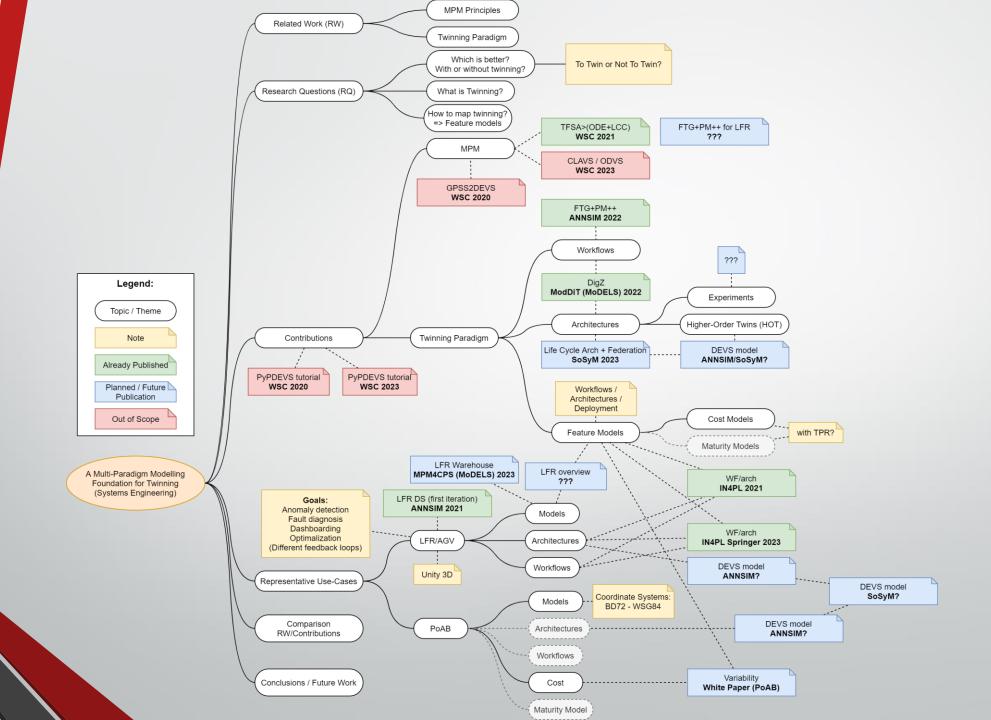
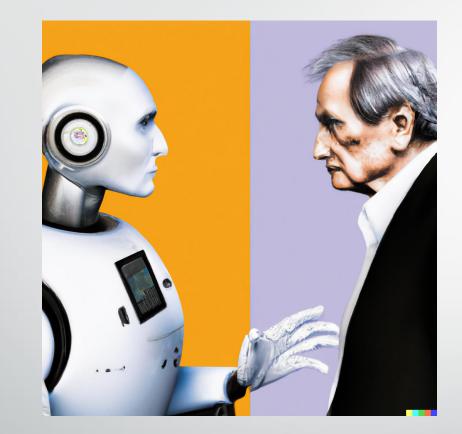


