Cogniphi

PAIRED TO PERFORM - AI Vision & the Digital Twin of your manufacturing and product life cycle

A. Complexities in Manufacturing – The need for Intelligent Solutions

Manufacturing is said to be the most resourceful sector of the global economy, well-positioned to produce growth and benefits to the entire economy. However, it is also the one that is faced with most challenges in terms of productivity, efficiency, skilled labour, inventory, demand forecasting, data management, data quality and adoption of technology.

Every manufacturing process involves human intelligence at some point in its cycle. In manufacturing systems and processes, there are a number of factors that interact with each other. A single goal is what any industrial facility strives for, which means that all the various components of an operation must work together to achieve that goal.

Environment and uncertainty necessitate that the plant's complexity is kept under control. Complexity can be managed through the application of theories such as chaos and nonlinear dynamics, information theory, or a combination of all.

Some processes are so complex that they cannot be achieved by humans only. Research in these fields is focused on two related topics: Artificial Intelligence (AI) and Machine Learning (ML). Manufacturing processes can be controlled and predicted in the maintenance phase thanks to their use.

Production processes are becoming increasingly digital. As this trend unfolds, many companies often struggle to determine how to drive real value both operationally and strategically. Indeed, digital solutions are promising and delivering significant value for organizations—value that could never have been realized prior to the advent of connected, smart technologies.

One of the critical issues in for a Manufacturing head is in Product Lifecycle management (PLM), which is very time-consuming in terms of efficiency, manufacturing, intelligence, service phases and sustainability in product design. The search for a sustainable solution has been an ongoing one for some time.

Production blind spots, such as machine break down due to faulty parts, are a major source for loss of money, energy and productivity. These are common in companies still dependent on manual monitoring and data collection. Traditionally, as long as machines run, the management is happy. However, there are numerous blind spots that bleed companies of precious resources.

Manufacturers today are seeking a way to transform their business through intelligent factory solutions that will not only provide efficiencies in production and design but also spark innovation and growth.

Identifying the challenges is one thing but taking them head on is another, especially for businesses that are attempting to scale up. As they say, being able to see the iceberg is fine but if your rudder isn't going to be fast enough you will not avoid the collision.

B. Transformation – The road travelled and the road ahead

Technological advancements have in recent years been giving manufacturers several options on how to meet and solve their major challenges. Many organisations, both big and small, have adopted digital technologies to improve processes, empower their work force, create new customer experiences, and to understand their market better.

Industry 4.0

Digital transformation was driven by Industry 4.0, a name given for the trend established for automation and data exchange in manufacturing technologies. It conceptualised rapid change in patterns and processes thanks to better interconnectivity and smart automation. Technologies were increasingly available that could enable manufacturers to connect and extract data even from unconnected legacy systems, and compute and visualize the data for intelligent management.

IIoT

The key component of data-driven digital transformation in the manufacturing world was Industrial Internet of Things (IIoT), which revolved around connecting machines and data management in "smart factories" to achieve improvements in productivity and quality. The manufacturing sector was leader in leveraging this technology that resulted in creating a network of connected machines, systems, devices and humans.

Key benefits from IIoT included improved productivity, predictive maintenance, analytics and the transformation of the workplace.

AI and ML

One of the primary technologies that enabled IIOT was Artificial Intelligence, a technological advancement that ushered in a new era of business in almost all sectors. Several fields of AI and Machine Learning changed the way we look at data in manufacturing plants. One of them is AI-based Vision Intelligence, also known as Computer Vision.

The use of AI and ML algorithms in the capture of visual data helped bring context to an otherwise blunt stream of information. This not only helped machines recognize and segment objects in a photo or a video feed but also prompted necessary action in time.

Manufacturing now sees humans and AI-powered robots working together, and production cycles are quicker. Factories are also able to quickly identify potential maintenance issues before they lead to downtime and many of them are moving to a 24-hour production plant, due to higher security and efficiency. Big data can also now be visually monitored, which enables companies to respond faster to fluctuations in production and demand.

