Ontologies in Computer Science

formalisms and applications

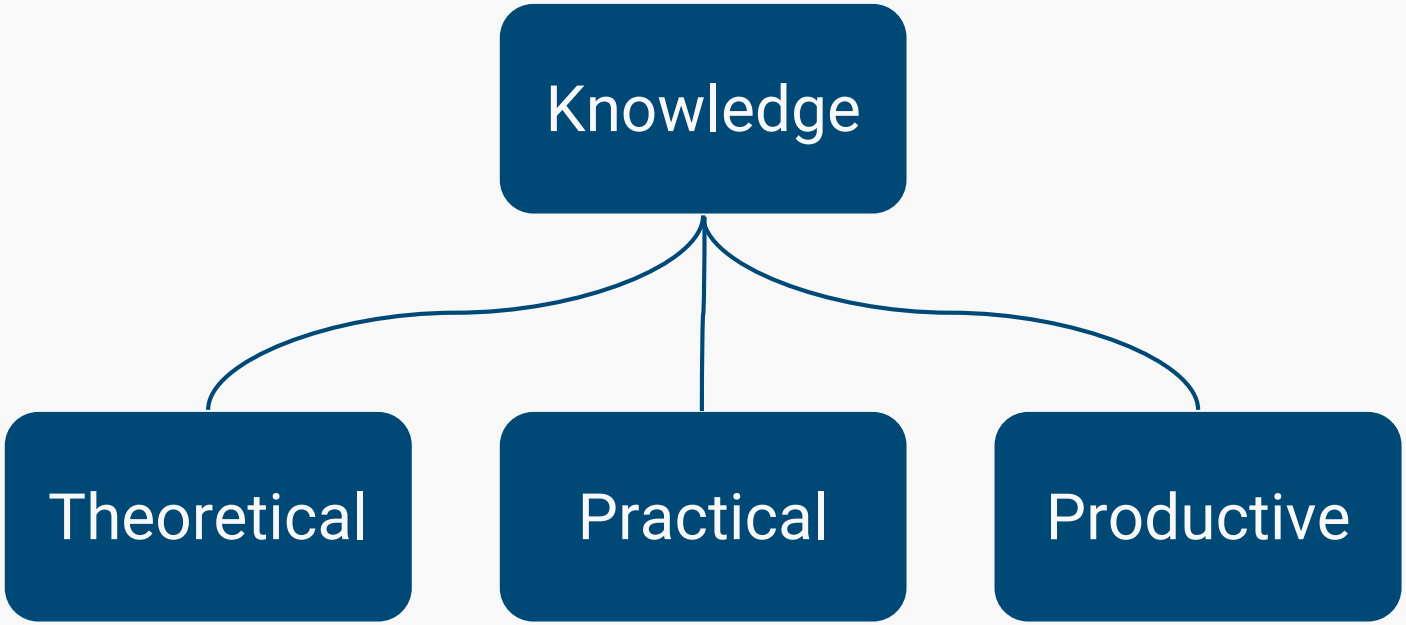
By
Olivier Bellemans

Contents

1. Introduction

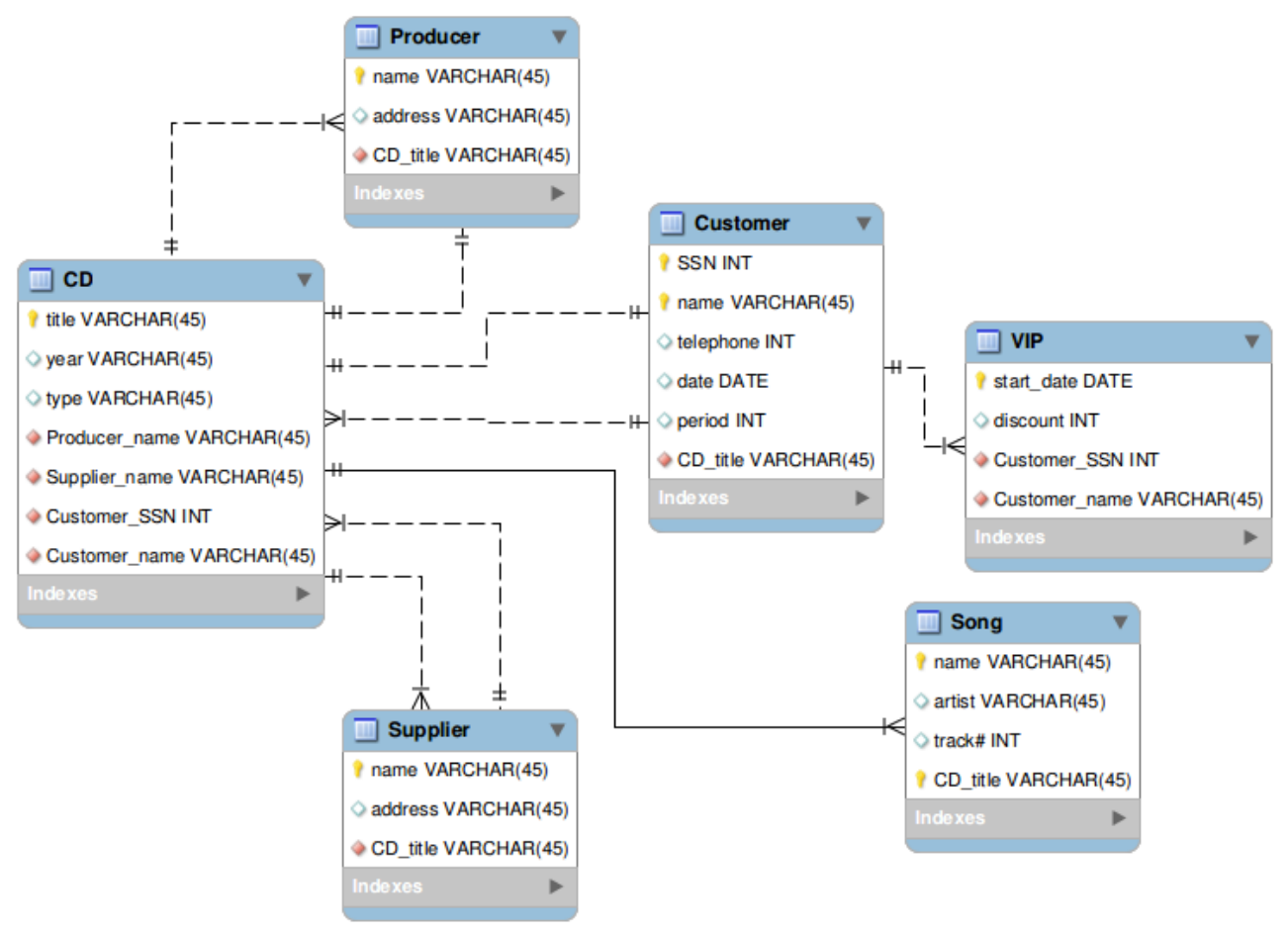
Ontology (philosophy)