# The Design and Architectures of Digital Twins

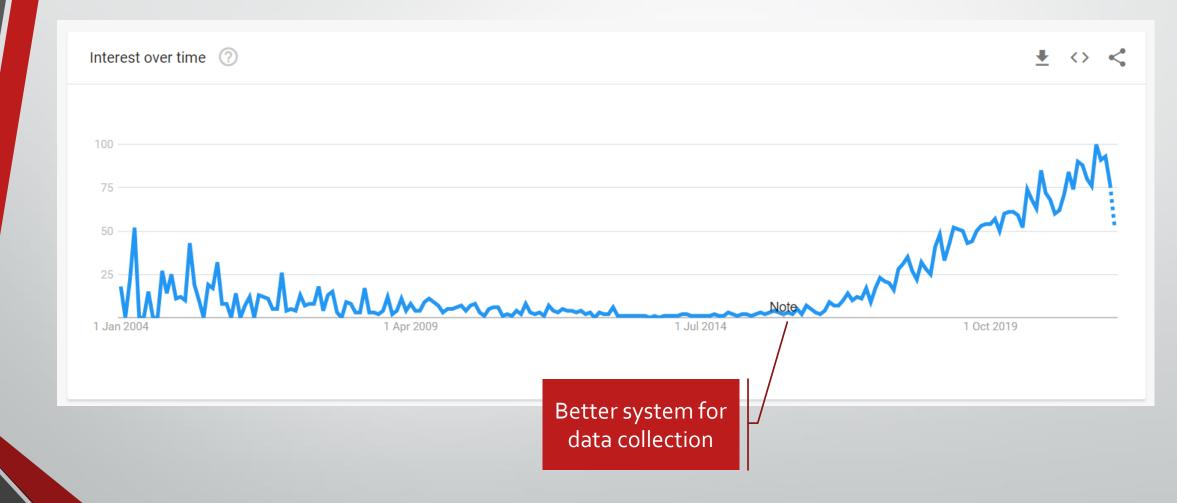
**Randy Paredis** 



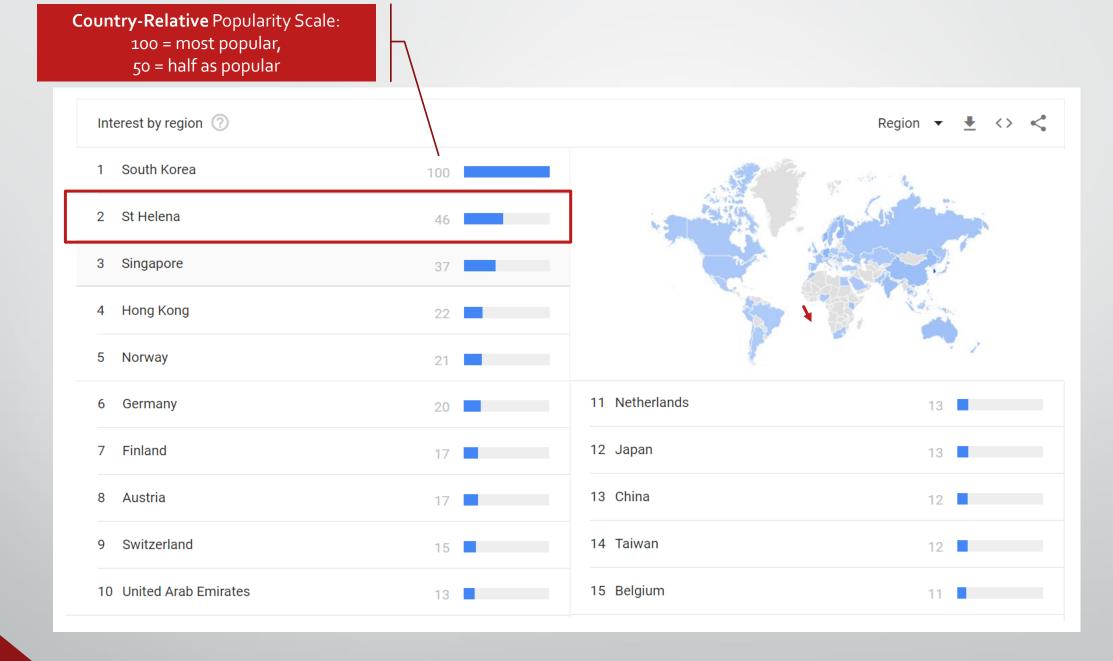


## The Design and Architectures of Digital Twins

**Randy Paredis** 

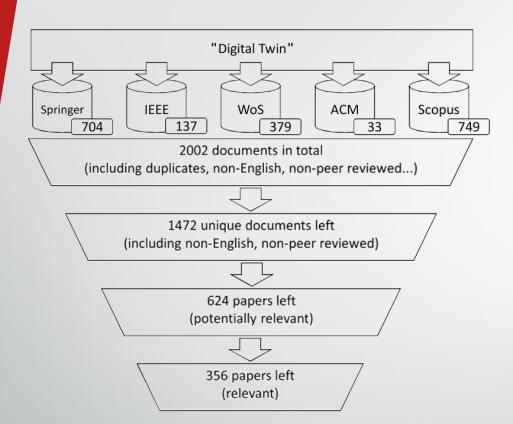


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#### Accessed: 7 January 2022

#### **Application Domains**



**Fig. 2.** Data collection initially produced 1472 unique documents, out of which 356 were identified as relevant for our study.

C - Manufacturing (252)	J - Ir (47)	<ul><li>Information</li><li>7)</li></ul>	
	D - En (17)	ergy	F- Construction (12)
	B - Mining (9)	Q - Health (8)	H - Trans- port (6) P - Edu- cation (4)

Fig. 5. Application domains of Digital Twins.



