



HAL
open science

Integrated Platform and Digital Twin Application for Global Automotive Part Suppliers

Jinho Yang, Sangho Lee, Yong-Shin Kang, Sang Do Noh, Sung Soo Choi, Bo
Ra Jung, Sang Hyun Lee, Jeong Tae Kang, Dae Yub Lee, Hyung Sun Kim

► **To cite this version:**

Jinho Yang, Sangho Lee, Yong-Shin Kang, Sang Do Noh, Sung Soo Choi, et al.. Integrated Platform and Digital Twin Application for Global Automotive Part Suppliers. IFIP International Conference on Advances in Production Management Systems (APMS), Aug 2020, Novi Sad, Serbia. pp.230-237, 10.1007/978-3-030-57997-5_27. hal-03635640

HAL Id: hal-03635640

<https://inria.hal.science/hal-03635640v1>

Submitted on 30 Jun 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

Integrated Platform and Digital Twin Application for Global Automotive Part Suppliers

Jinho Yang¹[0000-0002-9946-4432], Sangho Lee¹, Yong-Shin Kang¹, Sang Do Noh^{1*}[0000-0002-5610-5560], Sung Soo Choi², Bo Ra Jung², Sang Hyun Lee², Jeong Tae Kang², Dae Yub Lee³ and Hyung Sun Kim³

¹ Sungkyunkwan University, Suwon 16419, Republic of Korea

² Yura, Seongnam 13494, Republic of Korea

³ DEXTA Inc., Suwon 16419, Republic of Korea
sdnoh@skku.edu

Abstract. For global automakers that manufacture products through a globally distributed supply chain, it is essential for this supply chain to be managed efficiently to enhance the efficiency and responsiveness to uncertain changes in the market. These manufacturers face limitations associated with independent applications, such as difficulties in collecting information from distributed sites and the inability to make quick decisions. To solve this problem, researchers have been actively investigating the application of smart manufacturing technology to improve productivity as well as the optimal use of manufacturing resources in dynamic environments. Furthermore, different countries have different cultures, regulations, and policies. Hence, a universal integrated platform is required to address these difficulties. Accordingly, this study proposes an integrated cyber-physical system-based platform that reflects international standards and has versatile applications. This platform can be used to utilize information from various distributed manufacturing sites in real time. In addition, the proposed system was verified through a field application case study.

Keywords: Cyber-Physical System (CPS), CPS-based Platform, Digital Twin, Global Supply Chains, Smart Manufacturing

1 Introduction

Currently, several manufacturers design, engineer, and produce their products through a globally distributed supply chain. In particular, the automotive industry is a typical assembly industry wherein a small number of automakers procure tens of thousands of parts from several suppliers to produce automobiles. These agents form a global supply chain in which suppliers provide parts to automakers. It is estimated that more than 1,000 part suppliers directly or indirectly affect a single automaker [1].

Global automotive supply chains are also expanding geographically, owing to the increasing globalization and the reductions in production costs. As consumer preferences become more individualized, production systems have been recently shifting toward the build-to-order (BTO) model; such changes have been observed in Eastern

