Digital Twins: Only their motherboard can tell them apart

By Jack Fox

DTs are virtual representations of real-world environments, including their components, operations, and variables. DTs operationalize real-time data from Internet of Things (IoT) devices to optimize systems dynamically, allowing for increased visibility and certainty in complex business cases.

Although the term Digital Twin (DT) wasn't coined until 2002 by Dr. Michael Grieves, the concept has been saving lives since the 1960s. The earliest known example of technology with capabilities similar to DTs was implemented by NASA during the Apollo program. NASA created virtual simulations of the Apollo spacecraft to troubleshoot problems during space missions. During the infamous Apollo 13 mission, a fan short-circuited causing a fire that rapidly depleted the astronauts' oxygen supply. NASA engineers were able to troubleshoot and successfully solve the problem by simulating how various responses would impact the spacecraft and astronauts' chance of survival. By understanding the implications of their response in real-time, NASA was able to safely return the astronauts home.

DTs are more advanced than statistical models or Monte Carlo simulations. There are four primary elements where DTs excel: scope, simulation basis, data sourcing, and data interaction.

Element	Digital Twins	Monte Carlo Simulation	Statistical Model
Scope	Broad scope across the whole business	One particular aspect of business	One particular aspect of business
Simulation basis	Real world operational data	Test values from input	Test values from input
Data sourcing	IoT devices	User input	User input
Data interaction	Dynamic	Static	Static

These elements allow DTs to provide deeper and more meaningful insights than other simulations because they have a more comprehensive representation of a given system than other techniques.

There are three primary types of DTs: Product Twins, Process Twins, and Data Twins. Each of these different types has distinct advantages and applications. Before licensing a DT product, stakeholders should properly understand each of these types and what advantages or disadvantages they may provide.

Product Twin

Model how a product performs throughout its lifecycle in different scenarios.

Process Twin

Model a business process reacts to changes in components and order of operations.

Data Twin

Model how real world data changes will impact data from other sources.

While these three types are a common classification for DTs, not every DT fits cleanly into one of these three buckets. Some DTs, such as Palantir's ontology, use a combination of attributes from multiple of these types to properly represent and simulate real world events. These combinations can help create more meaningful

representations but also require more upfront setup and customization compared to the traditional classifications.

Digital Twin technology has seen widespread adoption in recent years and is expected to continue growing

After emerging in the last decade, many notable companies have adopted DTs. 75% of large enterprises are actively investing in DT technology [1]. Conversely, only 9% of companies had little to no interest in implementing DTs [2]. This disparity demonstrates large enterprises' positive outlook on DTs going forward. While DTs have seen adoption across many industries, several key segments have more heavily invested in DT technologies. The automotive and transport segment is the largest at 21% of the market [3]. The DT landscape is changing rapidly. The telecommunications segment is expected to be the fastest growing with a CAGR of 40% between now and 2030 [4]. As Digital Twins continue to advance and improve, adoption levels are likely to continue increasing.

These adoption trends have been spurred by the documented success of previous implementations. Technology implementations are notorious for underperforming their initial objective. This stems from a variety of compounding factors such as siloed resources, poor project management, lack of stakeholder alignment, and improper resource allocation [5]. However, of DT early adopters, 87% report achieving intended goals [6], demonstrating DT's value in many business situations. Industry trends suggest that DTs will only see increasing adoption going forward. To avoid being left behind, companies should begin evaluating applications of DTs in their operations.

Digital Twins can provide business value in a variety of use cases

DTs are a generalized technology that can be used to analyze and optimize various business situations. This wide range of applications and types can make it difficult for first time users to understand exactly how DTs provide value. To help illustrate how different types of DTs are being used today, here are some examples:

Product Twins save time and resources

Aerospace design companies are using Product Twins to help develop new wing designs and test them under various conditions. Aerospace products like wings and

engines need to be rigorously tested to understand their performance in different situations. Understanding how design changes are affected by real-world conditions like weather, temperature, wind speed or direction is critical to creating a robust solution. Minor changes like rivet placement or material changes can have substantial repercussions on overall performance. DTs are used to understand and predict how these engineering changes will perform in real-world operations. This benefits design companies because they can decrease design time and resources by minimizing the number of prototypes and testing environments.

Structural engineering companies use Product Twins to measure a building design's resistance to natural disasters like earthquakes or hurricanes. Skyscrapers are complex systems that rely on interconnected components. Understanding how these components interact and affect other design choices can be difficult without real-world prototyping and testing. DTs allow structural engineers to test how various materials and supports will react to external factors that are difficult to recreate like natural disasters. By simulating different designs' responses to external factors, structural engineers can ensure their buildings will overcome any potential disasters in the future. This saves the company building material and design time because they do not have to create multiple building models to understand disaster impact accurately.

System Twins increase operational efficiency while mitigating negative outcomes

Factories are using a System Twin to better organize site layout and expedite their production processes. Factories components are highly interconnected with changes to one impacting downstream operations. By modeling the physical layout of factories, DTs can model how these disparate components interact and respond to changes in process and layout. Moving a machine to a different part of the factory may have unintended consequences and create production bottlenecks. DTs can take these complex relationships into account and run simulations on various layouts and processes to find the optimal solution. Optimizing factories with DTs maintains production levels during optimization because the company does not need to cease operations to move machines or decrease production by testing suboptimal layouts.

