Working Modularly with OWL

Thomas Schneider

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About the project

Title

Composing and decomposing ontologies: a logic-based approach

People involved/interested

- Uli Sattler, Bijan Parsia, Thomas Schneider (Manchester)
- Frank Wolter, Boris Konev, Dirk Walther (Liverpool)
- Ian Horrocks, Bernardo Cuenca Grau (Oxford)
- Carsten Lutz (Bremen)

And now . . .

1. Why modularity?
2. A reuse scenario
3. Logical background
4. Tools
5. Comparison of modularisation approaches
6. Understanding ontologies via modules

Crash course: ontologies and description logics

Ontology = collection of statements about a domain *(axioms)*

- Language used: usually logic, often *description logic (DL)*
- *Inferences* can be drawn from axioms

Domains:

biology, medicine, chemistry, business processes, natural language, . . .

Example axioms + inference

- $\underbrace{\text{Duck}}_{\text{class}} \sqsubseteq \underbrace{\exists \underbrace{\text{feedsOn}}_{\text{property}} . \underbrace{\text{Grass}}_{\text{class}}}_{\text{class}}$

$$\forall x \Big(\text{Duck}(x) \longrightarrow \exists y \big(\text{feedsOn}(x, y) \wedge \text{Grass}(y)\big)\Big)$$

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- $\text{Tweety} : \text{Bird}$
- $\text{Tweety} : \exists \text{feedsOn}.\text{Grass}$

Reasoning tasks

- *Inference:* Does axiom α follow from ontology $\mathcal{O}$?
- *Satisfiability:*
  Is there a model of $\mathcal{O}$ that interprets class C as nonempty?
- *Instance checking:*
  Is individual x an instance of C in every model of $\mathcal{O}$?

Inter-reducible; optimised reasoners available

A case for modularity

Common practice in software engineering

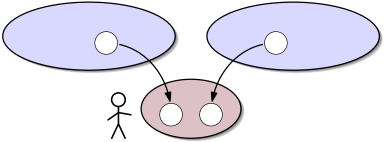
Modular software development allows for:

- Importing/reusing modules
- Collaborative development
- Understanding the code from the interaction between the modules

Wouldn't it be nice . . .

. . . to have this for ontology development as well?

Three scenarios



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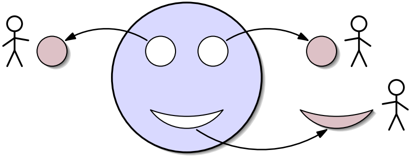
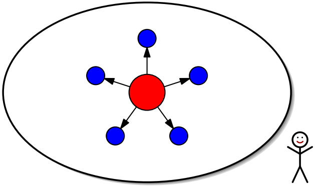
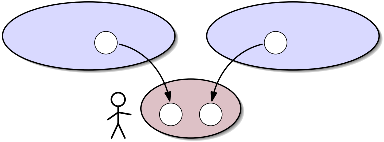


Collaboration



Understanding

Three scenarios



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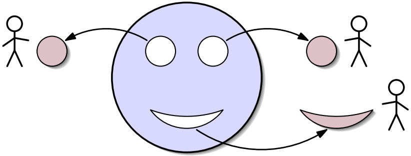

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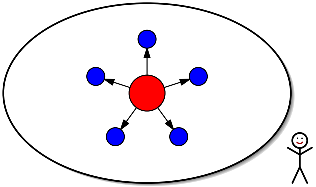
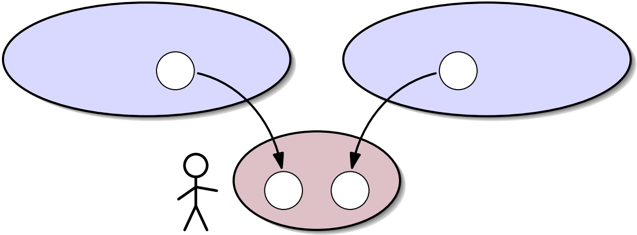


Understanding

Scenario 1: Import/reuse

“Borrow” knowledge about certain terms from external ontologies



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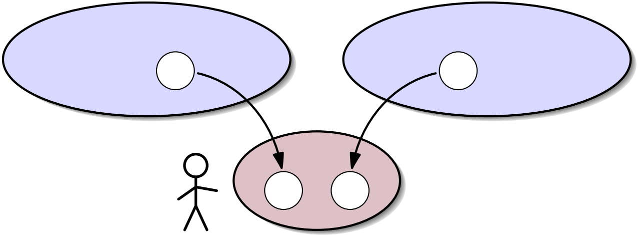

