

Rules and Reasoning for Graph Data

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[W3C Workshop on Web Standardization for Graph Data](#)

Creating Bridges: RDF, Property Graph and SQL

4-6 March 2019, Berlin, Germany

Background: Rules and ...

- Rules can define **one-step derivations** between (graph-relational) “forms” (patterns, shapes) that specify data **Inputs & Outputs**:

$Iform \longrightarrow Oform$ “ $Iform$ derives $Oform$ ”

or, equivalently,

$Oform \longleftarrow Iform$ “ $Oform$ is derived by $Iform$ ”

Here, $Iform$ and $Oform$ may contain variables:

- $Iform$ can be matched to data via variable bindings, adding variable-instantiated $Oform$ data
- $Oform$ -unifying queries can be reduced to $Iform$ queries, extracting variable bindings whenever arriving at data

Background: ... and Reasoning

- Reasoning can chain Rules for **multi-step derivations**, e.g.:
 - Forward (bottom-up) Reasoning, only **adding** data
 - Backward (top-down) Reasoning, only **querying** data
 - Forward/Backward-combined (bi-directional) Reasoning
- Reasoning may
 - resolve Rule conflicts, committing to one Rule per step
 - search Rule-chain space, e.g. breadth/depth/best-first
- Ontologies can complement Rules by derived classes to type Rule variables, thus pruning the conflict sets or search space
- Graph ([SPARQL/SHACL](#) and [Cypher/PGQL/...](#)) data forms permit enriched Reasoning via path queries, graph algorithms, etc. ³

Languages for Graph Rules and Reasoning

- 1) Augment languages for:
 - a) **Graph Databases by Rules and Reasoning**
 - b) **Relational Rules and Reasoning by Graphs**
- 2) Examples of such languages:
 - a) N3 (augmenting RDF triple-store Graph Databases)
 - b) LIFE (ψ -terms), F-logic (frames), RIF (frames), PSOA RuleML (psoa terms)
- 3) Metamodel helps Bridging Graph and Relational Databases

Technology for Graph Rules and Reasoning

- Graph Foundations for **Data** & Knowledge (Ontologies & **Rules**):
 - Graph Querying in SPARQL and Cypher/PGQL/...
 - Graph Reasoning in N3 with engines [Cwm](#), [EYE](#), [etc.](#)
(cf. [W3C Notation 3 Community Group](#))
 - Joint [Replication of Labeled Property Graphs](#)
- Graph-Relational Bridges: [RDB2RDF](#), [PSOATransRun](#), ...
 - Normalize F-logic frames into RDF-triple conjunctions (cf. [N3Basic](#))
- Semantics Bridges: Ontology languages defined via Rules:
 - [Extending OWL 2 RL in \(RIF and SPIN\) Rules](#)
 - [Warded Datalog+/-](#)
 - [Substantiating Knowledge with EYE](#)
 - [RDF Triple Stores vs. Labeled Property Graphs: What's the Difference? \(A Comparison: Semantics\)](#)

Beyond Deductive Reasoning / From Relations to Graphs

- Quantitative (probabilistic) extensions (focus: [StarAI](#) Workshops):
 - [Statistical Relational Learning/AI](#) (cf. [GraRe/DOR](#))
- Qualitative extensions (also combined, and from Relational to Graph Data):
 - Inductive (**F**unctional and **L**ogic) **P**rogramming (cf. [AAIP](#) Workshops)
 - Analogical Reasoning (cf. [Argument from Analogy](#))
 - [Association Rule Learning](#)
 - Abductive Reasoning (cf. [Abductive Logic Programming](#))
 - [Relevance Logic](#)
 - [Defeasible Logic](#)
 - [Argumentation Theory](#)