Chapter 1

Introduction

1.1 Overview

Digital Twins integrate internet of things, artificial intelligence, machine learning and software analytics to create spatial network graph, living digital simulation models that update and change as their physical counterpart change. They are used for enhancing performance and reducing operating cost, offer the business including increased reliability of equipment and production lines.

The widespread use of digital twins holds the promise to increase operational efficiency, allow for resource optimisation, improve asset management, deliver cost savings, improve productivity and safety. The digitisation of the built environment, enabled by an increase in computing power, cheaper sensors, Internet of Things (IoT), advanced analytics and greater sophistication of 3D visualisation and immersive environments, therefore has the potential to actively contribute towards achieving the UN Sustainable Development Goals (SDGs)

1.2 What is Digital Twin?

- Digital twins are virtual replicas of physical devices that data scientists and IT professionals can use to run simulations before actual devices are built and deployed.
- They are used for enhancing performance, reduce the operational cost, offer the business including increased reliability of equipment and pipelines.
- It continuously learns from sensor data and conveys various aspects of operating conditions.

Fig 1.1: Digital Twin

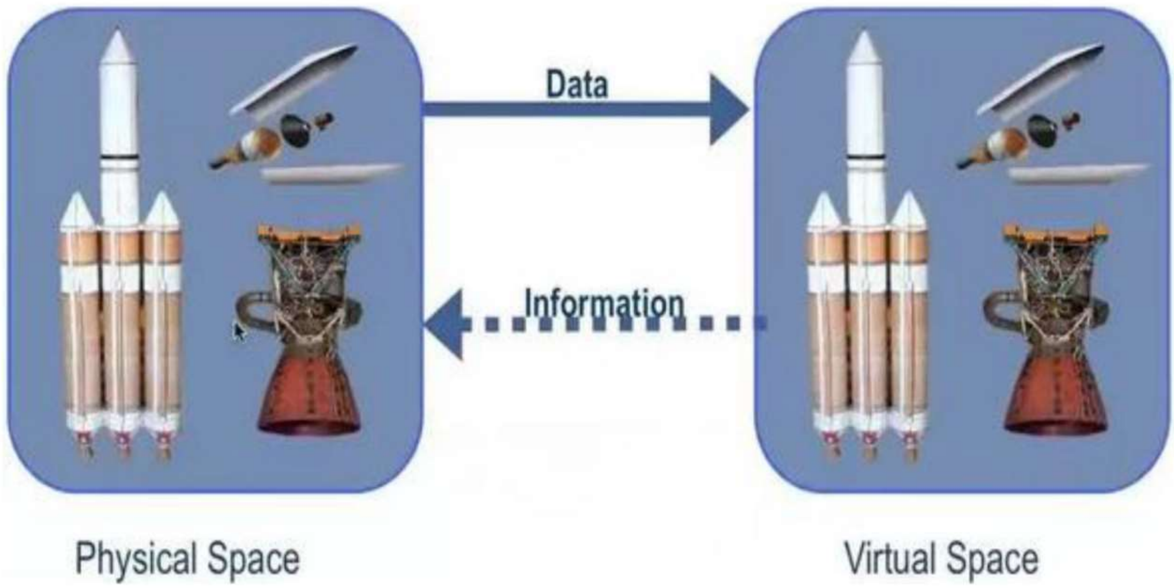


Fig 1.2: Three-dimension model for the DT

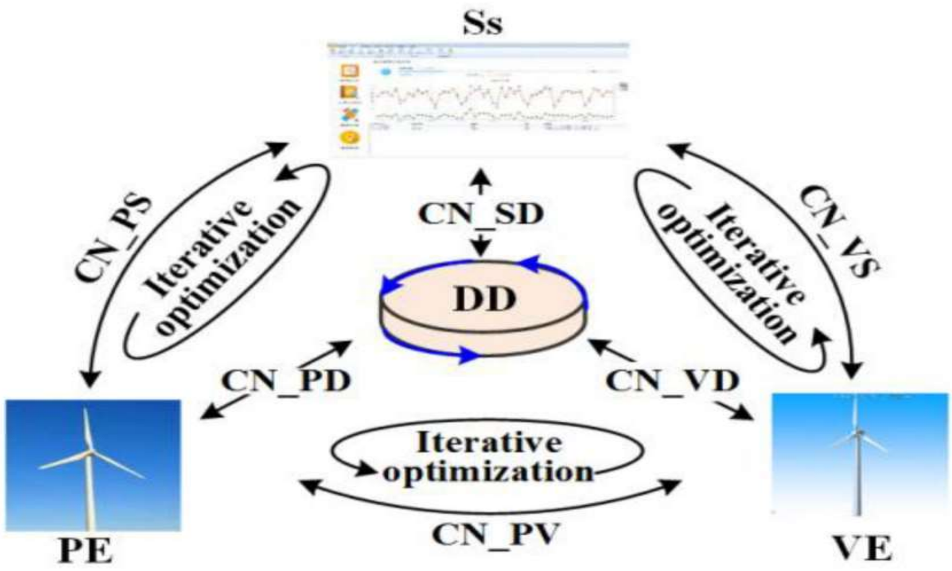


Fig 1.3: Five Dimensional DT

1.3.2 History