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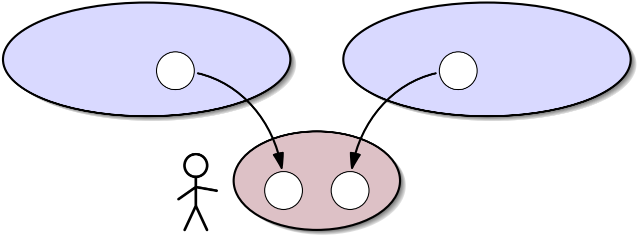

- Provides access to well-established knowledge
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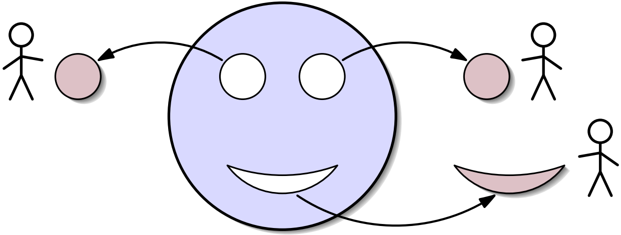
This scenario is well-understood and implemented.

Scenario 2: Collaboration

Collective ontology development



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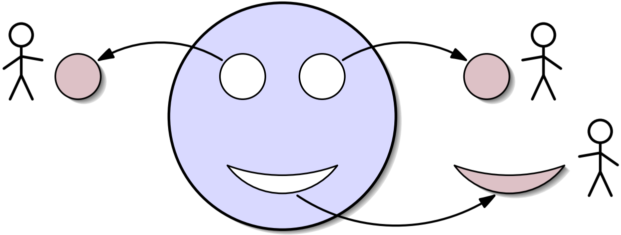

- Developers work (edit, classify) locally
- Extra care at re-combination

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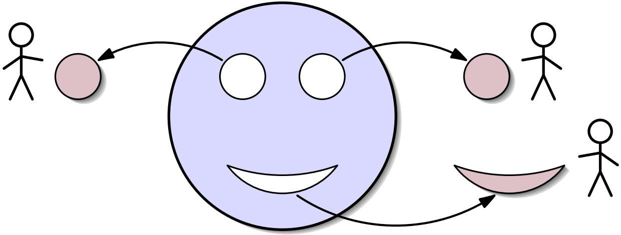

- Developers work (edit, classify) locally
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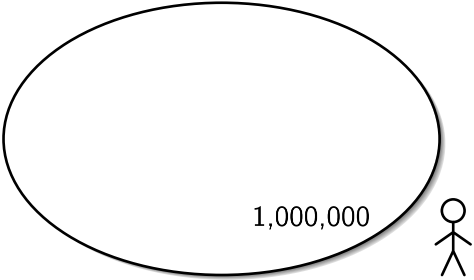
This approach is understood, but not implemented yet.

Scenario 3: Understanding

Visualise the modular structure of an ontology



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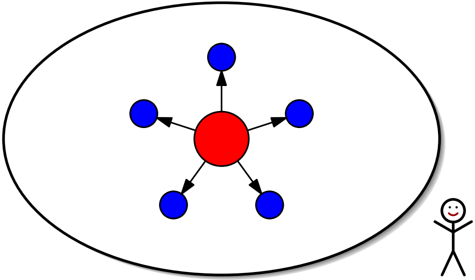

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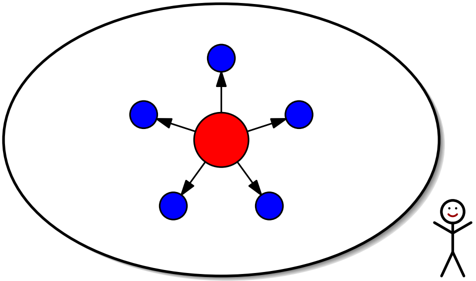
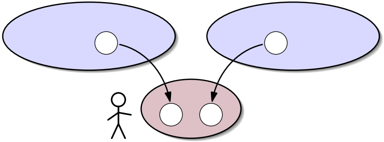


We're still playing with this.

Summing up



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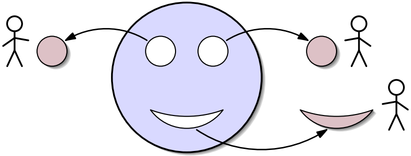

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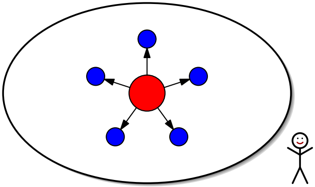
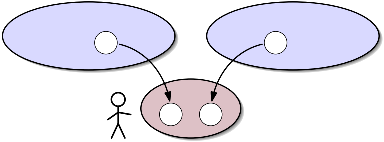


Understanding

Summing up



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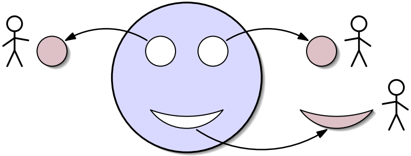

