University of Stuttgart
Institute of Industrial Automation
and Software Engineering

2 Development of a digital twin with a 3 semantic query and command interface for a 1 modular production facility

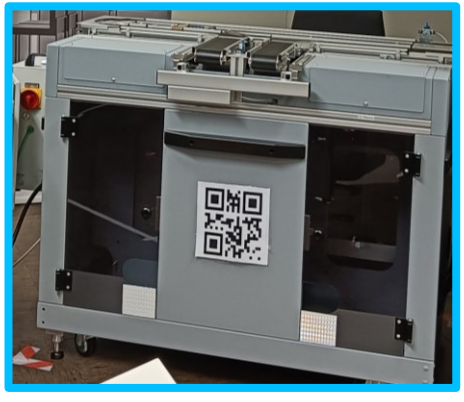
Conception Project

Motivation

Not flexible ; difficulties in reconfiguration

- CP factory
  - Proprietary systems from Festo
    1. MES
    2. Fleet Manager

CP Branch



CP Storage

Robotino v3

- Problems:
  - Modularity
  - Interoperability
  - Difficulty to maintain and operate

Solution

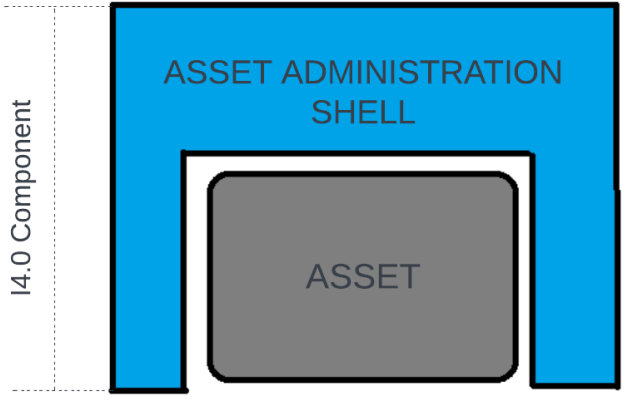
- Need for provision of **harmonised interface** using “Digital Twin” (digitizing industrial production)
- To achieve intuitive HMI, allowing workers to operate the system just using Natural Language
  - Semantics
  - Neural Language Model for language understanding

Basics

Digital Twin- Asset Administration Shell (AAS)

- What is Digital Twin (DT)? Generally, a Digital Twin (DT) is a *"virtual representation of a physical asset in a CPS, capable of mirroring its static and dynamic characteristics"* [1]

- AAS is a implementation for Digital Twin
  - Advantages & reasons:
    1. Semantically described information
    2. Promotes standardized DT to ensure interoperability
    3. It has good ready-to-use middleware