After the launch of Apollo 13 on April 1970, no one could have predicted it would become a fight for survival as the oxygen tanks exploded early into the mission. It became a famous rescue mission as the world held its breath, with technical issues needing to be resolved from up to 200,000 miles away. A key to the rescue mission, however, was that NASA had a digital twin model of Apollo 13 on earth which allowed engineers to test possible solutions from ground level. Of course, systems have now become predominantly virtual rather than physical simulations. With the concept already being practiced for a few decades, the phrase 'digital twin' was first mentioned in 1998 and was being referred to a digital copy of actor Alan Alda's voice in Alan Alda meets Alan Alda 2.0. Although the digital twins have been highly familiar since 2002, only as recently as 2017 has it become one of the top strategic technology trends. The Internet of Things enabled digital twins to become cost-effective so they could become as imperative to business as they are today

The digital twin concept gained recognition in 2002 after Challenge Advisory has hosted a presentation for Michael Grieves in the University of Michigan on technology. The presentation involved the development of a product lifecycle management center. It contained all the elements familiar with the digital twin including real space, virtual space and the spreading of data and information flow between real and virtual space. While the terminology may have changed over the years the concept of creating a digital and physical twin as one entity has remained the same since its emergence.

1.4 Characteristics of Digital Twin Technology.

The main characteristics of digital twin are:

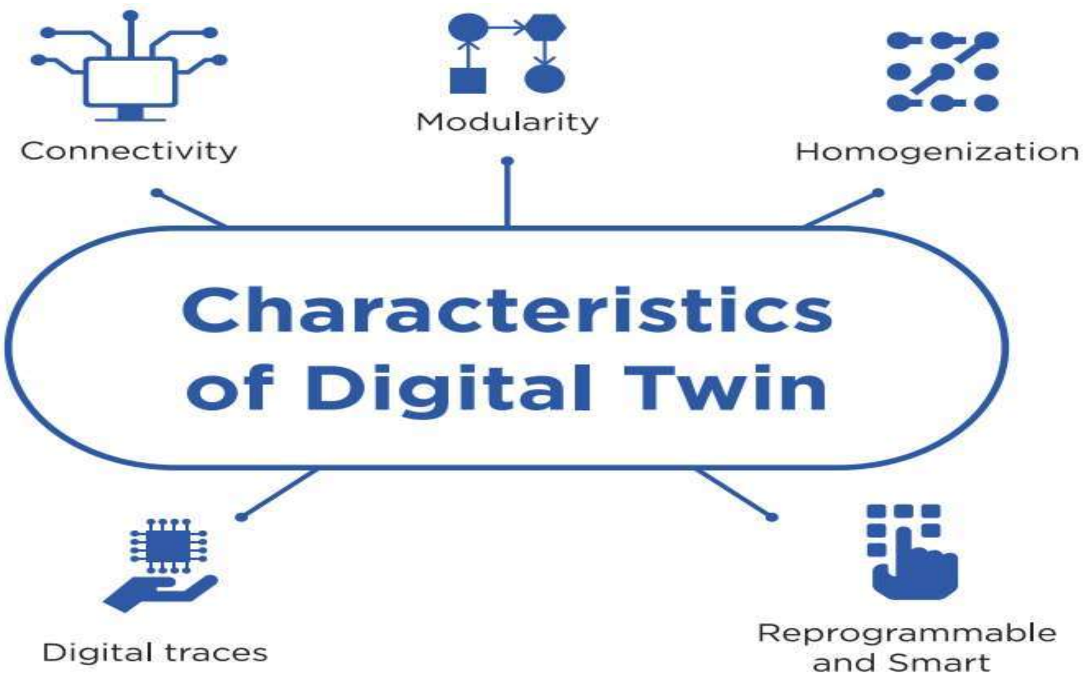


Fig 1.4: Characteristics of Digital Twin

track and monitor everything we do, thus leading to a smarter world. The number Of IOT devices recorded year on year shows the considerable growth Of this technology.

