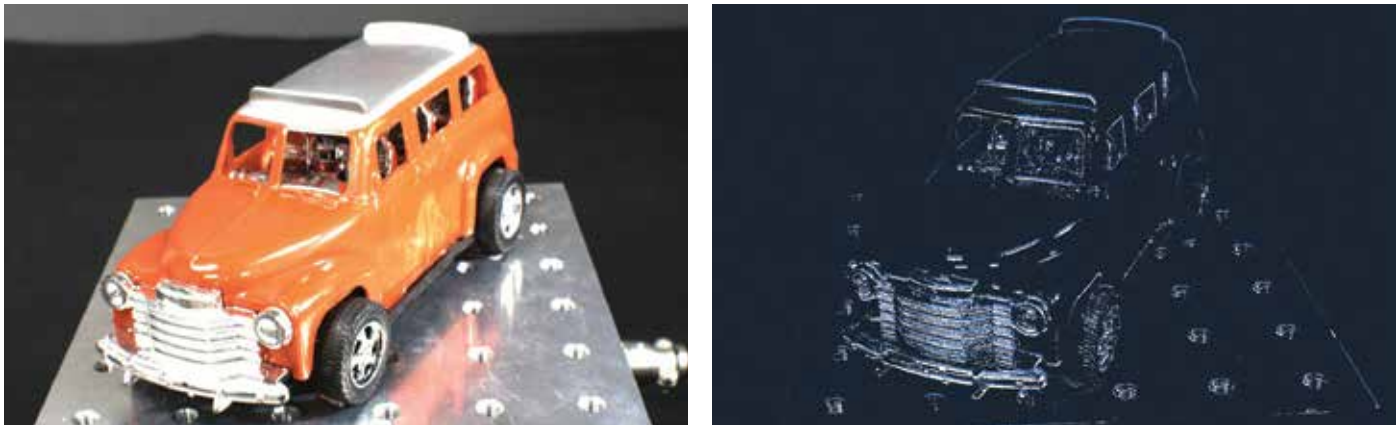
As in all imaging, resolution helps with accuracy, for detecting small vibrations in a narrow field of view, for instance, although Verre said the objective is not to reach a multi-megapixel image. However, the bio-inspired nature of the technology has led to some clever tricks to generate high-resolution images.

The human eye is constantly moving, making lots of micro-movements called saccades. The eye does not have a huge physical resolution because the number of receptors is limited, but the brain reconstructs a high-resolution image using these saccades.

In the same way, it's been shown that by putting Prophesee's VGA sensor on a piezoelectric stage and then shaking it, a multi-megapixel image can be reconstructed from the stream of events produced by the movement.

Verre said, while not a commercial solution, a metrology system maker in Japan has been experimenting with the sensor to work on surface inspection. The VGA sensor wasn't able to identify scratches on the surface initially, but when some small vibrations were introduced, over time, the sensor accumulated enough information to identify these defects.

'This is an interesting approach,' Verre



Prophesee

The event-based image (right) picks up the outline of the car as it is vibrated on a stage

said, 'that showed our technology can use the super high time precision we have to generate spatial resolution – you can trade off time resolution to generate spatial resolution.'

Mobile magic

The new Sony sensor opens up consumer imaging markets for the technology, and the investment from Sinovation Ventures, Xiaomi, along with Inno-Chip, reinforces this. Speaking about the Sinovation investment, Verre commented: 'They clearly see that our approach to AI is very original, potentially a technology platform that can serve applications from machine vision to IoT, mobile, automotive, drone, robots – all important segments worldwide.'

Sinovation was founded by Dr Kai-Fu Lee, a pioneer in AI, and has more than $2.5bn assets under management.

The involvement of Xiaomi, Verre said, is an investment from a strategic angle. Neuromorphic imaging has the potential to address some of the pain points found in mobile phone cameras, namely motion blur and slow motion video.

There have been various research papers, Verre said, on combining data from an event-based sensor with that from a frame-based sensor. Event data is not constrained by frame rate, by clock, and therefore it can give a better understanding of motion in the scene, and potentially correct for motion blur.

Also, a frame-based sensor running at 10fps could be augmented with event-based data to generate slow motion video without huge amounts of data. The event stream could be used to reconstruct a sequence of images in between each frame of a traditional rolling shutter sensor.

Connecting the dots

'One of the key challenges for us since the beginning has been to connect dots in the ecosystem,' Verre said. 'We started with this sensor technology with fundamental benefits. Very quickly we realised that to make sure you convey these benefits to the end user you need to work with camera makers and system makers, SoC vendors, software partners and system integrators. We invested a lot of time and resources to bring all these partners together. We are glad to work with companies like Imago in Germany and Century Arks in Japan, as well as Lucid Vision Labs, Framos and Macnica ATD Europe. It's important they help us to deliver a full solution to the market.'

Prophesee has released an evaluation kit for the Sony sensor; a software development kit with 95 algorithms, 67 code samples, and 11 ready-to-use applications; and a set of open source software modules to optimise machine learning training and inference for event-based applications, including optical flow and object detection. The open source tools have so far registered more than 500 unique users, Verre said, 'which implies more engineers and inventors are taking on our technology to start evaluating it, experimenting with it and creating solutions.'

'There will not only be Sony; other companies like Samsung and CIS companies will enter the space'

Cambridge Consultants developed an automated system to look for contamination in cell samples using the firm's evaluation kit, while Xperi built a driver monitoring solution using Prophesee's evaluation kit and SDK.

'Our effort will be to keep providing evaluation kits, development kits, camera reference designs to camera makers to facilitate the integration work so more cameras will use an event-based sensor,' Verre said. 'We will keep enriching our SDK with more fundamental algorithms, but also application examples, with models that are both commercial – part of the software is only accessible with a licence – but a lot is now available for free because we also want to have a wider community of users.'

Prophesee is also offering training to system integrators and customers. It has put in place a field application team with almost 20 field application engineers worldwide, as well as a network of eight distributors and system integrators for industrial imaging – companies like Framos and Macnina ATD Europe.

It has also reached an agreement with SynSense to develop low power solutions for event-based vision on edge computing. SynSense, founded in 2017, provides neuromorphic computing with a line of asynchronous, event-based vision processors that have low power consumption and low latency. The partnership will combine, in a single chip, SynSense's vision SNN processor, Dynap-CNN, with Prophesee's event-based Metavision sensors. The aim is to develop a line of modules that can be manufactured at high volume.

Verre said more functionality will be integrated into the sensor, 'working with more partners like Sony and other foundry and image sensor companies to make sure we can open up this market opportunity of event-based technology.'

Prophesee's technology lends itself to on-sensor processing much more so than a frame-based approach.

Verre added: 'There will not only be Sony; other companies like Samsung and CIS companies will enter the space, which will open up event-based sensing to more markets. Our role as a pioneer is to keep innovating, stay ahead, make sure we connect dots at the software and system level and work with as many partners as possible, companies like NXP and Qualcomm, so everyone in the ecosystem is able to build a full application.'

Getting a grip on polished hips and knees

Tahir Rabbani of Viztronics spoke at the Vision show about a 3D solution for imaging shiny orthopaedic implants. **Greg Blackman** reports

Denis Simonov/Shutterstock.com

To image the reflective surfaces of an implant, deflectometry was used to generate a point cloud

Orthopaedic implants are difficult to image. They are made from materials like titanium or chromium, polished to a mirror finish, and the surfaces are curved and irregular.

Viztronics, a start-up based in Dublin, Ireland, offering deflectometry solutions, has worked on a project to automate moving the metal blanks between processing stations and packing the final implants using robot bin picking.

