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BUILDING THE FUTURE OF MANUFACTURING: SIMULATION AND DIGITAL TWIN TECHNOLOGIES



Authors



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Mariusz Janiak, Ph.D., is an academic lecturer, engineer, and roboticist specializing in advanced control, motion planning, and distributed real-time systems. His background spans university research, collaborative EU projects, and industry-driven robotics development, including work on humanoid mobile robots and innovative media-production technologies.

He currently works at SoftServe as a solution architect, where he leads a team delivering systems for mathematical modeling, high-fidelity (co-)simulation, control, and optimization. His recent work centers on digital twins, industrial process optimization with a focus on energy reduction, physics-informed neural networks (PINNs), and complex system integration within the NVIDIA Omniverse ecosystem.



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Karol Suchoń is an engineer and numerical simulation specialist with a background in energy engineering and industrial computer science. His work focuses on high-fidelity computational modeling, including computational fluid dynamics (CFD) and structural analysis. He combines strong theoretical foundations with practical experience in applying advanced numerical methods to complex engineering challenges.

At SoftServe, he works on the development and integration of simulation workflows, the creation of digital twins, and the design of neural-network models capable of capturing and reproducing physical phenomena. His recent projects emphasize data-driven engineering, multiphysics analysis, and modern strategies for simulation-based optimization.

Executive Summary

Manufacturers today are being pushed to operate faster, leaner, and more sustainably—often all at once. Increasing demands for higher output, better quality, and shorter time-to-market are colliding with rapid product cycles, complex global supply chains, and persistent workforce shortages. In this environment, traditional approaches to designing and commissioning production lines are often falling short, driving the need for new more flexible ways to plan and operate production systems. Physical trials are expensive, commissioning disrupts operations, and much of the data generated on the shop floor goes unused.

Advanced manufacturing simulation and digital twin technologies are transforming how organizations design, test, and operate production systems before implementing changes in the real world.



Manufacturing line simulation enables manufacturers to analyze throughput, identify bottlenecks, and optimize layouts with a safe virtual environment.

