AUTOMATION 2024

JULY 2024 Volume 3

9th Annual
Industrial Automation & Control Trends Report

- Technology Trends that Empower Innovation
- Real-time Digital Manufacturing: Realized
- Open Automation Systems: An Update
- Insider Insights from Technology Suppliers

AUTOMATION.COM | ISA A subsidiary of the International Society of Automation

Introduction

9th Annual Industrial Automation & Control Trends Report

The automation industry moves at warp speed and staying on top of news and trends is what Automation.com does for the members of ISA - International Society of Automation and automation professionals around the globe through newsletters, webinars, and digital magazines. Here in this issue of AUTOMATION 2024 digital magazine, our 9th annual Industrial Automation & Control Trends Report gathers insights from Editor Emeritus Bill Lydon and others to show how real-time digital manufacturing is becoming a thing of the present, not just the future. The industry-shaping trends we cover include artificial intelligence, cloud and edge computing, the adoption of open industrial standards, and much more. Our contributors discuss how advances in dozens of technology areas are enabling innovation, supporting growth and stability, and advancing corporate resilience in the face of ongoing challenges. They and we understand that the successful deployment of new technology in industrial settings requires a deep understanding of both the tech and industrial operational needs. Take some time to review them and decide which might propel your company to succeed in new ways and let us know what resonates. All of us at ISA and Automation.com would love to hear from you.

Renee Bassett
Chief Editor, Automation.com
RBassett@automation.com

About AUTOMATION 2024

The AUTOMATION 2024 ebook series covers Industry 4.0, smart manufacturing, IIoT, cybersecurity, connectivity, machine and process control and more for industrial automation, process control and instrumentation professionals. To subscribe to ebooks and newsletters, visit: www.automation.com/newslettersubscription.

AUTOMATION 2024 is published five times per year (March, May, July, September, and November) by Automation.com, a subsidiary of International Society of Automation (ISA). To advertise, visit: www.automation.com/en-us/advertise.

groups/68581
automationdotcom
@automation_com

International Society of Automation
Setting the Standard for Automation™

company/internationalsocietyofautomation
InternationalSocietyOfAutomation
@ISA_Interchange

Renee Bassett, Chief Editor
rbassett@automation.com

Chris Nelson, Advertising Sales Rep
chris@automation.com

Richard T. Simpson, Advertising Sales Rep
rsimpson@automation.com

Gina DiFrancesco, Advertising Sales Rep
GDiFrancesco@automation.com

Sponsors Index

Table of Contents

Table of Contents

INSIDER INSIGHTS

Insider Insights

Automation trends from technology providers helping to empower manufacturers and shape the future of industry.

AI's Role in Hyperautomation and Cybersecurity

By Felipe Costa, MOXA Americas

> The IEC 62443 standard provides a robust framework for securing industrial control systems. Combined with AI's capabilities, it offers a powerful defense against cyber threats.

Undeniably, many of the trends discussed in the AUTOMATION 2022 Industrial Automation & Control Trends Report are more than trends now; they are moving to the "adoption" phase. Two of the trends gaining traction and paving the way for solid solutions to address current challenges are hyperautomation and the rise of open industrial standards. Now I will explore these two with a focus on cybersecurity.

As a cybersecurity and AI researcher and industrial professional, I've observed firsthand how these trends have evolved, particularly in integrating AI to enhance industrial operations and security, playing a critical role in today's industrial challenges.

The first trend highlighted by Bill Lydon in 2022 that I will address is the rise of hyperautomation. This concept, involving the use of advanced technologies like artificial intelligence (AI) and machine learning (ML) to automate processes, has significantly matured. Hyperautomation is now a crucial driver for industries seeking to enhance productivity and efficiency. AI-driven tools are increasingly used to streamline operations, reduce human error, optimize resource management, and support cyber threat detection and response

Another trend gaining traction is the adoption of open industrial standards. These standards facilitate interoperability and seamless integration of different systems and devices, essential for creating a cohesive and efficient industrial environment. However, the angle I would like to delve into is within cybersecurity.

Historically, industrial and corporate applications have heavily depended on definitions and designs from large technology organizations, making it challenging to understand what security truly means and how it relates to systems. This challenge is even more pronounced in industrial applications (ICS), where security knowledge has only recently started to develop compared to corporate environments.

It's crucial to recognize that the successful deployment of AI in industrial settings requires a deep understanding of both technology and the industrial context. Many industries have unique operational constraints and regulatory requirements that must be addressed. For example, while AI can significantly enhance security measures, its implementation must consider the specific operational technologies (OT) in use, which often differ from traditional IT systems. This is where the IEC 62443 standard, in association with AI, plays a perfect match.

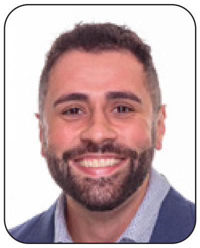
Now, correlating these two parallel worlds, cybersecurity is a long journey with many priorities (although in theory, we can only have one priority; this word derives from the Latin "prioritas" meaning "what comes first"). The integration of AI has become indispensable, helping to manage these other "priorities" efficiently.

My perspective as a cybersecurity expert aligns with the need for a comprehensive approach that incorporates industrial knowledge. The IEC 62443 standard provides a robust framework for securing industrial control systems. When combined with AI's capabilities, it offers a powerful defense against cyber threats. This synergy between AI and industrial cybersecurity not only improves threat detection and response but also enhances overall system resilience.

The IEC 62443 standard emphasizes the importance of understanding the specific needs and constraints of industrial environments, preparing the ground for educated decisions, and most importantly, tangibly defining what security is and how to measure it. AI technologies can analyze vast amounts of data to identify patterns indicative of cyber-attacks, thereby enabling proactive threat mitigation.

The priority of the company, defined by IEC 62443, is managing risks, and understanding where the most critical assets are to be protected. AI assists with "other priorities," helping asset owners make informed decisions based on data, responding to threats, and improving performance by leveraging AI.

In conclusion, the identified trends have materialized and are shaping the future of industrial automation and cybersecurity. However, further attention should be given to this topic now more than ever. Selecting industrial automation partners with the right expertise is fundamental. Historically, companies have risked using solutions from immature companies, which can do a disservice to technology. Poor results and even worse, incidents, could lead many to judge that the technology was not ready when, in fact, it was mistakenly deployed due to a lack of expertise.



Felipe Costa is senior product marketing manager for networking and cybersecurity for MOXA Americas. He is a seasoned cybersecurity director and industrial cybersecurity instructor certified by ISA and EC-Council. Costa holds more than 30 certifications and has about 20 years of experience in the industrial sector. He has presented and published articles globally, including at the NASA Artificial Intelligence Congress.

Web-based SCADA/HMI Clients Support Remote Services

By Paul Shu, ARISTA

For improving processes and allowing resources to be more productive, a thin client in a manufacturing environment is an ideal platform to deliver versatile benefits.

Modern manufacturing complexity requires automation systems to boost productivity and efficiency. The technologies most widely deployed on the plant floor—remote desktop services and web-based SCADA/HMI—are at the top of the list for delivering these benefits.

The hardware on the production floor is as important as the SCADA/HMI software, and thin clients can deliver important benefits:

Easy installation. A thin client tailored to run remote desktop services and support web-based HMI/SCADA can be deployed across the production floors with minimal installation efforts.

Low maintenance. The SCADA/HMI software residing on the server, the thin client, and the web client is operating-system-independent. Its replacement can be quick and easy, and no software installation is required if any failure occurs to the thin client or web client.

Industrial thin client/web client computers must meet environmental protection requirements for every stage of the manufacturing process and in every industry sector. The industrial thin client computers in the pharmaceutical industrial sector, for example, must meet IP66 environmental protection standards and be able to withstand cleaning solutions.

ARISTA's AMW mobile workstations are constructed with 316L stainless steel materials, specifically for pharmaceutical manufacturing clean rooms. Generally, 316

Arista Industrial Q8 Edge web clients and thin clients provide many flexibility and management benefits.

steel is specified for environments with strict cleanliness requirements, or when equipment is exposed to harsh chemical cleaners and corrosive environments that 304 stainless steels cannot withstand. 316L offers increased protection against salt, proteins, and strong acids or bases. It also possesses enhanced resistance to chlorides and chlorinated solutions that are common in controlled environments and cleanrooms.

A thin client/web client could also be designed for use in hazardous environments where the existence of flammable gases or vapors and/or combustible dust may be present in the air or become present during a spill or leak. A thin client/web client designed for Class 1 Division 2 hazardous zone applications helps prevent the ignition of flammable substances like gases, vapors, and liquids. ARISTA's ARP-2200AP series, for example, includes the panel-mounted thin client/web client products family. ARP-5500AX Series and ARP-3821AX are stainless steel, fully sealed, and fully enclosed thin and web clients and have no external vents. In this way, they protect the components from gases, dust, dirt, moisture, chemicals, oil, and other external contaminants in an explosive environment.

For improving processes and allowing resources to be more productive, a thin client in a manufacturing environment is an ideal platform to deliver versatile benefits. Manufacturing operations at times get stuck due to necessary IT setup time. This often leads to downtime and waste of resources. Thin client technology is developed to resolve such conflicts and provide a mature approach for processes to be conducted efficiently. More thin client advantages include:

Lower operational cost. Thin clients eliminate the stress of setting up a full-fledged workstation. Since all the computing is done on servers, machines do not require much energy to operate. This contributes to an overall cost reduction.

Centralized management. With a thin client set-up, only software-level protection is required. Security is required on the server level since all the data is stored on it. Additional heavy-duty security is not required for workstations and other devices. This significantly reduces the effort and time required in setting up workstations and working with every single machine in case of downtime.

High performance. thin clients can be integrated into almost every industry. Areas such as manufacturing, healthcare, or finance that need utmost accuracy can rely on the thin client without any second thoughts.

Paul Shu is President of ARISTA Corp., a leading provider of computing platforms and visualization display products for pharmaceutical manufacturing environments. He has worked in the industrial automation industry for over 20 years and is skilled in business development, cloud computing, visualization, sales management and computer repair. Shu has a Bachelor of Science (B.S.) with a concentration in Electronics Engineering.

The Transformation of Robotics & Motion Control

Advances have transformed both the robotics and motion control industries and the costs associated with deploying these innovations have been reduced dramatically. As a result, robotics technology and motion control systems are being deployed across various applications. Traditional technologies, like sensors and actuators, are being used alongside AI, machine learning, and edge computing to bring robotics and motion control to life. For example:

- Sensor systems are the primary means through which robots and other autonomous machines gather information about their environments to work safely and effectively.
- Vision systems can be thought of as very specialized sensors. Essentially, vision systems allow robots and autonomous machines to capture, process, and interpret visual information from the world around them to make decisions. This is crucial for performing tasks like navigation, inspection, and manipulation.
- Advances in artificial intelligence (AI) and machine learning (ML) are among the most important factors driving robotics and motion control systems.

By Drew Thompson, Sealevel Systems

> Sensor systems, vision systems, AI and machine learning, advanced actuators, and edge computing are the core technologies propelling these innovations forward.

Essentially, AI and ML enable robots and other autonomous machines to learn from data, adapt to new situations, and improve their performance over time.

- Broadly, actuators allow robots and autonomous machines to act upon, or react, to the data gathered from the various sensor systems. Advances in actuators from electric, hydraulic, and pneumatic systems have led to more precise, powerful, and efficient motion control.
- Edge computing and Internet of Things (IoT) technology enable real-time data processing and decision-making at the robot or individual machine level, reducing latency and improving efficiency in robotic systems.

Manufacturing, automated vehicles and more

Robots and robotic arms have been adopted as control systems and have made it possible for them to carry out precision assembly tasks that require pinpoint accuracy. Vision systems have dramatically improved the speed of quality control and product inspections by allowing automation of many of the tasks. AI and ML have led to a greater understanding of processes and to better resource allocation, energy efficiency, and overall process optimization.

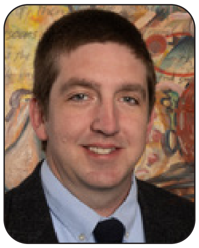
Robotics and motion control systems are driving substantial improvements in autonomous vehicle (AV) functionality, safety, and efficiency. The perception and sensing functionality of AVs has grown by leaps and bounds in the last few years, both in terms of accuracy and in the ability to react. Another area of rapid AV improvement is the motion planning and control functionality. The robotic and motion control hardware inside AVs is now able to compute the safest and most efficient path for the vehicle, all while considering factors like road conditions, traffic, and obstacle avoidance.

Many of the same advances in consumer-grade AVs apply to military and aerospace vehicles like unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs), as well as seagoing drones, called unmanned surface vehicles (USVs) or autonomous underwater vehicles (AUVs). In addition to the various vehicle-type drones, there is a whole class of autonomous combat robots currently in use or active development through such programs as the Modular Advanced Armed Robotic System (MAARS) or Special Weapons Observation Reconnaissance Detection System (SWORDS). There has also been a recent push to automate segments of military logistics through the use of autonomous trucks and UGVs. Specifically, to transport supplies and equipment in contested or dangerous areas, reducing the risk to human drivers and ensuring reliable logistics.

The future of robotics

The rapid advances in robotics and motion control systems have significantly transformed various industries by driving down costs and enhancing performance across multiple applications. Sensor systems, vision systems, AI and machine learning, advanced actuators, and edge computing are the core technologies propelling these innovations forward.

As robotics and motion control systems continue to evolve, their impact will undoubtedly expand, further integrating these technologies into everyday operations.



Drew Thompson is a technical writer and marketing specialist for Sealevel Systems, the leading designer and manufacturer of embedded computers, industrial I/O, and software for critical communications. A writer/editor by training, Thompson spends his days creating and delivering content relevant to Sealevel's technical community and business partners.

OEM Hacks for Mitigating Labor Shortages and Lowering Costs

By Mitsubishi Electric Automation, Inc.

It's common knowledge that lifecycle management for machines can save time, effort, and resources. It can also increase reliability, decrease unplanned downtime, and extend the life of machines. The same is true for automation components including PLCs, robots, and HMIs. Lifecycle management at the component level? Yeah, that's a thing.

Global disruptions, such as nationwide labor shortages, loss of experienced personnel, and margin pressures, are driving the adoption of lifecycle management down to the component level. Digital transformation technologies are increasing demand and creating capacity issues. It's all converging to the point where original equipment manufacturers (OEMs) need a better way forward. In other words, if an OEM's core competency is product innovation and design, and they're hemorrhaging experienced engineers and can't find replacements, they need to rethink the way things are done.

Having high-quality automation components is not enough. Advanced engineering software is now an essential ingredient for remaining competitive. When selecting engineering software, look for these essential attributes.

> Component-level lifecycle management makes trouble-free engineering possible. It can improve every phase of development and help deliver high-quality, low-maintenance machines at scale.

- A single programming environment for every phase of development—from design, to programming, debugging, and maintenance
- Advanced diagnostics for quickly identifying, communicating, and resolving issues even before team members arrive at the machine
- Advanced simulators that not only let you simulate the PLC logic but also the HMI and 3D digital twins

With the right software, you can address challenges across the lifecycle of the component. When the right software is used—during the design stage and through startup, the operating stage, and during optimization—you can accelerate time-to-market, reduce commissioning time, cut downtime and maintenance costs, and optimize runtime and overall equipment effectiveness (OEE).

The design stage is all about reducing time-to-market. For the design stage, look for these time-savers: intuitive drag-and-drop functionality, custom function blocks & libraries, advanced simulation, and a modern HMI.

The startup stage is all about reducing time to commission. One way to reduce commissioning time is to create easy access to the data needed to fine-tune your machine to the application's needs. Web pages and other user interface tools give you access to the information needed to make adjustments. They can also tell you how those adjustments have affected your process. For the startup stage, look for a system recorder module, HMI and VFD/Servo templates, PLC and HMI web server visualization, custom web pages and interfaces, and support for multiple languages.

During the operating stage, reducing downtime is key. All machines will go down at some point. Your software should have advanced diagnostic tools that help you quickly identify, communicate, and offer resolutions to team members before they even arrive at the machine. An important capability in this stage is event recorder modules that fully record and sync up the program state changes (electrical) and a camera (mechanical) for a set amount of time before and after an event takes place. An event recorder module uses the PLC program, HMI software, and a camera to observe the events leading up to an error.

Other key capabilities to look for include predictive maintenance, HMI backup and restore, enterprise system integration, and HMI mobile and reporting capabilities.

The final stage, optimization, is all about having actionable data to drive intelligent business decisions. For this stage, look for advanced process optimization and advanced data collection, reporting, and analysis. Since optimization is a cyclical process, there is always room for improvement.

Component-level lifecycle management makes trouble-free engineering possible. It can improve every phase of development and help you deliver high-quality, low-maintenance machines at scale. It can also help you mitigate risk in the technology lifecycle, extend your machine's period of profitability, lower service costs with predictive maintenance, and increase customer loyalty.

As one of many Mitsubishi Electric automation affiliates around the world, Mitsubishi Electric Automation, Inc., is part of a $40 billion global company serving a wide variety of industrial markets with a family of automation products including programmable logic controllers, variable frequency drives, operator interfaces, motion control systems, computer numerical controls, industrial robots, and servo amplifiers and motors.

Ultra-long-life Lithium Batteries Make Smart Devices Smarter

By Guy Peleg, Tadiran Batteries

> Standard bobbin-type $LiSOCl_2$ cells are uniquely capable of harnessing the passivation effect, but they cannot generate high pulses due to their low-rate design. A hybrid solution is best.

