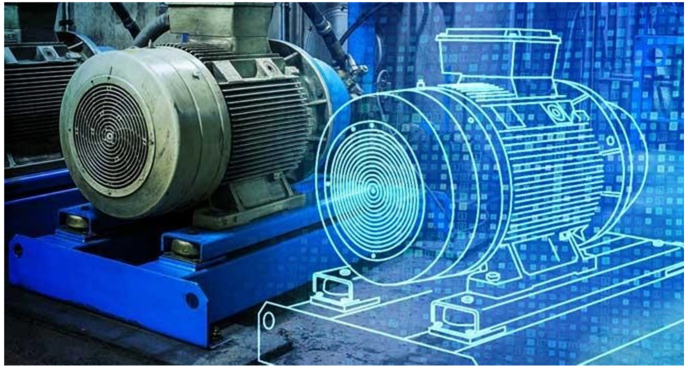
Digital Twins

Digital Quadruplets

Mustafa Yılmaz 150190737
Veysel Emre Köse 150180059
Feyza Özen 150190014
Ö. Malik Kalembaşı 150180112

What is a Digital Twin?



A digital twin is a digital representation of a physical system, process, or product that can be used for a variety of purposes, including simulation, analysis, and control.

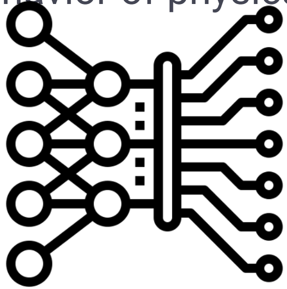
Digital twins are created by collecting data about the physical system and using it to build a digital model that reflects the characteristics, behaviors, and interactions of the system.

Digital Twin: Enabling Technologies

- Digital twins (DTs) are a rapidly growing technology that is being applied in a variety of industries.
- DTs are often used to optimize processes, improve efficiency, and reduce costs.
- The enabling technologies of DTs vary depending on their use case.