Viztronics proposed a couple of 3D imaging techniques – depending on whether looking at the diffuse metal blanks or the highly polished finished implant – to get enough coverage of the implant to find it's pose and pick it up reliably with a robot.

Automation and inspection are becoming more important for implant production, according to Dr Tahir Rabbani, R&D director of Viztronics, speaking at the Vision trade fair in Stuttgart. He said: 'The whole process of manufacturing is moving to 3D printing, and as you 3D print these parts it's very important to inspect the dimensions and also automate the manufacturing process.'

Unpolished implants have a diffuse metallic finish and can be imaged easily using any standard 3D vision technique. Viztronics used a structured light approach, using its ZFlex sensor, which comes in two versions, between them covering a field of view of 300 to 2,000mm and 50 to 500µm resolution.

Rabbani said: 'The diffused part has a very good structure under structured light illumination, where you can clearly see the stripes... But using the same technique on the polished implant, you're seeing the reflections from the sides of the bin rather than from the projector, and the point cloud is mainly noise and not really usable for bin picking.'

For the polished implant, Viztronics proposed deflectometry, a 3D imaging technique that exploits the reflective surface to generate a point cloud. Viztronics' set-up uses an LCD pattern projector, which goes through a sequence of structured light patterns that are reflected by the object. Two or more cameras image the reflections to calculate the point cloud. The technique doesn't give 3D information directly; it gives a surface normal and a surface curvature, from which a 3D surface can be calculated.

Deflectometry doesn't work well with binary light patterns because the camera can't focus on both the pattern and the surface at the same time – a binary pattern won't give a meaningful result. Viztronics' technology is based on phase shift, which is resistant to defocus and works well for deflectometry.

To calibrate a deflectometry set-up, the first step is to calibrate the two or more cameras, including the lens distortion. Then there's a multi-view geometric calibration, and the position of the LCD projector is taken into account.

For the structured light, Viztronics uses a progressively increasing set of frequencies, both in x and y axes. By analysing the pattern reflected by the object, Viztronics' software can calculate which pixel on the LCD screen was reflected and seen by the camera.

> 'The point cloud doesn't have full coverage, but there are enough points to match it to the CAD model'

The image gives a point cloud with enough coverage for the robot to pick up the part. Rabbani said: 'The point cloud doesn't have a full coverage of the implant, but there are enough points there that once you match it to the CAD model, you know the pose of the object as well as the position of the implant in the bin, and that's enough information for the robot to pick it up.'

Viztronics' deflectometry system is called DeflectoZ; combined with its Smart Phaze software, it's used for imaging reflective surfaces, such as ceramics, polished metal, glass and in this case orthopaedic implants.

As a next step, Viztronics wants to expand its solution to image both polished and unpolished implants using one sensor. For that, Rabbani said, the proposal is to use an LCD screen and the stereo cameras for both problems – to use triangulation for diffuse parts and deflectometry for polished parts in a single bin picking system.

CXV GLOBAL SMARTFACTORY™ VIAL COUNTER

Client: Global Life Science Manufacturer & Distributor
Location: Ireland

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A large Clinical Diagnostics company, focused on quality control products and informatics solutions, sourced CXV Global's SmartFactory™ Vial Counter to transform their vial production process. Their aim was to introduce greater quality control measures to their production process and reduce, by at least 50%, the time and costs associated with the vial counting and batch reconciliation processes. The customer's production site is filling 150 batches of vials per year and is consuming up to 1,883 hours annually from the manual counting of vials and the reconciliation of the batches.

Through the implementation of the CXV Global SmartFactory™ Vial Counter, the digitisation of the customers manual vial counting and reconciliation process, saves over 50% of the time and costs in the current process, whilst increasing the automation ratio. The resulting process efficiency savings increase the OEE of the manufacturing line whilst directly reducing the production costs.'

Customer Outcomes Achieved
A single stand-alone portable CXV Global SmartFactory™ Vial Counter reduces the time spent on reconciliation for all four lines by over 50%. Using one single solution, the organisation will increase its quality control process across all 4 lines, using the vial counting solution that can:

- Move easily between production lines
- Support the full spectrum of vial colours in the customer's product range
- Facilitates rapid changeover for counting different size trays and vials.

The new CXV Global SmartFactory™ Vial Counter provides a stand-alone vial counting station, eliminating vial counting errors, whilst reducing the time taken to count vials by up to 50% when compared to typical manual vial counting and reconciliation procedures. The system enables an additional 1,500 hours of additional production capacity in the first year, equating to 70 extra batches with an average size of 800 litres.

With a current production capacity of 200 batches annually, the time savings provided by the CXV Global SmartFactory™ Vial Counter is sufficient enough to remove the need to deploy additional fill lines within a 5 year window, based on a 15% year-on-year growth of batch production. Through the provision of the all in one Vial Counting station, utilising state of the art vision algorithms the CXV Global SmartFactory™ Vial Counter provides an automated vial counter to accelerate batch reconciliation and ensures that accurate counts are recorded and auditable throughout the vial production process. The customer can rest assured that the time it takes to carry out their large batch reconciliation process will be significantly reduced and 2 of the 3 people currently deployed to manually carry out this task can be redeployed elsewhere in the organisation to carry out higher value tasks.

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Customer Challenge

Reduce time spent on batch reconciliation by 50% across 4 production lines with a payback within 12 months.

50% reduction in cost of labour spent on initial vial count and reconciliation errors.

Improve quality control process by achievement of 100% counting accuracy eliminating human error and transposition inaccuracies.

Sun rises on quality control

As solar power becomes an increasingly important energy source, **Andrew Williams** looks at how infrared imaging is used to assess solar panels

In recent years, infrared thermography has become a popular solar cell inspection technique that enables manufacturers to detect hot spots and other anomalies that cannot be found by visual inspection.

There are a number of ways it's used. Near infrared and shortwave infrared cameras, for example, are able to see cracks and other defects on the inside and opposite side of a silicon wafer or ingot. Longwave infrared imaging can also be used to inspect and monitor the integrity of cells configured into solar panels once they have been installed, commonly by employing a thermal imager to detect hot spots or dead cells.

Mike Grodzki, product manager for scanning products at Teledyne, noted that infrared cameras can also be used to test photovoltaic cells by techniques called photoluminescence and electroluminescence, both of which can highlight flawed regions in the solar cell. Photoluminescence uses powerful illumination to induce luminescence, while electroluminescence requires an electric current to be applied to the cell or module and the emitted light measured.

Dr Jonas Kornelius Haunschild, head of the inline-wafer, process analytics and production control group at the Fraunhofer Institute for Solar Energy Systems ISE, explained that solar cells are inspected inline at two major stages in the production process. The first is an outgoing inspection of wafers or an incoming inspection of cells.

At this stage, the raw silicon wafer is inspected to verify wafer specifications and discard poor quality material.

The second stage is during the current-voltage (I-V) tests of the finished solar cells before module production begins. 'Depending on different companies, inspection is also done during processing, but these two are the most important ones,' said Haunschild.

Transparent to infrared

For inspection of incoming cells, the team at Fraunhofer ISE uses three different infrared systems: infrared transmission, infrared reflection and photoluminescence imaging. Haunschild described the first system, infrared transmission, as a simple method that uses a camera to detect 1,400nm infrared light focused on each side of the wafer.

'The wafer should be almost transparent to this wavelength – and so, in the images, defects, particles and cracks can be seen. Simple image processing algorithms catch the defects and the inspection system can sort them out,' he said.

Haunschild described infrared imaging as a kind of X-ray vision, because silicon is transparent to infrared light and therefore it can be used to see inside wafers and solar cells to detect defects.

'With normal optical inspection, these [defects] are not visible, but they are still there, limiting the performance of the solar cells and indicating where there is potential for improvement in the production chain,' he said.

