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Machine vision can help improve yields in agriculture

MACHINE VISION is taking root in agriculture.

The types of applications include crop and livestock health monitoring, weed control and irrigation, robotic harvesting, and quality control and sorting in food production.

And, increasingly, neural networks analyze information gleaned from images to help farmers perform routine tasks, such as applying herbicides, or make decisions, such as determining which crops or livestock need special attention to reach optimum health.

In this *Vision Systems Design* supplement, author Rien den Boer describes one such innovative use of machine vision and neural networks in aquaculture—a subset of agriculture. For the use case described in this supplement, INVE Aquaculture (Dendermonde, Belgium) hired Aris BV (Eindhoven, the Netherlands), to automate the process of quantifying and assessing live feed used to nourish juvenile farm-raised fish and shrimp.

Aris BV developed a stand-alone system, housed in a custom enclosure, that recognizes and counts live feed in a microwell plate with 12 cells. All the image processing and analysis is done locally using a YOLO object detection neural network as well as some traditional computer vison methods.

The AI-enabled machine vision tool devised for INVE Aquaculture is but one example of how machine vision and AI can improve yields in many types of agricultural operations.

Linda Wilson
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Machine vision tool assesses quality of live feed

SnappArt uses machine vision and deep learning to quantify and assess the quality of live feed used in hatcheries.

RIEN DEN BOER

INVE Acuaculture (Dendermonde, Belgium) has launched SnappArt—a tool to automate the process of quantifying and assessing live feed, which is used to nourish farm-raised fish and shrimp.

SnappArt replaces conventional manual counting with a method that requires significantly less time and effort while delivering greater accuracy.

Aris BV (Eindhoven, the Netherlands), a machine vision systems integrator specializing in work for the horticulture and meat processing industries, developed the SnappArt System on behalf of INVE Aquaculture.

The Eurostars program, which provides funding for R&D projects that lead to innovative products, supported the development of SnappArt, which is now available commercially.

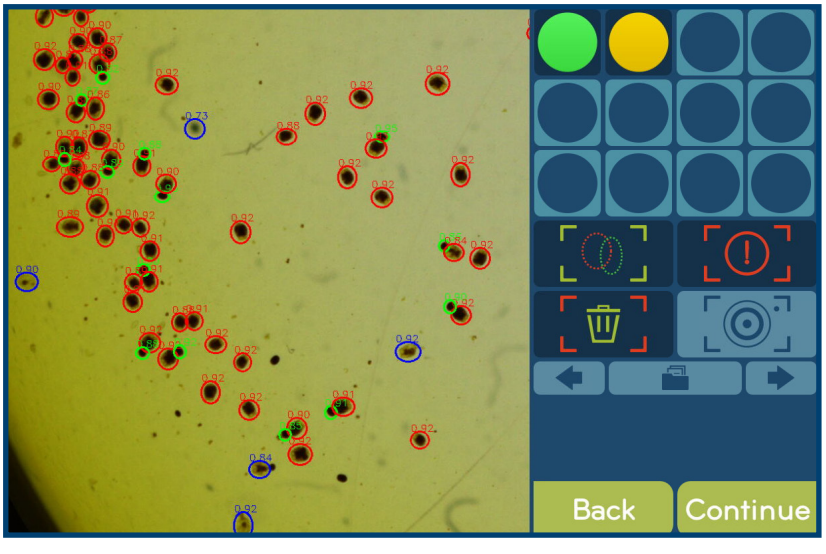

FIGURE 1. Using machine vision and AI, SnappArt automates the process of quantifying and assessing live feed used in hatcheries, such as the Rotifers pictured here. *(Courtesy of Aris BV)*

The fish farming process

Live feed such as Artemia are hatched in saltwater to produce a certain larvae stage (nauplii), which are rich in nutrients, to feed a wide variety of juvenile fish and shrimp. Ideal fish and shrimp growth fundamentally depends on meticulous feed management.

The fish farming industry is growing due to increasing global demand for seafood combined with overfishing in wild populations, driving the need for alternative, sustainable sources of fish. Aquaculture offers a controlled environment that can significantly enhance fish production and reduce the industry's impact on the environment.

Fish farming starts at hatcheries where larvae are hatched from fish eggs and are then nurtured in controlled environments until they are robust enough to survive in larger farming operations. The live feed is an essential nutrient to the larvae in these hatcheries.

Shortcomings of manual quality control

Without an automated process to inspect and assess live feed, quality control of live feed such as Artemia and Rotifers relies on labor-intensive and error-prone procedures conducted on limited sample sizes. Typically, Artemia and Rotifers are counted manually under a microscope, a job that skilled staff can do in five minutes per sample.

Besides inconsistent feed administration, bad quality control can ultimately lead to poor growth and susceptibility to diseases for the fish and shrimp and economic losses for the marine hatcheries and farms, and negative environmental consequences for society. Moreover,

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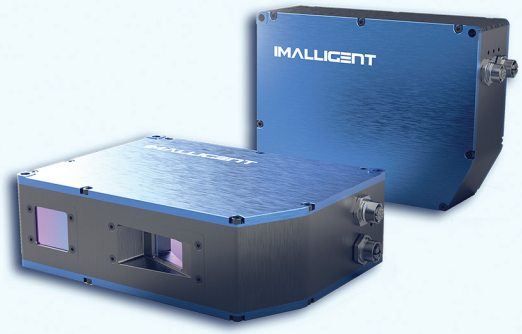

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skilled staff are hard to find, and counting methods are not globally standardized.

How the vision-enabled automated system works

At the heart of SnappArt lies its AI-driven image analysis software, ensuring rapid and precise analysis of samples. Coupled with an intuitive touch-screen user interface, the device facilitates seamless operation for hatchery personnel.

The initial steps in the automated process with SnappArt are like those used in manual counting methods. Operators first take a subsample from a hatching tank to estimate the density, stages, and quality of the feed. These are transferred to a microwell plate with 12 cells, which equals one sample. Each well has a diameter of 20 mm and contains as little as 350 uL sample volume.

The SnappArt device is optimized on this well size. It uses a 12 MPixel camera, the MER2 series from Daheng Imaging (Beijing, China) with a Sony IMX226 sensor. Because of the high magnification, a C-mount macro lens from NEW TRY (Shenzhen, China) was chosen to obtain good optical performance of 6.6 um per pixel from the center to the edge of the well.

All the image processing is done locally on a NVIDIA (Santa Clara, CA, USA) Jetson Orin Nano module, which employs a YOLO object detection neural network as well as some traditional computer vison methods to recognize and count the live feed.

The individual components of the device are housed in a custom plastic casing designed to withstand the saline environment of hatcheries. Additionally, the carrier board from Forecr.io (Tallinn, Estonia) is treated with a conformal coating for protection against adverse conditions.

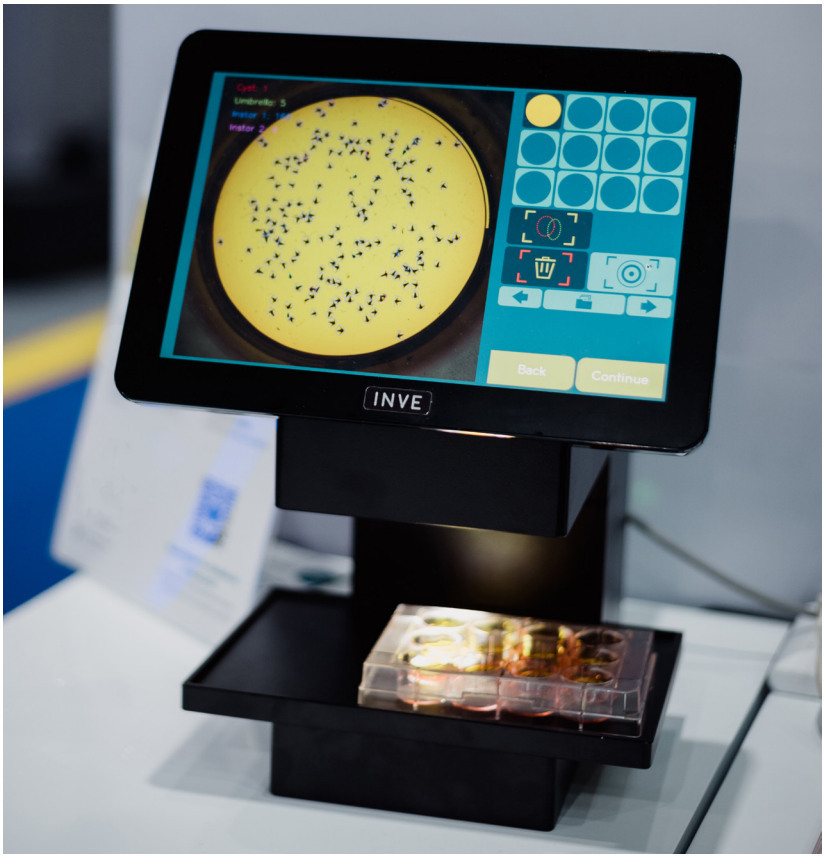

FIGURE 2: SnappArt can count a sample in less than one minute and then results are available immediately. *(Courtesy of Aris BV)*

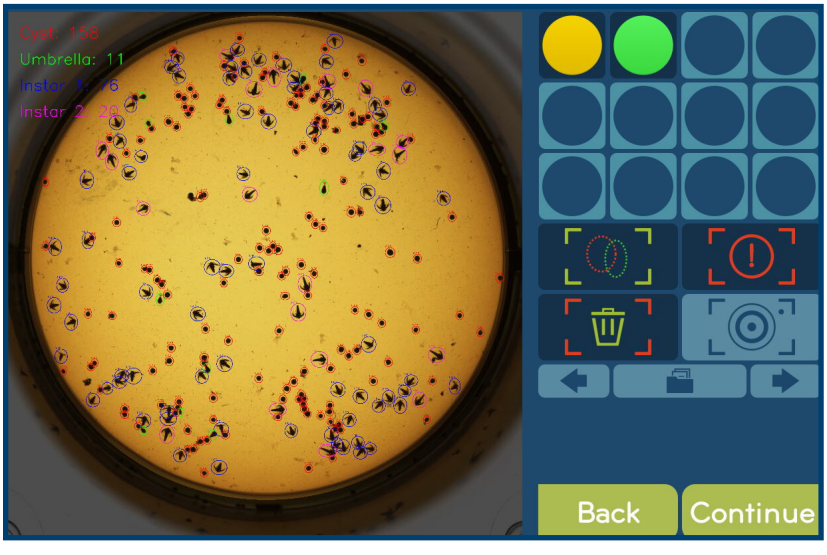

FIGURE 3. One well of a 4X3 well plate with a 350 uL sample from an Artemia hatching tank. *(Courtesy of Aris BV)*

SnappArt can count a sample in just over a minute and then results are available immediately. They can be read from the screen, which might be enough for remote or small hatcheries, or the cloud.

For the cloud option, the counts of each separate stage and each well of the Artemia or Rotifers are sent to a Microsoft Azure database using a MQTT protocol over Wi-Fi. The data are then uploaded to a Microsoft Power BI application with customizable dashboards to analyze statistics about quality over time. The data is updated continuously.

As an added benefit of the system, hatcheries could use data collected over time to help measure overall productivity outcomes as well as any anomalies in the fish and shrimp.

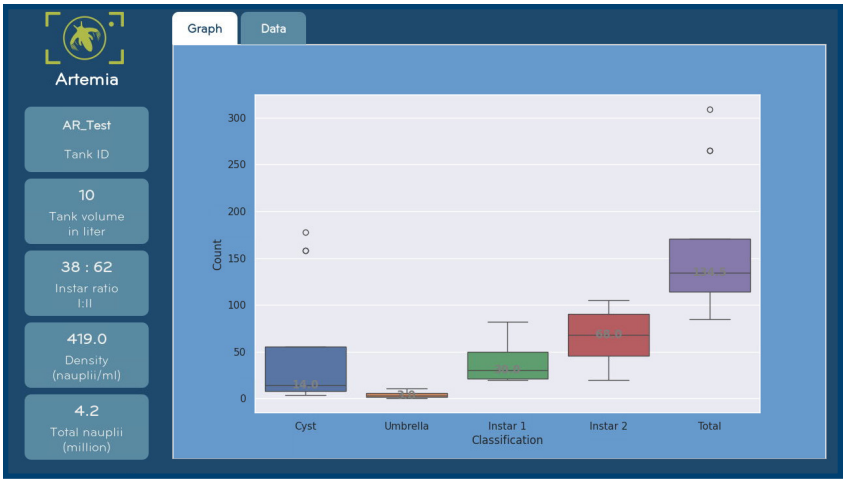

FIGURE 4. Overview of the results screen for a sample of Artemia. *(Courtesy of Aris BV)*

Development of the neural networks

For the development of the deep learning object detection networks, data were collected from multiple locations worldwide and labelling was discussed with multiple experts. Interestingly, the identification of the different stages of live feed development was not standardized. This led INVE and Aris to develop uniform definitions of the stages, and multiple locations and experts agreed on these definitions.

On the other hand, the sample preparation method is now standardized, and the resulting data are well conditioned. For this reason, the neural networks were able to classify Artemia and Rotifers successfully with modest datasets of a few hundred images.

For the annotation of images, CVAT, an open-source computer vision annotation tool, was used. Aris used an active learning approach in which predictions of models are used as a pre-annotation. This saved time because the models already had an accuracy above 90% early in the development process and only few annotations had to be added or corrected. The final accuracy is above 98%.

> SnappArt can count a sample in just over a minute and then results are available immediately.

Also, INVE Aquaculture and Aris have kept a representative dataset, which they plan to use to validate performance after each update to the models. Validated models are updated over a cloud portal.

SnappArt signifies a transformative shift in live feed management, offering hatcheries a system that helps them enhance profitability, optimize growth ratios, and elevate overall production efficiency.

Rien den Boer is general manager of Aris B.V. (Eindhoven, Netherlands).

Advances in SWIR imaging

SWIR imaging systems accomplish machine vision tasks conventional systems can't, such as identifying moisture content in fruit and vegetables or liquid fill levels in bottles.

CORY BOONE AND NICK SISCHKA

Machine vision using short-wave infrared (SWIR) wavelengths can accomplish unique tasks that would be difficult, or even impossible, using conventional imaging systems. For example, SWIR imaging can see through plastic containers that are opaque to visible light to measure their contents (see Fig. 1). Advances in SWIR camera sensors have significantly reduced their cost in recent years, opening up a new wave of SWIR machine vision applications. However, some of the newest SWIR sensors have prioritized shrinking pixel sizes to maximize resolution, but this has driven the cost of the sensors back up to where it used to be. While SWIR imaging is a powerful tool for extracting information that cannot be obtained through conventional imaging, focusing on SWIR wavelengths introduces new challenges for the optics used in these systems.

This article will dive into these trends in SWIR imaging and how they are shaping the machine vision landscape.

A new generation of sensors has made SWIR imaging more accessible

Recent developments in SWIR imaging sensor manufacturing led to a new generation of affordable sensors covering visible and SWIR wavebands from 0.4 to 1.7 µm. These new sensors also do this with low noise and high quantum efficiency—a term that describes the efficiency of incident light being converted to electric signals. While low noise and high quantum efficiency have been available in sensors designed for visible wavelengths for years, they have not been nearly as available for SWIR wavelengths until more recently.

The traditional sensors for SWIR applications are based on indium gallium arsenide (InGaAs), and they have been used to achieve high performance over SWIR wavelengths for years. However, they are difficult to manufacture and, therefore, expensive. They still achieve the best efficiency and sensitivity of all available SWIR sensor types, but their high manufacturing cost often makes them cost-prohibitive. The newer, more affordable generation of SWIR sensors do not achieve quite as high performance as InGaAs sensors, but their resolution, noise, and efficiency are often more than sufficient for many imaging systems—at a significantly lower cost.

Key considerations for SWIR imaging

Knowing which SWIR wavelengths are best for your application, from the beginning, is difficult to determine because our eyes cannot detect SWIR wavelengths. We do not have strong intuition regarding SWIR imaging.

FIGURE 1. SWIR cameras and lenses can look through some objects that are opaque under visible light, like this white bottle, to reveal the hidden substances inside them. *(Photos & images/Edmund Optics)*

When using visible wavelengths, for example, it is typically simple to guess whether a red light source will highlight red components to enhance contrast or if blue illumination will make the background appear darker. When creating a SWIR machine vision system, the system designer often needs to determine the spectral properties of all materials being inspected in advance, as interactions with SWIR light are not as intuitive.

