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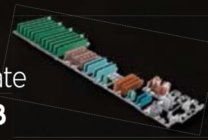

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AN EYE ON MACHINE VISION:

The Applications Pushing Its Potential

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From the Editor

By Rehana Begg, Editor-in-Chief

Machine Vision Spotlights Advancements for Industrial Innovation

MACHINE VISION TECHNOLOGY has become ubiquitous and is experiencing a surge in adoption. A recent survey commissioned by a vision systems provider revealed that over the next two years, the use of machine vision is expected to grow by 37%, with survey respondents reporting expected growth from the current 46% to an impressive 63% of potential applications.

Across the board, decision-makers are looking at transformative technologies that go beyond traditional solutions to improve visibility across operations. According to Gartner research, "by 2027, 50% of companies with warehouse operations will leverage AI-enabled vision systems to replace traditional scanning-based cycle-counting processes." Gartner further suggested that there will not be a singular vendor or solution that fits all possible use cases.

That timing is just around the corner and underscores the competitive pressure for industry players to either design their own or seek out solutions they can integrate. None of this was surprising when *Machine Design* asked several sources to explain the basic differences between machine vision and computer vision. It's a deceptively simple question because the scope of current technologies provides a wide lens and, as anticipated, elicited nuanced responses.

There were a few overlapping truths, of course. Each article in our vision systems package builds further insight into the range of approaches the industry is exposed to. Applications demonstrate various levels of maturity presented by veteran players, innovators and novices who are developing value-added workarounds and solutions.

A full complement of vision-related articles and video interviews have been posted online. And by the time you read this issue, *Machine Design*'s editors will have curated another package of articles focusing on sensors technology. You may access the coverage on *machinedesign.com* starting Oct. 7.

Design is the first step toward manufacturing. Designers of machinery use their talents to solve user-centric problems holistically. The most successful are those who have the talents and qualities to perform in today's increasingly multi-disciplinary environment. *Machine Design* is stepping up to the demand for diversity of content without sacrificing substance by offering supplemental digital coverage.

Still, there's something for everyone in this issue. For example, aerospace & defense enthusiasts may turn to p. 26 for "R&D Spotlight: Designing a Test Bench for Armored Vehicle Suspensions" and design engineers who make it their business to keep up with battery production, should check out, "Navigating the Electric Mobility Path with Solid-State Batteries" (p. 28).

Finally, our coverage of the International Manufacturing Technology Show (IMTS) on p. 24 is a mere sampling of this year's cutting-edge technologies and key trends. For a deeper dive, *Machine Design*'s technical editor, Sharon Spielman, compiled an eBook, "A Glimpse of IMTS 2024." It's also available on *machinedesign.com*.

We're tackling machine design trends, applications and solutions from all angles across multiple platforms. Sign up for our newsletters and we'll keep you informed.

Reach me at rbegg@endeavorb2b.com. ■

MachineDesign

EDITORIAL
Editor-in-Chief: **Rehana Begg**
rbegg@endeavorb2b.com

Managing Editor: **Jeremy Cohen**
jcohen@endeavorb2b.com

Technical Editor: **Sharon Spielman**
sspielman@endeavorb2b.com

Contributing Editor: **Sara Jensen**
sjensen@endeavorb2b.com

Market Leader - Electronic & Mechanical Group:
Michelle Kopier
mkopier@endeavorb2b.com

ART DEPARTMENT
Group Design Director: **Anthony Vitolo**
tvitolo@endeavorb2b.com

Art Director: **Jocelyn Hartzog**
jhartzog@endeavorb2b.com

PRODUCTION
Production Manager: **Sam Schulenberg**
sschulenberg@endeavorb2b.com

Ad Services Manager: **Deanna O'Byrne**
dobyrne@endeavorb2b.com

AUDIENCE MARKETING
User Marketing Manager: **Debbie Bouley**
dbouley@endeavorb2b.com

Article Reprints: reprints@endeavorb2b.com

LIST RENTAL
Smartreach Client Services Manager: **Kelli Berry**
kberry@endeavorb2b.com

SUBSCRIPTION SERVICES
OMEDA: machinedesign@omeda.com
847-559-7598 or 877-382-9187

DIGITAL
VP of Digital & Data Innovation: **Ryan Malec**
rmalec@endeavorb2b.com

SALES & MARKETING
Patrick Carmody
pcarmody@endeavorb2b.com
AK, AR, AZ, CA, CO, HI, IA, ID, IL, IN, KS, KY, LA, MI, MN, MS, MO, MT, ND, NE, NM, NV, Western OH, OK, OR, SD, TN, TX, UT, WA, WI, WY, Western Canada

Rebecca Ward
rward@endeavorb2b.com
DE, MD, NC, NJ, NY, Eastern OH, PA, SC, VA, WV

Liz Stott
lstott@endeavorb2b.com
AL, CT, FL, GA, MA, ME, NH, RI, VT, Eastern Canada

Holger Gerisch
hgerisch@endeavorb2b.com
UK, Europe (not Italy)

Diego Casiraghi
diego@casiraghi-adv.com
Italy

Helen Lai or Charles Liu
helen@twoway-com.com or liu@twoway-com.com
Pan-Asia

ENDEAVOR BUSINESS MEDIA.

Endeavor Business Media, LLC
30 Burton Hills Blvd, Ste. 185, Nashville, TN 37215
www.endeavorbusinessmedia.com

CEO: **Chris Ferrell**
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Automate 2024 Wrap-up: Shifting the Robotics Paradigm to Flexible, Agnostic Solutions

Functional success of robotic and control solutions is tied to available information, flexibility and software upgrades. Heads-up: AI is integral to the mix.

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Featured Content

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Designing a Winning Medal:
What's Behind the Flub of This Year's Olympic Bronze Medals?

A metallurgist weighs in on possible reasons behind the bronze medal deterioration and what could be done to mitigate a similar problem at the 2024 Paralympic Games.

THE TRADITION OF awarding highly regarded medals to Olympic winners was slightly tarnished this year, following reports from bronze medal athletes about their medals losing luster within days of receipt.

While the deterioration could be the result of any number of causes, the Paris 2024 Olympic organizers have reported that they are working with the Monnaie de Paris, the institution tasked with the production and quality control of the medals, and the National Olympic Committee to appraise the cause of the damage.

Keep in mind that these coveted bronze medals aren't made of bronze, per se. "This year's bronze medal is actually 97% copper, 2.5% zinc and a half a percent tin," said Tessa Axsom, director of CNC, Fictiv, a San Fransisco-based company that specializes in custom manufacturing of mechanical parts and processes.

Copper oxidation is likely the cause, according to Axsom.

Several news outlets reported that the discoloration and chipping was due to sustainability practices, "but that is not true," pointed out Axsom. "Using recycled metals to make the metals is not what's causing this. Copper oxidation is natural, and it reaches stability when it forms oxides and salts. So, when you have sweaty athletes wearing these metals, getting salt on them, you're going to get oxidation. The metal should have been protectively coated."

Basic Copper Reaction

Oxidation is a form of metallic corrosion and occurs during a chemical reaction when oxygen is present on the metal's surface.

The first phase in oxidation, Axsom explained, is a red or dull red color, but it could further discolor into a blackish, brownish hue and eventually the blue-green and purple patina, depending on the environment that the copper is exposed to.

◀ **The Olympic and Paralympic medals of the Paris 2024 Games have a unified design on one side.** *Paris 2024*

The medals should have been coated with a clear protective film to prevent discoloration and to provide a barrier between the copper and the atmosphere. An example of this protective layer would be a protective coating such as Everbrite. Axsom said that it could be the case that a protective coating was applied, but that the medals might have had some residual contaminants that prevented strong adhesion of the coating.

Axsom theorized that the chipping could be due to the brittle nature of copper-oxide powders of poly-crystals. This further enhances the theory of copper oxidation and explains why they seem to be chipping, she said.

Investigating the Cause of Corrosion

What would Axsom do if she was investigating the cause of the discoloration? She would collect a medal, cross-section it, inspect it under a scanning electron microscope and perform energy dispersive spectroscopy to determine the discolored areas' composition.

That would help determine how to reprocess the medals, said Axsom, a mechanical engineer who has specialized knowledge of metallurgy and material science, as well as design engineering for thermal management systems for aerospace.

"Perhaps they could be cleaned and recoated with a protective coating, or perhaps they would decide to melt these down and make new medals," she added. "Either way, figuring out what's occurring would help to provide the corrective actions to prevent recurrence, which is important in continuous improvement and when you have an issue that causes a failure of a part."

Olympic Medal Design and Process

Every design process begins with an idea. "For this year's Olympic medals, the organizers had the vision of creating something with Paris in mind, of course, and there's nothing more iconic than the Eiffel Tower," said Axsom. "They went back to the archives—and this is similar to what a design engineer would do when they're designing a new product—to see what had been done before, and what references they had that could provide insight for the future design."

This year's Olympic medal design includes a piece of metal taken from the original Eiffel Tower. The metal pieces are derived from metallic elements permanently removed through renovations and conserved in the process. The Eiffel Tower Operating Company approved the use of these coveted pieces of French history in the manufacture pf the Olympic medals.

