Inference rules in DL and SWRL

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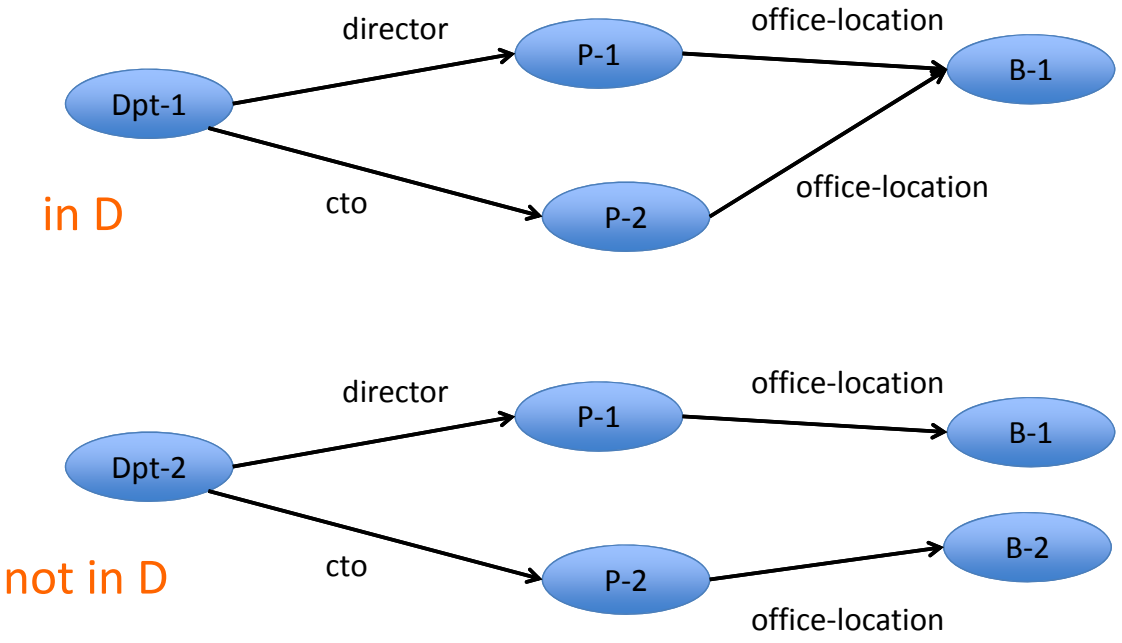
Expressivity of DL

- DLs have the tree model property
  - +/- each set of axioms has a model that is a tree
  - Impossible to specify cyclic models
- Example
  - A department is in the class D if and only if its director and chief technology officer (cto) are located in the same building



In DL (OWL 2)

Impossible to define D

Many other examples cannot be defined in OWL-2

Comes from the fact that most DLs enjoy the **Tree Model Property**.

if a Tbox has a model

then it has a model that doesn't contain cycles

A fact is a consequence of a Tbox if it is true in **every** model of the Tbox, so no "cyclic fact" is a consequence of a TBox.

Inference rules

Rules to produce

- New **type** assertions
  - x is a member of class C
- New **property** assertions
  - x is connected to y through property p

SWRL Rules - syntax

rule ::= antecedant -> consequent

antecedant ::= atom, atom, ...
consequent ::= atom, atom, ...

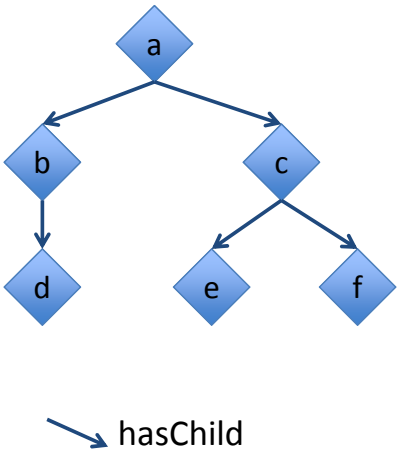
atom ::= description '(' i-object ')'
| dataRange '(' d-object ')'
| individualvaluedPropertyID '(' i-object i-object ')'
| datavaluedPropertyID '(' i-object d-object ')'
| sameAs '(' i-object i-object ')'
| differentFrom '(' i-object i-object ')'
| builtIn '(' builtinID { d-object } ')'

Person(?x), Person(?y), Person(?z), hasChild(?x, ?y), hasChild(?y, ?z) -> hasGrandChild(?x, ?z)

