DIGITAL INDUSTRIES SOFTWARE

Advanced robotics in tomorrow's factory

Addressing the production challenges of complexity, customization and openness

Executive summary
The field of industrial robotics has reached the next level of automation, with improved production flexibility and reduced programming time. To understand how to implement these new technologies it is important to know where your company stands in the journey to advanced robotics. This white paper provides examples of how companies are already implementing these technologies and the necessary practices to meet the challenges of complexity, customization and openness, ultimately improving their time-to-market.

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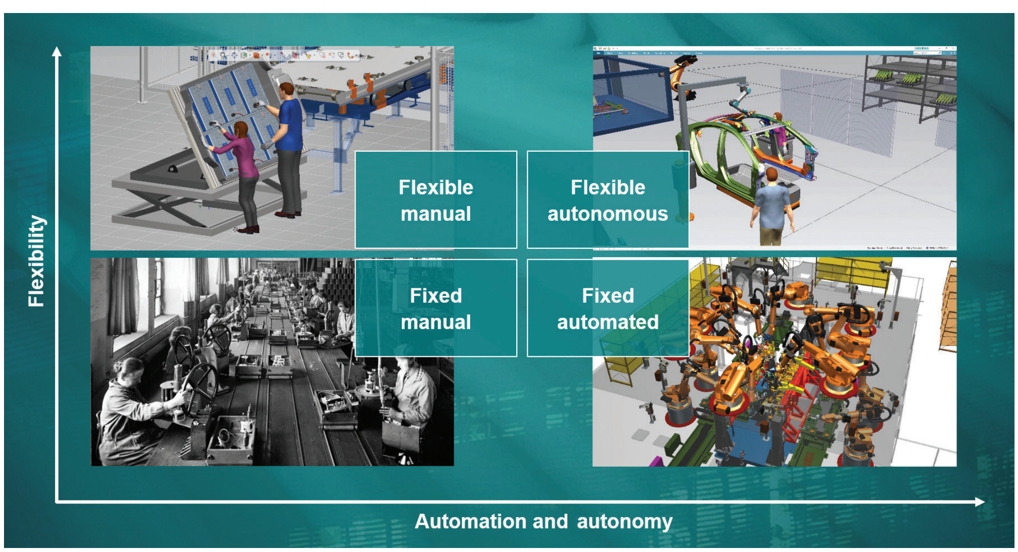
Introduction

Mass production was developed well over 100 years ago. Manual laborers worked on static assembly lines where they built products by hand from various parts and subassemblies. The introduction of automation to manufacturing freed humans from some of the most tedious and repetitive assembly-line tasks, which are ultimately faster and more reliable. These new technologies significantly improved the speed of production. Today, however, the gains made with automation have begun to plateau due to growing product complexity.

A growing trend in industrial and consumer products is an emphasis on customization, adding to the complexity of products. For automotive manufacturers this may be the addition of advanced driver assistance systems. For a consumer electronics manufacturer, it may be the inclusion of the latest antennas for 5G networking. Some customers may want a more tailored and personalized experience, further highlighting the need for customization and a process to handle highly complex products.

Because of this, many of today's products are too complicated to be produced with established automation technologies alone, forcing manufacturers to augment traditional robotics with manual assembly by human laborers. People are valued for their ability to rapidly understand and account for changes in a process. This value is evident for electronic and automotive manufacturers as well as logistics and warehouse operations. For example, the electronics manufacturing market is still largely dependent on the human workforce. Why? Electronics are updated far more frequently than in other markets; often, timeframes are measured in months, and relying on established, specialized robots used in today's factories would be far too costly. Compared to people, who can rapidly make changes and generate their own procedures for a new process, robots are not currently able to efficiently adapt to changes.

A flexible and automated (even autonomous) production system is the holy grail for many manufacturers that wish to simultaneously overcome the challenges of growing product complexity and greater customization. The ability to rapidly switch production from one product to another will be a defining feature of businesses on the path to lot sizes of one and the highly customizable products of tomorrow.