Europe, Southeast Asia, South America, and India [2]. In such an increasingly complex and uncertain automotive manufacturing environment, part suppliers must effectively manage their distributed global supply chains to enhance their efficiency and responsiveness [3]. Firms must manufacture high-quality, reasonably-priced products that satisfy the needs of various customers, while simultaneously meeting delivery times. For this purpose, researchers have been actively investigating the application of smart manufacturing (SM) technology to improve productivity as well as the optimal use of manufacturing resources in dynamic environments [4, 5]. SM is a collection of advanced technologies that facilitate effective and accurate real-time decision-making by combining various information and communication technologies (ICTs) with the existing manufacturing industry [6]. Although SM has not been clearly defined thus far, it can be described as “a fully-integrated and collaborative manufacturing system that responds in real time to meet the changing demands and conditions in the factory, supply network, and customer needs.” This enables technologies and systems to respond to internal and external changes in real time, thereby facilitating the construction of lighter and more flexible production systems [7,8]. However, the production plants of global manufacturing companies are spread across different countries, which have different cultures, systems, regulations, units of measure, and languages. This introduces limitations for independent applications, such as difficulties in collecting information from distributed sites and the inability to make quick decisions [9,10]. Consequently, studies on the design and application of cyber-physical systems (CPSs) have been conducted to address these limitations [11]. A CPS, which is a core technology of SM, extends beyond static systems and recognizes, adapts, and variably responds to situations, based on the data collected in real time in the field, thereby enhancing the efficiency of the entire production process [12, 13]. A cyber-physical production system (CPPS) is created by applying a CPS for manufacturing using a variety of technologies [6, 14]. A digital twin (DT) is one of the core technologies that constitutes such a system; it is a virtual model that can analyze, evaluate, optimize, and predict current situations by synchronizing and simulating the information and functions of the production site [15].

To address the difficulties faced by global automotive manufacturers who deal with different cultures and systems, this study proposes an integrated CPS-based platform that reflects international standards and has versatile applications. This platform can be employed to utilize site information from various distributed external data and systems in real time. In addition, a system that provides a cloud-based service to add and extend various applications is proposed.

2 Research Backgrounds

A CPS is defined as an innovative technology for managing interconnected systems between its physical assets and computational capabilities [16]. Currently, to realize competitive advantages in advanced ICT technology and big data, numerous manufacturers and researchers are investigating methods to implement the CPS structure and methodology in their respective industries [17, 18]. A CPPS consists of autonomous and cooperative elements and subsystems based on the data collected throughout the

production and logistics system; it comprises three main characteristics: intelligence (smartness), connectedness, and responsiveness towards internal and external changes [17]. To implement a CPPS, the integration of analyses and simulation-based approaches for big data collected in large quantities is considered more important than other components [17]. In this regard, a DT is a core technology that can more quickly and accurately conduct simulations by synchronizing the information and functions of the production site [15].

Grieve first introduced the concept of DT in 2003. Since then, it has continued to develop [19]. A DT is defined as “an integrated virtual model of information and functional units based on the composition of heterogeneous physical elements.” In the manufacturing field, a DT is also defined as a virtual factory that reflects the configuration information of a physical factory, for synchronizing information and functions related to the design, operation, and production in real time [19-22].

Compared to conventional simulation models, a DT possesses several advanced features. By combining predefined models and functions with ICT, it can quickly generate models that reflect site information as well as enhance processes through optimization and conduct dynamic diagnoses and predictions by calculating repeated simulation results [19, 22-25]. To apply a DT, a data exchange system that can be connected to the site must be constructed; four studies are actively being conducted to create this data exchange system [20, 26, 27].

To utilize CPS and DT for integrating and linking the information in distributed environments and for providing various services, a platform that provides a large-scale service system must be constructed. This is a highly complex problem [27]. Each component of a DT is configured as a heterogeneous system; to utilize these components for monitoring and predictions, an efficient platform that employs distributed computing-based modeling and simulation must be developed. Moreover, interoperability is essential to ensure the exchange of information between these systems [27].

3 CPS-based Integrated Platform and Applications

3.1 Platform and Applications

The proposed CPS-based integrated platform supports various design, engineering, manufacturing, and logistics applications and services for SM in global manufacturing companies. This platform integrates real-time information from heterogeneous environments and incorporates DT technology to construct virtual factories and site applications for smart assembly systems. The smart assembly system largely consists of 1) a smart quality control system comprising a quality impact analysis model between processes and a quality prediction algorithm that considers the characteristics of an operator performing manual assembly processes, and 2) a smart production control system comprising an analysis and control model for factors that impact productivity in the assembly process, such as the number of workers at the production site, skill levels, and task difficulties, and an optimal production control algorithm. The core advanced technology proposed in this paper is an advanced analytics technology based on DT and machine learning; it serves as a basis for service applications applicable to logistics and

production processes in the global automotive industry environment. Figure 1 depicts the conceptual architecture of the proposed CPS-based platform, and Table 1 presents an overview of the major technologies and applications that constitute this platform.