One way to determine the correct SWIR wavelengths needed for an application is to find existing documentation on the material being imaged. Plots of its absorbance

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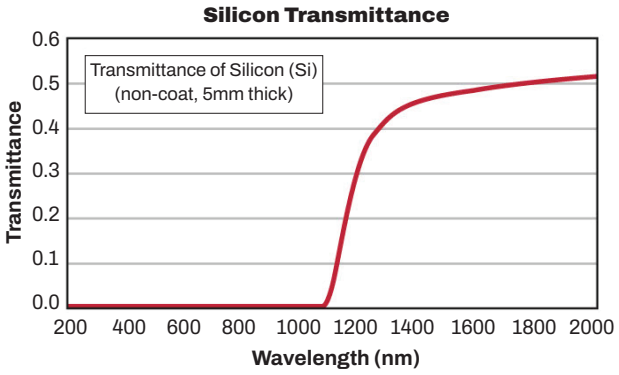

FIGURE 2. Transmittance plot for silicon that shows a high level of transmittance for wavelengths over 1100 nm.

FIGURE 3. SWIR imaging is great for moisture identification because of water's SWIR absorption, which is useful in fruit inspection. This makes moisture visible that would be otherwise very difficult to identify.

or transmittance show which wavelength(s) will appear bright or dark and which will give you the best contrast.

For example, silicon is known to be transparent to SWIR wavelengths longer than 1100 nm (see Fig. 2). Because of that, SWIR imaging is often used for various types of silicon defect identification including crack detection, bonding inspection, spotting internal defects on the wafers themselves, or detecting defects in circuits formed with different materials on silicon substrates.

A SWIR hyperspectral camera and a broadband illumination source can also be used during the system development phase to figure out the best wavelength(s) to focus on. This captures images covering many different wavelengths, as well as a spectral signature for each pixel. Using this information, the system designer can identify if one or several wavelengths of interest have a strong peak of absorption or transmission that allows the machine vision system to maximize contrast and accomplish its task. An example is shown later in the SWIR imaging applications section.

While the hyperspectral camera and broadband light source will likely be expensive, they will identify the key wavelength(s) of interest. Then, when the final system is created in higher volumes, a simpler SWIR camera and illumination source optimized for this specific wavelength are used, resulting in a more cost-effective final system.

When using the hyperspectral light source and camera for product development, sometimes contrast cannot be maximized by using a single wavelength or small group of wavelengths. In those cases, the final system may also need to use more complicated hyperspectral systems. In addition to more expensive cameras and illumination sources, this also increases the complexity and cost of the imaging lenses used. However, this is required in some material sorting applications like plastic recycling, food quality inspection , and foreign material detection.

SWIR imaging applications

A common application of SWIR in machine vision is identifying moisture (see Fig. 3). Water has an absorption peak around 1450 nm that appeas very dark to a SWIR imaging system. This is useful in many applications like moisture detection in fruit inspection, food processing, bottle fill level inspection, and agricultural applications.

Not all liquids absorb SWIR wavelengths the same way water does, allowing SWIR imaging to easily differentiate liquids that may look identical under visible inspection (see Fig. 4).

Unique challenges for SWIR imaging lenses

Many imaging lens assemblies designed for use with visible light can also transmit some SWIR radiation, but you can significantly increase the performance of your SWIR system by using lenses designed specifically for this wavelength range. This changes the waveband that the lens design is optimized for, the glass types used to maximize SWIR light throughput, and the coatings applied to the lens elements.

Materials like germanium, silicon, sapphire, and zinc selenide have higher transmission for SWIR wavelengths and can improve SWIR imaging performance, but they are more expensive than the glass types used in conventional imaging lenses.

The newest SWIR sensors are driving prices back up

The newest SWIR sensors that have entered the market are reversing the trend of making SWIR applications

more accessible. They offer smaller pixel sizes than other available sensor types and increase system resolution, but this drives costs back up to where they were before. Not only do they make SWIR cameras more expensive, but they place more demands on the imaging lenses used with them and make those more expensive as well. In order to achieve resolutions high enough to take full advantage of these new sensors, optical designs become more complicated and tolerances are tightened.

The cost of SWIR optics is already high because of the unique materials required. This two-fold increase in SWIR system costs associated with the newest SWIR sensors will likely result in the newest sensors not having as significant an impact on the machine vision landscape as the previous generation of SWIR sensors that made these applications more accessible.

SWIR imaging can accomplish impressive feats unachievable with conventional visible imaging, and the decreased cost of SWIR sensors in recent years has made SWIR imaging more accessible than ever before. But while the smaller pixel sizes of the newest SWIR sensors will benefit the highest-performance SWIR systems, for many, the newest sensors indicate a return to SWIR imaging being cost-prohibitive. Because of this, the newest sensors may be ignored by many machine vision system systems designers and fail to dethrone the previous wave of more affordable SWIR sensors.

FIGURE 4. Isopropanol, water, and acetone look essentially identical under visible light, but SWIR imaging results in high contrast between them, making it easy to differentiate between them.

Cory Boone is technical marketing manager and **Nick Sischka** is the director of imaging product development, both at Edmund Optics (Barrington, NJ, USA).

Federal Package uses smart camera system to inspect deodorant products

Edge-based AI-enabled camera system from Cognex spots cosmetic issues with plastic containers used for solid deodorant.

LINDA WILSON

Federal Package, a contract manufacturer of personal care products, deployed an edge-based AI-enabled camera system to inspect the outside of plastic containers used for solid deodorant.

The company purchased the camera system—the In-Sight 2800 from Cognex (Natick, MA, USA)—in 2022 to detect deodorant drips on the outside of the containers. Over time, however, the AI-enabled algorithms learned to detect other cosmetic imperfections with the containers.

And, while the project began with plastic deodorant containers, engineers have since purchased additional camera systems for inspection processes on other production lines.

Based in a Minneapolis suburb, 70-employee Federal Package (Chanhassen, MN, USA) specializes in producing solid deodorants, sunscreen, lotions, serums, and lip balm. In fact, it is the largest manufacturer of lip balm in the United States, producing 15 million tubes a year, explains Jeffrey Martin, marketing director at Federal Package.

"We do a lot of household brands and all the way down to the smaller, emerging independent brands," Martin says.

FIGURE 1. Vision system classifies cosmetic defects on deodorant containers. *(Courtesy of Cognex Corporation)*

As a contract manufacturer, Federal Package either works with a client's existing formula, fragrance, container, and packaging, or helps develop those elements to create a new product.

Before the deodorant inspection project, Federal Package used vision systems exclusively for optical character recognition (OCR) such as for inspecting lot numbers. "This was the first time we used it for some other kind of purpose," Noah Leuer, manufacturing engineering manager, explains.

FIGURE 2. Federal Package developed an automated process to spot drips and other imperfections on deodorant containers. *(Courtesy of Cognex Corporation)*

Goals of the vision system

The decision to add a machine vision system to replace human inspectors for deodorant containers was part of an overall plan to automate the entire line.

There were two primary goals for the automated inspection process, which Federal Package's employees implemented without outside integrators or consultants.

First, engineers wanted a fast and easy process to switch from producing one stock keeping unit (SKU) to another one. "We've done at least 60 to 80 different types of fragrances on that line of the same product. So, the colors on the front change and the names change, and we didn't want to have to set up the

FIGURE 3. To inspect deodorant containers, Federal Package set up two cameras, with each one taking a picture of one side of a deodorant container as it moves through the line. *(Courtesy of Cognex Corporation)*

camera every single time we do a new product because that would be very annoying," Leuer says.

The second goal was reliability. Federal Package wanted the new system to catch deodorant drips with a high rate of accuracy.

An edge-based, AI-enabled system

The solid deodorant products inspected on the line with the camera system are from Native (San Francisco, CA, USA) an all-natural brand. The products come in many fragrances including limited editions, and each one has a unique screen-printed label. There also are versions of the product for sensitive skin.

The deodorant products from Native have labels that are screen printed onto the plastic containers, which arrive at Federal Package ready-made from another supplier.

Federal Package chose two monochrome In-Sight 2800 2D vision systems for the deodorant line. "The monochrome works nicely for this solution because we are not looking for color," he adds.

The system is self-contained. It snaps and processes images, produces results, and sends instructions directly to other pieces of automation equipment without requiring a PLC. It uses a combination of AI- and rules-based algorithms to solve error-proofing projects, such as categorization.

"I don't have to have any other logic, it's all done on the camera, which is really convenient for us," Leuer says.

How the manufacturing and inspection process works

For the deodorant line, containers, which are positioned upside down and eight across per row, are filled with liquid deodorant. The containers then go through a cooling tunnel, which solidifies the product.

Afterward, a blade pulls the containers onto a single-track conveyor and the inspection process begins. Federal Package set up two Cognex cameras, with each one taking a picture of one side of a deodorant container as it moves through the line.

Because Federal Package doesn't control the orientation of each container as it passes by the cameras, they each take an image of whatever side is facing them.

There are four decision points for the system: front good, front bad, back good, back bad.

The cameras work at a rate of 100 containers per minute.

When products do not pass inspection, the smart camera sends a signal to a relay device, which then alerts an air cylinder to kick the product off the line and into a bin.

Even though the system is self-contained, Leuer says they decided to connect a laptop to the cameras, so employees can periodically check

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the images displayed on the screen as the products go by. They also can use the laptop to make changes to the system.

Automation equipment in other work cells add a plug to the bottom of each container to seal it and weigh each product. A pre-existing OCR process reads lot codes on the bottom of the containers using a CV-X camera from Keyence (Itasca, IL, USA).

Training the embedded vision algorithms

Cognex markets the product as an edge-learning solution because it is packaged with a set of preexisting algorithms for factory automation tasks such as presence/absence detection, sortation, and character reading. While Cognex completed training of the algorithms as part of the development process, end users do additional training with images specific to their use cases.

In Federal Package's case, employees used about 50 images per category: front good, front bad, back good, and back bad, Leuer says. "It was kind of intense to set up, but once we did, it works for a lot of different (Native deodorant) products."

At this point, Leuer says he is called in to address an issue with the system "once every three months." Otherwise, Federal Package's maintenance staff operates and monitors the system, which detects errors with nearly 100% accuracy.

Martin says he is surprised by the errors that the system catches. "I've looked at the pieces that get kicked out, and there's been a couple times where I've been kind of hard pressed to see what the defect is."

In addition to the drips, Leuer says the cosmetic imperfections that the system now spots include nicks in the plastic and errors in the screen-printed labels, such as those that are upside down or have smudged letters. "We've caught issues that we were not necessarily looking for just because it is looking for anything that is not normal," Leuer explains.

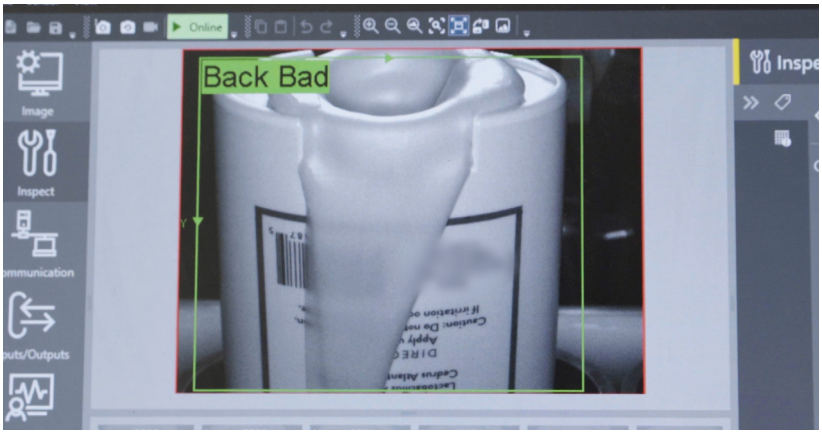

FIGURE 4. Federal Package trained the In-Sight 2800 from Cognex using images of deodorant containers in four categories: front good, front bad, back good, back bad. *(Courtesy of Cognex Corporation)*

Adding machine vision to other manufacturing processes

Federal Package's engineers have since deployed the In-Sight 2800 to inspect adhesive labels affixed to the outside of containers. These labels are used for many different products for myriad customers.

They chose the color version of the camera for this application because it recognizes label edges on containers of many different colors more easily than the monochrome version. For example, recognizing a white label on a white container would be more difficult with a monochrome camera, Leuer says.

After the automated inspection of the adhesive labels, employees inspect the containers looking for defects the cameras may have missed.

There are numerous labeling machines at Federal Package for adhesive labels, including those that affix security labels to the tops of containers, those that affix front and back labels on a container, and still others that apply a single label on round containers.

"There's a lot that can go wrong: bubbles, wrinkles, SKU issues," Leuer says.

In this application, the system catches 80% of the defects.

Leuer says Federal Package decided not to invest the time to improve the system's performance to the level achieved with the Native products because of employees' involvement in the inspection process. "We could spend more time to get them perfect, but we would gain very little and waste time," he explains.

So far, Federal Package has added the cameras to four labeling machines and plans to add them to other machines over time.

Overall, Leuer says, the process has persuaded him that machine vision should be an element of every new automation project at the plant. "We're adding vision to basically every project that we do now because it's so convenient for quality inspections," he says.

Automated inspection system added to bottle cap manufacturing process

A machine vision-based system inspects ceramic flip top beer bottle caps.

JIM TATUM

A German bottle cap manufacturer has added a machine vision-based automated inspection system to check for print and quality errors on beverage bottle caps made for beer breweries.

Each bottle cap is made of ceramic and is attached to a stopper that inserts into the neck of the bottle. The cap and stopper are held in place by an apparatus that includes a small bar that lays across the top of the cap and is attached to a hinged gasket. When the bar is flipped up, the gasket pulls the cap and stopper out of the neck, opening the bottle.

Traditionally, inspection of the bottle caps was performed by human inspectors, who manually inspected them for any flaws, either in the bottle cap materials or with the printing on the top of the cap. However, because the manufacturing process is automated, manual inspection is less efficient and more error prone.

So, the challenge was to develop an inspection system that not only can handle quality control requirements at the speed the production process requires but is easily operated, maintained, and simple to reconfigure and change, says Thomas Kelz, who is responsible for quality technology at K&S Anlagenbau GmbH (Lengenwang, Germany), the automation solutions company that developed the inspection system.

"Our aim is to make automated processes as safe and as reliable as possible," says Kelz. "Our approach is to take the 'hectic' out of production processes."

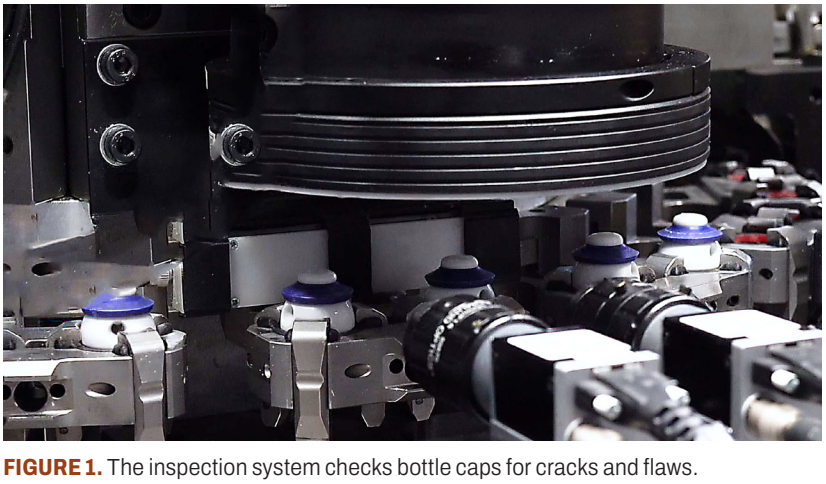

FIGURE 1. The inspection system checks bottle caps for cracks and flaws. *(Photos/K&S Anlagenbau)*

Integrating a machine vision-based inspection system into the production process

The inspection system is one application within the bottle cap manufacturing process. The machine vision processes in the system, such as the inspection system, are controlled by a PC onsite that has a graphical user interface capable of running multiple applications simultaneously. To communicate easily with other components in the system, the machine vision software has interfaces for OPC Unified Architecture, a cross-platform, open-source standard for data exchange from sensors to cloud applications, and Profinet, a technical standard for data communication over industrial Ethernet, which is especially designed for fast data delivery under tight time constraints. These interfaces allow consistent data exchange between the various components in the manufacturing process.

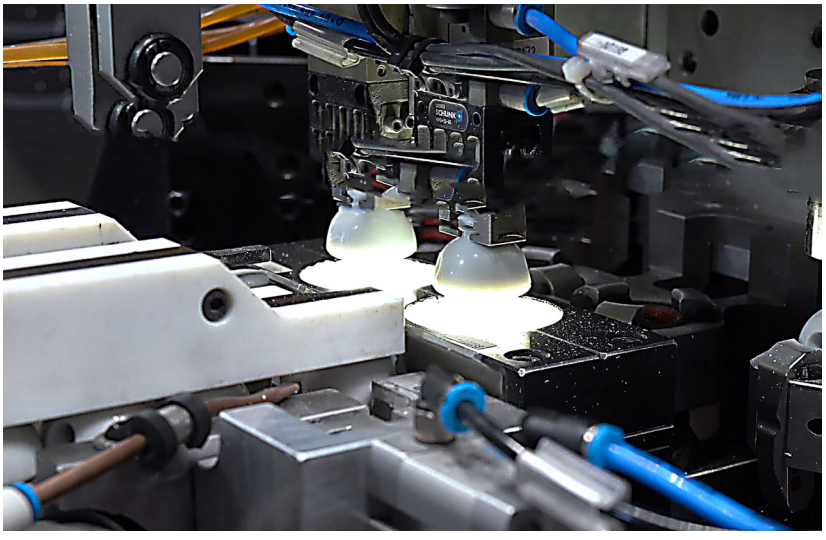

FIGURE 2. The system inspects the bottle cap tops for print and image errors.