The Olympic and Paralympic medals have a unified design on one side, which is encrusted with the Eiffel Tower iron. The reverse side of the Olympic medal is adorned with renderings of the goddess of victory Athena Nike, the Panathenaic Stadium, the Acropolis of Athens and the Eiffel Tower.

The back of the Paralympic medals features a graphic representation of the Eiffel Tower viewed from below. The words "Paris" and "2024" at the base of the tower are inscribed in universal Braille, the symbolic language of accessibility, in honor of French inventor Louis Braille. Dashes engraved on the edge allow visually impaired athletes to distinguish between the medals: I for gold, II for silver and III for bronze.

"In this case, the metals don't really have to function; they're not going to be seeing a lot of wear or weight or repeated cycles of use, but they have to look nice," explained Axsom. "This process is unique because they called on LVMH (Louis Vuitton Moet Hennessy) jewelry and watchmaking designer Chaumet."

Axsom envisaged a design engineer would seek the help of an industrial engineer and artists to design aspects that are heavily aesthetic. "I'm sure that they also had some mechanical engineers and some experts from their jewelry making department weigh in on the manufacturability of the design," Axsom surmised. "That is something that Fictiv does well for our customers.

"You can upload a 3D model and [luxury jeweler] Chaumet could have uploaded a version of their design and gotten manufacturability feedback for free with Fictiv's AI-driven DFM feedback on the platform," she added.

Rigorous Testing Process

Axsom said that each medal would have been heavily scrutinized for its aesthetics and composition and would be subjected to environmental testing. "The Olympic Committee sets forth requirements for the weight of each alloy based off each metal that's contained in each alloy," she said.

A likely process, as outlined by Axsom, consists of the following: They would probably use X-ray fluorescence to determine the composition or purity of certain metals. In addition, they would conduct visual inspections via the naked eye and microscopes. They might weigh the metals, performing process conformity testing. They could test the chemical baths used to clean the metals after production, followed by cleaning and rinsing.

For the clear coating or the sealant, environmental testing would hopefully be conducted, including destructive or nondestructive testing like salt spray or wear resistance. In this case, UV light exposure testing might be considered.

Corrective Action is Required

Axsom expressed one concern about the fact that the task of designing the medal was awarded to a luxury jeweler who may or may not have fully considered the environmental conditions. "These are athletes—they're not people going to a ball, or a fancy dinner," she said. "They are going to have salt water or sweat on them.

"I just wonder if perhaps the medals weren't protected enough in the first place, Axsom surmised. "This is something that they probably wouldn't have noticed if they weren't subjecting these medals to the actual environment during the quality control process." ■

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Basic Considerations When Commissioning a **Vision System**

Machine vision experts discuss fundamental questions clients should ask when they consider machine vision solutions.

by Rehana Begg, Editor-in-Chief

WHAT ARE SOME of the key considerations when designing a vision system? What are the questions prospective customers should ask when appraising whether a vision application is feasible, or whether it will provide the right ROI out of adopting one system over another?

Machine Design asked two vision system experts to provide high-level insights into these questions during a webinar on machine vision tools and trends.

The panelists were: Eric Hershberger, principal applications engineer, Cognex, and David L. Dechow, owner/consultant, Machine Vision Source.

Below is an edited version of their responses. The full interview can be downloaded at *https://machinedesign.com/55126152.*

***Machine Design:* What should a prospective customer ask you before deciding whether machine vision is a viable solution?**

Eric Hershberger: The big thing I see a lot is that everybody thinks of machine vision after the fact. We're always trying to fit small cameras in places that are not conducive to creating the right image.

We have all this fantastic technology but creating that great image with the light—the light together with the right placement will highlight what we're trying to inspect, or to subtract the surface or do something else—seems always to be the afterthought. So, you're always working with what you have. Some guys I work with—I always call them lighting ninjas—are just amazing at getting that light placement, but then going out to the line and trying to get that back again gets difficult.

We're always thinking about where the camera will be placed. We look at a lot of operator stations where operators are placing parts into a fixture, and we're verifying that all the parts are in the right location, or that the clips are connected and that the cameras are not going to be in the way of the operators. Operators don't like red flashy lights, or blue flashy lights, or green, or IR, which does different things with your imaging.

In the past, my sales team forgot to tell me about the skylight that's directly above where we're placing the camera. Skylights

Eric Hershberger, Principal Applications Engineer, Cognex

are great until the sun shines right to that [position] onto your inspection system. And if you haven't filtered correctly, or blocked out some of the external lighting, you're going to start to fail parts that are actually good, because you have external influences on that. Those are the big ones.

I, of course, always ask what kind of budget they are looking for? Personally, I always go as high resolution as possible. And sometimes that's not necessary. Sometimes, we can go with some of the easier sensor solutions that are much cheaper than the higher-end applications.

In the end, do you have a good idea of what you're looking for? Is it a defect? Do you have a bunch of samples that we can image and then show you what we do? That's what I do the most. I have piles and piles of parts in my office right now because we're running through evaluations. It's usually described as a six-car wreck, with parts flying around everywhere. But what are you trying to find? Knowing that up front is the most important thing.

David L. Dechow: I'll second that comment. Everything was spot on, but I'll second that comment. The one thing that I usually teach or communicate to the customer is, and the biggest mistake the customer makes is to come to me and say, "I want a machine vision system right here." That's not a good starting point.

The starting point, if you're thinking about using machine vision, is to understand and communicate the needs of the application very specifically. It should not be, "Does this need to be inspected here or not? Do I need to guide a robot here?"

Instead, ask: "What do you need to do?" Explain: "I need to make sure that this part doesn't go past this point with a scratch on it, because that will not prevent me from adding value to a bad part." Or, "I need to use something we don't even have, such as a robot. I need to use something right here to move this part from point A to point B. Now, how can I do that technologically?"

The best advice I can ever give customers or people thinking about automation, is to not think about it in terms of what technology they are going to use, but to think about it in terms of what they need to do, and how it adds value to the process. And then we can start coming up with the machine vision solution.

Partners can start coming up with all sorts of great concepts in terms of how to how to add that value using technology. To be fair, sometimes we just say, "No, I can't add value to that process." The point is, start with what you need to do to add value to your process. And then dive into the technology that will deliver that [goal].

***MD:* Can you sum up your thoughts on bringing someone along as they learn about machine vision?**

DD: The thought that's always in the back of my mind is to learn how to use the technology and use it correctly. Understand that it is there to provide value and to serve the process. Many people in today's industrial environment still get scared of machine vision, or may be a little bit loath to implement machine vision. With all the tools we have now, the deep learning and even into the algorithmic tools we've had for a long time, machine vision is more efficient, cost-effective and reliable than ever.

David L. Dechow, Owner/Consultant, Machine Vision Source

If you don't have the skill set to do it yourself, seek out someone who does. But don't shy away from machine vision as a technology, because that's really going to be part of the future in machine vision, enabling and robotics, enabling automation. So, a final word is, just use it. You're going to find that it will help the manufacturing process.

EH: In the past, we've seen a lot of new customers who had never installed cameras before. They tend to choose the hardest projects to start with and then have a very difficult time with it. It's a complicated project that probably doesn't have great specifications, is complex to support and, in the end, they end up failing. Then, with any subsequent project, that system didn't work. So, I always start with the simple successes and then try to work up from there.

But there are so many great resources now. Back when I started, it was kind of, toss a camera out there, toss a light and see what you can come up with. I'm a big fan of some of the certifications that are out there now, the classes that you can take from industry leaders and really get a good idea of some of the basics just within a week. And we're starting to see a lot more classes popping up at universities with different machine vision concepts. And there are all kinds of AI research, of course.

So, the fundamentals. Start playing with cameras and lighting, and just go for it. It is such a great time to do it, too. There are so many fun things to learn and enjoy with machine vision. ■

The Vision of Sustainable Agriculture: Laser-Focused on a Weed-Free Farm

Courtesy Carbon Robotics

Carbon Robotics' LaserWeeder uses artificial intelligence, an advanced vision system and laser technology for sustainable weed management and agricultural productivity.

by **Sharon Spielman,** Technical Editor

WHEN IT COMES TO sustainable agriculture, the challenge of finding effective weed management has led to some groundbreaking technologies. Carbon Robotics' LaserWeeder stands out among them, using cutting-edge computer vision and artificial intelligence (AI) to address the never-ending need for weed control in agriculture.

Founded in 2018, the company began with a vision to integrate advanced technology with traditional farming methods. Paul Mikesell, CEO, brought with him expertise in AI and robotics, translating insights gained from discussions with farmers to actionable solutions. His goal was clear: Harness Silicon Valley innovation to tackle region-specific agriculture issues.

The Role of Technology in Sustainable Ag

At the heart of the laser weeding machine's functionality is its sophisticated vision system. Using real-time data processing, the machine leverages deep learning models to distinguish between crops and weeds. This is accomplished through an array of cameras integrated with an AI-driven neural network, which continuously assesses its environment, making on-the-fly predictions and classifications.

