Debugging is-a structure in ontologies

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Defects in ontologies

- Syntactic defects
  - eg. wrong tags or incorrect format
- Semantic defects
  - eg. unsatisfiable concepts, incoherent and inconsistent ontologies
- Modeling defects
  - eg. wrong or missing relations

Example - incoherent ontology

- Example: DICE ontology
  - Brain $\sqsubseteq$ CentralNervousSystem $\sqcap$ BodyPart $\sqcap$ $\exists$systempart.NervousSystem $\sqcap$ $\exists$ region.HeadAndNeck $\sqcap$ $\forall$region.HeadAndNeck

A brain is a central nervous system and a body part which has a system part that is a nervous system and that is in the head and neck region.

  - CentralNervousSystem $\sqsubseteq$ NervousSystem

A central nervous system is a nervous system.

  - BodyPart $\sqsubseteq\neg$NervousSystem

Nothing can be at the same time a body part and a nervous system.

Slide from G. Qi

Example - missing is-a relations

- In 2008 Ontology Alignment Evaluation Initiative (OAEI) Anatomy track, task 4
  - Ontology MA : Adult Mouse Anatomy Dictionary (2744 concepts)
  - Ontology NCI-A : NCI Thesaurus - anatomy (3304 concepts)
  - 988 mappings between MA and NCI-A
    - 121 missing is-a relations in MA
    - 83 missing is-a relations in NCI-A

Influence of missing structure

- Ontology-based querying.

Medical Subject Headings (MeSH)

All MeSH Categories
- **Diseases Category**
  - **Eye Diseases**
    - **Scleral Diseases**
      - **Scleritis**

...

return 1363 articles

Influence of missing structure

- Incomplete results from ontology-based queries

Medical Subject Headings (MeSH)

All MeSH Categories
- **Diseases Category**
  - **Eye Diseases**
    - **Scleral Diseases**
      - ~~**Scleritis**~~

...

return 1363 articles

return 613 articles

55% results are missed !

Defects in ontologies

- Ontologies with defects, although often useful, also lead to problems when used in semantically-enabled applications.

→ Wrong conclusions may be derived or valid conclusions may be missed.

Debugging the missing and wrong is-a structure of taxonomies

Outline

- Definitions
- Approach
- Experiments
- Conclusion

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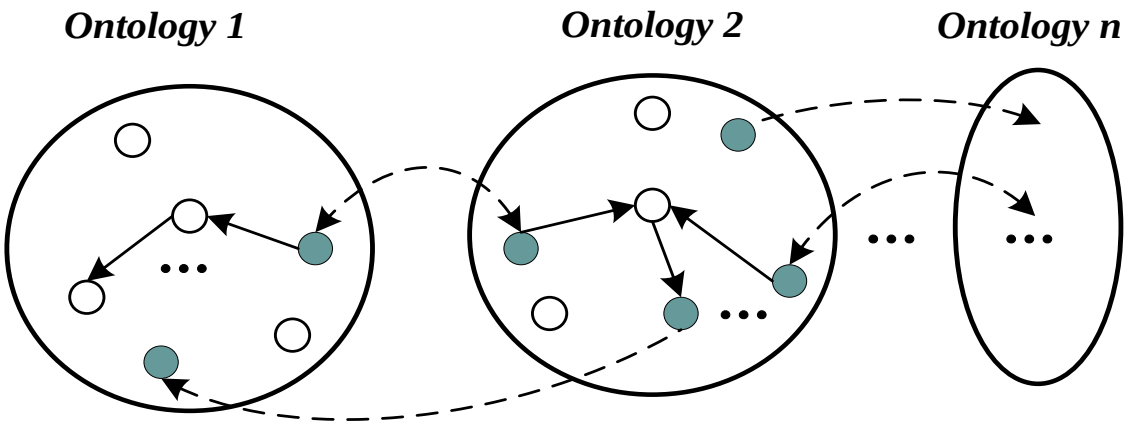
Taxonomy networks

A **taxonomy network** consists of a set of **taxonomies** and sets of **mappings** between these taxonomies.

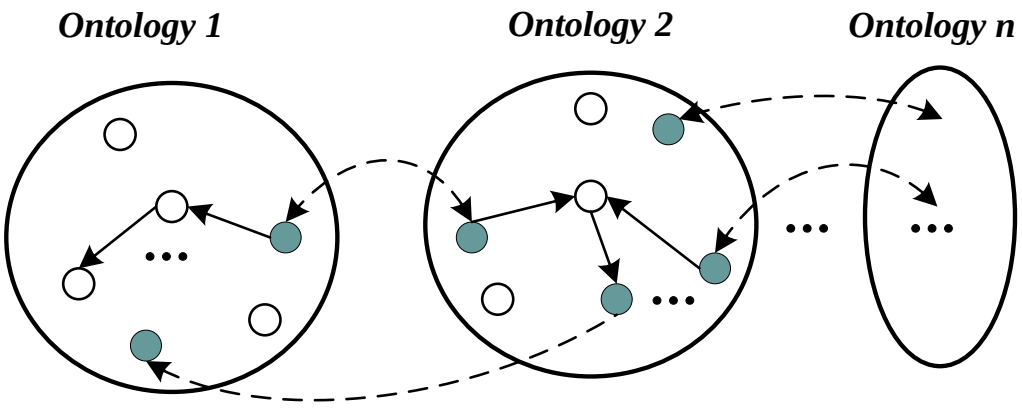


Defects in ontologies

- Syntactic defects
  - eg. wrong tags or incorrect format
- Semantic defects
  - eg. unsatisfiable concepts or inconsistent ontologies
- **Modeling defects**
  - **eg. wrong or missing relations**

  → Solution requires domain knowledge.

Assumptions and scope



- We focus on **taxonomies**,

  → *named concepts* and *is-a relations*.

- We assume that all **the existing mappings** in the taxonomy network are **correct**.

- The mappings represent equivalence and subsumption.

Debugging is-a structure in taxonomy networks

Given a set of taxonomies networked by sets of **correct** mappings, how to **detect and repair the missing and wrong is-a relations in these networked taxonomies**?

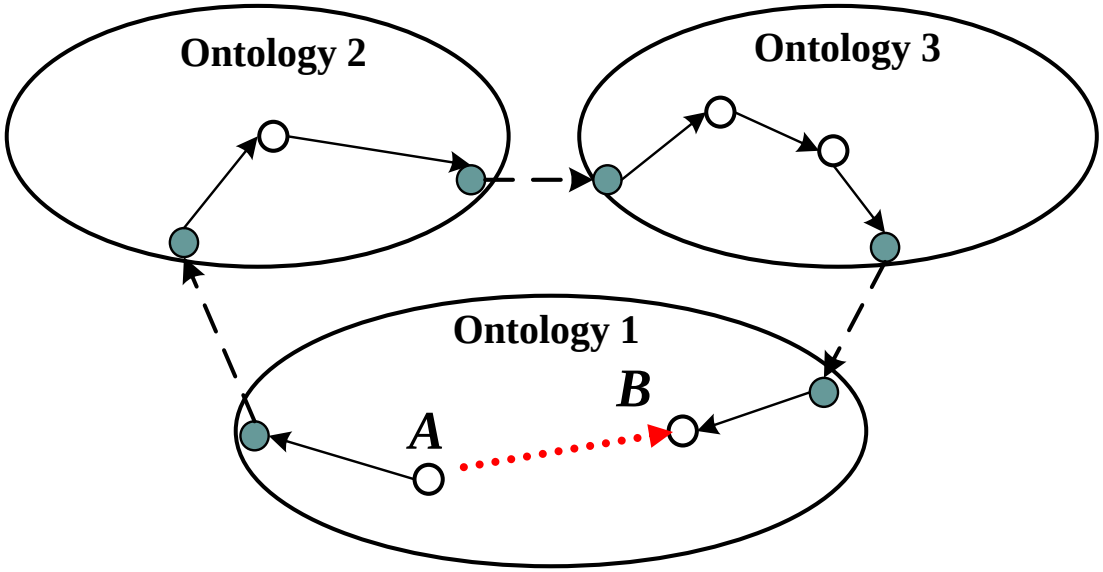
Detecting missing is-a relations

- Domain expert – manual inspection
- Using external knowledge
  - Ontology learning
  - Discovery of subsumption relations (Hearst patterns, logical patterns)
- Using knowledge intrinsic to the network

