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Robert David

SHACL (R|r)ules Interoperability

Enabling cross-model interoperability with rule-based reasoning

Vladimir Alexiev, Robert David

GRAPHWISE

AI THRIVES ON WHOLE DATA

Applications built on Graphs+GenAI

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AI THRIVES ON WHOLE DATA

Bringing Confidence to AI

LLM Grounding with **Multimodal Data**

Self-Service Data & Knowledge

Enhance AI performance and optimize costs

Get **Accurate** Search & Recommendation

Semantic Layer for AI Applications

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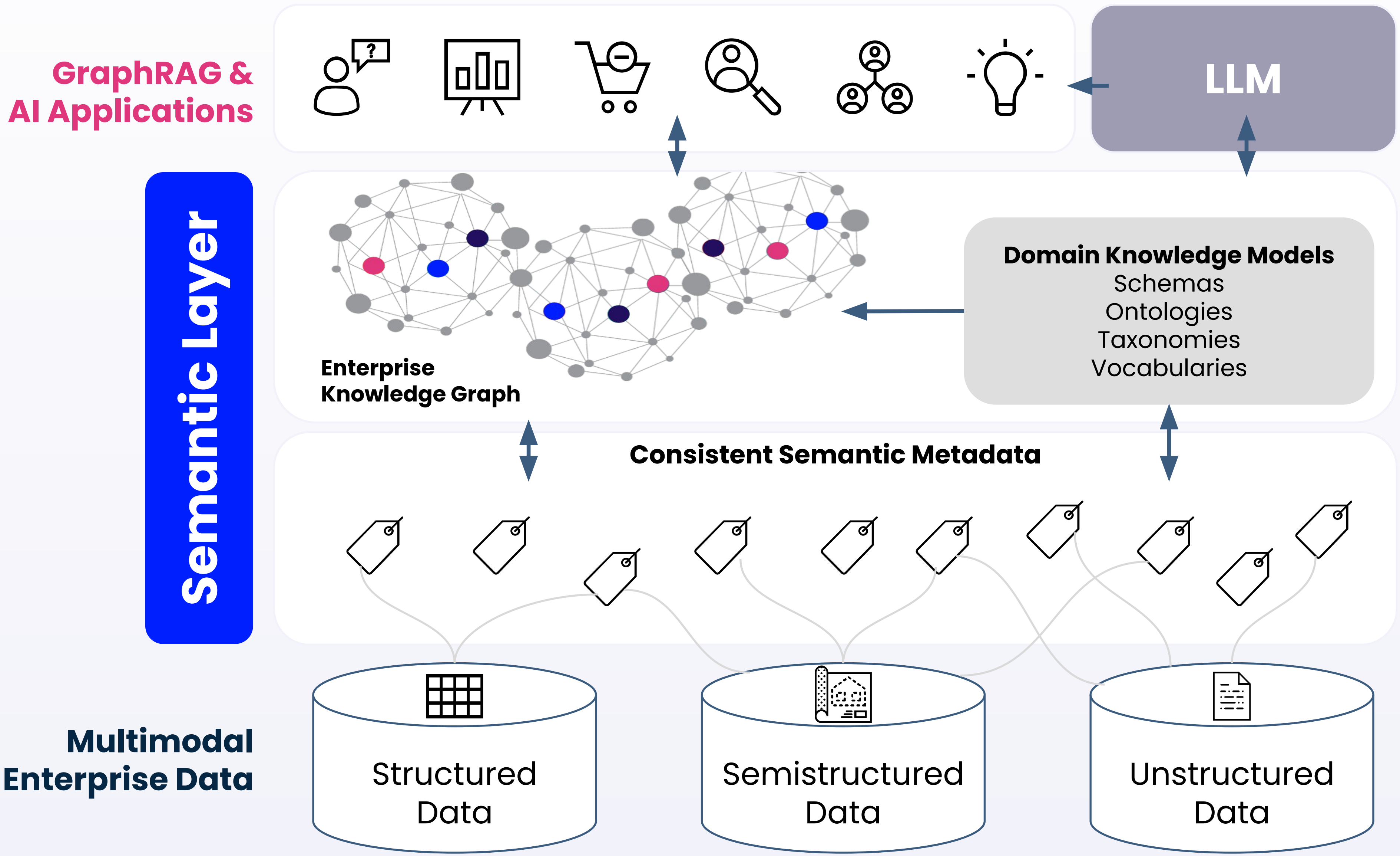

Models for DPP & Initiatives

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- Digital Product Passports (DPPs) are a core element of the EU circular economy strategy.
- DPPs are intended as digital records containing essential data on a product’s properties.
- Several data models were developed
  - Asset Administration Shell (AAS)
  - United Nations Transparency Protocol (UNTP)
  - RDF and Ontologies (e.g. CEON)
- They server different purposes and use different modeling schemes.