Unlike traditional object detection algorithms that rely on contours and edge detection, the LaserWeeder's neural networks are designed to comprehend higher-level plant characteristics, allowing for adaptive responses to varying soil conditions and environmental factors.

The application of high-powered lasers for weed eradication offers a shift in agricultural practices. By targeting weeds directly and avoiding the need for herbicide usage, the machine eliminates the risks associated with chemical exposure for farmers and consumers alike. This method not only preserves the integrity of the crops but also minimizes environmental impact.

Mikesell highlights two primary benefits of the laser technology: enhancing crop yield and reducing dependency on fertilizers and water, as the plants experience less stress from chemical applications.

"It doesn't knock your crops back, right, because if you're not spraying herbicide, you're not damaging your crops." Mikesell said, noting that farmers also need less fertilizer and water to grow crops. He added that because blades are no longer being dragged to the ground, torn-up topsoil isn't causing erosion.

System Performance and Real-World Challenges

Operational efficiency is built into the machine's design. The LaserWeeder navigates fields at a rate of approximately 1 to 2 acres per hour, an effective speed for thoroughness that also can be adapted to the weed density in the fields. The effectiveness of the vision system is demonstrated through KPIs which aim for more than 90% accuracy in weed identification, while ensuring that crop misidentification remains below 1%.

Before bringing the machine to market, Carbon Robotics engaged in extensive field testing from 2018 to 2022. This phase revealed the many environmental challenges that agricultural robotics must overcome such as heat humidity and dust.

"By the time we had machines to market, we'd been through several different generations of [the] machine—everything from the type of optics and servos to the type of GPUs and the types of neural nets that we were using," Mikesell said.

These rigorous field trials were important, he said, due to the unpredictable nature of outdoor conditions. The commitment to real-world application ensures that the laser reader performs consistently in a range of settings.

ROI, Future Outlook and Scalability

From an economic perspective, the company aims for a return on investment (ROI) for farmers that allows for payback within one to three years of equipment purchase. Yield increases of up to 50% have been reported, which demonstrates the machine's effectiveness for eliminating unwanted vegetation. By reducing herbicide reliance, farmers can gain insights into the extent of damage previously done to crops by chemical applications.

With regard to finding reliable suppliers for the integration of advanced components in the machine, Mikesell says that the company collaborates with several companies worldwide to ensure they source the best parts. ■

Can Machine Vision Solve the Pain Point of **Making Robotic Arms Intuitive?**

CynLr, a deep-tech robotics and cybernetics startup is tackling visual object intelligence. Its robotic arms solution can pick up unrecognized objects, including mirror-finished objects.

by Rehana Begg, Editor-in-Chief

WHEN IT COMES TO the field of advanced robotics, machine vision is an indispensable component in guiding robots to take commands and react by shifting from Point A to Point B.

"Robotic arms today are just machines with six motors, where you take a joystick, ask them to go to a particular position, record this position into another position, and record this position again," said Gokul NA, co-founder of CynLr (Cybernetics Laboratories)—a deep-tech robotics and cybernetics startup based in Bangalore, India—in a multi-part video series *with Machine Deisgn (available at https://machinedesign.com/55131392).* "The assumption is that it will keep repeating this action again and again and again within 20-micron precision."

Robotic arms are programmed to move within the parameters of preset positions and designed to operate with high precision. These robots lack adaptability and struggle when the objects they handle shift even slightly, leading to grasping and manipulation failures.

This is the crux of its limitation, said NA, as it underscores a universal challenge when manufacturers use advanced robotics in assemblies.

The Core of the Machine Vision Problem: Manipulating Unrecognized Objects

A significant part of manufacturing tasks involves basic repetitive actions, such as moving parts or assembling items. These tasks are largely manual despite high labor costs, argued NA.

"If my numbers are right, the U.S. pays around $1.3 trillion in wages in manual labor alone for manufacturing sector," NA said. "That's a lot of un-automatable tasks."

This deficiency is compounded by the fact that robots are limited to basic tasks, such as feeding parts into a machine, or moving parts from one location to another. "This is their primary task," NA pointed out.

Current vision systems make use of color images and pattern recognition to identify objects and construct depth, explained NA, but they falter when it comes to reflective or obscured items. This reflects that solutions are merely based on a basic understanding of vision, and it is why vision systems today do not scale, he said. If the robot cannot identify an object, it falters and won't know where to go.

Cameras are the preferred way to make the robotic system dynamic, NA said. The bottleneck for cameras is that they must identify objects at every point yet cannot adjust dynamically to changing situations.

CynLr responded to the innovation opportunity by developing a visual object intelligence platform that interfaces with robotic arms. The solution instructs robotic arms to pick up unrecognized objects without recalibrating hardware. It also works with mirror-finished objects, an ongoing challenge for robotic vision systems.

Hot Swapping: Platform Enables Standardized Production for Different Outputs

CynLr looked to human vision for guidance in solving the problem of coordinating vision for robot gripper manipulation, said NA. Humans intuitively use vision in intricate ways that entail layers of processing and contextual understanding. We instinctively process cues—such as depth perception, motion, autofocus and convergence—and effortlessly use the information to navigate or manipulate objects.

"More than 55% of your brain, at any given point of time, has to process visual data or visual information, or any of your processing to do allocating for," explained NA, adding that CynLr has interrogated those processing layers and that better solutions can be uncovered when exploring the extent to which computation is oversimplified in current machine vision systems. "That's what we are actually building—a sentience before intelligence," NA said.

CynLr develops functionality that will allow the robotic arm to handle unknown positions for objects in its view—to handle it, pick it, rotate and explore it and to bring it to a point that is familiar to the system. In essence, NA said that the platform enables product-agnostic assembly lines that can produce different outputs with little additional capital cost.

Showtime for Agnostic Vision-Guided Robotic Manipulators

CynLr is currently proving out its machine vision stack with deployments at Denso and General Motors. CynLr also showcased its general-purpose, semi-humanoid visual manipulation robot platform at the Robotics Summit & Expo in Boston show in May. Known as CyRO, it is billed as a dual-arm vision-guided robotic manipulator that can intuitively grasp objects it's never seen before and switches between two tasks on a movable station. ■

Deep Learning Algorithms Help Vision Inspection Systems See Better

Zebra Technologies' Andrew Zosel discusses how AI and deep learning tools help expand machine vision capabilities, particularly in inspection system applications.

by Rehana Begg, Editor-in-Chief

DEEP LEARNING FINDS numerous applications in machine vision solutions, particularly in enhancing image analysis and recognition tasks.

Algorithmic models can be trained to recognize patterns, shapes and objects in images, explained Andrew Zosel, senior vice president and general manager, Zebra Technologies, in a multi-part video series with *Machine Design (available at https://machinedesign.com/55130040).*

Deep learning models use various techniques—such as image classification, object detection, segmentation and optical character recognition (OCR)—to extract features from images and are trained to make decisions based on the context. Manufacturers benefit from the speed, accuracy and reliability that this computation brings, said Zosel.

Are the Disciplines of Machine Vision and Computer Vision Melding?

As machine vision systems mature, the differences between machine vision and computer vision become less obvious. Both machine vision and computer vision involve going over or analyzing visual inputs. However, machine vision requires the use of digital cameras before processing the images for an output decision. Machine vision systems also typically contain a camera, a lens, a processor and software to enable the machine to make these decisions.

Computer vision does not need the camera input and can work from saved images (real or synthetic) to interpret and produce a result.

"Basically, computer vision may be viewed as the broader category of anything that takes an image and processes it—anything from inspecting license plates to people counters and all kinds of more generic vision processing using a computer," said Zosel, who is responsible for Zebra's Advanced Data Capture, Machine Vision and Robotic Automation businesses.

In contrast, machine vision is a more specific term, typically used in industrial or factory and warehouse-type environments, said Zosel, "where you're actually looking at a product being made or created and being processed, and therefore leveraging camera and imaging and technology to do a specific task for an operation."

In addition to delineating machine vision from computer vision, Zosel answered questions on current uses for deep learning algorithms in machine vision systems and highlights the subtleties that Zebra Technologies has achieved in enhancing inspection accuracy.

The following questions have been edited for clarity and context.

Machine Design: **Can you demystify some of the expectations about machine vision? For example, what can a machine vision solution do today that it couldn't do in the past? And what have they yet to achieve?**

Andrew Zosel: Fundamentally, we see the world through our eyes and brain, and we are a vision processor ourselves. As people, we're an amazing machine vision system. Our vision helps guide us, helps with motion, etc., and helps us see and inspect parts.

And traditionally, machine vision has been applied to deterministic objects—things that are easily defined as good or bad, defined as specific, square measurements, etc. and less subtlety of comparing images and whatnot.

With advances in deep learning and AI, machine vision technology and machine vision capabilities come closer to how a human interprets the world. Still, we don't have the capabilities today—in the hardware, in the software and the algorithms—that are at the same level as the person. So, it's closer than it's ever been, but it's still significantly less. A person can perceive a defect or a scratch or, or a misalignment of something, typically much better than a machine vision system can.

