25th Anniversary Edition

International Conference on Control Systems and Computer Science

Artificial Intelligence Support for Dynamic Digital Twins

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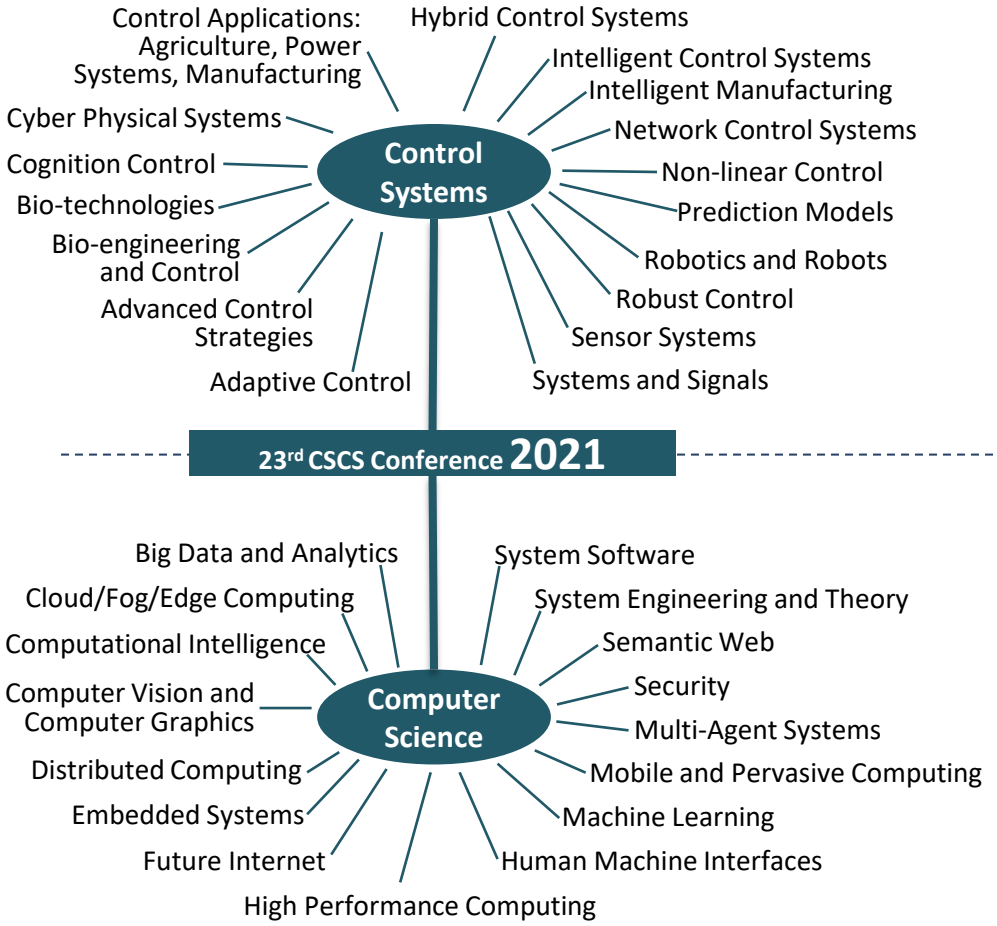
CSCS: Topics of Interest



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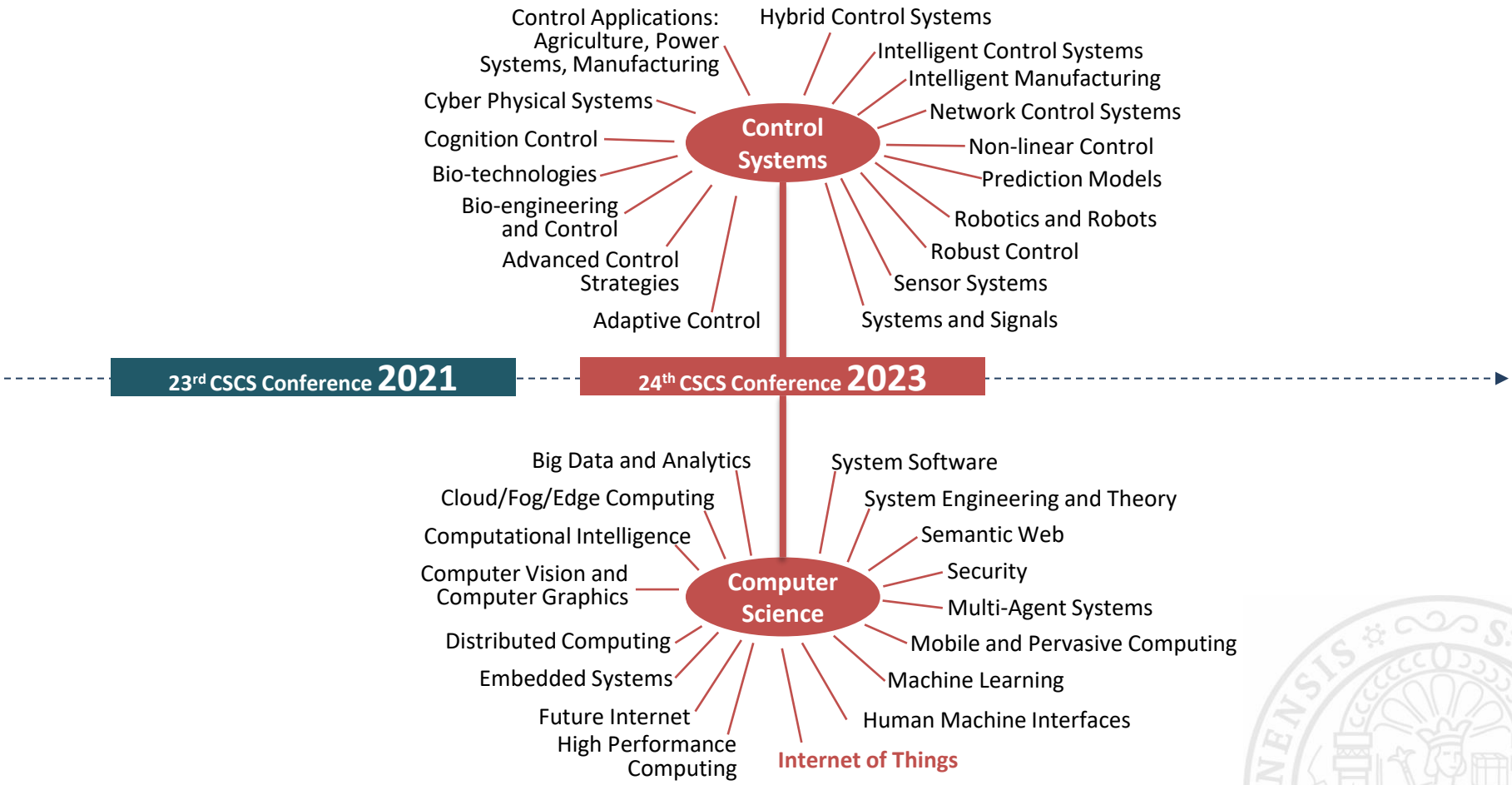

