# The Technological Change of Intelligent Manufacturing based on the Metaverse

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**Abstract.** To achieve international competitiveness, it is necessary to improve product quality, production capacity and seize market opportunities that increasing the production level of intelligence is the crucial method for the manufacturing enterprise. However, due to inadequate understanding of the conception and principles of emerging technology, the exact methods and application are difficult to meet the requirements. Therefore, in this paper we normalize the infrastructure of the metaverse and discuss the based techniques and methods as the supplementary for intelligent manufacturing which brings the more possibilities and application perspectives of manufacturing industries in future.

**Keywords*:*** Metaverse, Intelligent Manufacturing, Digital Twin, Extended Reality.

## 1 Introduction

As the market become more competitive, the need for increasing the level of manufacturing industry is more urgent to enhance international competitiveness. Currently, with the development of Mobile Internet, Internet of Things, Big Data, Cloud Computing, Blockchain, Extended Reality and Artificial Intelligence, the manufacturing industry is changing from traditional type to the intellectualized one, which is the key way to increase the productivity and improve the product quality and promote competitiveness around the world [1].

Metaverse is one of the most popular technologies to which much attention is paid at current time. Despite the short time, the conceptual framework of the metaverse suggests that the basic version could be supported by existing technology architecture. The metaverse is a collective virtual shared space, created by the convergence of virtually enhanced physical reality and physically persistent virtual space, including the sum of all virtual worlds, augmented reality, and the internet. In 1992, the metaverse was first proposed in the science fiction novel Snow Crash written by a science-fiction writer Neal Stephenson that is a persistent, immersive 3D virtual environment space copying the real world. The Acceleration Studies Foundation published Metaverse Roadmap in 2007, in which the definition and characteristics of the metaverse have been discussed


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[2]. In July 2007, at the 81st MPEG Meeting in Lausanne, Switzerland, Korea submitted a case proposal to the MPEG Working Group (ISO/IEC JTC 1/SC 29/WG 11) and the metaverse is the first foray into international standardization [3]. In the same year, the first monograph on the metaverse was published [4]. In 2013, Dionisio et al. surveyed the status of computing as it applies to 3D virtual spaces and outlines what is needed to move from a set of independent virtual worlds to the metaverse that constitutes a compelling alternative realm for human sociocultural interaction [5].

In this paper, we would discuss the technological revolution of Intelligent Manufacturing based on the metaverse as well as the corresponding application scenarios. Firstly, the conception of the metaverse has been defined in order to clarify the metaverse objectives and goals. Secondly, this paper introduces the infrastructure of metaverse. At last, based on the common feature as well as the based techniques of metaverse, the application perspectives and the detailed usage scenarios of metaverse in intelligent manufacturing are described and discussed. Based on the research and discussion, the normalized infrastructure of the metaverse and application schema would be brought to the field of the intelligent manufacturing.

## 2 Conception of Metaverse

By the widely discussion of the metaverse in various fields at the leading edge of technological development, the metaverse plays a critical role in design, production, test activities and acceptance check in the field of manufacturing.

As to the implication of the metaverse, it first entered the game entertainment field closely related to the public life, through the serious investment in the scientific research and the commercial operation. Nevertheless, its concept has been in the process of continuous evolution with various opinions emerging in an endless stream, but there is not the authoritative unified definition.

There are several typical application scenarios of metaverse mainly focus on social communication, game and shopping. For the purposes of this article, the definition in the metaverse will be aimed at intelligent manufacturing. In other words, the metaverse in this paper would be discussed in the background of the technological development of manufacturing industry. Therefore, our attention will be specifically directed to the following features that are considered central components of the metaverse.

Realism: The virtual space should be sufficiently realistic to enable users to feel psychologically and emotionally immersed in the alternative realm.

Interoperability: There should be a real-time connection and dynamic interaction between the virtual space and corresponding physical entity, just like digital twin. From virtual characters and real individuals, to the group organization of the two worlds, they all need to be connected, influenced and co-evolved.

Regularity: The virtual space raises the need for the rules and systems for check the interaction between the digital objects and keeps the balance and survival of the virtual world.

## 3 Based Infrastructure of Metaverse

Due to the early stages of the development currently, the architecture of the metaverse does not have a consistent definition. For instance, Jon Radoff carried out a seven-layer metaverse architecture, where the layers from bottom to top are: infrastructure, human interface, decentralization, spatial computing, creator economy, discovery, and experience, which is built from an industrial division [6,7].