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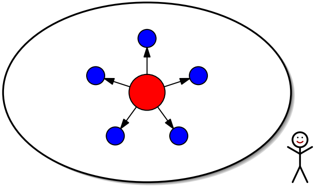

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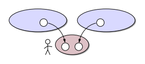
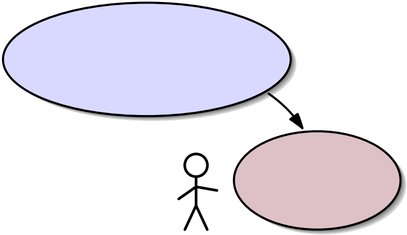


Import/reuse one external ontology



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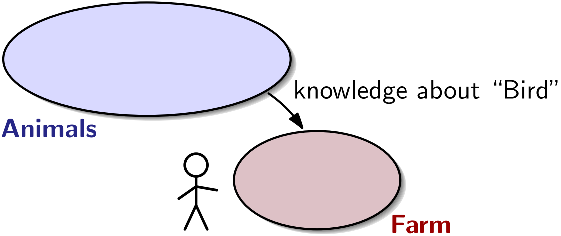

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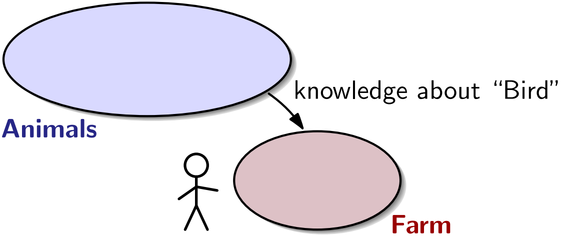
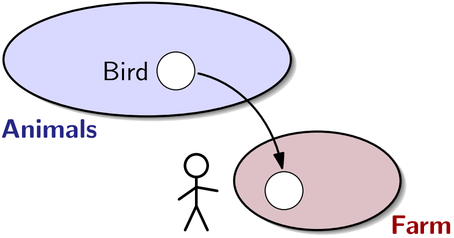


How much of **Animals** do we need?

A reuse scenario

Import/reuse a part of an external ontology



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- **Coverage:** Import *everything* relevant for the chosen terms.
- **Economy:** Import *only* what's relevant for them.

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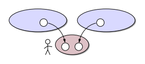

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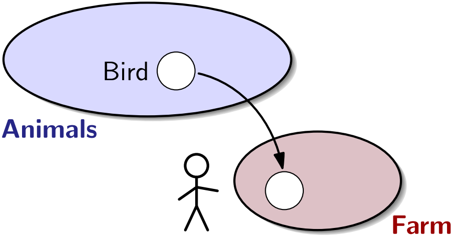

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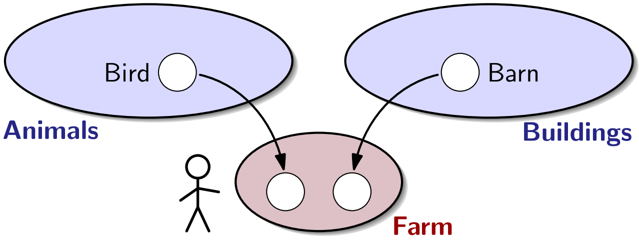
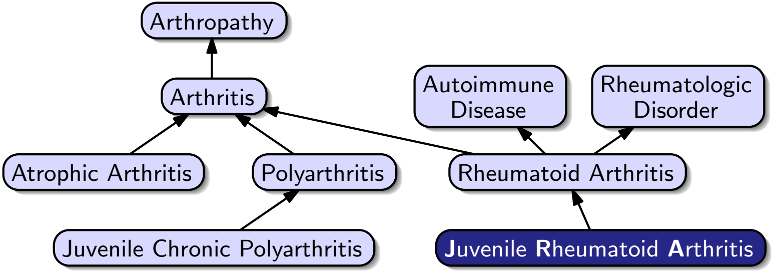
How to achieve coverage and economy?

