Repairing Networks of Ontologies using Weakening and Completing

Ying Li, Patrick Lambrix

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LINKÖPING UNIVERSITY

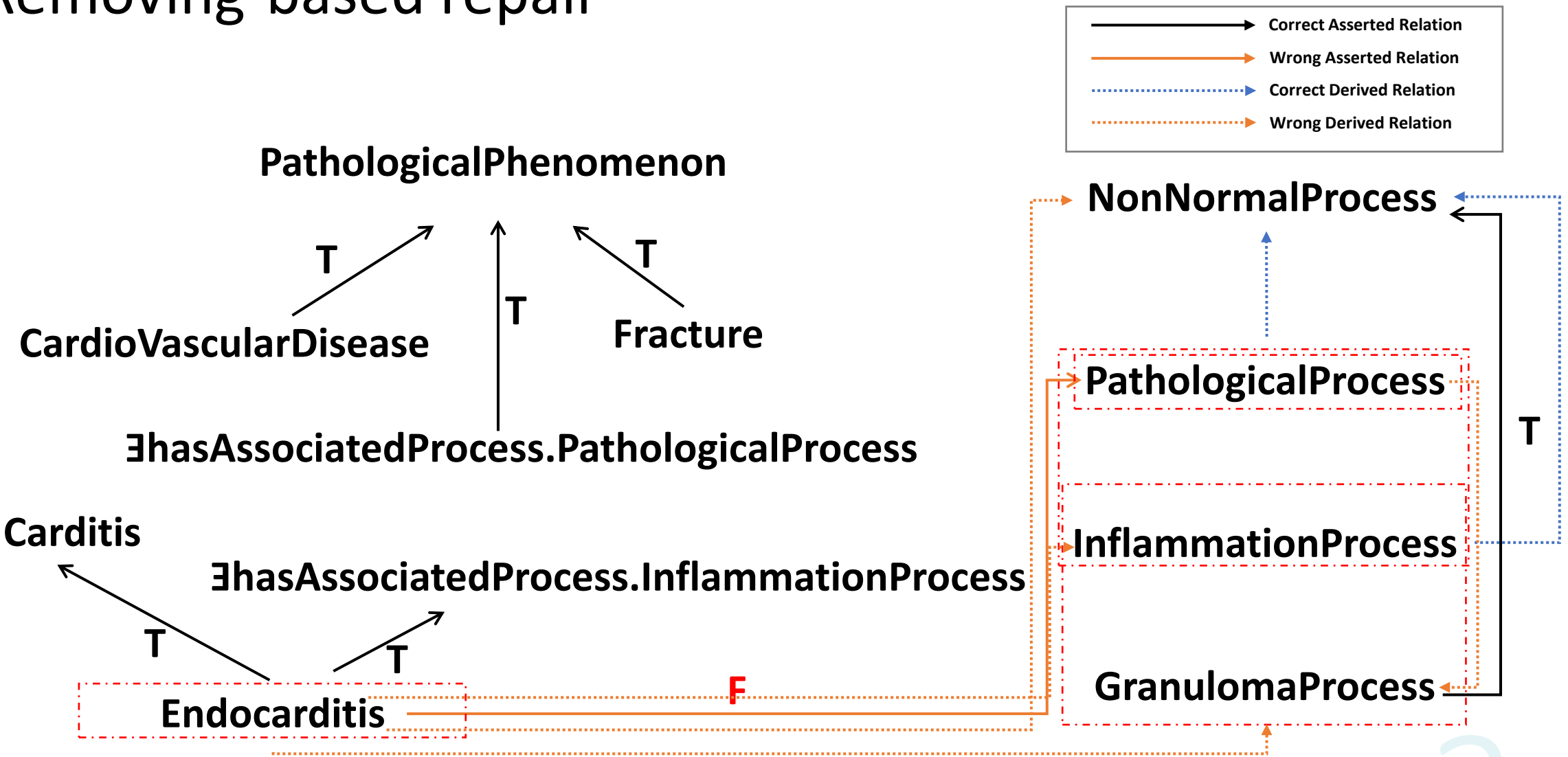
Background

The quality of ontologies and their alignments is crucial for developing high-quality ontology-based applications.

An ontology/ontology network which contains wrong knowledge may lead to logical problems (i.e., incoherence or inconsistency) or statements that are not correct in the domain of the ontology (modeling defects).

Traditional debugging techniques repair ontologies/ontology networks by removing unwanted axioms and mappings, but may thereby remove consequences that are correct in the domain.