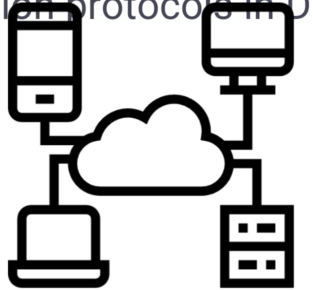
Machine Learning

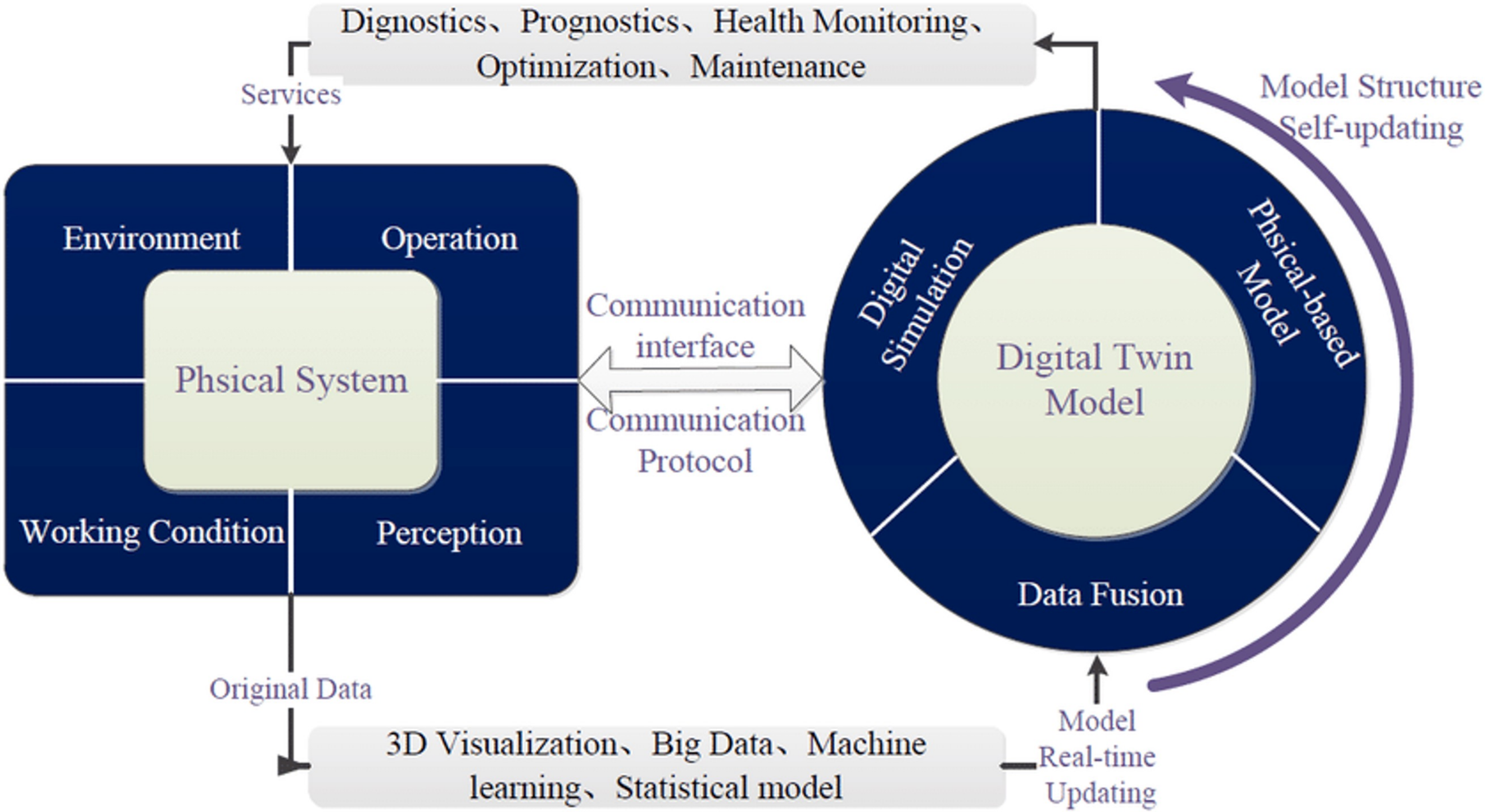
- Machine learning (ML) techniques are an essential enabling technology for DTs.
- ML algorithms allow DTs to analyze large amounts of data and make predictions or optimize processes based on that data.
- There are many different types of ML algorithms that can be used in DTs, including traditional ML algorithms, deep learning algorithms, and reinforcement learning algorithms.
- ML algorithms can be used for a variety of purposes in DTs, including optimizing process parameters, predicting the future behavior of physical assets, and identifying patterns and trends in data.



Communication Protocols

- In order for DTs to function effectively, they need to be able to communicate with the physical systems they are modeling.
- This requires the use of a communication medium, such as a network or a cloud platform, to facilitate the transfer of data between the real and digital twins.
- The choice of communication protocol depends on the specific requirements of the DT's application.
- Some commonly used communication protocols in DTs include MQTT, OPC UA, and WebSockets.




Dignostics、Prognostics、Health Monitoring、Optimization、Maintenance
Services
Model Structure Self-updating
Environment
Operation
Phsical System
Working Condition
Perception
Communication interface
Communication Protocol
Digital Simulation
Phsical-based Model
Digital Twin Model
Data Fusion
Original Data
3D Visualization、Big Data、Machine learning、Statistical model
Model Real-time Updating

