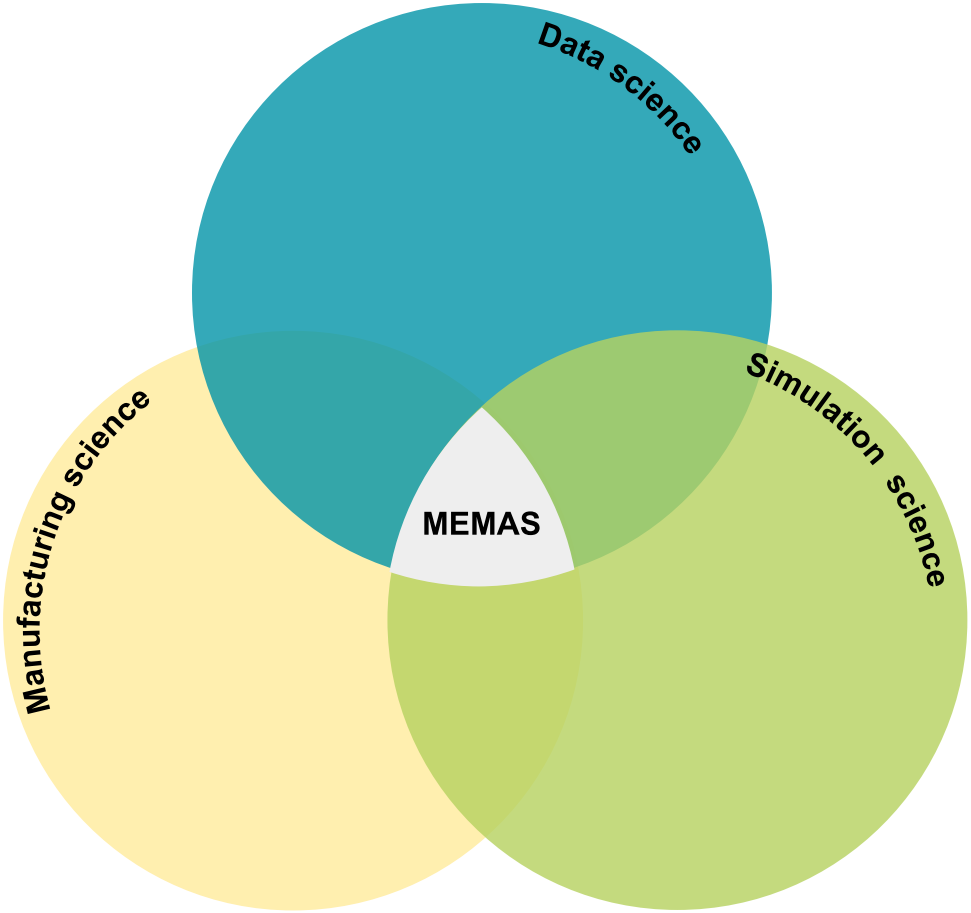
PROJECT MEMAS: A FRAMEWORK FOR FAIR DATA STORAGE IN COMPOSITE ENGINEERING

Project MEMAS - Metadata Enriched Manufacturing data for Automated Simulation

Pradnil Kamble, Institute of Vehicle Concepts, 12.-14. May 2025

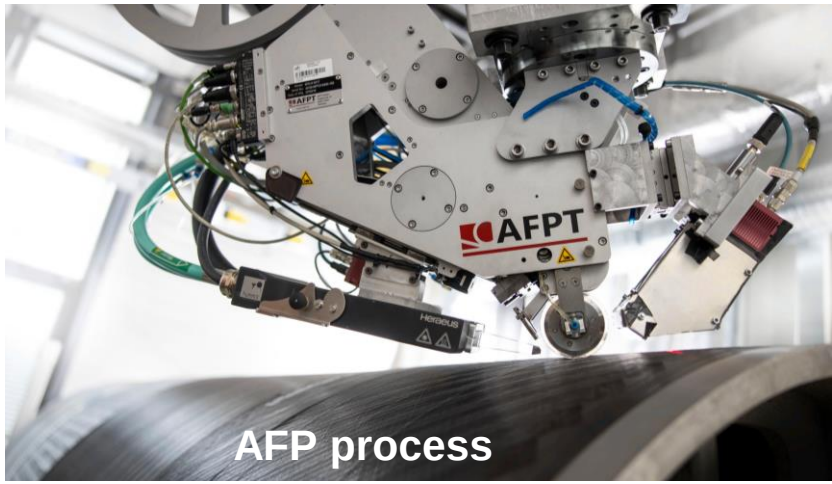
Presentation of project partners

- **DLR BT-SIN (aeronautic):**
  Mathieu Vinot – Project Lead
- **DLR BT-AQP (aeronautic):**
  Roland Glück
- **DLR FK-FLK (transport):**
  Nicolas Unger, Pradnil Kamble