**Digital Twins** consist of three components, a physical product, a virtual representation of that product, and the bi-directional data connections that feed data from the physical to the virtual representation, and information and processes from the virtual representation to the physical. [1]

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. The digital twin is ultra-realistic and may consider one or more important and interdependent vehicle systems. [5]

A **Digital Twin** is a coupled model of the real machine that operates in the cloud platform and simulates the health condition with an integrated knowledge from both data driven analytical algorithms as well as other available physical knowledge. [7]

**Digital Twins** is a unified system model that can coordinate architecture, mechanical, electrical, software, verification, and other discipline-specific models across the system lifecycle, federating models in multiple vendor tools and configuration-controlled. **[8]** 

**Digital Twins** are software systems comprising data, models and services to interact with a CPPS for a specific purpose. [9]

... and many more!

The **Digital Twin** is a set of virtual information constructs that fully describes a potential or actual physical manufactured product from the micro atomic level to the macro geometrical level. At its optimum, any information that could be obtained from inspecting a physical manufactured product can be obtained from its Digital Twin. [2]

**Digital Twins** are a virtual representation of the physical objects, processes and real-time data involved throughout a product life-cycle. [3]

A **Digital Twin** is an ultra-realistic virtual counterpart of a realworld object. **[4]** 

A **Digital Twin** is an ultra-realistic, cradle-to-grave computer model of an aircraft structure that is used to assess the aircraft's ability to meet mission requirements. **[6]** 

[1] D. Jones et al. 2020. "Characterising the Digital Twin: A systematic literature review". In CIRP Journal of Manufacturing Science and Technology. [2] M. Grieves. 2017. "Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems". In Transdisciplinary Perspectives on Complex Systems. [3] W. D. Lin and M. Y. H. Low. 2019. "Concept and implementation of a cyber-physical digital twin for a SMT line". In 2019 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). [4] H. Park et al. 2019. "Challenges in Digital Twin Development for Cyber-Physical Production Systems". In Cyber-Physical Systems. Model-Based Design. [5] E. Glaessgen and D. Stargel. 2012. "The digital twin paradigm for future NASA and U.S. Air Force vehicles". In Proc. 53rd AIAA/ASME/ASCE/AHS/ASC Struct. Struct. Dyn. Mater. Conf. [6] B. T. Gockel et al. 2012. "Challenges with Structural Life Forecasting using Realistic Mission Profiles". In 53rd AIAA/ASME/ASCE/AHS/ASC Struct. Struct. Dyn. Mater. Conf. [7] J. Lee. et al. 2013. "Recent advances and trends in predictive manufacturing systems in big data environment". In Manufacturing Letter 1. [8] M. Bajaj, D. Zwemer and B. Cole. 2016. "Integrating System Models with Architecture to Geometry". In AIAA Sp. Forum. [9] P. Bibow et al. 2020 "Model-Driven Development of a Digital Twin for Injection Molding". In CAiSE 2020. LNCS.

#### Digital Twin Definitions

A collection of definitions of digital twins

As a side result of the largest literature survey on digital twins to date,

 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. In: Journal of Systems and Software, 111361,

we have produced a collection of 112 definitions of the term "digital twin" from the publications of our corpus. This collection is reproduced below.

If you want to add a definition or modify an entry, please create a pull request.

#### Definitions

- "An always in sync digital model of existing manufacturing cells". B. A. Talkhestani, N. Jazdi, W. Schlögl, M. Weyrich. A concept in synchronization of virtual production system with real factory based on anchorpoint method. In: Procedia CIRP, 2018
- "An always current digital image of the production system". F. Biesinger, D. Meike, B. Krass, M. Weyrich. A digital twin for production planning based on cyber-physical systems: A Case Study for a Cyber-Physical System-Based Creation of a Digital Twin. In: 12TH CIRP CONFERENCE ON INTELLIGENT COMPUTATION IN MANUFACTURING ENGINEERING, 2019

