Why Manufacturing 4.0 Will Succeed

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Like other areas of the 4.0 era, Manufacturing 4.0 is all about using data and connectivity to make processes efficient and lean, as well as enabling intelligent systems to make decisions. Many technologies have enabled such growth and capabilities. Among them, artificial intelligence, machine learning, Big Data, cloud computing, and augmented reality tend to monopolize the spotlight; however, a few other supporting technologies are vital in accomplishing these goals. This article explores the role of sensors, programmable logic controllers, low-power components and systems, and vision systems as vital—albeit under-recognized—technologies that are helping to advance Manufacturing 4.0.

Sensors

Sensors play multiple roles in Manufacturing 4.0. In addition to capturing data used for insights and decision making, they capture data that's needed as a product moves through the manufacturing process. For instance:

Positional sensors are one of the most common types of sensors. These facilitate measurement of mechanical position, like whether a cylinder returns to its home position before it actuates on the next product on the assembly line.

Presence-detection sensors are similar; here, an optical presence-detection sensor would emit a beam of light or laser that is always visible unless something is blocking it, indicating 'presence' or 'no presence' of something in its view.

Size-detection sensor data can be used for quality control and to determine whether an assembly can safely move through equipment down the line.

Contact sensors might be used to sense whether a compartment door is open or closed or to cause a hard stop to prevent equipment damage—both with safety implications.

Vibration sensors are often used to determine equipment health; that is, vibration from a servo motor indicates that parts are wearing out. From this data, maintenance needs can be predicted before problems occur.

Without sensors, manufacturing automation simply could not happen. When dealing with a press that presses 45,000kg of pressure onto another surface, you need to know that the area is clear. Sensors are the digital eyes, ears, nose, and fingers of automation that remove any guesswork or assumptions, which leads to much safer, consistent, and efficient conditions. What's more, they require rugged designs that may need to withstand heat, moisture, oil, dust, and/or a variety of other possible harsh conditions.

From a data-collection standpoint, sensors are the gateway to the insights you seek in that they provide the raw data that's used to tell the story of what's happening along the production line. Many manufacturers are still in the process of retrofitting their legacy equipment; here, there's a lot of effort going into developing data access points that can tie into older programmable logic controllers without affecting its functionality. Others have streams of data coming in from multiple sources and struggle to figure out how to use it to yield useful insights.

Sensor fusion has also advanced the quality and type of data that can be collected, and the certainty of insights derived from the data. Here, you might use a laser sensor to detect height and a vision sensor to confirm. In many cases, using two or more different sensors provide redundancy in gathering data; however, sensor fusion enables you to combine data based on the various sensors' strengths to devise the insight. Still, the challenge is understanding how to apply today's tremendous sensor technology to gain useful insights.

Programmable Logic Controllers

When collecting information from machines, the communication is not from sensor to sensor—it's from sensor to Programmable Logic Controllers (PLCs) along the manufacturing network. PLCs are solid-state industrial computers that have been ruggedized and used for controlling manufacturing processes. PLCs are the brains of manufacturing: It's where logic and process information are stored, and it's where network communication begins.

The main function of PLCs is to receive inputs, make real-time, logic-based decisions, and send operating instructions through the outputs, ultimately determining the order of operations in complex processes. PLC input can come from switches, sensors, vision systems, and other sources, while output destinations can include sirens, relays, indicator lights, cylinders, solenoids, analog outputs, robots, and even other programmable logic controllers. PLCs ensure that the correct input is received as well. For instance, a machine might have a big red button that initiates the conveyor belt; however, the PLC watches to ensure that the power-on signal and maybe that a safety feature is initiated before the conveyor belt can be turned on.

