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Material handling for tomorrow's factory

Using simulation and planning to integrate flexible robotic technologies

Executive summary

Manufacturing and process complexity are rapidly reshaping the traditions of the manufacturing industry. Succeeding in this new landscape means adopting that complexity and using it as a market advantage against competitors implementing legacy processes. Factories of tomorrow will be more integrated than ever and enable greater flexibility in products. This white paper will examine the integration of flexibility using autonomous mobile robots at the station level as well as the plant level to achieve an optimized production environment.

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Abstract

Recent history has shown that traditional manufacturing – optimizing solely for unit efficiency – is not sustainable for all businesses. Instead, manufacturers are looking toward supply chain resiliency. That can come in many forms, from distributed production hubs within each resale market to rapidly changing what products are being produced. Speaking to the latter, autonomous mobile robots (AMRs) and automated guided vehicles (AGVs) may just be the flexibility manufacturers are looking for as a means to overcome growing product complexity. But before these technologies can be deployed, it is paramount to validate whether AMRs and AGVs can complete their required tasks, do so safely and provide added value to the facility. Without ensuring these requirements in a comprehensive digital twin, time can be lost integrating them, employees could be injured and investments can wither. The factory of tomorrow will likely be automated but getting there means optimizing the processes today.

Industrial manufacturing as a sector has been an early adopter of robotics and other forms of technological improvements for decades. Robotics have been one of the best options to increase production efficiency for large and often highly repetitive manufacturing processes. But the era of producing large quantities of just a few products in low-mix manufacturing is giving way to increased product personalization, requiring a more flexible production process with less waste than ever before.

Fortunately, the future of manufacturing is brimming with opportunity, full of new technologies designed to reduce waste and maximize process efficiency and flexibility through software and hardware capabilities. Almost all this promise is built on a foundation of digital transformation – and the digital twin. Everything from raw material tracking to process optimization to hardware selection stem from insights gained from the digital twin and closed-loop optimization of entire facilities.

The pinnacle of these improvements is a shift to completely flexible material handling with automated guided vehicles (AGVs) and autonomous mobile robots (AMRs). These two technologies are poised to replace more and more static conveyance systems as the industry moves toward more flexible production methods.

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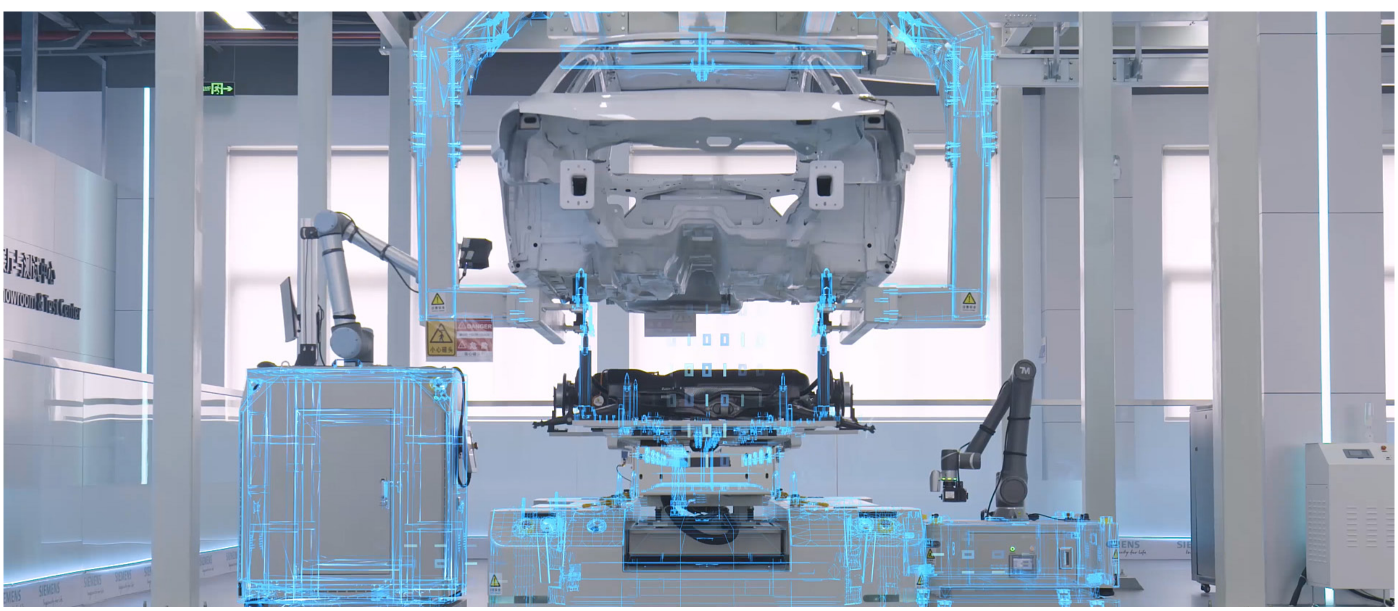


