Towards Principles for Ontology Integration
or
How to Keep the Cake and Eat it

Özgür L. Özçep

WSV, Department for Informatics, MIN Faculty
University of Hamburg

FOIS 2008
Saarbrücken, 02.11.08
Bibliographic Ontologies

Example

\[ O_1 = \{ \text{Articles are published only in journals.} \]  
\[ \text{Journals and proceedings are disjoint.} \]  
\[ \text{EntXY is published in the proceedings of FOIS.} \} \]

\[ O_2 = \{ \text{Articles are published in journals or proceedings.} \]  
\[ \text{EntXY is an article.} \} \]

Example (formal)

\[ O_1 = \{ \text{Art} \sqsubseteq \forall \text{publ}. \text{Journ}, \text{Journ} \sqsubseteq \neg \text{Proc}, \]  
\[ \text{publ}(\text{entXY}, \text{procFOIS}), \text{Proc(\text{procFOIS})} \} \]

\[ O_2 = \{ \text{Art} \sqsubseteq \forall \text{publ}.(\text{Journ} \sqcup \text{Proc}), \text{Art(\text{entXY})} \} \]

Terminological conflict: Ambiguity in the common vocabulary
Integrating Ontologies

- Ontology integration (Flouris et al. (2008))
  - Purpose: Fuse knowledge from ontologies covering similar domains
  - Input: Two ontologies covering similar domains
  - Output: New ontology

- Name-space dissociation: Article $\rightsquigarrow \{Article_1, Article_2\}$

- Semantic mappings:
  \[
  \begin{array}{ccc}
  O_1\text{-term} & \text{Type of mapping} & O_2\text{-term} \\
  Article_1 & \text{is subsumed by} & Article_2 \\
  Journal_1 & \text{is equivalent with} & Journal_2 \\
  \end{array}
  \]

- Bridging Axioms; e.g. $Article_1 \sqsubseteq Article_2$

- Semiautomatic construction of semantic mappings

- Adequacy criteria for ontology integration
1 Motivation

2 Adequacy Criteria

3 Reinterpretation Operators

4 Conclusion
Adequacy Criteria Formalized by Postulates

- Ontology integration result $O_1 \circ O_2$
- Postulates relative to an integration scenario
  - $O_2$ to be integrated into $O_1$
  - Common vocabulary for $O_1, O_2$
  - Disjoint internal vocabulary for $O_1$
  - $O_1$ and $O_2$ cover similar domains
  - $O_1$ and $O_2$ are well developed
First Group of Postulates ('Classical')

1.1 If $O_1$ and $O'_1$ are equivalent and if they use the same internal symbols, then $O_1 \circ O_2$ and $O'_1 \circ O_2$ are equivalent.

(left extensionality)

1.2 If $O_2$ and $O'_2$ are equivalent, then $O_1 \circ O_2$ and $O_1 \circ O'_2$ are equivalent.

(right extensionality)

2 In case of consistency $O_1 \circ O_2$ is equivalent with $O_1 \cup O_2$.

(vacuity)

3.1 $O_1 \circ O_2$ contains first ontology $O_1$

(monotony)

3.2 $O_1 \circ O_2$ contains second ontology $O_2$

(success)

- Need for generalization of monotony and success
- Two operationalizable subclasses (type 1 & type 2)
Second Group of Postulates (’Adaption’)

4.1 $O_1$ is preserved as substitution variant $O_1\sigma$ in $O_1 \circ O_2$.
   (left preservation)

4.2 $O_2$ is preserved as substitution variant $O_2\sigma$ in $O_1 \circ O_2$.
   (right preservation)

5.1 $O_1$ is recoverable from $O_1 \circ O_2$ by some substitution.
   (left substitution recovery)

5.2 $O_2$ is recoverable from $O_1 \circ O_2$ by some substitution.
   (right substitution recovery)

6 If $O_1$ and $O_2$ are reinterpretation compatible, then $O_1 \circ O_2$ is consistent.
   (weakened consistency)

- Left preservation and left subst. recovery generalize monotony
- Right preservation and right subst. recovery generalize success
1 Motivation