Candidate missing is-a relations

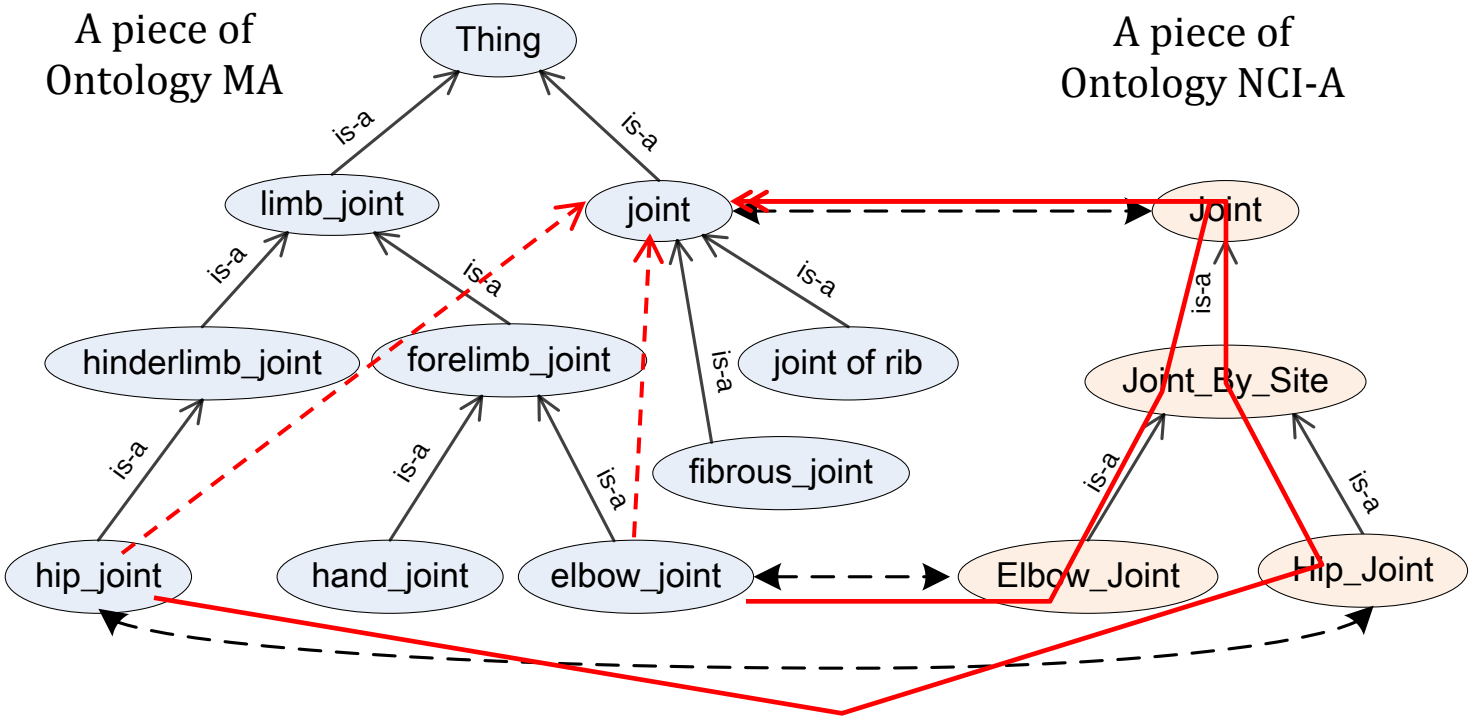
Given two concepts A and B in a taxonomy O in the network. If "A is-a B" is **logically derivable from the taxonomy network,** but **not from the taxonomy O alone**, then "A is-a B" is a **candidate missing is-a relation.**

The candidate missing is-a relations need to be validated by a domain expert → **wrong and missing is-a relations**



Candidate missing is-a relations

- Two small pieces of MA and NCI-A, both about concept "joint", and 3 equivalence mappings.



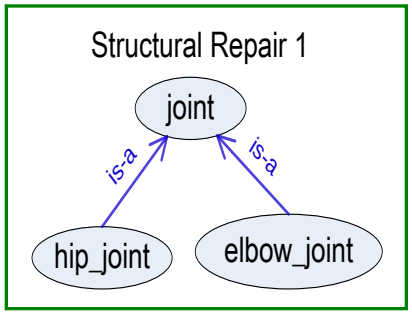
Repairing is-a relations

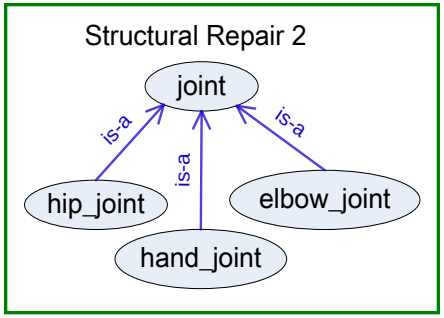
Repair the original taxonomies by

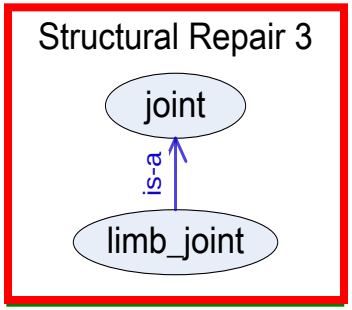
- adding a set of is-a relations to each taxonomy, such that the missing is-a relations can be derived from the extended taxonomy;
- removing a set of is-a relations from the taxonomies, such that the wrong is-a relations cannot be derived from the network

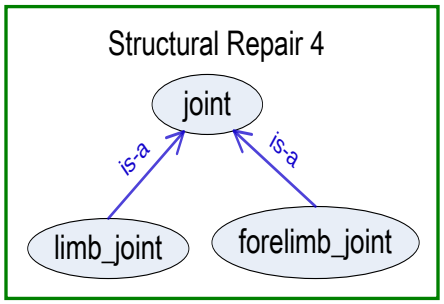
- Structural repair:
  - The is-a relations within the structural repair are called ’repairing actions’.