The bottle caps move through the production process via a conveyor system. Six Basler ACA2040-35GC cameras equipped with Basler ACC-LEN-200003567 lenses, and one Basler CXP-12 EVAL BOA4096-93 camera equipped with an Opto Engineering PCCDO23 lens, are deployed along the line and connected, via Ethernet cables, to a Spectra (Reutlingen, Germany) industrial PC. the inspection system checks each bottle cap for correct shape, flaws in the ceramic top and stopper cork materials, and ensures the printing on the top of each cap is correct.

"There are several cameras connected to this computer vision system and each camera is basically performing its own inspection tasks," notes Markus Heber, software integrator and general manager of Computer Vision Solutions (Langenzersdorf, Austria), who worked with K&S Anlagenbau to develop this inspection system. While the team used Basler cameras for this project, the system can work with any camera that has GigE Vision or GenICam interfaces, he says.

"The entire system is automated," Heber says. "If it says the bottle cap is OK, then it continues in the production process. If it is not OK, then it is immediately redirected to another area, where a human worker will follow up."

The PC is equipped with software, developed and written in-house by K&S Anlagenbau, that controls the inspection system. For the machine vision applications involved, Heber integrated MVTec (Munich, Germany) Halcon machine vision software into the control software using MVTec's HDevEngine, a machine vision library that acts as an interpreter to load and execute the machine vision algorithms, Heber says.

"It acts as the image processing backend and communicates with the GUI in the background," Heber says.

How the inspection system works

The inspection system uses matching, classification, and blob analysis technologies to perform the inspection analysis tasks. First, a camera captures an image of a bottle cap and transmits it to the computer. The computer, using the Halcon software, utilizes shape-based matching technology, which uses a pre-trained matching image—in this case, an image of a perfectly manufactured and printed bottlecap—to compare to the image captured by the camera. The pre-trained image is matched with the image captured by the inspection

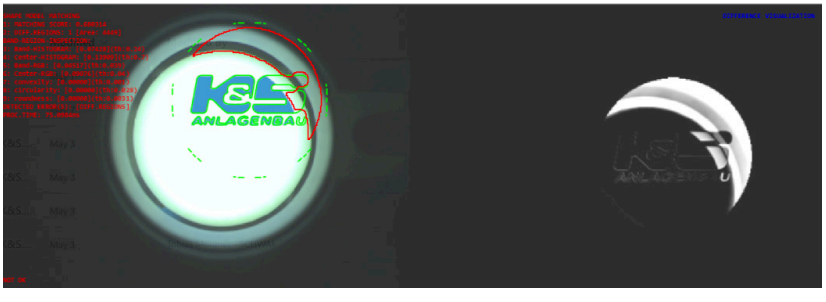

FIGURE 3. The GUI shows that the imprint on the bottle cap is "not ok."

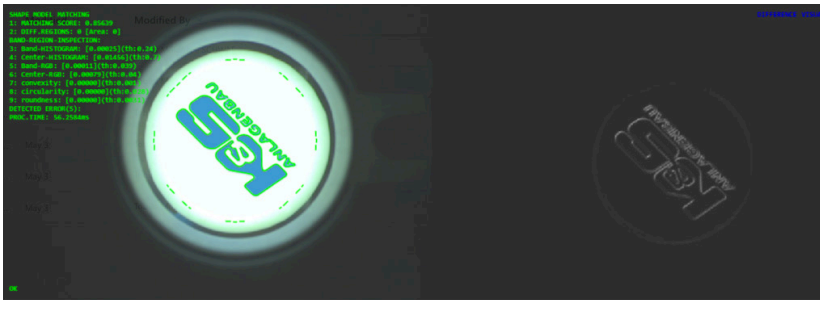

FIGURE 4. The GUI showing that the imprint on the top of the bottle cap is "OK."

camera, allowing the position and alignment to be determined with sub-pixel accuracy, Heber says. "This works even if the image is rotated, scaled, distorted, partially covered, or subject to non-linear lighting fluctuations," he says.

The system then uses classification technology to look for errors in the image being inspected. Such flaws and errors can include color deviations, missing or incorrect edges, and/or flawed structures. Corresponding deviations are segmented and analyzed using blob analysis technology, which essentially is an analysis of consistent image regions, known as blobs. In this case, the blobs are connected pixels with similar brightness, Heber says.

> There are several cameras connected to this computer vision system and each camera is basically performing its own inspection tasks.

If the system detects a defect, it displays the image in the GUI, highlighting that defect in color. This allows anyone monitoring the system to recognize the type and extent of the defect. For example, "if a bottle cap is not printed correctly, the HALCON software informs the system accordingly and the component is automatically ejected," Dr. Heber explains.

The system does not store images of the inspected items, Heber says. If the bottle cap passes inspection, the image captured for inspection by the system is deleted. If an error or defect is detected, the image is saved until the issue is resolved, then deleted.

Results

"The feedback we have received has been very positive," Heber says. Indeed, Heber and Kelz say the system can inspect 120 bottle caps per minute and has operated without any major issues since it was implemented in the bottle cap production facility two years ago.

The system is designed to be versatile and easily adaptable; Heber says he is working with K&S Anlagenbau on possible 3D applications for this system.

CAMERA MANUFACTURERS

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
1stVision Inc Andover, MA, USA; 978-474-0044; www.1stvision.com; info@1stvision.com								
Allied Vision Goldeye SWIR GigE and Camera Link Series	InGaAs	M	Area array	320 × 256, 640 × 480	SWIR	Digital I/O, Ethernet, GigE, Camera Link	344	106 MB/s
Allied Vision Mako and Alvium GigE and USB3 Series	CMOS	C+M	Area array	VGA–31 MPixels	NIR, VIS	Digital I/O, Ethernet, GigE, USB3, MIPI-CSI2	≥1000	400 MB/s
IDS Imaging GigE, 5GigE, and USB3 Series	CMOS	C+M	Area array	VGA-45 MPixels	NIR, VIS	Digital I/O, Ethernet, GigE, 5 GigE, 10 GigE, USB3	396	500 MB/s
Teledyne Dalsa Linea GigE, 5GigE, and Camera Link Line Scan Series	CMOS	C+M	Line scan	2048 × 1–32, 768 × 1	NIR, SWIR, VIS	Digital I/O, Ethernet, GigE, 5 GigE, Camera Link	—	≥80 kHz
Teledyne Dalsa Genie Nano GigE, 5GigE, Camera Link, and CoaXpress Series	CMOS	C+M	Area array	VGA–67 MPixels	LWIR, NIR, VIS	Digital I/O,Ethernet, GigE, 5 GigE, 10 GigE	≥1000	1608 MB/s
Active Silicon Ltd Iver, UK; 44-1753-650600; www.activesilicon.com; sales@activesilicon.com								
Harrier 10x AF-Zoom Camera	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS, 3G/HD-SDI, USB/HDMI, HDMI, IP H.264	60	—
Harrier 36x AF-Zoom Camera Global Shutter	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS, HD-SDI, USB/HDMI, HDMI, IP H.264	30, 60	—
Harrier 55x AF-Zoom Camera	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS, 3G/HD-SDI, USB/HDMI, HDMI, IP H.264	30	—
Harrier 18x AF-Zoom HDMI 4K Camera	CMOS	C+M	Area array	4K (3840 × 2160), 1920 × 1080	VIS	HDMI, CVBS	30 (4K), 60 (Full HD)	—
Harrier 23x AF-Zoom IP 4K Camera	CMOS	C+M	Area array	4K (3840 × 2160), 1920 × 1080	VIS	IP H.265/H.264	30 (4K), 60 (Full HD)	—
Tamron MP3010M-EV	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS, HDMI, CVBS, USB 3, 3G/HD-SDI, HD-VLC, H.264	60	—
Sony FCB-EV9500L	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS, USB 3, HDMI, 3G/HD-SDI, HD-VLC, CVBS, H.264	60	—
Sony FCB-EV9520L	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS , USB 3, HDMI, 3G/HD-SDI, HD-VLC, CVBS, H.264	60	—
Alkeria Srl Cascina, (PI), Italy; 39-050-778-060; www.alkeria.com; sales@alkeria.com								
ARIA	CMOS	C+M	Area array	0.4–2 MPixels	NIR, VIS	USB3	522	—
CELERA One	CMOS	C+M	Area array	2–12 MPixels	NIR, VIS	USB3	175	—
NOTA	CMOS	C+M	Area array	2–12 MPixels	VIS	USB3	161	—
CELERA P	CMOS	Polarized	Area array	5 MPixels	VIS	Dual-USB3	154	—
NECTA	CMOS	C+M	Line scan	2–8K	NIR, VIS	USB3	—	95 kHz
Allied Vision Technologies GmbH Stadtroda, Germany; 49-36428-677-0; www.alliedvision.com; info@alliedvision.com								
Alvium USB3 and CSI-2	CMOS, InGaAs	C+M	Area array	0.3–24.6 MPixels	NIR, UV, VIS, VSWIR	USB3, MIPI CSI-2	≤691	—
Mako	CCD & CMOS	C+M	Area array	0.3–12.4 MPixels	NIR, VIS	GigE	≤286	—
Manta	CCD & CMOS	C+M	Area array	0.3–24.6 MPixels	NIR, VIS	GigE	≤286	—
Prosilica GT	CCD & CMOS	C+M	Area array	1.2–31.4 MPixels	NIR, VIS	GigE	≤53.7	—

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Allied Vision Technologies GmbH Stadtroda, Germany; 49-36428-677-0; www.alliedvision.com; info@alliedvision.com								
Goldeye	InGaAs	M	—	0.1–1.3 MPixels	SWIR, VSWIR, XSWIR	Camera Link, GigE	≤344	—
Bonito PRO	CMOS	C+M	Area array	26.2 MPixels	NIR, VIS	CoaXPress	79.7	—
Alvium G1	CMOS, InGaAs	C+M	Area array	0.4–24.6 MPixels	VIS, VSWIR	GigE	≤276	—
Alvium G5	CMOS, InGaAs	C+M	Area array	0.5–24.6 MPixels	UV, VIS, VSWIR	5GigE	≤691	—
Alvium FPD-Link III and GMSL2	CMOS	C+M	Area array	0.4–24.6 MPixels	NIR, UV, VIS	MIPI CSI-2	≤499	—
Balluff Inc Florence, KY, USA; 859-727-2200; www.balluff.com; balluff@balluff.com								
BVS 3D-RV0	3D	C+M	Area array	1280 × 960	VIS	Digital I/O, GigE	bis 25	—
BVS CA-BN2	CMOS	C+M	Area array	1456 × 1088–5328 × 4608	VIS	Digital I/O, PCI Express	24.1–226.5	—
BVS CA-SF2	CMOS	C+M	Area array	728 × 544–5328 × 4608	VIS	Digital I/O, RS-232, USB3	15.4–436.9	—
BVS CA-GXT	CMOS	C+M	Area array	5328 × 3040–5328 × 4608	VIS	Digital I/O, 10GigE, RS-232	50.5–76.5	—
BVS CA-GX2	CMOS	C+M	Area array	1456 × 1088–6480 × 4856	VIS	Digital I/O, GigE	7.5–149.9	—
BVS CA-GX0	CMOS	C+M	Area array	728 × 544–5544 × 3692	VIS	Digital I/O, GigE, RS-232	5.8–299.8	—
BVS 3D-RV1	3D	M	Area array	4096 × 3008	VIS	—	9	—
BVS CA-BN4	CMOS	C+M	Area array	5328 × 4608	VIS	Digital I/O, PCI Express	55.5–234	—
Basler AG Ahrensburg, Germany; 49-4102-463-500; www.baslerweb.com; sales.europe@baslerweb.com								
Basler ace 2	CMOS	C+M	Area array	640 × 512–5328 × 4608	SWIR, UV, VIS	GigE, 5GigE, USB3, CXP-12	≤240	—
Basler ace U	CMOS	C+M	Area array	640 × 480–5473 × 3648	VIS	GigE, USB3	≤751	—
Basler ace L	CMOS	C+M	Area array	4096 × 2160–4096 × 3000	VIS	GigE, USB3	≤42	—
Basler boost	CMOS	C+M	Area array	1936 × 1464–13,376 × 9528	VIS	CXP-12	≤400	—
Basler blaze	CMOS	M	Area array	640 × 480	NIR	GigE	30	—
Baumer Optronic GmbH Radeberg, Germany; 49-3528-4386-0; www.baumer.com/vision; sales.cc-vt@baumer.com								
CX/CX.I cameras	CMOS	C+M	Area array	1280 × 1024–5312 × 4592	POL, UV, VIS	GigE, USB3, Digital I/O, power outputs	≤224	—
CX.XC cameras	CMOS	C+M	Area array	2448 × 2048–5312 × 4592	SWIR, VIS	GigE, Digital I/O	≤24	—
LX series	CMOS	C+M	Area array	800 × 620–9244 × 7000	NIR, UV, VIS	10GigE, Dual GigE, GigE, Camera Link, Digital I/O, power outputs	≤1622	—
AX series	CMOS	C+M	Area array	2048 × 1536, 2448 × 2048	VIS	Ethernet, RS232, Micro HDMI, USB, SD slot, Digital I/O, power outputs	≤77	—
IX series	CMOS	C+M	Area array	1280 × 800	VIS	GigE, Digital I/O	≤50	—
BGFRM Technology (Imalligent) Shanghai, China; 86-4001828892; www.imalligent.com; info@imalligent.com								
TRS-010B	3D	M	Area array	5120 × 5120	VIS	GigE	1	—
VRD-1300B	3D	C+M	Area array	2448 × 2048	VIS	GigE	8	—
VRD-600B	3D	C+M	Area array	2448 × 2048	VIS	GigE	8	—
VR-2300B	3D	M	Area array	2048 × 1536	VIS	GigE	8	—
VR-1300B	3D	M	Area array	2048 × 1536	VIS	GigE	8	—
VR-1300B	3D	M	Area array	2048 × 1536	VIS	GigE	8	—
VR-600B	3D	M	Area array	2048 × 1536	VIS	GigE	8	—
VR-400B	3D	M	Area array	2048 × 1536	VIS	GigE	8	—
VRH9-280B	3D	M	Area array	4200 × 2160	VIS	GigE	11.6	—

CAMERA MANUFACTURERS

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
BGFRM Technology (Imalligent) Shanghai, China; 86-4001828892; www.imalligent.com; info@imalligent.com								
VRH9-200B	3D	M	Area array	4200 × 2160	VIS	GigE	11.6	—
VRH9-160B	3D	M	Area array	4200 × 2160	VIS	GigE	11.6	—
VRH9-120B	3D	M	Area array	4200 × 2160	VIS	GigE	11.6	—
VRH9-080B	3D	M	Area array	4200 × 2160	VIS	GigE	11.6	—
VRH9-040B	3D	M	Area array	4200 × 2160	VIS	GigE	11.6	—
VRH9-020B	3D	M	Area array	4200 × 2160	VIS	GigE	11.6	—
Canon Medical Components USA Inc Irvine, CA, USA; 810-357-5022; https://mcu.canon/vsd; vsd-sales@mcu.canon								
SV-2000 Video Borescope Tablet Console or CCU	CMOS	C	Area array	400 × 400, 720 × 720	VIS	HDMI, USB 3.0	—	30 Hz
JCS-HR5U One-piece 1080p with USB	CMOS	C	Area array	1920 × 1080	VIS	HDMI, USB 3.0	—	59.94 Hz
IK-HD5UM 3CMOS, 1080p 2-Piece Remote Head	CMOS	C+M	Area array	1920 × 1080	NIR, VIS	3G-SDI, DVI, USB 3.0, RS-232	—	50, 59.94 Hz
Ultra HD IK-4K, 3-Chip Ultra HD 4K Video Camera (2-Piece Remote Head)	CMOS	C	Area array	3840 × 2160, 1920 × 1080	VIS	4- 3G-SDI, RS-232	—	59.94 Hz
JCT-TF5G/7G	CMOS	C	Area array	728 × 544, 1456 × 1088	VIS	Camera Link, PoCL	—	59.4 MHz
CMICRO Corp Takamatsu, Kagawa, Japan; 81-45-548-5448; www.cmicro.co.jp/en; support@cmicro.co.jp								
RSB400H	CMOS	C	Line scan	4096 × 3	VIS	Camera Link, CoaXPress	—	21.4 kHz
HOB200H	CMOS	M	Line scan	2048 (10 × 180 µm pixels)	VIS	Camera Link	—	69.9 kHz
FXS800A	CMOS	M	Line scan	8192	VIS	CoaXPress	—	72.4 kHz
NDB100H	InGaAs	M	Line scan	1024 × 2	Dual-band, SWIR	Camera Link, GigE	—	40 kHz
KFB300	3D	M	Area array	2048 × 1088	VIS	Ethernet	—	2 kHz
Cognex Natick, MA, USA; 508-650-3000; www.cognex.com; news@cognex.com								
In-Sight 3800 Vision System	CMOS	C+M	Area array	≤5MP (2448 × 2048)	VIS	Ethernet	200	—
In-Sight 2800 Vision System	CMOS	C+M	Area array	≤2MP (1920 × 1080)	VIS	Ethernet	—	≤45 Hz
In-Sight SnAPP Vision Sensor	CMOS	C+M	Area array	≤1.6MP (1440 × 1080)	VIS	Ethernet	45	—
In-Sight D900 Vision System	CMOS	C+M	Area array	≤5MP (2592 × 1944)	VIS	Ethernet	51	—
3D Displacement Sensors	3D	C+M	—	—	—	Ethernet	—	10 kHz
Cubert GmbH Ulm, Germany; 49-731-708156-00; https://cubert-hyperspectral.com; sales@cubert-gmbh.de								
ULTRIS S5 Hyperspectral Camera	CMOS	C	Area array	290 × 275 pixels	Hyperspectral	GigE	15	—
ULTRIS X20 Hyperspectral Camera	CMOS	C	Area array	410 × 410 pixels	Hyperspectral	GigE	8	—
ULTRIS X20 Plus Hyperspectral Camera	CMOS	C+M	Area array	410 × 410 (Spectral), 1880 × 1880 (Panchromatic)	Hyperspectral	GigE	8	—
ULTRIS XMR Hyperspectral Camera	CMOS	C	Area array	1000 × 1000 pixels	Hyperspectral	USB 3.0	17Hz (8 bit)/12Hz (12 bit)	—
ULTRIS SWIR-1 Hyperspectral Camera	InGaAs	C	Area array	200 × 200 pixels	Hyperspectral	USB 3.0	80	—

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Please visit www.vision-systems.com/directory for the comprehensive online company listings.

