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Optimal Digital Twin Model-based CPS (Cyber Physical System) Design for Smart Factory

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Abstract: Recently, with the development of the Internet of Things and Artificial Intelligence technology, research and application cases that collect and analyze data in real-time in various fields such as manufacturing and smart city to optimize for real-world problems are increasing. Representatively, a virtual physical system or digital twin technology that supports real-time synchronization in both directions with the virtual world digitized from the real world is attracting attention. In this paper, we intend to design a system that defines a digital twin, operates with the same functions as real-world objects in a virtual environment and maintains and manages state information to compose virtual digital twin objects that are visible to users.

Keywords: CPS (Cyber Physical System), Digital Twin, Smart Factory, Processing Control, Virtualization

1. INTRODUCTION

Smart Factory is one of the Industry 4.0 technologies that is causing a major change in the manufacturing industry. It is an intelligent and flexible production system that can produce and provide different products for each customer by reflecting consumer product demands in a real-time product design and production process. To implement a smart factory, technologies such as CPS (Cyber Physical System) are required to secure all data generated from the manufacturing site and manufacturing ecosystem and intelligently analyze it to create an optimal factory operation scenario [1]. CPS is an intelligent system construction technology that safely, reliably distributes, and controls physical systems such as people, processes, and facilities into a virtual computer and network. It is also called a digital twin, meaning that it is created and simulated virtually before making an actual product. If the target of CPS is defined as a factory, the CPS of the smart factory becomes a system that optimally operates the factory, and to find the optimal operation, a simulator is required and a controller to apply the found method is required. In other words, the CPS becomes a system in which the simulator and the controller are fused for optimal operation [2,3]. Through this, it can contribute to reducing waste and increasing efficiency by completely digitizing manufacturing site data and optimizing the management of factories and process facilities. Accordingly, a smart factory is realized in which products, processes, facilities, and factories are integrated and interconnected, and autonomous operation is performed flexibly and efficiently in all processes of manufacturing. The conceptual diagram showing the digital twin model of the manufacturing process is shown in Figure 1.

In this study, we propose and design the digital twin of the manufacturing industry by applying the interworking between the digital twin simulation and the actual process control platform through CPS implementation. Based on the simulation data through this, it is possible to quickly derive and verify improvement plans, thereby reducing costs and maximizing productivity by adjusting the balance to minimize lead types.

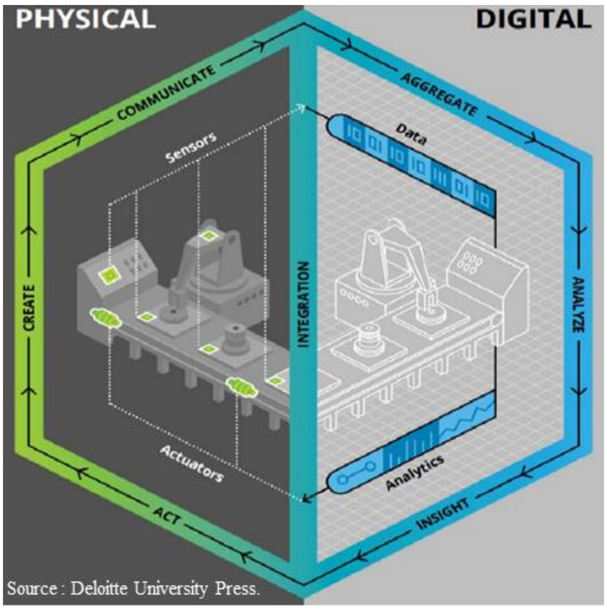

Fig. 1. The Manufacturing process digital twin model

2. DIGITAL TWIN PLATFORM DESIGN

In this paper, the concept of the digital twin is proposed as follows. The digital twin is a technology that replicates the real world to the virtual world, synchronizes them in real-time, and predicts, solves, and optimizes problems in the real world through simulation using this technology. The derived optimization information also has the characteristic of being reflected in the real world [4].

A digital twin in the manufacturing field can be described as a virtual factory in which information and functional elements related to the design, operation, and production of an actual factory are virtualized. The digital twin is first, information of the physical world is reflected in the virtual world in real-time, so that monitoring and tracking can be performed in real-time through the digital twin application. Second, it is possible to create added value through various interactions and high-level convergence, derive new analysis results, and accumulate knowledge based on not only real-time data but also past data. Third, the digital twin has simulation as its core function and performs a role similar to that of the existing simulation, but it can perform integrated analysis by supporting rapid decision-making through the utilization of the industrial Internet of Things network and securing interoperability with other manufacturing applications.

2.1 Physical system network configuration

Physical objects in the real world are digitized for their states and actions based on various sensors attached to each component and transmitted to a synchronization engine through a network, making it possible to utilize data on physical objects. Data collection and transmission technologies of sensors and controllers are implemented for virtualization technology that digitizes real-world components. Through this, products, processes, facilities, and factories are integrated and interconnected, and a smart factory is realized that enables flexible and efficient autonomous operation in all processes of manufacturing.

Figure 2 schematically shows the structure of the physical system network for CPS implementation. To experimentally verify virtual equipment by applying it to real equipment, the main components of process control equipment used in manufacturing were built as an integrated control system through virtual space. Real-time data for the data is expressed as a virtual component. Through this, the effectiveness was verified by implementing a real-time control system that can monitor the physical process of the process equipment and process and improve the user interface.

