THE SIGNIFICANCE OF DIGITAL TWINS IN PRODUCT DEVELOPMENT[1]

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Abstract
Performance improvements and features that include complex and cutting-edge technologies are becoming more and more necessary for products in order to provide customers a strong reason to buy. Adopting procedures that operate more quickly, produce better outcomes, and put businesses closer to their customers may be possible if digital twins' technology is incorporated into the early phases of product development. Digital twins provide immediate insights and simulations, revolutionizing product design and prototyping. It is a simulated environment that offers an instantaneous online representation of a tangible process or object. Before constructing the actual product, producers and designers can test new ideas and functionality thanks to product 3D technology. While 3D modelling is used to generate a virtual representation of the product, 3D rendering is utilized to create realistic images and animations of the product. Additionally, digital twins can assist businesses in increasing productivity by locating manufacturing process bottlenecks and enhancing consumer satisfaction through improved packaging design. It is anticipated that digital twins' solutions will transform manufacturing processes and offer fresh, innovative approaches to reduce expenses, enhance maintenance, manage assets, minimize downtime, and create new linked goods. Furthermore, digital twins give stakeholders access to a virtual sandbox for testing and optimization by creating a digital version that closely resembles the complexities of its physical equivalent.
Keywords: Digital Twins, Product Development, Businesses, Consumers

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INTRODUCTION

Digital twins are a key component of the digitization movement and transition. They are drastically changing many different businesses in this age of digital revolution (Tao & Qi, 2019). In a roadmap paper outlining the development of test simulations of spacecraft and capsules, NASA's John Vicker introduced the first widely recognized use of the "digital twin" concept. A digital twin is a virtual representation or simulation of the physical world, encompassing its components, processes, and services. It might be as intricate as a digital duplicate of a whole city, complete with all the infrastructure required for it to operate, for example. Electric wind turbines and smartphones are examples of products that can be prototyped and digitally fabricated before physical production (Vailshery, 2024).

Digital twins aid in enhancing product performance as well as effectively identifying and resolving issues. They speed up the time needed to develop new products by enabling remote monitoring. This technology has been used across a number of industries, including manufacturing to track product performance, the energy sector to optimize performance and lifetime, and the construction sector to create better plans for infrastructure projects. They are also used for testing in the automotive sector (Marmolejo-Saucedo, 2020).

Digital product development methods are changing quickly, and digital twins (digital copies of existing or future products that can mimic every feature of their physical counterparts) have emerged as a result of this. In comparison to the real world, interacting with or altering a product in a virtual environment can be quicker, simpler, and safer (Argolini et al., 2023). The size of the global digital twin market is expected to grow from its 2024 valuation of USD 14.4 billion to USD 468.8 billion by 2034 (Insightaceanalytic, 2025). Nowadays, nearly 75% of businesses that have used digital twin technology in sophisticated industries have already attained at least medium levels of complexity, according to surveys. Though the logistics, infrastructure, and energy sectors are most expected to expand, the automobile, aerospace, and defence industries now employ this technology at the highest levels (Canorea, 2024).

LITERATURE REVIEW

Grieves and Vickers provided a thorough description of the digital twin model level and described the digital twin as an information structure that fully describes physical objects from the microscopic atomic level to the macroscopic geometric level (Grieves & Vickers, 2017). The majority of notions in the literature define the digital twin as a hybrid of a digital shadow, which is a dataset obtained from the physical twin, and a digital master model, which is a template derived from the product development process (Wilking et al., 2021). A digital twin can be said to represent nearly every facet of a process or product through data transmission and sensor updates (Qi et al., 2021).

The entire process, including concept development, design, procurement, manufacturing, and recycling, must be taken into account when looking at a product's lifecycle from the standpoint of the manufacturer (Cao & Folan, 2012). Applications of digital twins have improved manufacturing product delivery in several ways, including increasing productivity, lowering product delivery risk, and efficiently managing the product lifecycle (Pires et al., 2019). However, creating a digital twin platform is challenging. For instance, early adopters mention difficulties incorporating digital twin technologies into their current digital product development environment and larger IT infrastructure. Additionally, digital twins necessitate new methods of operation, both inside and outside of R&D departments. Accordingly, a successful digital twin program is a change management endeavour that necessitates the support and commitment of top management as well as a robust program management team to monitor progress, create new procedures, and facilitate the organization's acceptance of them (Argolini et al., 2023).

