The Semantic Web in the Internet of Production: A Strategic Approach with Use-Case Examples

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***Abstract*—The semantic interoperability of data, models, systems, and knowledge in general is a core element of the Internet of Production, i.e., a cross-life cycle and interdisciplinary networking of all levels in manufacturing technology. Semantic Web technologies are a good choice for the implementation of such applications, but, despite numerous academic research projects, its true potential is still rarely used in practice. One reason is the lack of knowledge among practitioners about both the technology itself and possible application areas, as manufacturing engineers usually are no Semantic Web experts and vice versa. In this paper, we present five essential application areas for Semantic Web technologies in production engineering, and give five examples of how we use these in practice in the Internet of Production. Our two-folded presentation intends to clarify potentials within application areas, and at the same time support the ramp-up of practical applications based on our examples.**

***Keywords*—Semantic Web; Internet of Production; Use-Cases.**

realized in a productive system or product. Most applications in production did never leave an experimental stage.

There indeed are strong reasons to continue the research on Semantic Web technologies for production engineering. Following the achievements in the vision of "Industry 4.0" in the recent years, a proper infrastructure – a basic prerequisite for a networked production – has been created. Nowadays, the latest generation of products in automation technology are equipped with the necessary interfaces and communication protocols to enable distributed, data-driven applications. In particular, this means that "data" is now available outside the devices and applications with low effort. Availability and accessibility of data alone however are not sufficient to match the vision of the Internet of Production [2], which requires

Today’s presenter

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Johannes Lipp is a scientific researcher at the Fraunhofer FIT Office Aachen. He studied Computer Science at the **RWTH Aachen University** and researched at the Institute for **Information Management in Mechanical Engineering** (IMA) at RWTH for nearly two years.

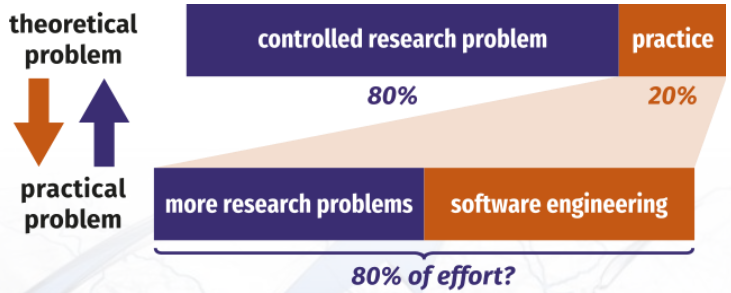
Johannes Lipp joined the "**Knowledge Pipelines**" group in December 2019 and continues in the research fields **Semantic Web, Ontologies, Data/Information/Knowledge Pipelines**, and Interoperability. Applications include the production and mobility sector, but are not limited to these.

Motivation

- **Semantic interoperability is essential for the Internet of Production.**

- **A lot of potential – but rarely fully utilized in practice**
  - Lack of knowledge about technologies and application areas
  - Manufacturing engineers vs. Semantic Web experts

- **The Semantic Web [2] already had its hype - why now?**
  - Proper infrastructure
  - Communication interfaces and protocols
  - Data is available at low effort



R. Verborgh: The Semantic Web identity crisis [1]

Transforming data into information and knowledge.

State of the Art & Approach

State of the Art

Both upper and domain ontologies are available, but not easy to use for non-experts.

- DOLCE [3], Cyc [4], SUMO [5], MASON [6] & more [7]
- Lookup services such as LOV [8]
- Administration shell [9]

Semantic Web applications exist, but as individual solutions or for specific applications.

- Dynamic processor orchestration [10]
- Worker assistance [11]
- AR visualizations [12]
- Open Service Lifecycle Collaboration
- ...

Research Gap

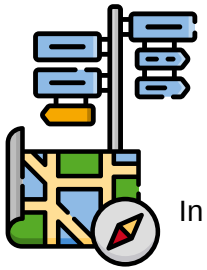
Easy transfer of paradigms and templates to the own domain.

