# INF3580 – Semantic Technologies – Spring 2010

## Lecture 9: More OWL, Role modeling

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# Generelle opplysninger:

Om obligene:

- oblig 1 er rettet
- e-post skal være sendt ut til alle som har levert
- frist for ny levering 8. april
- kommentarer ligger ute på kursets hjemmeside
- sammen med enkelte hint til løsningen

Angående sommeren:

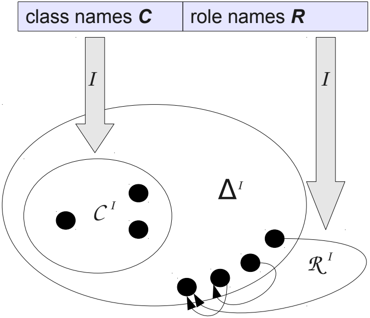
- Bli betalt for å jobbe med semantisk teknologi!
- Vi trenger studenter til å lære seg *Cambridge Semantics*
- Ta kontakt med Martin eller Audun.

# Today's Plan

1. Reminder: OWL
2. Role modeling
3. A worked example

# Outline

# Schematic representation of OWL/DL interpretations




- No reference/extension distinction
- That is, no function *IEXT*
- No properties in the domain
- Classes are sets
- Properties are relations
- Simple extensional semantics

# $\mathcal{ALC}$ Semantics

## Interpretation

An interpretation $\mathcal{I}$ fixes a set $\Delta^{\mathcal{I}}$, the *domain*, $A^{\mathcal{I}} \subseteq \Delta$ for each atomic concept $A$, and $R^{\mathcal{I}} \subseteq \Delta \times \Delta$ for each role $R$

## Interpretation of concept descriptions

$$
\begin{array}{rcl}
\top^{\mathcal{I}} & = & \Delta^{\mathcal{I}} \\
\bot^{\mathcal{I}} & = & \emptyset \\
(\neg C)^{\mathcal{I}} & = & \Delta^{\mathcal{I}} \setminus C^{\mathcal{I}} \\
(C \sqcap D)^{\mathcal{I}} & = & C^{\mathcal{I}} \cap D^{\mathcal{I}} \\
(C \sqcup D)^{\mathcal{I}} & = & C^{\mathcal{I}} \cup D^{\mathcal{I}} \\
(\forall R.C)^{\mathcal{I}} & = & \{a \in \Delta^{\mathcal{I}} \mid \forall b.(a,b) \in R^{\mathcal{I}} \rightarrow b \in C^{\mathcal{I}}\} \\
(\exists R.C)^{\mathcal{I}} & = & \{a \in \Delta^{\mathcal{I}} \mid \exists b.(a,b) \in R^{\mathcal{I}} \wedge b \in C^{\mathcal{I}}\}
\end{array}
$$

# $\mathcal{ALC}$ TBox and ABox

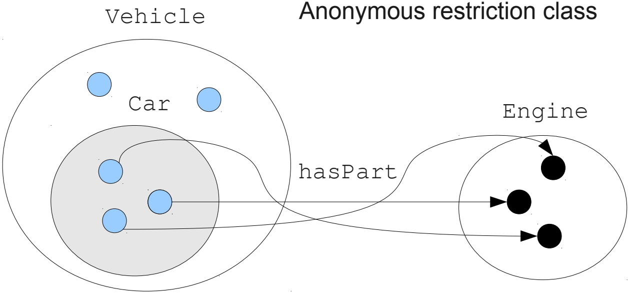
- The TBox
  - is for *terminological knowledge*
  - is independent of any actual instance data
  - is a set of $\sqsubseteq$ axioms
- The ABox
  - is for *assertional knowledge*
  - contains facts about concrete instances $a, b, c, \ldots$
  - A set of concept assertions $C(a)$ ...
  - and role assertions $R(b, c)$

# Recap of restrictions

- Existential restrictions
  - have the form $\exists R.C$
  - typically used to connect classes
  - $A \sqsubseteq \exists R.C$: Every $A$-object is $R$-related to *some* $C$-object
- Universal restrictions
  - have the form $\forall R.C$
  - restrict the things a type of object can be connected to
  - $A \sqsubseteq \forall R.C$ : Every $A$-object is $R$-related to $C$-objects *only*
  - $A$-objects may not be $R$-related to anything at all
- Example:
  - A car is a motorised vehicle
  - $Car \sqsubseteq Vehicle \sqcap \exists hasPart.Engine$

# Existential restrictions illustrated

$$Car \sqsubseteq Vehicle \sqcap \underbrace{\exists hasPart.Engine}_{\text{Anonymous restriction class}}$$



# A different perspective

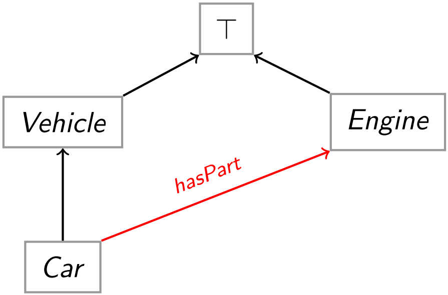



Figure: Connecting classes

# Outline

# Role characteristics and relationships

Role characteristics are mathematical properties of roles.