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Digital Twin Definitions

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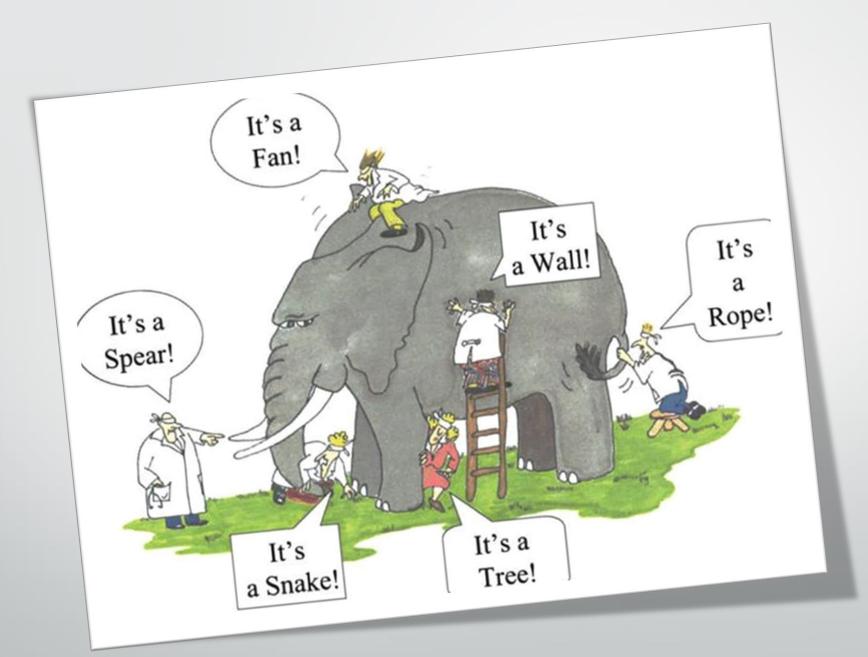
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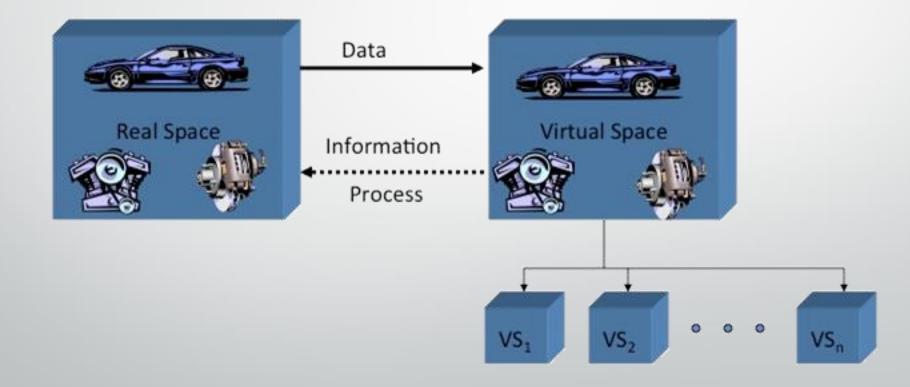


