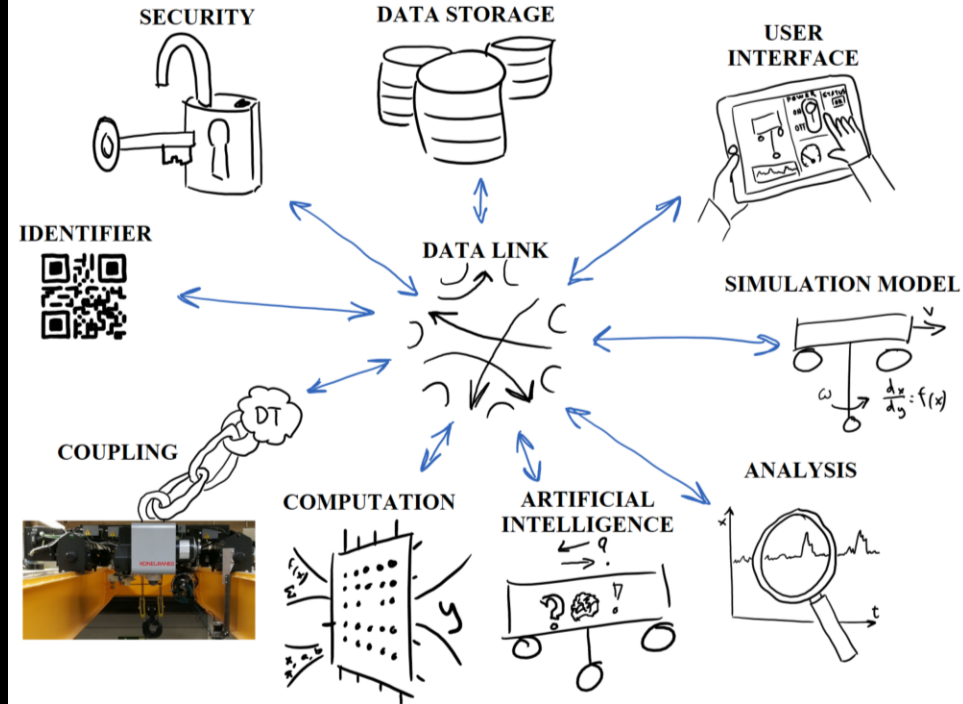


What is a digital twin?

Juuso Autiosalo
November 22nd 2019



Aalto-yliopisto
Aalto-universitetet
Aalto University



The presentation is based on:

(except two last slides)

Autiosalo, J., Vepsäläinen, J., Viitala, R., Tammi, K., 2019.

A feature-based framework for structuring industrial digital twins.

IEEE Access (Early access, Open access).