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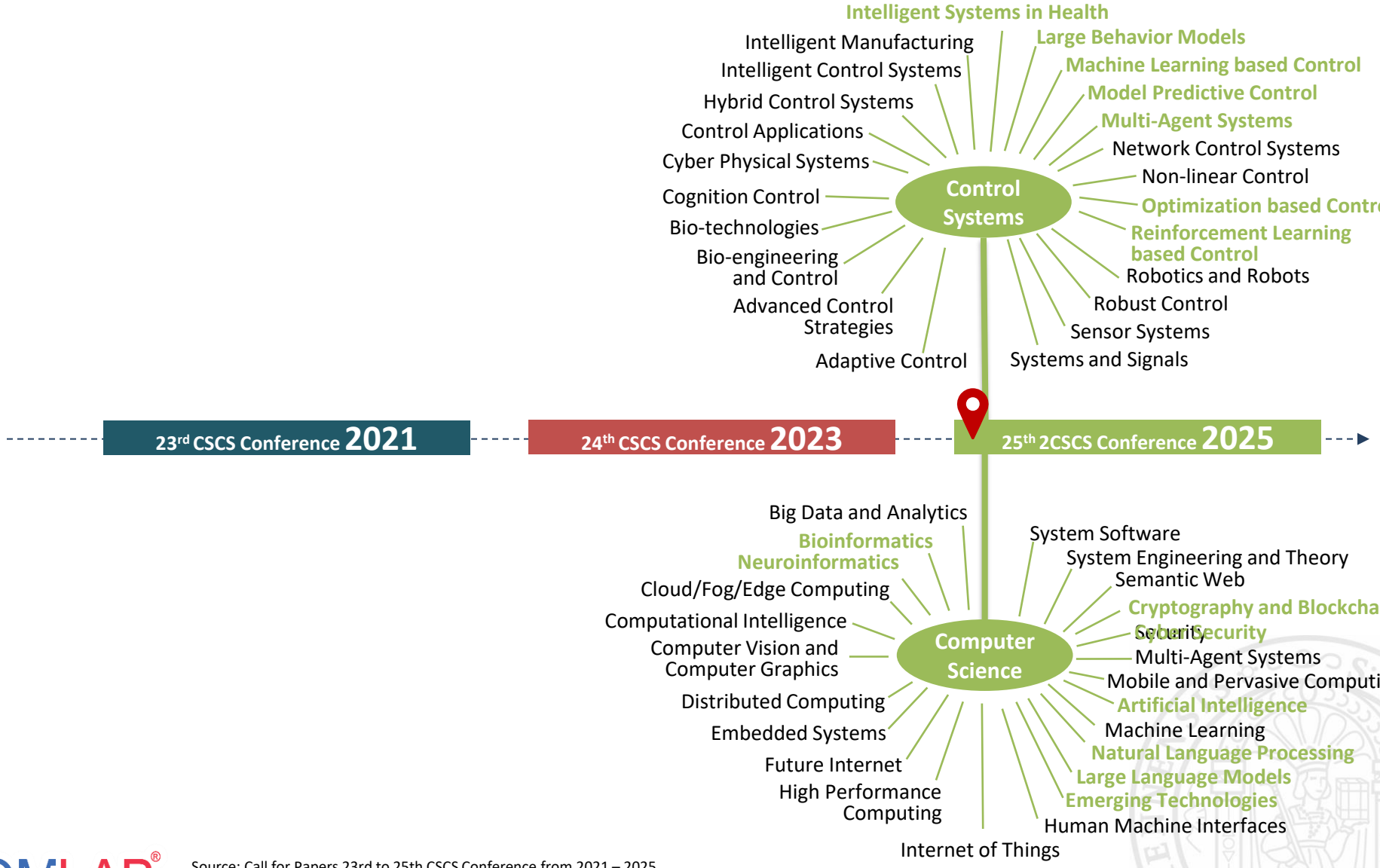
CSCS: Topics of Interest



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CSCS: Topics of Interest

Topics in the intersection?

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Contents

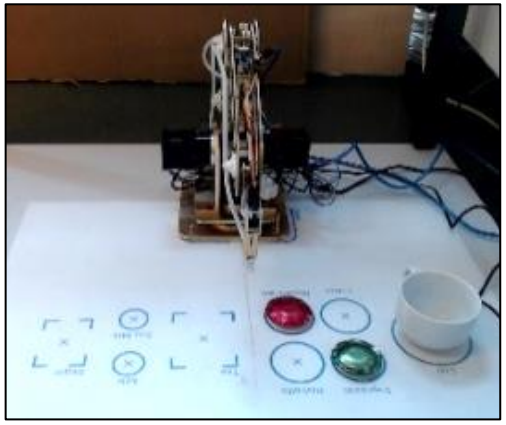
1. Dynamic Digital Twins
2. Conceptual Modeling & Artificial Intelligence
3. Case Studies
4. OMiLAB

1. Dynamic Digital Twins

For what purpose do we use Digital Twins?

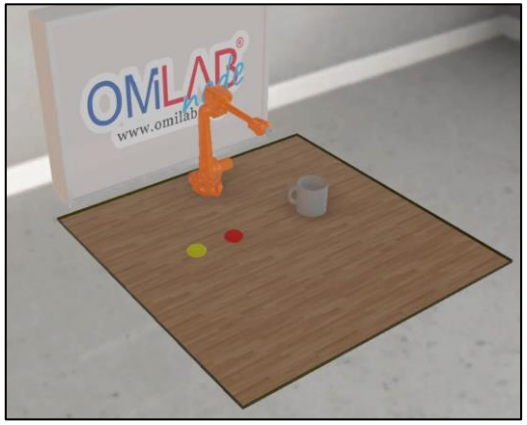
Source: https://www.planet-schule.de/mm/nie-wieder-keine-ahnung/malerei/epochen/surrealismus
(Original from RENÉ MAGRITTE, DER VERRAT DER BILDER, 1928-29)

