

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

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Background: Rules and ...

- Views in databases already correspond to simple Rules
- Rules can define **one-step derivations** between (graph-relational) “forms” (patterns, shapes) that specify data **Inputs & Outputs**:

Iform  *Oform* “*Iform* derives *Oform*”

or, equivalently,

Oform  *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 transferred 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](#)