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PRODUCTIVITY AND FAILURE ANALYSIS OF MICRO TESTBED USING CYBER-PHYSICAL SYSTEM-BASED SIMULATION

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ABSTRACT

The goal of this research is to develop digital twin model-based simulation analysis model for productivity and failure analysis of micro testbed. Targeting the micro testbed which is a miniaturized manufacturing line for mass customization, cyber-physical system-based digital twin model is constructed. Using the digital twin model, simulation models for productivity analysis which contains throughput, bottleneck, and machine availability analysis and failure analysis which contains machine tool wear and machine failure analysis are developed. Dashboard which visualizes the analysis results is also developed.

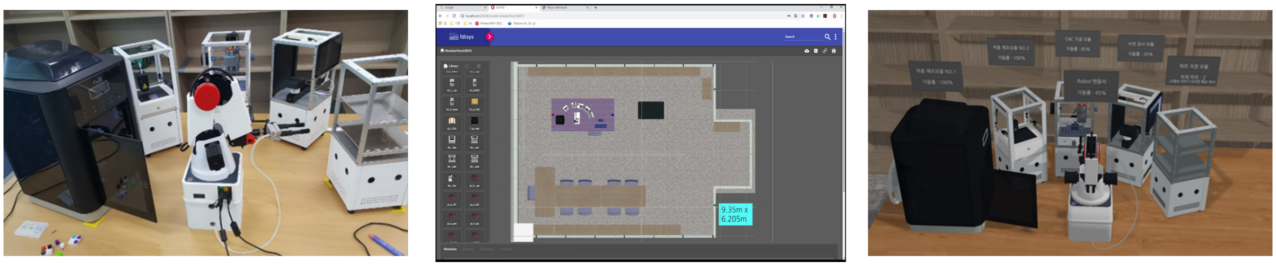
1 INTRODUCTION

In recent years, as IoT and sensor technologies have been advanced, construction of cyber-physical system (CPS)-based digital twin model connected with the real time data is enabled. How to utilize the constructed digital twin model is an important issue as mentioned in Kang et al. (2016). A way of utilizing the digital twin model is to carry out simulation-based analysis with the accumulated and real time data. In this research, we especially focus on productivity simulation for throughput, machine availability, and bottleneck analysis and failure simulation for machine tool wear and machine failure pattern analysis.

Target of the simulation is a micro testbed constructed in Korea Institute of Industrial Technology which is a micro version of the production system for mass customization. We first set the simulation environment constructing CPS-based digital twin model of the micro testbed and conducted the simulation-based analysis using the digital twin model..

2 DIGITAL TWIN MODEL OF THE MICRO TESTBED

Micro testbed is a module-based customizable manufacturing line composed of a miniaturized 3D printer, a computerized numerical control (CNC) machine, a vision inspection machine, a robot handler, and a buffer. Basic processes of the micro testbed is printing, machining, assembling, inspecting, handling, and storing of the parts. In each module, real time data such as start/end signal of the machine, movement of the machine, frequency of the machine, temperature of the machine, and energy consumption of the machine are collected with raspberry pi. In order to conduct the simulation, we first constructed a CPS-based digital twin model as shown in Figure 1. We built a 3D model library of each part of the micro testbed and developed layout design module for customizing the manufacturing line. When a layout of the manufacturing line is designed, a digital twin model for the customized line is automatically generated. Real time data and accumulated data of the physical system (micro testbed) is also automatically synchronized with the cyber system (digital twin model).



(a) Micro testbed (b) Layout design module (c) Digital twin model

Figure 1: CPS-based digital twin model generation.

3 SIMULATION USING THE DIGITAL TWIN MODEL

Since we have a digital twin model which is exactly same with the physical system of the micro testbed, we can support decision making processes regarding operations of the micro testbed by conducting simulation-based analysis. With the simulation we can predict the results of micro testbed operations in advance, and the simulation results can help administrators of the micro testbed make a decision. What we concentrated on in this research are productivity simulation and failure simulation. We developed simulation-based productivity and failure analysis model.

Purposes of the productivity simulation are to analyze throughput, machine availability, and bottleneck of the micro testbed. Since the micro testbed is designed for mass customization, manufactured products are varied, and the operational environment is highly complex because of the different manufacturing parameters such as production process and cycle time. In order to establish efficient production plan and scheduling, identification of bottleneck of each production process is important. We can analyze the bottleneck process with a production simulation, and the result can be used when a production plan and scheduling is conducted. Another issue is verification of the established production plan and scheduling. Since complex manufacturing environment causes difficulties of production plan and scheduling, verification of the plan and schedule is an important issue in micro testbed. By conducting digital twin-based simulation, we can figure out throughput, makespan, and machine availability of each time period. These results can be used in verifying the production plan and schedule. Moreover, when unexpected events occur, the simulation results can be used to support a decision making for replanning and rescheduling.

Goals of the failure simulation are to analyze machine tool wear and machine failure. With the accumulated data, we can extract the feature, pattern and probability distribution regarding the relationship between machine tool wear or failure and parameters such as frequency of tool parts, temperature of the tool parts, and processing time. Using the features and probability distribution as the input data, we developed simulation analysis model which can predict time of machine tool wear and machine failure. The results can be used to support decision makings regarding maintenance of the machines.

4 CONCLUSION

In this research, we developed digital twin model-based simulation models for productivity and failure analysis of micro testbed. We constructed a CPS-based digital twin model of the micro testbed and developed simulation analysis model using the digital twin. We also developed dashboard for visualizing the analysis results. The developed digital twin model-based simulation analysis model and framework will be applied and extended to similar manufacturing lines..

REFERENCES

Kang, H. S., Lee, J. Y., Choi, S., Kim, H., Park, J. H., Son, J. Y., and Noh, S. D. 2016. "Smart Manufacturing: Past Research, Present Findings, and Future Directions". *International Journal of Precision Engineering and Manufacturing-Green Technology* 3(1):111-128.