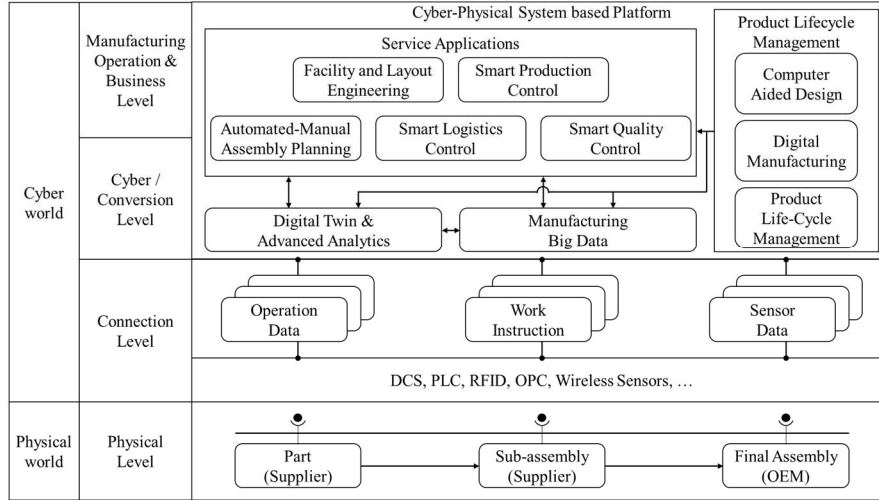


Fig. 1. Conceptual Architecture of Cyber-Physical System (CPS)-based Integrated Platform

Table 1. Summary of CPS-based platform and services

Name	Sub-technology or service name
CPS-based platform and cloud service	Digital-Twin
	Advanced Analytics
	Manufacturing Big Data & Repository
Cloud based application service	Facility and Layout Engineering
	Smart Production Control
	Smart Quality Control
	Smart Logistics Control
	Automated-Manual Assembly Planning

3.2 User Scenario

Primary users of the proposed platform and services are supervisors, operators, and managers. Operators are the personnel who directly operate equipment in the field, supervisors are those who direct operator activities, and managers are those who manage the overall production process. Each user has different strategic goals depending on his/her purpose of using the platform and services. Appropriate selection and operation of these key performance indicators (KPIs) are critical success factors for an enterprise [28]. Therefore, considering the environment of global manufacturers, this study proposes the use of KPIs based on international standards for the proposed platform [29, 30]. International Standard ISO 22400 presents 34 KPIs for understanding and

improving the performance of manufacturing systems. In the proposed platform, the KPI screen can be configured according to the specific purposes of each user.

Figure 2 presents the main screen of the user scenario proposed in this paper. The platform monitors sites in each region of the global supply chain in real time and analyzes and visualizes user-designated KPIs. This scenario consists of a dashboard, a simulation, an analysis, and information functions. The numerous functions described in Section 3.1 are performed. The user can view sites from high-level summaries to specific details, from the country to the factory itself, production lines inside the factory, and individual equipment. In addition, the platform tracks specific site information collected in real time, thereby helping the operator make decisions.