Digital Representations: The Purpose

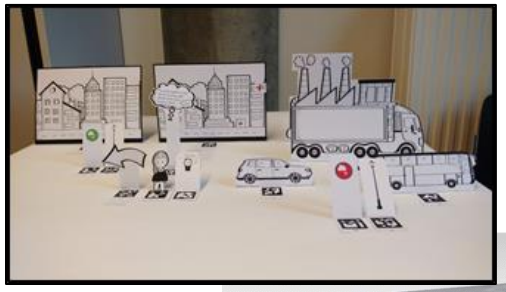


Operational Environment

digitalize

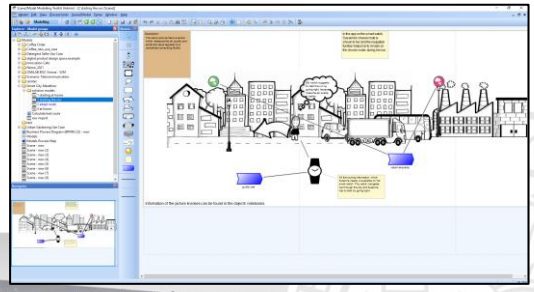


Digital Representation



Design Environment

digitalize

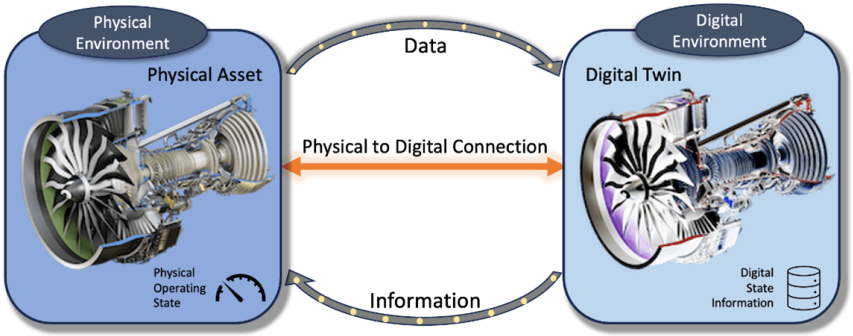


Digital Representation

Source: https://apphaus.sap.com/resource/scenes

The Purpose: Observation

Digital Twin of Physical Objects



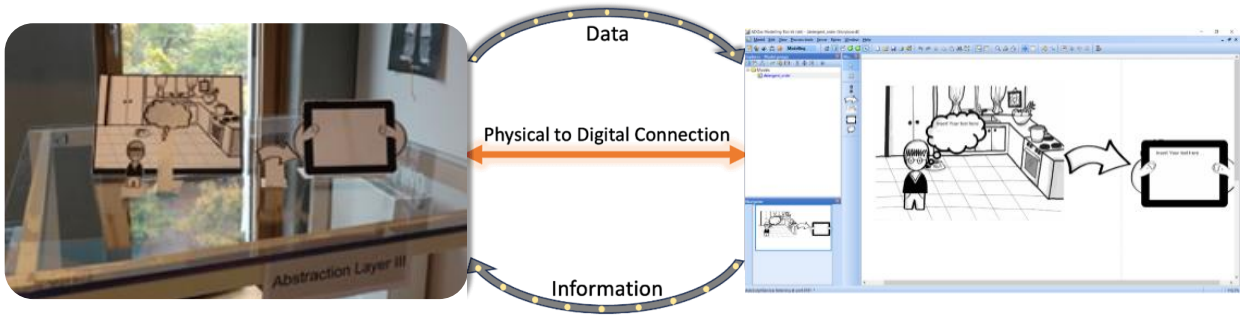
Example:
Observing a jet engine
(real-time or prototyping) [1]

Purpose: Digital Twin for Observation

[1] Banerjee et al. (2024) Digital Twin: A Quick Overview

The Purpose: Design & Operationalization

Digital Twin of Haptic Design Thinking



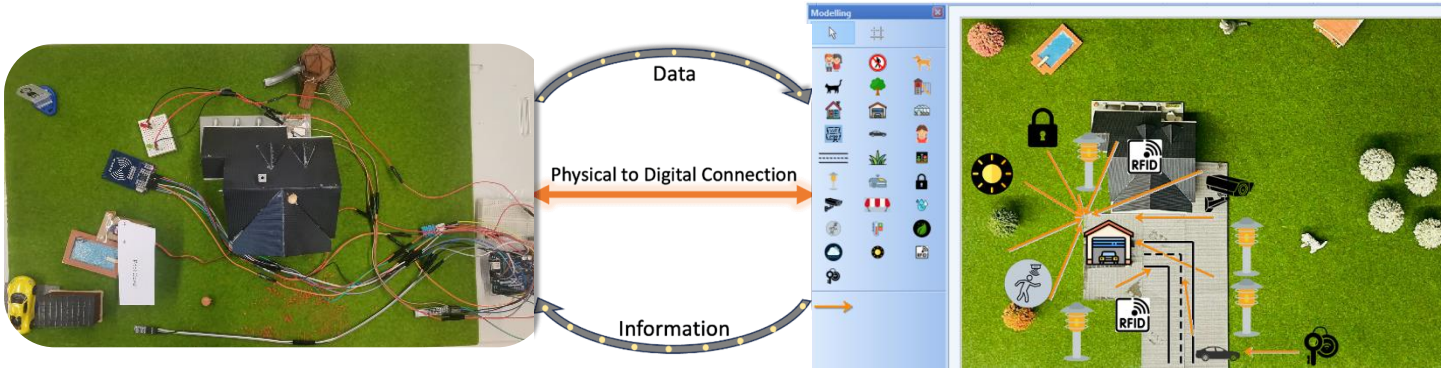
Example:
Designing Innovation Solutions
through Design Thinking

Purpose: Digital Twin for Design

[2] Muck (2024) A Dynamic Adaptation Framework for Haptic Modelling Methods: Creating Digital Twins from Design Thinking.

The Purpose: Design & Operationalization

Digital Twin of Cyber-Physical Environments



Example:
Engineering Cyber-Physical IoT Environments

Purpose: Digital Twin for Operationalization

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[3] Schnellmann & Proper (2025) The HESTIA Framework From an Internet of Things to an Internet of Meaning. (to be published In: Boucher, X., Buchmann, R. A., Fill, H.-G., Kiritsis, D. & Utz, W. (eds.) *Domain-Specific Conceptual Modelling: Volume 3: The OMiLAB Community of Practice. Springer, Cham*)

