Incoherence as a Basis for Measuring the Quality of Ontology Mappings

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Motivation

- Measuring the quality of an automatically generated alignment M is in most cases based on a comparison with a reference alignment (gold standard)
  - To compute e.g. precision and recall
- **PROBLEMS:**

  (1) Even though an alignment has acceptable precision and recall, internal logical problems might hinder a sensible use

  (2) Reference alignment are often not available
  That's why we need matching systems!
- **IDEA:** Measure logical aspects (incoherence) as a
  - complement to classical evaluation strategies and as
  - alternative to classical measures in absence of a reference alignment

Outline

- Definition: Incoherence of an alignment

An objection and a problem

- The objection: only useful in specific application scenario
- The problem: from {true,false} to [0,1]
  - Impact based measures
  - Measures based on revision effort

Implications

- Truth and Coherence: A simple proposition
  - How to make use of this proposition
- Future Work

Definition: Merged Ontology

Definition (Merged Ontology). The merged ontology of O_1 and O_2 connected via M referred to as $O_1 \cup_{M^t} O_2$ is defined as

$$O_1 \cup_{M^t} O_2 = O_1 \cup O_2 \cup \{t(c) \mid c \in M\}$$

where t is a translation function that maps correspondences to axioms.

Definition (Natural DL-Translation). The natural translation t_n is defined as a function that maps a correspondence to the accordant DL axiom. E.g. $t_n(\langle 1\#e, 2\#e', \sqsubseteq, 0.788 \rangle) = 1\#e \sqsubseteq 2\#e'$

Remark: Choice of the translation function leaves some room for different semantics.

Definition: Incoherence

- Similar to the incoherence of an ontology, incoherence of an alignment can be defined as follows:

Short reminder: An ontology is inconsistent if there exists no model.

An ontology is incoherent iff there exists an unsatisfiable cloncept.

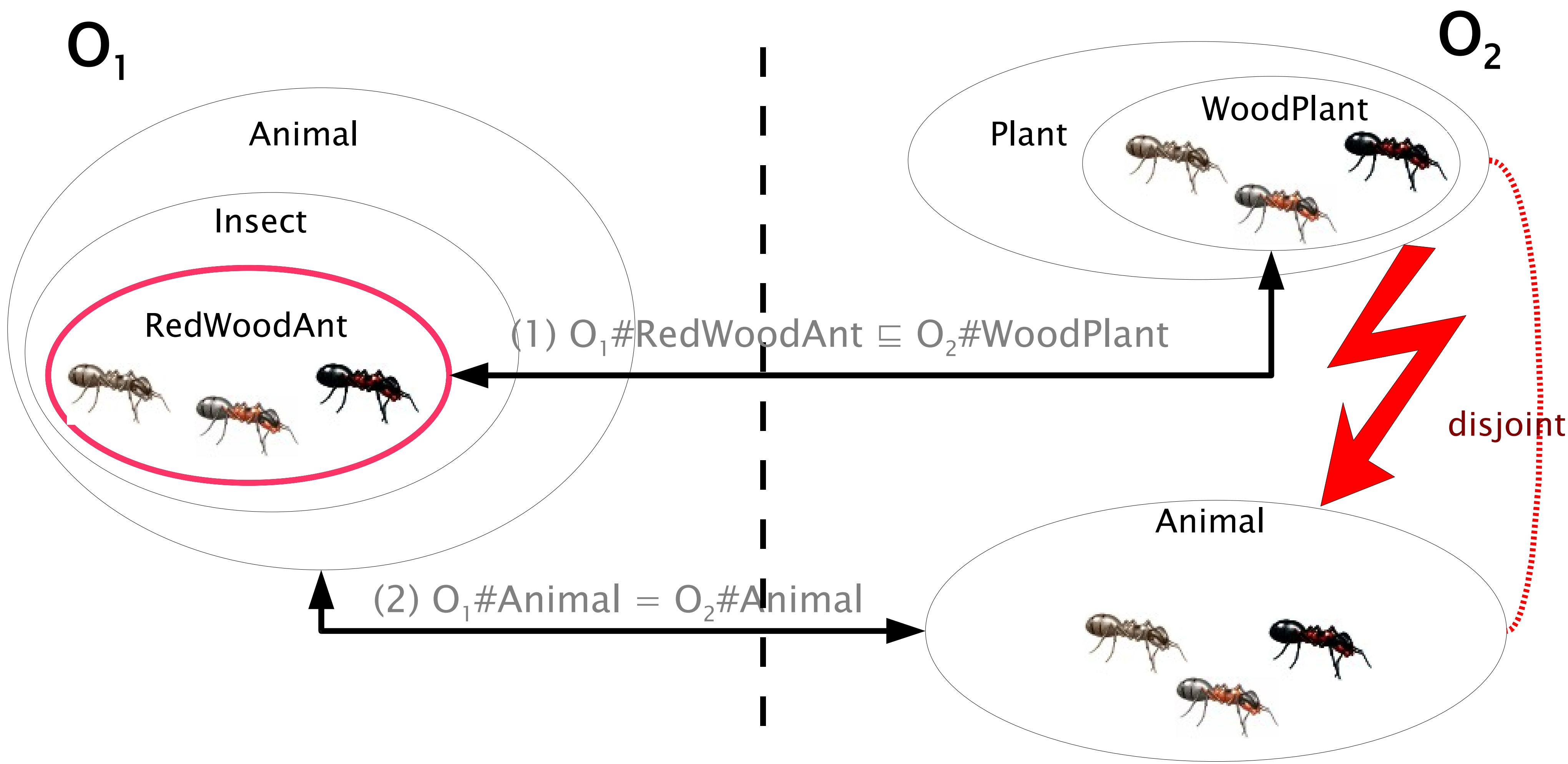
Definition (Incoherency of an alignment). An alignment M between O_1 and O_2 is incoherent due to translation function t iff there exists a concept i#C with $i \in \{1,2\}$ such that:
(1) i#C is satisfiable in O_i and
(2) i#C is unsatisfiable in $O_1 \cup_{M^t} O_2$

