Digital Twin KR3

Usecase and Application

Ahmed Ibrahim Almohamed

Saturday 20th July, 2024

1 Introduction

Digital Twin (DT) technology represents the creation of a virtual replica of a physical object or system that is used to simulate, monitor, and optimize its real-world counterpart. DTs integrate real-time data from the physical entity, utilizing advanced simulation, machine learning, and reasoning techniques to enhance decision-making and operational efficiency. [1] Efforts to advance the key technologies that underpin the primary capabilities of mirroring, shadowing, and threading are actively progressing in DT-driven industries. These capabilities are critical for the effective deployment and utilization of digital twins in various sectors. [1]

Mirroring or **Digital Model** involves the creation of an exact virtual replica of a physical object or system in real-time. This capability is essential for applications such as real-time monitoring and diagnostics, virtual prototyping, and pre-production testing of products. Industries such as manufacturing, healthcare, and aerospace benefit significantly from precise replication and analysis, which ensures quality and efficiency in their operations. [1]

Shadowing focuses on continuously updating the digital twin with real-time data from its physical counterpart. This real-time data integration is vital for predictive maintenance, real-time performance optimization, and condition monitoring. Sectors like energy, utilities, and smart cities leverage shadowing to maintain system efficiency and predict potential failures, thereby avoiding downtime and reducing maintenance costs. [1]

Threading entails the integration and synchronization of multiple digital twins across different systems and processes. This capability is crucial for complex system simulations, supply chain management, and coordinated operations across multiple locations. Industries such as logistics, large-scale manufacturing, and integrated urban infrastructure rely on threading to coordinate various elements seamlessly, ensuring smooth and efficient operations. [1]

In summary, the principles of mirroring, shadowing, and threading are fundamental to the key use cases and applications of digital twin technology. These concepts enable comprehensive and integrated approaches to monitoring, optimizing, and managing complex systems across a wide range of industries.

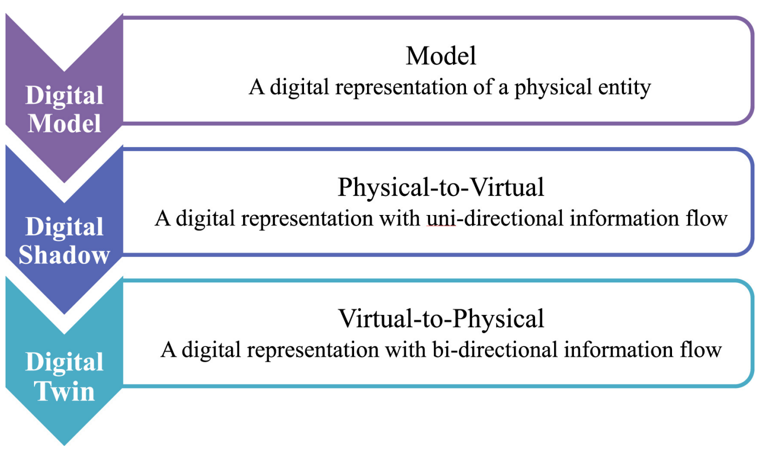

Figure 1: Levels of integration

2 Industry 4.0 and DT

In most industries, the development of Digital Twins is linked to the concept of Industry 4.0, i.e. the implementation of Digital Twin concepts , i.e. mirroring, shadowing and threading, is linked to or integrated with Industry 4.0 concepts such as the Internet of Things (IoT), cyber-physical systems (CPS), artificial intelligence (AI) and others. Today, any new implementation of digital twins should include one or more Industry 4.0 concepts. [2]

2.1 DT and CPS

Cyber-physical systems integrate cyberworld and dynamic physical worlds in a multi-dimensional and complex manner. CPS provide real-time sensing, information feedback, dynamic control and other services through the integration and collaboration of computing, communication and control, known as the "3Cs". [3]
Another concept associated with cyber-physical integration is the Digital Twin. A DT simulates real-world behaviour and provides feedback by creating high-fidelity virtual models of physical objects in virtual space. A DT reflects a bidirectional dynamic mapping process, breaking product lifecycle boundaries and providing a complete digital footprint of products. [3] This allows companies to predict physical problems earlier and with greater accuracy, to optimise the manufacturing process and to produce better products. [3]

