Extended Taxonomy of Digital Twins

WESC2023 - Mini Symposia: Digital twins for lifetime assessment of structures

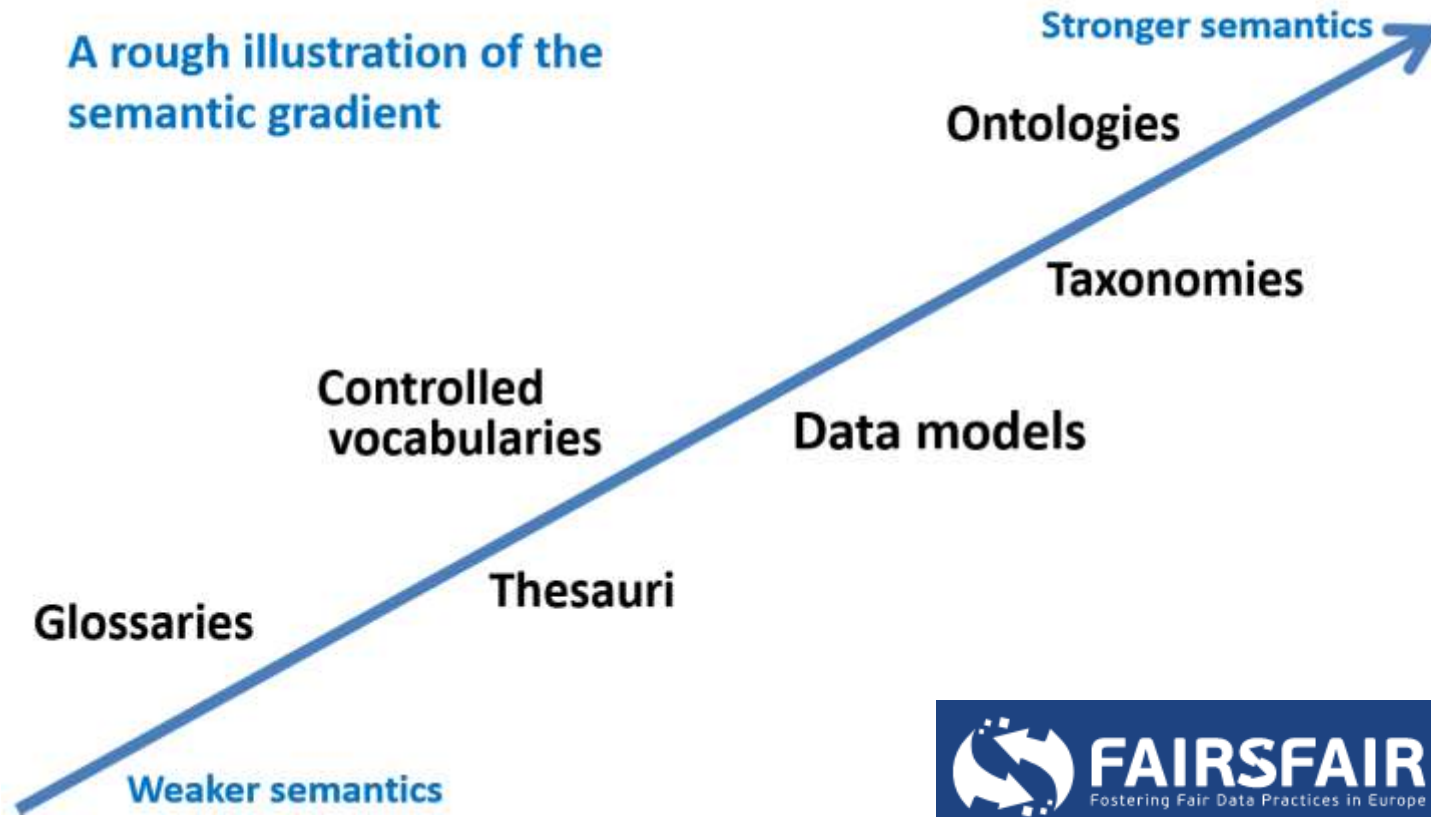**Yuriy Marykovskiy[1,2], Imad Abdallah[2], Sarah Barber[1] and Eleni Chatzi[2]**
[1]Eastern Switzerland University of Applied Sciences
[2]ETH Zurich

