Chapter

How Digital Twins Is Being Used in Industry 4.0

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Abstract

The impact of the 4th industrial revolution, or Industry 4.0, has generated innovations that help industrial automation, promoting the digitization of activities and processes that result in increased productivity, competitiveness, improved quality of products created, and increased capacity for companies to invoke through the use of technologies such as smart cities, energy, oil and gas, Internet of things, digital and auditory manufacturing, digital twins and systems integration, among the most diverse areas inserted in Industry 4.0. This chapter will present a summary of how the most diverse industry sectors such as smart cities, oil, gas sector, energy and other areas are applying digital twins as a tool to support the digitization of companies.

Keywords: digital twins, industry 4.0, smart cities, oil and gas, energy, opportunity, applicability

1. Introduction

The concept of digital twins, originated by NASA, emerged in 2012 when it became necessary to create virtual environments that corresponded to the data of physical objects, assisting the company in decision-making [1].

Based on the article developed by Dashkina et al. [2], it is identified that Industry 4.0 is strongly linked to digital twin technology, which corresponds to the particularity of linking the behavior of physical objects such as manufacturing lines, robots, and technical installations through the use of computers and software. The use of the digital twins concept is particularly relevant when it involves mechanical parts where their properties undergo physical wear and tear over time or even cracks in metal components. It is suggested to create monitoring routines for these components with the aim of creating process improvements through continuous feedback on the state of the parts.

Canedo [3] mentions that representing real objects in digital twins adds great value compared to local optimization as is done today. Optimization and efficiency are gains to be noted when using digital twins at the system-of-systems level, and according to the article [4], the use of digital twins is a significant factor in decision-making to positively impact product construction.

According to Pethuru and Preetha [5], through real data of objects, it is possible to create simulations that assist in predicting how physical objects will be affected based on the received data. In other words, constructing monitoring of physical objects in a controlled virtual area, it helps in the prevention and control of possible failures encountered during the use of real objects [1].

The power of using digital twins in Industry 4.0 can be explored in various areas such as IoT, smart cities, energy, oil and gas, and healthcare as a decision-making tool to assist in the continuous improvement of the process of building a sustainable business model.

2. Industry 4.0 and digital twins in the sectors

In this section, we will explore how digital twins are being applied in Industry 4.0 in the energy, oil and gas, smart cities sectors, and other areas.

2.1 Energy sector

Through research conducted in article [6] by Arowoiya, it was observed that the applicability of digital twins (DT) in the energy sector can assist in energy management, usage, and simulation creation in conjunction with real-world data [7–9] to predict potential issues found in buildings.

Another application of DT in the energy sector is related to temperature control in physical environments, where a large number of variables were manually controlled using thermometers, hydrometers, and anemometers as input for manual decision-making [6]. To address this issue, Escandón et al. [10] mentions the use of a neural intelligence network in conjunction with DT.

Simultaneously, to address the monitoring issue in buildings, ref. [6] cites article [11] that uses DT in conjunction with the creation of an integrated building information modeling (BIM) system with IoT, which sends alerts to operators, thus assisting in real-time monitoring of physical objects.

The increasing interest in academia and the industry regarding the use of DT in the energy sector stems from the possibility of real-time monitoring of an electrical network with the assistance of IoT and AI.

The energy sector can explore the creation of simulation software to assess the wear, performance, and associated costs of using specific equipment for energy production, whether on a small or large scale, by utilizing a cluster of computers.

2.2 Oil and gas sector

For ref. [12], the major risk of oil and gas extraction up to the platforms is extremely complex and risky, with the possibility of setbacks that can result in financial and catastrophic losses. It is necessary for the industry to take preventive measures to mitigate the risks.

With this issue, it is important for companies in the field to invest in technology and innovation in order to expand oil and gas extraction while mitigating the inherent risks of the circumstances. In the article [13], the author states that there are thousands of sensors, complex components, and processes to be followed, and Digital Twins (DT) can be used to assist the oil and gas sector in risk mitigation through predictive analysis of the data exposed by real objects.

In ref. [12], it is mentioned that DT can help the oil and gas sector by creating virtual environments with real data that assist administrators in testing deviations, recording and analyzing data, and advancing with the security of the business cycle.

By using the virtual environment with real-time data from real objects, DT can perform routines following a predefined process in conjunction with the assistance of AI to identify potential anomalies predictively, helping the process become increasingly secure and scalable.

One way to obtain data from oil and gas platforms, according to Priyanka et al. [12], is through the use of smart IoT modules that are installed between sensors and control points using the Routing Protocol for Lossy organizations (RPL) protocol, which will help make oil and gas extraction safer through predictive information. Additionally, according to Wanasinghe et al. [14], it helps the platform operator visualize risks in a centralized visual manner, which can aid in intervening in potential issues.