Of course, the exceptions are when things are very, very small or very high speed. For example, we can't see semiconductor parts unless they're under a microscope. Or, we wouldn't be able to see bottles whizzing by on a packaging line, unless somebody stopped motion. But machine vision systems can do that.

Historically, machine vision systems were used in applications that were either very fixed and non-organic type applications or applications where humans weren't capable because of high speed and high resolution.

Now, with AI and deep learning, there are more and more applications where humans and human inspection could be realistically replaced with machine vision tools. Advanced tools like anomaly detection or segmentation analysis—telling one part from another and saying, OK, this is part A, this is part B, based on subtle features—can be trained into an AI model and can be effectively used with those types of tools.

***MD:* Can you walk us through an application where you use that methodology?**

AZ: There are many assemblies, where one cable or one electronic component is plugged in to another, and these could be done by people, or they could be done by a machine. If you open your cell phone, for example, there are a lot of little connectors that are seated into other parts and the lens and camera system is plugged into the main board, and the display is plugged in. The seating of those two pieces together is critical; that they're plugged in and maintain that connection over time [is critical].

In traditional machine vision, you can look at the gap and try to measure it in the lens and lighting. But it has been a challenging application because, where do you set the threshold or what's good enough as far as how seated a connector is, for example. Some of the applications we've been able to do are some of the subtleties of that threshold of what's good enough, and what is going to maintain.

For instance, if you have a data set or a set of images that you train an AI model around, and you can show all the different nuances of connector seated and not seated, then you can set a different way of inspecting it, such that you get feedback from the feed on where it wasn't quite seated enough.

Or, if there's some way that the connector is slightly unplugged and eventually it becomes unplugged, you can feed that back to the original algorithm and say, "Okay, that is slightly unplugged, it is an unacceptable part and put it in the reject stack of the AI."

So, opportunities like that. Deterministic algorithms can be very complex and very difficult to program, and AI and deep learning and using that anomaly detection type algorithm or classification algorithm makes it easier. ■

Mechatronics Students Plot a 2.5D Vision Method to Improve Picking Precision

Skye Automation has devised a vision systems workaround for picking parts of varying heights. The method employs a 2D camera integrated with a robot.

by Rehana Begg, Editor-in-Chief

IF 3D VISION is too costly and 2D vision has precision limitations, could there be an in-between solution?

That's the problem that Evangeline Dryburgh and Amy Spenser, a pair of mechatronics engineering co-op students from the University of Waterloo, Canada, have been challenged to solve over the course of their summer internship.

The students devised a practical method for capturing the exact position of objects while working on a project involving a pick-and-place robot configured to pick objects from a flat plate. "We found that the pick area near the edges of the plate had a bit of distortion with taller objects," Dryburgh said. "We needed a way to get rid of the distortion and to tell the robot precisely where the objects were, no matter how tall [they were]."

The focal distance affects the way the image is presented to the guidance system, said Skye Gorter, president, Skye Automation, an industrial automation systems provider that focuses on robotics and machine vision based in Ontario, Canada. By applying a scatterplot to the calibration routine, his co-op student team algorithmically adjusted for those height changes on the parts.

"We're talking about traditional vision-guided feeder systems that are very common in the market today," said Gorter. "Products like FlexiBowl and other feeder systems present a nice solution to the market. But there is bit of a gap where they're designed truly for flexibility but lose precision when it relates to dimensional changes in the parts."

The 2.5D vision algorithmic method that the students worked on solves this problem and it can be applied accurately to any of those systems, Gorter said.

Building an Algorithm That Compensates for Height

The students' investigation started on one project, where the taller the objects were, the more distorted the images were. They came up with the 2.5 D vision method to alleviate the distortion and to accommodate taller objects that showed up as being in a slightly different position due to their height.

Instead of using an expensive camera, the pair worked with Skye Automation's programming lead, Nejma Latheef, to build an algorithm that would account for the way height affects the placement of objects and thus accommodate the distortion.

The 2.5D vision algorithmic method solves the problem of picking parts with different heights. Skye Automation's team said the solution can be applied to any feeder system application. *Skye Automation*

"People have heard of 2D and 3D, but 2.5D is not very common," pointed out Latheef, who does the mainstream programming for robotics as well as the front-end HMI designing and integration of various systems. "That's the name we gave it because it's more precise than 2D imaging, but it doesn't create any 3D images. That's why we call it 2.5D," she said.

Plotting Pick-Heights and Sending Data to the Robot

The students recorded the position of the object from the camera based on the typical pick height for the application and brought it closer to the camera. They recorded the pick action with two different heights and plotted the data using MATLAB. "Unfortunately, that didn't tell us much, so we had to change our thinking," said Spencer.

They recorded a third height and plotted the data in Excel. A schematic of the data showing the different heights (represented by green, orange and blue dots) confirmed that objects in the center of the plate (pick area) were stacked one on top of the other. This meant the robot perceived the part as being in the same spot at each height, Spencer explained.

But there was more distortion closer to the edges. "We were originally sending incorrect points to the robot, and we were seeing that when it was going to pick, it would be a millimeter shifted up into the right or up into the left," Spencer said. "We realized that we needed to find a way to fix that. And that's how we created 2.5D, which was an in between of taking our 2D image and creating a rudimentary third dimension with that information."

Spencer said that the novel positioning method allows them to continue using a 2D camera, and it will algorithmically adjust the position of the part that it sees.

The 2.5D method can be applied to any application where a 2D camera needs to be integrated with a robot, added Dryburgh.

The big benefit, pointed out Gorter, is that the method presents "higher reliability and greater degree of flexibility on a system that's designed for flexibility to begin with." The solution will be an added value his company can apply to future applications. ■

Q&A: Advancing Metrology with Handheld 3D Scanners

Let's explore how Hexagon's handheld 3D scanning technology allows for metrology-grade parts scanning, allowing for the digitalization of parts without the concern of fixturing or environmental conditions.

by **Sharon Spielman**, Technical Editor

The ergonomic design fits in the hand and is light enough to take anywhere and use comfortably for long inspection projects. *Courtesy Hexagon*

HEXAGON'S MANUFACTURING INTELLIGENCE Division offers handheld 3D scanning devices for flexibility and efficiency of measurement processes in a range of environments. The company's ATLASCAN Max and MARVELSCAN are engineered with a vision system that helps meet the growing demand for digitalized 3D scans throughout the product life cycle. They enable engineers and manufacturing personnel to scan components in a range of inspection contexts.

Suitable for applications in automotive, rail, industrial equipment and general manufacturing, as well as heritage and restoration projects, the scanners are designed to be user-friendly and an essential tool for quality inspection and reverse engineering tasks.

To learn more about the scanners, *Machine Design* reached out to Joel Martin, director of product management, North America, at Hexagon.

Editor's note: Questions and answers have been edited for space and clarity.

Machine Design: **What are the key performance metrics that machine design engineers should consider when evaluating this 3D scanner?**

Joel Martin: When evaluating a 3D scanner, machine design engineers should consider several key performance metrics to ensure they choose the right tool for their specific requirements, including:

- Speed—Efficiency in action and scanning speed impacts productivity. It's not just about how many millions of points per second the scanner provides, it's more about how well the technology fits the application. Users must ensure they're able to respond quickly, complete measurement tasks without excessive prep work or setup and return acceptable results without time-consuming do-overs. Design engineers should identify what problems they are trying to solve and work with scanner manufacturers to make sure that the technology fits the need. Too often we see companies trying to solve a problem with the wrong technology because it is all that was available at the time.
- Agility—Users should be poised to measure whatever the design and engineering teams bring, shift to new tasks without disruption and be ready for the next big idea before it becomes reality. Look for a scanner with a suite of scanning tools to best fit the requirements as needs change.
- Simplicity—Reduce complexity wherever possible, get new workers trained and productive quickly and ensure the right resources are in place to complete the work the business expects. Scanners need to be easy to use and fit the application. If the technology is too complicated to use or set up, then its adoption will be limited in actual use.

MD: **How easily can this scanner integrate into existing workflows?**

JM: Hexagon's new handheld scanners are designed to add value immediately. Because these scanners do not require complicated fixturing or special measuring environments and are battery-powered and completely wireless, designers can easily identify quality problems while they're still in the design or prototyping stage or on the assembly line. Providing easier-to-use, more flexible quality inspection tools improves designer innovation and allows metrology and measurement to be more accessible.

MD: **Are there any compatibility issues or specific requirements that machine design engineers should be aware of?**

JM: It's less about compatibility or specific requirements and more about choosing the right tool for the right job. Maybe even more important, finding a technology partner that will work as a consultant more than "just" a salesman. It's critical to work with a company that can offer multiple solutions and isn't just trying to solve a problem with one piece of "do-it-all" technology.

