openZDM

Open Platform for Realizing Zero Defects in Cyber Physical Manufacturing

Introduction to a Digital Twin concept

The concept of the digital twin originated from research conducted at the University of Michigan, aimed at establishing a product lifecycle management centre[1]. A digital twin is defined as a comprehensive digital representation of an entity, ranging from the micro-atomic to the macro-geometrical levels, as confirmed in [2] and [3].

In modern manufacturing, representing an asset or system in cyberspace is crucial due to the increasing automation requirements at various production levels. This representation is categorised into three classes based on the automation level in data flow and command transfer between the physical and cyber spaces[4]:

- **Digital model:** A static representation in cyberspace, lacking automated data communication between the physical and digital space as well as behavioural modelling.
- **Digital shadow:** The digital shadow is considered a partial digital replica of a physical system or asset in cyberspace. Characterising an entity as a digital shadow, real-time data transfer between the physical space to the cyberspace is required.
- **Digital twin:** The digital twin is the complete and dynamic digital representation of the system or asset in cyberspace. The digital twin is highly integrated with the physical asset, being capable of real-time communication of data, and behavioural modelling, enabling scenario testing, system optimisation and proactive decision-making.

Funded by the European Union

The role of ISO 23247

Published in 2021, ISO 23247[5] sets the development standards for digital twins in manufacturing. It describes the functional entities of a digital twin framework (Figure 1), for a manufacturing system or asset, which includes:

- **User Entity:** Manages the user interface for accessing and interacting with the digital twin.
- **Core Entity:** The central hub providing access to functionalities and managing the digital twin's operation and representation.
- **Data Collection and Device Control Entity:** Handles data processing and controls the represented assets or systems.
- **Cross-system Entity:** Provides common functionalities like data assurance and security across domains.