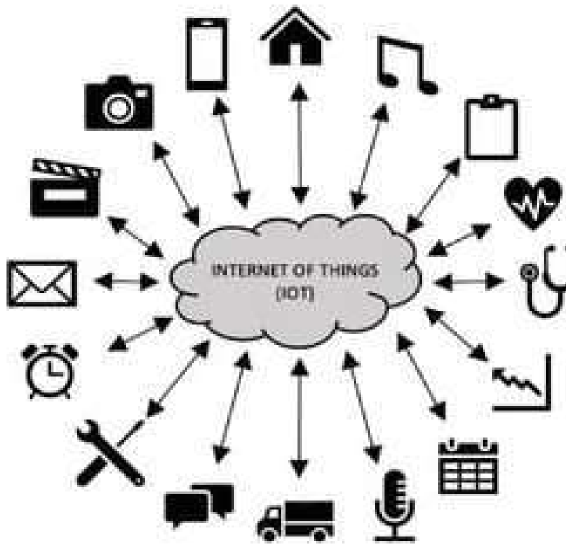


Fig 1.5: Underlying Technologies

1.6.2 Data Analytics

The term data analytics stems from the field of Data Science", a multidisciplinary subject that covers a range of concepts, with an emphasis on collecting and presenting data for analysis to gain greater insight. To perform data analysis, the need for raw data is paramount. There are several actions needed to turn this data into usable information, ready for use in algorithms and statistical analysis. These being the requirements, collection, processing and cleaning. The requirements set Out the necessary needs of the data and how it is used, ensuring that specific requirements are outlined, considering the intended use of the data. The second stage acts on the requirement of collecting the relevant data, identifying physically where and how the data

Will be collected. The collected data Will then go through a processing phase in which it is sorted according to specific requirements Despite the data being collected and sorted, it may have significant gaps or erroneous data.. The requirements set Out the necessary needs of the data and how it is used, ensuring that specific requirements are outlined, considering the intended use of the data.

1.6.3 Statistics

Statistics is the overarching term for the collection, classification, analysis, and interpretation of data. Briefly relevant in this case for data analysis as statistical models underpin machine

Chapter 2

Digital Twin architecture, creation and working

2.1 Architecture

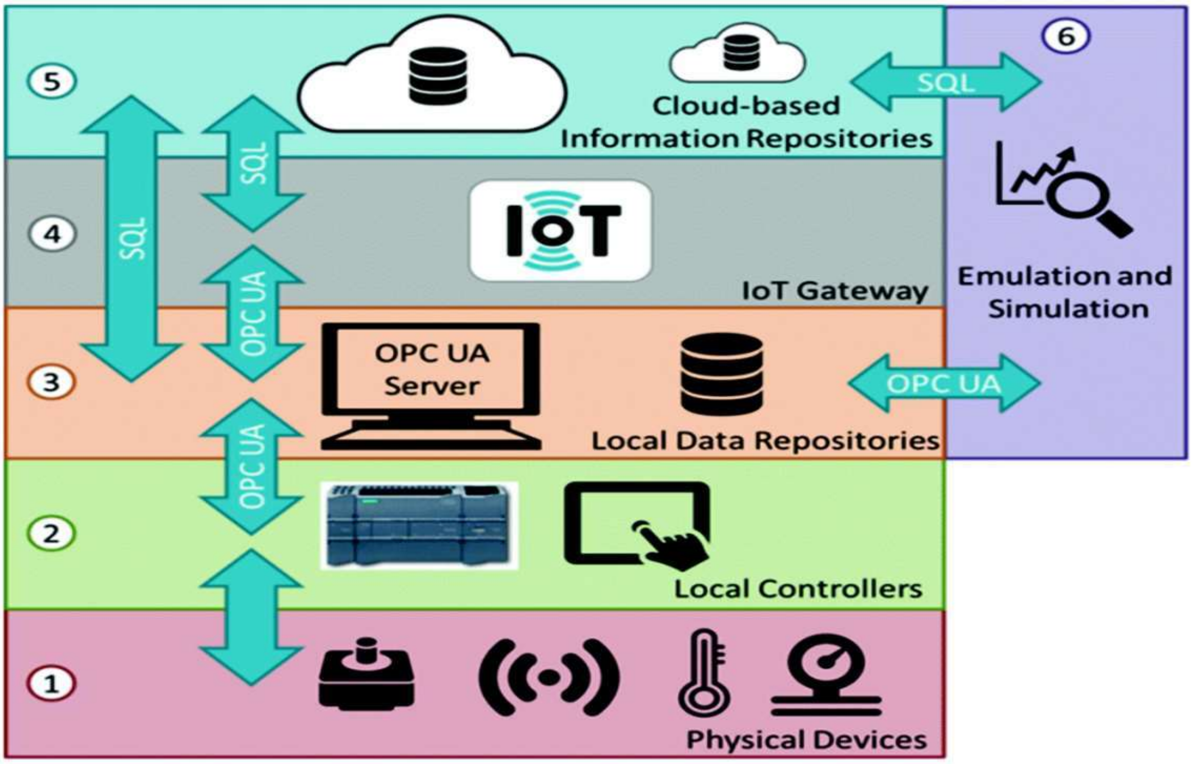


Fig 2.1: Architecture of Digital Twin

As in the above architecture generally six stages are involved in the digital twin architecture namely physical devices, local controllers, local data repositories, IOT gateway, cloudbased information repositories, emulation and simulation. The stages are explained in detail below

1.Physical devices

Devices such as sensors, routers which is source of our data.

