DIGITAL TWIN TECHNOLOGY: A REVIEW OF APPLICATIONS AND CHALLENGES

Abstract

"Twins" this immediate reminds two people who look alike. Although real-life twins may share genetic materials, features and common experiences, they will be made up of diverse events and lifestyle during life time. Digital twins can be perplexing term when it comes to understanding precisely what they are. A digital twin is a replica of an object, process or service in the physical world. Today "Digital Twin technology" are used in diverse industries for various application. This study is an attempt to understand the "Digital Twin Technology", its framework and its impact on sectors such as manufacturing, automobile, port, aerospace, etc. As digital twin technology can be as complex and simple as require, so, the study also focuses on various challenges faced in its implementation.

Keywords: Digital Twins, Digital Twin Technology, Twin Technology, Framework of Digital Twin

Authors

S**hailendra Pawaskar**
Assistant Professor
Pillai Institute of Management Studies and Research
Navi Mumbai
shailendrapawaskar@gmail.com

Ravindra Dhonde
Student, First Year M.M.S
Pillai Institute of Management Studies and Research
Navi Mumbai
ravindradhonde16@gmail.com

I. DIGITAL TWINS

Digital twins are virtual representations of products, processes, people, or even places, which exactly reflect their physical counterparts. Imagine, if you could track your product after it leaves your factory floor and enters the hands of your customers? Having a detailed understanding of how customers are using your product would give you a complete picture of the product's current and past state. That's digital twin technology and it doesn't end with products.

The term "Digital Twin" denotes to a digital replica of real asset, process, or a product. This "Twin" contains the details of its actual counterpart and makes an effort to exactly recreate it. One way to do this is, for instance, to model an object's geometry and then combine it with its metadata and Internet of Things (IoT) data. We can see a Digital Twin develop after all of this is done in real world scale and location while also adding time as the fourth dimension. Data accessibility determines the Digital Twin's level of quality.

According to NASA (2010), "A Digital Twin is an integrated multi-physics, multi-scale, probabilistic simulation of an as-built vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its corresponding flying twin." In fact, in the Apollo 13 space mission, NASA used 15 simulators to train astronauts and mission controllers (Allen, 2021)[1].

A digital twin is a virtual replica of an object, being, or system that can be constantly updated with data from its physical counterpart– Purdy - MIT Sloan (Sloan, 2021)[2]. In core, a digital twin is a computer software that simulates how a process or product would work using data from the real world. To improve the output, these systems can use artificial intelligence, software analytics, and the internet of things (Industry 4.0) (Marr, 2018)[3].These virtual models have become a mainstay in contemporary engineering to spur innovation and boost efficiency with the development of the machine learning a like big data. It is possible that digital twins allow for the virtual replication of physical infrastructure and activities using simulation, emulation, and other cutting-edge technologies like AI, ML, and predictive analytics.

1. Need of digital twin technology: To comprehend how digital twin technology affects manufacturing, port, automobile, aerospace, logistics operations? It is important to enhance the knowledge of current technological trends. In the current era, the demand for application of Digital twin technology is increasing in the field of manufacturing, port, automobile, aerospace and logistics industry. More companies are creating and implementing their own Digital twin models to enhance measures in terms of production, operational, efficiency.

A digital replica helps to analyse, understand and monitor the performance of a particular machine or a product under various circumstances in real-time scenarios. It is also helpful while creating complex designs or while maintaining, repairing complex parts of a particular machine. This will help to achieve higher operational capacity in the most efficient manner and will provide more output with minimum input.

Technological advancement may create a lot more chances, allowing businesses to expand and increase their income, customer service ability, which will lead to a larger customer base. To understand where we can apply Digital twin technology in various industries to achieve sustainable business growth.

Digital twin helps to prevent issues before they arise (in the real world).For instance, various automakers (Tesla, Porsche) have implemented this technology to monitor and analyse the overall health of vehicles or particular operational parts, which is helping them to identify problems and resolve them even before they exist.

2. Framework of digital twin technology (Yao, 2021)[4]**:** The digital twin framework can be categorised in 4 stages (Yao, 2021)[4]

Figure 1: Framework of Digital Twin Technology

- **Infrastructure:** Infrastructure should include website facilities, monitoring centres, cloud computing resources, updated hardware and networking facilities. It should be made available for the area where the "digital twin" approach is implemented.