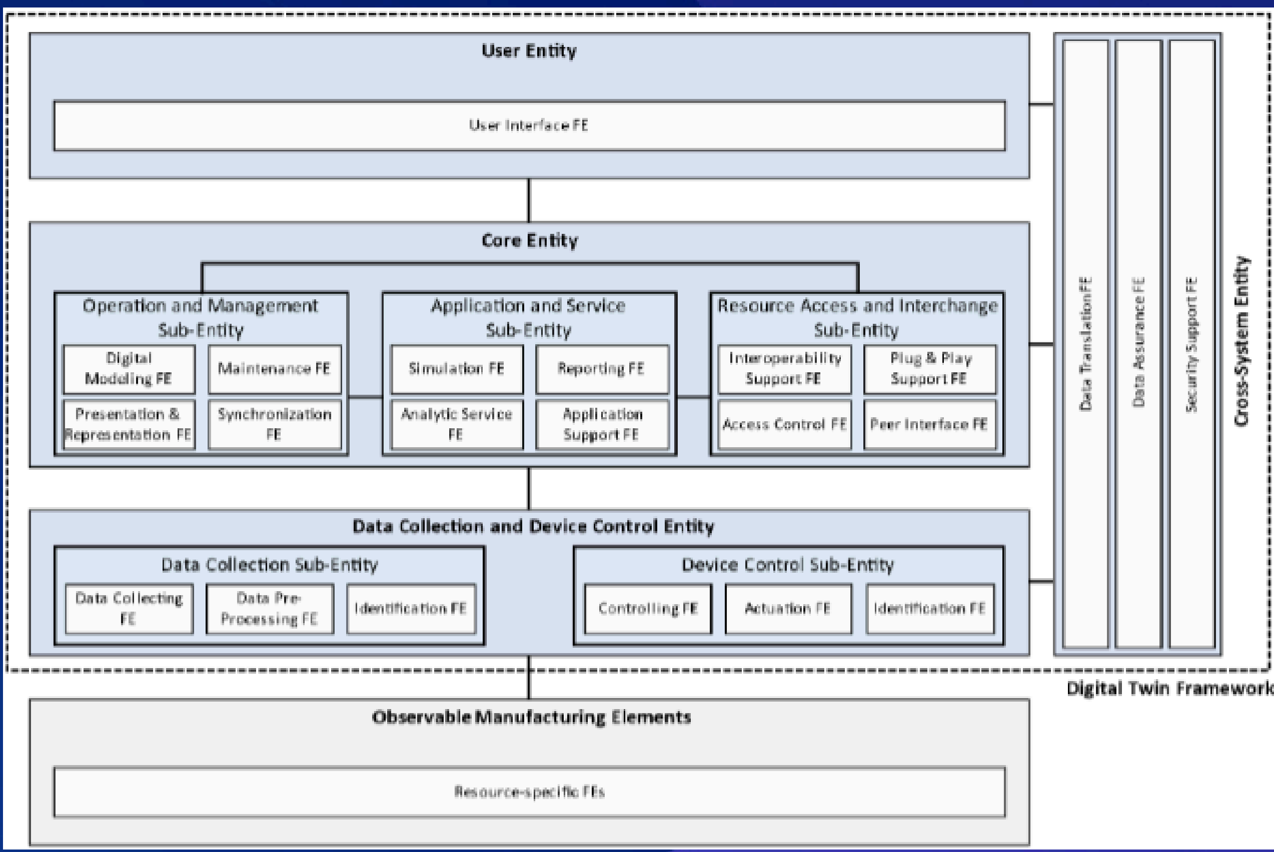

Figure 1: The digital twin framework based on ISO 23247[4] .

Funded by the European Union

Digital Twins in openZDM

The openZDM project aims to create digital twins that follow the structure defined in ISO 23247 and the characteristics that should define a digital twin as set out by [1] and [6]. It features:

- **User and Cross-system Entities:** Offer intuitive user interfaces for easy operation by production personnel, supported by the OpenZDM platform for data assurance and security.
- **Core Entity:** Employs a hybrid modelling approach combining data-driven and physics-based techniques for real-time and feedforward simulation, facilitating the prediction of system behaviour and defect detection.
- **Data Collection and Device Control Entity:** Supports extensive data sources and manages data preprocessing and system control, currently as a simulation proof of concept.

Implementation

Digital twins in openZDM are implemented through a five-step toolset process, presented hereafter with some also illustrated in Figure 2 and Figure 3:

- The first step is the initialisation where the name of the to-be-created digital twin is defined.
- Then, the assets that are to be included and modelled in the digital twin are defined by the user and their computer-aided models can be imported as well.
- Next is the modelling step, where the digital twin model is created, modelling the behaviour of the digital twin comparted of a combination of one or more assets. This can be a data-driven model, trained on past data and concerning a specific behaviour that is under investigation, or by differential equations, or by a mix of the previous two approaches, aiming for higher accuracy and replicability across different environments and domains.

Funded by the European Union

- Afterwards, is the workflow definition step where the created digital twin model is connected with the real-time data as well as the analytics that run on top of it.
- Last, a visualisation dashboard can be added where the digital twin data can be illustrated using various charts and representations, based on the user preferences.

Currently, the digital twin toolset supports the creation of data-driven models that can model and predict the behaviour of individual assets or systems. Nevertheless, the goal in the coming months is to introduce physics-based modelling capabilities into the toolset. This addition will enable users to integrate both data-driven and physics-based approaches, thereby creating more robust and accurate hybrid models.

To support the seamless deployment of applications and digital twins, the toolset and the twins themselves are containerized. Once the data-driven models are trained, they are also containerised and can be utilized via HTTP GET Requests. These models are executable within the workflow creation environment powered by Node-RED.

In addition, the toolset supports various communication protocols, including MQTT, HTTP Requests, and OPC UA. Dedicated Node-RED nodes have been developed to allow users to connect with the Asset Administration Shell (AAS) Middleware of the openZDM platform, enabling direct access to real-time data from AASs.

Lastly, the toolset supports a broad range of both NoSQL and SQL databases such as MongoDB, InfluxDB, Redis, and PostgreSQL. These databases are integral for storing critical operational information and logs, as well as for managing real-time data from physical assets and systems.

