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FÜR INFORMATIK

Faculty of Informatics

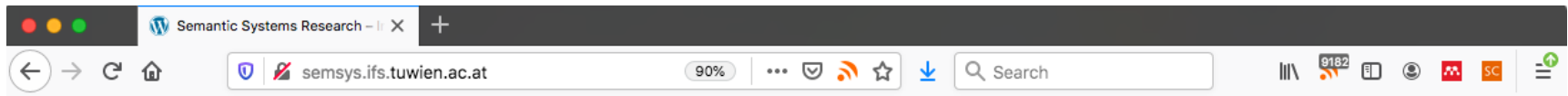
Semantic Systems Research Lab -Projects-

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SEMANTIC SYSTEMS RESEARCH



INFORMATION & SOFTWARE ENGINEERING GROUP
FACULTY OF INFORMATICS – TU WIEN


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The Semantic Systems Research Lab performs foundational and applied research in the area of information systems enabled by semantic (web) technologies. Its work is situated at the confluence of Semantic Web and Human Computation research areas, and focuses on the following main research questions:

 **Semantic Systems Research (TU Wien)** [Follow](#)
The Semantic Systems Research Lab @tuvienna. We perform foundational & applied research in the area of information systems enabled by Semantic (Web) technology

 **Semantic Systems Research (TU Wien)**
21 Sep 
A blogpost on the bridges between RDF and Property Graphs, from @khaller93
<http://semsys.ifs.tuwien.ac.at/bridges-between-rdf-and-prope...>
  1  3 [Twitter](#)

 **Semantic Systems Research (TU Wien)**

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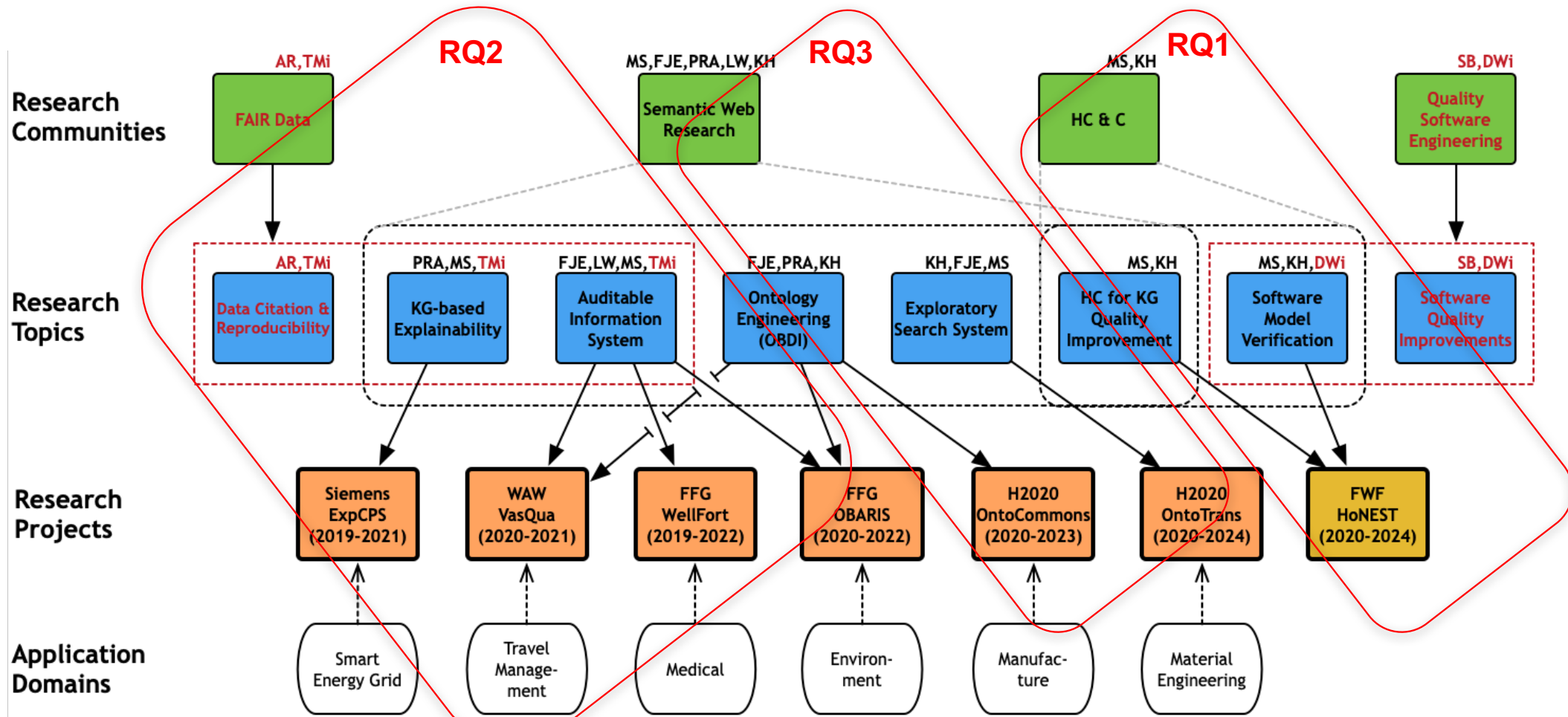
(Broad) Research Questions

(1) How to involve people in (semantic) system design both for information and software engineering? We investigate the use of Human Computation methods for acquiring and verifying knowledge structures such as ontologies and knowledge graphs ([HOnEst](#)). We also use Human Computation methods for verifying software engineering models.

(2) How to ensure that (semantic) information systems operate in reliable (trustworthy) and ethically acceptable ways? We perform work on using semantic technologies to make information systems auditable ([OBARIS](#), [WellFort](#), [VasQua](#)). Additionally, we extend this research to cyber-physical systems (CPS) where we aim to enable their explainability ([ExpCPS](#)).

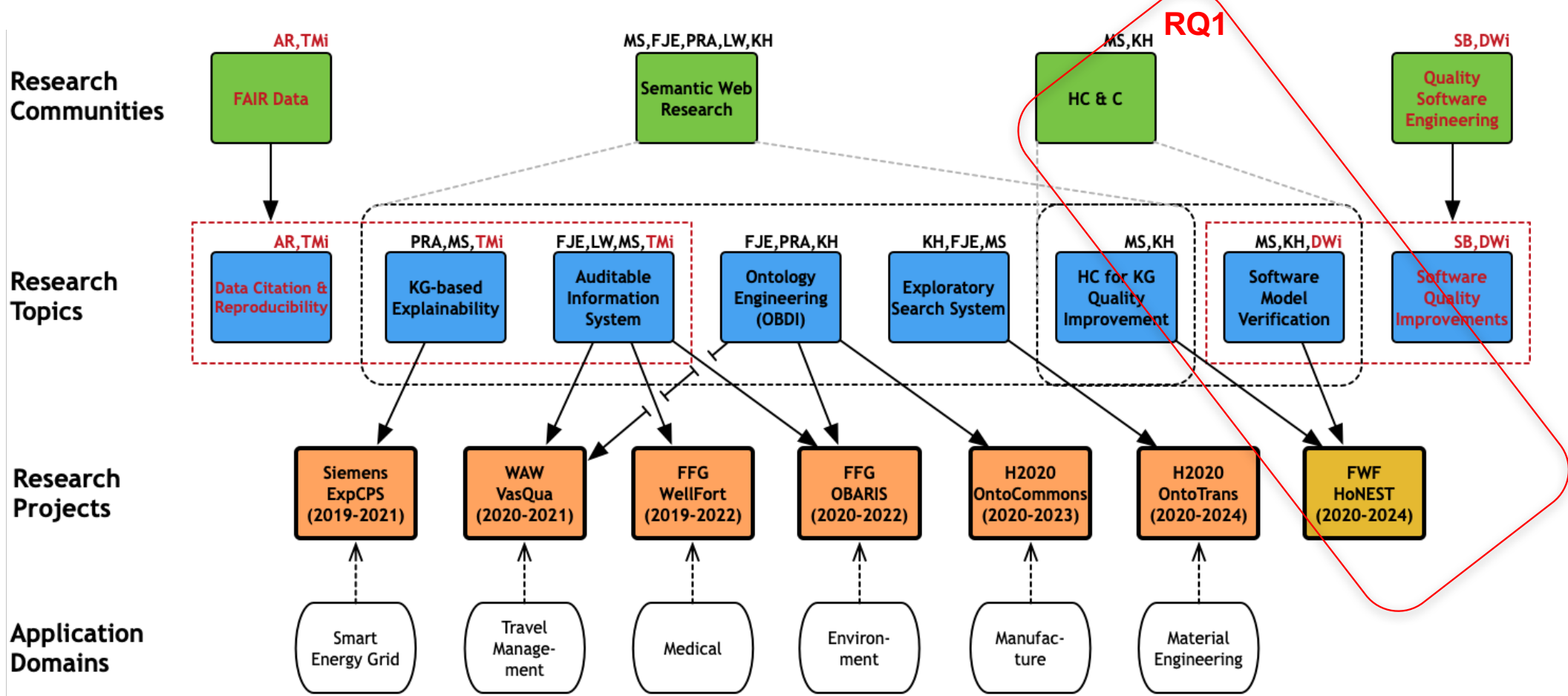
(3) How can semantic (web) technologies improve information systems? We investigate in particular the benefits of semantic methods from the area of data integration ([CitySPIN](#), CDL-Flex) and exploratory search ([OntoTrans](#), STAR) in information systems from a broad range of domains including Smart City, Industrie 4.0, material engineering, and medical science.

Research Areas and Projects



Research Areas and Projects

(1) How to involve people in (semantic) system design both for information and software engineering?





Ontologies and Knowledge Graphs



Google WU Wien

About 17,800,000 results (0.68 seconds)

<https://www.wu.ac.at> ...

WU (Vienna University of Economics and Business)
WU is home to more than 2,400 employees, many of them from all over the world. And they are all working to shape the future. Would you like join their ranks?

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Doctoral / PhD Programs
Information about admission to a doctoral/PhD program is ...

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WU Vienna is one of the largest and most modern educational ...

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The realization of a new WU campus represents an important ...

WU
WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

Vienna University of Economics and Business (Wirtschaftsuniversität Wien)

Public university in Vienna

The Vienna University of Economics and Business is a public university in Vienna, Austria, and is the largest university focusing on business and economics in Europe. It has been ranked as one of the best business schools in Europe and received Triple accreditation. [Wikipedia](#)

Address: Welthandelspl. 1, 1020 Wien

Ontology defects hamper the system's ability to provide factually correct and unbiased answers.

- often human involvement is needed to ensure high quality domain models



SIEMENS

CT Collaboration Platform | Contact | Help | Browse | Administration

Rollback (Design Patterns)
<https://workspace.cee.siemens.com/content/00000102/Wiki/Rollback.aspx?masterview=nwacollabprint>

[show less](#)

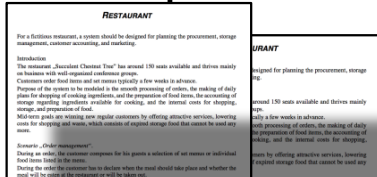
A rollback is an operation which returns to a previously stored state. The underlying assumption is that (1) checkpoints are defined where the systems state is stored and (2) the system is able to restore to these checkpoints (recovery). Consequently once an error occurs the systems state is reverted to prior checkpoint [Hanmer 2007]pp 154-155. Relations Error Handling [Hanmer 2007]pp 154-155.

Rollback

- > has an effect on
- > is related to
- > is supported by
- > is used in
- > is added by
- > is relevant for

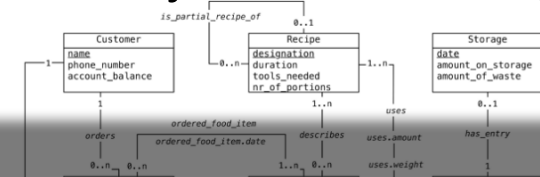
> architectural quality (13) > performance > reliability > autonomy > fault tolerance > resilience > availability > dependability > survivability > maturity > robustness > recoverability > viability > safety

System Specification



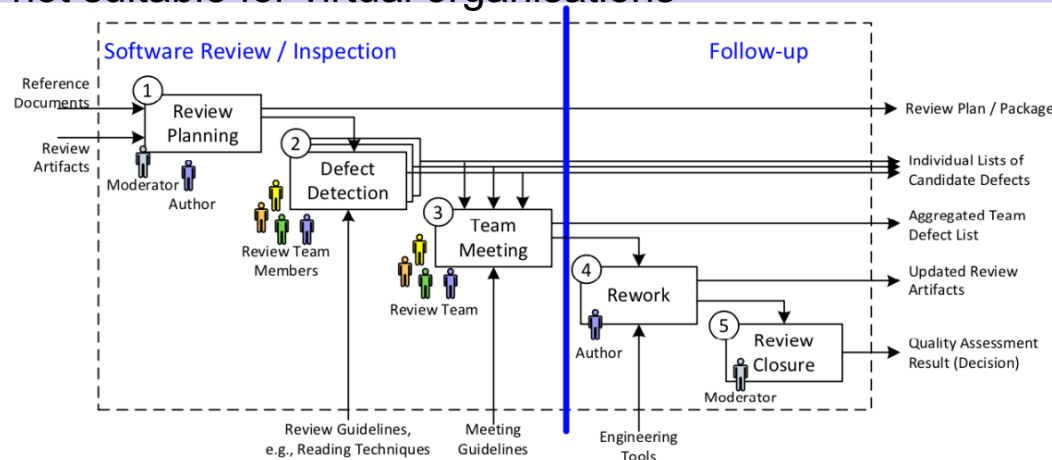
Does the model **completely and correctly** represent the system specification?