In **Figure 1** [14], it is mentioned that there are several frameworks developed for DT where a significant portion converges to include three major sections. The physical section includes accessories, sensors, and actuators. The virtual section includes multi-physics spaces, model simulations that contribute to data analysis, and finally, the connection between the physical and virtual spaces, which ensures the exchange of information between the two.

Another approach, according to Wanasinghe et al. [14], would be to create a DT framework using a five-component model, as shown in **Figure 2**. The physical environment contains all the physical accessories, sensors, and actuators. The virtual space contains a mirror of the physical environment for high fidelity in creating simulations. The service system contains another enterprise application responsible for service visualizations, service quality, diagnostic services, model calibration, algorithm services, and other services. The DT data fusion acts as a bridge between the physical environment, virtual model, and service system.

According to Wanasinghe et al. [14], the use of machine learning, deep learning, and artificial intelligence with intelligent mathematical algorithms will be important tools in the predictive evaluation of possible risks associated with the components used on platforms, thereby avoiding potential failures and accidents.

The oil and gas sector can explore simulation programs that can be created using real data and characteristics of the components, especially the variables of the environment that are part of the oil extraction process, to assist in the predictive identification of wear and tear through the use of mathematical models that help the company mitigate risks, costs, environmental problems, and assist in the scheduled replacement of components. In this context, it is relevant for the company to create scalable solutions in machine clusters due to the possibility of a high level of data processing that may be generated during the prediction process.

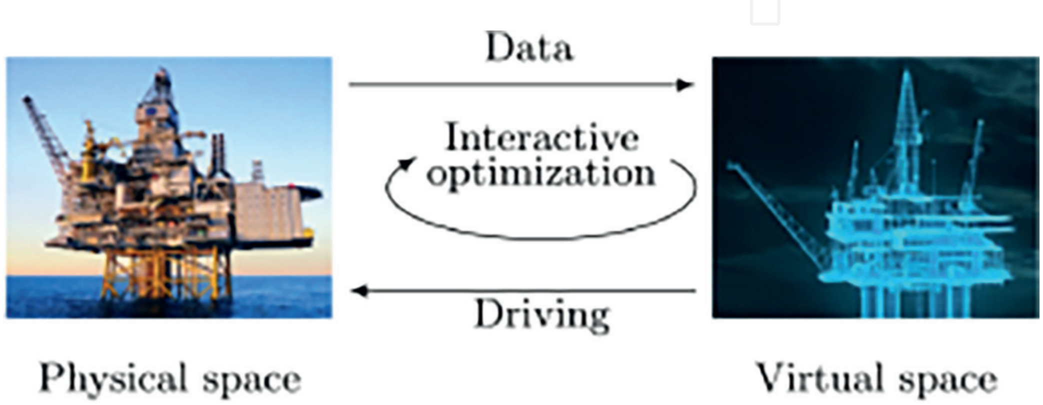

Figure 1.
Digital twin framework with three components (physical space, virtual space, and connection between them) [14].