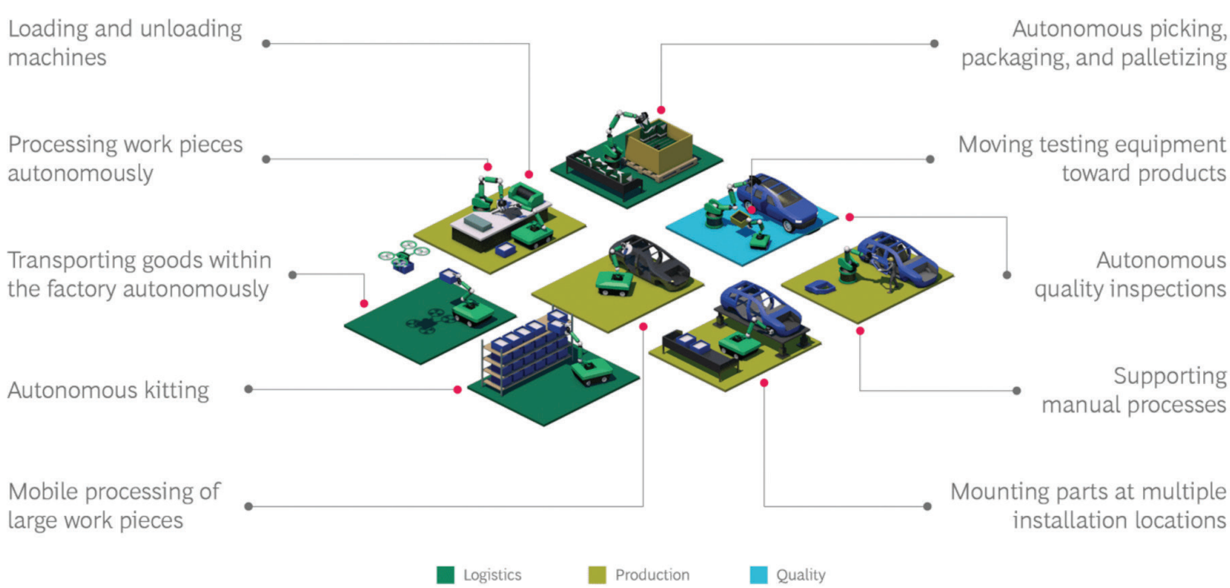


A changing robotics market

Customization and personalization
Customization that requires high-mix production and the complexity it brings are not the only novel requirements in a new era of manufacturing. Manufacturers are looking to strip out waste from their processes to produce high-quality, customized products at a competitive price faster than ever before. This often entails saving materials and energy in production, minimizing delays when product changes are required, moving to flexible production with a less experienced workforce and adapting existing production lines to minimize upfront investments and maximize future capabilities. Among these alternatives, flexible automation is considered the key element in addressing the needs of the manufacturing industry of tomorrow.

Based on projections at the IFR World Robotics Conference, industrial machine growth is expected to exceed 10 percent annually over the next three years. This growth is anticipated across many industries, including automotive, electronics and other process-oriented industries like plastics and chemical production. This projected growth is driven by inquiry and investment in new technologies.

EXHIBIT 3 | Advanced robotics has many applications in the factory of the future



Sources: BCG Global Advanced Robotics Survey, January–February 2019; BCG analysis.

The goal of advanced robotics

Implementing advanced robotics in tomorrow’s manufacturing is a challenge, but also an exciting journey. To understand why, it may be helpful to compare the applications and engineering paradigms of traditional industrial robotics with advanced robotics.

Traditional industrial robotics operate in a highly deterministic environment, with fixed robot cells, detailed shop floor layouts and no human co-workers. Any operations completed by the robots are designed to have a negligible or zero fault tolerance. This situation led to predetermined, offline programming based on a detailed simulation environment. Without concurrent operation and planning, iterating the manufacturing process for traditional industrial robotics takes time and resources.

The goal of advanced robotics is to shed this rigidity, enabling operations in an unknown or dynamic environment with frequently changing tasks to produce highly customized products. Expounding on the goal of flexibility, why not make these systems mobile to prevent bottlenecks in production? Advanced robotics are meant to save time and optimize production not only between robots, but with human collaborators. Doing all of this requires runtime decision-making and reactive programming for unforeseen events in the process with concurrent control of the open hardware standards and interfaces. And just like their human counterparts, these advanced robots need to be able to adapt and improve. But instead of using human senses and logic, they will continuously improve from data collected by the Industrial Internet of Things (IIoT) processed with artificial intelligence (AI).