System EER Diagram

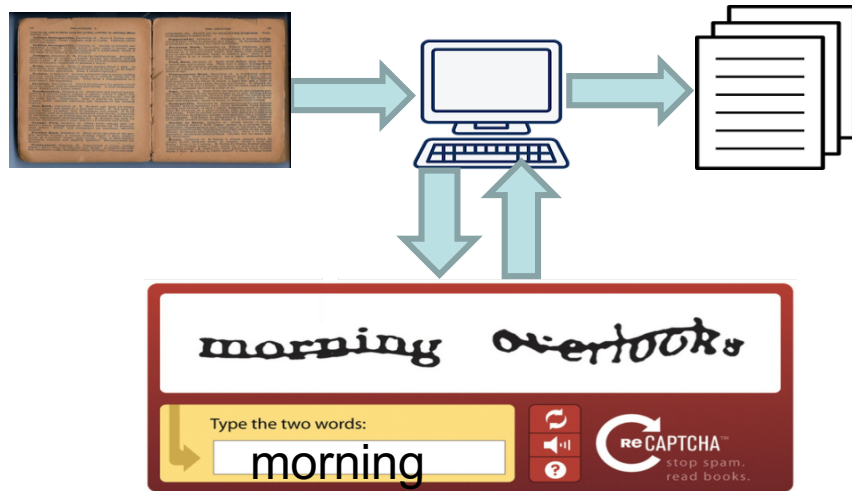


Incorrect system diagrams lead to faults in the follow-up artifacts:

- High costs
- Software model inspection
 - on-site verification processes:
 - not scalable to larger models
 - not suitable for virtual organisations



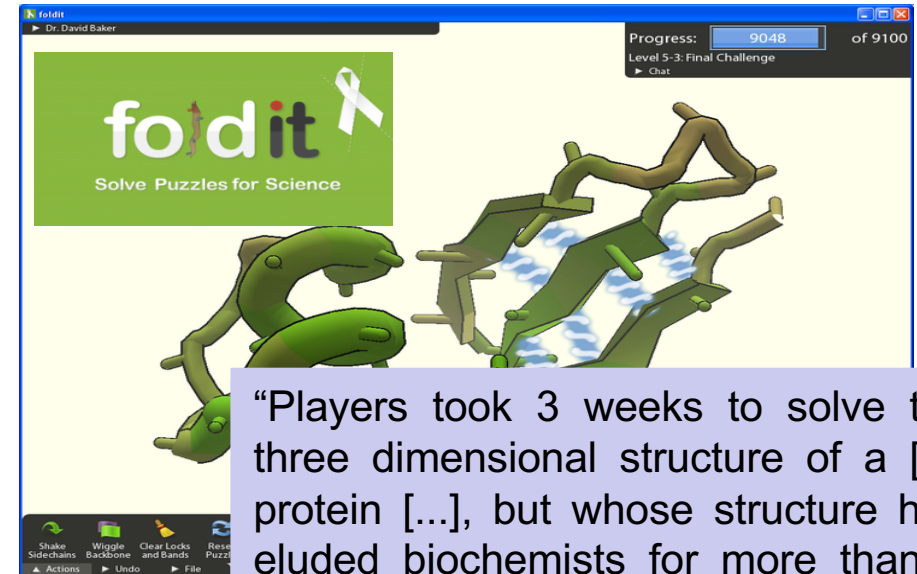
Human Computation harnesses Human Contributions on Large Scale



100 million/
day



Digitization of:
13 million NYT articles;
2 million books per year;



“Players took 3 weeks to solve the three dimensional structure of a [...] protein [...], but whose structure had eluded biochemists for more than a decade.”

<http://blogs.nature.com/spoonful/2012/04/foldit-games-next-play-crowdsourcing-better-drug-design.html>

S. Cooper, [other authors], and **Foldit players**: Predicting protein structures with a multiplayer online game. *Nature*, 466(7307):756-760, 2010.

Ontologies, taxonomies, Knowledge Graphs need manual verification

Semantic Web



Software Engineering



EER diagrams manually checked for completeness and correctness with respect to system specifications

*How to propose an HC based solution to the problem of **conceptual model verification** that is applicable across research areas?*

Contributions:

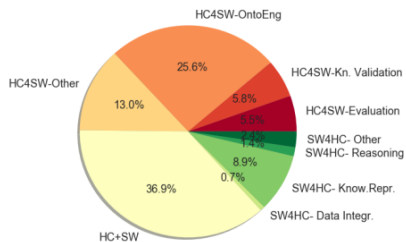
- Problem formalization*
- HC Approach*
- Evaluation in the Software and Knowledge Eng. Areas*



Human Computation

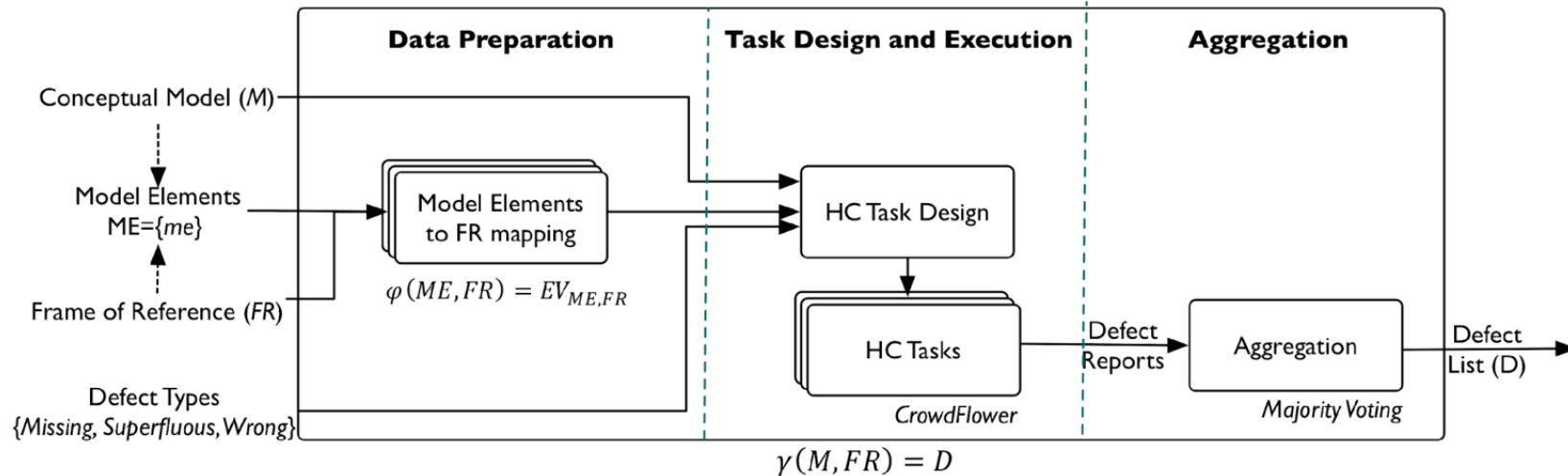
HC techniques primarily used to address cognitively easy tasks (e.g., labeling, object recognition)

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M. Sabou, L. Aroyo, K. Bontcheva, A. Bozzon, R. K. Qarout. Semantic Web and Human Computation: the Status of an Emerging Field. Sem. Web. J. 9(3): 291-302, 2018.

Problem Formalization & Generic Approach for Verifying Conceptual Models (VeriCoM)



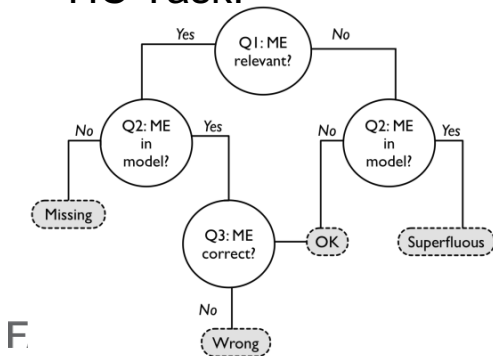
P1: ME-based.
MEs guide the verification.

$$M = \bigcup_n ME_n$$

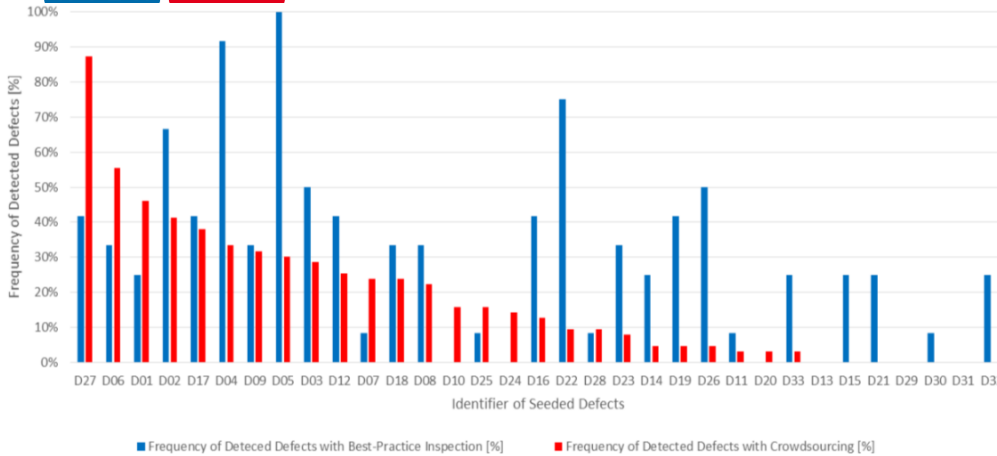
P2: Evidence-based.
Evidence for me from FR is used as context in the HC Task.

P3: Model as context.
Model fragment used as context in the HC Task.

P4: Defect types.
Defect types used to design HC Task.

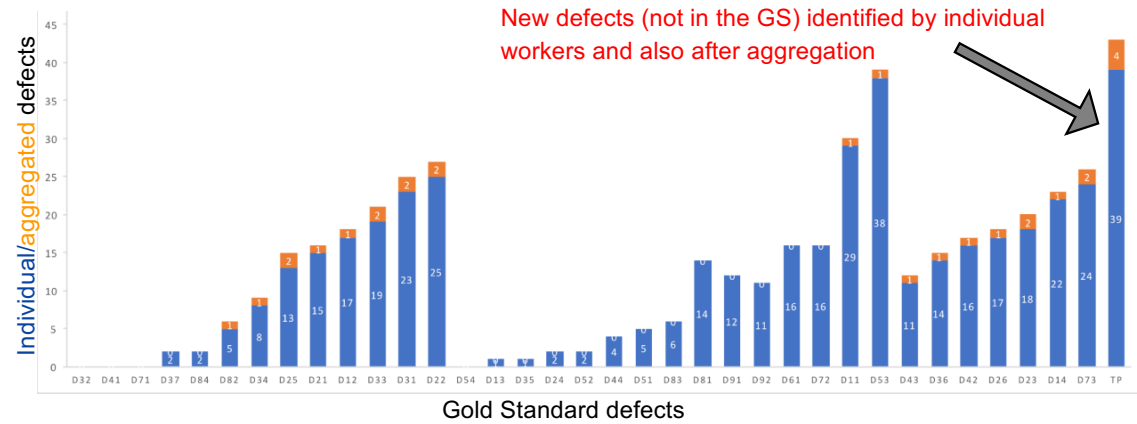


D. Winkler, P. Penzerstadler, S. Biffl: Verifying Conceptual Domain Models with Human Computation: A Case Study in Software Engineering. AAAI HCOMP 2018: 164-173

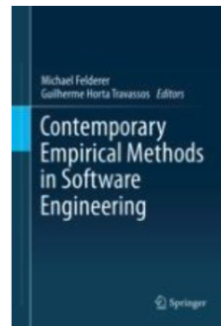


Crowd-based inspection comparable to traditional inspection [1]

In a Nutshell: Further Results



Open ended task design helps harness subtle insights and creativity [2]



Human Computation technique as a novel method for empirical software engineering experimentation [3].