Low-power smart devices are being deployed worldwide to support applications ranging from SCADA to remote sensing, tank-level, flow and environmental monitoring, predictive maintenance programs, and more. Applications that involve long-term deployments are predominantly powered by ultra-long-life primary (non-rechargeable) bobbin-type lithium thionyl chloride ($LiSOCl_2$) batteries, which are preferred for their exceptionally high capacity and energy density, wide temperature range, incredibly low self-discharge rate, and superior performance in harsh environments.

For example, Wavelet devices from Ayyeka use bobbin-type $LiSOCl_2$ batteries to power intelligent, AI-enhanced solutions that monitor hard infrastructure such as pipelines, control valves, flowmeters, tank levels, and more. These devices are modular, scalable, flexible, autonomous, sensor-agnostic, military-grade TLS v1.3 encrypted, and plug-and-play with no major coding skills required. Ultra-long-life bobbin-type $LiSOCl_2$ batteries deliver a reliable power supply without requiring access to the AC power grid.

Passivation: key to extended life

Most low-power devices, including Wavelet, draw average current measurable in micro-Amps with pulses in the multi-Amp range, typically powered by primary (non-rechargeable) batteries. Certain niche applications draw higher amounts of average current measurable in milli-Amps with pulses in the multi-Amp range, typically powered by an energy harvesting device in combination with a lithium-ion (Li-ion) rechargeable battery to store the harvested energy.

The battery's self-discharge rate is a critical consideration, as chemical reactions draw current from a cell even when it is disconnected or in storage. The self-discharge rate can vary based on numerous factors, most importantly the passivation effect.

Passivation involves a thin film of lithium chloride (LiCl) that forms around the anode of an inactive $LiSOCl_2$ battery to limit its reactivity. Whenever a continuous load is applied, the passivation layer initially causes high resistance and a temporary drop in voltage until the discharge reaction begins to dissipate the LiCl layer: a process that repeats during prolonged periods of inactivity. The level of passivation fluctuates based on variables such as how the cell is manufactured, the quality of the raw materials, current capacity, length of time in storage, storage and discharge temperature, and prior discharge conditions, such as removing the load from a partially discharged cell increases the level of passivation, especially as the battery ages.

All batteries are not created equal

Standard bobbin-type $LiSOCl_2$ cells are uniquely capable of harnessing the passivation effect, but they cannot generate high pulses due to their low-rate design. A hybrid solution is to combine a standard bobbin-type $LiSOCl_2$ cell that delivers low-level background current during standby mode with a patented hybrid layer capacitor (HLC) that delivers high pulses during active mode, often to power bi-directional communications. The HLC features a unique end-of-life voltage plateau that can be interpreted to deliver 'low battery' status alerts.

Significant differences exist between the highest quality bobbin-type $LiSOCl_2$ cells with a self-discharge rate as low as 0.7% per year (able to last up to 40 years) versus inferior quality cells with a self-discharge rate of up to 3% per year.

Unfortunately, it can take years for such quality differences to become fully measurable. As a result, due diligence is required when evaluating competing brands, thus requiring well-documented long-term test results along with real-life performance data from the field involving comparable devices operating under similar loads and environmental conditions. End-user testimonials are also extremely valuable.

A real-life example

Nationwide, the American Society of Civil Engineers (ASCE) estimates that 6 billion gallons of potable water are lost each day due to leaking pipes. Erie County, Pennsylvanie utilizes pressure-reducing valves to prevent leaking pipes and burst water mains across a 100-year-old system stretching 600 miles and serving over one million people.

Wavelet devices are combined with Ayyeka's Field Asset Intelligence software to deliver a comprehensive solution that continuously monitors pressure levels to identify potential ruptures and issue alerts via automated text messages, emails, or cell phones. Ultra-long-life bobbin-type $LiSOCl_2$ batteries extend operating life to reduce long-term maintenance costs.

Guy Peleg is vice president of marketing, sales, and business development for Tadiran Batteries. Based out of Lake Success, NY, USA, Tadiran manufactures a variety of industrial grade lithium batteries that offer unrivaled performance, including 40-year bobbin-type $LiSOCl_2$, TLM Series high power, and TLI Series 20-year rechargeable Li-ion cells.

Modern Edge Devices Bring Harmony to Disjointed Protocols

By Dan White, Opto 22

If TCP/IP won the "protocol wars" in the '90s, why are you still fighting protocol battles on the plant floor today?

Because industrial networks were around long before the Internet. As far back as the 1960s, machines communicated via serial networks like RS-232, RS-485, and CAN bus—with specialized proprietary fieldbus protocols like Modbus, Profibus, and DeviceNet. Even with TCP/IP on Ethernet, specialized protocols remained—Modbus now has a TCP/IP version, Profibus gave way to ProfiNET, DeviceNet to EtherNet/IP—even some new ones joined the protocol party.

After the industry demanded interoperability, OPC was born. Now we have OPC UA, a big step toward a unified architecture on OT networks.

Meanwhile on the IT side, using HTTP and HTTPS was common. It's how web browsers—and most of the internet—works today.

MQTT Sparkplug came later. It is built on efficient, secure, and scalable publish/subscribe communications. This makes it a great fit for digital transformation projects and the industrial internet of things (IIoT).

You want to digitally transform, but your existing machines don't support all these protocols. So, should you put off digital transformation while waiting for existing systems to fail or spend a ton ripping and replacing your controls to support the latest protocols?

> Without disturbing existing systems, edge devices make it easy to convert data from a custom fieldbus into open protocols for digital transformation.

Thanks to modern edge devices—computing systems that process data locally at the source—you don't have to make that choice.

Thankfully, the latest edge devices include serial ports and software tools for RS-232, RS-485, and CAN Bus—everything from simple USB-to-serial interfaces through dedicated, configurable, multi-channel I/O modules.

You can achieve bidirectional serial communication in open programming platforms like Node-RED, JavaScript, Python, C++, and more. Or, if you prefer ladder diagrams and function blocks, use an IEC

61131-3 compliant PLC programming platform.

Alternatively, PLCs sold today all run Ethernet-based fieldbuses. They're suited for coordinated motion-control applications where low latency and precise synchronization are paramount, but they may not fit for digital transformation.

Thankfully, you don't have to rip out and replace your PLCs. Edge devices today have SCADA tools and programming platforms with native drivers for all the most popular protocols. Without disturbing existing systems, edge devices make it easy to convert data from a custom fieldbus into open protocols for digital transformation.

One of those open protocols is OPC-UA, which creates interoperability among PLC and I/O platforms. You'll find options for both client and server functionality on the latest edge devices.

Native OPC UA servers expose I/O values from physical modules. SCADA-supported OPC UA servers provide southbound connectivity to fieldbuses and northbound connectivity to HMI dashboards and historians. And both clients and servers in IEC 61131-3 compliant PLC programming platforms provide endless interconnectivity options.

REST API and MQTT Sparkplug

REST application programming interfaces (APIs) are a common way to pass information across IT infrastructure. These APIs are a standard way to use HTTP or HTTPS messages to send and receive data in common formats like XML or JSON.

IT and programming professionals use tools like Swagger to understand, test, and integrate with someone else's API by exploring documentation, trying out endpoints, and generating client code for seamless integration. And yes, modern edge devices support this technology as well.

As for MQTT Sparkplug, this technology for IIoT communications employs a publish/subscribe architecture. Originally designed for an industrial SCADA application, MQTT Sparkplug should be at the heart of any digital transformation project.

With MQTT's Unified Namespace (UNS), you can model your data with context and create a plug-and-play architecture for all your machines. Your edge device gives you a single source of truth for your data (where it originates) and then securely publishes your data where it's needed. The result is you can use the latest in machine learning, artificial intelligence, advanced analytics, and anomaly detection.

Daniel White has worked at Opto 22 for more than a decade. His Tufts Engineering background, MBA in International Business, and prior industrial controls experience give him a unique edge on automation. White enjoys staying active through biking, basketball, skiing, and keeping up with his three young kids.

Hardware for the Demands of AI-Powered Machine Vision

By Axiomtek

Automation is progressing rapidly with Industry 4.0 initiatives aiming to improve quality, efficiency, and productivity across various industries, including manufacturing, food and beverage, logistics, healthcare, and more. For machine vision systems, that means enhanced data from industrial Internet of Things (IIoT) sensors and innovative high-resolution camera technology that can capture a wide range of information to help overcome issues related to real-world complexities. However, the most significant Industry 4.0 technology is artificial intelligence (AI), pushing the capabilities of machine vision systems to supercharge speed, efficiency, and accuracy

Machine vision systems empowered by edge AI can quickly and easily analyze images in real-time to recognize subtle nuances and patterns, compare patterns across an entire data set of images, and retain information from each analysis to learn and improve accuracy over time continuously.

With this in mind, integrating new technologies into existing manufacturing and assembly lines comes with challenges. System integrators must choose the right hardware that can support a wide range of complex components, diverse connectivity options, and the need to support current and future AI-powered systems with the processing power to analyze large quantities of data.

> Machine vision systems empowered by edge AI can quickly and easily analyze images in real time to recognize subtle nuances, compare patterns, and retain information to improve accuracy over time.

To meet these demands, advanced AI machine vision capabilities require industrial computers with a variety of characteristics.

High Processing power. Edge computers should have the flexibility to support a wide range of CPU and GPU requirements to meet a diverse range of future workloads. To help future-proof, systems should support the latest CPUs, such as, 12th, 13th, and 14th generation Intel Core processors. The latest DDR memory with high bandwidth is needed to support faster transfer of stored data for real-time analysis.

Comprehensive I/O support. A wide variety of interfaces for supporting the latest devices is a key feature to look for in a machine vision edge computer. Key features include chipsets with digital interfaces for high-speed industrial cameras and I/O support for audio systems, KVM devices, serial communications (RS232/422/485), displays, and external platforms.

Secure high-throughput networking. Every edge computer should feature secure, high-bandwidth connections to both internal and external networks via multi-gigabit Ethernet LAN ports. They should support 5G wireless connectivity for the increasing number of industrial sensors and devices used in remote monitoring, mobile robots, autonomous vehicles, asset tracking, AR, VR, and digital twins.

Intelligent PoE device management. Edge computers should ensure safe power supply to components through DC input power while providing intelligent power management, including managing and monitoring power consumption per port for remote power distribution technologies like USB and Power over Ethernet (PoE) for connected devices, including cameras, lights, and sensors.

Scalability. As AI technology evolves, edge computers should offer flexible expansion options and optional modules with additional I/O ports. This allows for easily scaling systems to accommodate current and future machine vision technologies, extending the system's lifespan.

Industry compliance and durability. Edge computers deployed near assembly lines must be robust and designed to withstand the harsh realities of industrial and manufacturing environments, including exposure to shock, vibration, extreme temperatures, humidity, electromagnetic interference, dust, and debris. For added assurance, any industrial edge hardware should comply with the latest performance and safety standards applicable to electronic equipment intended for use in industrial environments. This includes wide-operating temperature ranges, IEC/EN 61000-6-2 and 61000-6-4 EMC certifications, and IEC 60068-2-27 and 60068-2-64 certifications for shock and vibration resistance.

Customization options

Since each machine vision application and environment has unique requirements, off-the-shelf systems may not always meet specific needs. System integrators should consider edge computers backed by design and integration services to meet precise project specifications. These services can customize solutions to unique requirements.

Axiomtek, a provider of industrial PCs, is committed to advancing machine vision applications and emerging AI technologies. Our U.S.-based design engineering and integration services, alongside our DigiHub of SDKs and development resources, empower system integrators to deploy edge machine vision systems for any application.

Securing Cloud Connections for Industrial AI Engines

By Xavier Mesrobian, Skkynet

The future of industrial artificial intelligence (AI) looks bright. Initial studies and pilot projects point to significant efficiency gains and cost savings made possible by connecting production systems to AI engines. However, there is at least one serious challenge. How do we keep those production systems and their data completely secure? After all, most AI tools are cloud-based. What's needed is a secure, real-time connection from the plant to the AI system running in the cloud.

The recommended approach for industrial data security is complete network segmentation. The OT (operations) system should be fully isolated from the Internet and cloud systems. This is best done using a DMZ (demilitarized zone), keeping the production network behind closed firewalls. Governments and industry leaders worldwide agree on this basic industrial cybersecurity practice, and the NIS2 Directive and NIST CSF 2.0 require it.

Protocol challenges

Getting data from production to a cloud-based AI system through a DMZ requires two steps: plant-to-DMZ, and DMZ-to-cloud. However, OPC-UA and MQTT were not designed for this type of pathway. Although often used in Industrial IoT and Industry 4.0 systems, they were conceived in the early 2000s, long before people were thinking of moving industrial data to the cloud.

> Getting data from production to a cloud-based AI system through a DMZ requires two steps: plant-to-DMZ, and DMZ-to-cloud.

The OPC UA protocol by itself is simply too complex to reproduce well in a daisy chain across multiple servers. Information will be lost in the first hop. The synchronous multi-hop interactions needed to pass data across a DMZ would be fragile and result in high latencies.

MQTT, on the other hand, can be daisy-chained but it requires each node in the chain to be individually configured and aware that it is part of the chain. The quality of service (QoS) guarantees in MQTT cannot propagate through the chain, making data at the ends of the chain unreliable. MQTT is thus best used as the last step only, to move data from the DMZ to the cloud.

What about combining OPC UA and MQTT? Getting data securely from the plant to the DMZ is a challenge. Using OPC UA for that step has a serious pitfall—as it requires opening a firewall on the production network. Any OPC UA client on the DMZ would need to connect through the firewall to the OPC UA server in the plant. Opening a firewall into the plant for this connection is too high a risk, and most security administrators will not allow it.

Tunnel/mirror technology

Since neither OPC-UA nor MQTT alone or together are sufficient for passing data through a DMZ, another approach is needed—one that integrates well with both protocols. Secure tunnel/mirror software with a unified namespace provides a solution. It can make the connections at both ends and pass the data along the daisy-chained connections necessary for DMZ support.

Tunneling or mirroring connections typically use two software components. The first component makes the necessary connections at the production level to collect data from various industry protocols into a single unified namespace. It then tunnels the data to the second component running on the DMZ. The second component converts the data to MQTT and sends it from the DMZ to the AI service in the cloud. The mirroring capability of the tunnel/mirror software keeps the data consistent between the original data source, the DMZ, and the AI system.

As mentioned previously, all inbound firewall ports on the production system must be kept closed at all times. The tunnel/mirror system must be able to make outbound-only connections from the production network to the DMZ. In addition, some high-security, critical infrastructure applications require a hardware data diode to ensure that not a single data packet can be sent back from the DMZ to the industrial network. A tunnel/mirror system would need to support that level of secure architecture for those applications.

Other AI implementations may call for bidirectional data flow to enable hands-off supervisory control or similar data inputs back into the production system. The tunnel/mirror technology should be flexible enough to support that if needed. In any case, there should be no access to data beyond what the AI system uses. Plant engineering staff should have full control over which data should be made available.

Summing up, to optimize production systems many companies today are turning to industrial AI. The challenge they face is how to access the data they need without compromising security. This is difficult, but not impossible.

Xavier Mesrobian is the vice president of sales and marketing at Skkynet, a global leader in industrial data connectivity. With 25+ years in the industry, Skkynet software and services are used in over 27,000 installations in 86 countries including the top 10 automation providers worldwide.

Tunnel/Mirror simply better networking

Cogent DataHub™

For data protocols that are difficult to connect, the DataHub Tunnel/Mirror provides easy-to-configure, secure and robust networking. Eliminate the hassles of DCOM, detect network breaks quickly and recover from them smoothly. Access your remote data, not your plant systems. Connect and share data among locations with no DCOM or Windows security issues.

The DataHub Tunnel/Mirror goes beyond the basics, letting you integrate your data without exposing your network. Simply better networking.

Learn more at
CogentDataHub.com

SKKYNET™

SECURE INDUSTRIAL IoT REDEFINED

Automation is Essential for Manufacturing Growth

Why consider macroeconomic or wide-ranging technological trends? Because industrial growth and resilience depend on it.

By Bill Lydon

Industrial automation has become increasingly essential for manufacturing companies to grow and prosper. Investments in industrial automation improve overall manufacturing business performance in many areas including:

- Consistent production quality
- Customer service, including product customization
- Reduced variable labor cost

- Solved labor shortages and skills gaps
- Lower energy costs
- Lower production waste.

Industrial automation and controls benefit from technology developed and proven for high-volume commercial and business applications that deliver high performance at lower cost. The evolution of industrial controls and automation has leveraged commercial and business technological developments when they become established and reliable. Past examples include expensive and cumbersome operator workstations custom-built by automation and distributed control system (DCS) suppliers that later gave way to commercial off-the-shelf (COTS) PCs and Microsoft Windows platforms, providing greater value at lower cost and industrial networks running over standard Ethernet.

The best ideas and new trends don't arise in an intellectual vacuum. If you want to brainstorm innovations that go beyond solving problems and increasing productivity and performance, you must gather new ideas from multiple sources.

Automation professionals are becoming increasingly important to create value for their employers by keeping up to date with the latest automation technologies, techniques, and solutions to build superior applications.

Automation professionals are important contributors to the competitiveness and overall success of manufacturing companies. The cumulative leverage of applying various new methods and products to improve manufacturing efficiency and quality is significant. Certainly, high visibility and much-hyped new technologies are exciting and important. Yet, the more subtle, seemingly small improvements understood by automation professionals are, over time, just as critical to building success.

Open natural progression

The established industrial automation industry has experienced relatively few changes over the years, compared to other industries. Many of the major industrial automation innovations of the recent past, such as adopting Microsoft Windows, industrial Ethernet networks, and application virtualization were accomplished using COTS technology.

