

Digital Twins

state-of-the-art, use cases, and new trends

Carlos Canal - ITIS Software, University of Málaga

Sergio Laso - Quercus SEG, University of Extremadura

SummerSOC 2025

Hersonissos (Crete), June 16th - 21th, 2025

Digital Twins

Part I

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Contents

- ▶ Introduction
 - ▶ The Hype of Digital Twins
 - ▶ What is a Digital Twin?

QR
PDF

The Hype - News

NVIDIA Unveils 'Mega' Omniverse Blueprint for Building Industrial Robot Fleet Digital Twins

New framework enables next era of industrial AI and robot simulation through software-defined testing and optimization to factories and warehouses.

January 6, 2025 by [Madison Huang](#)



BIOTECHNOLOGY AND HEALTH

Digital twins of human organs are here. They're set to transform medical treatment.

The models can be used to plan surgeries and in the future could be used to help trial new drugs.

by [Jessica Hamzelou](#)
December 19, 2024

A healthy heart beats at a steady rate, between 60 and 100 times a minute. That's not the case for all of us, I'm reminded, as I look inside a cardboard box containing around 20 plastic hearts—each a replica of a real human one.

Why 'digital twins' could speed up drug discovery

13 December 2024

MaryLou Costa
Technology Reporter

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Digital twins help ScotRail reduce station and depot energy consumption

By [Rail Business UK](#) | 10 January 2025



Most popular

Latest



Dubai Metro Blue Line construction contract awarded

ScotRail begins HST

The Hype - Research works in DBLP

- 2025
- Sunil Gupta, Ravi S. Iyer, Sanjeev Kumar:
Digital Twins - Advancements in Theory, Implementation, and Applications. Springer 2025, ISBN 978-3-031-76563-6, pp. 1-196
 - Changhua Hu, Zeming Zhang, Chuanyang Li, Mingzhe Leng, Zhaoqiang Wang, Xinyi Wan, Chen Chen:
A state of the art in digital twin for intelligent fault diagnosis. Adv. Eng. Informatics 63: 102963 (2025)
 - Sergio Infante, Julia Robles, Cristian Martín, Bartolomé Rubio, Manuel Díaz:
Distributed digital twins on the open-source OpenTwin
 - Peng Zhu, Lei Deng, Pengfei Wang:
Design and implementation of a distributed digital twin network for unbalanced data

[–] Refine list



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3 more options

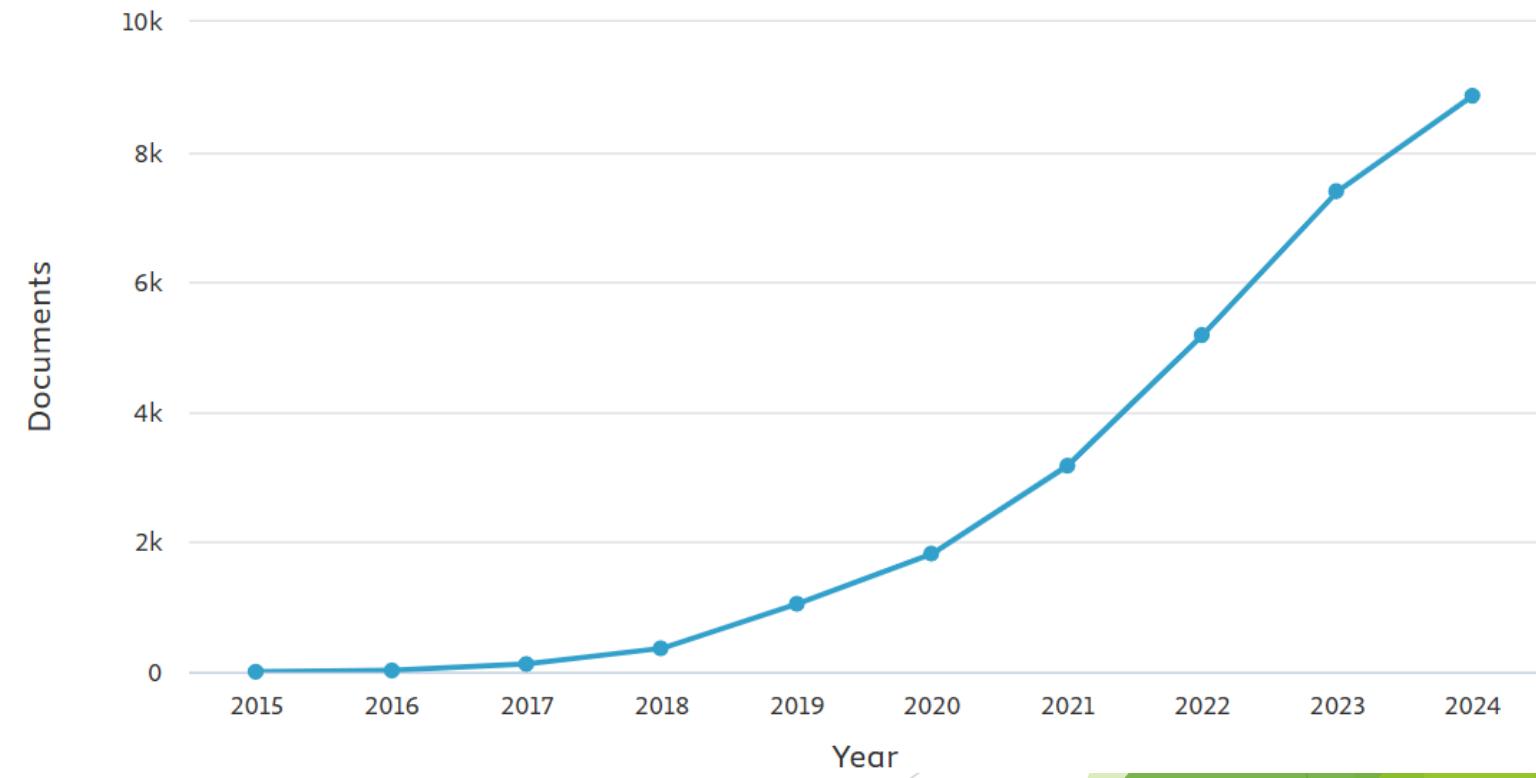
refine by year

Year	Count
2025	(50)
2024	(1,854)
2023	(1,721)
2022	(1,157)
2021	(671)
2020	(349)
2019	(195)
2018	(77)
2017	(16)
2016	(4)

The Hype - Research works in SCOPUS



Documents by year

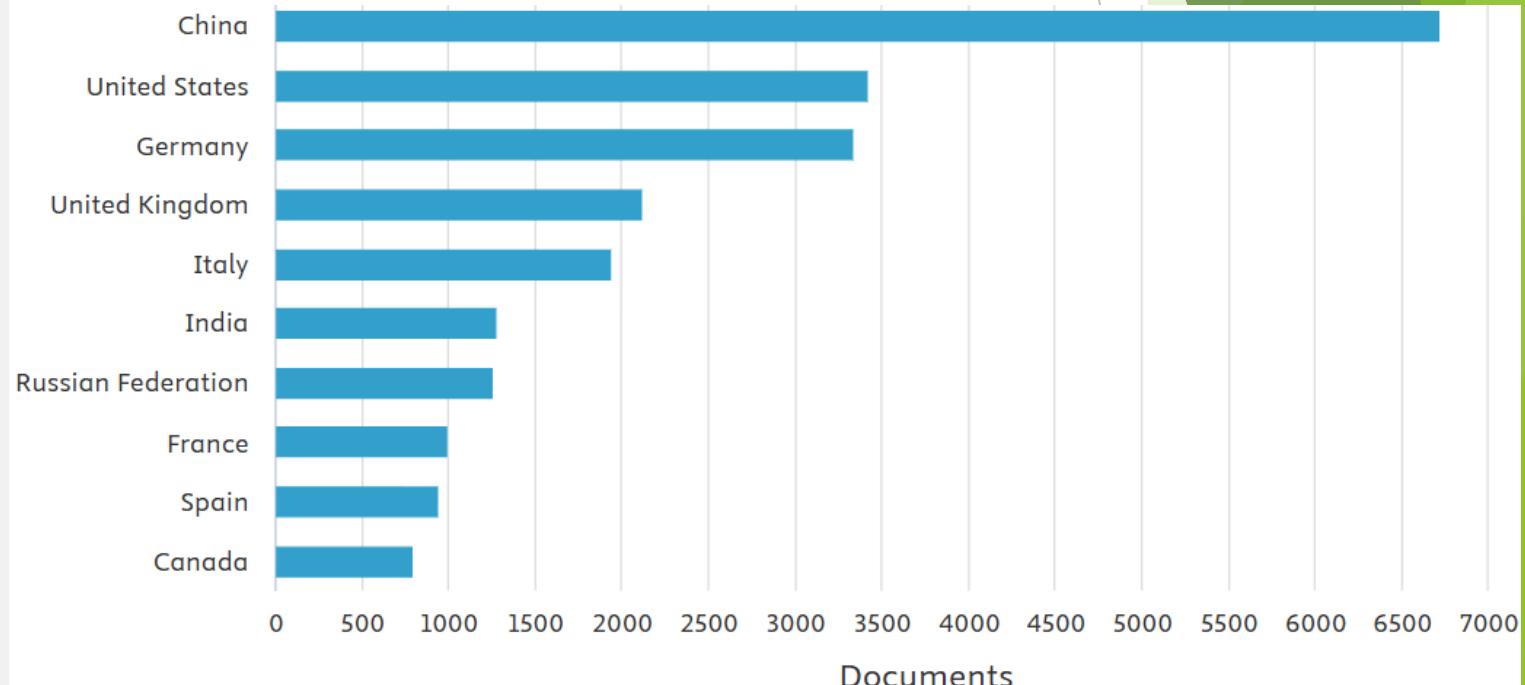


The Hype - By country

Country/Territory ↑

Documents ↓

■ China	6712
■ United States	3419
■ Germany	3328
■ United Kingdom	2109
■ Italy	1937
■ India	1269
■ Russian Federation	1250
■ France	992
■ Spain	936



Definition / Concept

- ▶ What is a Digital Twin?
 - ▶ What are its main components
 - ▶ its main features
 - ▶ and its required components?
- ▶ Let's ask someone informed...

An answer - ChatGPT

Good morning, what is a digital twin?

Good morning! A **digital twin** is a virtual representation of a physical object, system, or process that is continuously updated with real-time data. It mirrors the physical counterpart as accurately as possible and is used to monitor performance, predict outcomes, and support decision-making.

Key features of a digital twin:

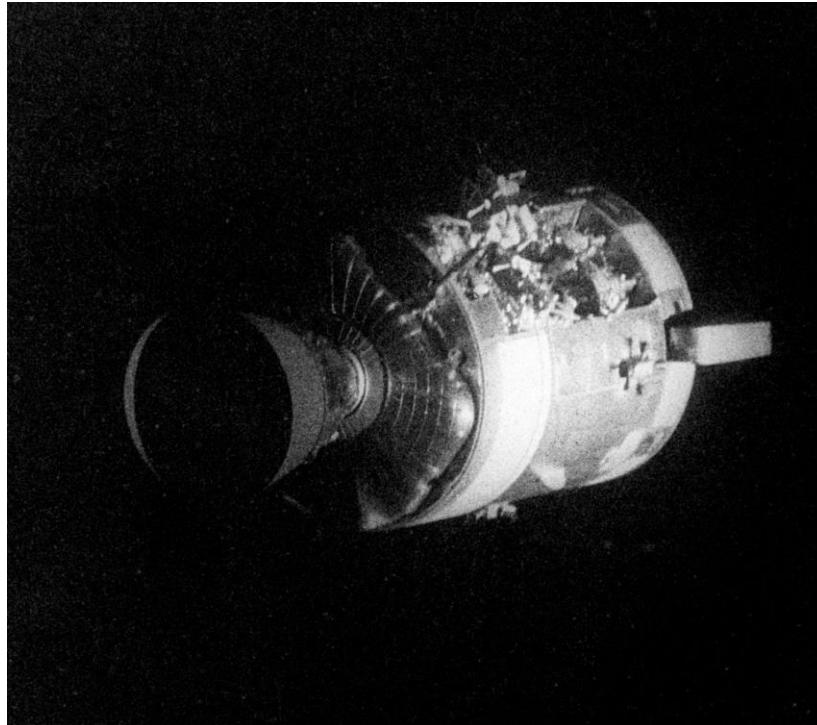
- **Real-time data:** It uses sensors or other data sources to stay in sync with the physical version.
 - **Simulation:** It can simulate different scenarios to predict how changes will affect performance or behavior.
 - **Analytics:** Uses AI and machine learning to analyze data and generate insights.
 - **Lifecycle integration:** It can track the full lifecycle of a product—from design to operation and maintenance.
- Gemini, Copilot, DeepSeek, and [Wikipedia](#) provide very similar answers.



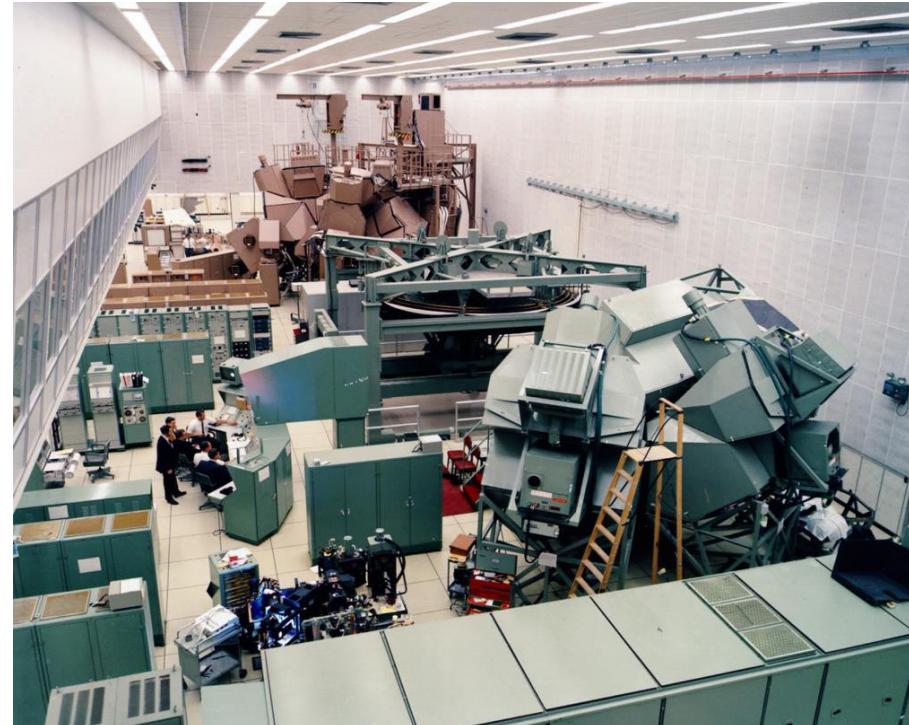
A brief history of Digital Twins



► The Apollo 13 Mission (1970)