'The rapid developments in camera and LED technology over the last few years… will hopefully result in cost-effective photoluminescence devices'

Sonpichit Salangsing/Shutterstock.com

In the second method, infrared reflection, a shorter wavelength of infrared light is shone onto the wafer from the same side as the detecting camera. Here, as Haunschild explained, the trick is that infrared light is 'coupled into the wafer and moves there like in an optical fibre'. At points of interference, especially microcracks, the light is decoupled and detected by the camera.

'Microcracks are much more clearly visible with this method [infrared reflection] than with classic infrared transmitted light. However, smaller defects such as SiN or SiC particles cannot be seen, so both methods have their justification,' he said.

The third approach used at Fraunhofer ISE is photoluminescence imaging, where infrared light of around 800nm is shone and absorbed by a sample. Using a method known as band-to-band recombination, luminescent radiation is then generated and detected by a silicon sensor. According to Haunschild, although this method is quite simple in principle, it is technically challenging because a very powerful laser and very good optical filters are required.

'The method [photoluminescence] can be used in all steps of the manufacturing chain to find electrical defects and process errors. Finished solar cells or modules can simply be excited via the contacts as an alternative to the laser. This method, called electroluminescence, is now offered at very low cost and is part of solar cell inspection or module control,' he added.

Remote monitoring

According to Magnus Herz, senior expert, R&D at TÜV Rheinland, although optical methods of fault detection in photovoltaic power plants have been used in the photovoltaic industry for many years, uptake has been limited because it takes a lot of time and labour to make these measurements across a large solar plant comprehensively. As an alternative, he said the strategy of using remote aircraft equipped with infrared cameras can be a cost-effective and much less time-consuming option for fault diagnosis over these solar farms.

He points out that solar module inspection benefits from infrared and electroluminescence imaging techniques – both of which are widely used indoors and outdoors. 'A combination of electroluminescence and infrared measurements was proposed to detect the most common defects in a solar module with high accuracy,' he said.

'Electroluminescence measurements take advantage of the radiative inter-band recombination of excited charge carriers in solar cells,' he explained. 'The solar cells are supplied with a defined external excitation current, while the camera takes an image of the emitted photons. Damaged areas of a solar module appear dark or radiate less than areas without defects. The high resolution of the electroluminescence images enables the resolution of some defects more precisely than in infrared images [alone].'

Image evaluation

Broadly speaking, the Fraunhofer ISE team views the hardware of its infrared devices as mature, and does not anticipate any further additional technical innovations in the near future. That said, Haunschild said there has been great progress in the area of image evaluation, particularly in photoluminescence imaging.

'Measurement results contain a lot of information about the quality of the wafers and, since no one can look at all the high-resolution data in production, powerful image analysis based on machine learning and artificial intelligence is needed to extract the essential information from the images to make them usable for quality control and process development,' he said.

'As a concrete example, we have been working on quality control of kerfless wafers from NexWafe in particular over the last year,' he continued. 'This is a very exciting technology with many advantages over classical silicon.

'The infrared reflection method could also be considered as still relatively new,' he added. 'It was developed in industry and has some advantages over classical infrared transmitted light.'

Meanwhile, although unaware of any major recent technological or operational breakthroughs in the use of infrared technologies for solar cell inspection, →

TÜV Rheinland

Drones equipped with infrared cameras can be used to inspect solar farms

→ Grodzki pointed out that higher resolution, shortwave infrared cameras can be used for higher detail – and that near infrared-sensitive CCDs can also be used in some cases.

He added that higher resolution and lower cost can be achieved with colloidal quantum dot SWIR sensors. 'Although the quantum efficiency of these devices is somewhat lacking today, the technology is quite promising,' he said.

Higher yields

When it comes to assessing the advantages of using infrared imaging, Grodzki pointed out that, although other techniques exist that enable users to detect defects on the surface of solar cells, only infrared can equip observers with more information about the material being used and the resulting outputs.

'The use of infrared techniques results in higher yields for the manufacturer,' he said. 'Finding the right mix of infrared detector, illumination and optics can be a challenge, but many machine vision distributors have the knowledge to assist with this.

'Another challenge for customers is price – higher sensitivity means a higher cost,' he added.

Meanwhile, Haunschild observed that decisions relating to the application of these infrared imaging methods in industrial processes always entail detailed cost-benefit considerations, and depend on the relative value placed on internal quality control.

'My personal impression is that a lot of emphasis is placed on this, especially in western countries, which is why infrared transmitted light or infrared reflection is widely used as part of the entrance test for microcrack control,' he said.

Teledyne

Solar panel inspection

Despite the undoubted benefits, Haunschild pointed out that photoluminescence imaging is quite expensive because a strong laser and a safe enclosure are needed – meaning it is mainly used in the laboratory and rarely on production lines.

'If prices can be reduced and the technical concepts simplified, this could also change, [and] we [Fraunhofer ISE] are actively working on this. We consider the hardware concept to be mature… for demanding scientific applications. If one is willing to compromise in favour of price, the rapid developments in camera and LED technology over the last few years open up new possibilities that will hopefully result in simple and cost-effective photoluminescence measurement devices,' he said.

'Researchers are working feverishly to introduce tandem solar cells… [which are] only partially measurable with the established infrared systems'

Future developments

Looking ahead, Grodzki is hopeful that detectors will become more responsive over time, which would reduce the requirement for costly and powerful infrared illumination – a development he views as especially relevant for shortwave infrared.

'Automated solar panel inspection will also be further enabled by the combination of drones and thermal imaging,' he added.

Meanwhile, Haunschild predicted that the introduction of new solar cell concepts will inevitably bring new inspection requirements.

'On the one hand, due to the boom of monocrystalline wafers, we see more and more specific defects, which are known from earlier years but had disappeared in the industrial environment. In particular, thermal donors can be a problem for heterojunction solar cell concepts. However, with appropriate hardware and the right image analysis, these defects can be evaluated and bad wafers can be detected,' he said.

'On the other hand, researchers are currently working feverishly to introduce tandem solar cells into the industrial environment,' he added. 'In principle, these are two solar cells [placed] on top of each other to capture and use even more light. This structure is only partially measurable with the established infrared systems and requires adjustments in the technology.'

Taking the heat out of solar

As Magnus Herz, senior expert, R&D at TÜV Rheinland, explained, one of the most important pieces of data captured by infrared images is the temperature difference between various parts of a solar cell module, or between modules or strings of modules.

'Inactive areas of a module or string usually appear hotter than surrounding active areas. When a photovoltaic module or string is not functioning, the energy generated is not converted to DC power and remains as excess heat, raising the temperature of the module or string,' he explained.

'A great number of failures on photovoltaic modules can be detected using infrared imaging, from hot spots to mismatch losses or installation failures,' he added.

Broadly speaking, there are two different types of infrared or thermographic cameras – those with cooled detectors and those with uncooled detectors.

The sensors used in cooled thermographic cameras are made from narrow band gap semiconductors. However, although such cameras possess very high sensitivity, they are not commonly used in photovoltaic applications because of the cost and complexity of the associated cooling system.

'Commonly used thermographic cameras are based on uncooled sensors that can work at ambient temperatures. The most common sensor architecture is the microbolometer,' Herz said.

Spectral vision foresees seed germination story

Greg Blackman finds out how seed producers are reaping the rewards of imaging

In the spring earlier this year, I helped sow a meadow with a mix of wild flower and grass seed in the hope that, eventually, the flowers and grasses would outcompete the thistles. Success so far has been limited. One of the better areas was a stand of linseed, but instead of the expected, more traditional blue flowers, these plants turned out to have white blossom.