Market trends

Customization and flexibility are two of the hottest words in industrial manufacturing right now. Customers want something made just for them, whether it is a personalized aftershave with their name on the bottle, a vehicle with all the features they need and none they don't, or a new phone with the latest radio antenna for 5G connectivity. All this customization means manufacturing is moving toward high-mix production and making millions of different products in very small lots.

At the same time, many products made today are far too complicated for established automation technologies alone, prompting manufacturers to augment traditional robotics with manual assembly by human workers. People are valued for their ability to expeditiously understand and account for changes in a process. But what if this flexibility were built into automated processes?

A flexible and automated (even autonomous) production system is the holy grail for many manufacturers wishing to transform growing product complexity into a competitive advantage while simultaneously meeting the demands for 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.

Small lot sizes are not inherently a problem, but current production processes cannot easily accommodate this without large investments in an increasingly complex infrastructure. To avoid this problem of exponential investments, which may or may not solve the problem, many businesses are looking for a more flexible approach to production. How can manufacturers make multiple products efficiently with minimal changes to the production floor between product introductions?

Implementing flexibility

AGVs and AMRs are a perfect fit for many companies seeking flexibility and supply chain resilience in their plants. By eliminating static conveyor systems from the floor, the entire process can be continually optimized. Are machines placed and clustered optimally to minimize AGV route lengths? Simulating the facility before deployment can solve this. Is a new product being launched that

requires production to ramp quickly to meet demand? One could prioritize the machines making these products when AGVs and AMRs begin their route. Maybe the transition to dynamic conveyance will be staggered to finish a production run. Knowing how traditional and flexible conveyance systems interact will be vital to efficient and economical operation.

Deploying mobile robotics is also far less intensive than traditional conveyor systems. As no foundation structure is needed beyond shallow charging tracks for AGVs, there is little impact on building requirements. This is why Porsche decided to implement AGVs in their production of the new Taycan electric vehicle. Although Porsche chose the technology to reduce their building requirements, smaller companies may adopt the approach to better handle production scaling as they grow.

Integrating these solutions into an existing, operating facility often is the largest obstacle to deploying AGVs and AMRs. These devices need to be aware of their surroundings to prevent collisions with both static and moving obstacles, human or otherwise. They need to reach and collect materials consistently and continuously without error. They must communicate with each other, even if they are not from the same manufacturer. And most of all, they must communicate with the rest of the plant to be able to control material through production or transit.

Integrate everything

One of the best options to minimize risk when updating an existing process or making a new one is to simulate the new operations. It eliminates upfront investment in machinery before knowing whether the new process will operate as expected on the shop floor. Without a comprehensive study of the actions within a plant, new equipment could be underutilized or even cause new problems, leading to lost investment.

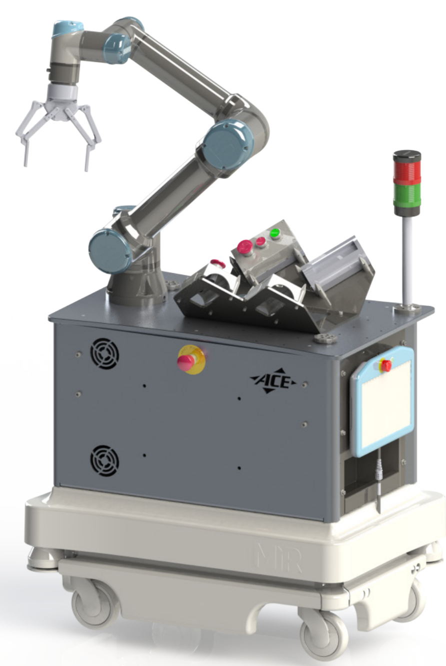
Just as important is the implementation of Internet of things (IoT) devices that serve to close the loop between the digital twin and the physical processes once the new processes have been initiated. Although these devices are often embedded in new production equipment, it is important to consider how to best utilize the large amount of data they generate and gain crucial insight into the production process.