In order to improve the applicability, we intend to conclude and simplify the architecture from a more macro perspective, as shown in Fig. 1. Combined with the features of the metaverse (Sec 2), we could include the three-module architecture: Interactive model, Regulation model and Environment model. Interactive model is the link between the real and digital world, which is the infrastructure layer. Regulation model is the computation, communication and storage and keep the healthy operation of the virtual world. At last, the environment is a breathing and parallel living world that continuously serves users. Moreover, the real space is composed of Regulation Model that represents the relationship over entities as well as Environment Model that contains entities. The intersection region between Interactive Model and Regulation Model shows the contact between the virtual world and the real world on the domain of Network of relationships. Similarly, the intersection site between Interactive Model and Environment Model shows the linkage between the individual in real world and the reflection in virtual world.

In conclusion, Interactive model, Regulation model and Environment model interact in the metaverse that are the based infrastructure.

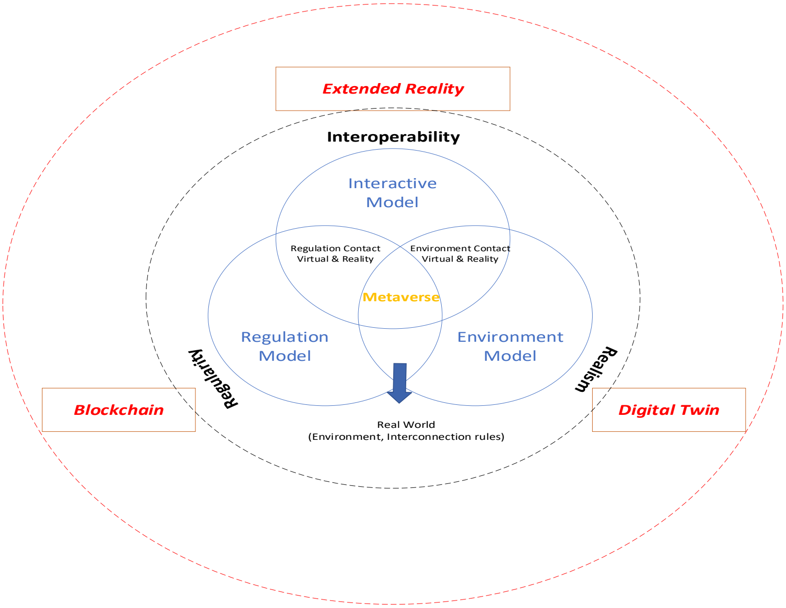


**Fig. 1.** Based Infrastructure of Metaverse

# 4 Discussion of Based Techniques and Methods

## 4.1 Digital Twin

Digital twin is to establish the dynamic twinning of the real world in virtual space that the mapping results are achieved by sensors. For the metaverse, digital twin is the basics of the virtual simulation environment which could cover the Environment Model in the based infrastructure of the metaverse to satisfy the realism characteristic.

In terms of the basic features, there are many common points between digital twin and metaverse: simulated, synchronous and systematic. However, except for the virtual environment, the metaverse is more complex that could operate and judge. Hence, the necessary technologies in metaverse should be aspired to more than digital twin.

## 4.2 Extended Reality

To establish the interactions between users and the metaverse, there are two main components to achieve an immersive user experience, Firstly, the metaverse need to receive the service data from the physical individuals to control the avatars to finish corresponding actions. Second the physical individuals need the feedback information. Hence, the real-time 3D rendering-related technologies like VR/AR are regarded as the main interaction interface, which is consistent with the Interactive Model in the based infrastructure of the metaverse.

Extended Reality (XR) includes virtual reality (VR), augmented reality (AR) and mixed reality (MR). The areas where most industries apply AR is within remote guidance and complex tasks such as maintenance. VR is mostly used for layout planning and more and more for virtual training [8]. In detail, Virtual reality refers to the simulation development of immersive virtual environment to achieve the model display, scene simulation, etc. Augmented reality is used to achieve the enhanced the display of virtual information based on the real world and the help of computer vision and other technologies. Mixed reality is a reality-virtual interactive design based on spatial computing and artificial intelligence (AI), which contributes to the digital twin. At present, XR is commonly used in combination with the AI technology to achieve real-time virtual and real interaction based on artificial intelligence (AI) algorithm with Internet of Things, sensor, and natural language processing (NLP), etc. For example, holographic calls, one kind of real-time interaction, are carried out based on the data acquisition obtained from sensors and Internet of Things, as well as the motion capture acquired from sensors and NLP.