Project MEMAS – Goals

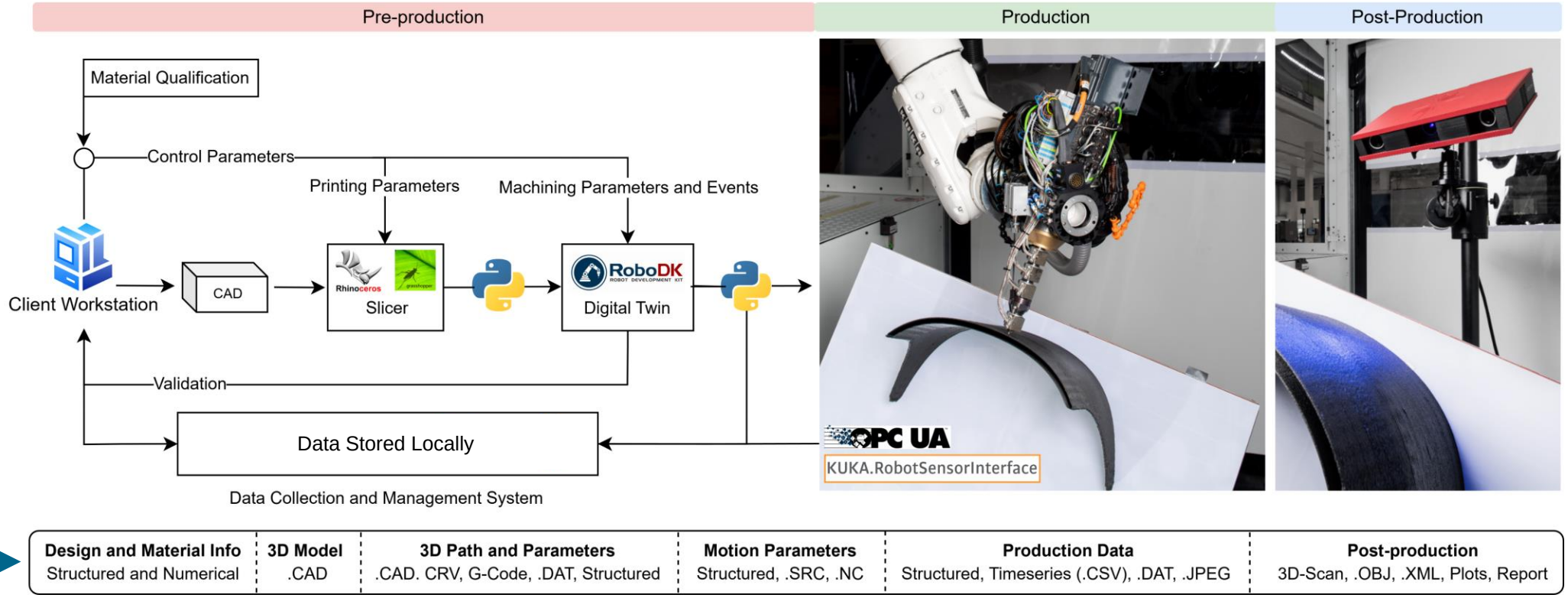
- Create digital models of each individual manufactured part to increase confidence in simulation and improve manufacturing quality
- Develop a metadata-based simulation framework