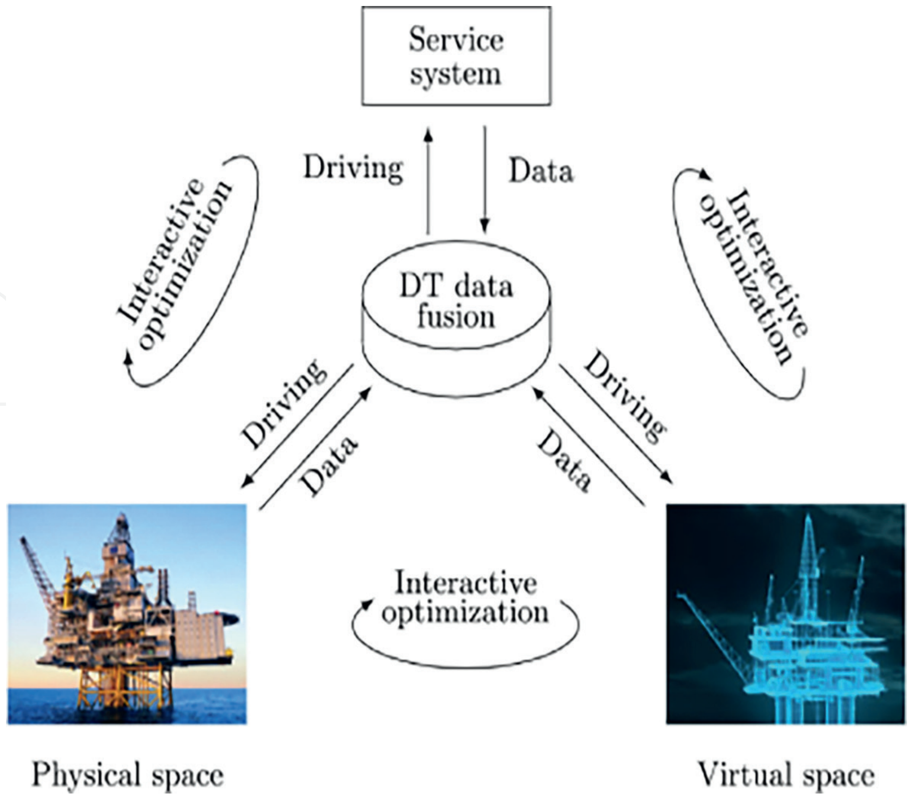

Figure 2.
Digital twins framework with five components (physical space, virtual space, connection between them, data and service) [14].

Wanasinghe et al. [14] mentions that simulations using DT will assist engineers in building new platforms or modifying their oil and gas extraction structures, reducing risks, as this step can be repeated whenever necessary to bring greater reliability, performance, and reduction of unnecessary costs before executing the operation.

Wanasinghe et al. [14] observed that DT can help engineers and individuals involved in problem-solving in a faster and cooperative way by obtaining real-time information from the platforms, enabling the creation of virtual rooms with the possibility of simulations to improve performance in critical decision-making for any occurring problems.

Another factor where DT can help in the oil and gas sector, according to Wanasinghe et al. [14], is the creation of training centers in conjunction with the use of VR, AR, and MR technologies to train new employees who can navigate within oil and gas centers with ease of operating equipment, inspecting systems, and interacting with ongoing operations. This is a significant factor for companies to explore this possibility since, according to research in articles [15–16], the oil and gas sector is facing a challenge called the "big-crew change," where in the near future, more than 50% of experienced workers will retire, causing the sector to lose skills and talents in the industry.

2.3 Smart cities sector

According to Zhuang et al. [17], the characteristics of Digital Twins (DT), such as the integration of various types of data from physical objects, involvement throughout the lifecycle of physical objects, co-evolution with them, and continuously accumulating relevant knowledge, can help the government [18] create more predictive and comprehensive prediction and indicators in a smart cities ecosystem.

In the field of smart cities, DT, as mentioned in ref. [17], can be used to build physical maps of the real city in a virtual area that receives real-time events from the mapped objects. This allows for transferring, modifying, deleting, and performing operations in a city area through the created 3D models, while checking for possible problems that may occur through these operations.

Mohammadi and Taylor [19] mentions a project being developed using DT concepts in smart cities called the Digital Twin City of Atlanta, which utilizes a VR platform developed with Unity, a cross-platform framework designed for video games. This environment helps discover interactions and interoperability of its human infrastructure systems.

According to Ivanov et al. [20], DT can bring opportunities for improvements in smart cities through observability of resident traffic flow, private business traffic, public transportation, and real-time information from private and public intelligent sensors that help monitor and analyze temperature and humidity as shown in **Figure 3**.

According to Ivanov et al. [20], through the collected data in a smart city, the following opportunities for improvements can be generated along with the use of IoT:

- Creating a DT of the public transportation network to monitor and predict possible availability and efficiency situations of transportation.