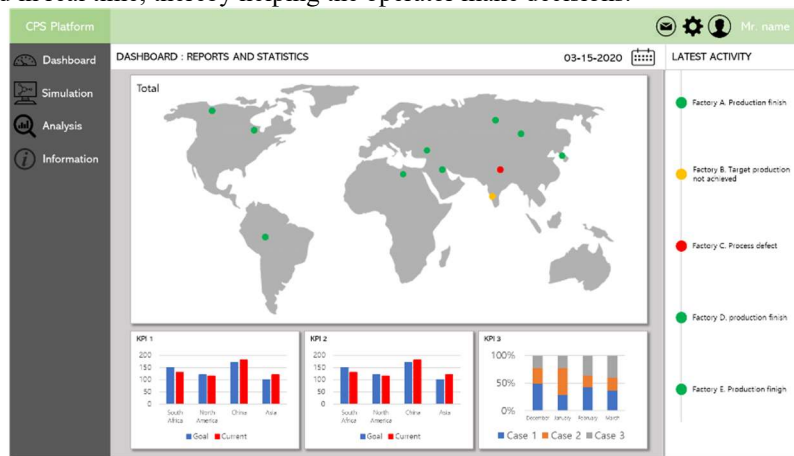


Fig. 1. Conceptual scenario main screen of CPS-based platform

3.3 Information Model for Digital Twin

This study proposes an information model for creating a virtual factory model that reflects real-time site information. To employ a DT, tuning is required to construct a simulation model from the collected site data. To reflect these requirements, this study used the Core Manufacturing Simulation Data (CMSD) proposed by the National Institute of Standards and Technology (NIST) of the United States. The information model proposed in CMSD was utilized for the configuration and tuning of parts, resources, production operations, and production planning [31]. The information model defined in this study consists of a header, a resource instance, a simulation execution, and results for the DT construction. The header corresponds to the simulation model and the library information in the model; the resource instance represents the instance configuration information of the manufacturing resource for constructing the cyber model

4 Implementation

This study is currently being conducted as part of an international joint research between South Korea and Sweden. It involves the design and implementation of various

applications for the CPS-based platform, such as cloud service, DTs, advanced analytics, and site applications. To construct the CPS-based platform, research is being conducted on detailed design, analysis of user requirements and standards, scenario establishment, and platform implementation. Moreover, a library that defines the information model and various data for DT construction is being built. A virtual factory model linked to the data of operators and processes collected in real time at the production site is also being built. Figure 3 presents a DT model for site application and the verification of the CPS-based platform. The model is linked to operator information collected at the site in real time using a short-range wireless communication device; a global automotive wiring harness manufacturer from South Korea is considered as the site. This can be used to construct a system that predicts a variety of problems and evaluates alternatives by linking algorithms for production management and predicting various quality issues. Furthermore, a platform that reflects international standards through a cloud-based service is provided, and it can be used in global environments involving different cultures and systems.

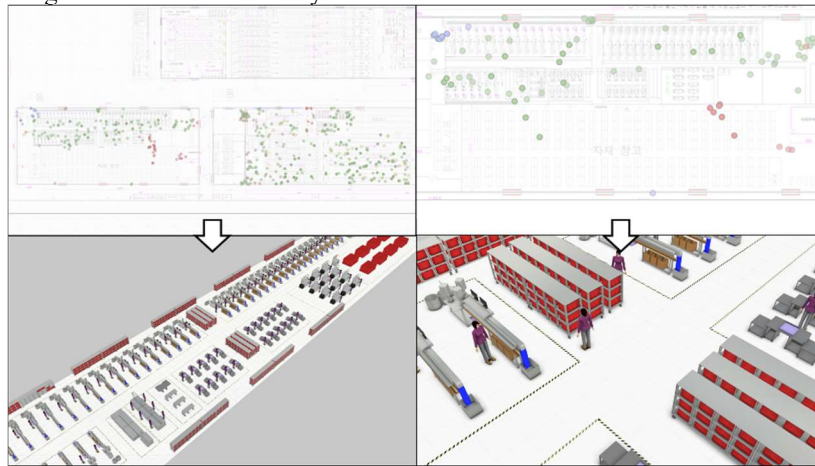


Fig. 2. Virtual factory model synchronized with real-time data

5 Conclusion

This paper presented a CPS-based integration platform for integrating and efficiently managing information from the distributed sites of global automotive manufacturers. The proposed platform was verified through a case study involving a global automotive wiring harness manufacturer from South Korea. The CPS-based platform and various service applications were designed and implemented in accordance with international standards, and a detailed information model for the DT was defined. However, there are a few limitations associated with collecting various data to implement smart manufacturing, in addition to the problem of identical data requiring different management systems. Future studies must investigate the construction of a data collection system to obtain valuable, high-quality data and support more accurate and rapid decision-making.