Mistakenly growing a variety of linseed with white flowers rather than blue is not the end of the world but, for seed producers, the plant variety that is packaged and sold to growers matters, sometimes down to the level of the single seed. According to Jens Michael Carstensen, CEO of imaging firm Videometer, which works heavily in the seed industry, it can be required by law that batches of seed are sufficiently pure to be traded.

Videometer provides hyperspectral imaging systems and generates almost half its revenue from systems sold for seed and grain analysis. (Inspecting other foodstuffs accounts for a quarter of its revenue, with the remaining quarter for solutions for pharmaceutical inspection, medical devices, cosmetics and other areas.)

For the kind of highly accurate analysis where each and every seed is sorted, Videometer would use a robot with validated picking, Carstensen said, 'so we are sure not only that we detect a seed that's the wrong variety, but that we also remove it.' The aim is to have validation throughout the process chain.

'A lot of effort is put into breeding the right kind of seed,' Carstensen said. 'By the same token, a lot of effort goes into making sure the supply chain works so that the seed sown is as good as it's supposed to be, it's the correct variety, and it germinates and grows into a strong plant.'

Spectral imaging can help in both production quality control and in plant breeding – two important parts of the seed industry. In plant breeding, the aim is to screen seeds to pick out candidates with the right traits.

In either breeding or production, spectral imaging can determine the variety and whether there are off-types contaminating a batch of seed, such as seeds from different crops or weed seeds. 'Purity is extremely important in seed production – that it's the right crop and the right plant variety,' Carstensen said.

Spectral imaging can also show whether the seed is damaged in any way, from insects or fungi, for instance, and whether the seed is likely to germinate. 'Saying whether a seed will germinate or not is tricky because normally you need to sow the seed and wait for it to germinate and grow,' Carstensen explained. He said that the Holy Grail would be to detect whether a seed is viable or not with imaging, something that's not possible at the moment, but spectral imaging can give indicators as to viability.

'We don't expect that, for all seeds, we can tell the entire germination story based on the dry seed, but for many seed types we can see how viable they are and how likely they are to germinate,' Carstensen continued. 'Seed suppliers can make decisions based on a partial knowledge of germination, and that will help them in their logistics.'

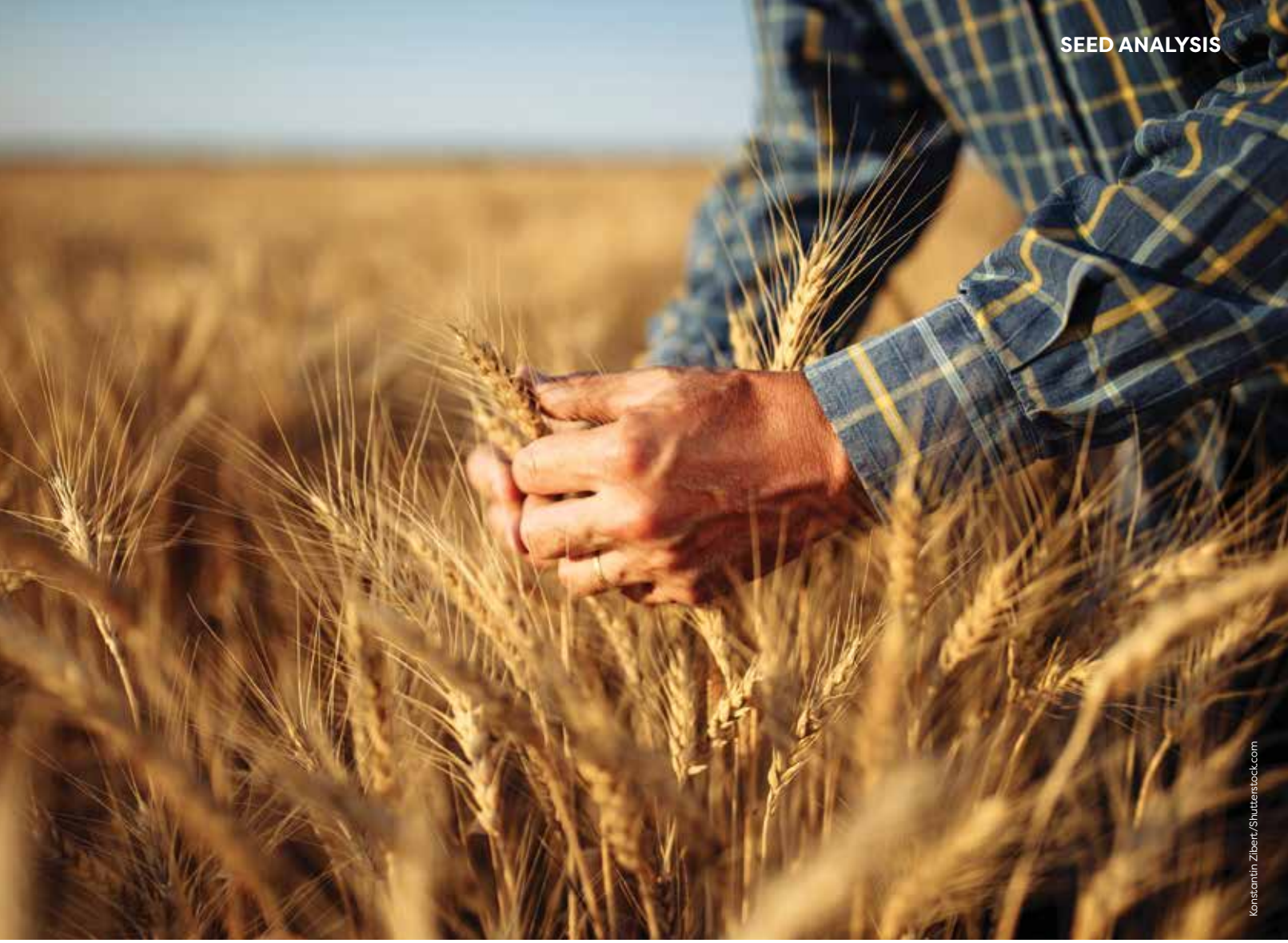
Along with pest damage, spectral imaging can assess whether a seed has been harvested immaturely – a chlorophyll fluorescence test can show how much chlorophyll there is in the seed and therefore its maturity – and also whether a seed has been stored for too long by identifying oxidative damage.

Spectral imaging can show a lot, but nevertheless, the organisations controlling seed testing – the International Seed Testing Association and the Association of Official Seed Analysts – require a germination test.

Videometer would typically use its standard system, VideometerLab, for seed analysis. This scans across a spectrum from 350nm to 1,000nm to create a data cube. 'We can go a little further into the deep UV and the near infrared, but there are challenges getting super apochromatic lenses to cover the complete spectrum,' Carstensen said.

The company has a machine learning engine that it trains with spectral imaging data from different crops and plants. The algorithms look for different markers in the seed, such as the variety or whether there's fungal damage.

'We work with all crops,' Carstensen said. 'We look for similar markers with spectral imaging, but each crop will be different and it's difficult to extrapolate from one crop to another. We work a lot with vegetable seeds



Konstantin Zibert/Shutterstock.com

and field crops – wheat, barley, rice, oil seed rape – but also flower seeds and tree seeds.'

Videometer began 20 years ago providing spectral imaging for very accurate colour determination in production – sorting based on very subtle nuances of colour.

'Spectral imaging is a mature technology,' Carstensen said, 'but it's something that's specialised in terms of who is providing it, because the data is massive and you have a lot of opportunity to get noise instead of signal.

'Spectral imaging cameras and components are only part of the solution,' he continued. 'A true solution for the industry would have to integrate a lot of components: illumination sources and illumination geometry, cameras, controlling electronics, machine learning – putting all this together is quite a multidisciplinary undertaking.'