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
e-con Systems Riverside, CA, USA; 408-766-7503; www.e-consystems.com; camerasolutions@e-consystems.com								
STURDeCAM34	CMOS	C	—	—	VIS	GMSL2	60	—
RouteCAM_CU22_IP67	CMOS	C	—	—	VIS	PoE	60	—
See3CAM_CU31	CMOS	C	—	—	VIS	USB 3.2/2.0	30	—
RouteCAM_CU25	CMOS	C	—	—	VIS	PoE	60	—
e-CAM56_CUOAGX	CMOS	C	—	—	VIS	MIPI CSI-2	79	—
Emergent Vision Technologies Inc Port Coquitlam, BC, Canada; 866-780-6082; www.emergentvisiontec.com; sales@emergentvisiontec.com								
HZ-10000-G	CMOS	C+M	Area array	4608 × 2176	VIS	100GigE	1000	—
LZ-16KG5	CMOS	C+M	Line scan	16K × 16	VIS	100GigE	—	400 kHz–16K (Single line), 133 kHz–16K (Trilinear)
HB-127-S	CMOS	C+M	Area array	13,400 × 9528	VIS	25GigE	17	—
HZ-21000-G	CMOS	C+M	Area array	5120 × 4096	VIS	100GigE	542	—
HB-25000-SB	CMOS	C+M	Area array	5320 × 4600	VIS	25GigE	98	—
HZ-100-G	CMOS	C+M	Area array	11,276 × 9200	VIS	100GigE	24	—
HZ-2000-G	CMOS	C+M	Area array	2048 × 1216	VIS	100GigE	3462	—
HB-30000-S	CMOS	C+M	Area array	6464 × 4852	VIS	25GigE	35.4	—
HR/HT-50000	CMOS	C+M	Area array	7920 × 6004	VIS	10GigE	23	—
HR/HT-12000-S	CMOS	C+M	Area array	4096 × 3000	VIS	10GigE	80	—
HR/HT-8000-S	CMOS	C+M	Area array	4096 × 2160	VIS	10GigE	110	—
PACE Series	CMOS	C+M	Line scan	4K × 2–9K 256 TDI	VIS	10GigE	—	70–172 kHz (Single line), 23–57 kHz (Trilinear)
Accel Series	CMOS	C+M	Line scan	8K × 4–16K × 16	VIS	25GigE	—	100–304 kHz (Single line), 33–100 kHz (Trilinear)
HR-8000-SB-U	CMOS	M	Area array	2848 × 2848	UV	10GigE	145	—
HB-8000-SB-U	CMOS	M	Area array	2848 × 2848	UV	25GigE	201	—
EPIX Inc Buffalo Grove, IL, USA; 847-465-1818; www.epixinc.com; epix@epixinc.com								
SILICON VIDEO 25	CMOS	C+M	Area array	5120 × 5120	VIS	Camera Link, Camera Link Extended-Full	212	1000 MHz
SILICON VIDEO 20	CMOS	C+M	Area array	5120 × 3684	VIS	Camera Link, Camera Link Extended-Full	30–240	—
SILICON VIDEO 1820CL	CMOS	C	Area array	4608 × 3288	VIS	Camera Link, Camera Link Extended-Full, Camera Link Extended, Camera Link Full, LVDS	24	4360 Mbps
SILICON VIDEO 10C6 & 10M6	CMOS	C	Area array	3840 × 2764	VIS	LVDS	7	1000 MHz
SILICON VIDEO 5C10/5M10	CMOS	C+M	Area array	2592 × 1944	VIS	LVDS	10	700 MHz
SILICON VIDEO 1C45, 1M45	CMOS	C+M	Area array	1280 × 960	VIS	LVDS	45–1200	1000 MHz
SVWGAC or SVWGAM	CMOS	C+M	Area array	752 × 480	VIS	LVDS	60–1338	1000 MHz
SILICON VIDEO 035	CMOS	C	Area array	640 × 480	VIS	Analog, NTSC, NTSC/ PAL/RS-170, PAL	30	768 kHz
SILICON VIDEO 9M001	CMOS	M	Area array	1280 × 1024	VIS	LVDS	43	600 kHz
Hamamatsu Corp Bridgewater, NJ, USA; 908-231-0960; www.hamamatsu.com; photonics@hamamatsu.com								
High Speed InGaAs Line Scan Camera (C15333-10E)	InGaAs	M	Line scan	1024 × 1	SWIR	GigE	40 klps	40 kHz
VGA InGaAs area Camera (C12741-03)	InGaAs	M	Area array	320 × 256	SWIR	USB3	216	—

CAMERA MANUFACTURERS

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Hamamatsu Corp Bridgewater, NJ, USA; 908-231-0960; www.hamamatsu.com; photonics@hamamatsu.com								
RGBNIR multiline Camera (C16006)	CMOS	C+M	Line scan	8192 × 4	NIR, VIS	Camera Link	20 × 4 klps	—
Compact InGaAs Line Scan Camera (C15853-02)	InGaAs	M	Line scan	1024 × 1	SWIR	USB 3.1 Gen1	40 klps	15 MHz
ORCA-Fusion (C14440-20UP)	CMOS	M	Area array	2304 × 2304	VIS	CoaXPress, Digital I/O, USB3	100	—
QVGA Standard/ extended InGaAs area Camera (C16090 series)	InGaAs	M	Area array	320 × 256	SWIR	USB 3.1 Gen1	500	—
Headwall Photonics Inc Bolton, MA, USA; 978-353-4100; www.headwallphotonics.com; sales@headwallphotonics.com								
Hyperspec MV.X Imaging System	CMOS	C+M	Line scan	—	Hyperspectral, NIR, VIS	Ethernet	—	—
Hyperspec MV.C VNIR	CMOS	C+M	Line Scan	—	Hyperspectral, NIR, VIS	USB 3.1	—	—
Hyperspec MV.C NIR Imaging System	InGaAs	C+M	Line scan	—	Hyperspectral,, NIR	Ethernet	—	—
HySpex by NEO Oslo, Norway; 47-40-00-18-58; www.hyspex.com; hyspexsales@neo.no								
Baldur S-384N	MCT	M	Line scan	—	Hyperspectral, SWIR	Camera Link, LVDS, 5V/12V/24V TTL	400	—
Baldur S-640iN	InGaAs	M	Line scan	—	Hyperspectral, SWIR	GigE, LVDS, 5V/12V/24V TTL	500	—
Baldur V-1024N	CMOS	M	Line scan	—	Hyperspectral, NIR, VIS	Camera Link	1000	—
IDS Imaging Development Systems GmbH Obersulm, Germany; 49-7134-96196-0; www.ids-imaging.com; info@ids-imaging.com								
IDS NXT rio & rome	CMOS	C+M	Area array	1440 × 1088–3088 × 2076	VIS	Digital I/O, GigE, RS-232	—	—
Ensenso × Camera Family	CMOS	M	Area array	1456 × 1088, 2448 × 2048	VIS	Digital I/O, GigE	—	—
Ensenso N Camera Family	CMOS	M	Area array	1280 × 1024	NIR, VIS	Digital I/O, GigE	—	—
GigE uEye CP Camera Family	CMOS	C+M	Area array	800 × 600–4912 × 3684	NIR, VIS	Digital I/O, GigE	≤396	—
USB 3 uEye CP Camera Family	CMOS	C+M	Area array	800 × 600–5536 × 3692	NIR, VIS	Digital I/O, USB3	≤251	—
IMPERX Boca Raton, FL, USA; 561-989-0006; www.imperx.com; sales@imperx.com								
65 MP C9440 CMOS Cheetah Camera	CMOS	C+M	Area array	—	NIR	CoaXPress	34.7	—
31MP C6440 CMOS Cheetah Camera	CMOS	C+M	Area array	—	NIR	CoaXPress, 10GigE	35.4	—
20MP C4440 CMOS Cheetah Camera	CMOS	C+M	Area array	—	NIR	CoaXPress, 10GigE	43	—
17 MP C5440 CMOS Cheetah Camera	CMOS	C+M	Area array	—	NIR	CoaXPress, 10GigE	61.3	—
31MP C6410 CMOS Cheetah Camera (optional Thermal Electric Cooler)	CMOS	C+M	Area array	—	NIR	Camera Link, PoE	3.7	—
Instrument Systems GmbH Munich, Germany; 49-8945-4943-0; www.instrumentsystems.com; sales@instrumentsystems.com								
LumiTop X20 Low Luminance Imaging Colorimeter	CMOS	C	Area array	5496 × 3672	VIS	GigE	—	—
LumiTop X150 High-Resolution Imaging Colorimeter	CMOS	C	Area array	14,192 × 10,640	VIS	CoaXPress	—	—

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Please visit www.vision-systems.com/directory for the comprehensive online company listings.

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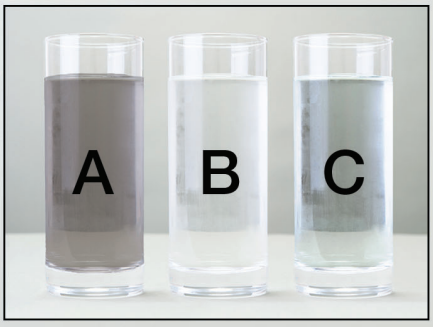

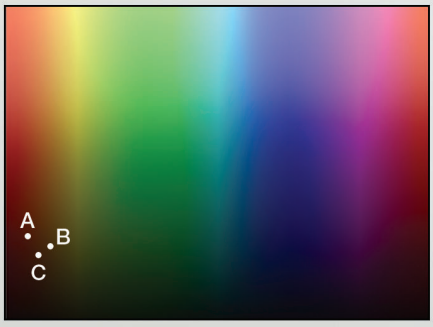

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CAMERA MANUFACTURERS

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Instrument Systems GmbH Munich, Germany; 49-8945-4943-0; www.instrumentsystems.com; sales@instrumentsystems.com								
LumiTop 4000 Imaging Colorimeter	CMOS	C	Area array	4096 × 3000	VIS	GigE	—	—
VTC 2400 IR Farfield Camera	CMOS	M	Area array	5 MPixels	IR	Ethernet	—	—
VTC 4000 IR Nearfield Camera	CMOS	M	Area array	12 MPixels, 1.4 × 1 mm (FoV)	IR	Ethernet	—	—
IO Industries Inc London, ON, Canada; 519-663-9570; www.ioindustries.com; sales@ioindustries.com								
Victorem 4KSDI-Mini	CMOS	C+M	Area array	4096 × 2160	VIS	HD-SDI	60	—
Victorem 120B68-CV	CMOS	C+M	Area array	4096 × 3008	VIS	CoaXPress	68	—
Redwood 654G71-CX	CMOS	C+M	Area array	9344 × 7000	VIS	CoaXPress	71	—
Volucam 120B68-V	CMOS	C+M	Area array	4096 × 3008	VIS	10GigE, HD-SDI	68	—
8KSDI	CMOS	C+M	Area array	8192 × 4320	VIS	HD-SDI	60	—
iX Cameras Ltd Woburn, MA, USA; 339-645-0778; www.ix-cameras.com; info@ix-cameras.com								
i-SPEED 511	CMOS	C+M	Area array	1920 × 1080	NIR, UV, VIS	Ethernet, GigE, HDMI, HD-SDI, Proprietary, USB3	100–1,000,000	10 GPx/s
i-SPEED 514	CMOS	C+M	Area array	1920 × 1080	NIR, UV, VIS	Ethernet, GigE, HDMI, HD-SDI, Proprietary, USB3	100–1,000,000	13 GPx/s
i-SPEED 717	CMOS	C+M	Area array	2072 × 1536	NIR, UV, VIS	Proprietary	2.45 million	17 GPx/s
i-SPEED 721	CMOS	C+M	Area array	2072 × 1536	NIR, UV, VIS	Proprietary	2.45 million	21 GPx/s
i-SPEED 727	CMOS	C+M	Area array	2072 × 1536	NIR, UV, VIS	Proprietary	2.45 million	27 GPx/s
JADAK, a Novanta Co North Syracuse, NY, USA; 315-701-0678; www.jadaktech.com; info@jadaktech.com								
Allegro LW-AL-CMV2000	CMOS	C+M	Area array	2048 × 1024	NIR, VIS	GigE, USB3	300	—
Allegro LW-AL-CMV4000	CMOS	C+M	Area array	2048 × 2048	NIR, VIS	GigE, USB3	150	—
Allegro LW-AL-CMV12000	CMOS	C+M	Area array	4096 × 3072	NIR, VIS	GigE, USB3	50	—
Allegro LW-AL-IMX172	CMOS	C+M	Area array	4000 × 3000	VIS	GigE, USB3	35	—
Allegro LW-AL-IMX178	CMOS	C+M	Area array	3094 × 2080	VIS	GigE, USB3	60	—
JAI San Jose, CA, USA; 408-383-0300; www.jai.com; camerasales.americas@jai.com								
Go-X Series	CMOS	C+M	Area array	2.3–24.5 MPixels	VIS	GigE, 5GigE, CoaXPress, USB3	4–112	—
Spark Series	CMOS	C+M	Area array	5–45 MPixels	VIS	Camera Link, Camera Link Extended, Camera Link Full, GigE, CoaXPress, USB3	9–253	—
Apex Series	CMOS	C	Area array	1.6–3.2 MPixels	VIS	Camera Link, Camera Link Extended, Camera Link Full, GigE, 5GigE, 10GigE, USB3	12–126	—
Fusion Series	CMOS	C+M	Area array	1.6–3.2 MPixels	Multispectral, NIR, VIS	GigE, 5GigE, 10GigE	107–226	—
Sweep+ Series	CMOS	C+M	Line scan	2048 × 1, 4096 × 1, 8192 × 1	Multispectral, NIR, VIS	GigE, 5GigE, 10GigE, Fiber Optic	—	16–97 kHz
KAYA Instruments Boca Raton, FL, USA; 561-698-2899; www.kayainstruments.com; info@kayainstruments.com								
Iron 661 CoaXPress 12G Camera	CMOS	C+M	—	127 MPixels	—	CoaXPress 12G	22	—
Iron 3265 CoaXPress 12G Camera	CMOS	C+M	—	65 MPixels	—	CoaXPress 12G / PCIe	71	—
Iron 4502 CoaXPress 12G Camera	CMOS	C+M	—	2.1 MPixels	—	CoaXPress 12G	2456	—
Iron 4521 CoaXPress 12G Camera	CMOS	C+M	—	21 MPixels	—	CoaXPress 12G	272	—
Iron CoaXPress 2020BSI Camera	CMOS	M	—	4 MPixels	—	CoaXPress 12G	74	—