Repairing missing is-a relations





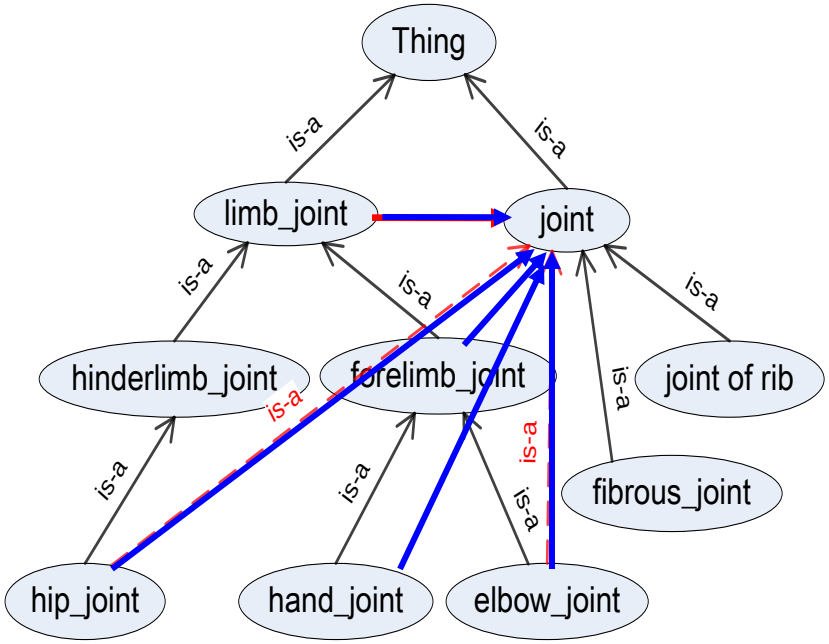




Question:

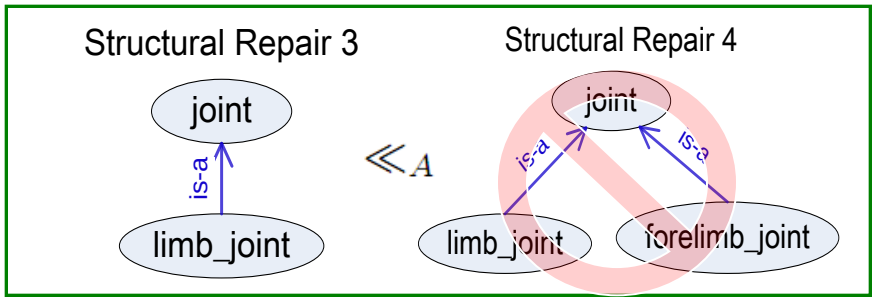
How can we recognize structural repairs that are interesting for a domain expert?

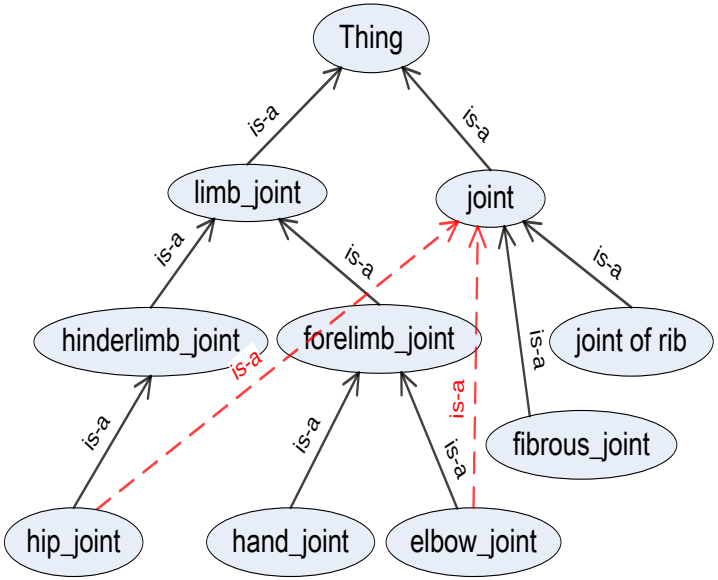
→ heuristics.



Axiom-based Heuristic

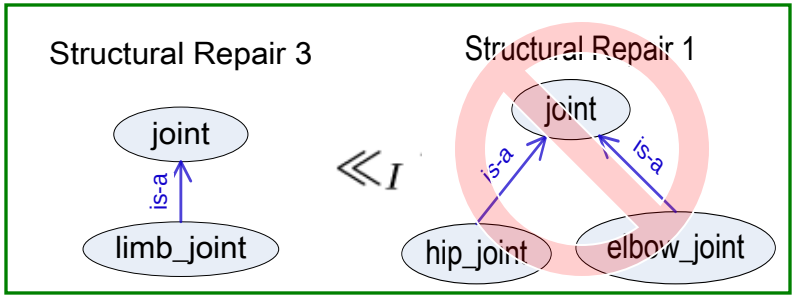
Prefer to use structural repair **without non-contributing** repairing actions.



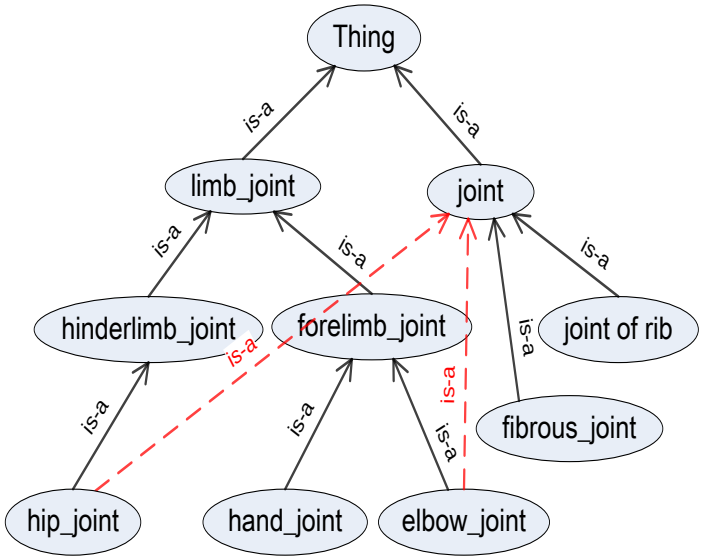


Information-based heuristic

Prefer to use structural repair with **more informative** repairing actions.

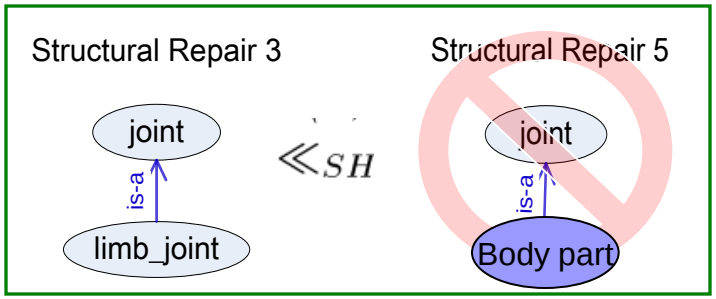


(limb_joint, joint) is more informative than **(hip_joint, joint)** and **(elbow_joint, joint)**

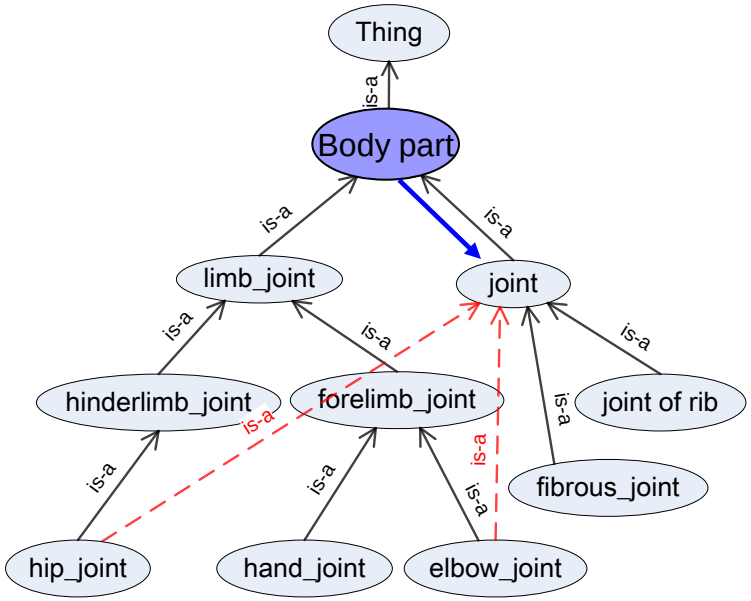


Strict hierarchy heuristic

Prefer to use structural repair which **does not change the existing is-a relations in the original ontology into equivalence relations**.



