Non-standard DL Reasoning: Modularisation and Debugging

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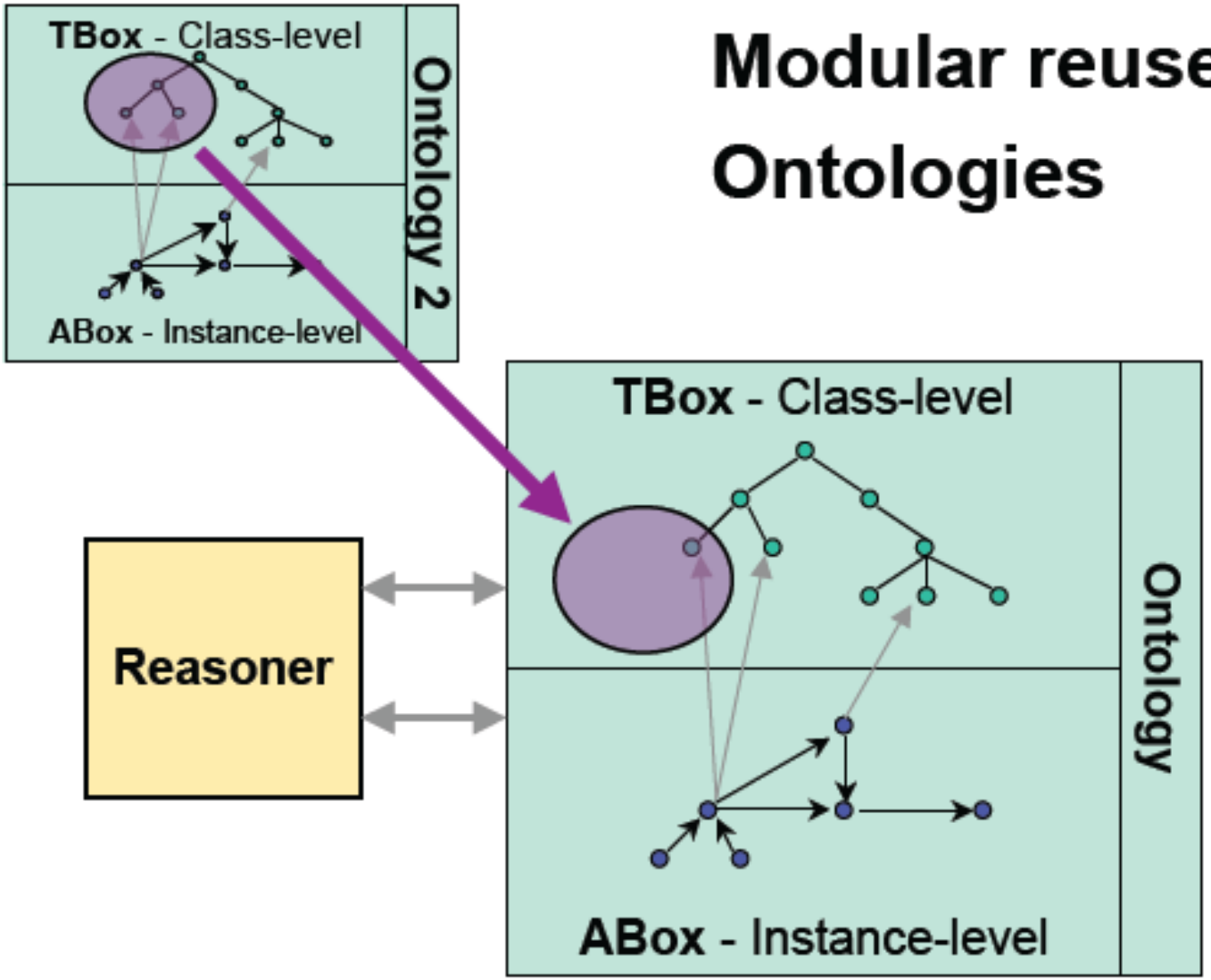
Contents

- Modularisation
  - Scenarios for modularisation
  - Modularisation for import/reuse
    - Scenario and a working cycle
    - Properties of the modularisation algorithms
      - Module coverage
      - Safety
  - Modularisation in OWL with Protégé
- Debugging
  - Root and derived unsatisfiable classes
  - Laconic and precise justifications
  - Debugging in OWL with Protégé

Scenarios for Modularisation. Motivation

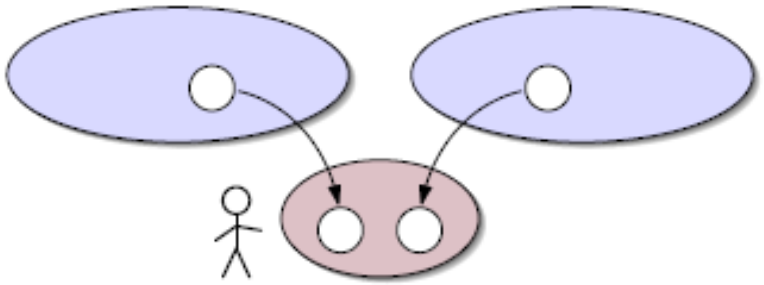


Reasons for modularisation

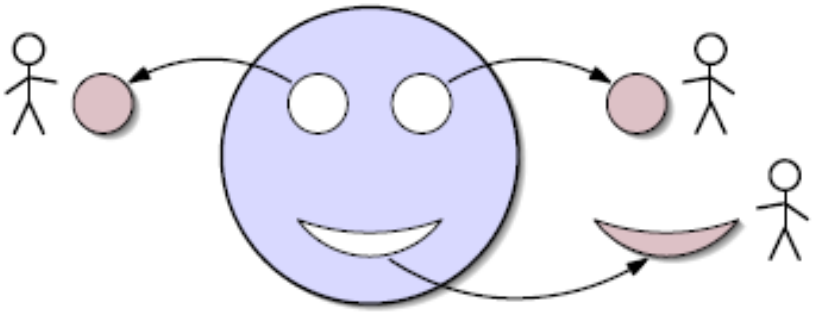
- Common practice in software engineering
  - Modular software development allows for:
    - Importing/reusing modules
    - Collaborative development
    - Understanding the code form the interaction between modules

- Common practice in knowledge engineering
  - Borrow terms from other DL knowledge bases
  - Cover topics that we aren't experts in
  - Enable collaborative development
  - To ensure common understanding
  - To gain insight into its structure & dependencies