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
KEYENCE Corp of America Itasca, IL, USA; 888-539-3623; www.keyence.com/usa; marketing@keyence.com								
VS-C2500X (25 MPixel C-Mount Smart Camera)	CMOS	C+M	Area array	5120 × 5120	VIS	Proprietary	35	—
VS-L1500X (15 MPixel Standard Zoom Smart Camera)	CMOS	C+M	Area array	4400 × 3296	VIS	Proprietary	44	—
CA-HF6400 (64 MPixel High-Speed Area Camera)	CMOS	C+M	Area array	8192 × 7808	VIS	Proprietary	17.4	—
CA-HL08MX (8K Resolution High-speed Line Scan Camera)	CMOS	M	Line scan	1 × 8192	VIS	Proprietary	—	97.7 kHz
XT-060 (Inline 3D Camera, 60mm FOV)	CMOS	C+M	—	3072 × 3072	VIS	Proprietary	—	—
LUCID Vision Labs Inc Richmond, BC, Canada; www.thinklucid.com; sales@thinklucid.com								
Helios2+ ToF 3D Camera High-Speed/HDR Mode	ToF	M	Area array	640 × 480	3D	GigE, PoE+	30	125 MB/s
Helios2 Narrow 31° x 24° Field of View ToF Camera	ToF	M	Area array	640 × 480	3D	GigE, PoE+	30	125 MB/s
Atlas 5GBASE-T Camera 2.8 MP to 31.4 MP	CMOS	C+M	Area array	≤6464 × 4852	NIR, VIS	5GigE, PoE	≤173	600 MB/s
Atlas 5GBASE-T IP67 Camera 2.8 MP to 24.5 MP	CMOS	C+M	Area array	≤5320 × 4600	NIR, VIS	5GigE, PoE	≤173	600 MB/s
Phoenix Camera 0.4 MP to 20 MP	CMOS	C+M	Area array	≤5472 × 3648	NIR, VIS	GigE PoE	≤286	125 MB/s
Triton IP67 Camera 0.4 MP to 24.5 MP	CMOS	C+M	Area array	≤5300 × 4600	NIR, VIS	GigE PoE	≤286	125 MB/s
Triton2 IP67 2.5 GigE Camera 1.6 MP to 24.5 MP	CMOS	C+M	Area array	≤5300 × 4600	NIR, VIS	GigE, 2.5GigE, PoE	≤166	312 MB/s
Triton2 SWIR IP67 Camera 3.2 and 5.2 MP	CMOS	M	Area array	2560 × 2048	SWIR	2.5GigE, PoE	85	125 MB/s
Triton10 - 10GigE Camera with RDMA	CMOS	C+M	Area array	≤5320 × 4600	NIR, VIS	10GigE	—	—
Atlas SWIR IP67 Camera 0.3 MP and 1.3 MP	CMOS	M	Area array	1280 × 1024	SWIR	GigE, PoE	85	1 Gbps
Atlas10 UV Camera	CMOS	M	Area array	2840 × 2840	UV	GigE, PoE	126	1250 MB/s
Atlas 10GBASE-T Camera 5.0 MP to 65 MP	CMOS	C+M	Area array	<9344 × 7000	NIR, VIS	GigE, 10GigE, PoE+	≤205	1250 MB/s
Triton2 4K Line Scan Camera	CMOS	M	Line scan	4096 × 2 px	NIR, VIS	2.5GigE, PoE	60 kHz	125 MB/s
Triton2 EVS Event-Based Camera (Shutter-free)	CMOS	—	Area array	1280 × 720	Event-Based, VIS	2.5GigE	>10k	125 MB/s
Mega Phase Industrial Inspection Technology (Shanghai) Co Ltd Shanghai, Guangdong, China; 86-1992-1093166; www.megaphase3d.com/en; sales@mega-phase.cn								
Sizector 3D Camera S162 Series S162170	3D	M	Area array	5328 × 3040	VIS	USB3	4, 14.5 (binning)	—
Sizector 3D Camera M Series M051040	3D	M	Area array	2472 × 2064	VIS	USB3	2.5, 8.6 (binning)	—
Sizector 3D Camera SX Series SQ081017	3D	M	Area array	2856 × 2848	VIS	USB3	1.4, 4.8 (binning)	—
Sizector 3D Camera SX Series SQ162053	3D	M	Area array	5328 × 3040	VIS	USB3	1, 3.6 (binning)	—
Hybrid Data Camera DH200	CMOS	M	Area array	4512 × 4512	Multispectral, NIR, UV	USB3	5, 18.5 (binning)	—
Mega Speed Corp Minnedosa, MB, Canada; 204-867-3767; www.megaspeedusa.com; sales@megaspeedusa.com								
Mega Speed MS140K	CMOS	C+M	Area array	1920 × 1080–64 × 16	VIS	GigE	35–225,000	—
Mega Speed MAX V1	CMOS	C+M	Area array	1920 × 1080–640 × 16	VIS	GigE	2400	—

CAMERA MANUFACTURERS

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Mega Speed Corp Minnedosa, MB, Canada; 204-867-3767; www.megaspeedusa.com; sales@megaspeedusa.com								
Mega Speed MAX V3	CMOS	C+M	Area array	1920 × 1080–640 × 16	VIS	GigE	35–200,000	—
Mega Speed X8 PRO	CMOS	C+M	Area array	1280 × 800–640 × 16	VIS	GigE	4000–512,000	—
Mega Speed MS35K PRO Cart	CMOS	C+M	Area array	1920 × 1080–640 × 480	VIS	GigE	3000	—
Mikrotron, a brand of SVS-Vistek GmbH Gilching, Germany; 49-8105-3987-60; www.mikrotron.de; info@svs-vistek.com								
EoSens®1.1M/CCX12-CM	CMOS	C+M	Area array	1280 × 864	VIS	CoaXPress-12	3674	3.78 GB/s
EoSens®2.0M/CCX12-CM	CMOS	C+M	Area array	1920 × 1080	VIS	CoaXPress-12	2247	4.34 GB/s
EoSens®3.0M/CCX5-CM	CMOS	C+M	Area array	1696 × 1710	VIS	CoaXPress-6	566	1.53 GB/s
EoSens®4.0M/CCX6-CM	CMOS	C+M	Area array	2336 × 1728	VIS	CoaXPress-6	563	2.12 GB/s
EoSens®9.5M/CCX12-M58	CMOS	C+M	Area array	4096 × 2304	VIS	CoaXPress-12	510	4.81 GB/s
EoSens®10M/CCX12-FM	CMOS	C+M	Area array	4608 × 2176	VIS	CoaXPress-12	478	4.46 GB/s
EoSens®21M/CCX12-FM	CMOS	C+M	Area array	5120 × 4096	VIS	CoaXPress-12	230	4.49 GB/s
EoSens®Creation 1.1MCCX12-CM2	CMOS	C+M	Area array	1280 × 864	VIS	CoaXPress-12	3674	3.78 GB/s
EoSens®Creation 2.0MCCX12-CM2	CMOS	C+M	Area array	1920 × 1080	VIS	CoaXPress-12	2247	4.34 GB/s
EoSens®Creation 2.0MCXGE-CM2	CMOS	C+M	Area array	1920 × 1080	VIS	10GigE	536	1.04GB/s
NET USA Inc Highland, IN, USA; 219-934-9042; www.net-usa-inc.com; info@net-usa-inc.com								
Corsight Intel Atom Based Smart Camera System	CMOS	C+M	Area array/ Line scan	1280 × 1024–2448 × 2048	NIR, VIS	Gigabit Ethernet, USB2.0, DisplayPort, WiFi, Bluetooth, GSM, RS-232, Digital I/O	35–1050	—
GigEPRO	CMOS	C+M	Area array	1280 × 1024–3840 × 2748	NIR, VIS	Gigabit Ethernet	7–61	—
3iCube	CMOS	C+M	Area array	1280 × 1024–3840 × 2748	NIR, VIS	USB3, iControl SKD, USB3 Vision: SynView SDK, UVC	7.5–60	—
HDselect	CMOS	C	Area array	1920 × 1080	VIS	USB3, HDMI	60	—
IOflex	CMOS	C	Area array	1920 × 1080	VIS	USB 2.0, UVC	30	—
iam Xilinx Zynq Ultrascal SOC (ARM + FPGA) Smart Camera incl. AI Accelerator	CMOS	C+M	Area array	728 × 544–4072 × 3046	NIR, SWIR, VIS	Gigabit Ethernet, Digital I/O	34–280	—
Omron Automation America Hoffman Estates, IL, USA; 224-575-6514; automation.omron.com/en/us; amy.wang@omron.com								
SWIR Series	CMOS	M	Area array	0.34, 1.3 MP	SWIR	GigE Vision, USB3 Vision, Camera Link	—	—
M Series USB3 Vision Cameras	CMOS	C+M	Area array	0.4–20 MPixels	VIS	USB3	≤527	—
M Series GigE Vision Cameras	CMOS	C+M	Area array	0.4–20 MPixels	VIS	GigE Vision 2.1	≤282	—
Omron FH Vision System	CCD & CMOS	C+M	Area array	640 × 480, 720 × 540, 1600 × 1200, 2040 × 1088, 2040 × 2048, 2448 × 2048, 2592 × 1944, 4084 × 3072, 4092 × 3000, 5544 × 3692	VIS	Camera Link, Digital I/O, Ethernet, GigE, RS-232, EtherCAT	≤524	—
Omron FHV7 Smart Camera	CMOS	C+M	Area array	720 × 540, 1440 × 1080, 2048 × 1536, 2448 × 2048, 3072 × 2048, 4000 × 3000	VIS	Digital I/O, Ethernet, GigE, RS-232, EtherCAT	≤430	—

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Opto Engineering Mantova, (MN), Italy; 39-0376-699111; www.opto-e.com; press@opto-e.com								
ITALA G series	CMOS	C+M	Area array	728 × 544–6480 × 4860	VIS	GigE	3.7–296.5	—
ITALA G.EL series	CMOS	C+M	Area array	1456 × 1088–5328 × 4608	VIS	GigE	4.8–74.2	—
ITALA G.SWIR series	CMOS	M	Area array	1296 × 1032	SWIR, VIS	GigE	87.8	—
ITALA G.IP series	CMOS	C+M	Area array	728 × 544–5328 × 4608	VIS	GigE	4.8–296.5	—
ITALA 10G series	CMOS	C+M	Area array	2472 × 2064–6480 × 4860	VIS	10GigE	21.7–231.2	—
COE LS-X series	CMOS	C+M	Line scan	4096 × 2	VIS	GigE	19–28	—
Percipio Technology Ltd Shanghai, China; 86-218-015-8012; www.percipio.xyz; info@percipio.xyz								
FM855-E1	3D	C+M	Area array	Depth 1280 × 960; RGB 2560 × 1920	IR, NIR	Ethernet, GigE	16	—
PS800-E1	3D	C+M	Area array	Depth 1280 × 960; RGB 2560 × 1920	IR, NIR	Ethernet, GigE	2.5	—
FS820-E1	3D	C+M	Area array	Depth 1280 × 800; RGB 1920 × 1080	IR, NIR	Ethernet, GigE	10	—
PS801-E1	3D	C+M	Area array	Depth 1280 × 960; RGB 2560 × 1920	IR, NIR	Ethernet, GigE	1	—
TL460-S1-E1	3D	C+M	Area array	Depth 640 × 480; RGB 1920 × 1080	IR, NIR	Ethernet, GigE	30	—
Photoneo sro Bratislava, Slovakia; 421-948-766-479; www.photoneo.com; sales@photoneo.com								
PhoXi 3D Scanner	CMOS	M	Area array	2064 × 1544	VIS	1GigE	3–4	—
Alpha 3D Scanner	CMOS	M	Area array	1440 × 1080	VIS	1GigE	3–4	—
MotionCam-3D	CMOS	M	Area array	1120 × 800	VIS	1GigE	20	—

CAMERA MANUFACTURERS

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Photoneo sro Bratislava, Slovakia; 421-948-766-479; www.photoneo.com; sales@photoneo.com								
MotionCam-3D Color	CMOS	C	Area array	1120 × 800	VIS	1GigE	20 (depth acquisition), 12 (color, depth acquisition)	—
Photonfocus AG Lachen, Switzerland; 41-55-451-00-00; www.photonfocus.com; sales@photonfocus.com								
MV4-D1280U-H01-GT photonSPECTRAL	CMOS	M	Area array	1280 × 1024	NIR, UV, VIS	10GigE, 10GigE Vision, Digital I/O, RS-422/LVDS	140	—
MV3-D640I-M01-G2 photonSPECTRAL	InGaAs	M	Area array	650 × 512	SWIR	GigE, GigE Vision, Digital I/O, RS-422/LVDS	300	—
MV4-D3904-L01-3D06-G2 photon3D	CMOS	M	Area array	3904 × 2192	VIS	GigE, GigE Vision, Digital I/O, RS-422/LVDS	12,000	12 kHz
MV4-D9344-G01-GT photonHiRES	CMOS	C+M	Area array	9344 × 7000	VIS	10GigE, 10GigE Vision, Digital I/O, RS-422/LVDS	18	—
MV4-D2048x1088-C01-HS02-GT photonSPECTRAL	CMOS	M	Area array	2048 × 1088	Hyperspectral, NIR, VIS	10GigE, 10GigE Vision, Digital I/O, RS-422/LVDS	340	—
Photron USA Inc San Diego, CA, USA; 858-684-3555; www.photron.com; image@photron.com								
FASTCAM Mini AX	CMOS	C+M	Area array	1024 × 1024	VIS	GigE	6400–900,000	—
FASTCAM Mini UX	CMOS	C+M	Area array	1280 × 1024	VIS	GigE	4000–800,000	—
FASTCAM Mini WX	CMOS	C+M	Area array	2048 × 2048	VIS	GigE	1080–80,000	—
FASTCAM NOVA R2	CMOS	C+M	Area array	2048 × 2048	VIS	1GigE/10GigE	1400–100,000	—
FASTCAM NOVA R3-4K	CMOS	C+M	Area array	4096 × 2304	VIS	1GigE/10GigE	750–150,000	—
FASTCAM NOVA R5-4K	CMOS	C+M	Area array	4096 × 2304	VIS	1GigE/10GigE	1250–200,000	—
FASTCAM NOVA S20	CMOS	C+M	Area array	1024 × 1024	VIS	1GigE/10GigE	18,750–1,100,000	—
FASTCAM NOVA S6	CMOS	C+M	Area array	1024 × 1024	VIS	1GigE/10GigE	6400–800,000	—
FASTCAM NOVA S9	CMOS	C+M	Area array	1024 × 1024	VIS	1GigE/10GigE	9000–900,000	—
FASTCAM NOVA S12	CMOS	C+M	Area array	1024 × 1024	VIS	1GigE/10GigE	12,800–1,000,000	—
FASTCAM NOVA S16	CMOS	C+M	Area array	1024 × 1024	VIS	1GigE/10GigE	16,000–1,100,000	—
FASTCAM MH6	CMOS	C+M	Area array	1920 × 1400	VIS	GigE	750–5000	—
FASTCAM MINi R5-4K	CMOS	C+M	Area array	4096 × 2304	VIS	1GigE/10GigE	1250–200,000	—
Pharsighted E9•80S	CMOS	C+M	Area array	640 × 480	VIS	1GigE/10GigE	272,000–2,457,000	—
Pharsighted E9•100S	CMOS	C+M	Area array	640 × 480	VIS	1GigE/10GigE	326,000–2,720,000	—
PHYTEC Messtechnik GmbH Mainz, Germany; 49-6131-9221-0; www.phytec.de; contact@phytec.de								
VM-016-M	CMOS	C+M	Area array	1280 × 800	VIS	MIPI CSI-2	60	—
VM-017-L	CMOS	C+M	Area array	2592 × 1944	VIS	FPD-Link III	60	—
VM-017-M	CMOS	C+M	Area array	2592 × 1944	VIS	MIPI CSI-2	60	—
VM-020-L	CMOS	C+M	Area array	1920 × 1200	VIS	FPD-Link III	96	—
VM-020-M	CMOS	C+M	Area array	1920 × 1200	VIS	MIPI CSI-2	120	—