(body part, joint) will introduce an equivalence relation between '**joint**' and '**body part**'.



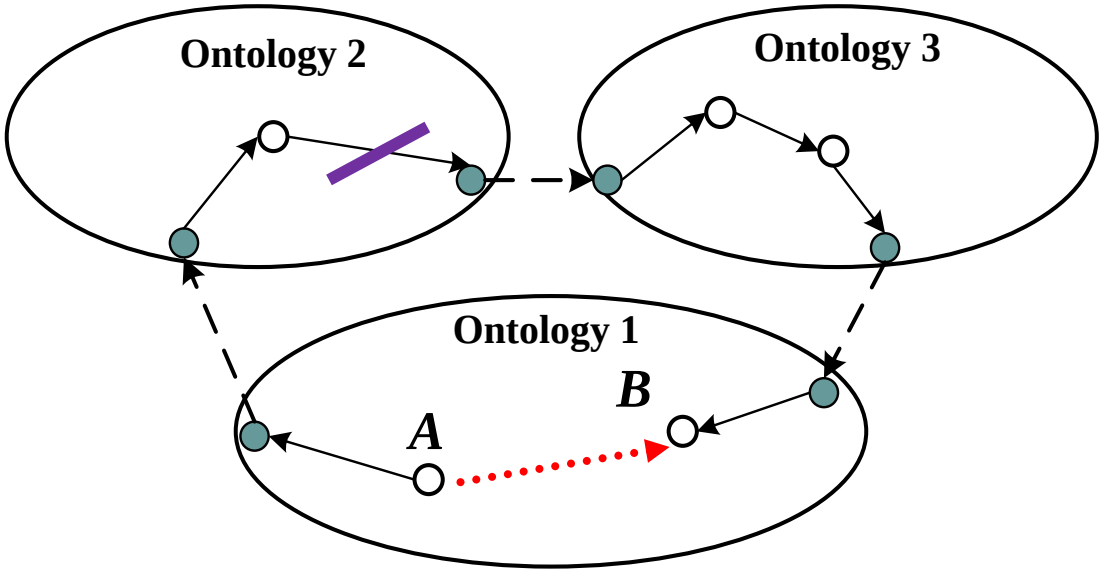
Single relations heuristic

- Assume that it is more likely that domain experts have missed a single relation than a chain of relations

  - *Assume it is more likely that*
    (ankle_joint, limb_joint)
    is missing than
    (ankle_joint, x_1) and (x_1,x_2), and ... and (x_{k-1}, x_k)
    and (x_k, limb_joint).