Videometer only uses LEDs and has done so for 20 years. Its systems combine a number of LEDs emitting at specific wavelengths throughout the UV, visible and near infrared range. The LEDs are strobed in an integrating sphere extremely quickly so that the system captures each image under a different wavelength of light, acquiring images as fast as the camera allows. 'Typically, we would take 20 wavelengths within half a second, calculate the data cube and analyse it to provide the result,' Carstensen explained.

'We [can't] tell the entire germination story based on the dry seed, but for many seeds we can see how viable they are'

He said that a lot has been made possible by the increase in computer speed – deep learning is one example. He also said that the power-over-price in LEDs has improved, especially in the UV, where it's now becoming feasible to do quite sophisticated measurements that weren't possible in the past because powerful deep UV LEDs used to be prohibitively expensive.

'We definitely believe that UV is important for spectral imaging,' Carstensen said. 'The challenge is that normal optics will not go to a shorter wavelength than 400nm, sometimes 350nm. You need specialised optics that are more expensive, and still hard to get – there's not a lot of choice when you go down to UV optics. You can get them, but if you have specific requirements within the UV range you run out of suppliers very quickly.'

Separating the wheat from the chaff

The seed companies that Videometer works with and that have been discussed so far are producing seed that will be sown to grow into a plant. But what about grain harvested for food? The Swiss R&D organisation, CSEM, has worked with machine builder, Bühler, to improve quality control on one of its milling machines.

Sébastien Blanc, senior R&D engineer at CSEM, spoke about the project at the Vision show in Stuttgart in October. The problem Bühler presented CSEM with was to reduce the error rate when measuring the mass flow of grains passing through its milling machines. Bühler's machines typically use a deflecting plate in the shoot to measure the force of grain passing down it and from that calculate the mass flow.

Without an accurate mass flow measurement, grains of different quality get mixed together – Bühler was registering error rates of up to 8 per cent in mass flow, →

Videometer

Videometer's spectral imaging solution for analysing seed

→ which can equate to around 200kg of grain per hour at the speeds at which these machines operate.

Blanc explained that Bühler wanted to lower the error rate to less than 3 per cent for grain moving at a speed of 1.5m/s. He said, on top of that, Bühler needed something that is compact, cheap and with low compute resources.

Blanc and the team at CSEM developed a vision system with embedded AI able to achieve an error rate of less than 3 per cent. The images could also be used to add a layer of quality control to the process.

The CSEM system uses a 1.5-megapixel RGB camera running at 60fps. This is paired with custom 150W illumination that can deliver 5µs pulses to avoid image blur. 'We used an Nvidia Jetson Nano to orchestrate all the peripherals and run the algorithm in real time,' Blanc explained during the trade fair. Everything is processed within the vision system. The team was also able to include a small web server running onboard, to which mobile devices can connect wirelessly.

Blanc said in his presentation: 'We developed a flow speed algorithm to measure the speed of the grain. We can get an accuracy of 40µm at a speed of 2m/s. This is thanks to the help of the powerful LEDs.'

Bühler is not interested in flow speed, however, it is interested in the mass flow in kilograms per second. This can be calculated from the flow speed multiplied by the cross section of the shoot, multiplied by the density of the grains, which depends on the water content of the grain. The vision system doesn't give the grain density, so the camera is combined with Bühler's standard mass flow measurement system to give real-time analysis.

CSEM also developed a neural network to detect grain type, using the saturation and brightness information in the images to identify the grain.

'We wanted to have an algorithm that is able to assess the quality of the grain, and for that we needed a way to segment the grains,' Blanc told the audience in Stuttgart. CSEM used weakly supervised training of its neural network to segment the grains.

'A data-driven approach [to AI] requires a lot of annotated data, which is sometimes cumbersome and hard to get,' he said. The team therefore annotated a single image of the grain, and then went into a process of data augmentation, cropping the single image into a lot of sub-images. 'We did a lot of stretching, rotating and flipping to generate a few thousand images that were used to train, test and validate a neural network,' he said. 'As an input into our neural network, we can provide 32 cropped images and as an output we get 32 masks of a single grain of segmentation,' he said. 'This is useful to fit an ellipse on these masks.'

'Spectral imaging is a mature technology, but it's something that's specialised… You have a lot of opportunity to get noise instead of signal'

A single image of wheat, for instance, was iterated three times, so 3 x 32 samples, which provides 86 valid grains on top of which ellipses were fitted. From the ellipses the group extracted the major and minor axes to make some statistical analyses and get an indication of grain quality.

'If it's not necessary, we don't push to go into the data-driven approach,' Blanc said. 'The algorithm to detect the type of grain is based on classical image processing.'

Bühler uses lots of optical and imaging methods in its grain sorting machines to squeeze the maximum amount of usable grain from a harvest. The percentage gains from optical technologies can be quite small, but because these machines are sorting huge amounts of grain per hour, the benefits for its customers can be massive. It also helps reduce waste in a food system that's getting pushed to the limit in terms of feeding the planet.

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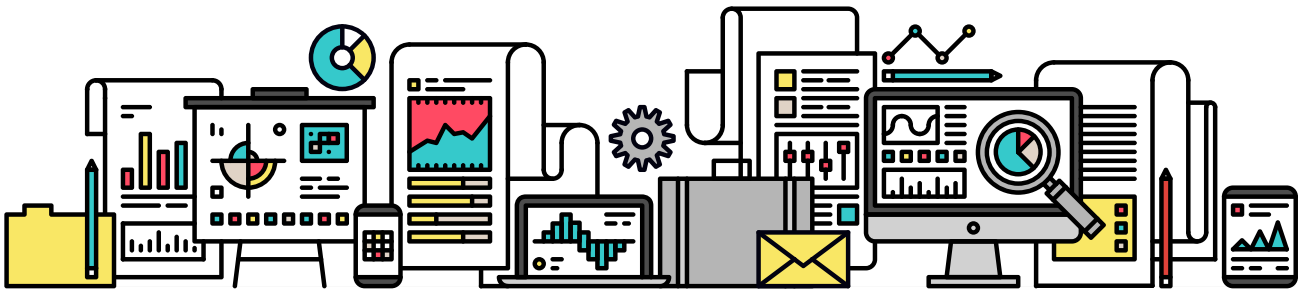

Event-based vision compared with machine vision

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Photometric stereo technique - 3D machine vision's next frontier

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The white paper presents a brief timeline of GigE Vision cameras; advantages of the interface; and information on using 10GigE up to 100GigE to stay on the leading edge of machine vision solutions in manufacturing and beyond

Deep learning: Its proper role and use in machine vision

MATROX IMAGING

Deep learning is a key enabler of Industry 4.0 in the manufacturing sector where machine vision is an important contributor. This white paper from Matrox Imaging details how and where machine vision benefits from deep learning technology, and how to get the best out of deep learning for machine vision.

Advantages of imaging lens ruggedisation

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GigE gives 3D lease of life

Greg Blackman speaks to Pleora's **James Falconer** about the latest versions of GigE Vision

asharkyu/Shutterstock.com

The number of 3D vision cameras and technologies is proliferating, and therefore attention turns to how to transport 3D vision data in a standardised way.

The answer for most machine vision interface standards is GenDC, or generic data container, a module within the latest version of GenICam that can be used to describe more complex data formats like 3D data. GenDC defines how image data is represented, transmitted or received independent of its format.

Coaxpress already supports GenDC in its latest version meaning the standard now has full 3D support; GigE Vision version 2.2 will include it too when it is released at the end of the year.