Models for DPP & Interoperability

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- Different models use different underlying (semantic) representations.
  - Asset Administration Shell (AAS)
    - SAMM - RDF representation of AAS models
  - United Nations Transparency Protocol (UNTP)
    - JSON-LD - JSON as a common data format + LD as an RDF representation
  - RDF and Ontologies (e.g. CEON)
    - native RDF + ontologies formalise the semantics of a domain
- All models make sense and there is no unified model to replace them.
- Still, managing DPP EU-wide and beyond requires interoperability of all these models.

We need interoperability between all models using a unified approach.

Interoperability via Semantic Layer

- Semantic Standards enable Interoperability
  - RDF - basic graph representation of data - semantics via triples
  - RDFS - Schemas for RDF to express classes, properties, …
  - OWL - ontology language to express domain semantics
  - SKOS - vocabulary representation, e.g. for UNCL
  - SHACL - constraint language for RDF graphs
- These standards can be combined to
  - express domain semantics in an **interoperable** way
  - to **infer** knowledge from data
  - to **validate** if the data is correct

Standards for interoperable DPPs

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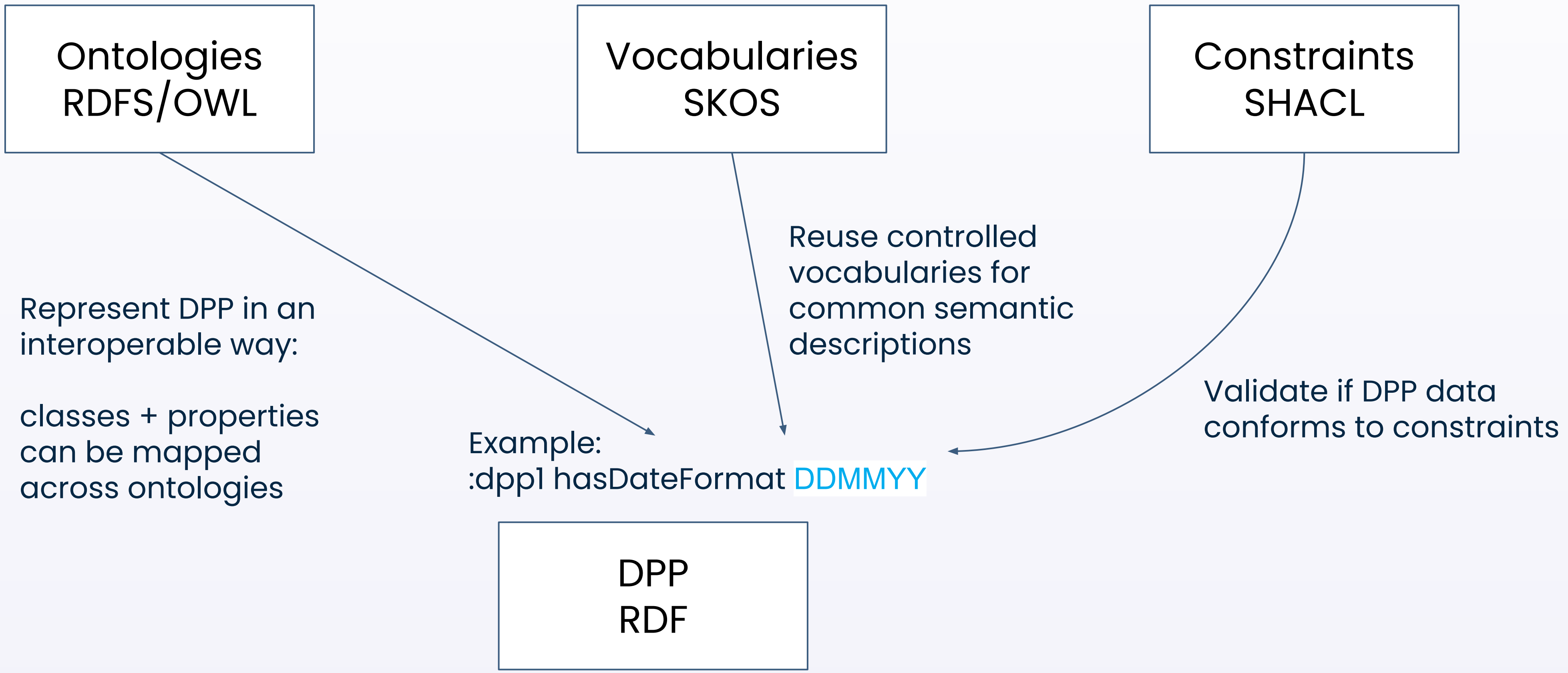