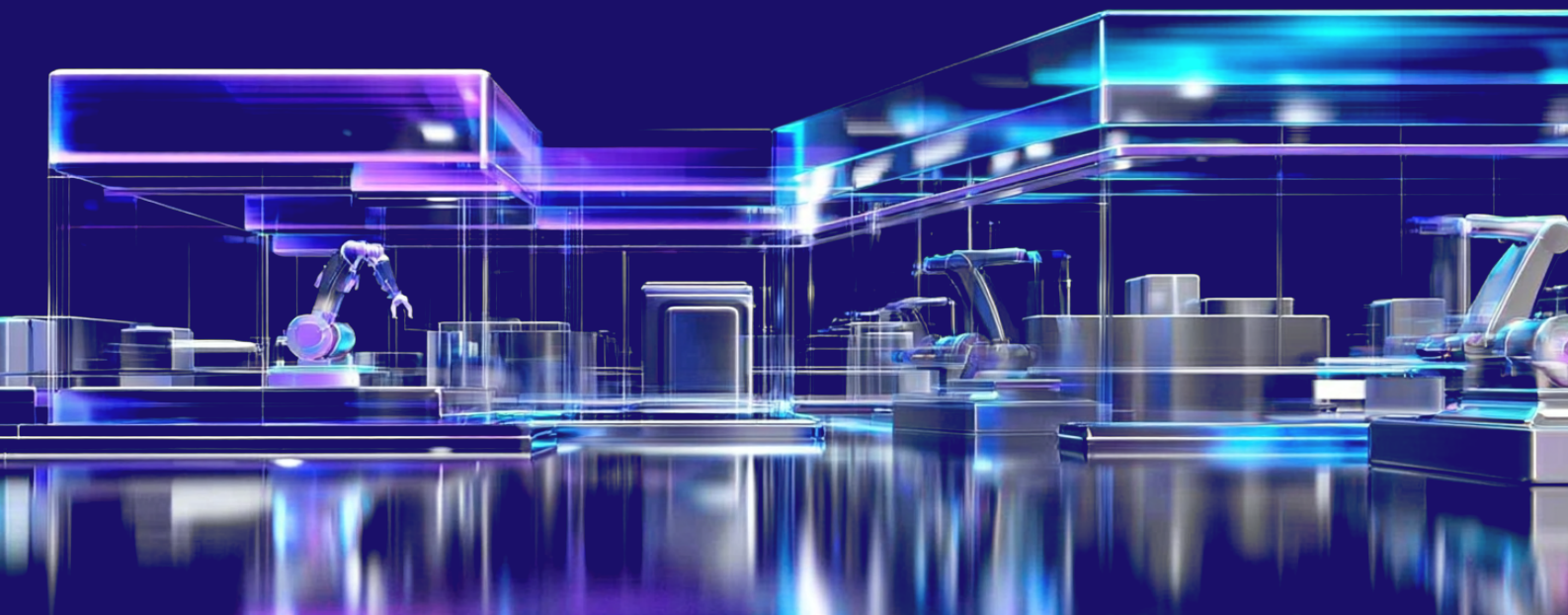


Factory digital twins extend these capabilities into daily operations by creating a real-time, data-driven replica of the factory that supports predictive maintenance, energy optimization, and continuous improvement.



Virtual commissioning, often embedded within simulation workflows, supports this transformation by allowing engineers to test automation logic against digital models before deployment. It ensures that control systems verified in the virtual phase perform reliably once implemented on the shop floor.

As the industry moves toward autonomous and AI-driven factories, simulation and digital twin technologies, supported by virtual commissioning, are laying the foundation for the next generation of industrial innovation.

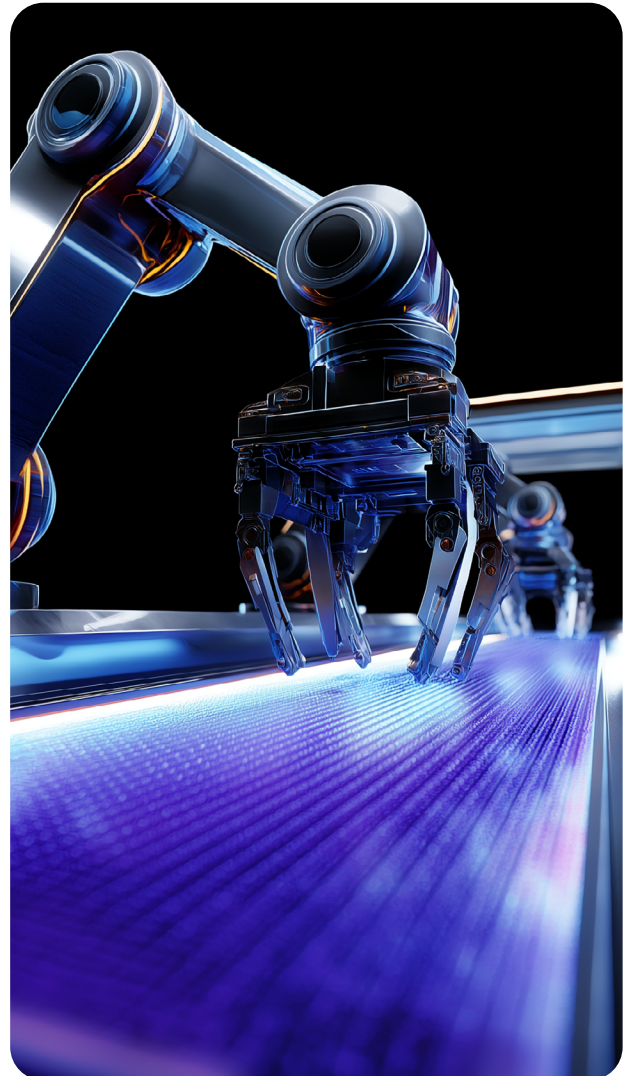


Manufacturing Line Simulation

Manufacturing line simulation represents a virtual model of a production line, allowing engineers to predict performance before any physical changes occur. Using specialized software, teams can model machine behavior, material flow, and operator interactions to test ideas safely in a digital space. This approach enables the analysis of throughput, identification of bottlenecks, and exploration of different layout configurations without disrupting existing operations.

Real-world applications include planning new lines, assessing capacity expansions, and testing “what-if” scenarios such as shifts in demand or supply chain delays. By simulating these factors early in the design process, manufacturers can make informed design decisions, mitigate risks, and accelerate project timelines.

Simulation also forms the foundation for virtual commissioning, where validated models are used to test control logic and automation software prior to deployment. This connection ensures that systems designed virtually can be implemented more smoothly in real life, shortening commissioning time and minimizing production disruptions.



Factory Digital Twin

A factory digital twin is a real-time, data-driven replica of a manufacturing environment. It continuously mirrors machines, systems, and processes by integrating live data from sensors, equipment, and enterprise systems. This virtual reflection enables manufacturers to monitor operations in real-time, detect inefficiencies, and make informed, quick decisions.