***MD:* What level of precision and accuracy can engineers expect from this 3D scanner, especially in complex industrial environments?**

JM: Accuracy is the foundation of precision. It refers to the level of size error between the scanned data and the actual object. A highly accurate 3D scanner ensures that the captured measurements closely match the real-world dimensions of the object. Resolution (also known as point spacing), on the other hand, determines the spacing between individual points in the point cloud. Higher resolution allows for capturing intricate surface details with greater fidelity.

***MD:* Are there any limitations on considerations related to the accuracy of scanned data for machine design applications?**

JM: Accuracy and resolution are independently important. There are many handheld technologies available today from hobby (0.5 mm) level scanners all the way to metrology grade (20 µm) scanners like the MARVELSCAN and ATLASCAN Max. It can also be important to understand what features need to be measured and if users want to extract those from the point cloud or if the sensor should measure them directly with vision or even a touch probe, like those found on portable coordinate measuring machines (CMMs).

***MD*: How does the use of this scanner enhance the efficiency of design processes for machine components or systems?**

JM: Measurement should be meticulous; but, when the business is waiting for results, it's imperative to be both meticulous and fast. Unfortunately, the process of scanning is, by its very nature, time consuming. Setting up the part and the scanner, positioning it properly, affixing and removing targets, and attaching and untangling cables, all add hours and cost to the process. And that's before scanning begins, which brings a whole new level of potential complications and delays.

In addition to the time-consuming process of scanning, the usual process often ends with designers having to redo work if they don't pass quality checks. The new handheld 3D scanners allow users to scan what is needed, where it's needed, without restrictions, allowing design engineers to scan and ensure the quality of their product as they design it.

***MD:* Are there any features or functionalities that streamline the workflow for machine design engineers? Can you elaborate?**

JM: MARVELSCAN allows for improved scanning speed and efficiency for parts and repetitive scanning applications. The patented Reverse Positioning System streamlines the workflow for design engineers by not having to take the time to place targets on an object. Instead, they can use an artifact in the environment to scan quickly and efficiently with no need for additional tracking devices, cables or connections. ■

With Software and Vision Systems Advances, **Welding Cobots are Ready for Primetime**

The American Welding Society speaks to UR's Will Healy III about the seamless integration of vision technologies and cobots.

by AWS Staff

AS WE APPROACH some of the industry's premier trade shows for welding and manufacturing, including FABTECH in October, one question that is on everyone's mind is, "What's next for welding automation?" To shed light on the topic, AWS connected with Will Healy III, global industry manager—welding at Universal Robots.

UR is the industry's leading provider of collaborative robots (cobots), has a worldwide installed base exceeding 75,000 arms and is the cobot provider of choice for many of the leading welding automation companies. Healy holds a B.S. in mechanical engineering from Purdue and has been involved with automation and industry for 20 years.

American Welding Society: What is the current state of automation within the welding industry?

Will Healy: Before drilling down, we need a quick recap of where we have been. As recently as two years ago, some welders were openly hostile and aggressive toward automation providers. They had this 1980s automotive industry mindset that robots were going to take their jobs. AWS's WeldingWorkforceData.com says that we need to fill 82,500 jobs annually. Technology may impact the nature of your specific job—a theme I am going to come back to—but my gosh, the welding industry jobs are always going to be there.

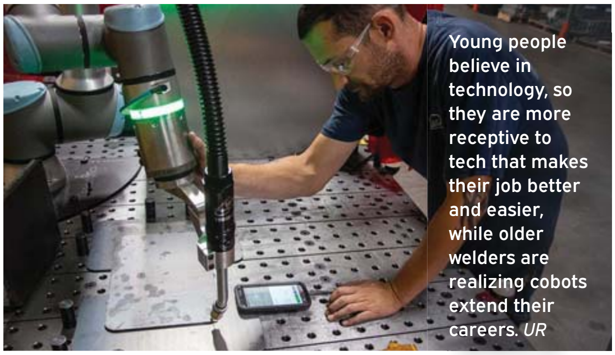
AWS: What changed with automation?

WH: Automation is exponentially easier and more approachable than ever before for job shops. This is especially true due to recent advances in cobots. There has been a hyper-focus on simplifying the cobot integration experience and improving the cobot operator experience through intuitive interfaces.

As a result, a welder is now capable of operating multiple pieces of equipment, boosting machine utilization numbers and shortening changeover time between parts. With these factors, shops can now run more parts per machine with overnight runs or lights-out manufacturing, boosting shop competitiveness and helping leaders win new business.

AWS: What changed with welding operators?

WH: There are a couple of factors. Welders understand mechanical operations, and with a cobot, you grab the arm, put it where you want it and push a button to record a point on a weld path. This kind of touch-to-teach programming makes cobots approachable, especially for young folks that have always had a mobile phone. In fact, one cobot provider using our robots, Hirebotics, developed a cobot programming software app that runs on a tablet or smartphone. Anyway, young people believe in technology, so they are more receptive to tech that makes their job better and easier.



Young people believe in technology, so they are more receptive to tech that makes their job better and easier, while older welders are realizing cobots extend their careers. *UR*

Older welders are realizing cobots extend their careers. In many cases, welding is physically tough, and those people eventually face a career shift. By becoming a cobot operator, they can keep welding or even enter a new career phase, such as supervising a group of cobot operators. I have had seriously tough guys get emotional to the point of tears when they realized cobots could extend their careers so they could put their kids through college, paying off their house or work to retirement age.

AWS: Automated welding has this reputation of sometimes missing the weld seam. What has been done to address that issue?

WH: You're right. The joke has always been that you can't weld air, which results from poor part fit-up. A couple of things have changed. First, people are getting smarter about which joints they automate. The bottom line: Automate the easy, boring, repeatable parts and save your skilled welders for the complex joints.

Second, more people need to understand a cobot is only part of the solution; repeatability requires a solid investment in tooling and fixturing. Third, integrators are getting better about assessing the real workflow. The classic case is where the operator has to pound on the part with a mallet to force it into a fixture. That's not documented anywhere, so integrators need to analyze the entire workflow.

Finally, more people are getting smarter about feeding the robot consistent parts, such as by switching from less-repeatable processes to laser cutting.

AWS: Are laser seam trackers an option for cobots?

WH: Yes, and companies such as Garmo Instruments make 2D laser seam trackers specifically for cobots. They have features such as:

- Vision programming, which means that the positioning of the torch during programming is calculated by the sensor, reducing the skill required.
- Seam finding: The sensor finds the right teach points of the welding joint before the weld in order to compensate the part deviation.
- Seam tracking: The programming of complex shapes is a consuming task. With the seam tracking solution, teaching the starting and the end point of the seam is made easier. The scanner scans four points of the piece and places it on the plane. The sensor then calculates the displacement and rotation offsets and applies them to the original program.

The seam tracker uses a Cat6e cable to connect to a PoE switch and then an Ethernet cable to the cobot. With URCap, our Java-based plugin that integrates into our graphical programming interface of Universal Robots, any integrator can easily create new, [user-friendly] programming screens.

AWS: What do advances in artificial intelligence and machine learning mean for cobots?

WH: How AI and robotics come together to create value for shops is the hot topic right now. UR has developed strategic partnerships with NVIDIA (a world leader in AI), Siemens (specifically the SIMATIC Robot Pick AI, a pre-trained, deep learning-based vision software) and Zivid Labs (which makes industrial 3D cameras). As a result, shops will be able to pick a wider variety of parts with unprecedented reliability.

Notice I said pick parts, which is an underappreciated side of cobots in the welding industry. Think of all the resistance welding operators who have the repetitive task of fishing two pieces of metal out of a bin and presenting them to the tongs. In the past, manual operators were needed because vision systems couldn't reliably pick greasy, reflective parts.

Now with the sheer processing power available, the system can crunch millions of data points from the vision system as the robot arm approaches the part. Add in AI, and now it is possible to use cobots for a range of applications that were challenging to automate in the recent past.

AWS: What's the next step for a welding company?

WH: Cobots were made for high-mix, low- to medium-volume applications, but for people new to automation, it can feel overwhelming to try to figure out that first cobot on your own. An easy step is to visit with automation providers at trade shows such as FABTECH where they can meet people with decades of shop automation experience and make valuable connections to potential partners in their automation journey. ■

Laser Beam Control with Fast Steering Mirrors and PICMA Piezo Actuators

Physik Instrumente's S-335 two-axis fast steering mirrors with PICMA piezo actuators aim to be the benchmark for laser beam steering in high-speed applications.

by Sharon Spielman, Technical Editor

ACTUATION TECHNOLOGIES FOR various applications—ranging from processing and stabilization to optical trapping and laser scanning—continue to advance for a range of industries and applications, including aerospace, optics and photonics, lasers, ophthalmology and optical scanning.

The combination of the PICMA piezo actuators and the S-335 fast steering mirror (FSM) from Physik Instrumente is designed to provide millisecond response and settling times as well as dynamic linearity. The FSM is made for fast and high-resolution motion in two degrees of freedom. Based on solid-state piezo drives, it is suitable for precise, high-speed laser beam control and high-resolution imaging applications. Its long angular travel range is made possible using motion-amplified piezo actuators, operated in a differential push-pull mode for each axis. Closed-loop control with feedback sensors provides repeatability and accuracy.

