INDUSTRY 4.0 AND THE DIGITAL TWIN FOR BUILDING INDUSTRY

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Abstract: Technology and innovations have powered the evolution of Industry 4.0, the fourth industrial revolution. State-of-the-art technologies such as the Internet of Things (IoT), cloud computing (CC), big data analytics (BDA), and artificial intelligence (AI)—all part of Industry 4.0—have greatly stimulated the building industry. Digital Twin is a significant enabler for Industry 4.0 initiatives. Within Industry 4.0, the amount of digital product information generated and collected over the entire lifecycle has been growing. Although digital twins have been around for several decades, the rapid rise of the internet of things (IoT) is that they have become more widely considered as a tool of the future. Digital twins are getting attention because they also integrate things like artificial intelligence (AI) and machine learning (ML) to bring data, algorithms, and context together.

A “digital twin”—or digital replica of a physical entity—can target building industry in several sub-areas:
- Facility management
- Product Lifecycle Management
- Smart Buildings
- Smart energy

All these areas are one giant step further by creating a Digital Twin—a virtual representation of real-world buildings that can be viewed and scrutinized in minute detail. This research describes business cases and best practices in design of IoT Solutions for building industry, powered by Digital Twins. A reference architecture and prototypes which demonstrate application of Digital Twins in Smart are created as a result of this study. This research is technology agnostic, but prototypes of sample solutions are considered in the context of Microsoft Azure (Azure solutions, covering Azure Digital Twins Service and Azure IoT Stack.)

Keywords: DIGITAL TWIN, IOT, INDUSTRY 4.0, MICROSOFT AZURE, AZURE IOT STACK

1. Introduction

Digital Twin has gained significant impetus as a breakthrough technological development that has the potential to transform the landscape of manufacturing today and tomorrow [1].

The demand for affordable housing has never been higher [2], affected by a concomitant need for social, utility, and transportation infrastructure. These challenges have ensured that the construction industry continues to review and revamp itself. The changes that occur here affect society in general—the construction costs will fall and this will be beneficial for the environment will benefit. This can be achieved by efficiently using limited resources and/or ensuring that buildings are being constructed eco-efficiency [3].

Despite the industry’s vast potential, increasing efficacy and productivity can only result from digitalization, new techniques for construction, and innovations. Tools such as three-dimensional (3D) scanning, building information modelling (BIM), drones, and augmented reality have all reached market maturity [4].

The fourth industrial revolution 4.0 or Industry 4.0 has introduced digital technologies, sensor systems, intelligent machines, and smart materials to the construction industry where BIM has become the central repository for collating digital information about a project [5].

Industry 4.0, a name coined to encompass the widespread integration of information and communication technologies that converge the physical and digital many areas of industry

Successful enterprises are using a full stack of technologies to achieve the goals of Industry 4.0: efficiency, speed, agility, and customer-centricity.

One of these technologies is the digital twin. Digital Twins is or digital replica of a physical entity that can target building industry in several sub-areas:
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One of the primary reasons digital twin technology is rapidly being adopted is there are multiple use cases across the industrial enterprise: engineering, manufacturing and operations, and maintenance and service. Digital twins are made possible (and improved) by a multitude of Industry 4.0 technologies—IoT, AR, CAD, PLM, AI, edge computing, to name a few—to create a powerful tool that’s driving business value [6].

What is Digital Twin?

Digital Twin is the exact representation of, for example, a building as digital data. One example could be a database that knows everything that happened during the construction phase of a building, like:

1. A timeline of every status change reported for all activities executed to deliver the project.
2. Who reported them?
3. Issues and Obstructions that needed to be faced during the construction process.
4. When those have been resolved and by whom.

Such a database should also be considered a Digital Twin. Sure, since it really is the exact representation of the buildings construction phase after all.

Figure 1: Digital Twin Model, described with Sablono [7].
While other applications of Digital Twin Technology use automated sensor technology to do so, the AEC industry has to rely on humans to put the required information into the system.

“Building Information Modeling (BIM)” and “Digital Twin Technology” sound very much alike. Therefore, it does not come as a surprise that “Building Information Modeling (BIM) with a consistent and structured data management is the key to generate such a digital [twin] building whose dynamic performance can be studied by building simulation tools for a variety of different boundary conditions”.[0]

**BIM vs. Digital Twins**
1. BIM Is For Design and Construction
2. BIM Isn’t Designed for Real-Time Operational Response
3. BIM Focuses on Buildings Rather Than People
4. Digital Twin can give you information about the current state of build subsystems, how they are being impacted by occupant behavior when assets like HVAC or lighting might fail and much more.
5. Digital Twin a model that evolves over time to deliver more value with each new stage of the asset’s lifecycle
6. In the future, Digital Twin will certainly supersede BIM software even at the design and build phase of an asset’s lifecycle.

The current study is an overview of the possibilities of using Digital Twins in the construction industry. It also presents prototypes that demonstrate solutions to real cases with the Digital Twins.