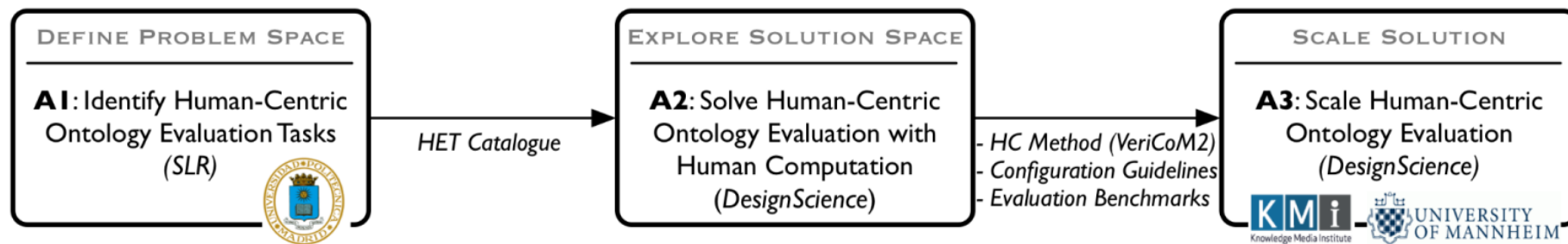
[1] D. Winkler, M. Kalinowski, M. Sabou, S. Petrovic, S. Biffi: Investigating a Distributed and Scalable Model Review Process. CLEI Electron. J. 21(1) (2018)

[2] M. Sabou, K. Käsznar, M. Zlabinger, S. Biffi, D. Winkler: Verifying Extended Entity Relationship Diagrams with Open Tasks. AAAI HComp, 2020:132-140.

[3] M. Sabou, D. Winkler, S. Biffi: Empirical Software Engineering Experimentation with Human Computation. M. Felderer et al., Contemporary Empirical Methods in Software Engineering 2020:173-215

HOnEst: **H**uman-centric **O**ntology **E**valuation (FWF)
 AIM: “scalable human-centric ontology evaluation”

- FWF Elise Richter
- 2020-2024
- UPM, KMi, UManheim



Systematic literature review [1]:
What semantic resources are evaluated with human-involvement, **why** and **how** is the evaluation performed?

Task design, **empirical studies**, support ontology engineer courses during **distance learning [2]**.

Hybrid human-machine system including reasoners and machine learning systems [3].

Industry Project: **SIEMENS** 

[1] M. Sabou, M. Fernandez, M. Poveda-Villalon, M. C. Suarez-Figueroa, S. Tsaneva. Human-centric Evaluation of Semantic Resources: A Systematic Mapping Study. Prepared for ACM Comp. Surveys.

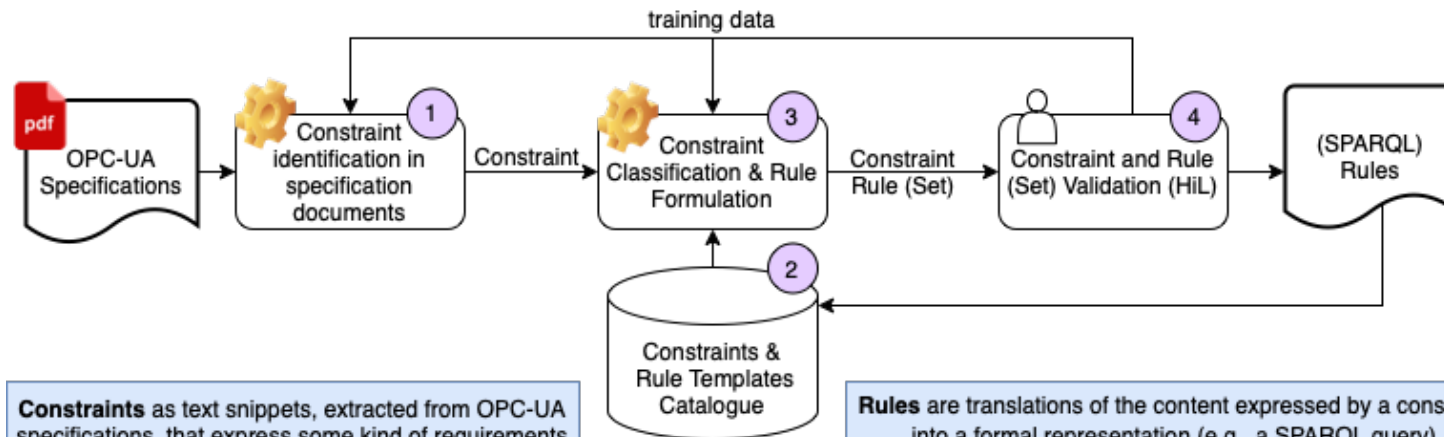
[2] S. Tsaneva, M. Sabou. A Human Computation Approach for Ontology Restrictions Verification. AAAI HComp 2021.

[3] A. Prock. Hybrid Human-Machine Ontology Verification Identifying Common Errors in Ontologies by Integrating Human Computation with Ontology Reasoners. Master Thesis, TU Wien, 2021.

ORE: OPC-UA Rule Editor (ORE) Project

Goal: supporting OPC-UA experts in identifying **constraints** in pdf documents of Companion Specifications and formalizing **rules** to validate if the constraints are satisfied in OPC-UA files.

- Siemens DE
- 2021
- (2022 extension)



Constraints as text snippets, extracted from OPC-UA specifications, that express some kind of requirements that the OPC-UA file conforming to those specifications should fulfil.

EXAMPLE
Each FiniteStateMachine can have at most one State of type InitialStateType, but a FiniteStateMachine does not have to have a State of this type.

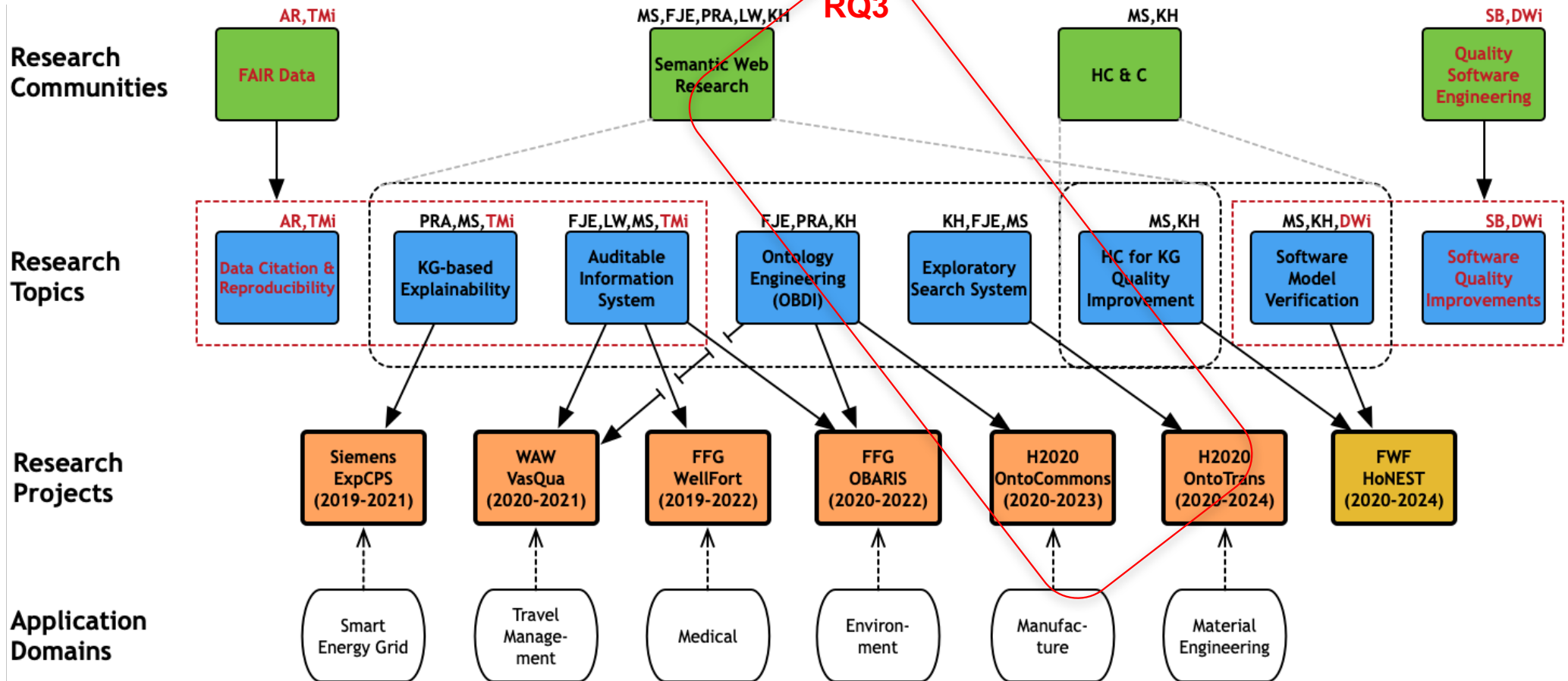
Rules are translations of the content expressed by a constraint into a formal representation (e.g., a SPARQL query). In this survey, rules are represented in a structured natural language so that they can be understood also by OPC-UA experts that are not familiar with the syntax of the formal rule language. Complex constraints can be translated in several rules that we refer to as a **Rule Sets**.

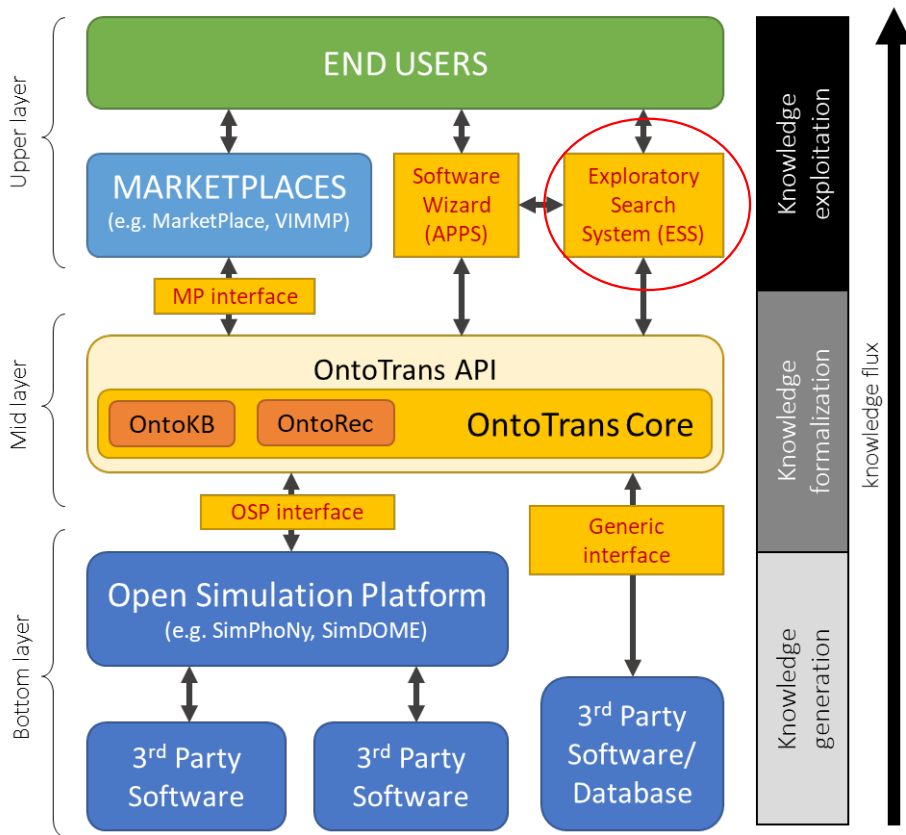
EXAMPLE
 1. The node *FiniteStateMachine* exists.
 2. The node *InitialStateType* exists.
 3. There should not exist a *FiniteStateMachine* with more than one *State* of type *InitialStateType*

Similarities to BRISE?

Research Areas and Projects

(3) How can semantic (web) technologies improve information systems?