<https://doi.org/10.1109/ACCESS.2019.2950507>

Short url: juu.so/fdtf

Contents

5 questions

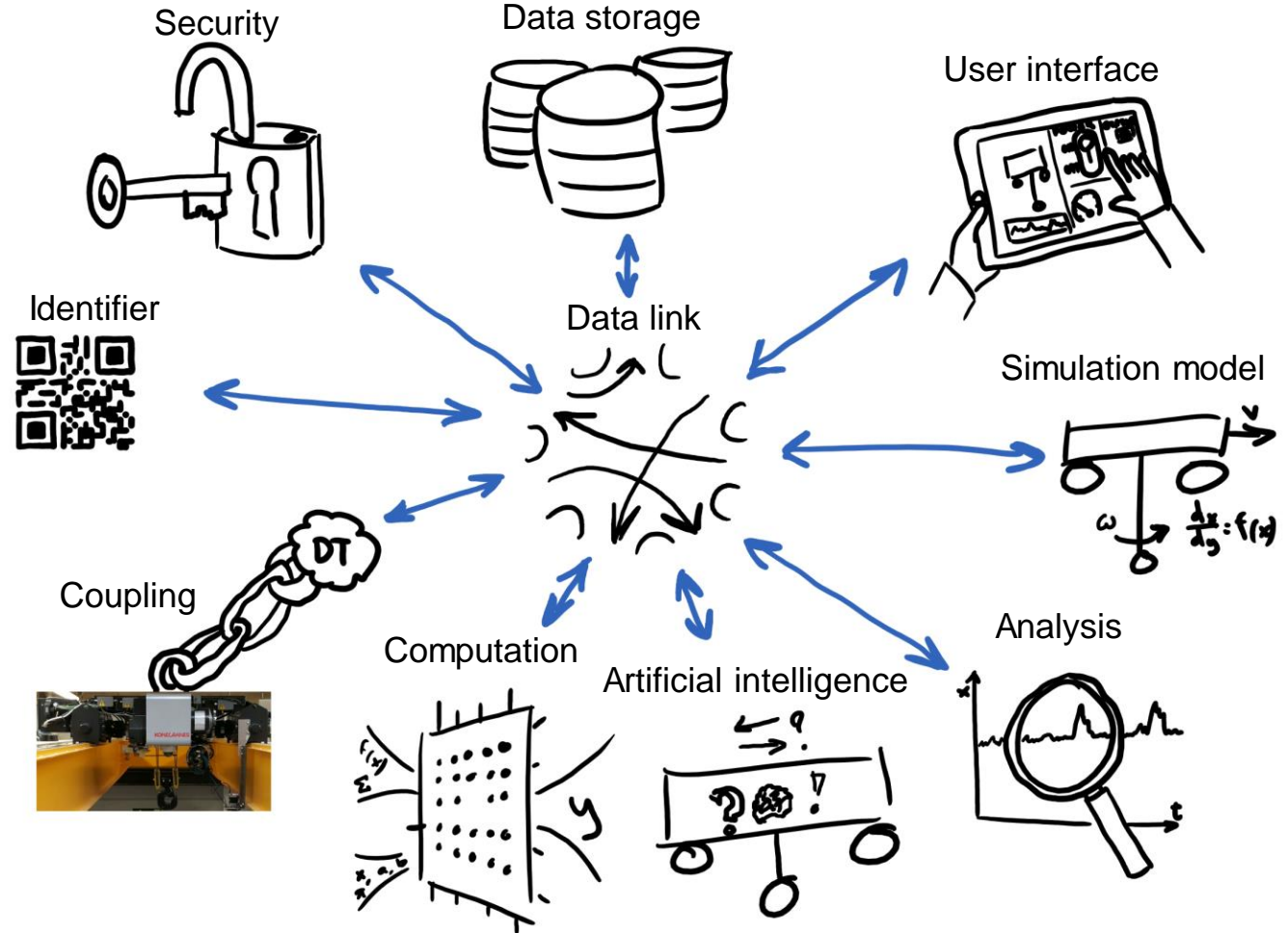
1. What is a digital twin?
2. How to compare digital twins?
3. How to build digital twins?
4. Why a data link?
5. What can you do to make the Digital Twin Web happen?

What is a digital twin?

What is a digital twin?

Digital twin is a virtual entity that is linked to a real-world entity.

Digital twin consists of **various features** that are selected and customized to serve the needs of diverse use cases.



What is a digital twin?

Number of samples is too small to make any final conclusions

First steps to verify the independence of the features

Correlation analysis between multiple digital twin implementations

Positive: features appear together

Negative: features “avoid” each other

Correlations between features

| | | | | | | | | | | |
|--------------|-----------|----------|------------|----------|--------------|------|------------|----------|-----|-------------|
| Data link | 1.0 | | | | | | | | | |
| Coupling | 0.2 | 1.0 | | | | | | | | |
| Identifier | -0.6 | -0.8 | 1.0 | | | | | | | |
| Security | 0.3 | -0.1 | -0.3 | 1.0 | | | | | | |
| Data storage | 0.3 | -0.4 | 0.5 | 0.0 | 1.0 | | | | | |
| UI | -0.3 | -0.2 | 0.3 | -0.7 | -0.1 | 1.0 | | | | |
| Simulation | -0.8 | 0.1 | 0.4 | -0.3 | 0.1 | 0.3 | 1.0 | | | |
| Analysis | 0.3 | -0.4 | 0.4 | 0.2 | 0.5 | -0.6 | -0.4 | 1.0 | | |
| AI | 0.0 | -0.8 | 0.5 | 0.5 | 0.4 | -0.4 | -0.3 | 0.7 | 1.0 | |
| Computation | -0.4 | -0.2 | 0.4 | -0.5 | 0.3 | 0.0 | 0.2 | 0.3 | 0.2 | 1.0 |
| | Data link | Coupling | Identifier | Security | Data storage | UI | Simulation | Analysis | AI | Computation |

How to compare digital twins?