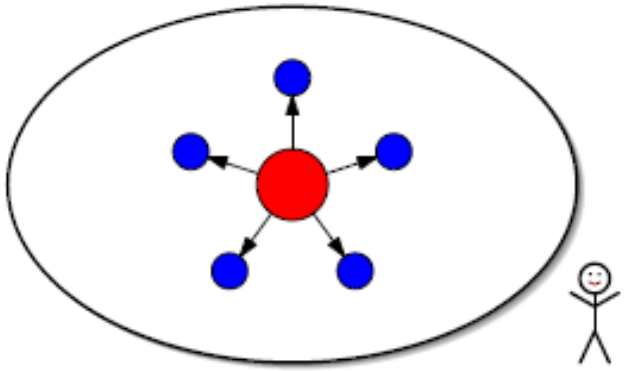
Scenarios for modularisation



Import/reuse



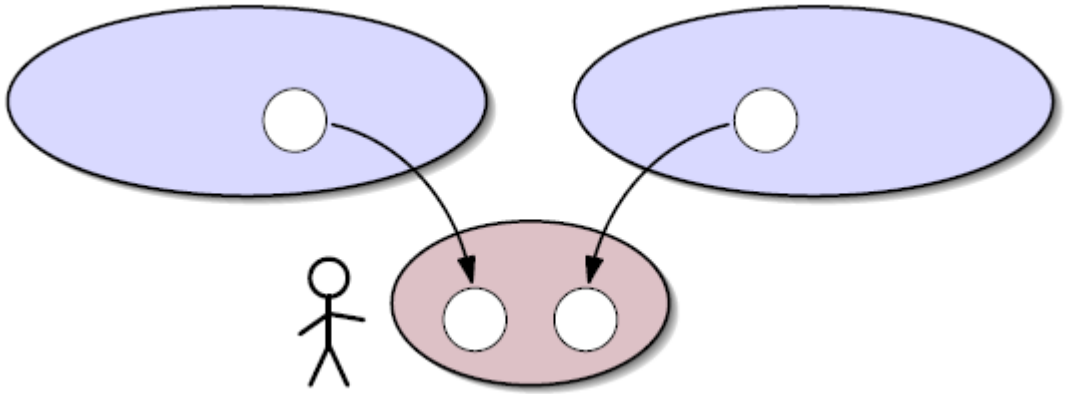
Collaboration



Understanding

Scenario 1. Import/Reuse

- “Borrow” knowledge about certain terms from external DL knowledge bases

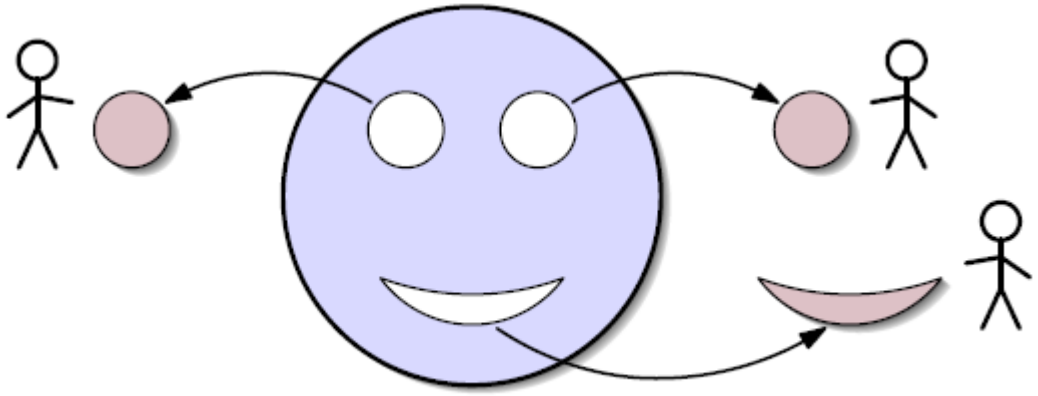


  - Provides access to well-established knowledge
  - Doesn’t require expertise in external disciplines

- This scenario is well-understood and implemented.

Scenario 2. Collaboration

- Collective knowledge base development

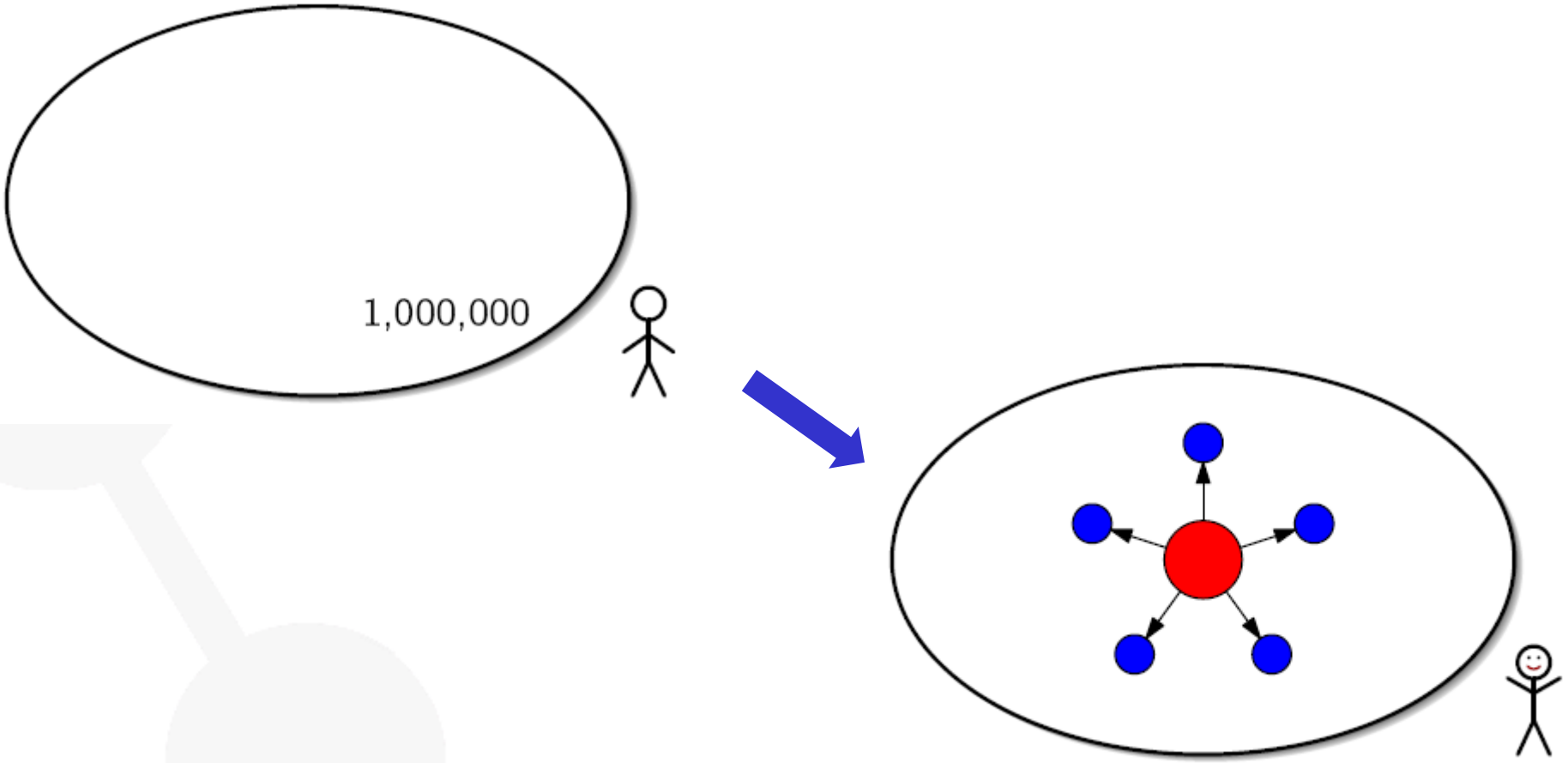


  - Developers work (edit, classify) locally
  - Extra care at re-combination
  - Prescriptive/analytic behaviour

- This approach is understood, but not implemented yet.

