

MICROSOFT AZURE DIGITAL TWINS

Dragan Kreculj¹ Aleksandra Mitrović² Đorđe Dihovični³ Nada Ratković Kovačević⁴, Aleksa Vučičević⁵

Abstract: Digital Twins technology is based on virtual representations of physical objects, processes, or systems, integrating real-time data and simulations to monitor, analyze, and optimize performance. There are numerous and complex Digital Twins software platforms. This paper explores the Azure Digital Twins platform, emphasizing its structure, encompassing entities, relationships, properties and behaviors. A well-defined framework enables users to simulate real-world scenarios, analyze data, and enhance decision-making processes. Digital Twins find extensive application across industries such as aerospace, automotive, healthcare, energy, and manufacturing, where they facilitate predictive maintenance, operational optimization, and cost reduction. By integrating with IoT (Internet of Things) and AI (Artificial Intelligence), Azure Digital Twins supports scenario simulation, predictive analytics, decision-making, promoting efficiency and productivity. The goals of this review are to provide a comprehensive understanding of the principles, architecture, and applications of Digital Twins technology, highlighting its potential to drive innovation and foster sustainable practices across diverse industrial sectors.

Key words: Digital Twins, Microsoft Azure, structure, technologies, properties, applications.

1. INTRODUCTION

Digital Twins platforms are denoted as specific software solutions that enable users to design, create, manage, and visualize various assets, systems, or processes. There is no unique definition of the term Digital Twins [1], [2], [3]. In [3], more than ten definitions taken from literature are listed. The key enabling technologies for the implementation of Digital Twins are [4]: Cloud Computing, Extended Reality, Internet of Things (IoT) and Artificial Intelligence (AI) which all contribute to the development of a digital representation that mirrors a physical object, to the collection of real-time data, and to the retrieval of information for insightful analysis [4].

Microsoft has developed its own digital twin platform, Azure Digital Twins. This cloud-based platform enables the creation and management of digital entities for various IoT devices, assets, and environments. Azure Digital Twins allow users to model the relationships and interactions between different components in a physical space, such as buildings, farms, factories, smart cities, devices, or machines [5].

Azure Digital Twins provide capabilities for real-time monitoring, analysis and simulation of these digital representations, helping organizations to optimize procedures, operations, improve maintenance practices, and enhance overall efficiency. By harnessing Azure Digital Twins, users can gain valuable insights, make data-driven decisions or accurate forecasting and drive innovation in certain industries. By defining and updating properties within Azure Digital Twins, users can track and monitor the real-time status of physical assets or environments represented by the Digital Twins. This information can be used for analysis, visualization and decision-making purposes to optimize operations and improve overall efficiency [1], [5].

Azure Digital Twins specifications refer to the characteristics, or attributes, that can be associated with the created entity on the appropriate platform. These properties can include information, such as location, status, metadata, relationships with other entities, and custom-defined parameters specific to

¹Professor, Academy of Applied Studies Polytechnic, Novi Beograd Section, Blvd. Zorana Djindjića 152 a, 11070 Belgrade, Republic of Serbia, email: dkreculj@politehnika.edu.rs

²Professor, Academy of Applied Studies Polytechnic, Novi Beograd Section, Blvd. Zorana Djindjića 152 a, 11070 Belgrade, Republic of Serbia, email: amitrovic@politehnika.edu.rs; Associate Professor, "Union – Nikola Tesla" University, Faculty of Information Technologies and Engineering, Juriša Gagarina 149a, 11070 Belgrade, Republic of Serbia

³Professor, Academy of Applied Studies Polytechnic, Novi Beograd Section, Blvd. Zorana Djindjića 152 a, 11070 Belgrade, Republic of Serbia, email: djihovicni@politehnika.edu.rs

⁴Professor, Academy of Applied Studies Polytechnic, Novi Beograd Section, Blvd. Zorana Djindjića 152 a, 11070 Belgrade, Republic of Serbia, email: nratkovickovacevic@politehnika.edu.rs

⁵Teacher of Technics and Technologies, Primary School "Jovan S. Popovic", Vojvodjanska 61, 11070 Belgrade, Republic of Serbia, email: aleksa.vucicevic@gmail.com

the Digital Twins. By defining and assigning properties to Digital Twins, users can effectively model and represent the physical systems in a virtual environment. Those properties have a crucial role in enabling real-time monitoring, analysis and simulation of such simulation models, ultimately helping organizations to optimize operations and make informed decisions based on the data collected from these virtual representations.

Figure 1 illustrates the Azure Digital Twins concept [5].