In 2018, when the current version of GigE Vision, 2.1, was introduced, a multi-part payload was added. This allows the user to put different data types into one single logical frame thus enabling the transport of 3D data as part of a single container.

The way the transport layer works in GigE Vision with a typical 2D image, explained James Falconer, product manager at Pleora Technologies and vice chair of the GigE Vision technical group, is to first send a leader, which describes the incoming image; then the image data; and then a trailer that signifies the end of that frame. Multi-part means different data types can be put in one container. That was the introduction of 3D into GigE Vision.

The GigE Vision standard was initially released in 2006, and, as part of that effort, the GenICam technical group formed alongside the GigE Vision group to help with interoperability.

'Typically, 3D technologies up until recently have had a proprietary transport mechanism, even if they are based on Ethernet,' Falconer said. 'More recently we've seen a large push, especially in Asia, to move that to a standards-based technology with GigE Vision as the underlying transport layer.'

Originally there wasn't a defined way on how to send 3D data, Falconer explained. 'Before the introduction of GigE Vision 2.1 there were cameras that would use GigE Vision to transmit 3D data, but they used to take an RGB pixel data and use that as a container to

Commercial products

New GigE Vision camera models on the market include updated versions of **Teledyne Flir's** Blackfly S line and Lucid Vision Labs' Atlas line, which has just entered production.

The additions to the Blackfly S GigE camera line – the BFS-PGE-50S4M-C and BFS-PGE-50S4C-C – are 5-megapixel models suitable for integration into handheld devices. The cameras use Sony's IMX547 global shutter sensor; offer lossless compression to move from 24fps to 30fps at full resolution; have 68 per cent quantum efficiency at 525nm; and 2.49e⁻ read noise.

The Atlas IP67-rated camera line from **Lucid Vision Labs** has a 5 GigE PoE interface and features Sony Pregius global and rolling shutter CMOS sensors. The first models available include the 7.1-megapixel Sony IMX420 sensor running at 74.6fps, and the 20-megapixel IMX183 sensor running at 17.8fps.

The cameras feature active sensor alignment for excellent optical performance; M12 Ethernet and M8 general purpose I/O connectors that are resistant to shock and vibration; and industrial EMC immunity. They operate over -20°C to 55°C and measure 60 x 60mm. The 5GBase-T Atlas is a GigE Vision- and GenICam-compliant camera capable of 600MB/s per second data transfer rates (5Gb/s) over CAT5e and CAT6 cables up to 100 metres in length.

In addition, **Kithara** has released a real-time driver for the frame grabber card PGC-1000 by PLC2 Design. The PCIe card acquires and converts GigE Vision data, for which Kithara's RealTime software suite provides real-time functionality.

The PCIe plug-in card handles the entire conversion process of captured GigE Vision data, thus relieving the CPU during image acquisition. In this way, multiple camera streams (4 x 10Gb/s or 1 x 40Gb/s) can be operated at minimal CPU load, and the captured image data can be stored on SSDs within the same real-time context. Additionally, real-time synchronisation of multiple cameras is achievable with the Kithara PTP feature.

stuff the XYZ components (as 3D data) in R, G and B parts respectively, and then they'd reconstruct the 3D data on the host side. That made it still a closed system, a proprietary system,' he said.

Now, with the multi-part payload in GigE Vision 2.1, and with GenDC coming as an alternative means for 3D transport in version 2.2, there are now more possibilities for 3D and other types of data to be transported on various standards. Specifically, GenDC extends beyond 3D and solves other use cases as well, such as new compression types.

'The benefit for the user goes back to interoperability,' Falconer said. 'If the user wants to use image processing software from one vendor, and that vendor is standards-compliant and supports GenDC or multi-part, then they can use a GigE Vision 2.1- or 2.2-compliant camera from another vendor and still use the software.'

There's now a desire to move to a standards-based Ethernet transport, Falconer said, but many 3D camera technologies are proprietary Ethernet-based. Pleora has released eBus Edge as part of its eBus SDK. EBus Edge is a set of libraries that allows the user to convert a proprietary 3D camera into a standards-based transport mechanism.

'We've seen a large push, especially in Asia, to move [3D data transport] to a standards-based technology with GigE Vision'

The user can write an application for transport over multi-part with eBus Edge to give 3D transport capability. 'Our libraries also allow you to customise the GenICam layer to add your own 3D-specific features and other features required to control your device or sensors,' Falconer said.

Pleora's eBus SDK gives a sample application that shows the user how to handle a stereoscopic 3D use case, for example, from both the GenICam and transport layers.

In embedded vision, for example, a user might want to connect one or multiple Mipi sensors to an edge device. 'EBus Edge supports multiple sources, so you can, for example, connect two Mipi sensors to a compute device and then, on the Ethernet transport side, you have two different logical streams of 2D GigE Vision data on the same Ethernet link,' Falconer explained. 'Alternatively, you can connect two Mipi sensors, gather the data in memory, do some processing to compute your 3D point cloud, and with our libraries take that data and transmit it using the multi-part payload giving you a 3D GigE Vision-compliant data stream to connect to software from any GigE Vision-compliant software vendor.'

EBus Edge transmits uncompressed 3D data using multi-part payloads with low, predictable latency over Ethernet directly to existing ports on a computer for analysis.

Alongside GenDC streaming, GigE Vision 2.2 will have multiple event data functionality. Up until GigE Vision 2.2, each asynchronous event message from the device to the host PC was sent separately. Version 2.2 allows the user to concatenate multiple event messages into a single message.

Going beyond version 2.2, Falconer said that the GigE Vision technical committee's next big task is to look at speeds greater than 10Gb/s.

GigE Vision guarantees data delivery through a proprietary mechanism called packet resend. The transmitter must store the data while the receiver is processing packets, which allows a receiver to request retransmission of packets. The amount of data that must be stored for the packet resends increases linearly with link speed.

Ethernet equipment can ask a transmitter to temporarily stop streaming. The transmitter must therefore be able to buffer data to cope with pauses on the Ethernet link. During an update given at the Vision trade fair in October, Falconer said the GigE Vision committee is looking to improve the standard to reduce the memory requirement for devices, with the aim of enhancing the robustness and stability of transferring data at speeds higher than 10Gb/s.

Euresys Featured product

Euresys/Sensor to Image IP Cores speed up the implementation of the GigE Vision protocol into any embedded project.

From the Top Level Design (which interfaces the imager, sensors, the GigE PHY to the FPGA internal data processing) to Working Reference Designs as well as hardware and software toolkits, Sensor to Image IP Cores deliver top-notch performance in a small footprint while leaving enough flexibility to the developer to customize his design.

The GigE Vision IP Cores are compatible with Xilinx 7 Series devices (and higher) and Intel/Altera Cyclone V devices (and higher). The toolkits exist in various configurations and come with sample applications and examples.