Repairing wrong is-a relations

- Find explanations (justifications)
- Remove part of the explanation



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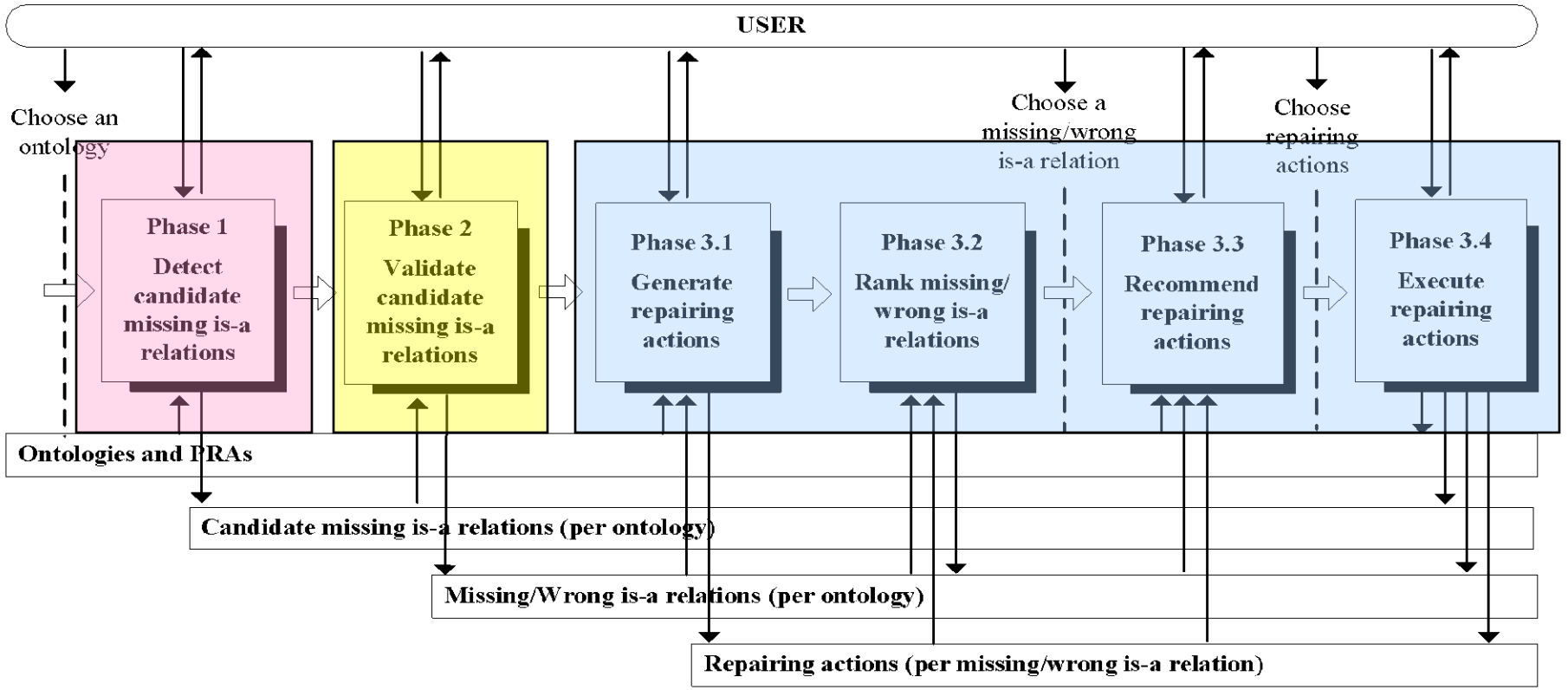
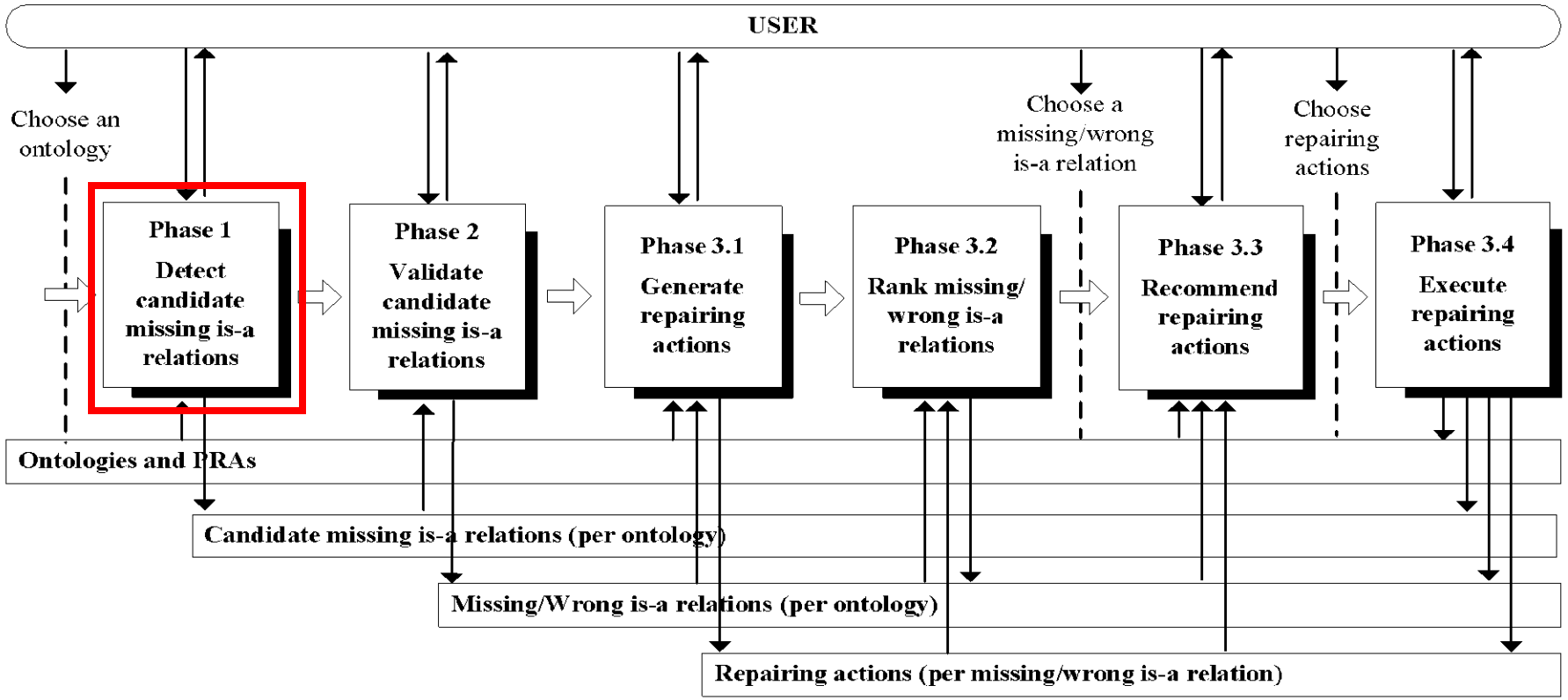
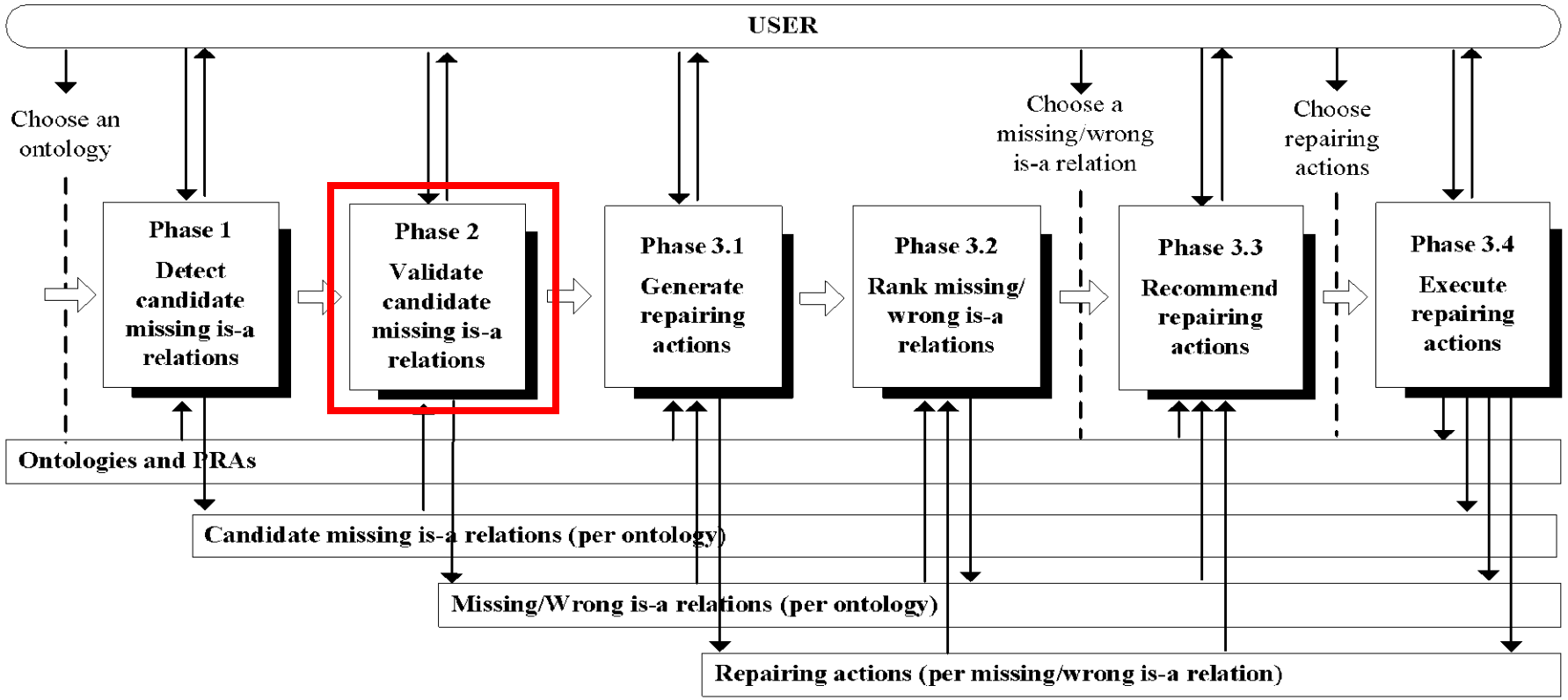
Overview of debugging approach