Complex manufacturing processes

1. Automated Fiber Placement (AFP@DLR BT-AQP)
2. Robotic Screw Extrusion Additive Manufacturing (SEAM@DLR FK-FLK)

Heterogenous Data in Robotic SEAM

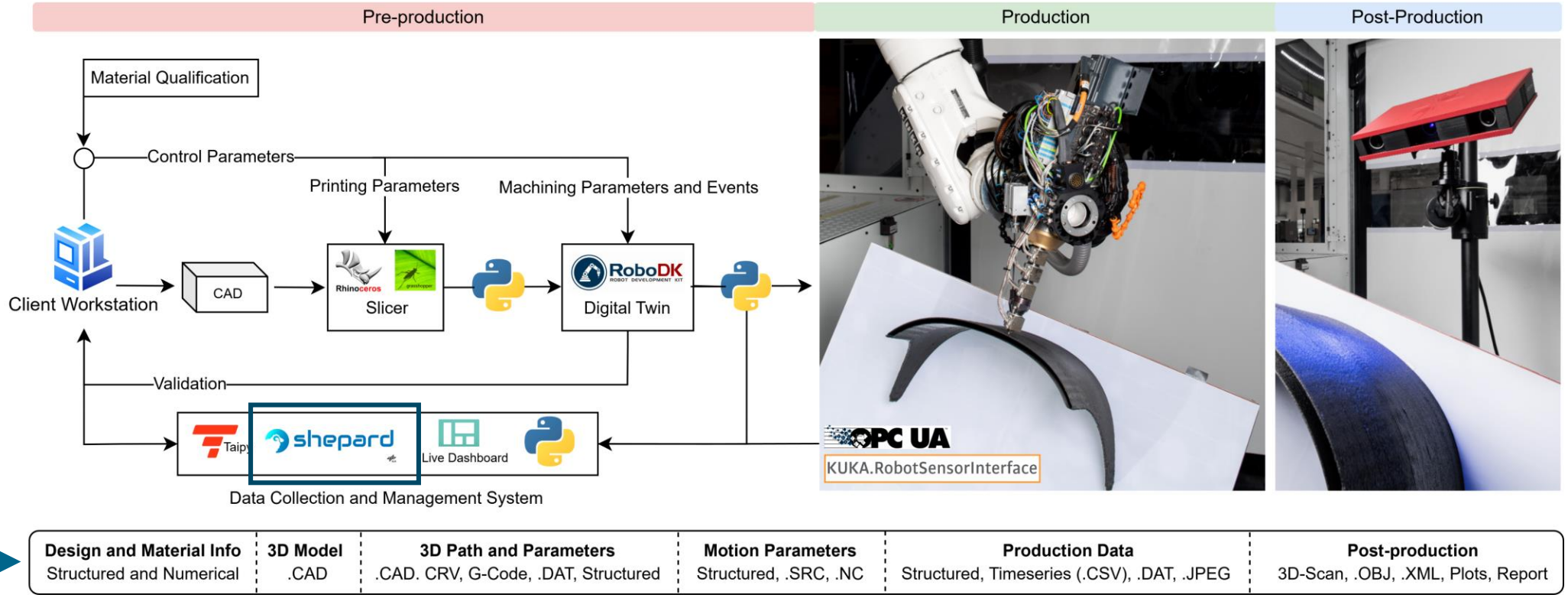


Design and Material Info	3D Model	3D Path and Parameters	Motion Parameters	Production Data	Post-production
Structured and Numerical	.CAD	.CAD. CRV, G-Code, .DAT, Structured	Structured, .SRC, .NC	Structured, Timeseries (.CSV), .DAT, .JPEG	3D-Scan, .OBJ, .XML, Plots, Report

unFAIR

- Data stored locally across directories, poor indexing and searchable metadata
- Python scripts to access data and retrieve for analysis – limited
- No consistent schema – hard to merge and reuse heterogenous data
- No Metadata enrichment and versioning – poor traceability

Heterogenous Data in Robotic SEAM



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Towards FAIR

- GUI for metadata enrichment
- API for flexible access with Python script (Object ID as persistent identifier)
- multi-database storage system for highly heterogenous research data, semantics and metadata
- Unified schema and semantic mapping for instance level retrieval

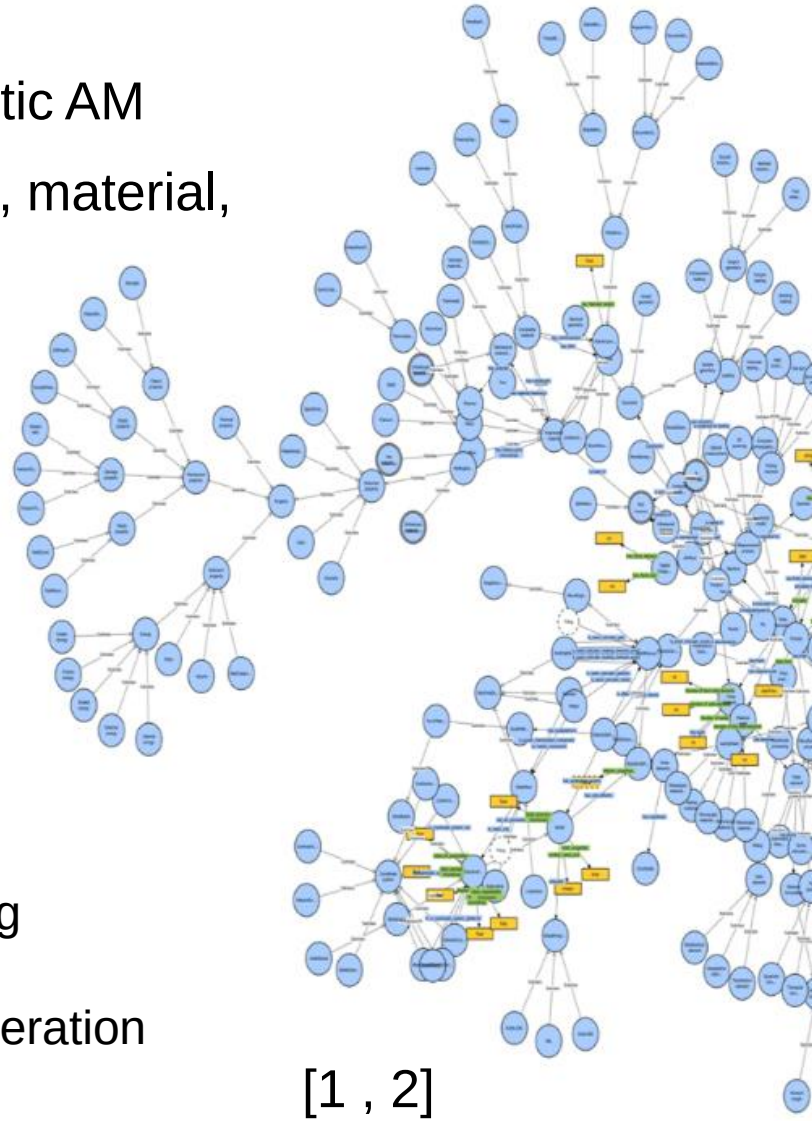
Multi-domain Ontology

Started with

- New conceptual approaches in common ontology design for robotic AM
- Identifying common concepts and testing (end effector, applicator, material, FEM analysis, mechanical testing …)