The Apollo 13



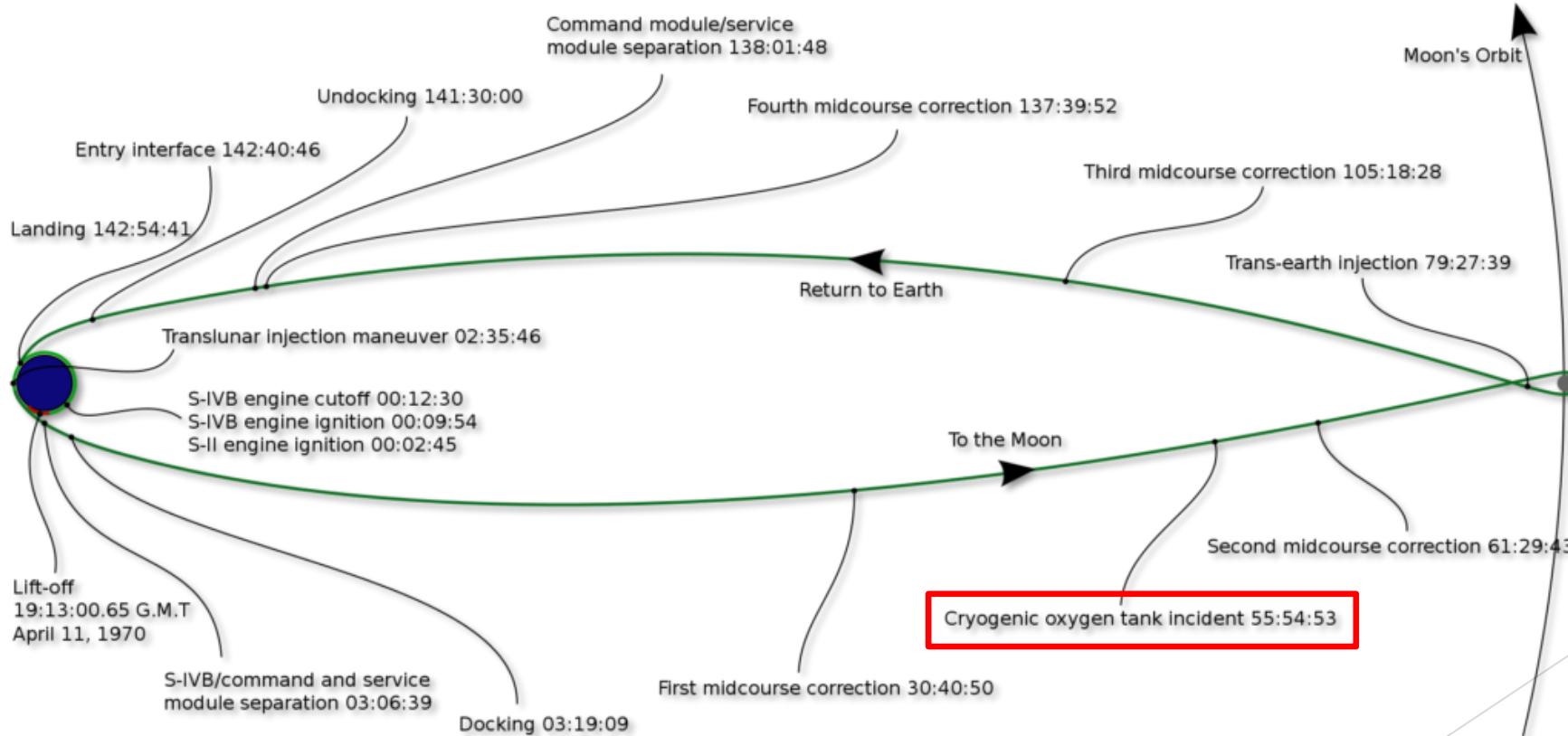
Its “Digital Twin” on Earth

<https://blogs.sw.siemens.com/simcenter/apollo-13-the-first-digital-twin>



The Apollo 13 Mission

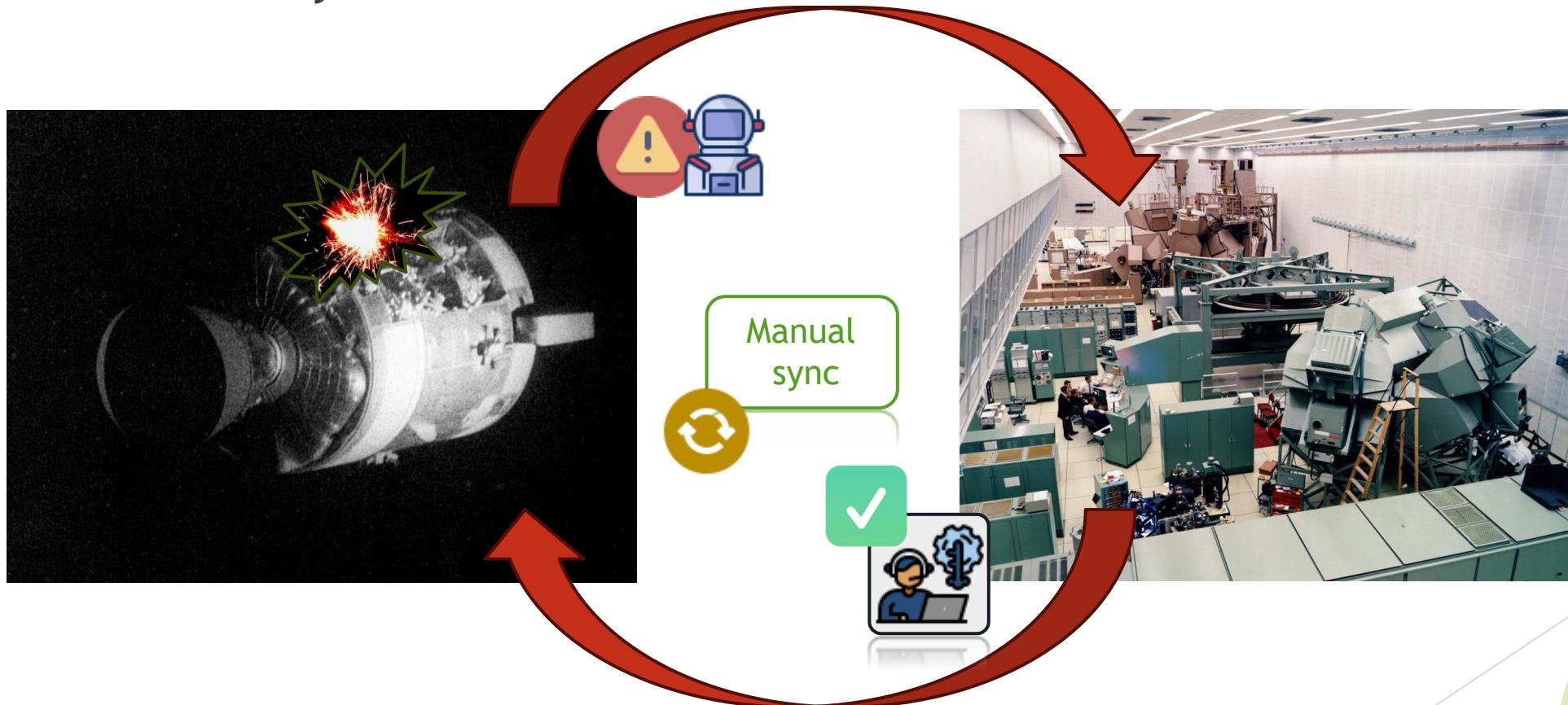
► The incident



The Apollo 13 Mission



- The very first twins?



- but synchronization was performed manually.

First definitions of a Digital Twin



- ▶ The concept was first established by M. Grieves:
 - ▶ within a course on *Product Lyfecycle Management* in the Univ. of Michigan (2003)
 - ▶ though instead of DT, he used the term *Mirrored Spaces Model* ☺
- ▶ The first definition comes from M. Shafto et al:

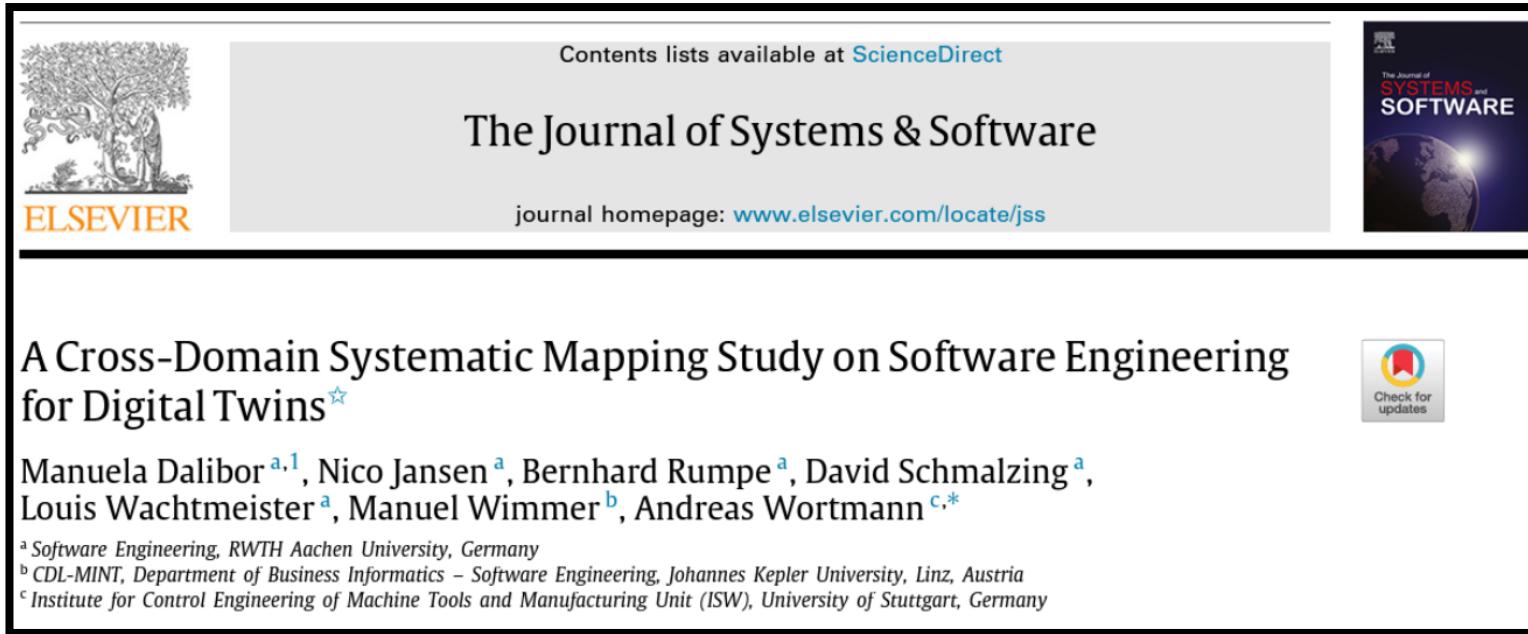
A **digital twin** is an integrated multi-physics, multi-scale, probabilistic simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its flying twin.

*Modeling, Simulation, Information Technology & Processing Roadmap
National Aeronautics and Space Administration (2012)*
- ▶ A more general definition appeared in a later paper by M. Grieves:

A **digital twin** is a virtual representation of what has been produced.

*Digital Twin: Manufacturing excellence through virtual factory replication
Florida Institute of Technology, White Paper (2014)*

... but there are many more



The image shows the front cover of a journal issue. At the top left is the Elsevier logo, featuring a tree and the word "ELSEVIER". To the right of the logo is the journal title "The Journal of Systems & Software" and the subtitle "Contents lists available at ScienceDirect". Below the title is the journal homepage URL "journal homepage: www.elsevier.com/locate/jss". To the right of the title is a small thumbnail image of the journal cover, which includes the journal title and a globe. In the center of the cover is the title of the article: "A Cross-Domain Systematic Mapping Study on Software Engineering for Digital Twins". Below the title are the names of the authors: Manuela Dalibor, Nico Jansen, Bernhard Rümpe, David Schmalzing, Louis Wachtmeister, Manuel Wimmer, and Andreas Wortmann. To the right of the author names is a "Check for updates" button. At the bottom of the cover are three small footnotes: ^a Software Engineering, RWTH Aachen University, Germany; ^b CDL-MINT, Department of Business Informatics – Software Engineering, Johannes Kepler University, Linz, Austria; and ^c Institute for Control Engineering of Machine Tools and Manufacturing Unit (ISW), University of Stuttgart, Germany.

► Companion website



Dalibor et al. “A Cross-Domain Systematic Mapping Study on Software Engineering for Digital Twins”,
The Journal of Systems and Software, vol. 193, 2022.

356 papers
reviewed

112 definitions
of the term
“Digital twin”

Several of these definitions

- ▶ Some of them are too vague:
 - ▶ Digital equivalent to a physical product.
 - ▶ Simulation method that can be used for evaluation and optimization.
 - ▶ Model-based representation of entities of the real world such as machines, cars, or persons.
 - ▶ Simplified numerical model.
- ▶ Some of them are specific of a certain domain:
 - ▶ Virtual replica of the printing hardware.
 - ▶ Set of virtual information that fully describes a potential or actual physical production from the micro atomic level to the macro geometrical level.
 - ▶ Virtual model of the physical plant.
 - ▶ Software model composed of 3D physical, mechanical, and electrical data along with detailed information about its assembly process and instructions on production.

Definition of the DT Consortium

*A digital twin is an integrated data-driven virtual representation of real-world entities and processes, with synchronized interaction at a specified frequency and **fidelity**.*

Digital Twin Consortium, [Glossary of digital twins](#) (2021)

Physical Twin



Digital Twin



*Bidirectional
Synchronization*



To sum up

- ▶ A Digital Twin is either a **fill the gap** of its physical (PT) counterpart?
 - ✓ model
 - ✓ simulator
 - ✓ dashboard
 - ✓ control loop
 - ✓ prediction system
 - ✓ machine learning (ML) system
- ▶ Yes (to all) but:
 - ✓ the physical twin could be any physical entity, but also a process, a software system, etc.
 - ✓ there is a synchronous and automated feedback loop communication between both twins.
- ▶ A **Digital Twin System** is a pair of coupled physical/digital twins.

Entrar en cada una de ellas,
preguntandoles (hacer
varias diapos si da tiempo).
Ver notas en Contents.
La segunda parte de la
diapo, luego

Properties of Digital Twin Systems

- ▶ Representativeness & Contextualization
 - ▶ the DT must mimic the status of the PT, considering only the features that are relevant to the context.
- ▶ Reflection
 - ▶ the PT is timely and univocally represented by the attributes, status, and behavior of its DT.
- ▶ Entanglement
 - ▶ the information representing the PT must be received in (close to) real-time by the DT.
- ▶ Predictability
 - ▶ the DT may be used to simulate the behaviour of the PT to determine the outcomes in a likely future or context.

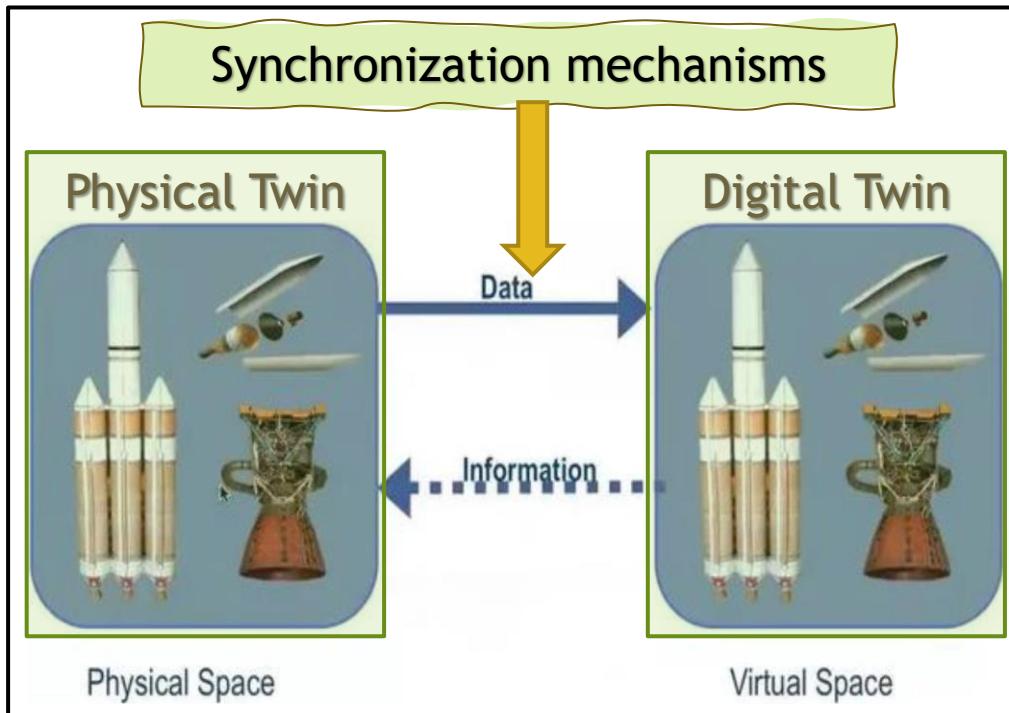


Properties of Digital Twin Systems (2)

- ▶ Persistency
 - ▶ the DT maintains a continuously updated and accurate virtual representation of the PT over time.
- ▶ Memorization
 - ▶ the DT must store all meaningful past and present data and the context in which they originated for later analysis.
- ▶ Replication
 - ▶ DTs may replicate the PT in different contexts, each replica addressing specific characteristics
- ▶ Composability
 - ▶ DTs can be composed so that both the individual and composed objects can be observed and controlled.
- ▶ Manageability
 - ▶ the DT enhances the PT by an API that facilitates its management, which also allows to deal with damages or problems of both PT/DT.