This paper tackles this issue by presenting ...

... essential application areas & examples from our research project ...

... in order to clarify potentials & support practical applications.

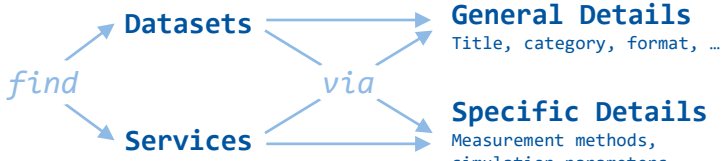
Application Areas for Semantic Web Technologies

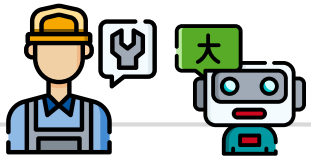


What's up there? **A**

Data / Service Catalog

In order to find something, you need a directory, like a library's catalogue for literature.





Integrating Domains

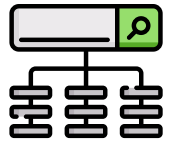
While collaborating among multiple domains, you need a translator. You can integrate information from different domains via semantic linking.

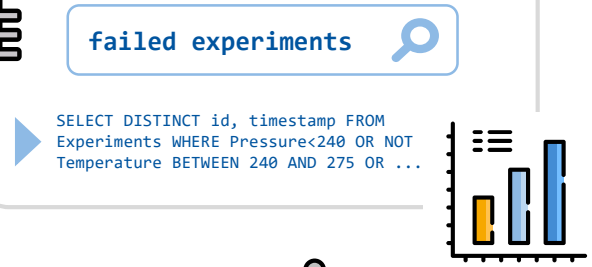
B *Dude, what do you mean?*

C *Let me ask you something…*

Database Access

Querying complex data requires much time and knowledge. Ontology-based data access offers queries in the language of the engineer.





D *Uhh, that's bullshit!*

Consistency and Reasoning

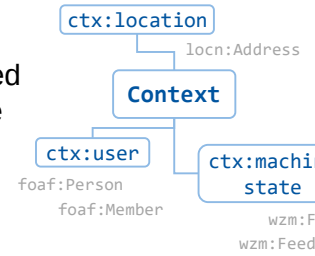
In a dynamic system, where various models come together, nonsense happens quite easily! Logical deductions can be used to detect such errors.

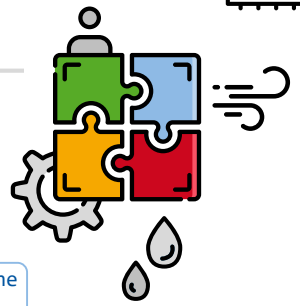
"42 experiments today, but the final report contains 39. → We lost information!"

"-550.34° does not look like a valid Celsius value…"

Data Aggregation

The characterization of a system is composed of heterogeneous data and models that are related to each other and thus reflect the system's situation and environment.