Objection: It's only about Merging

- Definition is based on merging two ontologies, but there are many different application scenarios
  - Query answering/rewriting
  - Instance migration
  - ...
- **None of these application scenarios require merging of ontologies!**

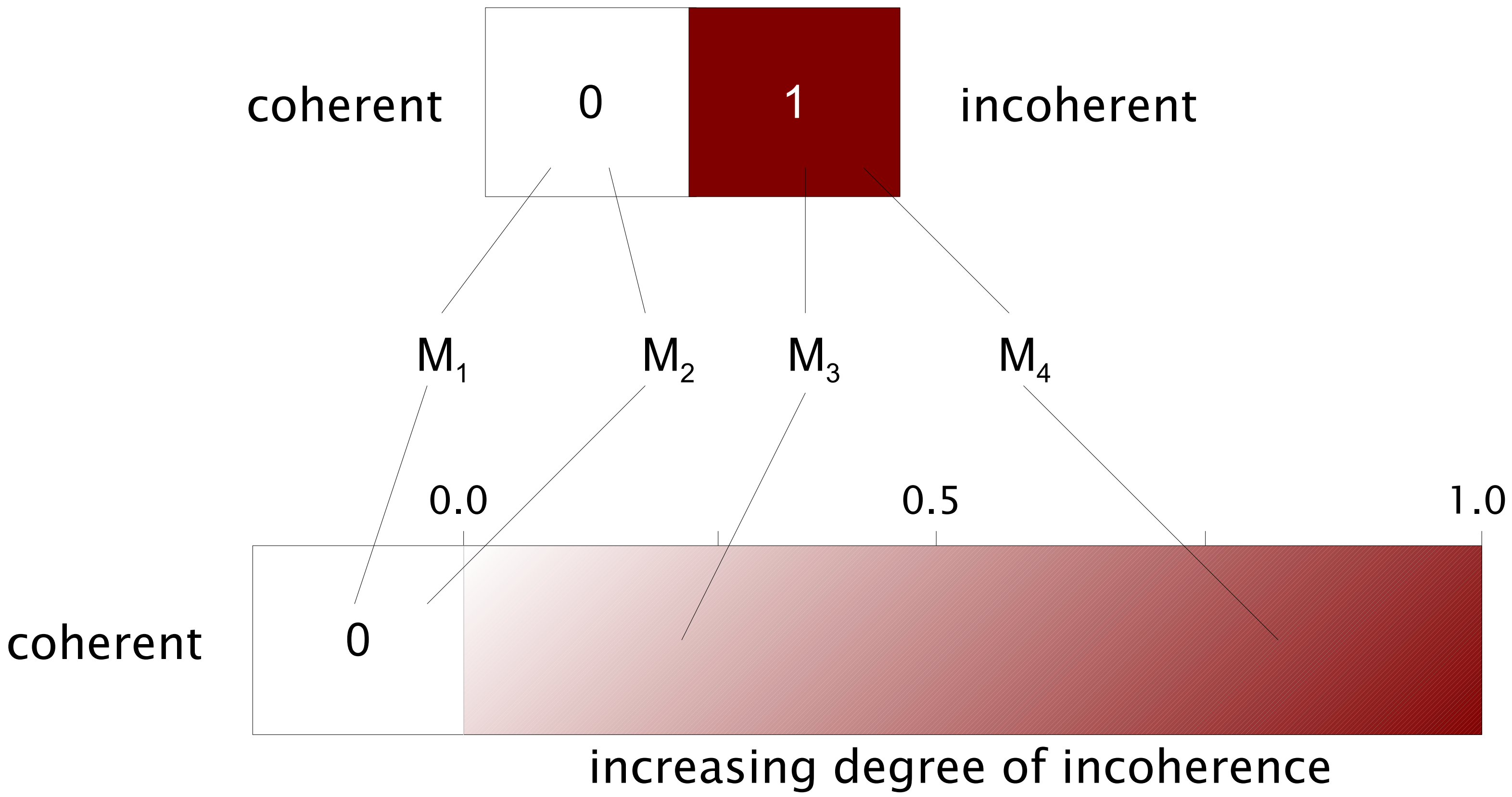
That's true, but incoherences will nevertheless often result in problems in these scenarios!