Digital Twin

It is, however, in Product Lifecycle management (PLM) that disruption will be most visible. The digital twin, which is a virtual replica of a real world component or product or process, is set to optimize business performance like never before.

By providing a complete digital footprint of products, the digital twin enables detection of physical issues sooner, predict outcomes more accurately, and build better products. It merges the product's physical and virtual space, and enables companies to have a digital footprint of all of their products, from design to development and throughout the entire product life cycle.

Digital Twin is all set to disrupt industries with manufacturing business, and is now upon us.

C. What's A Digital Twin And How Can It Help?

IBM defines a digital twin as "a virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation, machine learning and reasoning to help decision-making."

By creating a virtual model that is an exact counterpart of a physical object – be it a car or a bridge – you can analyse and test different scenarios to understand not only how a product performs, but how it will perform in the future under different conditions.

The continuous collection and processing of data provides an objective, data-driven design that can be used to accelerate digital transformation across a range of sectors, such as design, manufacturing and even aeronautical engineering.

The digital twin is meant to be an up-to-date and accurate copy of the physical object's properties and state of being, including shape, position, gesture, status and motion. At times it is also referred to as the "**device shadow**"

An example of digital twins is the use of 3D modelling to create digital companions for the physical objects. It can be used to view the status of the actual physical object, which provides a way to project physical objects into the digital world. When sensors collect data from a connected device, the sensor data can be used to update a "digital twin" copy of the device's state in real time.

A digital twin also can be used for monitoring, diagnostics and prognostics to optimize asset performance and utilization. In this field, sensory data can be combined with historical data, human expertise and simulation learning to improve the outcome of prognostics. Therefore, complex prognostics and intelligent maintenance system platforms can use digital twins in finding the root cause of issues and improve productivity.

The physical objects and twin models interact in a mutually beneficial manner as the physical manufacturing objects are virtualized and represented as digital avatars seamlessly and closely integrated in both the physical and cyber space.

A digital twin can be made for not only a physical counterpart but also for a process as well. That is usually termed as a digital process twin. A process twin can be created for the whole manufacturing cycle.

Digital Twin in a manufacturing process

In the manufacturing process, the digital twin is like a virtual replica of the near-time occurrences in the factory. Sensors placed throughout the physical process collect data from different dimensions, such as environmental conditions, behavioural characteristics of the machine and work that is being performed and this data is continuously communicated to and collected by the digital twin.

Digital twins have now become more affordable and could well drive the future of the manufacturing industry. Imagine the benefit for engineers: Virtual-world design by the digital twin, and Real-world usage on the shop floor.

Advanced ways of product and asset maintenance and management come within reach as there is a digital twin of the real 'thing' with real-time capabilities.

Digital twins also offer a great amount of business potential by predicting the future instead of just analysing the past of the manufacturing process. They provide businesses with an unparalleled view of how their products are performing and can help to identify potential faults, troubleshoot from afar, etc. Thus the digital twin enables better sustainability, transparency, reporting, measurement and optimization.

How it is different from traditional computer-aided design (CAD)

The Digital Twin does much more than CAD or a sensor-enabled IoT solution. CAD is completely encapsulated in a computer-simulated environment and is useful in modeling complex environments, whereas IoT systems measure things like position and diagnostics. What the Digital Twin does is interact between components and the full life cycle processes.

The unique power of a digital twin is that it can provide a near-real-time comprehensive linkage between the physical and digital worlds. It is this linkage that yields more realistic measurements of unpredictability. With the huge modern-day processing architectures and advanced algorithms this can lead to real-time predictive feedback and offline analysis. The benefits could well be fundamental design and process changes unattainable earlier.

D. How the real world is breaking new ground with the Digital twin concept?

Digital twins are now proving invaluable across multiple industries, especially those that involve costly or scarce physical objects. They are being used in medicine to replicate and study internal organs. They've propelled engineers to devise car and plane prototypes more quickly. They allow architects and urban planners to envision and then build skyscrapers and city blocks with clarity and precision.

Here are a few examples of how the Digital Twin concept has come to stay.