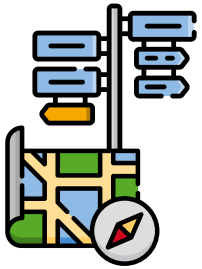




E *The situation? Well, it's complex…*

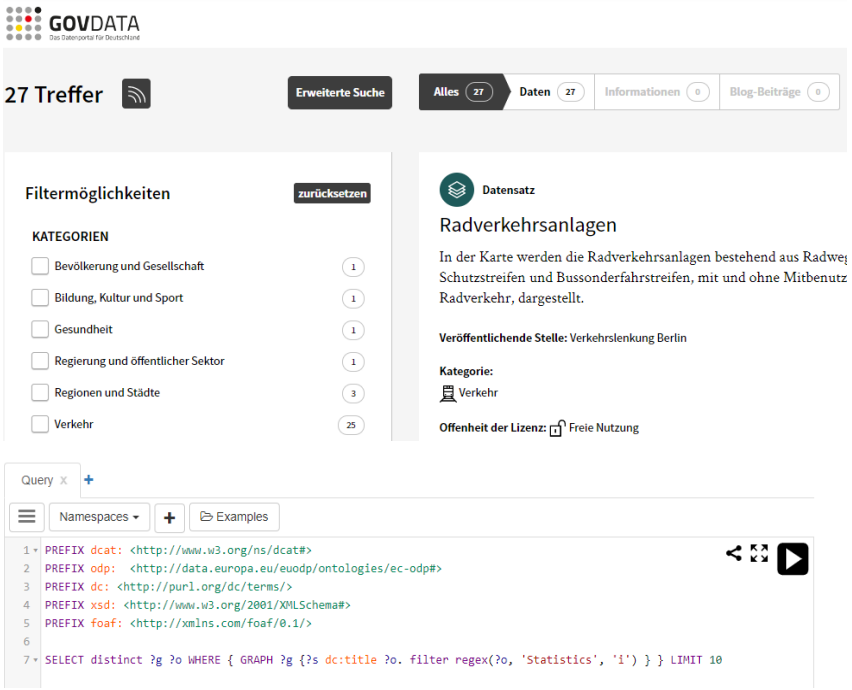
Application Areas for Semantic Web Technologies

What's up there?



A **Data / Service Catalog:** Catalogue of Research Data

"Find and access any kind of data in a catalogue"

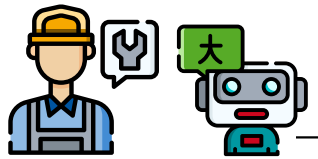


- Domain-specific details
  - Simulation parameters
  - …
- General details
  - Format
  - Domain / category
  - Contact person
  - Temporal / spatial coverage
  - Accrual periodicity
  - …

Use case interoperability

IoP / global interoperability

Application Areas for Semantic Web Technologies

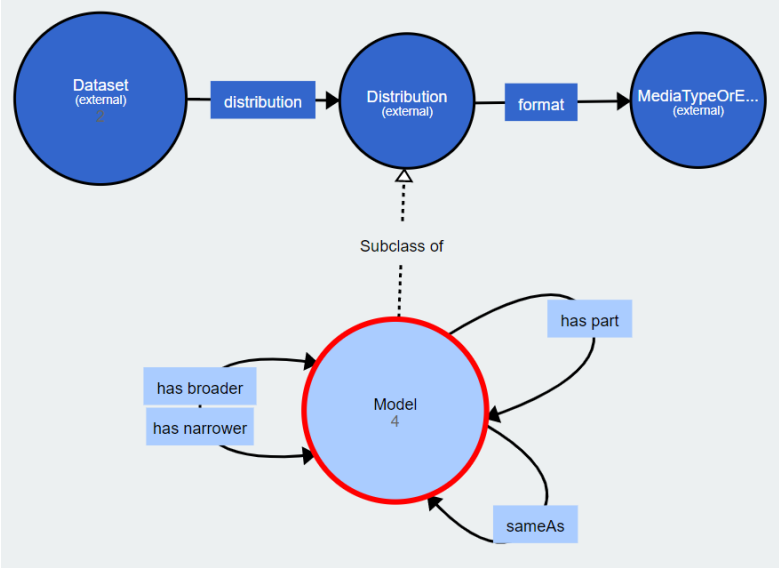


Dude, what do you mean?

B **Integrating Domains:** Integrating Lifecycle of Data and Models

"Use semantic links between data, even for different formats"