2.Local controllers

Local controllers control the data locally either manually or through some specified devices according to our need as show in above figure

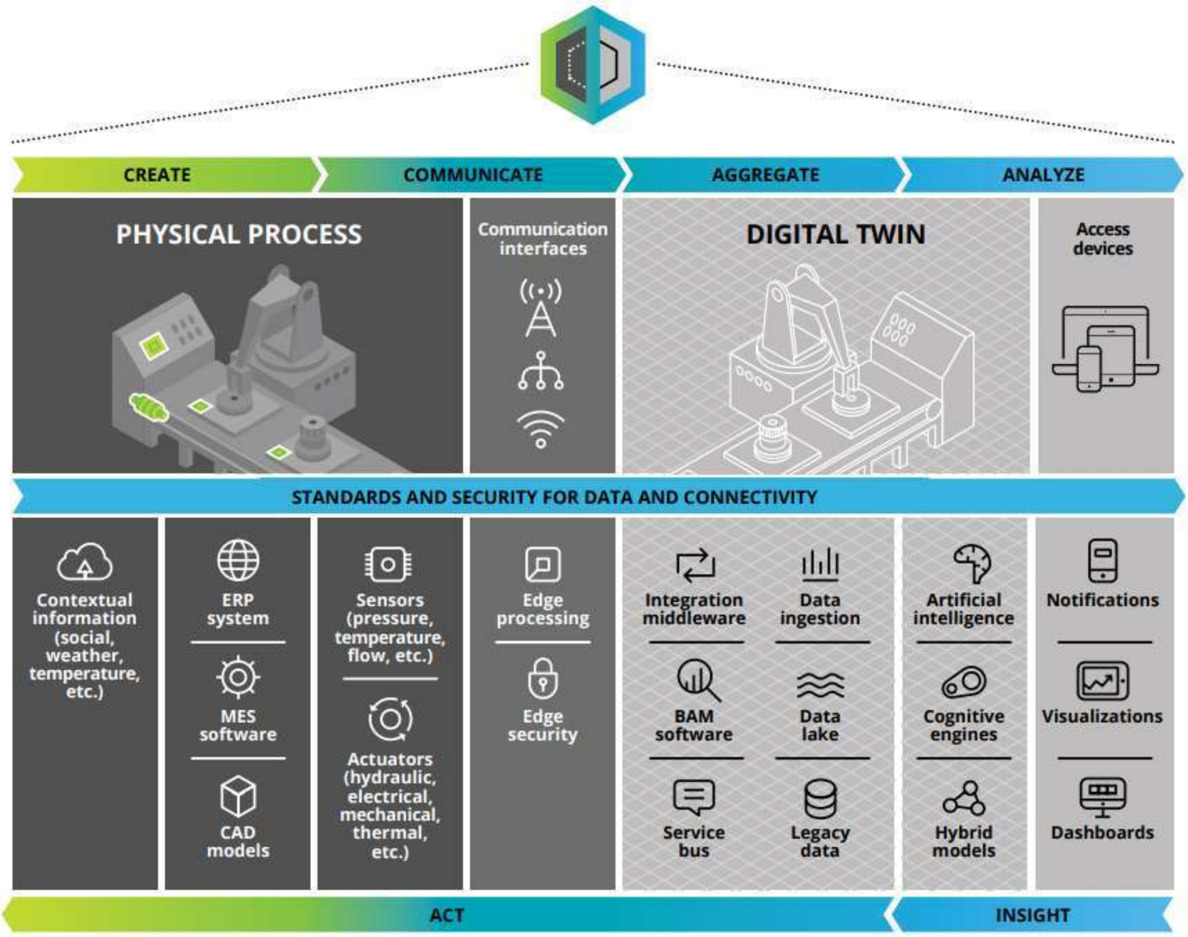


Fig 2.2: Digital twin conceptual architecture

Create:

The create step encompasses outfitting the physical process with myriad sensors that measure critical inputs from the physical process and its surroundings. The measurements by the sensors can be broadly classified into two categories: (1) operational measurements pertaining to the physical performance criteria of the productive asset (including multiple works in progress), such as tensile strength, displacement, torque, and color uniformity; (2) environmental or external data affecting the operations of a physical asset, such as ambient temperature, barometric pressure, and moisture level. The measurements can be transformed into secured digital messages using encoders and then transmitted to the digital twin.

