Extended Reality Applications For Digital Energy Twin

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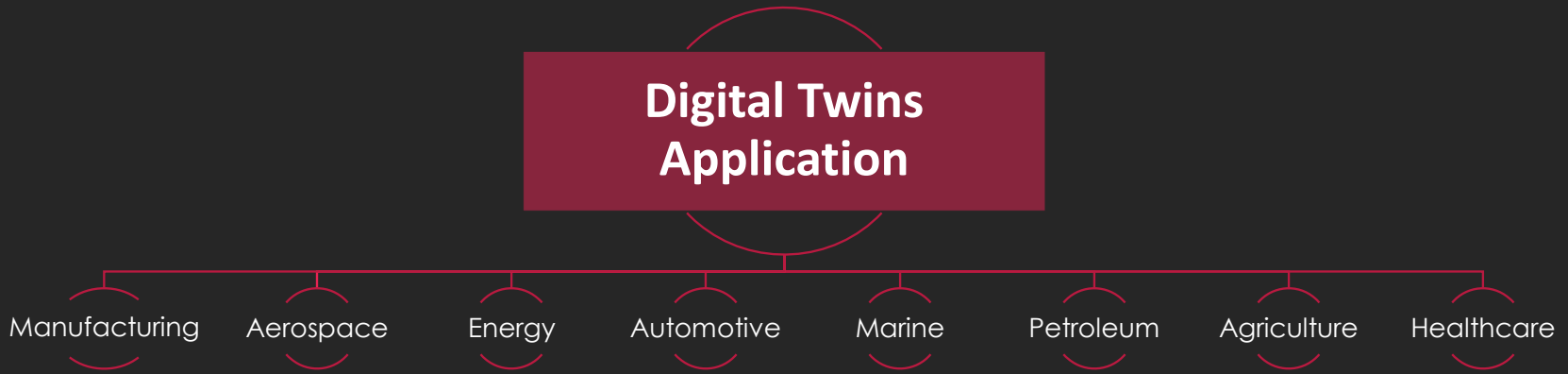
Digital Twin

- Digital twins are described as virtual counterparts to physical entities
- facilitate many beneficial use cases that allow cost-effective, user-friendly and safe scenarios

Digital twins have often been used in industry 4.0 applications

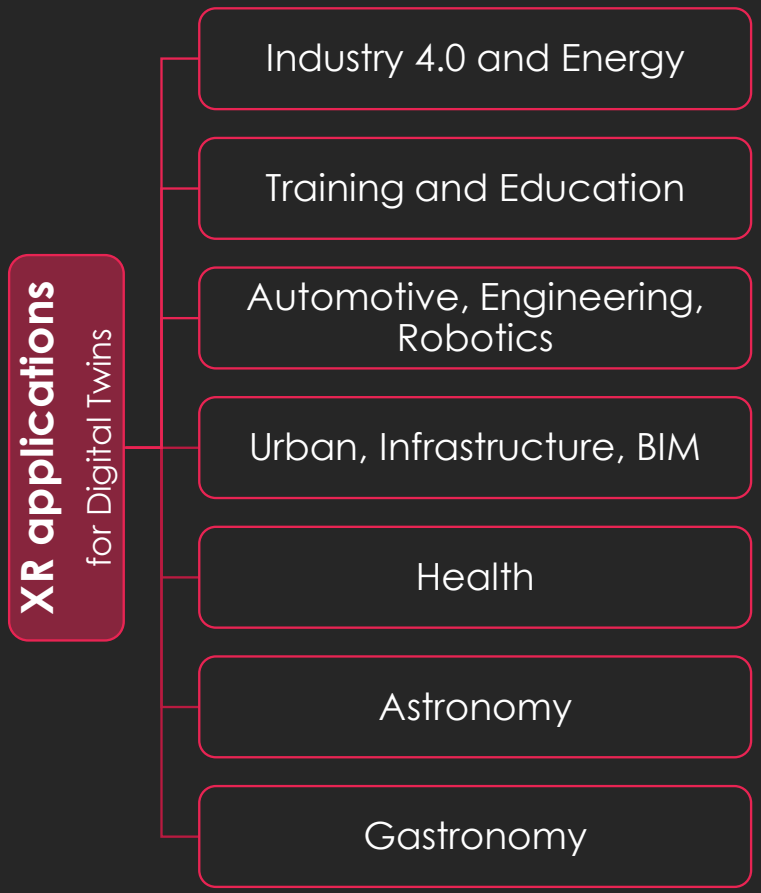


- The **data** provided in the digital twin should be visualized so that it can be practically used by stakeholders in the industry

- A major gap was identified in the literature: the realization of appropriate **visualization** of interaction forms

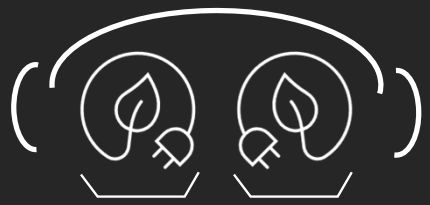
Extended Reality (XR)

- One technology that can help to overcome these issues and strengthen the visualization capabilities of digital twins is **XR**
- With the introduction of **consumer-based XR** devices, the design, research, and development of VR experiences for experiences outside of entertainment has reached a new peak
- XR can be used in many fields such as **industry 4.0**, **education**, **tourism**, **or health**


XR applications
for Digital Twins
Industry 4.0 and Energy
Training and Education
Automotive, Engineering, Robotics
Urban, Infrastructure, BIM
Health
Astronomy
Gastronomy

Digital Energy Twin

- Here we focus on the application of XR to a specific subcategory of the digital twin in the **energy** context
  - to observe the energy **performance** of a system and the impact of the system structure
  - the impact of the system structure or a specific function on **energy consumption**
  - workflow **optimization**