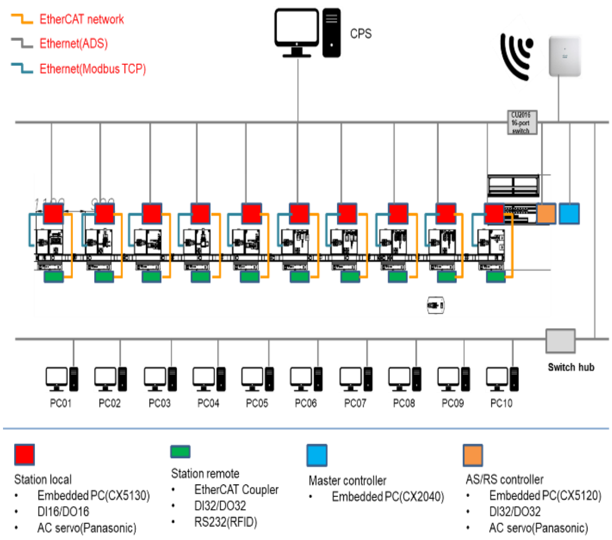

Fig. 2. The structure of the physical system network

2.2 Virtual Machine Digital Twin Modeling

To design the process control digital twin model proposed in this study, a series of processes were performed to virtualize and objectify real-world objects of the digital twin through the system structure shown in Figure 3, store the data, and simulate and visualize it. This process is an automated production line for the production of mobile drones and consists of 10 assembly stations. In addition, it is a collaborative robot-based drone manufacturing process designed for human-robot interaction. When the processor is completed, it is transferred to the warehouse through a mobile robot, loaded, and inventory management is performed. Through this, it is possible to build an automation line according to the purpose of the system and analyze the process through modeling.

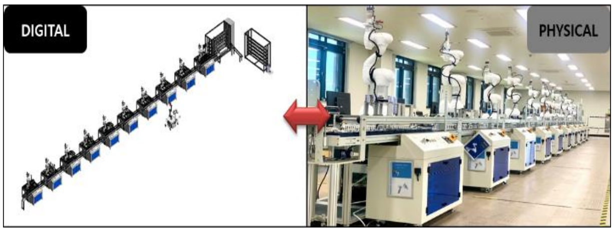

Fig. 3. The digital twin modeling of a manufacturing line

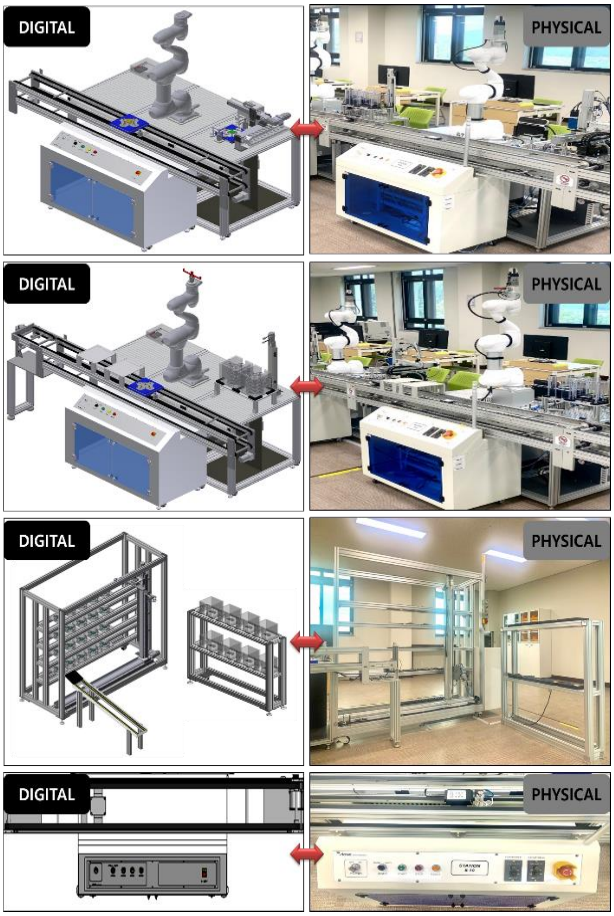

Fig. 4. The digital twin modeling of each station

A pre-verification simulation system is configured to control the virtual machine to perform the same function as the real machine. First, to build pre-verification simulation equipment, CAD data is secured through 3D modeling drawing work. After rendering the obtained CAD data, it is placed in the virtual space of the physical engine, and after verification of the PC-based controller code, the simulator function provided by the embedded PC is used to check whether the control operation is identical to that of the actual equipment. The actual equipment deployed was controlled. The digital twin modeling of each station is shown in Figure 4.

3. CONCLUSION

In this study, a digital twin is defined as a technology that replicates the real world in the virtual world, synchronizes it in real-time in both directions, and predicts, solves, and optimizes problems in the real world through simulation using this. In addition, through the digital twin simulation design of CPS for smart factory process realization, the operation system plan in virtual equipment for real data was studied. Virtual equipment and real equipment can have the same type of data structure and can help decision-making through various visualization methods for real objects. In addition, since it is possible to operate with the same control logic, it is possible to reduce user errors and reduce system construction time and cost. Until now, research on the collection and analysis of CPS data has been steadily carried out, but the visualization technology of virtual space through connection with real equipment was insufficient.

Based on this study, as a follow-up study, we intend to study a method to solve and monitor manufacturing site problems in a virtual space. We want to develop a digital twin process model that can be estimated and operated. In the future, when CPS simulation analysis technology is applied to process manufacturing convergence, it is possible to apply real-time simulation to the real environment by converting the layout and process data of the actual process into AR/VR, as well as the situation of the manufacturing site, facilities, human, and physical It is expected that it will be able to contribute to the improvement of the smart factory level by providing information and performance indicators such as resources and production to augmented reality in real time.

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