Communicate:

The communicate step helps the seamless, real-time, bidirectional integration/connectivity between the physical process and the digital platform. Network communication is one of the

1. The product or manufacturing process being considered is valuable enough for the enterprise to invest in building a digital twin.

2. There are outstanding, unexplained processor product-related issues that could potentially unlock value either for the customers or the enterprise.

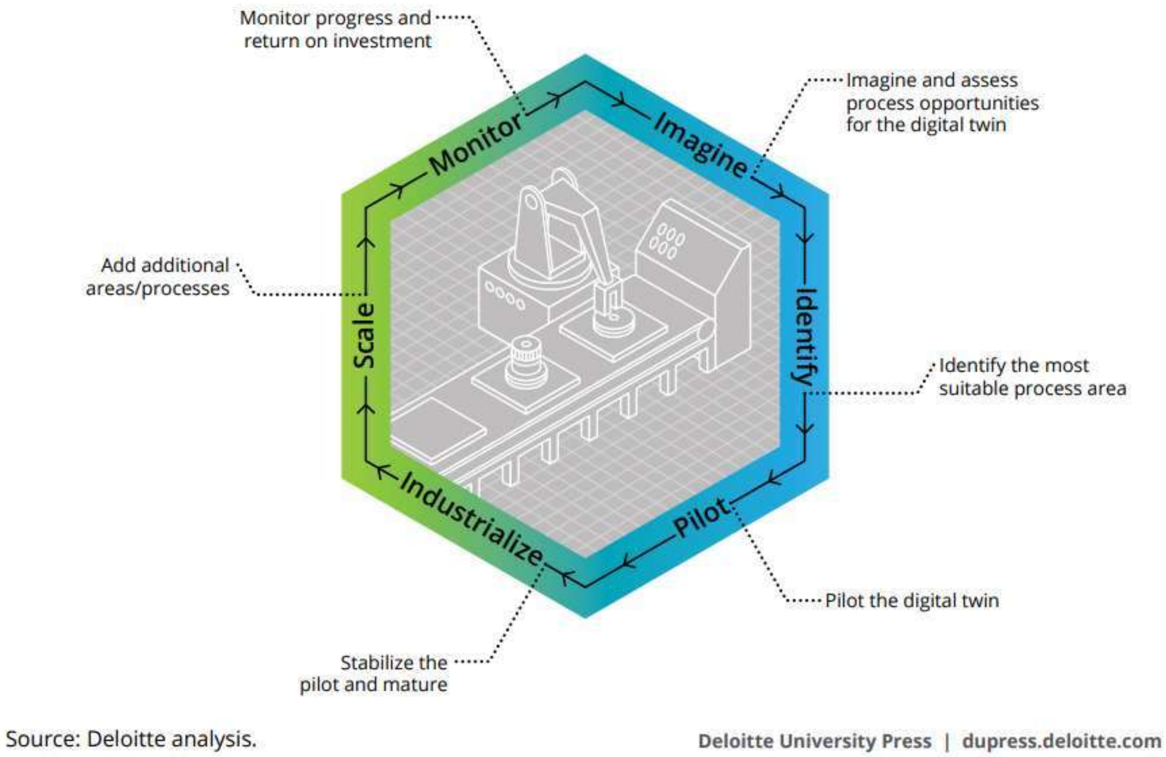


Fig 2.3: Start of Digital Twin

After the shortlist of scenarios is created, each scenario would be assessed to identify pieces of the process that can provide quick wins by using a digital twin. We encourage a focused ideation session with members of operational, business, and technical leadership for expediting the assessment.

Identify the process

The next step would be to identify the pilot digital twin configuration that is both of the highest possible value and has the best chance of being successful. Consider operational, business, and organizational change management factors in identifying which configurations could be best candidates for the pilot. Focus on areas that have potential to scale across equipment, sites, or