CLASS IEC REST API OPC UA

AAS Middleware

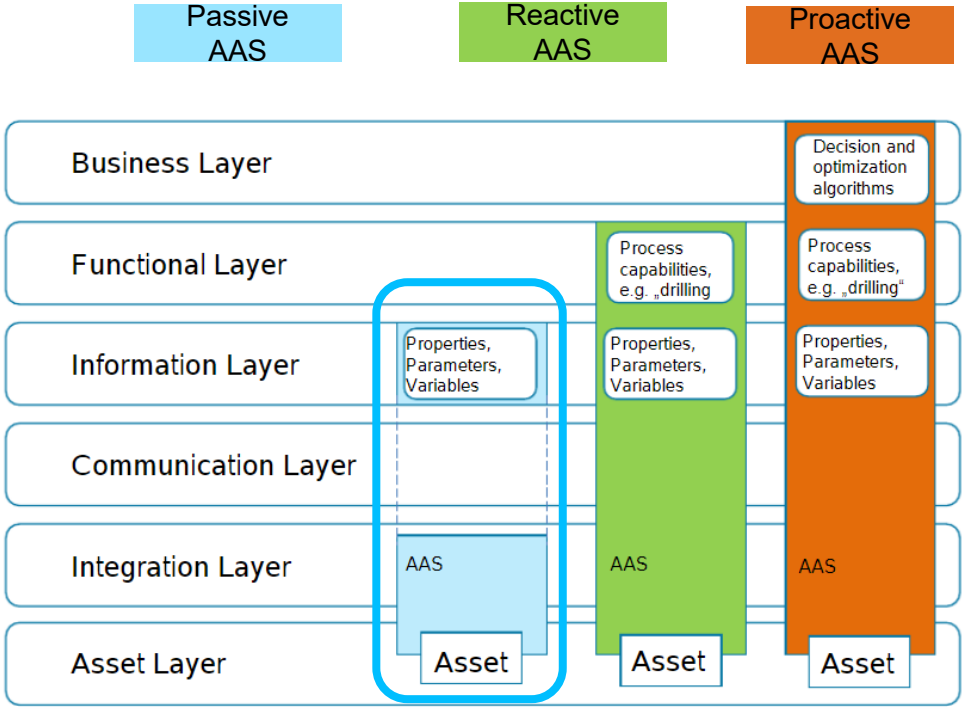
Evaluation

Criteria	1.2.0 BaSyx	0.2.1 FA³ST
Asset connections possibility (incl. with tool)	o	+
AASX file (static data upload)	+	o
Data query (Runtime) (REST API)	+	-
Configurations (AAS Registry, Database)	+	- (only file-based, memory)
Deployment (docker available)	+	+
Code maturity	+	- (still under development)
Documentation	o [1]	o [2]
AAS metadata template	o [v2.0.1]	+ [v3.0RC01]

+: fulfilled o: conditionally fulfilled -: not fulfilled

Reference Architecture Model for Industry 4.0 (RAMI 4.0)

