Digital Twin (DT)

The proper meaning of a digital twin is still argued with the publications giving several different meanings. Currently, the most descriptive meaning can be considered as: a dynamic digital replica of physical assets, processes and systems, which monitors the entire lifecycle.

More accurately, digital twin can also be described as the combination 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.

The term was first coined in 2002, during a presentation of Michael Grieves who ventured to this concept, positing three different sub-concepts:

* The real space.
* The virtual space.
* The link that is connected between real and virtual spaces.

This revolutionary concept led to new ideas emerging about digital twins, especially in the manufacturing industry. Specifically, they were interested in the notion that both digital and physical objects would have the same lifetime, allowing for the technicians or operators to observe the object remotely.

Among digital models, digital twins necessitate a fully integrated data connection between the physical and digital object that is also bilateral. This allows the digital object to act as a controller for the former. As a result, any change in the digital object is also reflected in the physical object and vice versa.

Transparency, whether the machine learning algorithm knows the reasoning of its predictions, is desirable and even necessary for the digital twin as the reasoning is important for the implementation of anomaly detection.

However, the market and the business are more hesitant to work on digital twins because of a lack in Return On Investment (ROI) because it does not directly bring revenue to the businesses.

A proposed framework for a digital twin associated with maintenance consists of five concepts:

* Standard compliance, the ability of a digital twin to follow the directed standards.
* Fidelity, the similarity of a digital object to its physical counterpart.
* Timeliness, the time at which the digital object reflects the changes on its physical counterpart.
* Smartness, the capability of a digital object to perform more complex operations. This step is connected to the predictive maintenance.
* Integration, a grade at which the digital object is connected to the physical object both internally and externally. In the case of a digital twin, the connection is both ways in a cyclic formation. Thus, any change in the data flow for both objects is reflected on the other.

Digital twins can be used in production planning and control, maintenance and layout planning. It can also be used for the formation of smart factories and infrastructures such as buildings and cities. For factories, the manufacturing robots can be controlled by a digital twin to properly to maintain its lifetime. Cities can be integrated digitally for a sustainable growth and giving a better quality of life for its citizens.

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

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

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 (PrM)

Predictive maintenance allows for the prediction of the remaining useful lifetime (RUL) or possible errors in a system by analysing the current data. Historical data of a system alongside a machine learning model can help predict a possible shift in the behaviour, allowing for the error to be solved on time. This early detection mechanism can save thousands of dollars every year for the companies, positing that it can be a viable maintenance protocol. This has also allowed for the predictive maintenance to become a common solution on taking preventive measures for the industry.

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. It is directly integrated with the digital twin, which follows all required standards but is unable to provide for all the standards in an operation.

However, data flexibility is seen as a critical issue on predictive maintenance as it can compromise the algorithm performance in a model. Moreover, processing raw and unlabelled data (from a lack of labelled data), sparseness of the data, higher dimensional data sets and the amount of noise arising from Big Data environment can become a problem for predictive maintenance models.

An example can be considered with the anomaly detection. While a malfunction of the system is an informative data, an error at the sensors can lead to an abnormal behaviour of data, leading to incorrect results at the end.

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

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>

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Real-time Streaming Protocols (RTSP)

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.

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

Predictive Maintenance on Robot Welding