Scenario 3. Understanding

- Visualise the modular structure of a DL knowledge base



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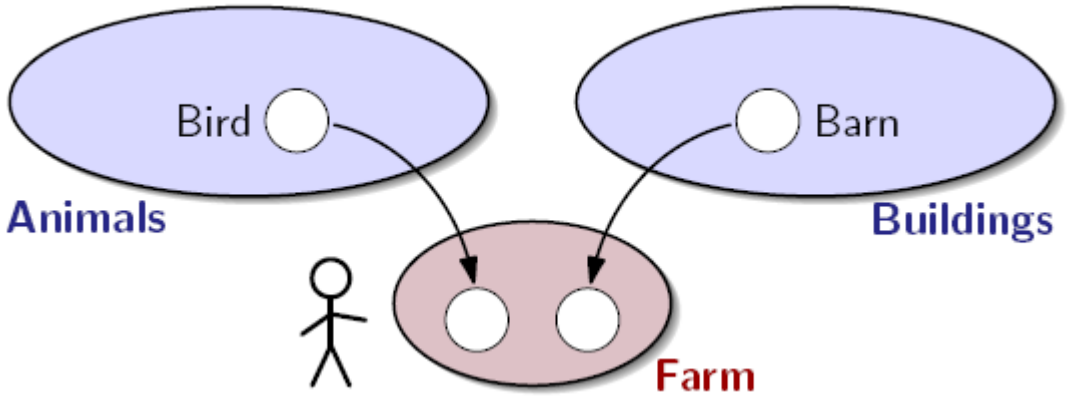
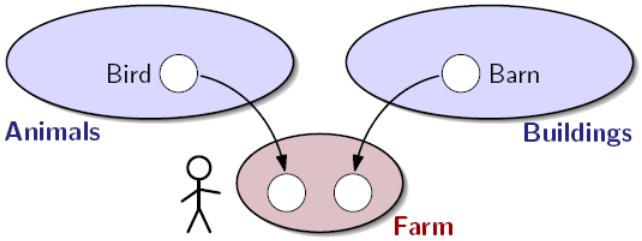
Scenario and main factors to be considered

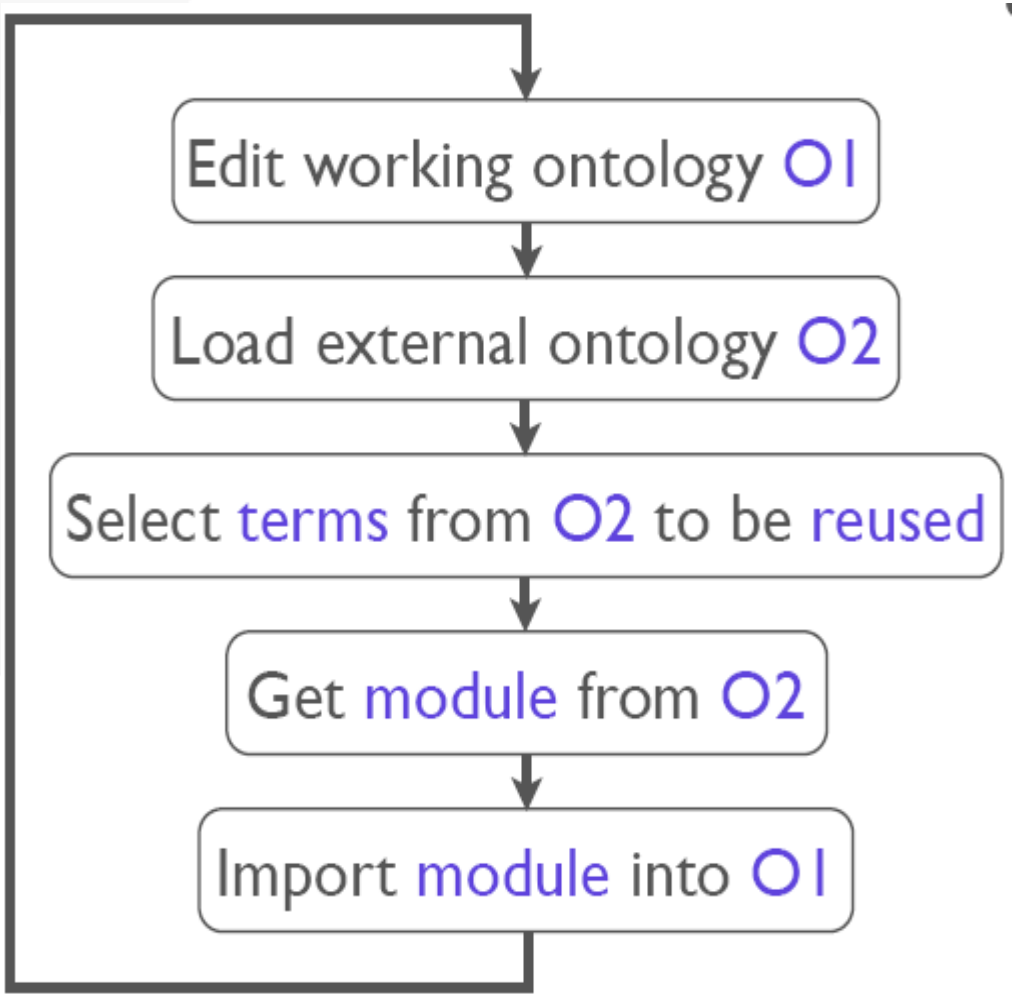
- Import/reuse a part of external knowledge bases



- How much of Animals and Buildings do we need?
  - **Coverage**: Import everything relevant for the chosen terms.
  - **Economy**: Import only what's relevant for them.