Removing-based repair



Remove all the wrong axioms from the ontology

Motivation

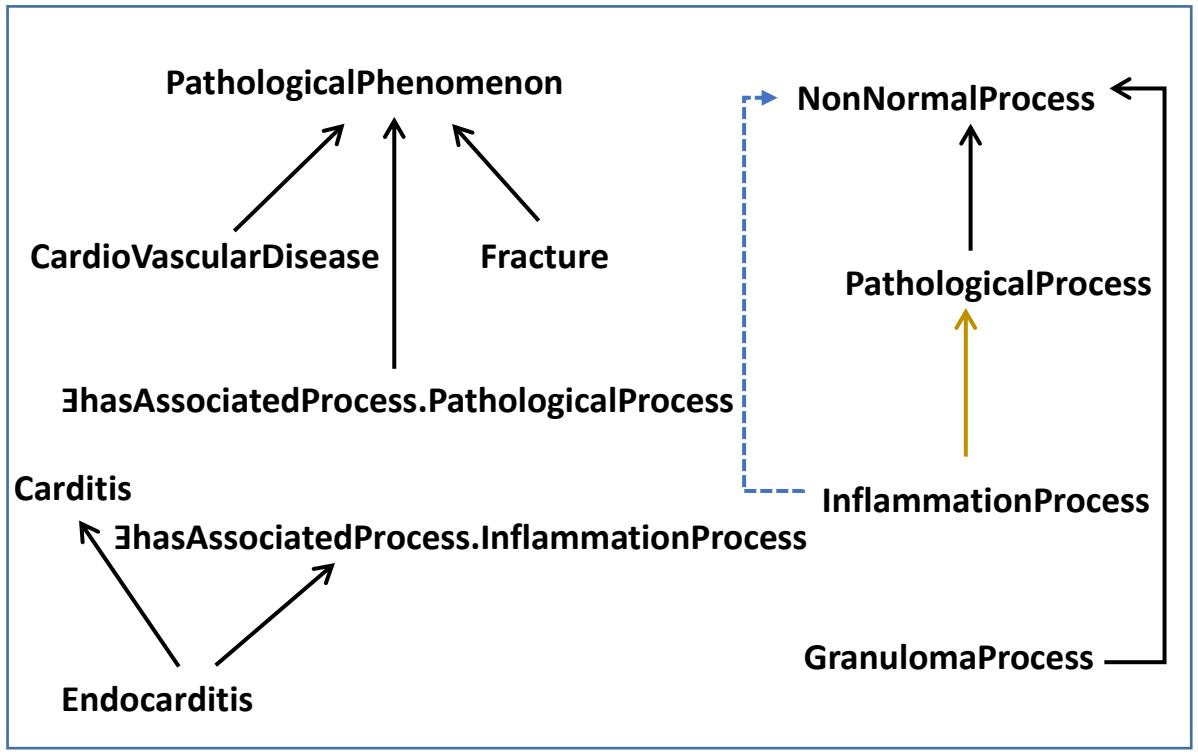
Preserve as much correct information as possible when removing wrong axioms from ontology networks.

More complete TBoxes

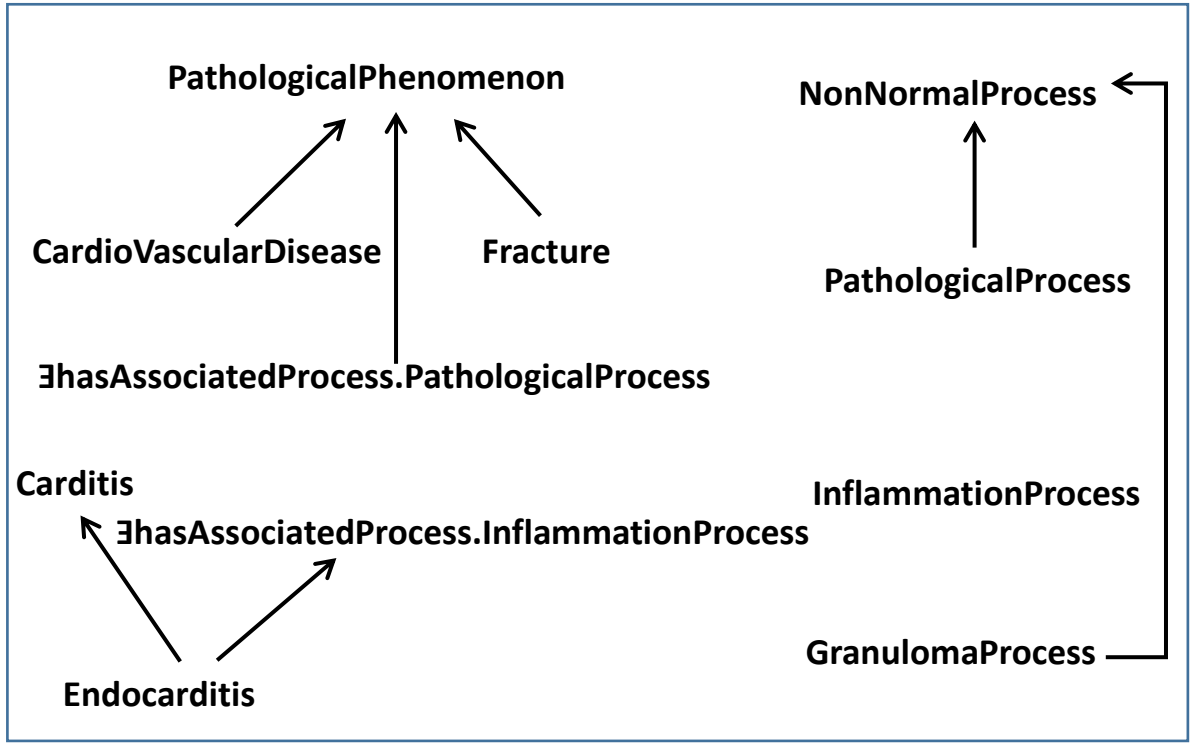
TBox T_1 is more complete than *TBox* T_2 iff