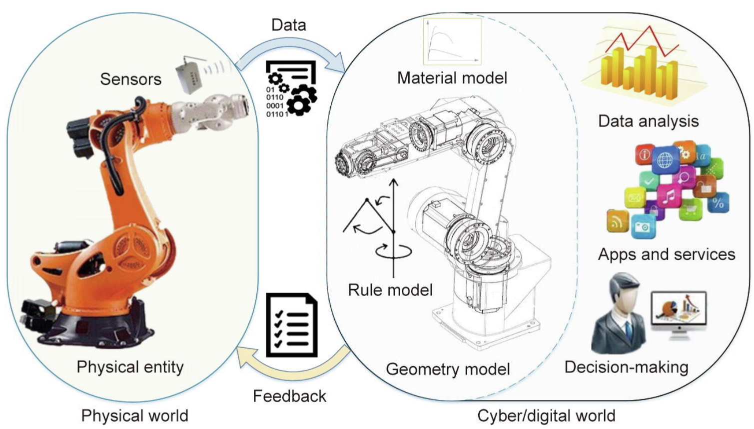

Figure 2: Integration of CPS and DTs

2.2 DT and IoT

Nowadays, we can connect physical objects remotely, accessing sensor data remotely, controlling the physical world remotely. The Internet of Things (IoT) is a concept which aims to combine data collected with data obtained from from other sources. [4]

The Internet of Things is an essential part of Industry 4.0. It is a means of communication between people, machines and products. One approach to the establishment of communication is **OPC UA**. [4]

OPCUA makes it easier to connect the digital twin to the physical twin with a third application. This could be to control and monitor the system. [5] It also allows the system to be centralised to create a main server to which more digital twins and physical twins can be connected. [5]

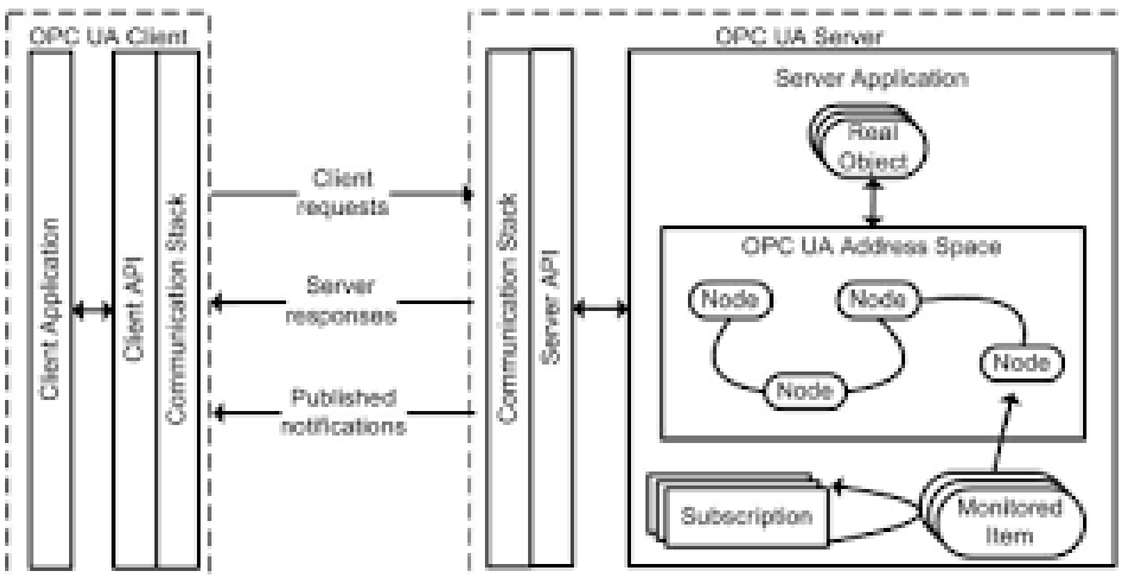

Figure 3: OPC Unified Architecture

3 Industrial robots

Industrial robots are automatically controlled, reprogrammable, general-purpose manipulating devices, programmable in three or more axes, which can be either fixed or mounted on a mobile platform for use in automation applications in an industrial environment. [6]
Robots can be used to weld, paint, assemble, disassemble,pick and place, pack and label, palletize. [7] They can be an aid to material handling. [7]