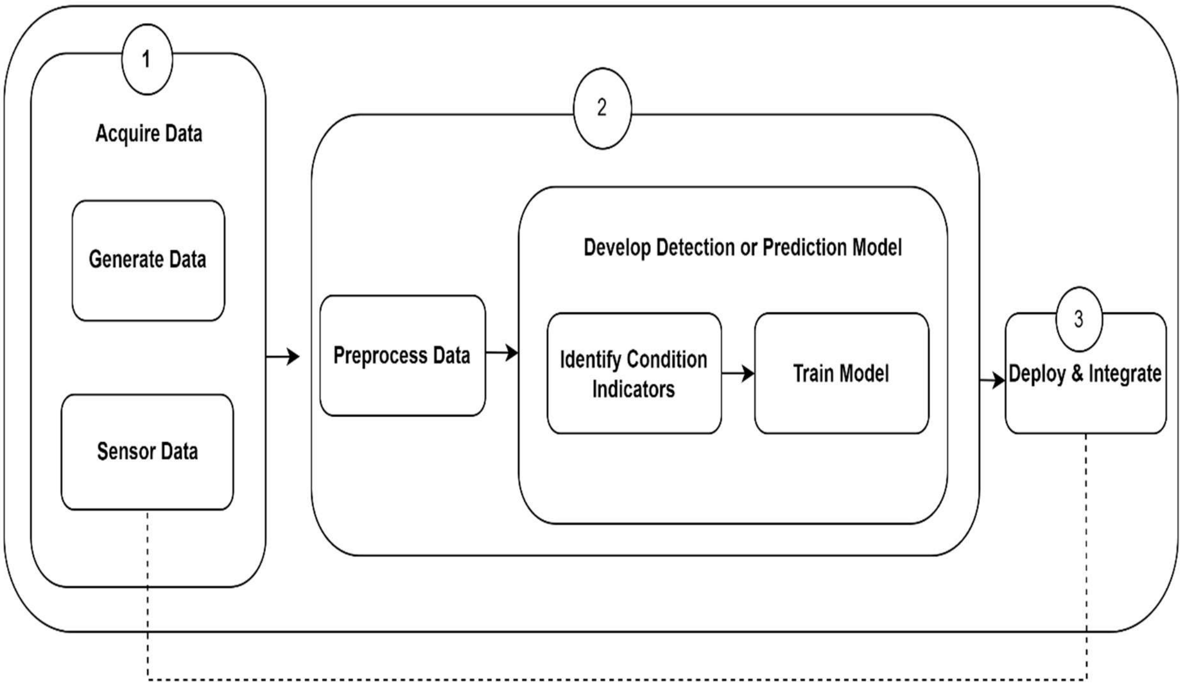


Fig 2.4: Approach

Capture Physics

Captures behaviour using sensors