Ontology (philosophy)

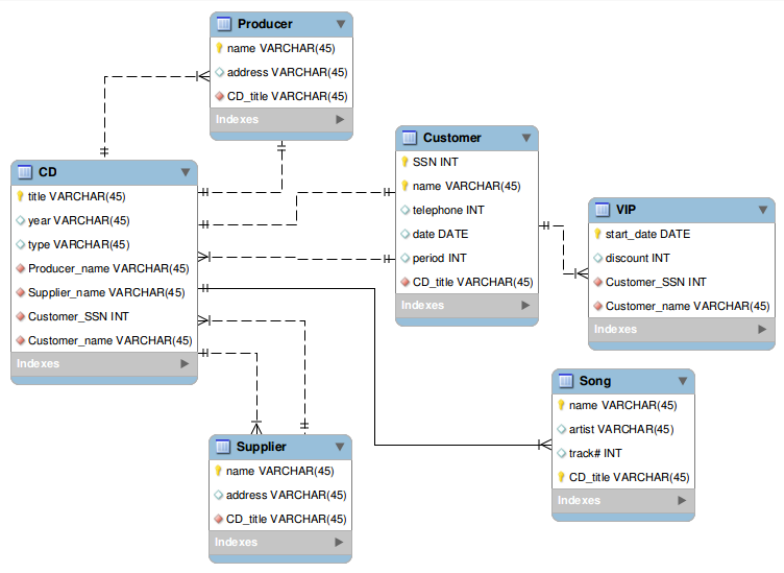


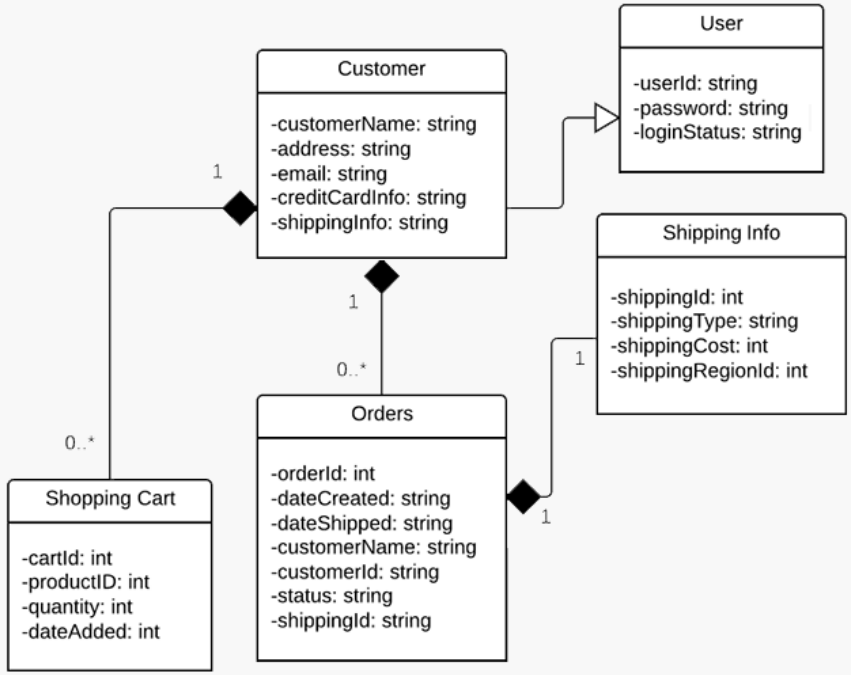
Aristotle's division of knowledge

Ontologies (computer science)