BMW

There are two versions of a BMW factory in Regensburg, Germany. One is a physical plant that cranks out hundreds of thousands of cars a year. The other is a virtual 3-D replica, in which every surface and every bit of machinery looks exactly the same as in real life. Whatever is happening in the physical factory is reflected inside the virtual one in real time: frames being dipped in paint; doors being sealed onto hinges; avatars of workers carrying machinery to its next destination.

It wasn't just frivolous experiment. Why did BMW spend time and resources to create a digital version of something that already existed in the real world?

Because BMW can now test or tweak parts of the assembly line without having to move around heavy machinery; the company estimates the technology will cut the time it takes to plan out factory operations by at least 25%.

A few months ago, factory managers created their first piece of new equipment inside the digital twin: a machine that puts door seals on a car frame. Earlier, they would have had to draw it and build cardboard simulations, a very time consuming task. With the digital twin we were able to work virtually, test it and have variations of the plan for more or less no money.

Healthcare

Digital twins are today replicating real-world objects ranging in size from millimeters to miles. The medical landscape is now exploring surgical procedures, risks of various drugs and conducting various trials using digital twins, including clinical studies of "cancer patient digital twins” to precisely track a patient’s physical state and adjust treatment accordingly. In Poland, a team of doctors and technologists is starting with one of the smallest objects imaginable: the human fetal heart.

Self Driving

Digital twins are being leveraged to improve the safety of self-driving vehicles. Vast quantities of data collected from real tests of self-driving cars are used to build complex digital-twin simulators. The simulations help predict how a car’s AI will react in surreal situations that could be dangerous and difficult to re-create.

Crucially, digital twins also allow researchers to run crash-test simulations countless times without having to destroy cars or endanger real people. The technology has become vital to the development of self-driving cars.

Smart Cities

City corporations are deploying the technology at an even larger scale, to create digital twins of a township or the city itself. The City twin can eventually be used as a public resource and “backbone infrastructure,” allowing, for example, transportation experts to see how a rail system might impact the region, for utility companies to map out 5G networks and for ecologists to study the potential impacts of climate change.

NASA

NASA was the first to dabble with twinning. As way back as the 1960s (it was then known as pairing technology), the early days of space exploration, NASA created physical replicas of spaceships and connected them to simulators so that if a crisis ensued on the actual vehicle thousands of miles away, a team could work out solutions on the ground.

But it is only now, thanks to enhanced computing power of cloud-based systems, the spread of 5G networks and improvements in 3-D rendering, that usage of digital-twin technology is set to explode.

Why is digital twin technology important?

There will soon be billions of things represented by digital twins, which will lead to new collaboration opportunities among physical world product experts and data scientists. All indications seem to predict we are on the verge of a digital twin technology explosion. More and more companies will learn of success stories and will want to deploy their very own digital twins to gain a competitive advantage.

A top-5 technology trend

Many experts consider it as one of the top 5 technology trends of this decade.
The digital-twin market already generated sales of more than $3 billion in 2020, according to research firms, and tech executives leading digital-twin efforts say we’re still at the dawn of this technology.

Concerns on Privacy and Cyber security

Creating digital replicas at increasingly large scale raises questions about privacy and cyber security. Many of these digital twins are made possible by a multitude of cameras and sensors that track real-time data and movement.

Workers at factories with digital twins may find their every movement followed; the hacker of a digital twin could gain frighteningly precise knowledge about a complex proprietary system.

Legislators and companies need to work together on this.

E. Digital Twin and AI Vision - A Perfect Synergy

Can you make tomato sauce without tomatoes, or a mango milk shake without mangoes? The answer is a simple No. So, how can you create a Digital twin without Computer vision capabilities?

Computer vision is a technology that deals with how computers can gain high-level understanding from digital images or videos such that they are able to automate tasks that the human visual system does. What Computer Vision does for manufacturing companies is give them the power to capture and process visual information in real-time by enabling almost instant feedback regarding the production process.

The Visual Context

From a Digital Twin perspective, Computer Vision or AI-based Vision Intelligence (also known in certain quarters as AI Vision) brings in a crucial context to data, namely vision, without which no digital twin will be entirely accurate. Without computer vision, digital twins will not be able to perform to their full potential.