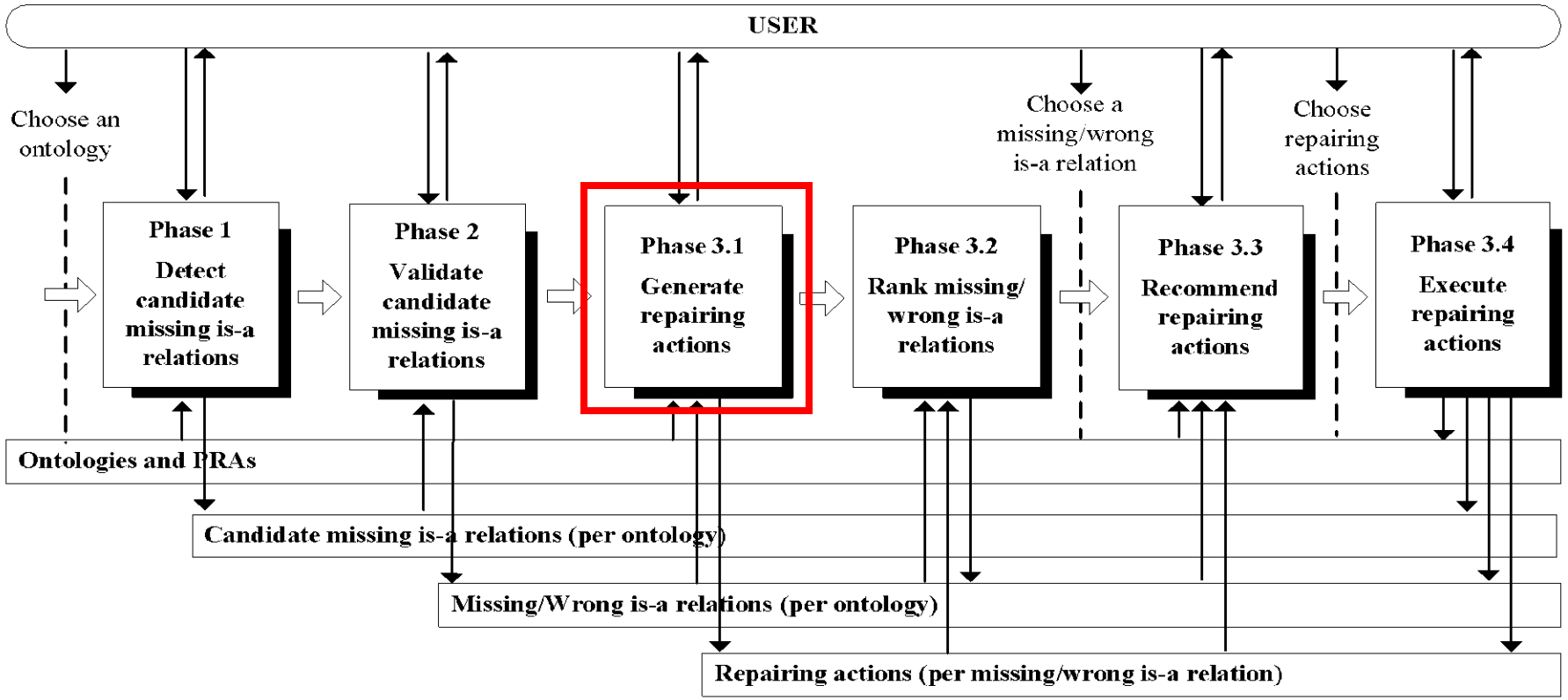
Phase 1: Detecting candidate missing is-a relations



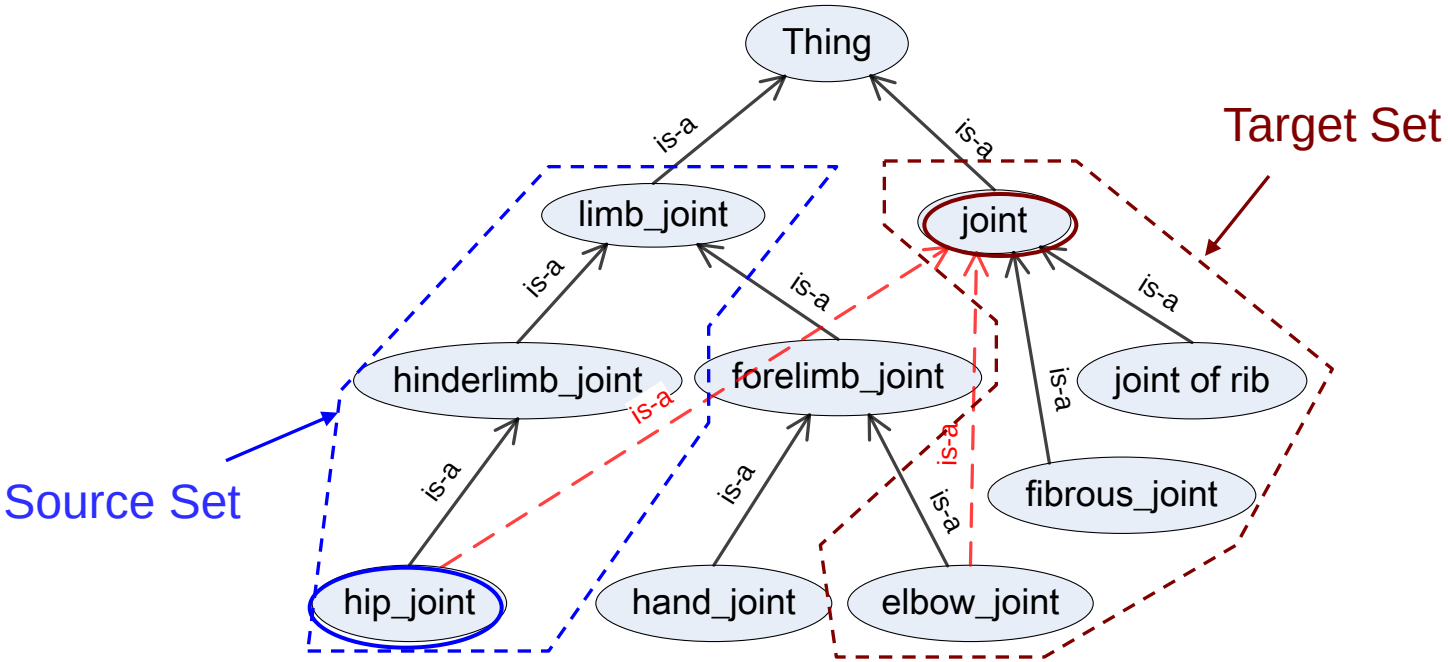
Phase 2: Validating candidate missing is-a relations