25th May 2021

Contents

- Semantic Artifacts and Knowledge Organisation Systems

- Digital Twin Taxonomy

- Use Cases

  - Linked data: Metadata

  - Application Ontology Development: Structural Health Monitoring of Wind Turbines
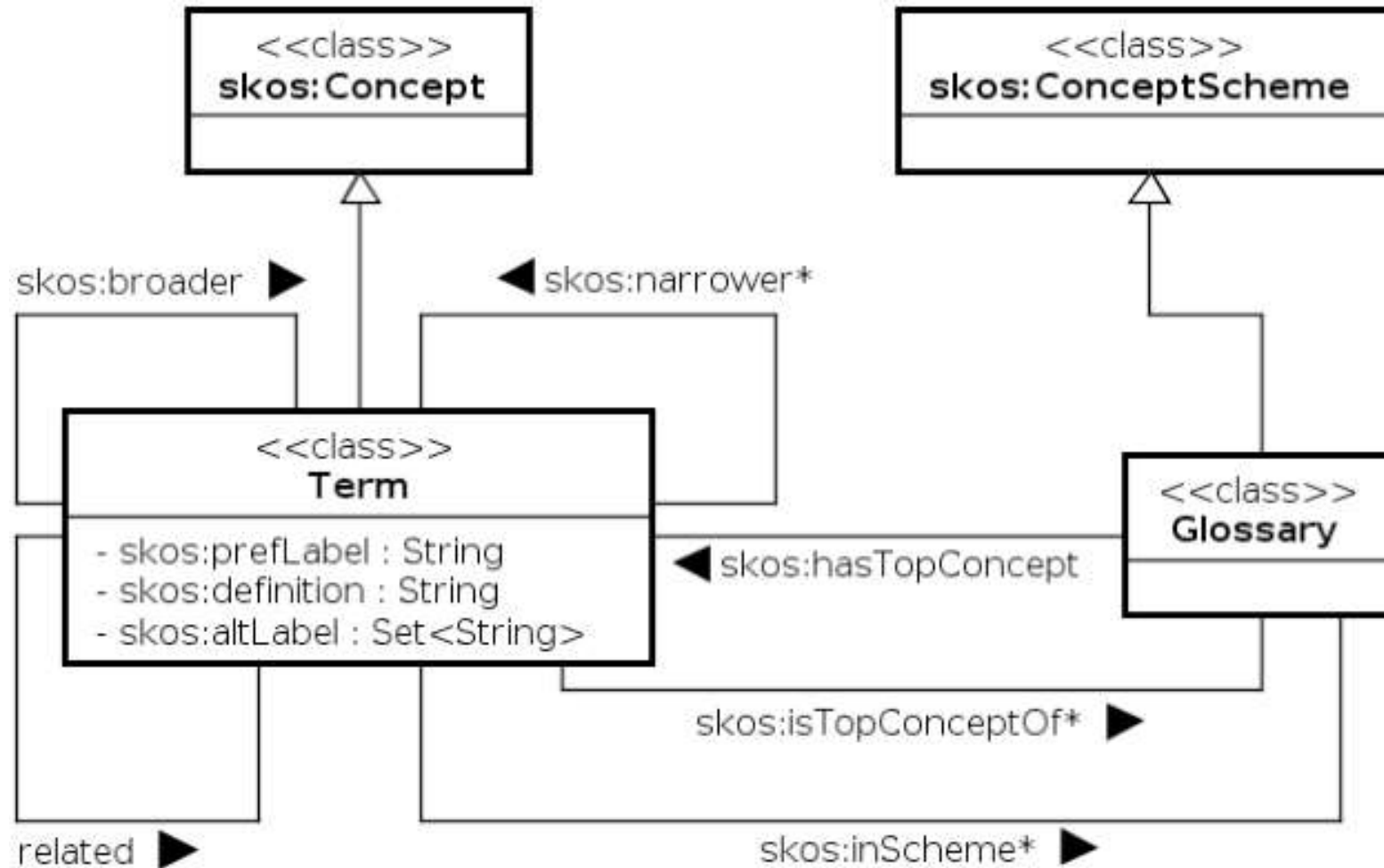
- Conclusions

Semantic artifacts

A rough illustration of the semantic gradient

Stronger semantics

Ontologies

Taxonomies

Controlled vocabularies

Data models

Thesauri

Glossaries

Weaker semantics

FAIRSFAIR
Fostering Fair Data Practices in Europe

Why should you care?