- A role can be:
  - reflexive/irreflexive
  - symmetric/asymmetric
  - transitive
  - functional/inverse functional

Role relationships: Roles $R$ and $S$ can be

- declared *disjoint*, meaning that $R^{\mathcal{I}} \cap S^{\mathcal{I}} = \emptyset$
- related as *inverses*, meaning that $S^{\mathcal{I}} = (R^{-})^{\mathcal{I}}$
- subsumed under each other, meaning that $R^{\mathcal{I}} \subseteq S^{\mathcal{I}}$
- chained, e.g. $R^{\mathcal{I}} \circ S^{\mathcal{I}} \subseteq S^{\mathcal{I}}$

# Corresponding mathematical properties and operations

A relation $R$ over a set $X$ is

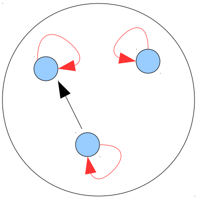
| | |
|---|---|
| **Reflexive:** | if $(a, a) \in R$ for all $a \in X$ |
| **Irreflexive:** | if $a \in X$ implies $(a, a) \notin R$ |
| **Symmetric:** | if $(a, b) \in R$ implies $(b, a) \in R$ |
| **Asymmetric:** | if $(a, b) \in R$ implies $(b, a) \notin R$ |
| **Transitive:** | if $(a, b), (b, c) \in R$ implies $(a, c) \in R$ |
| **Functional:** | if $(a, b), (a, c) \in R$ implies $b = c$ |
| **Inverse functional:** | if $(a, b), (c, b) \in R$ implies $a = c$ |

If $R$ and $S$ are binary relations on $X$ then

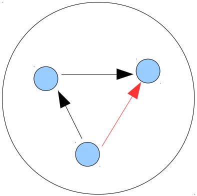
| | |
|---|---|
| $(\mathbf{a}, \mathbf{c}) \in \mathbf{R} \circ \mathbf{S}$: | if $(a, b) \in R$ and $(b, c) \in S$ for some $b \in X$ |
| $(\mathbf{b}, \mathbf{a}) \in \mathbf{R}^{-}$: | if $(a, b) \in R$. |

# Relation diagrams

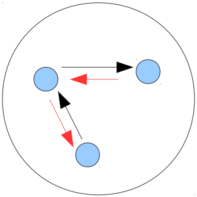
A reflexive relation:



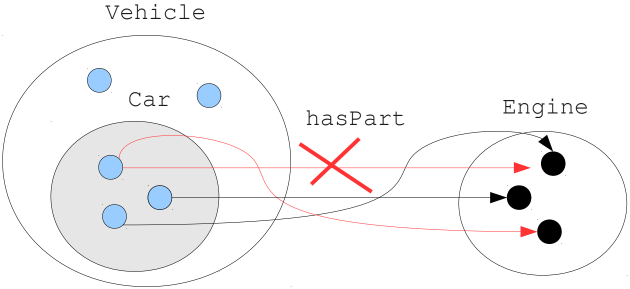
A transitive relation:



A symmetric relation:

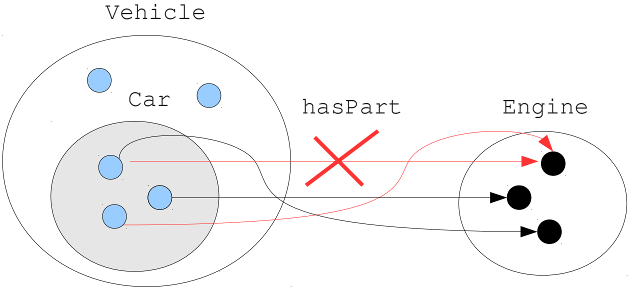


# Functionality




A (normal) car doesn't have more than one engine

# Inverse functionality

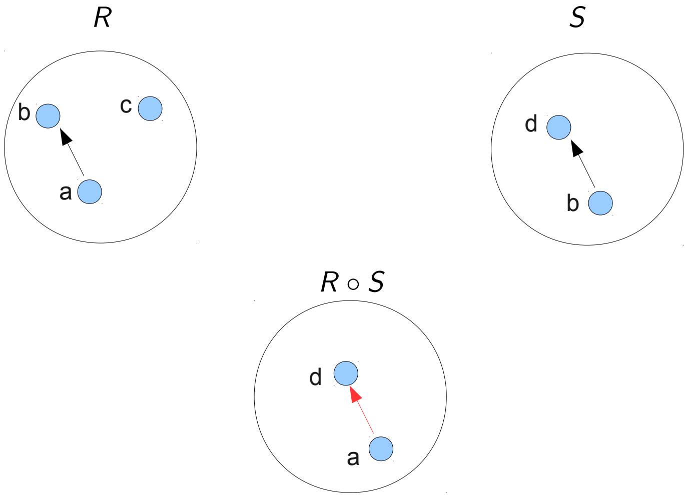



An engine doesn't sit in more than one car (simultaneously)

# Some role relationships: Inverses


Inverse roles $R$ and $R^{-}$.