Process Simulate

Process Simulate, as a part of the Tecnomatix® portfolio of digital manufacturing software within the Xcelerator™ portfolio from Siemens Digital Industries Software, is designed to validate and optimize AGVs and AMRs at the cell and station level. The portfolio provides many tools to design, validate and run AGVs, AMRs and the automation within their immediate surroundings. There are a variety of goals for deploying these technologies – perhaps to replace traditional conveyance systems or reduce the frequency of employees leaving their stations for required materials. But in almost all cases there are seven processes that should be implemented before physically integrating mobile robotics in a plant.

Cell and station level virtual commissioning enables engineers to check communication between devices and controllers throughout the plant floor and ensure proper signal exchange prior to installing any physical equipment or initiating processes. This is vital for automating production processes later in the integration process. But in early stages, it is to guarantee that an AMR can readily communicate with the machines it may encounter.

Robot reachability is the validation that a robot's arm can reach a target location. This is for both stationary arms and those mounted on an AMR platform. Feasibility and operation simulations are run for the robotics programs within the digital twin to ensure all necessary locations are reachable without collision and whether it was an effective configuration for the task.



LiDAR sensors are ubiquitous across both AGV and AMR platforms, but not all systems are run the same way. For AGVs, lidar sensor simulations are used to define the position for reflectors within the work area, whereas AMRs require a virtual scan of the shop floor. There is also detection range planning that must be done virtually, such that the mobile platforms can navigate the floor without tripping a fail-safe function.

AGV/AMR – Robot synchronization validation becomes vital when deploying multiple devices to a floor. Without virtually planning and validating blocking zones for a robot, a deadlock will likely occur. Preventing this means keeping the floor running without unnecessary interruption.

Human safety is critically important when deploying these technologies. Even in the event of a fully automated facility, there will likely be people on the floor at some point in time and the AMRs and AGVs need to handle the possible interruptions. Validating the safety of human operators means checking braking distances, detection range, deceleration rates and much more for the entire fleet. It is critical that this validation is done extensively in the digital twin of the factory before they are deployed physically.

Route and operation validation facilitate collision-free motion and operation for fork trucks, gates, turn tables and other shop floor devices within the digital twin. This process is further extended by using point cloud collision capabilities for all work areas.

Fleet manager connectivity makes the entire system supplier agnostic, allowing connections to external fleet management software packages. Supported fleet managers have been developed by Kollmorgen, Seer Robotics and SIMOVE, among others to integrate with Siemens' comprehensive digital twin technology. The vendor's fleet manager then drives the AGVs and AMRs within Process Simulate to obtain feedback on process effectiveness, communication reliability and device interactions.

Validating each of these processes within the digital twin is paramount to gaining the benefits delivered by mobile robotics. Integrating new technologies is bound to uncover problems but finding them during virtual testing greatly reduces the resources that would be used to do so physically. And when a new process is required it can be validated while the previous processes are still in operation, making flexibility more attainable.

Plant Simulation

Tecnomatix Plant Simulation is designed to validate and optimize AGVs and AMRs at the fleet, plant or facility level. To balance time, compute power and granularity for such comprehensive simulations, the detailed study results available from Process Simulate, such as cell timing or cell sequences, can be applied in Plant Simulation as it scales up to the complete production facility. Task times for robots are the most common simplification, though the method for doing so may change depending on the application.

A few of the most common attributes validated before installing mobile robotics platforms are system throughput (units per hour), path optimization, fleet sizing, control strategies and operational accuracy. Battery life and charging characteristics are also key elements when sizing a fleet. It is extremely important to simulate these processes as without upfront planning the fleet may underperform, requiring additional investment, or overperform, leading to underutilized devices and lost investment.

AGV requirements

A logical starting point for planning the addition of AMRs to a plant floor is to examine how many devices are required for the new processes to support the target capacity. Say a battery manufacturer wants to deploy a fleet of AGVs to move work pieces through the facility between manufacturing stations. A throughput and cost analysis will be the best way to determine how many are needed. Running the simulation on the comprehensive digital twin, multiple attributes are varied and tracked to determine the optimal number of AGVs. For this example, the manufacturer may want to track the volume of batteries being made, the number sold and the unit cost for production as more AGVs are added to the simulation.