How to compare digital twins?

5-step method

Step I: Identify features for the analysis.

Step II: Define the grading method(s).

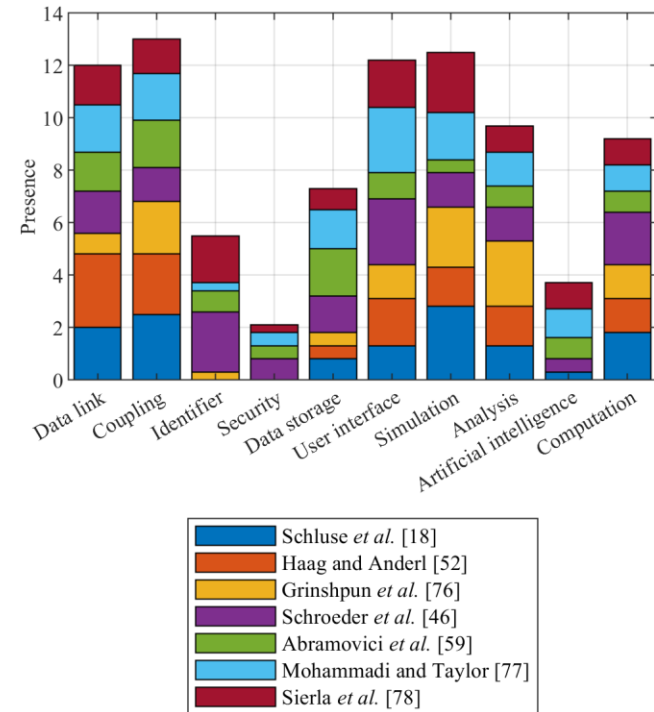
Step III: Assign grades for a DT implementation.

Step IV: Define weight factors w_i and the scale Sc .

Step V: Calculate the holistic score Hs .

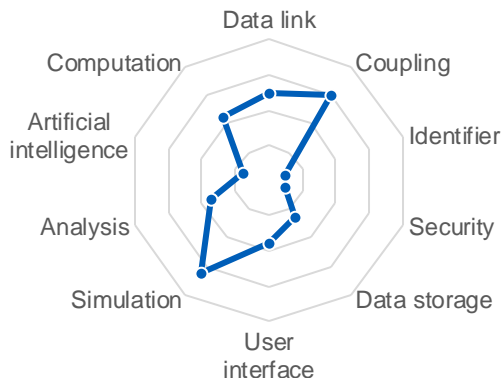
$$Hs = (\sum W_i \cdot V_i / \sum W_i \cdot V_{max}) \cdot Sc$$