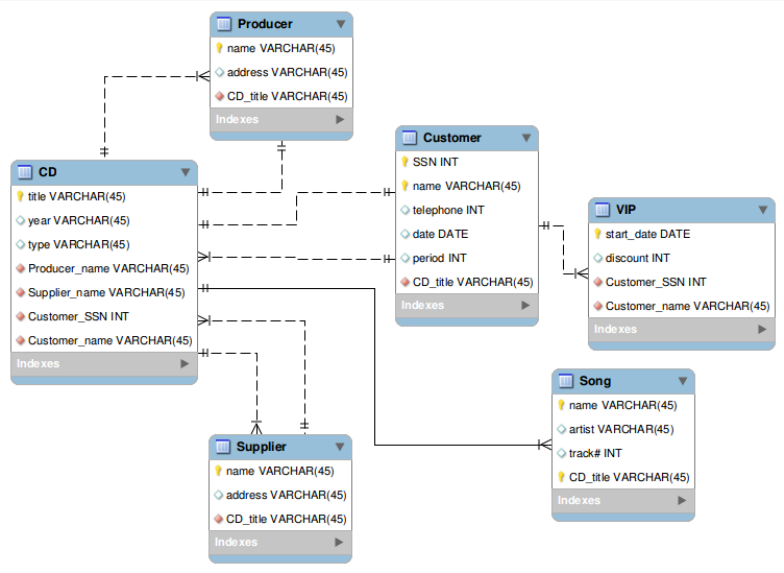


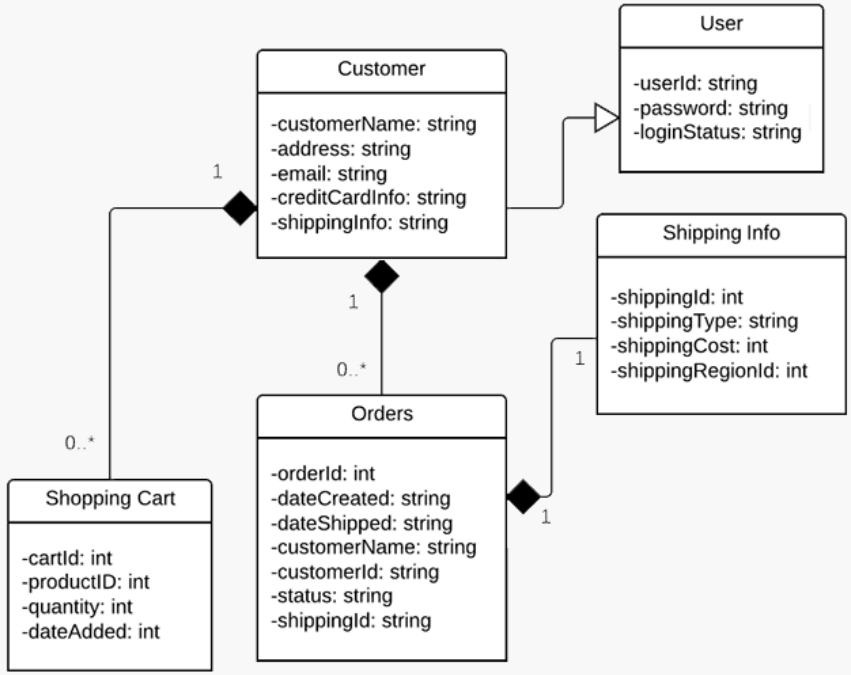
Ontologies (computer science)





Ontologies (computer science)





$$\forall x[Customer(x) \rightarrow User(x)]$$

$$\forall x[Order(x) \rightarrow \exists y[placedOrder(y, x)]]$$

Definition

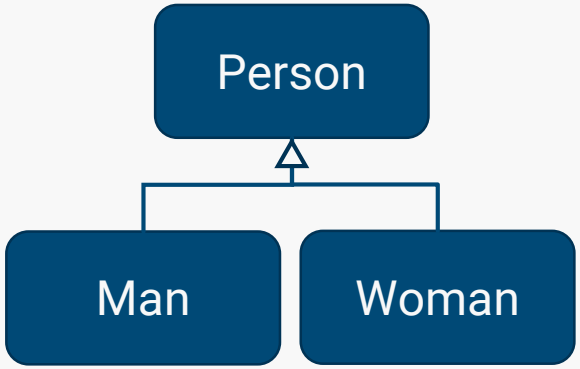
- An ontology is a model of a particular domain
  - Concepts (Types)
  - Relations