Architecture of a Digital Twin System

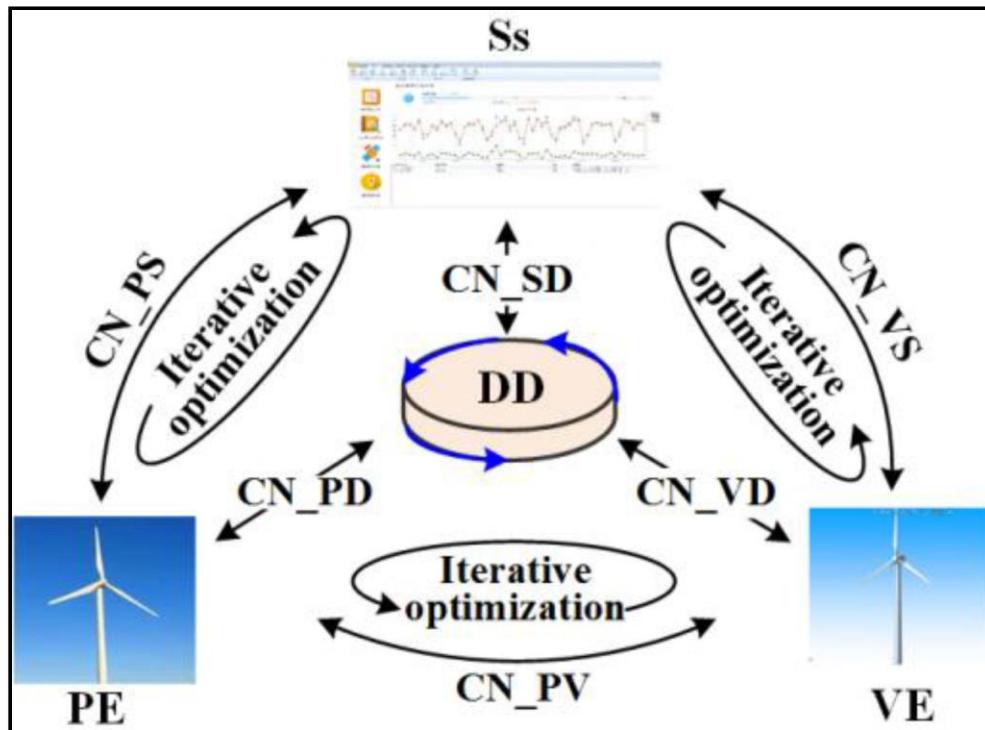
3D architecture



M. Grieves, “Digital twin: Manufacturing excellence through virtual factory replication,” White paper, 2014.

Architecture of a Digital Twin System

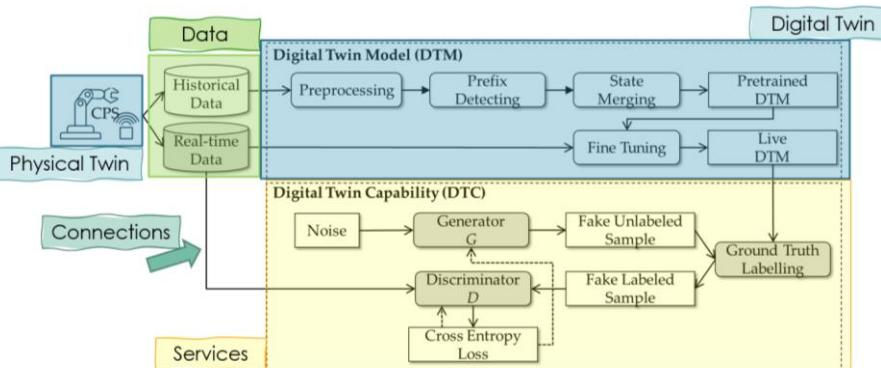
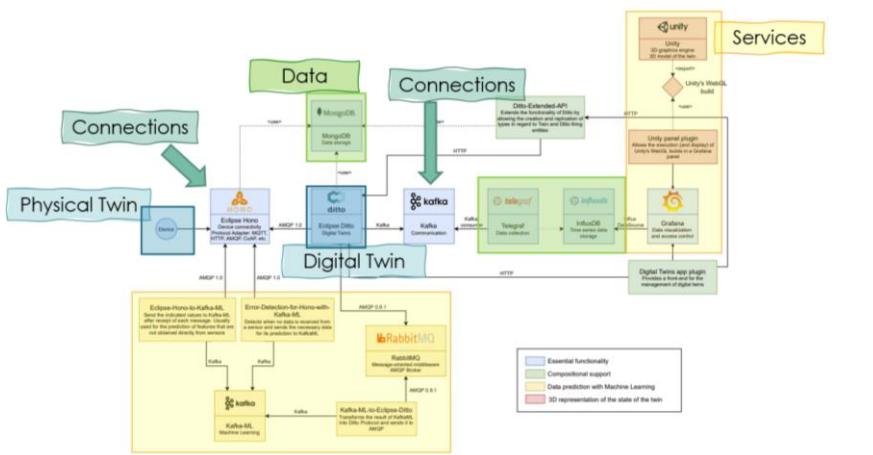
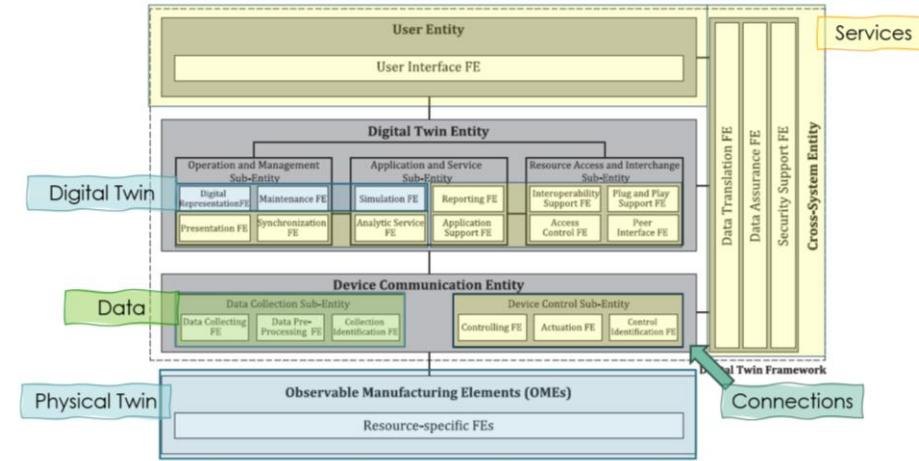
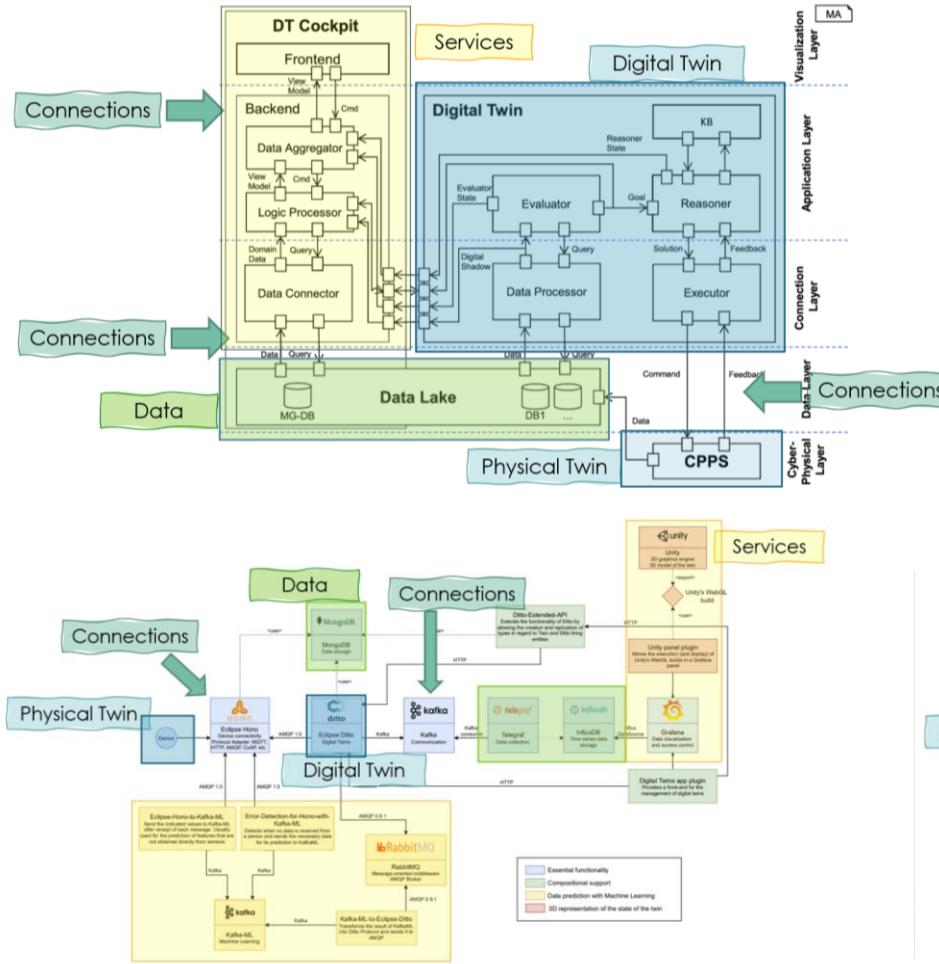
5D architecture



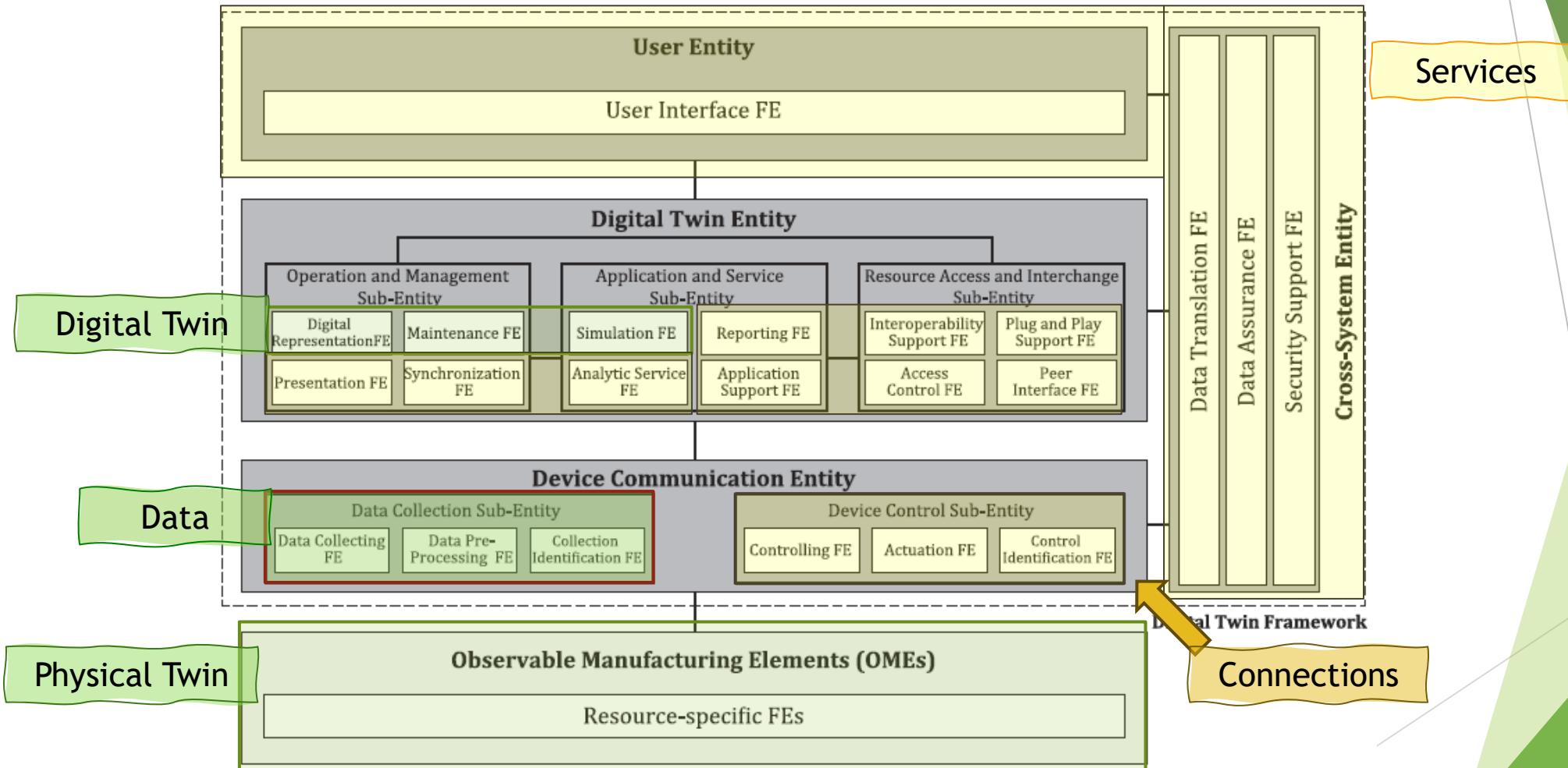
- Physical Entity (PE)
- Virtual Entity (VE)
- Data lake (DD)
- Services (Ss)
 - User dashboard
 - Data analysis
 - Anomaly detection
 - Predictive maintenance
 - ...

Tao, M. Zhang, Y. Liu, N.Y.C. Nee, "Digital twin driven prognostics and health management for complex equipment," CIRP Annals, vol. 67, no. 1, pp. 169-172, May. 2018.