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Pixelink Ottawa, ON, Canada; 613-247-1211; www.navitar.com/product/pixelink-cameras; sales.pixelink@ametek.com								
PL-X9524 (24 MP)	CMOS	C+M	Area array	5328 × 4608	VIS	10GigE	44	—
PL-X9520 (20 MP)	CMOS	C+M	Area array	4512 × 4512	VIS	10GigE	52	—
PL-X9512 (12 MP)	CMOS	C+M	Area array	4096 × 3000	VIS	10GigE	65	—
PL-X957 (7 MP)	CMOS	C+M	Area array	3216 × 2200	VIS	10GigE	154	—
PL-D7924 (24 MP)	CMOS	C+M	Area array	5328 × 4608	VIS	USB3	17	—
PL-D7920 (20 MP)	CMOS	C+M	Area array	4512 × 4512	VIS	USB3	21	—
PL-D7620 (20 MP)	CMOS	C+M	Area array	5472 × 3648	VIS	USB3	20	—
PL-D7512 (12 MP)	CMOS	C+M	Area array	4096 × 3000	VIS	USB3	35	—
PL-D7912 (12 MP)	CMOS	C+M	Area array	4096 × 3000	VIS	USB3	23	—
PL-D759 (9 MP)	CMOS	C+M	Area array	4096 × 2160	VIS	USB3	48	—
PL-D799 (9 MP)	CMOS	C+M	Area array	4096 × 2160	VIS	USB3	32	—
PL-D757 (7 MP HDR)	CMOS	C+M	Area array	3208 × 2200	VIS	USB3	57	—
PL-D797 (7 MP)	CMOS	C+M	Area array	3208 × 2200	VIS	USB3	27	—
PL-D755 (5 MP)	CMOS	C+M	Area array	2448 × 2048	VIS	USB3	80	—
PL-D753 (3 MP HDR)	CMOS	C+M	Area array	1936 × 1464	NIR, VIS	USB3	141	—
Princeton Infrared Technologies Inc (PIRT) Monmouth Junction, NJ, USA; 609-917-3380; www.princetonirtech.com; sales@princetonirtech.com								
1280SciCam Scientific SWIR Camera	InGaAs Photodiode array	M	Area array	1280 × 1024	IR, Multispectral, NIR, SWIR, VIS	Camera Link	95	—
MVCam SWIR Camera	InGaAs	M	Area array	1280 × 1024	IR, Multispectral, NIR, SWIR, VIS	Camera Link	90	—
1280BPCam	T2SL	M	Area array	1280 × 1024	E-SWIR, IR, Multispectral, NIR, VIS	Camera Link	100	—
PIRT1280A1-12	InGaAs	M	Area array	1280 × 1023	IR, Multispectral, NIR, SWIR, VIS	—	90	—
Radiant Vision Systems Redmond, WA, USA; 425-844-0152; www.radiantvisionsystems.com; info@radiantvs.com								
ProMetric I61 Imaging Colorimeter	CMOS	C+M	Area array	9568 × 6380	NIR, VIS	10 GigE	—	—
ProMetric I45 Imaging Colorimeter	CMOS	C+M	Area array	8192 × 5460	NIR, VIS	10 GigE	—	—
ProMetric I16-G Imaging Colorimeter	CMOS	C+M	Area array	5312 × 3032	VIS	Ethernet 1000	—	—
ProMetric Y45 Imaging Photometer	CMOS	M	Area array	8192 × 5460	NIR, VIS	10 GigE	—	—
ProMetric Y16-G Imaging Photometer	CMOS	M	Area array	5312 × 3032	VIS	Ethernet 1000	—	—
Raptor Photonics Ltd Larne, Co Antrim, UK; 44-282-827-0141; www.raptorphotonics.com; sales@raptorphotonics.com								
Falcon III	EMCCD	M	Area array	1000 × 1000	UV, VIS, X-ray	Camera Link	32	30 Hz
Ninox 1280	InGaAs	M	Area array	1280 × 1024	Hyperspectral, NIR, SWIR, VIS	Camera Link	60	10–60 Hz
Eagle	CCD	M	Area array	2048 × 2048, 1024 × 1024, 2048 × 512	NIR, UV, VIS, X-ray	Camera Link	—	7 Hz
Owl 320 HS	InGaAs	M	Area array	320 × 256	Hyperspectral, SWIR, VIS	Camera Link	—	349 Hz
Ninox Ultra 640 SWIR	InGaAs	M	Area array	640 × 512	NIR, SWIR, VIS	Camera Link	—	300 Hz
RDI Technologies/Fastec Imaging Corp San Diego, CA, USA; 858-592-2342; www.fastecimaging.com; sales.fastec@rditechnologies.com								
HS7 High-Speed Camera	CMOS	C+M	Area array	1920 × 1080	VIS	Digital I/O, Ethernet, 2.5GigE, USB 3.2, USB4, TB4	2500 (10 bits)	6180 MHz
HS5 High-Speed Camera	CMOS	C+M	Area array	2560 × 2048	VIS	Digital I/O, Ethernet, 2.5GigE, USB 3.2, USB4, TB5	253 (12 bits)	1898 MHz

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Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
RDI Technologies/Fastec Imaging Corp San Diego, CA, USA; 858-592-2342; www.fastecimaging.com; sales.fastec@rditechnologies.com								
TS5 Handheld High-Speed Camera	CMOS	C+M	Area array	2560 × 2048	VIS	Digital I/O, Ethernet, GigE, USB 1.0/2.0	253	1325 MHz
Fastec IL5	CMOS	C+M	Area array	2560 × 2048	VIS	Digital I/O, Ethernet, GigE, USB 1.0/2.0	253	1325 MHz
Saber1 Technologies LLC Lowell, MA, USA; 978-244-0490; www.saber1.com; shaun@saber1.com								
BVS-CA-GT1	IR	M	Area array	2856 × 2848	SWIR	10 GigE	127–194 dependent on bit depth	—
IP67-C5311	CMOS	C+M	Area array	5328 × 3040	VIS	GigE	7.4	—
CB500MG-CM	CMOS	C+M	Area array	7920 × 6004	VIS	PCIe	30	—
ORX-10G-310S9C	CMOS	C+M	Area array	6464 × 4852	VIS	10 GigE, CoaXPress	26	—
Iron 661	CMOS	C+M	Area array	13,400 × 9528	VIS	GigE	22	—
Schäfter+Kirchhoff GmbH Hamburg, Germany; 49-40-853-997-0; www.sukhamburg.com; info@sukhamburg.de								
SK4k-U3DR7C	CMOS	C	Line scan	4096 × 2 Bayer Pattern	VIS	USB3	—	43.4 kHz
SK8k-U3DR4	CMOS	M	Line scan	8192 × 1	VIS	USB3	—	43.4 kHz
SK2048_HA	CCD	M	Line scan	2048 × 1	VIS	USB3, GigE Vision, Camera Link	—	52.63 kHz
SK2048U3HU	CMOS	M	Line scan	2048 × 1	VIS	USB3	—	7.14 kHz
SK4096U3HW	CMOS	M	Line scan	4096 × 1	VIS	USB3	—	2.38 kHz
SK2048U3JR	CCD	M	Line scan	2048 × 1	VIS	USB3	—	4.69 kHz
SK1024_SH	CCD	M	Line scan	1024 × 1	VIS	USB3, GigE Vision, Camera Link	—	27 kHz
SK2048_SH	CCD	M	Line scan	2048 × 1	VIS	USB3, GigE Vision, Camera Link	—	14 kHz
SK22368GTFC-4L	CCD	C	Line scan	5400 × 3 RGB	VIS	GigE	—	5.1 kHz
Shenzhen SinceVision Technology Co., Ltd. Shenzhen, Guangdong, China; 86-1894-8315943; www.sincevision.com; pujan@cnsszn.com								
SH6-2101 High-Speed Camera	CMOS	C+M	Area array	3508 × 2480	VIS	10 GigE	1000	—
SH6-116 High-Speed Camera	CMOS	C+M	Area array	3508 × 2480	VIS	10 GigE	15,800	—
SH3-502 High-Speed Camera	CMOS	C+M	Area array	3508 × 2480	VIS	10 GigE	2000	—
SH3-108 High-Speed Camera	CMOS	C+M	Area array	3508 × 2480	VIS	10 GigE	8000	—
SH2-203 High-Speed Camera	CMOS	C+M	Area array	2048 × 2048	VIS	10 GigE	3200	—
SICK Inc Bloomington, MN, USA; 952-941-6780; www.sickusa.com; info@sick.com								
InspectorP61x	2D	M	Area array	1.2 MPixels	NIR, VIS	Serial, Ethernet, Fieldbus	≤70	—
InspectorP62x	2D	M	Area array	1.3 MPixels	NIR, VIS	Serial, Ethernet, Fieldbus	≤70	—
InspectorP63x	2D	M	Area array	1.3–1.9 MPixels	NIR, VIS	Serial, Ethernet, Fieldbus	≤70	—
Inspector83x	2D	C	Area array	1.3–5.1 MPixels	NIR, VIS	Serial, Ethernet, Fieldbus	≤70	—
Inspector85x	2D	M	Area array	5–12 MPixels	NIR, VIS	Serial, Ethernet, Fieldbus	≤70	—
picoCam2	2D	C	Streaming	1.58–5.01 Mpixels	NIR, VIS	Ethernet, GigEvision	≤70	—
midiCam2	2D	C	Streaming	1.58–12.29 MPixels	NIR, VIS	Ethernet, GigEvision	≤70	—
TriSpector1000	3D	M	Line scan	1536 datapoint/profile	—	Serial, Ethernet	—	—

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
SICK Inc Bloomington, MN, USA; 952-941-6780; www.sickusa.com; info@sick.com								
Ranger3	3D	M	Line scan	3202, 560 x 832 px 0 datapoint/profile	—	Ethernet, GigEvision	—	—
Ruler3000	3D	M	Line scan	3202, 560 × 832 px 0 datapoint/profile	—	Ethernet, GigEvision	—	—
Visionary-S	3D	M	Line scan	640 × 512	—	Ethernet	≤30	—
Visionary-T Mini	3D	C	Line scan	512 × 424	—	Ethernet	≤30	—
Visionary-B Two	3D	C	Line scan	1024 × 576	—	Ethernet, GigEvision	≤30	—
Sony Europe, Image Sensing Solutions Weybridge, Surrey, UK; 44-1932-817-494; www.image-sensing-solutions.eu; matthew.swinney@eu.sony.com								
XCG-CP510	CMOS	M	Area array	2448 × 2048	VIS	GigE	23	—
XCU-CG160	CMOS	C+M	Area array	1456 × 1088	VIS	USB3	100	—
XCL-CG510	CMOS	C+M	Area array	2448 × 2048	VIS	Camera Link, Camera Link Extended-Full, Camera Link Extended, Camera Link Full	35	—
XCG-CG160	CMOS	C+M	Area array	1456 × 1088	VIS	GigE	70	—
FCB-ER8550	CMOS	C	Area array	2688 × 1512	VIS	HDMI 1.4b	≤60	—
FCB-EV9520L	CMOS	C	Area array	1920 × 1080	VIS	LVDS	60	—
FCB-EW9500H	CMOS	C	Area array	2688 × 1512	VIS	HDMI	60	—
FCB-EV9500L	CMOS	C	Area array	1920 × 1080	VIS	LVDS	60	—
FCB-EV9500M	CMOS	C	Area array	1920 × 1080	VIS	MIPI	60	—
FCB-ER9500	CMOS	C	Area array	2688 × 1512	VIS	HDMI 1.4b	60	—
SPECIM Spectral Imaging Ltd Oulu, Finland; 358-10-4244-400; www.specim.com; info@specim.com								
Specim FX10	CMOS	M	Line scan	1024 × 224	Hyperspectral, NIR, VIS	Camera Link, GigE	330 (full), 9900 (1 band)	—
Specim FX17	InGaAs	M	Line scan	640 × 224	Hyperspectral, NIR	Camera Link, GigE	670 (full), 15,000 (4 bands)	—
Specim FX50	InSb	M	Line scan	640 × 154	MWIR	GigE	377	—
SWIR	MCT	M	Line scan	384 × 288	Hyperspectral, SWIR	Camera Link	450	—
Specim GX17	InGaAs	M	Line scan	480 × 164	Hyperspectral, NIR	Camera Link	800 (full)	—
SVS-Vistek GmbH Gilching, Germany; 49-8105-3987-60; www.svs-vistek.com; info@svs-vistek.com								
EXO Series	CMOS	C+M	Area array	≤6464 × 4852	VIS	Camera Link, GigE, USB3	≤105/79/160	—
EXO TRACER Series	CMOS	C+M	Area array	≤5496 × 3672	VIS	GigE, USB3	≤10/22	—
EXO Polarized Series	CMOS	M	Area array	≤4096 × 3000	—	GigE, USB3	≤24.5/75	—
EXO SWIR Series	CMOS	M	Area array	≤1280 × 1024	SWIR	GigE, USB3	≤260/125.4	—
FXO Series	CMOS	C+M	Area array	≤5328 × 4608	VIS	CoaXPress-12, 10GigE, 25GigE	≤671/124/671	—
FXO SWIR Series	CMOS	M	Area array	2560 × 2048	SWIR	CoaXPress-12, 10GigE	134/173.4	—
fxo487 (UV)	CMOS	M	Area array	2848 × 2848	UV	CoaXPress-12, 10GigE	≤195/87	—
HR Series	CMOS	C+M	Area array	13,272 × 9176	VIS	Camera Link, CoaXPress-6, CoaXPress-12, 10GigE	≤31.8/81/ 71/56.4	—
SHR Series	CMOS	C+M	Area array	≤19,200 × 12,800	VIS	CoaXPress-6, CoaXPress-12, 10GigE	≤8.7/20.3/8.7	—

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SWIR Vision Systems Inc Durham, NC, USA; 919-248-0032; www.swirvisionsystems.com; sales@swirvisionsystems.com								
Acuros CQD 1280 eSWIR Camera	CQD	M	Area array	1280 × 1024	IR, Multispectral, NIR, SWIR, VIS	GigE, USB3	90	—
Acuros CQD 1920 eSWIR Camera	CQD	M	Area array	1920 × 1080	IR, Multispectral, NIR, SWIR, VIS	GigE, USB3	60	—
Acuros CQD 640 SWIR Camera	CQD	M	Area array	640 × 512	IR, Multispectral, NIR, SWIR, VIS	GigE, USB3	280	—
Acuros CQD 1280 SWIR Camera	CQD	M	Area array	1280 × 1024	IR, Multispectral, NIR, SWIR, VIS	GigE, USB3	90	—
Acuros CQD 1920 SWIR Camera	CQD	M	Area array	1920 × 1080	IR, Multispectral, NIR, SWIR, VIS	GigE, USB3	60	—
Systematic Vision Corp Ashland, MA, USA; 508-532-1116; www.systematicvision.com; bill@systematicvision.com								
SVS-Vistek FXO Series	CMOS	C+M	Area array	5–24 MPixels	NIR, VIS	CoaXPress 2.0, 10 GigE	259	—
Princeton Infrared 1280MVCam	InGaAs	M	Area array	1280 × 1024	NIR, SWIR, VIS	Camera Link	100	—
Photonfocus MV8-D8424-G01-GT	CMOS	C+M	Area array	8424 × 6032	VIS	10GigE	24	—
Photonfocus MV4 Series	CMOS	C+M	Area array	1.3–65 MPixels	NIR, UV, VIS	GigE, 10GigE	80,000	—
Photonfocus MV3 Series	CMOS	C+M	Area array	0.1–0.3 MPixels	NIR, UV, VIS	Camera Link, GigE	344	—
Photonfocus MV2 Series	CMOS	C+M	Area array	1.3–5 MPixels	Multispectral, NIR, VIS	GigE	18,540	—
Mikrotron EoSens 2.0CXP2	CMOS	C+M	Area array	1920 × 1080	VIS	CoaXPress 2.0	2220	—
Mikrotron EoSens 1.1CXP2	CMOS	C+M	Area array	1280 × 864	VIS	CoaXPress 2.0	3660	—
JAI FSFE-3200D-10GE Flex-Eye	CMOS	C+M	Area array	2048 × 1536	Multispectral, NIR, VIS	10GigE	123	—
JAI FSFE-1600T-10GE Flex-Eye	CMOS	C+M	Area array	1440 × 1080	Multispectral, NIR, VIS	10GigE	213	—
JAI SP-45000-CXP4	CMOS	C+M	Area array	8192 × 5460	NIR, VIS	CoaXPress	51	—
JAI GO-X Series	CMOS	C+M	Area array	3.2–45 MPixels	NIR, VIS	CoaXPress, GigE, USB3	162	—
IOI Victorem CX Series	CMOS	C+M	Area array	0.4–26.2 MPixels	VIS	CoaXPress	523	—
Emergent Vision HZ-100-G	CMOS	C+M	Area array	11,276 × 9200	VIS	100GigE	30	—
Emergent Vision HZ-65000-G	CMOS	C+M	Area array	9344 × 7000	VIS	100GigE	71	—
Emergent Vision HB-25000-SB	CMOS	C+M	Area array	5320 × 4600	VIS	25GigE	98	—
Allied Vision Goldeye G/CL-034 TEC1	InGaAs	M	Area array	636 × 508	SWIR	Camera Link, GigE	303	—
Allied Vision Goldeye G/CL-030 TEC1	InGaAs	M	Area array	1280 × 1024	NIR, SWIR, VIS	Camera Link, GigE	100	—
Allied Vision Alvium 1800 U/C-130 VSWIR	InGaAs	M	Area array	1296 × 1032	NIR, SWIR, VIS	USB3, MIPI CSI-2	130	—
Allied Vision Alvium G5-130 VSWIR	InGaAs	M	Area array	1296 × 1032	NIR, SWIR, VIS	5GigE	130	—

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Please visit www.vision-systems.com/directory for the comprehensive online company listings.