1) all correct knowledge in T_2 can also be derived in T_1.
2) there is correct knowledge in T_1 that cannot be derived in T_2.

More complete TBoxes



T1



T2

Or(InflammationProcess ⊆ PathologicalProcess) = true
T_1 is more complete than T_2

Problem formulation

An ontology represented by TBox T

Domain expert

Definition 1. (Repair) Let $\mathcal{T}$ be a TBox. Let Or be an oracle that given a TBox axiom returns true or false. Let W be a finite set of TBox axioms in $\mathcal{T}$ such that $\forall\ \psi \in W$: $Or(\psi) =$ false. Then, a repair for Debug-Problem $\mathrm{DP}(\mathcal{T}, Or, W)$ is a finite set of TBox axioms A such that
(i) $\forall\ \psi \in A$: $Or(\psi) =$ true;
(ii) $\forall\ \psi \in W$: $(\mathcal{T} \cup A) \setminus W \not\models \psi$.

A repair A is a set of correct axioms that when added to the TBox where the axioms in W are removed will not allow deriving the axioms in W.

W is the set of the wrong asserted axioms that we want to remove from the ontology.

Repairing - Removing, Weakening and Completing

Given a set W, which contains the wrong asserted axioms validated by the domain expert that we want to remove from the ontology:

- Removing: removing the given asserted wrong axioms from the ontology.

- Weakening: finding correct axioms that are weaker than a given axiom; applied to the wrong axioms.

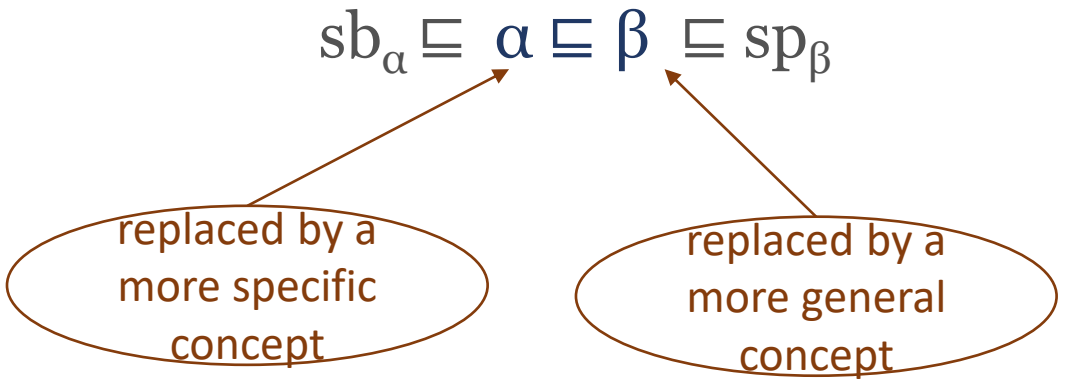
Dual operations where the former finds weaker axioms and the latter stronger axioms

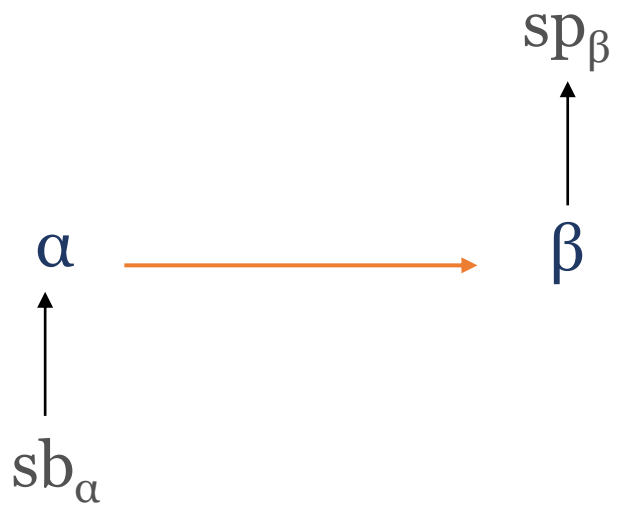
- Completing: finding additional correct axioms that are not derivable from the ontology yet and that would make a given axiom derivable; applied to the weakened axioms (more complete).

