International Journal of Interdisciplinary Innovative Research & Development (IJIIRD)
ISSN: 2456-236X
Vol. 03 Special Issue | 2019

The Digital Twins: Future of Information Age

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ABSTRACT

This is information age. Information is power. The science of today is the technology of tomorrow. This paper presents a digital twin-based approach. Digital twin is an ability to take a virtual representation of the elements and how the IoT devices operates and works. Basically, a digital twin (sometimes also "digital shadow") is a digital replica of real-world devices, processes or even persons. It does not necessarily represent all of them (something conceptually impossible, as you cannot represent a single atomic electron cloud with unlimited precision), but what matters is that the representation is accurate enough to support the goals that have been identified and that are being pursued. For example, if you want to check the proper working of an engine you need to represent all aspects that are functional to that goal (e.g., you may disregard the color used to paint parts of that engine). [1]

1. INTRODUCTION

A digital twin mimics in bits an object's atoms and their structural/functional relations. Digital twins can represent objects and entities as varied as a turbine, a robot, a whole ship, a cow, a human being or a city, and everything else in between.[2] So, the Digital Twin idea can be simply explained: as physical systems are now designed to be instrumented, you can collect data all along their life cycles: from invention, to design, to manufacturing, to operation and maintenance, until decommissioning. As all this data is persisted and understood through proper metadata management, you can start to develop intelligence by using analytics and machine learning. The accumulated data gives the pictures of the past and present conditions and performance. The intelligence gives you early warning and predictions, in short, the future. The Digital Twin is the proxy of a physical system in the digital space, it can tell you everything it knows about that system and offers predictions. Over time, the Digital Twin will also be used to control the physical system it is paired to.[3]

1.1 Technologies included

The technology draws on domains like machine learning, artificial intelligence and software analytics to provide a dynamic digital representation of its physical counterpart.

1.2 Digital Twins, AI and ML

Intelligence is commonly considered as the ability to collect knowledge and reason about knowledge to solve complex problems. Artificial intelligence is the study and developments of intelligent machines and software that can reason, learn, gather knowledge, communicate, manipulate and perceive the objects. It makes machines smarter and more useful. It works with the help of artificial neurons (artificial neural network) and scientific theorems (if then statements and logics).The field of artificial intelligence gives the ability to the machines to think analytically, using concepts.[4]

The fact is that digital twins can produce value without machine learning and AI if the system is simple. If for example there are limited variables and an easily discoverable linear relation between inputs and outputs then no data science may be required. However, the vast majority of target systems have multiple variables and multiple streams of data and do require the talents of data science to make sense of what's going on.

Unfortunately the popular press tends to equate all this with AI. Actually the great majority of the benefit of modelling can be achieved with traditional machine learning algorithms. It is possible though to see that the AI represented by deep learning, specifically image and video processing and text and speech processing (with CNNs and RNNs respectively) can also be incorporated as input into models alongside traditional numerical sensor readings.

For example, video feeds of components during manufacture can already be used to detect defective items and reject them. Similarly audio inputs of large generators can carry signals of impending malfunctions like vibration even before traditional sensors can detect the problem.[5]

1.3 Digital Twins and IoT

In simple words Internet Of things is nothing but things that have internet. Athing in the internet of things can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low or any other natural or man-made object that can be assigned an IP address and is able to transfer data over a network. An IoT ecosystem consists of web-enabled smart devices that use embedded processors, sensors and communication hardware to collect, send and act on data they acquire from their environments. IoT devicesshare the sensor data they collect by connecting to an IoT gateway or other edge device where data is either sent to the cloud to be analysed or analysed locally. [6] Clearly, the explosion of IoT sensors is part of what makes digital twins possible. And as IoT devices are refined, digital-twin scenarios can include smaller and less complex objects, giving additional benefits to companies.

Digital twins can be used to predict different outcomes based on variable data. This is similar to the run-the-simulation scenario often seen in science-fiction films, where a possible scenario is proven within the digital environment. With additional software and data analytics, digital twins can often optimize an IoT deployment for maximum efficiency, as well as help designers figure out where things should go or how they operate before they are physically deployed.[7]

2. APPLICATIONS

A digital twin is a precise visualization of a physical object such as a product or infrastructure component. They are typically used to display information about the physical object collected with systems and sensors.