Deep Learning and Big data have contributed to the accuracy of AI Vision, which in turn has made it a critical ally in developing digital twins. Moreover, as machine learning models enable computers to identify, segment, and categorize images based on the complete picture, **data inflow will also be complete with context**. Digital twins with computer vision capabilities can perform a wide range of tasks more efficiently than digital twins that do not have them.

A digital twin powered by AI Vision will be far more productive than a rule-based expert system. The digital twin will be able to see and interact with real-world objects thanks to computer vision technology.

By transferring images to algorithms and enabling almost instant feedback regarding the production process, AI Vision is able to capture and process visual information in real time, which is absolutely critical for creating the most accurate Digital Twin as possible and help improve it by providing a much better understanding of the product and potential glitches or flaws that can be spotted in normal use in the future.

Today, computer vision use cases are becoming more and more extensive in any modern manufacturing line. The applications are no longer limited to structured, repetitive tasks, but also play an integral part in better understanding of data.

Machine Vision

There, in fact, is a subset of computer vision that is now referred to as Machine Vision (MV), which focuses on the manufacturing sector's needs. Based on cameras, radars, sensors, lights, and software, MV algorithms are capable of detecting deviations like quality defects, and automatically initiating corrective actions. Needless to say, it can process visual information faster than the human eye.

Inseparable

In the modern digital manufacturing process, computer vision use cases and digital twins are inseparable, and both of them play a key role. Computer vision helps in monitoring the entire process and finding potential sources of problems. Digital twins help improve the final product by providing a much better understanding of it.

The advancements in this sector will lead to a more profound collaboration between computer vision and digital twins, allowing them to make significant crossover breakthroughs and succeed in a wide range of use cases in the future.

F. Potential Use Cases in Manufacturing

Digital twins can collaborate with vision intelligence and many other trending technologies such as the internet of things, big data, cloud computing and blockchain to create several use cases for large industries and manufacturing companies. These technologies will not only help to create efficient process and manufacturing simulations but also help them to continuously improve over time.

Computer vision and digital twin technology is a great combination that manufacturing industries can take advantage of as some use cases for vision-enabled digital twins will reveal.

Improving production processes

Digital twins help create a digital version of a product or device, which provides priceless insights about improving operations, increasing efficiency, reducing costs, or discovering issues or glitches before they happen. But it’s more than just a model of the physical object.

Digital twins are supported by cameras and other IoT-enabled sensors so that the twin can receive continuous, real-time data coming from the physical product. Thus, one can literally observe on your dashboard how your products react and behave.

The manufacturing process is today born in the digital world, with all the elements in the sequence of design, production and final product going through a virtual vetting based on digital twinning. This vetting helps to manage in the real-life version the performance, effectiveness, and quality of various assets in the production process

Such an approach that combines computer vision, digital twins and data analytics provides a more detailed view of asset and production management. It allows manufacturers to optimize costs and improve their solutions.

When it comes to digital manufacturing, digital twins are utilized especially in these three areas:

Engineering - Virtual representations and close-up views enables detection of faults in products, machines, and processes in a cost-effective way. Hence, upfront you get a vision of what the ready-made product should be like and how it should work.

Customisation – No longer is it necessary for market feedback to force changes in a manufacturing process. With digital twin technology, it's easy to customize the existing product and at virtually zero cost, and with lowest turnaround time. It also gives you an option to understand from customer usage data from how custom configurations affect sales performance.

Operations - Manufacturers can now get a thorough picture of the production performance in the real environment well in advance so that they are able to improve the product or asset, and identify potential glitches before they happen. The technology helps to first create a virtual representation of the product, and it then gather data from it. And the best part is that you just need a prototype and IoT sensors that will make it accessible to build its digital twin.

Product Life Cycle

An interesting case study of a Product-based application, from development of idea to development of product to use, is seen in an industrial manufacturer's successful attempt to solve vexing field issues by adoption of the digital twin.

The quality issues were causing high warranty liabilities and maintenance costs, as well as creating stress on the supply network, customer confidence and brand image.