- EU - H2020
- 2020 - 2024

OntoTrans

(A) representing manufacturing process challenges in a standard ontological form (User Case)

(A) connecting User Cases with existing appropriate information sources i.e. available data and materials modelling solutions

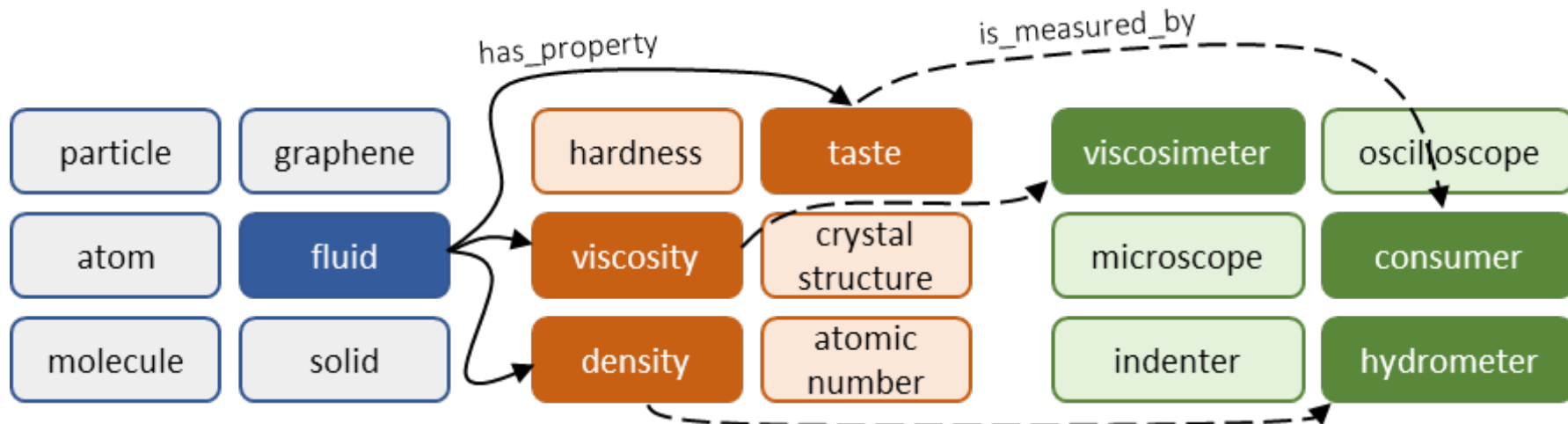
(A) recommending consistent materials modelling workflow options

aim: support the development of dedicated Apps delivering a smart guidance for materials producers and product manufacturers

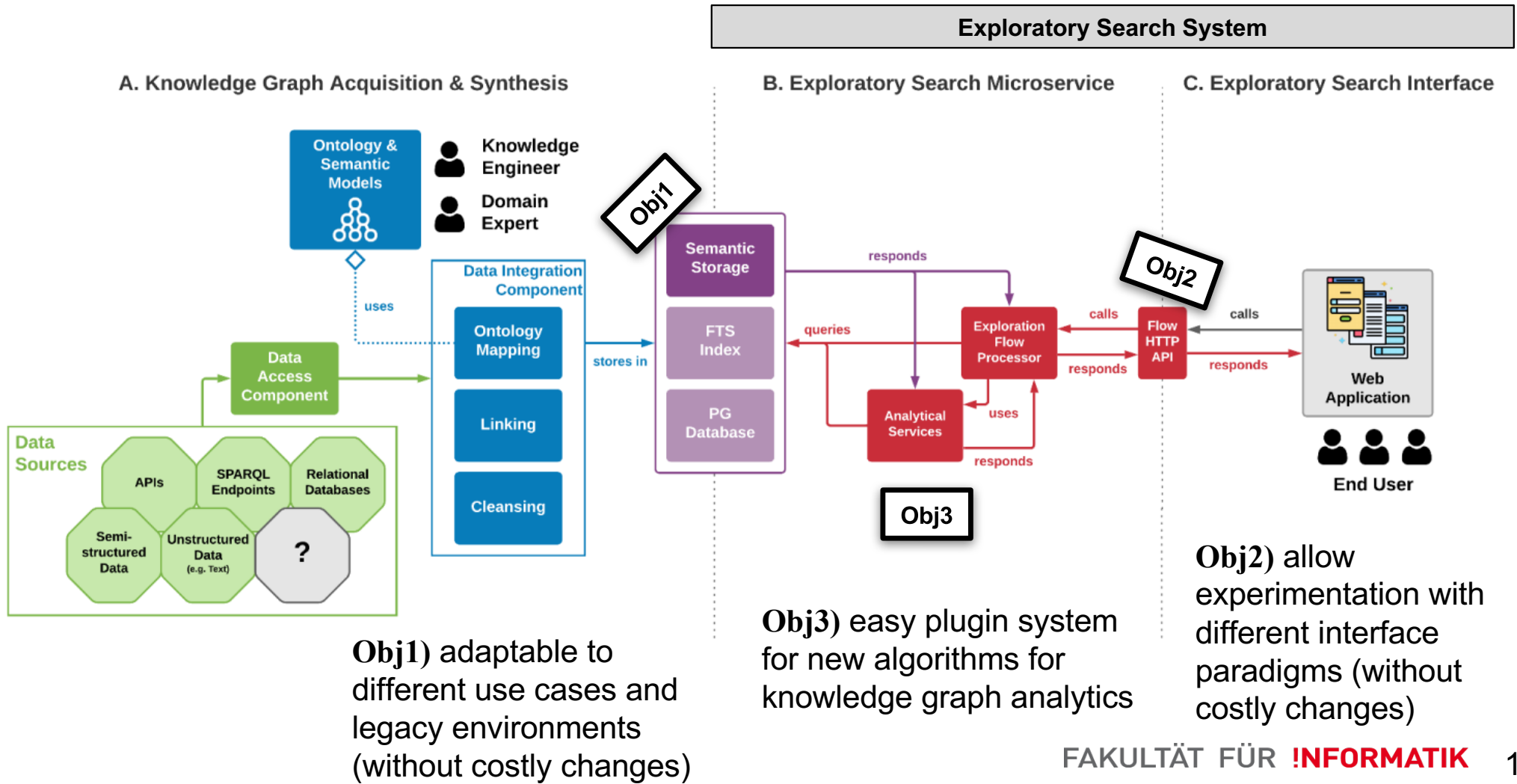
Industrial Partners:



End users and translators may not have a clear view of the information they need but rather require support to discover new information and learn about the domain. OntoTrans will support them with an ESS which will rely on data science algorithms to identify emerging patterns in the available semantic information.



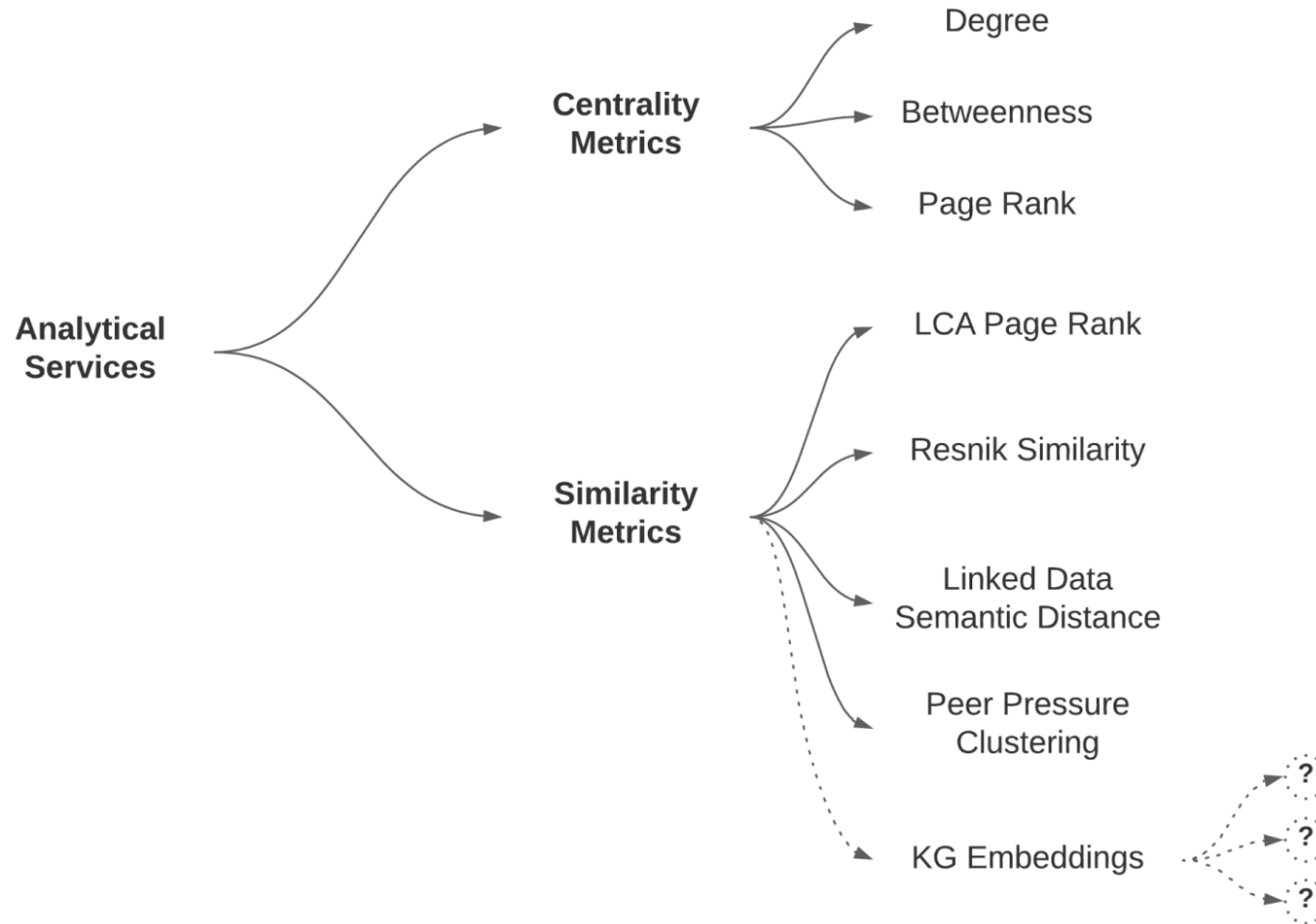
Exploratory Search Platform



Obj3) Analytical Pipeline

- Analytical Services analyze the (semantic) structure of a knowledge graph
 - can make use of:
 - i. SPARQL
 - ii. Gremlin
 - iii. Full-Text Search Index
 - iv. Other Analytical Services
 - new services can be plugged into the application
- Centrality metrics assign an “importance” value to entities in the knowledge graph.
- Similarity metrics assign a “similarity” value to a pair of entities in the knowledge graph.

Analytical Services



Exploratory Search Interface (UC1)

SPARQL HIERARCHIE ROBOTICS ENGINEER DE

UNIVERSAL ROBOTS UR5

ALLE PRODUCTION PLANT ROBOT END EFFECTOR **ROBOT TYPE** END EFFECTOR TYPE SKILLS

18 Ergebnisse (12 Millisekunden)

UNIVERSAL ROBOTS UR5
Robot Type
The slightly bigger UR5 is ideal for automating low-weight processing tasks like picking, placing and testing. The medium-sized robot arm is easy to program, fast to set up and, just like the other collaborative members of the UR family, offers one of the ...

UNIVERSAL ROBOTS UR10E
Robot Type
Keine Beschreibung

UNIVERSAL ROBOTS UR16e
Robot Type
Keine Beschreibung

UNIVERSAL ROBOTS UR3E
Robot Type
Keine Beschreibung

UNIVERSAL ROBOTS UR5E
Robot Type
Keine Beschreibung

UNIVERSAL ROBOTS UR10
Robot Type
Keine Beschreibung

UNIVERSAL ROBOTS UR5
Robot Type
The slightly bigger UR5 is ideal for automating low-weight processing tasks like picking, placing and testing. The medium-sized robot arm is easy to program, fast to set up and, just like the other collaborative members of the UR family, offers one of the fastest payback times in the industry.

Origin: Denmark
Reach: 850 mm
Handling Payload: 5 Kg
Degrees Of Freedom: 6
Compatible End Effectors:

Schunk Gripper EGA
End Effector Type
Electric 2-finger parallel gripper with lightweight profile rail ...

Robotiq Gripper Hand-E
End Effector Type
Robotiq's Hand-E Gripper is simple to integrate in your producti ...

Robotiq Gripper 2F-85
End Effector Type
The 2F-85 and 2F-140 Adaptive Grippers are the world's best-sell ...

