



Debugging is-a structure in ontologies

**Patrick Lambrix, Valentina Ivanova,
Zlatan Dragisic, Fang Wei-Kleiner**

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.

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

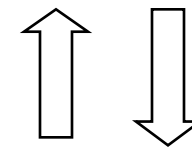
I Diseases Category

I Eye Diseases

I Scleral Diseases

I Scleritis

...



Influence of missing structure

- Incomplete results from ontology-based queries



Medical Subject
Headings (MeSH)

All MeSH Categories

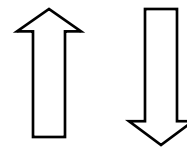
I Diseases Category

I Eye Diseases

I Scleral Diseases

~~I 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

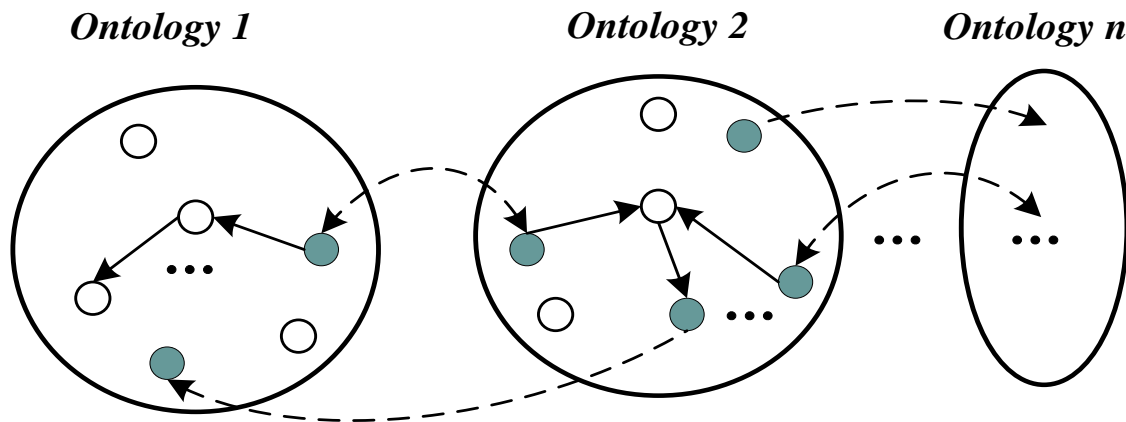


Outline

- Definitions
- Approach
- Experiments
- Conclusion

Taxonomy networks

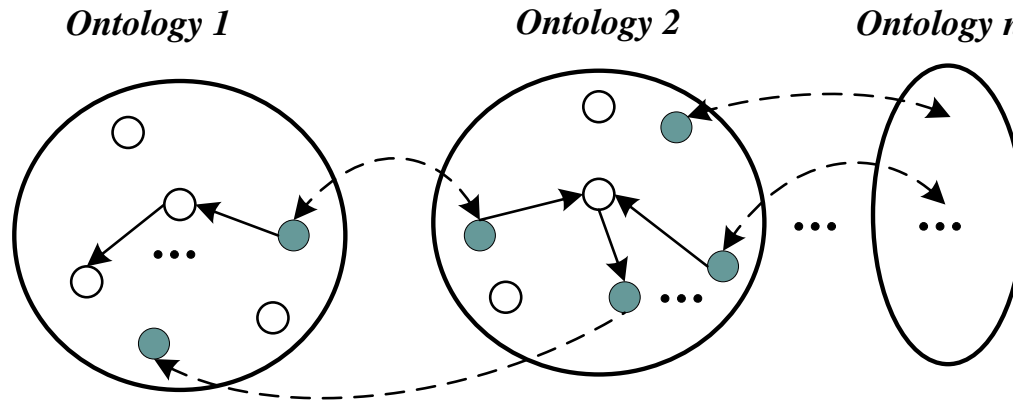
A **taxonomy network** consists of a set of **taxonomies** and sets of **mappings** between these taxonomies.