# Chaining of roles



# Some relations from ordinary language

- Symmetric relations:
  - _ sibling of _
  - _ different from _
- *Non*-symmetric relations:
  - _ brother of _
  - _ likes _
- Asymmetric relations:
  - _ taller than _ (under a strict interpretation)
  - _ member of _
- Transitive relations:
  - _ taller than _
  - _ part of _ (under certain qualifications)
- Functional relations:
  - _ was born by _
- Inverse functional relations:
  - _ gave birth to _

# Som inverses and chains

Some inverses:

- Uncle/nephew
- Gave birth to/was born by
- To the left of/to the right of
- Taller than/shorter than
- etc.

Some role chains:

- $\texttt{fatherOf} \circ \texttt{brotherOf} \sqsubseteq \texttt{uncleOf}$
- $\texttt{isLocatedIn} \circ \texttt{isPartOf} \sqsubseteq \texttt{isLocatedIn}$

# Datatype properties and object properties

OWL enforces a separation between datatype- and object properties:

Object properties:

- Also known as *abstract roles*
- connect objects with objects
- Example in Turtle syntax:

```
foaf:knows a owl:ObjectProperty .
```

Datatype properties:

- Also known as *concrete roles*
- connect objects with literal values, i.e. with elements of datatypes.
- Example in Turtle-syntax:

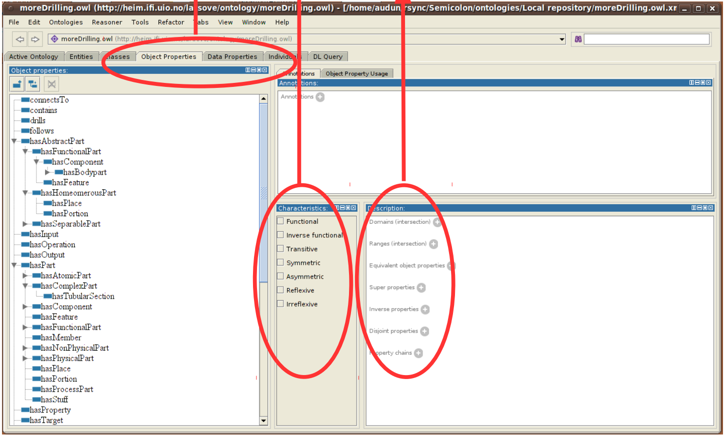
```
ex:age a owl:DatatypeProperty .
ex:age rdfs:range xsd:positiveInteger .
```

# Managing roles in Protege

Object/datatype property tabs

Role characteristics

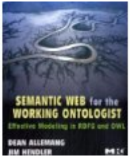
Domain/range, role relationships



# Outline

# Example: Merging product information

The example is an adaptation from Allemang and Hendler: "Semantic Web for the Working Ontologist":




Suppose we want to integrate product information, and that

- data is stored in two different tables
- in two different databases
- one contains information about the product per se
- and the other about the facilities needed to produce them

# Table excerpts I

| Product | | | | |
|---|---|---|---|---|
| **ID** | **Model Number** | **Division** | **Manufacture Location** | **Available** |
| 1 | ZX-3 | Manufacturing | Sacramento | 23 |
| 2 | ZX-3P | Manufacturing | Seoul | 14 |
| 3 | ZX-3S | Support | Hong Kong | 100 |
| 4 | B1431 | Control | Hong Kong | 4 |
| 5 | B1430X | Engineering | Elizabeth | 14 |
| 6 | DBB-12 | Accessories | Cleveland | 87 |

Figure: Table of products

# Table excerpts II

| Product | | |
|---|---|---|
| **ID** | **Model Number** | **Facility** |
| 1 | B1430X | Assembly Center |
| 2 | 1180-M | Machine Shop |
| 3 | TC-43 | Factory |
| 4 | ZX-3P | Factory |
| 5 | B1431 | Assembly Center |
| 6 | SP-1234 | Machine Shop |

Figure: Parts and the facilities required to produce them

# The challenge

We wish to integrate the two tables, so that e.g.