The level of usability, flexibility, and multivendor interoperability in the business enterprise and information technology (IT) sector is significant. Open systems create ecosystems that leverage human and investment capital to create solutions. These ecosystems can create more value and innovation than any single company.

Disruptive innovations

Disruptive innovations create new value so users can achieve better results and, in many cases, more functionality. These innovations may be new applications or may replace traditional methods and solutions. In addition, disruptive innovation can change organizational structure including roles and responsibilities that are not initially obvious.

Amazon, Uber, iTunes, and Airbnb are well-known disruptive examples that are not directly related to industrial manufacturing and automation but do illustrate the creative application of technology and new concepts that have dramatically changed commerce.

Industrial examples include the use of hydraulics to replace mechanical methods (i.e., cable, pulley), digital systems to replace pneumatic proportional-integral-derivative (PID) controllers, and mechatronics to replace gearboxes and mechanical camming with programmable coordinated motion.

The subtle part of disruptive innovation is that many times it is the combination and creative and innovative application of new off-the-shelf technology to build new and better solutions that result in significant improvements, ease of use, and added functions. “The Innovator’s Dilemma” by Clayton Christensen explains how successful

companies fail by sticking to their established business models, overlooking disruptive innovations while newer and/or less-established organizations often do otherwise. An example is Kodak, which was slow to fully embrace digital and instead continued to focus on its traditional film business.

Competitive success factor

Manufacturing and process companies that do not take advantage of the appropriate disruptive innovations are likely to become uncompetitive at some point and be leapfrogged by their competitors. Conversely, companies that leverage disruptive innovations position themselves to become leaders in their industry. History provides numerous examples of companies using innovative thinking and technology to become industry leaders.

Ford dominated the early automotive industry. More than 100 years ago, Henry Ford and his team at the Highland Park assembly plant launched the world's first moving assembly line. It simplified the production of the Model T's 3,000 parts by breaking production into 84 distinct steps performed by groups of workers as a rope pulled the vehicle chassis down the line.

Andrew Carnegie built his steel-making business leveraging technology with new processes such as the Bessemer process. He installed new material-handling systems including overhead cranes and hoists to speed up the steel-making process and boost productivity. Carnegie was relentless in his efforts to drive down costs. He would tear out and replace equipment at his mills if better technology was developed to reduce costs and make his mills more efficient.

Federal Express Corporation, founded in 1971, leveraged barcode and computer technology to achieve dramatic growth. One of FedEx's great contributions was the tracking system launched in the 1970s, which has become standard in shipping. It was initially an internal process for quality control. When the system went online, it included early prototypes of handheld computers that scanned package barcodes with wands.

Looking for insight and innovation

You might think creativity starts with a random idea, but the truth is that the best ideas and new trends don't arise in an intellectual vacuum. If you want to brainstorm innovations that go beyond solving problems and increasing productivity and performance, you must gather new ideas from multiple sources.

We have been conditioned to believe the only way to get big results is to make a big change. This can sometimes be true, but these opportunities are typically expensive and rare. Many times, the little-change ideas can be as powerful as the big ones. Smaller changes have the advantage of being an additive, instead of an overhaul, and thus may be able to yield big results while being less costly, less risky, and less disruptive.

Look to the insights of others and consider macroeconomic trends or technological advances from outside your industry. That's where the little-change ideas for your operations can be found.

ABOUT THE AUTHOR

Bill Lydon is editor emeritus of Automation.com and *InTech* magazine, publications from the International Society of Automation. He has more than 25 years of experience designing and applying automation and control technology, including computer-based machine tool controls, software for chiller and boiler plant optimization, and a new-generation building automation system. Lydon was also a product manager for a multimillion-dollar controls and automation product line, and later cofounder and president of an industrial control software company. He now acts as an industrial automation business coach and consultant on manufacturing digitalization and other topics.

Real-time Digital Manufacturing: REALIZED

Applying digital transformation techniques and new system design approaches make integrated, sensor-to-enterprise systems possible.

By Bill Lydon

Worldwide manufacturing had a wake-up call with the pandemic and supply chain disruptions. Outsourcing for lower costs has created pain and is a pressure point with negative impacts both on sales and on increasing profitability risk. However, the foundations of manufacturing and production are being reshaped by the integration of manufacturing production into the entire industrial business system. A digital manufacturing architecture offers a streamlined approach to enterprise-wide clarity that allows stakeholders to adjust operations based on real-time insights, i.e., data transparency.

Worldwide industrial digitalization

The impact of open manufacturing initiatives continues to advance worldwide as countries and industries recognize the need to modernize with Industry 4.0, and other related initiatives being adopted and accelerating. These provide models for all industrial manufacturing organizations to achieve holistic and adaptive open automation system architectures. Germany's Industry 4.0 initiative ignited worldwide cooperative efforts in other countries including China, Japan, Mexico, India, Italy, Portugal, and Indonesia to apply technology to increase production competitiveness.

At the same time, the lack of investments by companies, governments, and schools in vocational and technical education is a major issue. In the decades after the Second World War, high school dropouts could walk onto factory floors all around America and find decent, secure, middle-class jobs; this is no longer the case. Companies for many years have not invested in meaningful internships and apprenticeships, further drying of the skilled labor pipeline. Certainly, unskilled labor continues to be eliminated by automation, but industry still requires skilled and knowledgeable people educated to work with new manufacturing technologies.

Industry still requires skilled and knowledgeable people educated to work with new manufacturing technologies.

These trends are being helped by the rise of real-time manufacturing business systems. Digital transformation is creating an integrated real-time system from sensor to enterprise and cloud, which is now possible with the application of open standards and technology. Manufacturing and production companies increasingly are digitalizing to overcome the inefficiencies of siloed systems that create overlaps in processes and, more importantly, gaps in knowledge that stifle collaboration, efficiency, and ultimately growth.

Digital transformation is empowering companies to realize holistic manufacturing business. This is achieved with a real-time distributed manufacturing architecture (DMA).

Achieving lean, high-velocity manufacturing requires product, material, and information flow all working in concert. Information flow impacts the efficiency of a responsive manufacturing supply chain. Intelligent manufacturing systems ensure optimized, fast, and reliable product and material flow. These systems should be integrated and networked so that product/process data and business manufacturing information can smoothly "flow." A key manufacturing competitive advantage is not how well each system works but how well they all work together.

Simplified hierarchies

Industrial automation is changing from hierarchical Purdue models to more responsive architectures, achieving the goals of integrated real-time manufacturing. I wrote about the roots of this change in 2012 in an article titled "Simplifying Automation System Hierarchies." Now, these architectures are being deployed at a growing rate to achieve more efficient and profitable manufacturing. New technology is making it possible to streamline this model to eliminate layers, increase performance, and lower software maintenance costs.

The traditional strict hierarchy architecture is giving way to a more responsive and direct model to create real-time highly responsive manufacturing businesses. Field devices can communicate information directly with applications including historians, advanced cloud analytics, real-time maintenance monitoring, and other functions. This simplifies the applications of these functions and eliminates Level 2 and Level 3 software costs, complexity, performance drag, and ongoing software maintenance.

Over the years, industrial automation architecture has been marked by increasing computing pushed toward final field devices, leveraging distributed computing to increase performance, quality, reliability, availability, responsiveness, and lower software maintenance costs. The limiting factor at each step has been the cost, ruggedness, and reliability of technologies. This has changed with significant commercial, consumer, and Internet of Things (IoT) technology and communications advances at low cost that are pervasive in daily life. The smartphone—an everyday device many people possess—is an obvious example of a rugged, powerful computer with integrated communications and display.

The most commonly used industrial automation architecture model to define manufacturing operations management is the five-level Purdue Reference Model (PRM), which later formed the basis for the ISA-95 standard. This five-layer hierarchical architecture served the industry well for years, being easily deployed with the existing available technology. The model is typically expressed as:

- Level 5: Business systems
- Level 4: Plant level (enterprise resource planning [ERP], material requirements planning [MRP], and manufacturing execution systems [MES])
- Level 3: Operation unit
- Level 2: Machine/process automation
- Level 1: Controller
- Level 0: Sensor/actuator.

Traditional automation systems generally reflect this architecture with software running on general-purpose computers at Levels 2, 3, 4, and 5. Levels 2, 3, and 4 typically have database and communications interfaces that buffer and synchronize information between each level in addition to the associated human-machine interface (HMI) and user interfaces. The constraints of computing costs and networking bandwidth dictated this configuration based on past technology. The multilevel computing model is complicated, creating a great deal of cost, ongoing configuration control, and lifecycle investment. Fortunately, this model is changing to enable a more efficient and streamlined automation system architecture.

Industrial manufacturing organizations have been eliminating the barriers between functional silos that create overlaps in processes and gaps in knowledge that impede collaboration, efficiency, and, ultimately, growth. Manufacturing companies are integrating more tightly into the business, and this is also reflected by the integration of systems from sensor to enterprise. The transformation to integrated, real-time, data-driven manufacturing eliminates inefficiencies, increases responsiveness, increases profits, and encourages competitiveness.

The shift to digital manufacturing architecture (DMA) is a fundamental building block for transformation that has implications from the enterprise level to the farthest end of manufacturing and production—sensing and control devices (Figure 1). This distributed system includes applications on embedded processors in sensors, actuators, barcode readers, cameras, and other field devices that can be controlled locally, but equally important, they can also be accessed remotely for complex calculations and adjustments at any time.

This architecture allows for real-time transaction processing and synchronization with manufacturing, creating a closed loop. In addition to being highly integrated, effective DMAs:

- Provide immediate visibility throughout the entire enterprise
- Deliver unified, accurate, and timely data for decision making
- Adjust and optimize based on changes in supply chain and customer demand.

In the new model, controllers can communicate information to all levels directly using the appropriate methods and protocols.

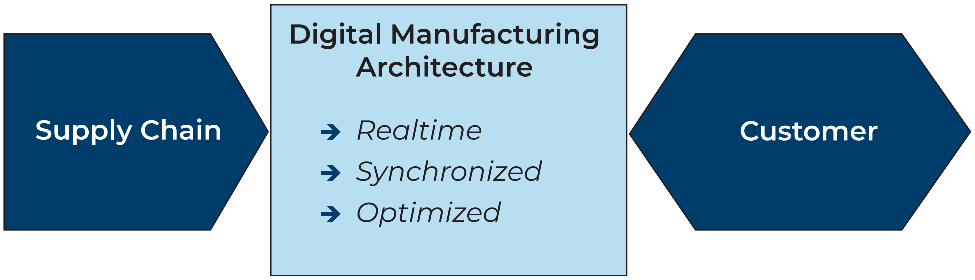


Figure 1. Digital manufacturing architecture (DMA) optimizes and synchronizes internal and external production resources in real-time based on changing parameters.

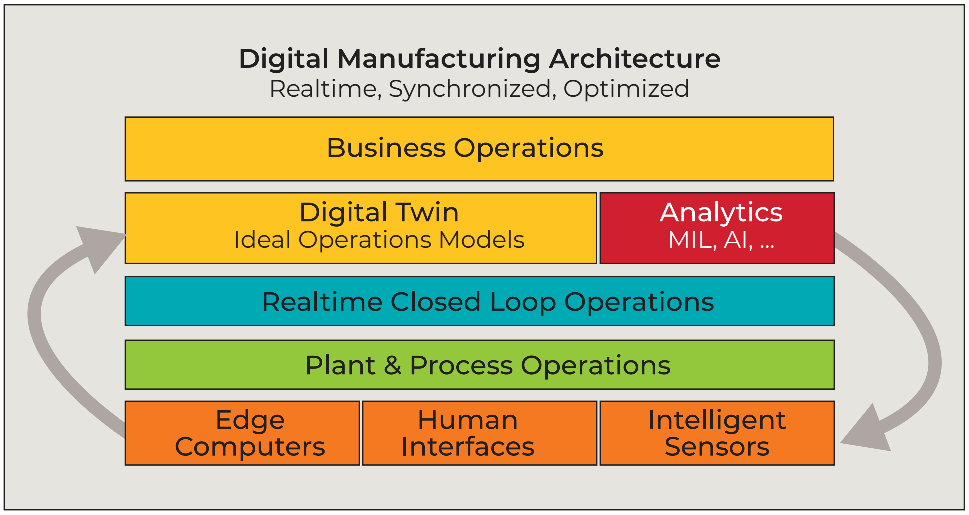


Figure 2. Digital manufacturing architectures allow for variability from the factory floor to the edge.

Ethernet communication has become the high-speed and pervasive technology used by industrial automation protocols and business systems. More controllers are supporting multiple Ethernet ports to interact directly with industrial and business networks that exist throughout industrial plants. Historians, analytics, real-time maintenance monitoring, and other functions are now being incorporated into controllers. This simplifies the applications of these functions and eliminates traditional architecture software costs, complexity, performance drag, and ongoing software maintenance. More powerful controllers and communications enable the coordination between controllers without requiring a separate computer to coordinate them as well.

The most effective architecture requires orchestrating and optimizing all elements of the process for flexibility in the face of external changes including supply chains, customer demands, costs, availability, energy, and sustainability requirements. The emerging DMA technology leverages advances in distributed computing and open systems to accomplish this and achieve synchronized, real-time, optimized production (Figure 2).

Customer orders, supply chain factors, and factory operations are fed into the digital twin, an ideal operating model of the plant and its

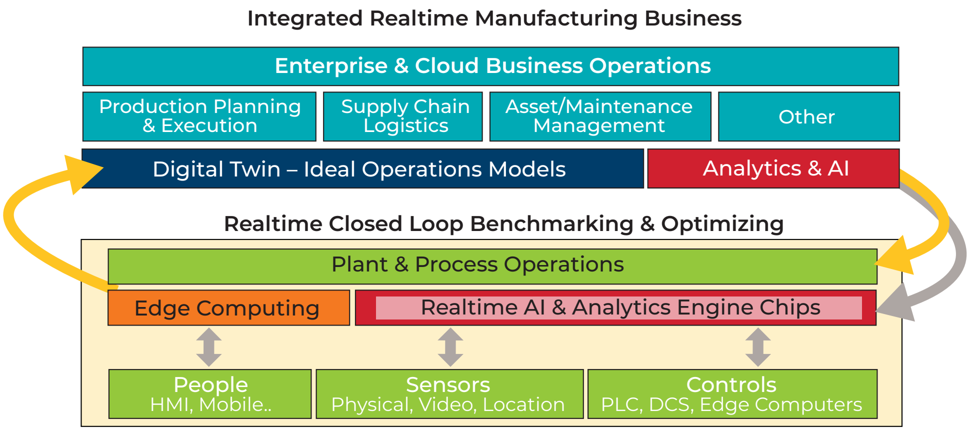


Figure 3. Optimized closed-loop operations of all industrial functions.

processes. Real-time linkages throughout the system create a closed loop (Figure 3) with constant feedback, whereby analytics, artificial intelligence, and machine learning adjust and optimize operations.

Digital manufacturing architecture requirements are driving industrial cybersecurity integration with mainstream information technology (IT), cloud, and IoT protection technologies and methods to create more secure manufacturing environments. Major technological advances include the incorporation of firmware/hardware in controller intelligent sensors, actuators, and other field edge devices.

Real-time digital manufacturing is about becoming a more effective, holistic, and competitive business. This increases reliability, quality, production, profitability, safety, flexibility, informed decision-making, and overall competitiveness as a business.

ABOUT THE AUTHOR

Bill Lydon is editor emeritus of Automation.com and *InTech* magazine, publications from the International Society of Automation. He has more than 25 years of experience designing and applying automation and control technology, including computer-based machine tool controls, software for chiller and boiler plant optimization, and a new-generation building automation system. Lydon was also a product manager for a multimillion-dollar controls and automation product line, and later cofounder and president of an industrial control software company. He now acts as an industrial automation business coach and consultant on manufacturing digitalization and other topics.

Open Automation Systems – **Update on the State of the Art**

Experts from UniversalAutomation.org, ExxonMobil, and other industry groups tell how modern software techniques are improving process automation systems.

By Andre Babineau, John Conway, David DeBari, Alex Eaton, Kelly Li, Sarat Molakaseema and Josh Swanson

In the world of industrial manufacturing, where operational technology (OT) systems control, automate, and keep mission-critical manufacturing processes safe, there has been a strong and steady push to adopt more open automation systems by employing modern software technologies that are already mainstream in the IT industry.

Some of the characteristics of these new open process automation systems are:

- Standardized communication protocols for improved interoperability of systems.
- Automation software that is decoupled from the hardware on which it executes, meaning the software applications essentially become vendor-independent.
- Object-oriented technologies for efficient creation and re-use of software component libraries.
- Event-driven architectures that simplify the integration of real-time automation systems and applications with other enterprise applications, such as analytics, asset management systems, and resource planning systems.

Some characteristics of open process automation systems are standardized communication protocols, object-oriented technologies, event-driven architectures, and automation software decoupled from the hardware it runs on.

Multiple benefits can be gained from these more open and modern approaches. To name just a few:

1. Industrial manufacturers are better able to efficiently and more cost-effectively manage control system hardware end-of-life and obsolescence issues.
2. Better return-on-investment as enterprises digitize and invest more-and-more in advanced application software.
3. Using "proven-in-use" software components and standard IT infrastructure management tools increases the reliability of plant assets, as well as the cybersecurity and safety of the entire operation.

4. Using best-in-class “Plug & Produce” software components increases innovation over the lifecycle of controlled assets.

5. Enabling modular plants, modular machines, remote operations and other flexibility makes operations more agile and the global supply chain much more resilient.

6. Last, but not least, attracting young software engineers into the automation profession to run the plants of the future with more modern technologies and architectures.