According to the McKinsey report, digital twins are already having a big impact on how well products are developed. They can cut down on development durations by 20–50%, lower the cost of pre-production prototypes, minimize problems, or increase the likelihood of a product's commercial success. Additionally, it makes it possible for businesses to provide a greater variety of value-added post-purchase services, such as in-service performance optimization and predictive maintenance (Canorea, 2024). However, the expense of using digital twin technology in a corporation is high. The growth of the global market is hampered by the high implementation costs. Digital twins and related technologies such as 3D CAD, augmented reality (AR), virtual reality (VR), computer-aided design (CAD), enterprise resource planning (ERP), model-based system engineering (MBSE), manufacturing operations management (MOM), manufacturing process management (MPM), and product lifecycle management (PLM) are expensive to implement. If the business or organization does not have the requisite technological foundation and support infrastructure, the cost of creating and deploying a digital twin technology will rise. Consequently, a deterrent to enterprises' adoption of digital twin technology is its high implementation costs (Straits Research, 2024).

Public perception of a brand is largely determined by its positioning and core principles. A brand will stand out as identifiable and acceptable if the general public is aware of what it is and the values it promotes (Milovanović et al., 2018). Designers and engineers can iteratively improve product designs, adjust performance parameters, and foresee possible problems before they materialize in the real world by using simulations and predictive modelling. Additionally, digital twins give stakeholders more visibility, control, and agility, which helps them quickly adjust to shifting operational difficulties and market needs (Xcubelabs, 2024).

Given the interconnectedness of IoT devices, protecting the privacy and security of sensitive data within digital twin systems is extremely difficult. Cybercriminals have the ability to seriously hurt digital users financially and emotionally. Ordinary people, small and large business systems, and even the states themselves confront significant challenges as a result of these actions. Despite the fact that this problem is a topic of much international discussion, it appears that cybercriminals are constantly coming up with innovative ways to get around security measures in order to continue their illegal activities (Baltezarević & Baltezarević, 2021).

The following are some possible effects of digital twins on future approaches to product development: a) By offering real-time feedback, simulation capabilities, and predictive insights, digital twins facilitate iterative and agile product development processes, lowering time-to-market and improving product quality. b) Using digital twins to develop personalized product experiences based on user preferences and needs encourages client happiness, loyalty, and engagement. c) Digital twins enable businesses to embrace sustainable practices, reduce waste, and maximize resource use by modelling the environmental impact of goods and procedures. d) Organizations can save money and improve operational efficiency by anticipating and preventing equipment breakdowns, minimizing downtime, and extending the lifespan of assets through proactive maintenance made possible by digital twins. e) Throughout the course of the product development lifecycle, digital twins promote innovation, creativity, and knowledge sharing by facilitating collaborative design and co-creation activities across cross-functional teams, stakeholders, and partners (Xcubelabs, 2024).

Furthermore, digital twins can teach driver assistance systems using synthetic sensor data by utilizing augmented reality (AR) and game technologies (like Unity), sometimes known as mixed reality (MR). A thorough simulation of every situation aids in confirming safety regulations and developing cars that can react appropriately even when the driver is not there (Rinf.tech, 2023). In addition to better understanding the hidden wants and wishes of consumers, it is possible to respond to market demands more precisely and efficiently by keeping up with trends and creating more creative communication strategies (Baltezarevic, & Baltezarević, 2020). A comprehensive digital twin is more than just a tool for development. It also serves as an interactive presenting tool, clarifying the subtleties of the suggested solution and confirming that it is in line with the goals of the client. The demand for expensive preproduction prototypes has decreased, occasionally from several to just one. Additionally, items created with digital twins have noticeably higher quality at the start of production due to the wide range of virtual testing and validation. This relates to business success as well; some companies have seen a 3-5% increase in sales of products based on digital twins. This is ascribed to improved features, flawless quality, and extremely high levels of customer satisfaction (De Villaumbrosia, 2023).

CONCLUSION

A virtual version of a physical object that has been painstakingly created to precisely replicate its real-world counterpart in terms of structure, behaviour, and functioning is called a digital twin. Digital twins act as a transformative bridge, allowing real-world things to be smoothly connected to their virtual equivalents. Synchronization and replication are the foundation of this synergy. This digital duplicate gives stakeholders access to real assets and previously unheard-of insights, opening up a world of possibilities for optimization and creativity.

This important technology can be used in the early phases of product development. It can be a useful tool for future product design, development, and innovation given the increasing need for customized products and the introduction of Industry 4.0. Using information from linked smart devices, it can be utilized to create a digital thread and forecast future system performance. Digital twins use real-time data to enhance and optimize production operations. They enable developers and designers to model a wide range of conceivable scenarios, reducing unexpected downtime brought on by mistakes and accidents. By carrying out preventive maintenance, digital twin technology lowers maintenance expenses. Through simulations and the identification of errors and inefficiencies, it offers chances for ongoing improvement. Before real prototypes are even made, designers can optimize their designs by experimenting with various combinations, materials, and scenarios using the virtual representation of physical objects. Finally, engineering teams spend less time iterating a product because of digital twins, which lowers the total expenses associated with the product life cycle.

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