Working cycle





Farm

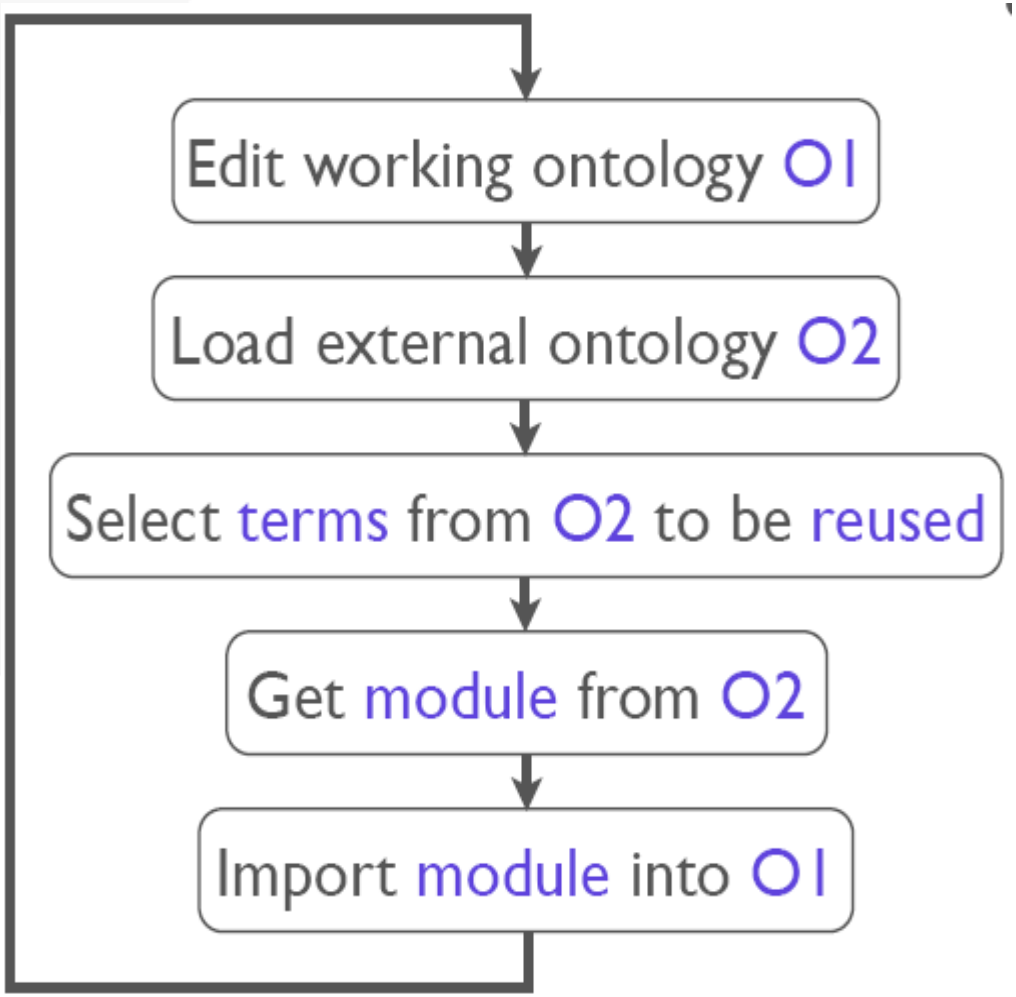
Animals

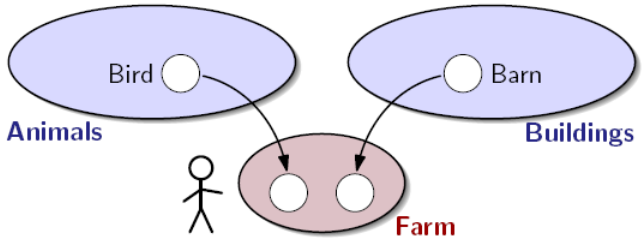
Animal, feedsOn

Animals'

Farm U Animals'

Working cycle





Farm U Animals'

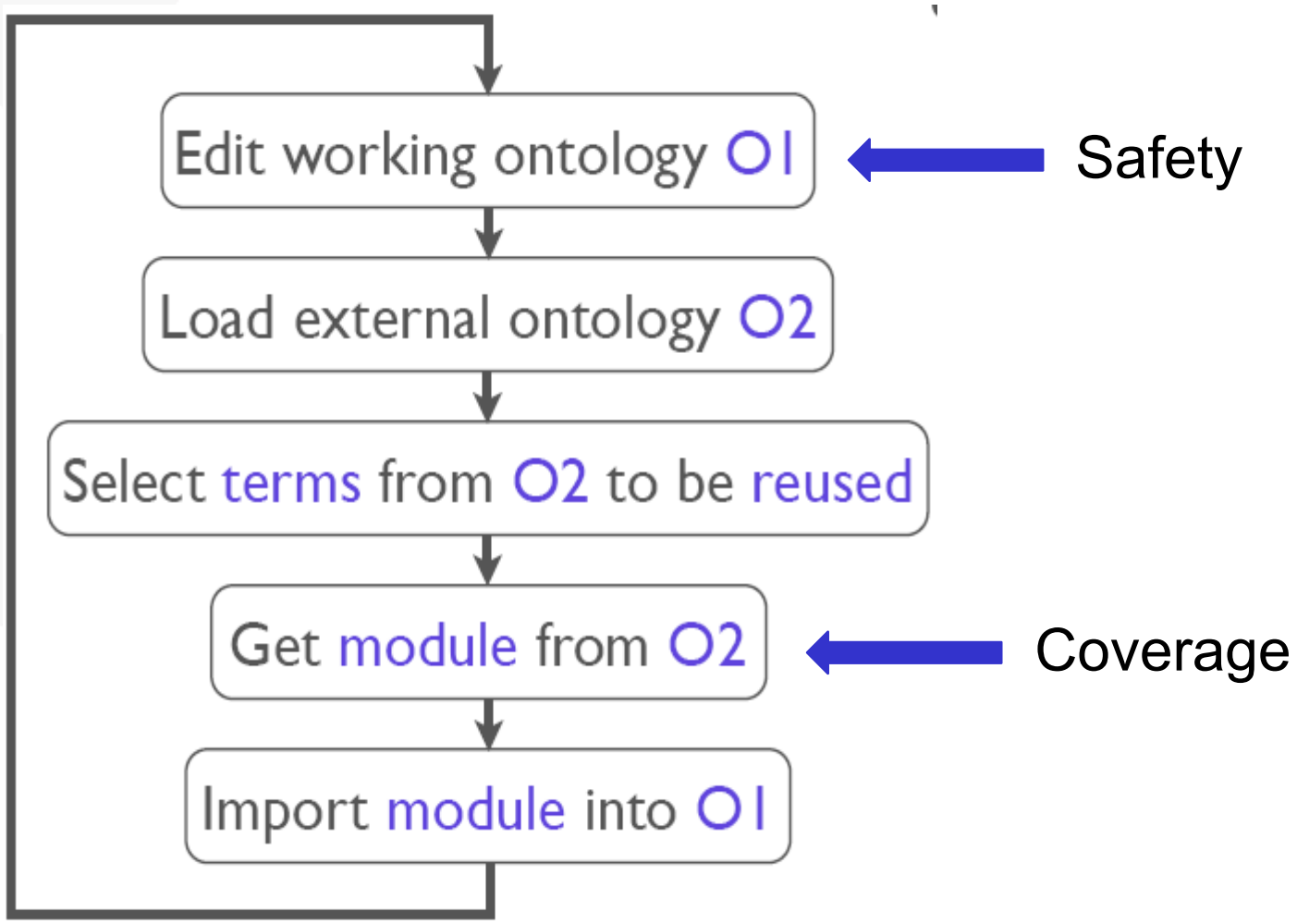
Buildings

DuckHousing, Silo

Buildings'

Farm U Animals' U Buildings'

Coverage and Safety



Coverage

- **Goal**: Import everything the external knowledge base knows about the topic that consists of the specified terms.
- **Question**: Which DL axioms do we need to import?