Digital twins provide insight into every layer of production, from machine health and energy use to workflow performance and quality outcomes. By integrating simulation models with live factory data, they support predictive maintenance, process optimization, and resource efficiency.

The result is greater operational flexibility, reduced downtime, and improved sustainability. As digital twins evolve, they're becoming a cornerstone of smart factories, bridging the gap between design, execution, and continuous improvement.

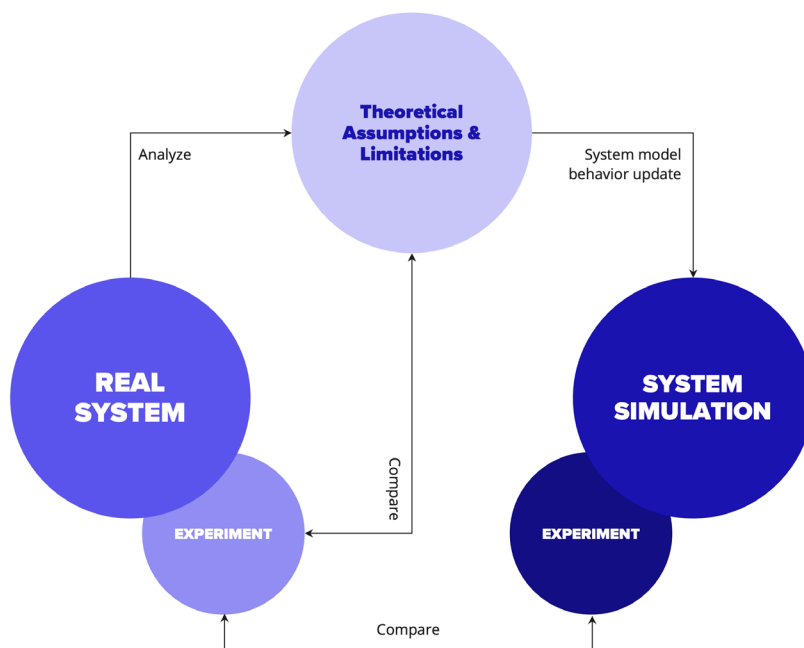
Synergy: From Simulation to Digital Twin Through Virtual Commissioning

Simulation, virtual commissioning, and digital twins are most effective when used together as stages in a connected digital workflow. Simulation lays the groundwork, providing a detailed virtual model for analysis and optimization. Virtual commissioning builds on this foundation by testing the control systems and automation logic within that simulated model before real-world deployment.

Once equipment is live, the same validated model can evolve into a digital twin, continuously updated with real-time data from the production floor. This creates a closed feedback loop: lessons from the digital twin inform new simulations, and those insights drive smarter system updates and designs.

Together, these capabilities allow manufacturers to move from reactive troubleshooting to proactive, data-driven improvement — ensuring every stage of the production lifecycle is optimized before, during, and after implementation.

What to Simulate in Digital Twins



Robotics & Autonomous Systems

Robots, drones, autonomous vehicles, manipulators, control systems.

AI Model Training & Testing

Synthetic data generation, edge-case validation, continuous AI improvement.

Equipment & Infrastructure

Physical assets, machines, factory layout, conveyors, sensors.

Operational Scenarios

Production workflows, failure modes, maintenance, emergency response.

Human & Workforce Simulation

Operator actions, ergonomics, collaboration, safety zones.

Technology Ecosystem

SoftServe's simulation and digital twin solutions are built on a robust ecosystem of advanced visualization, physics modeling, and data integration technologies. This foundation enables manufacturers to design, test, and optimize production systems virtually before implementing them on the shop floor, creating a continuous link between digital and physical operations.

Core tools such as NVIDIA Omniverse™ and Isaac Sim provide realistic, real-time simulation environments that replicate material flow, robotics behavior, and system dynamics with high fidelity. Combined with physics engines and modeling tools, these platforms allow engineers to explore design alternatives and validate performance entirely in a virtual domain.

To maintain alignment with real-world conditions, SoftServe integrates IoT connectivity, cloud computing (AWS, Google Cloud, Azure), and data management tools. This ensures that every digital twin remains continuously synchronized with live factory conditions and evolves alongside production changes.

Business Impact & ROI

Adopting simulation and digital twin technologies delivers tangible business results across design, commissioning, and operations. By enabling manufacturers to model, test, and optimize production systems virtually, these tools reduce risk, accelerate innovation, and turn data into a strategic asset. The result is a measurable improvement in efficiency, flexibility, and long-term competitiveness.

