Digital Twin

Mihai et al. *Digital Twins: A Survey on Enabling Technologies, Challenges, Trends and Future Prospects*. 2022.

Digital twin consists of three main components, the real space (physical object), the virtual space (digital object) and a communication link that serves as a medium for these two spaces according to the presentation of Michael Grieves in 2002.

This idea implied revolutionary thoughts for the manufacturing industry mainly as the equal lifetime of both real and virtual objects would lead to the latter being a mirror for the former, allowing for the technicians to observe the object remotely.

While the proper meaning of digital twin can be argued, the most descriptive meaning is currently considered as:

A dynamic digital replica of physical assets, processes and systems, which monitors the entire lifecycle.

Machine learning models to contain enough transparency over the motivations of their predictions. On the other hand, transparency is desirable to digital twin models and even required because of the anomaly detection that it is used for.

For the market, the issue of costs is more prominent and most business are still hesitant to implement such a system to this day. The reason originates from Return On Investment (ROI), which is difficult to quantify on a digital twin as it does not directly bring revenue to the businesses.

More accurately, digital twin can be described as the whole of several technologies that are used to implement a digital representation of a physical object. In addition, enabling technologies for a digital twin can also take many forms such as machine learning to understand the data, artificial neural network for future prediction, application security and remote control assistance.

Digital twin can be united with cloud computing for a large amount of complex simulations and multi-variable analytics, while also providing heavy-processing capabilities. A cloud platform also allows for a harmonious connection and hosting of the digital copies of the physical entities.

Cyber-physical systems can mean two different things: it is either a system of inter-connected digital twins made of real complex systems and their virtual counterparts. The physical system is comprised of the equipment, sensors and human operators that all work for the same goal. On the other hand, it can also mean only the physical system with its sensors that is utilised for the virtual imitation process.

Kritzinger et al. *Digital Twin in manufacturing: A categorical literature review and classification*. 2018. <https://www.sciencedirect.com/science/article/pii/S2405896318316021>

Among the levels of integration, digital twin requires a fully integrated data connection between the physical and digital object that is reciprocal, allowing for the latter to act as a controller for the former. Thus, any change in the digital object also results at a change in the physical object and vice versa.

The lower level of integrations, on the other hand, does not have a cyclic data flow between two objects as a digital model is only the digital representation of the physical object without any data flow while a digital shadow allows for a singular data flow from the physical object to the digital object.

Digital twin can be used in production planning and control, maintenance and layout planning. Publications analysed at this article also mentions that the majority of them focused on production planning and control by around 50% pertaining to the digital twin.

Liu, Vatn, Yin. *A generic framework for qualifications of digital twins in maintenance*. 4 November 2023. <https://www.sciencedirect.com/science/article/pii/S294985542300031X>

A proposed framework for qualifying a digital twin for maintenance consists of standard compliance (ability of a digital twin to follow the established standards), fidelity (how close the replication of the physical object is), timeliness (how quickly the digital twin reflects changes), smartness (the capability of a digital twin to perform more complex operations, directly connected to predictive maintenance) and integration (level of the digital twin that is connected both internally and externally, directly connected to the connectivity of a digital object).

Predictive Maintenance

Liu, Vatn, Yin. *A generic framework for qualifications of digital twins in maintenance*. 4 November 2023. <https://www.sciencedirect.com/science/article/pii/S294985542300031X>

Predictive maintenance allows for the prediction of remaining useful lifetime or possible errors in a system or a group of systems by analysing the data and other convenient resources at hand. Primarily, machine learning and the historical data of the system is used to predict a possible shift in the behaviour and this early detection mechanism can save thousand of dollars every year for companies, making it a viable branch to invest upon.

Per the capability level of the predictive maintenance, the level of integration is equated to the digital twin, which follows all required standards but is unable to provide any indicator for the entire standards it followed during an operation.

Ayvaz, Alpay. *Predictive maintenance system for production lines in manufacturing: A machine learning approach using IoT data in real-time*. 1 July 2021. <https://www.sciencedirect.com/science/article/pii/S0957417421000397>

Predictive maintenance has become a common solution for the industry to take preventive measures efficiently. Data flexibility has been seen as a critical issue for the predictive maintenance as it can compromise the algorithm performance for the model. In addition, processing raw and unlabelled data, the sparseness of the data, the possibility of the data being in higher dimensions and the noise arising from big data environment can also become a problem for the predictive maintenance models. Still, data driven AI algorithms that can utilise the data from IoT devices can help with this modelling problem.

Studies have observed different ML paths such as supervised classification, regression from high dimensional data, reinforcement learning and unsupervised learning problem.

Elkateb et al. *Machine learning and IoT – Based predictive maintenance approach for industrial applications*. February 2024. <https://www.sciencedirect.com/science/article/pii/S1110016823011572>

From an example for a knitting machine, it is explained that various steps such as data normalisation, feature selection (splitting data into train and test), boosting the weak learners and lastly cross-validation are utilised to gain a good score for the process.

Nunes, Santos, Rocha. *Challenges in predictive maintenance – A review*. February 2023. <https://www.sciencedirect.com/science/article/pii/S1755581722001742>

Predictive maintenance arose from condition-based maintenance, related to IoT, which allowed for intervention to a system depending on the values of the sensors that are capable measuring and processing the signals that represent the physical parameters of an object.

Prediction of RUL (remaining useful life) is one of the integral concepts for the predictive maintenance and the latter is affiliated with big data as well, such as the concepts of veracity, velocity, value, volume and variety.

(perhaps continue reading)

Wolf, Sielaff, Lucke. *A Standardized Description Model for Predictive Maintenance Use Cases*. 2023. <https://www.sciencedirect.com/science/article/pii/S2212827123002445>

Image Processing

Real-Time Streaming Protocols

Santos-González et al. *Implementation and Analysis of Real-Time Streaming Protocols*. 2017.

RTSP is a non-connection-oriented application layer protocol that uses a session associated with an identifier. To share video and audio data, it uses User Datagram Protocol (UDP) and for control, it used Transmission Control Protocol (TCP) if it is needed. It supports the operations:

Retrieval of media from media server through a request from a client.

Invitation of a media server to a conference, to either play back media or record all or a subset of the media in a presentation.

Addition of media to a presentation, specifically utilised on live presentations as it can inform the client about whether the media is available or not.

The URL for RTSP is very similar to HTTP, which it is closely affiliated with in terms of syntax. There are several request methods such as DESCRIBE, SETUP, PLAY, PAUSE and TEARDOWN.

DESCRIBE is used to obtain the description of an object appointed by the URL RTSP, with the client requesting and server responding.

SETUP is used to establish how the stream is transported, the request containing the URL of the stream and transportation method while the server responds by configuring the media through selected parameters, making it readied for PLAY.

PLAY request starts the data stream through the server using the ports that were configured during the SETUP.

PAUSE temporarily pauses one or all requests to resume later.

TEARDOWN request stops the shipment of data and releases all resources, which is its main difference from PAUSE request.

<https://www.sciencedirect.com/science/article/pii/S0951832019307902#ec-research-data>

Turbofan Engine Degradation Simulation (possibly the database of the above research paper)