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Digital Twin Technology in Embeded Systems

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ABSTRACT :

The core of the upcoming industrial revolutions is the digitization of manufacturing systems. The "Digital Twin," which is a digital version of the "Physical Twin," would facilitate easy visualization and the integration of cognitive capabilities into the system, hence aiding in the successful maintenance of process quality. By obtaining data from the side channel emissions and ensuring that the Digital Twin is current, we address two problems related to the Digital Twin modeling. Initially, we will examine a range of analog emissions to determine whether they act as side-channels, providing information about the different states of the physical and cyber realms. Next, we will provide a Digital Twin that is enabled by a dynamic data-driven application system and can verify whether it is the most recent version of the Physical Twin. Based on the direction of data transmission, two primary categories—physical-to-virtual and virtual-to-physical—are used to further examine digital twin modeling and twinning enabling technologies.

Keywords:- Bi-directional, Data Analytics, Digital Twin, Cyber-Physical Systems, Virtual Model, Real-Time.

Introduction

For practical reasons, such as simulation, integration, testing, monitoring, and maintenance, a digital twin is a digital model of an intended or real-world physical product, system, or process (a physical twin). The digital model acts as the practically indistinguishable digital counterpart of the physical twin. Product Lifecycle Management is based on the concept of the digital twin, which is present for the duration of the physical entity it simulates. The digital twin representation is based on the value-based use cases that it is designed to execute since the information is detailed. When virtual prototyping is used, for instance, the digital twin may exist before the real thing. It is possible to model and replicate the intended entity's whole lifecycle during the development stage by utilizing a digital twin.

An existing entity's digital twin can be employed instantly and consistently synchronized with the corresponding physical system. Even if the idea was first proposed earlier, NASA developed the first useful definition of a digital twin in 2010 in an effort to enhance the physical model simulation of spacecraft. The development of digital twins is the outcome of ongoing advancements in engineering and product design. From manual drafting to computer-aided drafting/computer-aided design to model-based systems engineering and rigorous link to signal from the physical equivalent, product drawings and engineering requirements have advanced throughout time. By identifying physical problems early on, the digital twin might help businesses anticipate outcomes with greater precision, design and construct better products, and ultimately provide better customer service. With this type of smart architecture design, companies may realize value and benefits iteratively and faster than ever before.

Analyzing analog emissions to extract information from the physical realm is the first significant contribution. By disclosing information, these analog emissions could operate as side channels. Through the physical implementation system, side-channels have been used to retrieve information about the cyber domain (e.g., secrets keys) without resorting to brute force or weaknesses in the cryptographic algorithm. Recent work by researchers has shown that useful information about the cyber domain can be extracted at the system level using side-channel analysis. These side-channels also convey information about the cyber realm since the information about the cyber domain is expressed in the physical domain. Hence, this information can be used to build an effective Digital Twin of the system. Developing a strategy for maintaining the Digital Twin's existence is the second contribution. Concepts from Dynamic Data-Driven Application Systems form the foundation of this paradigm. By offering a dynamic feedback for updating the models based on real-time data from the physical domain, the idea is utilized to influence data-driven models, in our case the Digital Twins.

The purpose of this research is to use the Digital Twin to demonstrate the cognitive capability of manufacturing systems. By using notions of dynamic data driven application, dynamically guided sensor data processing solves the primary technical difficulty of modeling and updating a living Digital Twin of a Physical Twin. The goal of this research is to close the gap between the Physical Twin and Science. Digital Twin for maintaining the most up-to-date virtual representation of the cyber-physical manufacturing system.

iii. WHY DO WE NEED DIGITAL TWIN

- It helps in designing and optimization part.
- It helps to predict the aging effect.
- It is capable of monitoring the performance of the physical object throughout the whole life cycle.
- A digital twin also integrate historical data from past machine usage to factor into its digital model.

DIGITAL TWIN SYSTEM MODEL

Digital Twins of physical assets, like the structures or machinery in Figure 1, require a three-dimensional representation, whereas Digital Twins of intangible assets, such biological systems or chemical processes, do not. However, the graphic depiction is only one component of the whole. A digital twin is just a 3D model if it cannot communicate with its physical counterpart. We employ IoT devices to collect data. These gadgets gather information on the object or system in real-time using sensors, cameras, and other equipment. This input is then transmitted to the Digital Twin platform where it is used to update the digital model and provide insights into the performance of the physical object or system.