Four stages of adoption

Industry 4.0 and, in turn, advanced robotics are positioned to improve visualization, enable early validation of designs and facilitate collaboration across a business. To meet these goals, advanced robotics processes focus on implementing a comprehensive digital twin, providing modern and adaptable solutions based on sensing technology and doing all of this while retaining a flexible and open ecosystem.

Every company that is considering or already on the path to implementing advanced robotics will want to proceed in phases to achieve the final goal of advanced robotics. Companies can reside in one of four phases; entrants, veterans, pioneers and visionaries, with most companies today in the first two phases. To reduce overall cost and complexity, these phases are often spread across several years depending on the business and how much investment they can make to progress to the next phase.

To understand what is required to reach phase four, a company should determine which level best describes their current processes. Then they can define the path that makes the most sense to achieve an advanced robotics process.

Entrants
The first stage on the journey to advanced robotics is the adoption of widely available fixed automation robotics or similar technology. Businesses within this phase are considered entrants and most of their operations are performed manually. Process plans are designed and assigned by humans and tasks handled by robots are generated based on a specific location and time. Although these machines can be completely reprogrammed for new tasks within the software environment, helping to accelerate deployment of robotics production systems and downloading the new program to the robot involves significant machine downtime and reduces the overall facility efficiency. Once a machine is running again with a new process, calibration is performed manually based on fixed locations and parts.

Simulation of robotic motion and validation of production processes is also done in this phase, but it is limited to predominately physical aspects of the machines. Mechanical interferences can be checked to ensure full motion, including the validation of the native robot programming, to ensure desired motion. But these capabilities have room for improvement, especially in a world of highly customized products.

With so many labor-intensive tasks required to get a fixed automation robot running a new task, it is easy to see why a facility that handles many different products may want to automate the entire process. Doing so would reduce machine downtime, increasing throughput and profits.

By implementing engineering simulation and the validation of mixed-model production scenarios and using Tecnomatix® portfolio tools for assembly plants, Volvo was able to increase engineering productivity by transitioning to the new software package. Volvo's Asia-Pacific facility significantly reduced floor documentation generation time, producing greater output with a smaller manufacturing engineering staff.

Veterans

In the veteran phase, manufacturers begin adding some higher-level features in addition to what is available in the entrant phase. This phase is where many using advanced robotics sit, and it requires implementing a digital twin to validate the entire robotic production process, including mechanics and control algorithms. Each of the manual tasks can be simulated within the digital twin to optimize the motion paths of the robots and gain a greater understanding of the overall system. Digitalizing this workflow is key to making improvements later in the transition to advanced robotics.

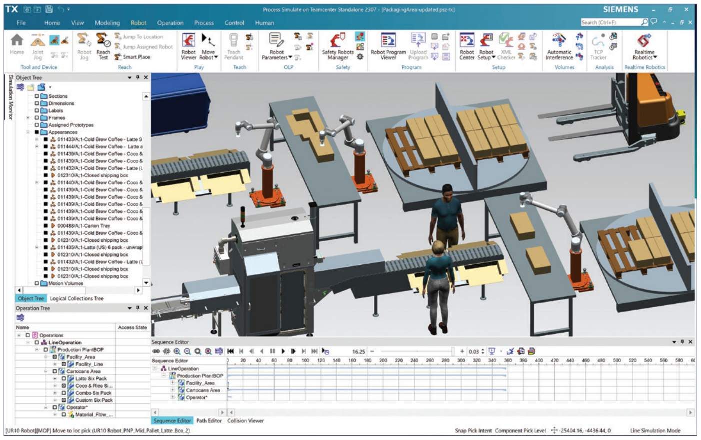
Process planning is still designed and assigned by humans and robot motion is still manually generated. But the functionality based on the digital twin allows for some higher-level input and display when working with these machines. Robot motion is generated according to system signals and the logic within the programmable logic controller (PLC) on top of what was available in the entrant phase (location and time), a process usually referred to as virtual commissioning.