Acknowledgment

This research was supported by the Ministry of Trade, Industry and Energy (MOTIE) and Korea Institute for Advancement of Technology (KIAT) through the International Cooperative R&D program [P0009839, Cyber Physical Assembly and Logistics Systems in Global Supply Chains (C-PALS)] and this study is part of the Cyber Physical Assembly and Logistics Systems in Global Supply Chains (C-PALS) project funded by Eureka SMART and Vinnova.

References

1. Jung J.-S.: Logistics Innovation in the Automotive Industry, Research Report, Korea Institute for Industrial Economics & Trade, Sejong (2001)
2. Lee C.-B., Lee J.C.: A Classification of Logistics Outsourcing in the Global Automotive Industry. *Korea Logistics Review* 29(6), 163-174 (2019)
3. Ambe, I. M., Badenhorst-Weiss, J. A.: An automotive Supply Chain Model for a Demand-Driven Environment. *Journal of Transport and Supply Chain Management* 5(1), 1-22 (2011)
4. Pires, M. C., Frazzon, E. M., Danielli, A. M. C., Kück, M., Freitag, M.: Towards a simulation-based optimization approach to integrate supply chain planning and control. *Procedia Cirp* 72, 520-525 (2018)
5. Frazzon, E. M., Albrecht, A., Pires, M., Israel, E., Kück, M., & Freitag, M.: Hybrid approach for the integrated scheduling of production and transport processes along supply chains. *International Journal of Production Research* 56(5), pp.2019-2035 (2018)
6. Kang, H. S., Lee, J. Y., Choi, S., Kim, H., Park, J. H., Son, J. Y., Kim, B. H., Noh, S. D.: Smart manufacturing: Past research, present findings, and future directions, *International journal of precision engineering and manufacturing-green technology* 3(1), 111-128 (2016)
7. Wiktorsson, M., Noh, S. D., Bellgran, M., Hanson, L.: Smart factories: South Korean and Swedish examples on manufacturing settings. *Procedia Manufacturing* 25, 471-478 (2018)
8. NIST Engineering Laboratory Program: Smart Manufacturing Operations Planning and Control (2014)
9. Ivanov, D., Sethi, S., Dolgui, A., Sokolov, B.: A survey on control theory applications to operational systems, supply chain management, and Industry 4.0. *Annual Reviews in Control* 46, 134-147 (2018)
10. Ivanov, D., Sokolov, B., Kaeschel, J.: A multi-structural framework for adaptive supply chain planning and operations control with structure dynamics considerations. *European Journal of Operational Research* 200(2), 409-420 (2010)
11. Ivanov, D., Dolgui, A., Das, A., Sokolov, B.: Digital supply chain twins: Managing the ripple effect, resilience, and disruption risks by data-driven optimization, simulation, and visibility. In *Handbook of ripple effects in the supply chain*, Springer, Cham., 309-332 (2019)
12. Miclea, L., Sanislav, T.: About dependability in cyber-physical systems. In: 2011 9th East-West Design & Test Symposium (EWDTS), 17-21. IEEE, (2011)
13. Ribeiro, L., Björkman, M.: Transitioning from standard automation solutions to cyber-physical production systems: An assessment of critical conceptual and technical challenges. *IEEE Systems Journal* 12(4), 3816-3827 (2017)
14. Monostori, L.: Cyber-physical production systems: Roots, expectations and R&D challenges. *Procedia Cirp* 17, 9-13 (2014)