Interpretation

- Find all the variable bindings that satisfy the antecedent
- For each such binding the consequent must be satisfied

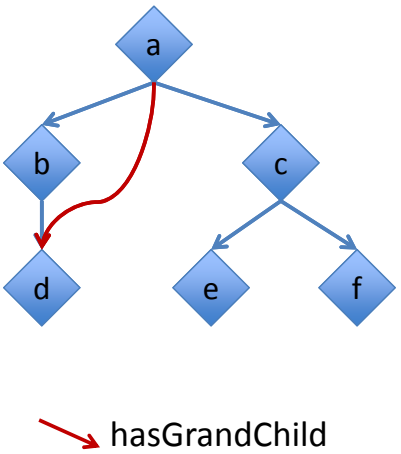
hasChild(?x, ?y), hasChild(?y, ?z)
-> hasGrandChild(?x, ?z)



Interpretation

hasChild(?x, ?y), hasChild(?y, ?z)
-> hasGrandChild(?x, ?z)

?x=a, ?y=b, ?z=d -> hasGrandChild(a,d)



Interpretation

hasChild(?x, ?y), hasChild(?y, ?z)
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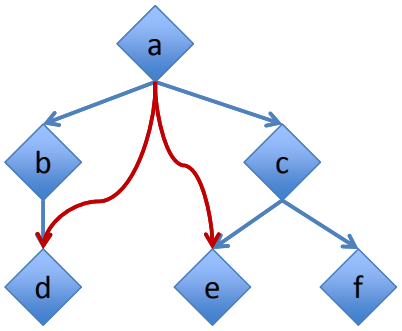
?x=a, ?y=b, ?z=d -> hasGrandChild(a,d)
?x=a, ?y=c, ?z=e -> hasGrandChild(a,e)



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hasChild(?x, ?y), hasChild(?y, ?z)
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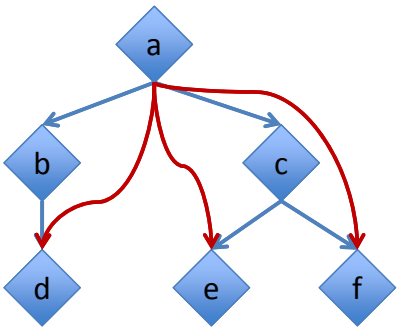
?x=a, ?y=b, ?z=d -> hasGrandChild(a,d)
?x=a, ?y=c, ?z=e -> hasGrandChild(a,e)
?x=a, ?y=c, ?z=f -> hasGrandChild(a,f)



Interpretation

hasChild(?x, ?y), hasChild(?y, ?z)
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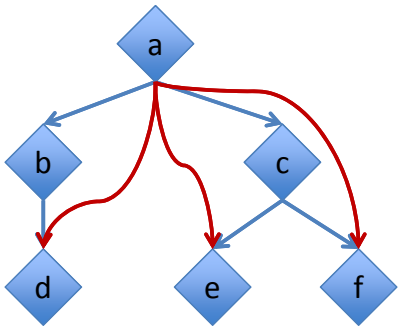
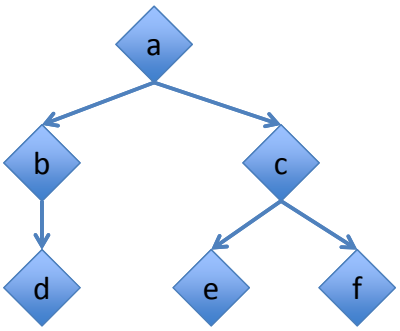


an interpretation that satisfies the rule

DifferentFrom

Variables with different names may represent the same individual !

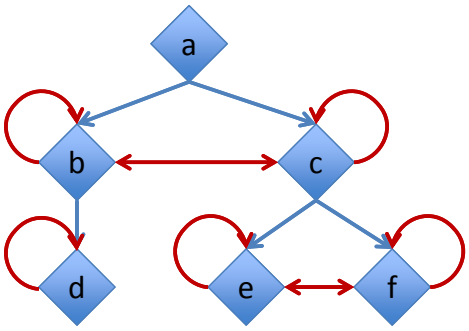
hasChild(?x, ?y), hasChild(?x, ?z)
-> hasSibling(?y, ?z)