PLCs are also helping to drive manufacturing efficiency by providing operational data for closed-loop digital twins (CLDTs). The idea of CLDTs is to use a virtual model that, ideally, accounts for all systems and variables that affect production efficiency. Here, the PLCs provide historical and real-time I/O data that, along with data from other systems, can be used to fine-tune machine settings, staffing, material storage, and other operational aspects. CLDTs can be implemented at any scale, ranging from a single piece of equipment to an entire production line to entire manufacturing operations.

In edge-enabled environments, virtualized PLCs are gaining some momentum and eliminating the need for physical PLCs and enclosures. Otherwise, PLCs for the entire manufacturing floor can be housed in a single case, or designed modularly, grouped by function (power, processing, I/O selection, etc.). Modular PLCs have the advantage of easier maintenance because they're not tied to other systems. Whether physical or virtualized, PLCs are the masterminds of manufacturing processes.

Low-Power Components and Subsystems

Also relevant in terms of under-appreciated tech is the use of low power components in every electronic device, electrical device, and subsystem, including PLCs. Low-power exists at the lowest level of design components—transistors, printed circuit boards (PCBs), resistors, field programmable gate arrays (FPGAs)...all of it. And as far as enabling Manufacturing 4.0, low-power is a big enabler because it's significantly reduced the size of components. Without advancements in low-power components, an electro-mechanical system might have had a whole box of relays that could be as big as a wall in your house.

As components and subsystems have gotten smaller, they've also gotten better because they produce less heat, are more efficient, and are more compact. These aspects have enabled designers to build out complex machinery and processes without taking up an entire manufacturing facility. And, of course, smaller size has also meant lower cost. We're now able to apply various technologies and methods that have been available but cost-prohibitive in the past. Elon Musk mentioned in an interview that it costs $140,000 per ton to send something to Mars. His point is that we have the technology to go there, but no one is funding such a project at that cost.

Vision Systems

You might think of vision systems as advanced robots capable of identifying objects, communicating critical information to other systems, and acting on what they see. Applications generally fall into one of four categories:

Guidance—locating the position and orientation of a part

Identification—tasks like identifying parts, recognizing bar codes, sorting inventory, and the like

Gauging—measuring and calculating the distance between two points and determining whether the measurement meets specifications

Inspecting—which includes detecting defects or abnormalities

In manufacturing environments, vision systems can be trained to recognize objects that can be measured, counted, decoded, or positioned. As with other machine learning applications, training requires large datasets in which characteristics of shape, size, orientation, edges, patterns, colors, and the like are labeled. For example, in training a system to identify defects in a finned tube, the system might be trained to identify tubes of a specified length and circumference with strip fins (not wire fins) that are plain (not serrated) with welds placed 0.14" apart. The trained system stores an image—a collection of pixels in a distinct formation—that's used as the basis of comparison.

In use, vision systems deliver pass/fail results. Continuing the example, the system's camera would acquire an image of the finned tube as it completes its manufacturing journey. The image is made up of captured light with areas of black, white, gray, and possibly color. This is delivered to an image sensor that captures reflected light and converts it into pixels of a distinct formation. The system then interprets the image and determines if it matches an exact formation of pixels it's been trained to recognize.

The use of vision systems has advanced manufacturing in several ways, such as improving product quality, reducing waste (materials and time), reducing downtime, creating traceability and accountability, and facilitating compliance.

Conclusion

Manufacturing 4.0 is advancing at lightning speed thanks to amazing technologies. While artificial intelligence, Big Data, cloud computing, and additive manufacturing often capture the headlines, a number of less-glamorized technologies have played important roles as well:

- Sensors capture data used for insights and decision making, keeping the product moving smoothly through the manufacturing process.
- PLCs are the brains of manufacturing: It's where programs, information, and backups are stored and how communication occurs.
- Low-power components and subsystems enable us to apply technologies and methods that were previously cost- and/or size-prohibitive.

Vision systems have given robots the ability to see objects, communicate critical information to other systems, and perform tasks.

Flashy technologies might steal the spotlight, but these less-glamorized technologies are vital to Manufacturing 4.0 and beyond.