**2. Application of Digital Twins in Building Industry**

The vision of “Construction 4.0” refers to the Industry 4. In addition, is a fundamental challenge for the construction industry. In terms of automated production and level of digitalization, the construction industry is still significantly behind other industries. The trends like Big Data or the Internet of Things offer great opportunities for the future development of the construction sector. Prerequisite for the successful Construction 4.0 is the creation of a digital twin of a building. Building Information Modeling (BIM) with a consistent and structured data management is the key to generate such a digital building whose dynamic performance can be developed by building simulation tools for a variety of different boundary conditions. Along the total life cycle from design to construction, operation and maintenance towards remodeling or demolition, the digital twin follows all modifications of the real building and dynamically readjusts itself in case of recorded performance differences. Thus, for the whole life span of the real building, performance predictions generated with the virtual twin represent an accurate basis for well-informed decisions. This helps to develop cost-effective operation modes, e.g. by introducing new cyber-controlled HVAC systems. The digital twin may also analyze the building’s dynamic response to changes in occupation or energy supply; it also indicates the need for building maintenance or upgrades. [8]

There are different areas for Digital Twins application in building industry:
- Energy Models for Optimization
- Analyze complex structures
- Structural Health Monitoring:
- Reduce maintenance costs
- Optimize models
- Materials testing
- Smart Cities [9]
- Any kind of other IoT solution, in building industry [10]

**Figure 2: Digital Twins Concept.**

**3. Digital Twins support in Microsoft Azure**

Microsoft Azure – the Microsoft Public cloud offers Azure Digital Twins Service, which simplifies a lot the implementation of solutions, based on Digital Twins concept. It provides a specific extendible object model, focused on problems in building industry.

Digital Twins object models describe domain-specific concepts, categories, and properties. Models are predefined by users who want to tailor the solution to their specific needs. Together, these predefined Digital Twins object models make up an ontology. A smart building's ontology describes regions, venues, floors, offices, zones, conference rooms, and focus rooms. An energy grid ontology describes various power stations, substations, energy resources, and customers. With Digital Twins object models and ontologies, diverse scenarios and needs can be customized.

With Digital Twins object models and an ontology in place, you can populate a spatial graph. Spatial graphs are virtual representations of the many relationships between spaces, devices, and people that are relevant to an IoT solution. This diagram shows an example of a spatial graph that uses a smart building's ontology.
Azure Digital Twins Object Model

Azure Digital Twins Graph Viewer:

Azure Digital Twins Graph Viewer is an OSS project, hosted in GitHub. It is used to manage and visualize your digital space:

The solution supports:
- Stored in a Static Web Site
- AAD authenticated
- Azure SignalR
- Azure Function AAD Authenticated for query and SignalR hub

Azure Digital Twins in Modern IoT Solutions

There are many areas in IoT solutions, where Digital Twins technology can be used:
- Device Configuration Management System
- Device monitoring
- Device provisioning
- Software update
- Multi-tenancy
- Integration with other solution
- Raise alarms (event driven design)

3. Sample Prototypes

Smart Spaces: [Facility Management]

The problem:
The main case is that the office spaces were used inefficiently (for instance small conf rooms were occupied when bigger ones were free) or someone booked a room but the meeting did not take place.

Used services:
Azure Digital Twins Service, Azure IoT and Cognitive Services (Azure AI)

Smart spaces solution architecture:

Smart Spaces solution consists of desktop application, IoT devices and services in the Microsoft Azure cloud.

To get information about conditions in each conference room and to check the number of people inside are used Azure Digital Twins and Cognitive Services.
- There are two IoT devices connected to the Azure Digital Twins, which has an IoT Hub service underneath.
- These two IoT devices have some sensors, for example temperature sensor. In the Azure Digital Twins service, there are defined User Defined Function (UDF) which is responsible for analyzing insights from specific sensors and on this basis providing clear information.
- UDF to analyze temperature data from the specific room, and provide information if it is suitable to start another meeting or if the temperature is too high.
- Azure Digital Twins provides API, so it is possible to connect to it from the web, desktop or mobile applications to retrieve information about every room.
- Cognitive Services – Computer Vision API and Logic App:

One of the IoT devices has a camera connected (right side of the architecture diagram). Snapshots are taken each specific period of time. Then the photo is sent to the Azure IoT Hub and stored in the Azure Storage in the blob container. There is a Logic App created to detect if there is any new image. Then the image is sent to the Computer Vision API to get information about the number of people recognized on the picture. The result is stored in the Azure Table Storage. Data is analyzed via Azure Cognitive Service.

Device Configuration Management System & Multi-tenancy

Device Configuration is one of the main components of modern IoT solutions. This module is responsible for:
- Device monitoring
- Device management
- Device provisioning
- Software update

Digital Twins can be used to persist the complex model of spaces and connected devices, which is actually the data model used in Device Management module.
3. Conclusions

Overview of the current research

Current research covered several areas:

Application of Digital Twins Technology in Building Industry

- Problems
- Use cases
- Available technologies
- Implementation of prototypes for several use-cases

Future work:

Research will extended, based on data analytics over data from Digital Twins. The major focus will be solving the real life cases about prediction and maintenance, related to structures maintenance and facility management.

References