- **Robotics**: A digital twin of an industrial robotallows a remote operator to control it with accuracy.
- **Manufacturing**: Digital Twin is poised to change the current face of manufacturing sector. Digital Twins have a significant impact on the way products are designed manufactured and maintained. It makes manufacturing more efficient and optimized while reducing the throughput times.
- **Automobile**: Digital Twins can be used in the automobile sector for creating the virtual model of a connected vehicle. It captures the behavioural and operational data of the vehicle and helps in analysing the overall vehicle performance as well as the connected features. It also helps in delivering a truly personalized/ customized service for the customers.
- **Retail**: Appealing customer experience is key in the retail sector. Digital twin implementation can play a key role in augmenting the retail customer experience by creating virtual twins for customers and modelling fashions for them on it. Digital Twins also helps in better in store planning, security implementation and energy management in an optimized manner.
- **Healthcare**: Digital Twins along with data from IoT can play a key role in the health care sector from cost savings to patient monitoring, preventative maintenance and providing personalized health care.
- **Smart Cities**: The smart city planning and implementation with Digital Twins and IoT data helps enhancing economic development, efficient management of resources, reduction of ecological foot print and increase the overall quality of a citizen’s life. The digital twin model can help city planners and policymakers in the smart city planning by gaining the insights from various sensor networks and intelligent systems. The data from the digital twins help them in arriving at informed decisions regarding the future as well.[8]

3. METHODOLOGY

The general idea is to create a digital partner; digital twins are created entirely based on the specifications of their physical counterpart, whereby they document all its changes and developments. In order to do so, digital twins require data obtained from a system’s or device’s history, the experts working in the domain and even data from other (third party) entities, processes, and systems. Thus, a digital twin is able to provide information about and current status reports of its physical counterpart.. The digital twin representing this system includes the environment in which it will be operating as well as the interactions with other systems and is used for validation and testing before actual installation. [9] Information along with AI algorithms is integrated into a physics-based virtual model and by applying Analytics into these models we get the relevant insights regarding the physical asset. The consistent flow of data helps in getting the best possible analysis and insights regarding the asset which helps in optimizing the business outcome. Sensors attached to the physical object collect massive amounts of data, which allows the digital version to act like the physical object. This shows a business exactly how each individual machine on their production floor is functioning, for example, rather than making assumptions based on a generalized expectation for how the machine should function, when it will need repairs or how it could perform more efficiently.

4. COMPANIES IMPLEMENTING DIGITAL TWINS

4.1 NASA

The idea of digital twins is predated by pairing technology, developed by NASA to help in the operation, repairs and maintenance of spacecraft traveling outside the range of physical monitoring. These "twin" systems are what made it possible for engineers and astronauts to test repairs for the ill-fated Apollo 13 mission, bringing the craft and crew back to earth safely. NASA now uses digital twins, thanks to the development of sensors, to gather data, make recommendations to crew members and plan for the needs of future aircraft. Aside from maintenance, digital twins can also be used to improve and evolve customer experience.

4.2 Microsoft

Microsoft talks a lot about digital twins for discrete manufacturing. However, they talk about it as a concept rather than a product. Microsoft Azure IoT does have the concept of a 'device twin' that is part of their device management solution. A device twin is automatically created when a device is connected to the MS IoT Hub.[15]

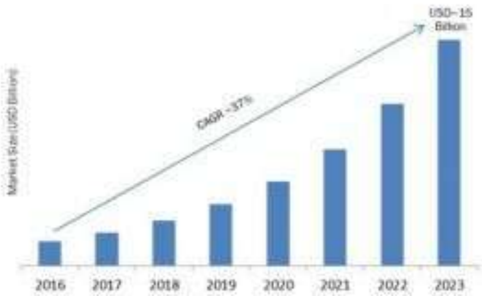

Fig 1 Portraying the growth of digital twin

To create a digital twin of any physical asset, the engineers collect and synthesize data from various sources including physical data, manufacturing data, operational data and insights from analytics software.

4.3 Amazon

Amazon refers to a 'device shadow' as their version of a digital twin. A device shadow is a JSON file that contains the state information, meta-data, timestamp, unique client token, and version of a device connected to the device shadow service.

4.4 IBM

When you combine cognitive sensing, artificial intelligence and Watson Internet of Things, you can build a smarter digital twin. Not only is the technology intriguing, but there are several compelling business reasons why it makes sense, too. With a robust digital twin, you can:

- Leverage operational insights to improve product performance.
- Quickly identify problems, root causes and potential impacts.
- Automate discovery of new knowledge and insights, which can enable new business models and new user experiences, and deliver true differentiation.[10]

IBM has a ton of marketing collateral around digital twins, including a number of reports and videos. In fact, IBM is definitely the vendor who has invested the most in promoting the concept of a digital twin.