15. Tao, F., Zhang, M., Nee, A. Y. C.: Digital twin driven smart manufacturing. Academic Press (2019)
16. Rajkumar, R., Lee, I., Sha, L., Stankovic, J.: Cyber-physical systems: The next computing revolution. In: Design Automation Conference, 731-736. IEEE, (2010)
17. Monostori, L., Kádár, B., Bauernhansl, T., Kondoh, S., Kumara, S., Reinhart, G., Sauer, O., Schuh, G. Sihn, W., Ueda, K.: Cyber-physical systems in manufacturing. *Cirp Annals* 65(2), 621-641 (2016)
18. Monostori, L., Kádár, B., Bauernhansl, T., Kondoh, S., Kumara, S., Reinhart, G., Sauer, O., Schuh, G. Sihn, W., Ueda, K.: Cyber-physical systems in manufacturing, *Cirp Annals* 65(2), pp. 621-641 (2016)
19. Lee, J., Bagheri, B., Kao, H. A.: A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing letters* 3, 18-23 (2015)
20. Grieves, M.: Digital twin: Manufacturing excellence through virtual factory replication, White paper, 1-7 (2014)
21. Cheng, Y., Zhang, Y., Ji, P., Xu, W., Zhou, Z., Tao, F.: Cyber-physical integration for moving digital factories forward towards smart manufacturing: A survey. *The International Journal of Advanced Manufacturing Technology*, 97(1-4), 1209-1221 (2018)
22. Liu, Q., Zhang, H., Leng, J., Chen, X.: Digital twin-driven rapid individualised designing of automated flow-shop manufacturing system. *International Journal of Production Research*, 57(12), 3903-3919 (2018)
23. Gabor, T., Belzner, L., Kiermeier, M., Beck, M. T., Neitz, A.: A simulation-based architecture for smart cyber-physical systems. In: 2016 IEEE International Conference on Automatic Computing (ICAC), 374-379. IEEE, (2016)
24. Tao, F., Cheng, J., Qi, Q., Zhang, M., Zhang, H., Sui, F.: Digital twin-driven product design, manufacturing and service with big data. *The International Journal of Advanced Manufacturing Technology* 94(9-12), 3563-3576 (2018)
25. Uhlemann, T. H. J., Schock, C., Lehmann, C., Freiburger, S., Steinhilper, R.: The digital twin: Demonstrating the potential of real time data acquisition in production systems. *Procedia Manufacturing* 9, 113-120 (2017)
26. International Standard, 008-01-2012: Standard for Core Manufacturing Simulation Data–XML Representation, Simulation Interoperability Standards Organization (2012)
27. Yun, S., Park, J. H., Kim, W. T.: Data-centric middleware based digital twin platform for dependable cyber-physical systems. In: 2017 Ninth International Conference on Ubiquitous and Future Networks (ICUFN), pp. 922-926. IEEE, (2017)
28. Kang, N., Zhao, C., Li, J., Horst, J. A.: A hierarchical structure of key performance indicators for operation management and continuous improvement in production systems. *International Journal of Production Research* 54(21), 6333-6350 (2016)
29. International Standard, ISO 22400–1: Automation Systems and Integration – Key Performance Indicators (KPIs) for Manufacturing Operations Management - Part 1: Overview, Concepts and Terminology, International Standard Organization (ISO), Geneva (2014)
30. International Standard, ISO 22400–2: Automation Systems and Integration - Key Performance Indicators (KPIs) for Manufacturing Operations Management - Part 2: Definitions and Descriptions, International Standard Organization (ISO), Geneva (2014)
31. Riddick, F. H., Lee Y. T.: Core manufacturing simulation data (CMSD): A standard representation for manufacturing simulation-related information. In: Fall Simulation Interoperability Workshop (Fall SIW) SISO (2010)