Semantic models as main building block of DT, makes it a lot easier to do logical reasoning for inference, e.g. for decision support tools and recommendation systems
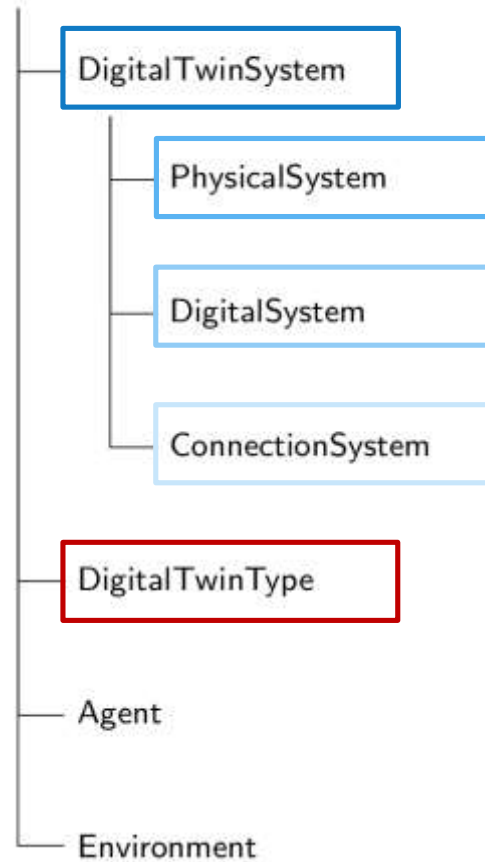
AEROSENSE
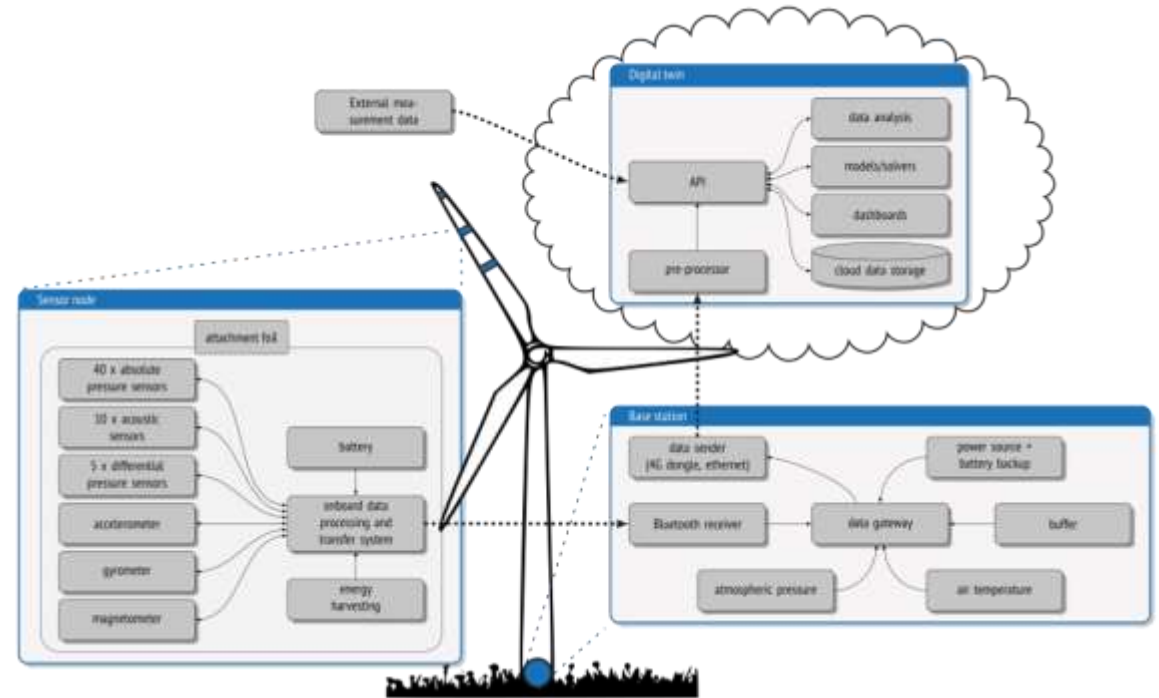
Simple Knowledge Organisation System (SKOS)

Image From: Ledvinka, Martin & Kremen, Petr & Saeeda, Lama & Blasko, Miroslav. (2020).
TermIt: A Practical Semantic Vocabulary Manager.