#### **Architecture Models**

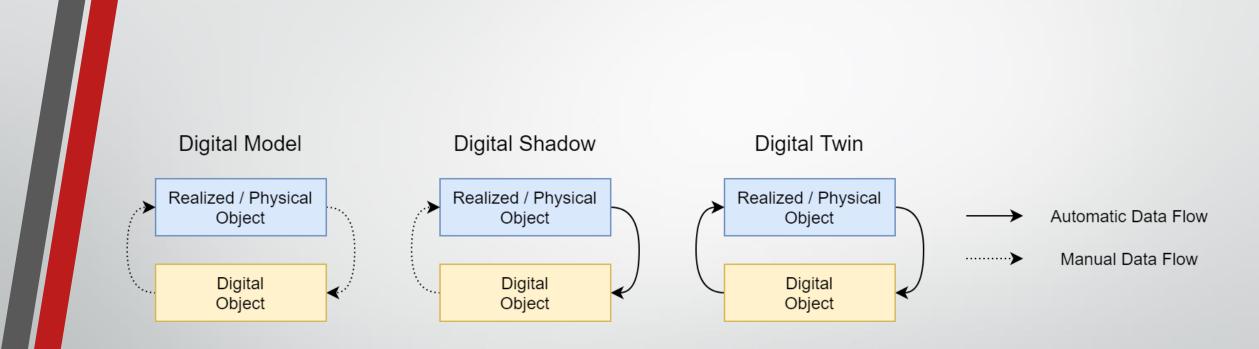
Refining the Idea

#### 2002

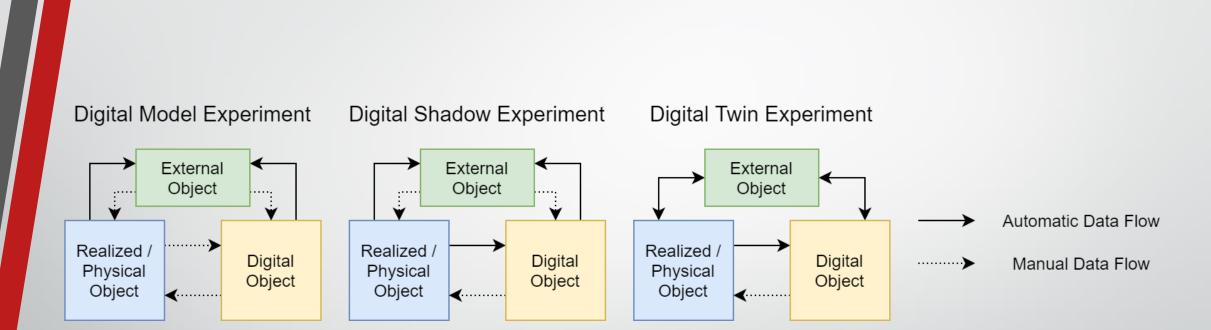
## **Conceptual Ideal for PLM**



#### **Digital Twin Variants**



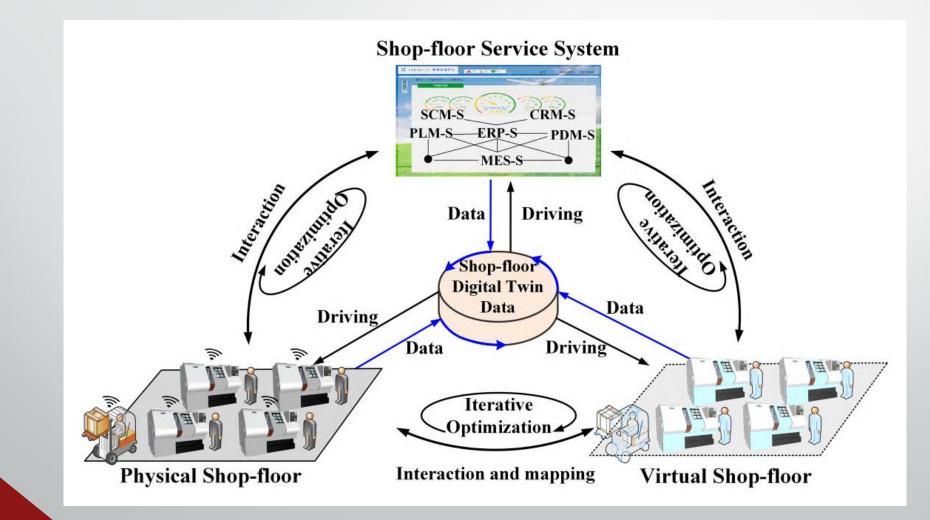
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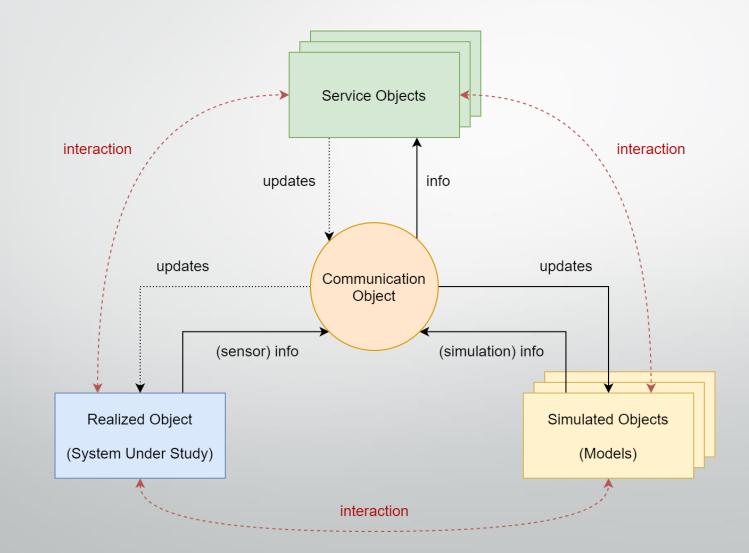
#### Digital Twin Variants: Digital X

R. Paredis, C. Gomes and H. Vangheluwe. 2021. "Towards a Family of Digital Model/Shadow/Twin Workflows and Architectures". In Proceedings of the 2nd IN4PL, pp. 174-182.