- **Data gathering :** Data includes conventional information such as traditional surveying and mapping, as well as three-dimensional information, including 3D Geographical information systems (GIS), (Building Information Modelling) BIM, oblique photography, geo-location data derived from internet usage, real-time perception data derived from the Internet of Things, other sensing softwares and unstructured media such as videos, pictures, and documents.

- **Information model construction:** Information collected from various information resources will be used to model the virtual world**.** For instance, the model for port operations includes as elements, the wharf apron loading and unloading zone, yard, buildings, parking areas, and green space. This will produce quantitative information about monomers. For the real-time operation monitoring and data visualization, such as real-time operation video images, air pollution index, traffic flow, etc. In Internet of Things perception data should be quickly loaded, fused, and presented on the model platform in real-time.

- **Application service platform construction:** Public services, operation and maintenance, planning, and construction management should all be included in application platforms. Prior to implementation, it is crucial to test how each plan and construction project will be received after it has been completed. The status of where the digital twin is applied can be fully displayed during physical operations using this model's virtual and real components, and bottlenecks can be found to increase capacity and efficiency. Any changes in planning or programmes can be predicted in advance for their impact on the overall development pattern.

3. Flow of data in information management in digital twin: Following Diagram shows the flow of data in Information management in Digital Twin

Figure 2: Information flow in Digital Twin Technology

Data sensed by AI gadgets and various sensing software's will be collected and gathered in the system. Then organizing the available data and performing various analytical operations like Prescriptive analysis and predictive analysis. After an analysis, the data is shared and maintained for future operations and decision making process. Sharing data within the business process for smooth flow of real time operations or Publishing data on company and other websites.

4. Impacts of Digital Twin in Various Industries

- **Manufacturing industry:** The most notable impact of Digital Twin in the application of Manufacturing, is that manufacturers are constantly searching for a way to track and monitor products in an effort to save time and money, which is a major driving force and motivation for any manufacturer. The current expansion is consistent with the idea of Industry 4.0 (Marr, 2018)[3], which uses device connectivity to make the idea of a digital twin a reality for manufacturing processes. "Digital Twin" may provide feedback from the production line as well as real-time machine performance status. This helps the maker be able to anticipate problems prior to the result. Utilizing digital twins improves device connectivity and feedback, which raises dependability and performance. In a manufacturing environment, Digital Twin has the potential to be a very useful tool since it creates a testing environment and a system that reacts to real-time data. When used for simulation and data analytics, the capacity to create a digital twin of an engine or auto part might be useful, because Artificial Intelligence (AI) can analyse real-time vehicle data to forecast component performance in the present and the future, testing becomes more accurate. Digital Twin can use machine and deep learning techniques while simultaneously learning and monitoring.

For example:

- ➢ General Electric (GE), in full General Electric Company, a major American corporation and one of the largest and most-diversified corporations in the world. Its products include electrical and electronic equipment, aircraft engines, etc.
- ➢ The automobile sector where digital twins are also used, especially by Tesla (Ried) [5].

- **Port industry:** The digitization of various operational activities has given advantage to implementation of digital twin technology in ports. The Building Information Modelling platform allows us to utilize IOT, sensing information software, and other software applications to simulate port construction and operation, by creating a virtual representation of port infrastructure elements, real-time status updates, scene visualizations, and management coordination, at the same time as integrating the port's planning, design, and construction. Global logistics chains rely on ports as hub windows for international trade because they serve as gateways to the world. Using IoT sensors, cargo damage and contamination can be monitored on individual containers. A digital twin of the container will be created based on the operational and warehousing data. Here the digital twin technology and machine learning ensures that containers are deployed as efficiently as possible.

For example:

- A variety of AI gadgets can be deployed on the jetty to monitor how materials used in the construction of the jetty react to different weather conditions and to obtain readings of the water level at various intervals. By tracking this information in a virtual world, we can avoid major and minor problems that will impact port operations in the real world.
- It would be helpful to deploy a smart or AI-powered camera for yard management in order to track the exact location of containers.
- Quay Crane (QC) and Rubber Tyre Gantry (RTG) cranes will be equipped with sensors that use artificial intelligence to monitor their overall health and how often maintenance is required. Our crane handling operations can also be fully automated.
- Livorno, Italy (Sinay, 2021)[6] and The Port of Oulu, Finland (Oulu, 2021)[7]