Digital Twin: A Notion of a Digital Representation

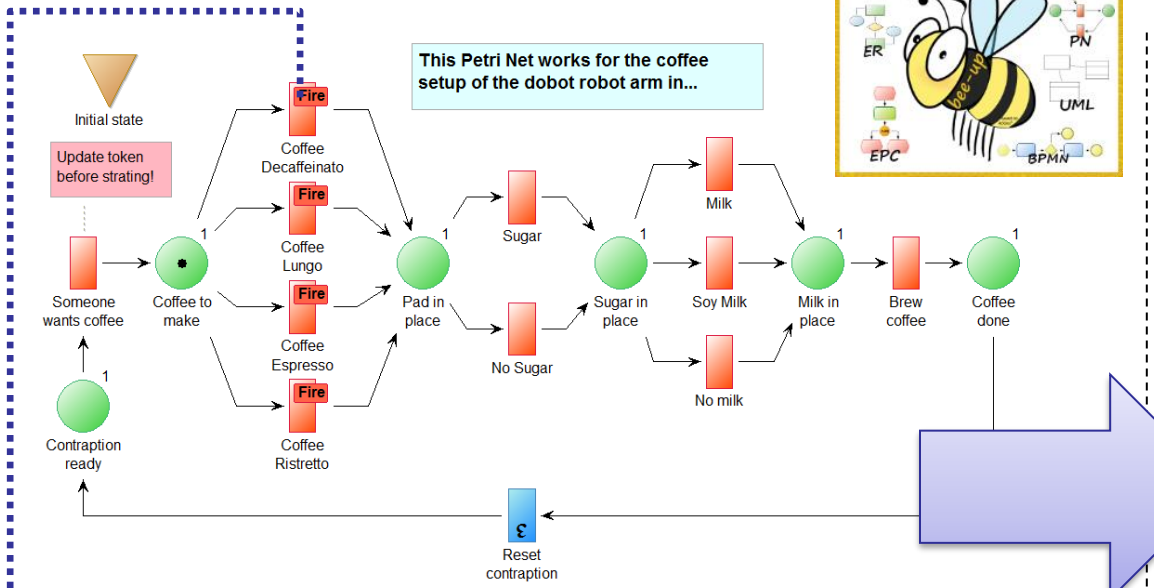
A Digital Twin is a **digital representation** of a system that mirrors its state and behavior through continuous data flow, focusing on monitoring, simulation, and optimization of predefined components.

A Dynamic Digital Twin is an **adaptive digital representation** of a system capable of reflecting structural and contextual changes to enable intelligent adaptations and operations beyond mere data updates.

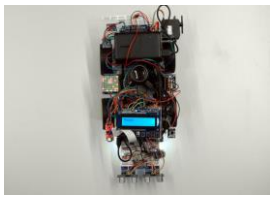
2. Conceptual Modeling & Artificial Intelligence

Two ingredients in today's presentation

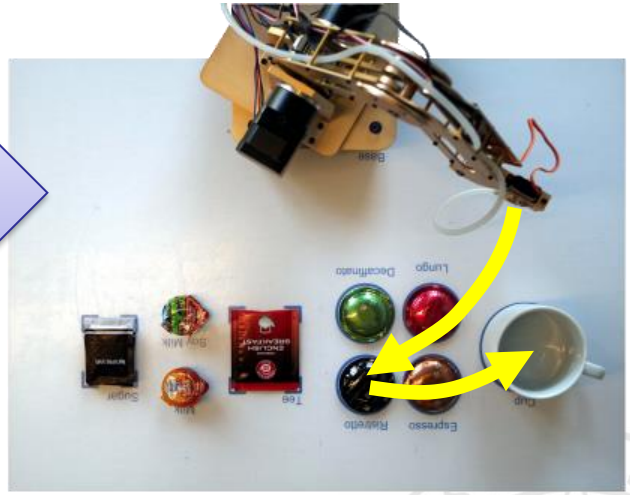
Experiment Setting



OMiLAB -Rob



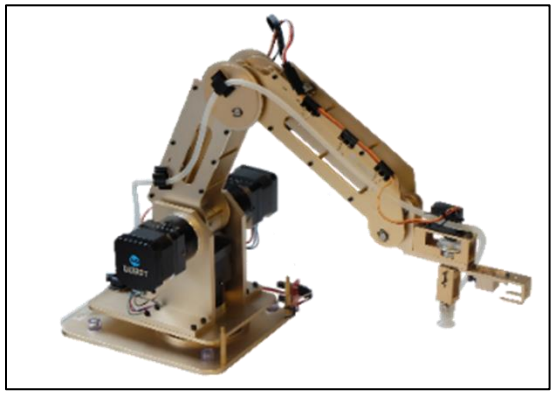
```
HTTP_SEND_REQUEST (str_roboturl + "po[redacted]Z")
str_method:("PUT") …
HTTP_SEND_REQUEST (str_roboturl + "po[redacted]Z")
str_method:("PUT") …
HTTP_SEND_REQUEST (str_roboturl + "grabOn")
str_method:("POST") …
…
```

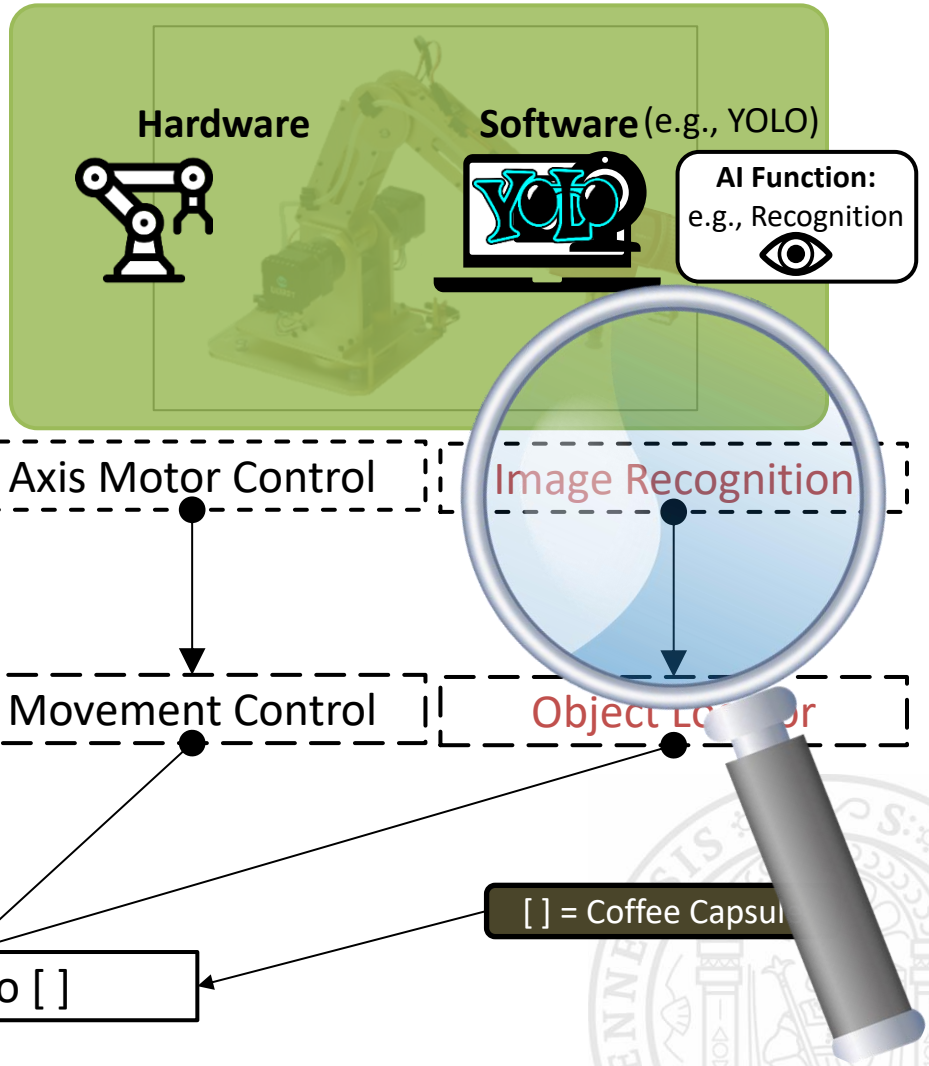


Modell: Petri Netz in Bee-Up

OMiLAB Robot Arm: https://univie.community.omilab.org/experiment/omilab-robotic-arm-1/