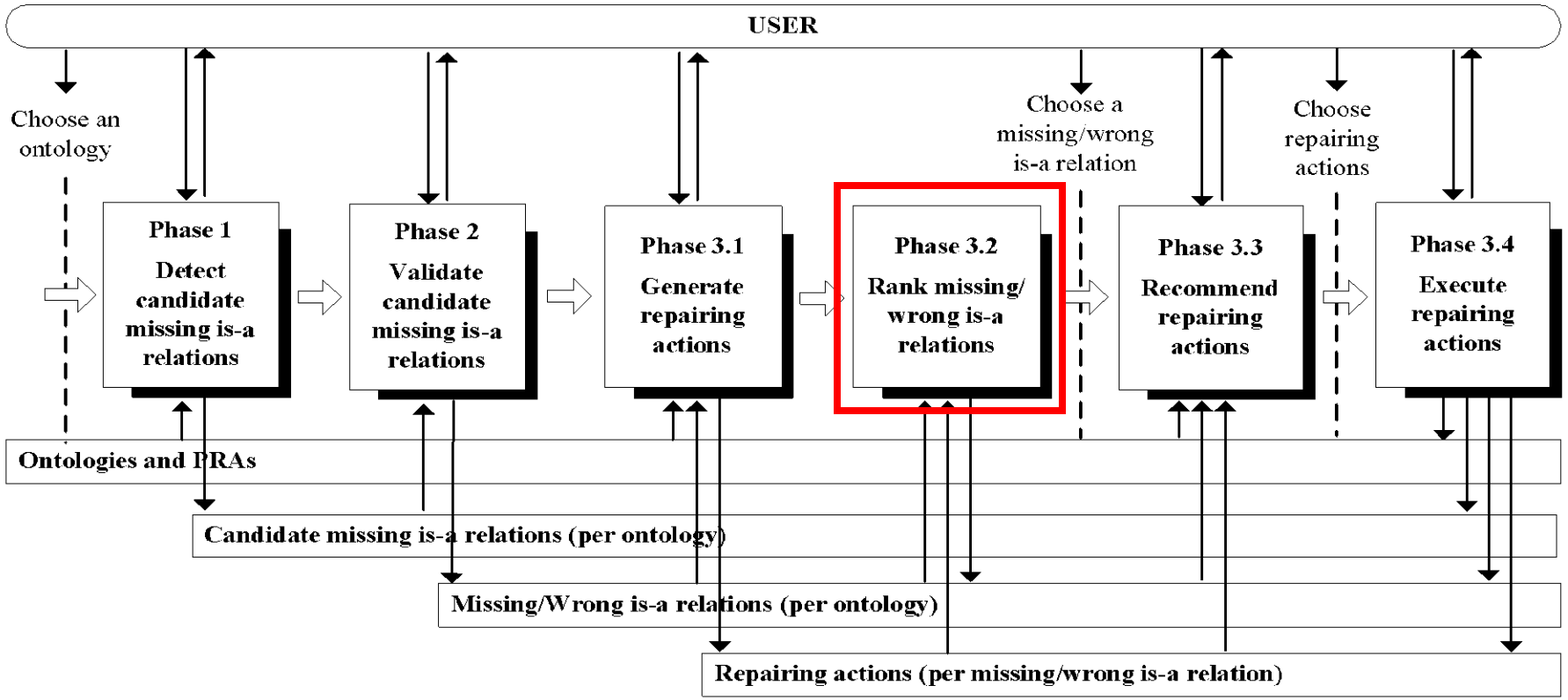
Phase 3.1: Generating repairing actions for missing is-a relations



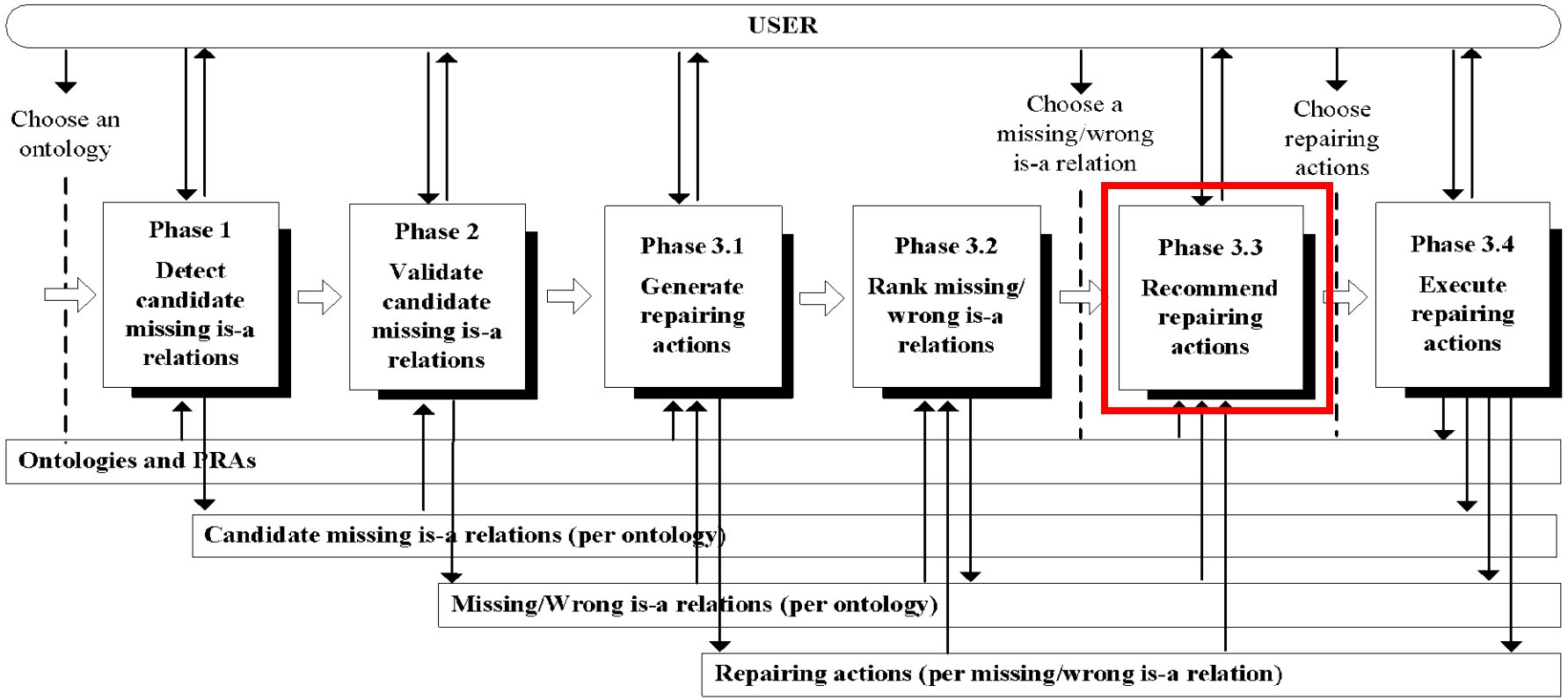
Example


Thing
is-a
is-a
limb_joint
joint
Target Set
is-a
is-a
is-a
hinderlimb_joint
forelimb_joint
joint of rib
is-a
is-a
is-a
is-a
is-a
Source Set
fibrous_joint
hip_joint
hand_joint
elbow_joint