Counterexample: Instance migration



O_2 is **inconsistent** after instance migration!

Problem: { 0, 1 } -> [0, 1] ?



Impact based measures

(derived from the field of ontology debugging)

- Unsatisfiability Measure. Count the number of unsatisfiable concepts in $O_1 \cup_M O_2$ that have not been unsatisfiable in O_1 resp. O_2
- Concepts becoming unsatisfiable are understood as negative *impact* of the alignment

$$m^t_{sat}(O_1, O_2, M) = \frac{|\text{ Unsatisfiable concepts in } O_1 \cup_M O_2 \text{ satisfiable in } O_1 \text{ resp. } O_2\ |}{|\text{ Concepts satisfiable in } O_1 \text{ and } O_2\ |}$$

- Problem: A merged unsatisfiable concept will make all its subconcepts unsatisfiable.
  - We might only be interested in counting the root unsatisfiable concepts (see paper for *Root Unsatisfiability Measure*)

Measures based on revision effort

(based on our previous work)

- Maximum Cardinality Measure. Count the minimum number of correspondences that have to be removed to arrive at a coherent subset
- The number of correspondences which have to be removed is understood as the *effort of revising* the alignment

$$m^t_{card}(O_1, O_2, M) = \frac{|M - M'|}{|M|}$$

where $M' \subseteq M$ is a coherent alignment and there exists no $M'' \subseteq M$ with $|M''| > |M'|$ such that M'' is coherent.

- Variant of this measure is the *Maximum Trust Measure*
  - Revision effort measured with respect to total of confidence values of removed correspondences (see paper)

Complexity Considerations

- Unsatisfiability Measure
  - Classify the merged ontology and count unsatisfiable concepts
- Maximum Cardinality Measure
  - Requires lots of reasoning in the merged ontology
  - Requires to solve the hitting set problen (**NP-complete!**)
  - First implementation works for alignments between ontologies up to several hundred concepts
  - Will not be directly applicable for large matching problems, but approximation is possible

Truth and Coherence

Proposition (Upper bound for precision). Let M be an alignment and let R be a reference alignment between O_1 and O_2. Further let R be coherent due to translation function t. Then we have precision(M, R) $\leq$ 1 – $m^t_{card}(O_1, O_2, M)$.

M* = M ∩ R (by definition)

different way to write it

$$precision(\mathcal{M},\mathcal{R}) = \frac{|\mathcal{M}\cap\mathcal{R}|}{|\mathcal{M}|} = \frac{|\mathcal{M}^*|}{|\mathcal{M}|} \leq \frac{|\mathcal{M}'|}{|\mathcal{M}|} = 1 - \frac{|\mathcal{M}-\mathcal{M}'|}{|\mathcal{M}|} = 1 - m^t_{card}(\mathcal{O}_1,\mathcal{O}_2,\mathcal{M})$$

definition of precision

definition of max-card-measure

M*is a coherent subset of M and M' is the largest coherent subset of M

Note: There is an small error in the equation presented in the paper, don't be confused.

How to use this proposition?

- Example 1: Several matchers have been applied on the same problem
  - Each matcher generated an alignment. Which one should we choose?
  - Upper-Bound Proposition cannot be used to decide this question!
  - BUT: It might help us to decide **which one we should not choose**!
- Example 2: A matcher is applied to a matching problem of an new/ unknown domain (experience missing), that requires a precision of e.g. at least 0.9
  - Which threshold should be used?
  - Compute upper bound for precision stepwise increasing threshold, provides useful information about threshold

Future Work

- Experiments
  - How useful is the upper bound of precision?
  - Different coherence characteristic for different matching systems?
  - ...
- Is there a interdependence between coherence and recall?
- Support different „distributed semantics“ (=different translation functions), for example DDL
  - In principle possible as long as chosen semantics provides a translation into DL
- Support matching datatypeproperties on objectproperties
  - Natural translation does not support this, we already implemented a weaker translation

Thanks for your attention,
questions?