Architectures in the Literature

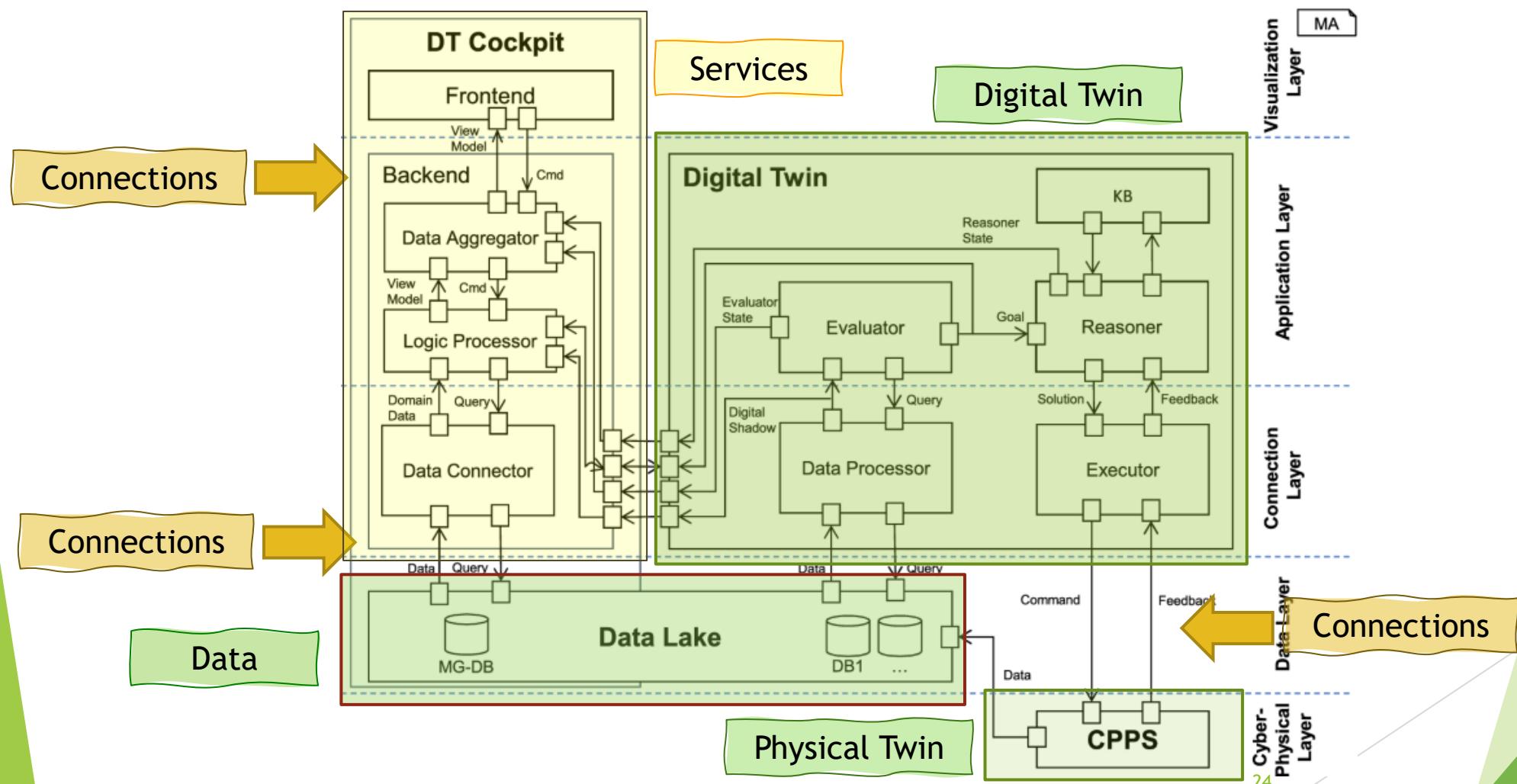


Digital Twin Architecture in MontiArch

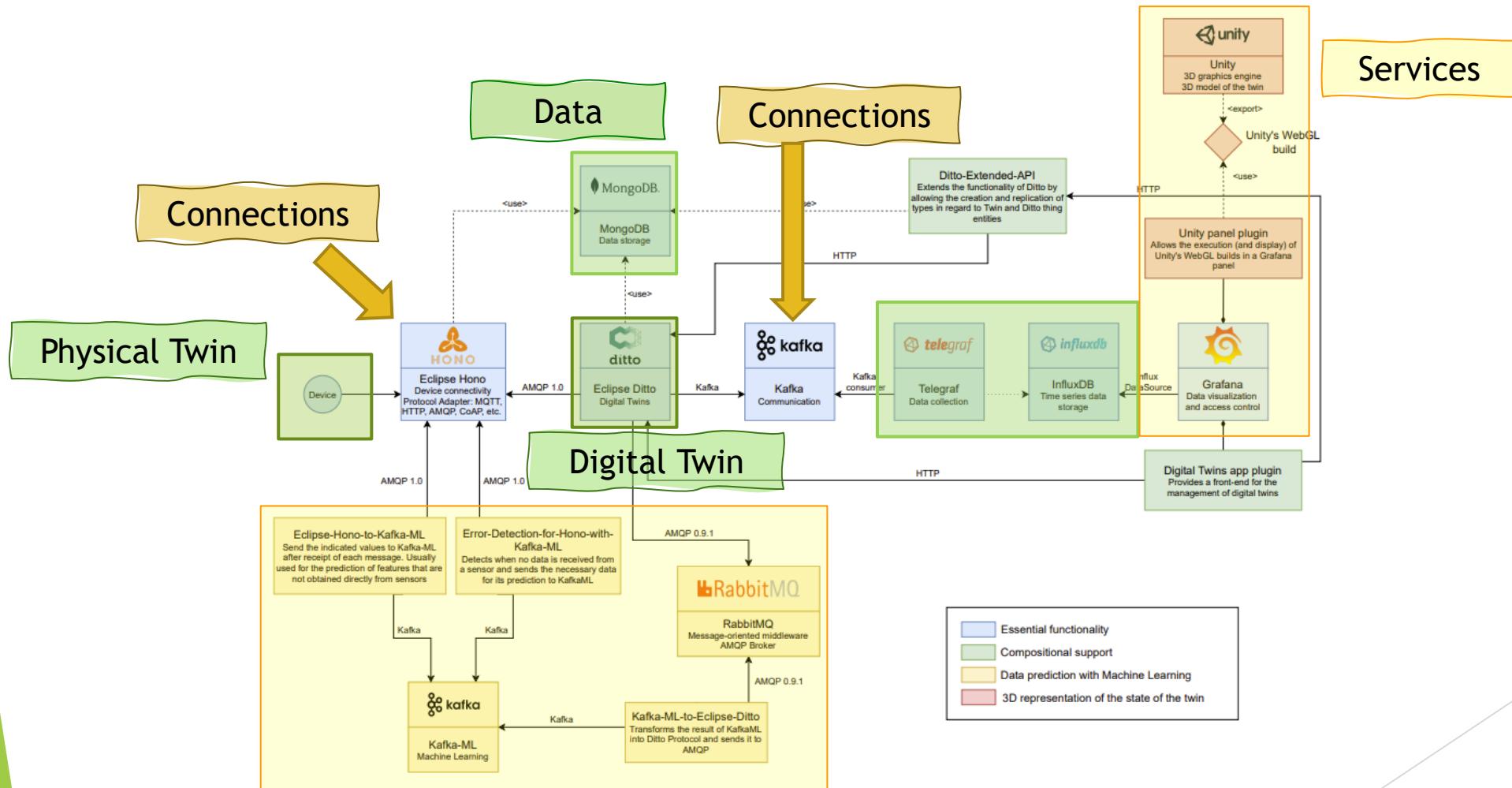


M. Dalibor, J. Michael, B. Rumpe, S. Varga, and A. Wortmann, "Towards a model-driven architecture for interactive digital twin cockpits," In Proc. ER'20.

Digital Twin Architecture by ISO

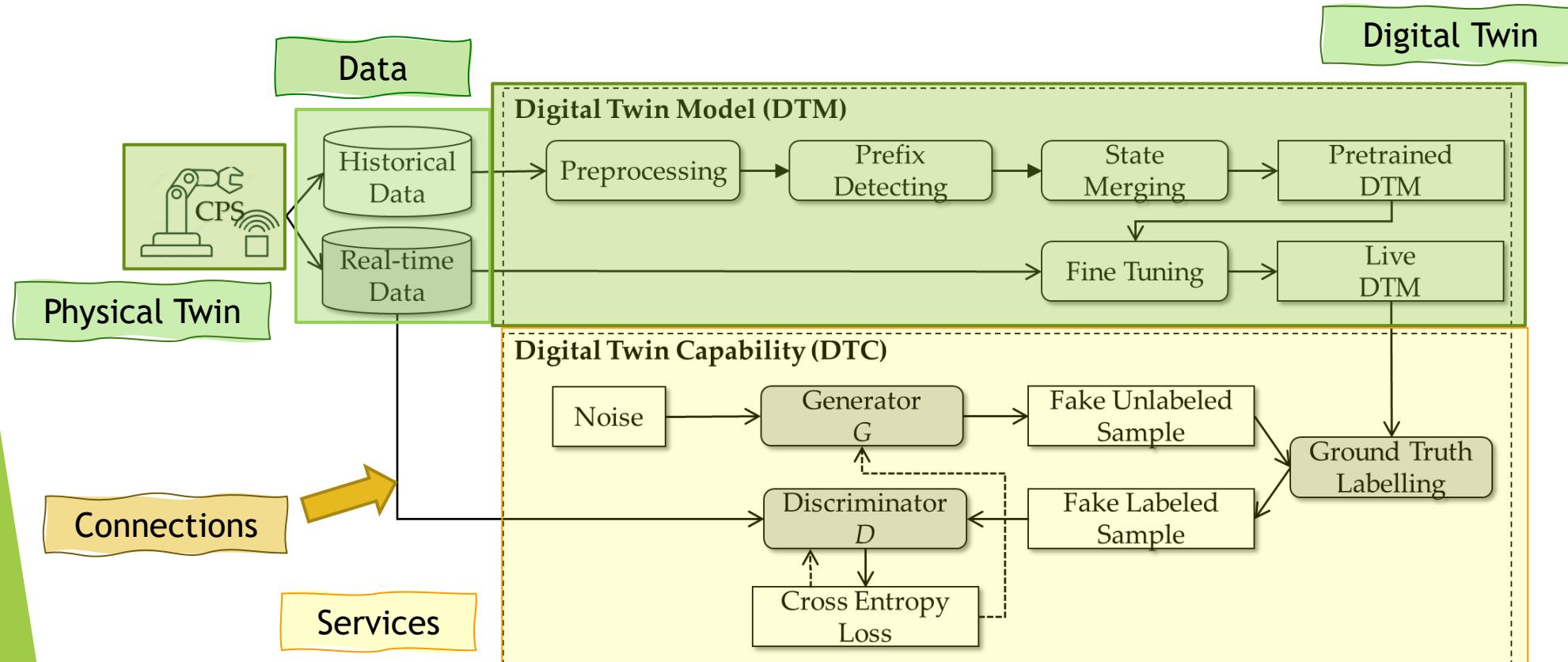


Digital Twin Architecture in OpenTwins



J. Robles, C. Martin and M- Diaz - OpenTwins: an open-source framework
for the development of next-gen compositional digital twins

Digital Twin Architecture for CPS

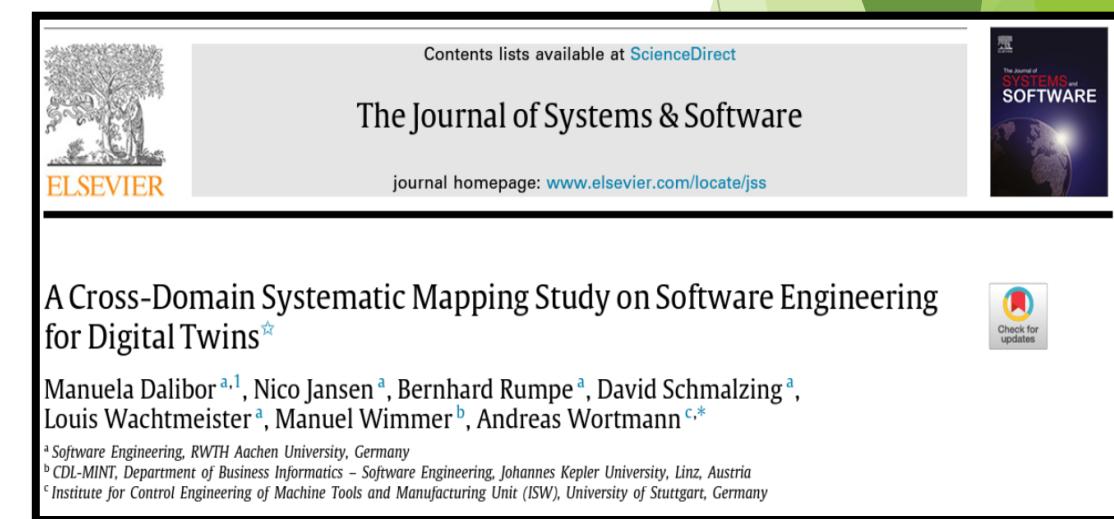


Q. Xu, S. Ali, and T. Yue. 2023. Digital Twin-based Anomaly Detection with Curriculum Learning in Cyber-physical Systems. ACM Trans. Softw. Eng. Methodol. 32, 5, Article 113 (September 2023), 32 pages.

Fields of application

- ▶ Digital Twins can be used in virtually any field:
 - ▶ Manufacturing: Monitor machinery for predictive maintenance.
 - ▶ Smart cities: Model traffic flow, infrastructures, or energy use.
 - ▶ Healthcare: Simulate patient health scenarios.
 - ▶ Aerospace & automotive: Test performance or design changes.

Manufacturing	252	70,79%
Information and Communication	47	13,20%
Energy	17	4,77%
Construction	12	3,37%
Mining	9	2,53%
Sanidad	8	2,25%
Transportation and Storage	6	1,68%
Education	4	1,12%
Agriculture	1	0,28%



The Journal of Systems & Software

Contents lists available at ScienceDirect

journal homepage: www.elsevier.com/locate/jss

A Cross-Domain Systematic Mapping Study on Software Engineering for Digital Twins[☆]

Manuela Dalibor^{a,1}, Nico Jansen^a, Bernhard Rumpe^a, David Schmalzing^a, Louis Wachtmeister^a, Manuel Wimmer^b, Andreas Wortmann^{c,*}

^a Software Engineering, RWTH Aachen University, Germany
^b CDL-MINT, Department of Business Informatics – Software Engineering, Johannes Kepler University, Linz, Austria
^c Institute for Control Engineering of Machine Tools and Manufacturing Unit (ISW), University of Stuttgart, Germany

Check for updates



Some Applications

► Digital Wind Farm System



US 20160333855A1

(19) United States

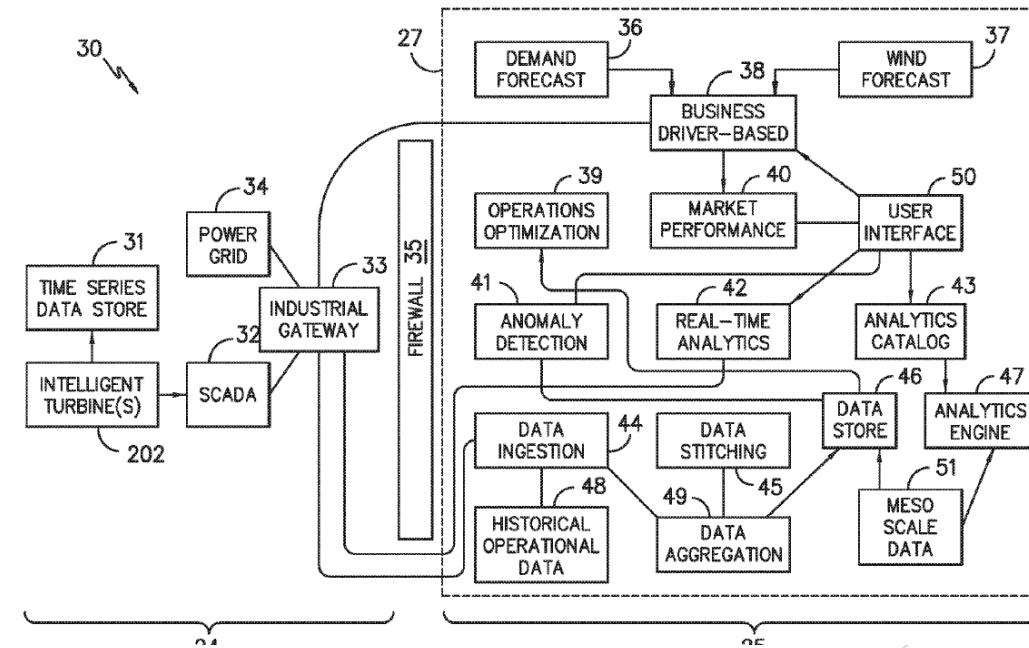
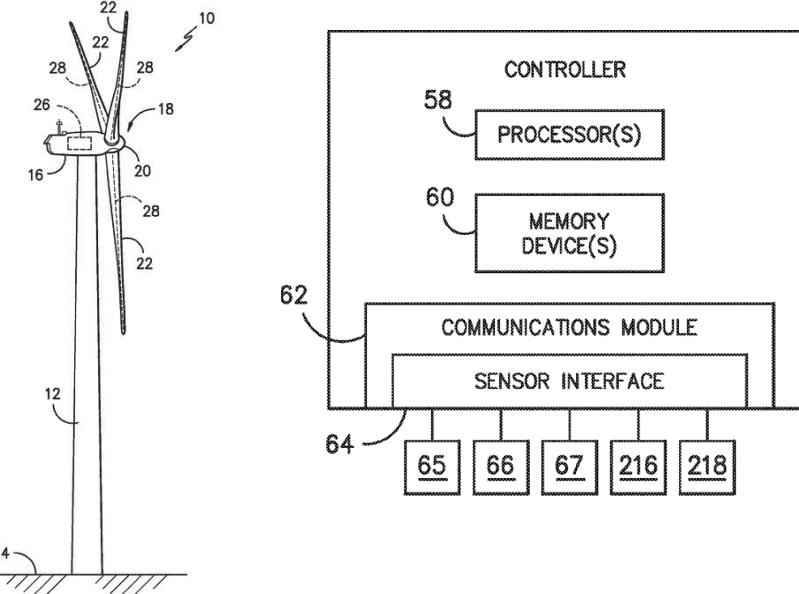
(12) Patent Application Publication

(10) Pub. No.: US 2016/0333855 A1

(43) Pub. Date: Nov. 17, 2016

(12) United States Patent

Lund et al.

