On fixing semantic alignment evaluation measures

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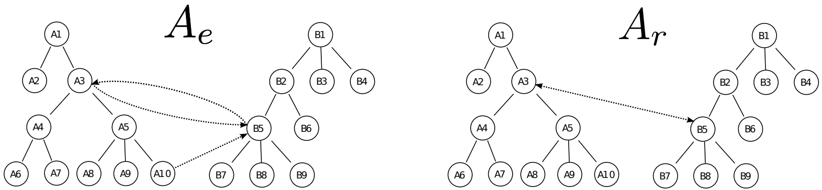
Problems of precision and recall

These two alignments are equivalent :

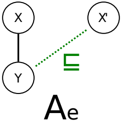
- $A_3 \sqsubseteq B_5$ and $A_3 \sqsupseteq B_5 \Leftrightarrow A_3 \equiv B_5$
- $A_3 \equiv B_5 \models A_{10} \equiv B_5$

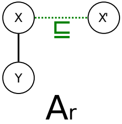


But with the classical model: *Precision* $= 0$ and *Recall* $= 0$!

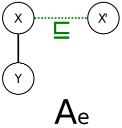
Semantic properties

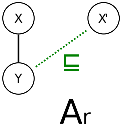
A solution : proposing measures respecting semantic properties [Euzenat, 2007]



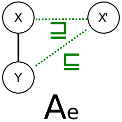


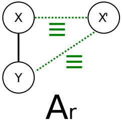
$A_r \models A_e \Rightarrow Precision = 1$
max-correctness





$A_e \models A_r \Rightarrow Recall = 1$
max-completeness





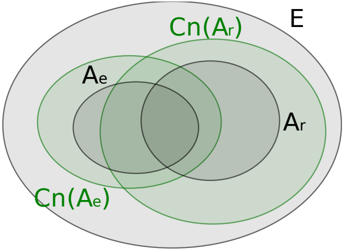
$A_r \equiv A_e \Leftrightarrow Precision = 1$ and $Recall = 1$
definiteness

1 - Ideal precision and recall

Replace A_e and A_r by their semantic closure $Cn(A_e)$ and $Cn(A_r)$
Semantic closure $Cn(\ldots)$ = set of correspondences deduced from alignment and ontologies

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

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



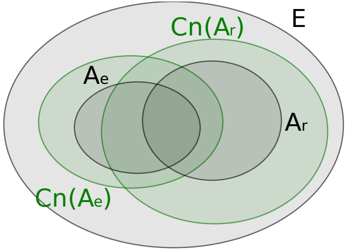
+ The three properties are satisfied
− Not always defined : $Cn(\ldots)$ could be infinite

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 :

$$Cn(A_{e_1}) = Cn(A_{e_2}) \Rightarrow \begin{cases} P(A_{e_1}, A_r) = P(A_{e_2}, A_r) \\ R(A_{e_1}, A_r) = R(A_{e_2}, A_r) \end{cases}$$

2. the **overlapping-positiveness** property:

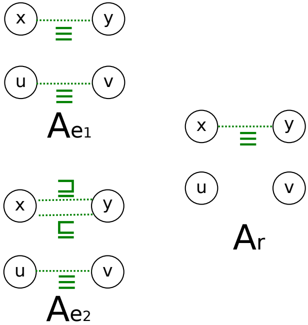
$P(A_e, A_r) = 0$ and $R(A_e, A_r) = 0$ iff $Cn(A_e) \cap Cn(A_r) = Cn(\emptyset)$

Limitations of semantic precision and recall

1st problem: Two semantically equivalent alignments could have different precision values

Case 1: problem occuring at alignment level:

a correspondence could be split into several correspondances



$A_{e_1} \equiv A_{e_2}$ but:

$P_s(A_{e_1}, A_r) = 1/2$

$P_s(A_{e_2}, A_r) = 2/3$

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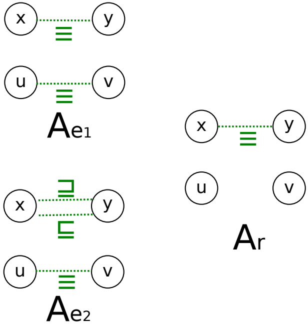

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A solution: normalize alignments

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: $\Gamma = \{\sqsubset, \sqsupset, \equiv, \between, \perp\}$
   - Operators: meet ($\cup$), join ($\cap$), compose($.$), inverse($^{-1}$)
2. A pair of entities or formulas appear at most once in each alignment

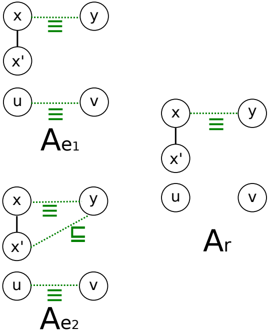
Examples :