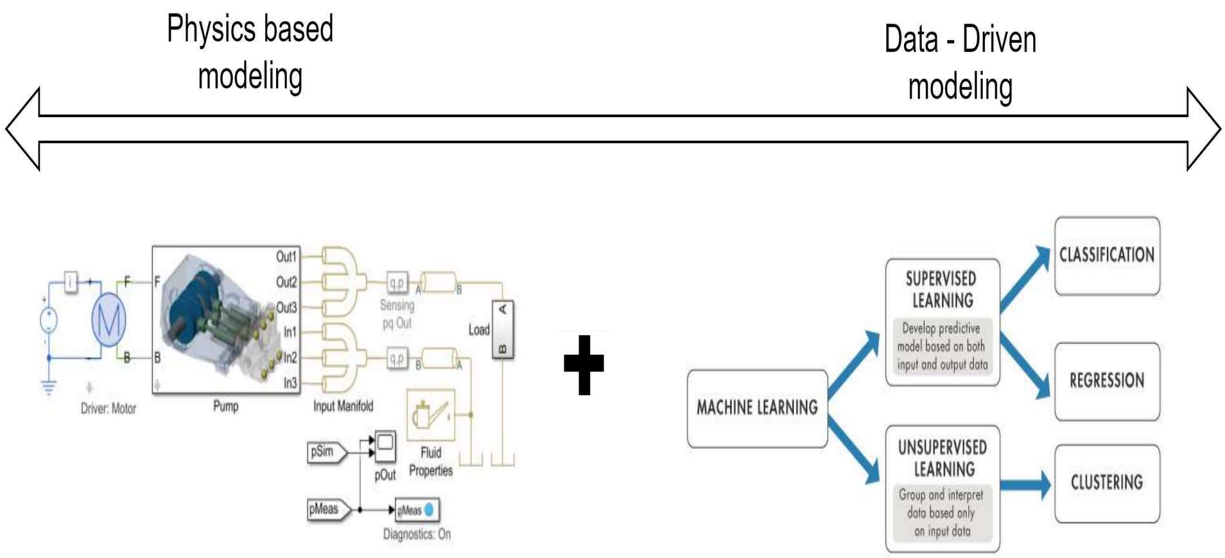
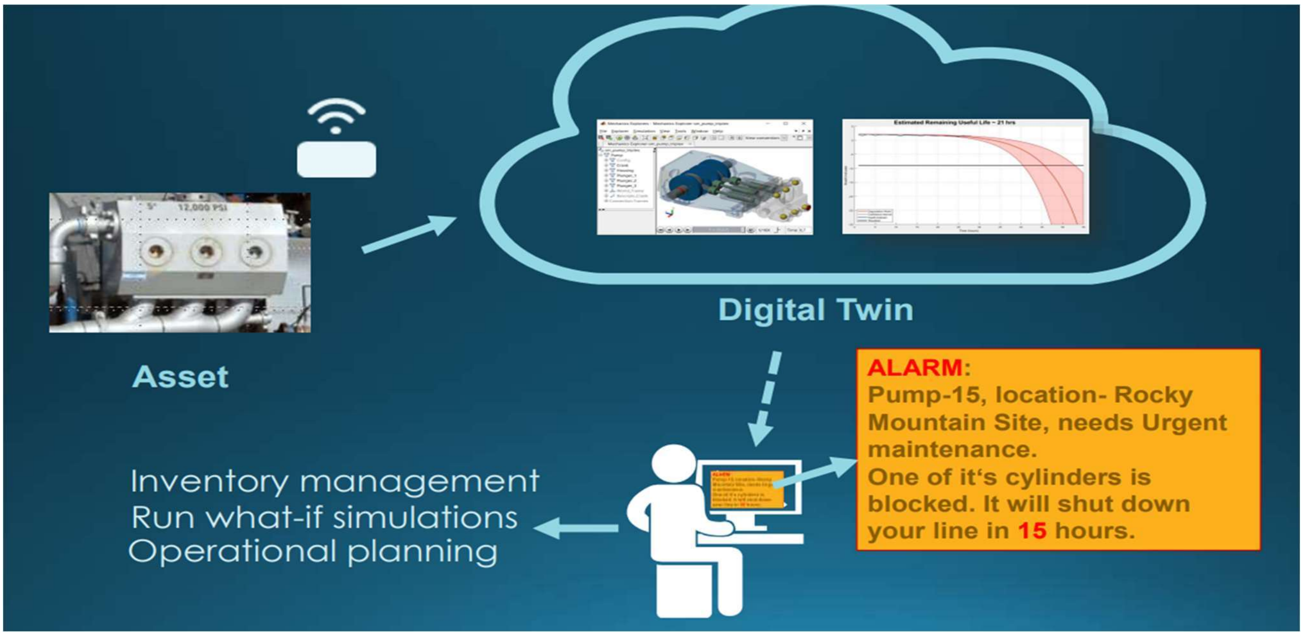