This article summarizes the initiatives related to open automation and describes the technologies behind open automation architectures and the ExxonMobil Open Process Automation (OPA) test sites.

Several major ongoing industrial initiatives/organizations today promote this new world of open automation software and the portability of industrial control applications. A few examples are: The Open Process Automation Forum, NAMUR, OPC Foundation, and UniversalAutomation.org

Open Process Automation Forum. In late 2016, the Open Process Automation Forum (OPAF), an industry consortium, was formed by end users, vendors, suppliers, and academics within The Open Group to advocate for the definition of a highly standardized reference architecture for process automation systems, thereby allowing for the modular integration of products from multiple vendors into a single control system. This modular standardized architecture is achieved through the incorporation of existing standards and specifications wherever applicable, making the Open Process Automation Standard (O-PAS) a ‘standard of standards.’

The diagram (Figure 1) outlines a sample control system architecture using O-PAS components. A new OPAS system is centered around the use of Distributed Control Nodes (DCNs) which connect to a standardized and secure network backbone, the O-PAS Connectivity Framework (OCF). A DCN can provide a controller with logic-processing capabilities, an I/O module, or both (similar to a traditional PLC or DCS controller with attached IO).

The OCF utilizes the OPC-UA communication protocol, allowing any connected DCN access to the data it needs across the network using a common, standardized data model. This availability of data across the OCF allows for the decoupling of I/O hardware from compute hardware, which provides greater flexibility in network design and easier extensibility when additional I/O or compute power is needed.

O-PAS-compliant systems can also be integrated with existing control system offerings through the use of O-PAS Communication Interfaces (OCIs), which translate from other communication protocols into OPC-UA as used by the OCF.

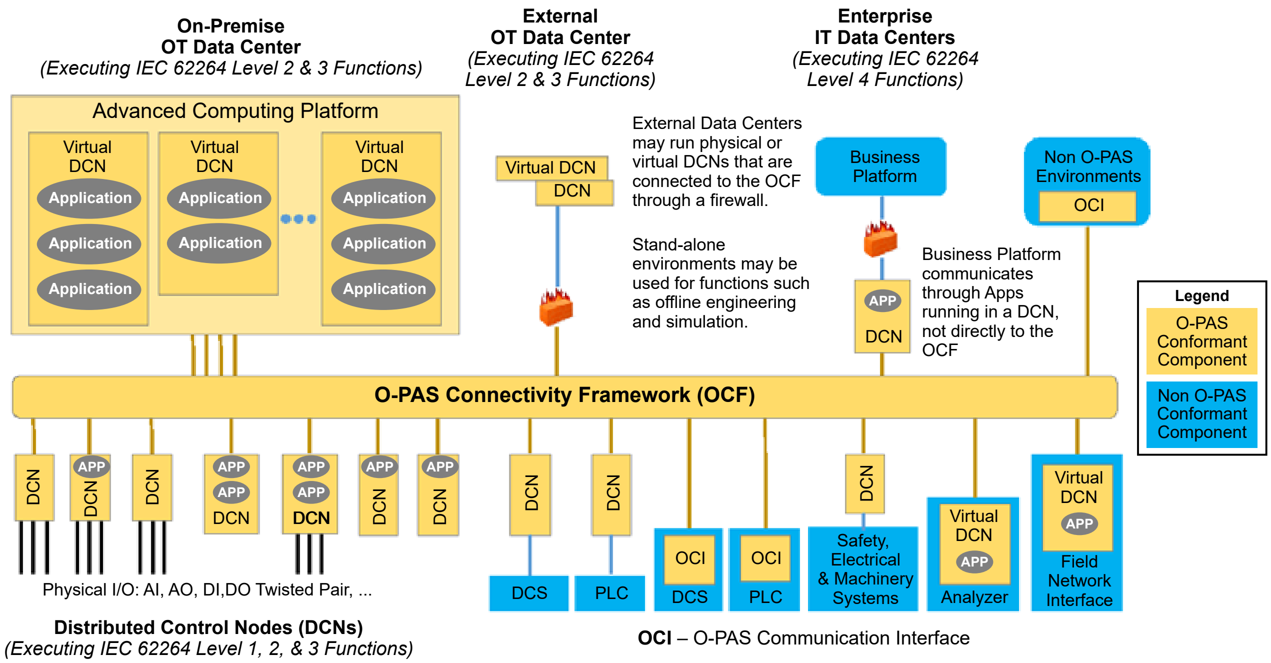


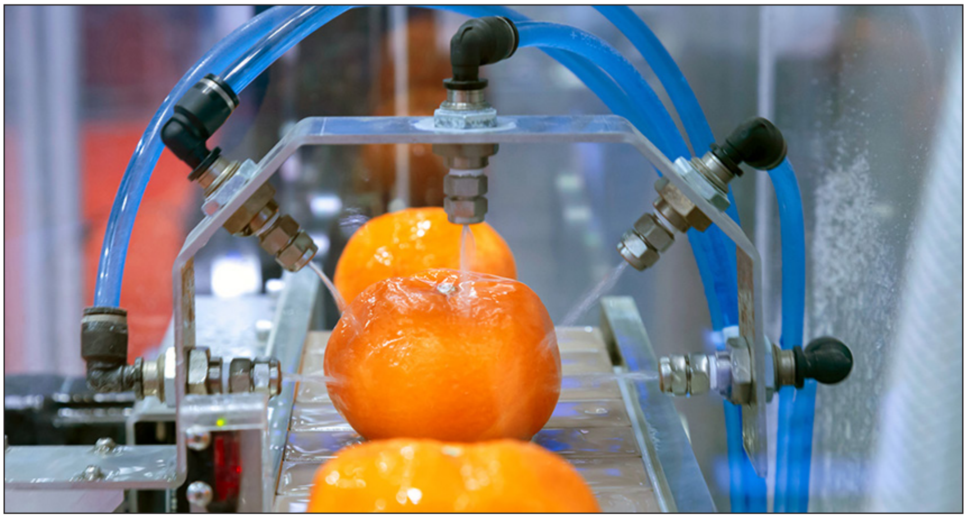
Figure 1. A sample control system architecture using O-PAS components.

Today (Q2 2024), OPAF has more than 120 corporate and academic institution members from across the world. OPAF working groups meet regularly to discuss business and technical initiatives and are currently working toward the version 3.0 release of the OPAF standard, with a focus on application portability and system orchestration. Additionally, OPAF has established liaison agreements with various groups in industry, such as the OPC Foundation, the International Society of Automation, NAMUR, and UniversalAutomation.Org to take advantage of parallel and complementary efforts within industry to standardize open automation platforms.

NAMUR. NAMUR is an international user association of automation technology and digitalization in the process industries. The mission of the association is to contribute to the value generation of its member companies by helping to create efficient (costs, availability), sustainable, safe, and reliable processes.

Believing that automation competence leads to reliable processes, NAMUR embraces a holistic approach to process technology, defining minimum requirements related to equipment and systems, fair dialogue with manufacturers, and the identification of future automation technology and digitalization requirements and development needs.

NAMUR members positively influence regulations by cooperating in national and international standardization and including user



requirements. Members engage with standardization committees, authorities, and supervisory bodies to actively design industry standards and avoid non-economical and inappropriate standards for the industry. NAMUR also focuses on the future. To attract qualified engineering talent, NAMUR addresses issues that are relevant to process control, promotes advancements in practical applications, and represents the positive significance of automation technology and digitalization in the process industry.

The NAMUR Open Architecture (NOA) enables plant and asset monitoring and optimization through easy and secure access to production data. Smart sensors, field devices, mobile devices, and the ubiquitous use of IT equipment are generating increasingly more data that can be difficult to access within the classic automation architecture. NOA is compatible with current developments in automation, such as the Advanced Physical Layer (APL) and the Module Type Package (MTP). NOA will enable a wide range of new use cases by opening and unlocking more data, which enables field devices, process analyzers, electronic equipment monitoring, mechanical equipment management, and optimization using additional process measurements and data.

A detailed description of the NOA concept can be found in the NAMUR Recommendation NE 175. To accelerate productive solutions, NAMUR and ZVEI (the German Electro and Digital Industry Association) set up a joint project and several sub-working groups to drive the development of the different building blocks for NOA like MTP and APL. Modular production will play an important role in the process industry 4.0 transition and MTP embodies an interface and capability description of intelligent equipment modules via standardized equipment data models and description language.

MTP provides a vendor-independent description of the process module with various facets, such as HMI, process control, maintenance, diagnostics, safety, and security, as well as alarm management, which reduces the time it takes to engineer and commission automation equipment modules.

Many companies in the process industry are excited by the chance to access stranded data simply and securely and to use new monitoring and optimization functions. From the beginning of the NOA development, the NAMUR members have been involved with international organizations, such as BioPhorum and ISPE (International Society for Pharmaceutical Engineering) and presented the NOA concept at international events like those sponsored by the Open Group, since global acceptance is crucial for the success of NOA.

OPC Foundation. OPC Unified Architecture (OPC UA) is an information exchange standard for secure, reliable, manufacturer- and platform-independent industrial communications. It enables data exchange between products from different manufacturers and across operating systems. The OPC UA standard is based on specifications that were developed in close cooperation between manufacturers, users, research institutes, and consortia, to enable consistent information exchange in heterogeneous systems.

OPC UA is an IEC standard and is therefore ideally suited for collaboration with other organizations. As a global, independent, non-profit organization, the OPC Foundation coordinates the further development of the OPC standard in collaboration with users, manufacturers, and researchers. Activities include:

- Development and maintenance of specifications
- Certification and compliance testing of implementations
- Cooperation with other standards organizations.

The OPC Foundation has launched the OPC UA FX (Field eXchange), an initiative that will further enable OPC UA adoption by covering the use cases and requirements for the field level.

The goal of this initiative is to deliver an open, cohesive approach to implementing OPC UA, including time-sensitive networking (TSN) and associated application profiles. This will advance the OPC Foundation by providing vendor-independent end-to-end interoperability into field-level devices for all relevant industry automation use cases. The OPC Foundation's vision is to become the worldwide industrial interoperability standard by integrating field devices with the shop floor.

UniversalAutomation.Org. UniversalAutomation.Org (UAO) is a not-for-profit, international association established in 2021 to drive a vision of "plug and produce" automation using vendor-independent software components (think app store) that are enabled by the IEC61499 standard.

The association is growing rapidly: As of June 2024, it has 89 members from the user, vendor, and academic communities.

UAO believes "open automation" as it exists today is not open enough. It believes interoperable and portable application software is an essential enabler for Industry 4.0. In practice, UAO is a combination of two things:

1. A standardized automation layer across vendors, based on the IEC 61499 standard, in the form of royalty-free license and runtime execution engine source code, which is available to its members on GitHub.
2. An ecosystem of members from the user, vendor, and academic communities, who are committed to driving the adoption of the UAO runtime.

UAO offers are available on the market and are being deployed by end users across various industry segments. For example, ExxonMobil and several other OPAF members use the UAO runtime as one of the components of their open-process automation architectures.

Universal automation will allow OEMs, integrators, and end users to build automation solutions by plugging together best-of-breed apps using no-code graphical tools. In industry, we call this "plug and produce".

Much in the same way that consumers can easily access the latest mobile phone technologies and apps, industrial stakeholders, with plug-and-produce applications, will be able to experience ease of use at lower costs through much simpler, less labor-intensive behind-the-scenes integration.

The IEC 61499 standard defines an event-driven architecture for distributed information and automation systems. It is object-oriented by design, and it establishes a clear separation between the application and the devices on which the application will execute. This combination of event-driven architecture, object-oriented programming, and hardware/software decoupling lays the foundation for plug-and-produce applications that are vendor-agnostic (Figure 2).

Open Systems Performance

Proprietary systems have done a great job bringing automation to where we are today. Defenders of proprietary systems argue they are required to achieve a high level of real-time performance and determinism.

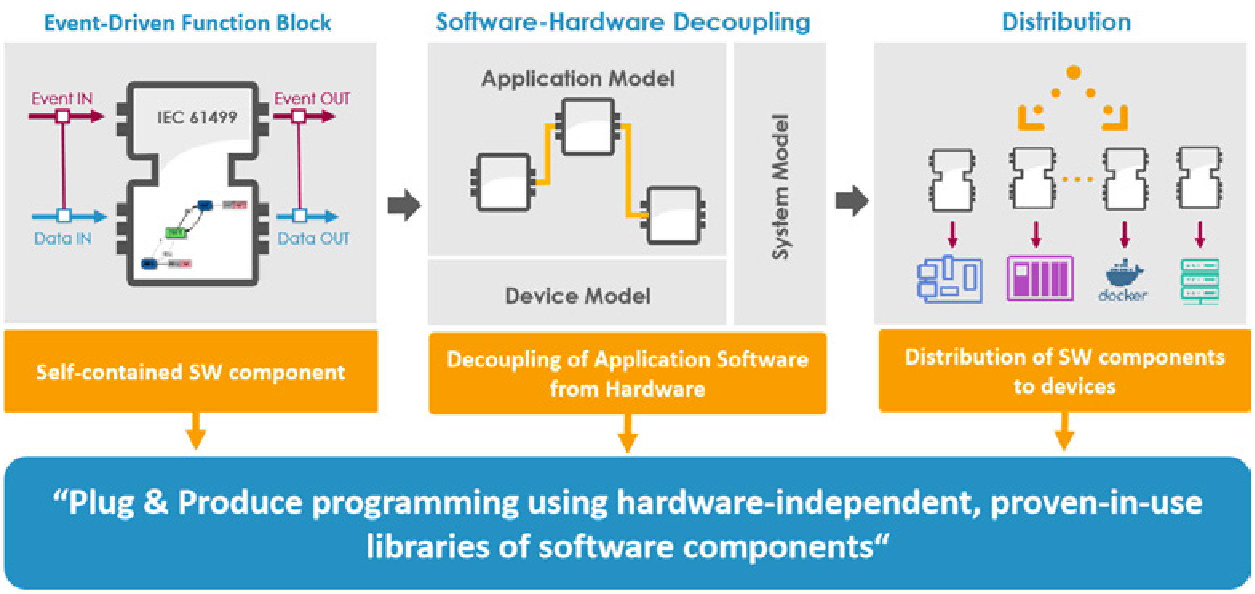


Figure 2. The IEC 61499 standard enables an event-driven architecture, object-oriented programming, and hardware/software decoupling that lays the foundation for plug-and-produce applications.

While this may have been true 15 years ago, when compute power was expensive and open-source software systems were less developed, it is no longer true today. According to Moore's Law, computer power continues to double every 18 months, and open-source software, like Linux, is already running mission-critical enterprise systems.

Linux operating system. In the past, manufacturers typically used commercially available proprietary real-time operating systems. In parallel, the use of open-source Linux operating systems continued to expand, driven by the growth of the Internet and the associated data centers, to the point where the majority of internet traffic flows through Linux-powered systems. Linux is now being used extensively in consumer and industrial appliances that have embedded compute power.

To meet the stringent requirements of control systems and other hard-deadline computing, a real-time patch for the Linux kernel scheduler was developed, prioritizing predictable performance. This has found use in industrial automation applications, as well as other embedded applications, providing the deterministic foundation for Linux to operate in control system environments.

Today several industrial automation companies use Linux as the OS for their real-time control systems. Some examples include PLCNext from Phoenix Contact; ctrl X OS from Bosch Rexroth; ROS 2 (Robot Operating System 2). Kernel-RT patches are available from vendors such as Canonical and Red Hat

Because the real-time scheduling patches simply change scheduling behavior, all the other benefits brought by Linux are available to industrial workloads, such as portability, customization, and process isolation.

In addition, Linux is being used as the foundation for next-generation offerings to meet or exceed existing embedded solutions. For example, Linux-based certified functionally safe systems are currently in development. Certification in both the industrial and automotive markets will be available for general consumption before the end of the year.

Some vendors have even built high-availability (HA) solutions on top of a Linux platform, which when combined with network-based I/O, allows for failover to happen exclusively at the application level, without proprietary, expensive hardware.

Automation platforms like PLCNext from Phoenix Contact and crtl X OS from Bosh Rexroth also promote the use of other apps programmed in multiple languages. And they even provide an app store with the possibility to download and run other apps alongside the real-time control apps.

These systems typically have a common data layer through which different apps can access the system IO. Apps can be traditional control programs e.g. IEC 61131, or more modern programming languages such as C++ and Python. Mechanisms are in place to segregate real-time control applications from “right-time” applications, allowing the programmer to achieve the desired level of performance and determinism.

The Bosch Rexroth ctrlX OS platform combines Linux with EtherCAT to address the very demanding multi-axis motion control

domain which requires a very high level of performance and micro-second determinism.

The argument that Linux is not a "real-time OS" is clearly no longer true, as Linux has proven its deterministic capabilities, and is trusted in mission-critical applications by many different organizations, with more choosing it as the foundation of the next iteration of their solutions.

Event-driven protocols and programming. Typical automation systems in the past used scan-based execution models and client/server or request/response communication models and protocols to ensure that the behavior of the control system was predictable and deterministic.

Enterprise IT applications on the other hand had long ago switched to change/event-driven execution models and change/event-driven communications and protocols to leverage and monetize the benefits offered by the change/event-driven approach.

In the recent past IT – OT integration has received significant traction among end users seeking to integrate more and more their control systems with their enterprise applications. In these examples, they need to embrace and use the change/event-driven approach both in control execution and communications. A good number of control systems in the market today already support and use change/event-driven communication models and protocols in their products.

Additionally, a good number of modern protocols, like OPC UA and MQTT, Ethernet IP, and Profinet, inherently support event-driven communication models. All or most of these protocols are already in use and supported in control systems in today's market.

