Editorial

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Digital Twins

Digitale Zwillinge

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The term Digital Twin has been used more and more frequently in the last years. In this context, the impression is created that every type of model is a Digital Twin or can be designated as such. This conceptual vagueness and inflationary use make it difficult to deal scientifically with the concept behind it. Despite these obstacles and reservations, the aim of this Special Issue is to stimulate the scientific discourse about the Digital Twin.

Most definitions of the Digital Twin are based on the conceptual idea of Michael Grieves [1], who is widely referred to as its originator: A real object and its virtual replica are automatically and bidirectionally coupled, as depicted in Fig. 1.

The roots of the Digital Twin concept can be found in the areas of product life cycle management (PLM) and aerospace [2, 3]. The Digital Twin was new to PLM in the sense that it was not given at the time to have a digital replica of every product manufactured, and in particular, that the digital replica also had an effect on the real product. For automation engineers, however, Fig. 1 looks very familiar, in the sense of a closed-loop control system. So, is the Digital Twin just a buzzword for the influence on the physical process based on a model and sensor data, as it is common in automation technology?

It has become apparent, that the term Digital Twin is misleading in the way that its literal meaning implies a single entity, mostly interpreted as some kind of model. Historically, it is rather more thought of as a meta concept [1]. This concept can be applied to different domains and can be tailored to specific target criteria, resulting in different implementations of Digital Twins. Regardless of the specific application, a Digital Twin in its full form provides a comprehensive toolkit which can be used, among other things, to monitor, analyze, control, and optimize a system over its entire life-cycle. This toolkit represents the added value in the application of the Digital Twin.

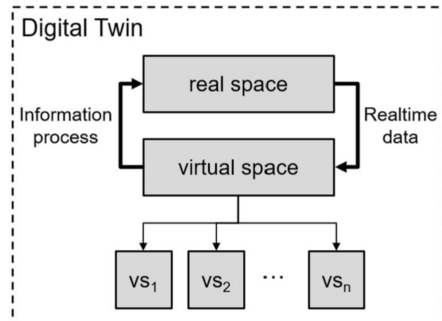

Figure 1: Basic structure of the "Digital Twin".

In this sense, the Digital Twin goes beyond the control of a technical system in automatic mode. For use in different lifecycle phases, quite different models with varying degrees of detail are generally required, some of which can be simulated and some of which can be explored algorithmically. This is particularly exciting when it comes to the Digital Twin of large, complex systems – which are the focus of this Special Issue: production plants, ships, airports, critical infrastructures, even entire cities.

With this issue we want to contribute to the understanding of principles and fundamentals of Digital Twins, foster the scientific discussion of the requirements from various areas and outline aspects that may be relevant for a successful implementation of the concept. The contributions to this Special Issue span from the automation engineer's perspective to a wider interpretation and provide a base for further discourse.

This Special Issue of "at" begins with three articles from the field of automation (with views provided by a university, a company and a Fraunhofer institute) that focus on the methodology for designing and applying Digital Twins. This is followed by four articles on applications for the Digital Twin, with particular focus on different fields of work of German Aerospace Center (DLR). The variety of DLR's activities – much of them on other fields than aerospace – provide exciting topics for future joint research.

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In “An approach for leveraging Digital Twins in agent-based production systems”, Birgit Vogel-Heuser, Felix Ocker and Tobias Scheuer design a Multi-Agent System to control a decentralized production system. The agents represent either resources or products. Each agent has a knowledge base which is initially fed with information from a Digital Twin of the resource or the product, respectively. While the information exchange between the agent and the Digital Twin is currently only one-time and one-way, this might be intensified in future work.

Nicolai Schoch, Mario Hoernicke and Katharina Stark propose a “Semantic function module pipeline generation” to support and partly automate the engineering of modular production systems, to form a “production pipeline”. The authors put emphasis on the semantic descriptions which are required to compose and configure the modules according to the required production process. The Digital Twin consists of the semantic model and the algorithm which automates the pipeline generation and optimization, initially in the engineering phase but also during operation.

Michael Jacoby, Friedrich Volz, Christian Weißenbacher, Ljiljana Stojanovic and Thomas Usländer present “An approach for Industrie 4.0-compliant and data-sovereign Digital Twins”. They show how standards and technologies of both Industrie 4.0 and the International Data Spaces (IDS) can be combined in an architecture for Digital Twins which allows data sharing between enterprises and provides interoperability and data sovereignty alike. The approach applies the concept of the Asset Administration Shell (AAS), which is the implementation of the Digital Twin according to the German Industrie 4.0 initiative. Furthermore, the authors address the important topic of the composition of Digital Twins (provided by different suppliers) to form a Digital Twin of a larger system.

In „ Digital Twin conceptual framework for improving critical infrastructure resilience”, the authors Eva Brucherseifer, Hanno Winter, Andrea Mentges, Max Mühlhäuser and Martin Hellmann focus on the resilience of critical infrastructures such as water and energy supply systems, transportation systems, telecommunications systems, etc. A Digital Twin of a critical infrastructure could potentially be very useful to detect anomalies, assess the impact and to derive counter-measures, both during operation of the system and crisis situations. In addition to the bi-directional information exchange between the infrastructure and the Digital Twin, the authors consider the role of the human in the control center.

Jan-Erik Giering and Alexander Dyck formulate a “Maritime Digital Twin architecture” to provide holistic product support over the life-cycle of ships. This concept is intended to cover the design phase with an early stage Twin, a Digital Twin prototype and an experimentable Digital Twin. A Digital Twin aggregate supports the operational and decommissioning phases within the life-cycle. In this sense, there are parallels to use cases in manufacturing, while a ship has increased requirements with regard to complexity of the product and maritime regulations. Safety and security are another challenging aspects.

The Digital Airport Twin is discussed by the authors Andreas Deutschmann, Sebastian Schier-Morgenthal, and Sven Kaltenhäuser in „Digitaler Airport Zwilling – Herausforderungen bei der digitalen Transformation von Flughafen im Kontext des Airportmanagements“. Here, the airport with its diverse and interwoven discrete processes in a highly regulated environment is described by the authors as a use case for Digital Twins. Developing models and simulations is challenging but required to provide a foundation so that the Digital Twin can be used to analyze processes and what-if scenarios spanning all involved organizations.

In „Urban Digital Twins – A FIWARE-based model“ the authors Martin Bauer, Flavio Cirillo, Jonathan Fürst, Gürkan Solmaz and Ernö Kovacs present Digital Twins for a variety of functionalities within a Smart City such as data provision as well as reactive, predictive and forecasting tasks. With the purpose of adding smart functionality to the city, these Digital Twins form a system-of-systems that can be implemented utilizing a modular open source software platform. An API is presented that enables the interaction between Digital Twins as well as the extraction and integration of information from the physical city based on AI technologies.

We thank all authors (also the ones whose manuscript have not been included in this Special Issue) for their efforts and wish all readers new insights.

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