Digital Twin Conceptual Model: Core

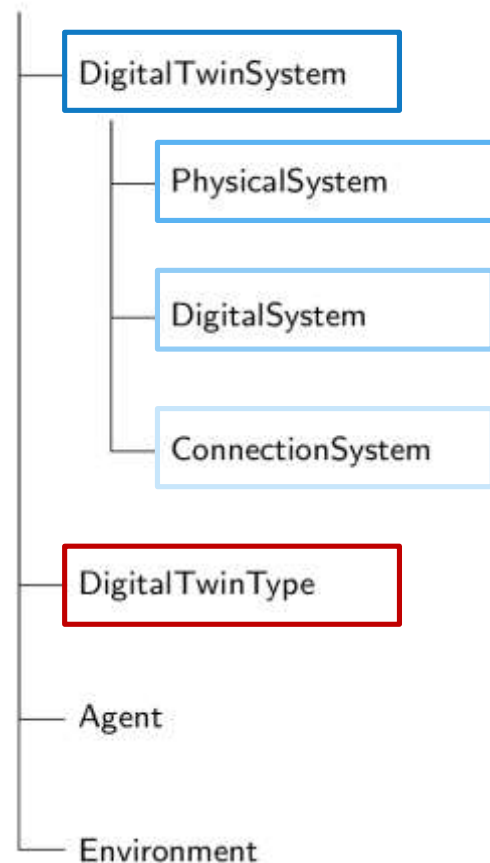**"Duality" and "Strong similarity"**

Digital Twin Type – an example introduced by Kritzinger
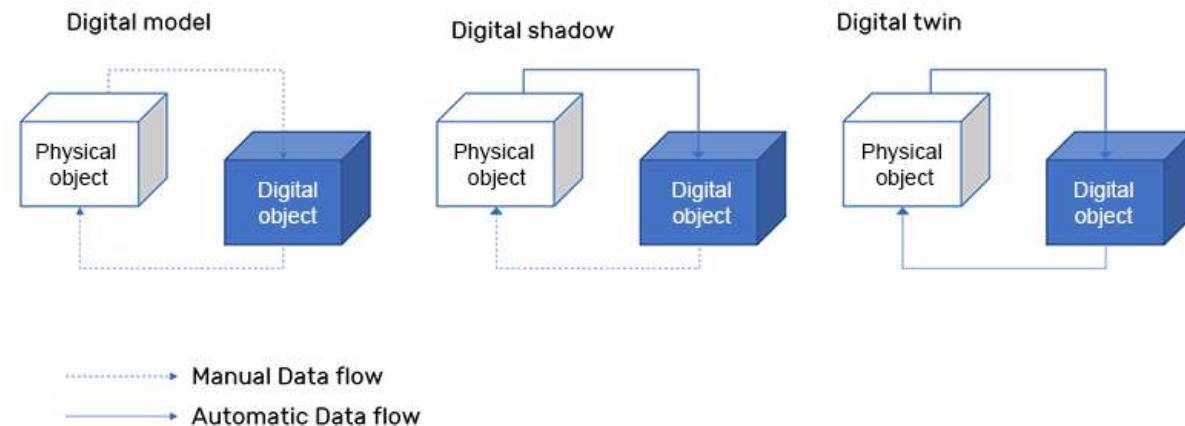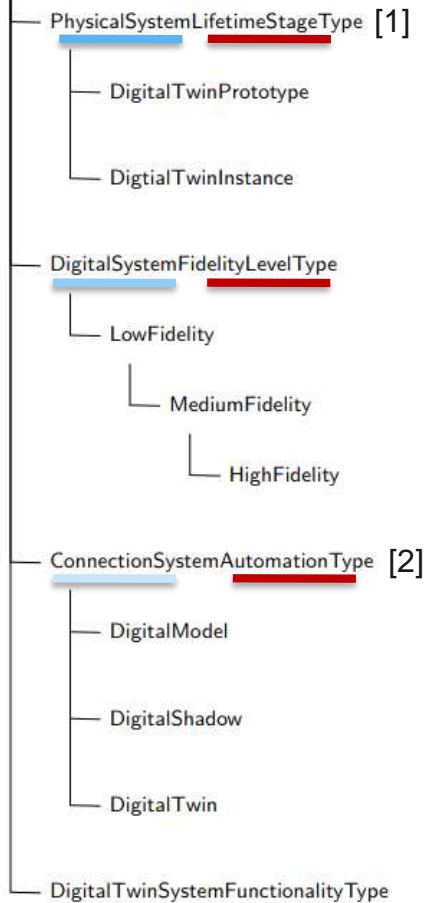
[1] Grieves, M., Vickers, J. (2017). Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems. In: Kahlen, J., Flumerfelt, S., Alves, A. (eds) Transdisciplinary Perspectives on Complex Systems. Springer, Cham.

[2] Kritzinger, Werner, Matthias Karner, Georg Traar, Jan Henjes and Wilfried Sihn. "Digital Twin in manufacturing: A categorical literature review and classification." IFAC-PapersOnLine 51 (2018): 1016-1022.