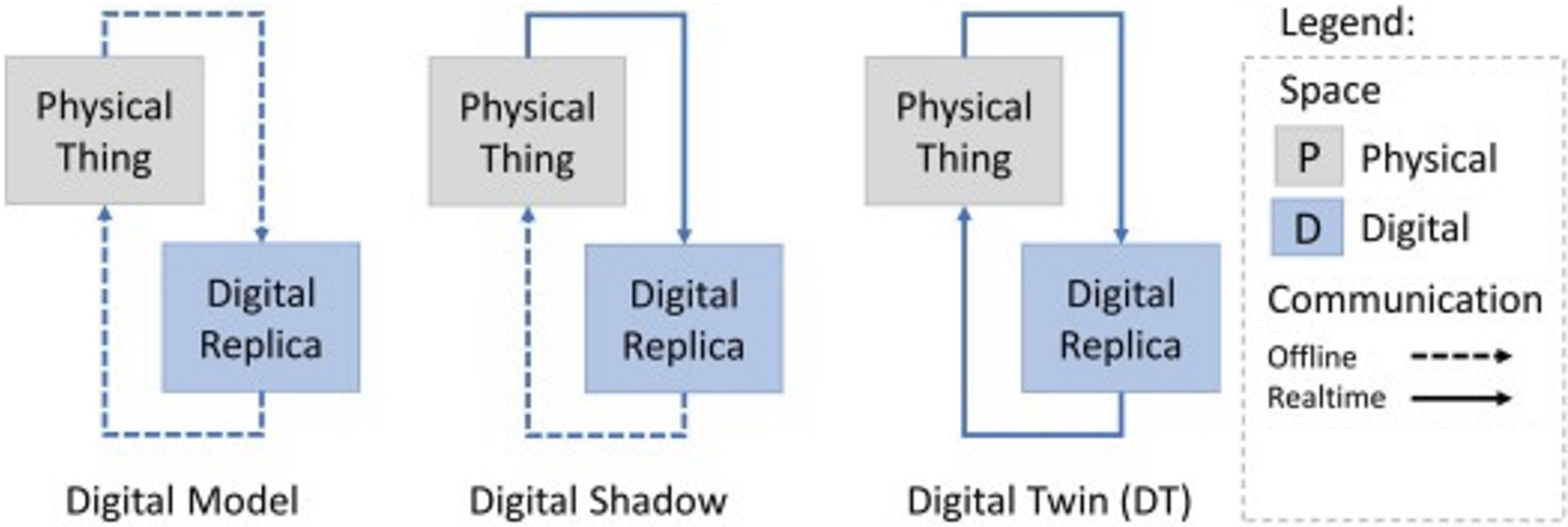
Big Data and Cloud Computing

- DTs generate and process large amounts of data, making it necessary to use big data techs to store, process, and analyze that data.
- Big Data techs such as Hadoop and Spark are commonly used in DT systems to handle the large volumes of data generated by DTs.
- Cloud computing is also an important enabling technology for DTs, as it provides the scalability and flexibility needed to support DT systems.

Virtual Reality and Augmented Reality

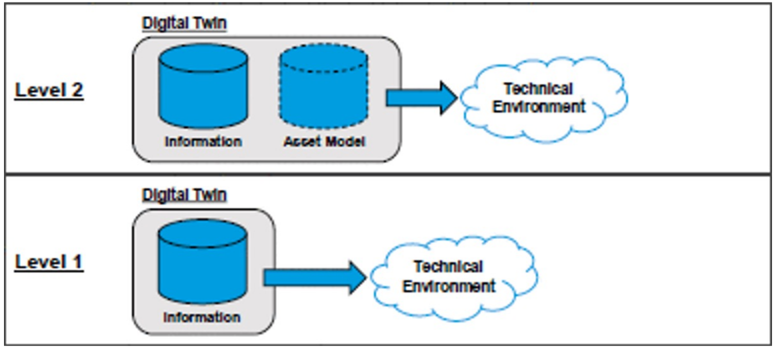
- VR and AR technologies are increasingly being used to visualize and interact with DTs in real-time.
- They can be used for training, maintenance, and design purposes in DT applications.
- For example, VR can be used to simulate the operation of a DT in a virtual environment, while AR can be used to overlay virtual information onto the real world to aid in the operation of a DT.

Digital Twin Components



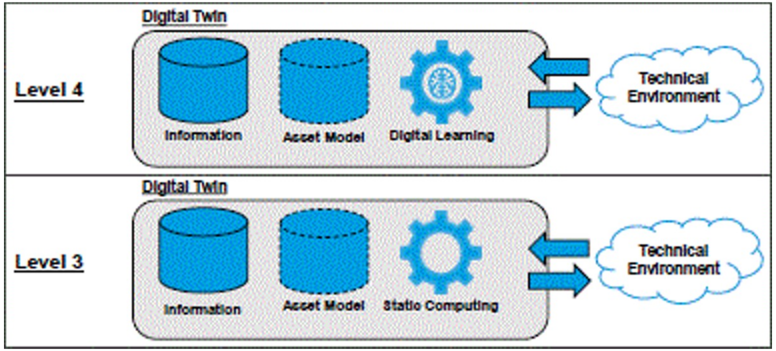
Digital Twins By Levels

- **Level 1:** The DT provides various information about the physical asset to the corresponding environment. The information contains several asset's data of lifetime stages, semantically structured by an information model. The interaction with the environment is passive, pull-oriented and without any reaction to environmental information.
- **Level 2:** Addition to level 1, provides at minimum one model of the asset, e.g. CAD or simulation model. The interaction is still passive, pull-oriented and without any reactions.