Offered Handling Functions:

Move Handling function Keine Beschreibung	Approach Handling function Keine Beschreibung	Depart Handling function Keine Beschreibung	Retract Handling function Keine Beschreibung
Execute motion Handling function Keine Beschreibung	Move to product Handling function Keine Beschreibung		

Keyword Search

COMAU AURA
Robot Type
Keine Beschreibung

Origin: Italy
Reach: 2790 mm
Handling Payload: 170 Kg
Degrees Of Freedom: 6

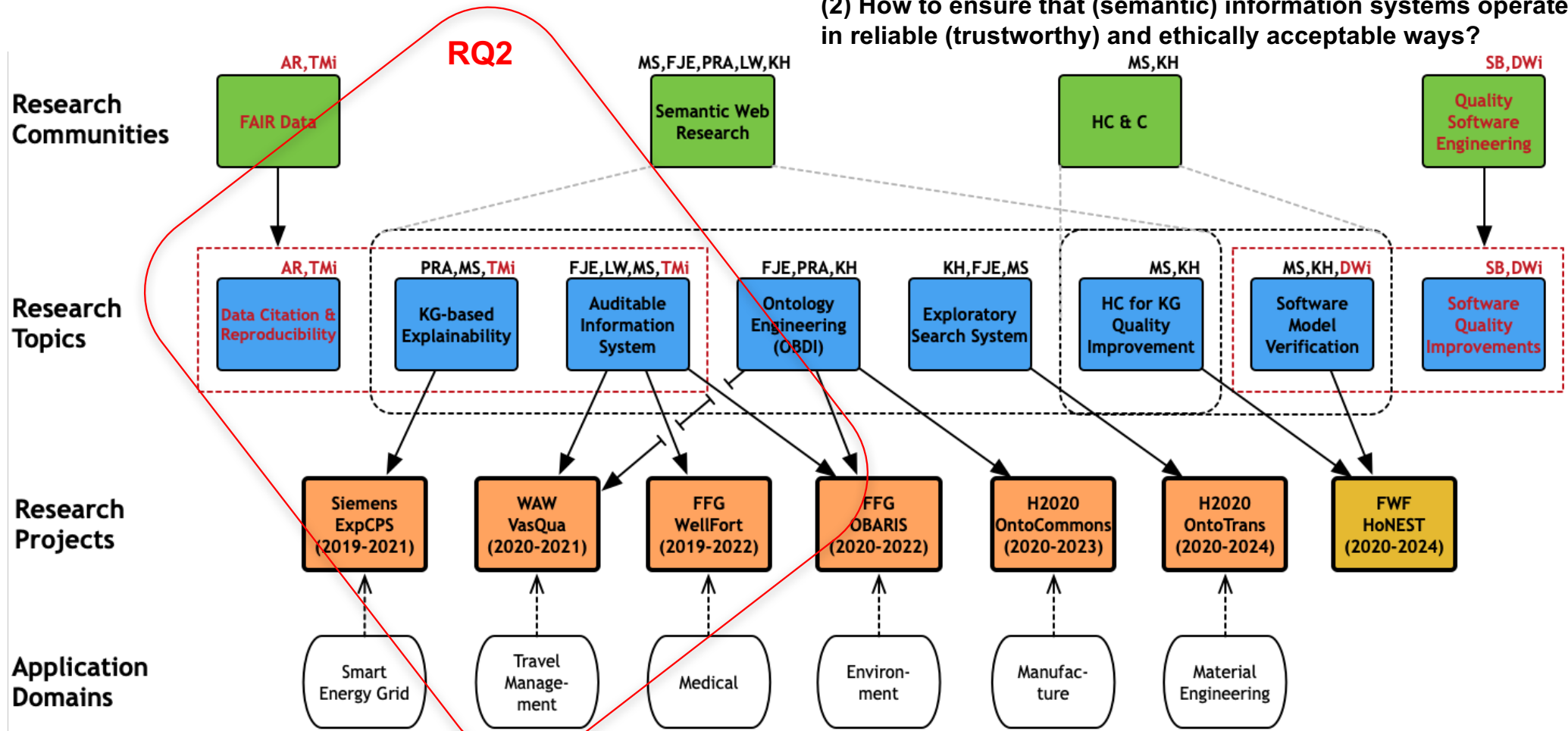
Related Robot Types

 COMAU E.DO 6 AXES Robot Type Keine Beschreibung	 STAUBLI TX2 90XL Robot Type Keine Beschreibung	 ROZUM PULSE 75 Robot Type Keine Beschreibung	 PRECISE AUTOMATIC PAVS6 Robot Type Keine Beschreibung
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Recommendations/
Infobox

Research Areas and Projects

(2) How to ensure that (semantic) information systems operate in reliable (trustworthy) and ethically acceptable ways?



How to design and implement Auditable Semantic AI Systems (SAIS)?

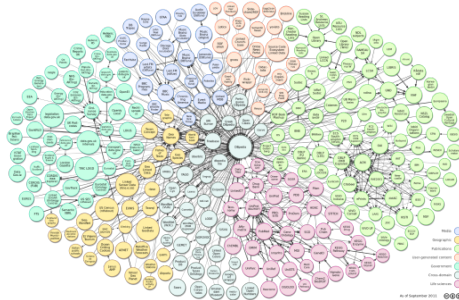
- FFG IKT der Zukunft
- 2020-2022

- **G1: Provide a taxonomy and characterization of SAIS**
- G2: Establish a technology stack for SAIS
- G3: Provide data integration & management methods for SAIS
- **G4: Create an auditability framework for SAIS**
- G5: Introduce and evaluate SAIS stack in concrete environmental use cases



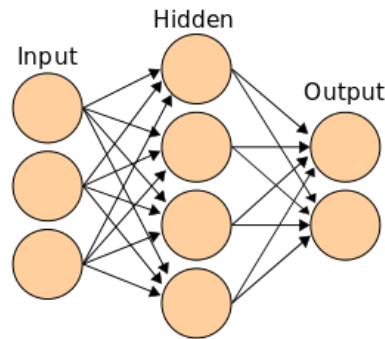
G1: Provide a taxonomy and characterization of SAIS

1. Semantic Web



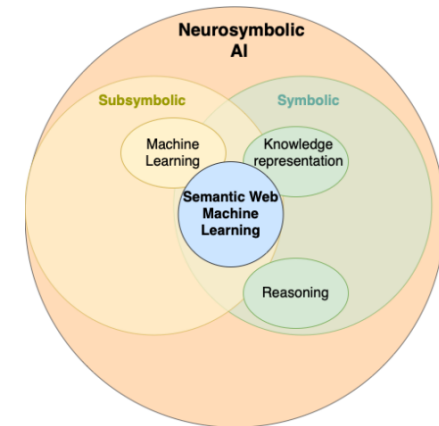
- + symbolic knowledge
- + explainability
- vulnerable to noisy data
- knowledge acquisition bottleneck

2. Machine Learning



- + knowledge from sparse data
- + broad applicability
- intransparency
- often lots of training data required

3. Semantic Web Machine Learning



Focus on **semantic web** resources and **machine learning** approaches

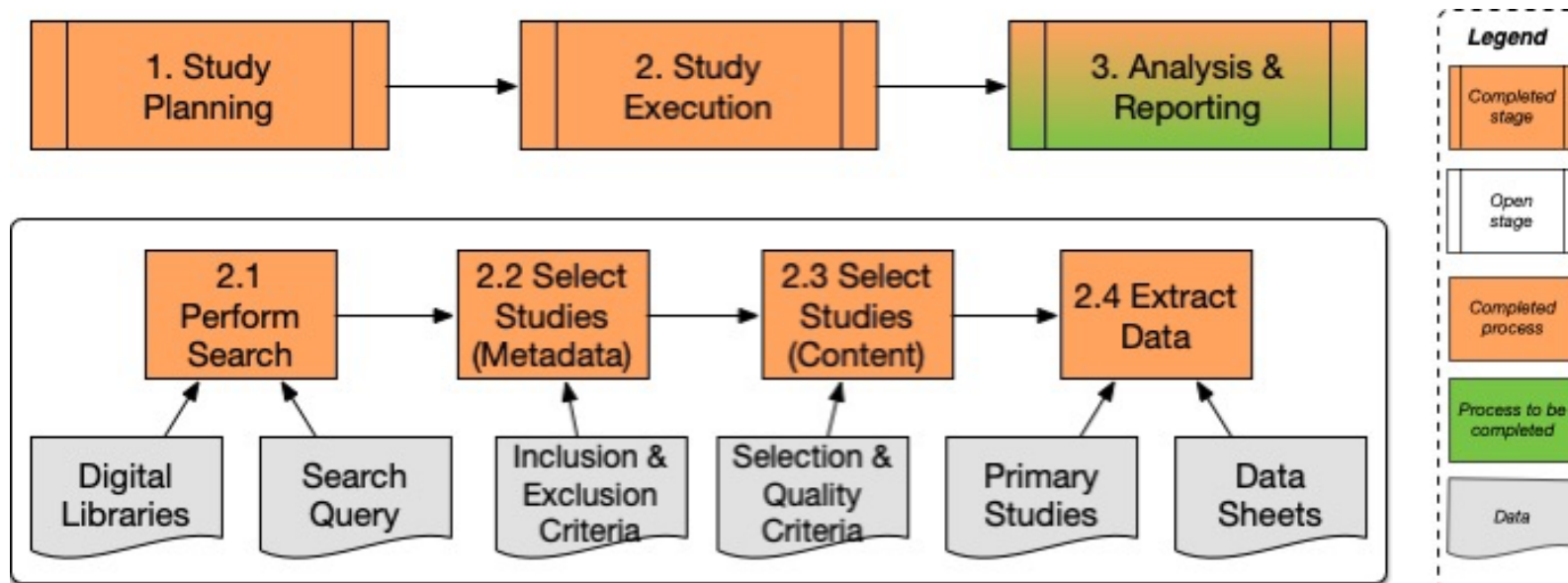
= SWeMLS, subset of neurosymbolic AI

Systematic Mapping Study: Methodology

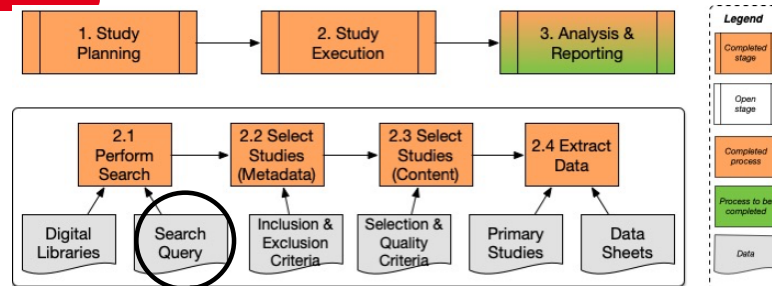
G1: Provide a taxonomy and characterization of SAIS

Query Date: October 2020

Research Team: 10 participants



Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering.

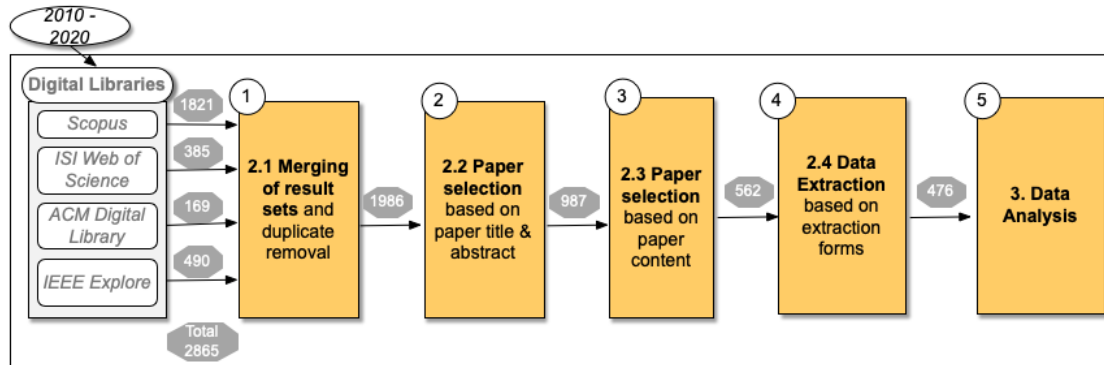


G1: Provide a taxonomy and characterization of SAIS

Sub-Query	Used Search Keywords
<i>Q1 (SW module)</i>	knowledge graph, linked data, semantic web, ontolog*, RDF, OWL, SPARQL, SHACL
<i>Q2 (ML module)</i>	deep learning, neural network, embedding, representation learning, feature learning, language model, language representation model, rule mining, rule learning, rule induction, genetic programming, genetic algorithm, kernel method
<i>Q3 (System)</i>	Natural Language Processing, Computer Vision, Information Retrieval, Data Mining, Information Integration, Knowledge Management, Pattern Recognition, Speech Recognition