Figure 1 – Azure Digital Twins concept [5]

The platform Azure Digital Twins also integrates with the wider and well-known Azure Data analytics program to gain more precise and additionally applicable values. Moreover, due to the utility of instant optimization and risk testing, some studies have shown that Digital Twins help increase business efficiency, reduce costs and improve outputs.

2. STRUCTURE

Digital Twins platforms are complex, and composed of several connected modules. In [1], it is assessed that the application domain has a significant impact on the architecture of Digital Twin implementations across various domains.

Figure 2 illustrates the generic implementation of the Digital Twins [6].

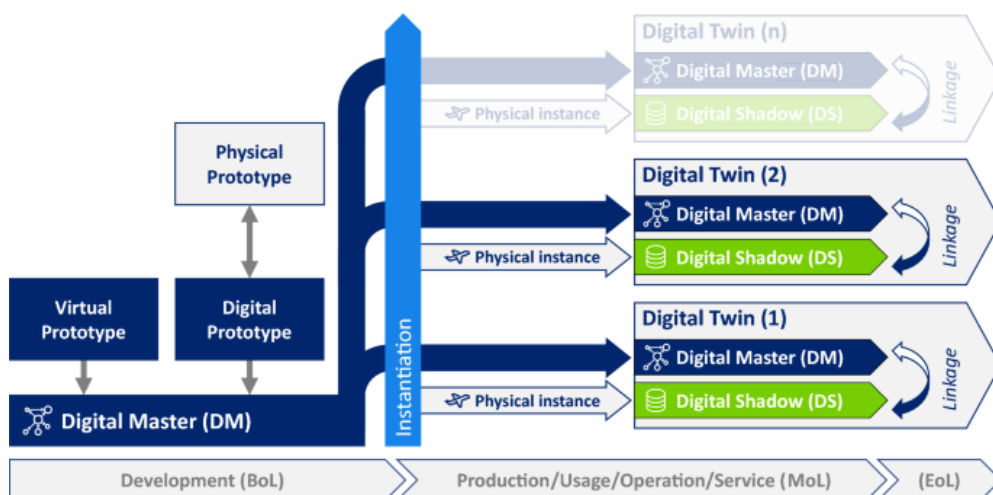


Figure 2 – The generic implementation of the Digital Twins [6]

Microsoft Azure Digital Twins are organized around the concept of creating a comprehensive digital representation of physical environments, assets, and systems. The platform allows users to model relationships, properties, and behaviors for various elements within a virtual space.

The basic elements of the Azure Digital Twins structure include the following [7]:

- Models - define the types of entities and relationships within the digital twin environment, such as devices, sensors, rooms, and buildings,
- Instances - represent specific instances of the defined models, capturing real-time data and status information from physical assets,
- Relationships - establish connections between different instances to simulate interactions and dependencies between certain elements in the digital twin environment,
- Properties - store metadata and attributes associated with each instance, enabling detailed monitoring and analysis of the digital twin data,
- APIs (Application Programming Interfaces) - provide interfaces for interacting with and querying the digital twin models, instances, and data, facilitating integration with other applications and services.

Moreover the structure of Azure Digital Twins is designed to support the creation, management and utilization of specific digital twins for a wide range of use cases, enabling organizations to gain valuable insights and optimize operations in various industries.

For common components of Digital Twins technologies, the following are considered [7]:

- IoT sensors - these sensors collect real-time data from physical assets and environments;
- Data analytics - advanced analytics tools process and analyze the data collected by IoT sensors to derive insights and patterns;
- Simulation models - these models replicate the behavior and interactions of physical assets in a virtual environment;
- Visualization tools - graphical interfaces and dashboards provide users with a visual representation of the digital twin and its data.

Microsoft Azure Digital Twins is a specific advanced IoT platform that empowers developers to replicate real environments in digital form, fostering a deeper understanding through simulation, analysis, and automation of connected ecosystems. It provides essential APIs, and tools, as pre-built templates for efficient digital twin modeling and then for control. This platform offers in-depth insights into physical environments, enabling informed decision-making and addressing real-world challenges through precise modeling and analysis capabilities.

3. TECHNOLOGIES AND KEY PROPERTIES

Digital Twins technology has unique properties. The number of platforms based on that technology is significantly increasing.

Azure Digital Twins can be used in various industries, including smart buildings, manufacturing and healthcare, to monitor, analyze and optimize operations in real time. This platform harnesses cloud computing and IoT technologies to deliver scalable and efficient solutions for creating and managing digital twins.