- **Automobile Industry:** The impact of digital twin in automobile industry is remarkable. The ability to connect to a network and integrate data with a centralised intelligence system is the major benefit of digital twins. Data pertinent to a whole industry may be used to make conclusive decisions that help every car and every individual client. For instance, a customer's driving style may be determined by an algorithm's comparison of Big Data with sensor data from a particular vehicle's powertrain and chassis. The algorithm may then suggest not just when it is best to get the car serviced, but also how extensive that maintenance should be. Using this information, service intervals may be tailored to the way a client uses their car, and particular components can be serviced as needed. A sports vehicle that spends the majority of its time on a race circuit, may have its hard-working suspension bushes changed at the ideal moment and for cars that are primarily used for long distance highway driving the engine maintenance is particularly crucial. The ability to detect possible component wear and tear, even before the problems manifest themselves, is a major advantage of this technique, which is vital from a safety standpoint. Contingency planning and algorithm accuracy are continually improved by artificial intelligence in the vehicle's central intelligence system. Customers are asked through the PCM to consent to data being gathered anonymously since protecting customer data during the testing period and after the introduction of series production is of utmost importance. For e.g. Porsche (Porsche, 2022)[8] and Tesla (Ried)[5]

- **Aerospace Industry**: Despite the fact that airplanes are being constructed to last longer, engines are becoming more robust, and maintenance methods are improving, expenditure on maintenance and repairs in the aerospace sector keeps rising. A sizable portion of aircraft operating expenditures goes toward airplane maintenance. Therefore, it should come as no surprise that airlines prioritise lowering MRO (maintenance, repair, and overhaul) costs while preserving asset operability. The technological advancement in Airlines are bridging the gap between the physical and digital worlds with the use of "digital twins". To reduce unexpected downtime for engines and other systems, a lot of aerospace industries have started using digital twins. With the help of this technology, they are able to gain not just early warning on forecasts but also a plan of action based on simulated scenarios that account for the weather, the performance of the asset, and a number of other factors. The benefit will be airlines have been able to maintain their aircraft in operation for extended periods of time. They may do proactive and predictive maintenance with the use of digital twins to improve platform operational availability and efficiency, lengthen its usable life, and reduce the life cycle costs. With the use of a digital twin, it is feasible to anticipate the asset's remaining usable life with great precision.

For instance,

- Sensors are installed at typical failure areas, such as hydraulic pressure and brake temperature, in a digital twin of the landing gear. This makes sure that the digital twin gets updates from these points in real time. This information aids in predicting the probability of an early malfunction and aids in estimating the landing gear's remaining useful life.
- Boeing by employing the digital twin asset creation methodology has been able to achieve up to a 40% increase in the first-time quality of the components and systems it employs to construct commercial and military airplanes (Meyer, 2021)[9]

5. Future areas of digital twin

- **Logistics Industry:** Logistics professionals are increasingly adopting open API techniques and moving to cloud-based IT solutions. To optimise their supply chains, businesses are using machine learning and cutting-edge analytics tools. Professionals in logistics are even using augmented, mixed, and virtual reality technologies for jobs like vehicle loading and warehouse picking. These tasks produce data ideal for building digital twins in these settings. With the use of digital twins in warehousing, materials will be easier to monitor, locate, and forecast. Inbound and outbound logistics operations can be monitored and planned effectively to avoid overcrowding and transporter delays (DHL, 2022)[10]

- **Healthcare Industry:** The impact that advancing technology is having on healthcare is extraordinary because it is making previously unthinkable things possible. Due to the availability of the device at lower cost and simpler implementation in the Internet of Things, has resulted in the increase of connections. The potential use of digital twins in the healthcare industry is only expanding due to the greater connection. A digital twin of a person, which provides a real-time examination of the body, is one potential future use. Digital Twin, which is being utilised to simulate the effects of some medications, is a more realistic application. Using a digital twin to plan and carry out surgical treatments is another application. Similar to other applications in a healthcare setting, using a Digital Twin enables researchers, physicians, hospitals, and healthcare providers to replicate environments that are particular to their needs, whether they are for current usage or future advances. Though digital twin technology is still in its infancy in the healthcare industry, it has enormous potential for everything from bed management to the large-scale ward and hospital management. Predictive maintenance and ongoing repairs of medical equipment could benefit from Digital

Twin. In a medical setting, Digital Twin and AI may be able to make judgments that could save lives based on current and past data.

- **Neuroscience:** Recent research suggests that non-invasive brain stimulation may be a useful treatment option for ailments like epilepsy or Alzheimers (AD). However, further research is required to better understand the processes and characteristics unique to each patient. Individualized hybrid brain models that combine electromagnetic physics with physiology — known as Neuro Twins or NeTs — are set to play a critical role in understanding and improving the effects of stimulation. Digital twin technology can provide the model-driven, personalised therapy, providing revolutionary solutions. Which can reflect the ways in which electric fields interact with brain networks and take into account neuro imaging data which can construct a computational framework?