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?**

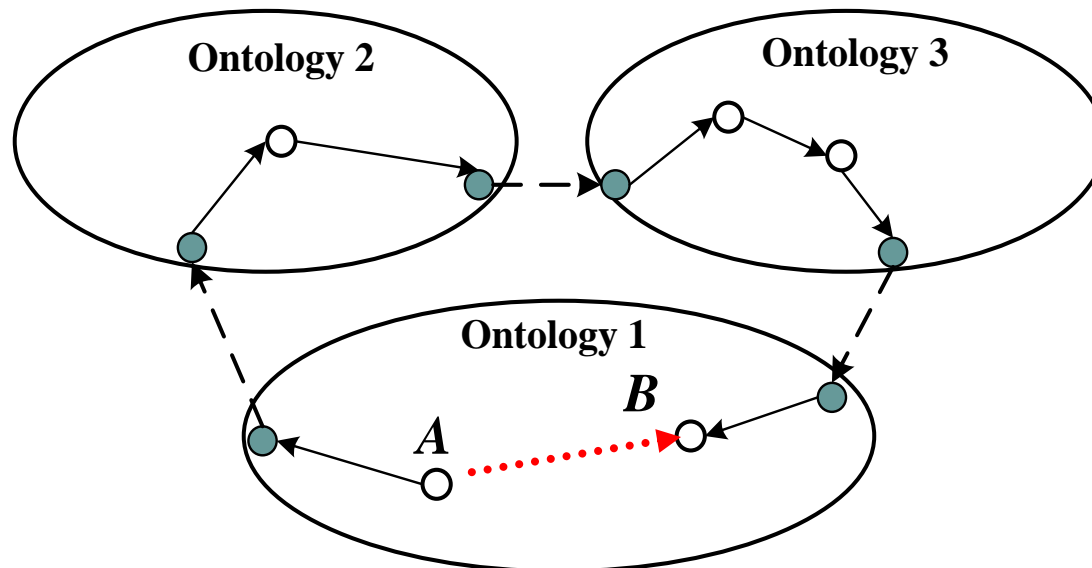
Detecting missing is-a relations

- 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

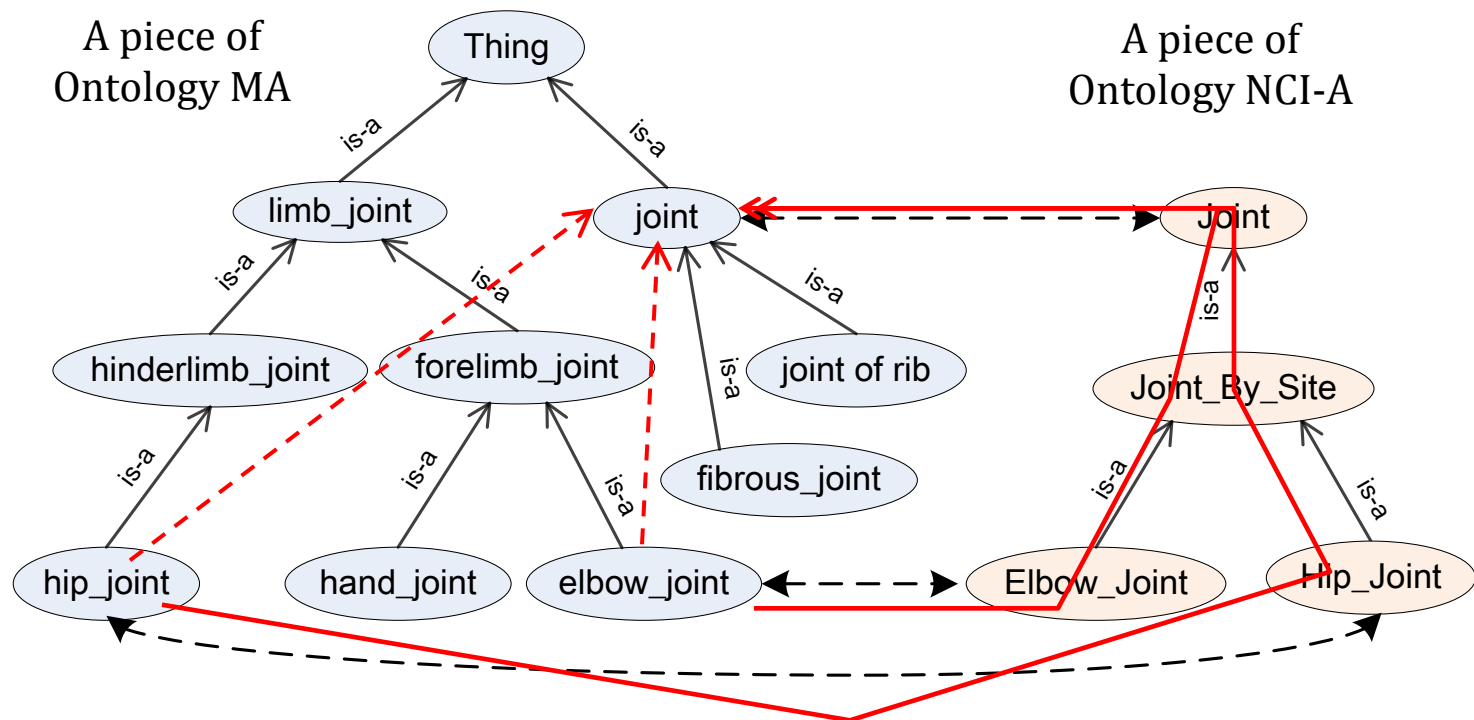
Given two concepts *A* and *B* in a taxonomy *O* in the network. If “*A* is-a *B*” is **logically derivable from the taxonomy network**, but **not from the taxonomy *O* alone**, then “*A* is-a *B*” is a **candidate missing is-a relation**.

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

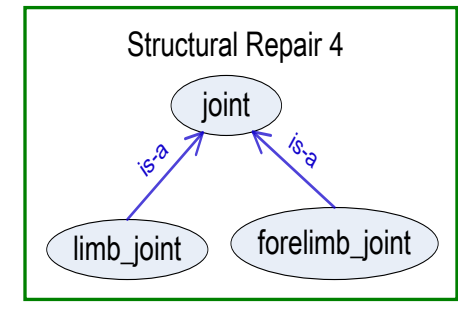
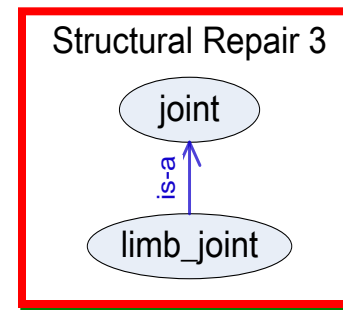
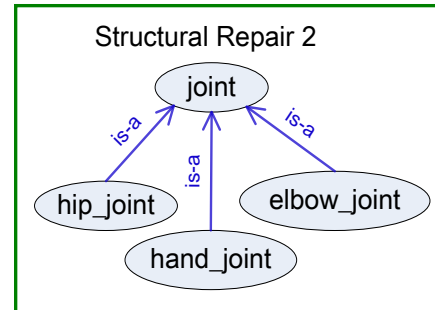
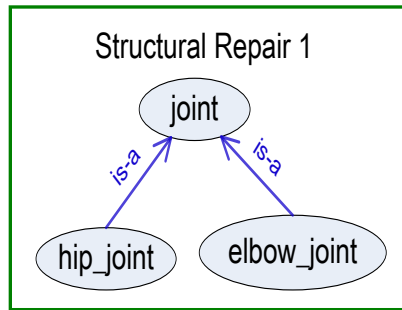
Repair the original taxonomies by

- 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'.

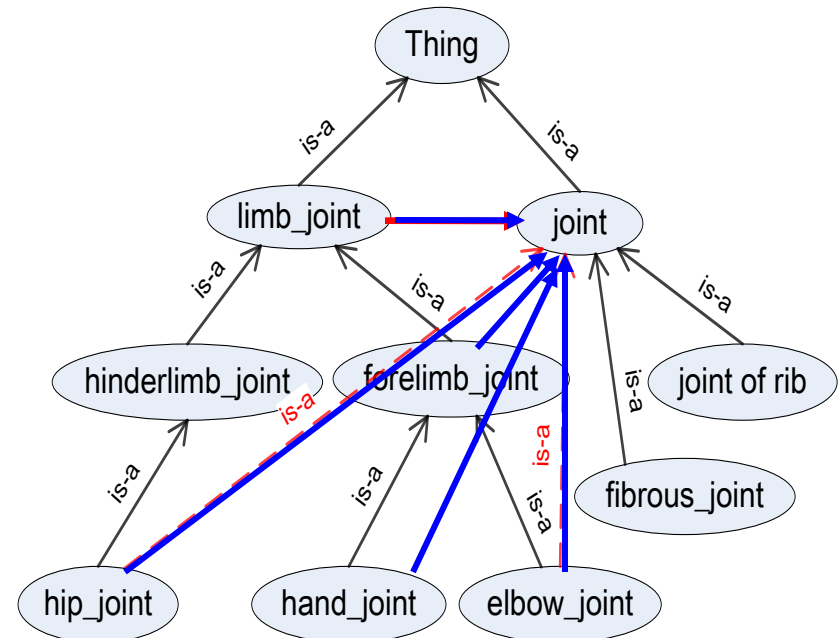
Repairing missing is-a relations



Question:

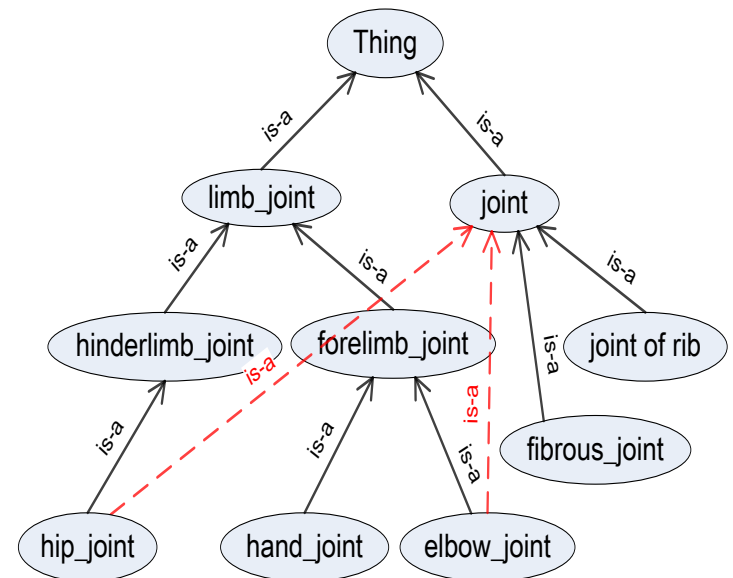
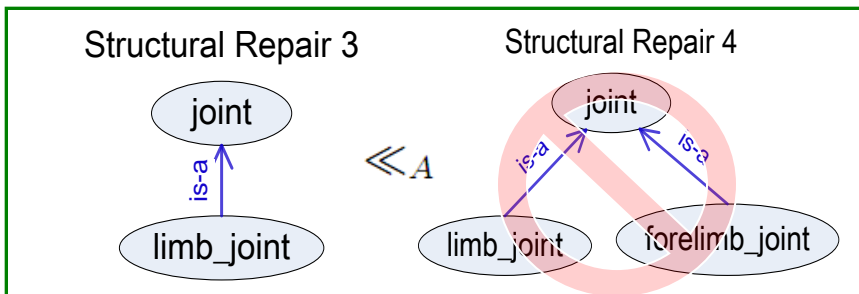
How can we recognize structural repairs that are interesting for a domain expert?

→ heuristics.



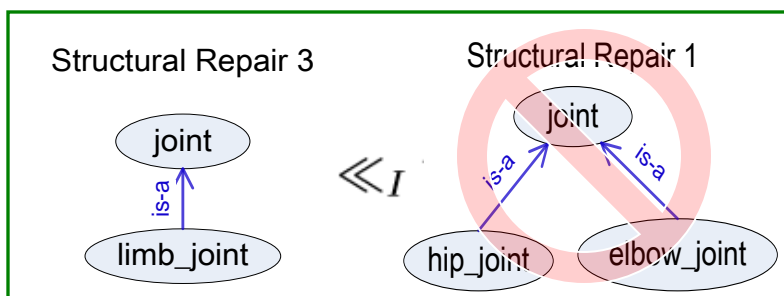
Axiom-based Heuristic

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

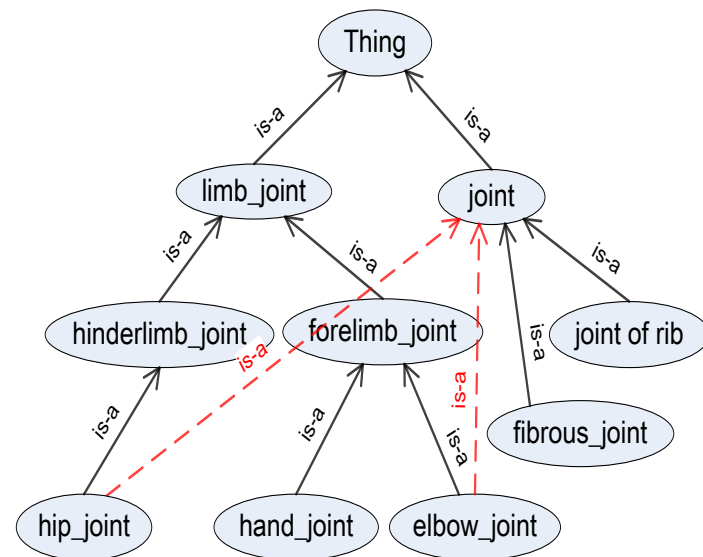


Information-based heuristic

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

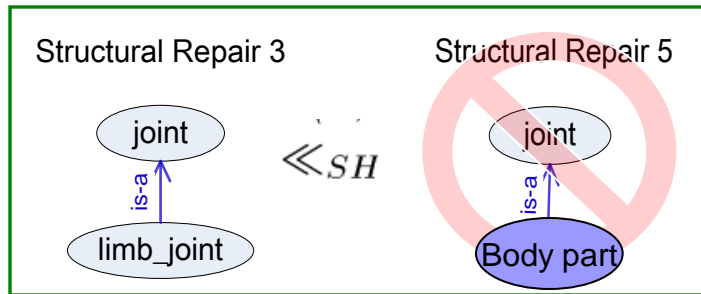


(limb_joint, joint) is more informative than **(hip_joint, joint)** and **(elbow_joint, joint)**

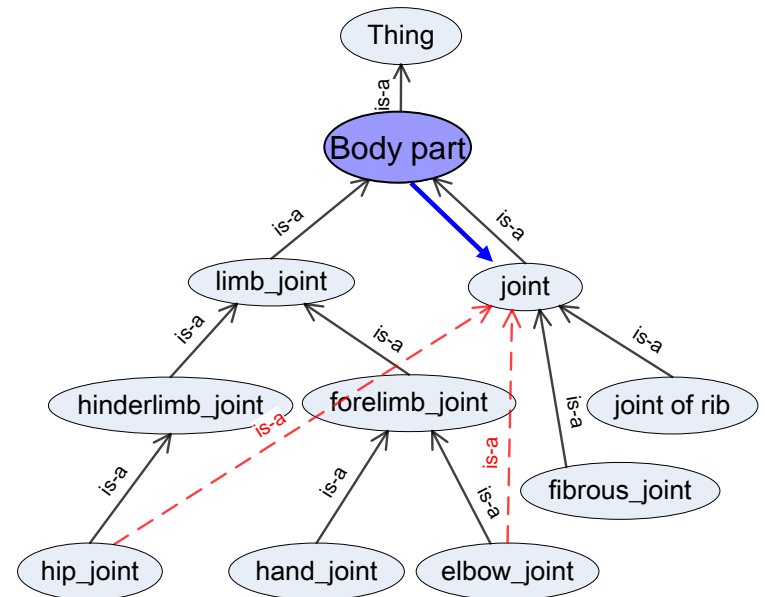


Strict hierarchy heuristic

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'.