Weakening - finding correct weaker axioms

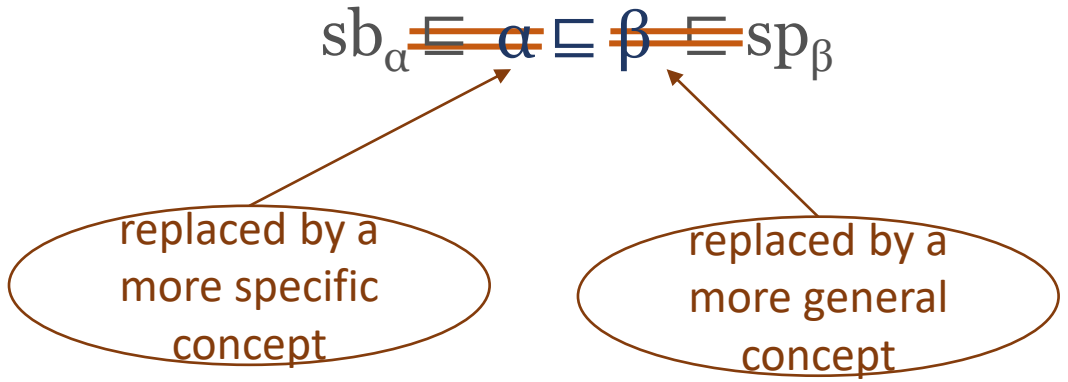
$$\alpha \sqsubseteq \beta$$

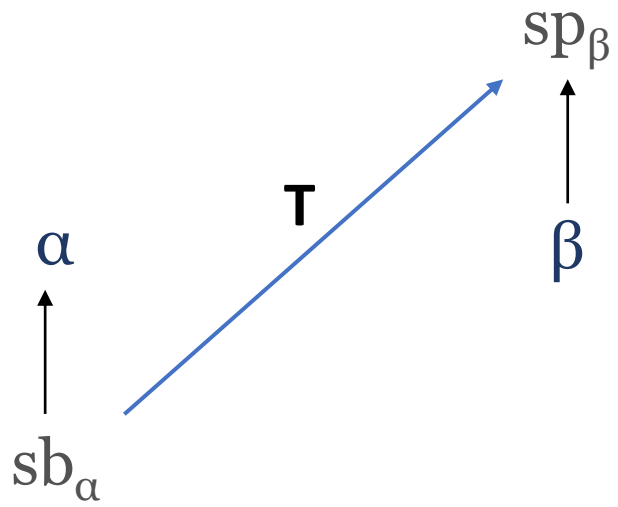
Weakening - finding correct weaker axioms