A reuse scenario

Import/reuse parts of several external ontologies



The *Health-e-Child* project



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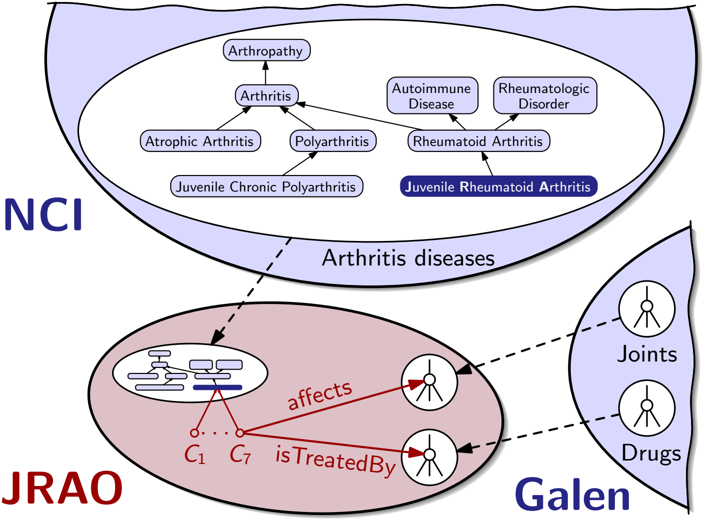
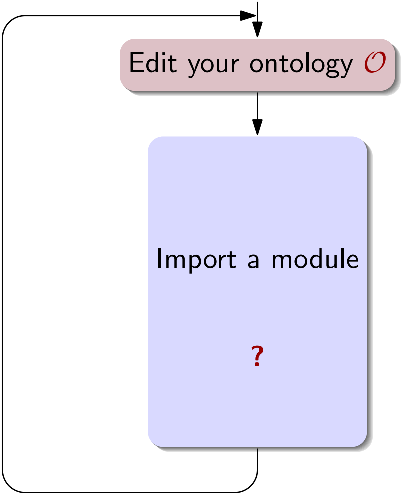


A working cycle

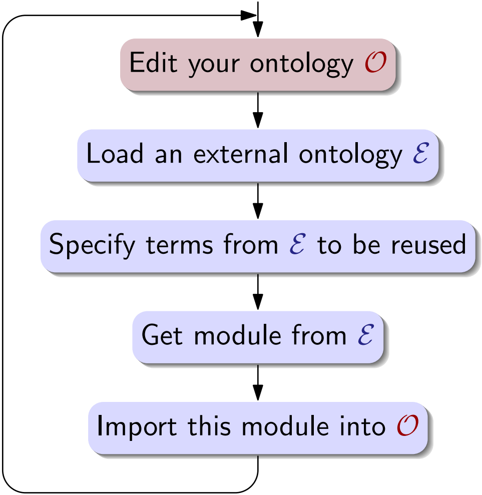


Edit your ontology $\mathcal{O}$

Import a module

?

A working cycle



Edit your ontology $\mathcal{O}$

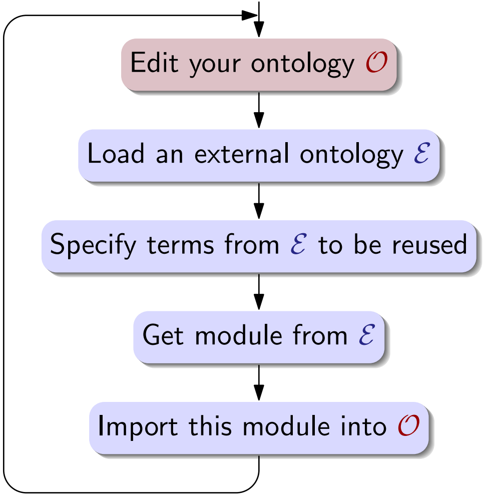
Load an external ontology $\mathcal{E}$

Specify terms from $\mathcal{E}$ to be reused

Get module from $\mathcal{E}$

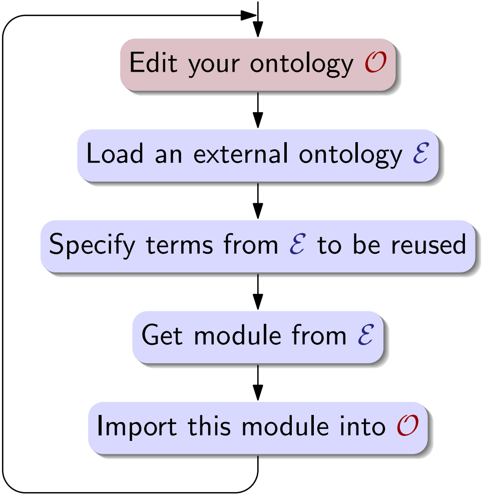
Import this module into $\mathcal{O}$

A working cycle



Edit your ontology $\mathcal{O}$	**Farm**
Load an external ontology $\mathcal{E}$	**Animals**
Specify terms from $\mathcal{E}$ to be reused	Animal, feedsOn
Get module from $\mathcal{E}$	**Animals′**
Import this module into $\mathcal{O}$	**Farm** ∪ **Animals′**

A working cycle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Farm ∪ **Animals′**