Experiment Setting





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Flexible Image Recognition

Input : Scene S, Knowledge Base KB
Output : A graph
Function $OneShotSceneRecognition(S, KB)$
$G \leftarrow \emptyset$
$E \leftarrow ElementLocalisation(S)$
for each element e $\in E$ do
    $(label, KBDescription(e), isKnown) \leftarrow Compare(e, KB)$
    if $isKnown$ then
        $G \leftarrow AddNode(e, \text{label}, KBDescription(e))$
    else
        $Description(e) \leftarrow Describe(e)$
        $(label, KBDescription(e), isKnown) \leftarrow Compare(Description(e), KB)$
        $Description(e) \leftarrow KBDescription(e) \cup Description(e)$
        if $isKnown$ then
            $G \leftarrow AddNode(e, \text{label}, Description(e))$
        else
            $G \leftarrow AddNode(e, \text{USO}, Description(e))$
        end if
    end if
end for
return G
End function

[4] Averty & Kotzinos (2025) Enhancing the S2M Tool - A ResNet50Encoder-Based Add-On for Flexible Object Recognition in Design Thinking. (to be published In: Boucher, X., Buchmann, R. A., Fill, H.-G., Kiritsis, D. & Utz, W. (eds.) *Domain-Specific Conceptual Modelling: Volume 3: The OMiLAB Community of Practice. Springer, Cham*)

Artificial Intelligence: An Abstract View

Some Functions	Some Platforms	Foundations
Classification	scikit-learn	Classification: SVM, Decision Tree, NN, …
Prediction	Alpha Go	Prediction: RNN, LSTM, GNN, …
Recognition	YOLO CNN	Recognition CNN, Computer Vision, …
Generation	ChatGPT	Generation GAN, VAE, Transformer Model, …

SVM: Support Vector Machine
NN: Neural Network
RNN: Recurrent Neural Network
LSTM: Long Short-Term Memory Network
GNN: Graph Neural Network
CNN: Convolutional Neural Network
GAN: Generative Adversarial Network
VAE: Variational Autoencoder

Artificial Intelligence: An Abstract View

Some Functions

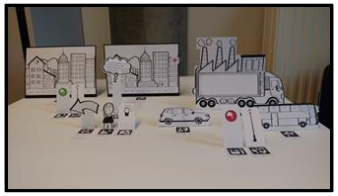
Classification

Prediction

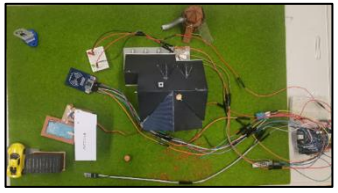
Recognition

Generation

Our Cases



Design Environment



Cyber-Physical Environment

Some Platforms

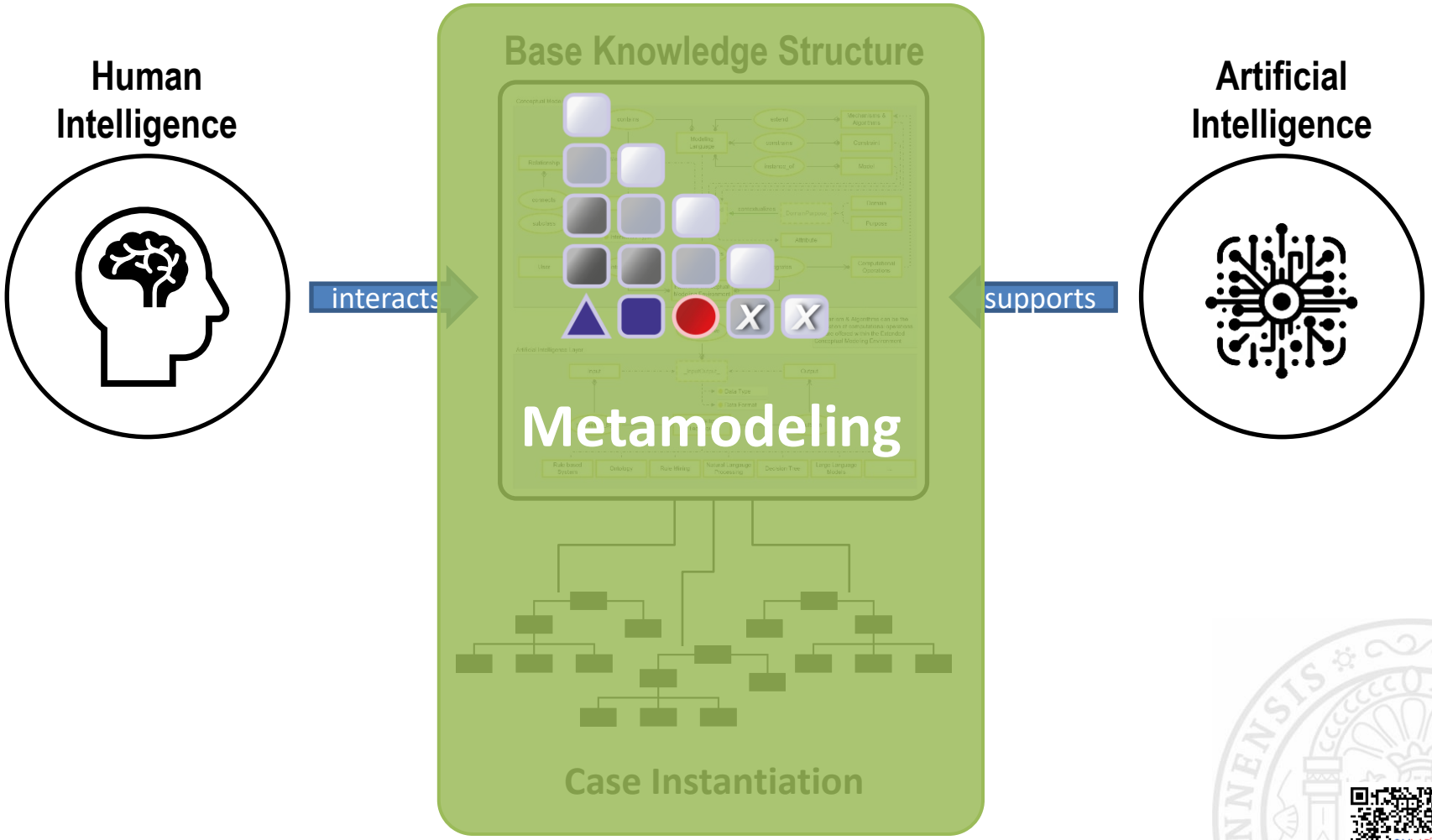
scikit-learn

Alpha Go

YOLO CNN

ChatGPT

Conceptual Modeling: The Metamodeling Approach



[5] Voelz & Strauss (2025) IA4CM: An Intelligence Augmentation Approach for Designing Domain-Specific Conceptual Modeling Methods. (to be published In: Boucher, X., Buchmann, R. A., Fill, H.-G., Kiritsis, D. & Utz, W. (eds.) *Domain-Specific Conceptual Modelling: Volume 3: The OMiLAB Community of Practice. Springer, Cham*)

Source of Knowledge within Artificial Intelligence

predictive, generative, reactive etc.