Ontology

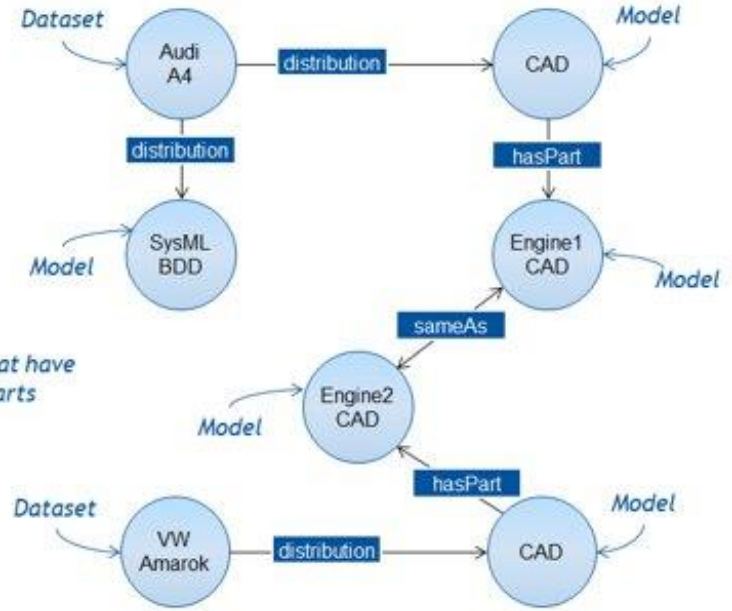


Implementation

- **Audi A 4**
  - SysML BDD describing the car's components
  - CAD model describing the appearance
- **VW Amarok**
  - CAD model describing the appearance

Find models that have the same parts

```
SELECT DISTINCT ?id1 ?id2 ?model1 ?model2
WHERE {
   ?id1 :sameAs ?id2 .
   ?model1 :hasPart ?id1 .
   ?model2 :hasPart ?id2 .
}
LIMIT 25
```

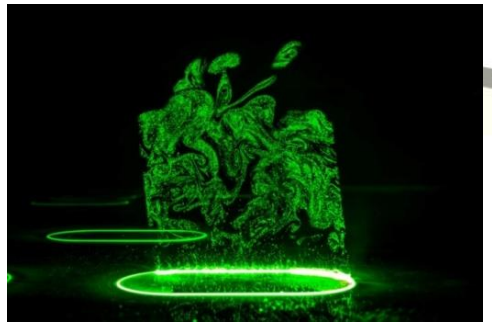


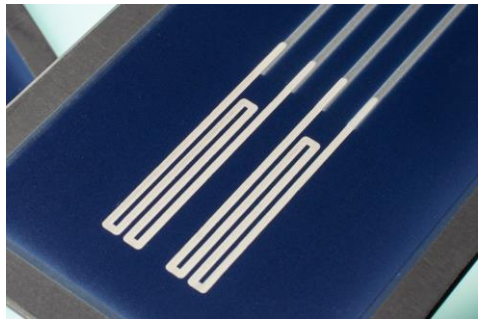
Application Areas for Semantic Web Technologies

