Conference Paper

Hardware and Software Infrastructure of Digital Twin Technology

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Abstract

This article describes of hardware and software infrastructure that provides the implementation of digital double technology. The basic approaches to determining the technologies that make up the infrastructure for the implementation of the digital twin, as well as the benefits of implementing this technology are considered. The need for processing and storing big data, as well as the benefits of implementing this technology, is substantiated.

Keywords: digital twin, digital model, big data, product lifecycle, cyber-physical system, automation, machine learning, smart maintenance.

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1. Introduction

Digital twins — precise, virtual copies of machines or systems — are revolutionizing industry. Driven by data collected from sensors in real time, these sophisticated computer models mirror almost every facet of a product, process or service. Many major companies already use digital twins to spot problems and increase efficiency [1].

The goal of developing and implementing the digital twin technology is to increase business efficiency throughout the life cycle of a product or process (Fig.1).

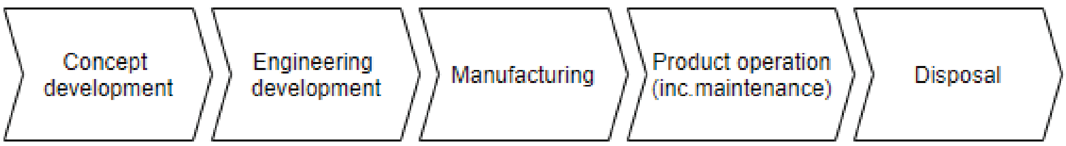

Figure 1: Product lifecycle model

A digital twin is a model with a low level of abstraction, a computer form of a specific physical product. It may include its geometry, manufacturing method, and other information. A digital double can be very detailed, reflecting a wide range of product characteristics. It may contain:

- digital model of the product (shape, size);
- specification of materials;
- manuals and product maintenance data;
- information on the behavior of the product in various conditions.
- information on manufacturing methods and supply chain

In industrial and scientific sources, the definitions of ”digital twin” are different. According to some of them, the digital double is an integrated model of a product already built, which is designed to contain information about all parameters and defects of the product and is regularly updated during physical use - sometimes such an object is called a ”digital shadow” of the product. Another common definition is a digital model, obtained based on information from sensors installed on a physical object, which allows you to simulate the behavior of an object in the real world. None of these definitions, however, give enough attention to processes as an important aspect of the digital double.[2-4]

Some experts identify three types of twins: digital twin prototypes (DTP), digital twin instances (DTI) and aggregated twins (Digital Twin Aggregate, DTA).

DTP (prototype) is a virtual analogue of a physical object existing. It includes data for a comprehensive description of the model, including information on its creation in real conditions. These are production requirements, a three-dimensional model of an object, a description of technological processes and services, and requirements for disposal.

DTI (instances) - data on the description of a physical object. Most often they contain an annotated three-dimensional model, data on materials used in the past and present time, and components, information on the processes performed in all time periods, test results, records of repairs, operational data received from sensors, monitoring parameters.

DTA (aggregated twin) is a computing system that combines all digital twins and their real prototypes and allows you to collect data and exchange them. [5]

Fundamentally, a digital twin can be defined as a constantly changing digital profile containing both previous and most relevant data about a physical object or process, which allows optimizing business efficiency. It is based on a large amount of accumulated data obtained during measurements of several indicators of an object in the real world. The analysis of the accumulated data allows you to obtain accurate information about the performance of the process, as well as lead to conclusions about the need to make changes both in the manufactured product and in the production process itself.

2. Infrastructure of Digital Twin technology

Infrastructure is a complex of interconnected service structures or objects that include and provide the basis for the functioning of the system. The modern infrastructure for supporting production processes (including digital twin technology) must be decentralized - the user must be able to access resources from anywhere, regardless of their location.

Any object or process is in an operational environment that changes throughout the entire life cycle, while under the influence of external factors the characteristics of the object will change. At the stage of development of the concept, the factors are the needs of stakeholders and regulatory documentation, at the stage of development - technical solutions of designers, at the stage of production of the product - machines and tools used to manufacture the product (or implementation of the process), at the stage of operation - various external influences arising during operation or maintenance. For the successful implementation of this technology, it is necessary to introduce an infrastructure that ensures the collection and processing of incoming information.

The basic component of such an infrastructure is a life cycle management system - a software package, which in turn consists of several subsystems that implement all or some of the functions at the enterprise:

- Manage system descriptions
- Requirements Management
- Project management
- Management of design processes
- Product composition management
- Product line management
- Compliance Management
- Content and document management
- Recipe, packaging and brand management
- Supply chain management
- Electromechanical data management
- Process control of technological preparation of production
- Settlement data management
- Operation, maintenance and repair

- Reports and analytics
- Collaboration Tools
- Visualization (including VR and AR)
- Platform extension services
- Integration Services
- Enterprise knowledge management platform

To collect data from a real physical object, several sensors are used that convert external influences into a form convenient for processing. Due to the large number of necessary parameters (acceleration, orientation, temperature, stress) and the large number of points for taking these parameters, a trend has arisen for ”smart sensors” - compact sensors that can measure and transmit many parameters simultaneously. Typically, these sensors are equipped with wireless interfaces for easier integration into the product design and data acquisition system. An important problem that arises in the process of implementing the technology is to ensure the reliability of the data received from the sensors. In the process of testing and operation, data from the object can be falsified - as a result of a sensor malfunction or malicious intent. Blockchain is a promising technology for data tracking - for example, now this technology, in combination with electronic identifiers (RFID and NFC), is being successfully implemented to ensure the security of supply chains and ensure product quality, and to counterfeiting control.

