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Role of digital twins in management a new paradigm

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Abstract
Digital twins are virtual replicas of physical systems, designed to simulate, monitor, and control real-world entities. The five layered digital twin technology stack from physical to decision layers, these digital counterparts enable real-time analytics and decision-making. Advanced functionalities like artificial intelligence, optimization algorithms, and automatic reasoning are integrated into the service and decision layers, enhancing their utility in management processes. As digital twins evolve, they are set to revolutionize organizational operations, offering unprecedented levels of efficiency, adaptability, and intelligence for the future.

Keywords: Digital Twins, Five layers, IoT, simulation, new paradigm

Introduction

At large for common world, the word ‘Digital Twin’ is a novice while other digital terminologies are very much popular. Prime focus of Digital Twin technology is on product, process and performance. A digital twin is a computer program that uses real world data to create simulations that can predict and visualize how a product and process will perform. Digital twins is new technological model that show case the difficult tasks once impossible to make them possible for the management while they are exhibiting their decision making process. According to a report from ResearchAndMarkets.com: "The global digital twin market size, which was about US$ 3,21 Billion in 2020, is expected to grow to US $184.5 billion by 2030, witnessing a 50% CAGR between 2020 and 2030." Digital twins are now a key component of the Fourth Industrial Revolution that play a critical role in our lives. The Gartner survey also estimates that, by 2027 over 40 percent of large companies worldwide will be using Digital Twin in their projects to increase their revenue. As per another global technology research it is expected to grow the digital twin business to US$ 32 billion by 2026. So the pace of the usage of digital twins is fast absorbing to leverage it.

It is a cutting edge technology that would transform possible every facet of product, process and service say overall business. A digital twin is a virtual depiction of an object, system or process that spans its lifecycle, is restructured from real-time data, and uses replication, machine learning and reasoning to help decision making. Innovation and technology management in companies are influenced and shaped the business potential by the digital technologies such as digital twins (Hilboling *et al*; (2020), Betchfeldt and Faullant (2021). Both digital twins and simulations are use digital models, however the simulations is used for particular point or a small in scale while digital twin extract a bigger view out of many simulations. It is a virtual environment that showcasing a physical object or environment by which the management can have bigger picture at a 360 degree so that they can better focus in decision making without a lapse of communication gap. Zhou *et al*; (2020) suggested that digital twins can help in understanding, predicting and optimizing the manufacturing processes through and intelligence analysis. Digital Twins increasingly become popular due to increase in Industry 4.0 technologies.

Digital twins are revolutionizing the landscape of modern management by providing a real-time, virtual representation of physical assets, systems, or processes. This technology leverages real-time data feeds from sensors, advanced analytics, and machine learning algorithms to create a dynamic model that mirrors its physical counterpart. Managers can utilize these digital replicas for various purposes such as predictive maintenance, resource allocation, and risk mitigation.

Digital twins have various applications that can be used in different business areas (Fuller *et al* 2020; Qi *et al* 2021) By simulating different scenarios, analyzing patterns, and integrating with other systems, digital twins offer a comprehensive view of operations that aids in informed decision-making. This not only enhances operational efficiency and cost-effectiveness but also fosters innovation, ensures compliance, and contributes to sustainability goals.

Review of Literature

The literature on digital twins is expansive, covering a range of topics from foundational concepts to advanced applications. The literatures review consists of various online articles, journals and blogs. Journal articles often delve provide empirical studies and case analyses that validate the efficacy of digital twins in various sectors like manufacturing, healthcare, and hospitalities, infrastructure such as energy projects etc. Blogs and online articles offer a more accessible understanding, discussing the practical implications, real-world applications, and future trends. They also highlight the challenges and ethical considerations associated with digital twin technology. Overall, the literature presents a multi-faceted view, affirming the technology's potential to revolutionize management processes and operational efficiency.

2023, Digital Twins: benefits use cases, challenges and opportunities by M.Attaran and B.G. Celik. This article mainly explores the concept of digital twins and its use and challenges and the potential of digital twins in construction and safety, education, healthcare, mining, logistics, qulity control, Building and various other sectors. Digital twins leveraged business applications and predict that the digital twin technology will expand to more use case scenarios and industries. This paper highlights the evolution and development of digital twins and reviews its technologies and examines the trends and challenges.

2022, Digital twins' implications for innovation by Mira Holopainen *et al*; This study focuses on understanding the implications of the use of digital twins for innovation. Case studies were used to gather required information and evidence. The findings states that that three distinct issues that describe the current state of digital twins. First, the efforts of different companies towards value centric innovation through digital twin solutions are recognized. Second the findings indicate that innovations related to digital twins allows a new kind of cooperation that is an open platform. Finally the study concludes that digital twins have various applications on multiple scopes. Further states that using the results of the study the managers can enhance the companies' digital transformation by acknowledging the multiple uses of the digital twins.