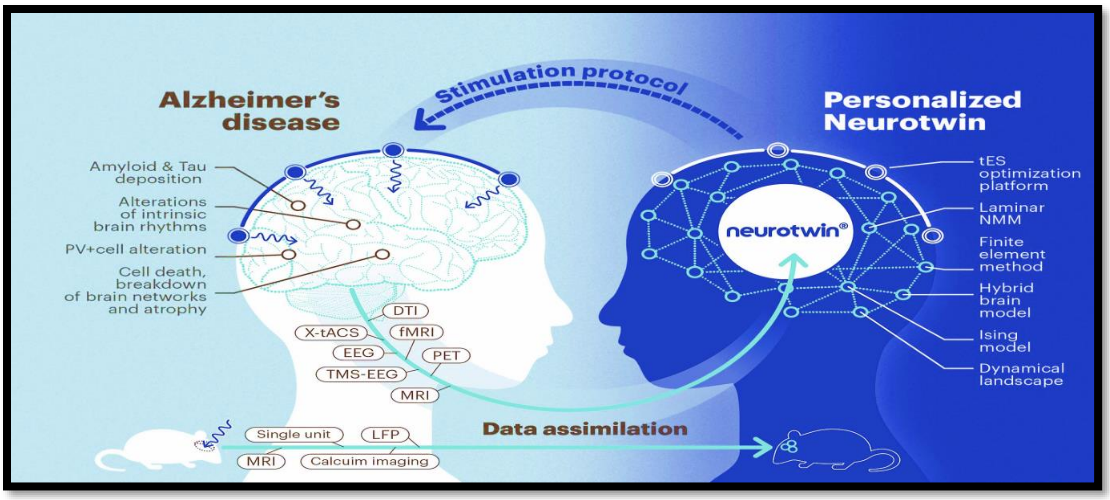

Figure: 3 Data assimilation –Neuroscience (Neurotwin, 2020)[11]

Digital twin technology will enable us to propose techniques to restore healthy dynamics and characterise the dynamical landscape of the individual brain.

- **Importance of Digital Twin**

  - Enhanced manufacturing lines and equipment dependability
  - Reduced risk in multiple areas, such as product availability, market reputation and maintenance expenses by foreseeing issues before they happen.
  - Better product quality and increased understanding of how your goods work in various real-time applications and conditions.
  - Higher earnings.
  - Time saving.
  - It helps to reduce CO_2 emission.
  - Provides more sustainable growth.
  - More effective delivery and supply chains.
  - It helps to resolve complex technical issues and Improved customer support since customers can remotely configure customised items.

- New business opportunities, including mass customization, mixed manufacturing, small-batch manufacturing.

- **Challenges in applying digital twins:** The widespread use of digital twins faces substantial difficulties. Digitally matching complex assets and their behaviour in the real-time and with accuracy can quickly exceed company culture, financial and computational resources, and data governance capabilities.

Below are some of the potential difficulties arising that are identified while using digital twins.

- **Cost:** Investments in technical platforms, model creation, and high-touch maintenance are significant requirements for digital twins. While majority of these expenses are declining, it is still necessary to weigh the implementation of a digital twin against other strategies that can produce comparable results at a lower cost.

- **Precise representation:** No digital twin will be an exact replica of its physical counterpart for the foreseeable future. It is incredibly difficult and expensive to match the physical, chemical, electrical, and thermal state of a complex asset. As a result, engineers frequently have to combine the intended characteristics of the twin with practical and financial limitations in their models.

- **Data quality:** Good data are necessary for good models. In digital twin applications that rely on data from hundreds or thousands of remote sensors functioning in challenging field settings and communicating over unreliable networks, that may be a challenging thing to guarantee. Companies will need to create procedures at the very least to manage gaps and irregularities in product data streams as well as to recognise and isolate erroneous data.

- **Interoperability:** Although openness and standardisation have advanced significantly, there are still commercial and technical obstacles to data interchange. Additionally, if a digital twin depends on the simulation or AI tools provided by a particular vendor, it can be difficult or impossible to recreate that capability using different suppliers, essentially forcing businesses into long-term partnerships with a single source.