DifferentFrom

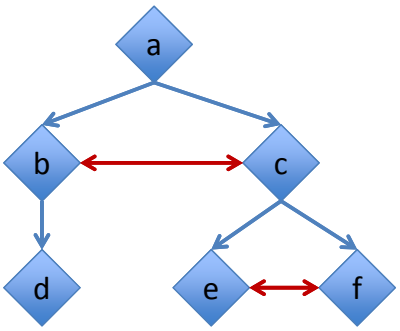
Variables with different names may represent the same individual !

hasChild(?x, ?y), hasChild(?x, ?z)
-> hasSibling(?y, ?z)



DifferentFrom

hasChild(?x, ?y), hasChild(?x, ?z), DifferentFrom (?y, ?z)
-> hasSibling(?y, ?z)

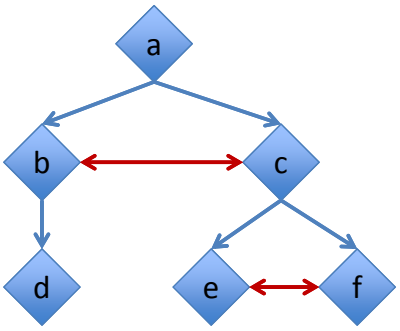


DifferentFrom

hasChild(?x, ?y), hasChild(?x, ?z), DifferentFrom (?y, ?z)
-> hasSibling(?y, ?z)

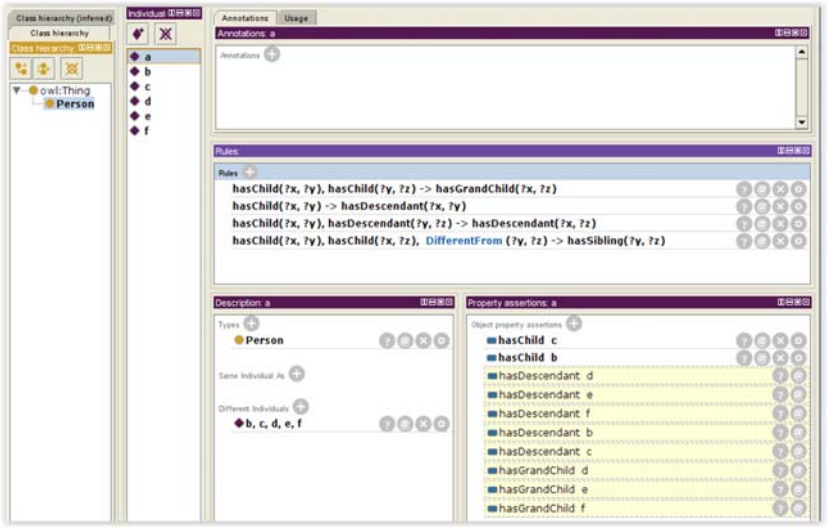
But works only if

DifferentIndividual(b,c)
DifferentIndividual(e,f)



Example

hasChild(?x, ?y) -> hasDescendant(?x, ?y)
hasChild(?x, ?y), hasDescendant(?y, ?z) -> hasDescendant(?x, ?z)



DL-safe rules

Query answering for DL-axioms + rules is undecidable

It is decidable if rules are DL-safe

A rule r is called DL-safe if each variable in r occurs in a non-DL-atom in the rule body.

Practically: the variables in rules can only be bound to known individuals

DL-safe rules

Axioms:

TBox: Parent ≡ hasChild some Person

ABox: Parent(a), Parent(b), Parent(c), Person(d), hasChild(a,d)

Rule:

hasChild(?x, ?y) -> PersonWithChild(?x)

consequence:

?

DL-safe rules

Axioms:

TBox: Parent ≡ hasChild some Person

ABox: Parent(a), Parent(b), Parent(c), Person(d), hasChild(a,d)

Rule:

hasChild(?x, ?y) -> PersonWithChild(?x)

consequence:

PersonWithChild(a)

without the DL-safe restriction:

PersonWithChild(a), PersonWithChild(b), PersonWithChild(c)

Builtin predicates

To deal with numbers, strings, etc.