Topic: Fox, Bird, feedsOn

On-topic:

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

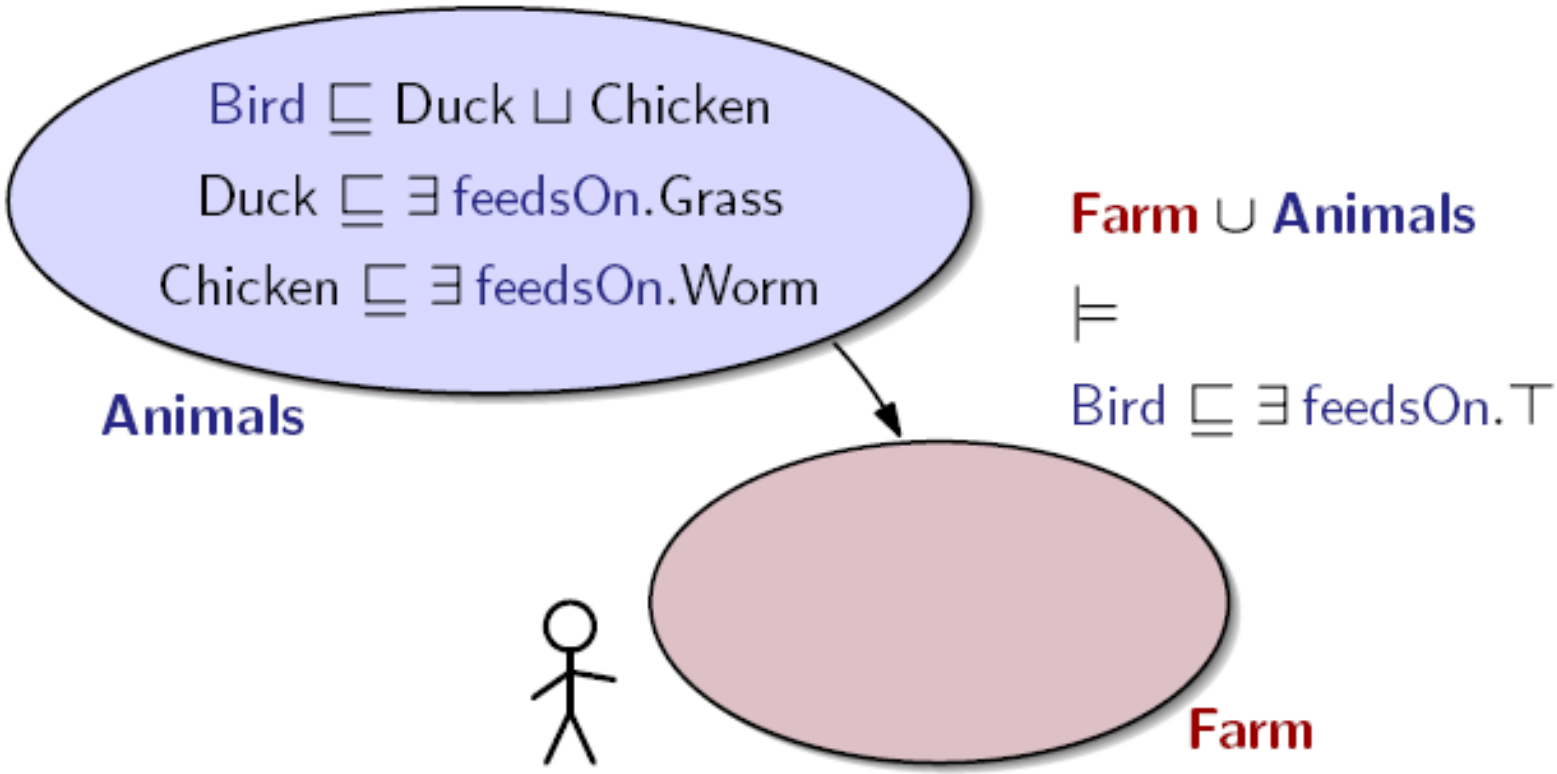
Off-topic:

$$\text{Duck} \sqsubseteq \text{Bird}$$

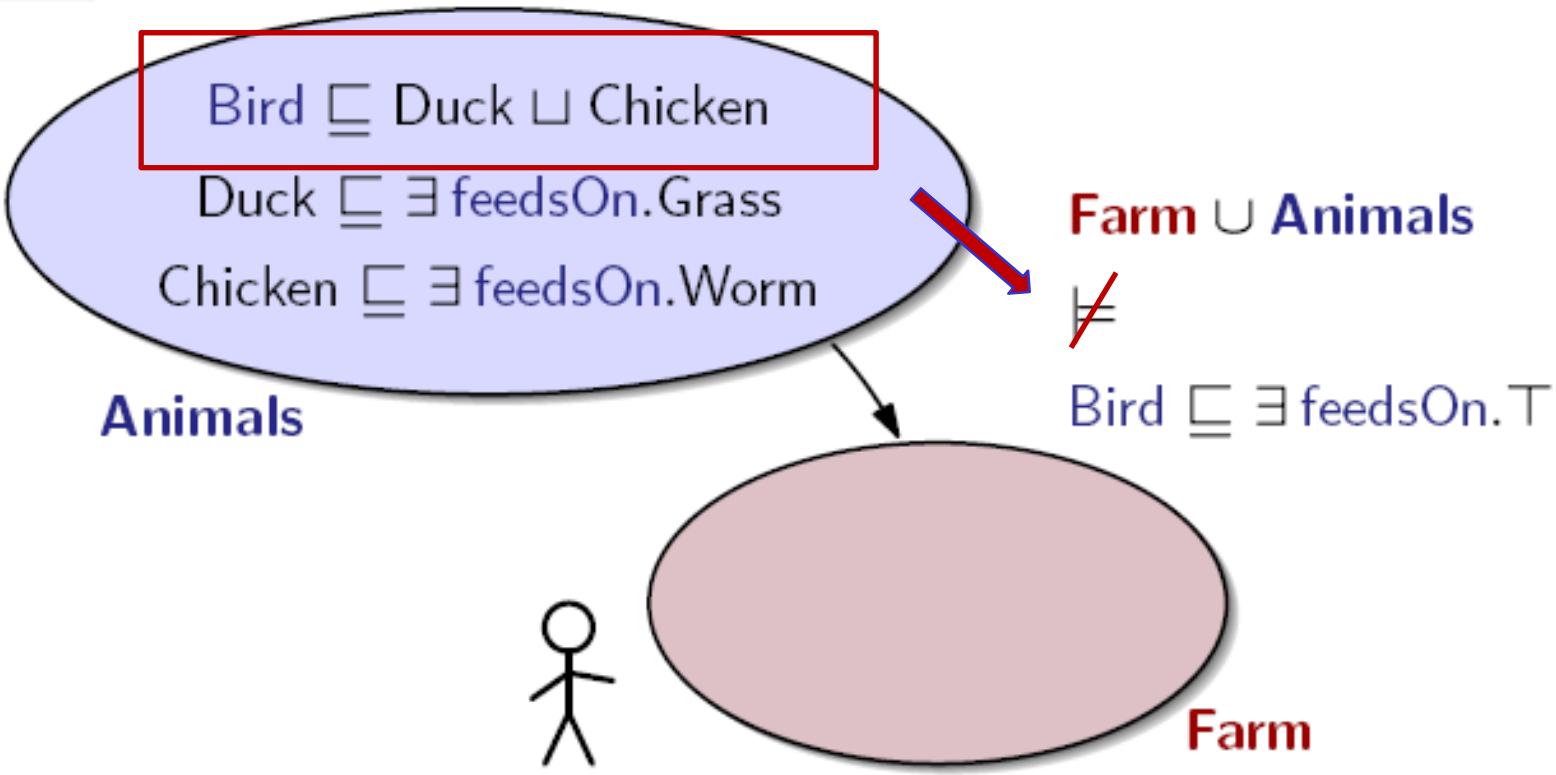
Goal = preserve all on-topic knowledge

Coverage. Example

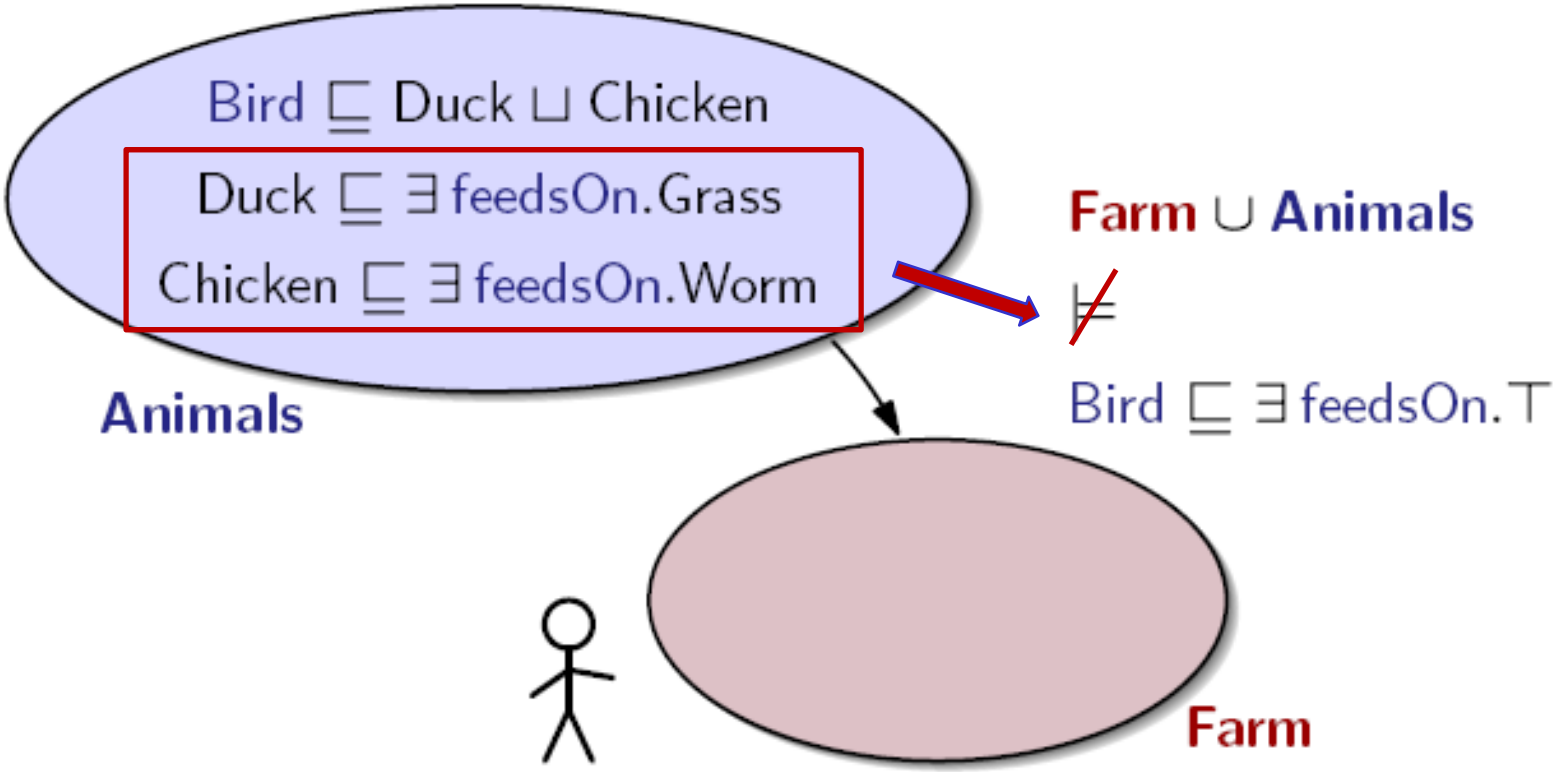
- Let's imagine that we want to import the Animals KB, which contains three axioms, and we want to derive that a bird has to eat something.



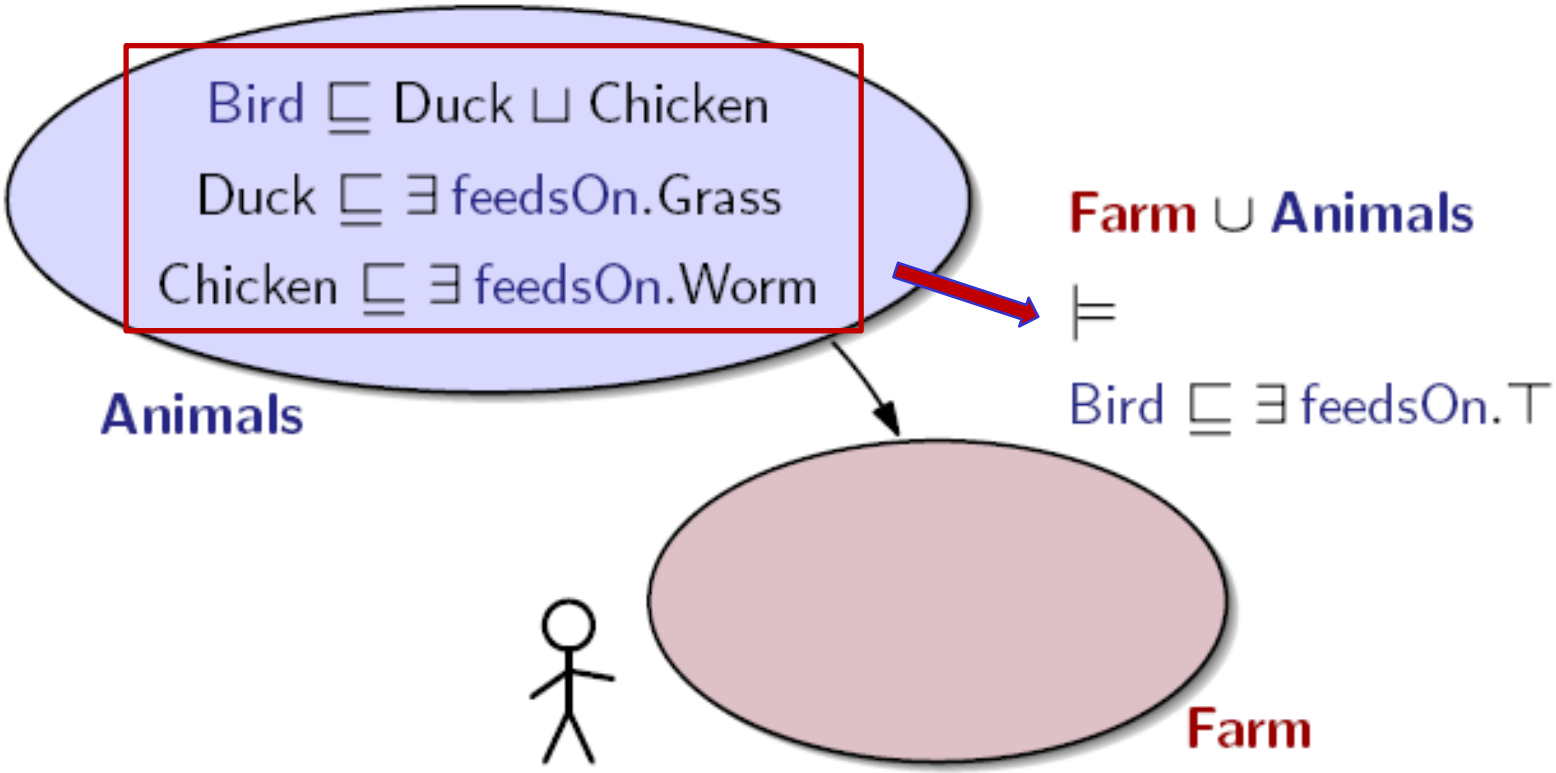
Coverage. Example



Coverage. Example



Coverage. Example

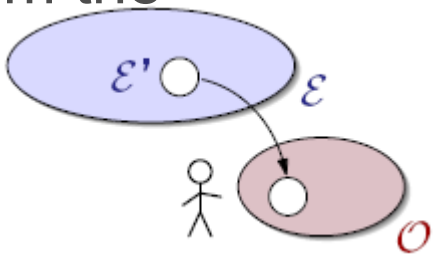


Coverage. Formal definition and algorithm

- The module Ɛ’ covers the knowledge base Ɛ for the specified topic if for all classes A, B built from the specified terms:

  if $O \cup \mathcal{E} \models A \subseteq B$,

  then $O \cup \mathcal{E}' \models A \subseteq B$.



