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APPLICATION OF DIGITAL TWIN TECHNOLOGY IN THE DEVELOPMENT OF LOGISTICS PROCESS

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Abstract: „A digital twin is a living model that drives a business outcome" *(Colin J. Parris, GE).* Digital twin technology is appearing more and more fields, including logistics, which nowadays generates new research opportunities for the logistics professionals. However multiple key technologies had already been developed. The aim of this article is to present the technology, development and types of digital twins, as well as to provide an overview of the possibilities of their application in logistics. Furthermore, the purpose of the publication is to present the research guidelines of the field.
Keywords: digital twin, fourth industrial revolution, logistics, artificial intelligence

1. INTRODUCTION

Digital platforms have changed the relationship between customers, employees and employers, also transforming jobs and skills. Around the world more and more people are participating in the digital economy, so it is important to take full advantage of the digital revolution. The digital transformation is a general-purpose technology that has the ability to continuously transform itself, increasing productivity in all industries and sectors. These major transformations are rare, but have many benefits in long-term. There are some similar technologies from the past, for instance the steam engine, the generator and the printing machine [1].

We believe that digital twin technology can be considered as one of the most determining catalysts of the future logistics. Because of the improving technology, the logistics' industry has already developed a lot. The main reasons for using the digital twin is effective monitoring and sustainability [2].

This aim of this publication is to present the digital twin and to describe the major definitions too. The article presents the digital twin evolution with details from the year 1956, where artificial intelligence as a concept was evolved.

The article also gives more detail about the review of literary history as well as the logistical application of the digital twin. At the end of this publication future research directions are defined.

2. DIGITAL TWIN

One of the important technologies of the fourth industrial revolution is the digital twin which became possible by data analysis and the Internet of Things (IoT). The useable data has increased thanks to the IoT. The digital twin can handle this amount of data by creating an interconnected physical and virtual twin (Digital Twin). The use of digital twin allows for quick analysis as well as accurate real-time decisions [3].

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A digital twin is a collection of information that describes a potential or existing product. We can get all information from the digital twin what we can get from the physical object's observation. There are two versions of digital twin. One is a digital twin prototype, which contains information that can be used to describe a real product. These could be the manufacturing process, 3D model, parts list. The other version is the digital twin instance, which is a virtual product linked to a physically existing object. It contains the geometric data of the real object, 3D model, bill of materials, maintenance results, information. Different versions of the digital twin are working in a digital environment which is based on a copy of the surrounding environment of the real product around the digital copy [4].

2.1. Digital Twin technology

In the specialized literature, the definition of a digital twin is often confused with a digital model or even a digital shadow.

The digital model is a digital version of an existing or planned physical object. There is no automatic data exchange between the physical model and the digital model, only manual data flow. This means that a change made to the physical object after the digital model was created, has no effect on the digital model [3]. This definition is demonstrated by Figure 1.

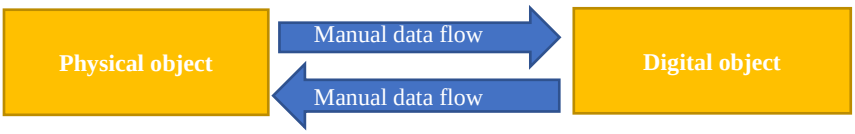

Figure 1. Digital Model

The digital shadow is a digital representation of an object. In this case, changing the physical object leads to changing the digital object. It does not work on reverse. There is a one-way flow between the physical and digital object [3]. This definition is demonstrated by Figure 2.

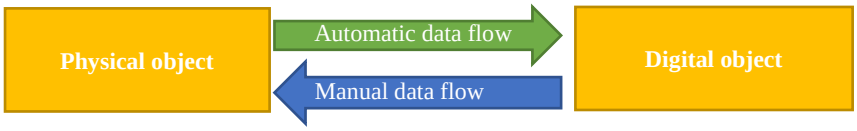

Figure 2. Digital Shadow

In a digital twin, data flows between existing physical object and a digital object, in both directions. If a change was made on the physical object it automatically leads to a change on the digital object, and vice versa [3]. This definition is demonstrated by Figure 3.