STOCHASTIC

AI Artifacts

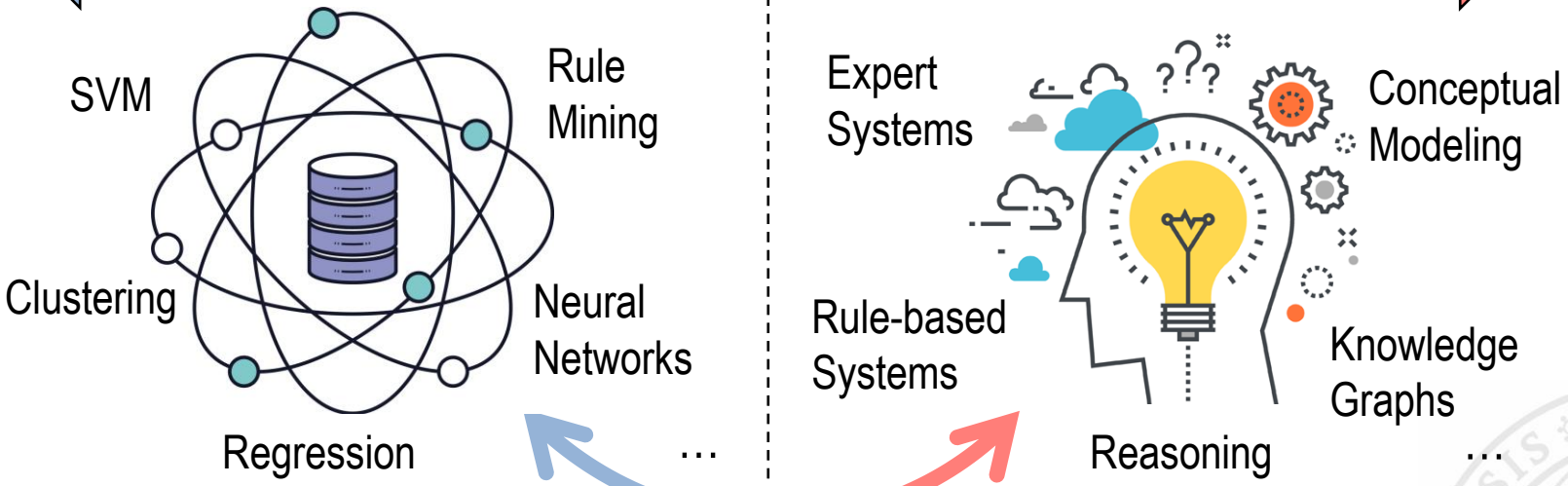
DETERMINISTIC

Data-Driven
(identifying patterns in raw data)

Semantic-Driven
(representing and reasoning with explicit knowledge)

Realized in the Past

Design for the Future



Numbers such as weights represent knowledge.

Symbolic structures and rules represent knowledge

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3. Case Studies

Artificial Intelligence Support

Some Functions

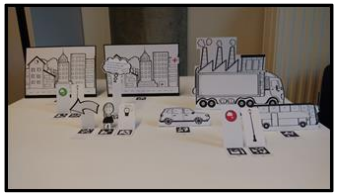
Classification

Prediction

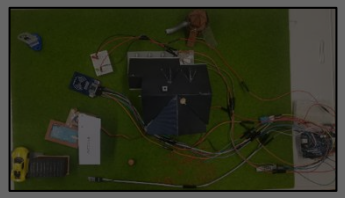
Recognition

Generation

Our Cases



Design Environment



Cyber-Physical Environment

Some Platforms

scikit-learn

Alpha Go

YOLO CNN

ChatGPT

Digital Twin of Haptic Design Thinking

- Physical **Design Thinking** Environment

→ **Result**: haptic design artefact and common understanding by participants

- Digital Diagrammatic **Conceptual Modelling**

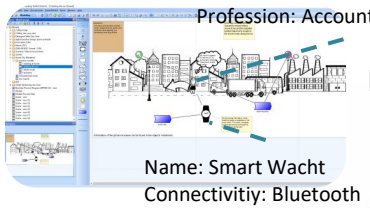
→ **Result**: processable representation of the idea

Goal: Capture results from physical design thinking workshops by automatically creating digital twins

Design Artefact

Recognition

Mapping



Digital Twin

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Digital Twins for Design
The Scene2Model Example

Scene2Model

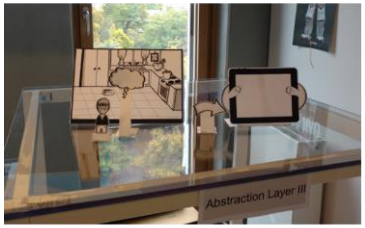
- Scene2Model [3,4]
  - modelling environment, consisting of an ADOxx-based modelling tool in its core and facilitating components
  - enables the transformation of haptic Design Thinking scenes into digital models that can be further adapted, processed, and shared

Transformation of haptic Design Thinking scenes into dynamic Digital Twins.

AI Functions:

Classification **Recognition** **Generation**

Design Artefact



Recognition Mapping

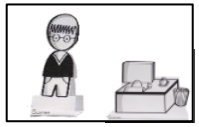
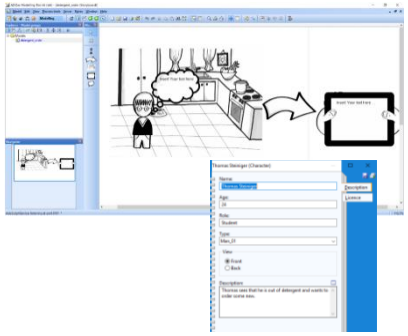


figure recognition

Digital Twin of Design Thinking



Context Information

Utilizing

Additional Services [5]

adaptable figure library

object description & attribute generation

Scene summary

evaluation in Collective Intelligence environments

[2] Muck (2024) A Dynamic Adaptation Framework for Haptic Modelling Methods: Creating Digital Twins from Design Thinking.
[6] Miron et al. (2019) Transforming haptic storyboards into diagrammatic models: The scene2model tool.
[7] Voelz et al. (2024) Digital Twins for Haptic Design Thinking: An Innovative Prototype.