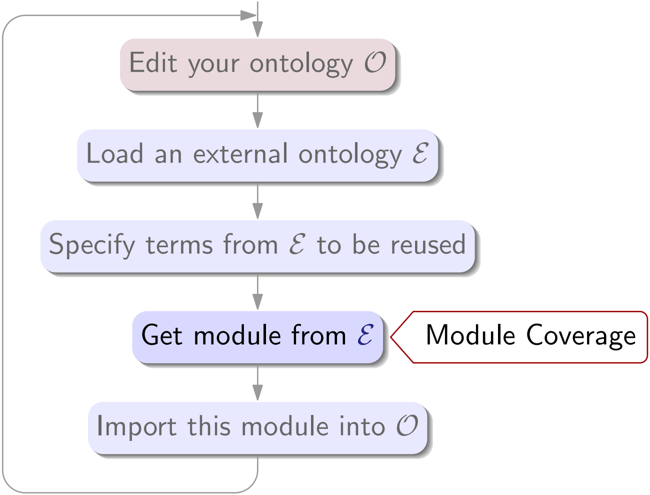
Buildings

DuckHousing, Silo

Buildings′

Farm ∪ **Animals′** ∪ **Buildings′**

A working cycle



Edit your ontology $\mathcal{O}$

Load an external ontology $\mathcal{E}$

Specify terms from $\mathcal{E}$ to be reused

Get module from $\mathcal{E}$

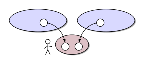
Module Coverage

Import this module into $\mathcal{O}$

Module coverage

Goal: Import everything the external ontology knows about the topic that consists of the specified terms.

Module coverage



Goal: Import everything the external ontology knows about the topic that consists of the specified terms.

Example 1:

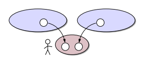
- Topic: Fox, Bird, feedsOn
- On-topic: Off-topic:

$$\mathsf{Fox} \sqsubseteq \forall\,\mathsf{feedsOn}.\mathsf{Bird}$$
$$\mathsf{Fox} \sqcup \mathsf{Bird} \sqsubseteq \exists\,\mathsf{feedsOn}.\top$$
$$\mathsf{Bird} \sqsubseteq \neg\mathsf{Fox}$$
$$\mathsf{Bird} \sqsubseteq \mathsf{Bird} \sqcup \mathsf{Fox}$$

$$\mathsf{Duck} \sqsubseteq \mathsf{Bird}$$

- Goal = preserve all on-topic knowledge

Module coverage



Goal: Import everything the external ontology knows about the topic that consists of the specified terms.

Question: Which axioms do we need to import?

Module coverage

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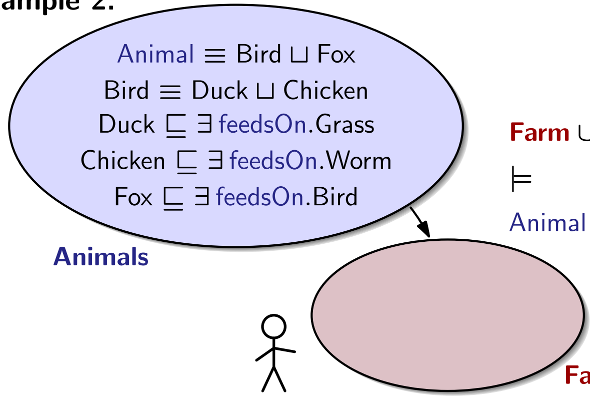

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Farm ∪ **Animals**

$\models$

$\text{Animal} \sqsubseteq \exists\, \text{feedsOn}.\top$

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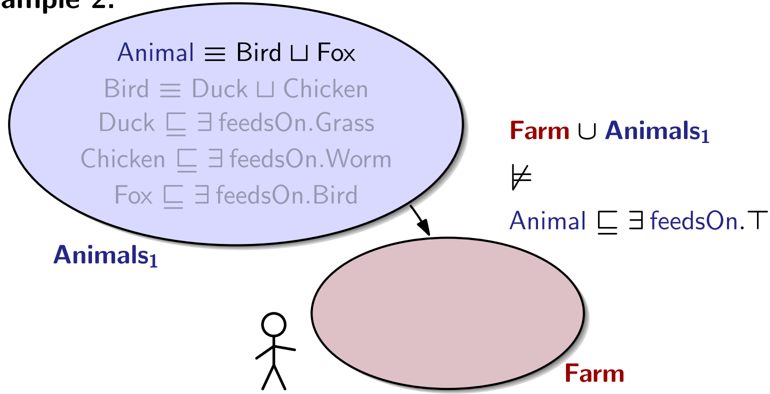

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$\textbf{Farm} \cup \textbf{Animals}_1$

$\not\models$

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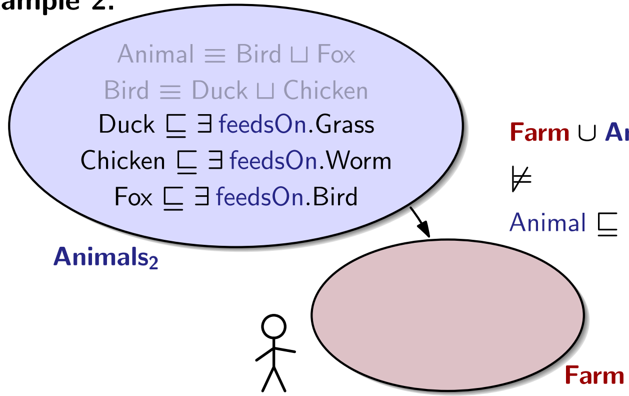