Presence of features

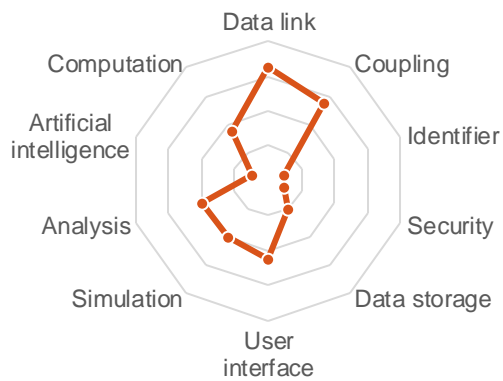


Feature profiles

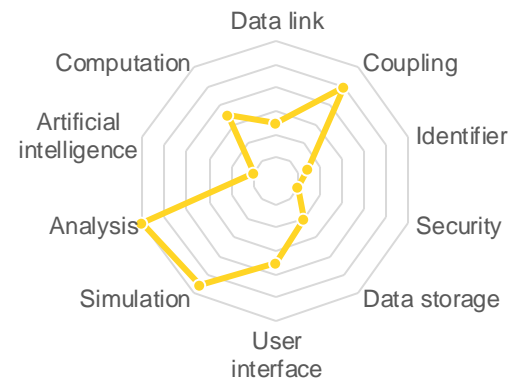
Schluse et al., 2018



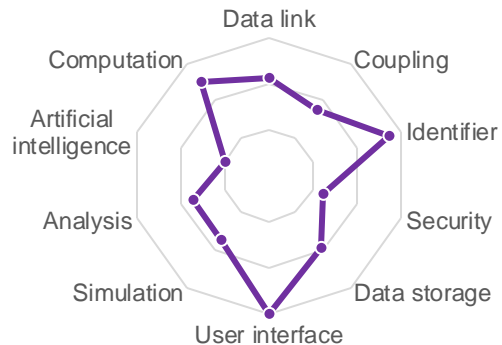
Haag and Anderl, 2018



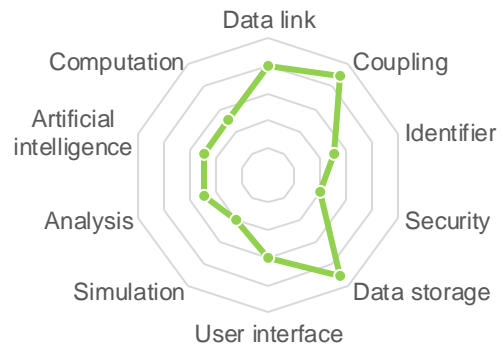
Grinshpun et al., 2016



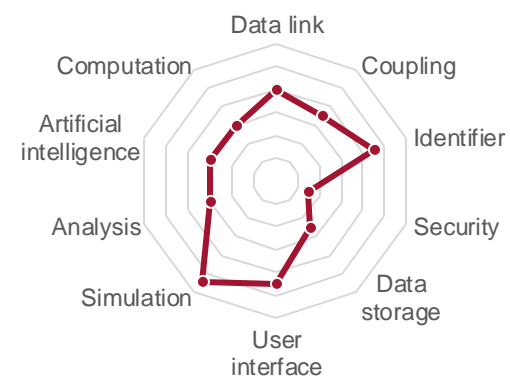