2 Adequacy Criteria

3 Reinterpretation Operators

4 Conclusion
Decoupled Ontologies

- Construction pattern
  \[ O_1 \circ O_2 = \text{decoupled ontologies} \cup \text{bridging axioms} \]
- Two types of decoupling
  - Preservation of \( O_1 \), internalization of \( O_2 \): \( O_1 \cup O_2\sigma_S \) (type 1)
  - Adoption of \( O_2 \), internalization of \( O_1 \): \( O_2 \cup O_1\sigma_S \) (type 2)
- Consistent and minimal decoupling
  \[ MR(O_1, O_2) = \text{Set of minimal symbol sets with consistent decoupling} \]
- Compromise decoupling symbol set for selection function \( \gamma_1 \)
  \[ S^* = \bigcup \gamma_1(MR(O_1, O_2)) \]
**Example**

\[
O_1 = \{ \text{Art} \sqsubseteq \forall \text{publ}. \text{Journ}, \text{Journ} \sqsubseteq \neg \text{Proc}, \\
\text{publ}(\text{entXY}, \text{procFOIS}), \text{Proc}(\text{procFOIS}) \} \\
O_2 = \{ \text{Art} \sqsubseteq \forall \text{publ}. (\text{Journ} \sqcup \text{Proc}), \text{Art}(\text{entXY}) \}
\]

- \( MR(O_1, O_2) = \{ \{ \text{Art} \}, \{ \text{entXY} \} \} \)
- **Scenario 1:**
  \( \text{Art}_2 \) is strictly broader than \( \text{Art}_1 \)
- **Scenario 2:**
  \( \text{entXY}_1 \) denotes a publication in the proceedings of FOIS
  \( \text{entXY}_2 \) denotes follow-up journal paper
Bridging Axioms

- Construction pattern
  \( O_1 \circ O_2 = \text{decoupled ontologies} \cup \text{bridging axioms} \)

- Hypotheses without knowledge of ontologies

  \[
  A(S^*, \sigma) = \{ s \sqsubseteq s', s' \sqsubseteq s \mid s \in S^*_{\text{ConcRole}} \} \cup \{ s = s' \mid s \in S^*_{\text{const}} \}
  \]

- Refinement of hypotheses knowing decoupled ontologies

  \[
  MB(S^*, \sigma, O_1 \cup O_2 \sigma) = \text{Inclusion maximal subsets of } A(S^*, \sigma) \text{ compatible with } O_1 \cup O_2 \sigma
  \]

- Compromise-set of refined bridging axioms

  \[
  BA_1(S^*) = \bigcap \gamma_2 MB(S^*, \sigma_{S^*}, O_1 \cup O_2 \sigma_{S^*}) \quad \text{(type 1)}
  \]

  \[
  BA_2(S^*) = \bigcap \gamma_2 MB(S^*, \sigma_{S^*}, O_2 \cup O_1 \sigma_{S^*}) \quad \text{(type 2)}
  \]
## Reinterpretation Operators

### Definition

**Weak type-1 and type-2 operators based on**  \( \gamma = (\gamma_1, \gamma_2) \)

\[
\begin{align*}
O_1 \otimes_1 \gamma_1 O_2 &= O_1 \cup O_2 \sigma S^* \cup BA_1(S^*) \\
O_1 \otimes_2 \gamma_2 O_2 &= O_2 \cup O_1 \sigma S^* \cup BA_2(S^*)
\end{align*}
\]

- decoupled ontologies
- consistency preserving bridging axioms

### Observation

1. \( \otimes_1 \gamma \) fulfills all postulates but success
2. \( \otimes_2 \gamma \) fulfills all postulates but monotony
Integration Result for Bibliography Example

Example

\[ O_1 = \{ \text{Art} \sqsubseteq \forall \text{publ. Journ}, \text{Journ} \sqsubseteq \neg \text{Proc}, \text{publ(}\text{entXY, procFOIS})\}, \text{Proc(}\text{procFOIS})\} \]
\[ O_2 = \{ \text{Art} \sqsubseteq \forall \text{publ. (Journ} \sqsubseteq \text{Proc}), \text{Art(}\text{entXY})\} \]

- \( \gamma_1(MR(O_1, O_2)) = \{ \{\text{Art}\} \} \)
- \( S^* = \{ \text{Art} \} \)
- \( A(\{\text{Art}\}, \sigma_{S^*}) = \{ \text{Art} \sqsubseteq \text{Art}', \text{Art} \sqsubseteq \text{Art}' \} \)

\[ O_1 \otimes_1 O_2 = O_1 \cup O_2[\text{Art/Art}'] \cup \{ \text{Art} \sqsubseteq \text{Art}' \} \]
\[ O_1 \otimes_2 O_2 = O_2 \cup O_1[\text{Art/Art}'] \cup \{ \text{Art}' \sqsubseteq \text{Art} \} \]
Conclusion

- Postulates in the line of belief revision
- Operationalizing postulates (type 1 and type 2)
- Caveat: No postulate demanding bridging axioms
- Non-uniform substitution cannot guarantee fulfillment of preservation and recovery postulates
- Stronger reinterpretation operators
Thank you for your attention!