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$$\mathbf{Farm} \cup \mathbf{Animals_2}$$
$$\not\models$$
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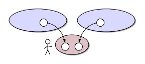

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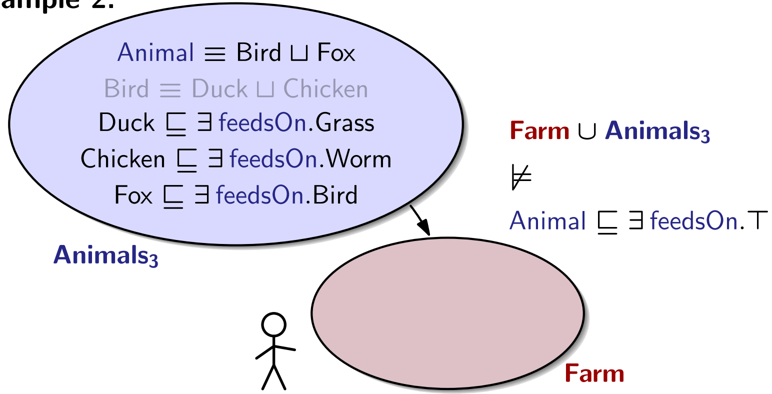

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Animals$_3$

Farm $\cup$ **Animals$_3$**

$\not\models$

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Farm

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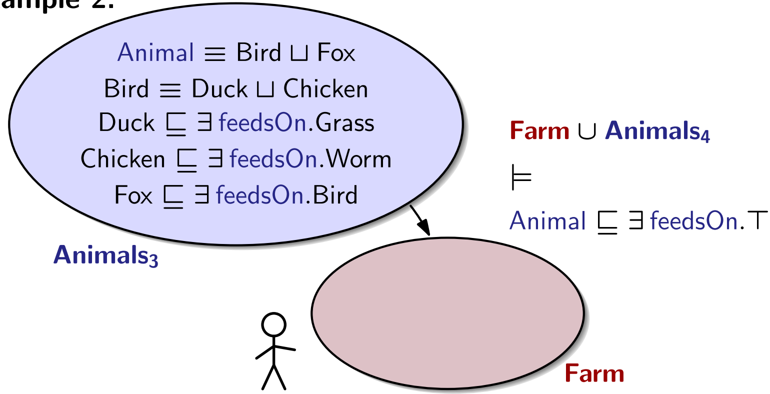

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Animals$_3$

Farm $\cup$ **Animals$_4$**

$\models$

$\mathsf{Animal} \sqsubseteq \exists\, \mathsf{feedsOn}.\top$

Farm

Module coverage

- The module $\mathcal{E}'$ covers the ontology $\mathcal{E}$ for the specified topic $\mathcal{T}$ if for all classes A, B built from terms in $\mathcal{T}$:

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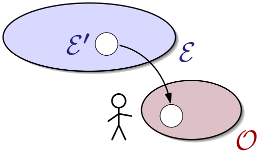

- Coverage $\hat{=}$ preserving entailments

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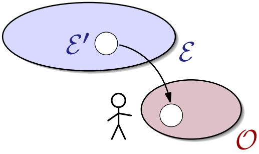
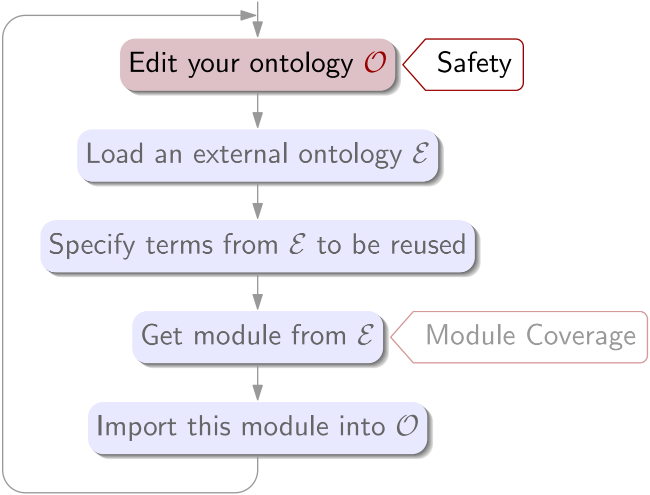


- Coverage $\hat{=}$ preserving entailments

- No coverage $\rightsquigarrow$ no encapsulation $\rightsquigarrow$ no *module*
- With coverage: trade-off minimality ↔ computation time

A working cycle



Edit your ontology $\mathcal{O}$

Safety

Load an external ontology $\mathcal{E}$

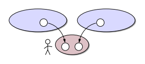
Specify terms from $\mathcal{E}$ to be reused

Get module from $\mathcal{E}$

Module Coverage

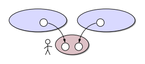
Import this module into $\mathcal{O}$

Safety



Goal:	Don't change the meaning of imported terms. = Don't add new knowledge about the imported topic.
Question:	Which axioms are we allowed to write?