Weakening - finding correct weaker axioms



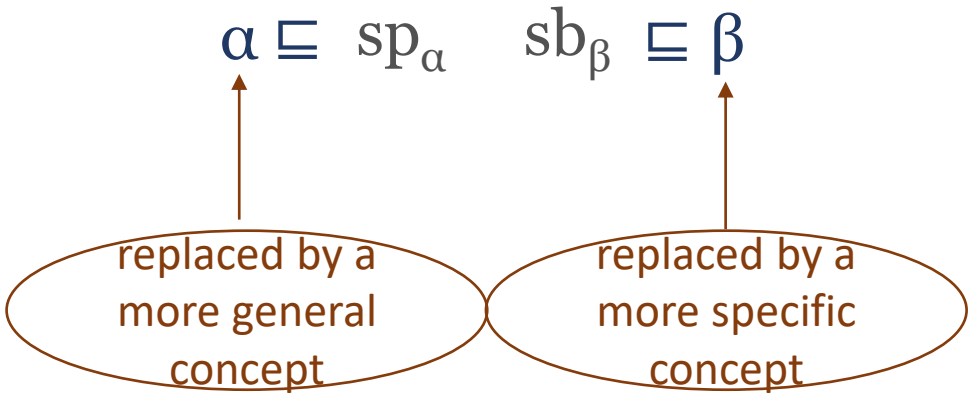


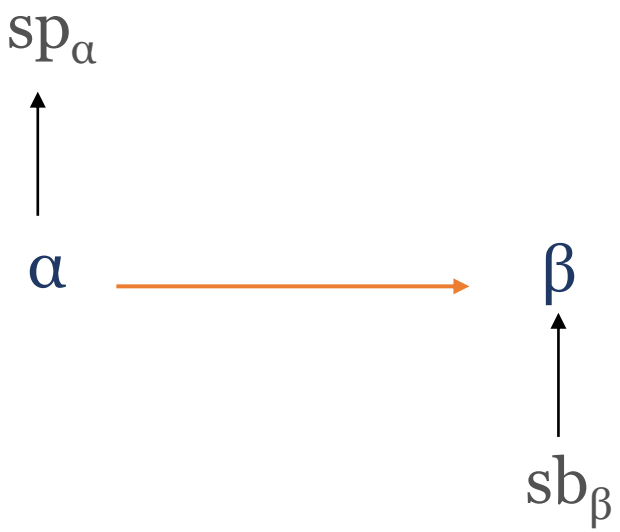
Replace wrong $\alpha \sqsubseteq \beta$

with correct $sb_\alpha \sqsubseteq sp_\beta$

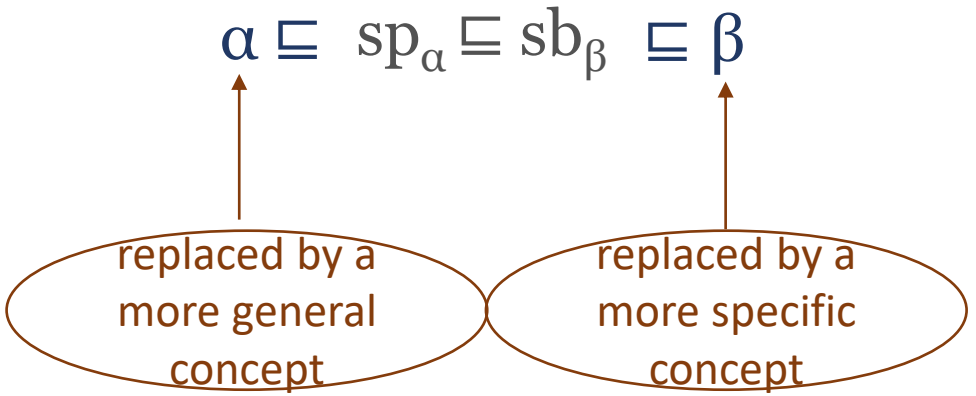
Completing - finding correct stronger axioms

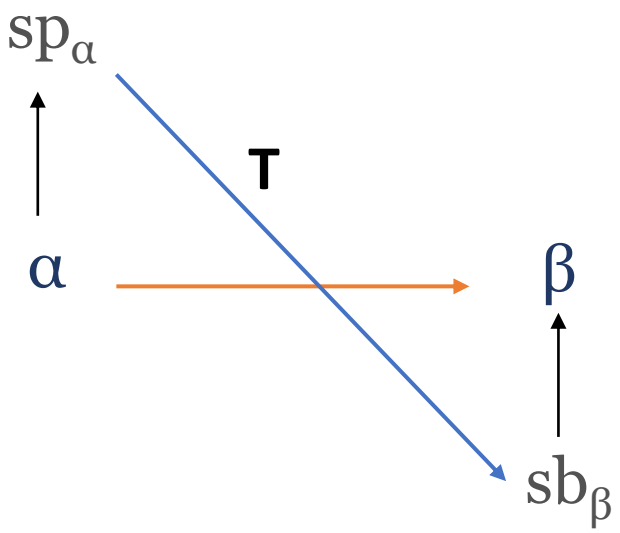
Completing - finding correct stronger axioms





Completing - finding correct stronger axioms





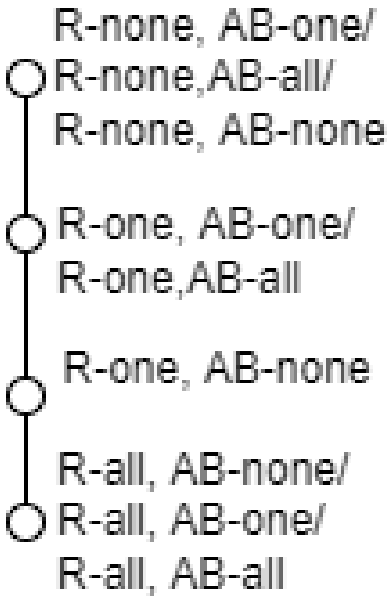
Replace correct $\alpha \sqsubseteq \beta$