In line with the above developments, UniversalAutomation.Org (UAO) takes this one step further by applying the event-driven architecture to real-time control execution as defined by the IEC 61499 standard.

To guarantee performance/determinism for demanding applications, resource-based prioritization is part of the UAO runtime.

This allows a high-priority resource to interrupt lower-priority resources, ensuring that tasks requiring a rapid response time are executed in a predictable and deterministic manner.

This is nothing new. Even scan-based systems have similar mechanisms to ensure that high-priority tasks can interrupt the general scan as and when required. The introduction of function blocks programmed in high-level languages such as C++ adds to the challenge of guaranteeing determinism, even in scan-based systems.

Schneider Electric, one of the founding members of UAO recently demonstrated the deterministic performance of event-driven systems well below the millisecond level using the UAO resource prioritization mechanism on a Raspberry Pi running Linux. Despite running event chains that required more than 50ms to complete (matrix convolution calculations), higher-priority resources were able to interrupt the longer-running resource to execute the higher-priority tasks. A deterministic response in the range of a few hundred microseconds was achieved (additional technical details can be found here).

In addition, event-based systems can implement “cyclic” tasks just like scan-based systems can. Reading of physical inputs is typically programmed as a high-priority cyclic task.

Automation engineers with a background in traditional PLC programming indeed find it easier to understand scan-based systems compared to event-driven systems. However, the converse is also true: Young software engineers with experience in high-level languages struggle with scan-based systems.

At the end of the day, at a low level, all systems are event-driven. Users must take care to ensure that their performance/determinism requirements are met.

From Theory to Practice: ExxonMobil OPA Testing

In 2016, ExxonMobil (an OPAF founding member) entered into a development agreement with Lockheed Martin to begin a proof of concept for an open automation system architecture. In early 2017 they successfully used the IEC 61499 standard as a component for achieving that goal. Since 2018, several end users, with vendor support, have demonstrated their proof of concepts, prototypes, and test beds using IEC 61499-based control algorithms.

This demonstrates that an open, standards-based, secure, and interoperable automation architecture will elevate the end user's ability to improve business performance and success through modern technologies.

ExxonMobil has extensively used IEC 61499-based control logic in their Open Process Automation Program since early 2017. The UAO Runtime has been tested extensively to prove that it has the capabilities to create reliable and predictable control logic applications.

The first step for any user of IEC 61499 is to become familiar with the event-driven nature of the logic tools and the Execution Control Chart (ECC) capabilities. Once the user realizes that the system clock and a scheduled interval (e.g., 100ms, 1sec, etc.) can be used as the event, the leap from purely time-based scan typical of IEC 61131-based products to event-driven execution in IEC 61499 is straight forward and enlightening. The freedom and independence from a specified, cyclical schedule offer new options for how to schedule and configure control logic applications that are more tailored to the actual process automation requirements.

The standard of measure for companies like ExxonMobil includes the ability to safely automate, manage, and operate highly energetic chemical processes that are typically found in hydrocarbon refining and chemical manufacturing operations. The key criteria used for evaluating control systems and components include determinism, scalability, reliability, failure modes, and recovery, as well as a robust capability to implement existing and trusted process control code and methods, including the creation of new and novel control algorithms.

The usage of control logic in the UAO Runtime has been demonstrated and tested down to 1ms time cycles in a pilot plant prototype. While the responses from physical equipment, like valves and pumps, to control signal changes suffer from delay and deadtime that make 1ms timing impractical for general usage, the goal was to test whether control logic and the UAO Runtime based on the IEC 61499 standard, could be used for some types of rotating machinery timing requirements.

The integration of basic control logic with Model Predictive Control (MPC) was also tested, demonstrating several orders of magnitude faster response (from 15sec to 40 msec) than in a legacy automation system. The advanced control algorithms were operated through connections to the PID logic blocks and directly communicated to the output I/O channels.

Several end user companies have successfully repeated these use-case demonstrations in their prototypes and test beds and have gained confidence that IEC 61499-based products offer an excellent, standards-based choice for automation in an open architecture.

The performance and capability of the IEC 61499 standard have convinced ExxonMobil to use the UAO Runtime in control logic applications for their previously announced Open Process Automation Program's Lighthouse Project, which is scheduled for commission and startup at the end of 3Q24.

The project will replace an automation system composed of PLCs and DCS equipment with an OPA-based automation system to support the on-going operations of an existing manufacturing plant. This open system integrates the features of IEC 61499 and the UAO Runtime, OPC UA, DMTF Redfish, IEC 62443 security, container-based execution, Kubernetes/Orchestration, and existing control strategies and systems to create new levels of capability. This demonstrates that an open, standards-based, secure, and interoperable automation architecture will elevate the end user's ability to improve business performance and success through modern technologies.

High Availability. In addition to determinism, a key requirement in the process industries is high availability. Processor failure is a critical event that must be addressed immediately to ensure process safety and continuity.

The traditional approach to achieving high availability has been to use a primary and secondary processor with a high-speed data link between them to share process state data. If the primary processor fails, control of the process I/O systems is handed over to the secondary processor. During the transfer, the current process states are maintained achieving a bump-less transfer.

This approach has two drawbacks:

1. It relies on very specific and expensive proprietary hardware.
2. The operator must schedule a maintenance order to replace the failed processor and manually re-establish the secondary backup.

Schneider Electric and Red Hat overcame these drawbacks by implementing a software-defined high-availability scheme using the RedHat for Edge Linux distribution and the Schneider Electric Soft dPAC HA solution (a containerized version of the UAO EcoRT). This high-availability solution is fully software-defined, meaning it is no longer hardware-dependent. Soft dPAC HA provides the bump-less transfer of the control load automatically as soon a failure is detected and transfers process state data over a high-speed Ethernet connection.

In addition, because of the software-defined nature of the solution, Schneider Electric and Red Hat were able to redeploy the application to another compute resource on the network, thereby automatically replacing the failed processor with zero human intervention. This is possible as long as the network compute resource has the capabilities to run the workload to be deployed.

This approach to high availability ensures process continuity without human intervention and allows the customer to remove obsolete hardware and software without process interruption.

Conclusion

The long march to open automation systems is underway driven by user demands for more innovative solutions and the continuing acceleration of technology that has tended to leave proprietary automation systems lagging in its wake. The use of an open technology like Linux on automation platforms has already become mainstream and open automation architecture initiatives like OPAF are fully embracing emerging hardware-independent technologies like UniversalAutomation.org and OPC UA.

Concerns over performance have proven to be unfounded because new, open technologies have been successfully executing demanding applications.

So the question is not whether open systems will become mainstream. The question is how long will it take for open systems to become the dominant automation architecture. For many end users across industry segments, who already trust the determinism, availability, and flexibility open, IEC61499-based offers provide, the answer is now.

ABOUT THE AUTHORS

Andre Babineau is strategic initiatives director with Schneider Electric.

John Conway is chief of staff with UniversalAutomation.org (UAO).

David DeBari is senior engineering associate I&C with ExxonMobil Engineering & Technology Company.

Alex Eaton is OPA subject matter expert with Wood PLC.

Kelly Li is commercial lead - Open Process Automation with ExxonMobil Engineering & Technology Company.

Sarat Molakaseema is chief architect officer with UniversalAutomation.org.

Josh Swanson is industrial edge architect with Red Hat, Inc.

By Bill Lydon

Technology Trends that Empower Innovation

Advances in 18 technology areas are empowering and inspiring manufacturers.

Open standards, more powerful desktop computers, and lower-cost software make design, modeling, and automatic code generation for PLCs and PACs practical for improving automation. Other technologies go beyond problem-solving to achieve productivity and performance enhancements. Here's a look at advances in 18 technology areas that are worth paying attention to.

TECHNOLOGY TRENDS

- **AI, ML, and expert systems**
- **Cloud computing**
- **Hyperautomation**
- **Low-code/no-code platforms**
- **Edge computing platforms**
- **Modular design and programming**
- **BioPhorum activity**
- **Semantic/contextual data**
- **Communications**
- **Multiplatform open ecosystems**
- **Open source IEC 61499 Eclipse Foundation 4diac/Forte**
- **OPC Foundation field level communications**
- **Digital twins**
- **Intelligent sensors**
- **Spatial computing/intelligent vision**
- **Connected worker technology**
- **Remote expert services**
- **Robotics**

AI, ML, and expert systems

The commercial use of artificial intelligence is accelerating at all levels with the wide commercial application of AI, natural language processing, machine learning, and other expert systems. Increased processing power at lower cost is accelerating the technology. It is tempting to apply new technology immediately but as with any technology, these are new tools that need to be understood and applied properly; they are not instant "silver bullets" to solve all problems and increase operations efficiencies. The quality and value of AI applications depend directly on internal algorithms and data sources.

In the context of industrial automation and controls, poorly applied AI can have negative outcomes impacting performance, personnel, and plant safety. The European Commission AI ACT Legal Framework notes: "What does 'reliable' mean in the AI context? We speak of a 'reliable' AI application if it is built in compliance with data protection, makes unbiased and comprehensible decisions, and can be controlled by humans."

The AI ACT Regulatory Framework defines four levels of risk for AI systems: unacceptable risk, high risk, limited risk, and minimal risk. Mission-critical industrial control and automation applications are within the AI ACT high-risk category. AI systems identified as high-risk include AI technology used in:

- critical infrastructures (e.g., transport), that could put the life and health of citizens at risk.
- educational or vocational training, that may determine the access to education and professional course of someone's life (e.g., scoring of exams).
- safety components of products (e.g., AI application in robot-assisted surgery).
- employment, management of workers and access to self-employment (e.g., CV-sorting software for recruitment procedures).

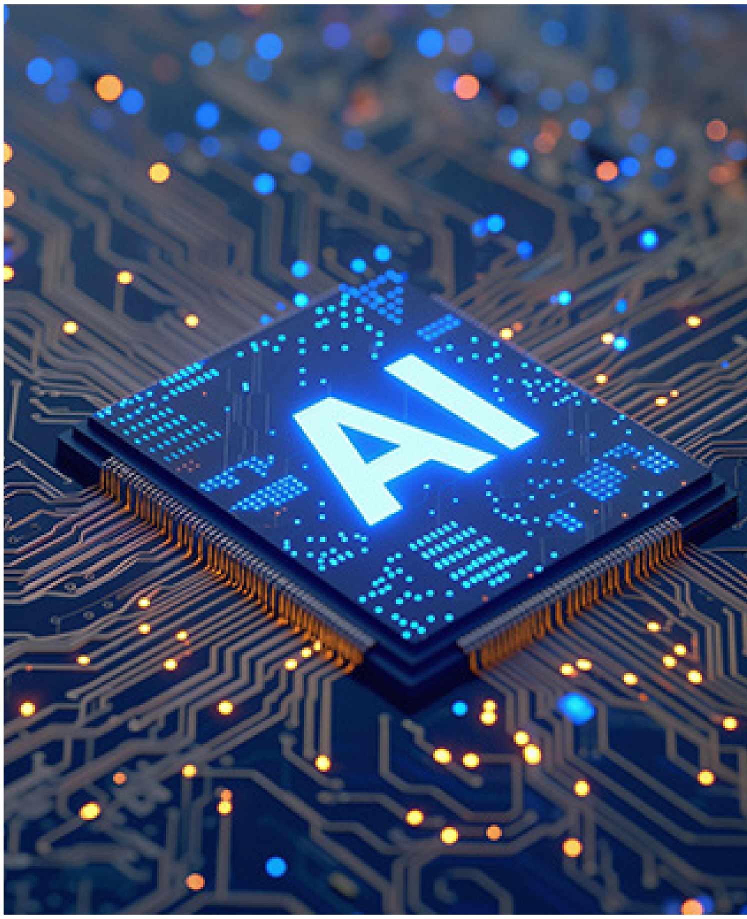
- essential private and public services (e.g., credit scoring denying citizens opportunity to obtain a loan).
- law enforcement that may interfere with peoples' fundamental rights (e.g., evaluation of the reliability of evidence).
- migration, asylum, and border control management (e.g., automated examination of visa applications).
- administration of justice and democratic processes (e.g., AI solutions to search for court rulings).

Properly applied AI, ML, and expert systems offer industrial companies enormous potential to significantly cut operating expenses, and improve staff efficiencies, quality, productivity, operations, and reduce maintenance and repair costs. AI technologies help achieve the goals of all industrial automation to increase productivity and efficiency. AI industrial applications properly designed with the right data can more effectively handle unforeseen scenarios in complex and rapidly changing environments based on patterns and trends in the data without being explicitly programmed for every possible scenario with little to no human interaction.

Properly applied AI, ML, and expert systems offer industrial companies enormous potential to significantly cut operating expenses, and improve staff efficiencies,

The goals of AI applications should be in line with the company's overall strategy and then define potential AI use cases for evaluation and prioritization for projects.

There are an increasing number of no-code, self-serve software tools simplifying the application of these technologies by industrial subject matter experts rather than data scientists. Industrial automation and control systems have a wealth of data that can be used more effectively with these technologies.



In addition, AI processor chips enable high-performance applications to run within controllers and edge computers for demanding applications. Server and cloud AI/ML/expert system solutions are suitable for a wide range of applications, but network communication speed and latency factors pose limitations for many real-time industrial and process applications that are overcome with AI chips embedded in industrial edge devices and sensors.

There are offerings from the market including Nvidia, Intel Myriad-X, Google Edge TPU, and Hailo. These new technologies are proven in other areas including video analytics with image recognition and related applications. These chips can be applied using plugin add-on board modules that are aggressively priced, conforming to the popular M.2 and mPCIe connector standards found in many computers including embedded industrial PCs, adding high-performance AI processing without degrading other applications in the computer.

This is analogous to early PC coprocessor add-ons to achieve high-performance floating-point mathematical calculation performance and video display coprocessors to achieve high-resolution/performance graphics. For example, the original IBM PC included a socket for the Intel 8087 floating-point coprocessor (aka FPU), which was a popular option for people using the PC for computer-aided design or mathematics-intensive calculations, or system architecture encompassing cloud, enterprise, and embedded applications. AI chips for embedded edge applications are particularly valuable for real-time industrial automation and control effectiveness.

RELATED ARTICLES

Cloud computing

Cloud computing is delivering efficient and powerful applications at a lower cost. These applications are being applied to improve manufacturing with technology solutions from suppliers including Amazon Web Services (AWS) and Microsoft architectures—important industrial digitalization building blocks from sensor to enterprise and cloud. Cloud software architectures and tools built on open standards are highly refined and easy to use to develop a wide range of applications including historians, AI, expert systems, machine learning (ML), and digital twins. Evidence of the commitment to the integration of the entire manufacturing business is membership and participation in the OPC Foundation by technology companies including AWS, Microsoft, IBM, and Capgemini.

Cloud applications are providing many functions previously only available with onsite systems. This is particularly important for small and medium-sized manufacturers that did not have the financial strength to make the large investment required for onsite systems. Cloud applications provide small and medium manufacturers with the functions previously only available to large companies to increase efficiency and profits. In the U.S., companies with fewer than 100 employees make up more than 94 percent of all U.S. manufacturers. In Europe, there are approximately 22.6 million small and medium-sized enterprises (SMEs) in the European Union in 2021.

For example, comprehensive system as a service (SaaS) manufacturing business solutions is an efficient way to achieve integrated digitalization of all functions, including enterprise resource planning (ERP), manufacturing execution system (MES/MOM), quality management system (QMS), analytics and Industrial Internet of Things (IIoT), and supply chain management (SCM). PLEX Systems, now a Rockwell Automation company, is an example with a full suite of cloud-based SaaS manufacturing business solutions.

RELATED ARTICLES

Hyperautomation

Hyperautomation is an advanced automation strategy to drive profound digital transformation to gain a competitive advantage. Hyperautomation involves the orchestrated use of multiple technologies, tools, and platforms including AI, ML, event-driven software architecture, robotic process automation (RPA), robotics, business process management (BPM), and low-code/no-code tool technologies. In the context of industrial manufacturing, hyperautomation is the digitalization and integration of the entire business, from plant process to business enterprise, including ERP, supply chain, logistics, and customer fulfillment.

RELATED ARTICLES

Low-code/no-code development

A software revolution has been ignited by no-code/low-code development platforms. Low-code/no-code software is a high-impact manufacturing automation trend that empowers industrial professionals who understand manufacturing and production to directly apply technologies without being data scientists or trained programmers. These “citizen developers” create applications with artificial intelligence, expert systems, predictive maintenance, optimized machine operations, and flexible manufacturing techniques using drag-and-drop interfaces, natural language tools and quality-tested models to build applications.

Without needing to manually code systems, developers can deploy automated solutions faster than before and adjust them more efficiently as needed. The higher level of adaptability provided by low- and no-code solutions is critical in the manufacturing sector where people must respond to constantly changing conditions. This is analogous to how spreadsheets democratized the use of computers for a wide range of applications enabling subject matter experts to directly apply their knowledge. Today’s no-code/low-code platforms are very comfortable technologies for people since they use smartphone, tablet, and PC applications in their daily lives.