Safety



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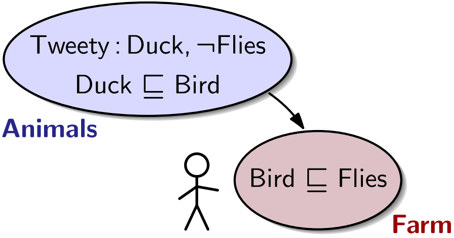

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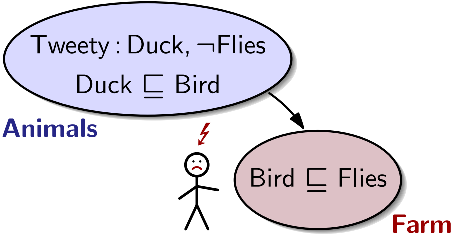

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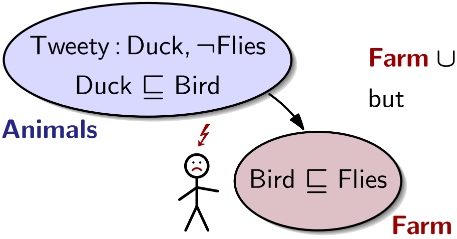
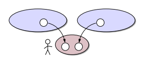


Farm ∪ **Animals** $\models$ Bird ⊑ Flies

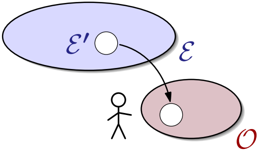
but **Animals** $\not\models$ Bird ⊑ Flies

Safety



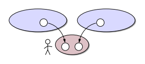
- *Our* ontology $\mathcal{O}$ uses the imported terms safely if for all classes A, B built from the imported terms:

$$\begin{array}{lrcl} \text{If} & \mathcal{E}' & \not\models & \mathsf{A} \sqsubseteq \mathsf{B}, \\ \text{then} & \mathcal{O} \cup \mathcal{E}' & \not\models & \mathsf{A} \sqsubseteq \mathsf{B}, \end{array}$$



- Safety $\hat{=}$ preserving non-entailments

And now . . .



1. Why modularity?
2. A reuse scenario
3. Logical background
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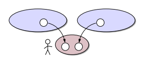
Module coverage



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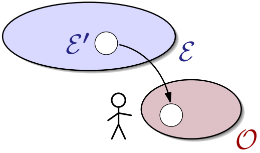

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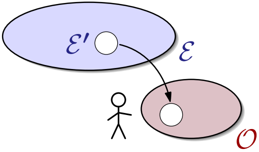

- Coverage $\hat{=}$ preserving entailments

- $\mathcal{O}$ may allow "more" interpretations of imported terms than $\mathcal{E}$.
- If so, include more "restricting" axioms into $\mathcal{E}'$.
- Finish when all terms $\notin \mathcal{E}'$ can be interpreted as $\bot$ or $\top$.
- *Locality* says whether this is possible.

Notions of covering modules

- Minimal coverage-providing modules

  based on conservative extensions
  hard to compute (intractable/undecidable)

- Locality-based modules

  based on the above considerations
  not minimal, hard to compute

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While there is non-local axiom $\alpha$ w.r.t. $\underbrace{\mathcal{T} \cup \mathrm{sig}(M)}_{\textit{extended topic}}$ do:
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- We often extract the $\top$-module of the $\bot$-module of $\mathcal{E}$.

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Module extraction in Protégé 4

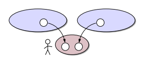
Nightly build:

http://owl.cs.manchester.ac.uk/2008/iswc-modtut/equinox.zip

- Realises import scenario
- Provides coverage via locality-based modules
- Will soon provide safety too . . .
- To be released as Protégé 4 plugin in the near future

(Thanks to Matthew Horridge.)

