

Digital Manufacturing (Industry 4.0)

“The early adopters of Industry 4.0 report stronger ability to respond to the COVID-19 crisis”

McKinsey
& Company



Digital manufacturing is the application of computer systems to manufacturing services, supply chains, products and processes. Digital manufacturing technologies link systems and processes across all areas of production to create an integrated approach to manufacturing, from design to production and on to the servicing of the final products.



The Three Aspects of Digital Manufacturing

It can be broken down into three main areas; product life cycle, smart factory, and value chain management.

Each of these relates to a different aspect of manufacturing execution, from design and product innovation to the enhancement of production lines and the optimisation of resources for better products and customer satisfaction.

The product life cycle begins with engineering design before moving on to encompass sourcing, production and service life. Each step uses digital data to allow for revisions to design specifications during the manufacturing process.

The smart factory involves the use of smart machines, sensors and tooling to provide real time feedback about the processes and manufacturing technology. By uniting operations technology and information technology, this digital transformation allows for greater visibility of factory processes, control, and optimisation to improve performance.

The value chain management focuses on reducing resources to create an optimal process with decreased inventories while maintaining product quality and customer satisfaction.

What are the Advantages of Digital Manufacturing?

There are a number of benefits by uniting manufacturing processes across different departments while reducing the potential for errors by creating an automated exchange of data.



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Increased efficiency is accomplished by a **joined-up manufacturing process which eliminates errors** due to lost or misinterpreted data which is common for paper-based processes.

With a **quicker turnaround across all levels of the value chain**, digital manufacturing offers reduced costs, while allowing for design changes to be implemented in real time and also lowering maintenance costs.

The **real-time manufacturing visibility** afforded by digital technologies provides improved insights for critical decisions and a faster pace of innovation.

Furthermore, it allows an entire manufacturing process to be created virtually so that **designers can test the process before investing time and money** into the physical implementation.

Cloud-based manufacturing can be used for this modelling, taking open access information from a number of sources to develop reconfigurable production lines and thereby improve efficiency.

Industry 4.0 Fundamentals

Since the first Industrial revolution, many engineers attempted to resolve problems related to operations, machinery and their maintenance, by doing so, they tried to improve the efficiency of production processes. Decades ago, due to the introduction of computers and computational methods, a new wave of solution to manufacturing related problems emerged, those provided solutions were more accurate therefore a significant boost was given to the Industries worldwide. By 2050 The Globe's population is destined to reach 9.3 Billion and



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different challenges and issues are adding pressure on the current industry supply chains like transport, deadlines, cost, quality etc; the term Industry 4.0, the Fourth Industrial Revolution originally initiated in Germany, has proven to be an attractive topic in recent literatures, A new era of change birthed and it is directly linked to the Internet of Things, Cyber Physical System, Information and Communications Technologies. As the fourth industrial revolution shapes up, human operators are at the center of the change, they experience a complexity increase in their daily routines, and they are required to be highly flexible and to adapt to a very dynamic working environment. The paper discuss the term Industry 4.0, its context, raison dater, challenges and highlight the critical issue of the employees' driven adaptability and attitudes to change.

Electronics and Mechatronics

Mechatronics is the convergence of mechanical engineering with electronics and electrical circuits, plus control and software engineering. Some people also add telecommunications to the fields that mechatronics encompasses.

Jim Devaprasad, a professor in the engineering and technology school at Lake Superior State University, broadened his mechatronics definition to include a manufacturing element. He also pointed out that mechatronics is what people once termed "systems engineering."

Although mechatronics began as the study of mechanical and electrical interactions, it has since changed. Mechatronics now involves studying how those electromechanical happenings affect other equipment. Some of that equipment relates to industrial automation, such as robots.



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Professionals who study mechatronics often build the automated systems that manufacturing plants increasingly use. But a mechatronics system is not necessarily specific to industrial automation. For example, if a digital thermostat has a feedback sensor and a microprocessor, it's a mechatronics system. But that thermostat may not have any automated elements — and digital thermostats are not solely associated with industrial automation.

During the design process of a system or product, mechatronics professionals prioritize system-based thinking and interdisciplinary problem-solving. System-based thinking means that a person takes a holistic view to understand how each part relates to another and affects the system as a whole. The interdisciplinary aspect indicates that people who specialize in mechatronics can anticipate working with people from different fields to collaborate for the best results.



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IoT and Digital Twin



A digital twin is the digital proxy of a physical asset or device. A digital twin can help you successfully deploy and use an IoT application.