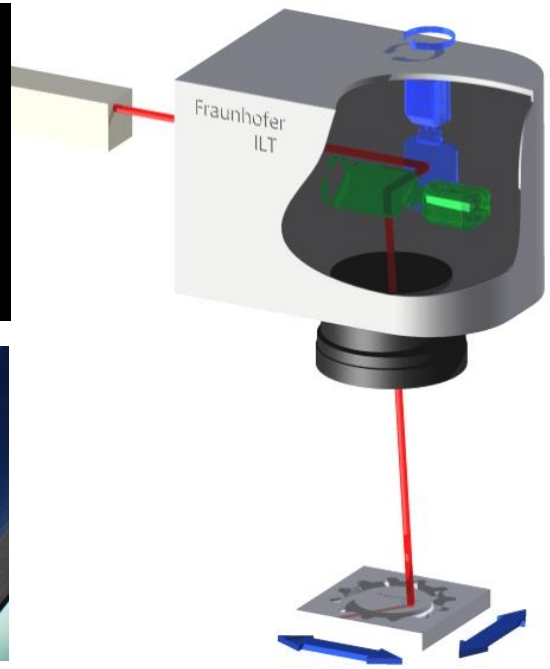
Let me ask you something…

C **Database Access:** OBDA for Laser-Measurements

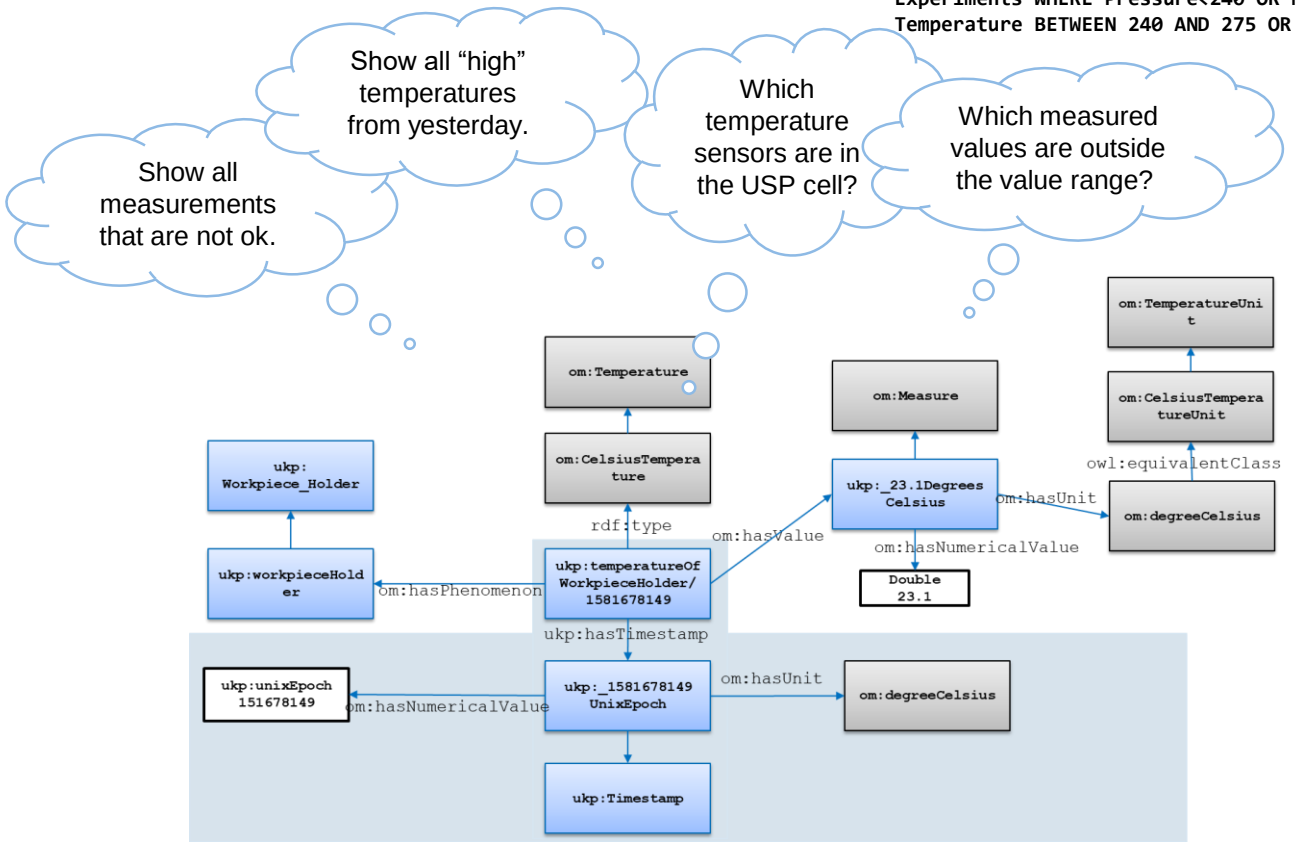
"Easily articulate database queries in your own language"








```
SELECT DISTINCT id, timestamp FROM
Experiments WHERE Pressure<240 OR NOT
Temperature BETWEEN 240 AND 275 OR ...
```



Source: Fraunhofer ILT

Application Areas for Semantic Web Technologies

Uhh, that‘s bullshit!