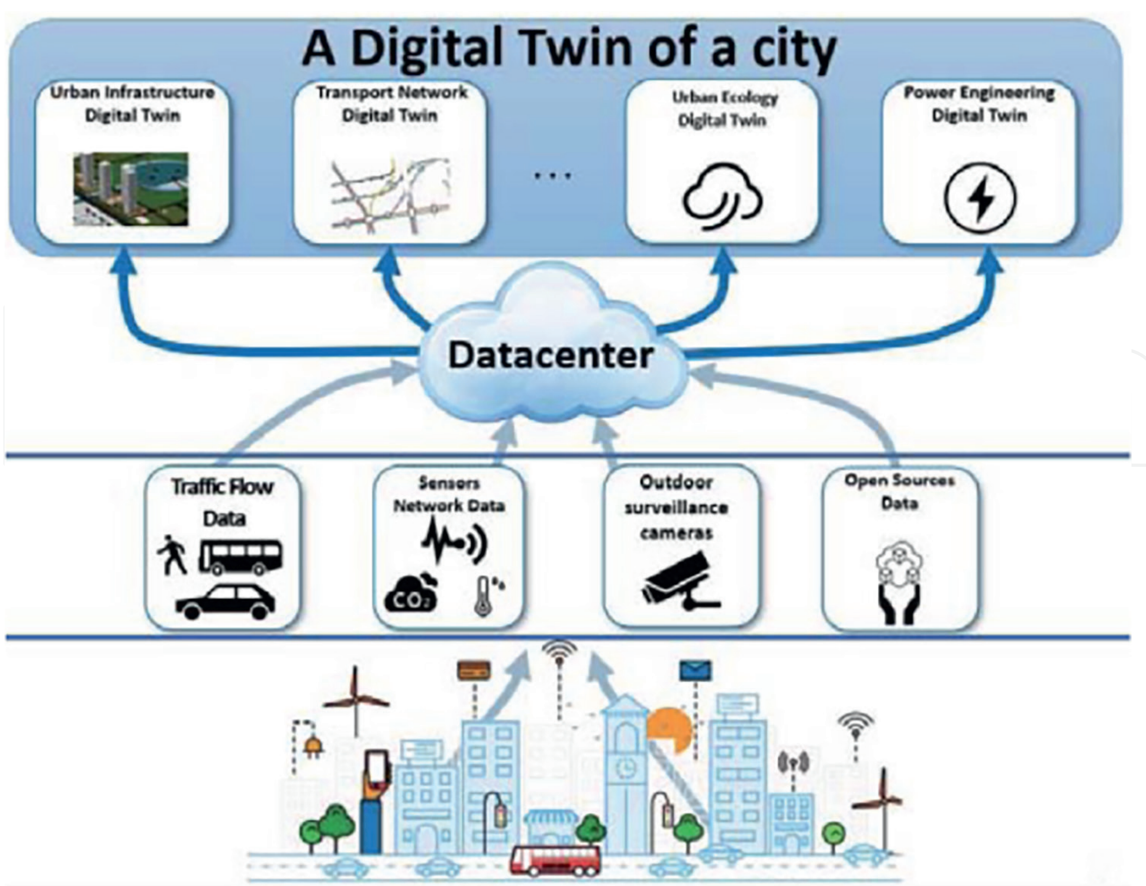

Figure 3.
An example of the interface's appearance of the use of digital twins in smart cities [20].

- Creating a DT of the city's ecological system to promote monitoring and predict changes in the environment, including changes in soil, water, air quality, etc.
- Improving the efficiency of city design solutions evaluation.
- Identifying potential sources of risks.
- Controlling pollution through continuous environmental analysis.
- Energy rationing through on-demand usage of city energy.
- Improving efficiency and reducing costs through on-demand waste removal instead of scheduled waste collection.

To analyze the large amount of data received by sensors in a smart city within a DT, it is necessary, as stated in ref. [21], to include statistics, data analysis intelligence, and a computational model.

Ivanov et al. [20] states the need to create a large warehouse that can handle a significant amount of data, sufficient bandwidth to collect and analyze the data received, and computational power to support the high degree of processing that can be done through techniques such as machine learning.

2.4 Other areas

This section aims to show how some other areas are exploring digital twins in various sectors.

In the article [22], it is mentioned that the manufacturing industry has been using DT through monitoring, simulations, and remote control of physical assets using virtual objects. This, in turn, helps in understanding and improving customer satisfaction by enhancing existing products, operations, and services.

Also, in the same article [22], in the field of agriculture, it is possible to use DT by creating virtual environments representing a farm with the goal of increasing productivity and production efficiency while reducing energy and costs.

Regarding education and training, Attaran and Celik [22] explains that the use of DT through Virtual Reality (VR) has been assisting in the training of doctors by complementing and refining the traditional educational model.

3. Discussion

In this chapter, which focused on the study in the areas of oil and gas, energy, smart cities, and other general fields, the observation was made on how the industry has been using DT (Data Technology) to enhance process quality through the following main characteristics.

3.1 Usage of real data in virtual environments

The use of real data is connected and directly utilized in a virtual environment, thereby assisting in the creation of simulations that aid in better decision-making.

3.2 Virtual reality (VR)

The use of virtual reality has aided in the development of more effective training and improved interactions with real objects in a virtual world.

3.3 Monitoring

Real-time monitoring of physical objects in a virtual environment will help in predicting potential issues through the use of IA.

4. Conclusion

In Industry 4.0, one of the pillars being explored in the industry is Digital Twins. This work aimed to demonstrate how Digital Twins are being used in the sectors of smart cities, energy, oil and gas, and other areas, and how they have helped in reducing risks, and costs, improving processes, and enabling real-time monitoring of physical objects through the use of the Internet of Things and artificial intelligence.

Thanks

I would like to thank my family, Urbano Chagas and CESAR for the opportunity to share about the topic discussed.

Abbreviations

DT	digital twins
BIM	building information modeling
IoT	Internet of Things
VR	virtual reality
AR	Augmented reality

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