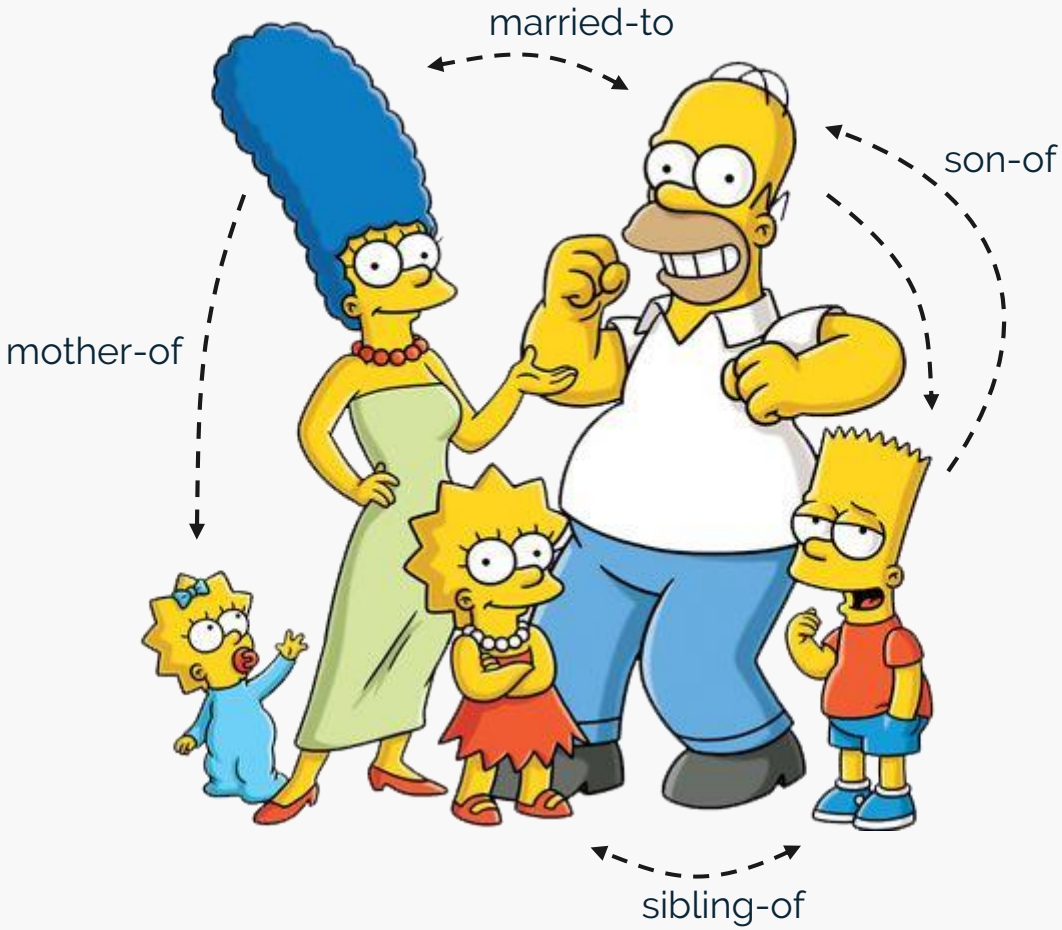
Definition

- An ontology is a model of a particular domain
  - Concepts (Types)
  - Relations
- Serves a purpose
  - Shared understanding
  - Automated reasoning
  - Interoperability

Example

Example





2. Formal Logics

Logic Introduction

whenever it rains it is cloudy,
it is not cloudy,

therefore it does not rain

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$rain \rightarrow cloudy, \neg cloudy \models \neg rain$

$p \rightarrow q, \neg q \models \neg p$

Predicate Logic: Syntax

- Connectives: $\vee, \wedge, \neg, \rightarrow$
- Quantifiers: $\forall x, \exists x$
- Symbols for:
  - Functions
  - Predicates
  - Variables

