On fixing semantic alignment evaluation measures

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Problems of precision and recall

These two alignments are equivalent:

- $A_3 \sqsubseteq B_5$ and $A_3 \sqsupseteq B_5 \iff A_3 \equiv B_5$
- $A_3 \equiv B_5 \mid= A_{10} \equiv B_5$

But with the classical model: Precision $= 0$ and Recall $= 0$!
Semantic properties

A solution: proposing measures respecting semantic properties

[Euzenat, 2007]

\[
\begin{align*}
A_r & \models A_e \Rightarrow \text{Precision} = 1 \\
& \text{max-correctness}
\end{align*}
\]

\[
\begin{align*}
A_e & \models A_r \Rightarrow \text{Recall} = 1 \\
& \text{max-completeness}
\end{align*}
\]

\[
\begin{align*}
A_r & \equiv A_e \Leftrightarrow \text{Precision} = 1 \text{ and Recall} = 1 \\
& \text{definiteness}
\end{align*}
\]
1 - Ideal precision and recall

Replace $A_e$ and $A_r$ by their semantic closure $Cn(A_e)$ and $Cn(A_r)$

**Semantic closure** $Cn(\ldots) = \text{set of correspondences deduced from alignment and ontologies}$

$$P_i = \frac{|Cn(A_e) \cap Cn(A_r)|}{|Cn(A_e)|}$$

$$R_i = \frac{|Cn(A_e) \cap Cn(A_r)|}{|Cn(A_r)|}$$

+ The three properties are satisfied

− Not always defined: $Cn(\ldots)$ could be infinite
2 - Semantic precision and recall

Use both alignments and their semantic closure

\[ P_s = \frac{|A_e \cap Cn(A_r)|}{|A_e|} \]
\[ R_s = \frac{|Cn(A_e) \cap A_r|}{|A_r|} \]

+ The three properties are satisfied
+ Always defined (contrarily to ideal precision and recall)
− But they still have some drawbacks...
Limitations of semantic precision and recall

Semantic precision and recall have **two drawbacks**: 

1. Two semantically equivalent alignments could have different precision values
2. An alignment can have null precision and recall even if its semantic closure intersects those of the reference alignment
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Two other properties that a perfect semantic model must satisfies : 

1. the **semantic-equality** property : 
   \[ Cn(A_{e1}) = Cn(A_{e2}) \Rightarrow \begin{cases} 
   P(A_{e1}, A_r) = P(A_{e2}, A_r) \\
   R(A_{e1}, A_r) = R(A_{e2}, A_r) 
\end{cases} \]

2. the **overlapping-positiveness** property: 
   \[ P(A_e, A_r) = 0 \text{ and } R(A_e, A_r) = 0 \text{ iff } Cn(A_e) \cap Cn(A_r) = Cn(\emptyset) \]
Limitations of semantic precision and recall

1\textsuperscript{st} problem: Two semantically equivalent alignments could have different precision values

Case 1: problem occurring at alignment level:
a correspondence could be split into several correspondances

\[ A_{e_1} \equiv A_{e_2} \text{ but: } 
\begin{align*}
P_s(A_{e_1}, A_r) &= 1/2 \\
P_s(A_{e_2}, A_r) &= 2/3
\end{align*} \]
1\textsuperscript{st} problem: Two semantically equivalent alignments could have different precision values

Case 1: problem occurring at alignment level:
a correspondence could be split into several correspondances

\[ A_{e1} \equiv A_{e2} \text{ but:} \]
\[ P_s(A_{e1}, A_r) = \frac{1}{2} \]
\[ P_s(A_{e2}, A_r) = \frac{2}{3} \]

A solution: normalize alignments
Syntactic normalisation of alignments

**Goal of normalization**: allows measures to satisfy the semantic-equality property when reasoning only at alignment level.