Challenges when we begin

- Searching for suitable ontologies (cross-domain)
- Available ontologies were comprehensive, too large and complex
- Lack of modularity



[1 , 2]

➢ HMC events led to discovering ontologies
➢ Integration of *Prov-O* ontology and *Ontology of units of Measure* ongoing
➢ Discussion ongoing with the *PolyMat* ontology developers https://dlr-dw.gitlab.io/poly-ontologies/polymat-ontology/index.html for further cooperation

Data standardization through json schema

Challenge: harmonization of data formating for RDMS

- Management and storage of data about fixtures, test standards, test instruments, materials
- Adapted from the framework of https://inst.intra.dlr.de/

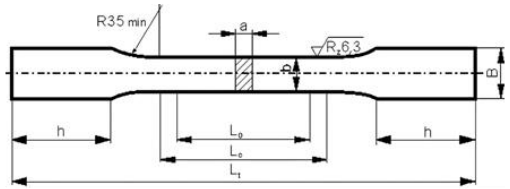
Definition of json schemas

↓

Automatic generation of web interface

↓

Data storage on shepard



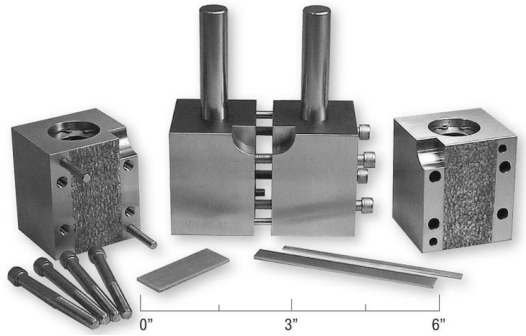
https://gwp.eu/leistung/rundzugprobenfertigung-nach-din-50125/

https://www.pruefmittel24.com/artikel/nummer/75030300

https://www.kistler.com/DE/de/c/produkte-fuer-die-fahrzeugentwicklung-und-pruefung/AC01-products-for-the-automotive-development-and-testing-sector

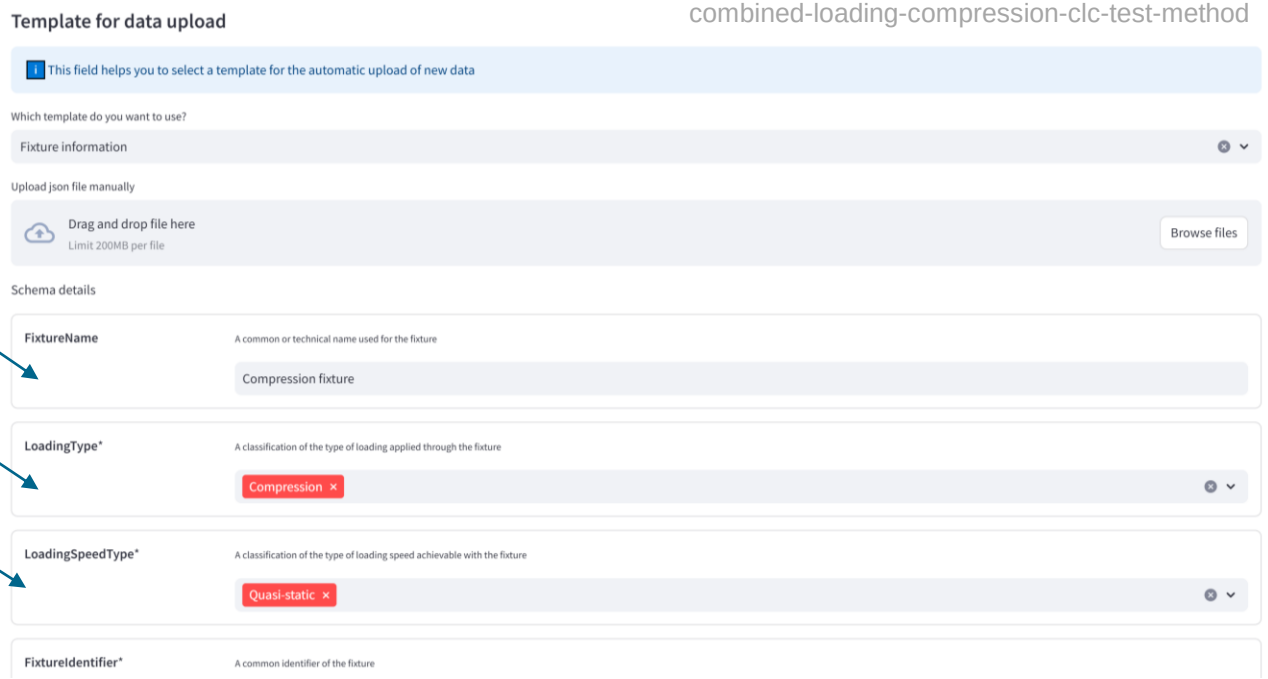
Data standardization through json schema

```
"$schema": "https://json-schema.org/draft/2020-12/schema",
"$id": "xxx",
"title": "Fixture information",
"description": "json schema for fixture information",
"type": "object",
"properties": {
    "FixtureName": {
        "title": "Name of the fixture",
        "description": "A common or technical name used for the fixture",
        "type": "string"
    },
    "LoadingType": {
        "title": "Type of loading",
        "description": "A classification of the type of loading applied through the fixture",
        "type": "string",
        "enum": ["Tension", "Compression", "Shear", "Bending", "Impact"],
        "$ref": "https://inst.intra.dlr.de/schemas/RegexPatterns.json#/properties/allowed_symbols"
    },
    "LoadingSpeedType": {
        "title": "Type of loading speed",
        "description": "A classification of the type of loading speed achievable with the fixture",
        "type": "string",
        "enum": ["Quasi-static", "Dynamic", "Fatigue"],
        "$ref": "https://inst.intra.dlr.de/schemas/RegexPatterns.json#/properties/allowed_symbols"
    },
```