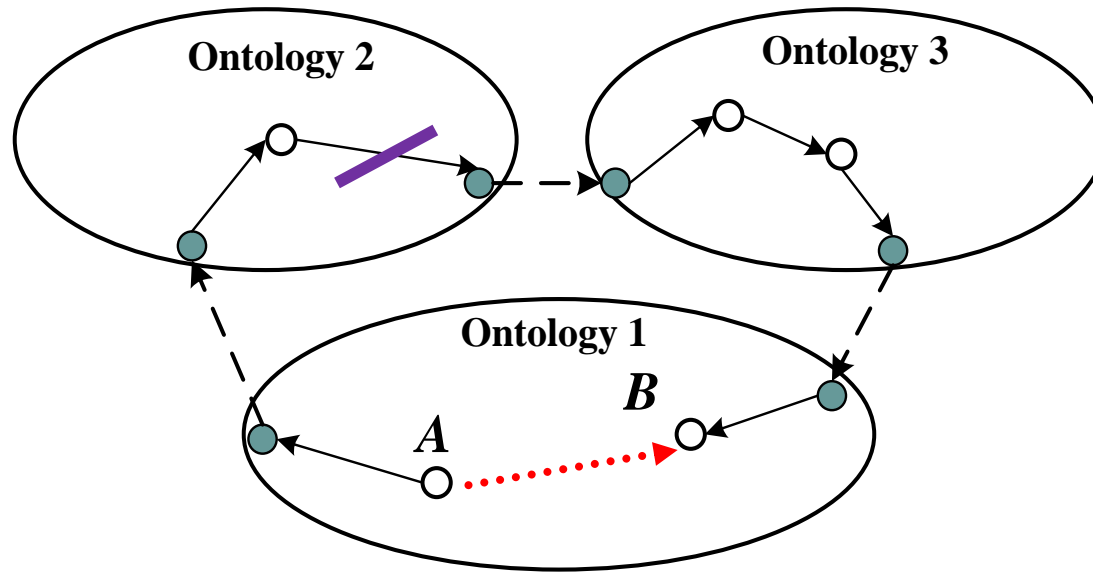


Single relations heuristic

- 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

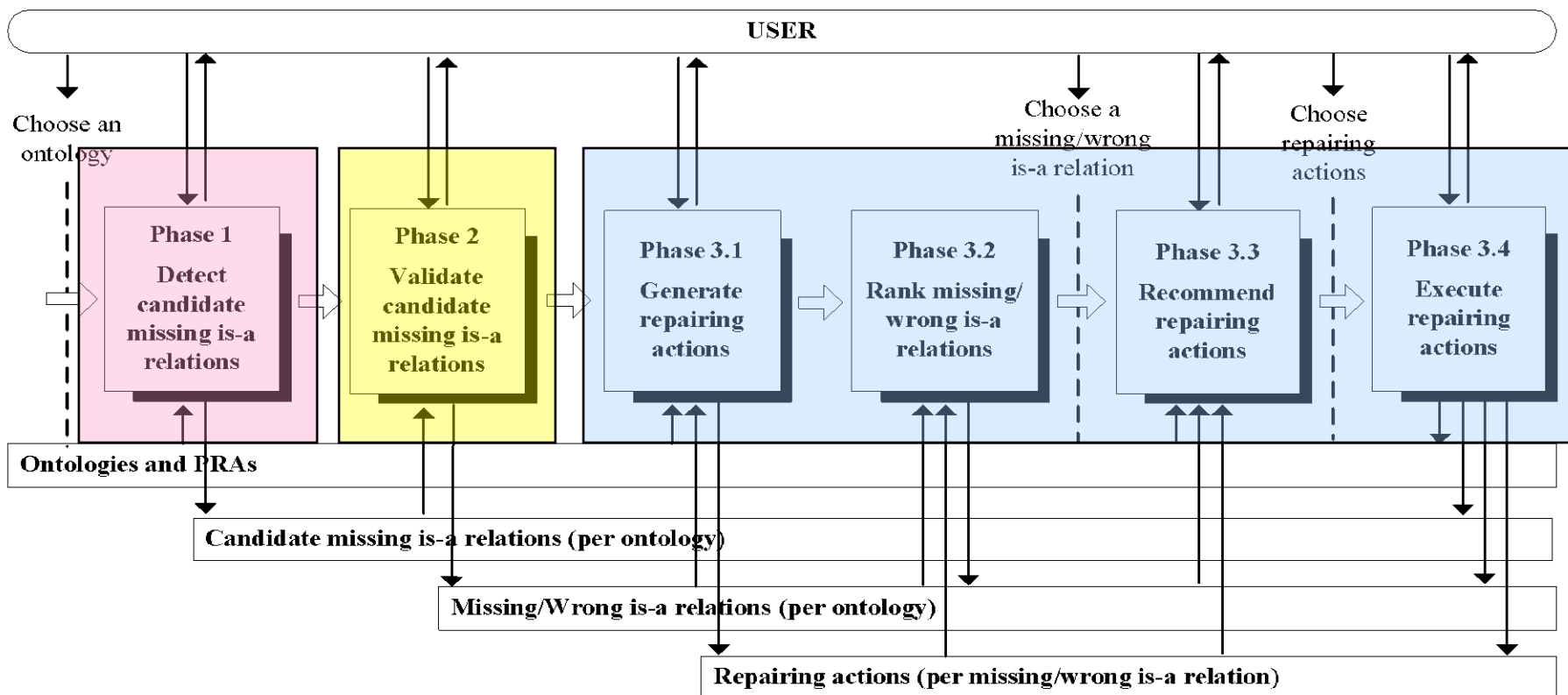