- Coverage = preserving entailments (that is, no difference between using Ɛ or Ɛ’)
  - In general, undecidable
- Use a syntactic approximation
  - Fast!
  - Modules are not minimal in size, but guarantee coverage

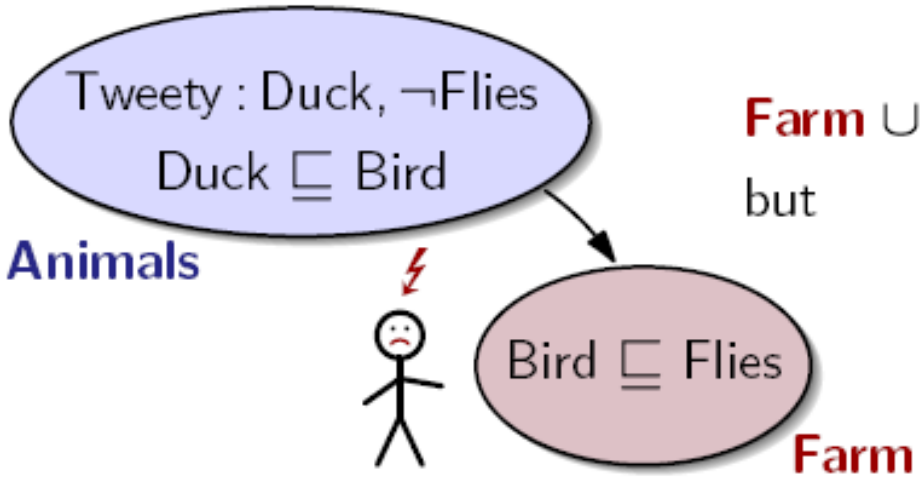
$T \leftarrow$ topic; $M \leftarrow \emptyset$

While there is non-local axiom α w.r.t. $\underbrace{T \cup \mathrm{sig}(M)}_{\textit{extended topic}}$ do:

$M \leftarrow M \cup \{\alpha\}$

Safety

- **Goal**: Don't change the meaning of imported terms.
  - That is, don't add new knowledge about the imported topic.
  - e.g., because you are not an expert in this topic
- **Question**: Which axioms are we allowed to write?



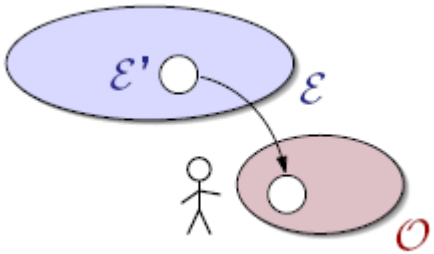
$\mathbf{Farm} \cup \mathbf{Animals} \models \mathrm{Bird} \sqsubseteq \mathrm{Flies}$

but $\mathbf{Animals} \not\models \mathrm{Bird} \sqsubseteq \mathrm{Flies}$

- Our knowledge base O uses the imported terms safely if for all classes A, B built from the imported terms:

  If $\mathcal{E}' \not\models A \subseteq B$,

  then $O \cup \mathcal{E}' \not\models A \subseteq B$



- Safety = preserving non-entailments

- Safety is also provided by locality (= sufficient condition).

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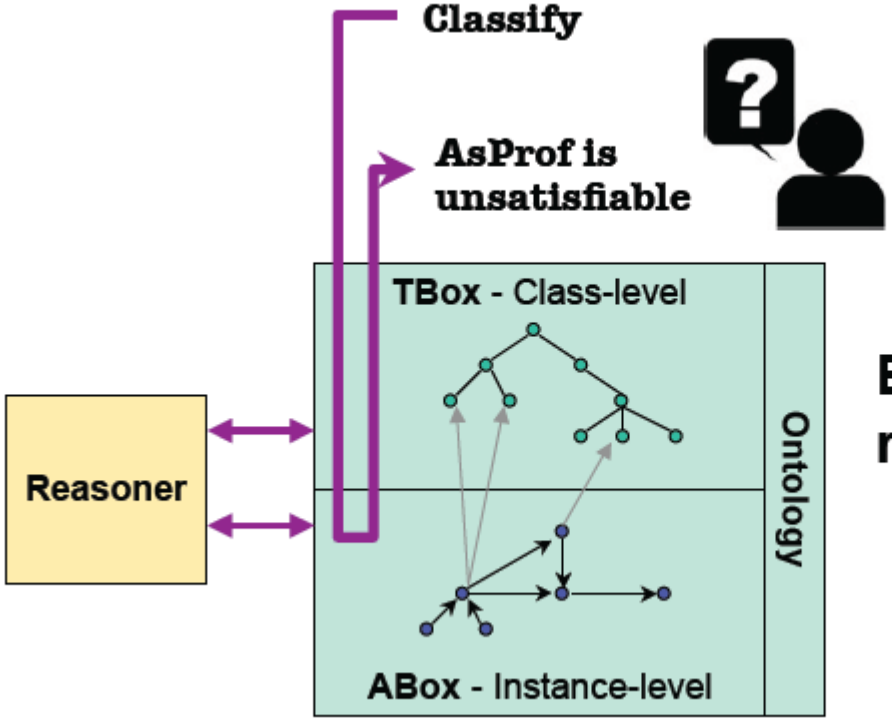


Explanation of reasoning

Root Unsatisfiable Classes

- How do we know which unsatisfiable classes to focus on?
- Example: the TAMBIS ontology contains **144** unsatisfiable classes

- How do we know where to start?
  - The satisfiability of one class may depend on the satisfiability of another class
  - The tools show unsatisfiable class names in red

Root Unsatisfiable Classes

- A class whose satisfiability depends on another class is known as a derived unsatisfiable class
- An unsatisfiable class that is not a derived unsatisfiable class is a root unsatisfiable class
- Root unsatisfiable classes should be examined and fixed first