Now it is possible to see the spacing and interconnectivity of the facility before a machine is physically installed on-site. It is also possible to validate the software running on the PLCs and human machine interface (HMI) programs in the virtual environment by interfacing directly with the programming software. Simulating the desired operation at the automation level on down allows for manually optimizing the machines so they run as efficiently as possible. It also means even less downtime for the facility as shorter lead times are needed for implementing new or replacement units.

As in the entrant phase, programming the robots still happens offline, but since the PLC is included in the digital twin, more comprehensive work can be done in the office opposed to on the shop floor. If a large group of robots are completing the same task, the changes can be downloaded to all robots simultaneously instead of manually programing each robot to work properly with its respective task and environment.

This digitalization also offers the ability to experience the complete facility using virtual reality (VR). In this environment, engineers can evaluate or commission the manufacturing process while immersed in its digital twin. It also allows the comprehensive validation of mechanics and automation, PLC programing and human machine interface programming in VR.

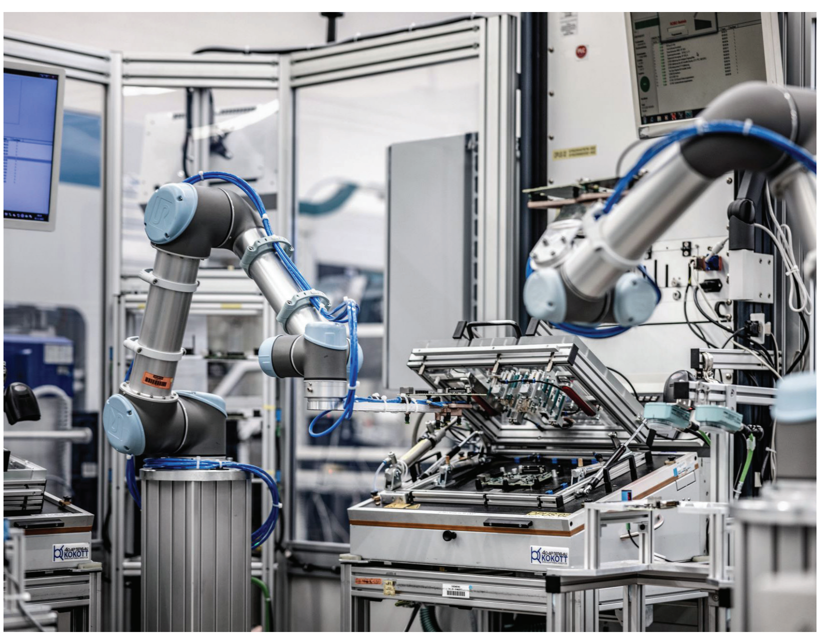
Moreover, these features don't require users to be large original equipment manufacturers (OEMs) to be profitable. Guangzhou's MINO Auto Equipment sought to simulate and synchronize multi-robot and equipment assembly and shorten project lifecycles by implementing Tecnomatix, which is part of Siemens Xcelerator, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software, for production planning and extensive virtual commissioning. MINO's implementation led to improved collaboration across entire projects, reducing project cycles by over 20 percent and contributing to revenue growth from high-value automotive OEM customers.



Pioneers

Progressing into phase three, these pioneers of their industries are beginning to automate their production systems. As with the two previous phases, process planning is still done by hand, but that is where the similarities diverge. Robot motion can still be generated based on previously available information, but now there is access to sensor data for feedback optimization. This could be vision data, force readouts or information from other specialized sensor arrays for the relevant process. The sheer volume of data requires these robots be designed and programmed for adaptive planning based on location, time, signal, PLC logic and sensor data. This results in a higher fidelity simulation and implementation of the production process in nondeterministic working conditions.

Production process simulation can now be performed with varied or flexible parts and a dynamic environment. With easy-to-use, task-based programming for feedback control, the manufacturer can create a connected download for the entire shop floor. Semiautomatic programming on the part of the machine frees more resources for other optimization tasks within the facility.



Now that the robots understand the process, the information they collect and act on can be aggregated to create a process library of sorts. The re-use of this information is referred to as task-based programming. These tasks function almost as drag-and-drop instruction sets for the robots and, due to this simplicity, can be uploaded while the robot is on-line. This approach significantly expands the flexibility of the facility.