Standards for interoperable DPPs

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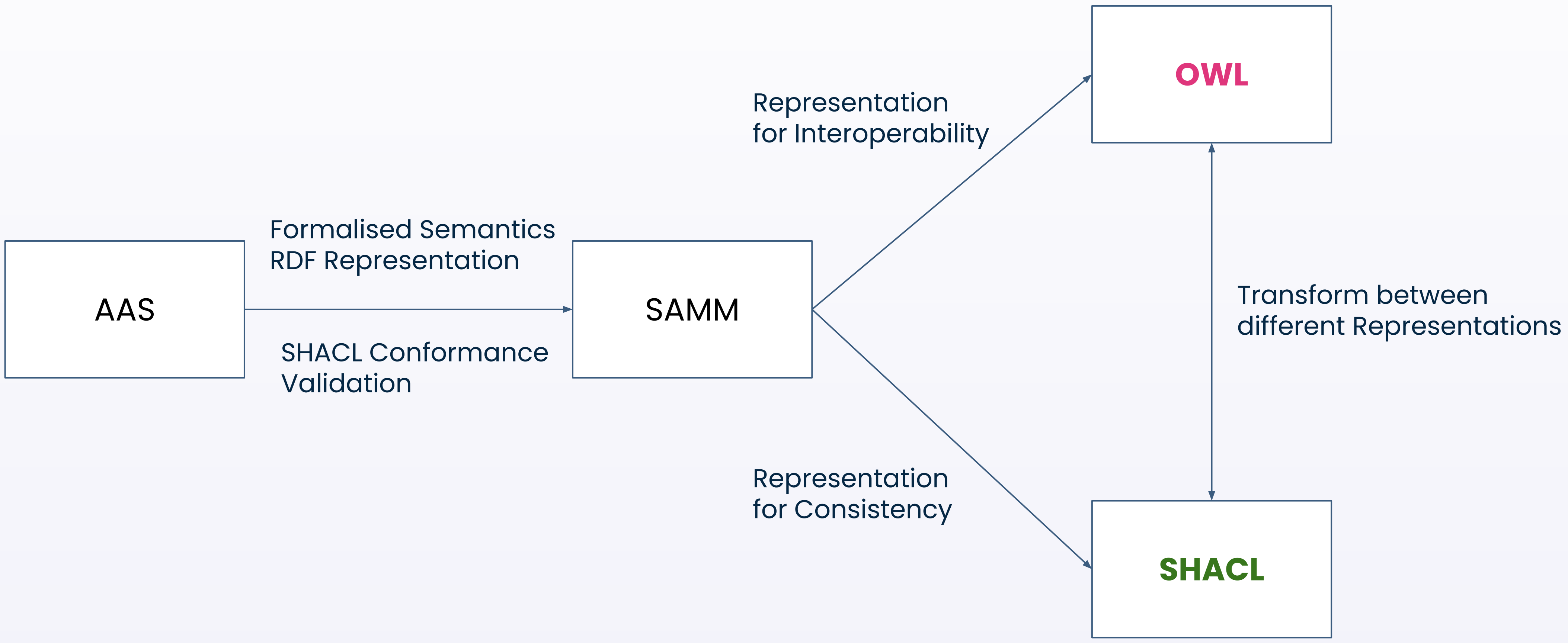
AAS