A digital twin may also be called a twin or a shadow. Digital twin technology may be referred to as device virtualization and can be implemented in differing ways.

About Implementing the Framework



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On an IoT platform, a digital twin is a virtual representation of a physical asset, a machine, a vehicle, or a device. It digitally represents the data, processes, operation states, and lifecycle of the asset.

Implementing IoT with digital twin capabilities in a factory, an airport, or a machine plant enables:

- **Better visibility:** You can continually view the operations of the machines or devices, and the status of their interconnected systems.
- **Accurate prediction:** You can retrieve the future state of the machines from the digital twin model by using modeling.
- **What-if analysis:** You can easily interact with the model to simulate unique machine conditions and perform what-if analysis using well-designed interfaces.
- **Documentation and communication:** You can use the digital twin model to help you understand, document, and explain the behavior of a specific machine or a collection of machines.
- **Integration of disparate systems:** You can connect with back-end applications related to supply chain operations such as manufacturing, procurement, warehousing, transportation, or logistics.

The digital twin capabilities of an IoT platform depend on its design and implementation. Typically, you can implement a digital twin framework in two ways:

- **Simple device models:** In this method, you create and use a JSON document that stores the following information about a machine:
 - Name, serial number, and location



- A set of observed attributes that the machine's sensors observe (for example, the current speed of the machine)
- A set of desired attributes that the IoT application can set (for example, the desired speed of the machine)

In this method, you use the attributes of the machines that its sensors capture. This method works best in situations where the sensors may not be continually available, or when communication with the sensors takes place asynchronously.

- **Industrial twins:** This method presents information about the design of a machine and model of a sensor device. The information represents the physics-based properties of the machine.

This method works well with industrial IoT applications that obtain the required information from product lifecycle management (PLM) tools. In this type of implementation, you can represent the physical attributes, design information, and the real-time data of a machine in an asset-versus-model graph.

Robotics and Autonomous Systems





Robots and autonomous systems are revolutionising production worldwide, and robots and essentially autonomous support systems are taking a foothold in households.

If you want to be more than just an onlooker of how the world is transforming all around us, then this is the place. Accept responsibility and help shape our future!

Robots are evolving from stationary devices that perform manufacturing tasks to mobile, information gathering, computing, and decision making platforms. The autonomous vehicles participating in the DARPA Grand Challenges highlighted the significant progress that has been made in this area and the enormous work that remains to be done. At the University of Michigan, we are exploring the feedback control principles of bipedal robotic locomotion, with the goal of endowing machines with the ability to walk on two legs with the agility of a human. We also use artificial intelligence techniques for dealing with planning and uncertainty, localization and mapping, sensor processing and classification, and continuous learning.

Specialties

- Bipedal Robot Locomotion
- Field Robotics
- Human-Robot Interaction
- Mobile Manipulation
- Prosthetics and Exoskeletons



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Design for Additive Manufacturing

Design for Additive Manufacturing (DfAM) is the art, science and skill to design for manufacturability using 3D printers. Different from traditional manufacturing, this additive design process empowers engineers to create more intricate shapes and production parts while reducing weight and material consumption. It's a complete reversal of the conventional ways of thinking about design.

Digital Manufacturing

Digital manufacturing can be defined as an integrated approach to manufacturing that is centered around a computer system. A machine is able to read a CAD (computer aided design) file in order to deliver it in a few hours. Within the same process, it is possible to prototype, produce and fabricate Molds to aid production.

When consumers' habits and expectations are evolving, it is necessary that we find a new production mode. Within the Factory of the Future, Digital manufacturing appears as an answer to this evolution. It allows an iterative production, beneficial to meet consumer's demand. Quicker and producing high-quality prototypes, digital manufacturing enhances productivity. It allows real-time inventory monitoring which allows companies to master their whole production line and intervene when it is necessary to adapt the product to the changing market.



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AI, ML Analytics

There are transformative technologies in the world today with consistent effect and reliability in their promise to alter or change the ecosystem. Industries have transformed, and early adopters with it, while others race to understand how best to adapt or integrate said emerging technologies into their organizations in an effective and seamless manner.

Among those, artificial intelligence is far from being a new concept. As a technology, it's been with us for a while now, but things have changed. We look at cloud-based service options, the applicability of AI on several critical organizational functions, and the power of computing, among many others.