D **Consistency and Reasoning:** Production Planning for Injection Molding

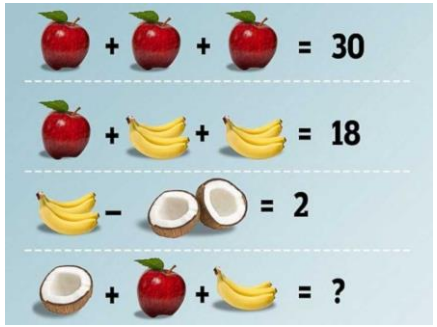
"Validation and logical deductions"

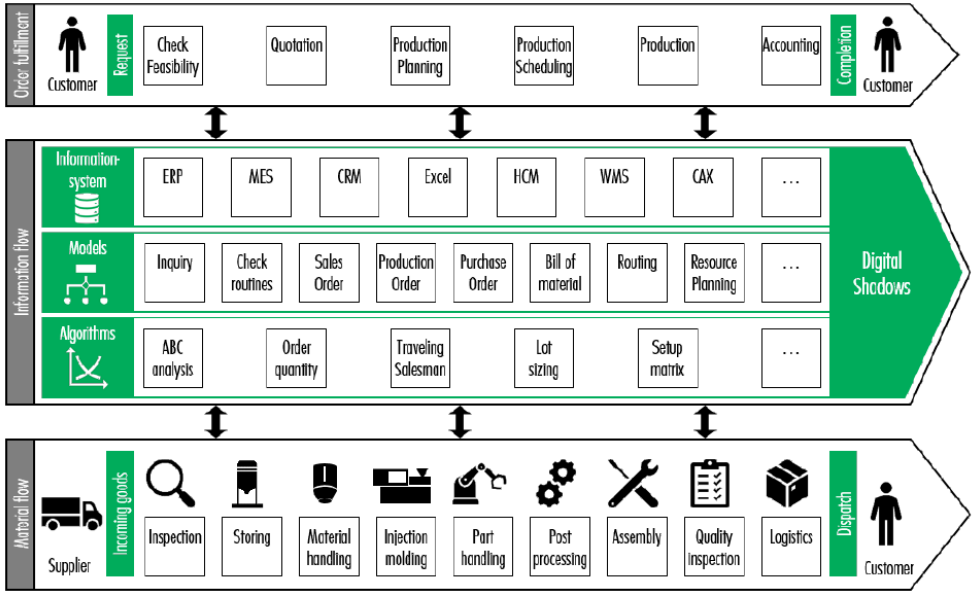
Shapes Graph

```
@prefix dash: <http://datashapes.org/dash#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix schema: <http://schema.org/> .
@prefix sh: <http://www.w3.org/ns/shacl#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

schema:PersonShape
    a sh:NodeShape ;
    sh:targetClass schema:Person ;
    sh:property [
        sh:path schema:givenName ;
        sh:datatype xsd:string ;
        sh:name "given name" ;
    ] ;
    sh:property [
        sh:path schema:birthDate ;
        sh:lessThan schema:deathDate ;
        sh:maxCount 1 ;
    ] ;
    sh:property [
        sh:path schema:gender ;
        sh:in ( "female" "male" ) ;
    ] ;
    sh:property [
```

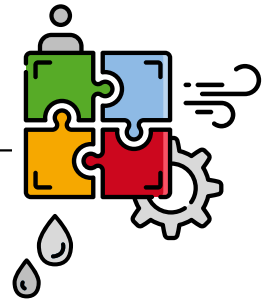
Data Graph Example Data in Turtle Format

```
@prefix ex: <http://example.org/ns#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix schema: <http://schema.org/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

ex:Bob
    a schema:Person ;
    schema:givenName "Robert" ;
    schema:familyName "Junior" ;
    schema:birthDate "1971-07-07"^^xsd:date ;
    schema:deathDate "1968-09-10"^^xsd:date ;
    schema:address ex:BobsAddress .

ex:BobsAddress
    schema:streetAddress "1600 Amphitheatre Pkway" ;
    schema:postalCode 9404 .
```