Digital Twin System Type – an example based on Amazon classification approach

DigitalTwinType
- PhysicalSystemLifetimeStageType
- DigitalSystemFidelityLevelType
- ConnectionSystemAutomationType
- DigitalTwinSystemFunctionalityType
  - SupervisoryDigitalTwin [1]
    - OperationalDigitalTwin
      - SimulationPredictionDigitalTwin
        - IntellegentLearningDigitalTwin
          - AutonomousManagementDigitalTwin
  - L1DescriptiveDigitalTwin [2]
    - L2InformativeDigitalTwin
      - L3PredictiveDigitalTwin
        - L4LivingDigitalTwin
  - CognitiveDigitalTwin [3]

L1 DESCRIPTIVE — Engineering design and visual representation.

L2 INFORMATIVE — Integration of IoT, asset history, and maintenance data.

L3 PREDICTIVE — Predictions of unmeasured quantities and future states based on historical data.

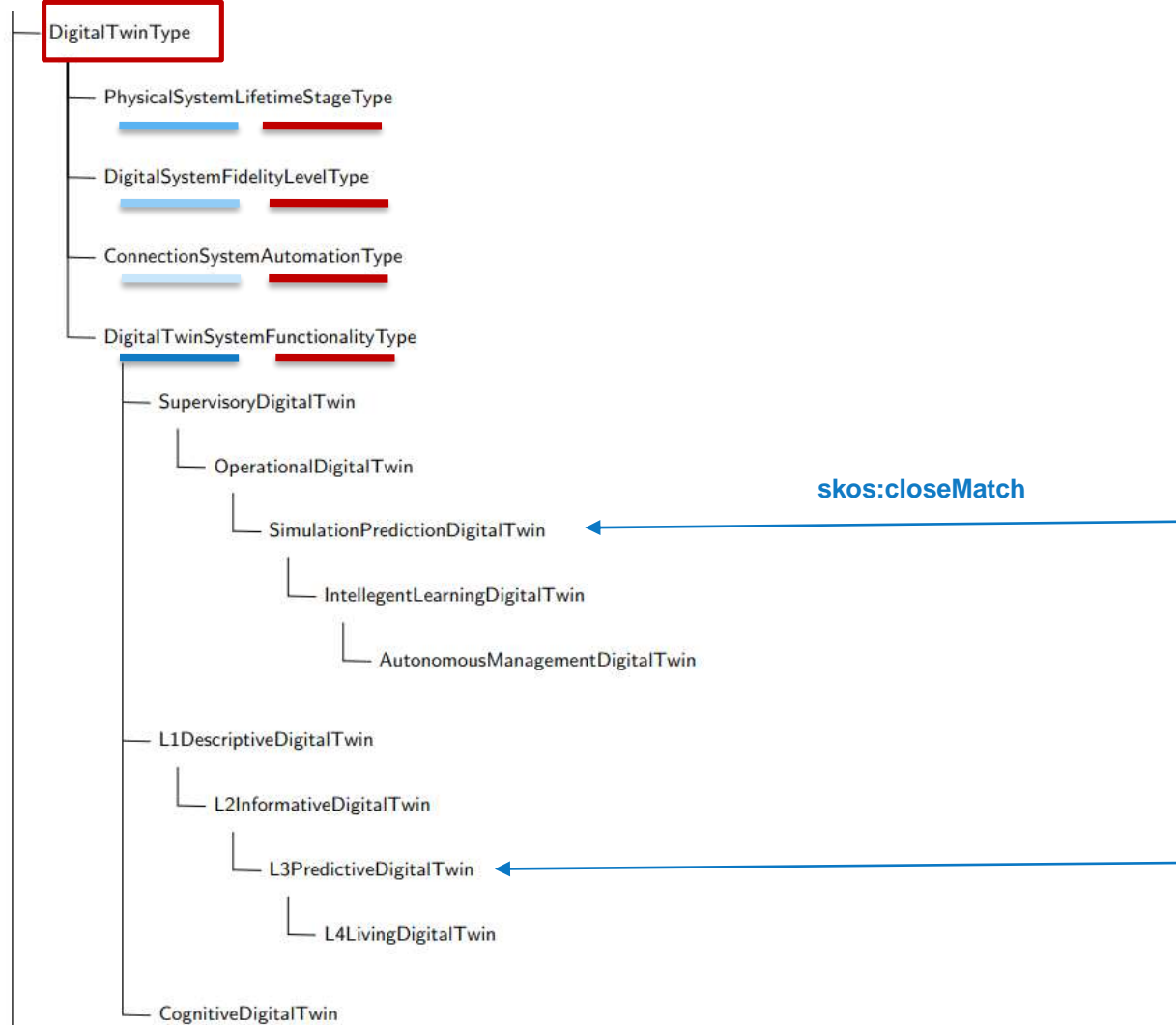**L4 LIVING DIGITAL TWIN** — Updatable models to drive actionable insights.