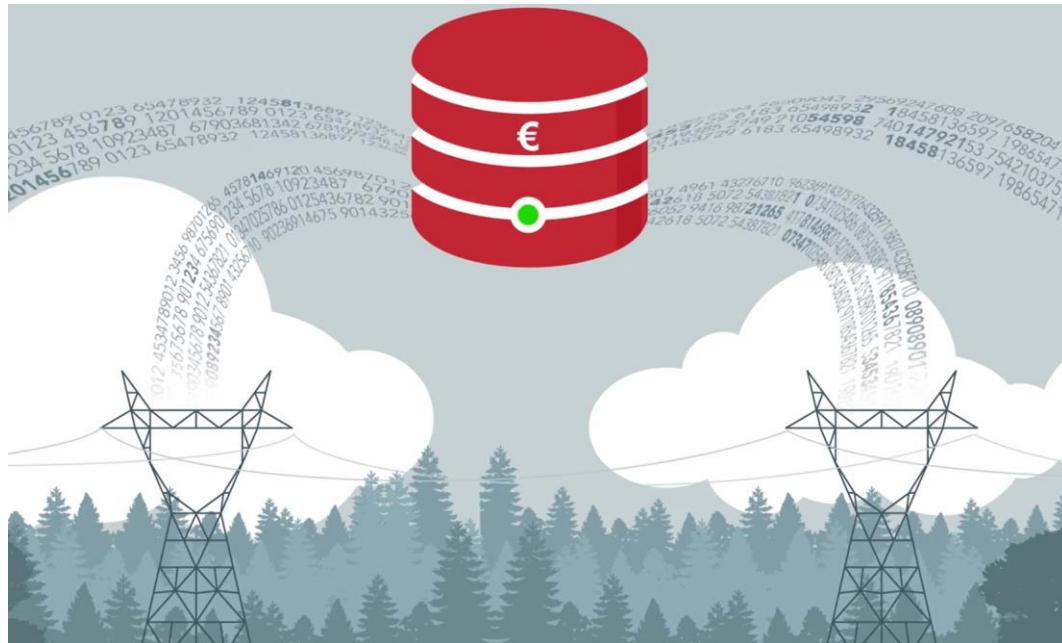


A. M. Lund et al., "Digital twin interface for operating wind farms," U.S. Patent 9 995 278, Jun. 12, 2018

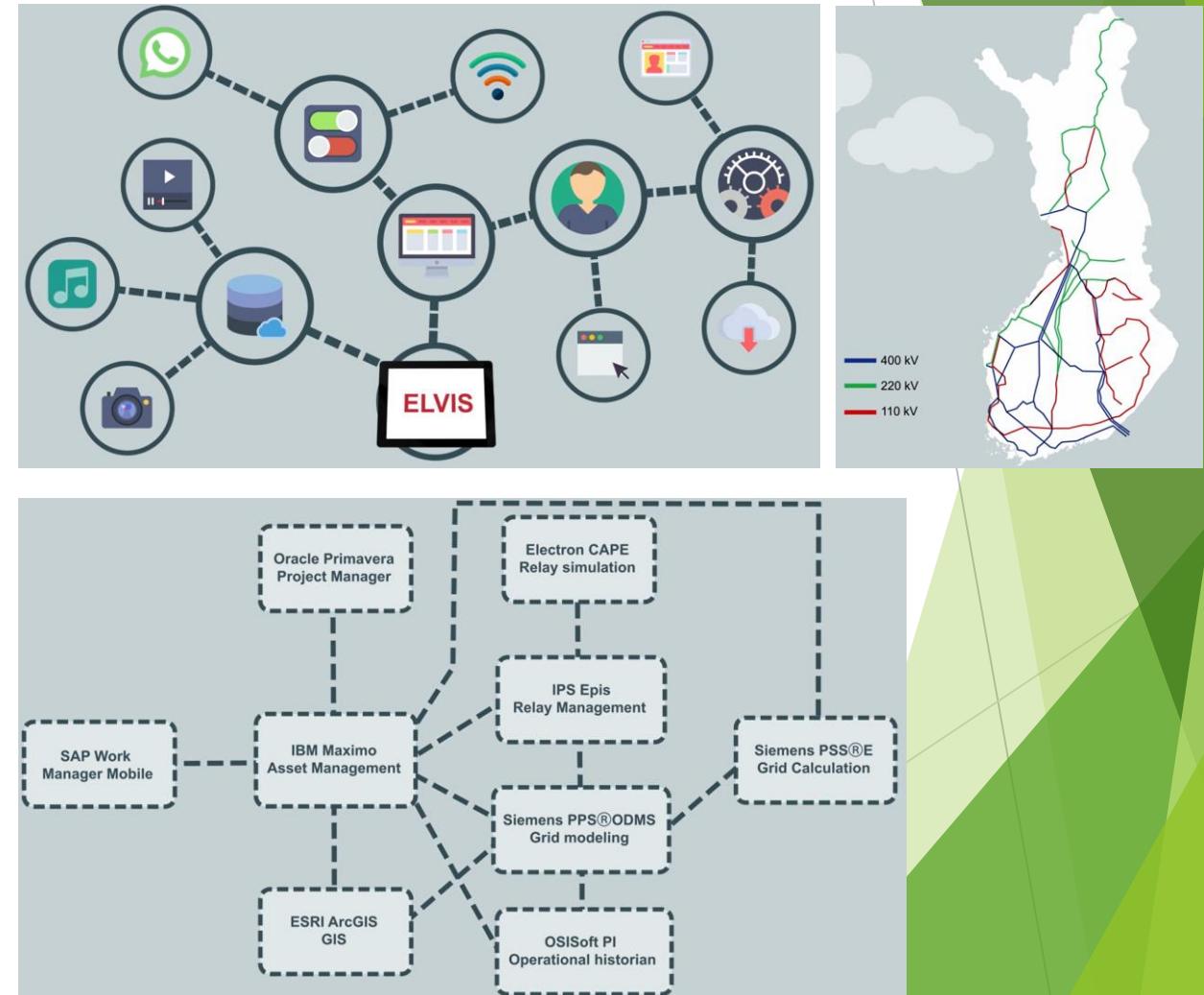
A. M. Lund et al., "Digital wind farm system," U.S. Patent Application 15/075 231, Nov. 17, 2016

Some Applications

► Finland's Electricity Network

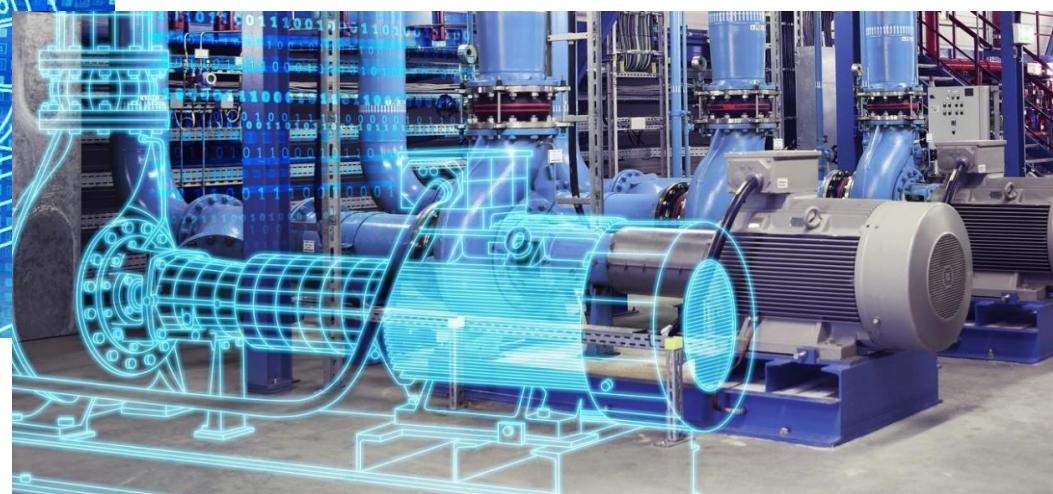
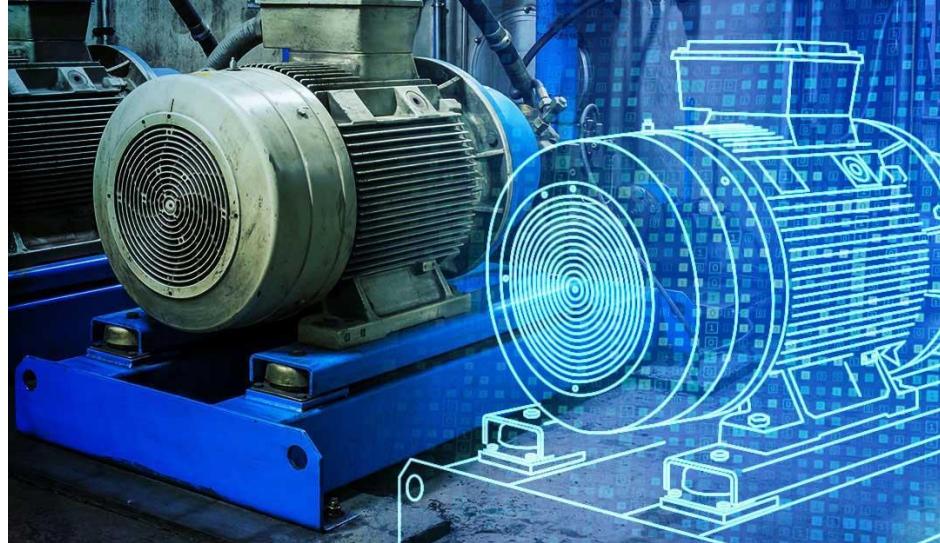


Siemens, For a digital twin of the grid Siemens solution enables a single grid model of the Finnish power system, [Online], 2017.



Some Applications

- Oil and gas extraction

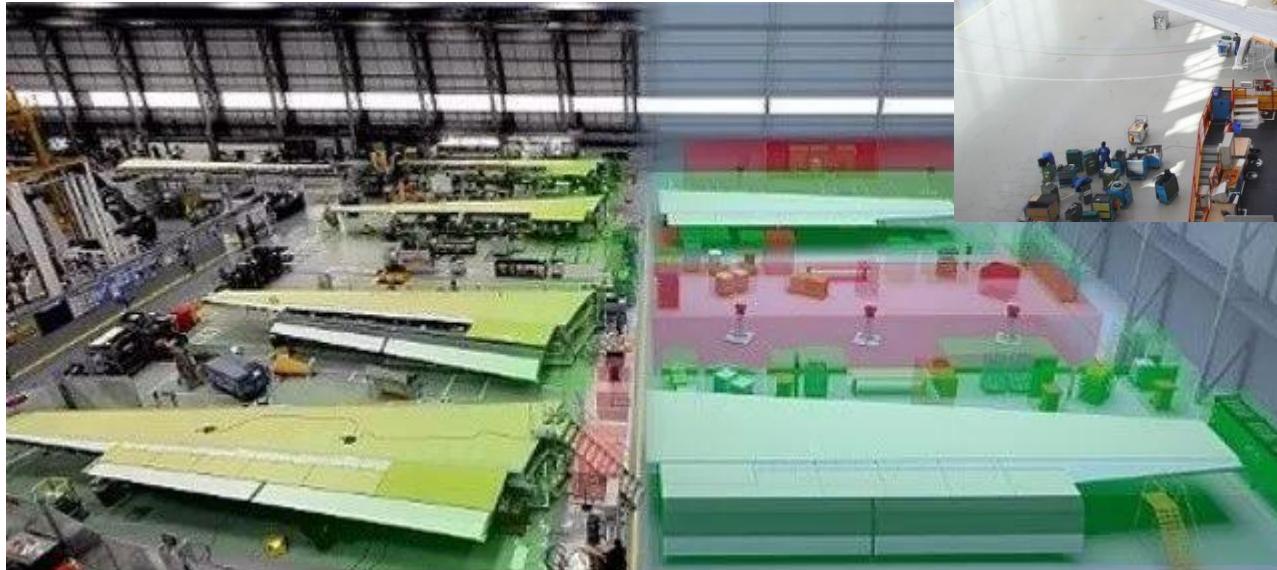


Digital Twin Insider, BP Digital Twin Technology to Enhance Global Oil and Gas Operations,
[Online], 2024.



Some Applications

- Oil and gas extraction



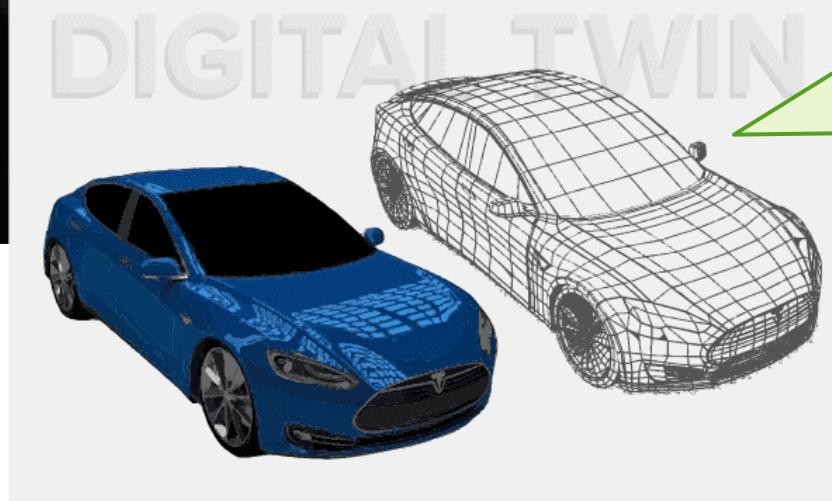
SME, IIoT Platform Creates A Digital Twin of F-35 Manufacturing Facilities, [Online], 2017.





Some Applications

► Tesla's Digital Twins



“Literally every Tesla sold has a digital representation that reflects its real-world counterpart”



Some Applications

- ▶ Agriculture
 - ▶ Addressing issues such as:
 - ▶ Farms and animal welfare
 - ▶ Irrigation
 - ▶ Resource usage
 - ▶ Machinery
 - ▶ Crop yield



ELSEVIER

Agricultural Systems

Volume 189, April 2021, 103046



Digital twins in smart farming

Cor Verdouw ^{a b}   , Bedir Tekinerdogan ^a, Adrie Beulens ^a, Sjaak Wolfert ^{a c}

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<https://doi.org/10.1016/j.aggsy.2020.103046> 

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C. Verdouw, B. Tekinerdogan, A. Beulens, S. Wolfert. Digital twins in smart farming, Agricultural Systems, vol. 189, 2021, DOI: <https://doi.org/10.1016/j.aggsy.2020.103046>



Some Applications

- ▶ Smart Cities
 - ▶ Urban Digital Twins (UDTs)
 - ▶ Addressing issues such as:
 - ▶ Urban planning
 - ▶ City infrastructures
 - ▶ Traffic
 - ▶ Energy consumption



N. Mohammadi and J. E. Taylor, "Smart city digital twins," 2017 IEEE Symposium Series on Computational Intelligence (SSCI), Honolulu, 2017, pp. 1-5, doi:10.1109/SSCI.2017.8285439.

Some Applications

- ▶ Healthcare
 - ▶ Addressing issues such as:
 - ▶ Developping personalized treatments
 - ▶ Drug discovery and development
 - ▶ Monitoring chronic disease healthdata
 - ▶ Organ-specific digital twins: heart, lung, kidney,...
 - ▶ Optimizing hospital operation and workflows
 - ▶ Training surgeons
 - ▶ Emergency response
 - ▶ Remote patient monitoring
 - ▶ Population health

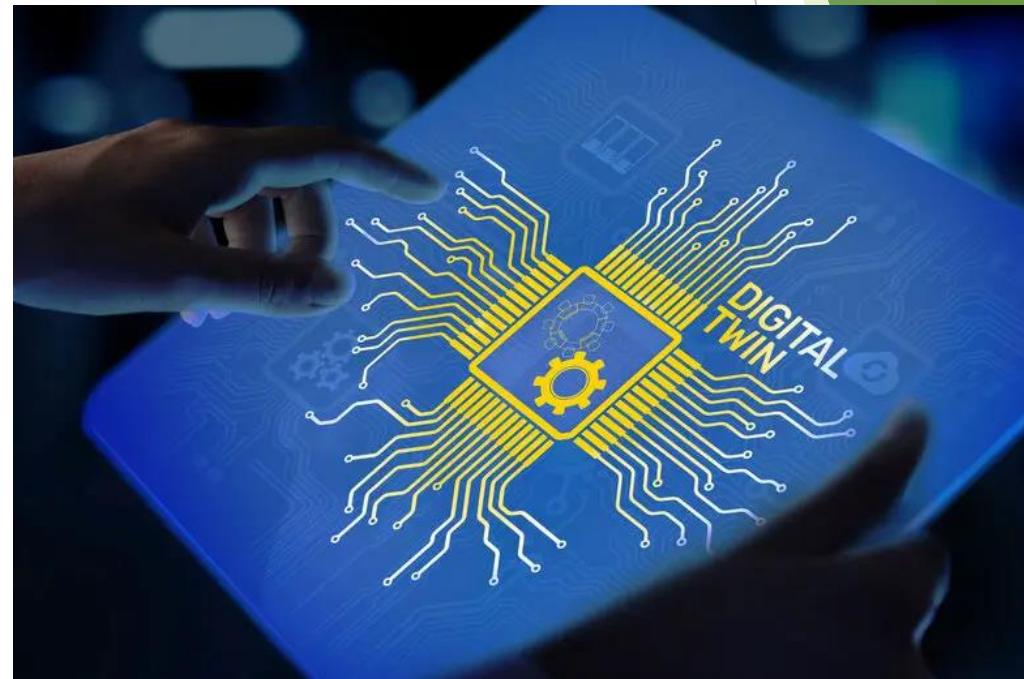


Katsoulakis, E., Wang, Q., Wu, H. et al. Digital twins for health: a scoping review.
Digit. Med. 7, 77 (2024). <https://doi.org/10.1038/s41746-024-01073-0>



Some Applications

- ▶ Information and Communication
 - ▶ Addressing issues such as:
 - ▶ Network infrastructures
 - ▶ Ericsson Site Digital Twin
 - ▶ Telecom sites
 - ▶ UE Hexa-X 6G project



R. Dong, et al., "Deep Learning for Hybrid 5G Services in Mobile Edge Computing Systems: Learn From a Digital Twin," in IEEE Trans. Wireless Communications, vol. 18, no. 10, pp. 4692-4707, Oct. 2019, doi: 10.1109/TWC.2019.2927312.