In fact, AI's impact on several industries is predicted to grow quite rapidly and is expected to be in the high billions by 2025. AI or artificial intelligence is a buzzword, but organizations continue to struggle with their digital transformation to become data-driven. What's the challenge, and how can it be solved?

The thing is, businesses are embedding AI solutions into their business portfolio, but face issues in the form of cost, privacy, security, integration, and even regulatory forms. But could analytics play a role in the acceleration of the onboarding of AI in enterprises. After all, enterprises that have deployed analytics are two times as likely to receive senior management buy-in for AI adoption.

While many believe AI to be part of a big digital revolution, analytics rank as a part of the evolution that could lead to successful AI implementation. For example, machine learning models are most effectively trained on huge datasets. Similarly, in an organization that is analytically aware, more specifically



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those that deal with data integration and preparation, data wrangling, and more, AI is a natural progression.

Artificial intelligence, in a way, is a straightforward transition for those organizations with a mature analytics system. Research even suggests that global technology leaders that are most successful with adopting AI-based technologies often incorporate a data strategy into their core business functionalities – APIs, interfaces, and more.

An enterprise-wide policy on data standards is one method to streamline analytics and the machine learning practice. Furthermore, maintaining said data policy could help identify stakeholders and in monitoring enterprise-wide access and strategy, resulting also in the reduction of employee confusion.

AI Matures Over Time with Analytics

Artificial intelligence and machine learning function towards maturity over a period depending on the data and quality of said data. This speaks to specific organizations' investment in data warehouses or data storage, as a part of the process of aligning assets for AI implementation. After all, data quality is a direct measure for the quality of data predictions.

In time, we are likely to witness companies focus on solving the challenge of acquiring and maintaining accurate data for AI to live up to its promise of a data and business revolution. At the same time, it is also important to understand that penetration and maturity aren't always associated with a positive correlation. For instance, even with the deepest analytics penetration of all sectors, e-Commerce is known to hold the lowest maturity.



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AR/VR/MR/Haptics

Haptics for VR/AR/MR includes the perceptions of touch and all the technologies to recreate digital touch sensations. There are a lot and not all of them are useful for XR use cases. Haptics for extended reality can enhance your XR experience if it is used properly.

If done right, haptics for extended reality can increase user engagement and immersion, as well as the sense of presence. It can also decrease user fatigue and dizziness caused by an imbalance of perceptions between reality and virtual world. It impacts positively effectiveness, for example for XR training.

To be more practical, we can illustrate the theory with use cases of haptics for VR/AR/MR. There are five generic ones:

- User interface feedback and confirmation
- User immersion
- Remote presence
- User awareness
- Notifications

About UI confirmation, we can take the example of buttons, or keyboards in real life. They give a touch feedback as a confirmation to the user after the interaction. Therefore, by integrating haptics for extended reality, this feedback can be reproduced, and therefore, enhance the UX.



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Additive Manufacturing



It is yet, another technological advancement made possible by the transition from analog to digital processes. In recent decades, communications, imaging, architecture and engineering have all undergone their own digital revolutions. Now, AM can bring digital flexibility and efficiency to manufacturing operations.

Additive manufacturing uses data computer-aided-design (CAD) software or 3D object scanners to direct hardware to deposit material, layer upon layer, in precise geometric shapes. As its name implies, additive manufacturing adds



material to create an object. By contrast, when you create an object by traditional means, it is often necessary to remove material through milling, machining, carving, shaping or other means.

Although the terms "3D printing" and "rapid prototyping" are casually used to discuss additive manufacturing, each process is actually a subset of additive manufacturing.

While additive manufacturing seems new to many, it has actually been around for several decades. In the right applications, additive manufacturing delivers a perfect trifecta of improved performance, complex geometries and simplified fabrication. As a result, opportunities abound for those who actively embrace additive manufacturing.

Cybersecurity

Digital manufacturing aims to create highly customizable products with higher quality and lower costs by integrating Industrial Internet of Things, big data analytics, cloud computing, and advanced robots into manufacturing plants. As manufacturing machines are increasingly retrofitted with sensors as well as connected via wireless networks or wired Ethernet, digital manufacturing systems are becoming more accessible than ever. While advancement in sensing, artificial intelligence, and wireless technologies enables a paradigm shift in manufacturing, cyber-attacks pose significant threats to the manufacturing sector. This paper presents a review of cybersecurity in digital manufacturing systems from system characterization, threat and vulnerability identification, control, and risk determination aspects as well as identifies challenges and future work.



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