Digital Twins By Levels

- **Level 3:** In contrast to level 2 the interaction of the DT is active by requesting environmental information. It evaluates this information and infers deterministic decision and reactions.
- **Level 4:** In addition to all attributes of level 3, Its interaction with the environment and inference are based on learning behavior influenced by machine learning algorithms. Therefore, the DT is able to develop over lifetime.



Use cases: Smart Factory and Industry 4.0

- No longer necessary to interact via a central processing controller.
- Individual machines now interact with one another.
- The manufacturing line is equipped to generate any number of distinct goods.
- The production line may operate more effectively and without interruption.
- Production machinery that is adaptable and intelligent are required.

Those are the challenges that the Digital Twin tries to solve.

Use cases: Infrastructure

A huge number of people are involved in every phase of the complicated working life of civil infrastructures.

Digital Twins aims to:

- Increase safety and service life
- Decrease construction and maintenance costs

Smart buildings, smart infrastructures and smart cities.

Services: Anomaly Detection

- Due to its logical and perceptive role in integrating data analytics into conventional production facilities, the Digital Twin has grown in importance in Industry 4.0.
- Engineers of smart factories are now more acquainted with their facilities thanks to Digital Twins, which analyze run-time data gathered from the physical systems.

Services: Predictive Maintenance

- Predictive Maintenance is another function that the Digital Twin claims to offer.
- Predictive Maintenance has long been desired since it may clearly benefit the industry in terms of cost, time, and resources.
- As a result, much research has already been done to create workable designs that can precisely forecast a machine's failure (i.e., self-diagnosing).

Digital Twin Enabled 6G

- 6G is the next generation of wireless communication technology that is expected to follow 5G and will likely offer even faster and more reliable connectivity than its predecessor.

- Digital twins could potentially be used in a number of applications related to 6G, such as optimizing the design and operation of 6G networks, or using digital twins to monitor and maintain the performance of 6G infrastructure.

- 6G requires a new framework that can be used to manage, operate, and optimize the 6G wireless system and its underlying IoE services. A framework for 6G can be based on digital twins.

Digital Twins 6G Enabled: Scalability and Reliability

- The expected massive number of devices in 6G motivates us to design a scalable and reliable architecture based on digital twins. Digital twins face scalability and reliability challenges pertaining to the implementation of massive ultra-reliable low latency communication (mURLLC) services.

- Training twin models for large data-sets faces many challenges, such as the need to deal with a complex ML model of large size and the high computing power needed for training.

- Therefore, we can use a hybrid approach by combining the features of both centralized and distributed digital twins to offer a trade-off between computational power, storage capacity, and latency.

Digital Twin Enabled 6G: Example

As an example, a digital twin of a 6G antenna could be used to simulate the performance of the antenna under different conditions, such as different frequencies, weather conditions, and antenna configurations. This could allow engineers to optimize the design of the antenna and predict its performance before it is built, reducing the risk of costly mistakes.

Comparison of edge, cloud and edge-cloud based digital twins

	Description	Edge-based twin	Cloud-based twin	Edge-cloud-based twin
Scalability	Scalability refers to fulfilling latency requirements for massive number of 6G devices. Furthermore, the addition of new nodes should not significantly degrade the system performance in terms of latency.	High	Lowest	Low
Latency	This metric represents the overall delay that accounts for latency from service request until service provision in providing 6G services.	Low	High	Medium
Geo-distribution	This metric tells us about the geographical distribution of twin objects for enabling a 6G service.	Distributed	Centralized	Hybrid
Elasticity	This metric refers to on-demand dynamic resource allocation for digital twins operation in an elastic way in response to highly dynamic requirements.	High	Low	High
Context-awareness	Context-awareness is the function that deals with the knowledge about the end-devices location and network traffic.	High	Low	Medium
Mobility support	Mobility support deals with the ability of digital twins to seamlessly serve mobile end-devices.	High	Low	Medium
Twins Robustness (reliability)	Robustness refers to seamless operation of digital-twin-enabled 6G application in case of failure of twin objects.	Highest (for multiple edge-based twins)	Lowest	Medium

Digital Twins, 6G and Blockchain

Digital twins, 6G, and blockchain technology are all separate technologies that could potentially be used together in various ways.

To manage the decentralized datasets in a transparent and immutable manner, blockchain is a promising candidate. There are two goals for using blockchain in a digital twin-enabled 6G network: storing pretrained models, and immutable, decentralized management of training data for ML models.

Digital twins could be shared securely using blockchain technology, allowing multiple parties to access and use the digital twin while maintaining control over who has access to the data.