Predicate Logic: Semantics

$$\forall x[Man(x) \rightarrow Person(x)]$$

Predicate Logic: Semantics

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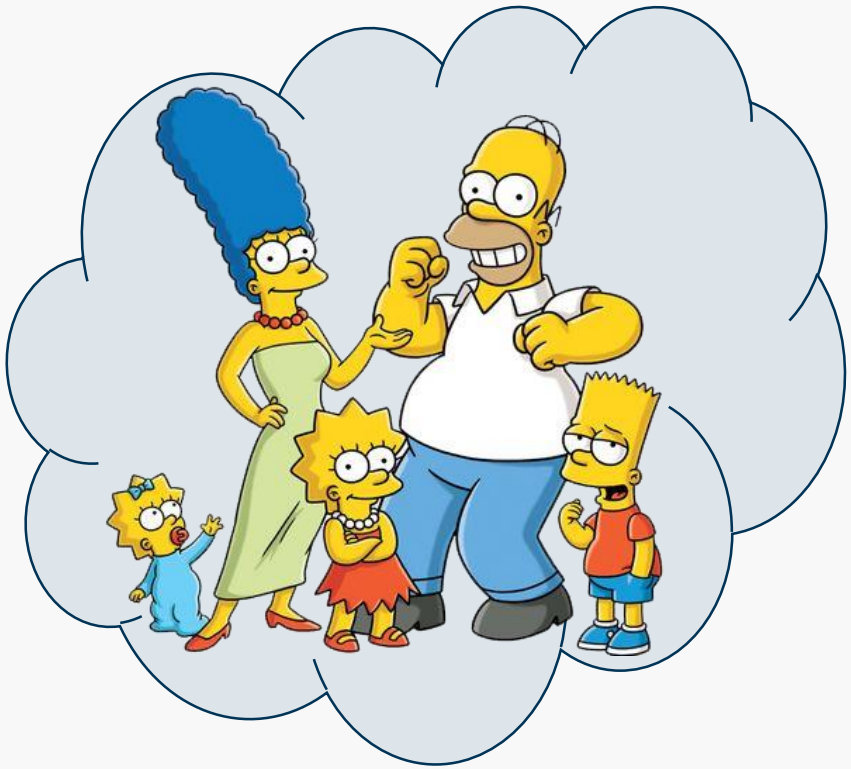
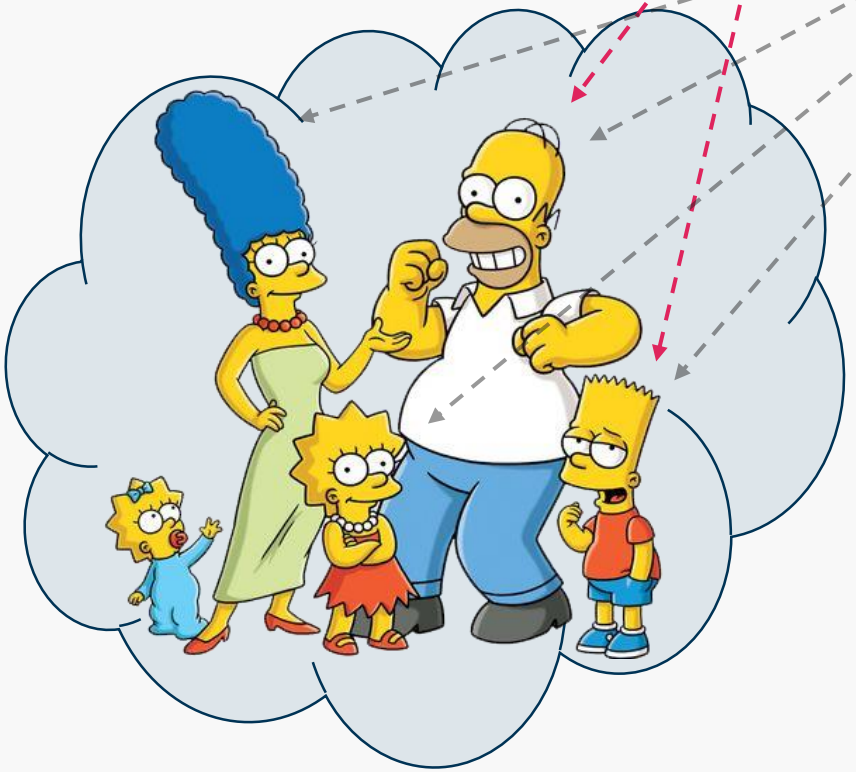


Predicate Logic: Semantics

$$\forall x[Man(x) \rightarrow Person(x)]$$



Predicate Logic: Conclusions

- The Good
  - Formal semantics
  - Automated reasoning
- The Bad
  - Verbose, indirect syntax
  - Undecidability

Description Logics

"A man is also a person"

Description Logics

"A man is also a person"

- Predicate Logic

$$\forall x[Man(x) \rightarrow Person(x)]$$

- Description Logic