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Artificial Intelligence Support

Some Functions

Classification

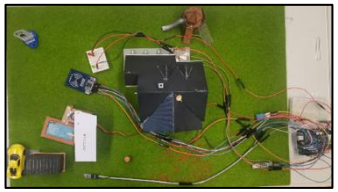
Prediction

Recognition

Generation

Our Cases

Design Environment



Cyber-Physical Environment

Some Platforms

scikit-learn

Alpha Go

YOLO CNN

ChatGPT

Digital Twin of Cyber-physical Systems

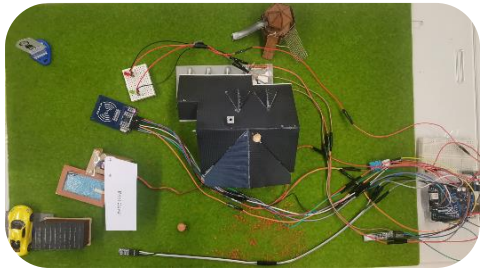
- Dynamic **Cyber-physical Environments**

→ **Result**: components are constantly changing

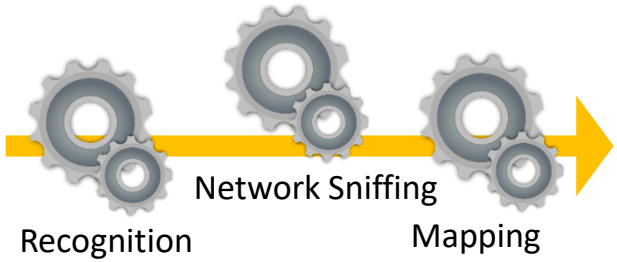
- Digital Twin of **Cyber-Physical Systems**

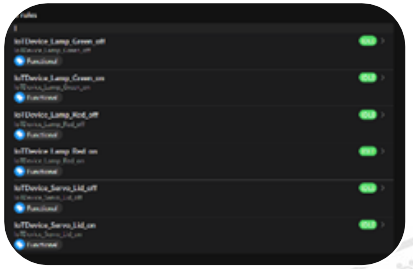
→ **Result**: accurately represent the live state of the physical counterpart

Goal: Create a Digital Twin that is as dynamic as the Environment it represents



Physical Environment





Digital Twin

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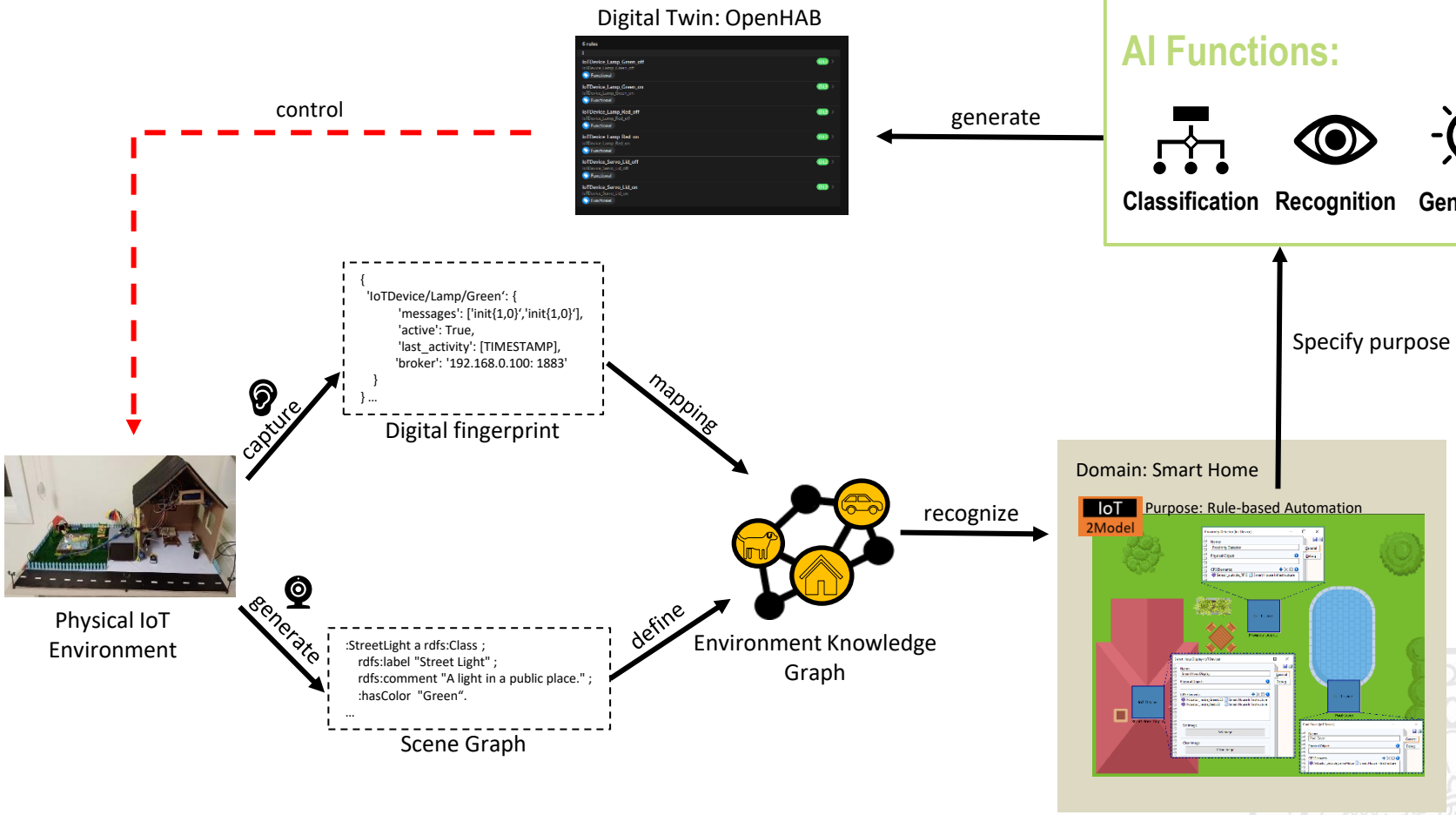
Digital Twins for Operationalisation
The IoT2Model Example

Transformation of physical IoT environments into dynamic Digital Twins.

AI Functions:

Classification | Recognition | Generation



[8] Amlashi et al. (2024) Artificial Intelligence and Internet of Things: A Neuro-Symbolic Approach for Automated Platform Configuration.