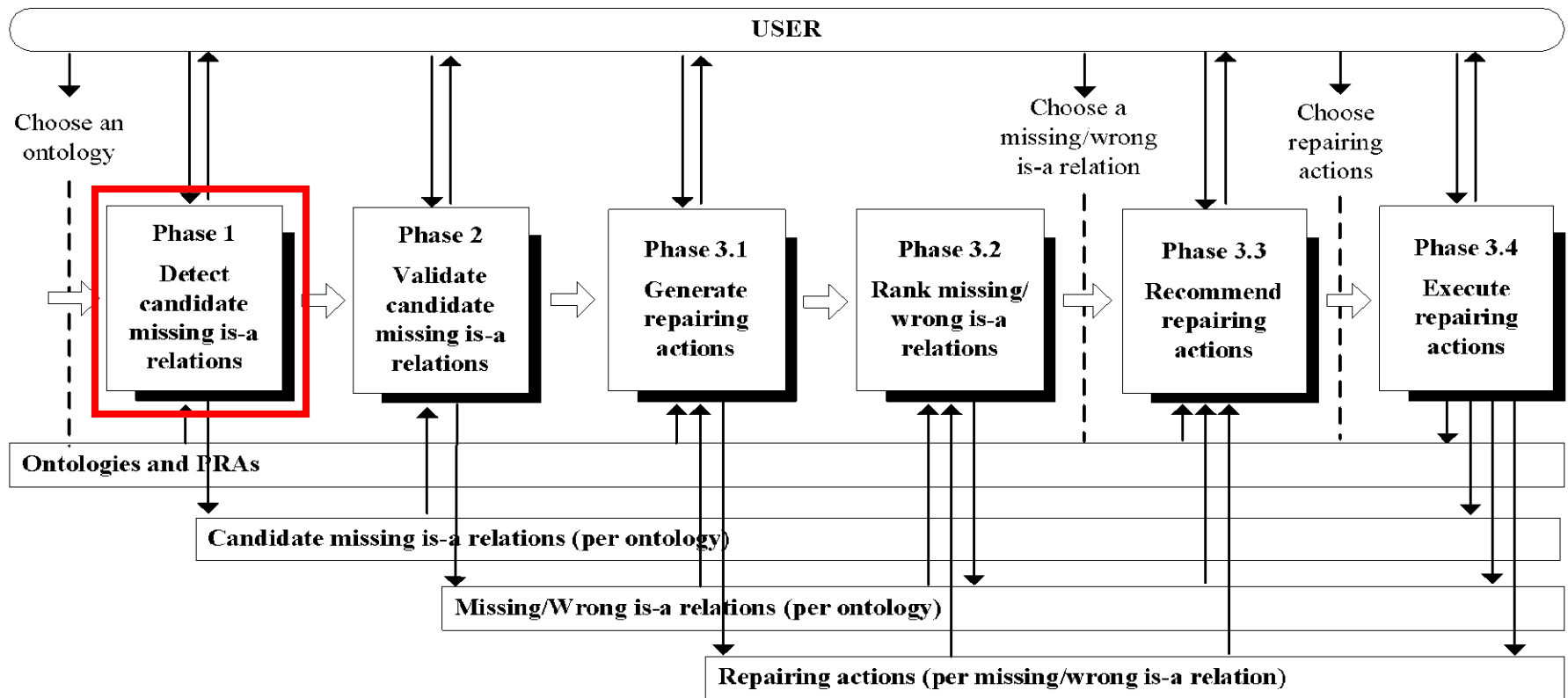
Outline

- Definitions
- Approach
- Experiments
- Conclusion

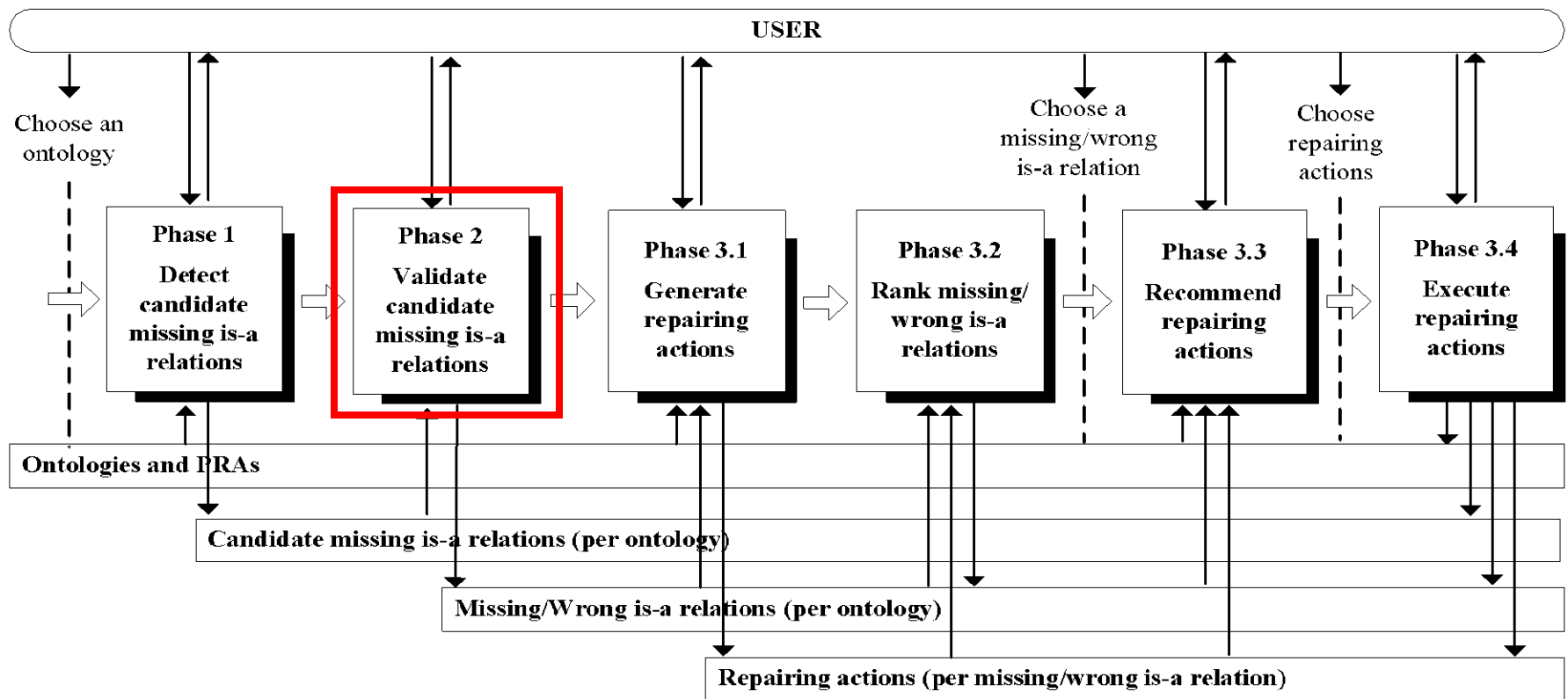
Overview of debugging approach