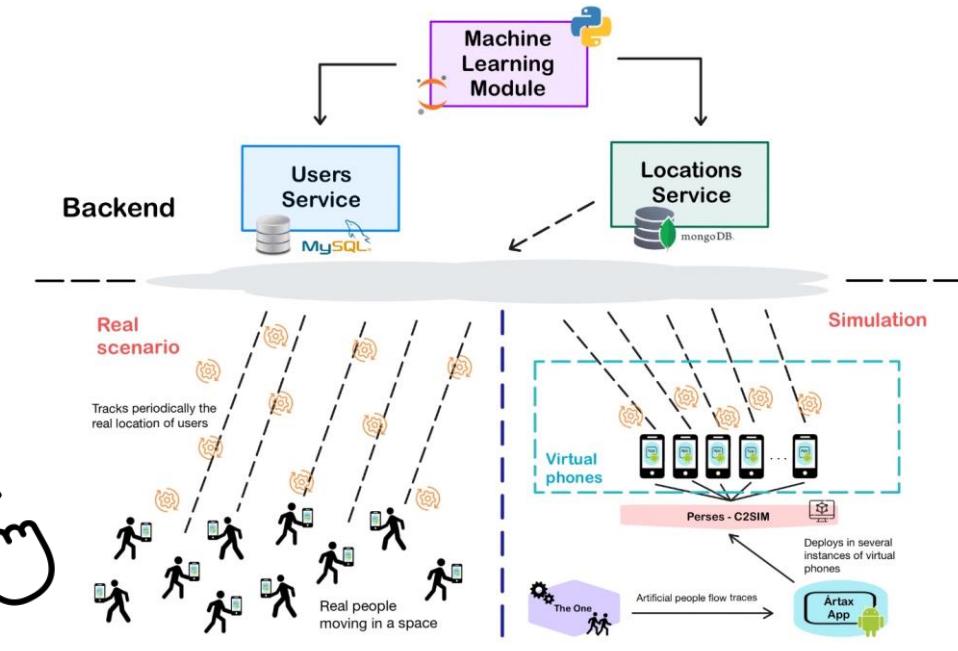


Some Applications

- ▶ Artax - a DT for people's movement in crowds
 - ▶ as part of the research project:
Including People in Smart City Applications
 - ▶ the phone builds a *Digital Avatar* of its owner
 - ▶ virtual profile with their habits, preferences, etc.
 - ▶ including their movements as a sequence of GPS positions
 - ▶ that can be served to third-parties on demand
- ▶ Individuals are considered as first-class entities of the DT
 - ▶ providing RT information from individuals in a specific area

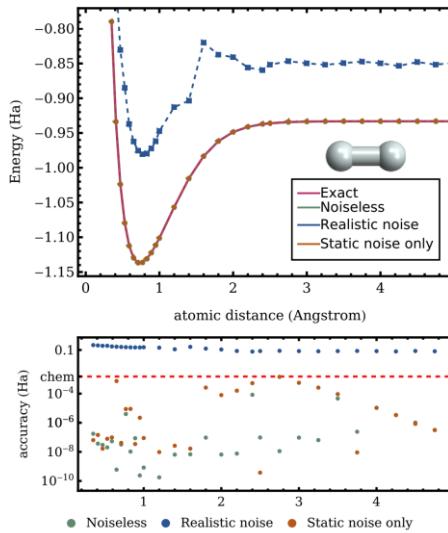
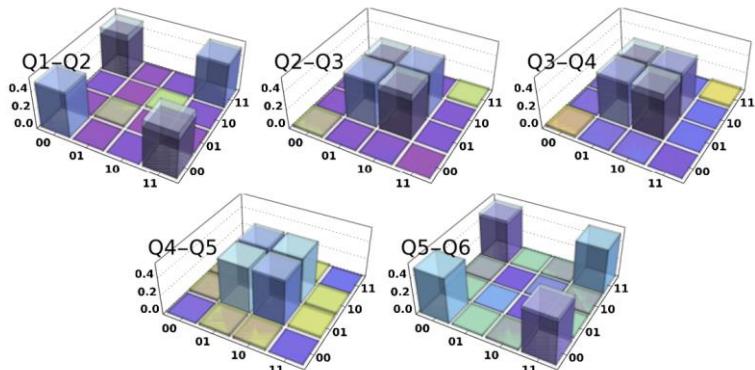
A. Perez-Vereda, R. Hervas, C. Canal. Digital Avatars: A programming framework for personalized human interactions through virtual profiles. *Pervasive and Mobile Computing*, 87:101718 (17 pp.), Elsevier, 2022.

I. Alba, J. Troya, C. Canal. Towards a Digital Twin System for Human Crowd Motion Prediction. *EDOC 2024. Lecture Notes in Business Information Processing*, vol 537. Springer (2025).



Some Applications

- ▶ A DT of Noisy Quantum Computers
 - ▶ parametric error model of transmon qubit devices
 - ▶ for understanding and mitigating noise in NISQ QPUs



C. Gustiani, T. Jones, S. C. Benjamin. The Virtual Quantum Device (VQD): A tool for detailed emulation of quantum computers. *Quantum* 9: 1642 (2025).

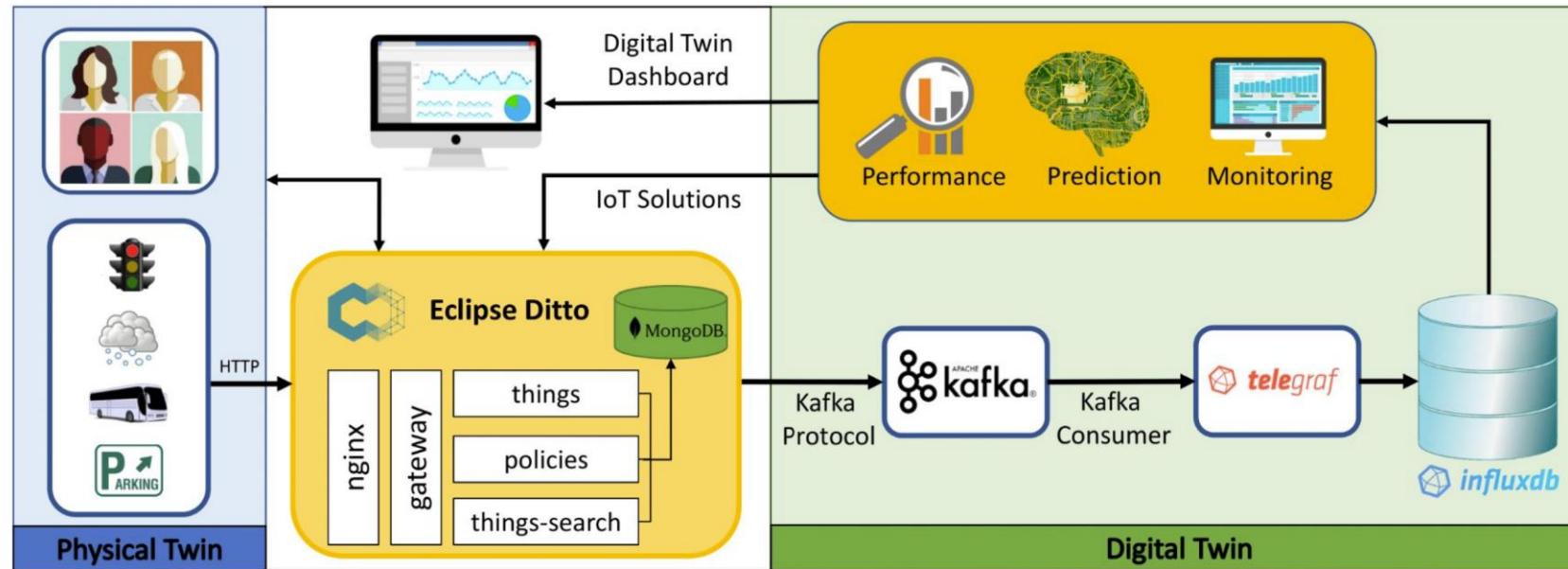
Research Challenges

- ▶ Many industrial initiatives for building DTs
 - ▶ developed in an *ad-hoc* manner
- ▶ Lack of Software Engineering methods in their development
 - ▶ standards
 - ▶ methodologies
 - ▶ frameworks & tools
 - ▶ data fusion & curation
 - ▶ interoperability, **composition & deployment**
 - ▶ **validation & evaluation**
- ▶ We find efforts in all these fields but not clear outcomes yet

A. Sharma, E. Kosasih, J. Zhang, A. Brintrup, A. Calinescu. Digital Twins: State of the art theory and practice, challenges, and open research questions, Journal of Industrial Information Integration, vol 30, 2022, 100383. <https://doi.org/10.1016/j.jii.2022.100383>.

Composition of DTs

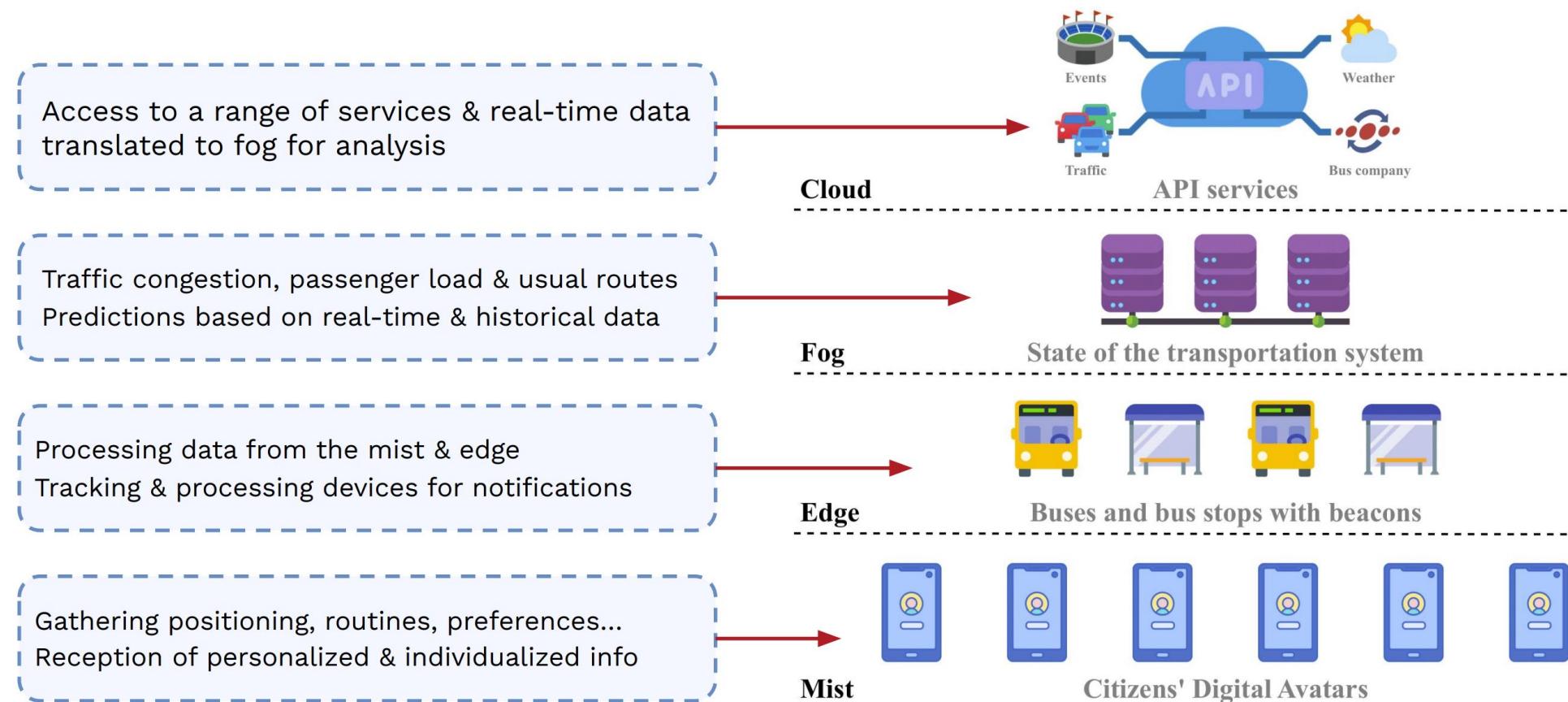
- ▶ Integration of citizens into UDTs through their Digital Avatars
- ▶ Case study: Public transportation system of the city of Malaga



R. García-Luque, L. Toro-Gálvez, N. Moreno, J. Troya, C. Canal and E. Pimentel. "Integrating Citizens' Avatars in Urban Digital Twins". Journal of Web Engineering, 22(06):913-938, Elsevier, 2023.



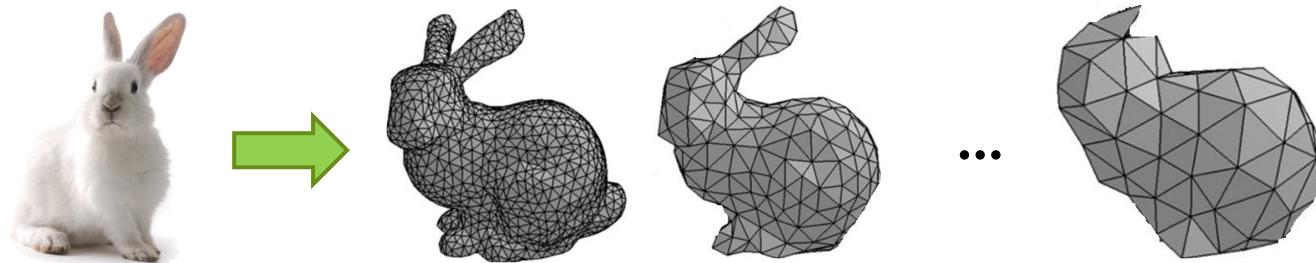
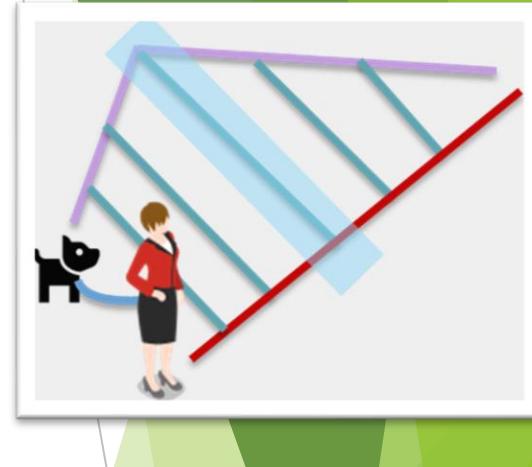
Deployment in the Cloud-to-IoT Continuum



S. Laso, L. Toro-Gálvez, J. Berrocal, J. Troya, C. Canal, J.M. Murillo. "Towards a Urban Digital Twins Continuum Architecture". Software Architecture. ECSA 2023 Tracks, Workshops, and Doctoral Symposium. ECSA 2023. LNCS, vol 14590. Springer (2024) https://doi.org/10.1007/978-3-031-66326-0_17

Validation and fidelity assessment

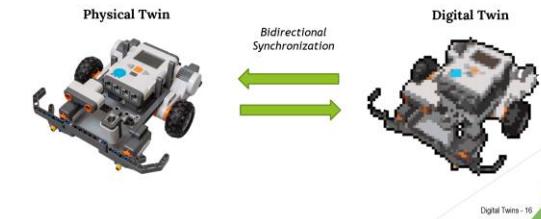
- ▶ How can we determine if a DT *accurately represents* its PT?
- ▶ How can we measure the *fidelity* between two models of the same system?
- ▶ **Fidelity:** the degree to which a model reproduces the actual state and behavior of a system in a measurable way.



Definition of the DT Consortium

A digital twin is an integrated data-driven virtual representation of real-world entities and processes, with synchronized interaction at a specified frequency and **fidelity**.

Digital Twin Consortium, *Glossary of digital twins* (2021)



Paula Muñoz. Measuring the Fidelity of Digital Twins using Trace Alignments.
Ph.D. thesis, University of Málaga (2025).