4. OMiLAB: Digital Innovation Environment

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OMiLAB: Research Lab

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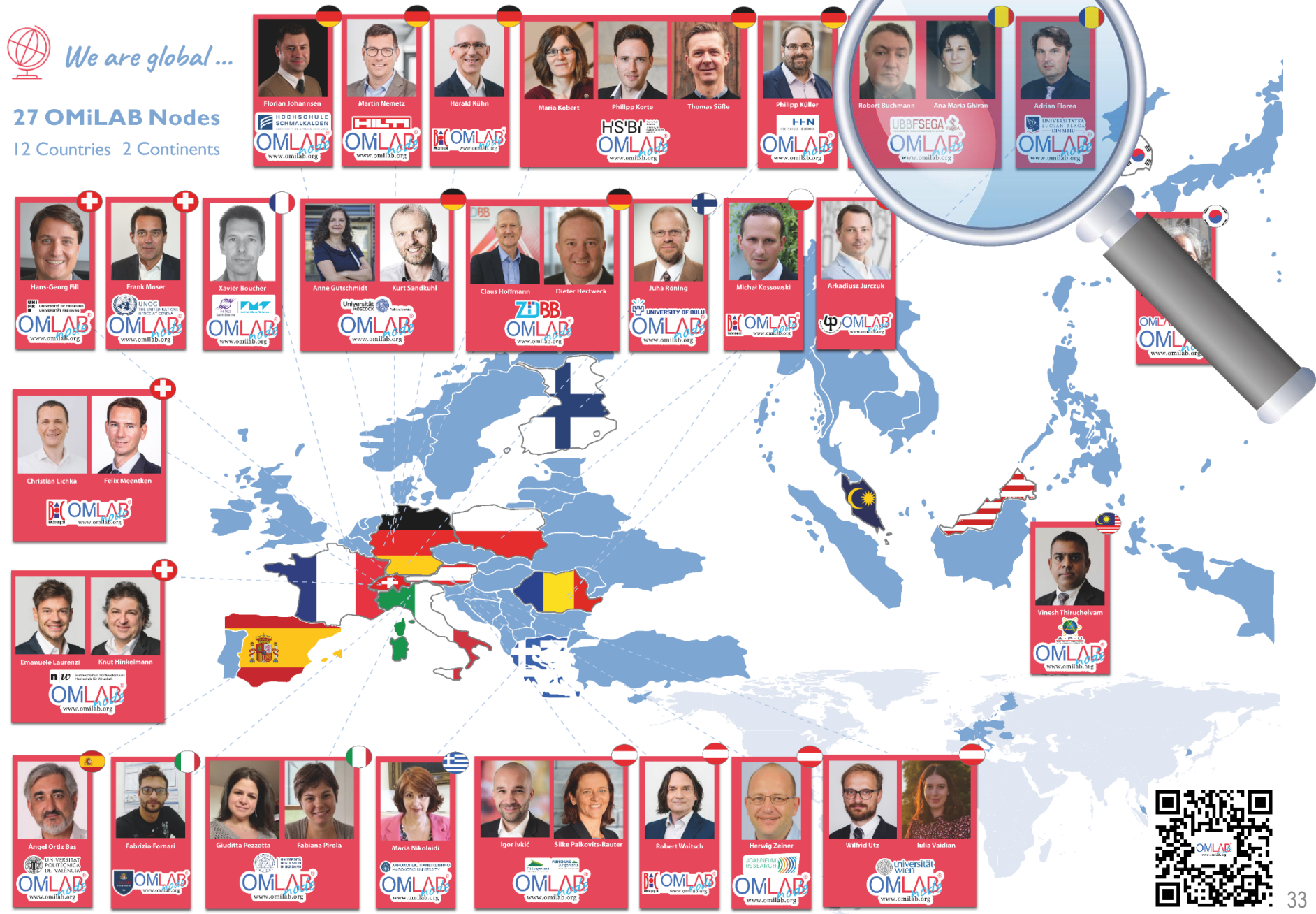
[9] Karagiannis et al. (2020) OMiLAB: A Smart Innovation Environment for Digital Engineers

OMiLAB: A Community of Practice

We are global ...

27 OMiLAB Nodes

12 Countries 2 Continents



Concluding Remarks

Challenge:

How can we make human-interpretable objects interact with machine-interpretable objects?

Our Metamodeling Approach:

A shared metamodel enables the interaction between meaning created in our minds and machine-interpretable representations of this meaning.

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Thank you!

Heraclitus

There is nothing permanent except change.

Access today's material

https://www.omilab.org/activities/events/cscs2025_keynote/

References

[1] Banerjee, B., Chakravarthy, K., Fisher, W., Riley, R., Sabile, E., Sabino, H., Scully, T., Silvas, J., Sinclair, A. E., Soberanis, P., Upadhyay, H., Wells, D., Werner, J. (2024) Digital Twin: A Quick Overview. **The ITEA Journal of Test and Evaluation** 45(1).

[2] Muck, C. (2024) A Dynamic Adaptation Framework for Haptic Modelling Methods: Creating Digital Twins from Design Thinking. University of Vienna.

[3] Schnellmann, M., Proper, H. A. (2025) The HESTIA Framework From an Internet of Things to an Internet of Meaning. (to be published In: Boucher, X., Buchmann, R. A., Fill, H.-G., Kiritsis, D. & Utz, W. (eds.) **Domain-Specific Conceptual Modelling: Volume 3: The OMiLAB Community of Practice**. Springer, Cham)

[4] Averty, P., Kotzinos, D. (2025) Enhancing the S2M Tool - A ResNet50Encoder-Based Add-On for Flexible Object Recognition in Design Thinking. (to be published In: Boucher, X., Buchmann, R. A., Fill, H.-G., Kiritsis, D. & Utz, W. (eds.) **Domain-Specific Conceptual Modelling: Volume 3: The OMiLAB Community of Practice**. Springer, Cham)

[5] Voelz, A., Strauss, C. (2025) IA4CM: An Intelligence Augmentation Approach for Designing Domain-Specific Conceptual Modeling Methods. (to be published In: Boucher, X., Buchmann, R. A., Fill, H.-G., Kiritsis, D. & Utz, W. (eds.) **Domain-Specific Conceptual Modelling: Volume 3: The OMiLAB Community of Practice**. Springer, Cham)

[6] Miron, E.-T., Muck, C., Karagiannis, D. (2019) Transforming haptic storyboards into diagrammatic models: The scene2model tool. In: **Proceedings of the 52nd Hawaii International Conference on System Sciences**, pp. 541–550.

[7] Völz, A., Muck, C., Utz, W. (2024) Digital Twins for Haptic Design Thinking: An Innovative Prototype. In: **19. Internationale Tagung Wirtschaftsinformatik**, Wirtschaftsinformatik 2024 Proceedings.

[8] Amlashi, D. M., Voelz, A., Karagiannis, D. (2024) Artificial Intelligence and Internet of Things: A Neuro-Symbolic Approach for Automated Platform Configuration. **Neurosymbolic Artificial Intelligence**, Special Issue on Neuro-Symbolic AI and Domain Specific Conceptual Modelling.

[9] Karagiannis, D., Buchmann, R. A., Boucher, X., Cavalieri, S., Florea, A., Kiritsis, D., Lee, M. (2020) OMiLAB: A Smart Innovation Environment for Digital Engineers In: L. M. Camarinha-Matos, H. Afsarmanesh, A. Ortiz (Eds.), **Boosting Collaborative Networks 4.0**, Springer International Publishing, Cham, 2020, pp. 273–282.