



# Combining Ontology and Rule Languages on the Semantic Web





# Motivation

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## What are rules?

- Statements that express a business/domain policy.

## They specify:

- Derivations

A VIP customer is a customer with purchase > 1M in the last year

- Integrity constraints

The driver of a rental car must be 25 years or older

- Reactions

When a share price drops by more than 5%, then sell it



# Motivation

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The combination seems to take advantage of the best of both formalisms:

- DLs are appropriate for structuring knowledge in terms of concepts and relationships
  - Only tree-like rules
- Rule Languages are appropriate for expressing complex rules.
  - Only universally quantified variables
  - No disjunction and disjointness



# Rules as FOL

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Horn Clause: A clause with at most one positive literal

- **Clauses:** Subsets of FOL that have the following form:

$$\forall x_1, \dots, x_n (L_1 \vee \dots \vee L_m) - L - \text{Literal}$$

$$\forall x_1, \dots, x_n (A_1 \vee \dots \vee A_k \vee \neg B_1 \vee \dots \vee \neg B_r)$$

A - Positive literal

B - Negative literal

$$A_1 \vee \dots \vee A_k \leftarrow B_1 \wedge \dots \wedge B_k$$

$$A_1 \dots A_k \leftarrow B_1 \dots B_k$$



## Rules as FOL (continuation...)

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Horn Clause: A clause with at most one positive literal

- **Rule**

$A \leftarrow B_1, \dots, B_k$

$A :- B_1, \dots, B_k.$

A - **head (consequent)**

B's - **body (antecedent)**

- **Fact**

A.

- **Goal**

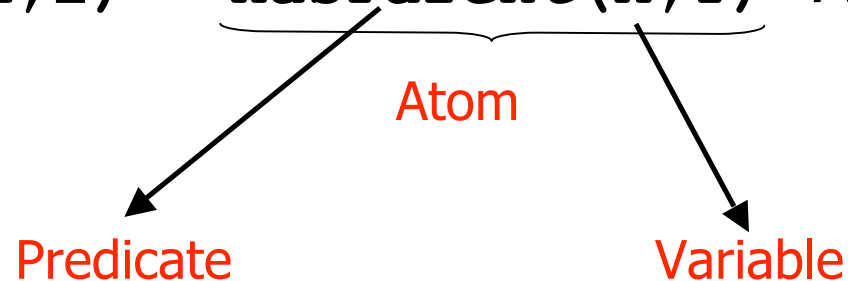
$B_1, \dots, B_k$



## Rules as FOL (continuation...)

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`hasAunt(X,Z) ← hasParent(X,Y) ∧ hasSister(Y,Z)`



`hasParent(Rafael,Edna)`

`hasSister(Edna,Karin)`



Constant



# SWRL - Semantic Web Rules Proposal

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Extends the axioms of OWL-DL to include Horn clauses.

- Antecedent and consequent atoms are concepts or roles of the form  $C(x)$ ,  $P(x,y)$ ,  $\text{sameAs}(x,y)$ ,  $\text{differentFrom}(x,y)$  where  $x$  and  $y$  are either variables, individuals or data values.
- Built-Ins for comparisons, mathstrings, date, time, Etc.
- Undecidable, simulates role value maps.

```
artist(?x) ^ artistStyle(?x,?y) ^ style(?y) ^ creator(?z,?x)
      =>styleObject(?z,?y)
```



# Other approaches for combining Ontology and Rule Languages

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**1.** OWL - Rules that can be expressed as subsumption axioms

**2. Two Components:** DL and Datalog

2.1 AL-Log: Concepts in body

2.2 CARIN: Concepts and roles in body

2.3 DLSafe: Concepts and roles in head and body. Each variable is required to occur in a non-DL atom

2.4 SWRL: Concepts and roles in head and body



# Approaches for combining Ontology and Rule Languages

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## Example AL-Log

- Query answering is based on constrained SLD-derivation and tableau algorithm. A derivation terminates with the last query of the form  $\& \beta_1, \dots, \beta_m$  which is a constrained empty clause
- Query answering is decidable

## Examples

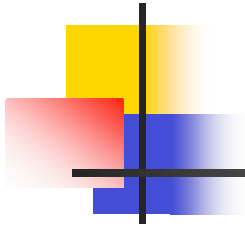
```
curr(X,Z) ← exam(X,Y),subject(Y,Z) & X:St, Y:Co, Z:Tp.  
exam(paul,ai).
```

... .

```
AC U BC = Co
```

```
FP ⊆ FM NFP=FP ∩ ¬∃TC.Co John:FP johnTCai
```

# Implementation - Swoop



## People

- Bijan Parsia
- Bernardo Cuenca
- Evren Sirin
- Aditya Kalyanpur
- Daniel Hewlett
- Ron Alford
- Edna Ruckhaus



## Features

- Parses and displays SWRL files
- Editing rules
- Expressivity rule and set of rules
- OWL Syntactic sugar rules are transformed into OWL axioms
- Query answering for Allog using a hybrid reasoner: Datalog + Pellet