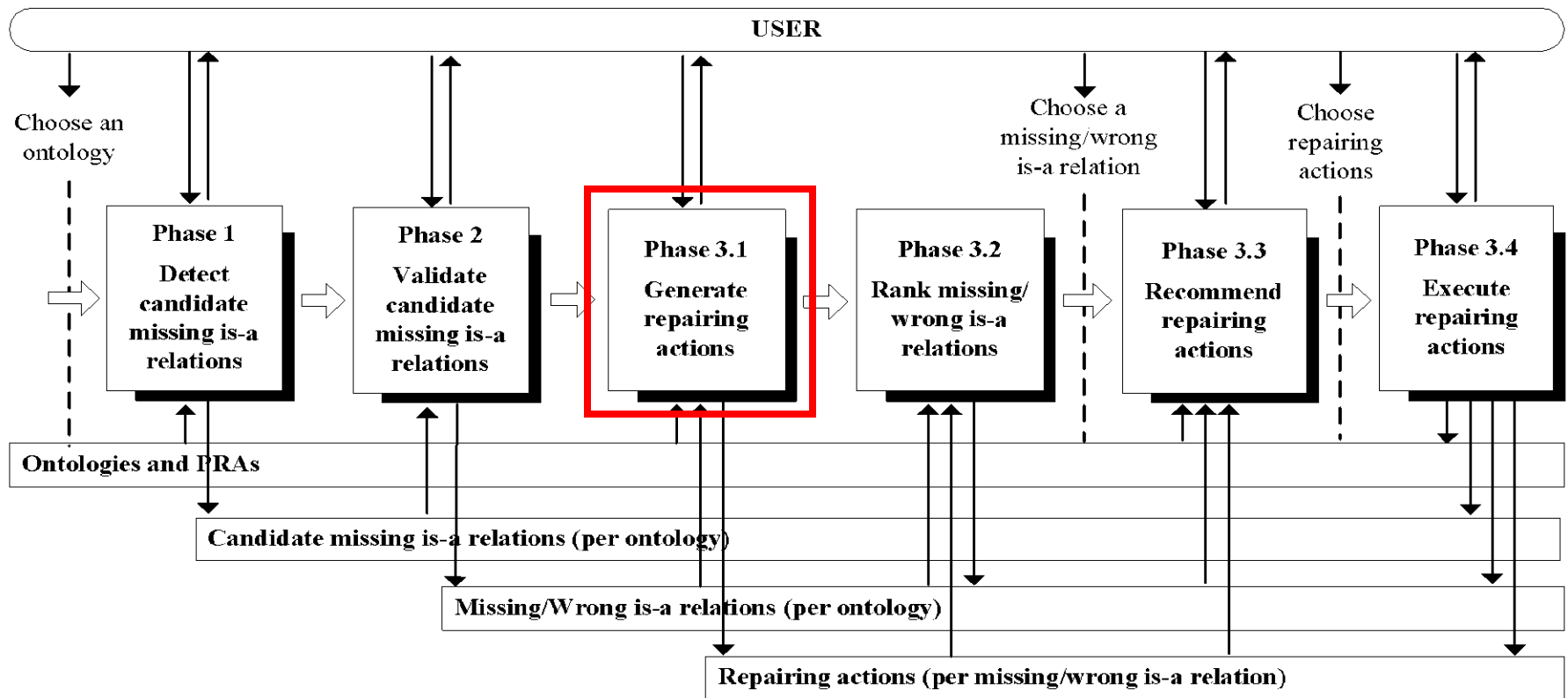
Phase 1: Detecting candidate missing is-a relations



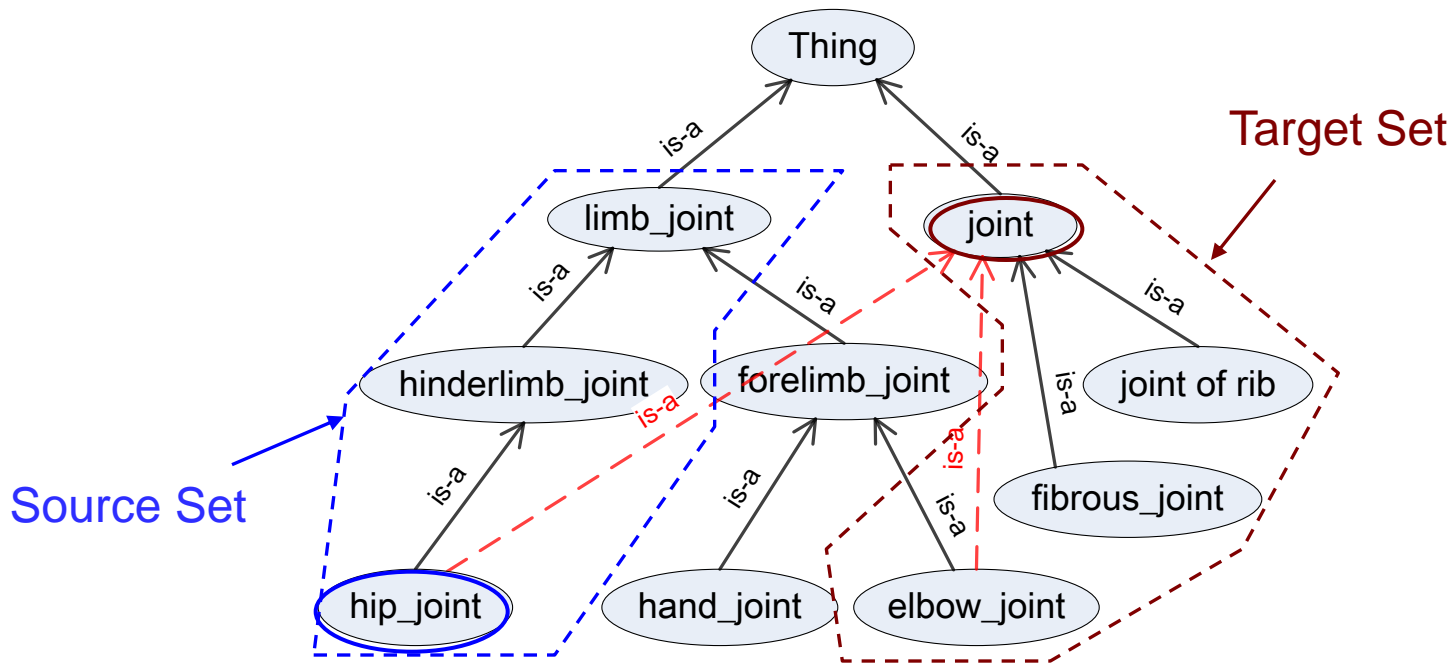
Phase 2: Validating candidate missing is-a relations