Web-based module extraction



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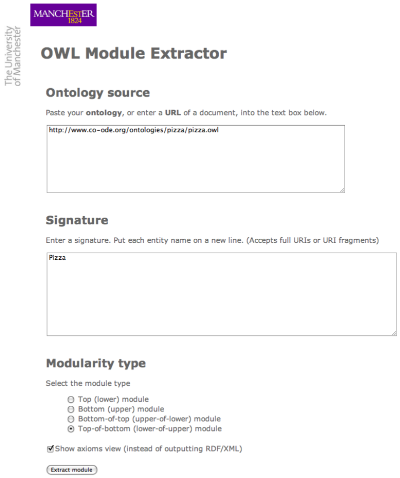


OWL Module Extractor

Ontology source

Paste your **ontology**, or enter a **URL** of a document, into the text box below.

http://www.co-ode.org/ontologies/pizza/pizza.owl

Signature

Enter a signature. Put each entity name on a new line. (Accepts full URIs or URI fragments)

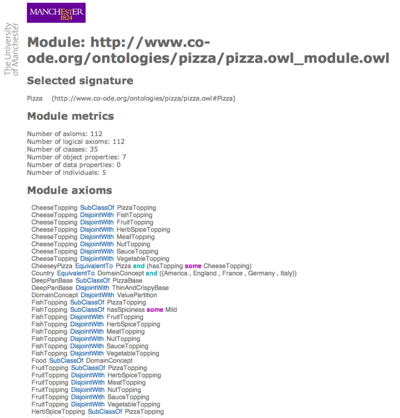
Pizza

Modularity type

Select the module type

- ○ Top (lower) module
- ○ Bottom (upper) module
- ○ Bottom-of-top (upper-of-lower) module
- ● Top-of-bottom (lower-of-upper) module

☑ Show axioms view (instead of outputting RDF/XML)



Module: http://www.co-ode.org/ontologies/pizza/pizza.owl_module.owl

Selected signature

Pizza (http://www.co-ode.org/ontologies/pizza/pizza.owl#Pizza)

Module metrics

Number of axioms: 112
Number of logical axioms: 112
Number of classes: 35
Number of object properties: 7
Number of data properties: 0
Number of individuals: 5

Module axioms

CheeseTopping SubClassOf PizzaTopping
CheeseTopping DisjointWith FishTopping
CheeseTopping DisjointWith FruitTopping
CheeseTopping DisjointWith HerbSpiceTopping
CheeseTopping DisjointWith MeatTopping
CheeseTopping DisjointWith NutTopping
CheeseTopping DisjointWith SauceTopping
CheeseTopping DisjointWith VegetableTopping
CheeseyPizza EquivalentTo Pizza **and** (hasTopping **some** CheeseTopping)
Country EquivalentTo DomainConcept **and** ({America , England , France , Germany , Italy})
DeepPanBase SubClassOf PizzaBase
DeepPanBase DisjointWith ThinAndCrispyBase
DomainConcept DisjointWith ValuePartition
FishTopping SubClassOf PizzaTopping
FishTopping SubClassOf hasSpiciness **some** Mild
FishTopping DisjointWith FruitTopping
FishTopping DisjointWith HerbSpiceTopping
FishTopping DisjointWith MeatTopping
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Food SubClassOf DomainConcept
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Try it! ☺

- Ontology: http://www.co-ode.org/ontologies/pizza/pizza.owl
- Signature “Pizza”, “VegetarianPizza”, or “Country”
- Select “Show axioms view”

(Thanks to Matthew Horridge.)

This tool currently ignores non-logical axioms (annotations etc.).

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Kind of "module"	Covrg.	Min.	Covered DLs	Complexity
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interpolants-based (no subsets!)	✓	✓✓	few	hard

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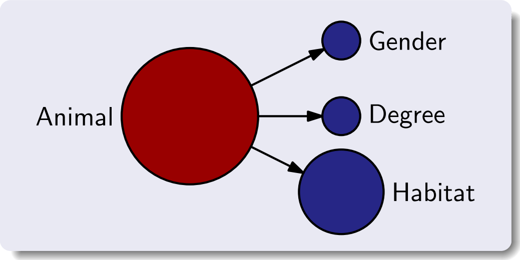
We bet Robert . . .

- Ontology about periodic table of the chemical elements
- What is “the meat” of it?
- We can find it using locality-based modules.

Impetus for the “Meat” idea

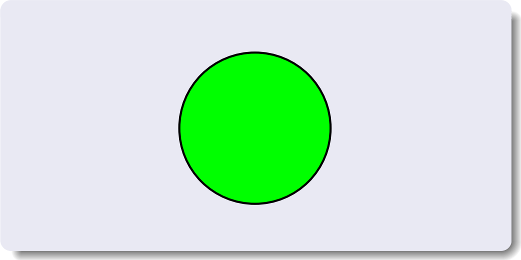
Partition of koala.owl via E-connections in Swoop



- 🔴 importing part
- 🔵 imported but non-importing part
- 🟢 isolated part

→ “imports vocabulary from”

Partition for the periodic table ontology



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- Struggle with visualisation
- Blowup-free methodology for bigger modules?
- What does the collection of *all* modules tell us?
- Modules for topics of axioms?