Rectangle(?x), hasWidthInMetres(?x, ?w), greaterThan(?w, 10)
-> WideRectangle(?x)

Rectangle(?x), hasHeightInMetres(?x, ?h), hasWidthInMetres(?x, ?w),
multiply(?a, ?w, ?h), greaterThan(?a, 100)
-> LargeRectangle(?x)

Builtin predicates

swrlb:equal
swrlb:notEqual
swrlb:lessThan
swrlb:lessThanOrEqual
swrlb:greaterThan
swrlb:greaterThanOrEqual

Builtin predicates

swrlb:add
swrlb:subtract
swrlb:multiply
swrlb:divide
swrlb:integerDivide
swrlb:mod
swrlb:pow
swrlb:unaryPlus
swrlb:unaryMinus
swrlb:abs
swrlb:ceiling
swrlb:floor
swrlb:round
swrlb:roundHalfToEven
swrlb:sin
swrlb:cos
swrlb:tan

Builtin predicates

swrlb:stringEqualIgnoreCase
swrlb:stringConcat
swrlb:substring
swrlb:stringLength
swrlb:normalizeSpace
swrlb:upperCase
swrlb:lowerCase
swrlb:translate
swrlb:contains
swrlb:containsIgnoreCase
swrlb:startsWith
swrlb:endsWith
swrlb:substringBefore
swrlb:substringAfter
swrlb:matches
swrlb:replace
swrlb:tokenize

When you don't need SWRL: DL rules

Some SWRL rules can be encoded in OWL expressions

Example

Man(?x) ∧ hasBrother(?x,?y) ∧ hasChild(?y,?z) → Uncle(?x)

becomes

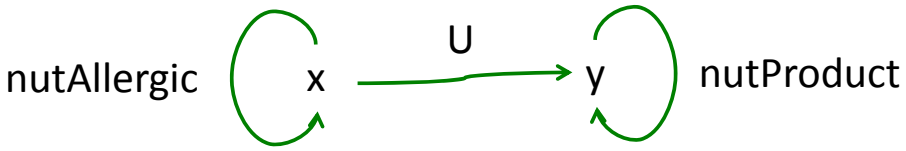
Man ⊓ ∃hasBrother.∃hasChild.⊤ ⊑ Uncle
Man and (hasBrother some (hasChild some Thing)) ⊑ Uncle

it's sometimes tricky ...

NutAllergic(?x) ∧ NutProduct(?y) → dislikes(?x,?y)

NutAllergic ≡ ∃nutAllergic.Self
NutProduct ≡ ∃nutProduct.Self
nutAllergic o U o nutProduct ⊑ dislikes

U = universal property (x U y is always true)

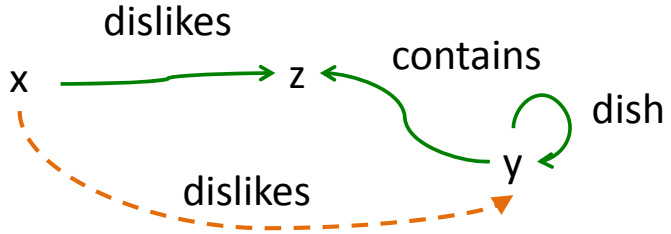


... more

dislikes(?x,?z) ∧ Dish(?y) ∧ contains(?y,?z) → dislikes(?x,?y)

becomes

- **Dish ≡ ∃dish.Self**
- **dislikes o contains⁻ o dish ⊑ dislikes**



Rules versus SPARQL queries

- Rules are “executed” globally
  - all rules must be satisfied simultaneously
- Rules may have interactions
  - the outcome of a rule may trigger another one
- SPARQL queries are executed independently

Simulating rules with queries

define a 'construct' query for each rule
repeat
  - execute each query
  - add the results to the RDF graph

until nothing new is created

parent(?x, ?y)∧ ancestor(?y, ?z) → ancestor(?x, ?z)

```
construct {?x ancestor ?z.}
where {?x parent ?y. ?y ancestor ?z.}
```

SWRL and Protégé

There is a “rule” view in Protégé

to activate it:

- menu Window -> Views -> Ontology Views -> Rules
- (a black dot appears)
- click the Class Annotation | Class Usage pane

The syntax uses ',' for the logical and (not '^')

C(?x), p(?x, ?y) -> D(?y)

SameAs and DifferentFrom must start with an uppercase letter.

SWRL inference in Protégé

- Pellet and HermiT support SWRL inference
  - simply run the reasoner to perfom swrl inference
    - menu Reasoner -> Start Reasoner or Classify or Synchronize
- HermiT does not support the builtin atoms: add, multiply, lessThan, ... (=> hardly usable)
- Reasoners make the rules DL-safe by binding the variable only to explicitly asserted individuals

  => reasoning is not complete with respect to the axioms