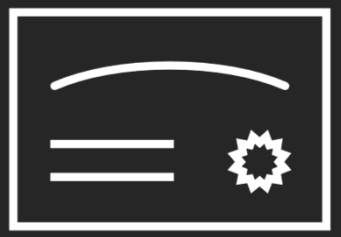


Digital Energy Twin

- **Inspecting** and **visualizing** energy data
- **Simulation** and production line **planning**
- **Education** and **training**
- **Remote** control and **collaboration**

Inspecting and visualizing energy data

- Various types of **measurements**, **simulations**, and **calculations** of energy-related data like energy and heat consumption, the capacity of energy-providing units can be provided in AR or VR presentation
- This information can be visualized directly as **text**, **2D**, or even **3D** graphical representations on top of the relevant production line units
- The user can see, inspect, and interact with historical, real-time (current) as well as predictive energy data based on mathematical models



Simulation and production line planning

- The Digital Twin software delivers 3d model data of all objects included in the currently mirrored production line as well as additional virtual elements.
- Energy data might not be the only interesting information but either planning production lines from scratch using VR headsets
- Visually augmenting the real existing production line with the additional virtual parts using AR headsets proves to be useful for planning scenarios

Education and training

- Digital twins in XR can be a great tool to educate **different user groups** about complex systems.
- Can help users obtain an **understanding** of the interaction with the digital twin **without** interacting with the **real device**
- This makes it **cheaper**, **safer**, and more **accessible** as it allows training at all times

Remote control and collaboration

- Allow users to remotely operate the digital twin
- Virtual reality environments can offer a more natural and intuitive interaction and visualization form

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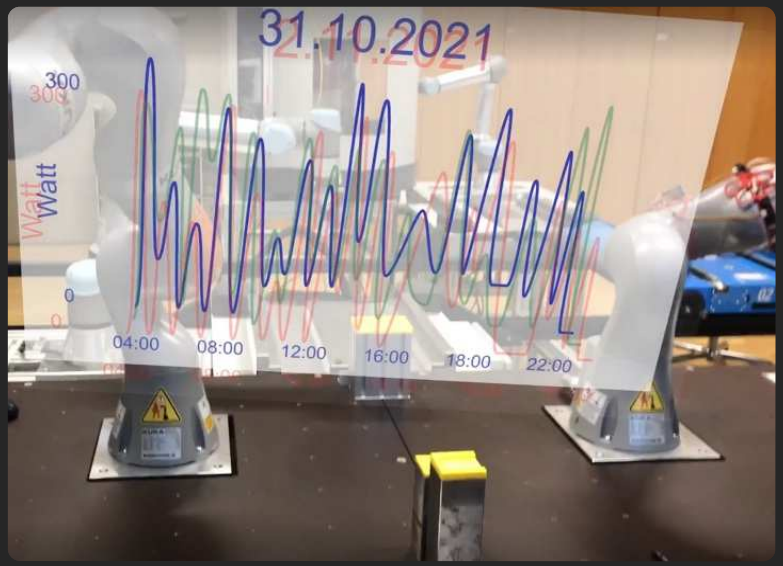
Implementation

- One of the most common methods for developing XR environments is game engines
  - Unreal Engine:
    - VR development (C++ and blueprints)
  - Unity:
    - AR development (C#)
- The AR application is developed for Microsoft HoloLens 2
- The VR application is developed for Valve Index

AR application:

- The "digifi" software delivers energy information and 3d models including movement to the AR application via **JSON** and **protobuf**
- All relevant energy and 3d movement data can be delivered to the AR application in three ways:
  - JSON data flow from TWIN software
  - Importing database tables using CSV files
  - Historical, live, and predictive data from an online/cloud database system

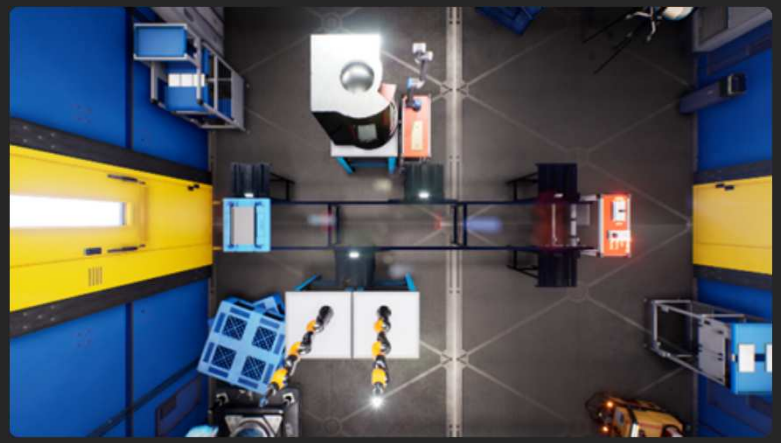
The augmented reality application provides **graphical representations** of relevant entries in the database that **complement** the production unit the user is viewing



VR application:

- We have developed a custom VR character controller for the virtual experience
  - Predefined **grip** position for each object
  - **Teleportation**
  - **Inventory** system
- users can access and change some of the global parameters of the scene, such as lighting conditions, time of day, and global simulation speed using inventory system

Different perspective in VR:



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Different visualization of Data in VR:

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- In this paper, we briefly discuss the opportunities and benefits of using XR technology in the digital twin domain
- These applications can be extended in DET to provide a better understanding of the workflows
- We show a proof-of-concept for implementing AR/VR in the DET context
- we can expect that developers can improve the functionality of XR experiences by considering the currently successful idea of DET in non-immersive environments