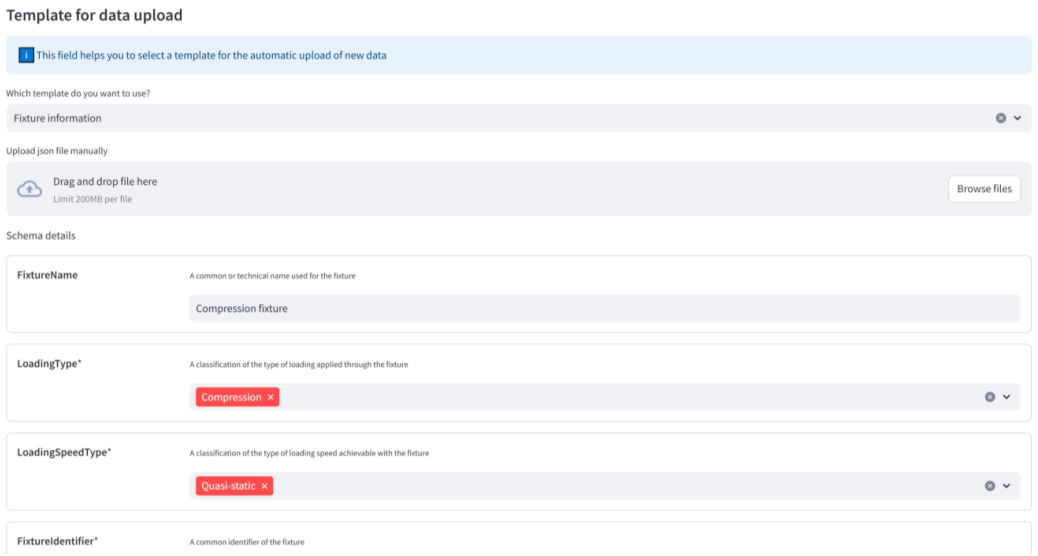


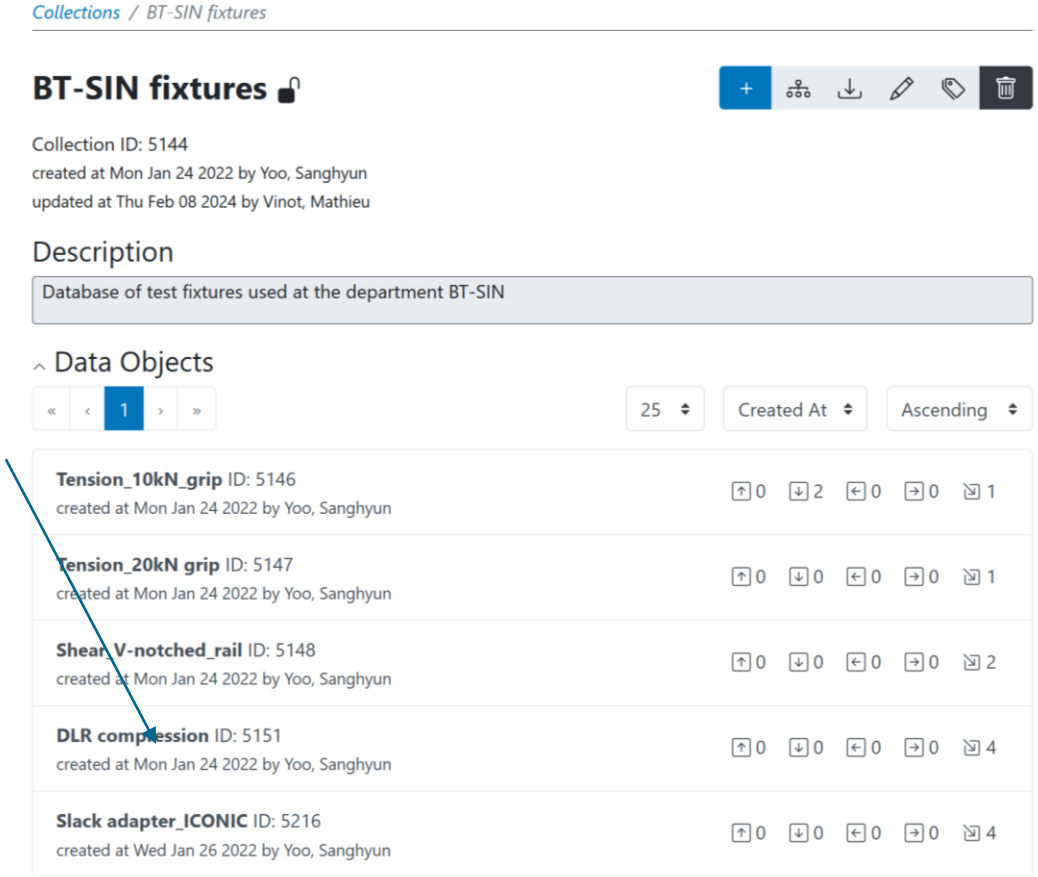
https://www.compositesworld.com/articles/the-combined-loading-compression-clc-test-method