Schroeder et al., 2016



Abramovici, Göbel and Savarino, 2017

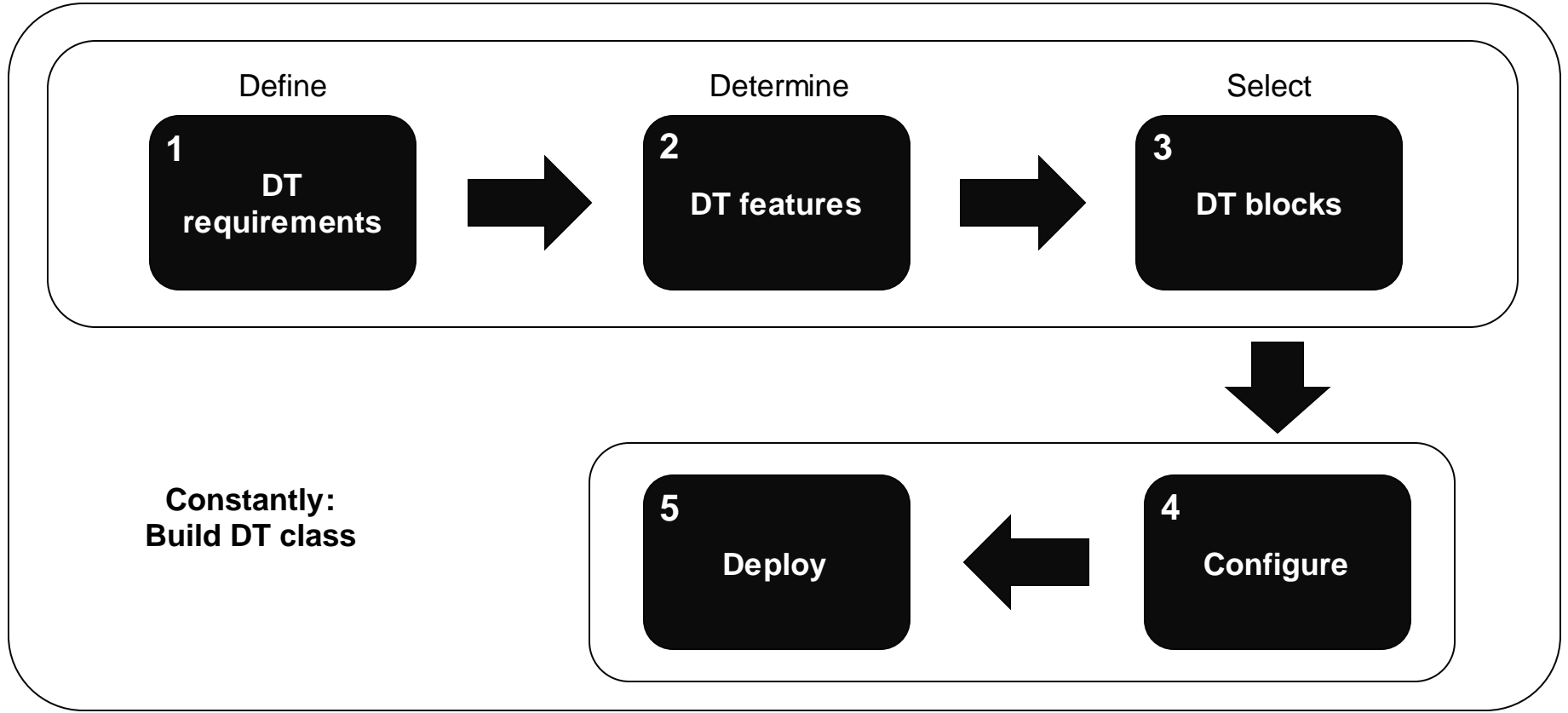


Sierla et al., 2018



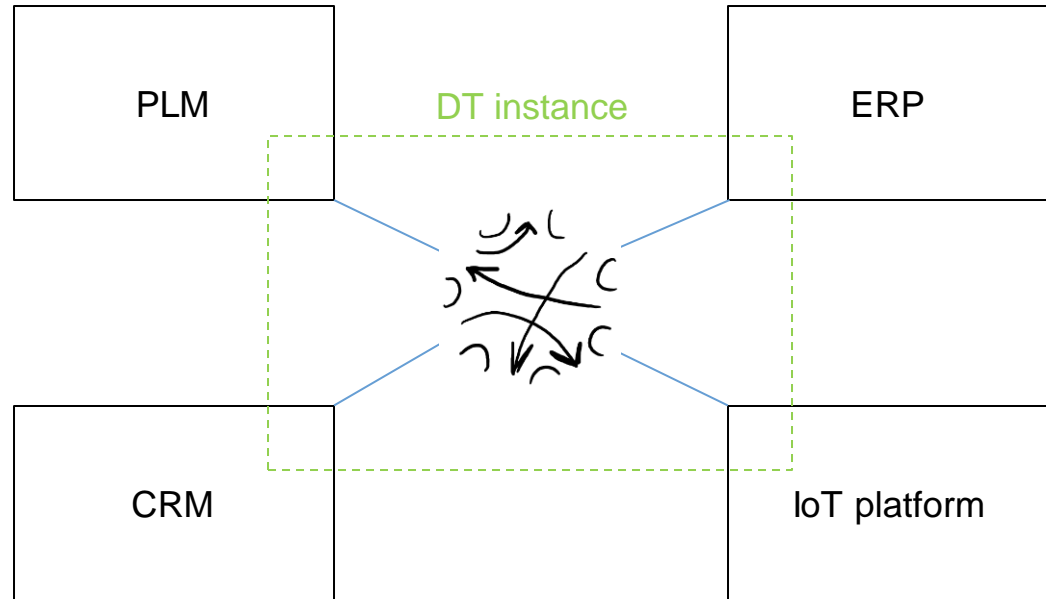
How to build digital twins?

How to build digital twins?



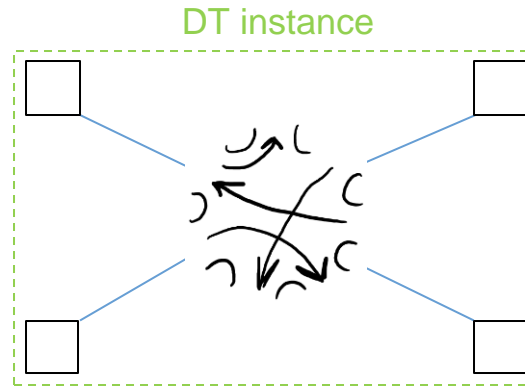
How to build digital twins?