- **Education:** Employees, clients, and suppliers will all need to adapt new working practices as a result of the deployment of digital twins. That creates difficulties for managing change and developing capabilities. Organizations must make sure users are sufficiently motivated to make the necessary change and have the knowledge and resources necessary to connect with digital twins. To fully appreciate the benefits offered by this development, leveraging the new technology needed for digital twins often demands a significant culture shift.

- **Cyber security:** Cybercriminals will find digital twins to be attractive targets. The data linkages that link physical items to their digital siblings give malicious actors looking to sabotage an organization's operations a new point of entry. When digital twins are used to manage their physical counterparts, their compromise could have immediate and potentially disastrous real-world effects. Due to these qualities, managing digital twin cyber security effectively must be a top concern and will bring fresh difficulties for many firms.

- **Internet:** Application of various technologies is only possible if internet access is available. In the current scenario 5G technology is being used; but we should look for better and stable options like OneWeb, which is a communications company that aims to build broadband satellite Internet services. Also OneWeb technology provides stable connectivity is still an issue for technical reformation (OneWeb, 2022)[12]

II. CONCLUSION

Implementing digital twins in various sectors like manufacturing, port, automobile, aerospace and logistics can provide sustainable growth for a longer period. Using digital twins in manufacturing will enhance the efficiency of machinery and reduces the risk. In the automobile and aerospace industry, the digital twin helps in designing complex designs or solving complex problems (before they even occur). This will help to achieve higher operational capacity in the most efficient manner and will provide more output with minimum input.

Digital twins have made their way up from their humble beginnings in the aerospace and defence sectors to currently improving operational value chains in an engineering, manufacturing, and automotive sectors. While digital twins may seem like a long way off for the logistics sector today. We can implement this technology in the healthcare industry, and neuroscience.

Digital twins are more than just digital copies. Analysing data and monitoring systems through the combination of the digital and physical worlds can prevent problems before they occur. Replicating the real world in a means of digital twin and simulations helps to predict the future and understand present situations and even the world around us, thanks to the convergence of progress in the internet of things, big data, cloud computing, open APIs, artificial intelligence, and virtual reality. Industries are adapting to overcome these constraints even if there are still problems and restrictions in computer resources, exact representation, overall cost, data quality, governance, and organisational culture. Using digital twins will lead to better results and potent new business concepts. The manufacturing, port, automotive and aerospace sectors are currently leading the way in utilising digital twins to manage their most important assets, with the smart cities, healthcare industry and neuroscience, etc. following closely after.

REFERENCES

[1] Allen, B. D. (2021, 11 1). NASA. https://ntrs.nasa.gov/citations/20210023699 Retrieved on 29-8-2022.
[2] Pushkar P. Apte and Costas J. Spanos, (2021), "The Digital Twin Opportunity", https://sloanreview.mit.edu/article/the-digital-twin-opportunity/#:~:text=This . Retrieved on 28-8-2022.

[3] Marr, B. (2018). “What is Industry 4.0? Here's A Super Easy Explanation For Anyone”, https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-anyone/?sh=162e98be9788, Retrieved on 28-8-2022.
[4] Yao, H., Wang, D., Su, M., & Qi, Y. (2021, March). Application of Digital Twins in Port System. In Journal of Physics: Conference Series (Vol. 1846, No. 1, p. 012008). IOP Publishing.
[5] Ried, S, “Learnings from the Digital Twin’s Data Architecture of Tesla”, https://www.cloudflight.io/en/blog/learnings-from-the-digital-twins-data-architecture-of-tesla/, Retrived on 26-8-2022.
[6] Sinay. (2021), “What is a Digital Twin?”, https://sinay.ai/en/what-is-a-digital-twin/, Retrived on 26-8-2022.
[7] https://smartcityoulu.com/en/news/port-of-oulu-digital-twin/ Retrived on 25-8-2022.
[8] Porsche. (2022). , “A digital chassis twin for predictive driving functions and component status updates”, https://media.porsche.com/mediakit/innovation-sustainability-performance/en/innovation-sustainability-performance/digital-twin
[9] Meyer, H., Zimdahl, J., Kamtsiuris, A., Meissner, R., Raddatz, F., Haufe, S., & Bäßler, M. (2020). Development of a digital twin for aviation research.
[10] DHL’s Report (2022), “ Digital Twins in Logistics”, https://www.dhl.com/content/dam/dhl/global/core/documents/pdf/glo-core-digital-twins-in-logistics.pdf, Retrived on 24-8-2022.
[11] https://www.neurotwin.eu/ Retrived on 24-8-2022.
[12] https://oneweb.net/ Retrived on 24-8-2022.