These are all plotted against the number of manufacturing stations and AGVs in operation. From the plant simulation, the ideal number of AGVs can be uncovered, whether it is selected by cost per unit, production speed or another metric is up to the individual company, but quantifying gains from the upgrade is invaluable in early stages of adoption. All these simulated processes are run within the experiment manager and can be left to run until it reaches predefined stopping points (reached target, maximum runs, etc.). This is equally important to both the end user as well as the integrator of the AGV system.

Path optimization and fleet manager control strategies

For understanding conveyance needs as well as cell and station level behavior, the next step is to let the AGVs operate within the virtual factory. During this test, each device's locations and paths will be recorded. After running this virtual test for an eight-hour shift, or another representative amount of time, inefficiencies may begin to arise that were not included in the initial plan. The AMRs may create a bottleneck as they move through a section of the plant floor. Some AMRs may not reach the far corners of the facility. Others may meet their carrying capacity before serving specific areas in need. More may fail to reach required machines for lack of adequate charging. Even worse, some could die on the floor from a lack of charge due to insufficient battery size or unsatisfactory charging times. All these situations may lead to identifying a need to add AGVs beyond the nominal fleet size.

These are critical problems to understand and solve while deciding a fleet management control strategy and before time is spent implementing, configuring and programming the fleet manager. Solving these problems as they arise during production could lead to expensive rebuilds of the charging areas to reach all machining stations or more direct programming to force an AMR to check a defined area first before continuing its regular route.

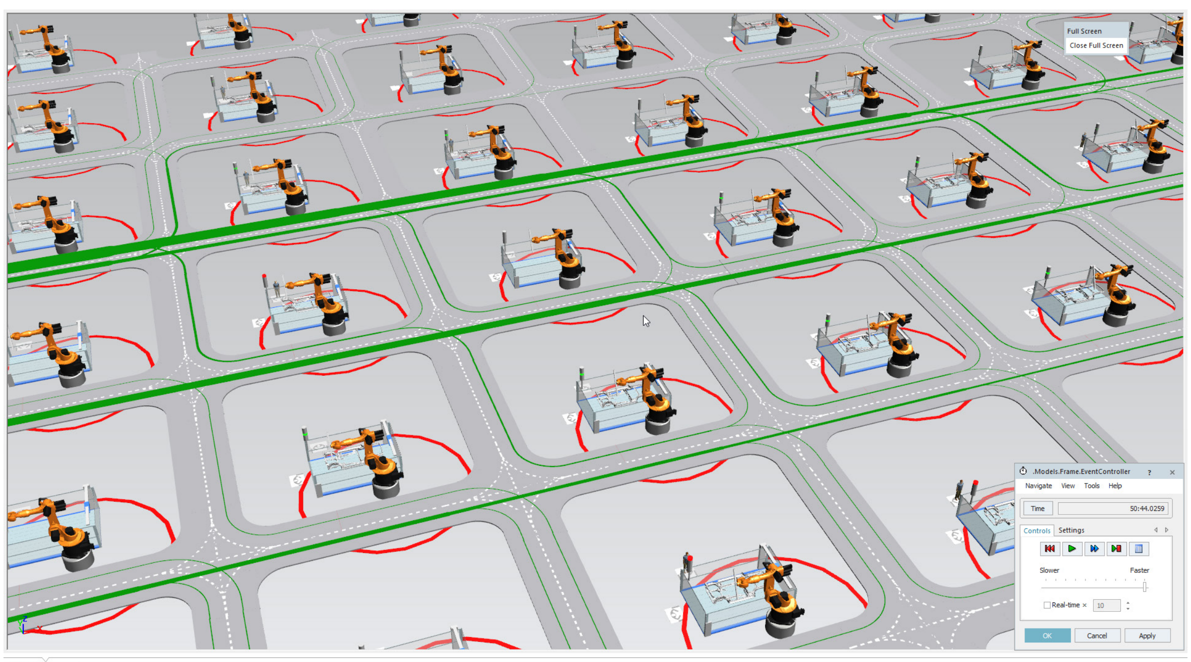
Closed-loop digital twin

The previous processes are not limited to preinstallation practices either. Given a comprehensive digital twin of the facility and the ability to collect and manage IIoT in a platform like MindSphere®, the industrial IoT as a service solution from Siemens, closing the loop between simulation and production provides accurate insights for continuous optimization and more effective troubleshooting. Testing enhanced or amended fleet manager programs using accurate historical data available through MindSphere will reduce, perhaps to zero, the need to run iterations on the production floor.