DT Levels framework adapted from: Verdantix, Five Digital Twin Strategies For Industrial Facilities, 2019.

[1] Wagg, D. J., Worden, K., Barthorpe, R. J., and Gardner, P.: Digital Twins: State-of-the-Art and Future Directions for Modeling and Simulation in Engineering Dynamics Applications, ASCE-ASME J Risk and Uncert in Engrg Sys Part B Mech Engrg, 6
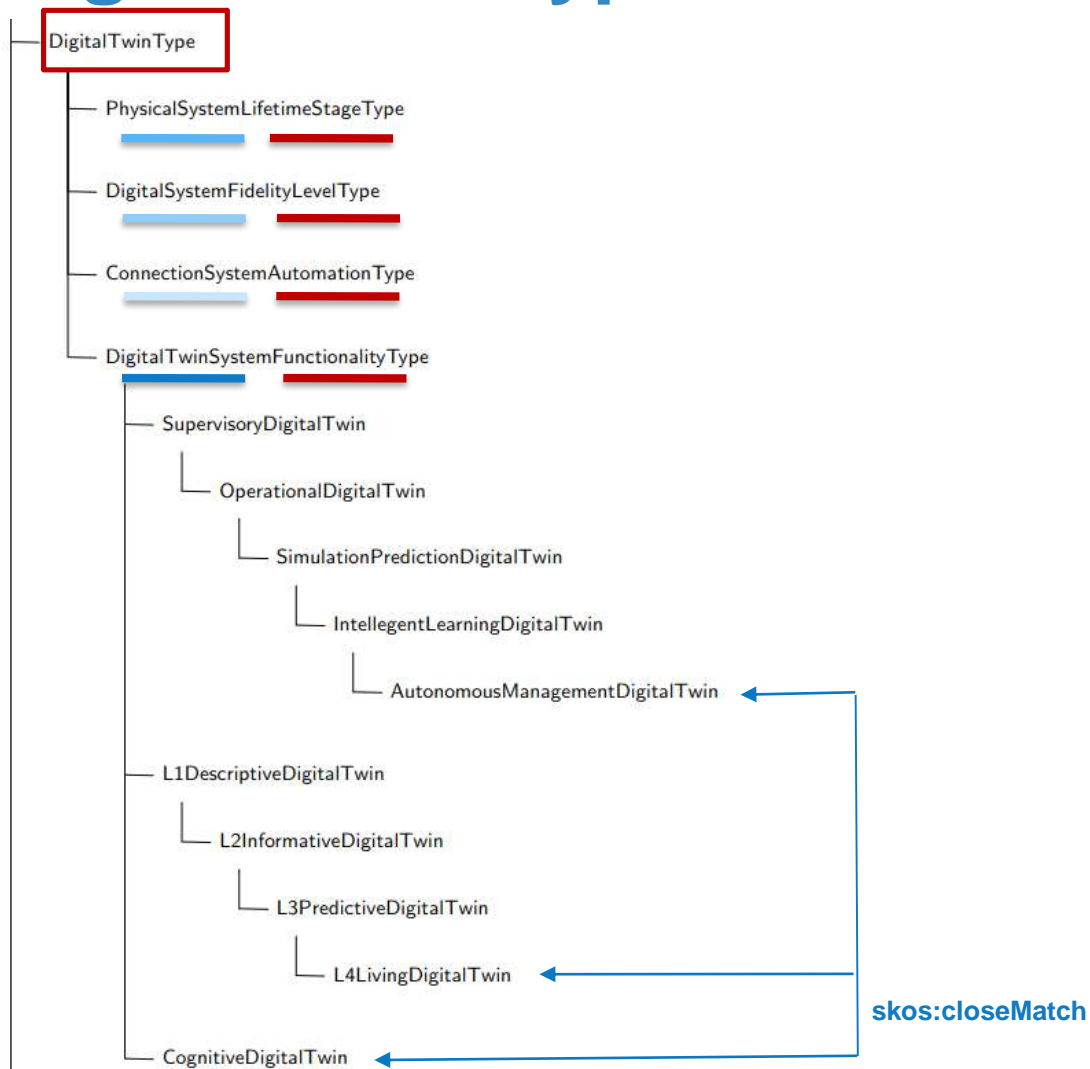
[2] Digital Twins on AWS: Driving Value with L4 Living Digital Twins by Adam Rasheed, David Sauerwein, Seibou Gounteni, and Pablo Hermoso Moreno | on 06 OCT 2022 | in AR & VR, Artificial Intelligence, Compute, High Performance Computing, Internet of Things, Storage, Thought Leadership