Automatic field recognition incl. data types and generation of user input fields



Data standardization through json schema

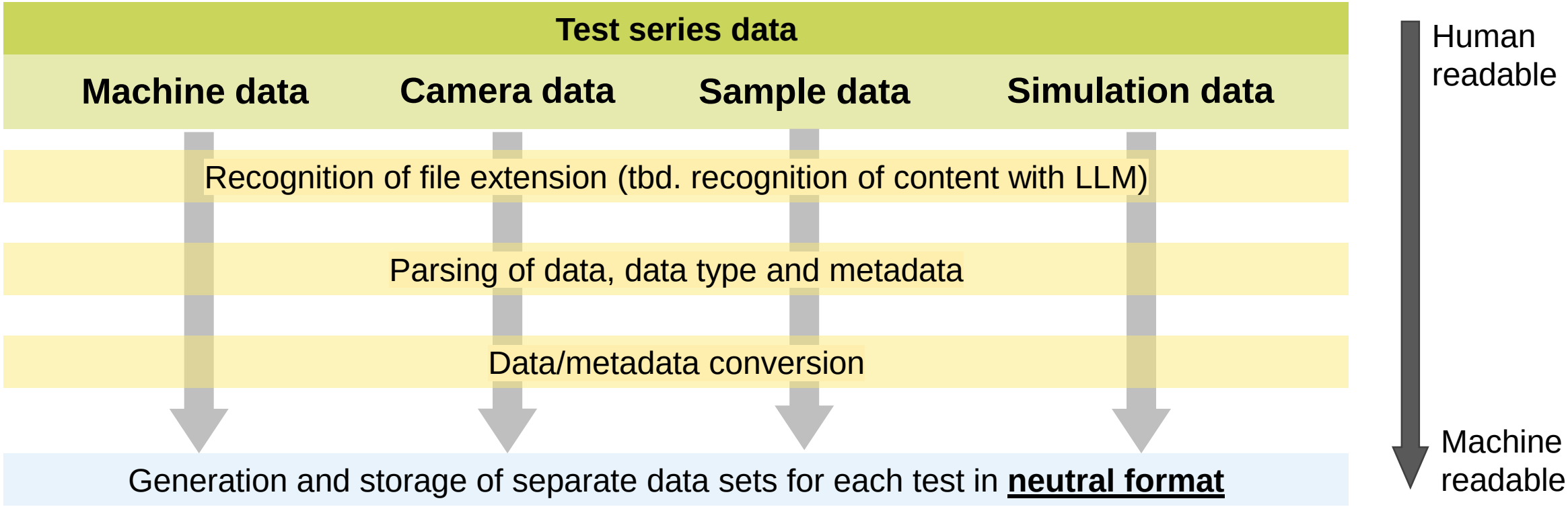




Automatic parsing of research datasets

Challenge: accessibility to non-experts