A digital twin approach was adopted to address the identified problem. The original design-stage BOM (development elements) was combined with information produced from manufacturing-stage BOM (procured parts and assembly details). These results allowed engineers to run analytics and provide insights in production variation that impacted quality. As a result, the team delivered unexpected insights to improve the assembly process.

The digital twin effort was continued in the field with the after-sales department leveraging the digital twin process. It added the field product maintenance BOM to the other two BOMs to create a digital journey covering the full product cycle.

The end result was the opening up of a new era of business opportunity, including asset availability management, spare parts inventory optimization, predictive maintenance, and superior customer service.

Driving Business Value through strategic performance

Investing in a digital twin have changed the way many companies conduct business and helped them to achieve measurable business values, such as longer-lasting product performance, faster design cycles, potential for new revenue streams, and better warranty cost management.

Twinning has contributed significantly to business value in these strategic areas:

Quality – Detecting, controlling and predicting trends
Service – Warranty and service costs, Customer experiences
Operations – Product design and engineering changes, equipment performance
Record – Serialisation and digital tracking of parts and raw materials
Market – Reduced time to market, cost and impact on supply chain
Revenue growth – Product upgrades, market dynamics

G. How does Twinning work?

Digital twins are designed to model complicated assets or processes that interact in many ways with their environments for which it is difficult to predict outcomes over an entire product life cycle.

The fundamental functions of Digital twins are:

- **Watch -** Keep an eye on the environment by collecting data from sensors and gadgets and using that data to show the current status.
- **Process -** Alter operational settings in order to discover the optimal asset or process using what-if simulations to assess and report the current state of the equipment.
- **Perform -** Learn from the collected data, recognize problems, find several possible solutions to each problem, and to select the best one.

The degree of complexity of a digital twin can vary based on the demands and volume of data processed. It is necessary to decide whether your digital twin will simply monitor your prototype or whether it will use advanced data analytics to alert you of anomalies and suggest solutions when creating a digital twin.

A journey of Interactivity

Digital twinning of a manufacturing process best explains how it works. It is essentially a journey between the physical and digital worlds. The digital twin serves as a virtual replica of what is actually happening on the factory floor in near-real time. The solution consists of:

- **Data capture**

  Cameras and other sensors collectively capture data ranging from behavioral characteristics of the productive machinery and works in progress to environmental conditions within the factory itself. These data are continuously communicated to and aggregated by the digital twin application.

- **Data analysis**

  The software application continuously analyzes incoming data streams. Over a period of time, the analysis may uncover unacceptable trends in the actual performance of the manufacturing process in a particular dimension when compared with an ideal range of tolerable performance.

- **Process optimisation**

  The comparative insight and real-time analysis provided by the digital platform receiving the streamed information trigger investigation and a potential optimisation of a portion of the process or the complete process in a transparent manner.

Enablers of a Digital Twin application

The basic enabling elements of a Digital Twin can be listed as below:

- **Sensors—**Sensors create signals that enable the twin to capture operational and environmental data pertaining to the physical process in the real world.
- **Data—** Operational and environmental data from the sensors are aggregated with enterprise data such as the bill of materials, engineering drawings, design specifications or customer complaint logs.
- **Integration—**Sensors communicate the data between the physical world and the digital world, and vice versa through integration technology and network communication.
- **Analytics—** Insights are generated through visualization routines, algorithmic simulations and other analytics techniques.
- **Digital twin—**The digital twin itself is the application that combines the above components into a near-real-time digital model of the physical world and process. It basically identifies intolerable deviations from optimal conditions along any of the specified dimensions. And prompts an action back in the physical world if it is warranted. This the digital twin does by way of actuators, subject to human intervention.

Creation of the Digital Twin

It is basically a two-stage activity:

1. Designing the twinning processes and information requirements in the product life cycle—from the design of the asset to field use and maintenance of the asset in the real world

2. Integrating the physical asset and its digital twin for real-time flow of sensor data and operational and transactional information from the company's core systems.