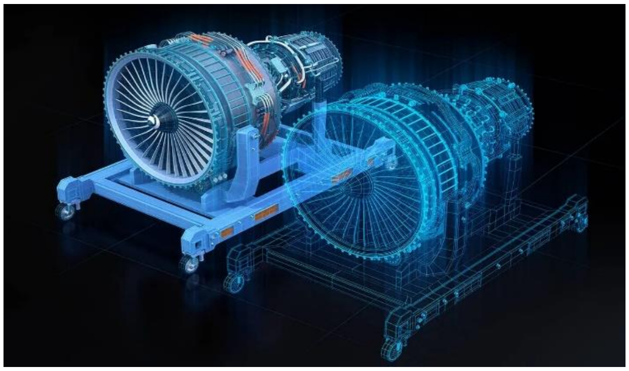

Fig 1: Digital twin model

Depending on the use case and industry they are used in, digital twins have varying functions. As a result, there are numerous approaches to creating a digital twin. While more visible Digital Twins might merely need 3D scan data, certain Digital Twins that reproduce systems with a high degree of fidelity require complicated mathematical models as their inputs.

DIGITAL TWIN SYSTEM ARCHITECTURE

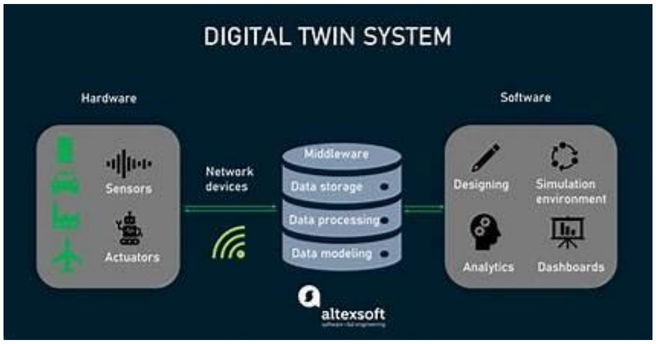

Fig 2:Digital twin Architecture

Hardware components: The Internet of Things sensors, which start the information exchange between assets and their software representation, are the primary technology enabling DTs. Actuators, which translate digital impulses into mechanical motions, and network equipment such as routers, edge servers, and Internet of Things gateways are also included in the hardware section.

Data management middleware: A centralized repository to compile data from various sources is its fundamental component. Connectivity, data integration, data processing, data quality assurance, data visualization, data modeling and governance, and other related duties should ideally be handled by the middleware platform. Common IoT platforms and industrial platforms, which frequently include pre-built tools for digital twinning, are examples of such systems.

Software components: The analytics engine, which transforms unprocessed observations into insightful business information, is an essential component of digital twinning. It is frequently driven by machine learning models. Simulator software, design tools for modeling, and dashboards for real-time monitoring are further essential components of a DT puzzle.