## 4.3 Blockchain

The expectation for the metaverse is that could connect every entity and complex network in the real world, so there is an enormous amount of data, such as maps, roles, etc. In a narrow sense, a blockchain is a chained data structure that combines blocks of data in chronological order and uses cryptography to ensure that they cannot be tampered with or forged[9]. In a broad sense, it has the several functions: verifying and storing data by block chain data structure, updating data based on distributed node consensus algorithm, ensuring data transmission security by means of cryptography, manipulating data through the intelligent contract composed of automatic script code [10]. Based on the above analysis, blockchain is the authentication mechanism which brought the stabilization and efficient to the metaverse, corresponding to the Regulation Model in the based infrastructure. Generally speaking, blockchain could bring the regulation contact between the real world and the virtual world to build the rules in the metaverse.

## 5 Application Perspectives of Metaverse in the Intelligent Manufacturing

For further clarification about the metaverse used in the intelligent manufacturing, we need to dig the application perspectives of the based Infrastructure of metaverse.

As to the current state of development in the field of the intelligent manufacturing, the existing technologies only execute a mono-direction mapping from input data space of the real world to recognition result space in the virtual world [12]. In other words, it is difficult to map the processes and results in the virtual world to the real world. In addition, this mapping has strong time and secrecy higher. However, with the development of science and technology, there would be more complex application scenarios and requirements. So we need to introduce the metaverse to the intelligent manufacturing.

The metaverse and intelligent manufacturing are combined to form a virtual production line outside the real production line. Digital twin is used to simulate the production line process through the quality data, to predict the product quality and evaluate the value of manual intervention in the production process. Under the circumstances, blockchain can be used to manage the relationship between nodes and data. We could introduce blockchain technology into the management of manufacturing and form a distributed and supervised registration network of products. The introduction of blockchain technology can build an unbreakable complete control system, and further improve the security, convenience, and credibility of product production management. The users could use the XR technology to interact with virtual production line to control the process of production and get the result of human intervention in the automatic line.

With the integration of the metaverse and the intelligent manufacturing industry, more usage scenarios can be carried out to contribute to the quality guarantee, productivity improvement and iterative improvement, just like the virtual maintenance training, aided production and maintenance, production line roaming system and failure diagnosis. Namely, the application perspectives of Metaverse in the intelligent manufacturing cover the whole life cycle of industrial production as shown in Fig 2.

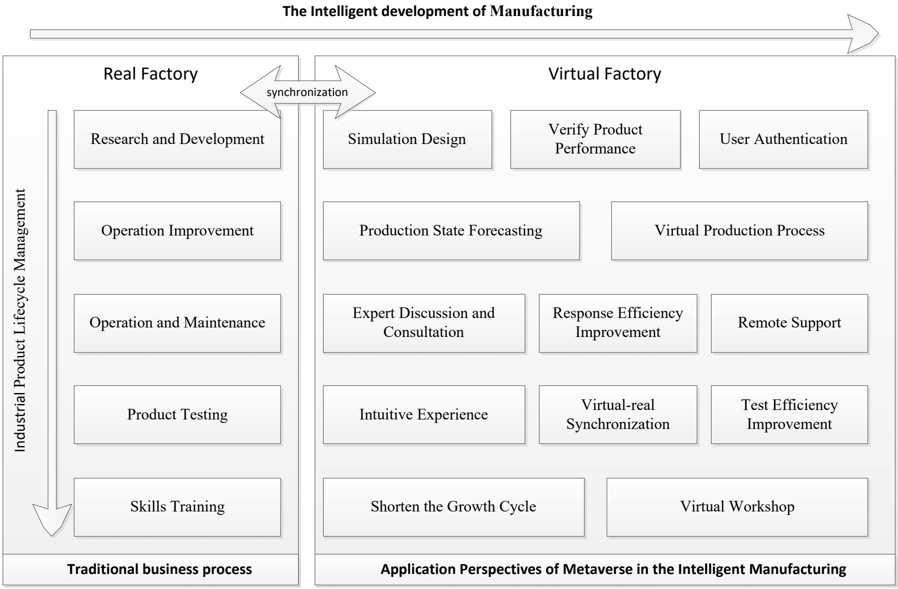


**Fig. 2.** The intelligent development of Manufacturing based on Metaverse

### 5.1 Research and Development

Compared with the current industrial software for product design, the research and development under the application of industrial metaverse would improve the efficiency and reduce the cost of product development to a greater extent. In terms of the product design, the industrial metaverse can control the environmental factors of product application and make intuitive and accurate simulation of the various parts in the product designed in the industrial metaverse, which can effectively verify product performance. As for the collaborative design, the industrial metaverse can break regional restrictions and support multi-party collaborative design, and users can also participate in product design and experience the products designed in the virtual environment. With regard to the user experience, the product development based on the metaverse is closer to the user needs through the deep participation of users.