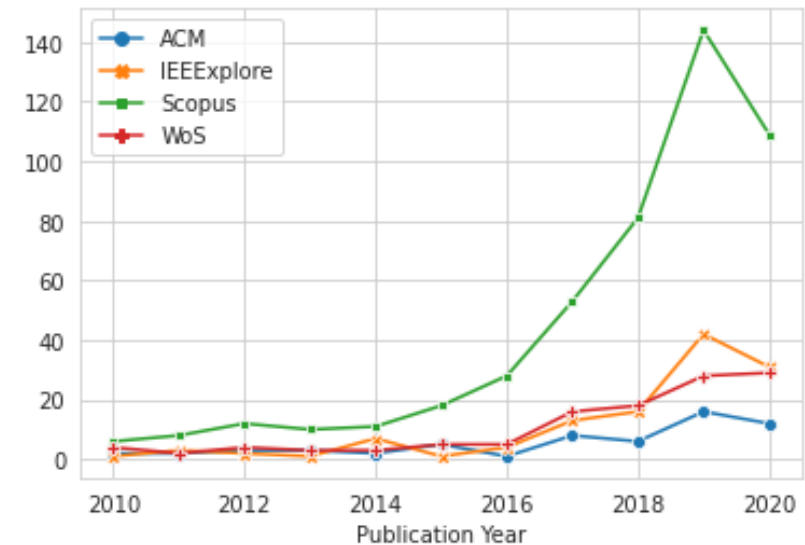
Systematic Mapping Study: Result Set

G1: Provide a taxonomy and characterization of SAIS



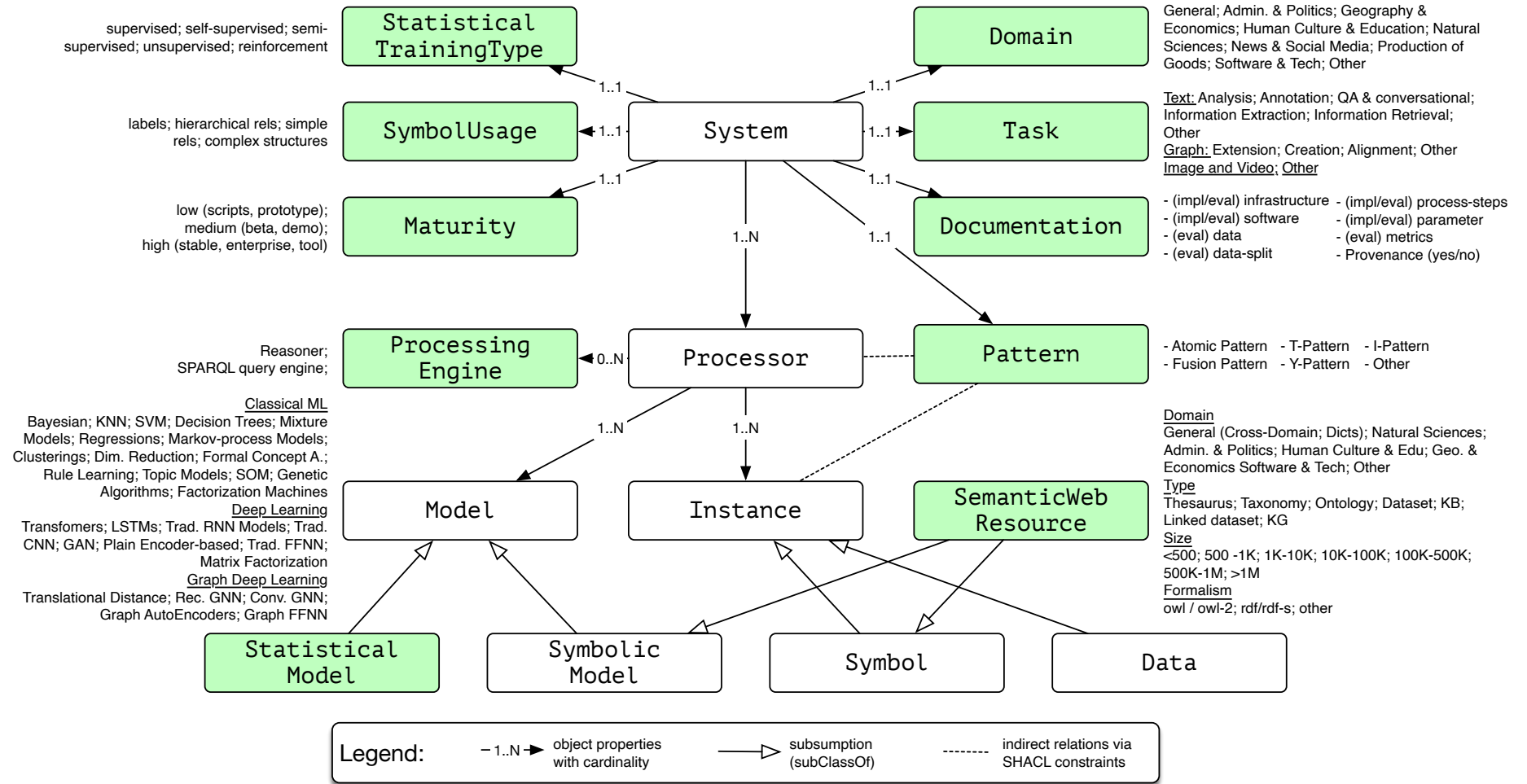
Bibliographic analysis:

- 1) Scopus accounts for largest portion
- 2) Strong increase of papers over last years



SWeML System Classification

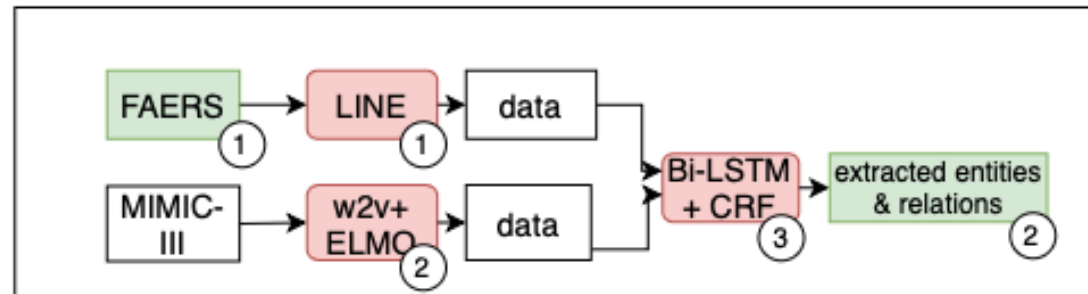
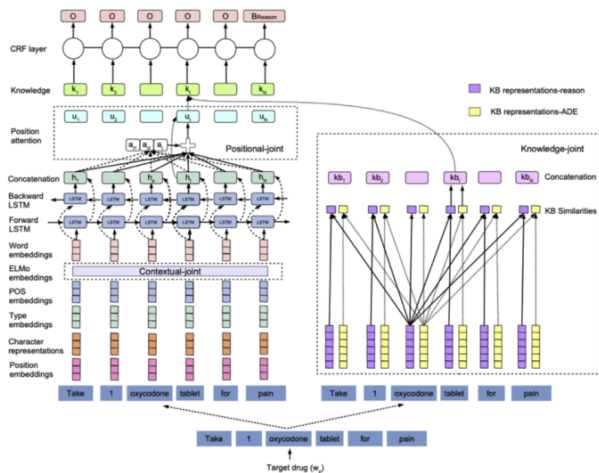
G1: Provide a taxonomy and characterization of SAIS



SWeML System Design Patterns

G1: Provide a taxonomy and characterization of SAIS

- Based on [1], compositional design patterns for hybrid systems
- SMS retrieved papers beyond these patterns, e.g. [2]



data “model-free”
(textual, tabular, images,...)

ML inductive inference
(predict, classify, ...)

sym “model-based”
(symbolic, relational)

KR deductive inference
(reasoning, querying,...)

[1] Van Harmelen, F., & Teije, A. T. (2019). A boxology of design patterns for hybrid learning and reasoning systems: *Journal of Web Engineering*, Vol 18, pp. 97-124, 2019.

[2] Dandala, B., Joopudi, V., Tsou, C. H., Liang, J. J., & Suryanarayanan, P. (2020). Extraction of Information Related to Drug Safety Surveillance From Electronic Health Record Notes: Joint Modeling of Entities and Relations Using Knowledge-Aware Neural Attentive Models. *JMIR medical informatics*, 8(7), e18417.

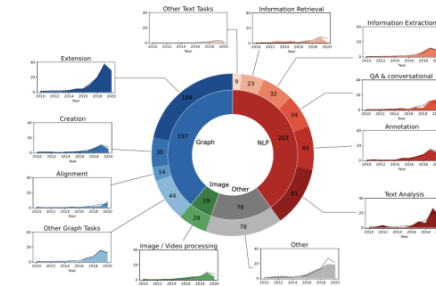
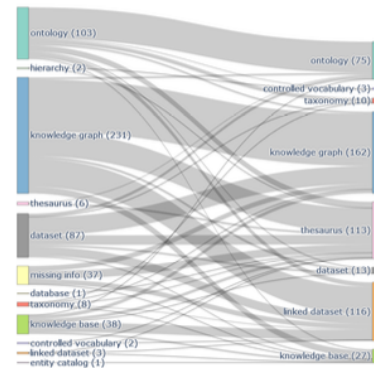
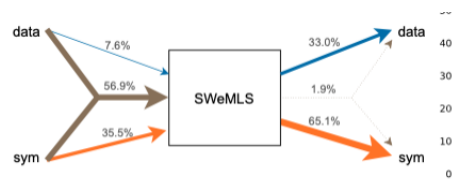
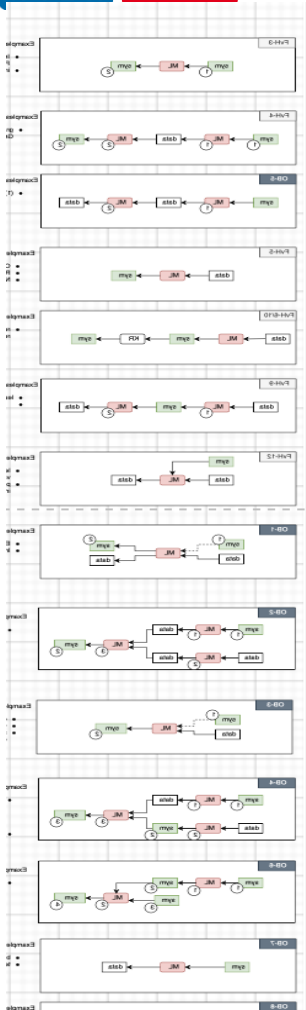
G1: Provide a taxonomy and characterization of SAIS

Follow for more detailed analysis in upcoming publications:

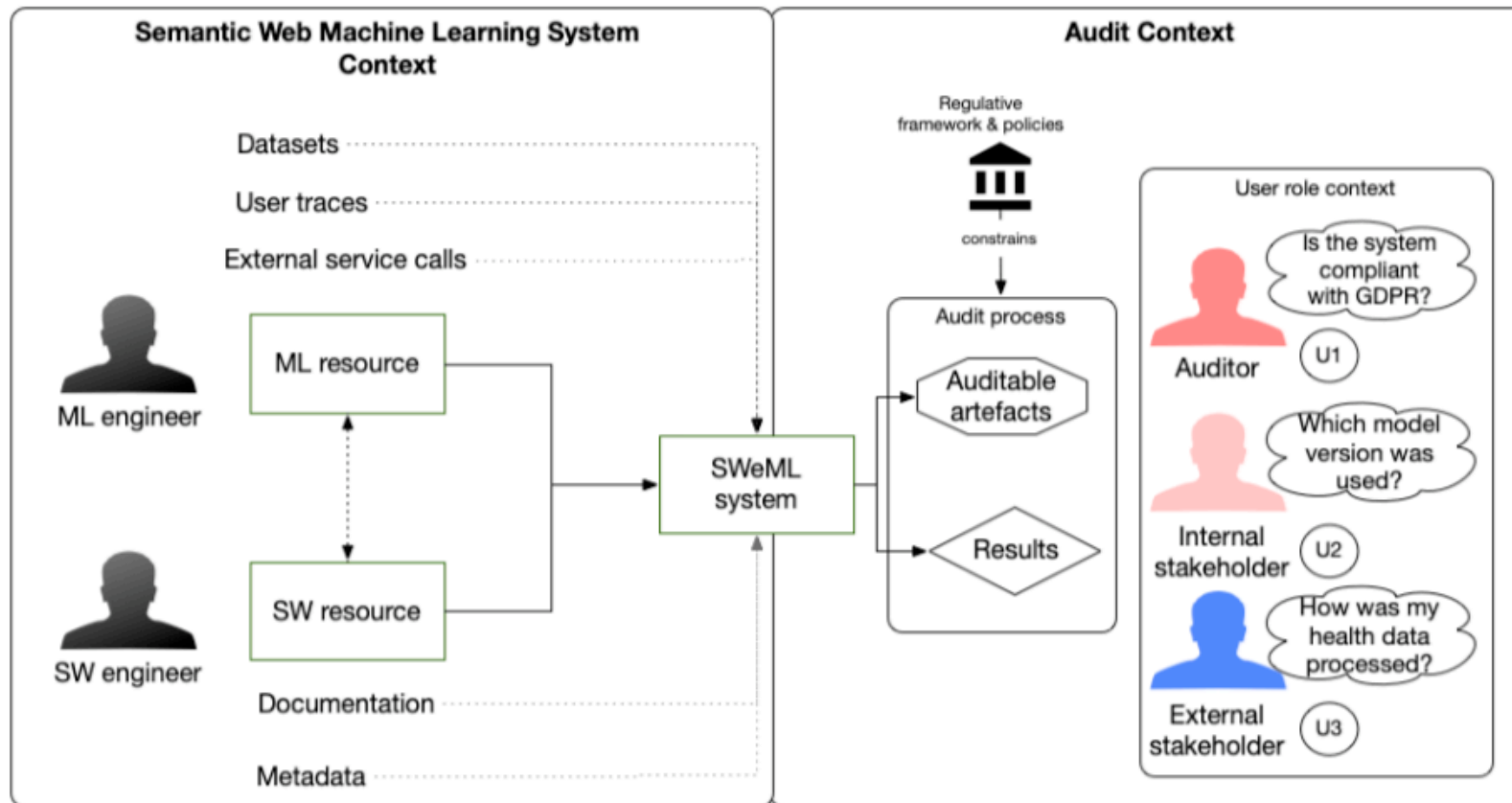
<http://semsys.ifs.tuwien.ac.at>

<http://www.obaris.org>

<https://twitter.com/LaWaltersdorfer>



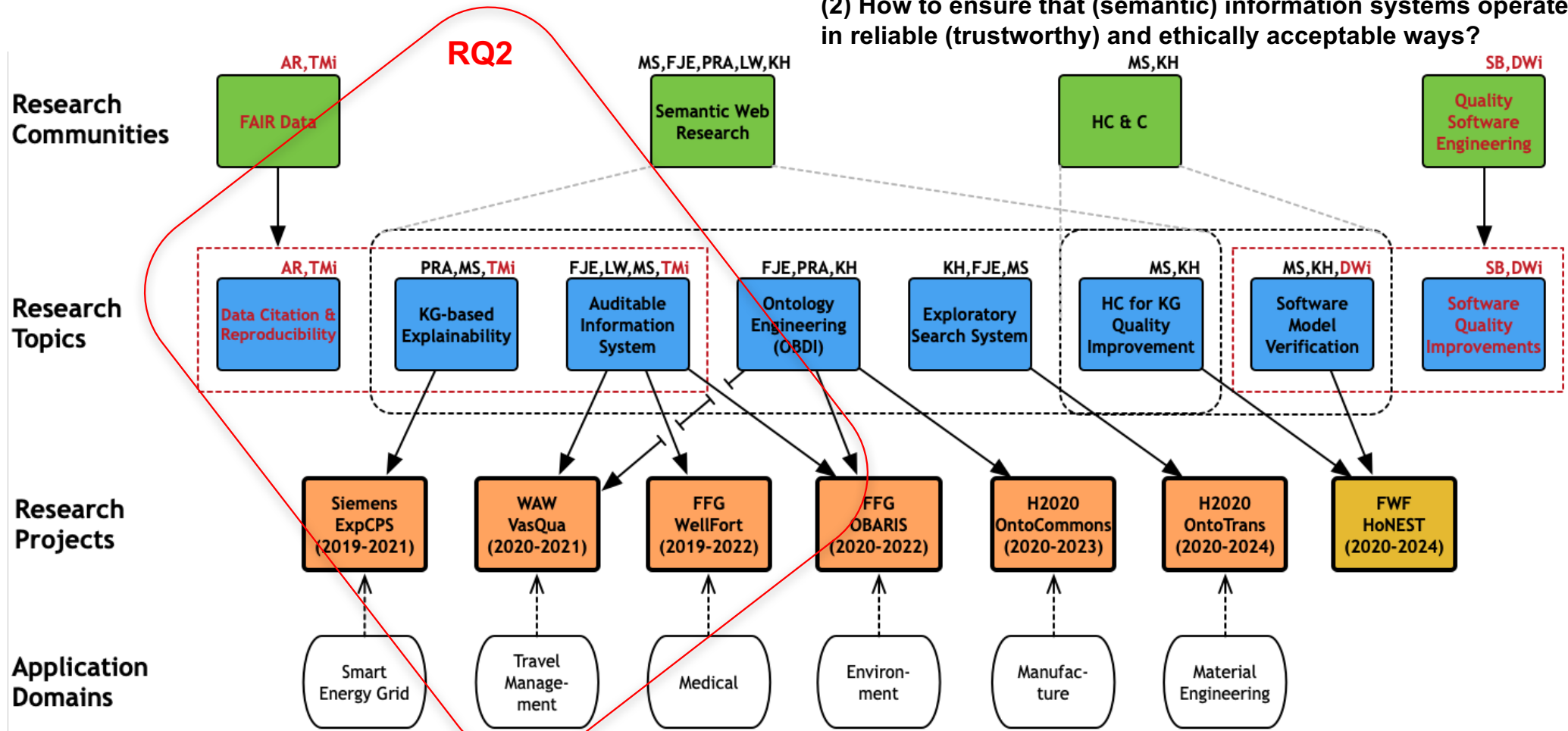
G4: Create an auditability framework for SAIS



Ongoing PhD work of
Laura Waltersdorfer

Research Areas and Projects

(2) How to ensure that (semantic) information systems operate in reliable (trustworthy) and ethically acceptable ways?





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Faculty of Informatics

Explainable Cyber-Physical Systems (ExpCPS)

- Siemens AT
- 2019-2021

Explainable Cyber Physical Energy Systems based on Knowledge Graph

**Peb Aryan, Fajar Ekaputra, Marta Sabou, Daniel Hauer
Ralf Mosshammer, Alfred Einhalt, Tomasz Miksa, Andreas
Rauber**

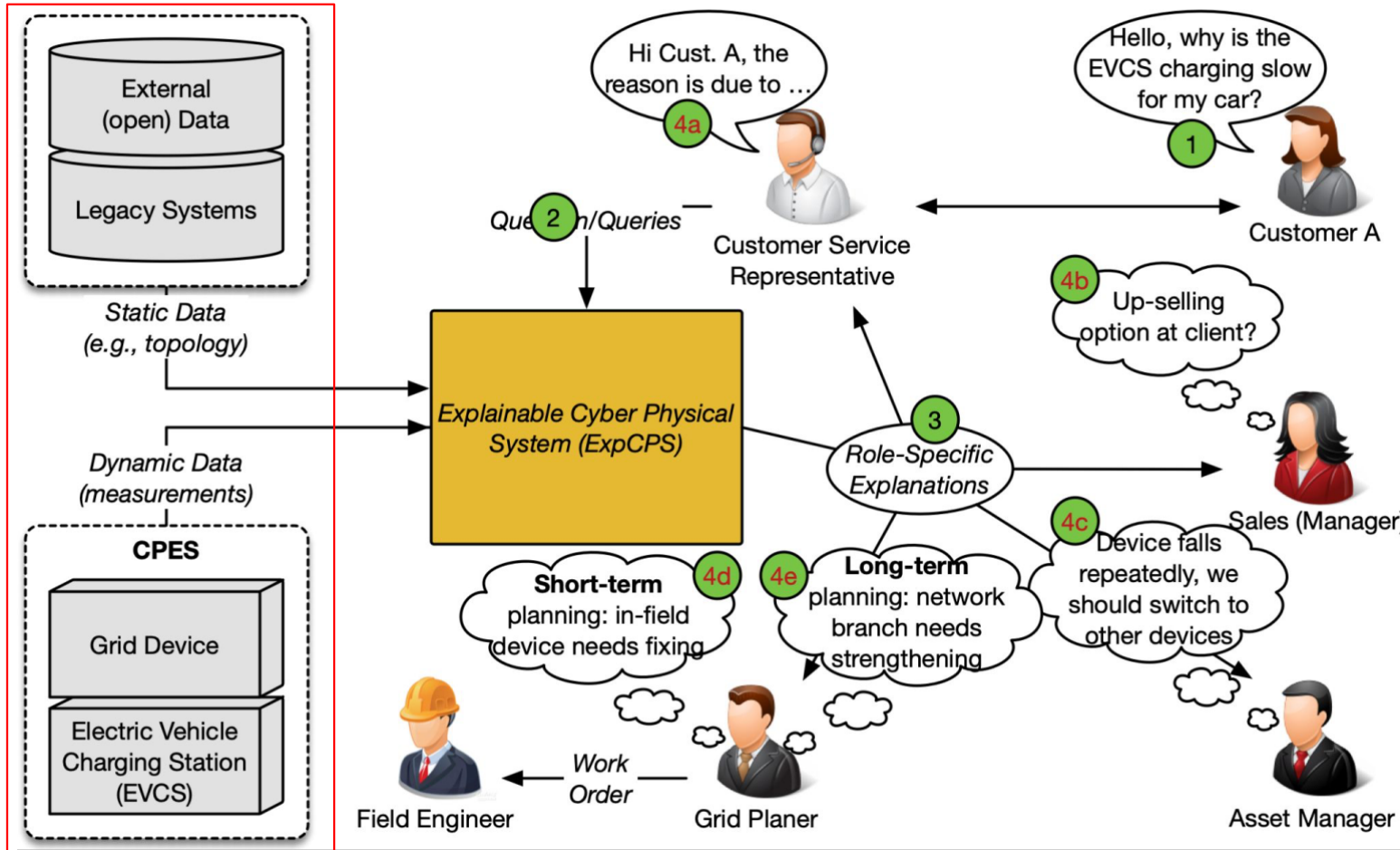
Information & Software Engineering Research Group,
Institute of Information Systems Engineering,
Faculty of Informatics - TU Wien

MSCPES 2021 18.05.2021

Siemens AG

funded by the Austrian Research Promotion Agency (FFG)
in the PoSyCo project (FFG No. 3036508)

Motivation



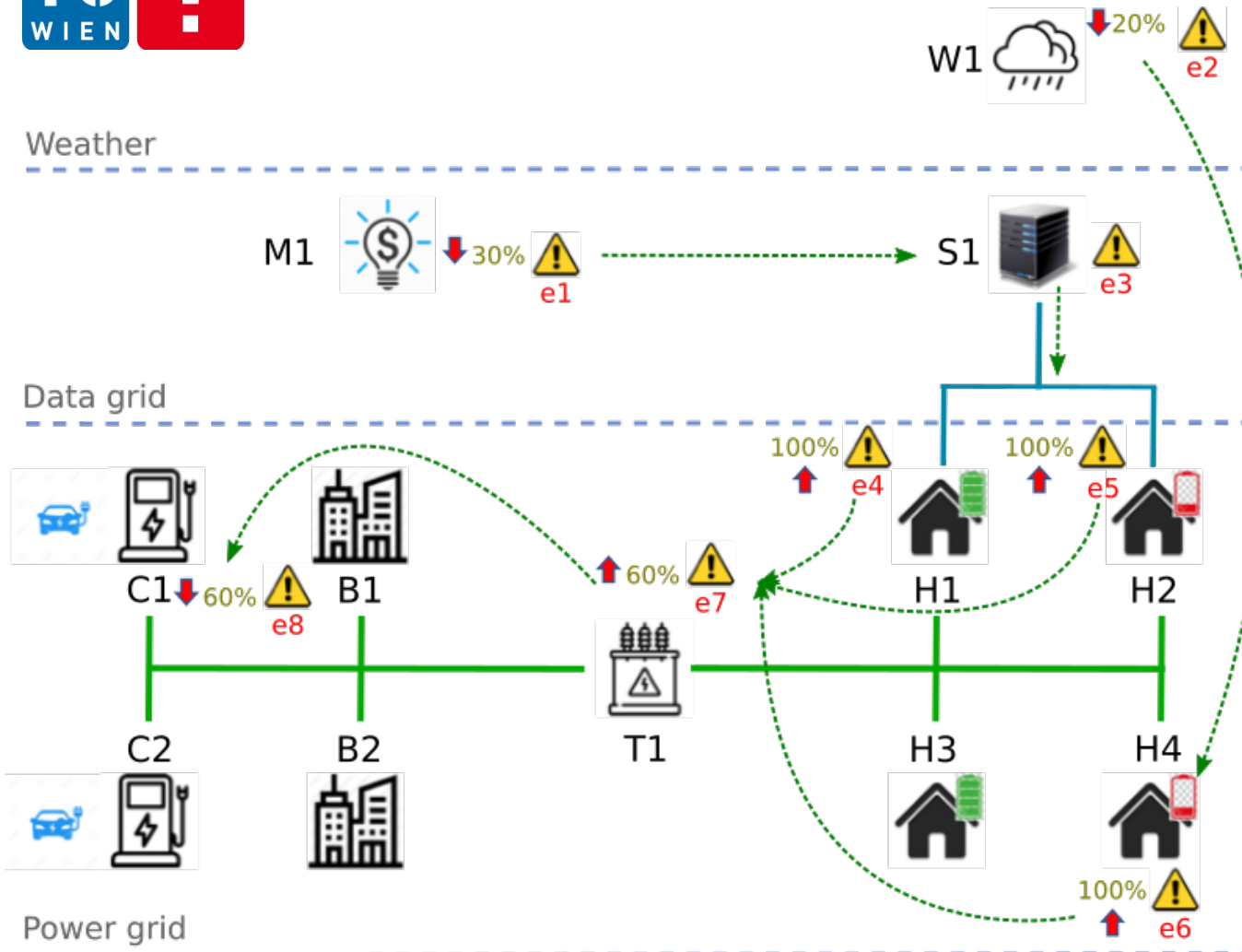
Explanations could support the work of several Smart Grid stakeholders:

- Customers
- Grid operators (sales, operations, planning)
- Third parties (EVCS operators)