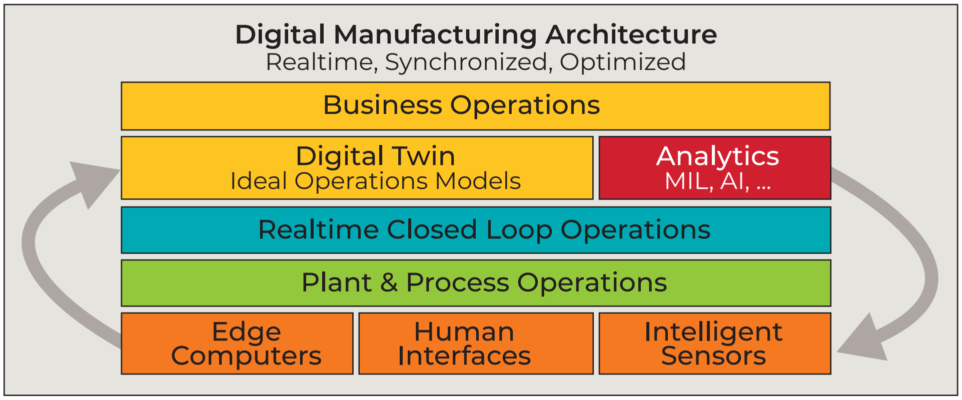
Since 1969, industrial automation and control people have been empowered with no code ladder logic programming that evolved into the IEC 61131-3 International Electrotechnical Commission (IEC) standard, first published in 1993. The standard continues to be enhanced and extended in IEC committees and by the not-for-profit PLCopen trade organization. Noteworthy enhancements include industrial safety, motion control, robotics, OPC UA, and other functions.

RELATED ARTICLES

Edge computing platforms

Industrial edge computing devices provide distributed intelligence at or near physical processes to sense, control, run local programs, and communicate with industrial controllers, plant operations, enterprise systems, and cloud applications. Edge computing devices include industrial PCs, Raspberry Pi, Android, and embedded system-on-a-chip (SoC). This is required for real-time closed-loop manufacturing business operations to be responsive, profitable, and competitive.

Edge devices are part of a distributed computing architecture. They perform tasks that in many cases productively interact with enterprise and cloud computing applications. There is now a wide range of edge computers at various power and price points, from multicore processors to Raspberry Pi devices. Sensors with embedded processors and built-in communications are edge devices that provide a new level of functionality.



Edge devices, part of a distributed computing architecture, productively interact with enterprise and cloud computing applications.

The major value of edge computing is executing applications close to physical production, achieving fast response times with very low latency, and capturing real-time data. The incorporation of higher-level functions directly into this new breed of powerful field devices and industrial controllers, coupled with real-time transaction-processing business systems, is diminishing the need for industrial middleware software.

Business systems have evolved more rapidly than industrial systems to meet the requirements of business functions including supply chain, customer service, logistics, and Internet commerce. Middle-level software and computers have served their purpose of buffering, synchronizing, translating, and refining sensor and controller information, but also created brittle systems with a great number of middle-level computers, duplicate databases, complex configuration control, and software that is expensive and difficult to maintain.

Edge computing is computing that takes place at or near the physical location of either the user or the source of the data. Distributed functions at the edge include optimization, expert systems, and AI with new classes of devices.

Rugged edge computing platforms provide gateway functions plus many other functions including distributed control, optimization, webservers, OPC UA server and clients, AI, REST APIs, image recognition, and cloud communications (AWS, AZURE, etc.). Many incorporate multiuser environments such as Docker and Kubernetes, enabling the addition of user applications written in standard programming languages including Python and JavaScript.

Intelligent/smart field edge devices. Intelligent or smart field edge devices are a new class of smart field devices. These include sensors and actuators that are intelligent and communicate directly to controllers, enterprise, and cloud applications. These devices incorporate distributed control functions including optimization, web servers, OPC UA servers and clients, REST APIs, and cloud communications (with AWS, Azure, etc.). User-based initiatives are defining the new architecture based on these concepts including the NAMUR Open Architecture (NOA) and Open Process Automation Forum (OPAF) standards.

Edge gateways. Industrial edge gateways are typically rugged industrial computers running middleware software that connect to programmable logic controllers (PLCs), drives, and other edge devices. These edge gateways contextualize information and map it to enterprise software and databases. Edge gateways are ideal for providing edge computing functions that leverage installed legacy controls and automation, extending capital equipment investments.

RELATED ARTICLES

Semantic/contextual data

Industrial control and automation communications are evolving using semantic/contextual conceptual data models from the manufacturing edge to enterprise/cloud increasing system efficiency, responsiveness, and effectiveness. The semantic/contextual information inherently describes the meaning of data and sensors from machines and processes, which can be used directly by applications without interpretation or references. This is significantly different than getting data from traditional controllers and machines that provide nondescriptive data, for example, registry values that represent temperature or tool position information.

The major value of edge computing is executing applications close to physical production, achieving fast response times with very low latency, and capturing real-time data.

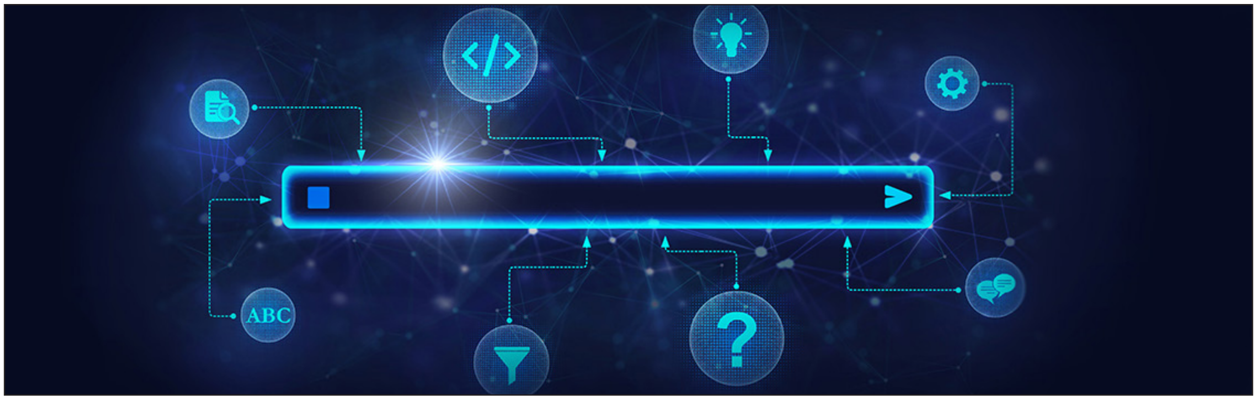
Advances in technology are making this economically feasible, providing significant benefits. Semantic/contextual information also simplifies performing cybersecurity checks on information by testing for proper data ranges based on application.

Semantic technology combines elements of semantic analysis, natural language processing, data mining, knowledge graphs, and related fields. Semantic technology encodes meanings separately from data and content files, and separately from application code enabling machines as well as people to understand, share, and reason with them at execution time. With semantic technologies, adding, changing, and implementing new relationships or interconnecting programs differently can be just as simple as changing the external model that these programs share.

With traditional information technology (IT), meanings and relationships must be predefined and "hard-wired" into data formats and the application program code at design time. This means that when something changes, previously unexchanged information must be exchanged, or two programs need to interoperate in a new way, requiring humans to get involved. Offline, the parties must define and communicate between them the knowledge needed to make the change, and then recode the data structures and program logic to accommodate it, and then apply these changes to the database and the application. Then, and only then, can they implement the changes. This is a common issue requiring the PLC representation of data to be mapped to application data representations.

These technologies formally represent the meaning involved in information. For example, ontology can describe concepts, relationships between things, and categories of things. These embedded semantics with the data offer significant advantages such as reasoning over data and dealing with heterogeneous data sources.

Semantic technologies provide an abstraction layer above existing IT technologies that enables bridging and interconnection of data,



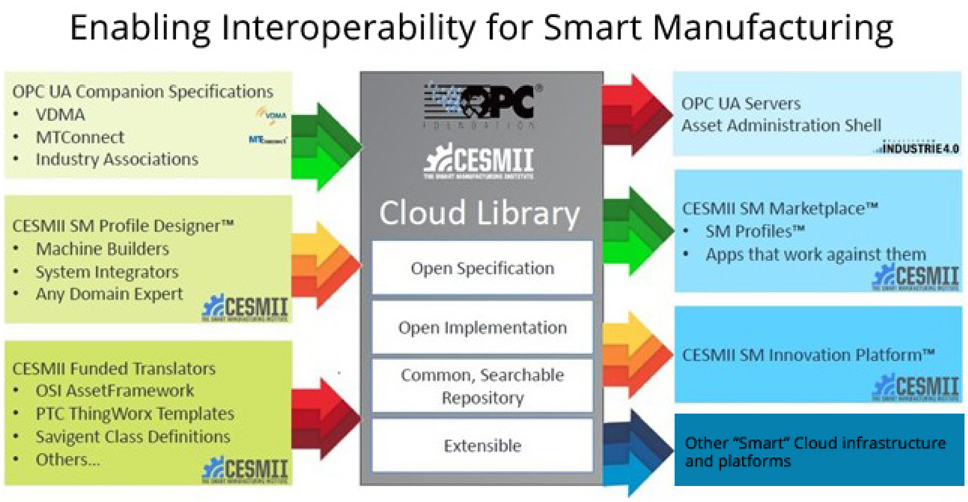
content, and processes. Second, from the portal perspective, semantic technologies can be thought of as a new level of depth that provides far more intelligent, capable, relevant, and responsive interaction than information technologies alone. Semantic technologies would often leverage natural language processing and machine learning to extract topics, concepts, and associations between concepts in text.

The OPC ecosystem. The OPC Foundation has become the unifying focal point for IT, operational technology (OT), industrial/ process controls, manufacturing automation, IoT, and cloud organizations participating in more than 65 joint working groups focused on defining and implementing standard contextual and semantic data models from industrial field devices, including sensors/ actuators to enterprise and cloud systems to achieve the goals of secure/ reliable communications, multivendor vendor, platform and domain agnostic, and interoperability from sensors to enterprise and cloud applications. OPC Foundation standards, semantic data models, and ecosystem simplify application engineering and enterprise software development while improving system quality.

There are more than 850 OPC Foundation members and thousands of OPC-compliant products. In addition to a wide range of industrial members, the active participation of IT technical leaders is notable, including Microsoft, AWS, Google, IBM, and SAP.

OPC Foundation standards are becoming widely adopted by IT, OT, and cloud suppliers creating a valuable and efficient distributed industrial manufacturing architecture. OPC UA Companion Specifications, complete use case models, and templates achieve a unified vendor-independent data interchange that simplifies data exchanges, lowers application engineering labor, and improves quality.

The OPC Foundation's globally available UA Cloud Library was co-developed with the Clean Energy and Smart Manufacturing Innovation Institute (CESMII). CESMII is the United States' non-profit institute dedicated to smart manufacturing working to reduce cost, complexity, and time-to-value so all manufacturers can engage in smart manufacturing.



OPC UA FX is the first IP field device approach incorporating semantic contextual data connectivity.

The UA Cloud Library makes OPC UA information models available in the cloud on a global scale, providing users with an efficient way to find and use OPC models. This simplifies application engineering for users to access all known OPC UA information models via an open, global, single source of truth. This also facilitates global OPC UA information model coordination and harmonization efforts by making it easy to search and cross-reference the latest OPC UA companion specifications in real-time. This makes the application of OPC UA Companion Spec as simple as adding a printer to a computer.

RELATED ARTICLES

Modular design and programming

Modular design and programming enable subject matter experts to directly create applications without writing code, resulting in superior-quality applications. Industrial automation has many common functions and processes that are encapsulated in software modules and configured to meet application requirements. Industrial automation continues to move toward open-standard, modular, model-based design with standardization including OPC UA Companion Specifications and module type package (MTP).

Modular building blocks can be deployed in any number and combination to put together a production line or process. This is a higher level of structured software design using self-contained, tested, and validated modules. Modular building blocks can then be deployed in any number and combination by application engineers to build control and automation solutions to satisfy unique production requirements.

Industrial automation, distributed control system (DCS), and PLC vendors have products that use program modules within their proprietary architecture that are powerful, creating engineering efficiency. These building blocks cannot be used with other vendor products since they are not published to open architecture standards. The trend is toward open multivendor interoperable open standard models including OPC UA Companion Specifications and MTP.

This is part of a no-code evolution that is accelerating enabled by newer low-cost technologies. Current examples on this trendline include ISA88 and PackML.

ISA88. The ISA88 Batch Control architecture and standard are used throughout the world to systemize and modularize recipe-driven processes. Industrial automation and process system vendors created their proprietary software applications to support these and other modular design models. The value of this approach has been proven and now is being defined in open standards.

PackML. Packaging machine language (PackML) is an industry technical standard for the control of packaging machines developed by OMAC, adopted by ISA as TR88.00.02. The primary goals of PackML are to encourage a common "look and feel" across a plant floor and to enable and encourage industry innovation. PackML includes standards-defined machine states and operational flow, overall equipment effectiveness (OEE) data, root cause analysis (RCA) data, flexible recipe schemes, and common supervisory control and data acquisition (SCADA) or MES inputs.

BioPhorum activity. The BioPhorum mission is to create an environment where the global biopharmaceutical industry can collaborate to accelerate its rate of progress for the benefit of all. The BioPhorum's vision is to develop the guidelines for Module Type Package (MTP) files to be used with modular equipment commonly found in biopharmaceutical processing plants. MTP files are used to achieve plug-and-play operations, dramatically reducing engineering labor, lowering project execution time, and increasing quality.

At the heart of plug-and-play is the VDI/VDE/NAMUR 2658 standard that defines MTP. The objective of BioPhorum's plug-and-play concept is to effortlessly integrate intelligent unit operations in the S88 procedural batch engine of the overlying supervisory automation system of a good manufacturing practice (GMP) compliant facility.

The "MTP" focuses on creating standardized nonproprietary descriptions of modules for process automation. MTP is advancing the concepts of ISA88 and ISA95 into open vendor-independent plug-and-produce models that include attributes like alarm management, safety and security, process control, human-machine interface (HMI), and maintenance diagnostics. OPC UA is used as a way to communicate MTP data between systems.

MTP also focuses on addressing common complaints users have when vendors deliver various pieces of equipment that do not

Resources for Modular Design and Programming

- PLCopen standards define common modules for IEC 61131-3 Motion Control, Safety, and OPC UA functions.
- The NAMUR standard 2658 on modular production is being fed into the IEC 63280 standard for automation engineering of modular systems in the process industries for internationalization.
- OPC UA companion specifications allow models of modular defined programming for industrial equipment and processes.
- The joint VDI-VDE-NAMUR 2658 standard defines the module type package (MTP).

directly and intelligently communicate with control, automation, asset management, and business systems, requiring significant investment to integrate into plant operations. Today, the addition of hardware, software, and application engineering for interfaces to integrate these decreases system reliability and increases lifecycle maintenance costs.

The process automation industry has been heavily affected by the influx of new technologies and, as we enter the next decade, several organizations are providing roadmaps to help process automation companies enable the best practices to leverage these technologies and drive competitiveness and productivity forward.

The Industry 4.0 for Process effort describes smart-networked sensors as a foundational part of the Industry 4.0 process architecture. These sensors will communicate with controls and automation systems simultaneously and directly with business systems. This effort—the application of Industry 4.0 concepts to improve process automation—is being driven by NAMUR and VDI/VDE in collaboration with several prominent leaders in the industry, including ABB, BASF, Bayer Technology Services, Bilfinger Maintenance, Endress+Hauser, Evonik, Festo, Krohne, Lanxess, Siemens, and Fraunhofer ICT. The concepts are expressed in NAMUR's Process Sensor 4.0 Roadmap, which describes smart networked sensors as a foundational part of the Industry 4.0 process architecture.

PLCopen RELATED ARTICLES

BioPhorum RELATED ARTICLES

Industrial edge semantic/contextual data

OPC Foundation standards provide semantic/contextual data models from field edge devices and application-specific companion specifications that enable plug-and-play system configuration. MQTT Sparkplug and OPC UA FX provide industrial edge-to-enterprise and cloud data communications.

OPC UA FX. OPC UA FX plug-and-play multivendor field device standard was launched in 2018. OPC Field Level Communications (FLC)

FX semantic/contextual standardizes semantic/contextual field device communications between multivendor controllers and throughout the manufacturing business enterprise.

Regarding the advanced physical layer (APL), OPC UA FX is supporting Ethernet APL two-wire Ethernet for process automation and hazardous locations based on IEEE and IEC standards.

OPC UA and MQTT are both open-source technologies representative of the industrial automation architectural shift toward greater flexibility and interoperability of systems.

OPC UA over MQTT. Low-cost sensors and IIoT technology is making possible monitoring and control of more systems over many transport methods, including bandwidth-constrained wired, wireless, and cloud connections over common carriers. OPC UA messaging over the message queuing telemetry transport (MQTT) protocol provides a lightweight solution for those applications where network bandwidth is limited. This combination delivers both the strengths of OPC UA data models—dramatically reduced application engineering labor and improved reliability—and the benefits of MQTT communications efficiency over constrained networks. More importantly, OPC UA and MQTT are both open-source technologies representative of the industrial automation architectural shift toward greater flexibility and interoperability of systems.

MQTT Sparkplug. Another possibility that allows users to create their unique data model definitions unique to their company is Sparkplug open-source specification hosted at the Eclipse Foundation that provides MQTT clients the framework to integrate data from their applications, sensors, devices, and gateways within the MQTT infrastructure. The Sparkplug Specification aims to define an MQTT topic namespace, payload, and session state management that can be applied generically for the requirements of real-time SCADA/control HMI solutions.

MQTT Sparkplug is a messaging protocol built on top of MQTT that enables users to free form define semantic/contextual information for their applications. Cirrus Link Solutions owns a patent related to Sparkplug and as a member of the Eclipse Foundation Sparkplug working group operates under the Eclipse Intellectual Property Policy. Under that policy, Cirrus Link granted an irrevocable (subject to a defensive termination provision), nonexclusive, worldwide, royalty-free, transferable patent license for the final specification.