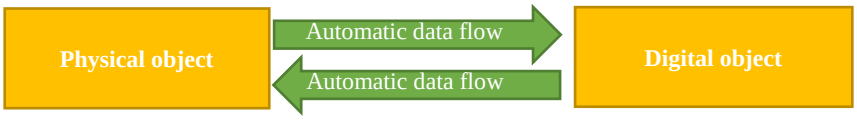

Figure 3. Digital Twin

3. EVOLUTION OF THE DIGITAL TWIN

Scientists and engineers have been making mathematical models of real objects for many years. These models have become increasingly sophisticated. Nowadays the improvements in technology make it possible to connect physical devices to digital models. Thus, the change experienced in physical objects appears in the digital models. Recognition from the model allows decisions to be made about the physical object [5].

3.1. Major milestones in the development of Digital Twin technology

In these days modelling options have become more sophisticated. These developments are also affected by the IoT, artificial intelligence, digital reality technologies, and digital twin technology.

Over the years, digital twin technology has evolved from artificial intelligence, the most important milestones are the followings:

1956: Artificial intelligence as a field of research was founded in a room at Darthmouth College by John McCarthy. During the workshop, researchers from several disciplines gathered to establish a research area on thinking machines. Nowadays, artificial intelligence usually performs tasks that require human thinking. Examples include visual perception, speech recognition, decision making and translation between languages [6].

1970: NASA has been using mirrored systems to monitor inaccessible physical spaces since the 1970s. The most famous example of this is the simulated environment developed during the Apollo 13 mission. Using this environment, the engineers found a solution to the exploded oxygen tank by simulating and then analyzing the condition. This example can be considered the predecessor of the digital twin, but it is not yet a fully digital twin, as there is no continuous connection and no real-time data flow between the physical and virtual models. Today, NASA uses digital twins to come up with new ideas, schedules, and new generation vehicles and to develop aircraft too [7]-[8].

1977-2001: The aircraft simulator and AutoCAD, has been released. AutoCAD has become an important tool in engineering. This has increased and widespread the use of simulation tools [5].

2002: In the beginning of 2002s, the basic concept of the Digital Twin Model was developed and presented at the University of Michigan. The presentation was prepared by Dr. Grieves as a product lifecycle management. It included all the devices that belong to the digital twin. These are real space, virtual space, the relationship of data flow from real space to virtual space, the flow of information from virtual space to real space and virtual subspaces. The model was based on the physical and virtual system [9]. McLaren Formula1 also began using digital twin technology to develop products and forecast performance in these years [5].

2011: Digital Twin will come to the front at NASA's Air Force Research Laboratory (AFRL). Its plan is to integrate existing digital twin technology, measure current capabilities, and identify gaps using components from an existing U.S. Air Force vehicle [10].

2015: General Electric (GE) Introduces Digital Wind Farm [5].

2017-2018: According to a Gartner report, the digital twin is among the TOP 10 technology trends. The digital twin has appeared in the product portfolios of all major software and industrial companies [5].

3.2. Specific literature analysis of the actuality of the topic area

For the literature review, we defined keywords which helped to make an overview of the number of articles published in the topic so far, as well as the year of their publication. For this, we used the Web of Science database. We did not specify a time interval for my search. We did a search on September 27, 2021, and since then might appeared new articles in the database.

Keywords:

- „artificial intelligent” as a topic
- „digital twin” as a topic
- „digital twin” as a title
- „digital twin model” as a topic

The year of the first article published in the field of “artificial intelligent” was 1985. After a few years, another publication appeared in 1992, and the number of publications increased significantly from the year of 2014. Figure 4 shows publication numbers through the years with the „artificial intelligent” search topic.

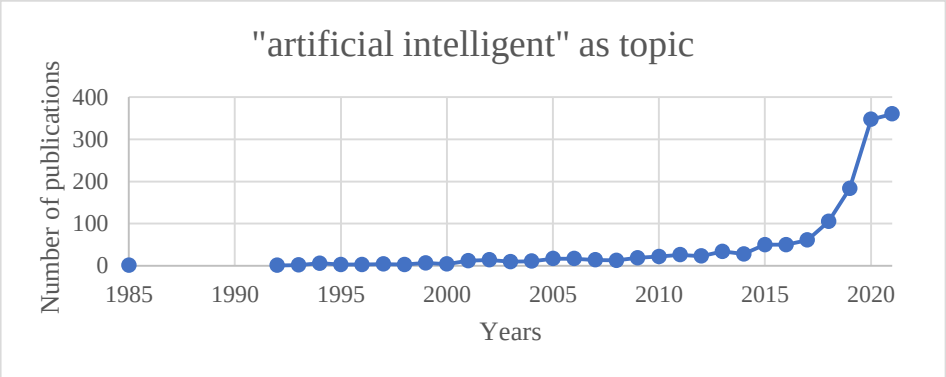

Figure 4. Web of Science search results „artificial intelligent”

We split the “digital twin” search into two parts. In the first part, we searched for publications in the database as a topic. The first publication in this topic was in 1994, followed by a significant increase in the number of publications from 2018. In the second part, we searched for the keyword in the title, so we got slightly fewer results. The first article titled the „digital twin” was published in 2014.