5. CHALLENGES

Firstly,it is necessary to keep adequate two-way connection between physical and virtual spaces to support the real-time interaction. It mainly addresses challenges on technologies of sensors, communication, database and data processing, etc.

Secondly,due to the variability, uncertainty and fuzziness of physical space, building models in virtual space to mirror entities with high fidelity is a fundamental issue. In addition, when inconsistencies between models and entities appear, how to identify and utilize them wisely is also difficult.

Thirdly, as the continuous physical space and discrete virtual space are in different scales, how to transcend the divergence to realize the seamless integration of the two sides is challenging. With virtual space evolving with the physical one along the lifecycle, data from entities, models and systems are generated continuously. In this situation, how to integrate and converge increasing data is a challenge. Also, security is another focus that ensures the normal operation of physical and virtual spaces against the malicious.[11]

5.1 Hardware

It is possible though to see that the AI represented by deep learning, specifically image and video processing and text and speech processing (with CNNs and RNNs respectively) can also be incorporated as input into models alongside traditional numerical sensor readings.

For example, video feeds of components during manufacture can already be used to detect defective items and reject them. Similarly audio inputs of large generators can carry signals of impending malfunctions like vibration even before traditional sensors can detect the problem.

5.2 Connectivity

Connectivity is another challenge for many digital twin concepts, primarily because physical entities, especially those that are interesting to study from a digital twin perspective, do not remain stationary. Providing connectivity to thousands or millions of physical assets attached to an airplane, a car, or other physical assets that might be constantly moving or in areas with poor cellular reception is challenging.

Furthermore, because most IoT architectural patterns currently rely on data caching on the edge and processing in the cloud models, the bandwidth required to gain value from a digital twin scenario that could potentially be processing billions of data points is tremendous.[12]

6. DIGITAL TWIN BENEFITS

The concept of digital twin remains beneficial in many ways. It eliminates the use of symbols or numbers extracted from the visual information for conceptualization. Instead of looking at the factory report, the digital twin simulations let users directly see the progress as the product moves along the manufacturing stages. Comparing the digital and physical product becomes easier as the twin model tracks the progress of the physical product development directly, and clearly indicates deviations from the idealized processes.

6.1 Technological Survey

The most powerful benefit of digital twin however is in collaboration. Tracking the state of the physical product under the development through a replicated digital model lets individuals monitor the performance from anywhere.

According to the results, the majority of organizations are using or plan to use digital twins in the next year. Here’s the breakdown:

7. CONCLUSION

Global digital twin market is projected to grow at a CAGR of over 37%, in value terms, during 2017-2022. High demand from the electronics and electrical/machine manufacturing industry, owing need of digitalization for the designing and manufacturing process of electronic equipment such as industrial equipment, computers, printers, transformers, generators, motors, and home electronic equipment, are some factors, which are expected to propel demand for digital twin over the next five years.

Right now, the term ‘digital twin’ is really just a concept that has a lot of marketing hype from some of the vendors. In general, the current solutions provided by some of the key IoT platforms are pretty basic. There is a lot of work needed for digital twins to become reality for developers.

With time the complexities and the challenges addressed above would be solved and could be implemented successfully in various fields. Mainly it would find its application in the areas which are risky for human beings.

8. FUTURE SCOPE

In the future we’ll see twins expand to more applications, use cases and industries and get combined with more technologies such as speech capabilities, augmented reality for an immersive experience, AI capabilities, more technologies enabling us to look inside the digital twin removing the need to go and check the ‘real’ thing and so on.

Speaking about the future, analysts point at mainly 2020-2021 as the years where digital twins will be leveraged in key business applications (of course there are already plenty of examples and also in 2018 and 2019 digital twin technology is a hot topic).

Gartner sees the main place of digital twins in an IoT project context until give and take 2020. The company expects half of large industrial firms to use digital twins by 2021. The digital twin paradigm offers value propositions that are unique to each industry and helps realize the true essence of physical-digital convergence. It is poised to become an inseparable part of any digital transformation journey. As we continue to see advances in sensor technology, data science techniques, and physics-based models, more sophisticated digital twins will emerge. They will be able to provide companies with deeper insights on the monitored assets or processes, and, with feedback control, allow companies to modify and improve the performance of assets or processes in real time.[14]

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