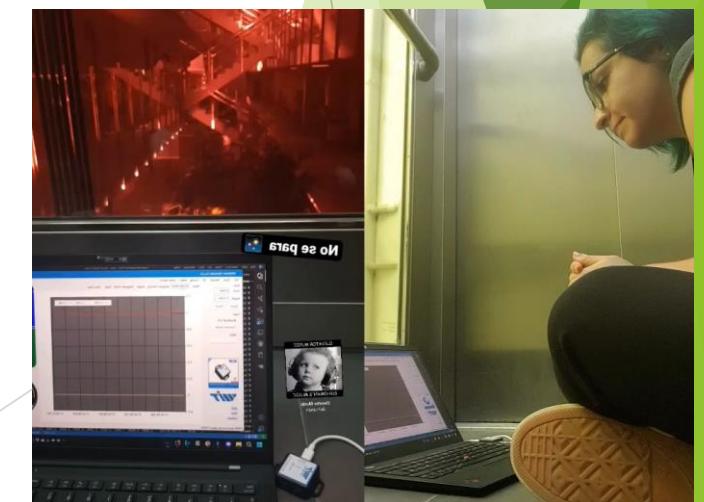
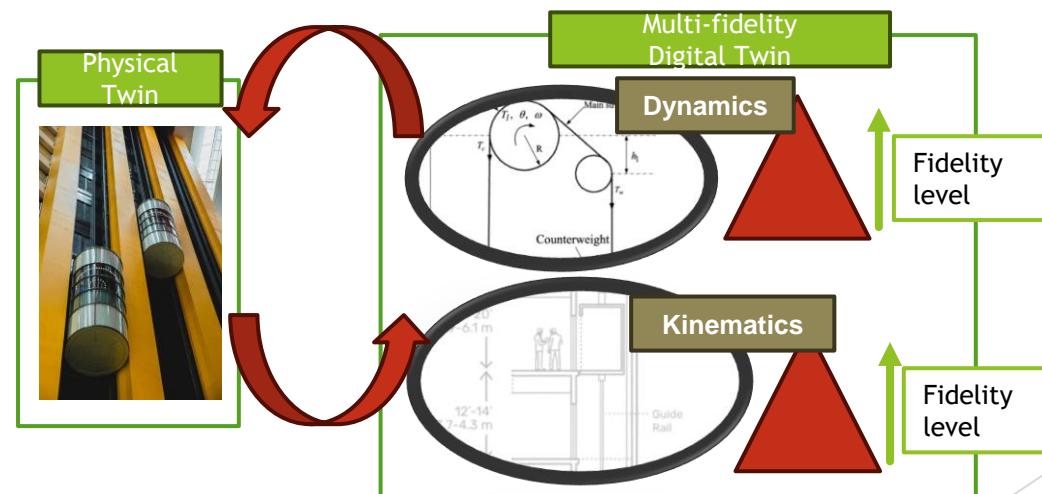


Validation and fidelity assessment

- ▶ Fidelity depends on the *purpose* of the DT
 - ▶ and it is related to *abstraction* and *resolution*
- ▶ Abstraction: process of selecting the essential aspects of a model, ignoring those that are not relevant for its purpose.
- ▶ Resolution: level of detail used to represent certain aspects of the real world in a model.

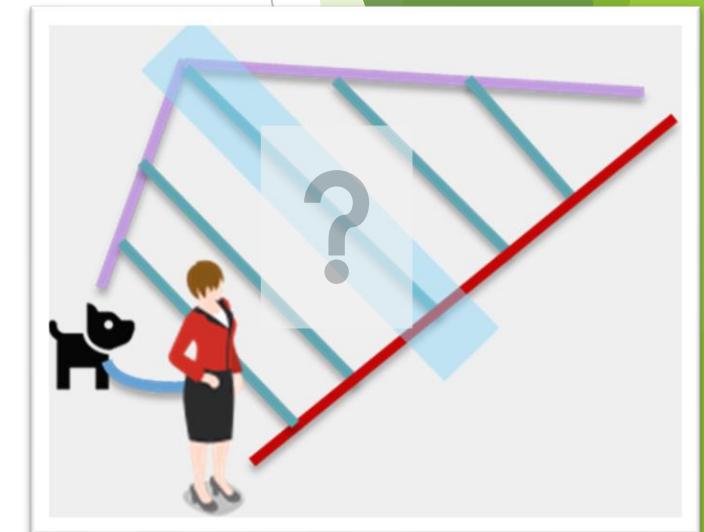
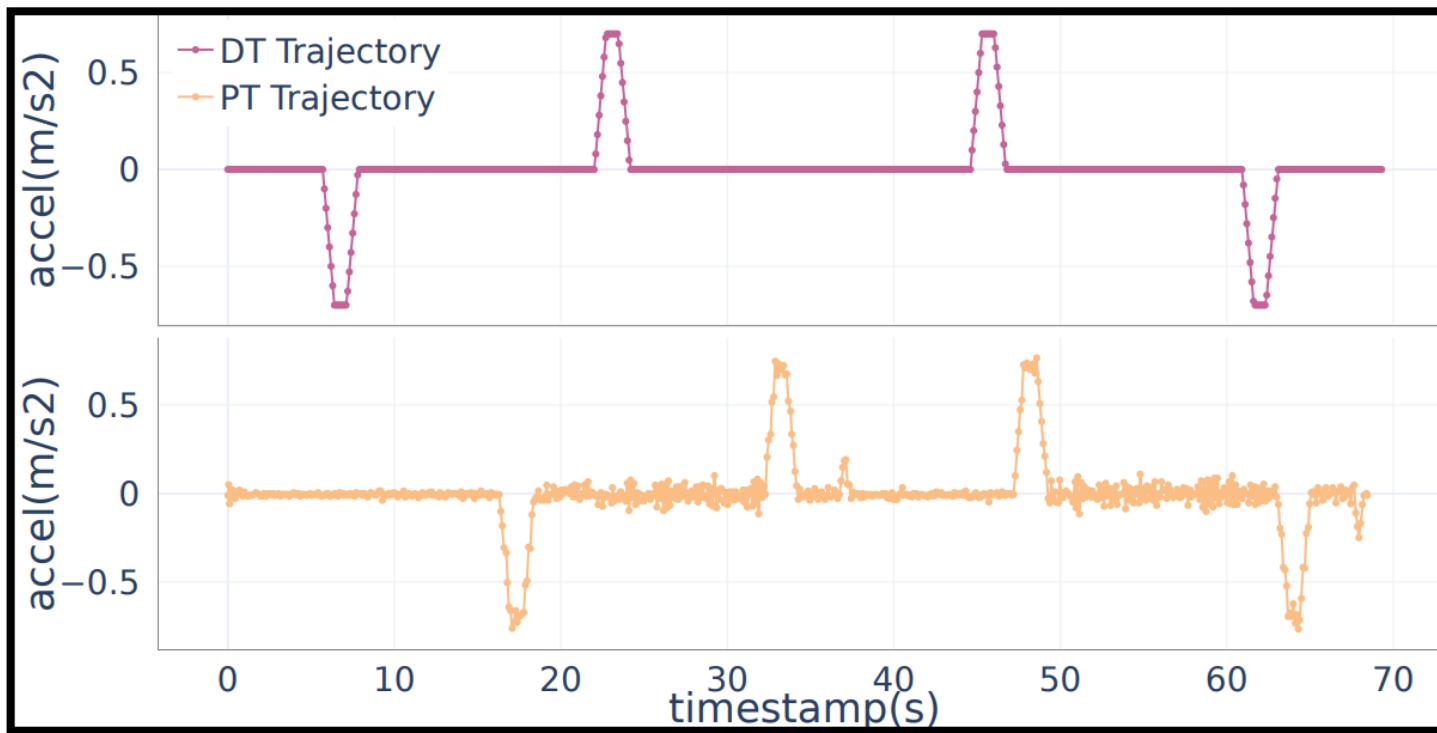
Case Study

Mondragón elevator



Trace alignment for measuring fidelity

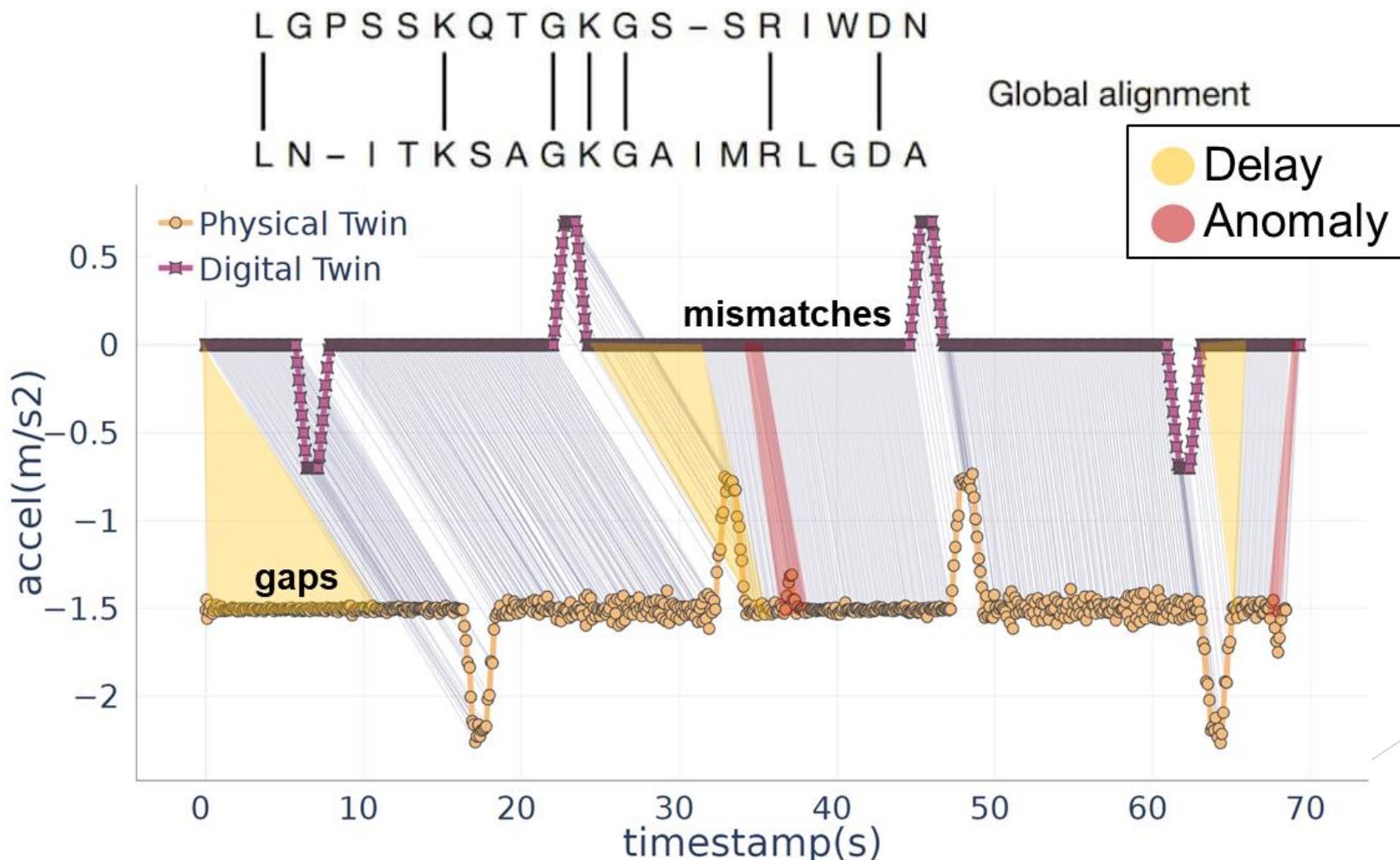
- A trace is a sequence of *snapshots* of the state of each twin



P. Muñoz, M. Wimmer, J. Troya, A. Vallecillo "Measuring the Fidelity of a Physical and a Digital Twin Using Trace Alignments" IEEE Transactions on Software Engineering, Volume 50, Issue 12, 3122-3145, 2024

Sequence alignment

- ▶ Optimized version of the Needleman Wunsch algorithm



Technologiers & Platforms

- ▶ Few domain-agnostic proposals
- ▶ Low maturity level
 - ▶ there are no proposals empirically evaluated
- ▶ Lack of a common understanding
 - ▶ about which components a DT should have
 - ▶ at least, agreement on: model, datalake, sync, and services
- ▶ Main components/techniques involved
 - ▶ Mathematical & Physical models, Simulation & Analysis tools, Databases, MDE, CAD & 3D tools,...

M. Dalibor, N. Jansen, B. Rumpe, D. Schmalzing, L. Wachtmeister, M. Wimmer, A. Wortmann. A Cross-Domain Systematic Mapping Study on Software Engineering for Digital Twins, Journal of Systems and Software, vol. 193, 2022, <https://doi.org/10.1016/j.jss.2022.111361>.

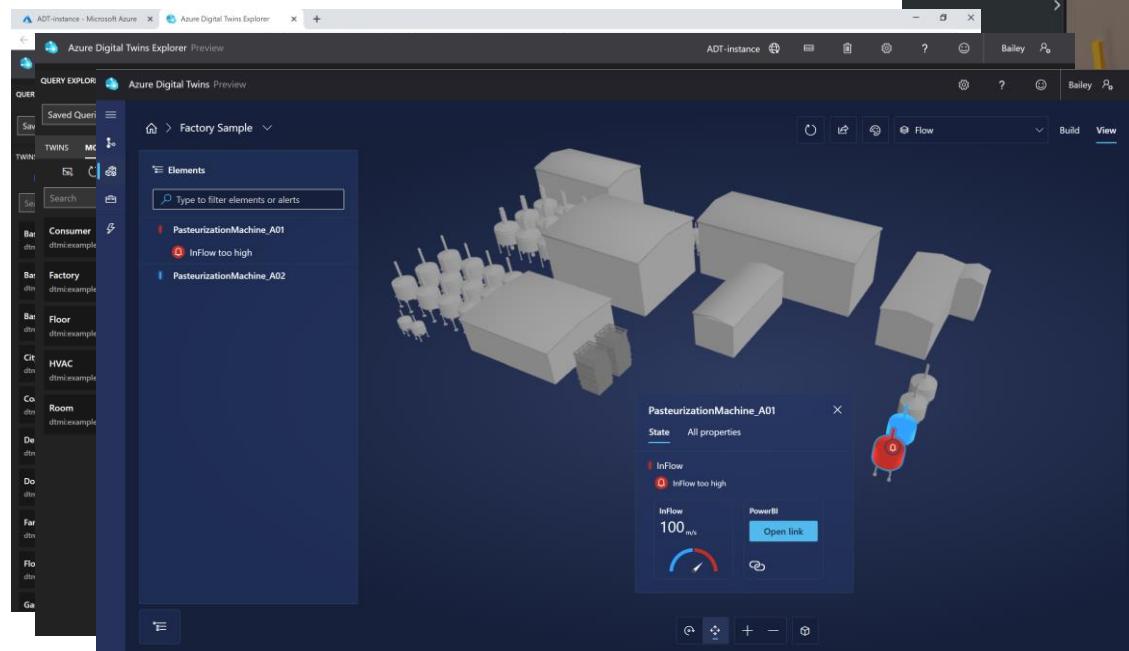
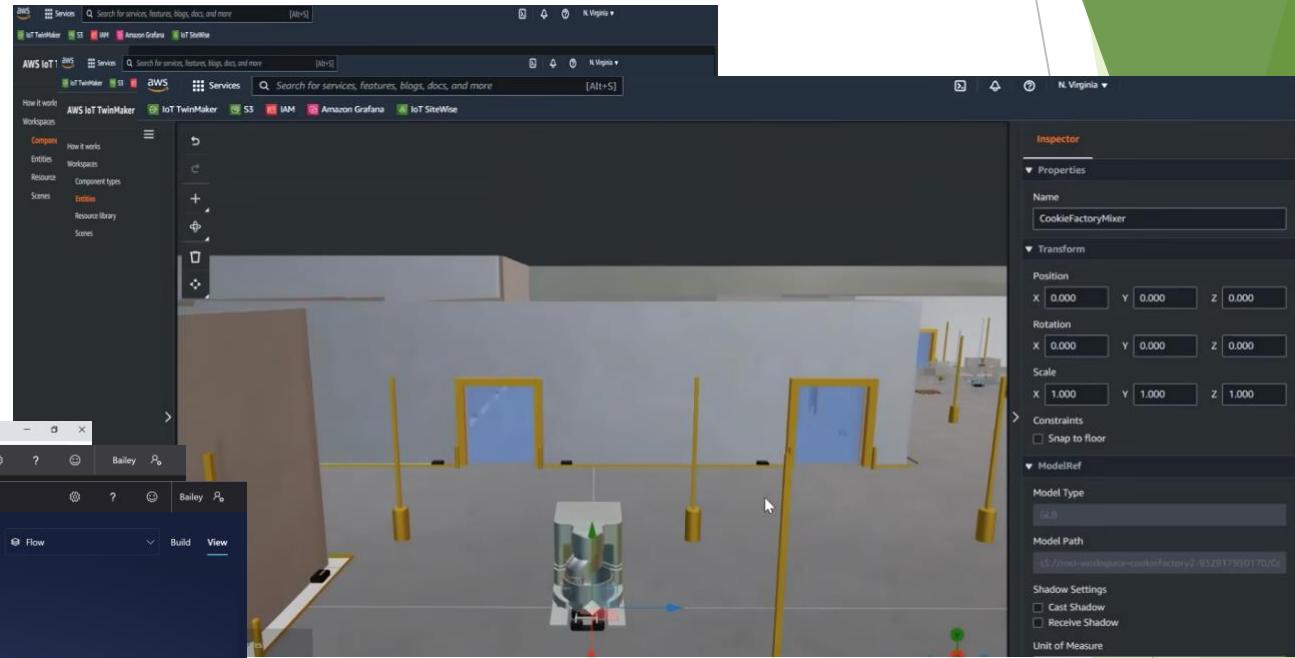
Technologies & Platforms