Monoliths



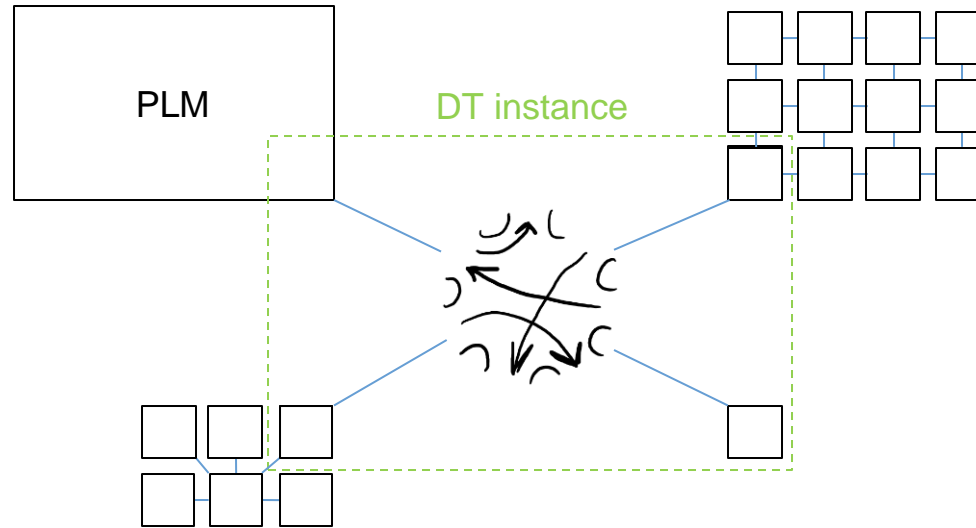
How to build digital twins?

Microservices



How to build digital twins?

Monoliths
and
Microservices



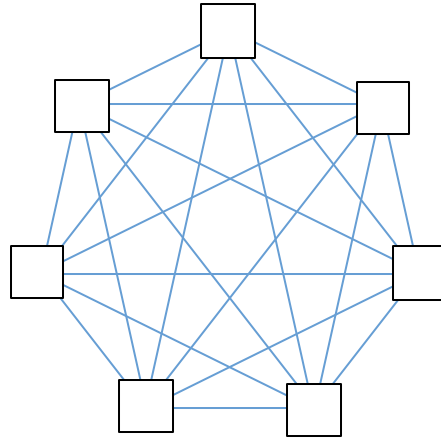
Why data link?

Why data link?

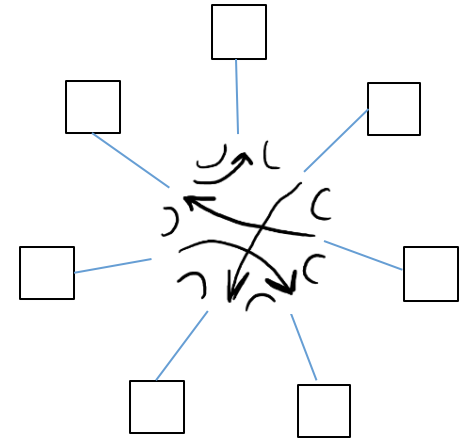
Graph theory: $n(n-1)/2$

| Blocks | Grid APIs | Star APIs |
|--------|-----------|-----------|
| 3 | 3 | 3 |
| 4 | 6 | 4 |
| 5 | 10 | 5 |
| 6 | 15 | 6 |
| 7 | 21 | 7 |