Funded by the European Union

This is expected to ensure that the digital twins are robust, versatile, and adaptable to various industrial environments, thereby enhancing their utility in real-world scenarios.

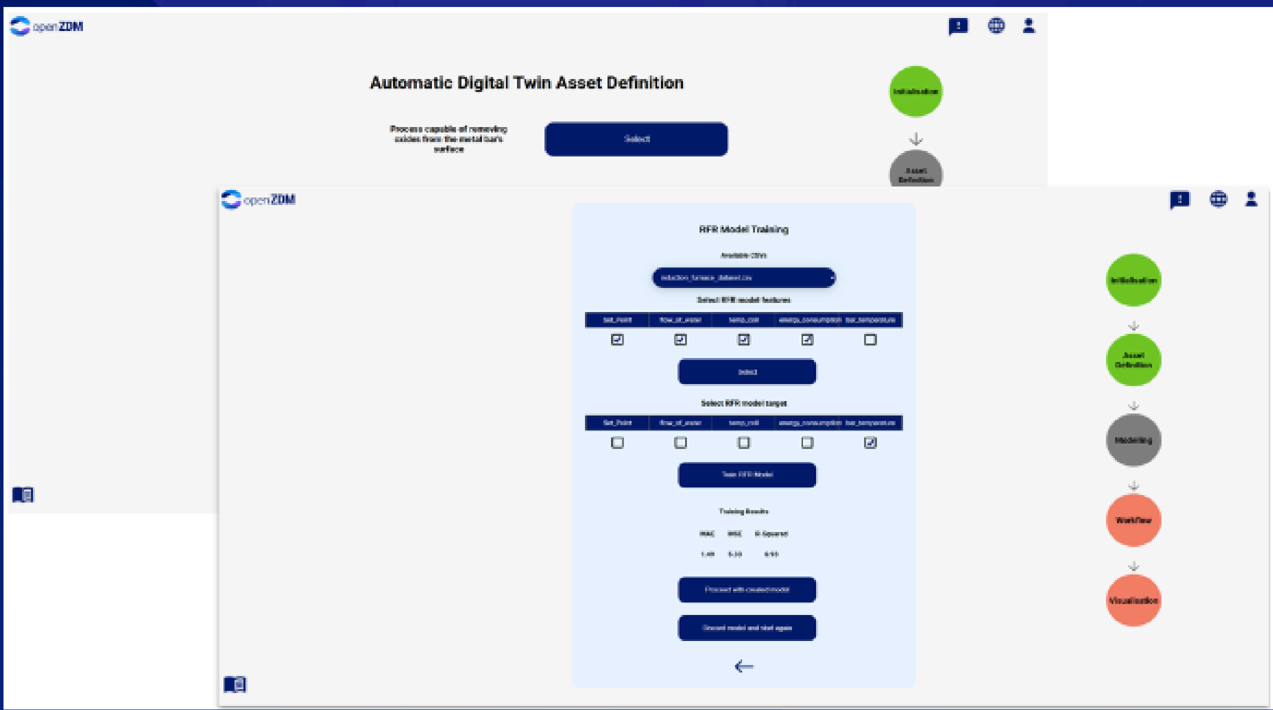

Figure 2: The asset definition and modelling steps of the digital twin toolset.