#### Digital Twin 5D Model



## Digital Twin Adapted 5D Model



## Variability

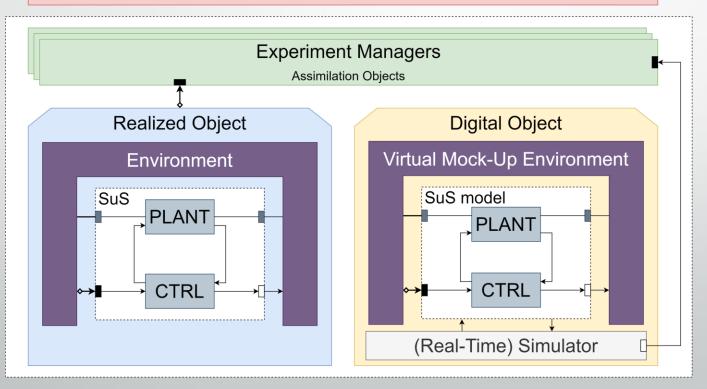
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## **Digital Model**

Reasoners

Historical Information Service

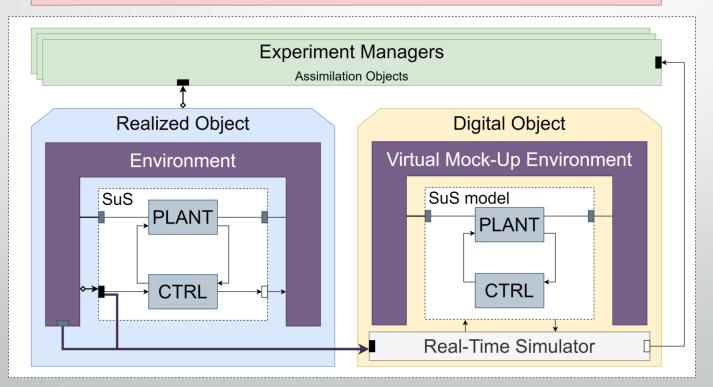
gives access to data, models, experiments, measurements..., stored in a database



## **Digital Shadow**

Reasoners

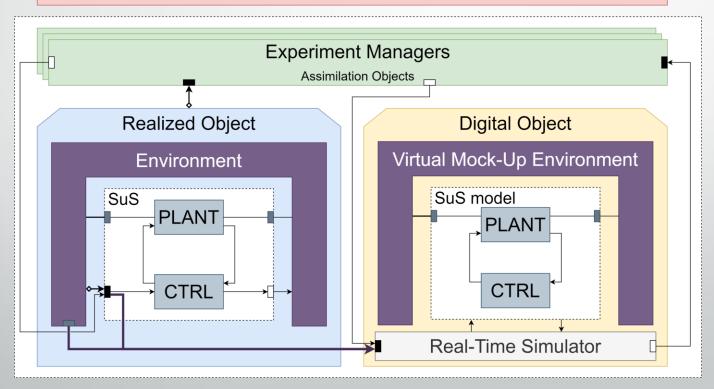
Historical Information Service gives access to data, models, experiments, measurements..., stored in a database



## **Digital Twin**

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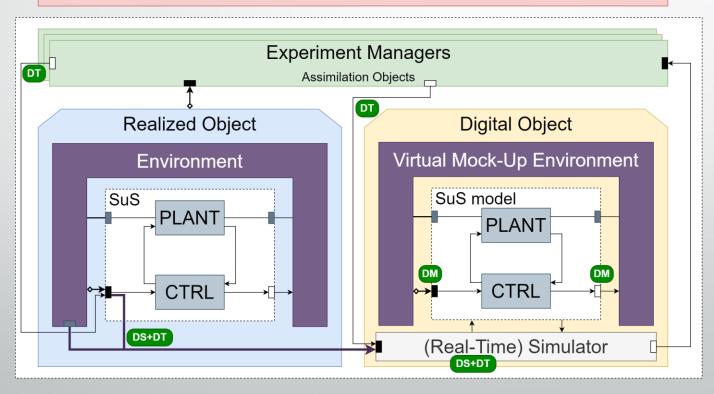
R. Paredis and H. Vangheluwe. 2022. "Towards a Digital Z Framework Based on a Family of Architectures and a Virtual Knowledge Graph". In Proceedings of the 25th MoDELS, pp. 491-496.