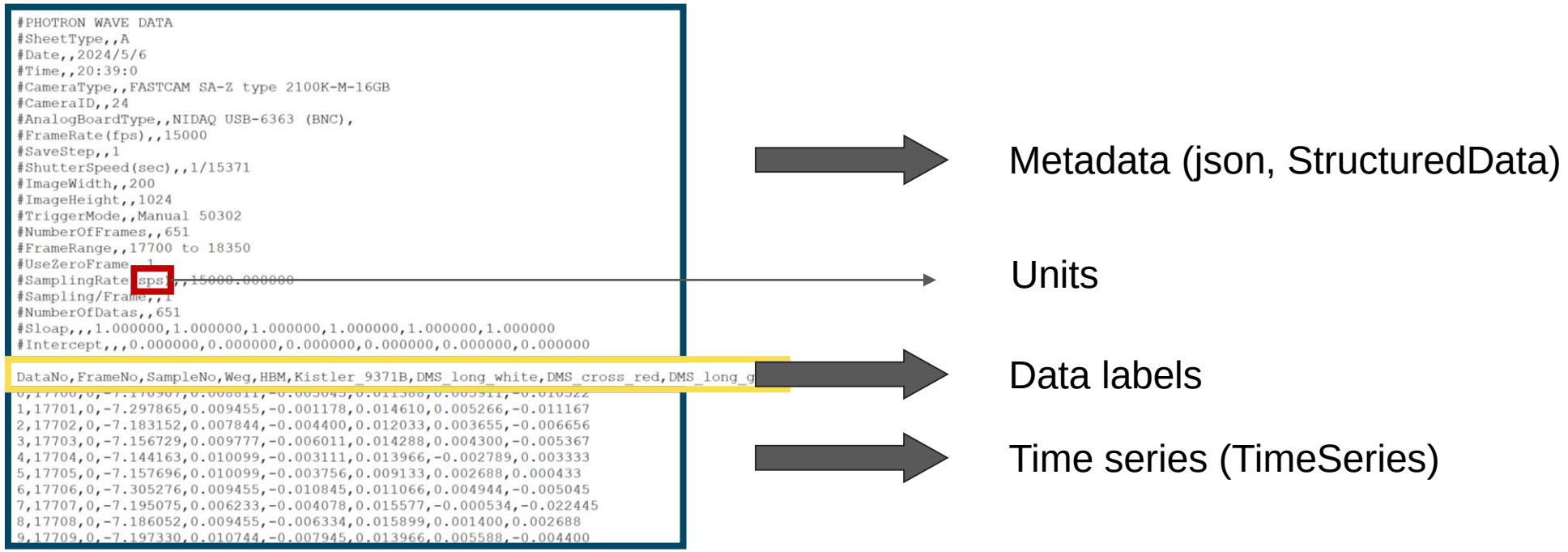
- Automatic parsing of heterogeneous and multi-source research files
- Minimization of human errors



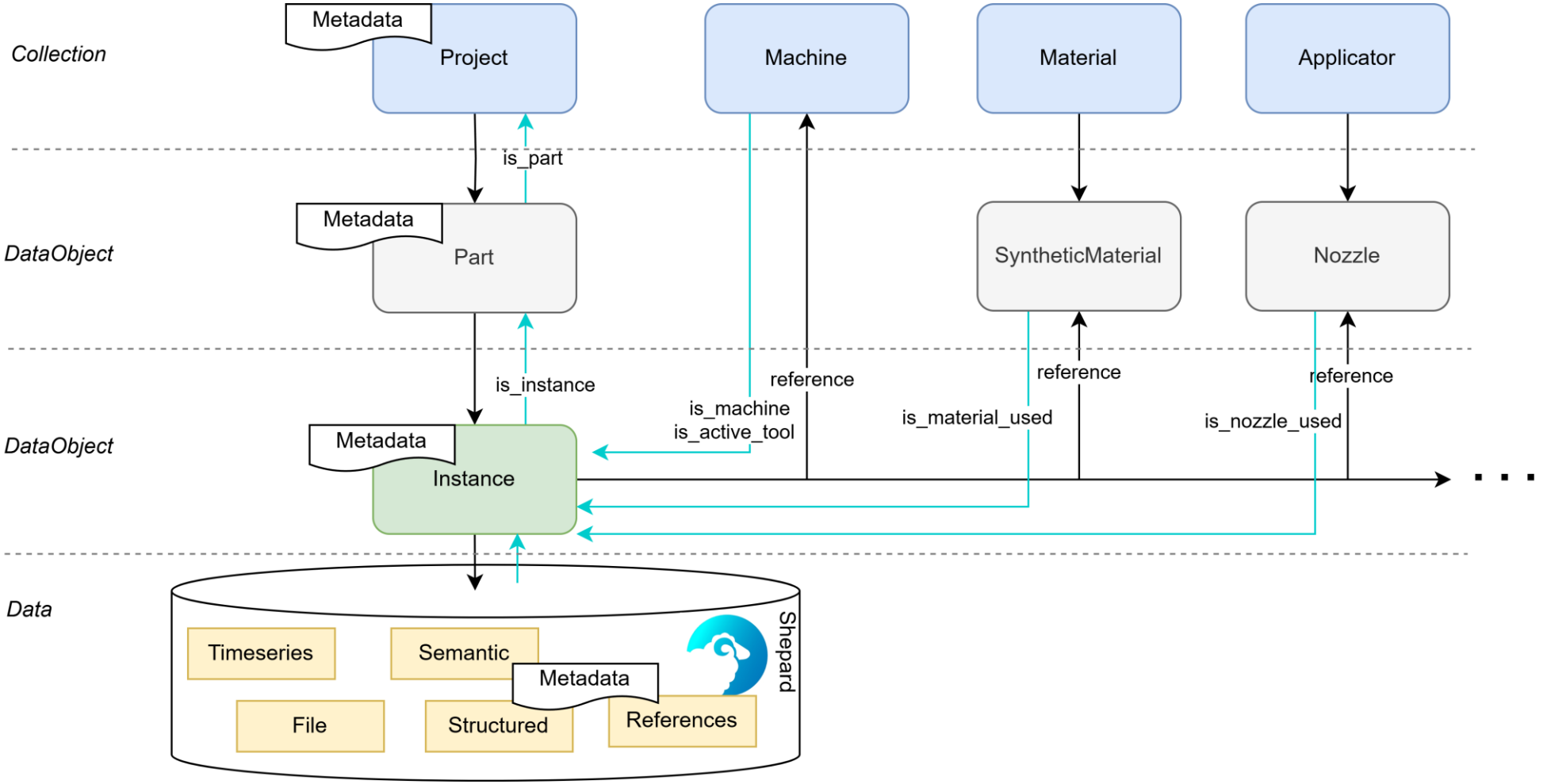
Automatic metadata extraction from research datasets