3.1 types of industrial robots

Articulated Robot are the most common industrial robot,resembling a human arm, hence the name robot arm or manipulating arm. Articulated arms have multiple joints that allow them to move in a variety of ways. [7]

4 Usecases for DT

4.1 System specifications

The existing system consists of a KuKa robot "KR3-R540" with a KC4 controller as a physical twin, with the team from last semester creating a digital mirror of the system using ROS2 and Gazebo. The next step in this project is to develop a digital shadow of the system. This will involve connecting the physical twin to the digital model in a unidirectional way. After that we should be able to go to the next step by implementing a full digital twin or bi-directional communication between the digital model and the physical twin, reading and monitoring data from the sensors in real time and sending commands to the physical twin via the digital model.

4.2 Usecases

We can take a step towards potential use cases that we can implement by thinking about Industry 4.0 concepts such as CPS and IoT. We will also have a look at some use cases in automatic small parts storage with industrial robots and Digital Twins.

4.2.1 ThuRoboticLab (TRL)

At THU, several KuKa KR3 R540 robots are utilized in the Robotics Lab, serving as laboratory equipment to aid students in their learning. The robots are primarily programmed offline, meaning that a program is written on a PC without testing, then copied to a USB stick, which is subsequently plugged into the robot cells for uploading. While this approach is straightforward, it lacks security. For instance, there is no mechanism to ensure that the code does not move the joints beyond the robot's main limits, potentially leading to defects over time. Additionally, the programming language used for these robots is KukaLanguage (KL), which is not ideal for generalizing robotics concepts. A more versatile language, such as Python or C++, would be more suitable, particularly within a ROS2 environment. Moreover, this offline programming method, or simply using the robot HMI for control, consumes a significant amount of time that could be better spent practicing more concepts. To address these issues, we propose creating a virtual environment to run a digital twin of the robots. This would allow students to use a more accessible programming language to test their exercises. This environment will be connected to the real robot via OPC UA, linking the digital and physical robots. Additionally, visualizations reflecting the real data of the robot will enable students to verify the outcomes of their runs effectively.

4.2.2 Optimized Order Picking and Packing

References

[1] Y. Jiang, S. Yin, K. Li, H. Luo, and O. Kaynak, “Industrial applications of digital twins,” *Philosophical Transactions of the Royal Society A*, vol. 379, no. 2207, p. 20200360, 2021.

[2] F. Pires, A. Cachada, J. Barbosa, A. P. Moreira, and P. Leitão, “Digital twin in industry 4.0: Technologies, applications and challenges,” in *2019 IEEE 17th international conference on industrial informatics (INDIN)*, vol. 1. IEEE, 2019, pp. 721–726.

[3] K. M. Alam and A. El Saddik, “C2ps: A digital twin architecture reference model for the cloud-based cyber-physical systems,” *IEEE access*, vol. 5, pp. 2050–2062, 2017.

[4] H. Arnarson, “Digital twin simulation with visual components,” Master’s thesis, UiT Norges arktiske universitet, 2019.

[5] A. Øvern, “Industry 4.0-digital twins and opc ua,” Master’s thesis, NTNU, 2018.

[6] N. G. Dagalakis, “Industrial robotics standards,” *Handbook of Industrial Robotics*, vol. 2, pp. 449–59, 1999.

[7] M. Hägele, K. Nilsson, J. N. Pires, and R. Bischoff, “Industrial robotics,” *Springer handbook of robotics*, pp. 1385–1422, 2016.