with correct $sp_\alpha \sqsubseteq sb_\beta$

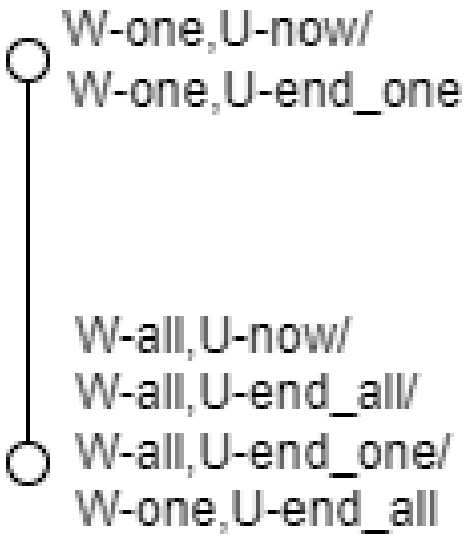
Combining removing, weakening and completing

- Removing before / after weakening / completing
- Completing one at a time and adding new correct axioms as soon as they are found / wait until the end
- Removing one at a time / all at once
- The order of removing axioms (which axiom will be removed first, second.....)

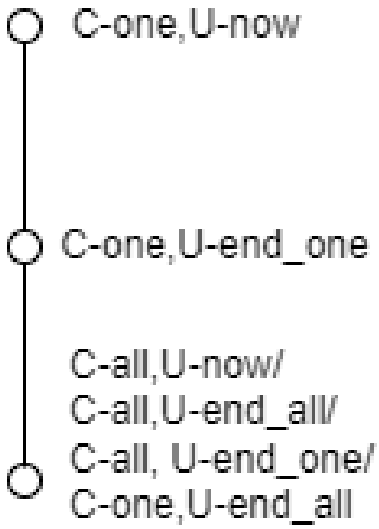
Compare algorithms using the Hasse diagrams



R: removing wrong axioms (one at a time/ all at once/none)
AB: adding back wrong axioms (none/one/all)



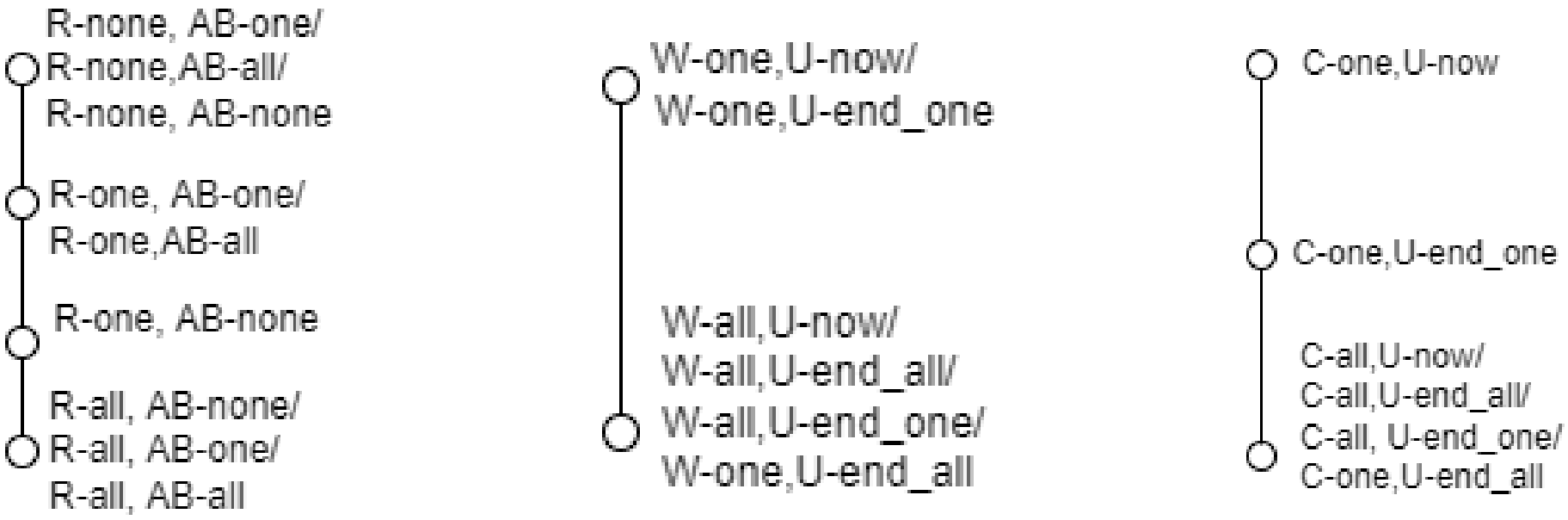
W: weakening (one at a time/all at once)
U: update the ontology