Explanations are the result of combining data from various sources:

- CPES assets sensors
- Open data (weather)
- Legacy systems

Flexibility Scenario



Features

- M1 : energy market
- S1 : Flex application server
- W1 : weather
- H1-H4 : residential houses
- B1-B2 : commercial buildings
- C1-C2 : EV charging stations

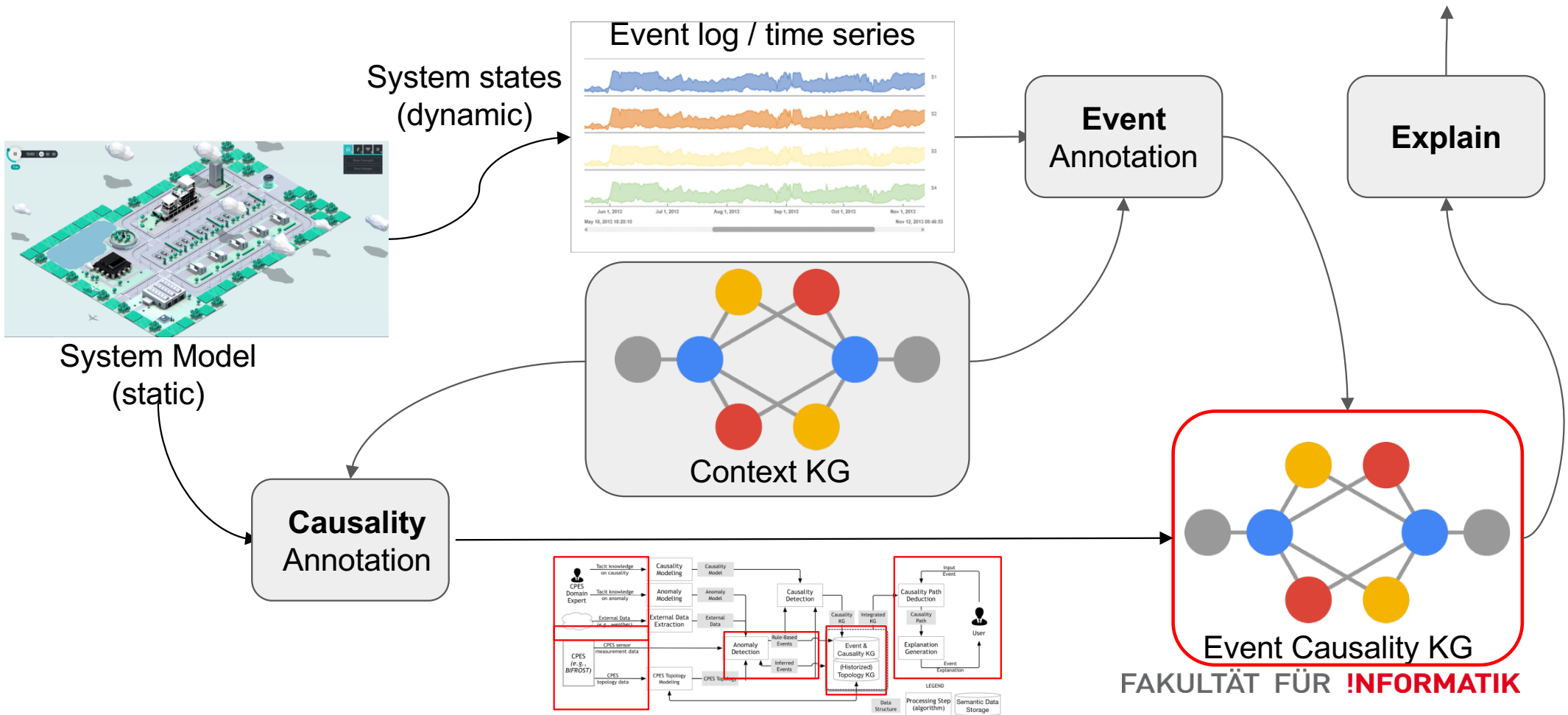
Events

- e7 : trafo overload
- e4, e5, e6 : high consumption
- e3 : flex notification
- e1 : energy market (real-time)

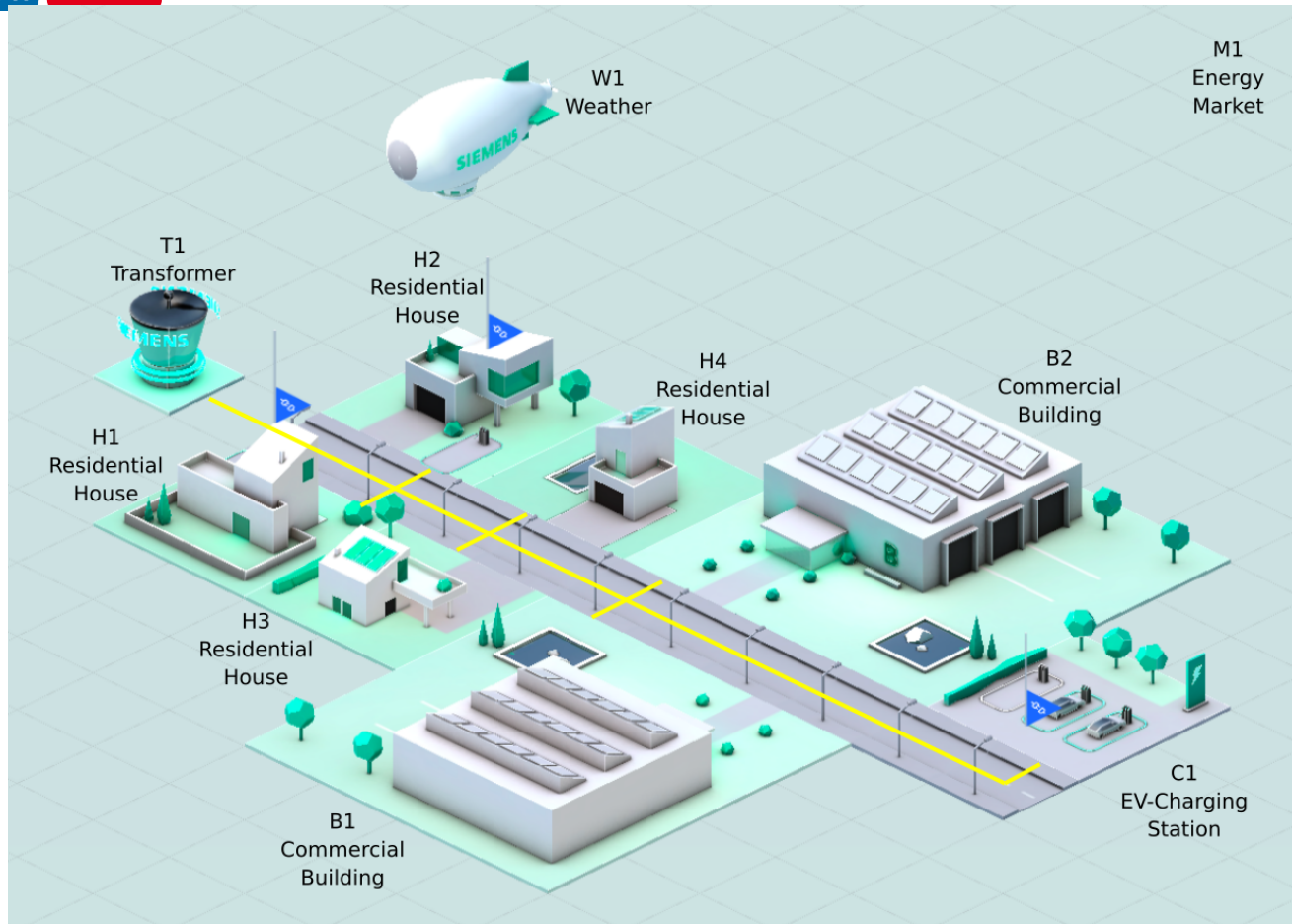
Example explanation

- e7 because e(4,5,6)
- e(4,5) because of e3; because of e1
- e6 because of e2

Explanation Generation Process



Implementation Result



OverloadEvent at 10:30:14

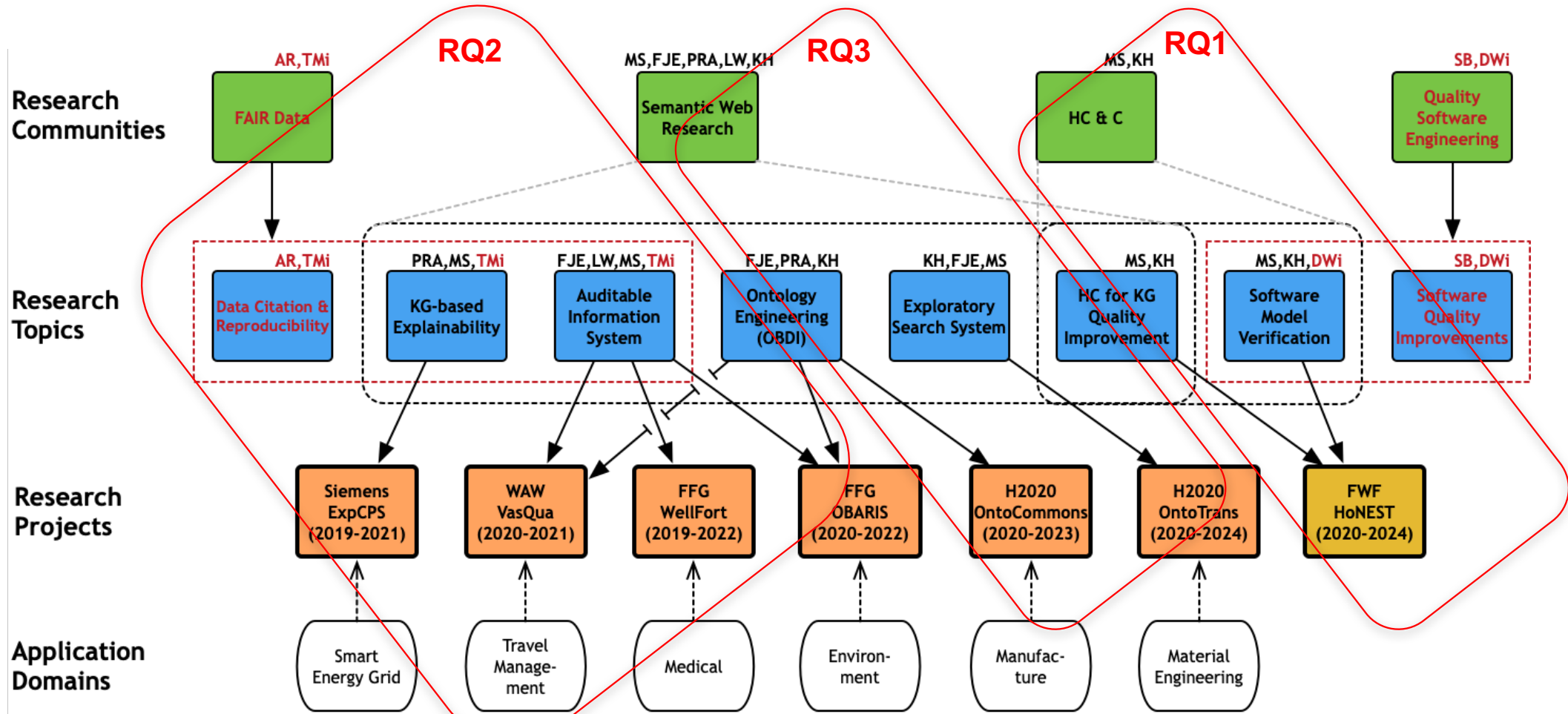
- Overload (TRAF0-BUILDING) **caused by** PeakConsumption (EV-STATION,RESIDENTIAL-SINGLE,COMMERCIAL-FACTORY)
- PeakConsumption (RESIDENTIAL-SINGLE) **caused by** LowSolarOutput (SOLAR-PANEL)
- LowSolarOutput (SOLAR-PANEL) **caused by** LowSolarIntensity (AIRSHIP)
- PeakConsumption (RESIDENTIAL-SINGLE) **caused by** FlexRequest (AIRSHIP)

Explanation details

```

{ 3 items
  "event": "OverloadEvent"
  "location": "TRAF0-BUILDING:a937d270"
  "causedBy": [ 7 items
    0: { ... } 2 items
    1: { 3 items
      "event": "PeakConsumptionEvent"
      "location": "RESIDENTIAL-SINGLE:b0938500"
      "causedBy": [ 1 item
        0: { 2 items
          "event": "FlexRequestEvent"
          "location": "AIRSHIP:a01e6a50"
        }
      ]
    }
  ]
  2: { ... } 2 items
  3: { ... } 3 items
  4: { ... } 2 items
  5: { ... } 2 items
}
  
```


Summary: Research Areas and Projects





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Semantic Systems Research Lab
Thank you!
Happy 2022!