Retailers are using System Twins to optimize floor layout and checkout process. Similar to factories, stores require substantial physical infrastructure that cannot be easily moved or changed. Individual shoppers' habits are difficult to predict and understand. DTs are capable of accounting for and modeling these complex interactions to optimize key metrics like distance to goods, shopping time, and checkout wait time. This is useful for stores because they do not need to take time

rearranging the store and operate a suboptimal layout, allowing for layout improvement without disrupting operations.

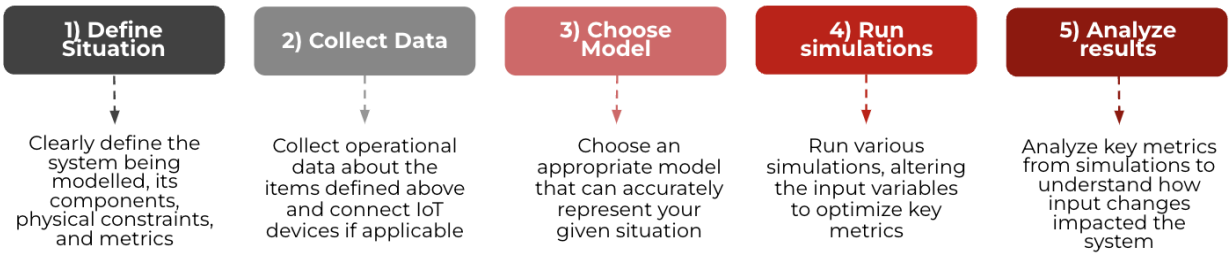
Data Twins can provide optimization based on real-time data

Logistics companies are using Data Twins to optimize delivery routes based on real-time traffic data. Delivery routes are heavily dependent on external variables outside of the company's control. Variables such as weather conditions, congestion, crashes, and construction can impact and change delivery routes on an hourly or minute basis. DTs allows logistics companies to dynamically allocate resources in the most optimal way. This technology allows them to adapt to real time changes in traffic patterns and avoid large congestion caused by accidents or other factors, decreasing fuel costs and delivery time.

Hospitals are using Data Twins to optimize resource allocation based on real-time patient data. Hospital schedules must take into account a variety of factors such as resource availability, patient demand, and operation time. Hospitals must be able to dynamically reallocate resources based on a surge in demand or lack of resource availability. DTs allow hospitals to manage these complex relationships and ensure that all patient needs are met without the need for significant manual overhead.

Digital Twins can be created using a simple high-level process

Creating DTs is an inherently complex process that requires a comprehensive understanding of sophisticated interactions. This process can be simplified into a high-level five-step:



Properly defining and modeling a given situation will require significant analysis. Every situation will require customized development to properly capture physical constraints, component interaction logic, and evaluation metrics. It is important to create a DT that fully models your given situation. Without the proper representation of your system, the model's simulations will not provide useful insights or visibility into your business's operations.

Users should select Digital Twins whose distinct capabilities and restrictions align with their situation

There are many different DT platforms currently available on the market. Each has unique features and purposes that determine what use cases are applicable. Some specific examples on the market include:

- **NVIDIA Omniverse** allows users to build and visualize DTs in a unified 3D model. Use cases include optimizing distribution centers, factories, store layouts, and autonomous vehicles.
- **AVEVA** can build DTs for engineering operations and perform predictive maintenance. Applicable industries include energy, oil & gas, utilities, distribution, and manufacturing.
- **Ansys Twin Builder** is used to create DTs that model product designs in physical environments and perform predictive maintenance. Use cases include product design, engineering, mining, and heavy industries.

Each platform will have distinct capabilities that can allow situations to be modeled more accurately. Platforms that properly align with the given use case will make development easier by leveraging underlying logic already developed in the model. Rather than develop custom physical logic for use cases like engineering, users should leverage platforms like AVEVA that natively capture physical logic. Every platform will not be suited to model a given business process. Choosing the correct platform whose capabilities align with your business needs will boost performance and insights.

Pairing Digital Twins with Generative AI can extend capabilities

With the recent buzz about Generative AI, it should come as no surprise that people have begun using it in tandem with DTs. This combination has been described as a

"Universal Model." This Universal Model allows humans to leverage the insights of Generative AI and the digital representation simulations of DTs. This combination creates several powerful capabilities. Users could employ a graph-based Generative AI model to create and modify DTs using natural language. Large Language Models (LLMs) could analyze the output of DT simulations to explain and gain insights into how to optimize evaluation metrics for the given situation. LLMs could create training data used as inputs in DT simulations lacking sufficient operational data. We will likely see this combination leveraged in real-world applications soon.

DTs have emerged as a rapidly growing technology with applications in many fields. The list of applicable use cases will continue to expand as this technology evolves in the market. Generative AI and future developments will continue to shape this evolution. To stay ahead of these developments, companies should begin exploring how they can use DTs today.

There is so much more to learn about Digital Twins

This article covers the basic information and applications of DTs. If you are interested in how DTs can be leveraged to improve your business, here are several more resources:

General Resources

- What is a Digital Twin?
- Digital Twin Consortium
- Guide to The 18 Best Digital Twin Software of 2024

Examples of Successful Implementations

- Kroger Uses Simulation and Digital Twins for a Better and Faster Shopping Experience
- Digital twins: 5 success stories
- 11 Amazing Digital Twin Examples for Industries

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References

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[2] Digital twin market: Analyzing growth and emerging trends

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[5] Why IT Projects Still Fail

[6] Digital Twins: A Closer Look at Adoption Trends and Industry Statistics