The S-335 two-axis tip-tilt mirror offers 35mrad of mechanical angular deflection in two axes and 70mrad optical deflection. For ultra-long lifetime, all PI piezo mirror mounts are equipped with PICMA multilayer piezo stacks that are ceramic-encapsulated and have excelled in 100 billion cycles of life testing for the Mars Rover Space mission.

PI also provides voice-coil driven steering mirrors with larger travel ranges as well as space-qualified fast steering mirrors for LEO satellites.

FSMs are used to direct laser light or improve image resolution by correcting errors in a wavefront before it reaches an imaging sensor. Image resolution can also be improved when operated in pixel shift mode, where sub-pixel resolution can be achieved by actively moving the sensor or the light reaching the sensor by fractions of a pixel.

A standout attribute of the system is its parallel-kinematics design, which uses coplanar rotational axes and a singular moving platform driven by differential actuators. This is designed to offer jitter-free, multi-axis motion with temperature stability.

Because of the interplay between the technologies, *Machine Design* reached out to Physik Instrumente to learn more about the actuators to understand their durability, which directly affects the long-term reliability of these FSMs. Stefan Vorndran, vice president of marketing, provided answers.

Editor's note: Questions and answers have been edited for clarity, space and style.

Machine Design: **What specific design features of the piezo actuators contribute to their resistance to environmental factors such as humidity and temperature fluctuations? How do these features compare with traditional actuators?**

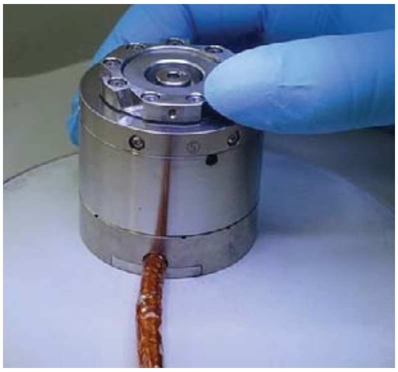
Stefan Vordran: The function of piezo actuators is based on solid-state effects that occur inside the crystalline structure of the piezo cells. Most piezo actuators have a wide operating temperature range, typically up to 150°C and 200°C, and –40°C. Some, [such] as the ceramic insulated PICMA actuators, can operate down to cryogenic temperature ranges. Modern piezo actuators are mostly based on a multilayer ceramics—similar to multilayer ceramic capacitors, where all layers

Stefan Vorndran, Vice President - Marketing, Physik Instrumente. *Images courtesy Physik Instrumente*

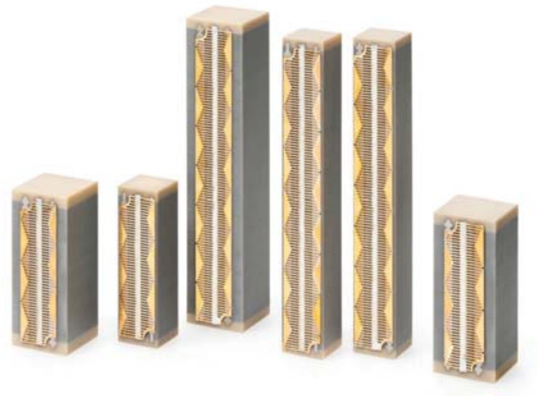
and electrodes are produced in an automated process. Traditional discrete piezo actuators are made of individual ceramic wafers, stacked with bonded electrodes in between.

Since they are based on ceramics, temperature fluctuations do not affect piezo actuators as much as traditional actuators based on combinations of aluminum and steel. Piezo actuators don't require lubricants such as most traditional actuators, which is another advantage.

High humidity can be an issue with traditional piezo actuators that rely on a conformal coating to protect its electrodes. These coatings will eventually be



Custom two-axis, piezo-driven fast steering mirror mount for the Solar Orbiter satellite is pictured here.



Ceramic encapsulated PICMA piezo actuators are the driving force inside the PI's fast steering mirror (FSM) mounts. PICMA actuators were selected by NASA for the Mars mission, after completing 100 billion test cycles without failures.

permeated by moisture. PI's patented PICMA multilayer piezo actuator technology uses a ceramic coating that significantly better protects the actuator and provides a much longer lifetime.

For applications that require immersion in liquids, piezo actuators can be hermetically sealed.

***MD:* Can you elaborate on the manufacturing process for the piezo actuators? What quality control measures are in place to ensure their reliability over such extensive operational lifetimes?**

SV: The multilayer cofiring technology (electrodes and ceramic layers are sintered together in a kiln) is a particularly innovative manufacturing process. The first step is to cast tapes of piezoceramic materials, which are then provided with electrodes while still in the green state. Many single tapes are laminated together to give a piezo element, which is then sintered together with contact electrodes in a single process step.

PI's patented design comprises an all-ceramic outer layer of the actuator, which acts as insulation. Any further coatings—made of polymer materials, for example—are therefore not required. This means that PICMA piezo actuators remain stable even when subjected to high dynamic loads. They achieve a reliability and a lifetime, which is 10 times higher than that of conventional multilayer piezo actuators. During long-term tests for the Mars Expedition, NASA tested PICMA actuators and found zero failures after 100 billion cycles of service life testing.

***MD*: In terms of integration and compatibility, how do the actuators interface with existing mechanical systems or control electronics? Are there specific design considerations or adaptations that engineers should keep in mind when incorporating these actuators into their projects?**

SV: The ceramic heart of the piezo actuator is usually integrated in a protective housing for with integrated mounting interfaces. The piezo actuator itself is typically driven with an operating voltage of 0 to 100°V and its extension is proportional to the drive voltage. For better linearity and position reproducibility in the nanometer range, position sensors are applied to the ceramics or integrated in the housing.

Piezo drivers and controllers are readily available to provide closed-loop position control. Traditional piezo controllers were based on analog servo circuits, modern controllers use DSPs and digital servo controls, allowing automatic calibration and easy switching between different control algorithms for optimized adaptation to different applications.

Engineers should be looking for controller models with interfaces that best match their requirements. Available interfaces are analog (0-10V), USB, Ethernet, SPI and EtherCAT. ■

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A Glimpse of IMTS 2024

The International Manufacturing Technology Show (IMTS) highlighted innovations in manufacturing technology with trends in automation, sustainability and digital transformation, while drawing record attendance and fostering networking opportunities.

by **Sharon Spielman,**
Technical Editor

AS ONE OF THE largest manufacturing trade shows, the International Manufacturing Technology Show (IMTS) 2024 displayed the latest innovations and technologies that are shaping the future of the industry.

New product introductions, automation solutions and advanced technologies were among the plethora of exhibits (more than 1,600) at the event. "IMTS 2024 has more of everything," said Peter Eelman, chief experience officer at the Association for Manufacturing Technology (AMT), the producer of the show.

He wasn't wrong, and while it would be impossible to include everything that was relevant to *Machine Design*'s audience, we did put together some insights from the show, which readers can find on our dedicated IMTS 2024 hub at *www.machinedesign.com/magazine/76504.*

This biennial event will convene again at Chicago's McCormick Place, Sept. 14-19, 2026.

Mitsubishi Electric Automation Celebrates 50 Years

Sometimes, trade shows intersect with company milestones, and that was the case for Mitsubishi Electric Automation Inc. this year. The company celebrated its 50-year milestone of support to the machine tool industry through service and repair in North America at its gold-themed booth. Visitors got to participate in giveaways, view a demo of machine tending solutions and preview the M800V/M80V Series CNC controller, with additional functions to the M800/

M80 Series, which was released in 2014. These include high-definition 3D machining simulation to minimize trial cutting and a streamlined operator interface.

In addition to their presence in the South Hall, they were also at the Student Summit with their Diamondworks workforce development program, as well as in the conference area for "How Their First Robot Purchase Enabled a 70-year-Old Company with 11 Facilities on 3 Continents to Profitably Expand their Domestic Manufacturing," a presentation by Patrick Varley, mechatronics product marketing manager.

Innovation Awareness: Cognizant Joins MxD

MxD, a digital manufacturing innovation center and National Center for Cybersecurity in Manufacturing, announced that Cognizant joined as a member. Cognizant will establish a collaboration space on MxD's 22,000-square-foot future factory floor, with methods for improving production operations at scale. Cognizant's Manufacturing Innovation Center opening at MxD took place on Sept. 9, 2024.

The facility will have cutting-edge technology demonstrations, workforce training and a focus on cybersecurity, which is essential for modern manufacturing. "I am delighted to welcome Cognizant to MxD," said Berardino Baratta CEO of MxD. "This partnership will accelerate innovation and bring significant value to the industry."

Cognizant is known for its expertise in modernizing technology and processes. The new Manufacturing Innovation Center will highlight how manufacturers can achieve differentiated results and foster collaboration. Demos will include an innovation lab and operations command centers.

"We are thrilled to introduce our manufacturing Innovation Center at MxD," said Nishanth Vallabhu, vice president of manufacturing at Cognizant. "Our center leverages MxD's ecosystem to help clients unlock value through technology, data and AI."

