Long Phan*, Saku Pöysäri, and Jyrki Latokartano

Achieving Industry 4.0 in manufacturing SMEs: A Case Study on Digital Twin Integration for Industrial Robots and Legacy Systems

Abstract: Industry 4.0 has driven the digitalization of manufacturing industries, with digital twin (DT) technologies emerging as a competitive edge. However, while large companies with extensive resources are leading this front, small and medium-sized enterprises (SMEs) – particularly in discrete manufacturing (DM) - are lagging behind in this digital trend. Some main reasons for this are high technical complexity, financial constraints, scalability issues, legacy system integration, and the volatile nature of DM SMEs. To address some of these challenges, this paper presents an approach for adopting DT tailored to manufacturing SMEs, realizing by a partial proof-of-concept. This DT system integrates industrial robot and manufacturing equipment: both modern and legacy devices. It features the use of OPC UA to integrate technologically constrained hardware. This approach highlights a DT system with security, reliability, scalability, and real-time control, while keeping the cost reasonable and compatible with legacy hardware.

Keywords: digital twin, discrete manufacturing, SMEs

*Corresponding Author: Long Phan, Tampere University, Finland, E-mail: long.phan@tuni.fi

Second Author: Saku Pöysäri, Tampere University, Finland, E-mail: saku.poysari@tuni.fi

Third Author: Jyrki Latokartano, Tampere University, Finland, E-mail: Jyrki.latokartano@tuni.fi

1   Introduction

Since the introduction of the Industrial 4.0 in the early 2010s, the manufacturing industry has seen transformative advancements in digital technologies. Manufacturing companies are in the race toward the concept of the "smart factory", where optimization and efficiency promise the greatest rewards [1]. To gain a competitive edge, many companies have started to adopt DT – a technology with many potential and perceived benefits that can revolutionize manufacturing processes [2]. However, while large

companies with substantial resources are leading this transformation, SMEs – particularly in DM – are lagging behind. Their key challenges in deploying DT are high technical barriers, financial constraints, scalability issues, legacy system integration, and the inherent volatility of DM SMEs [3].

Despite these pressing obstacles, there are limited research in (1) quantifying the impact of DT in DM SMEs and (2) developing flexible, scalable, and cost-effective DT adoption strategies, including approaches for legacy system integration. The immaturity of new technologies and the integrability of existing ones cause technological risks, which in turn reduce companies' willingness to utilize DTs [4].

To address these topics, this paper aims to present an approach for adopting DT tailored to DM SMEs, demonstrated through a partial proof-of-concept implementation. This DT setup at cell level integrates robotics and manufacturing equipment, from modern wireless tools to legacy devices that have limited communication capabilities. To integrate the wide range of hardware, this DT system features the use of OPC UA. This approach highlights a DT system with security, reliability, scalability, and real-time control, while keeping the cost reasonable and compatible with legacy hardware. Through this practical DT solution, this research seeks to provide DM SMEs with a practical digital twining approach, enabling them to remain competitive in an increasingly digitalized market.

2   Background

This study is a part of a Master's Thesis conducted at Tampere University, Faculty of Engineering and Natural Sciences. In this study, the definition of a Digital Twin is derived from [5], which requires a bidirectional flow of data between an existing physical object and its digital counterpart to achieve full integration.