This applies to anyone who makes, uses, sells, offers to sell, and imports Sparkplug implementations as long as such implementations successfully pass the corresponding Sparkplug Technology Compatibility Kit (TCK) and remain in compliance with the Eclipse Foundation TCK License. This also allows customers to purchase their Sparkplug solution from any vendor whose solution has successfully passed the corresponding Sparkplug TCK and who remains in compliance with the Eclipse Foundation TCK License.

OPC UA RELATED ARTICLES

MQQT RELATED ARTICLES

Internet protocol communications

The industrial edge plays an important role in defining how Internet protocol (IP) communication transports transform industrial systems with open IP-based transport protocols. These include single-pair Ethernet (SPE), Ethernet-APL, and 5G wireless private networks, which is a particular advantage for intelligent sensors, actuators, and other industrial field devices.

Single-pair Ethernet. The industrial edge is entering mainstream computing and IoT with the integration of single-pair Ethernet standard 10BASE-T1, making IP communications embedded in end-field devices cost-effective, including sensors and actuators. Ethernet-based networks supporting industrial controls and automation leverage the advantages of Ethernet infrastructure products produced in high volume, including lower costs of hardware, software, and support. SPE finally is the way to unlock more information directly from sensors, actuators, drives, motor starters, and other devices.

SPE network technology (IEEE 802.3cg) provides communications over two wires using the Internet Protocol. SPE delivers standard unmodified Ethernet built on IP to enable intelligent field devices including sensors, motor controls, and actuators to achieve industrial digitalization and accomplish the vision of Industry 4.0. SPE leverages standard IP message routing to deliver data anywhere in an Ethernet architecture.

SPE has significant engineering, maintenance, and installed cost advantages over standard Ethernet with more than 75 percent smaller cable diameter, reduced weight, cost, and 30 percent more bend radius than CAT 5. It also provides the potential to reuse existing installed twisted pair field wiring to carry SPE communications, simplifying plant and machine retrofits. The standard also provides a power over data line (PoDL) option with up to 50 Watts of power for edge devices.

There is an option for SPE Multidrop 802.3cg with auto-negotiation at 10<bits/s, PoDL, 16 device drops, and 50-meter length. Multidrop for sensor networking has tremendous installed cost advantages over point-to-point networking

Ethernet-APL. Ethernet-APL is a ruggedized, two-wire, loop-powered Ethernet physical layer that uses 10BASE-T1L plus extensions for installation within the demanding operating conditions and hazardous areas of process plants to directly connect field devices. Ethernet-APL enables process industries to benefit from the integration of the entire process manufacturing business including automation, OT, and IT systems. Ethernet-APL configurations

Ethernet-APL enables process industries to benefit from the integration of the entire process manufacturing business including automation, OT, and IT systems.

include intrinsically safe circuits suitable for Zone 0, Zone 20, or DIV 1 installations. Since Ethernet-APL is logically Ethernet, any industrial network protocol devices that electrically conform to 10BASE-T1L Ethernet physical layer standard (IEEE 802.3cg-2019) can take advantage of this physical layer.

EtherNet/IP, Profinet, and other protocols can run simultaneously on an Ethernet-APL network as they do today on standard Ethernet with the same bandwidth and latency issues. This provides for a transition from these legacy protocols to new open intelligent protocols.

5G wireless private networks. Wireless 5G private networks are emerging in manufacturing as a method to support mobile workers and monitor and control equipment. Industrial digitalization requires acquiring reliable, timely, and actionable information for real-time control in the hands of stakeholders including process operators, maintenance technicians, environmental health and safety people, and supply chain people. This information is in many areas including production plants and outdoor areas out of the reach of Wi-Fi, and public cellular signals.

Private cellular is enabling the achievement of digitalization goals to take advantage of many things including analytics, machine learning, and digitally guided procedures with pervasive communications throughout operations. The broad use of Wireless 5G technology benefits from the economies of scale that created refined technology. Wireless 5G is superior to industrial Wi-Fi because of higher speeds, easy deployment, and lower initial and lifecycle costs. Older controllers without Ethernet connections can be interfaced to the plant system network using Ethernet gateways, which are available from several suppliers.

MQTT. MQTT is an OASIS standard for IoT connectivity. It is a publish/subscribe, extremely simple, and lightweight messaging protocol designed for constrained devices and low bandwidth, high latency, or unreliable networks. The design principles are to minimize network bandwidth and device resource requirements while attempting to ensure reliability and some degree of assurance of delivery. These principles also turn out to make the protocol ideal for the IoT world of connected devices, and for mobile applications where bandwidth and battery power are at a premium.

RELATED ARTICLES

Open source controller software

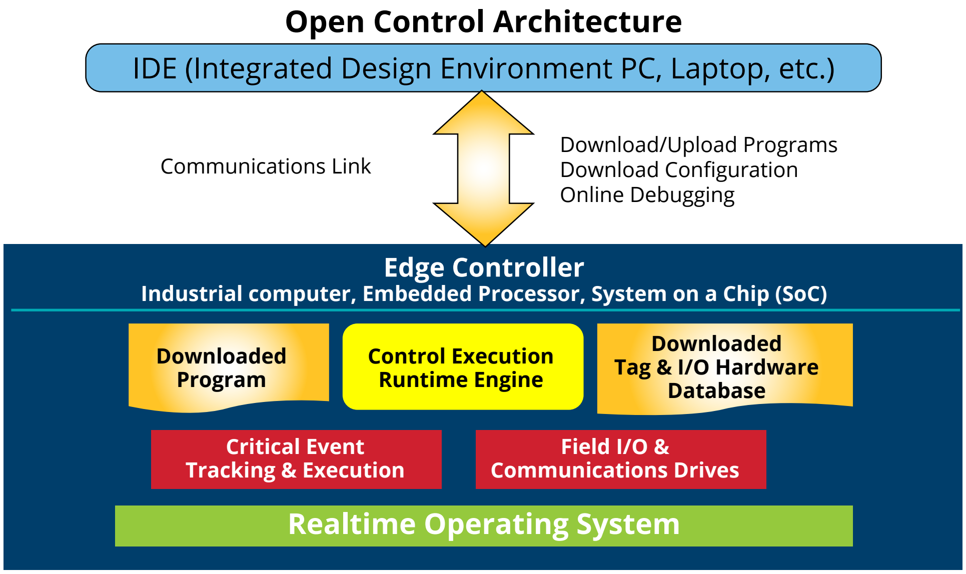
Many options exist for programming industrial computers and embedded SoC CPUs using open-source controller software based on IEC 61131 and IEC 61499 standards. Unlike the computer industry, industrial and process controllers have been closed-architecture devices using unique application programming software and runtime software engines. Many of the vendors provide functionally equivalent programming based on the IEC 61131 standard that is nonetheless unique to their proprietary controllers. In addition, PLCopen has defined functions that have been adopted by many.

These IEC standards have enabled the use of standard industrial computers and embedded CPUs to implement control and automation system using standard IEC languages. The basic architecture consists of a control and automation integrated design environment (IDE), a runtime control engine, input/output (I/O) drivers, and communications drivers. Users create an application in the IDE, and on most platforms, perform basic simulation functions, automatic program documenting, and online debug functions.

The created program is downloaded to a target control execution engine in an edge platform that runs the user-created program. Traditionally, the edge platform has been proprietary PLC or DCS hardware. Today, a wide range of hardware options are available, including industrial computers, SoC CPUs, and embedded processors.

Resources Related to Communications

- ODVA Ethernet-APL and PA-DIM Commitments Support Open Automation
- Inside the Rise of 5G Industrial Automation Networking
- Dow's Private Cellular Network Empowers Manufacturing People
- Wireless Infrastructure Strengthens Manufacturing



IEC standards have enabled the use of standard industrial computers and embedded CPUs to implement control and automation with standard IEC languages.

IEC 61131. The IEC 61131 was first published in 1993, and the current version was published in 2013. IEC 61131 has been widely adopted throughout the world, as illustrated by the number of certified vendors listed on the PLCopen website. The IEC 61131-3 standard defines five programming languages for control and automation programming:

- Function block diagram (FBD): Visual drag and drop programming.
- Ladder diagram (LD): A graphical language that represents electrical relay logic, functions (i.e., timers, counters, proportional-integral-derivative [PID] controllers, communications, and analytics.
- Structured text (ST): A high-level language structured and syntactically similar to other computer programming languages. Functions include IF-THEN-ELSE, mathematical (i.e., square root, transcendental) case statements, array, structures, and data transformation functions.
- Sequential function chart (SFC): Program flow control (i.e., machine control, packaging machines, batch process control [ISA88, a common language for PLC programmers]).
- Instruction list (IL): lightweight programming language for applications with limited CPU and memory.

IEC 61131-3 functions have inputs and outputs with strong data types. IEC 61131 data type syntax includes Boolean, integer, real, string, array, structures, and user-defined functions. Users can create functions and function blocks using the languages mentioned above as well as standard programming languages (i.e., C/C+, Python). Most IDE implementations include engineering tools that allow users to connect field control engines for online debugging including breakpoints, watch windows, strip chart recorders, trend graphs, and integrated HMI.

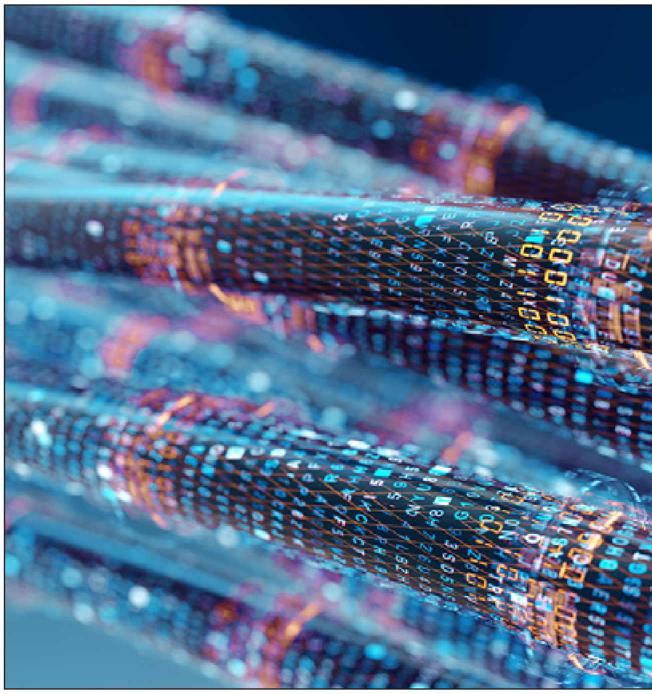
IEC 61499. IEC 61499 was initially published by the International Electrotechnical Commission (IEC) in 2005. The specification of IEC 61499 defines a generic model for DCS and is based on the IEC 61131 standard. In IEC 61499, the cyclic execution model of IEC 61131 is replaced by an event-driven execution model. IEC 61499 enables an application-centric design in which one or more applications, defined by networks of interconnected function blocks, are created for the whole system and subsequently distributed to the available devices. All devices within a system are described within a device model. The topology of the system is reflected by the system model. The distribution of an application is described within the mapping model. Therefore, applications of a system are distributed but maintained together.

Like IEC 61131-3 function blocks, IEC 61499 function block types specify both an interface and an implementation. In contrast to IEC 61131-3, an IEC 61499 interface contains event inputs and outputs in addition to data inputs and outputs. IEC 61499 defines several function block types, all of which can contain a behavior description in terms of service sequences.

The IEC 61131 program execution model is deterministic, and IEC 61499 has an event-driven execution model defined by the user as a build program. IEC61131 deterministic cycle reads inputs, resolves program logic defined by the user, and writes outputs. IEC 61499 has an event-driven execution model where users write program logic explicitly defined execution sequence. The event-driven IEC 61499 execution model creates a level of complexity that needs to be managed as applications become larger. The current OPAF testbeds have been using both IEC 61131 and IEC 61499 successfully.

IEC 61499 models a distributed control system allowing automation applications to run across networks independent of the underlying hardware. This can be an advantage but is more complicated because the network bandwidth, quality of service (QoS), and reliability become important considerations for control availability, reliability, and automation performance.

Processors and networking technologies have advanced significantly allowing the selection of higher-power computing platforms and network technologies.



In contrast to proprietary controller companies, software companies—examples are CODESYS and Straton—are offering IEC 61131 IDE and runtime software engines. The Eclipse Foundation's 4diac project is open-source IEC 61499 software, while UniversalAutomation.org has created a controlled-source IEC 61499 runtime environment. (See the article "Open Automation Systems: An Update on the State of the Art" elsewhere in this issue.)

Eclipse Foundation 4diac/Forte. The Eclipse Foundation 4diac project created an open-source IEC 61499 software provided under Eclipse Public License, Version 2.0. The 4diac open standard includes the IDE development environment. The 4diac IDE is based on the Eclipse open-source framework, which allows easy integration of other plug-ins, providing new or extended functionality.

The Eclipse IDE is an established platform for general computer programming. IEC 61499-based systems follow an application-centric design, which means that the application of the overall system is created first. Each application is created by interconnecting the desired function blocks in terms of a function block network (FBN). As soon as the hardware structure is known, it can be added to a project's system configuration and the already existing application can be distributed onto the available devices.

The 4diac FORTE is a small portable implementation of an IEC 61499 runtime environment targeting small, embedded control devices (16/32 bit), implemented in C++. Supported operating systems include eCos, NET+OS 7, Posix: Cygwin, Linux (i386, PPC, ARM), rcX, VxWorks, PikeOS, Windows, and freeRTOS. It supports online reconfiguration of its applications and the real-time capable execution of all function block types provided by the IEC 61499 standard.

The 4diac FORTE is a small portable implementation of an IEC 61499 runtime environment targeting small, embedded control devices (16/32 bit), implemented in C++.

4diac FORTE supports all IEC 61131-3, edition 2 elementary data types, structures, and arrays. It provides a scalable architecture that allows 4diac FORTE to adapt to the needs of your application. Applications can consist of any IEC 61499 element as basic function blocks (BFBs), composite function blocks (CFBs), service interface function blocks (SIFBs), adapters, and sub-applications.

The 4diac function block library (4diac LIB) contains function blocks, which are available on the 4diac FORTE and can therefore be used to create IEC 61499-compliant control applications.

RELATED ARTICLES

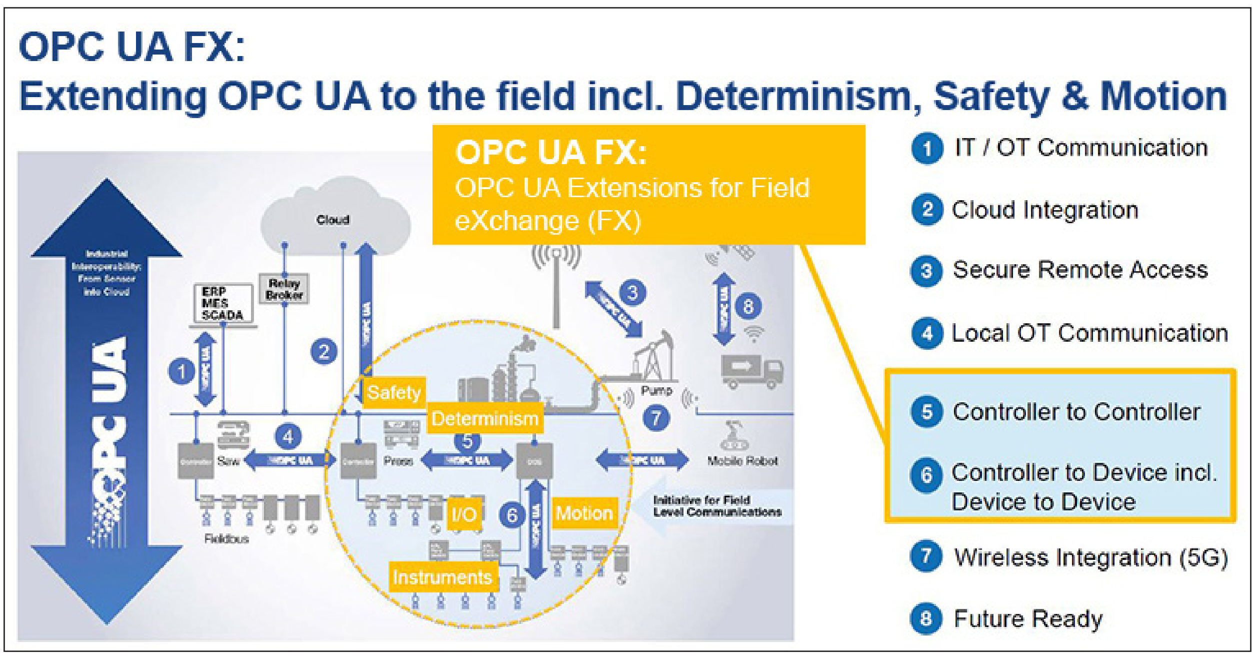
OPC Foundation field level communications

OPC Foundation field level communications (FLC) is modernizing the most basic industrial communications with mainstream computing semantic/contextual communications, modernizing the most basic industrial communications to the industrial edge including sensors, actuators, and all forms of field devices. OPC UA FX is the first IP field device approach incorporating globally standard semantic contextual data connectivity. It is a serious contender to become the unifying industrial protocol to support open architecture multivendor industrial digitalization.

OPC FLC is the first multivendor open-standard semantic contextual data connectivity communication solution between sensors, actuators, controllers, enterprises, and cloud that meets all the requirements of industrial automation, factory automation, and process automation. OPC UA FX continues to make rapid progress in modernizing the most basic industrial communications with mainstream computing data concepts to the industrial edge.