Figure 5 and 6 shows publication numbers through the years with the „digital twin” search topic and search title.

We searched the database for the keyword “digital twin model” as a topic area. Figure 7 shows the results. The total number of published articles is 56, it can be observed that the number of publications has increased significantly in recent years as well.

As a result of our literature analysis, the number of publications and the use of the Web of Science database clearly shows that the number of articles dealing with the topic has increased significantly.

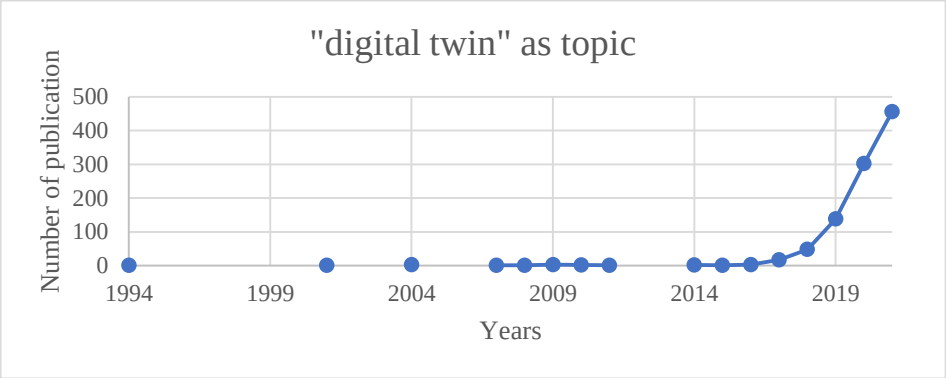

Figure 5. Web of Science search results „digital twin”

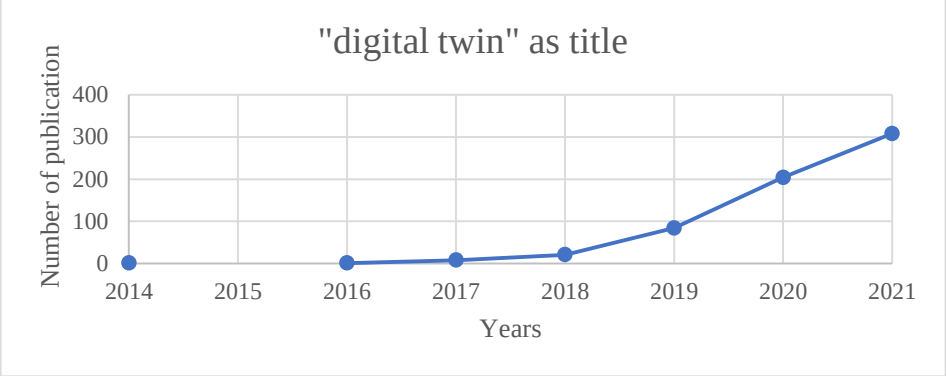

Figure 6. Web of Science search results „digital twin”

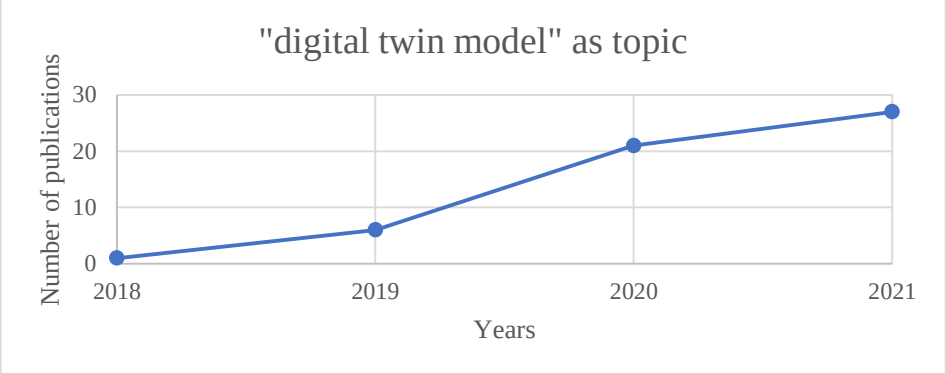

Figure 7. Web of Science search result „digital twin model”

4. APPLICATION OF DIGITAL TWIN TECHNOLOGY IN LOGISTICS

Digital twin technology has already appeared in many industries. With artificial intelligence and digital twin technology, an intelligent model can be created throughout the supply chain. Using virtual reality creates a better option that helps with various tasks such as vehicle loading [2], [11].