Some of the key properties of Azure Digital Twins are as follows [8]:

- Open modeling language to create custom domain models of any connected environment using Digital Twins Definition Language;
- Live execution environment to bring the Digital Twins "to life" in a live graph representation;
- Input from IoT and business information systems to connect assets, including IoT devices, using Azure IoT Hub, Logic Apps, and REST APIs;
- Output twin change events to Azure Data Explorer, Azure Synapse Analytics, Event Hubs, and other downstream services [8].

By defining and updating properties within Azure Digital Twins, users can track and monitor the real-time status of physical assets, or environments represented by the Digital Twins. This information can be used for analysis, visualization, and decision-making purposes to optimize operations and improve overall efficiency assets, or environments represented by the created Digital Twins.

The Azure Digital Twins platform offers a diverse range of modules, including data ingestion, analytics, and visualization modules, among others. These pre-built components enhance the platform's functionality by providing additional capabilities and features that can be seamlessly integrated into digital twin solutions. By utilizing these modules, users can improve the performance and flexibility of their systems. Furthermore, Azure Digital Twins modules enable accelerated development, streamlined operations, and the creation of intelligent, connected products, unlocking new opportunities for innovation and efficiency.

Figure 3 illustrates the input and output parameters of Azure Digital Twins [5].

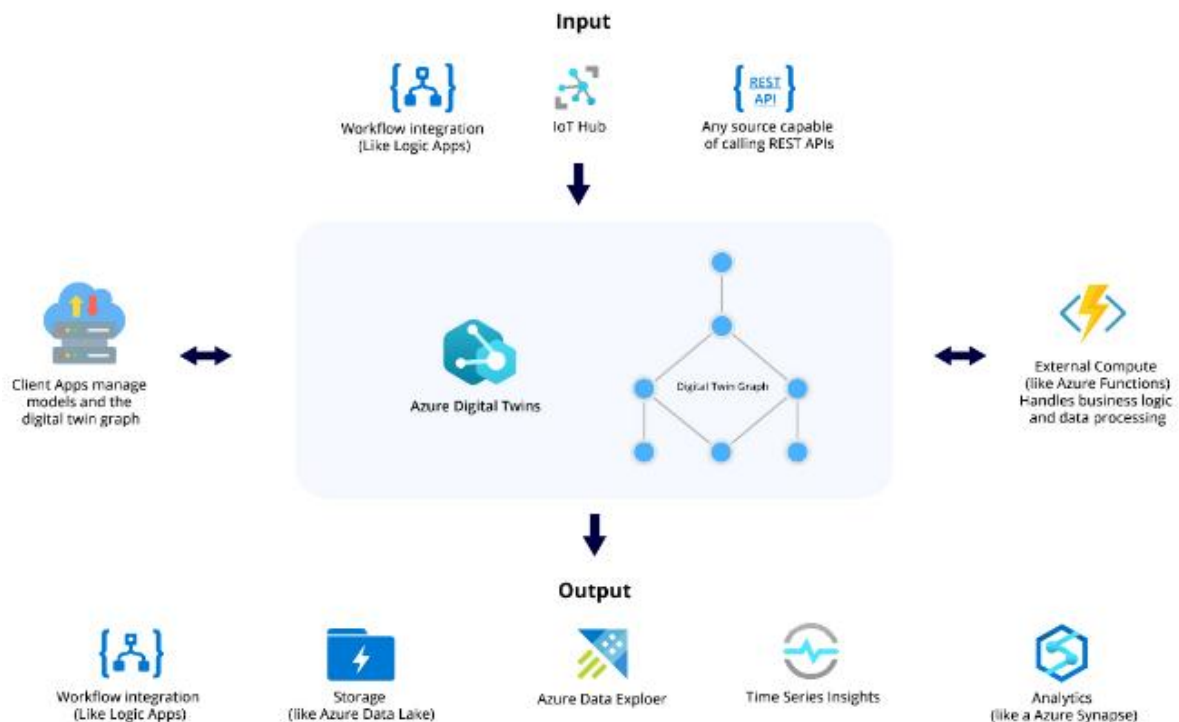


Figure 3 – Azure Digital Twins input and output parameters [5]

Azure Digital Twins is a Platform as a Service (PaaS) that facilitates the creation of twin graphs based on digital models of complex environments, including factories, buildings, farms, energy networks, railways, airplanes, etc. These digital (and three-dimensional) models enable comprehensive insights, driving improvements in product quality, optimizing operations, reducing costs, and enhancing customer experiences [7].

Microsoft Digital Twins platform as a service complies with security, protocols, resources, and connectivity for data and use of files for the presentation in 3D of real-world physical entities. Azure Digital Twins offers a wide range of options, including databases, predictive analytics, programming language and an intuitive interface [9].