For example, an electronics OEM could switch their facility from producing one phone to a new revision in days or even hours. The ability to switch the task of a robot at will is the precursor to achieving the goal of a lot size of one. With a robust scheduling system, signals can be sent to a designated robot or the entire facility to begin work on the next set of products without the downtime required in previous phases. Sensor feedback reduces the complexity of this process through the machine's understanding of what it is working on. Calibration is also accelerated. Relying on a closed-loop, the calibration includes dynamic cells and varying parts to switch processes without the need to be recalibrated.

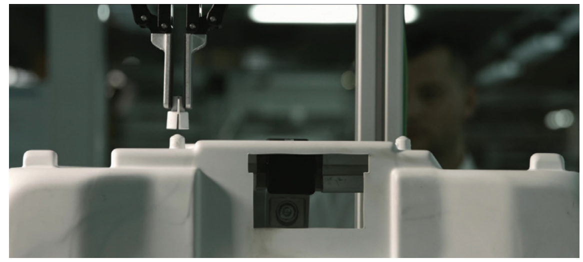
As an example, a facility may be assembling five to ten dishwashing machine models. Of these, there could be variable sizes and a few different form factors. It is difficult to assume every product would have the same dimensions and different units may have different hole spacings. An individual model may even have dimensional variances depending on the tolerances of the manufacturer. Products like these may also be far less rigid than products assembled with traditional robotics that can contribute to suboptimal spacing and a loss of alignment. Instead of programming for every possible array of holes, general definitions are given to the robot. The holes are known to be approximately so far apart, but with the sensor feedback the robot can readjust the positioning to correctly place a fastener in each hole. This reduces the number of instructions, which in turn reduces the time needed to get these machines operational for new product lines or small changes to the original design.

This scenario occurred in a partnership amongst Siemens and B/S/H/ to deliver products rapidly and more efficiently than previous solutions. An integrated toolset reduces the number of questions that need to be answered before changing a production process and allows production planning based on available resources on-site.

Visionaries

The companies that implement advanced robotics and reach phase four are set to become the visionaries in their field. Phase four is the complete automation of robotic function; it reaches the upper right corner of the flexibility/automation diagram. Now comprehensive design, simulation and deployment of a flexible production system is possible. Automated process planning and implementation is done by relying on machine learning. Optimization algorithms integrated with physics simulation are used to train and validate the advanced robotics control scheme. The motion paths are generated automatically based on real-time system data implemented in the previous stages and the system can respond immediately to changes in production.

Machines are updated with automatic program generation while remaining on-line and as with phase three, each machine implements on-line closed-loop calibration for both dynamic cells and product variations. By bundling each robot with edge computing devices, the robots can learn and improve their processes with machine learning. Including 5G communication in the robot-edge device systems can also enable a completely mobile, secure and reconfigurable facility.



In effect, phase four uses all the technologies introduced with the adoption of advanced robotics. AI drives the manufacturing process and best practices are driven by data to self-optimize and produce the best results in your facility.

In the future, automated mobile robots (AMRs) could be used to deliver parts and completed assemblies around the manufacturing floor, replacing traditional conveyor belts. The AMRs could then be included in the complete simulation of the workshop floor to optimize delivery based on robot load or obstructed paths due to humans on the floor.

The last goal of building and refining this environment is to open it and allow partners like ArtiMinds to optimize their robotic algorithms within a realistic operating environment complete with physics calculations. Partners would be able to test everything that could be tested in real life without needing to build expensive prototypes.

Conclusion

Advanced robotics processes were designed as pillars for the future digital platform, providing core values like integrated validation for AI, data analytics using IIoT, virtual commissioning with automation systems and an open application programming interface (API) for near-infinite customization. With each one of these technologies, Siemens wants to foster a flexible ecosystem for our partners. Since manufacturing is the convergence of tools and processes, the software side of automation will need to be adopted as well. Providing a worker is great, but they need to know how to complete the assembly of a high-quality product.

Mass production has been evolving for over a century and will continue to evolve into the future, but advanced robotics is where today meets tomorrow. By implementing adaptive machines that cannot only sense what they are working on, but react to that information, factories and other facilities that rely on automation are taking a step toward complete customization and openness. Advanced robotics take the complexity that has grown since the inception of mass production and leverages it to develop a highly connected and efficient workflow that can meet the changing needs of a diverse landscape of high-mix production output.

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