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DEVELOPMENT OF PRODUCTION DIGITAL TWIN IN MANUFACTURING USING FISCERTECHNIK FACTORY MODEL

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ABSTRACT

Recently, there have been more opportunities to see and hear the term Digital Twin (DT) in various situations. However, the reality is that the DT concept tends to precede and that there is a lack of places and materials to absorb the DT content and its implementation. This paper presents a case study at Tokyo University of Science to develop the Production Digital Twin in manufacturing by using Fischertechnik factory model and Matlab/Simulink software tool. DT can support not only the education in universities but also human resource development in manufacturing industries through the study and practice concerning production line optimization, virtual commissioning, cyber-physical system implementation, real-time monitoring of production data, and furthermore lead the innovation in manufacturing in Japan.

1 INTRODUCTION

Recently, there have been more opportunities to see and hear the term Digital Twin (DT). In particular, it is often stated as one of the key elements to realize the super-smart society set forth in Society 5.0 described in the 6th Science and Technology Basic Plan (2021-2025) in Japan. Tokyo University of Science (TUS) has been operating the Digital Twin Lab (DT-Lab) since 2020 in order to spread DT technology to manufacturing industries (Matsuo et al. 2022). DT is a mechanism or a concept that can simulate physical entity behaviors, monitor the ongoing status, detect anomalies, and predict future trend by linking physical and virtual spaces (sometimes in a real-time manner), and is conceived as a major tool to realize smart factories in the manufacturing industry, for example by optimizing equipment lines and detecting machine failures. However, the reality is that the DT concept tends to precede and that there is a lack of places and materials to absorb the DT content and its implementation methodology. Thus, considering the widespread role of DT in manufacturing, the author group started by characterizing DT in the manufacturing process, and after discussions with industry stakeholders, found that DT can be divided into several twins from upstream to downstream depending on the application twins as shown in Fig. 1, i.e., Design Twin, Engineering Twin, Production Twin, Inspection Twin, and Operation Twin, and that the mechanism connecting them horizontally is so-called Digital Thread. It is also found that there is an urgent need in industry to carry on the traditional Japanese-style manufacturing method based on the Kaizen continuous improvement and the Takumi on-site craftmanship. Hence, the author group decided to focus on developing the Production Twin in Figure 1 so that university students and industry learners can get started the DT study easily and speedy.

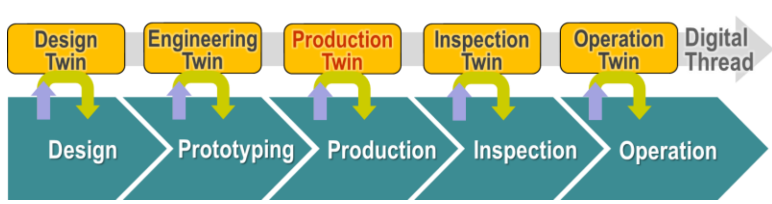
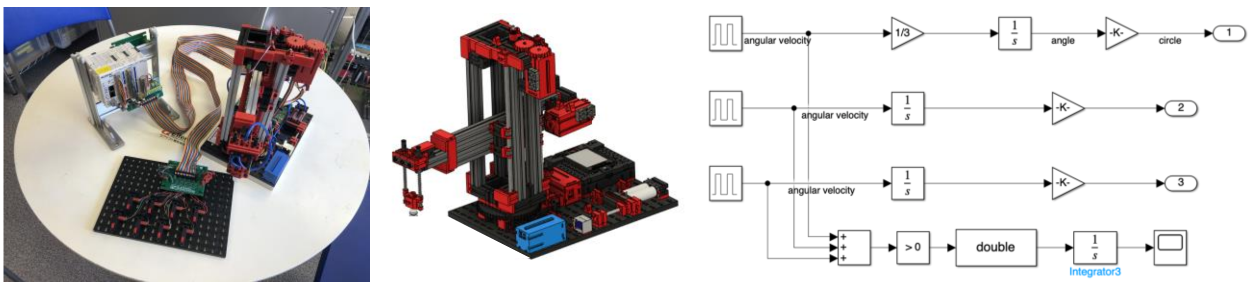


Figure1: Digital Twin chain in manufacturing process defined at TUS.

2 FISCHERTECHNIK FACTORY MODEL AND PRODUCTION DIGITAL TWIN

The main problem when developing a Production Digital Twin is the difficulty in treating the real physical entities such as robots and equipment installed in the factories. Therefore, the authors decided to adopt the Fischertechnik training models, which are the miniature of factory equipment, due to the easy use with industrial PLCs and the scalability. Figure 2 shows a sample of the Production Twin model composed of a robot model called Vacuum Gripper Robot 24V (VGR, Figure 2(a) right side), and a PLC controller (Figure 2(a) left side). This system is controlled by the PLC with a ladder program inside. As is well known, DT consists of three elements, i.e., a physical entity, a digital counterpart, and the bi-directional data connection. Figures 2(b)(c) show the digital model and the kinematic model of VGR. The PLC and the PC are connected using an Ethernet cable. The kinematic model is built by Matlab/Simulink on PC. The motion data is acquired through Modbus protocol communication between the PLC and Simulink on the PC. Additionally, the temperature and pressure data are acquired by the sensors attached to the motor and air pipe of VGR.



(a) Physical model (b) Digital model (c) Kinematic model built on Simulink

Figure 2: Production Twin model for the Vacuum Gripper Robot.

The next step to be considered is building a production line using other Fischertechnik training models. Figure 3 is an advanced Production Twin model for a production line in the manufacturing process, which are composed of four modules: a sorting line, a vacuum gripper, and two punching machines each with a conveyor belt. The system can simulate the product sorting and carrying to the destination. It is controlled by PLCs and manipulated by a touch panel shown in the right side of Figure 3. The currently running research topics with this system are on the cyber-physical data fusion using Kalman filter, the shop floor machine setting optimization and the anomaly detection of the equipment using IoT sensors. With this model, the author group is aiming at not only the education in universities but also human resource development in manufacturing industry through the study and practice concerning production line optimization, virtual commissioning, cyber-physical system implementation, real-time monitoring of production data, and further lead the innovation in manufacturing in Japan. In education, the curriculum on IT/OT convergence through the construction of DT for a factory model will start immediately. As for the industry learning, Dojo Virtual Learning Factory to learn Japanese-style Lean Production through internet is being planned.

Figure 3: Advanced Production Twin model simulating a production line in the manufacturing process.

REFERENCES

Matsuo, Y.,K. Asada, H. Watanabe, and K. Fujii, 2022, "Overview of the HEXAGON-TUS Joint Research: A Strategic Effort to Infiltrate Manufacturing Digital Twin Competency into Industry," In *15th World Congress on Computational Mechanics (WCCM-XV), 8th Asian Pacific Congress on Computational Mechanics (APCOM-VIII).*