   The focus while creating a Digital Twin has to be on the kinds of information that will be required across the asset's life cycle, and how to structure it such that it can be reused. The data model should enable different systems and applications to connect and exchange information and get updated. Hence, it is the data structure that is a focal element of a digital twin, which can give it flexibility, scalability and ease of use.

H. How to get started?

Understand the benefits of Digital Twin

Companies look at realizing significant value and benefits out of creation of the digital twin. Some or all of these benefits may well be critical for you.

- Speed to market with a new product
- Design and build a better product
- Improved processes and operations
- Lower physical defects
- Predict outcomes more accurately and faster
- Emerging new business models to drive revenue

It is a top management decision whether your enterprise should adopt the technology. Once that decision is taken and the organization appreciates the value it can add, it necessarily has to get well prepared for this journey.

List your top 3 problems

Make a list of the top three problems you would like to gain insight into. That will help you decide which of the following types of digital twin solution meets your requirements:

- Parts Twinning – Use of a digital twin to create virtual representations of parts or components of an item.
- Product Twining –Creating virtual representations of a product for evaluation and innovative reasons.
- System and Process Twining –Creation of virtual representations of processes and systems within a facility.

Prepare for it well

It will be too overwhelming for a company to try and derive all the benefits in one go. The key is to start in one area, deliver value there, and continue to develop. Understand first the definition, the approach and the way a digital twin can be created to drive value.

Decide on the priorities on the application areas of digital twin – Product, Production, and Performance or if a combination of these three digital twins (called as the digital thread) is what is required. The decision will largely depend on the company's ability to bring together data collected from various stages of the production life cycle.

Bring your stakeholders on board, and convince them of the benefits of a Digital twin. If the convincing is done properly, you will probably be able to select the solution with cutting-edge features rather than just the most affordable one.

Document your design process and establish your data sources. Since a digital twin requires data that best represents the real-world item or process, the data must cover the lifecycle of a product and include design specifications, production processes or engineering information.

Over-use of technology is one pitfall to be avoided. It is quite likely that some rule-based processes are best with fixed algorithms. Application of artificial intelligence may not be required in these types of digital counterparts.

During the initial pilot stage it is also common to find the digital twin "misbehaving". Creating a feedback loop to correct itself over time is a prime necessity.

Digital Twinning is a continuing research topic. Conduct extensive research on your unique use case prior to developing a digital twin.

Requirements

The Digital Twin is a powerful and compelling application. It is a journey of interactivity between the digital and physical world, and may involve a massive number of cameras and other sensors.

The most demanding requirement for implementing a digital twin is the infrastructure to handle the massive amounts of data it processes and the associated computing, bandwidth and storage costs. Unlike limitations in digital capabilities in the past which caused the technology to remain elusive to most enterprises, the costs and new capabilities in communications & information technology and handling of data have eased the entry barrier to using digital twins a great deal.

A digital twin thrives on data. In an ideal environment, data capturing digital transformation technologies should be in place before implementing a digital twin. The more data that can be captured from your shop floor the more accurate its digital twin will be.

Compatibility is a key factor in selecting the solution. The digital twin software must be capable of integrating the data within your ERP software, IoT platforms etc. to create accurate representations.

Choose the right vendor

The Digital Twin solutions provider should ideally have expertise in connecting assets like IoT devices and existing business systems, as well as designing digital models and knowledge graphs using AI algorithms, particularly in Vision Intelligence algorithms.

Most importantly also, the vendor should be one who can devote time and attention to make a Needs report and provide consultancy before, during and after the project.

Do not rush into selecting the solution or the vendor. Ask potential vendors for demos. Let them utilise historical data at your facility. Short list vendors and ask them to forecast the RoI that can be expected. Choose the vendor and solution you think can lead to a leaner manufacturing process, can integrate AI and can reduce the time needed for running simulations. At the end of it all, revenue growth should be the goal.

About Cogniphi

Cogniphi is a technology company that enables customers to achieve transformational outcomes through cognitive digital solutions. Cogniphi's AI Vision is a proprietary technology framework that's built to provide organizations with actionable alerts on the go along with insights into productivity and operational inefficiencies.

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