- ▶ A number of proprietary solutions are available
 - ▶ usually they are domain-oriented.
- ▶ Cloud-based general-purpose platforms
 - ▶ Azure DT, AWS IoT TwinMaker, GCP
- ▶ Lack of open-source frameworks
 - ▶ Fireware
 - ▶ EU-based heavy-weight platform
 - ▶ Eclipse Ditto
 - ▶ basic & most popular DT middleware
 - ▶ OpenTwins
 - ▶ open platform that builds on Ditto



Technologiers & Platforms

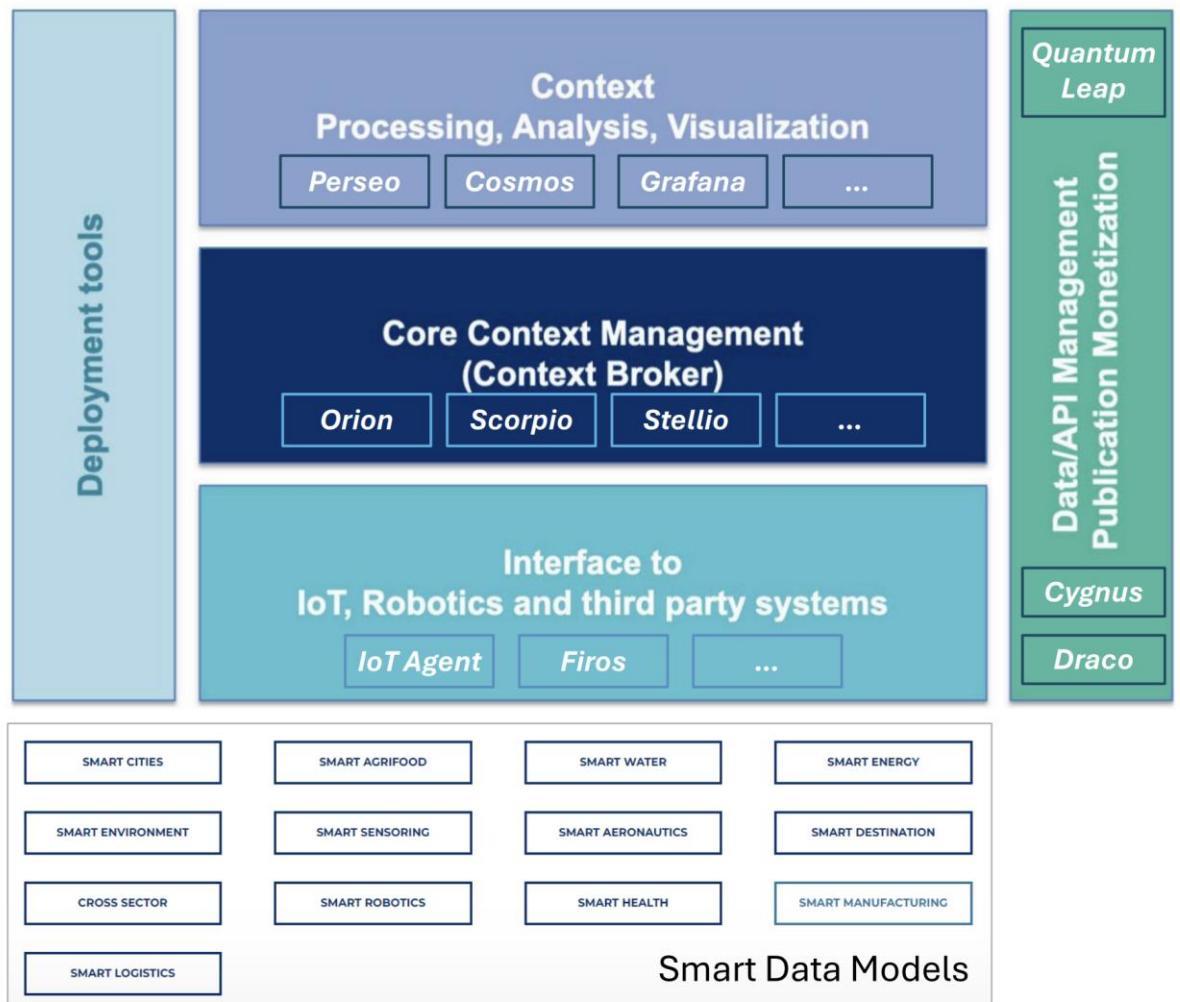
► AWS IoT TwinMaker



► Azure Digital Twins

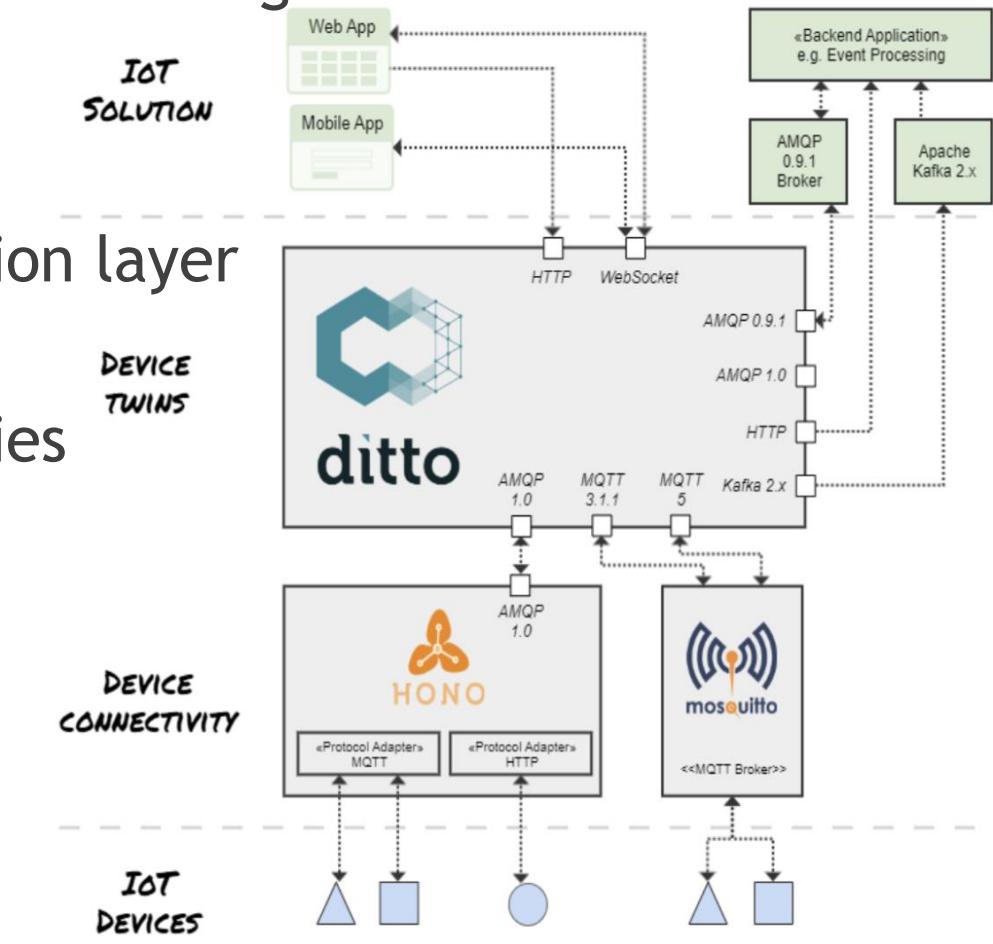
Fiware

- ▶ Open-source ecosystem with components for:
 - ▶ interacting with IoT sensors & devices
 - ▶ vertical integration with other information systems
 - ▶ processing historical and RT data
 - ▶ creating dashboards
 - ▶ KPI monitoring and analysis
 - ▶ visualization
 - ▶ ...



Eclipse Ditto

- ▶ Open-source & domain-agnostic framework for building DTs
- ▶ Offers an abstract layer for working with things in the IoT
- ▶ Integration of devices through a communication layer (Eclipse Hono) or MQTT (Eclipse Mosquitto)
- ▶ Provides state persistence & search capabilities
 - ▶ through a MongoDB-like datalake
- ▶ Accesses things always in an authorized way
- ▶ Gets notified about changes
- ▶ Provides APIs - Device as a Service
- ▶ Integration with other tools & platforms



Eclipse Ditto - Limitations

- ▶ Ditto offers basic functionality for integrating IoT things

```
curl -X PUT -u ditto:ditto \
  "https://ditto.eclipseprojects.io/api/2/things/io.eclipseprojects.ditto:floor-lamp-0815" \
  -H 'Content-Type: application/json' \
  --data-raw '{
    "definition": "https://eclipse-ditto.github.io/ditto-examples/wot/models/floor-lamp-1.0.0.tn.json"
  }'

{
  "thingId": "io.eclipseprojects.ditto:floor-lamp-0815",
  "pollCid": "io.eclipseprojects.ditto:floor-lamp-0815",
  "definition": "https://eclipse-ditto.github.io/ditto-examples/wot/models/floor-lamp-1.0.0.tn.json",
  "attributes": {
    "manufacturer": "",
    "serialNo": "https://some.domain/switchable-1.0.0.tn.json#id"
  },
  "features": {
    "Spot": {
      "definition": [
        "https://eclipse-ditto.github.io/ditto-examples/wot/models/dimmable-colored-lamp-1.0.0.tn.json#id",
        "https://eclipse-ditto.github.io/ditto-examples/wot/models/colored-lamp-1.0.0.tn.json#id",
        "https://eclipse-ditto.github.io/ditto-examples/wot/models/switchable-1.0.0.tn.json#id"
      ]
    }
  },
  "properties": {
    "dimmer-level": 0.0,
    "color": {
      "r": 0,
      "g": 0,
      "b": 0
    },
    "on": false
  }
}'
```

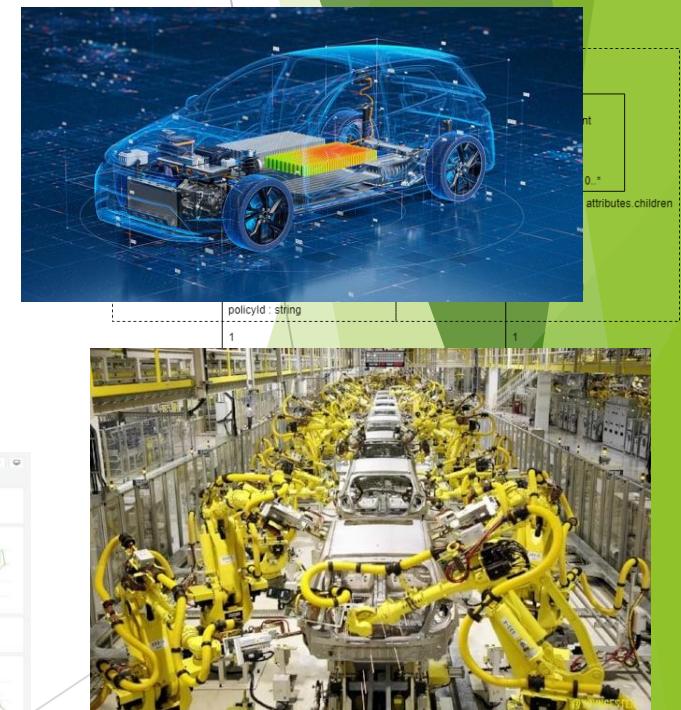
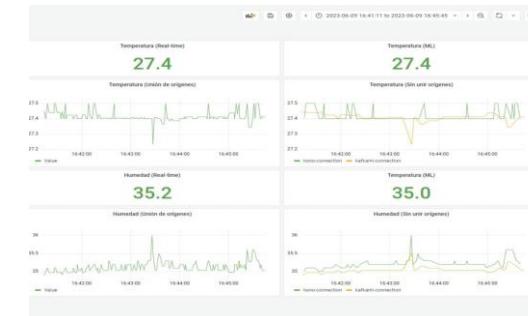
- ▶ but it lacks many features required in DTs:

- ▶ historical data management
- ▶ analysis
- ▶ simulation
- ▶ visualization, 3D visualization
- ▶ ML/AI integration
- ▶ Twin composition
- ▶ ...



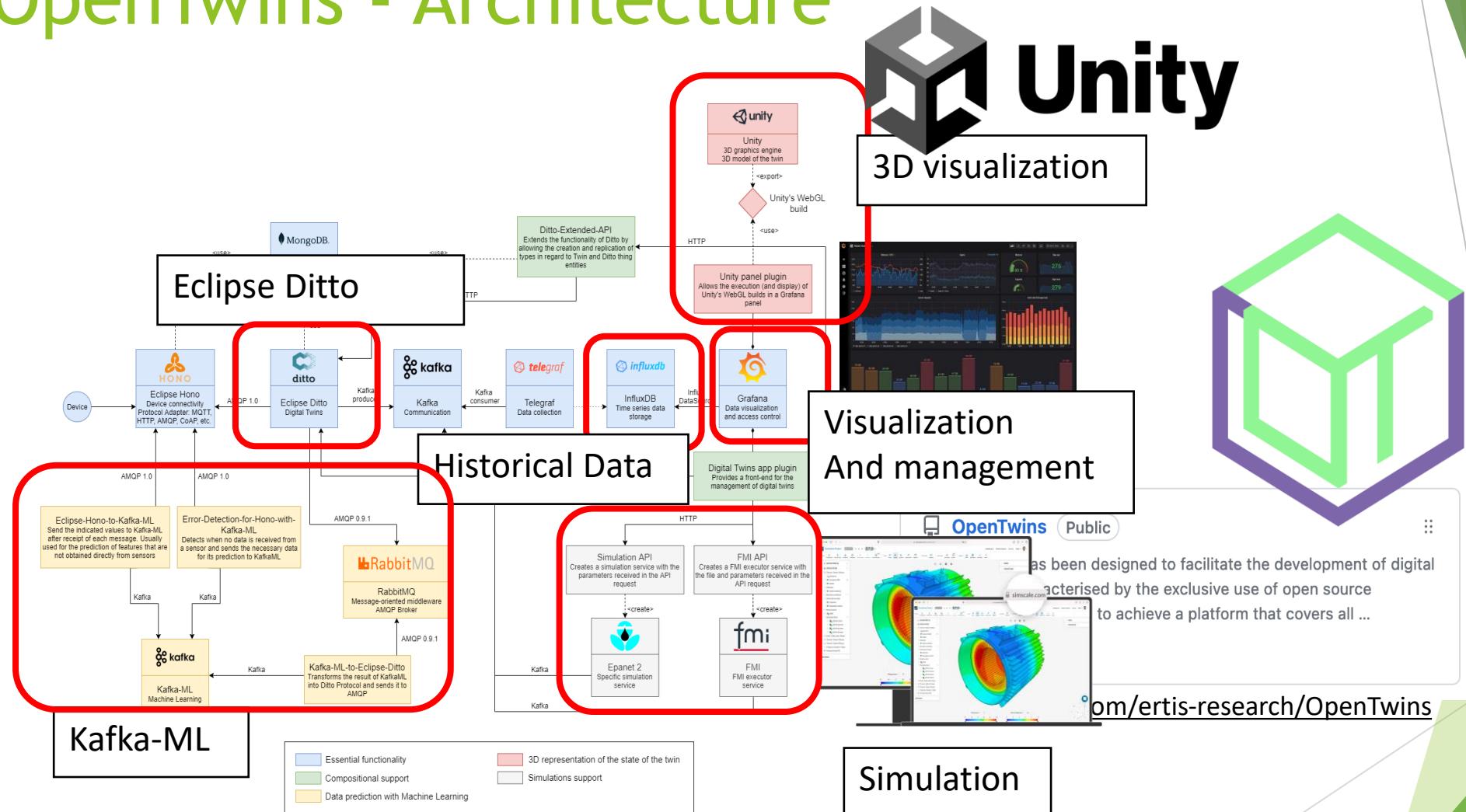
OpenTwins

- ▶ Open-source platform for developing compositional DTs
 - ▶ user-friendly management of DTs, types, policies and connections
 - ▶ DT types and instances for twin composition
 - ▶ 3D visualization
 - ▶ using WebGL, Unity, Grafana & Blender
 - ▶ Machine Learning
 - ▶ using Kafka-ML for communication with Ditto
 - ▶ integration with simulation models
 - ▶ Using fmi



Robles, J., Martín, C., & Díaz, M. (2023). OpenTwins: An open-source framework for the development of next-gen compositional digital twins. *Computers in Industry*, 152.

OpenTwins - Architecture



<https://github.com/ertis-research/OpenTwins>



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Any questions?