Justifications

- Justifications are a kind of explanation
  - Justifications are minimal subsets of an ontology that are sufficient for a given entailment to hold
  - Also known as MUPS (Minimal Unsatisfiability-Preserving Sub-TBox), MinAs

$$\mathcal{O} = \{\alpha_1, \alpha_2 \ldots \alpha_n\} \qquad \mathcal{O} \models \eta$$

$$J \subseteq \mathcal{O} \qquad J \models \eta$$

$$\forall J' \subset J \qquad J' \not\models \eta$$

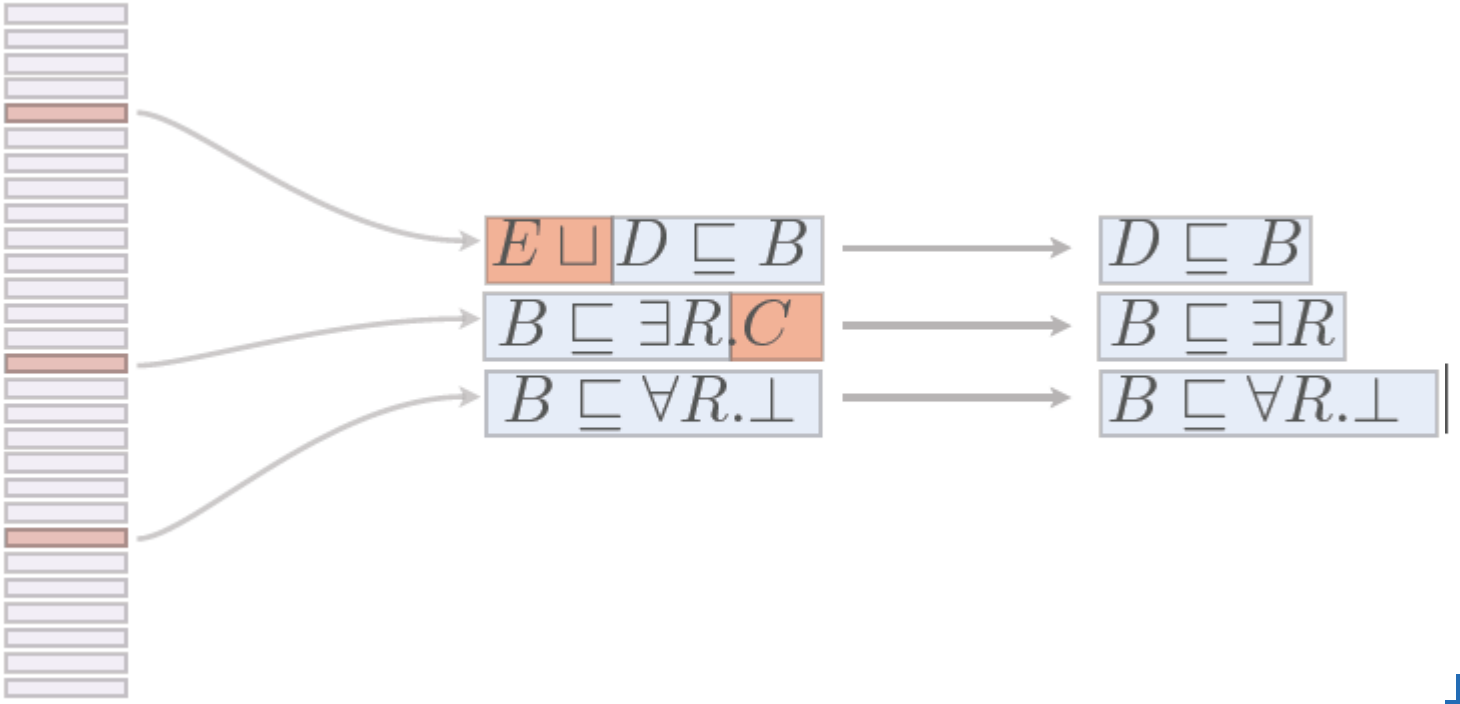
Justifications and root unsatisfiable classes

- There may be multiple justifications for an entailment
- For a given entailment, if there are multiple justifications they may overlap
- Removing one axiom from each justification breaks the justifications so that the entailment is no longer supported by the remaining axioms.

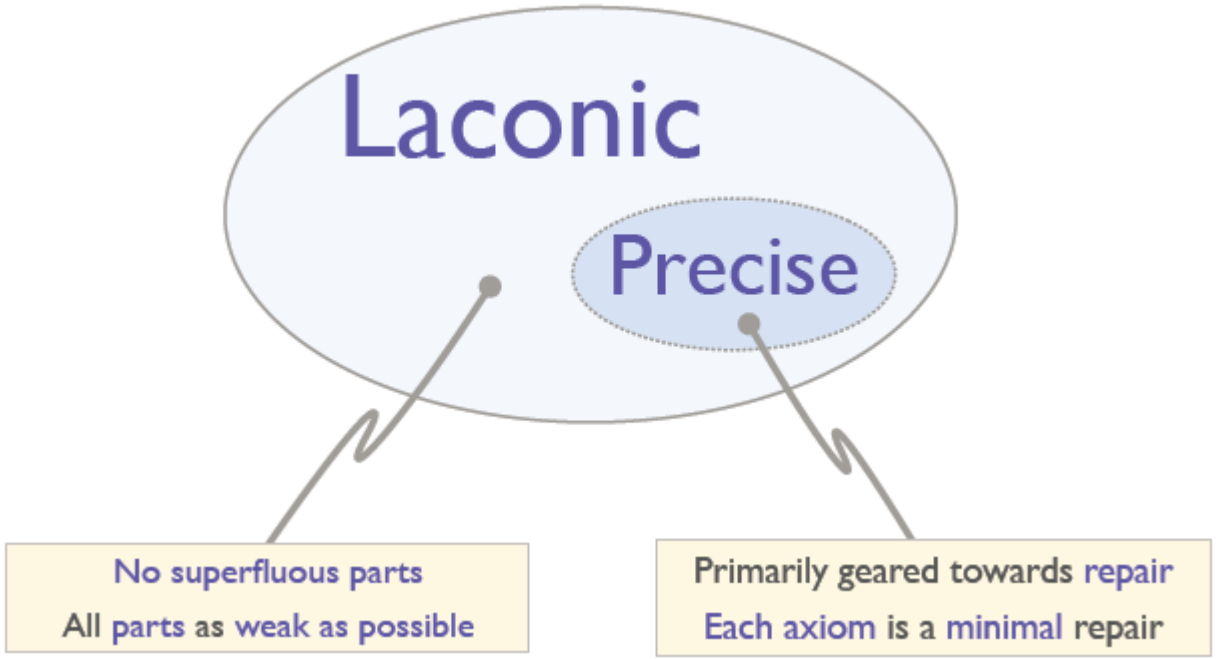
- A class is a **derived unsatisfiable class** if it has a justification that is a superset of a justification for some other unsatisfiable class.
- An unsatisfiable class that is not derived is a **root unsatisfiable class**, i.e., none of its justifications contains a justification of another unsatisfiable class.

Protégé approach to finding justifications

- Black box approach (expand-contract strategy)
  - Create an empty ontology
  - Expand until expression is unsatisfiable
  - Prune until the expression is satisfiable
  - Several optimisations, including the use of modularity
  - Aiming at removing superflous axioms



Regular, Laconic and Precise Justifications



$$\mathcal{O} = \{ A \sqsubseteq D \sqcap = 1R.C \sqcap B$$
$$D \sqsubseteq \forall R.C \sqcap F$$
$$E \equiv \exists R.C \sqcap \forall R.C \} \models A \sqsubseteq E$$

$$A \sqsubseteq D \sqcap \geq 1R$$
$$D \sqsubseteq \forall R.C$$
$$\exists R.C \sqcap \forall R.C \sqsubseteq E$$

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