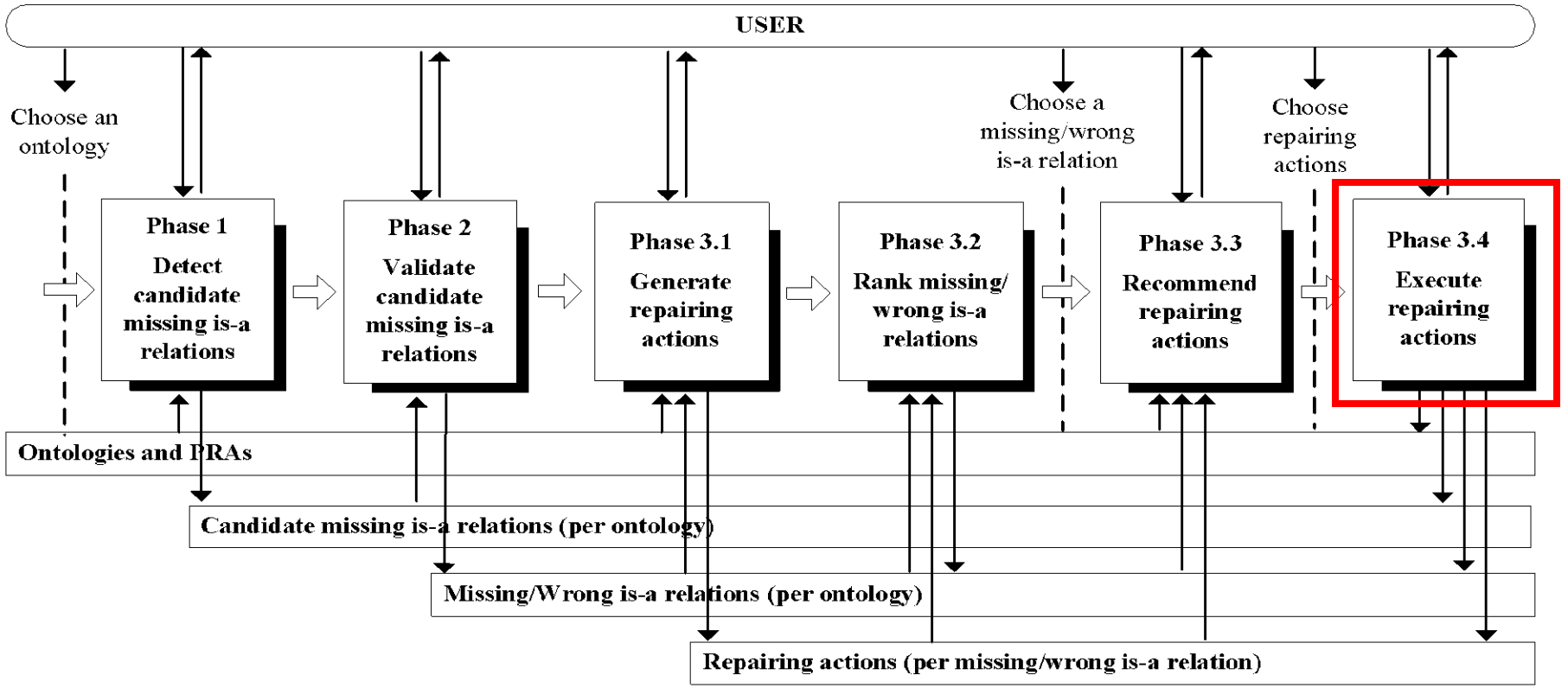
Phase 3.2: Ranking missing is-a relations



Phase 3.3: Recommending repairing actions for missing is-a relations



Phase 3.4: Executing repairing actions for missing is-a relations



Repairing wrong is-a relations

- Phase 3.1: generate repairing actions
  - Based on justifications
- Phase 3.2: rank wrong is-a relations
  - Based on number of possible repairing actions
- Phase 3.3: recommend repairing actions
  - Based on occurrences in different derivation paths
- Phase 3.4: execute repairing actions
  - Compute consequences

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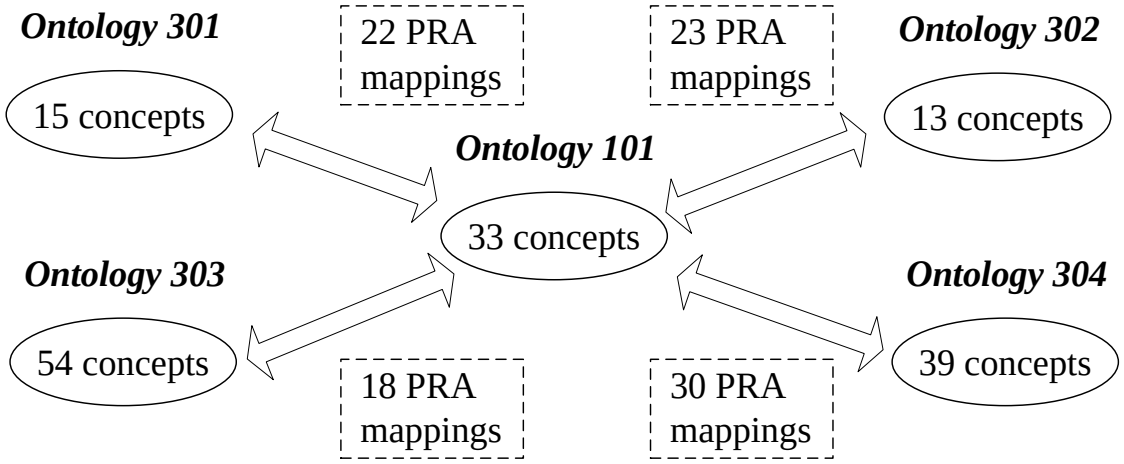
Experiment “missing” - bib

- Bibliography dataset (2010 OAEI Benchmark)



Experiment “missing” - bib

- Bibliography Dataset – 1 network
  - Missing is-a relations
    - 22 in 101 (of which 12 redundant)
    - 1 in 301
    - 1 in 302
    - 1 in 303
    - 23 in 304 (of which 14 redundant)
  - The whole debugging process took about 5 minutes.

Experiment “missing” - bib

- Bibliography Dataset – 4 small networks
  - Missing is-a relations
    - For 101-301: 1 for each ontology
    - For 101-302: 17 (of which 11 redundant) for 101 and 1 for 302
    - For 101-303: 1 for 303
    - For 101-304: 4 for 101 and 5 (of which 1 redundant) for 304
  - The whole debugging process took less than 5 minutes.

- Comparison 1 network / 4 networks
  - 301, 302, 303: same results in both scenarios
  - More missing is-a relations found and repaired in the scenario with 1 network

Experiment “missing” - Anatomy

Experiment on Anatomy dataset (2008 OAEI Anatomy)

MA: 2744 concepts, 1807 asserted is-a relations

NCI-A: 3304 concepts, 3761 asserted is-a relations

PA: 988 equivalence relations, 1 subsumption

→

new is-a relations: 205 for MA, 177 for NCI-A

total: 3 hours debugging time (almost all time on validation)

In most cases, the ranking and recommendations seemed useful.

Experiment “wrong and missing” - Anatomy

Experiment on Anatomy dataset (2010 OAEI Anatomy)

MA: 2744 concepts, 1807 asserted is-a relations

NCI-A: 3304 concepts, 3761 asserted is-a relations

PA: 986 equivalence relations, 1 subsumption

→

new is-a relations: 107 for MA, 64 for NCI-A

removed is-a relations: 3 from MA, 12 from NCI-A

total: 5 hours debugging time (almost all time on validation)

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Extensions

- Taxonomies
  - Debugging wrong and missing is-a structure and mappings within networked taxonomies (WoDOOM12, ESWC13)
    - Experiment on Anatomy dataset (2010 OAEI Anatomy)
    - ToxOntology – MeSH (Swedish National Food Agency)
  - Aligning ontologies = detecting missing mappings (ESWC13)
- ALC acyclic terminologies (JIST12)
- Repairing missing is-a relations is an abduction problem (JIST12)

Future work

- Algorithms for more ontologies in more expressive languages
- Complexity of the abduction problem for different languages
- Preference criteria for solutions

References

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- Ivanova V, Laurila Bergman J, Hammerling U, Lambrix P, Debugging taxonomies and their alignments – the ToxOntology – MeSh use case, *1st International Workshop on Debugging Ontologies and Ontology Mappings*, 25-36, 2012.
- Lambrix P, Dragisic Z, Ivanova V, Get my pizza right: Repairing missing is-a relations in ALC ontologies, *2nd Joint International Semantic Technology Conference – JIST12*, LNCS 7774, 17-32 2012.
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- Ivanova V, Lambrix P, A unified approach for aligning taxonomies and debugging taxonomies and their alignments, *10th Extended Semantic Web Conference – ESWC13,* 2013.

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- WoDOOM – International Workshop
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