$$Man \sqsubseteq Person$$

Description Logics

"A crazy cat lady is a woman with two or more cats"

Description Logics

"A crazy cat lady is a woman with two or more cats"

- Predicate Logic

$$\forall x[CrazyCatLady(x) \leftrightarrow Woman(x) \wedge \exists y[ownsCat(x,y) \wedge \exists z[z \neq y \wedge ownsCat(x,z)]]]$$

- Description Logic

$$CrazyCatLady \equiv Woman \sqcap \geq_2 ownsCat$$

Description Logics: Syntax

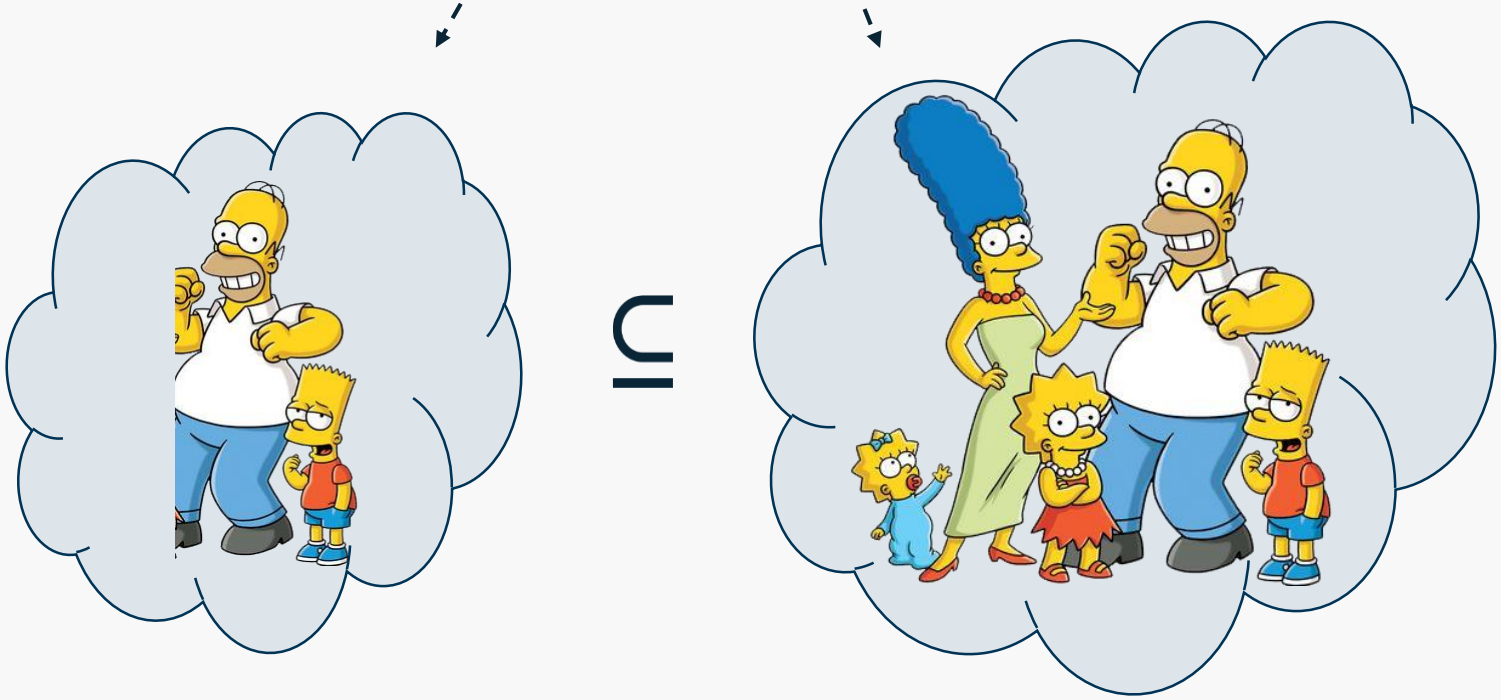
- Concept constructors: $\sqcup, \sqcap, \neg, \forall r.C, \exists r.C, \geq_n r$ (common ones)
- Concept axioms: $\sqsubseteq, \equiv$
- Symbols for:
  - Concepts
  - Roles / Relations