- $x \sqsubseteq y$ becomes $x\{\sqsubset, \equiv\}y$
- $x \sqsubseteq y$ and $x \sqsupseteq y$ become $x\{\sqsubset, \equiv\} \cap \{\sqsupset, \equiv\}y$, i.e., $x\{\equiv\}y$

Limitations of semantic precision and recall

1st problem: Two semantically equivalent alignments could have different precision values

Case 2: problem occuring at ontological level (redundancy)



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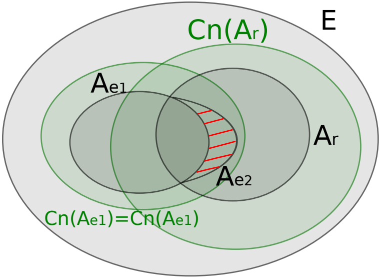

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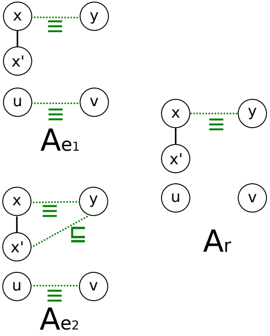

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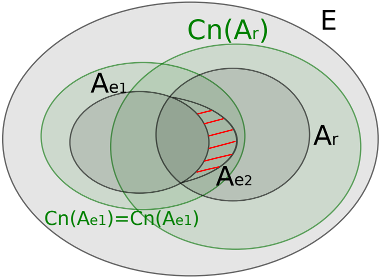
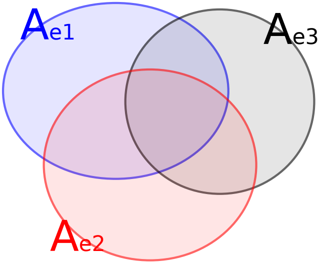


A solution: Λ-bounded precision and recall

Λ-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

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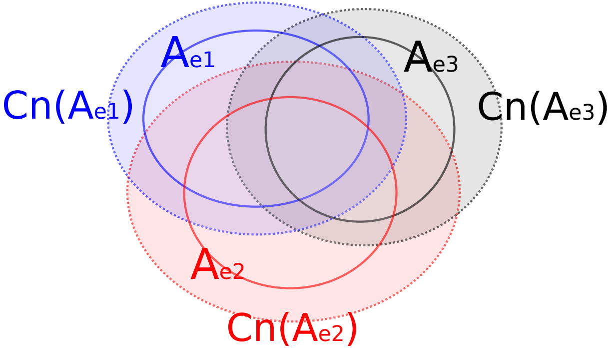
Ideal evaluation model (not always defined):

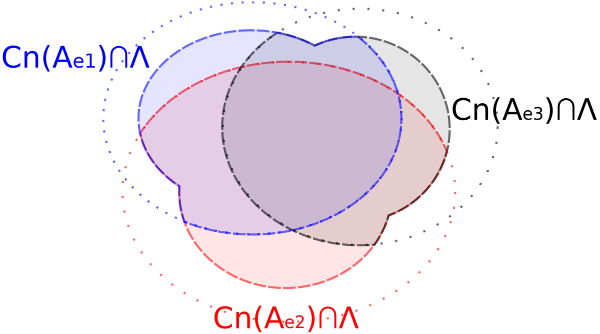


$$P_i = \frac{|Cn(A_e) \cap Cn(A_r)|}{|Cn(A_e)|} \quad R_i = \frac{|Cn(A_e) \cap Cn(A_r)|}{|Cn(A_r)|}$$

Λ-bounded precision and recall

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

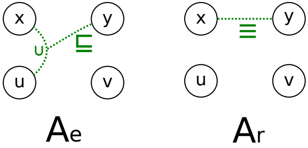
Bounded evaluation model (always defined):



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

Limitations of semantic precision and recall

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



$$\left.\begin{array}{l} A_e \models x \sqsubseteq y \\ A_r \models x \sqsubseteq y \end{array}\right\} Cn(A_e) \cap Cn(A_r) = \{x \sqsubseteq y\}$$

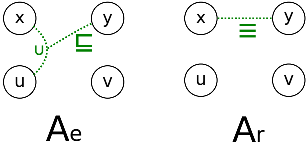
$$\text{but } P_s(A_e, A_r) = 0 \text{ and } R_s(A_e, A_r) = 0$$

Semantic relaxed precision and recall

Idea: introducing semantics in relaxed precision and recall [Ehrig and Euzenat, 2005]

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

Example on σ precision: $\sigma_{prec}(x \cup u\{\sqsubset, \equiv\}y, x\{\equiv\}y)$?



A_e states $x \cup u\{\sqsubset, \equiv\}y$

O_1, O_2, and $x\{\equiv\}y \models x \cup u\{\sqsupset, \equiv\}y$

$$\sigma_{prec} = \frac{|\{\sqsubset, \equiv\} \cap \{\sqsupset, \equiv\}|}{|\{\sqsupset, \equiv\}|} = 0.5$$

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
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