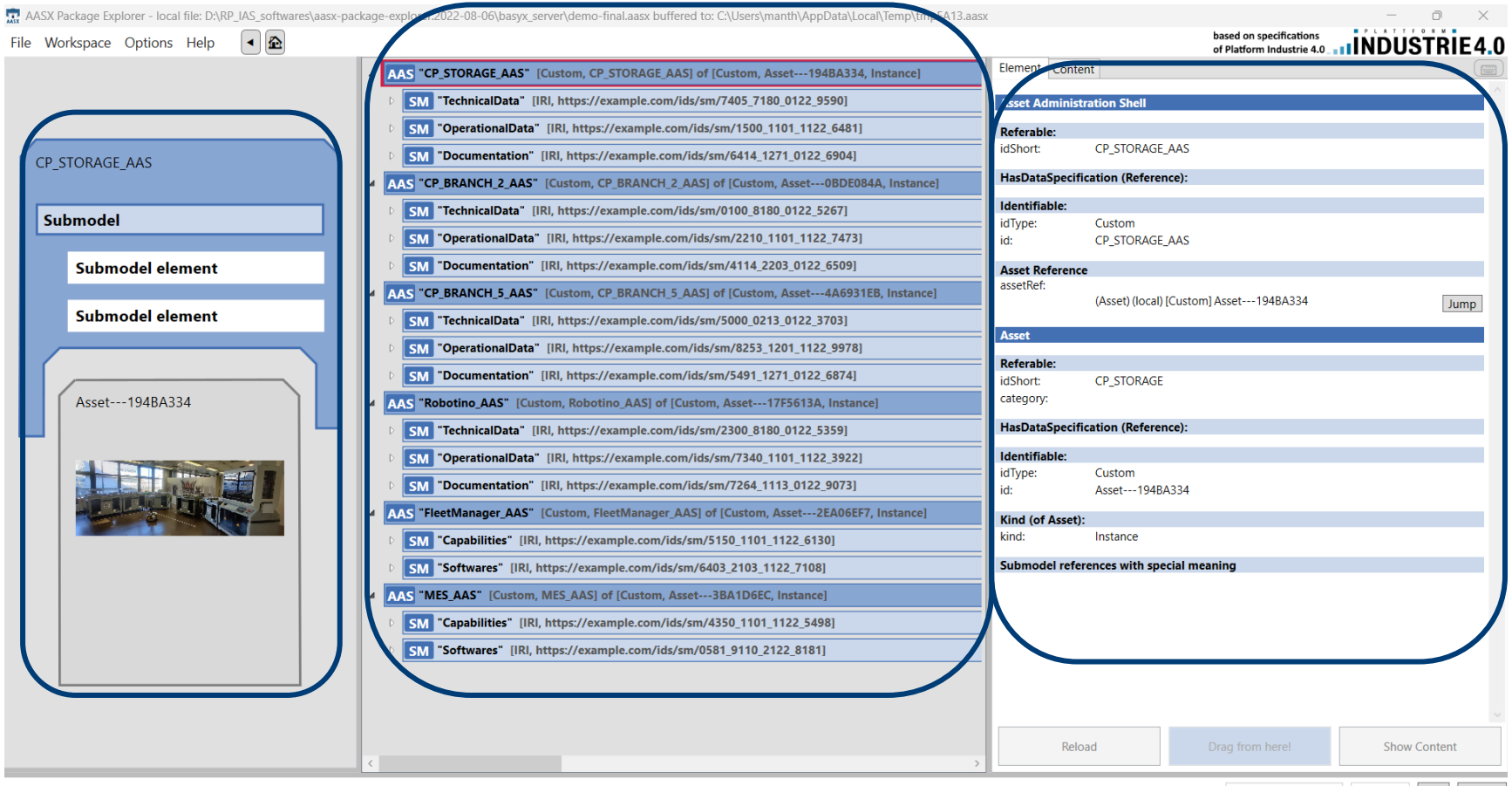
For Passive AAS



[4] adapted from

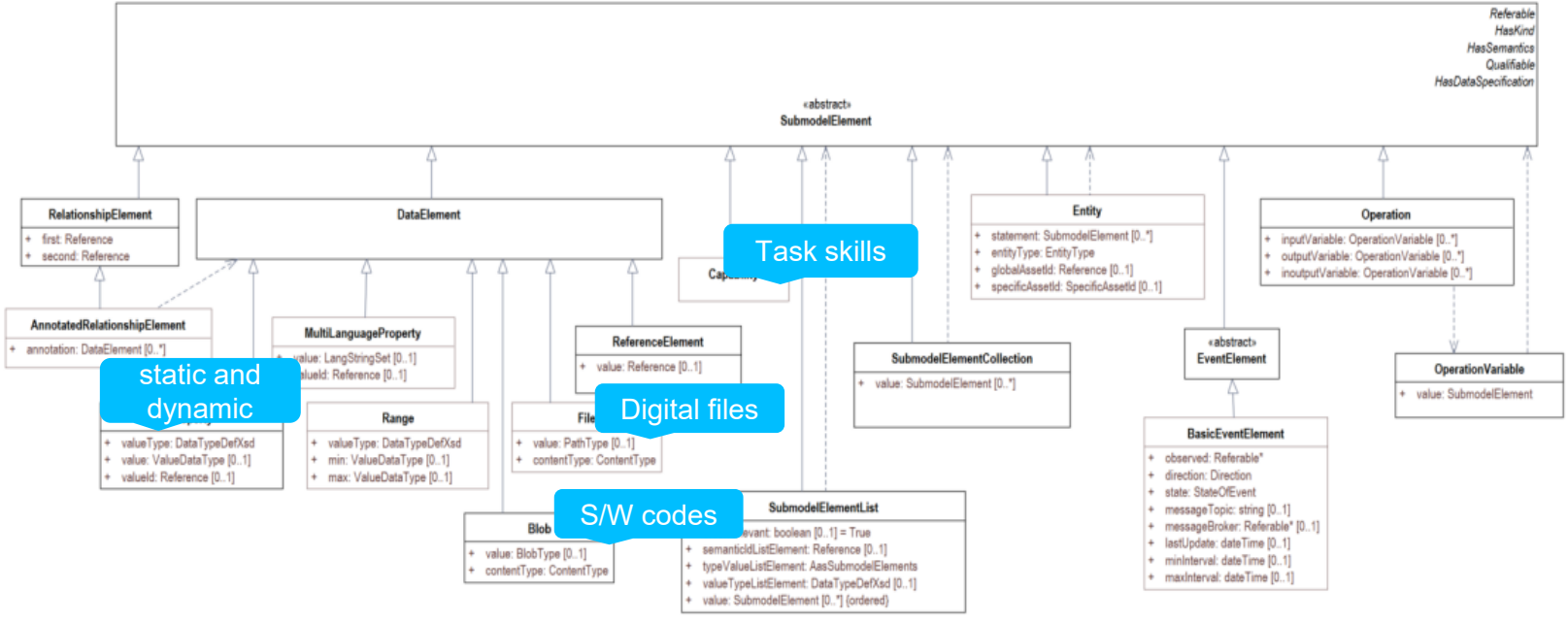
AAS at design time

Passive AAS



AAS Metamodel

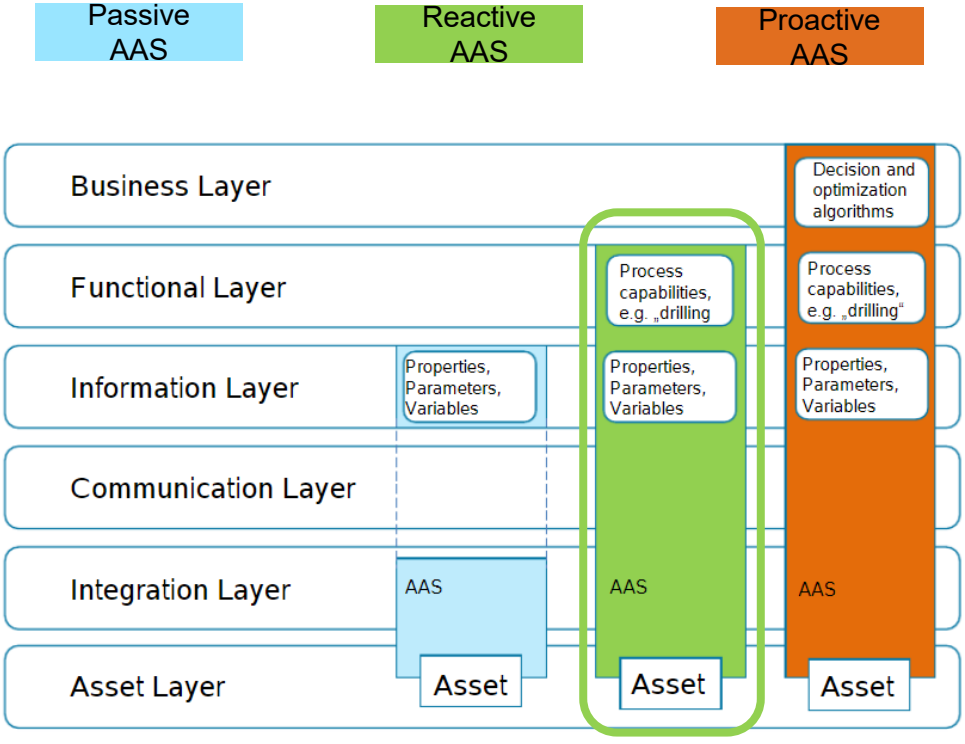
Submodel Element detailed view