CREATING A DIGITAL TWIN

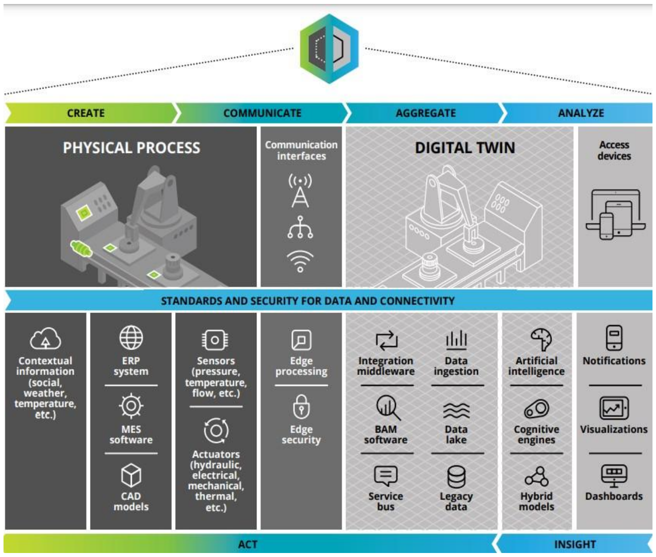

Fig 3: Creating conceptual architecture

Create: Equipping the physical process with a wide range of sensors to measure vital inputs from the physical process and its surroundings is part of the create step. The sensor measurements can be roughly divided into two categories: environmental or external data that affects the operations of a physical asset, such as ambient temperature, barometric pressure, and moisture level; and operational measurements related to the physical performance criteria of the productive asset (including multiple works in progress), such as tensile strength, displacement, torque, and color uniformity. Encoders can be used to convert the measurements into safe digital messages, which can subsequently be sent to the digital twin.

Communicate: The communication phase facilitates the bidirectional, smooth, real-time integration connectivity between the digital platform and the physical process. One of the revolutionary developments that has made the digital twin possible is network connectivity, which consists of three main parts.

Edge processing: Connecting sensors and process historians, the edge interface processes signals and data from these sources close to the source and sends it to the platform. This reduces network communication and converts proprietary protocols into more comprehensible data forms. Significant developments in this field have removed a number of obstacles that previously restricted the practicality of a digital twin.

Communication Interfaces: Information is sent from the sensor function to the integration function with the aid of communication links. There are a lot of options in this area because, depending on the digital twin configuration under consideration, the sensor generating the in-sight could be placed almost anywhere: inside a factory, inside a home, inside a mining operation, or outside in a parking lot, among many other places. Edge security New sensor and communication capabilities have created new security issues, which are still developing. The most often used security techniques include device certificates, encryption, application keys, and firewalls. As more and more assets become IP enabled, there will probably be an increasing need for new technologies to enable digital twins safely.

Aggregate: The aggregate stage facilitates the processing, preparation, and feeding of data into a data repository for analytics. Either on-site or cloud-based data aggregation and processing are options. Over the past several years, the technology domains that underpin data gathering and processing have seen enormous evolution, enabling designers to build massively scalable architectures with increased agility and at a fraction of the cost associated with earlier iterations.

Analyze: Data analysis and visualization take place in the analyze step. Advanced analytics platforms and technologies enable data scientists and analysts to create iterative models that produce insights and suggestions and aid in decision-making.

Insight: The insights from the analytics are displayed through dashboards with visualizations in the insight step. These highlight unacceptable discrepancies in one or more dimensions between the performance of the digital twin model and the physical world analogue, suggesting areas that might require further research and modification. The "digital thread," a notion that is closely related to the digital twin, should probably be discussed in any meaningful discussion of the digital twin. At its most basic, a digital thread is an uninterrupted, smooth data stream that links the design, construction, and field usage phases of a product's life cycle. It functions as the conduit for the flow of product-related data.The capacity to store, retrieve, model, and analyze such data is what makes it possible to model production and drive efficient supply chain communications.

Act: In order to accomplish the impact of the digital twin, actionable insights from the preceding steps can be fed back into the physical asset and digital process in the act step. After passing via decoders, insights are sent into the actuators on the asset process, which are in charge of movement or control mechanisms. They can also be updated in back-end systems that regulate ordering behavior and supply chains, all of which are susceptible to human intervention.17 The closed loop connection between the digital twin and the real world is completed by this interaction.

The physical asset and procedures are modeled using the aforementioned stages in the digital twin application, which is often created in the enterprise's primary system language. Furthermore, for data management and interoperable communication, standards and security measures may be used throughout the process.

Conclusion

Companies may benefit from the digital twin in the form of concrete value, new revenue sources, and assistance in addressing important strategic issues. Companies may be able to begin their journeys to develop a digital twin with less capital investment and a faster time to value than ever before because to new technological capabilities, flexibility, agility, and lower costs. Throughout a product's life cycle, a digital twin can be used for a variety of purposes and can provide real-time answers to queries that were previously unanswerable, offering benefits that were almost unthinkable only a few years ago. Maybe the better question is where to start in order to receive the most value in the shortest amount of time, rather than whether to start at all, and how to stay ahead of the game.

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