C: completing (one at a time/all at once)
U: update the ontology

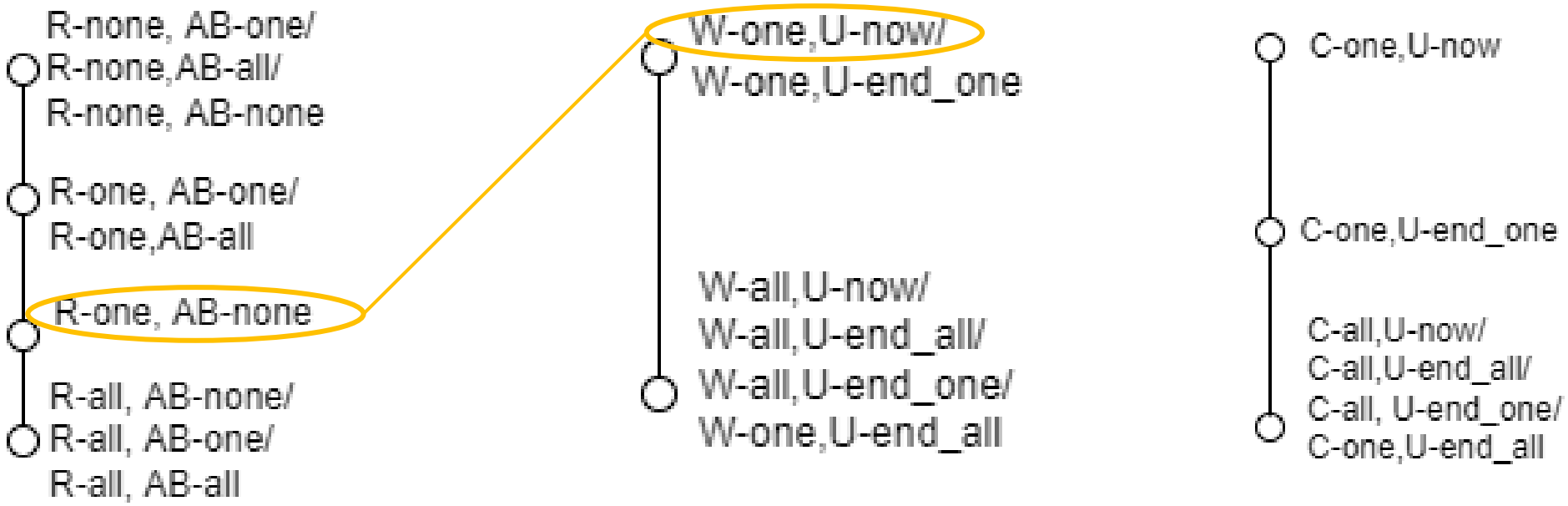
Using operators higher up in the diagrams leads to more complete ontologies and more validation work.