[2]

Reference Architecture Model for Industry 4.0 (RAMI 4.0)

For Reactive AAS



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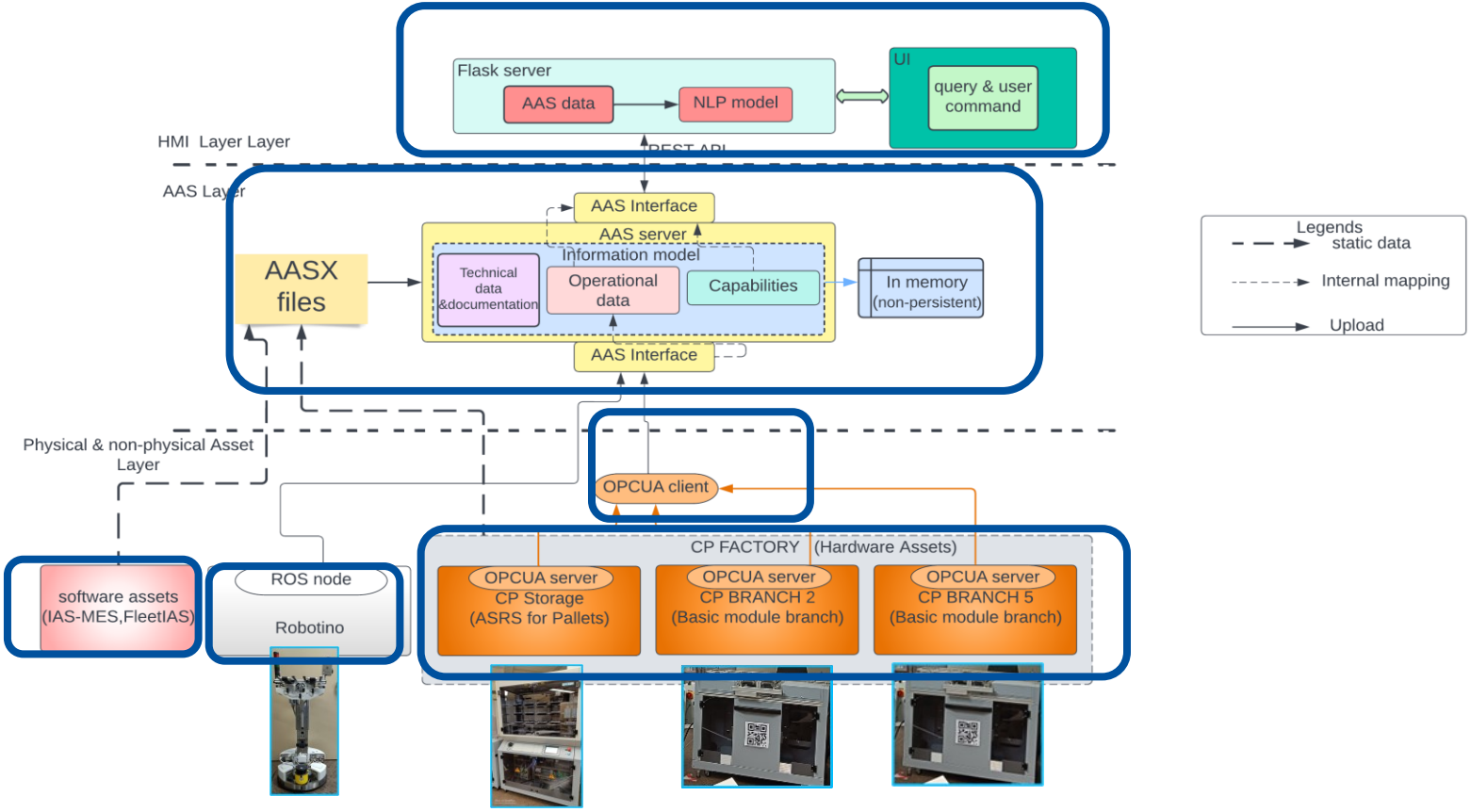
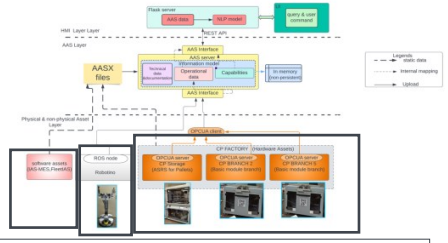
Architecture