The OPC UA FX specifications also focus on controller-to-controller (C2C) communications and OPC UA Safety Stack and extensions for safety.

OPC UA FX can be used to transport data over any IP network; it inherently supports a wide range of transports. Ethernet APL two-wire Ethernet for process automation and hazardous locations is based on IEEE and IEC standards with preparations for APL testing in the OPCF Certification Lab. The OPC Foundation is working closely to align with the time-sensitive networking (TSN) profile for industrial



The UA Cloud Library makes OPC UA information models available in the cloud on a global scale providing users with an efficient way to find and use OPC models.

automation (TSN-IA-Profile), which will be standardized by the IEC/IEEE 60802 Standardization Group. This will help ensure that a single, converged TSN network approach is maintained so that OPC UA can share one common multivendor TSN network infrastructure with other applications.

RELATED ARTICLES

Digital twins

The digital twin has become one of the most powerful concepts of Industry 4. 0. The concept should be familiar to automation and control people since it is a higher level of closed-loop control that ideally incorporates all the factors of a manufacturing business that affect production efficiency and profitability including incoming material quality, order flow, economic factors, customer orders, production plans, work in process (WIP) flows, and machine efficiencies. Digital twins are a virtual representation of a real-world process constantly updated with its real-time twin to achieve complete manufacturing closed-loop control that is optimized and responsive to changes.

The implementation of model-based, real-time, closed-loop monitoring, control, and optimization of the entire manufacturing and production process, the digital twin concept is helping organizations achieve real-time integrated manufacturing. The digital twin virtual model of the ideal manufacturing operations and processes constantly benchmarks actual production metrics in real-time, providing a wealth of information that organizations use to identify and predict problems before they disrupt efficient production. The digital twin is a prominent example of a practical macro-level closed-loop control that is now feasible with the advanced hardware, software, sensors, and systems technology available.

A critical part of digital twin creation is the need to have a complete information set, including the capture of real-time information with a wide range of sensors based on these requirements. To facilitate this information collection, some common strategies include leveraging existing connected sensors, adding new sensors to existing PLCs and controllers, Installing edge devices, and installing smart sensors.

Leveraging existing connected sensors. This is typically the popular first step since it does not require physical installation of new sensors. What it does require is application engineering and a software project to link information to the IT network. It may also require new software to be added to SCADA, PLC, HMI, and/or DCS systems to accomplish communication with enterprise and other systems.

Adding new sensors. If there are unused sensor interfaces on the controller or available slots to add new interface cards, which can accommodate more sensors, then adding new sensors to existing controllers can be an option. This also requires application engineering to add these sensors to the program in the controller. It may also require the addition of new software to HMI and DCS systems to facilitate communication with enterprise and other systems. In this strategy, there is a risk that making changes in these controllers and systems will create performance and operating issues, so it may require a significant amount of systems and application engineering to ensure reliable operation.

Installing edge devices. In addition to practical concepts, like digital twins, the IIoT has led to companies bringing a wide range of edge devices to market. These edge devices are designed to capture information and communicate directly to enterprise systems and cloud applications, particularly AWS and Microsoft Azure. Many new sensors are not required to be part of the control and automation strategies in the plant but are required to monitor operating parameters for a complete digital twin and close the information loop. Edge devices typically connect directly to the IT network. The advantage to this is that they are non-intrusive, having no or very minimal impact on existing control software architecture. This can be an efficient way to communicate directly with production, maintenance, and business systems.

Installing smart sensors. New classes of smart sensors are emerging that can communicate directly with production, maintenance, and business systems. Wireless sensors can be an efficient way to acquire data with standard technology, including *Wireless*HART and ISA100, primarily used in process applications. For discrete points, the IO-Link wireless version is an option. Some sensors also can communicate over standard wireless Ethernet Wi-Fi using various software interfaces.

OPC UA is emerging as a fundamental technology for implementing the digital twin. Digital Factory OPC UA technology provides an efficient and secure infrastructure for the communications of contextual information, from sensors to business enterprise computing, for all automation systems in manufacturing and process control. OPC UA is leveraging the accepted international computing standards and putting automation systems on a level playing field with the general computing industry.

OPC UA uses common computing industry-standard Web services, which are the preferred method for system communications and interaction for all networked devices. The World Wide Web Consortium (W3C) defines a Web service as “a software system designed to support interoperable machine-to-machine (M2M) interaction over a network.” This is precisely the task of automation systems. OPC UA is being built into many sensors and other devices, to simplify the communication process.

RELATED ARTICLES

Intelligent sensors

Embedding intelligence in sensors, is a foundational part of Industry 4.0 concepts, is a growing trend. Sensors communicate with controls and automation systems, and simultaneously and directly with business systems. Intelligent sensors are also part of the NAMUR New Open Architecture (NOA), a collaboration with VDI/VDE and Fraunhofer ICT.

IoT is becoming a reality with sensors and actuators embedded in physical objects—from roadways to pacemakers—linked through wired and wireless networks and leveraging internet protocol. Industrial controllers are starting to follow this trend by providing data refinement, local historians, analytics, and advanced control at the source in end devices.

Modern controllers are communicating with all levels of systems using the "IP plumbing" that is pervasive in manufacturing plants including capabilities to send Email, FTP files, and serving up Web pages.

These devices incorporate powerful new SoC CPUs to simplify automation architectures. The new breeds of industrial controllers and embedded industrial end devices are incorporating this power and adding features that include embedded Web servers, email clients, and Web services. These capabilities enable field devices including sensors, motor controls, and actuators to communicate directly with controllers, enterprise systems, and cloud applications.

It is common to now see dual-core CPUs in controllers and several companies have announced quad-core-based controllers. These more

powerful industrial controllers are becoming automation computing engines that are starting to collapse the typical five-level model and make automation systems more flexible and responsive.

The incorporation of higher-level functions directly into this new breed of powerful industrial controllers is starting to eliminate the need for middle-level software. Middle-level software and computers have served their purpose of buffering, synchronizing, translating, and refining sensor and controller information. But they have also created a great number of middle-level computers, databases, and software programs that are expensive and difficult to maintain.

The new high level of communications and computing at end devices is opening the possibilities for holistic and adaptive automation to increase efficiency.

The interim solution is a migration to more powerful computers and the virtualization of existing middle-level software. This migration and virtualization improve performance and centralize software maintenance and configuration control. Over time the functions of this middle-level software are being taken over by the new more powerful controllers. The new high level of communications and computing at end devices is opening the possibilities for holistic and adaptive automation to increase efficiency. This is a logical evolution in step with the Internet of Things trend and will lead to more responsive and efficient production.

RELATED ARTICLES

Spatial computing/intelligent vision

Spatial computing enables computers to blend in with the physical world in a natural way, seamlessly bringing together the virtual and physical worlds. Spatial computing brings people into the digitalization loop, empowering them to dramatically increase operations in

manufacturing efficiency, creating experiences and applications that were previously impossible. Spatial computing devices display the real world and simultaneously real-time operating parameters in a way that appears three-dimensional. The numbers of smart glasses and helmets have grown dramatically from consumer- to industrial-grade accelerating adoption. Features include integrated audio for hands-free operation and communication with other workers and remote experts. These devices can also include multiple 360-degree cameras, Wi-Fi, Bluetooth, and GPS that can be used for personnel tracking in hazardous and safety areas. There are versions integrated into industrial helmets for special and hazardous area requirements.

Workers can use this equipment to bring up assembly instructions, procedures, and operating manuals displaying step-by-step instructions in the worker's field of vision. In assembly areas, workers can be guided with pick-by-vision instructions including customer order information. Assembly of individual items can be confirmed with voice-controlled barcode scans, using the camera built into the glasses.

Maintenance personnel have hands-free access to manuals, repair guides, graphical plant diagrams, and troubleshooting tips along with assistance on machinery procedures and remote experts, as well as receiving early warnings of safety risks. These solutions can enable plant personnel who need to look and hear equipment and processes to diagnose issues remotely, giving them information to prepare the proper tools and potential repair parts before physically going in the field.

Rather than a supervisor physically having to come to help a production line worker, augmented reality (AR) allows the supervisor to see exactly what the worker is seeing and provide help remotely.

This allows organizations to multiply their experienced personnel and efficiently provide valuable mentoring to new people.

Further enhancements include adding QR codes or signs on machines, work cells, and process equipment. These codes can be used to automatically bring up information using smart devices, making it simple and safer for workers.

Another viable technology is the use of wired and wireless industrial video cameras—some including audio—which can be used to keep track of machines and process vital signs remotely. Combined with image recognition software, videos can be used for real-time closed-loop quality monitoring and control.

A great example is a factory worker using a smartphone, tablet, or smart glasses can simultaneously view a physical machine, real-time variables, and technical manuals. Spatial computing is related to both AR and virtual reality (VR). AR means overlaying digital content onto the real world, typically using a phone or smart glasses. Mixed reality (MR) employs a blend of AR and VR enhancing the user's understanding of operations, for example, showing a representation of the inside of a machine and the real-time operating data.

Devices that employ spatial computing might also have speech recognition features to support voice commands, enabling hands-free operation. In addition, people can collaborate with remote experts who can see the same information and can advise.

While using robotic systems helps with general efficiency and productivity of an assembly plant, there are additional benefits that accompany the incorporation of a vision system with the robot. A robotic vision system consists of one or more cameras connected to a computer. The computer contains a processing software program that helps the robot interpret what it sees, for example identifying parts in assembly processes without requiring specific placement and performing real-time quality analysis.

RELATED ARTICLES

Connected worker technology

Employees can be empowered with mobile devices, giving them information and control capabilities that have traditionally been fixed in the control room to work more efficiently and effectively. Devices include smartphones, tablets, and smart glasses incorporating front-facing high-definition cameras, audio, and visual information. This capability has been available for some time, but the cost has become significantly lower driven by commercial and consumer products.

New technology is enabling remote monitoring capabilities to improve operational effectiveness. This presents users with opportunities and challenges to be evaluated for practical applications. The goal is to improve manufacturing or processing uptime and efficiency. Subject matter experts are becoming increasingly hard to find and companies need to find ways to use them more efficiently. The latest remote monitoring tools allow experts to analyze problems and abnormal situations and determine ways to improve and optimize operations without traveling to the site.

Worker productivity and responsiveness are being improved with technologies that directly connect workers to manufacturing systems making them an informed integral part of production in real time. Mobile computing and communications technology cost reductions and increased performance continue to increase the ability to increase the capabilities and value of workers in production. The connection of workers is being accelerated using the wide expanding range of commercial off-the-shelf technologies including voice and video headsets, Smart glasses, and virtual reality devices and systems that are providing workers with productivity enhancers including:

- Manuals anywhere
- Equipment identification and lookup
- Real-time superimposed data
- Audiovisual linking to subject matter experts
- Direct access to production availability information.

RELATED ARTICLES

Remote expert services

Connectivity and edge processors empower suppliers to offer remote expert monitoring services. Experts and analytic software continuously monitor controllers and control systems for abnormal situations and advise site personnel of current problems or predictions of future problems. Control suppliers that offer these services have experts and software that can quickly detect issues with the controllers, components, and software that they provide.

A big advantage of the services approach is a third party has a remote, 24/7 operations center to constantly monitor your systems.

Since most plants have equipment from multiple suppliers, the value of this service may be limited if the provider does not monitor all equipment and applications. In some general equipment and process control applications, contract experts can detect and advise on plant production issues. Subject matter experts in specific manufacturing and process areas can be used on demand for special problems and issues. A big advantage of the services approach is a third party has a remote, 24/7 operations center to constantly monitor your systems.

Some providers may collect performance analytics information to learn how machinery is performing and provide alerts when data falls outside of predefined parameters. This requires the development of rules with input from plant staff because they understand the plant operations. Alternatively, manufacturing companies can run an inference engine with rules developed by plant staff that understand the dynamics of operations.

Ultimately, when most problems and issues are identified, someone needs to be onsite with the right tools, information, and spare parts to get things working. Determining the best methods to achieve improved uptime and efficiency is the overall challenge.

RELATED ARTICLES

Robotics

The cost and ease of use of robotics have changed dramatically, particularly with collaborative robots (cobots). More possibilities are being created with the growing trend of modular industrial robot components that can be used to assemble the optimal robot structures for different applications on an individual and flexible basis. In addition, easy-to-use software tools are allowing people and plants to directly define robot actions without programming.

The 2023 annual report from the International Federation of Robotics says that robot installations hit a new record level of 553,052 units and, for the second year in a row, annual installations exceeded the 500,000-unit mark, adding another 5 percent to the previous record figure of 526,144 units installed in 2021.

The major customer industries, automotive and electronics, installed substantially more robots than in 2021. Supply chain disruptions and the scarcity of inputs as well as different local or regional headwinds still hampered the completion of projects, but the problems were less severe than in the previous year.

The electronics industry was the largest customer of robots, a position it gained in 2020 and has maintained since, claiming 28 percent (+1 pp) of all robots newly installed in 2022. The automotive industry followed with 25 percent of installations (+3 pp), growing in both the car manufacturer and the parts supplier segments. The metal and machinery industry retained its third place (12 percent; -1 pp), followed by the plastic and chemical products industry (4 percent) and the food and beverage industry (3 percent). Note that for 17 percent of the robot installations (-3 pp), there is no information on the customer industry.

Cobots. The application of robotics and particularly the growing use of cobots has become a high-return-on-investment opportunity for manufacturers. A cobot is a high-impact automation tool that can improve manufacturing in companies of all sizes and improve worker safety. Cobots are a new breed of lightweight and inexpensive robots, with safety features specifically designed to enable people to work cooperatively with these devices in a production environment.

Cobots can sense both humans and obstacles and respond by automatically, stopping before they cause harm or destruction. With these robots, protective fences and cages are not required, and therefore they can enable flexibility and lower implementation costs. Cobots are particularly attractive investments with a typical cost of less than $40,000 U.S. Robot software provides simplified programming, allowing deployment without hiring specialized engineers. The programming process, which involves moving the robot arms and end effectors to the desired positions, is a physical form of the popular computer programming concept called "what you see is what you get" (WYSIWYG). It is designed to be intuitive for users and has been proven in many implementations to broaden the application of technology.

Integrated vision and end effectors. Coupling robots with vision systems and image recognition software expands robot use for more free-form applications. Robots can grab dissimilar parts in assembly settings, pack boxes in shipping facilities, organize bins, load machine tools, inspect parts, and perform many other helpful tasks.

End effectors include devices for picking up a wide range of parts of various types. An end effector is the last link (or end) of the robot device at the end of a robotic arm, designed to interact with the environment. In addition, end effectors with built-in tools are being used to perform industrial applications including grinding, sanding, welding, riveting, screwing bolts to a specific torque, spray painting, machine part tending, and material handling.

The number of innovative robotics end effector devices has increased significantly. It is worth noting, there is an acceleration of robot use and other applications including restaurants, construction, and health care, creating a broader array of end effectors.

RELATED ARTICLES

Automated material flow

Driverless vehicles, personal robots, and other innovations may be in the future for today's average consumer but for industry, the technologies are available now to increase productivity and efficiency, automating industrial material flow. These technologies transform operations supporting Lean production methods, eliminating numerous non-value-added human touches each requiring multiple manual double checks and associated activities such as adding handwritten tags to pallets of material.

Material flow status is synchronized in real-time with physical production activities for the most productive process flow and coordinated with warehouse management system (WMS) and quality control software. Work centers are streamlined with minimal material buffer quantities required due to synchronized and just-in-time (JIT) delivery of materials and assemblies.

Robotics, mechatronics, vision, and other technologies are creating opportunities for automated material handling to improve productivity with JIT material flow to machines and people. This is important for all manufacturing to increase productivity including automated machines, batch manufacturing, and manual assembly.

Integrated into industrial digitalization, automated material handling systems are complete integrated solutions including a combination of automated material handling equipment, software, and controls, designed in a way that they can automatically move, sort, store, or transport goods, products, or materials within a facility or warehouse without the need for direct human intervention.

An automated material handling system typically includes components to streamline material handling processes and optimize operational efficiency. Some standard components of an automated material handling system may consist of conveyor systems, linear magnetic transport systems, robots, WMS, autonomous mobile robots (AMRs), automated guided vehicles (AGVs), and more.

Leveraging systems to improve operations are a primary driver for automated production material flow. This enables improved operations including stage by component (SBC) delivery of every component required in the production process to an operator or assembly person when they need it. One advance allows automated guided vehicles (AGVs) to be deployed with laser navigation, accurate to a quarter of an inch. This enables the facility to avoid the requirement for in-floor wires and combines IT, engineering, and operations systems to manage material flow for production from the shop floor to the enterprise systems. Overall goals include:

- System-driven quality and compliance
- Ensuring correct material/batch deliveries
- Confirming material quality status before use
- Delivering real-time materials traceability at the point of use
- Providing end-of-order reconciliation based on actual consumption
- Maintaining systems clearance of foreign materials before starting the next order.

Automated material flow facilitates manual workstation Lean 5s methods of workplace organization where the location of everything in the workspace is defined and clearly marked with material delivered as required based on production plans.

RELATED ARTICLES

ABOUT THE AUTHOR

Bill Lydon is editor emeritus of Automation.com and ISA's *InTech* magazine. He has more than 25 years of experience designing and applying automation and control technology, including computer-based machine tool controls, software for chiller and boiler plant optimization, and a new generation building automation system. Lydon was also a product manager for a multimillion-dollar controls and automation product line, and later cofounder and president of an industrial control software company.