Sensor to Image's offering also includes USB3 Vision, CoaXPress and CoaXPress-over-Fiber interface IP Cores as well as Image Sensor IP Cores for MIPI CSI-2 and Sony's IMX Pregius sensors.

www.euresys.com/en/Products/IP-Cores/Vision-Standard-IP-Cores-for-FPGA/GigE-Vision-IP-Core-(1)

Products

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Computing

FPGA accelerator for edge pre-processing

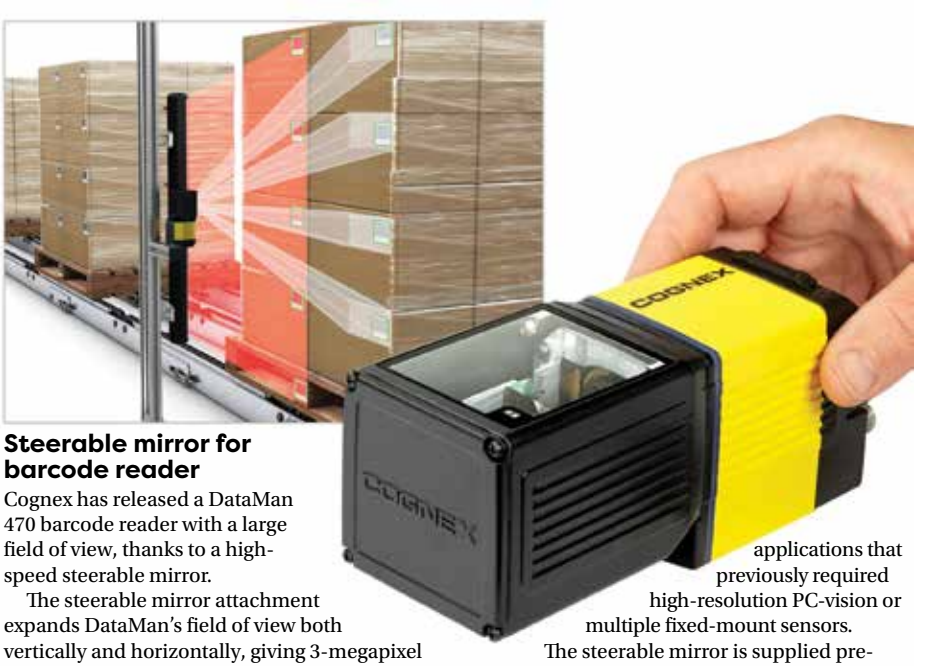
Vision Components has developed an FPGA-based accelerator for edge pre-processing of image data with Mipi camera modules. The hardware accelerator with multiple Mipi-CSI-2 inputs and outputs enables complex image processing and image data analysis. The board can merge data from several Mipi cameras.

The accelerator will be available early in 2022, initially with a completely open FPGA for customer programming and demo applications. In a second phase, Vision Components will launch its own FPGA designs for specific applications, such as colour conversion, 1D barcode identification, epipolar correction and other functions.

In addition, there are plans to enable the electronics for AI acceleration. Vision developers can integrate the accelerator into their future electronics designs just as easily and comfortably as a conventional Mipi camera module.

The accelerator transfers image pre-processing results to a higher-level CPU via the Mipi channel. This allows users to perform even complex tasks by means of in-depth pre-processing in the dedicated FPGA module, while they also benefit from the flexibility of an embedded system.
www.vision-components.com

Lenses



Steerable mirror for barcode reader

Cognex has released a DataMan 470 barcode reader with a large field of view, thanks to a high-speed steerable mirror.

The steerable mirror attachment expands DataMan's field of view both vertically and horizontally, giving 3-megapixel and 5-megapixel barcode readers an effective resolution greater than a 50-megapixel sensor.

Coupled with the latest in liquid lens technology, this system can change both the field of view and depth of focus dynamically. A single DataMan system can now be used for pallet scanning, aggregation and other large area applications that previously required high-resolution PC-vision or multiple fixed-mount sensors.

The steerable mirror is supplied pre-assembled on the front of a DataMan 470. The unit is configured using a built-in web-based wizard for fast deployment. The user simply enters their application specifications and the wizard automatically calculates the optimal scanning pattern, ensuring high read rates in short cycle times. **www.cognex.com**

LD line scan lenses

Phenix Optics has introduced the LD line scan lens series. These new lenses offer three focal lengths and an image resolution power of 100 megapixels. The lenses provide high resolution, low distortion and a large aperture of f2.8. The LD series is suitable for high-resolution cameras, as well as 5µm 8k line scan cameras.

The lenses are compatible with the V-mount or F-mount, often used with large sensors, and can be connected to different industrial cameras by using specific adapters.
www.phenixoptics.com.cn/en

Illumination

SWIR hyperspectral line light

New from MTD Line Lights is the MTD-LED HSL SWIR, a high-power hyperspectral SWIR LED line light emitting in the range of 1,000 to 1,700nm.

The light combines up to 12 different SWIR wavelengths into a homogenous broadband spectrum. Each wavelength is separately programmable, so the spectra can be adapted to customer requirements. An integrated temperature control gives a stable spectral output. The SWIR intensity at a working distance of 300mm is comparable to a high-power halogen light without any significant heat radiation.

The line lights are provided in 300mm modules with different cooling options.
www.mtd-gmbh.de

Cameras

Ace 2 with Gpixel sensors

Basler is expanding its portfolio of digital industrial cameras to include models with CMOS sensors from the manufacturer Gpixel. The 16 new models in the Basler Ace 2 camera family offer customers a good mix of performance and price for cost-conscious factory automation applications, robotics and automated optical inspection.

Two global shutter sensor models have been added: Gmax2505 and Gmax2509, with resolutions of 5 and 9 megapixels. In the Ace 2 Basic line, these offer a compact, affordable solution, together with the company's lenses, accessories and the Pylon camera software suite. The maximum benefit of this camera-sensor combination is delivered by the Ace 2 Pro models with the features Compression Beyond and Pixel Beyond. All 16 models are equipped with USB 3.0 or GigE interfaces and deliver frame rates from 12 to 64 frames per second.

With a starting price of €429 for the 5-megapixel global shutter version, the 16 new models can keep down the total cost of ownership of an image processing system.

www.baslerweb.com

Harrier 4k autofocus-zoom

The Harrier 18x AF-zoom HDMI 4k camera is the latest in Active Silicon's Harrier range of cameras. The model is a compact autofocus-zoom camera with real-time 4k video output and 18x optical zoom.

Fitted with an 8.4-megapixel Sony CMOS sensor, the camera provides HDMI video at 4k and HD video formats at 30 or 25fps, and simultaneous CVBS analogue output.

The camera also offers features including: real-time true, wide dynamic range; day and night mode with infrared cut filter removal; and digital noise reduction and digital image stabilisation. With its small size and high resolution, the block camera is ideal for applications where broadcast-quality UHD vision is required, such as medical and surgical imaging, high-end security and high-speed industrial inspection.

Other HD Harrier modules deliver 3G/HD-SDI, HDMI, USB3 and IP H.264 Ethernet with optical zooms of 10x to 40x.

www.activesilicon.com

EoSens 21CXP2

New from Mikrotron is the EoSens 21CXP2 camera. The camera combines a 21-megapixel global shutter CMOS sensor with the Coaxpress 2.0 interface.

The camera is supplied with a rugged, compact metal enclosure for industrial environments. It is equipped with precise triggering, 2 x 2 binning and simplified set-up for integration into factory automation, 3D laser triangulation, automated optical inspection of LEDs and PCBs, metrology, surface analysis and broadcasting systems.

The EoSens 21CXP2 is capable of acquiring 5,120 x 4,096-pixel colour or monochrome images while operating at 230fps. By deploying ROI and on-chip binning modes, the camera will capture images as fast as 5,120 x 128 pixels at 5,582 fps or 5,120 x 32 pixels at 12,764 fps. The sensor achieves 66dB dynamic range.

Sensitivity is enhanced when users apply the camera's 2 x 2 binning mode, heightening the signal-to-noise ratio up to 51dB, while enabling faster readout speeds. In addition, a large full-well capacity of 120ke⁻ permits high light signals to be captured without blooming.

www.mikrotron.de

Bobcat 320 SWIR cameras

Three new 320 x 256-pixel SWIR cameras have been introduced by Xenics to its Bobcat 320 family.

The first is the Bobcat+ 320, a high-performance SWIR camera for demanding applications with an optional extension into visible wavelengths covering 400 to 1,700nm. The camera also has two readout modes: integrate then read (ITR) and integrate while read (IWR). In IWR mode, with overlapping read and integrate phases, the user can optimise the exposure time for a given frame rate requirement. The camera also has two selectable gains, including a configuration with 60dB of dynamic range.