Azure Digital Twins comprises various components, including spatial intelligence graphs, digital models, device topology models, and the capability to perform directed and purposeful real-time analytics [5].

4. APPLICATIONS

Applications of Digital Twins technology have been growing at an exponential rate in recent years [2]. This technology is transforming the way businesses operate. The benefits of creating a Digital Twins solution are said to be too vast and still not entirely explored. [1], [2].

Microsoft Azure Digital Twins can be applied in various industries and use cases to enhance operations, improve efficiency, and drive innovation. These are being increasingly used in the industry to enhance maintenance, operations, and performance. Azure Digital Twins have been implemented to design a chosen digital twins architecture, that represents existing IoT devices in a so-called cloud environment, and which connects to other devices to send and receive relevant real-time data [7].

Digital Twins technology is utilized for specific and detailed virtual replicas of entities (physical devices, machines, products), formed by combining data with Machine Learning (ML) and software analytics, to make digital models that update and change continuously and synchronously with their real-life counterparts.

Azure Digital Twins provides a versatile platform applicable across various industries and a wide range of use cases. Among these, the most common applications include [10]:

- Smart Buildings - Azure Digital Twins can be used to build digital twin models of buildings, and to analyze and visualize data from sensors and other devices in those buildings; this can be used to optimize building performance, improve energy efficiency, and enhance the occupant experience.
- Smart Cities - Azure Digital Twins is used to make digital twin models of entire cities to analyze and visualize data from various sensors and devices in the city; this will optimize traffic flow, improve public safety, and reduce greenhouse gas emissions.
- Industrial IoT - Azure Digital Twins is support for forming digital twin models of industrial environments, also providing means to analyze and visualize data from sensors and similar devices; this should optimize production, improve equipment performance, and enhance the overall efficiency of the facility.
- Supply Chain Optimization - Azure Digital Twins can be used to create digital twin models, of supply chain networks, to analyze and visualize data from sensors and other devices distributed throughout the supply chain; that will optimize logistics, improve inventory management, and enhance the efficiency of the supply chain.
- Remote Monitoring and Control - Azure Digital Twins can be used to build digital twin models of remote environments, such as offshore platforms and remote mining sites, to analyze and visualize data from sensors and some other devices that are distributed in the environments; this is useful for monitoring and controlling the environment conditions, preventing pollution, improving safety, and also reducing downtime of the assets.

The use of Digital Twins in industry presents an important opportunity to enhance sustainability by optimizing operations, reducing waste, and improving the overall efficiency of components, systems, processes and services. As the industries tend to minimize their environmental impact, these technologies will have crucial roles in driving innovation and implementing sustainable practices. [11].

5. CONCLUSION

Digital twins software systems are cutting-edge technologies that create virtual models of physical assets, systems, or processes. Microsoft Azure Digital Twins is a powerful tool for creating smart digital models and advanced IoT solutions. This software is referred to as an advanced IoT platform that empowers developers to replicate physical entities in digital forms. It is based on key APIs, tools and pre-built templates to create improved digital twin models.

The main modules in Microsoft Azure Digital Twins allow users to define and configure the properties, behaviors and relationships of digital twins, as they integrate data from various sources to create a comprehensive digital representation of physical assets. With these modules, users can easily

deploy and scale their digital twin solutions, enabling them to harness the power of IoT and AI technologies for smarter decision-making and improved operational efficiency.

The use of digital twins change the way in which companies can optimize their processes, form improvements of their products or services, make predictions to maintenance services, and decrease the various influential risks. Digital Twins are being increasingly used in the industry to enhance maintenance, operations and performance. They can monitor the health and performance of components in real-time and in simulated-life conditions, enabling predictive maintenance to identify potential issues in time before they lead to costly downtime, or failures. The sectors with the most extensive adoption of digital twins include: aerospace, automotive, education, healthcare, energy, transportation, and manufacturing.

Digital Twins are in connection with the IoT and AI, allowing for the generation of different digital twin scenarios for future prediction and optimal decision-making. This technology is implemented in smart buildings, smart cities, industrial IoT, supply chain optimization, remote monitoring and control.

Microsoft Azure Digital Twins are distinguished by their scalability and seamless cloud integration, making them ideal solutions for organizations seeking to enhance operations. The platform's scalability ensures that it can adapt to varying workloads and expand to accommodate growing business needs, while its cloud integration enables efficient data management, real-time updates, and remote accessibility. These features empower organizations to optimize processes, reduce operational costs, and foster targeted innovations. By utilizing Azure Digital Twins, businesses can gain deeper insights into system performance, streamline workflows, and accelerate the development of intelligent, data-driven solutions tailored to their specific needs and goals.

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