#### **Digital T Architecture Variability**

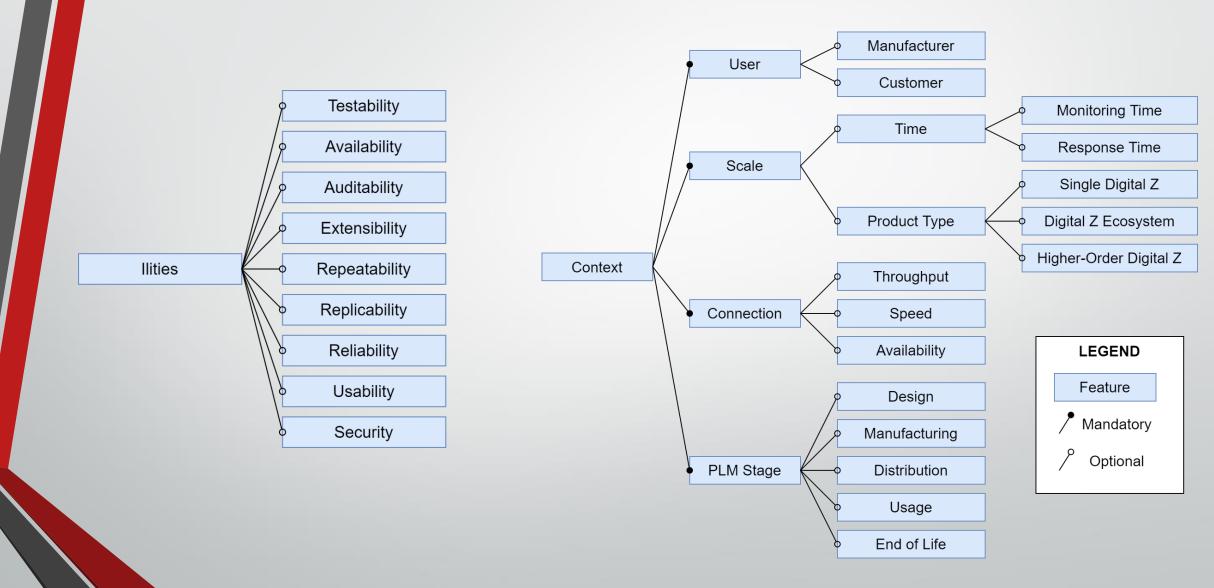
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Historical Information Service

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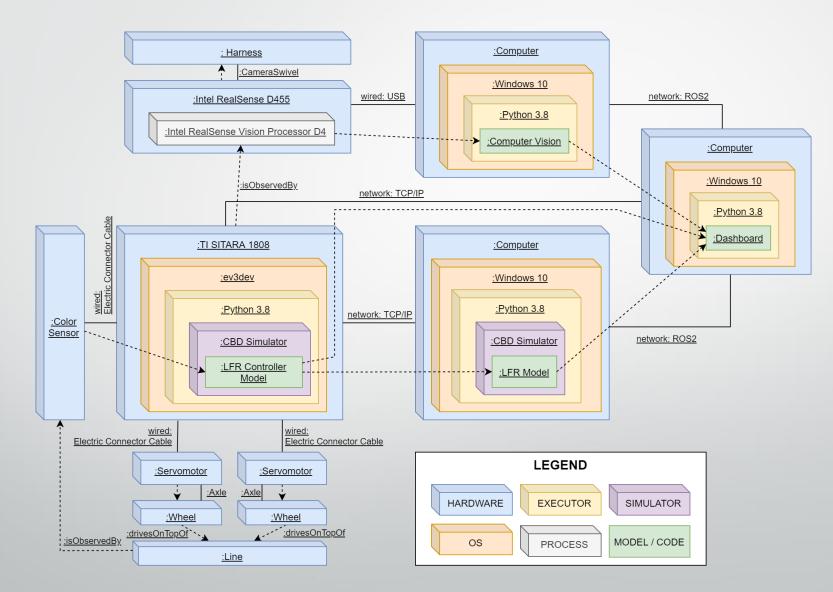


#### **Pol Variability**



R. Paredis, C. Gomes and H. Vangheluwe. 2023. "A Family of Digital T Workflows and Architectures: Exploring Two Cases". In Communications in Computer and Information Science, vol 1855 - Innovative Intelligent Industrial Production and Logistics (IN4PL), Springer, pp. 93-109.