### 5.2 Operation Improvement

Through the industrial metaverse, we can immerse ourselves in the construction and operation process of the virtual factory, conduct the real-time interaction between the equipment and production lines, and optimize the production process and carry out intelligent production scheduling more intuitively and conveniently. In the early stage of construction, the metaverse and intelligent manufacturing can be used to build a virtual factory that is consistent with the building structure, production line layout, production process and equipment structure of the real factory, so as to realize the rationality of capacity configuration, equipment structure and personnel movement line in advance. In other words, any change in the operation improvement of the real factory can be simulated in the virtual factory to predict the production state and optimize the production process.

### 5.3 Operation and Maintenance

Compared with the current predictive maintenance based on the big data analysis, the operation and maintenance based on the metaverse can break the space limit and effectively improve the response efficiency and service quality of equipment operation and maintenance. In the virtual space established by the industrial metaverse technology, the operation and maintenance staff would be free from the geographical restrictions to realize the remote real-time confirmation of equipment conditions and timely repair of problems. For difficult and complex problems, experts all over the world can be gathered in the industrial virtual factory to discuss the technical solutions and improve production efficiency.

### 5.4 Product Testing

For products with high standards and complex testing requirements, the industrial metaverse can provide a virtual environment for validation and testing. Through the combination of the physical and virtual space to achieve synchronous testing, tester could get the more perceptual intuition of product internal and external changes, improve the efficiency and accuracy of test certification. The industrial metaverse can provide virtual testing space for products. Moreover engineers can test and experience the products with a lower cost to improve the efficiency of product testing and certification.

### 5.5 Skills Training

In terms of the virtual maintenance training, the metaverse would shorten the period of cycle in talent cultivation as well as the after-sales service. For example, under the background of metaverse, one enterprise could adequately train staff through the virtual workshop rather than the words in the books or the images in the videos [11]. Besides, the evaluation of the training could be presented directly and visually that all the results of the operations can be presented in the virtual environment. The method not only can bring the efficient, low-cost and high-quality training, but also can create the quick and effective products training. For a buyer, excellent product training is as important as the product. The metaverse can take an assisted learning way that realized diagnosis, knowledge acquisition, maintains management and learning assistant by friendly interface, which satisfied maintain personnel in different level.

## 6 Discussion

Digital twin is one of the hottest technologies to be used in the intelligent manufacturing field. In terms of the comparison between digital twin and metaverse in the intelligent manufacturing, the similarity and difference between them are instructive contributing to the inherited development. In detail, as to a manufacturing enterprise, promoting sustainable development and savings in developing costs are the significance factors in the development planning and design. The common points are the virtual scene and cooperativity between the real individual and the agent. However, the fuzzy boundaries between the real and virtual world would be appeared in metaverse, and the more regularity would control the agent just as the individual under the real-world rule. Along with the introduction of XR in metaverse, the artificial interaction would bring the direct interference from the real person to the virtual mechanical device.

Given a scenario of metaverse, the status and condition of production line would be brought to the administrator just as the status with the help of digital twin. Nevertheless, without the sensor, the virtual world would shut down under digital twin and it would remain in operation in metaverse. Therefore, in metaverse, the real world and virtual world are both connected and independent.

In conclusion, digital twin is used to help an enterprise improve the level of industrial intelligence, and the metaverse could bring the social interaction not only between people but also between organizations. The former is just to promote production and the latter is based on the former achievement to achieve the communication and extension.

## 7 Conclusions

Based on the in-depth analysis of the development and technological base of metaverse, this paper analyzes and summarizes the conception and the features of the metaverse in the three-module architecture: Interactive model, Regulation model and Environment model corresponding to the central components of the metaverse. Additional, based on the discussion of the based techniques and methods, the more application perspectives would be used in the field of intelligent manufacturing in order to improve product quality, production capacity and seize market opportunities. Through the discussion the existing technology and the metaverse, more usage scenario can be taken to the enterprise and the product user that bring the all-round development in the intelligent manufacturing.

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