Challenge: accessibility to non-experts

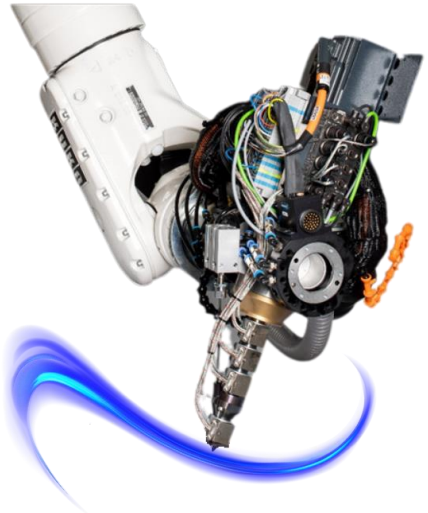
- Automatic parsing of heterogeneous and multi-source research files
- Minimization of human errors



Systematic Data Structure



Conclusion



- FAIR data storage for heterogenous data in Robotic AM
  - **F**indable: Object ID, metadata, structure and semantic annotation
  - **A**cessible: Central database. data accessible via their ID and limited with permissions (individuals or groups)
  - **I**nteroperable: Ontology-based annotation enables application to other ontologies via equivalencies
  - **R**eusability: Structured workflow, ontology and metadata richly describe data + parsing tools make it machine-actionable
- Foundation to enable scalable querying, integration, and machine-actionable reuse
- Going forward, all data will be structured, documented, and published online.
- Project results in detail will be presented at the Fair Friday long talk on 6th June.
- The topic remains under active consideration at our institute for future research.

Reference

[1] M. Vinot, N. Unger, P. Kamble, R. Glück, and N. Toso, "Project MEMAS: ontology-based storage system for manufacturing and simulation data in the field of composite materials," 2023. DOI: 10.5281/zenodo.10074677

[2] N. Unger, P. Kamble, M. Vinot, and R. Glück, “Project MEMAS: Integrated Data Management for Additive Manufacturing enabling High-Fidelity Modeling,” 2024. DOI: 10.5281/zenodo.14067020

[3] R. K. A. Aravind and P. Kamble, Optimizing Heterogenous Data Management for Robotic Screw Extrusion Additive Manufacturing, Ph.D. dissertation, Universität Koblenz, 2024.

Project Team

Mathieu Vinot

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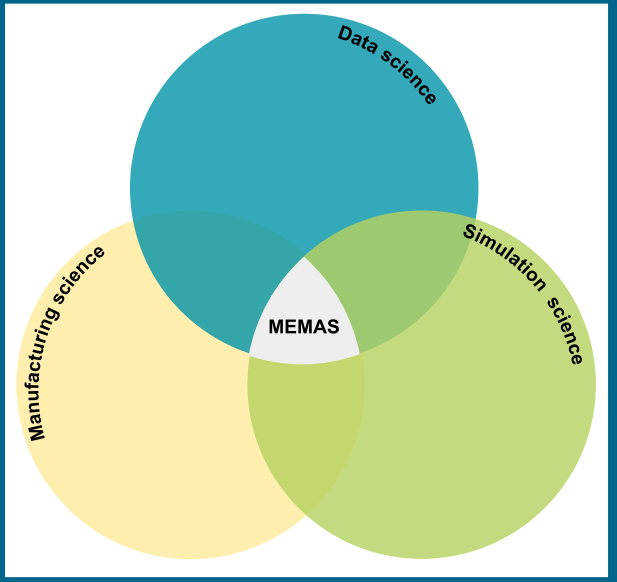

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