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Teledyne DALSA Billerica, MA, USA; 978-670-2002; www.teledynedalsa.com; tdi_sales.americas@teledyne.com								
BOA2 XA Series	CMOS	M	Area array	1664 × 1216, 1920 × 1440, 2560 × 2048	VIS	Digital I/O, Ethernet, RS-232	80, 60, 40	—
BOA Spot Series	CMOS	C+M	Area array	640 × 480, 1280 × 960	VIS	Digital I/O, Ethernet, RS-232	45, 30	—
BOA3	CMOS	M	Area array	1280 × 960, 2560 × 1936, 4096 × 3072	—	Digital I/O, Ethernet, RS-232	50, 35, 13	—
Teledyne DALSA Waterloo, ON, Canada; 519-886-6000; www.teledynevisionsolutions.com; tdi_sales.americas@teledyne.com								
Calibir GX	Microbolometer	M	Area array	640 × 480	LWIR	GigE	30, 60	—
MicroCalibir	Microbolometer	M	Area array	640 × 480	LWIR	USB2	60	—
Falcon4-CLHS	CMOS	M	Area array	2240 × 1248, 4480 × 2496, 6144 × 6144, 8192 × 8192	VIS	Camera Link HS	1200, 609, 330, 120, 90	—
Genie Nano-CL	CMOS	C+M	Area array	2448 × 2048, 2464 × 2056, 4112 × 2176, 4096 × 4096, 5112 × 5112	NIR, VIS	Camera Link, Camera Link Full	35,141, 88, 64, 45, 30	—
Genie Nano-CXP	CMOS	C+M	Area array	4096 × 4096, 5120 × 5120, 6144 × 6144, 8192 × 8192	NIR, VIS	CoaXPress	120, 80, 40, 30	—
Genie Nano-1GigE Polarized	CMOS	M	Area array	2448 × 2048	VIS	GigE	57	—
Genie Nano-1GigE	CMOS	C+M	Area array	640 × 480, 728 × 544, 800 × 600, 816 × 624, 1280 × 1024, 1456 × 1088, 1608 × 1104, 1632 × 1248, 1936 × 1216, 2048 × 1536, 2448 × 2048, 2592 × 2048, 4112 × 2176, 4112 × 3012, 4912 × 3684, 4096 × 4096, 5120 × 5120	NIR, VIS	GigE	862, 311, 566, 160, 83, 213, 90, 85, 39, 84, 116, 151, 55, 140, 35, 51, 56, 40, 30, 20, 13, 31, 34.4	—
Genie Nano-5GigE	CMOS	C+M	Area array	2064 × 1544, 2464 × 2056, 4112 × 3008, 4112 × 2176, 4500 × 4500, 5420 × 5420, 8192 × 5420	VIS	5GigE	190, 141, 64, 88, 64, 30, 19	—
Genie Nano-10GigE	CMOS	C+M	Area array	6144 × 6144, 8192 × 8192	VIS	10GigE	18, 13	—
Linea	CMOS	M	Line scan	2048 × 1, 4096 × 1, 8192 × 1, 16,384 × 1	VIS	Camera Link, Camera Link HS, GigE	—	80, 71, 52
Linea Color	CMOS	C	Line scan	2048 × 2, 4096 × 2, 8192 × 2	VIS	Camera Link, GigE	—	48 × 3, 26 × 3
Linea 2	CMOS	C	Line scan	4096 × 3, 4096 × 4	NIR, VIS	5GigE	—	40 × 3, 32 × 4

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Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Teledyne DALSA Waterloo, ON, Canada; 519-886-6000; www.teledynevisionsolutions.com; tdi_sales.americas@teledyne.com								
Linea HS	CMOS	M	TDI	4096 × 192, 8192 × 192, 13,056 × 192, 16,384 × 128, 16,384 × 192, 32,768 × 64	NIR, VIS	Camera Link HS	—	400
Linea HS2	CMOS	M	TDI	16,384 × 288	NIR, VIS	CameraLink HS	—	1000
Linea HS Color	CMOS	C	TDI	16,384 × 256	NIR, VIS	Camera Link HS	—	100 × 3
Linea HS Multifield	CMOS	C	TDI	16,384 × 256	NIR, VIS	Camera Link HS	—	133 × 3
Linea ML	CMOS	M	Line scan	8192 × 4, 16,384 × 4	NIR, VIS	Camera Link HS	—	300
Linea ML Color	CMOS	C	Line scan	8192 × 3, 16,384 × 3	VIS	Camera Link HS	—	100 × 3
Linea ML Multispectral	CMOS	C	Line scan	8192 × 4	NIR, VIS	Camera Link HS	—	75 × 4
Linea SWIR	InGaAs	M	Line scan	1024 × 1, 512 × 1	SWIR	GigE	—	40
Linea Lite	CMOS	M	Line scan	2048 × 2, 4096 × 2, 8192 × 2	VIS	Camera Link, GigE	—	120, 50
Linea Lite Color	CMOS	C	Line scan	2048 × 2, 4096 × 2	VIS	Camera Link, GigE	—	40 × 3, 25 × 3
Piranha4 Series	CMOS	M	Line scan	2048 × 2, 4096 × 2, 8192 × 2	VIS	Camera Link	—	200
Piranha4 Color	CMOS	C	Line scan	2048 × 3, 4096 × 3, 8192 × 3	VIS	Camera Link	—	70 × 3
AxCIS	CMOS	M	Line scan	14,304 × 2, 28,608 × 2	NIR, VIS	Camera Link HS	—	120
AxCIS Color	CMOS	C	Line scan	14,304 × 3, 28,608 × 3	NIR, VIS	Camera Link HS	—	150, 180
Teledyne e2v, a business unit of Teledyne Digital Imaging US Inc Chestnut Ridge, NJ, USA; 845-425-2000; imaging.teledyne-e2v.com; e2v-imaging.us@teledyne.com								
OctoPlus OCT	CMOS	M	Line scan	2048 × 1	NIR	Camera Link, USB3	—	20, 80, 130, 250 kHz
Teledyne FLIR Richmond, BC, Canada; 604-242-9937; www.flir.com/mv; mv-sales@flir.com								
Blackfly S USB	CMOS	C+M	Area array	0.4–24.5 MPixels	VIS	USB3	15–522	—
Blackfly S GigE	CMOS	C+M	Area array	0.4–24.5 MPixels	VIS	GigE	5–291	—
Blackfly S Board Level	CMOS	C+M	Area array	1.6–20 MPixels	VIS	USB3, GigE	10–226	—
Forge 5GigE	CMOS	C+M	Area array	5–24.5 MPixels	VIS	5GigE	25–122	—
Forge 1GigE SWIR	InGaAs	—	Area array	1.3 MPixels	SWIR, VIS	GigE	1–93	—
Bumblebee X 5GigE	CMOS	C	Stereo	3 MP	VIS	5GigE	5-38.5	—
Dragonfly S	CMOS	C+M	Area array	5 MP	VIS	USB3	1.7–49	—
Forge 1GigE IP67	CMOS	C+M	Area array	1.2-12 MPixels	VIS	GigE	—	—
Oryx 10GigE	CMOS	C+M	Area array	3.2–31 MPixels	VIS	10GigE	26–216	—
Ladybug6	CMOS	C	Spherical	72 MPixels	VIS	USB3	15	—
Ladybug5+	CMOS	C	Spherical	30 MPixels	VIS	USB3	30	—
Firefly S	CMOS	C+M	Area array	0.4–1.6 MPixels	VIS	USB3	60–121	—
Teledyne FLIR LLC Wilsonville, OR, USA; 877-773-3547; www.flir.com; sales@flir.com								
FLIR A6260 SWIR	InGaAs	C+M	Area array	640 × 512	SWIR	GigE, SDI	0.0015–125 Hz (180 Hz burst)	125 Hz (full), 25,614 Hz (max)
FLIR A6750 Series	InSb or Strained-Layer Superlattice	C+M	Area array	640 × 512	LWIR, MWIR	GigE, SDI	0.0015–125 Hz	125 Hz (full), 4175 Hz (max)
FLIR A8580 Series	InSb or Strained-Layer Superlattice	C+M	Area array	1280 × 1024	LWIR, MWIR	GigE, CoaXPress, SDI	0.0015–45 Hz (GigE), 60 Hz (CXP)	60 Hz (full), 3709 Hz (max)

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Teledyne FLIR LLC Wilsonville, OR, USA; 877-773-3547; www.flir.com; sales@flir.com								
FLIR X6980 Series	InSb or Strained-Layer Superlattice	C+M	Area array	640 × 512	LWIR, MWIR	GigE, CoaXPress, Camera Link, SDI, HDMI	0.0015–1004 Hz	1004 Hz (full), 29,133 Hz (max)
FLIR X8580 Series	InSb or Strained-Layer Superlattice	C+M	Area array	1280 × 1024	LWIR, MWIR	GigE, CoaXPress, Camera Link, SDI, HDMI	~0.5–181 Hz	181 Hz (full), 6026 Hz (max)
FLIR Ax8	Microbolometer	C+M	Area array	80 × 60	LWIR	Ethernet	9 Hz	9 Hz
FLIR A400 Smart Sensor	Microbolometer	C+M	Area array	320 × 240	LWIR	Ethernet, Wi-Fi	30	30 Hz
FLIR A400 Image Streaming	Microbolometer	C+M	Area array	320 × 240	LWIR	GigE, Wi-Fi	30	30 Hz
FLIR A500 Smart Sensor	Microbolometer	C+M	Area array	464 × 348	LWIR	Ethernet, Wi-Fi	30	30 Hz
FLIR A500 Image Streaming	Microbolometer	C+M	Area array	464 × 348	LWIR	GigE, Wi-Fi	30	30 Hz
FLIR A700 Smart Sensor	Microbolometer	C+M	Area array	640 × 480	LWIR	Ethernet, Wi-Fi	30	30 Hz
FLIR A700 Image Streaming	Microbolometer	C+M	Area array	640 × 480	LWIR	GigE, Wi-Fi	30	30 Hz
FLIR Boson+	Microbolometer	M	Area array	640 × 512, 320 × 256	LWIR	USB, CMOS	60, 30	60, 30
FLIR Boson	Microbolometer	M	Area array	640 × 512, 320 × 256	LWIR	USB, CMOS	60, 30, 9	60, 30, 9
FLIR Lepton	Microbolometer	M	Area array	160 × 120, 80 × 60	LWIR	SPI	9	9
Teledyne Lumenera Ottawa, ON, Canada; 613-736-4077; www.teledynelumenera.com; lumenera.info@teledyne.com								
Teledyne Lumenera Lt1610 / Lt1610B	CMOS	C+M	Area array	1608 × 1104	VIS	USB3	96	—
Teledyne Lumenera Lt1630 / Lt1630B	CMOS	C+M	Area array	1632 × 1248	VIS	USB3	86	—
Teledyne Lumenera Lt1900 / Lt1900B	CMOS	C	Area array	1944 × 1096	VIS	USB3	60	—
Teledyne Lumenera Lt1950 / Lt1950B	CMOS	C+M	Area array	1936 × 1216	VIS	USB3	162	—
Teledyne Lumenera Lt2020 / Lt2020B	CMOS	C+M	Area array	2064 × 1544	VIS	USB3	55	—
Teledyne Lumenera Lt2420 / Lt2420B	CMOS	C+M	Area array	2464 × 2056	VIS	USB3	35	—
Teledyne Lumenera Lt3200 / Lt3200B	CMOS	C+M	Area array	3216 × 2208	VIS	USB3	50	—
Teledyne Lumenera Lt3840 / Lt3840B	CMOS	C+M	Area array	3840 × 2160	VIS	USB3	44	—
Teledyne Lumenera Lt4030 / Lt4030B	CMOS	C+M	Area array	4112 × 2176	VIS	USB3	31	—
Teledyne Lumenera Lt4020 / Lt4020B	CMOS	C+M	Area array	4112 × 3008	VIS	USB3	22	—
Teledyne Lumenera Lt5470	CMOS	C+M	Area array	5472 × 3084	VIS	USB3	32	—
Teledyne Lumenera Lt4430	CMOS	C+M	Area array	4432 × 4436	VIS	USB3	28	—
Teledyne Lumenera Lt5500	CMOS	C+M	Area array	5472 × 3648	VIS	USB3	19	—
Teledyne Lumenera Lt4510	CMOS	M	Area array	4152 × 4152	VIS	USB3	26	—
Teledyne Lumenera Lt6480	CMOS	C+M	Area array	6480 × 4860	VIS	USB3	17	—
The Imaging Source LLC Charlotte, NC, USA; 704-370-0110; www.theimagingsource.com; info@theimagingsource.com								
38 Series	CMOS	C+M	Area array	4096 × 2160–5320 × 4600	NIR, VIS	GigE, USB3, Digital I/O	≤42	—
37 Series (housed & board-level)	CMOS	C+M	Area array	720 × 540–4000 × 3000	NIR, VIS	USB3, Digital I/O	≤539	—
33 Series	CMOS	C+M	Area array	720 × 540–5472 × 3648	NIR, VIS	GigE, USB3, Digital I/O	≤539	—

CAMERA MANUFACTURERS

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
The Imaging Source LLC Charlotte, NC, USA; 704-370-0110; www.theimagingsource.com; info@theimagingsource.com								
36 Series (Embedded)	CMOS	C+M	Area array	720 × 540–4000 × 1944	NIR, VIS	MIPI, FPD-Link III	≤120	—
DxK 39GX265-Z20	CMOS	C+M	Area array	2048 × 1536	NIR, VIS	GigE	≤36	—
Thermo Fisher Scientific Liverpool, NY, USA; 315-451-9410; www.thermofisher.com/cidtec; sales.cidtec@thermofisher.com								
MegaRAD3	CID	C+M	Area array	730 × 512	UV, VIS	USB 1.0/2.0	30	—
SpectraCAM XDR	CID	M	Area array	2048 × 2048	UV, VIS	GigE	0.5	—
Toshiba Teli Corp Tokyo, Japan; 81-42-589-8771; www.toshiba-teli.co.jp/en/; teli-global@toshiba-teli.co.jp								
EX670AM Series | EX370BMG-X	CMOS	C+M	Area array	8192 × 8192, 6144 × 6144	VIS	CoaXPress2 (CXP-12 Quad)	64.5, 120	4329, 4530 MB/s
DDU2607M series | DDU1607M Series | DDU1207M series	CMOS	C+M	Area array	5120 × 5120, 4000 × 4000, 4096 × 3000	VIS	Dual USB3	28.3, 47, 62	742, 752, 750 MB/s
DU1207M Series | DU657M Series	CMOS	C+M	Area array	4096 × 3000, 2560 × 2560	VIS	USB3	32, 55	393, 360 MB/s
BU2409M Series | BU1206M Series | BU805M Series | BU502M Series	CMOS	C+M	Area array	5320 × 4600, 4096 × 3000, 2840 × 2840, 2448 × 2048	VIS	USB3	15, 31, 46, 75	367, 393, 371, 376 MB/s
BU1207M Series | BU505M Series | BU302M Series	CMOS	C+M	Area array	4096 × 3000, 2448 × 2048, 2048 × 1536	VIS	USB3	31, 75, 120	393, 376, 377 MB/s
BU406M Series | BU205M	CMOS	C+M	Area array	2048 × 2048, 2048 × 1088	NIR, VIS	USB3	90, 170	377, 379 MB/s
BU238M Series	CMOS	C+M	Area array	1920 × 1200	VIS	USB3	165	380 MB/s
BU160M Series | BU040M Series	CMOS	C+M	Area array	1440 × 1080, 720 × 540	VIS	USB3	240, 523	373, 203 MB/s
BU132M | CSCS60BM18	CMOS	M	Area array	1280 × 1024	VIS	USB3, PoCL (Base)	61	80 MB/s
BU2006M Series | BU1203MC Series | BU602M Series	CMOS	C+M	Area array	5472 × 3648, 4000 × 3000, 3072 × 2048	VIS	USB3	19, 30, 60	379, 360, 384 MB/s
BG505LM Series | BG302LM Series	CMOS	C+M	Area array	2448 × 2048, 2048 × 1536	VIS	GigE	22, 36	110, 113 MB/s
BG160M Series | BG040M Series	CMOS	C+M	Area array	1440 × 1080, 720 × 540	VIS	GigE	72, 291	112, 113 MB/s
BC505LM Series | BC302LM Series	CMOS	C+M	Area array	2448 × 2048, 2048 × 1536	VIS	Camera Link, PoCL (Base|3taps)	36, 56	180, 177 MB/s
BC160M Series | BC040M Series	CMOS	C+M	Area array	1440 × 1080, 720 × 540	VIS	PoCL (Base|3taps)	148, 523	230, 203 MB/s
CSC6M100CMP11 | CSC6M100BMP11	CMOS	C+M	Area array	2560 × 2560	VIS	Camera Link, PoCL (Full)	99.2	650 MB/s
Videology Industrial-Grade Cameras Mansfield, MA, USA; 401-949-5332; www.videologyinc.com; sales@videologyinc.com								
SCAiLX 10-40X ZoomBlock Camera	CMOS	C+M	Area array	1920 × 1080	VIS	Ethernet	60, 50, 30, 25	—
25Z2.4-36X Global Shutter 23x Autofocus Zoom Block Camera	CMOS	C+M	Area array	1936 × 1226	VIS	EX-SDI, LVDS, CVBS	60, 50, 30, 25	—
24C46X-2 Board Camera	CMOS	C+M	Area array	1920 × 1080	—	CoaXPress, Twisted Pair	30, 25	—
24M8.29NIP Board Camera	CMOS	C+M	Area array	3840 × 1260	VIS	Ethernet	—	30
24M2.17IP IP Camera Board	CMOS	C+M	Area array	1920 × 1080	VIS	Ethernet	30	—
Vieworks Co Ltd Anyang-si, Gyeonggi-do, South Korea; 82-70-7011-6161; www.vieworks.com; vision@vieworks.com								
VC Series	CMOS	C+M	Area array	2048 × 1088–14,192 × 10,640	VIS	Camera Link, CoaXPress, CoaXPress 2.0, 10GigE, CoaXPress-over-Fiber	454	—