Key business impacts include:

Higher productivity and OEE: Optimized layouts, predictive maintenance, and early fault detection increase throughput while reducing unplanned downtime.

Faster time-to-market: Virtual validation shortens design cycles and commissioning time, enabling new lines and products to launch **up to 30-50% faster**.

Lower operational costs: **Reduced** reliance on physical trials, less rework, and more efficient resource utilization translate directly into cost savings.

Improved sustainability: Digital twins support energy optimization, waste reduction, and better asset utilization to meet environmental goals.

Greater resilience: Virtual testing and real-time visibility allow manufacturers to respond quickly to demand shifts, supply chain disruptions, or production constraints.

Case Study

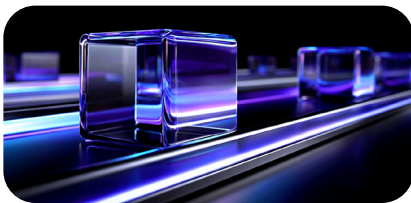


Krones—one of the largest companies in Europe producing complete fluid filling systems—uses a combination of a digital twin and manufacturing line simulation to improve process safety. However, earlier simulation methods posed challenges, requiring 3–4 hours per run and proving too slow for real-time optimization in dynamic beverage production environments.

The multi-scale bottle filling process carries a high risk of fluid spillage during bottle transport along the production line. Any spillage forces the line to stop, resulting in downtime and lost productivity. Predicting if and when spillage will occur is difficult due to:



The complex physical behavior of fluids



A dynamically changing production environment



Rapid shifts in process parameters or product changeovers

Traditional fluid simulations can take hours to complete, while real-world production conditions may change within minutes. Process safety can be improved by lowering line speed or reducing fill height, but these adjustments come at a cost:



Reduced throughput



Lower fill volumes per bottle



Decreased overall efficiency

Compounding the challenge, even small changes, such as a new bottle design, a variation in fluid temperature, or a slight increase in fill height, can trigger spillage, even when previous conditions appeared stable. To reduce analysis time, the Kronos team implemented **Slosh AI**, an artificial intelligence tool designed to predict spillage likelihood. While significantly faster than full fluid simulation, its predictions are less accurate in edge cases, which can still result in unexpected spillage during production. To address these challenges, **SoftServe**, **CADFEM**, and **Ansys** developed a **manufacturing line digital twin solution** that:



Simulates and displays the production line in real-time, including bottle transport, conveyor speeds, and transport wheel behavior.



Uses native ANSYS GPU solver for fluid dynamics and Slosh AI to predict whether spillage is likely; if a scenario is risky or uncertain, high-fidelity simulation is triggered.



Combines and visualizes fluid simulation results in real time in NVIDIA Omniverse™, showing fluid behavior in a realistic production environment.



Creates a globally connected simulation environment, enabling remote access and collaboration from anywhere in the world.



Figure 1: Manufacturing Line simulation combined with high-fidelity simulation in NVIDIA Omniverse™

The solution also provides a **user-friendly interface** that allows engineers to:

- ✓ Change the fluid type, bottle design, filling height, and line output.
- ✓ Run **quick AI-based predictions**; the system clearly indicates when high-fidelity simulation is required.
- ✓ Store and reload simulation cases for review.
- ✓ View **high-fidelity fluid behavior** in a dedicated window without lengthy post-processing.



Figure 2: User interface showing AI-based spillage prediction

The implemented system:

- ✓ Reduced simulation time **from hours to minutes**.
- ✓ Provided an **easy-to-use environment** for setting up and running simulations.
- ✓ Eliminated most manual post-processing by visualizing results in real time.
- ✓ Allowed users to access the platform through a standard web browser.