With more than 300 members, MxD remains committed to empowering U.S. manufacturing through technology innovation and workforce development.

Big Tech, Sustainability

Two noticeable trends at this year's show were the presence of major tech companies and a strong emphasis on sustainability initiatives.

At this year's International Manufacturing Technology Show (IMTS), the Smartforce Student Summit attracted more than 14,000 students who seemed eager to explore the latest advancements in manufacturing technology. *Images courtesy IMTS*

While there was no shortage of state-of-the-art machining equipment at this year's event, between the robots, cobots and tooling were the tech companies—including big names such as Google, Microsoft and AWS—for smart manufacturing and the latest in artificial intelligence (AI) and machine learning as well as predictive and prescriptive maintenance.

These industry leaders, along with a host of other companies presented on the Main Stage, where representatives shared insights that reflect the latest trends and innovations in manufacturing.

As the manufacturing sector faces increasing pressure to decrease its environmental impact, many exhibitors presented solutions designed to create more efficient processes and reduce waste. Technologies that emphasize eco-friendly practices not only support regulatory compliance but cater to a growing market demand for sustainable products and practices.

Inspiring STEM Students, Future Engineers

The Smartforce Student Summit put the latest in manufacturing technology from the highest profile industry exhibit partners on display to provide educators and students with fun and engaging learning experiences centered around the industry's vision of the "manufacturing technology classroom of the future."

According to U.S. Bureau of Labor Statistics, STEM occupations are projected to grow 10.4% compared with 3.6% for non-STEM occupations. As an increasing number of the nation's youth consider manufacturing careers, the Smartforce Student Summit was designed to inspire students who are seeking an education in STEM that leads to a career path in manufacturing.

As we look forward to IMTS 2026, it is clear that the advancements made today will shape the trajectory of the manufacturing sector and drive it toward greater efficiency, reduced environmental impact and more collaboration across disciplines. ■

R&D Spotlight: Designing a Test Bench for Armored Vehicle Suspensions

Engineers at Moog and Piedrafita Systems custom-designed a test rig that simulates the movement of a hydraulic vehicle's tracks over uneven terrain.

by **Rehana Begg,** Editor-in-Chief

TEST ENGINEERS UNDOUBTEDLY agree on the need for a test rig that can evaluate the reliability of a vehicle's suspension system. However, developing and building a high-performance fatigue bench that could be used in the design and specification of armored vehicle suspensions raises the bar on the unique specifications needed for combat scenarios.

Designed for battlefield tasks, these formidable machines are heavyweight and move in terrains with many obstacles at high speed and low visibility. The requirements are highly demanding due to the vehicle characteristics and usage.

Armored vehicles are designed to "make high velocity movements with high forces within the suspension elements," said Luis Barrada, technical director, Piedrafita Systems. "There is a high frequency and low amplitude movement present, caused by the track pitch. It is imperative to have a reliable system that can withstand those hard conditions and deliver the correct suspension characteristics over the lifetime of the system. A fatigue bench or rig that could handle these conditions would be necessary to ensure this."

Cue the engineers at Moog's industrial segment who routinely combine electric, hydraulic and hybrid technologies to design and manufacture applications in energy, industrial machinery, simulation and test markets.

Spain-based Piedrafita Systems, which develops rotary suspension solutions for military land platforms, worked closely with Moog engineers to design the Merlin test bench, a high-performance test rig that would be used in designing heavy-duty vehicle suspensions. Piedrafita Systems specified the need for a fatigue test system capable of delivering forces up to 500 kN (80,000 joules per meter) at a speed of 8m/s and up to 200 Hz.

"Piedrafita asked Moog how to make feasible this new system," said Juan Carlos Molinero, project manager for Simulation & Test at Moog. "After our study and performance tests, we collaborated with Piedrafita to develop a concept that could test an armored vehicle's suspension."

The Merlin test bench was unveiled in July 2023, bringing to market a system capable of simulating intense vibrations, and was deemed crucial for assessing shock absorbers and suspension systems in combat scenarios.

A custom-designed test bench developed by Moog and Piedrafita Systems simulates the movement of a hydraulic vehicle's tracks over uneven terrain. The system incorporates hydraulic actuators with digital servo valves, a test controller, power cabinet, digital pumps and an accumulator bench with piping. *Moog*

Not the First Rodeo for Fatigue Test Bench Design

The parameters may have been unprecedented, but it would not be the first time Moog had worked with Piedrafita on pioneering a novel solution. The companies collaborated in 2013 on the design of a fatigue test bench for developing a shock absorber. Back then, the pair designed a fatigue test bench for military ground vehicles operating in extreme conditions that could deliver up to 80kN at 5 m/s velocity.

This time, however, Piedrafita and Moog's design and test engineers went above and beyond to deliver a test bench system that not only simulates the movement of an armored vehicle's tracks over uneven terrain but can reach five times higher forces at twice the velocity and double the frequency range. This level of vibration is crucial for evaluating the resistance and performance of shock absorbers as well as suspension systems in combat scenarios.

The system combines the heavy-duty loading typically found in a high-capacity hydraulic press with the speed and fidelity of a motorsport 4/8-poster rig.

According to the engineers, the test rig is designed to replicate the movement of an armored vehicle over an APG track, as the vibrations experienced during the run are critical in assessing the resistance and related capabilities of the shock absorbers and suspension during combat. The test bench includes a high-performance controller and customized actuators that can reproduce vibration up to 100 G, according to Moog's chief engineer, Ian Whiting. Nonstandard turbocharged valves were used to achieve the 500kN, 8m/s, 200Hz and 100 G corners of the operating envelope.

"Our new test system is capable of carrying out tests for 70-ton tracked vehicles, with a weight of around 5.5 tons per wheel," added Piedrafita's Barrada.

A Better Design for a Rotary Hydropneumatic Suspension System

The test rig's delivery is a milestone feeding into a larger project intended to improve heavy armored vehicles mobility, particularly new and legacy main battle tanks.

Piedrafita Systems has been developing a rotary hydropneumatic suspension system for armored vehicles in consortium with Repack-S and IB Fischer CFD+Engineering GmbH. The SRB Project is backed by a grant from the European Defence Industrial Development Programme (EDIDP).

Piedrafita Systems acts as the coordinator on the collaboration and leverages its expertise in designing and validating damping systems. The test bench enhances the company's proficiency when it comes to standing up to the challenges of designing suspension solutions and improving mobility of heavy armored vehicles and battle tanks.

Optimizing Lifecycle Efficiency

Essential components making up the test system include: a Moog test controller, two hydraulic actuators with Moog digital servo valves, an HPU with Moog digital pumps and a power cabinet, and an accumulator bench with the required piping.

Moog's Analysis and Simulation Toolbox was also used to demonstrate the likely performance of the proposed twin-actuator servo system. Typical functions of the software include processing customer data, building Simulink models and running model cases studies.

The simulation software was used to relay the required motions and forces to the test article, according to Moog's engineers. ■

Navigating the Electric Mobility Path with **Solid-State Batteries**

As with most emerging technology, challenges must be overcome. For the transition to higher-capacity power, the most immediate challenge is consolidating a cost-effective and robust manufacturing strategy.

by **Gian Carlo Tronzano,** Head, e-Mobility Global Competence Center, Comau

BEHIND THE WORLD'S shared CO_2 emission targets and electric vehicle (EV) adoption goals lies the fundamental need for increasingly advanced power technologies and new production processes. From a technological standpoint, it can be argued that the backbone of electric mobility is the power technology that propels it. And while traditional lithium-ion batteries have been the mainstay of EVs, the industry is rapidly progressing toward higher-capacity solutions.

Emerging technologies such as solid-state batteries promise even greater energy density and faster charging times. This, in turn, will help enhance the range and performance of EVs, making them more viable for a broader range of consumers. However, the most immediate challenge in the transition to electric mobility is to consolidate a reliable and cost-effective manufacturing strategy.

What is Driving Battery Demand?

The pan-European goal of creating an autonomous supply chain is expected to drive battery demand between now and 2030. Despite recent uncertainties about the rate of growth, the battery market—which includes cells, modules, packs and electric motors—is estimated to exceed €170 billion by 2030.

Developing manufacturing processes that can produce high-quality batteries at scale while keeping costs down is another driving factor. This is why some companies in this sector are developing extensive expertise in electrification, enabling them to experiment with cutting-edge technologies and anticipate many trends in e-Mobility.

Using a holistic approach to battery production can help ensure the delivery of complete solutions for more efficient and sustainable battery technologies. Comau

There are companies that have helped automate the production of next-generation sodium-based battery cells, one example being a powerful solution for end-of-line battery disposal and recycling. The latter was realized as part of the Flexible Battery Dismantling project within EIT Manufacturing, a dedicated innovation community funded by the European Union within the European Institute of Innovation and Technology (EIT).

The Stages of Cell Formation

Cell formation encompasses the core processes that transform assembled components into stable, electrically charged battery cells. A crucial phase in the battery manufacturing process, the first stage involves activating the electrochemical properties of the cells using a series of controlled charging and discharging cycles—the first of which initiates the electrochemical reaction.