Concept overview



Asset connections



- Software assets IAS-MES, FleetIAS
  - Python applications added as blob file

- Command skills :
  - Modular encapsuled as task skills

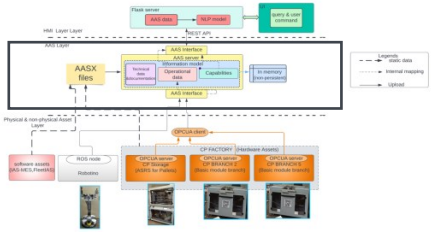
    e.g.: move_robotino_dock_2 REST API call

  - POST REST API request for assigning order

    e.g.:

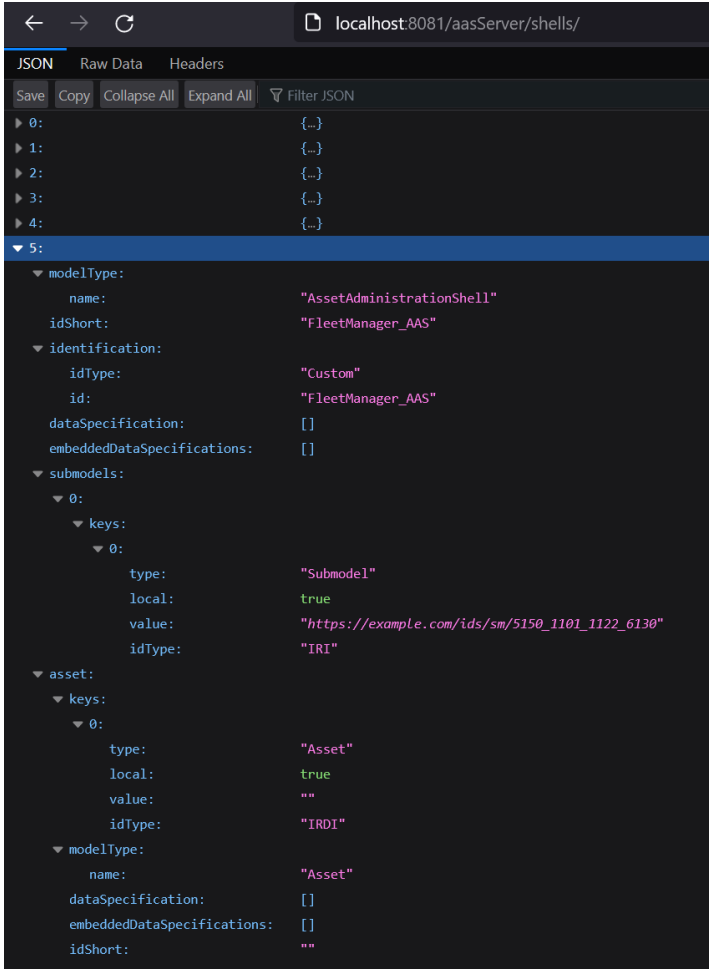
```
{
    "name": "Test",
    "description": "Test",
    "assigendWorkingPlan": 2021,
    "assignedWorkingPiece": 16,
    "orderNo": 1,
    "orderPos": 1,
    "mainOrderPos": 1,
    "customer": null,
    "status": "[0,0,0,0,0,0]"
}
```

AAS as the digital twin



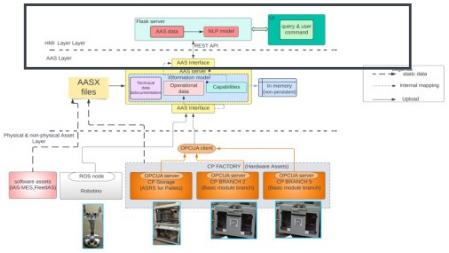
- Contains information model
- AAS server provides harmonized interfaces
  - API (RESTful API)