Combinations of removing, weakening and completing

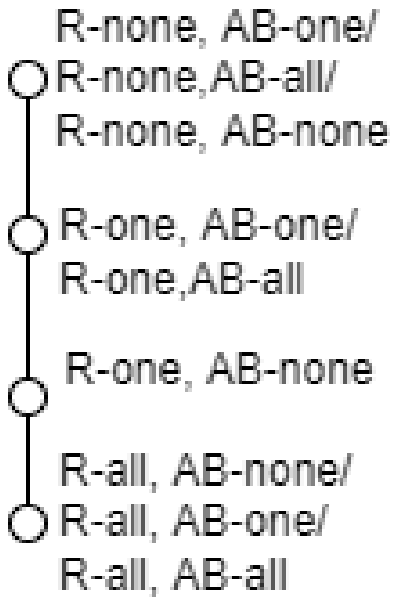


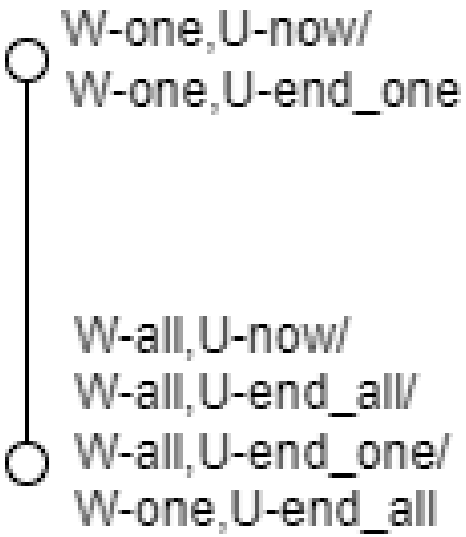
No previous work

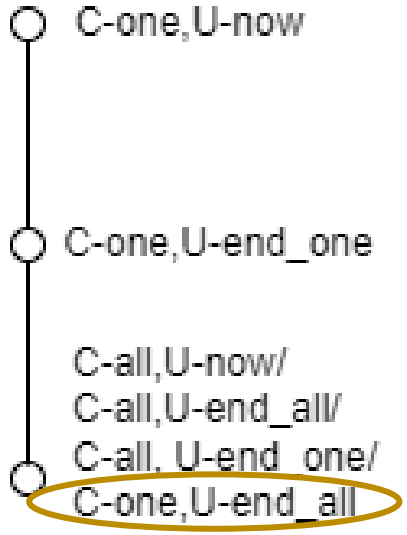
Previous work on removing and weakening



Previous work on completing







Ontology networks

Definition 1. *Let $\mathcal{T}_1$, ...,$\mathcal{T}_n$ be TBoxes representing ontologies $\mathcal{O}_1$, ..., $\mathcal{O}_n$, respectively. For $i, j \in [1..n]$ with $i < j$, let $\mathcal{A}_{ij}$ be an alignment between ontology $\mathcal{O}_i$ and $\mathcal{O}_j$. The network of the ontologies and their alignments is then represented by $\mathcal{T} = (\bigcup_{i=1..n} \mathcal{T}_i) \cup (\bigcup_{i,j=1..n,i<j} \mathcal{A}_{ij})$.*

Problem formulation

An ontology network represented by TBox T

Domain expert

Definition 3. *(Repair) Let* $\mathcal{T} = (\bigcup_{i=1..n} \mathcal{T}_i) \cup (\bigcup_{i,j=1..n,i<j} \mathcal{A}_{ij})$ *represent a network of ontologies* $\mathcal{O}_i$ *represented by TBoxes* $\mathcal{T}_i$*, and their alignments* $\mathcal{A}_{ij}$*. Let* Or *be an oracle that given a TBox axiom returns true or false. Let* W *be a finite set of TBox axioms in* $\mathcal{T}$ *such that* $\forall\, \psi \in W : Or(\psi)$ *= false. Then, a repair for Debug-Problem* $DP(\mathcal{T}, Or, W)$ *is a finite set of TBox axioms* A *such that (i)* $\forall\, \psi \in A : Or(\psi)$ *= true, and (ii)* $\forall\, \psi \in W : (\mathcal{T} \cup A) \setminus W \not\models \psi$.

A repair A is a set of correct axioms that when added to the TBox where the axioms in W are removed will not allow deriving the axioms in W.

W is the set of the wrong axioms that we want to remove from the ontology network.

Repairing Ontology Networks - choices

- The unwanted axioms (W) can appear in the ontologies as well as in the mappings OR only in the mappings.

  → Both cases: use techniques for ontology repair on the Tbox representing the network

Repairing Ontology Networks - choices

- The correct axioms to be added (A) can be axioms in the ontologies as well as mappings.

  → use techniques for ontology repair on the Tbox representing the network

  OR

  The correct axioms to be added (A) can only be mappings.

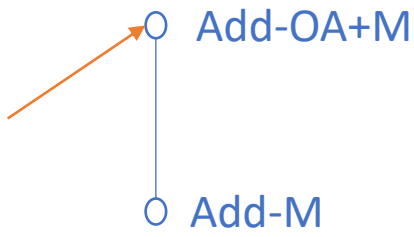
  → adapt techniques for ontology repair on the Tbox representing the network to deal with different status of axioms in the ontologies and mappings

Repairing Ontology Networks - choices

- The correct axioms to be added (A) can be axioms in the ontologies as well as mappings.

  → use techniques for ontology repair on the Tbox representing the network

  More validation work
  Leads to more complete ontology network

OR

The correct axioms to be added (A) can only be mappings.

→ adapt techniques for ontology repair on the Tbox representing the network to deal with different status of axioms in the ontologies and mappings

Repairing Ontology Networks - choices

use the **whole network** when computing the sub- and super-concepts of α and β during weakening or completing axiom $\alpha \sqsubseteq \beta$.

OR

use **only axioms within the respective ontologies** when computing the sub- and super-concepts of α and β during weakening or completing axiom $\alpha \sqsubseteq \beta$.

Repairing Ontology Networks - choices

use the **whole network** when computing the sub- and super-concepts of α and β during weakening or completing axiom $\alpha \sqsubseteq \beta$.

OR

use **only axioms within the respective ontologies** when computing the sub- and super-concepts of α and β during weakening or completing axiom $\alpha \sqsubseteq \beta$.

Conclusion

Alleviate the problem of removing too much information when removing unwanted axioms or mappings from ontology networks using weakening and completing.

Many choices that influence the amount of validation work and the completeness of the ontologies and ontology networks.

Experiments on OAEI conference in short paper; other experiments ongoing

System available soon.