Standards for interoperable DPPs

Standards for interoperable DPPs



Standards for interoperable DPPs

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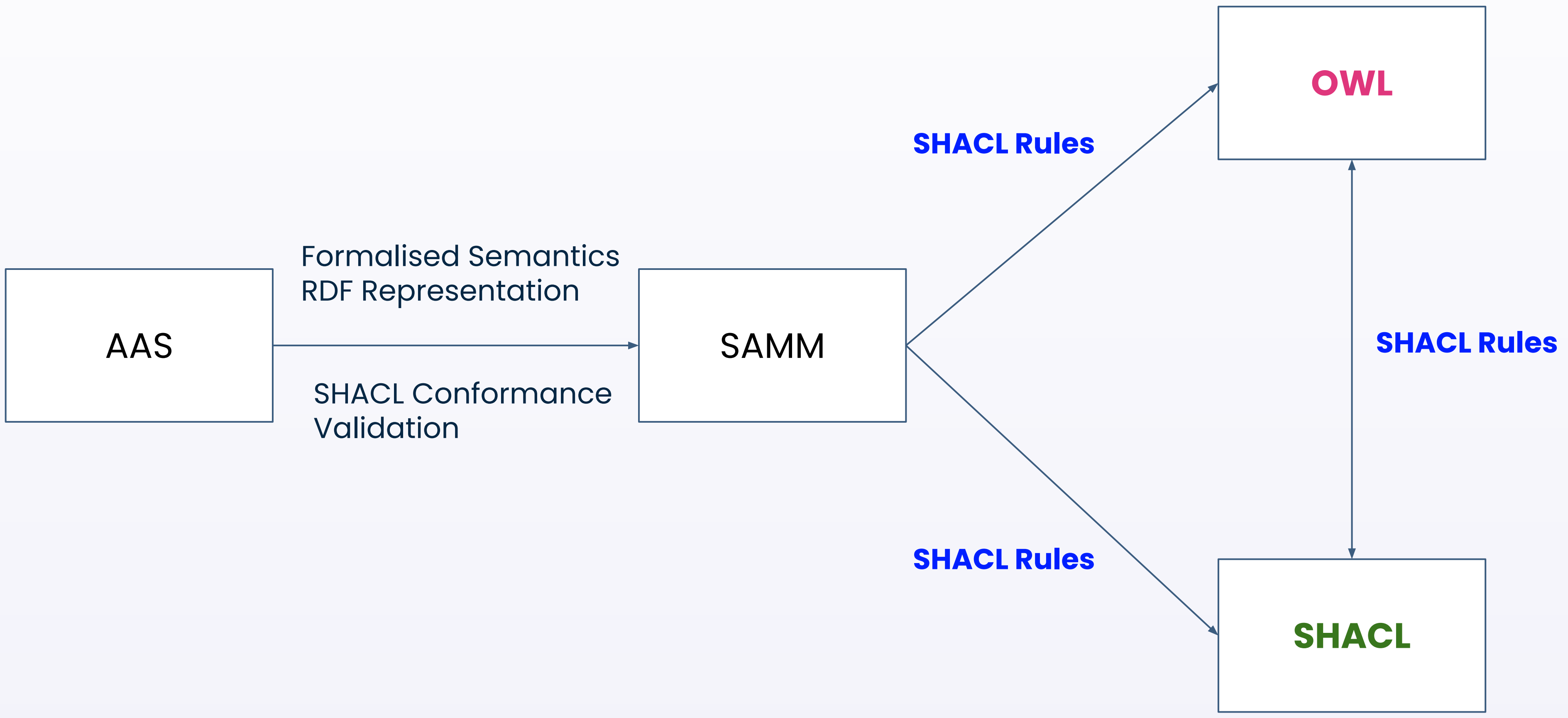

Transformations via SHACL Rules

- SHACL 1.2
  - Upcoming new version of the SHACL W3C recommendation
  - Beyond validation, add new sub-modules for node expressions, UI, Profiles and Rules
  - General toolkit for data validation, inference and transformation
- SHACL 1.2 Rules
  - based on Datalog, RDF adaption of rule language
  - not coupled to validation; can be used standalone
  - supports non-monotonic reasoning with recursion, negation, aggregation

Example: SAMM

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```
:MachineOnlineStatus a samm:Aspect ;
    samm:properties ( :onlineStatus ) ;
    samm:operations ( ) .