Digital Twins' Impact on Organization control: perspectives of formal and social control, (2022) by Juhani Ukko *et al*; This study examines the connection between different digital-twin characteristics and organizational control. The study is based on the survey of 139 respondent students of universities who are using the digital twins. The results show that the characterstics, exploration affect the extent the digital twin can be utilized for social control and the extent to which the digital twins can be utilized for formal control. The authors explain that this study offers a new angle for literature review.

Digital Twins the New Paradigm

(***Source*:** midjourney)

Fig 1

Digital twins represent a groundbreaking paradigm shift in the realm of digitalized management, serving as a transformative bridge between the physical and digital worlds. By creating real-time, virtual replicas of physical assets, systems, or processes, digital twins enable a level of data-driven decision-making that was previously unattainable. This technology leverages the power of sensors, advanced analytics, machine learning, and simulation to offer a dynamic, 360-degree view of operations. Managers can now engage in predictive maintenance, optimize resource allocation, and conduct risk assessments with unprecedented accuracy and efficiency. The digital twin model goes beyond mere monitoring to allow for what-if scenarios and simulations, providing a sandbox for innovation and strategic planning. This facilitates not only immediate operational improvements but also long-term strategic development, thereby aligning daily operations with overarching organizational goals. Moreover, the integration capabilities of digital twins make them a cornerstone in the Internet of Things (IoT) ecosystem, enhancing inter-operational and data exchange among various business systems. This new paradigm is redefining the contours of digitalized management by offering a holistic, real-time operational view that is essential for agility, competitiveness, and sustainability in today's fast-paced business environment.

Tools of Digital Twins and the Management

Many digital twin tools are specifically designed to replicate organizational management structures and processes, providing executives with a comprehensive, at-a-glance view of operations. Many platforms like Auto Desk Digital Twin, Xmpro,SAP Leonardo IoT, Oracle IoT production Monitoring cloud, Predix, Mimic Simulation. Anysis Twin Builder, aPriori Manufacturing, Bosch IoT Suite, and Microsoft's Azure Digital Twins offer robust solutions that

integrate seamlessly with existing IT infrastructures, pulling in real-time data from various sources such as ERP systems, IoT sensors, and human inputs. These tools offer customizable dashboards that can display key performance indicators (KPIs), workflow statuses, and even predictive analytics, all updated in real-time. Advanced features like scenario simulation and 'what-if' analysis allow managers to test different strategies and make data-driven decisions quickly. Some platforms also offer industry-specific modules, such as supply chain optimization for manufacturing or patient flow management for healthcare. By consolidating disparate data streams into a unified, interactive interface, these digital twin tools enable top management to grasp the pulse of the entire organization instantly, thereby facilitating agile and informed decision-making

The Five Layered Digital Twin Process

The digital twin replicate the physical system in virtual system or object by simulating using the five stack technology which also forms part of Industry 4.0 technologies. This five-layered digital twin technology stack comprises Physical, Data, Integration, Service, and Decision layers. The Physical layer represents the real-world entities, while the Data layer focuses on data collection, storage, and management. The Integration layer ensures seamless communication between different systems and data formats. The Service layer incorporates advanced functionalities like artificial intelligence and optimization algorithms for analytics and computation. Finally, the Decision layer leverages these insights for strategic and operational decision-making, such as cost reduction and production optimization. Together, these layers create a cohesive and intelligent system that enhances management processes.

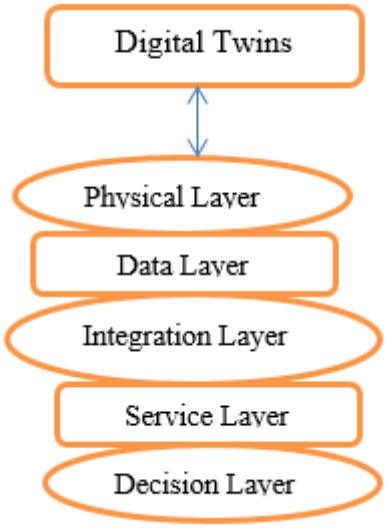

Fig 2

Physical Layer: In the context of digital twins, the "physical layer" usually refers to the real-world objects, systems, or processes that the digital twin aims to replicate and monitor. This includes materials and Equipment & Components. In a management process, especially for small businesses or projects, this physical layer is crucial as it serves as the source of data and real-world context. Sensors, actuators, and other IoT devices are often attached to this physical layer to collect data, which is then sent to the digital twin for analysis and simulation. Managing this layer effectively is essential for ensuring data accuracy and, consequently, the reliability of the digital twin. Proper calibration, maintenance, and quality assurance measures are typically required to keep the physical layer in optimal condition.