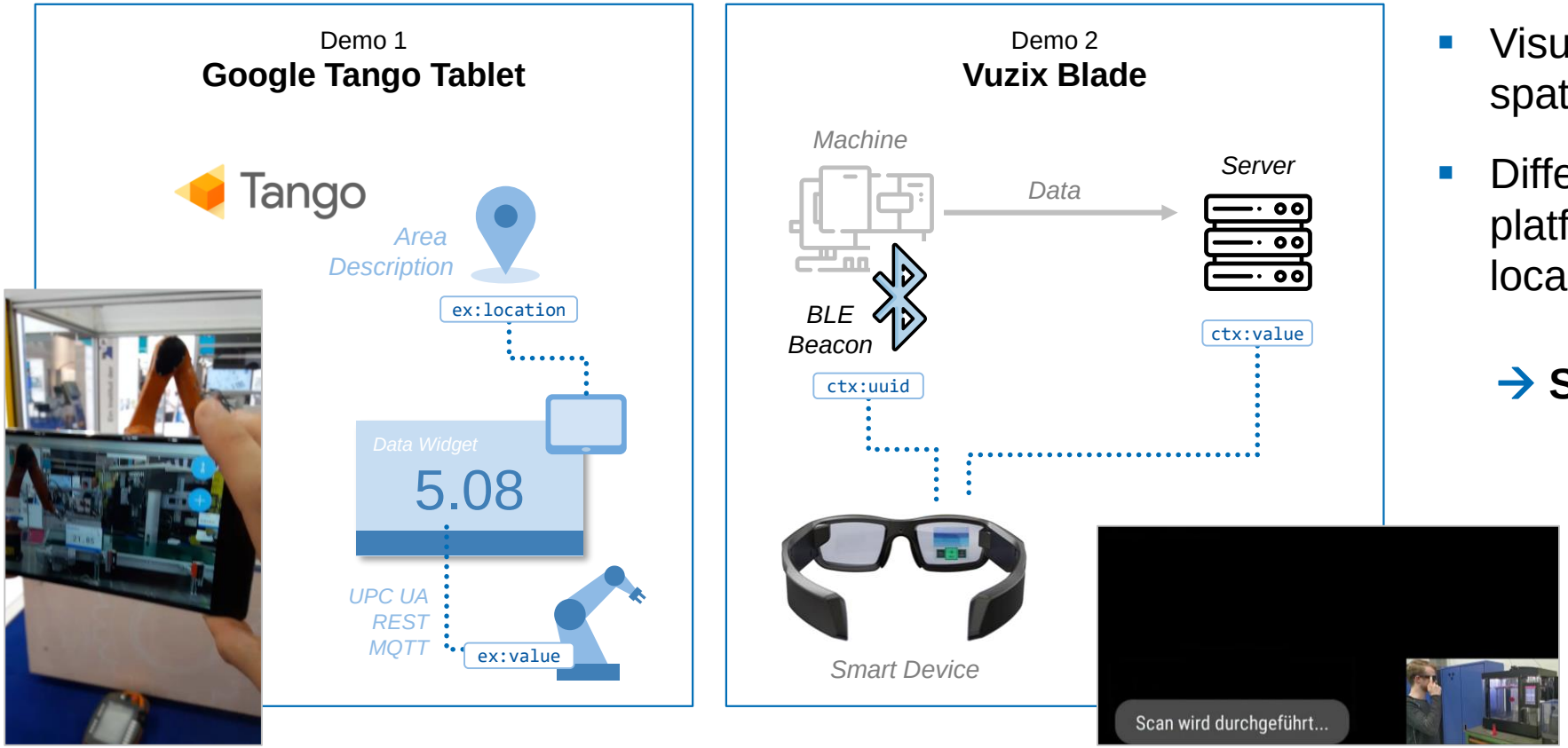


Application Areas for Semantic Web Technologies



The situation? Well, it's complex…

E **Data Aggregation:** Context-sensitive User Interface



- Visualization of data with spatial context
- Different technologies and platforms for spatial localization