#### **Deployment Variability**



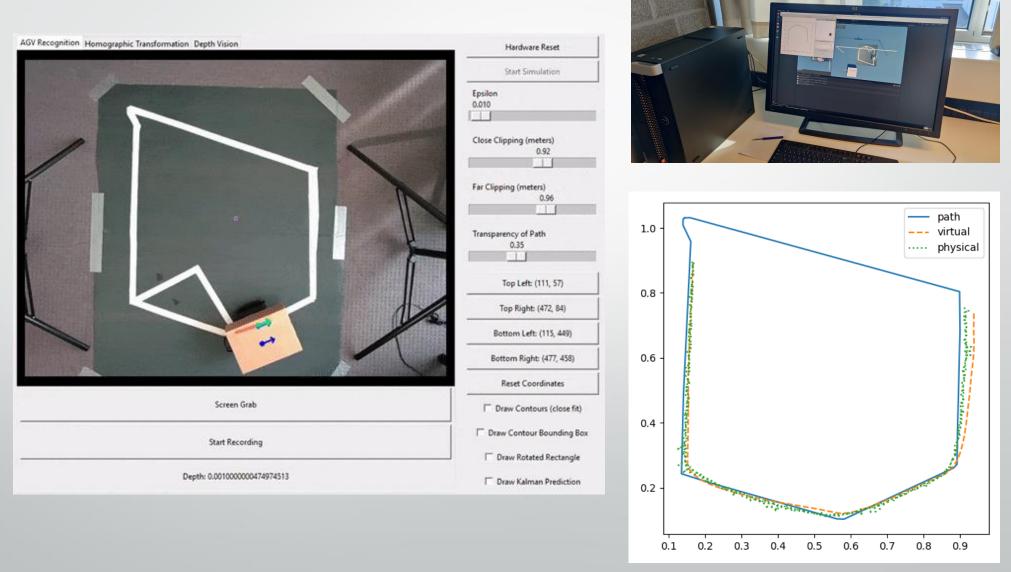
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#### Some Use Cases

Twinning in the Wild

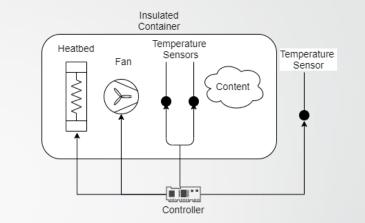


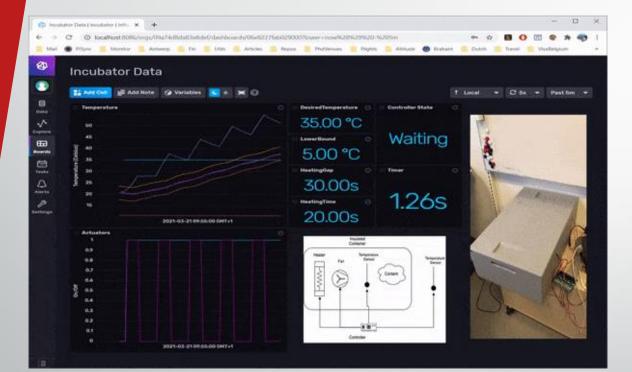
#### AGV/LFR Digital Shadow

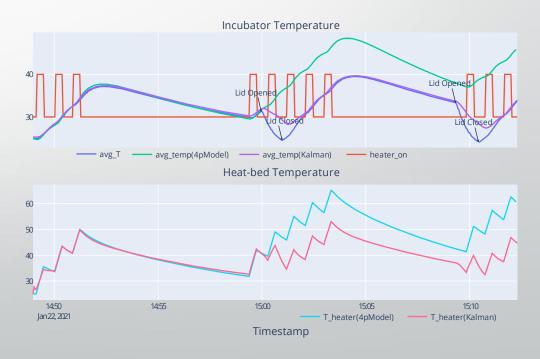


Paredis, R. and H. Vangheluwe. 2021. "Exploring A Digital Shadow Design Workflow By Means Of A Line Following Robot Use-Case". In 2021 Annual Modeling and Simulation Conference (ANNSIM).

#### **Incubator** Digital Twin







Feng, H., Gomes, C. a., Thule, C., Lausdahl, K., losifidis, A., and P. G. Larsen. 2021. "Introduction To Digital Twin Engineering". In 2021 Annual Modeling and Simulation Conference (ANNSIM).