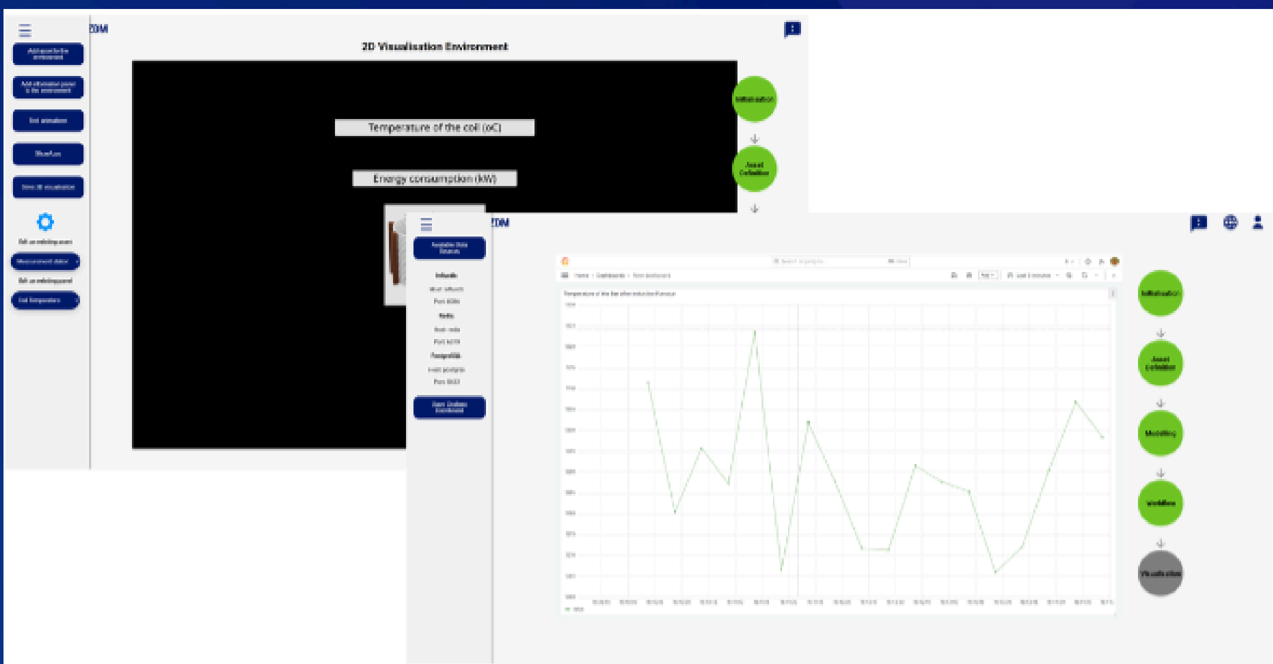

Figure 3: The visualisation creation step of the digital twin toolset.

Funded by the European Union

Summary

Digital twins in openZDM are carefully designed to adhere to the latest standards for digital twins in manufacturing as well as encapsulating the core values from concept pioneers.

Furthermore, openZDM builds upon this foundation through the support of a hybrid modelling technique that combines the capabilities of both physics-based and data-driven modelling approaches.

Lastly, future work will focus on finalizing the physics-based modelling capabilities within the digital twin toolset. This development will facilitate the creation of comprehensive hybrid models that leverage both modelling techniques. Moreover, efforts will be expanded to enhance the data-driven modelling approaches, thereby broadening the scope and accuracy of predictive analytics and simulations within the digital twin framework.

Funded by the European Union

List of Sources:

[1] M. Grieves, Origins of the Digital Twin Concept. 2016. doi: 10.13140/RG.2.2.26367.61609.
[2] A. Fuller, Z. Fan, C. Day, and C. Barlow, “Digital Twin: Enabling Technologies, Challenges and Open Research,” IEEE Access, vol. PP, pp. 1–1, May 2020, doi: 10.1109/ACCESS.2020.2998358.
[3] S. P. A. Datta, “Emergence of Digital Twins - Is this the march of reason?,” jim, vol. 5, no. 3, pp. 14–33, Nov. 2017, doi: 10.24840/2183-0606_005.003_0003.
[4] A. Thelen et al., “A Comprehensive Review of Digital Twin -- Part 1: Modeling and Twinning Enabling Technologies.” arXiv, Sep. 30, 2022. Accessed: Jul. 10, 2024. [Online]. Available: http://arxiv.org/abs/2208.14197
[5] https://www.iso.org/standard/75066.html
[6] M. W. Grieves, “Digital Twins: Past, Present, and Future,” in The Digital Twin, N. Crespi, A. T. Drobot, and R. Minerva, Eds., Cham: Springer International Publishing, 2023, pp. 97–121. doi: 10.1007/978-3-031-21343-4_4.

Funded by the European Union