[3] Zheng, X.; Lu, J.; Kiritsis, D. The emergence of cognitive digital twin: vision, challenges and opportunities. International Journal of Production Research 2021, 0, 1–23
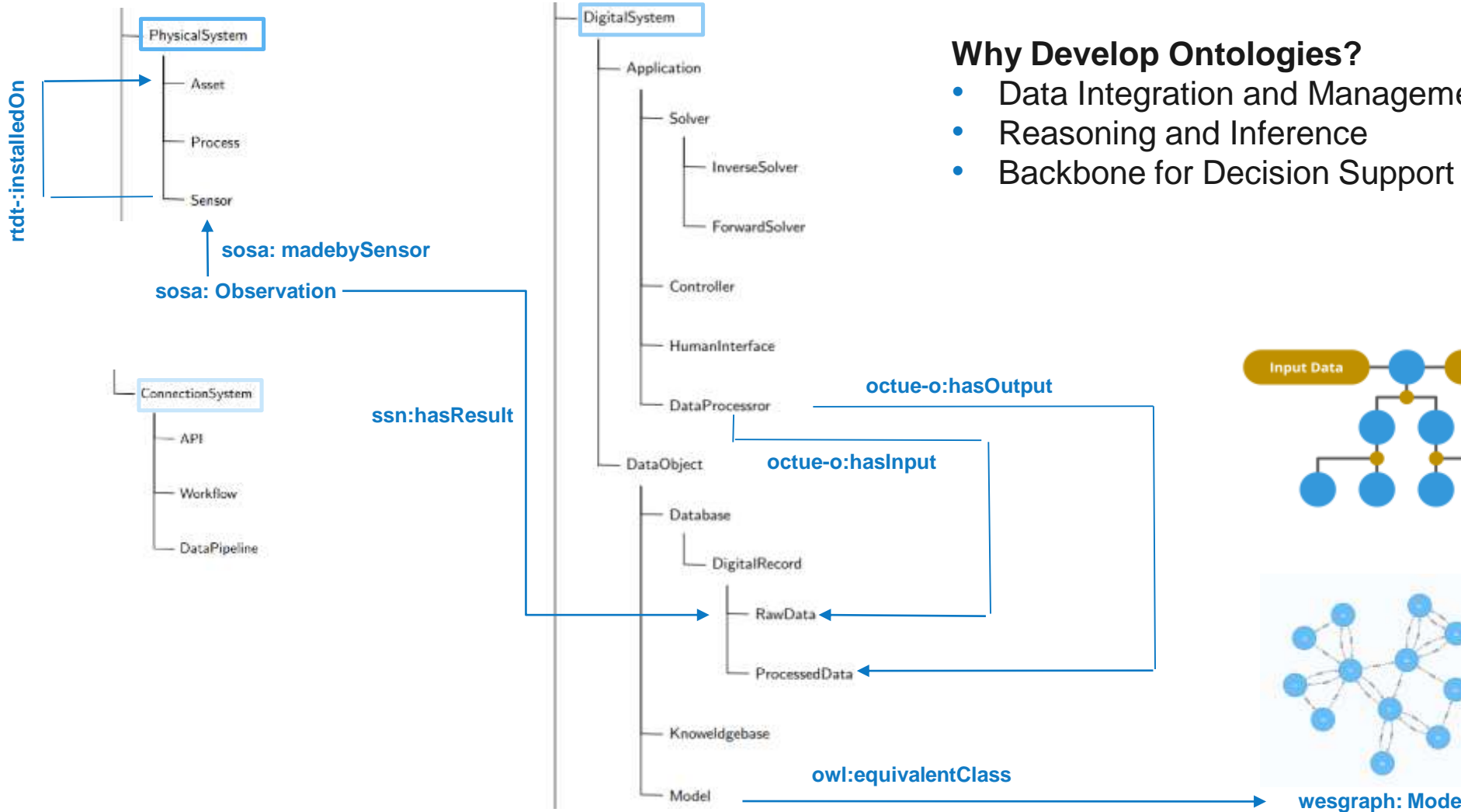
Digital Twin Type: SKOS Mapping