The Data Layer:

In Digital Twins the data layer serves as the backbone for management processes by providing the necessary data infrastructure. This layer is responsible for collecting, storing, and managing data from various sources, including sensors, IoT devices, and external databases. In a management context, the data layer enables real-time monitoring, analytics, and decision-making by providing accurate and timely information. The resource data, sensor data and actuator data plays a crucial role in this process. Resource in production data refers to the key assets and inputs—such as raw materials, labor, machinery, and energy—used in the manufacturing process. This data is crucial for optimizing efficiency, reducing costs, and improving product quality. Sensor data related to the real-time measurements and information collected by sensors, often used for monitoring, analysis, and automation purposes. Actuator data pertains to the status and performance metrics of actuators, which are devices that convert signals into physical actions. This data is crucial for controlling and optimizing mechanical systems.

Integration Layers: This layer involves with Cyber-Physical Systems (CPS), Network and IoT devices. The integration layer enables seamless data flow and communication by standardizing data formats and protocols. This layer is crucial for ensuring that all components of the system can interact with each other effectively, thereby facilitating real-time analytics, monitoring, and decision-making. Technologies like APIs, middleware, and data integration tools are commonly used in this layer. In the context of integration, CPS ensures seamless interaction between the digital and physical worlds by standardizing communication protocols and data formats. This enables real-time data exchange, monitoring, and control, thereby enhancing the system's adaptability, resilience, and functionality. The integration of CPS is often facilitated through technologies like IoT devices, sensors, actuators, and advanced networking capabilities.

Service Layer: The service layer in digital twin architecture serves as the hub for advanced functionalities and applications, encompassing a wide range of technologies and methods. Modeling tools are used to create accurate digital representations of physical systems, while automatic reasoning algorithms help in making real-time decisions based on the data collected. Artificial Intelligence (AI) techniques are employed for predictive analytics, anomaly detection, and even autonomous control of the physical systems. Digital representation ensures that the virtual model is a true reflection of the physical entity, facilitating physical and virtual synchronization. Optimization algorithms are used to improve system efficiency, reduce costs, and enhance performance. Together, these components enable a seamless and intelligent interaction between the physical and digital worlds, making the service layer a critical component for the effective functioning and utility of digital twins.

Decision Layer : Based on the outcome and support of service layer the decision layers involves with decision making process of the management by using digital twin technology

so as to enable the best possible, product, process and performance. This layer in a digital twin architecture is focused on leveraging the insights and analytics generated by the system to make strategic and operational decisions. This layer plays a pivotal role in cost reduction by analyzing data to identify inefficiencies and recommending optimized processes. It also aims to increase production by forecasting demand and automating resource allocation. Control and monitoring functionalities ensure that the system operates within defined parameters, thereby reducing risks and enhancing reliability. Additionally, the decision layer helps in minimizing system degradation by predicting maintenance needs and scheduling timely interventions. Overall, the decision layer serves as the command center for actionable insights, enabling organizations to achieve their operational and financial goals.

Digital twins and future of Management

Digital twins are heralding a new paradigm for future management, fundamentally transforming how organizations operate, strategize, and innovate. This cutting-edge technology creates a seamless interface between the physical and digital realms, offering real-time, virtual replicas of assets, systems, and processes that are rich in data and analytics. By doing so, digital twins provide managers with unparalleled insights into the intricacies of their operations, enabling predictive maintenance, resource optimization, and risk mitigation with a degree of accuracy and foresight that was previously unimaginable. This is not just a step forward in digitalization; it's a leap into a future where data-driven decision-making becomes the norm, not the exception. The technology's ability to simulate 'what-if' scenarios offers a safe and cost-effective environment for experimentation, thereby accelerating innovation and strategic planning. Moreover, digital twins are poised to become the linchpin in the Internet of Things (IoT) ecosystem, enhancing interoperability among disparate systems and facilitating real-time data exchange for holistic management. As organizations grapple with increasing complexity and uncertainty, the digital twin paradigm offers a robust framework for agility, resilience, and sustainable growth. It's more than just a technological advancement; it's a managerial revolution that is setting the stage for the next era of business, characterized by heightened efficiency, competitiveness, and adaptability.

Conclusion

The concept of digital twins in management is a transformative approach that integrates physical systems with their digital counterparts through a five-layered technology stack. Data Ingestion, Data Processing, Data Storage, Analytics and Computation, and Visualization and Interaction—work in harmony to enable real-time monitoring, analytics, and decision-making. The service and decision layers add further depth by incorporating advanced technologies like AI, optimization algorithms, and automatic reasoning to drive cost reduction, increase production, and ensure system reliability. The service layer stands as a critical component in the digital twin architecture, acting as the nexus for advanced functionalities that bridge the gap between data and actionable insights. The service layer elevates the utility of digital twins from mere data repositories to intelligent decision-making systems. It enables real-time synchronization between physical and virtual entities, thereby enhancing the system's adaptability and resilience. As digital twins evolve, the service layer will likely continue to be the focal point for innovation, driving greater efficiencies and smarter decision-making in various management processes. As we look to the future, digital twins are poised to become an integral part of management processes, offering unprecedented levels of efficiency, adaptability, and intelligence. Their role is expected to expand, incorporating even more advanced technologies and methodologies, thereby revolutionizing how organizations operate and make decisions.

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