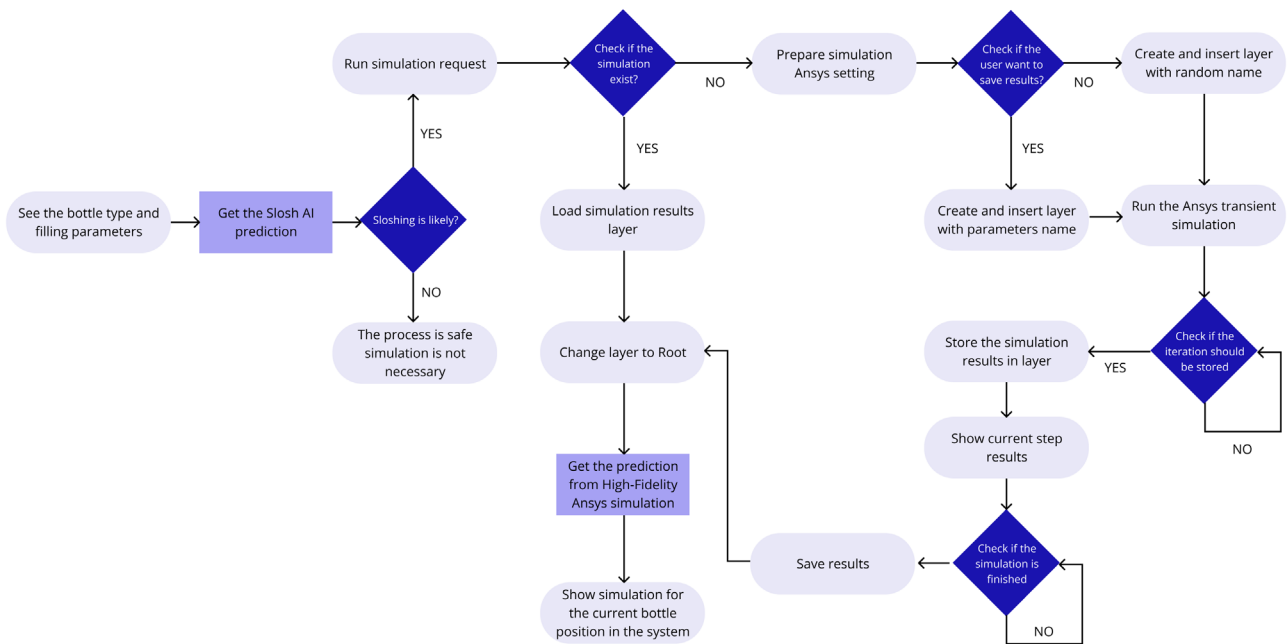


Figure 3: The algorithm behind the solution

As a result, Kronos achieved:



Shorter design and service cycles for new and existing manufacturing lines.



Maximum line output without increasing the risk of spillage.



Greater flexibility to adapt lines to changing conditions, product designs, and environmental factors.

Learn how AI-enhanced digital twins have transformed Kronos's bottling processes.

Read the full case study to discover what's achievable when innovation, precision, and collaboration intersect

[Read The Case Study](#)



Future Outlook

The developed solution provides a strong foundation for future advancements in intelligent manufacturing. As digital twins, simulation, and virtual commissioning mature, factories will evolve into self-optimizing, data-driven systems that adapt in real time.

AI-Driven Optimization

Real-time data combined with AI will enable factories to automatically adjust processes, predict issues, and improve performance continuously.

Autonomous Production

Combining simulation, virtual commissioning, and digital twins will lead to self-adapting, fully autonomous production lines.

Industrial Metaverse

Platforms like NVIDIA Omniverse™ will create collaborative, immersive spaces for design, testing, and validation.

Sustainability Focus

Digital twins will help minimize energy use, reduce waste, and support carbon-reduction goals.

Continuous Evolution

The current system establishes a scalable base line for integrating advanced analytics and cross-factory intelligence over time.

Conclusion

Manufacturing line simulation, virtual commissioning, and digital twin technologies are reshaping how factories are designed, tested, and optimized. Together, they create a connected digital thread linking engineering, automation, and operations, reducing time-to-market, lowering costs, and improving performance across the production lifecycle.

SoftServe helps manufacturers realize these benefits by combining deep engineering expertise with advanced simulation and AI capabilities. Our solutions support measurable performance improvements today while establishing a scalable foundation for autonomous, data-driven factories of the future.

To discuss how these technologies can drive measurable impact across your operations, contact us.

[CONTACT US](#)

About US

SoftServe is a premier IT consulting and digital services provider. We expand the horizon of new technologies to solve today's complex business challenges and achieve meaningful outcomes for our clients. Our boundless curiosity drives us to explore and reimagine the art of the possible. Clients confidently rely on SoftServe to architect and execute mature and innovative capabilities, such as digital engineering, data and analytics, cloud, and AI/ML.

Our global reputation is gained from more than 30 years of experience delivering superior digital solutions at exceptional speed by top-tier engineering talent to enterprise industries, including high tech, financial services, healthcare, life sciences, retail, energy, and manufacturing.

Visit our [website](#), [blog](#), [LinkedIn](#), [Facebook](#), and [X \(Twitter\)](#) pages for more information.

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