3   Aims

The overall aim of this research is to propose a realistic

approach for developing DT tailored to DM SMEs, enable them to have more options when adopting this emerging technology. This method emphasizes the use of OPC UA and legacy system integration while keeping the cost reasonable and ensuring scalability. While this research primarily focuses on proposing an approach, it is a part of a larger project to develop a fully functional DT system. Preliminary results from this partial case study are also presented in this paper, offering insight into the practical feasibility and initial implementation challenges of the proposed approach.
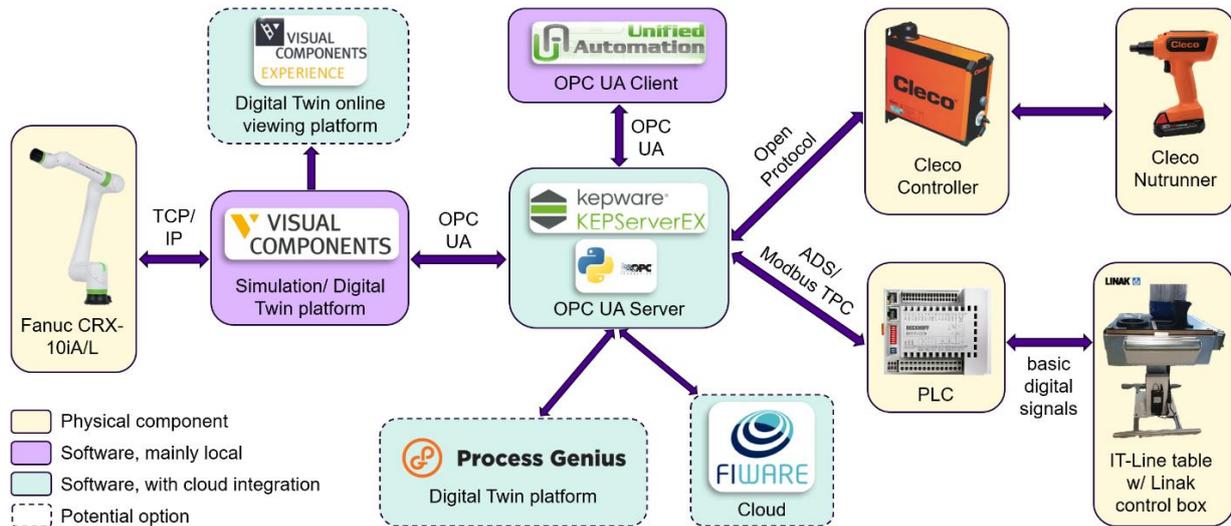

Figure 1: Digital Twin system integration diagram

4 Materials and Methods

Figure 1 illustrates the Digital Twin setup used in this study, highlighting physical equipment (yellow boxes), software components (purple and green boxes), and their connections via communication protocols indicated by labeled purple arrows.

The physical components: The main physical hardware of the system includes a Fanuc robot CRX-10iA/L, Cleco cordless nutrunner CCBPW223 and its controller mPro200GC, and an IT-Line height-adjustment table with Linak control box CBD6SP00020A-009.

The virtual "twin": The digital 3D representation of the system is modelled in and with Visual Components.

The connection and integration: At the heart of this DT system is the OPC UA server – where all physical and virtual components are connected to. This server facilitates information exchange between controllers, PLC, 3D models, OPC UA client, and other platforms.

Legacy device integration: The height-adjustment assembly table with Linak's controller - classified as a legacy device in this study – does not has advanced communication protocols. By default, the controller uses LinBus to connect with a computer for basic parameter configuration but lacks real-time monitoring and bidirectional communication. This study aims to establish two-way communication with an OPC UA server by (1) integrating a PLC to send commands to the Linak's controller and (2) installing sensors for feedback. These modifications enable real-time control and monitoring, ensuring continuous information flow.

5 Bibliography

[1] L. S. Dalenogare, G. B. Benitez, N. F. Ayala, and A. G. Frank, "The expected contribution of Industry 4.0 technologies for industrial performance," *Int. J. Prod. Econ.*, vol. 204, pp. 383–394, Oct. 2018, doi: 10.1016/j.ijpe.2018.08.019.

[2] I. Onaji, D. Tiwari, P. Soulatiantork, B. Song, and A. Tiwari, "Digital twin in manufacturing: conceptual framework and case studies," *Int. J. Comput. Integr. Manuf.*, vol. 35, no. 8, pp. 831–858, Aug. 2022, doi: 10.1080/0951192X.2022.2027014.

[3] M. Slot, R. Damgrave, and E. Lutters, "A structured digital twinning approach to improve decision-making in manufacturing SMEs," *CIRP J. Manuf. Sci. Technol.*, vol. 55, pp. 359–374, Dec. 2024, doi: 10.1016/j.cirpj.2024.10.010.

[4] M. Gulewicz, "Digital twin technology — awareness, implementation problems and benefits," *Eng. Manag. Prod. Serv.*, vol. 14, pp. 63–77, Mar. 2022, doi: 10.2478/emj-2022-0006.

[5] W. Kritzinger, M. Karner, G. Traar, J. Henjes, and W. Sihn, "Digital Twin in manufacturing: A categorical literature review and classification," *IFAC-Pap.*, vol. 51, no. 11, pp. 1016–1022, Jan. 2018, doi: 10.1016/j.ifacol.2018.08.474.