The cells then undergo multiple cycles of charging and discharging, which together help form a solid electrolyte interphase (SEI) on the electrode surfaces. The SEI layer stabilizes the electrolyte and ensures the resilience of the battery. Throughout this phase it is necessary to closely monitor both the voltage and temperature to ensure the cells do not overheat or become subject to voltage spikes.

After the cells are activated and the SEI layer is formed, they are stored at a temperature of 40°C for several days to accelerate the aging process. The high temperature aging also serves to stabilize the cells before the rigorous testing phase, which involves exposing the cells to various stress conditions such as high temperatures, high charge/discharge rates and deep discharges to both ensure they are safe and to evaluate their reliability.

Cell formation is integral to the development and manufacturing of high-quality batteries and plays an increasingly important role in delivering reliable and efficient energy storage solutions. The fact that these end-to-end cell formation systems can now be sourced locally from a renowned leader in industrial automation represents an important step toward advancing the European battery manufacturing industry.

An Example: Prismatic Assembly—from Cell Prep to Testing

Moving from cell formation to battery manufacturing, the automated production of cells, modules, packs and batteries requires an optimal combination of carefully designed processes and technologies tailored to the unique characteristics of each project. This is largely due to the underlying cell and structure complexity. For example, the assembly line for prismatic cells is typically structured in four main areas, with the process beginning once the cells have been activated:

- Cell preparation
- Stacking
- Welding
- Testing.

The cells are first unloaded from the battery trays or bins, where they are controlled and subjected to different types of checks, including optical character verification (OCV) and the position of the poles. They then undergo various treatments based on their characterization. Naked cells undergo plasma treatment, which is a precursor to the wrapping process. If they are already wrapped, or painted, the plasma treatment is not necessary and thermal pads and glue can be directly applied. All this is ideally carried out quickly, with an average cycle time of a few seconds per cell.

During the stacking phase, the cells are coupled to form a packet, the size of which can vary from a half dozen to more than 20 cells. At this stage, the dimensions, the force and the positioning parameters of each cell are checked. It is also essential to verify that there are no short circuits. Plates are then added around the cells and pressed together to form the module. Once the busbars are attached, the newly created module moves to the welding phase.

Laser welding is the final assembly phase of the battery module and arguably one of the most delicate processes. This is due to the critical quality parameters that are required of the welded points. Verification of the points to ensure the absence of short circuits can be done with a high-voltage test. At the end of the test, the module is completed with busbar guards. Laser marking and labeling make the module unique and traceable, ready to be shipped to the battery pack assembly plant.

Testing and quality control are also performed at the battery level. Some companies are launching new technologies that use thermography and artificial intelligence to perform noninvasive automatic in-line testing and quality control.

Designed for industrial-scale battery production, this new technology automatically evaluates surface defects and electrical resistance of soldered joints connecting individual battery cells. High electrical resistance, due to poor joint quality, can create high energy loss and generate heat. Increased joint temperature causes potential safety problems and reduces efficiency. By automatically evaluating each joint before final assembly, this can protect cycle times and save manufacturers time and costs. ■

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Make it Standard:
How Stocking Standard Products Benefits both OEM and Supplier

Learn about the importance of stocking standard products, including the service advantage of keeping a variety of O-rings ready to ship.

by **Scott Christensen,** Americas Purchasing Manager, Trelleborg Sealing Solutions

WHY IS IT IMPORTANT for suppliers to have standard products on hand? Seal suppliers tend to focus on custom products as they typically involve the most recent technology and provide a competitive advantage. Likewise, original equipment manufacturers (OEMs) often keep their sights on the latest and most innovative solutions their suppliers bring to the table.

However, OEMs also look for the fastest and most accessible source for standard products when they need them. Seal suppliers who can provide timely solutions to a customer's problem with standard products, such as an O-ring, are often the ones who have a readily available stock of parts. A sealing partner that can offer custom solutions as well as standard products for an OEM proves to be the most valuable.

Advantage of Stocking O-rings

Often overlooked compared to more complex sealing technologies, suppliers might not keep a wide range of standard O-rings in stock. However, those that do have a major advantage when it comes to service. Following supply chain disruptions caused by political unrest, workforce shortages and natural disasters, customers increasingly focus on supply assurance.

According to a 2022 analysis from Deloitte, the second-most cited operational concern for manufacturers was suppliers who are struggling to meet demand. If companies don't keep standard products on the shelf, another company does. Stocking them makes for a more competitive supplier. Repair shops are often small mom-and-pop operations that don't realize they need standard O-rings until disassembling the defective unit, and they assume they will be available at any time.

Other Advantages to Stocking Standard Products

Committing to a stock of standard products can also generate new business for a seal supplier. For example, an OEM came to Trelleborg with a drawing for an O-ring in an industry standard material and asked for an equivalent. In this instance, we had the corresponding O-ring size in an equivalent material in stock and provided an immediate quote, as well as a quick turnaround to supply the product. Stock availability fostered a new relationship with the customer.

To take this concept a step further, seal suppliers can increase their service level even more and offer customers advanced planning for regular shipments of standard products. If a customer routinely purchases larger diameter standard O-rings that are less likely to be in stock, the customer's commitment to buy a certain quantity of O-rings every month enables suppliers to ensure their availability.

Stocking Standard Products for Efficiency, Speed and Quality

Utilizing industry standard design profiles and sizes ensures that designers and end-users can easily and quickly specify sealing components, allowing the reuse of hardware designs and contributing to cost savings. Standardization also supports ease of repair, refurbishment and reuse through readily available replacement parts.

Trelleborg used its technical expertise and standard products to help Lion Hydraulics improve productivity and in-house assembly times by switching to a standard Dualseal for their static seals on hydraulic cylinders.

The hydraulics company was using a two-piece O-ring and back-up ring combination when Trelleborg introduced them to the single-piece standard polyurethane (PU) Dualseal, which retrofitted their existing groove. In addition to saving assembly and production time, the switch to the PU Dualseal also alleviated quality issues that had been experienced in the field with their nitrile rubber back-up ring. ■

Ad Index

MACHINE VISION MARKET SNAPSHOT

IF WE LOOK at the **machine vision system market** as a whole, it was valued at $49.7 billion in 2023, and is estimated to reach $159.2 billion by 2032, growing at a CAGR of 13.9% from 2024 to 2032, according to Allied Market Research's report *Machine Vision System Market by Type, Product, Application and End Use.*

According to research by market intelligence specialist Interact Analysis in a survey carried out by Cognex and Sago, a look at the industrial robots segment—a key application for machine vision—shows the market for machine vision hardware used with industrial robots was worth an estimated $947 million in 2022, and the market is predicted to reach $1.6 billion by 2027, growing at a CAGR of 11.3%.

Zebra Technologies' 2024 Manufacturing Vision Study shows that 61% of manufacturers expect artificial intelligence (AI) to drive growth by 2029—up from 41% currently—which indicates manufacturers' intent to improve data management and leverage new technologies that enhance visibility and quality throughout manufacturing processes.

HIGHEST MARKET SHARE

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BY PRODUCT: *Vision sensors & barcode readers*

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BY APPLICATION: *Inspection*

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BY END USER: *Manufacturing*

WORD SEARCH, HIDDEN THEME

Find all the words in the list and then fill in the blanks with the unused letters beginning in the top left to reveal the hidden theme.

Find puzzle answers here: machinedesign.com/55142696

G	N	I	N	R	A	E	L	E	N	I	H	C	A	M
M	A	G	C	S	H	I	N	Y	E	V	I	I	S	I
O	N	O	N	A	S	J	W	A	T	N	B	X	Y	L
M	A	C	H	I	N	E	V	I	S	I	O	N	C	N
L	G	T	B	X	R	N	C	P	J	E	L	A	A	O
C	Y	N	P	M	G	U	E	O	R	G	M	A	R	A
O	P	T	I	C	S	C	T	A	R	E	O	D	U	A
M	E	G	J	G	T	T	W	C	R	P	C	E	C	Q
P	R	W	W	I	A	T	I	A	A	M	R	S	C	K
L	A	Q	O	E	F	M	Y	S	F	F	Y	I	A	T
I	W	N	N	O	Q	S	I	P	Z	M	U	G	U	O
A	D	Z	S	R	O	B	O	T	I	C	S	N	Y	Z
N	R	E	R	U	T	P	A	C	A	T	A	D	A	J
C	A	S	N	O	I	S	N	E	M	I	D	R	R	M
E	H	A	L	G	O	R	I	T	H	M	S	C	X	Y

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accuracy	dimensions	manufacturing
algorithms	hardware	optics
camera	imaging	process
compliance	inspection	quality
data capture	machine learning	robotics
design	machine vision	software

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DID YOU KNOW?

The earliest known true lenses have been found in "eyes" of Egyptian statues dated circa 2575 BCE but are believed to be too good to be the first lenses of this design.

**Source:* *www.spiedigitallibrary.org*

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