- places can be correlated with production facilities

However, we would like to do so in manner such that

- we do not have to go through the rows one-by-one
- in a manual editing process

Rather we would like to

- Specify a set of general relationships between the respective columns
- that enables a reasoner to *infer* the correlations whenever they exist

# Exposing RDBs as RDF

Information in a table can be encoded as RDF:

The recipe is:

1. Come up with a URI for the database as such, and in this namespace:
    - Make each row in the table a resource,
    - construct the resource name from the table name and the primary key
2. make each cell a triple where
    - the resource corresponding to the row is the subject of the triple
    - the predicate name is constructed from the table and column name
    - the cell value is the object of the triple

This is called *exposing RDBs as RDF* and can be done by several tools:

For instance:

- D2RQ
- SquirrelRDF
- OpenLink Virtuoso

# Desirable features

These tools have one or more of the following features

- the data is exposed as *virtual RDF*,
- that is, conversion is on-demand rather than up-front
- they offer general-purpose mapping from RDB to ontology
- that is, tables can be mapped to classes of one's own choosing
- and columns can be mapped to properties

D2RQ, for one, has all features.

# The RDF encoding

There are $5 \times 6 = 30$ triples for the first table, among others

### Manufacture location triples

```
mf:Product1 mf:Product_Manufacture_location "Sacramento" .
mf:Product2 mf:Product_Manufacture_location "Seoul" .
mf:Product3 mf:Product_Manufacture_location "Hong Kong" .
mf:Product4 mf:Product_Manufacture_location "Elizabeth" .
mf:Product5 mf:Product_Manufacture_location "Hong Kong" .
mf:Product6 mf:Product_Manufacture_location "Cleveland" .
```

We assume that `mf:` abbreviates the namespace of the database.

# .. contd

Similarly there are $3 \times 6 = 18$ triples for the second table, among others

## Production facility triples

```
p:Product1 p:Product_Facility "Assembly Center" .
p:Product2 p:Product_Facility "Machine Shop" .
p:Product3 p:Product_Facility "Factory" .
p:Product4 p:Product_Facility "Factory" .
p:Product5 p:Product_Facility "Assembly Center" .
p:Product6 p:Product_Facility "Machine Shop" .
```

We assume that `p:` abbreviates the namespace of the database.

# Solution

The challenge can now be solved by a two-step procedure:

1. Declare the respective **Model Number** columns equivalent properties:
    - if a product *x* has a `mf:Model_Number` value of "ZX-3P"
    - then *x* also has the same value for `p:Model_Number`

- This can be done manully, by adding the following triples:

```
mf:Product_Number rdfs:subPropertyOf p:Product_Number .
p:Product_Number rdfs:subPropertyOf mf:Product_Number .
```

- or it can be done in Protegé

# solution contd.

2. Declare one property to be *inverse functional*

- The range of such a property can be considered a set of unique keys
- i.e. elements of the range provide unique identifiers for each element of the domain.

Thus,

- If, say, `mf:Model_Number` is declared to be inverse functional,
- then records with the same `mf:Model_Number` represent the same product,

Inverse functionality,

- can be declared manually by adding a triple such as

  ```
  mf:Model_Number a owl:InverseFunctionalProperty .
  ```

  which will land you in OWL-full
- or by using the `owl:hasKey` facility of OWL 2 (consult the spec)

# A sample trace

## A SPARQL query

```
SELECT ?location ?facility WHERE{
         ?product mf:Manufacture_Location ?location .
         ?product p:Product_Facility ?facility.
        }
```

- SPARQL finds `mf:Product4`
- which has `mf:Manufacture_Location` “Hong Kong”
- and `mf:Product_Number` “B1431”

# trace contd.

- "B1431" is also the `p:Product_Number` of `p:Product5`
- these properties are equivalent
- so "B1431" is also the `mf:Product_Number` of `p:Product5`
- whence, since `mf:Product_Number` is inverse funtional, we have `p:Product5 = mf:Product4`
- now, `p:Product5` has `p:Product_Facility` "Assembly Center",
- and `mf:Product4` has `mf:Manufacture_Location` "Hong Kong"
- So ("Hong Kong", "Assembly Center") is a solution for the query

# Other common role modeling patterns

- Transitivity and reflexivity for ordering relations, e.g.
  - the mereological notion of part-whole
  - being a part of a part of is being a part of
  - everything is part of itself
- Inversely related ordering relations, e.g.
  - `hasPart` and `partOf`
  - if `a` has `b` as a part then `b` is a part of `a`
- Asymmetry for strict ordering relations, e.g.
  - the mereological `isProperPartOf`
  - if `a` is a proper part of `b` then `b` cannot be a proper part of `a`
- Functional properties where sameness should be inferred, e.g.
  - the `hasFather` relation,
  - where fathers may be known by different names