The second new introduction is the Bobcat 320 TE0, an uncooled (TECless) camera priced at €5,000 (unit price in volume order of 20 units). This makes SWIR more affordable for industrial applications.

The third camera is the Bobcat 320 WL, an uncooled and windowless camera to minimise the number of optical elements and consequently internal reflections. Bobcat 320 WL is suited for applications such as laser beam analysis or wavefront sensing, where unwanted reflections from optical surfaces should be limited to avoid interference fringes.

As the camera is also TECless, both the Bobcat 320 TE0 and WL are in the same price range. All three cameras have a GigE interface.

www.xenics.com

Ultris 5 hyperspectral

Cubert has extended its family of light field snapshot hyperspectral cameras with the Ultris 5. The camera uses a 5-megapixel sensor to record complete data cubes of 250 x 250 pixels and 50 spectral bands at 15Hz across its 450 to 850nm waveband. The camera is housed in a 30 x 30 x 50mm package.

The camera is suited to automated inspection, process control and robot guidance, but is especially capable of meeting the stringent demands of medical imaging and food quality applications. Snapshot data cubes take the full hyperspectral data cube in one capture without the need to combine lines or co-registered image sequences, making the real-time identification of tumour margins for surgical imaging possible and high-throughput inspections of food quality and safety.

Configurations of the Ultris 5 are available for endoscope and microscope use and custom wavelength ranges upon request.

www.cubert-gmbh.com

Cameras

AllPixa Evo line scan family

Chromasens has added three models compatible with Coaxpress 2.0 to its AllPixa Evo line scan camera family. By merging CXP 2.0 with trilinear CMOS sensors yielding resolutions up to 3 x 15,360 pixels, new AllPixa Evo 8k, 10k and 15k cameras acquire true RGB colour, mono or TDI images at a maximum line frequency of 100kHz.

The camera has four CXP 2.0 channels, each with a transfer output of 12.5Gb/s (CXP-12) or a total of 50Gb/s of bandwidth if all four channels of the camera are connected to a GenICam-compliant frame grabber. CXP 2.0 runs over a single coax cable that carries video, camera control and triggering functions with 13W of DC power at 24 VDC.

The AllPixa Evo CXP cameras have frame and line trigger options, such as an adjustable encoder input. They also offer multi-flash functionality capable of triggering up to four different flash controller channels synchronised to line acquisition. By doing so, multi-flash acquires several images with different illumination geometries or colours simultaneously in only one scan by line-multiplexing. All three cameras incorporate keystone correction and colour conversion matrices.

www.chromasens.com

Software

Halcon 21.11

MVTec Software will launch the latest version (21.11) of its Halcon machine vision software on 17 November.

One highlight of Halcon 21.11 is the addition of instance segmentation to the range of deep learning functions. This technology combines the benefits of semantic segmentation with those of object detection, and enables the pixel-precise assignment of objects to different classes. It is particularly useful in applications where objects are very close together, touch each other or overlap, such as in random bin picking.

MVTec has also improved the barcode reader for the 128/GS1-128 code, so that codes that are blurred can be read. Another improved feature is that dictionaries can now be used with fewer operator calls, thus speeding up and simplifying the development process. The same holds for improvements to Generic Shape Matching.

Finally, with the Halcon 21.11 release, users of the previous version also benefit from the advantages of Intel's OpenVino toolkit. The corresponding plug-in, which can also be used for other MVTec software products in the future, makes it possible to access AI accelerator hardware that is compatible with the OpenVino toolkit from Intel. This allows deep learning inference to run much faster on Intel processors, including CPUs, GPUs and VPUs.

www.mvtec.com

Interface card

Analogue video interface board

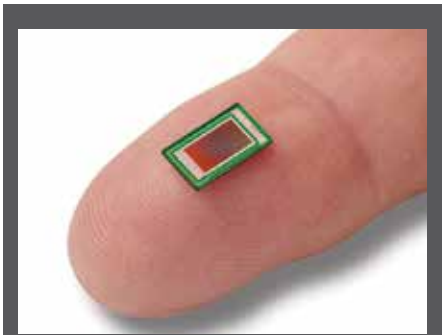
Aivion has released the TL9801, a small form factor CVBS analogue video output interface board for zoom block cameras. TL9801 can be mounted on the rear side of the camera. With a 44mm to 38mm size, the board fits the Aivion zoom block cameras AZM-FS10L, AZM-FS36-LVH and the Sony cameras FCB-EV7520A, FCB-EV7520 or FCB-EV7100. This solution is suitable for cameras where analogue CVBS PAL or NTSC output signals are required.

Depending on the camera model, the CVBS video signals from the zoom module camera are passed through a 30-pin micro coax connector, or through a 24-pin FFC connector via the TL9801. The video output standard PAL or NTSC has to be set within the camera. The TL9801 also has a USB2 UART camera control interface and the power input is regulated from 9V to 12V. The operating conditions for this board are -5°C to +60°C.

Depending on the camera model, the CVBS output signal is available on a MCX coaxial connector or a board-to-wire connector.

www.evision-systems-video.com

Image sensors



Topaz CMOS sensors

Teledyne e2v has introduced its Topaz series of industrial CMOS sensors with 2-megapixel and 1.5-megapixel resolution devices. These 1,920 x 1,080-pixel and 1,920 x 800-pixel format sensors use low noise, global shutter pixel technology to enable compact mobile designs for many applications.

Housed in a 4.45mm-wide chip scale package, the Topaz sensors have an optical array centre that matches the mechanical centre of the package, allowing for a slim camera design. This makes them particularly suitable for miniature OEM barcode engine designs, mobile terminals and sleds, IoT, contactless authentication systems, wearable devices, drones and robotics.

The sensors' 1/3-inch optical format is made possible thanks to the 2.5µm global shutter pixel that employs in-pixel correlated double sampling and dual light-guides to achieve good signal-to-noise ratio at low light, with low crosstalk for crisp images.

The sensors have a readout noise of 3.3 electrons; frame rates of 100 frames per second in 8-bit output mode; two-lane Mipi outputs; and fast wake-up mode, which decodes within 10 milliseconds after power up.

http://imaging.teledyne-e2v.com

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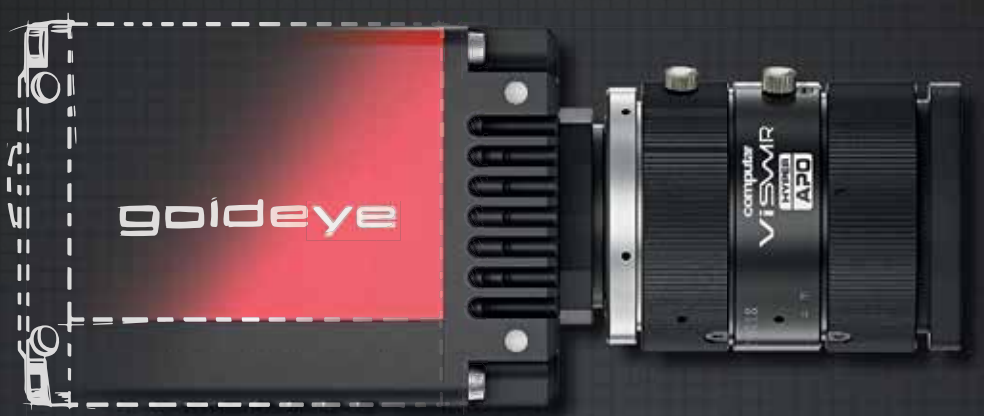

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