Grid style



Star style



DT block



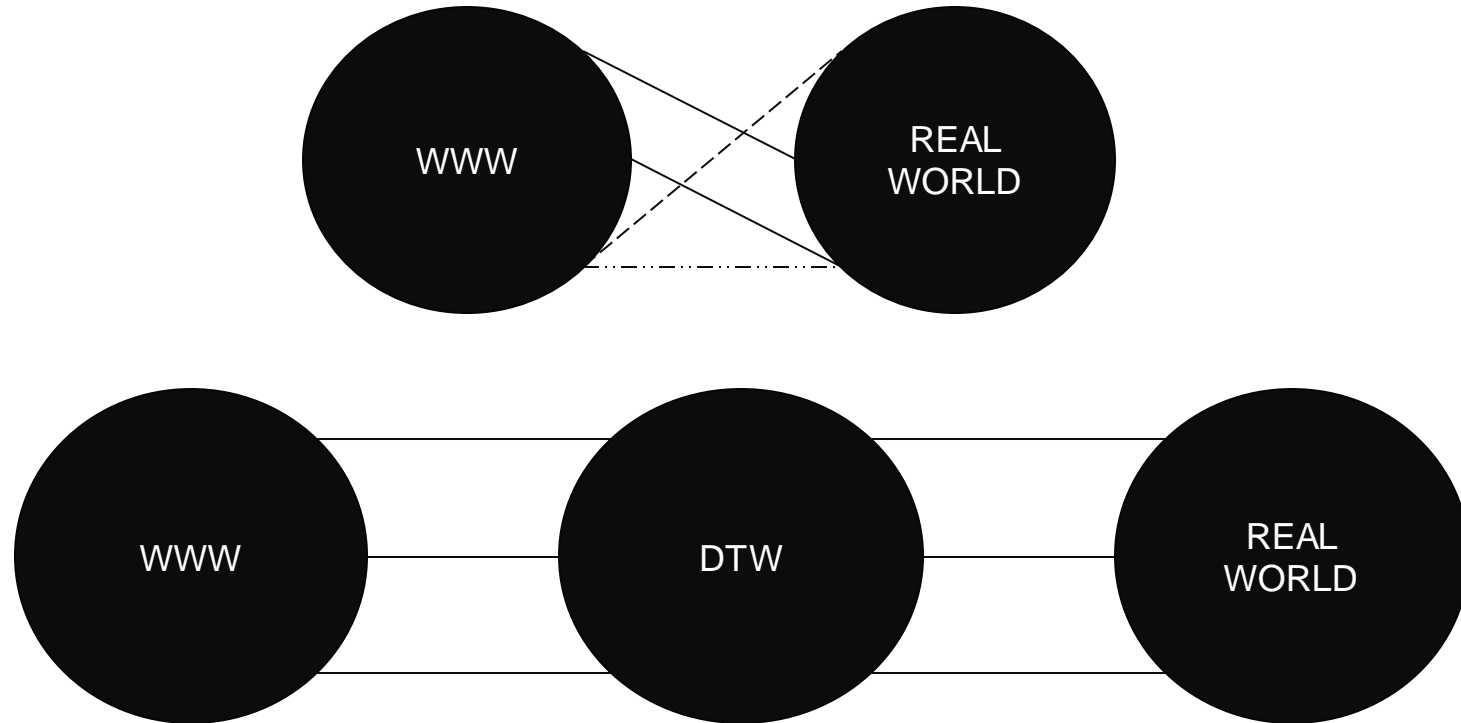
API



data link

Why data link?

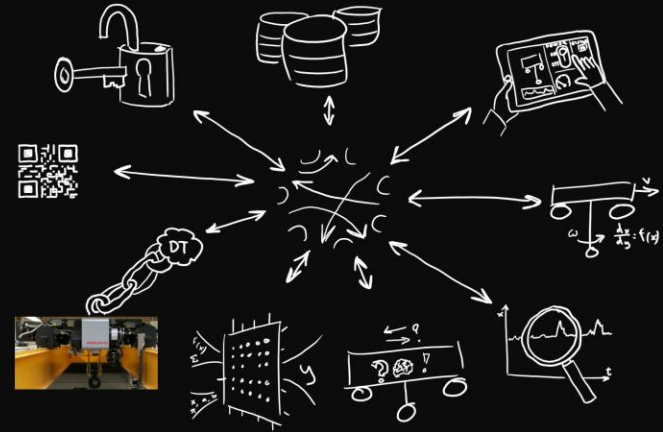
To enable the Digital Twin Web (DTW)



DTW = Semantic linking between real-world entities and the resources of the World Wide Web

What can you do to make the Digital Twin Web happen?

Free sharing of ideas
dtw.fi



Aalto-yliopisto
Aalto-universitetet
Aalto University

Juuso Autiosalo

November 22nd 2019