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— L4LivingDigitalTwin
— CognitiveDigitalTwin

skos:closeMatch

Digital Twin Type: SKOS Mapping

skos:closeMatch

Use Cases: Application Ontology Development

PhysicalSystem
- Asset
- Process
- Sensor

rtdt-:installedOn

sosa: madebySensor

sosa: Observation

ConnectionSystem
- API
- Workflow
- DataPipeline

ssn:hasResult

DigitalSystem
- Application
  - Solver
    - InverseSolver
    - ForwardSolver
  - Controller
  - HumanInterface
  - DataProcessror
- DataObject
  - Database
    - DigitalRecord
      - RawData
      - ProcessedData
  - Knoweldgebase
  - Model

octue-o:hasOutput

octue-o:hasInput

owl:equivalentClass

Why Develop Ontologies?
- Data Integration and Management, Standardisation
- Reasoning and Inference
- Backbone for Decision Support Systems

Input Data   Output Data

wesgraph: Model

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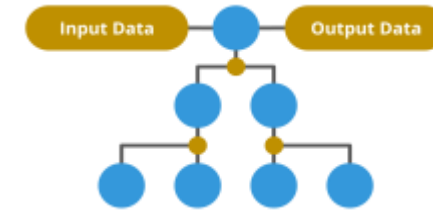
Use Cases: Linked-Data / Annotation

- Accademia data models – Research output visibility, classification, recommendations

  - Dublin Core

  - Semantic Scholar (knowledge graphs)

- Commercial – Services and Product SEO

  - Microdata: JSON-LD
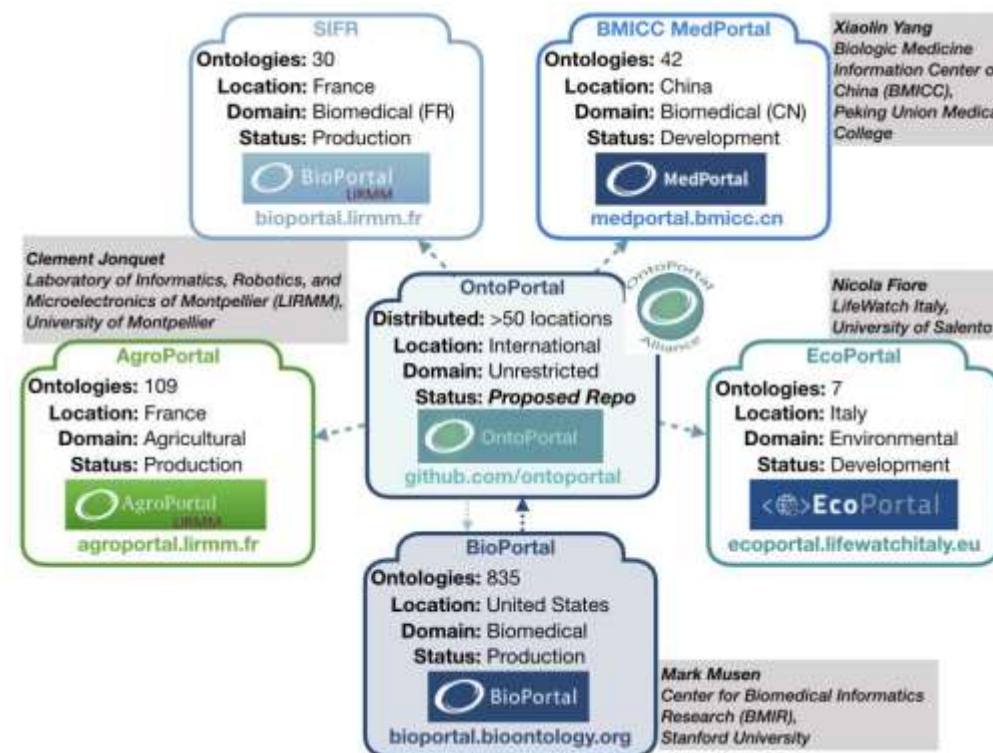
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Thank you for your attention!

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Aerosense at WESC:

- **Julien Deparday - How to analyse blade aerodynamics on an operating wind turbine with low-cost pressure sensors?**

- **Florian Hammer - Application of an Open Source Data Platform for Wake Effect Investigation**

- **Gregory Duthé - A Graph Neural Network Approach for Aerodynamic Sensor Placement**

- **Imad Abdallah - Simulations and experimental validation of structural damage detection using aerodynamic pressure data**

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