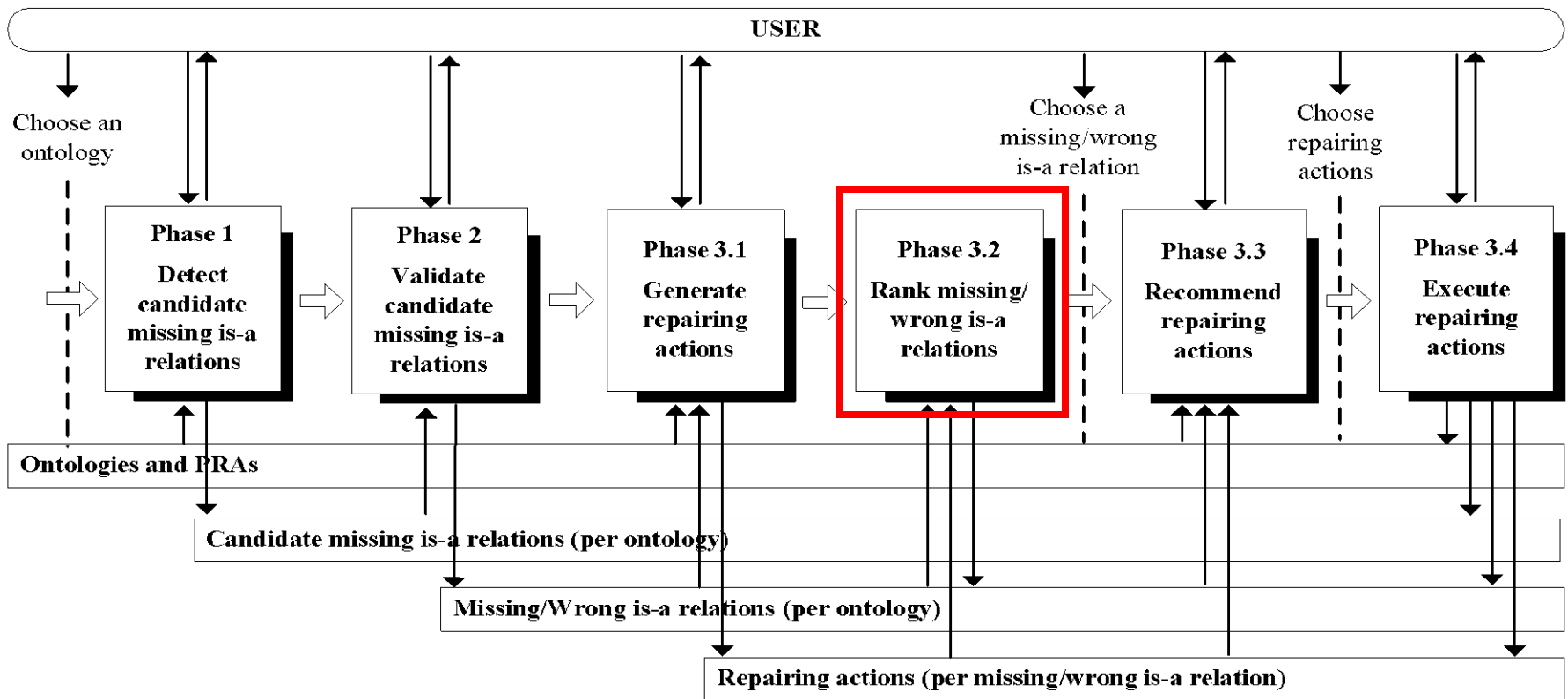
Phase 3.1: Generating repairing actions for missing is-a relations