1. Use **alignment relation algebra**, i.e., write each alignment relation as a disjunction of elementary relations [Euzenat, 2008]
   - Elementary relations: \( \Gamma = \{ \sqsubseteq, \sqsupseteq, \equiv, \notin, \perp \} \)
   - Operators: meet (\( \cup \)), join (\( \cap \)), compose(\( . \)), inverse(\( -1 \))

2. A pair of entities or formulas appear at most once in each alignment

**Examples**:

- \( x \sqsubseteq y \) becomes \( x\{\sqsubseteq, \equiv\}y \)
- \( x \sqsubseteq y \) and \( x \sqsupseteq y \) become \( x\{\sqsubseteq, \equiv\} \cap \{\sqsupseteq, \equiv\}y \), i.e., \( x\{\equiv\}y \)
Limitations of semantic precision and recall

1\textsuperscript{st} problem: Two semantically equivalent alignments could have different precision values.

Case 2: problem occurring at ontological level (redundancy)

\[
P_s(A_{e1}, A_r) = \frac{1}{2}
\]
\[
P_s(A_{e2}, A_r) = \frac{2}{3}
\]
Limitations of semantic precision and recall

1\textsuperscript{st} problem: Two semantically equivalent alignments could have different precision values

Case 2: problem occurring at ontological level (redundancy)

\[ x \equiv y \equiv x' \]

\[ u \equiv v \equiv u' \]

\[ A_{e_1} \]

\[ x \equiv y \equiv x' \equiv u \equiv v \equiv u' \]

\[ A_{r} \]

\[ \Lambda-bounded \ precision \ and \ recall \]

\[ P_s(A_{e_1}, A_r) = 1/2 \]

\[ P_s(A_{e_2}, A_r) = 2/3 \]

A solution: \( \Lambda \)-bounded precision and recall
**Idea:** Restricting semantic closures to a set of alignments for enabling ideal precision and recall measures

Classical evaluation model:

\[
P = \frac{|A_e \cap A_r|}{|A_e|} \quad R = \frac{|A_e \cap A_r|}{|A_r|}
\]
Λ-bounded precision and recall

**Idea:** Restricting semantic closures to a set of alignments for enabling ideal precision and recall measures

Ideal evaluation model (not always defined):

\[ P_i = \frac{|Cn(A_e) \cap Cn(A_r)|}{|Cn(A_e)|} \quad R_i = \frac{|Cn(A_e) \cap Cn(A_r)|}{|Cn(A_r)|} \]
**Idea:** Restricting semantic closures to a set of alignments for enabling ideal precision and recall measures

**Bounded evaluation model (always defined):**

\[
P_i = \frac{|Cn(A_e) \cap Cn(A_r) \cap \Lambda|}{|Cn(A_e) \cap \Lambda|}
\]

\[
R_i = \frac{|Cn(A_e) \cap Cn(A_r) \cap \Lambda|}{|Cn(A_r) \cap \Lambda|}
\]
Limitations of semantic precision and recall

2nd problem: the semantic closures of $A_e$ and $A_r$ intersects but $A_e$ has null semantic precision and recall values.

\[ A_e \models x \sqsubseteq y \]
\[ A_r \models x \sqsubseteq y \]

\[ Cn(A_e) \cap Cn(A_r) = \{x \sqsubseteq y\} \]

but $P_s(A_e, A_r) = 0$ and $R_s(A_e, A_r) = 0$
**Idea:** introducing semantics in relaxed precision and recall [Ehrig and Euzenat, 2005]

- Relaxed measures are function of proximity functions $\sigma$ between individual correspondences.
- New $\sigma$ measures based on relation algebra

Example on $\sigma$ precision: $\sigma_{\text{prec}}(x \cup u\{\sqsubseteq, \equiv\} y, x\{\equiv\} y)$?

\[
\sigma_{\text{prec}} = \frac{|\{\sqsubseteq, \equiv\}|}{|\{\sqsubseteq, \equiv\}|} \cap \frac{|\{\sqsubseteq, \equiv\}|}{|\{\sqsubseteq, \equiv\}|} = 0.5
\]
Conclusion

- Identified specific problems remaining with semantic precision and recall
- Expressed them as properties
  - semantic-equality
  - overlapping-positiveness
- Defined two specific measures for countering them
  - Λ-bounded measures: do not provide absolute values
  - Relaxed semantic measures: properties are respected only at correspondence level
- Work to integrate them in a common framework
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Marc Ehrig and Jérôme Euzenat.
Relaxed precision and recall for ontology matching.

Jérôme Euzenat.
Semantic precision and recall for ontology alignment evaluation.

Jérôme Euzenat.
Algebras of ontology alignment relations.