Description Logics: Semantics

$$Man \sqsubseteq Person$$

Description Logics: Semantics

$$Man \sqsubseteq Person$$



Description Logics: Conclusions

- Improves on predicate logic
  - Compact syntax
  - Decidable

3. Ontology Languages

Ontology Languages

- RDFS
- OWL Web Ontology Language

OWL Web Ontology Language

```
<?xml version="1.0"?>
<rdf:RDF xmlns="http://www.obe.be/test#"
     xml:base="http://www.obe.be/test"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
     xmlns:owl="http://www.w3.org/2002/07/owl#"
     xmlns:xml="http://www.w3.org/XML/1998/namespace"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
    <owl:Ontology rdf:about="http://www.obe.be/test"/>

    <!-- Properties -->
    <owl:ObjectProperty rdf:about="http://www.obe.be/test#childOf">
        <rdfs:subPropertyOf

rdf:resource="http://www.w3.org/2002/07/owl#topObjectProperty"/>
        <owl:inverseOf rdf:resource="http://www.obe.be/test#parentOf"/>
    </owl:ObjectProperty>

    <owl:ObjectProperty rdf:about="http://www.obe.be/test#parentOf">
        <rdf:type
rdf:resource="http://www.w3.org/2002/07/owl#IrreflexiveProperty"/>
        <rdfs:domain rdf:resource="http://www.obe.be/test#Person"/>
        <rdfs:range rdf:resource="http://www.obe.be/test#Person"/>
    </owl:ObjectProperty>

    <owl:ObjectProperty rdf:about="http://www.obe.be/test#siblingOf"/>

    <!-- Classes -->
    <owl:Class rdf:about="http://www.obe.be/test#Man">
        <rdfs:subClassOf rdf:resource="http://www.obe.be/test#Person"/>
    </owl:Class>

    <owl:Class rdf:about="http://www.obe.be/test#Person"/>

    <owl:Class rdf:about="http://www.obe.be/test#Woman">
        <rdfs:subClassOf rdf:resource="http://www.obe.be/test#Person"/>
    </owl:Class>

    <!-- Individuals -->
    <owl:NamedIndividual rdf:about="http://www.obe.be/test#Bart">
        <rdf:type rdf:resource="http://www.obe.be/test#Man"/>
    </owl:NamedIndividual>

    <owl:NamedIndividual
rdf:about="http://www.obe.be/test#Homer">
        <rdf:type rdf:resource="http://www.obe.be/test#Man"/>
        <parentOf rdf:resource="http://www.obe.be/test#Bart"/>
        <parentOf rdf:resource="http://www.obe.be/test#Lisa"/>
        <parentOf
rdf:resource="http://www.obe.be/test#Maggie"/>
    </owl:NamedIndividual>

    <owl:NamedIndividual
rdf:about="http://www.obe.be/test#Lisa">
        <rdf:type rdf:resource="http://www.obe.be/test#Woman"/>
    </owl:NamedIndividual>

    <owl:NamedIndividual
rdf:about="http://www.obe.be/test#Maggie">
        <rdf:type rdf:resource="http://www.obe.be/test#Woman"/>
    </owl:NamedIndividual>

    <owl:NamedIndividual
rdf:about="http://www.obe.be/test#Marge">
        <rdf:type rdf:resource="http://www.obe.be/test#Woman"/>
        <parentOf rdf:resource="http://www.obe.be/test#Bart"/>
        <parentOf rdf:resource="http://www.obe.be/test#Lisa"/>
        <parentOf
rdf:resource="http://www.obe.be/test#Maggie"/>
    </owl:NamedIndividual>

</rdf:RDF>
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    </owl:Class>

    <owl:Class rdf:about="http://www.obe.be/test#Person"/>

    <owl:Class rdf:about="http://www.obe.be/test#Woman">
        <rdfs:subClassOf rdf:resource="http://www.obe.be/test#Person"/>
    </owl:Class>

    <!-- Individuals -->
    <owl:NamedIndividual rdf:about="http://www.obe.be/test#Bart">
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    </owl:NamedIndividual>

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rdf:about="http://www.obe.be/test#Homer">
        <rdf:type rdf:resource="http://www.obe.be/test#Man"/>
        <parentOf rdf:resource="http://www.obe.be/test#Bart"/>
        <parentOf rdf:resource="http://www.obe.be/test#Lisa"/>
        <parentOf
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        <parentOf rdf:resource="http://www.obe.be/test#Bart"/>
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</rdf:RDF>
```
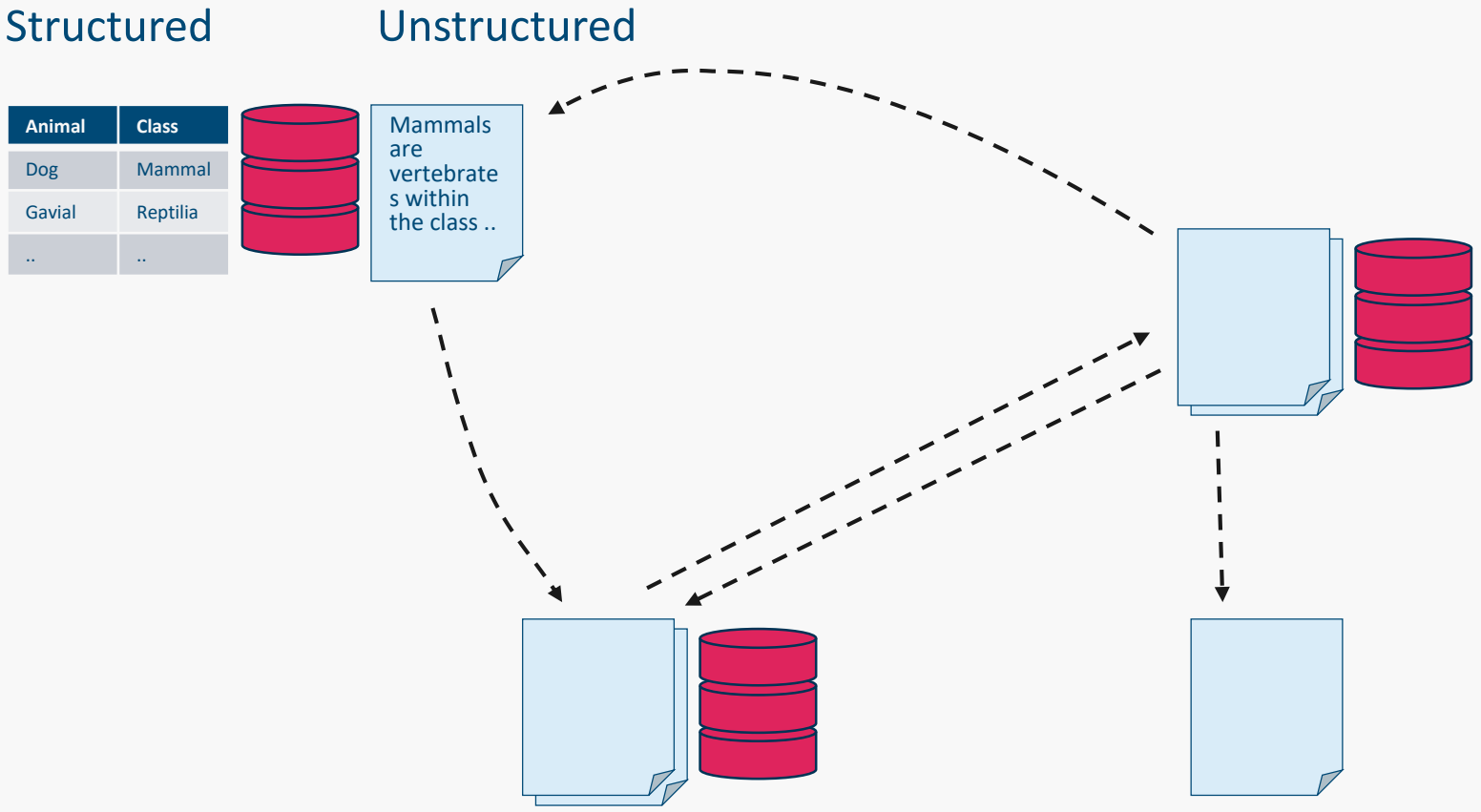