:onlineStatus a samm:Property ;
    samm:description "The current machine online status."@en ;
    samm:characteristic [
        a samm-c:Enumeration ;
        samm:dataType xsd:string ;
        samm-c:values ( "ON" "OFF" "BOOTING" ) ] .
```

Example: SAMM Triples

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:MachineOnlineStatus rdf:type samm:Aspect

:MachineOnlineStatus samm:properties _:N003a204d285f4918bfac75aaf00fee3b

_:N003a204d285f4918bfac75aaf00fee3b rdf:first :onlineStatus

_:N003a204d285f4918bfac75aaf00fee3b rdf:rest rdf:nil

:onlineStatus rdf:type samm:Property

:onlineStatus samm:characteristic _:N15fee727b0b6465da147a6639dc9ec0a

_:N15fee727b0b6465da147a6639dc9ec0a samm:dataType xsd:String

_:N15fee727b0b6465da147a6639dc9ec0a samm:values _:N6bade8ba119d4834b690ae6c16b18aef

_:N6bade8ba119d4834b690ae6c16b18aef rdf:first "ON"

_:N6bade8ba119d4834b690ae6c16b18aef rdf:rest _:Nd679068094854026a7473a43e6281a40

_:Nd679068094854026a7473a43e6281a40 rdf:first "OFF"

.....

Example: OWL

```
:MachineOnlineStatus a owl:Class .

:onlineStatus a owl:DatatypeProperty ;
        rdfs:comment "The current machine online status."@en ;
        rdfs:domain :MachineOnlineStatus ;
        rdfs:range :OnlineStatusValues ;

:OnlineStatusValues a rdfs:Datatype ;
        owl:oneOf ( "ON"^^xsd:string "OFF"^^xsd:string "BOOTING"^^xsd:string ) .
```

Example: SHACL Constraints

```
:MachineOnlineStatusShape a sh:NodeShape ;
    sh:class :MachineOnlineStatus ;
    sh:property [
        sh:path: :onlineStatus;
        sh:description "The current machine online status."@en ;
        sh:datatype xsd:string ;
        sh:in ( "ON"^^xsd:string "OFF"^^xsd:string "BOOTING"^^xsd:string )
    ] .
```

Example: Rule Transformation

- SHACL 1.2 Datalog-style Rules
  https://w3c.github.io/data-shapes/shacl12-rules/
  - 3 basic rule formats
    - DATA { *triple template* }
    - RULE { *head template* } WHERE { *body pattern* }
    - IF { *body pattern* } THEN { *head template* }

Examples:

RULE { ?x rdf:type owl:Class . } WHERE { ?x rdf:type samm:Aspect . }

RULE { ?x rdf:type owl:DatatypeProperty . }

WHERE { ?x rdf:type samm:Property . ?x samm:characteristic ?c . ?c samm:dataType xsd:string . }

Example: Rule Transformation

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Input:

:onlineStatus rdf:type samm:Property

:onlineStatus samm:characteristic _:N15fee727b0b6465da147a6639dc9ec0a

_:N15fee727b0b6465da147a6639dc9ec0a samm:dataType xsd:String

Rule:

RULE { ?x rdf:type owl:DatatypeProperty . }

WHERE { ?x rdf:type samm:Property . ?x samm:characteristic ?c . ?c samm:dataType xsd:string . }

Output:

:onlineStatus rdf:type owl:DatatypeProperty

SHACL 1.2 Rules: pros & cons

- Pro:
  - General declarative language for data transformations
  - Works on any RDF graph
  - Supports non-monotonic inference with recursion, negation, aggregation
  - Semantics defined in the W3C spec
- Cons:
  - No disjunction in rules and stratified negation, aggregation; therefore no multiple models as result
  - Difficult to represent error handling in rules; no empty model on non-match

SHACL (R|r)ules Interoperability

- SHACL 1.2 Rules provide a declarative approach to transform between different models and representations.
- SHACL validation helps to avoid quality problems with transformations.
- Rules and constraints combine into a human-in-the-loop approach to develop model interoperability.

THANK YOU