An important condition for the implementation of this technology is the integration of computing power directly into the product or equipment that ensures the production process. Such equipment belongs to the category of cyber-physical systems and allows you to create a process control system with a decentralized structure, with the properties of self-organization. Main components of typical cyber-physical system show on fig.2 [5]

Processing incoming information is impossible without the availability of a data acquisition system and computing clusters. Throughout the product life cycle, a large amount of data and information is generated, for the storage and processing of which storage servers and computing clusters are used. An important requirement for these subsystems is scalability - the ability to quickly increase the amount of computing power and information capacity in accordance with the growth of incoming data.

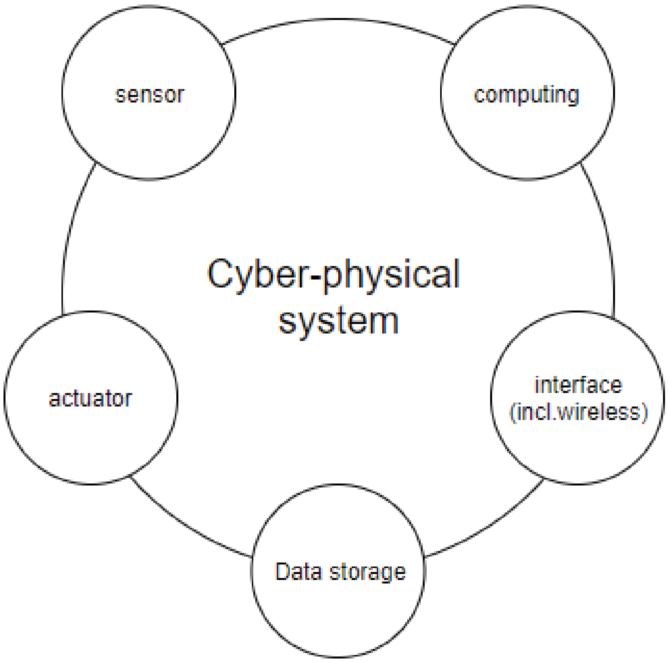

Figure 2: main components of cyber-physical system

3. Results and Discussions

The advantages arising from the implementation of Digital Twin technology depend on the level of abstraction of the digital model, as well as the complexity of the infrastructure used. When developing a digital product double, data management is simplified, which leads to an increase in labor productivity at the stages of development and production. Processing of large data generated by cyber-physical systems in production allows you to quickly identify the relationship between the change in technology and the quality of the resulting products, which leads to an increase in the effectiveness of the quality control system in the enterprise. The use of digital twins in RnD allows you to quickly verify and validate the product or discover non-obvious relationships between various parameters of a complex system.

Registration and processing of external factors acting on the facility allows the use of the technology of "predictive maintenance" - the development of a technical plan in accordance with the actual level of impact on the facility. The use of this technology allows to reduce costs arising from equipment wear. The principle of scheduled maintenance considers the estimated impact on the product without considering real, unplanned impacts. With such an approach to servicing, both cost overruns are possible (if the product's real resource is more than expected), and emergencies arise due to unforeseen effects. In the case of applying the predictive approach, maintenance is carried out in accordance with the principle of necessity and sufficiency for restoring the product's resource, which eliminates cost overruns, and allows you to prepare in advance for the maintenance process. An example is the steam turbine service approach first introduced by Duke Energy - a vibration-sensing sensor has been integrated into the product. As soon as the vibration level began to exceed normal values, it was concluded that an early failure would occur, which served as the reason for the start of maintenance, while early detection of the problem (turbine blade defect) allowed the company to save more than $4 million. The maintenance process itself can be improved with the help of information support - for example, interactive instructions using augmented reality technology can reduce personnel qualification requirements and significantly reduce maintenance time. In combination, all modern technologies used to increase the efficiency of maintenance are called "Smartenance" (Smart Maintenance)

The most significant advantage provided by the technology of "digital twin" is the ability to create process control systems of a fundamentally new type. The most significant obstacles to the automation of complex systems are:

- Many possible states of the process, while the number of undesirable states far exceeds the number of desired

- High state transition rate

At the same time, modern technical systems generate a large amount of operational information that exceeds the ability to process this information by a person and classical (Kalman) control systems. To reduce such risks, new management systems based on machine learning and knowledge management are being developed. The creation of such systems is impossible without a large amount of data on the behavior of the object in various conditions, because they are necessary for the machine learning process. The introduction of such control systems is most important for complex technical objects and processes, in the event of failure of which catastrophic consequences occur (nuclear reactors, hydropower plants, etc.). It should be noted that in the development of such control systems, the presence of errors in the training data set can lead to a deterioration in the quality of management; therefore, increased attention should be paid to cleaning this data, as well as paying attention to anomalous parameters in datasets.

4. Conclusion

The features of the «digital twin» technology considered in the article can be used to develop a concept of application in the enterprise's business processes. Successful implementation of these technologies is impossible without the use of hardware and software infrastructures that provide the collection and processing of a large amount of data received from a product or production system. The data obtained can be used to iteratively improve the product. The introduction of this technology improves the efficiency of both individual business processes and the enterprise as a whole.

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