Fig 2.5: Physics and Data Driven model

2.5 Overview of Digital twin that how it operates

A digital twin is an up-to-date representation of a real asset in operation.



2.6 Use Case - Fault classification of a pump

Objective:

- Using machine data to determine what needs to be fixed

Solution:

- Develop predictive Maintenance Algorithm

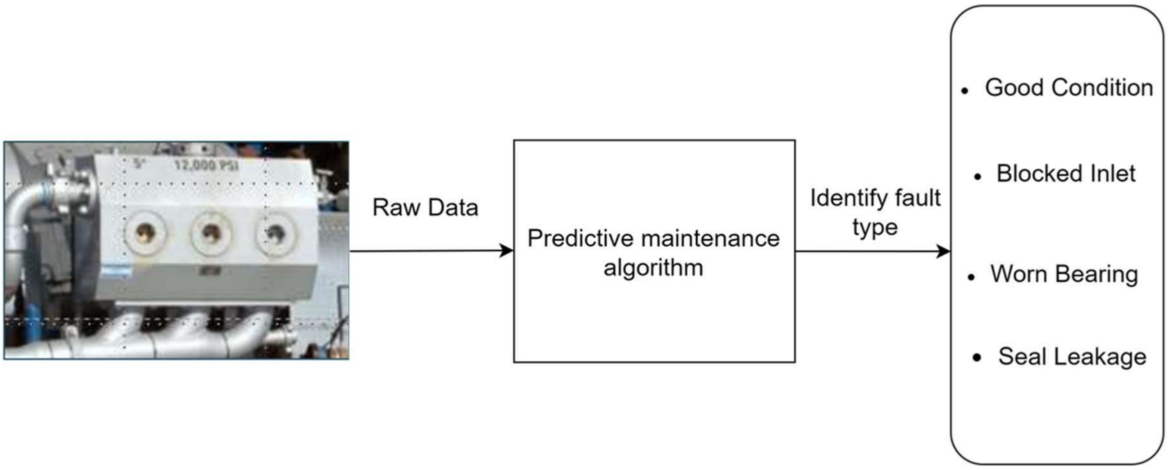


Fig 2.6: Fault detection of pump

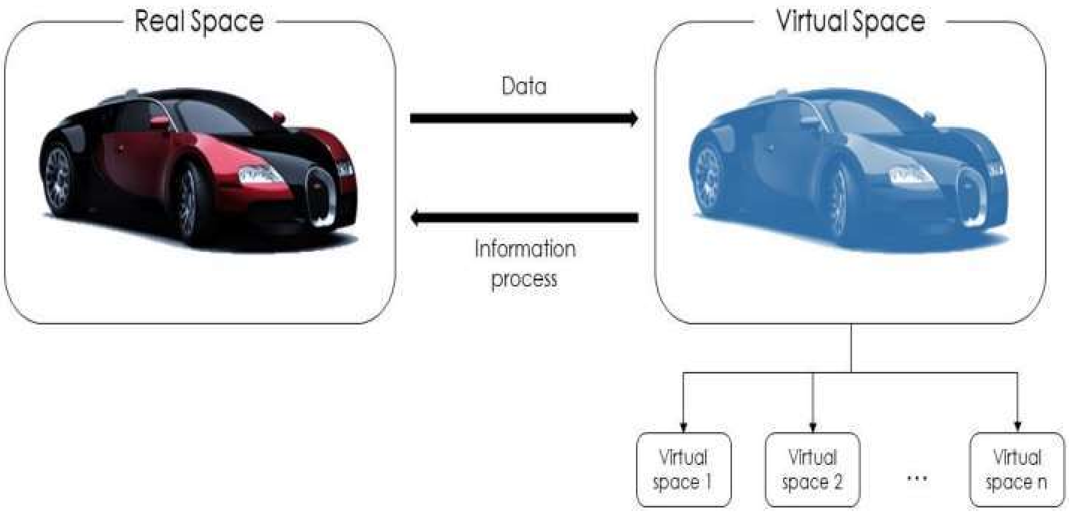


Fig 3.1: Types of Digital Twin

3.2 Applications of Digital twin

Digital twin technology is used in many applications such as Customer experience, Performance tuning, Digital machine building, Smart cities, Healthcare, Maintenance to improve the productivity, customer experience of the product by giving the virtual experience of the product in the initial stages before the actual launch of product and improving the performance of the product according to the needs and requirements of the customer.

3.2.1 Automotive

Digital twins are highly used for creating virtual models of connected vehicles. Automotive companies simulate and analyze the production phase to identify the potential problems during production or when the car hits the roads.

3.2.2 Performance tuning

A digital twin helps determine the optimal set of actions that can help maximize some of the key performance metrics, and also provide forecasts for long-term planning. For example, the performance of a scientific device, which is deployed on a spacecraft, can be tuned from Earth using digital twin as a 3D real-time visualization.

3.2.3 Digital machine building

A digital twin can be used as a digital copy of the real machine, created and developed simultaneously. Let’s take the example of a German machine manufacturer that decided to digitally map the packaging and special machinery that it produced for many industries. The data of the real machine was loaded into the digital model before the actual manufacturing began.

3.2.4 Healthcare

A digital twin can help virtualize a hospital system in order to create a safe environment and test the impact of potential changes on system performance. Not just operations, digital twins can also help improve the quality of health services delivered to patients. For example, a surgeon can use a digital twin for a digital visualization of the heart, before operating it.

3.2.5Smart cities

A digital twin can be used for capturing the spatial and temporal implications to optimize urban sustainability. For instance, 'Virtual Singapore', a part of the Singapore government's Smart Nation Singapore initiative, is the world's first digital twin of an existing city-state, providing Singaporeans and effective way to engage in the digital economy.

3.2.6 Customer experience

Customers play a key role in influencing the strategies and decisions in any business. The ultimate aim of any organization is to gain and retain a large customer base; and this is means enhancing your customer's experience A digital twin can help boost the services directly offered to customers. For example, a digital twin could be used for modelling fashions on a visual twin of the customer.

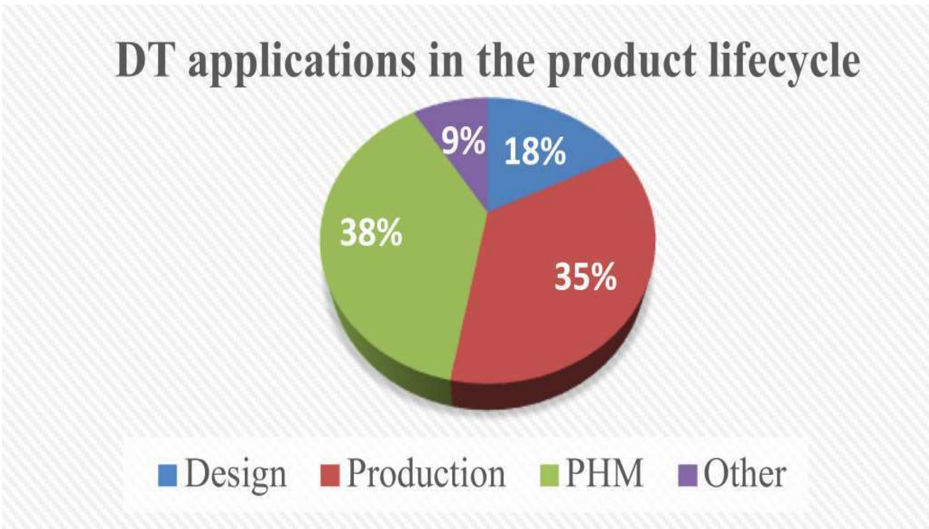


Fig 2.2: DT applications