PUT	/shells/{aasId}/aas/submodels/{submodelIdShort}/submodel/submodelElements/{seIdShortPath}
GET	/shells/{aasId}/aas/submodels/{submodelIdShort}/submodel/submodelElements/{seIdShortPath}
DELETE	/shells/{aasId}/aas/submodels/{submodelIdShort}/submodel/submodelElements/{seIdShortPath}
GET	/shells/{aasId}/aas/submodels/{submodelIdShort}/submodel/submodelElements/{seIdShortPath}/value
PUT	/shells/{aasId}/aas/submodels/{submodelIdShort}/submodel/submodelElements/{seIdShortPath}/value



Better usability

Intuitive HMI



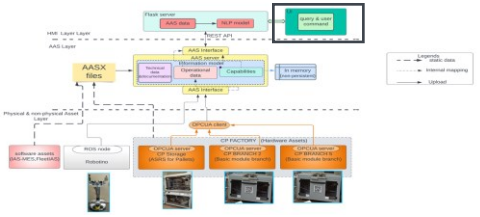
- Easy operation using Natural Language Processing (NLP)
- Helps in understanding human language to perform command and query
- NLP models are adapted from few foundational models like BERT, RoBERTa, etc.
- Sentence transformers (python based) library is used which provides pre-trained and finetuned models.
  - We make semantic similarity estimation/calculation.
- Two types of semantic search :
  - Symmetric Semantic Search
  - Asymmetric Semantic Search

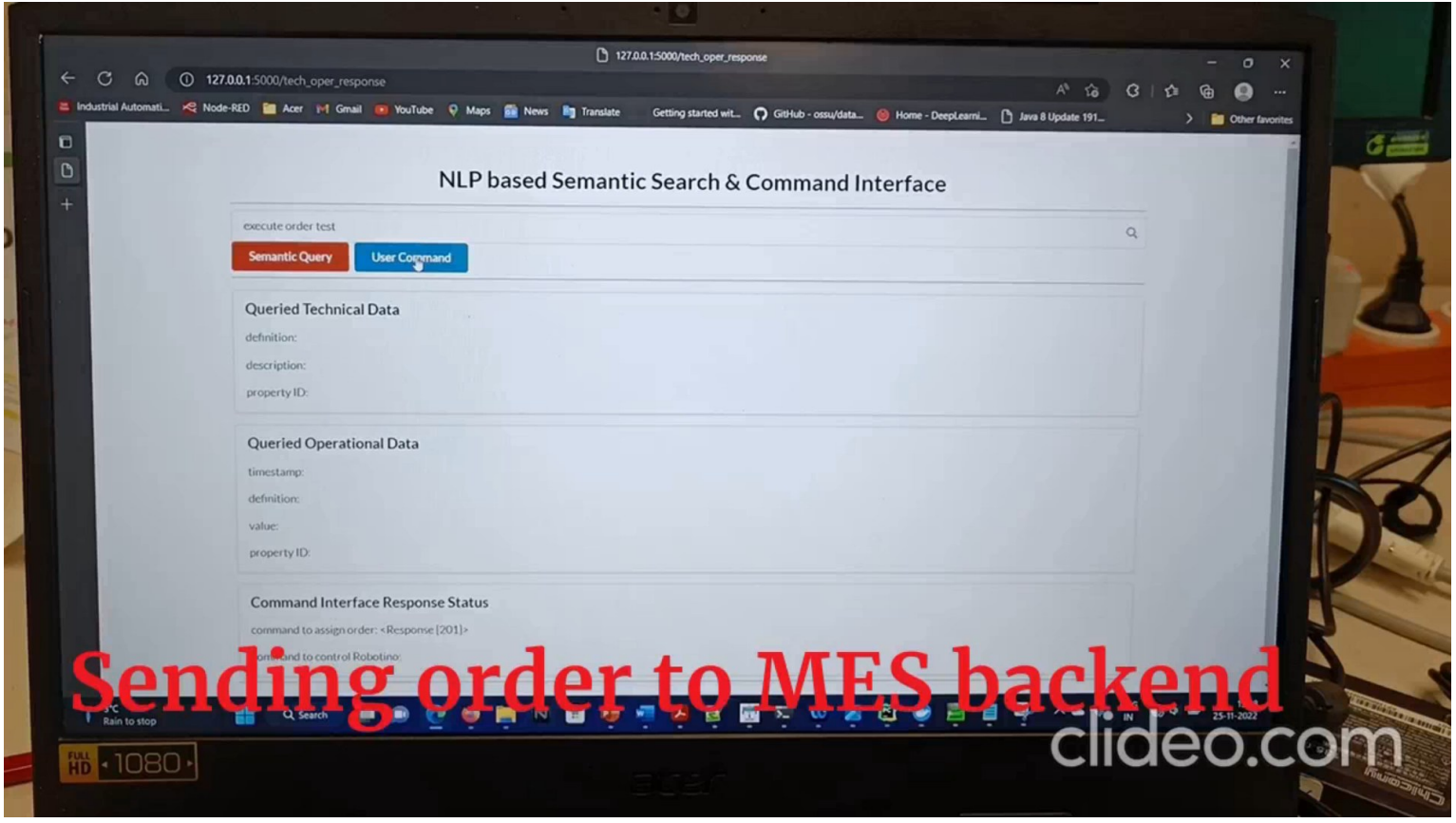
Query input : *How to learn Python online?*
Corpus data : *How to learn Python on the web?*