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Vieworks Co Ltd Anyang-si, Gyeonggi-do, South Korea; 82-70-7011-6161; www.vieworks.com; vision@vieworks.com								
VP Series	CMOS	C+M	Area array	5120 × 5120–24,000 × 12,000	VIS	Camera Link, CoaXPress, CoaXPress 2.0	35.4	—
VN Series	CMOS	C+M	Area array	15,360 × 15,360–23,760 × 18,012	VIS	CoaXPress	72	—
VNP Series	CMOS	C+M	Area array	23,760 × 18,012–48,000 × 24,000	VIS	CoaXPress, CoaXPress 2.0	30	—
VX Series	CMOS	M	Area array	5120 × 5120	VIS	GigE	4.7	—
VQ Series	CMOS	C+M	Area array	728 × 544–5472 × 3648	VIS	GigE	291	—
VZ Series	CMOS	C+M	Area array	720 × 540–5496 × 3672	VIS	GigE, 2.5GigE, USB	528	—
VT Series	—	M	TDI	3200 × 32–23,360 × 256	VIS	Camera Link, CoaXPress, CoaXPress 2.0, GigE	—	300 kHz
VT Sense Series	—	M	TDI	4640 × 256–16,384 × 256	VIS	CoaXPress, CoaXPress 2.0, CoaXPress-over-Fiber	—	543 kHz
VTC Series	—	C	TDI	2160 × 80	VIS	Camera Link, CoaXPress, GigE	—	140 kHz
VL Series	—	C+M	Line scan	2048 × 2–16,384 × 2	VIS	Camera Link, CoaXPress 2.0, 5GigE, 10GigE,	—	200 kHz
Vision Components GmbH Ettlingen, Germany; 603-598-2588; www.vision-components.com; sales@vision-components.com								
MIPI Camera Modules	CMOS	C+M	Area array	≤5496 × 3672	NIR, VIS	MIPI CSI-2 + trigger	≤530	6 Gbit
VCSBC Nano Z 00xx	CMOS	C+M	Area array	1600 × 1200	NIR, VIS	Digital I/O, Ethernet, GigE, RS-232	60–230	—
VC nano Z-LED Series	CMOS	C+M	Area array	≤1920 × 1200	NIR, VIS	Digital I/O, Ethernet, RS-422/LVDS	≤174	—
VC pro Z Series SoC Based Smart Camera Family	CMOS	C+M	Area array	≤1920 × 1200	NIR, VIS	Digital I/O, Ethernet, RS-232	≤174	—
Vision Research Wayne, NJ, USA; 973-692-4041; /www.phantomhighspeed.com; phantom.marketing@ametek.com								
Phantom TMX 7510 UV	CMOS	C+M	Area array	1280 × 800	NIR, UV, VIS	Digital I/O, Ethernet, 10 GigE	76,000	—
Phantom S711	CMOS	C+M	Area array	1280 × 800	NIR, VIS	CoaXPress 2.0, Digital I/O	7360	—
Phantom Miro®C321	CMOS	C+M	Area array	1920 × 1080	NIR, VIS	Digital I/O, Ethernet, 16GB RAM	1480	—
Xenics nv Leuven, Belgium; 32-16-38-99-00; www.exosens.com/brands/xenics; advancedimaging@exosens.com								
Manx series	InGaAs	M	Line scan	2048 × 1	SWIR	CoaXPress	256	—
Cheetah+ series	InGaAs	M	Area array	640 × 512	SWIR	CoaXPress	1700	—
Wildcat+ series	InGaAs	M	Area array	640 × 512	SWIR	Camera Link, USB3	220	—
Dione series	Microbolometer	M	Area array	320 × 240, 640 × 480, 1024 × 786, 1280 × 1024	LWIR	16bit DV/MIPI CSI-2/USB/UVC	60	—
Crius series	Microbolometer	M	Area array	640 × 480, 1280 × 1024	LWIR	CL/SDI/ DF40/MIPI CSI-2	60	—
XIMEA Münster, NRW, Germany; 49-251-202-408-0; www.ximea.com; info@ximea.com								
High-Speed Cameras with up to 3600 Fps	CMOS	C+M	Area array	1280 × 864	VIS	Digital I/O, Fiberoptic, PCIe, Proprietary	3500+	64 Gbps
Multiple Camera Platform	CMOS	C+M	Area array	1936 × 1216, 2064 × 1544, 2464 × 2056, 4112 × 2176, 4112 × 3008	NIR, VIS	PCIe, Proprietary, USB3	340	—

CAMERA MANUFACTURERS

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
XIMEA Münster, NRW, Germany; 49-251-202-408-0; www.ximea.com; info@ximea.com								
Embedded Vision Cameras	CMOS	C+M	Area array	1936 × 1216, 2064 × 1544, 2464 × 2056, 4112 × 2176, 4112 × 3008	Multispectral, NIR, VIS	Digital I/O, PCIe, Proprietary, USB3	166, 218, 165, 95, 69	20 Gbps
xiMU, MU196 - Micro 19.6 Mpix, 5k Camera - USB 3.1 CMOS	CMOS	C+M	Area array	5120 × 3840	NIR, VIS	Digital I/O, USB3	30	5 Gbps
xiMU, MU050 - Micro 5.0 Mpix, 2k Camera - USB 3.1 CMOS	CMOS	C+M	Area array	2608 × 1964	NIR, VIS	Digital I/O, USB3	14.5	5 Gbps
xiMU, MU051 - Micro 5.1 Mpix, 2k Camera - USB 3.1 CMOS	CMOS	C+M	Area array	2472 × 2064	NIR, VIS	Digital I/O, USB3	49.5	5 Gbps
xiC, 2.3-24.5 Mpix Camera - USB 3.1 CMOS	CMOS	C+M	Area array	1936 × 1216, 2064 × 1544, 2464 × 2056, 4112 × 2176, 4112 × 3008	NIR, VIS	Digital I/O, USB3	165, 122, 76, 43, 31	5 Gbps
xiX, small 2.3-24.5 Mpix Camera - PCIe	CMOS	C+M	Area array	1936 × 1216, 2064 × 1544, 2464 × 2056, 4112 × 2176, 4112 × 3008	Multispectral, NIR, VIS	Digital I/O, PCIe, Proprietary, USB3	166, 218, 165, 95, 69	20 Gbps
xiX, large with detached sensor heads, 16-151Mpix Camera - PCIe	CMOS	C+M	Area array	1936 × 1216, 2064 × 1544, 2464 × 2056, 4112 × 2176, 4112 × 3008	Multispectral, NIR, VIS	Digital I/O, PCIe, Proprietary, USB3	166, 218, 165, 95, 69	20 Gbps
xiJ/xiRAY, Scientific sCMOS Cameras for (soft-) Xray, XUV, UV, VIS - cooled, high resolution	CMOS	C+M	Area array	2048 × 2048, 3296 × 2472, 4864 × 3232, 6576 × 4384	UV, VIS, X-ray	PCIe, Proprietary, USB3, Digital I/O, FireWire	<82	<20 Gbps
xiSPEC, Hyperspectral USB3 Camera	Multispectral	C	Line scan/ Area array	2048 × 8, 2048 × 5, 512 × 272, 409 × 217	Hyperspectral, NIR, VIS	USB3	170 hypercubes	5 Gbps
Zebra Technologies Lincolnshire, IL, USA; www.zebra.com; laurie.partington@zebra.com								
CV60	CMOS	C+M	Area array	≤4096 × 3000	NIR, VIS	Ethernet, RS-232, USB3, GigE	≤50	—
VS70	CMOS	M	Area array	≤2592 × 1952	—	Ethernet, RS-232, USB3	≤60	—
VS40	CMOS	M	Area array	≤2592 × 1952	—	Ethernet, RS-232	≤60	—
VS20	CMOS	M	Area array	≤1280 × 800	—	Ethernet, GigE	≤60	—
Iris GTX	CMOS	C+M	Area array	≤4000 × 4000	—	—	≤70	—
Zivid Oslo, Norway; 47-21022472; www.zivid.com; info@zivid.com								
Zivid One Plus	3D	C+M	Area array	1920 × 1200	VIS	USB3	10	—
Zivid 2	3D	C+M	Area array	1944 × 1200	VIS	10GigE	10	—
Zivid 2+	3D	C+M	Area array	2448 × 2048	VIS	10GigE	10	—

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Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
1stVision Inc Andover, MA, USA; 978-474-0044; www.1stvision.com; info@1stvision.com								
Allied Vision Goldeye SWIR GigE and Camera Link Series	InGaAs	M	Area array	320 × 256, 640 × 480	SWIR	Digital I/O, Ethernet, GigE, Camera Link	344	106 MB/s
Allied Vision Mako and Alvium GigE and USB3 Series	CMOS	C+M	Area array	VGA–31 MPixels	NIR, VIS	Digital I/O, Ethernet, GigE, USB3, MIPI-CSI2	≥1000	400 MB/s
IDS Imaging GigE, 5GigE, and USB3 Series	CMOS	C+M	Area array	VGA-45 MPixels	NIR, VIS	Digital I/O, Ethernet, GigE, 5 GigE, 10 GigE, USB3	396	500 MB/s
Teledyne Dalsa Linea GigE, 5GigE, and Camera Link Line Scan Series	CMOS	C+M	Line scan	2048 × 1–32,768 × 1	NIR, SWIR, VIS	Digital I/O, Ethernet, GigE, 5 GigE, Camera Link	—	≥80 kHz
Teledyne Dalsa Genie Nano GigE, 5GigE, Camera Link, and CoaXpress Series	CMOS	C+M	Area array	VGA–67 MPixels	LWIR, NIR, VIS	Digital I/O,Ethernet, GigE, 5 GigE, 10 GigE	≥1000	1608 MB/s
Active Silicon Ltd Iver, UK; 44-1753-650600; www.activesilicon.com; sales@activesilicon.com								
Harrier 10x AF-Zoom Camera	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS, 3G/HD-SDI, USB/HDMI, HDMI, IP H.264	60	—
Harrier 36x AF-Zoom Camera Global Shutter	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS, HD-SDI, USB/HDMI, HDMI, IP H.264	30, 60	—
Harrier 55x AF-Zoom Camera	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS, 3G/HD-SDI, USB/HDMI, HDMI, IP H.264	30	—
Harrier 18x AF-Zoom HDMI 4K Camera	CMOS	C+M	Area array	4K (3840 × 2160), 1920 × 1080	VIS	HDMI, CVBS	30 (4K), 60 (Full HD)	—
Harrier 23x AF-Zoom IP 4K Camera	CMOS	C+M	Area array	4K (3840 × 2160), 1920 × 1080	VIS	IP H.265/H.264	30 (4K), 60 (Full HD)	—
Tamron MP3010M-EV	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS, HDM,I USB 3, 3G/HD-SDI, HD-VLC, CVBS, H.264	60	—
Sony FCB-EV9500L	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS, USB 3, HDMI, 3G/HD-SDI, HD-VLC, CVBS, H.264	60	—
Sony FCB-EV9520L	CMOS	C+M	Area array	1920 × 1080	VIS	LVDS, USB 3, HDMI, 3G/HD-SDI, HD-VLC, CVBS, H.264	60	—
Saber1 Technologies LLC Lowell, MA, USA; 978-244-0490; www.saber1.com; shaun@saber1.com								
BVS-CA-GT1	IR	M	Area array	2856 × 2848	SWIR	10 GigE	127–194 dependent on bit depth	—
IP67-C5311	CMOS	C+M	Area array	5328 × 3040	VIS	GigE	7.4	—
CB500MG-CM	CMOS	C+M	Area array	7920 × 6004	VIS	Pcle	30	—
ORX-10G-310S9C	CMOS	C+M	Area array	6464 × 4852	VIS	10 GigE, CoaXPress	26	—
Iron 661	CMOS	C+M	Area array	13,400 × 9528	VIS	GigE	22	—
Systematic Vision Corp Ashland, MA, USA; 508-532-1116; www.systematicvision.com; bill@systematicvision.com								
SVS-Vistek FXO Series	CMOS	C+M	Area array	5–24 MPixels	NIR, VIS	CoaXPress 2.0, 10 GigE	259	—
Princeton Infrared 1280MVCam	InGaAs	M	Area array	1280 × 1024	NIR, SWIR, VIS	Camera Link	100	—
Photonfocus MV8-D8424-G01-GT	CMOS	C+M	Area array	8424 × 6032	VIS	10GigE	24	—
Photonfocus MV4 Series	CMOS	C+M	Area array	1.3–65 MPixels	NIR, UV, VIS	GigE, 10GigE	80,000	—
Photonfocus MV3 Series	CMOS	C+M	Area array	0.1–0.3 MPixels	NIR, UV, VIS	Camera Link, GigE	344	—

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CAMERA DISTRIBUTORS

Product	Sensor type	Color/ Mono	Scan type	Image format	Spectrum digitized	Interface	Frame/s	Data rate
Systematic Vision Corp Ashland, MA, USA; 508-532-1116; www.systematicvision.com; bill@systematicvision.com								
Photonfocus MV2 Series	CMOS	C+M	Area array	1.3–5 MPixels	Multispectral, NIR, VIS	GigE	18,540	—
Mikrotron EoSens 2.0CXP2	CMOS	C+M	Area array	1920 × 1080	VIS	CoaXPress 2.0	2220	—
Mikrotron EoSens 1.1CXP2	CMOS	C+M	Area array	1280 × 864	VIS	CoaXPress 2.0	3660	—
Product	**Sensor type**	**Color/ Mono**	**Scan type**	**Image format**	**Spectrum digitized**	**Interface**	**Frame/s**	**Data rate**
JAI FSFE-3200D-10GE Flex-Eye	CMOS	C+M	Area array	2048 × 1536	Multispectral, NIR, VIS	10GigE	123	—
JAI FSFE-1600T-10GE Flex-Eye	CMOS	C+M	Area array	1440 × 1080	Multispectral, NIR, VIS	10GigE	213	—
JAI SP-45000-CXP4	CMOS	C+M	Area array	8192 × 5460	NIR, VIS	CoaXPress	51	—
JAI GO-X Series	CMOS	C+M	Area array	3.2–45 MPixels	NIR, VIS	GigE, USB3, CoaXPress	162	—
IOI Victorem CX Series	CMOS	C+M	Area array	0.4–26.2 MPixels	VIS	CoaXPress	523	—
Emergent Vision HZ-100-G	CMOS	C+M	Area array	11,276 × 9200	VIS	100GigE	30	—
Emergent Vision HZ-65000-G	CMOS	C+M	Area array	9344 × 7000	VIS	100GigE	71	—
Emergent Vision HB-25000-SB	CMOS	C+M	Area array	5320 × 4600	VIS	25GigE	98	—
Allied Vision Goldeye G/CL-034 TEC1	InGaAs	M	Area array	636 × 508	SWIR	Camera Link, GigE	303	—
Allied Vision Goldeye G/CL-030 TEC1	InGaAs	M	Area array	1280 × 1024	NIR, SWIR, VIS	Camera Link, GigE	100	—
Allied Vision Alvium 1800 U/C-130 VSWIR	InGaAs	M	Area array	1296 × 1032	NIR, SWIR, VIS	USB3, MIPI CSI-2	130	—
Allied Vision Alvium G5-130 VSWIR	InGaAs	M	Area array	1296 × 1032	NIR, SWIR, VIS	5GigE	130	—

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