Modern data and simulation driven multi criteria decision approaches are required by the operation and optimization of complex production and logistic enterprises. Digital enterprise systems are complex, so the optimal solution may be different, depending on the current situation. In decision making, the digital twin concept can be properly applied, covering the entire life cycle of a device or process by forming a closed chain [14].

4.1. Digital twin application to improve packaging

Most products delivered through logistics networks are packaged. Single-use packaging or reusable containers are used for packaging. Developing, tracking, and managing packaging is a huge challenge in logistics. One of the main reasons for this is the growth of e-commerce, another main reason is the variety of seasonal packaging. This leads to huge waste generation as well as reduced operational efficiency due to inadequate amount utilization. Digital twin technology can also be used to develop stronger, lighter and more environmentally friendly packaging materials. The digital twin is very effective even for the maintenance of the container fleet, as well as for the monitoring of reusable tanks and the detection of problems [2], [11]. Packing materials have the opportunity to be revolutionized through digital twin.

4.2. Digital twin application to improve transportation

Container packaging methods play an important role in protecting products and optimizing the applications. Sensors transport valuable products such as medicines, electronic components. These sensors monitor the exact parameters: temperature, shock, and vibration. A digital twin copy of the shipment would use the data collected by the sensors to allow for a new use of this data. Packaging data and product data can help companies increase efficiency. Packaging choices can be optimized and can minimized the unused capacities [2], [11].

4.3. Digital twin application to improve warehouses and distribution centers

In warehouses and distribution centers the digital twin is an important key. The digital twins in warehouses have a number of benefits. They create new opportunity which will help the logistics company increase efficiency in transportation and maintenance. There are various techniques like drone based inventory counting, automated driving, automated storage that can be further optimized with digital twin technology. Digital twin technology can continuously improve performance in warehouses as well as distribution centers. Any modification of the process can be tested and marked by simulation. Especially in e-commerce, where volume and inventory change are fast [2], [11].

4.4. Digital twin application to improve the global logistics infrastructure

The digital twin model of logistics networks also includes highways, streets, railways, people's homes, and workplaces. The digital twin has a huge future in these areas that can work effectively to optimize logistics networks.

5. RESEARCH DIRECTION

Based on this article, it can be seen, that there is a huge potential in digital twin technology, especially in the field of logistics. In our opinion is that one of the most important research directions will be the development of packaging and transportation.

Demand for packaging and containers is growing, mainly due to increased e-commerce. COVID19 also contributed significantly to the increased demand. Companies must not only control the movement of containers, but also check for pollution and damage. Using the digital twin, detailed digital models of container flow and physical appearance can be created. This will automatically show problems such as dents, cracks, an unexpected shipping event, and so on. This way decisions about when to use, repair and shut down a particular container will be influenced earlier than before [11].

Single-use packaging has long been a threat to the environment, especially the food packaging. Using the digital twin, errors can be easily filtered out by designing and then testing the packaging in digital area. Today, more and more companies are using biodegradable or reusable packaging. The digital twin can be used to monitor reusable container fleets and their possible damage [13].

Combining product data and packaging data helps improve efficiency, such as packaging selection and optimizing container loading. Fragile and expensive products (pharmaceuticals, electronic components) are shipped with sensors, so these sensors continuously transmit data during cargo transportation. The digital twin object of the transport will be able to operate in the future based on the data collected by sensors [12].

6. SUMMARY

The article introduced the concept of the digital twin, digital technology and the history of the development of technology. Previously published articles were summarized with the Web of Science website, used key words were: artificial intelligent, digital twin and digital model. The number of publications in this area shows that innovations and developments have emerged.

The digital twin has already achieved tremendous success in many areas, but has not reached full use in logistics yet. In this article we presented the application of the digital twin in logistics and chose a possible future research area.

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