→ **Semantical mapping of the concepts.**

Allocation of the Use-Case Examples

Application Examples

Example 1
Catalogue of Research Activities

Example 2
OBDA for Laser-Measurements

Example 3
Integrating Lifecycle Data and Models

Example 4
Context-sensitive User Interface

Example 5
Production Planning for Injection Molding

Application Areas

A **Data / Service Catalog**

B **Integrating Domains**

C **Database Access**

D **Consistency and Reasoning**

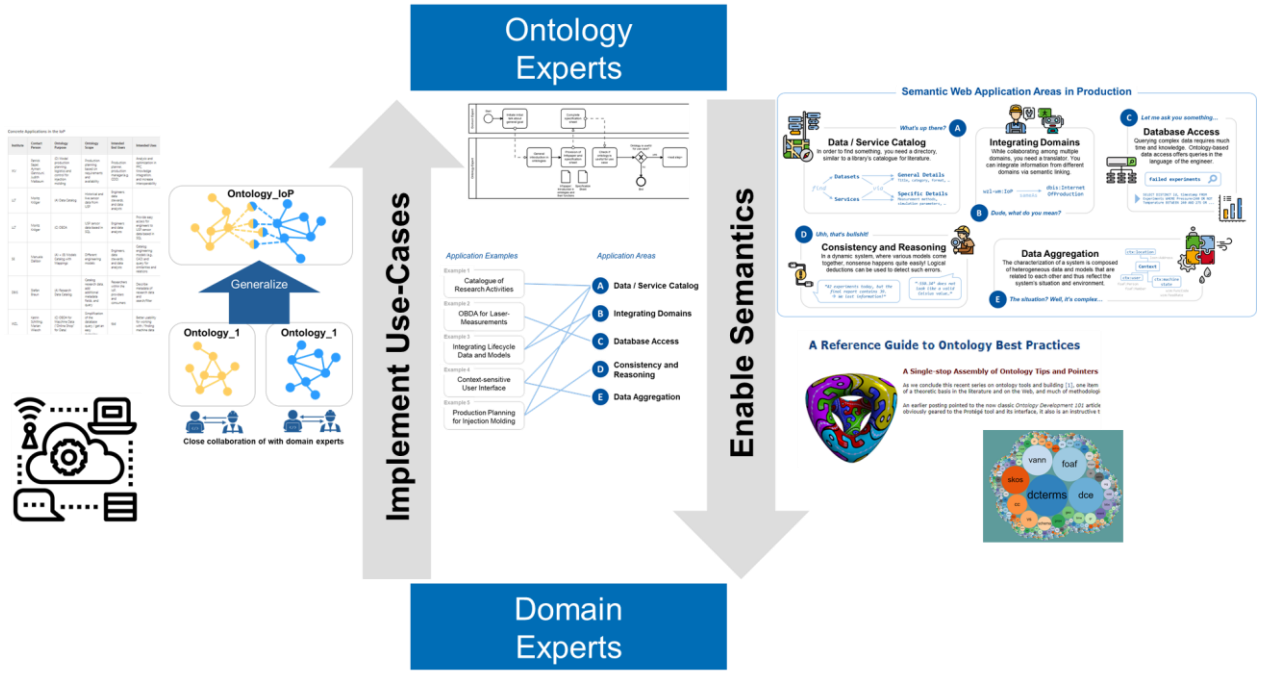
E **Data Aggregation**

Conclusion

- **The 20% “practice problems” turn out to take 80% of the effort**
- **We need to tackle substantial research challenges to foster adoption**

- **Outcome of this paper**
  - Enable semantics for domain experts
  - Support use-case implementation

- **Future work**
  - Evolve application areas (esp. area D)
  - Implement use-cases and derive archetypes
  - Further investigate challenges in practice



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Thank you for your attention

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