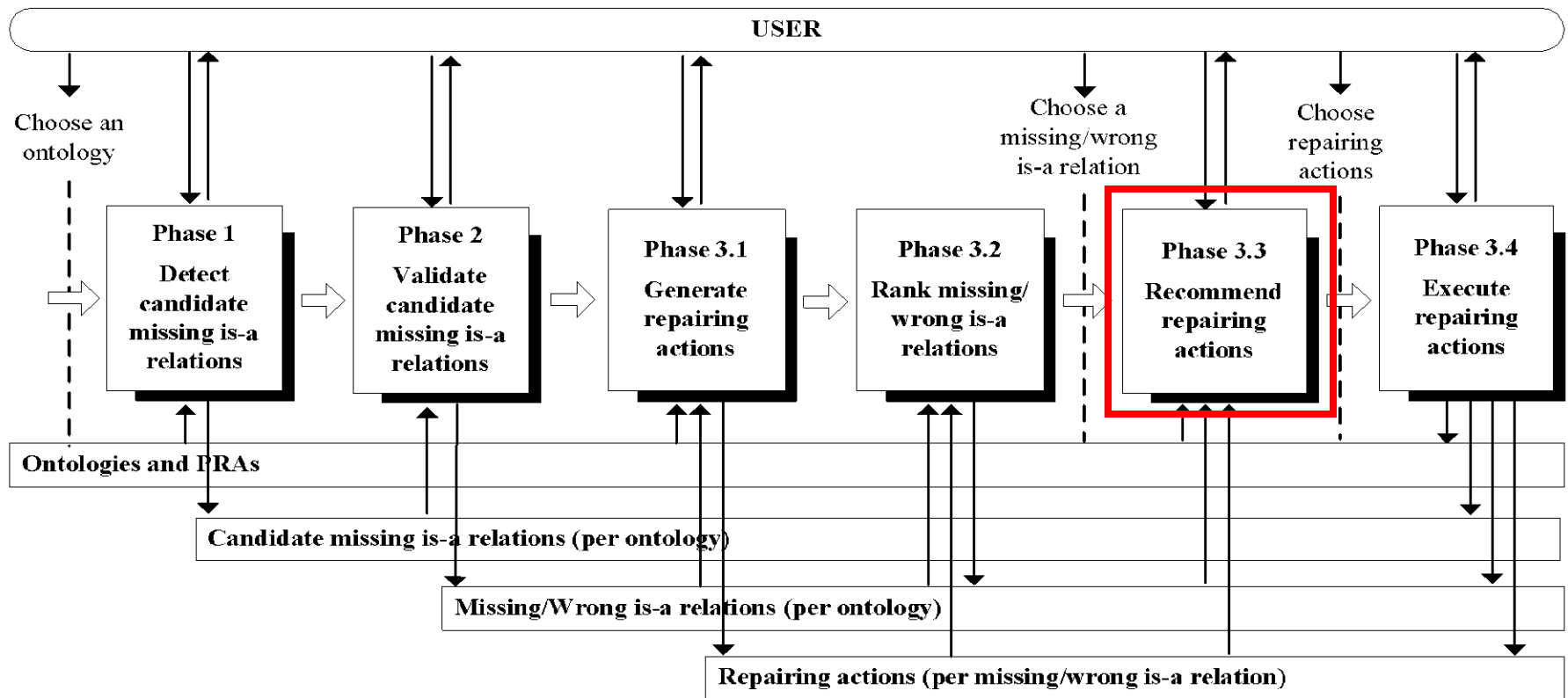
Example



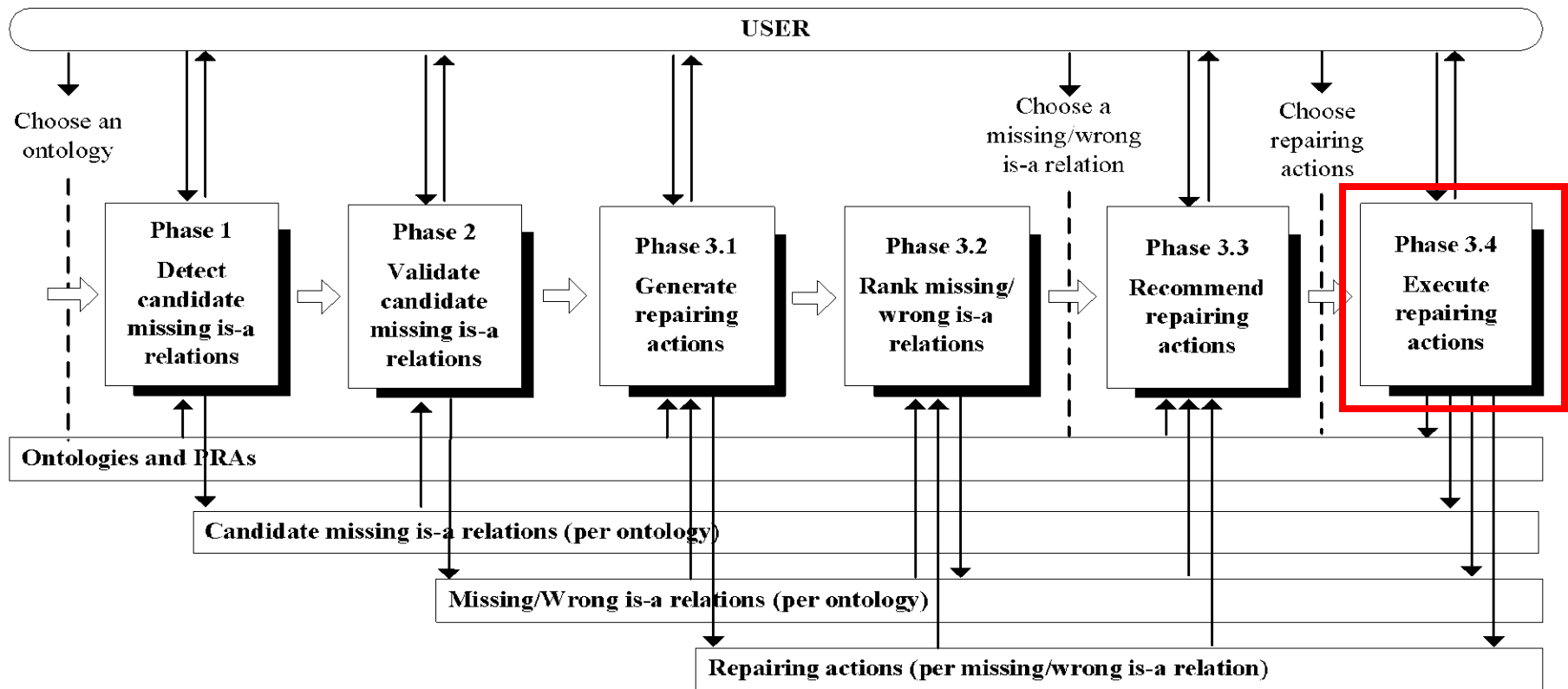
Phase 3.2: Ranking missing is-a relations



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

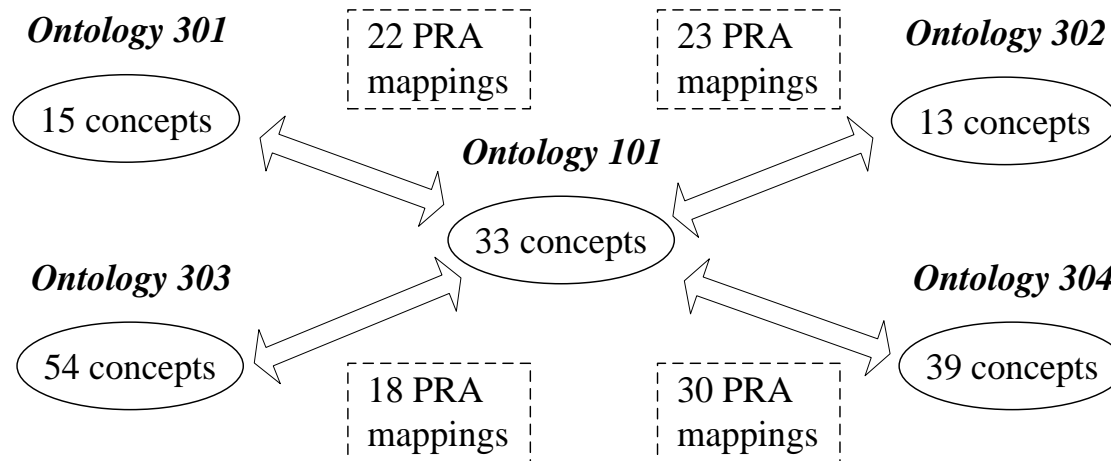


Outline

- Definitions
- Approach
- Experiments
- Conclusion

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)



Outline

- Definitions
- Approach
- Experiments
- Conclusion

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

- Lambrix P, Liu Q, Tan H, Repairing the missing is-a structure of ontologies, *4th Asian Semantic Web Conference - ASWC09*, LNCS 5926, 76-90, 2009.
- Lambrix P, Liu Q, Debugging is-a structure in networked taxonomies, *4th International Workshop on Semantic Web Applications and Tools for the Life Sciences –SWAT4LS*, 58-65, 2011.
- 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.
- Lambrix P, Ivanova V, A unified approach for debugging is-a structure and mappings in networked taxonomies.
- Ivanova V, Lambrix P, A unified approach for aligning taxonomies and debugging taxonomies and their alignments, *10th Extended Semantic Web Conference – ESWC13*, 2013.

References

- <http://www.ida.liu.se/~patla/DOOM/publications.shtml>
- WoDOOM – International Workshop
on Debugging Ontologies and Ontology Mappings