Query input : *What is Python?*
Corpus data : *Python is an interpreted, high-level and general-purpose programming language*

Results

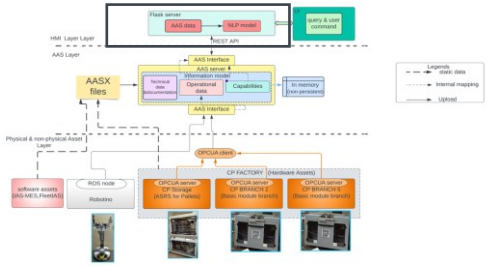
NLP based Command Interface

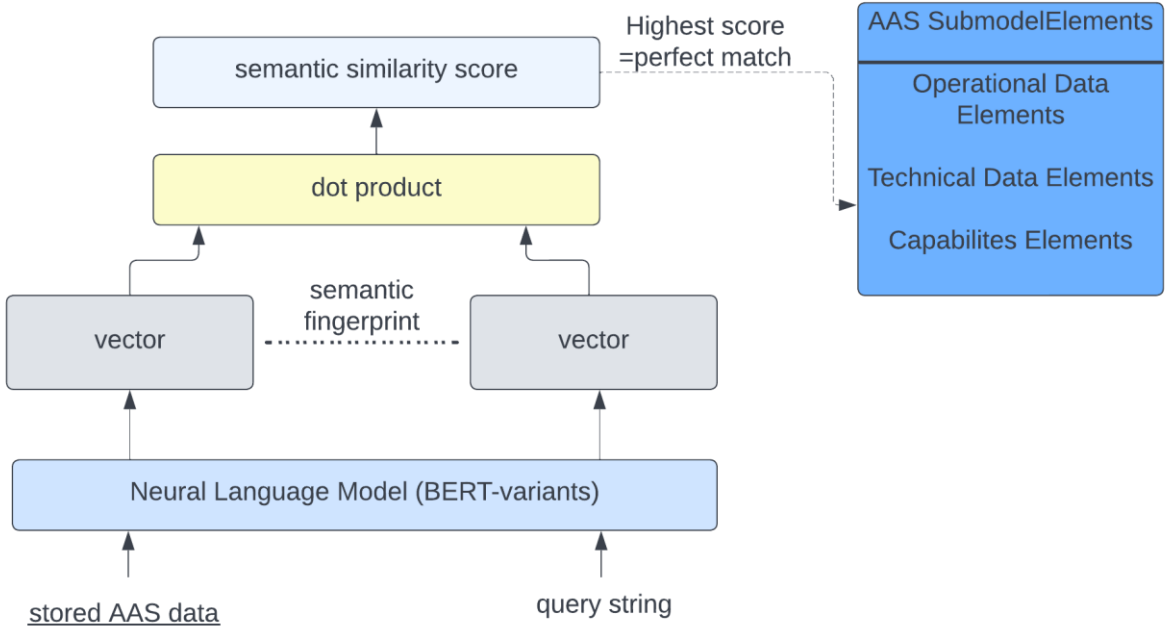




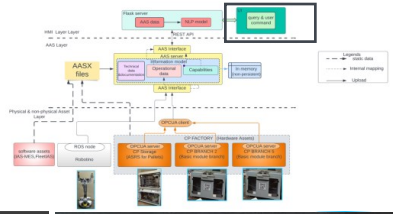
Better Usability

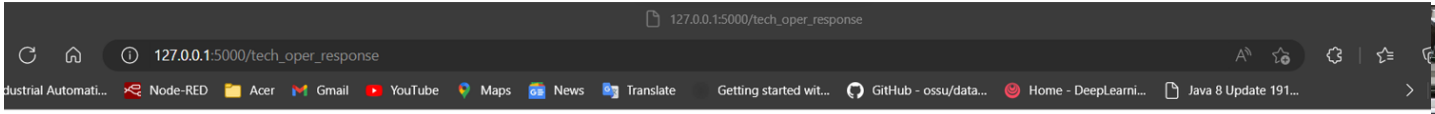
Semantic score based on AAS data & query