use tools

4. Applications

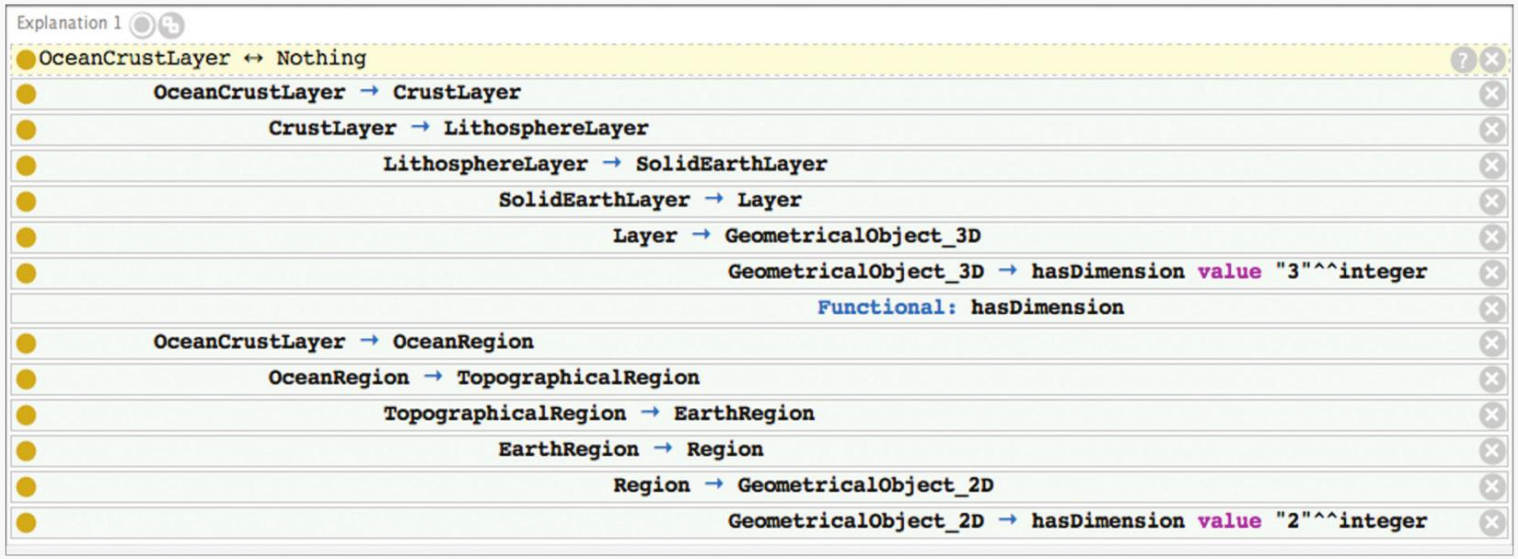
Semantic Web



Grimm, S., Abecker, A., Völker, J., & Studer, R. (2011). Ontologies and the Semantic Web.

Engineering

- NASA Jet Propulsion Laboratory



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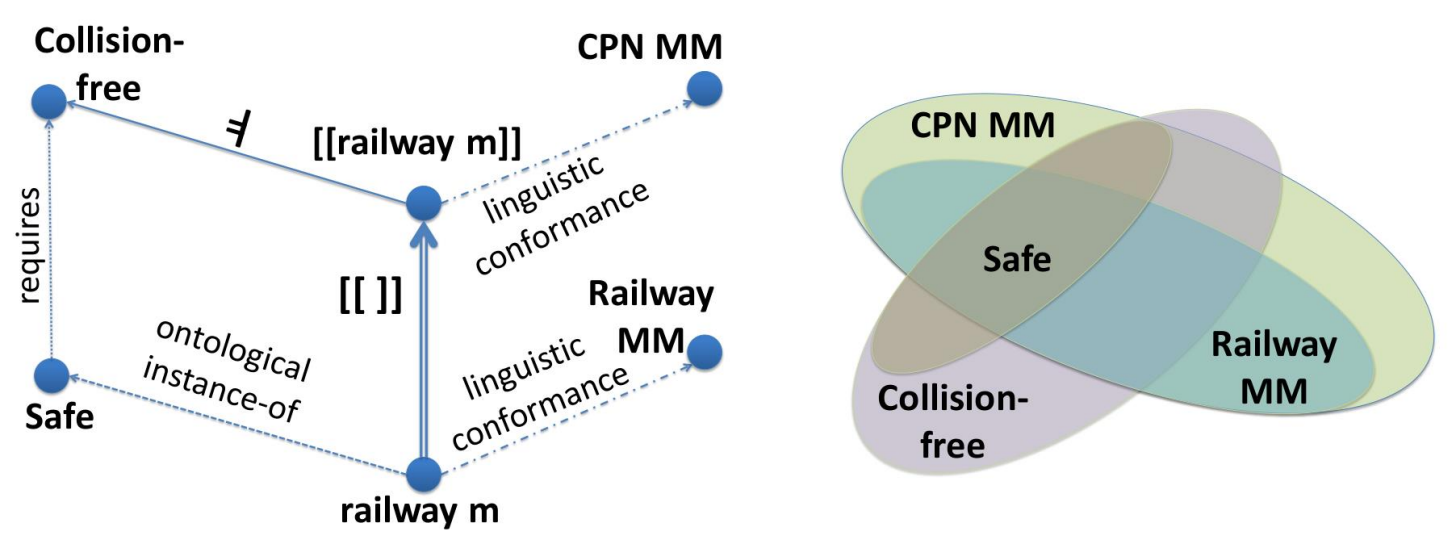
MDE

- Integrating language & ontology engineering



Barroca, B., Kühne, T., & Vangheluwe, H. (2014). Integrating language and ontology engineering.

Recap & Questions

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