Battery validation

For AGVs, this may be the most important validation step. In simple workflows for AGVs, all devices follow a single path. They leave the charging station and are directed down the line, passing all the required stations for the task it is fulfilling before dropping off the workpiece and returning to the charging area. But should an AGV need to make multiple stops, the battery charge could drop too low to operate properly. For AMRs, this is not as big of a problem since they can be re-outed and returned to a charging bay.

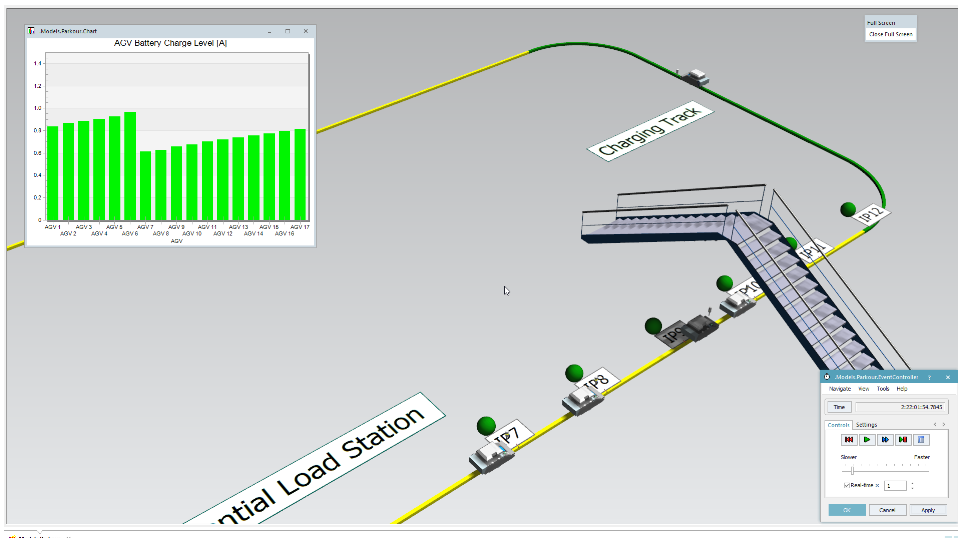
AGVs must stay in the line. So if a single device loses power, eventually the entire fleet will stop and drain their remaining power waiting for the leading AGV to advance



stations. Battery validation is needed to examine and define both the available battery power and the length of the charging lane to ensure none of the AGVs will stop along the line and bring the facility to a halt. This solution is dependent on interactions the AGV has with machines and workers on the floor, making it a priority to ensure an AGV can make it to the charging station even while encountering delays.

Line integration

Line Integration (line level virtual commissioning) is the process of integrating a head level programmable logic controller (PLC) or a set of PLCs with device controls, station PLCs and fleet management. This is an exceedingly complex process, naturally prone to more errors that will only be discovered while ramping up production. Virtually commissioning or testing the integration with the digital twin greatly reduces surprises, and even facilitates the discovery of areas for improvement as the behavior of the system is observed on the comprehensive digital twin of the facility in Plant Simulation. As a matter of fact, in some instances commissioning can be performed completely virtually, using Plant Simulation for the digital twin, Siemens PLCSIM Advanced for virtual PLC controls and Siemens SIMOVE for AGV control and AGV fleet management.



Conclusion

For a business looking for a more flexible production process, whether due to pressure to produce increasingly complex products or bolster supply chain resiliency, AGVs and AMRs are two of the best solutions available. But new processes must be resolved to enable these new technologies and integrate them into a wider process. And the pressure is only increasing to adopt these approaches as manufacturing moves toward greater customization and eventually lot sizes of one. Integrating advanced material handling with disparate machine builders, software providers and established processes require a comprehensive solution based on a digital twin to better understand how the processes are operating and optimize them with greater knowledge. Working in the virtual world before committing to physical implementation enables manufacturers to implement process simulation combined with plant simulation to achieve flexible production for increasingly complex and customized products. With our software expertise and manufacturing background, Siemens is a great partner to bring the tools of tomorrow's factory to businesses today.

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