Results





Qu

NLP based Adaptive Semantic Query & Command Interface

module 2 junction

Semantic Query | User Command

Queried Technical Data

name: Junction_branch2

description: Pneumatic rotary cylinder with two end-position sensors

Semantic ID: https://admin-shell.io/SemanticIdNotAvailable /1/1

Queried Operational Data

timestamp: 11/30/2022, 14:49:11

name: Junction_branch2

value:[False] ← status

Semantic ID: https://example.com/ids/cd/2435_8142_1122_8850

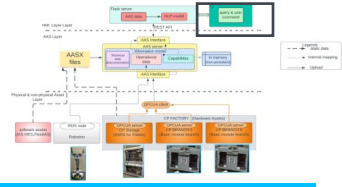
Command Interface Response Status

command to assign order:

command to control Robotino:

Results

Experimental Evaluation



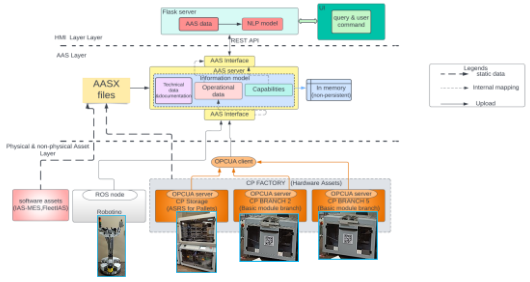
Adaptive query (user input)	Symmetric Semantic Search		Asymmetric Semantic Search	
	Technical data	Operational data	Technical data	Operational data
1. “module 2 junction status” 2. “Branch 5 junction”	✓	✓	✗	✓
1. “robotino lidar info” 2. “robotino laser”	✓	✓	✗	✓
“CP storage stopper information”	✓	✗	✓	✓
“stopper storage”	✓	✓	✗	✓
“Robotino odometry”	✓	✓	✗	✓

Selected NLM for test:

- Symmetric Semantic Search : all-distilroberta-v1
- Asymmetric Semantic Search : msmarco-distilbert-base-tas-b

Correct response: ✓
Incorrect response: ✗

Summary & Future work



Passive AAS

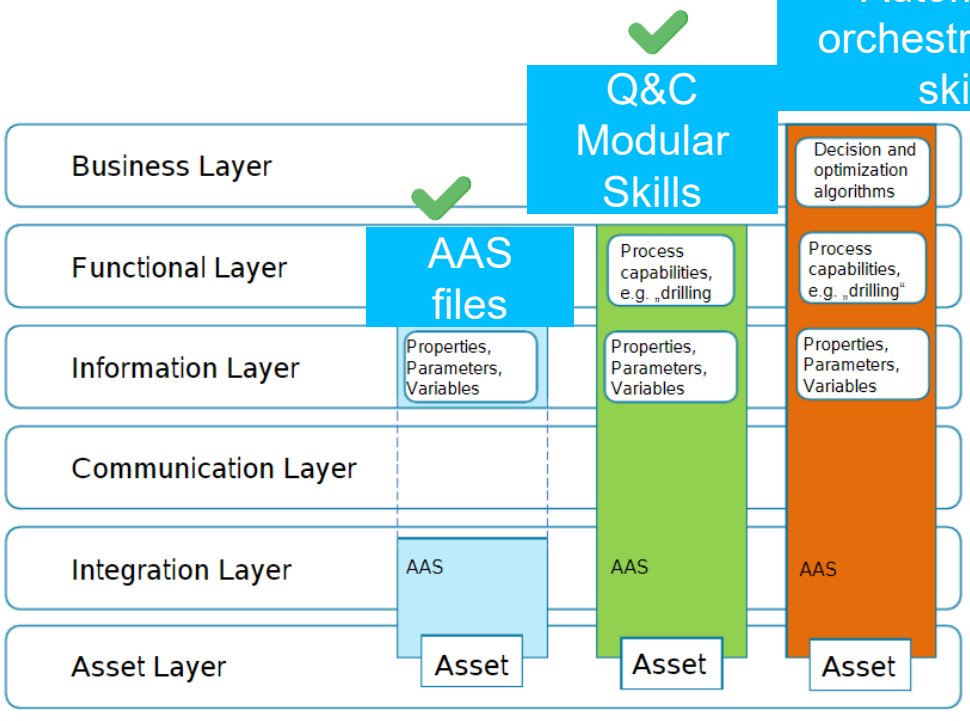
Reactive AAS

Proactive AAS

Automated orchestration of skills

Future work

Q&C Modular Skills



[4] adapted from

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Thank you!

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References

[1] B. Ashtari Talkhestani, W. Schlögl, and M. Weyrich, “Synchronisierung von digitalen Modellen,” atp Ed., vol. 59, no. 07–08, p. 62, Sep. 2017.

[2] BaSyx - Eclipsepedia

[3] FA³ST Service — FA³ST Service documentation (faaast-service.readthedocs.io)

[4] Belyaev, Alexander & Diedrich, Christian. (2019). Specification "Demonstrator I4.0-Language" v3.0.

[5] Part 1 (plattform-i40.de)