WIMS'12 International Conference on Web Intelligence, Mining and Semantics, June 13-15, 2012, Craiova, Romania

# A-BOA: Basics, Applications, Theoretical Foundations, and Demonstration

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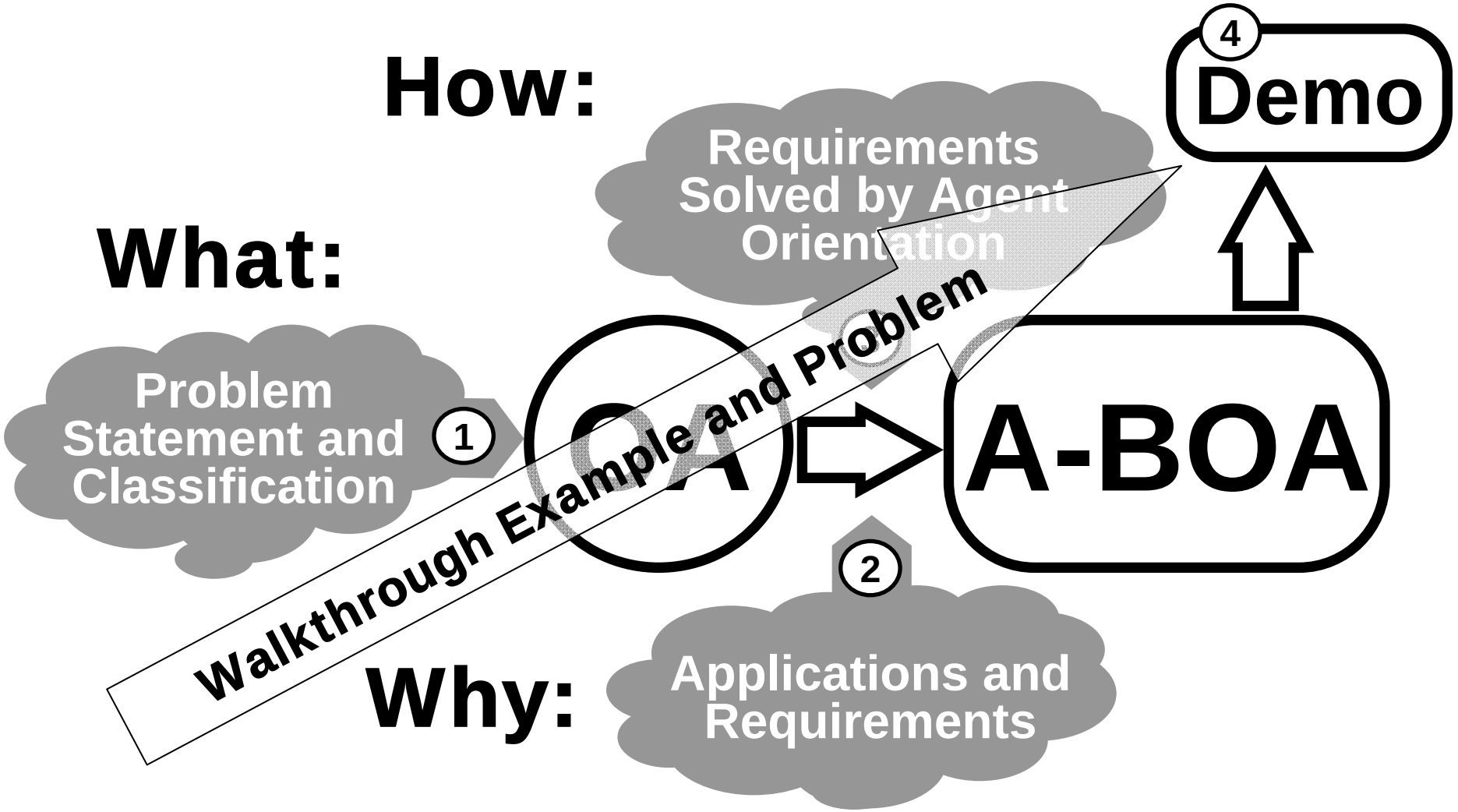
# Components, IPR, Sponsors

- **A-BOA Tutorial** has been developed at the **Intelligent Systems Research Group** affiliated at the **Department of IT** of **Zaporozhye National University**
- A Theoretical Framework for Agent Negotiations on **Semantic Contexts and Propositional Substitutions** has been developed in **RACING project**
- **Structural Difference Discovery Engine** (**SDDE**) agent-based software tool has been developed by **Maxim Davidovsky** as a part of his PhD Project
- **Instance Migration Engine** (**IME**) software tool have been developed in **Performance Simulation Initiative** (**PSI**) project funded by **Cadence Design Systems GmbH**
  - All rights with respect to **IME** are retained by **Cadence Design Systems GmbH**
- **A-BOA Wiki** containing support materials for A-BOA Tutorial – a **Semantic MediaWiki** based resource
- Questions and answers are supported using live contextual collaboration in **LiveNetLife**
- **A-BOA tutorial** at WIMS 2012 is sponsored in part by **DataArt**

# Plan

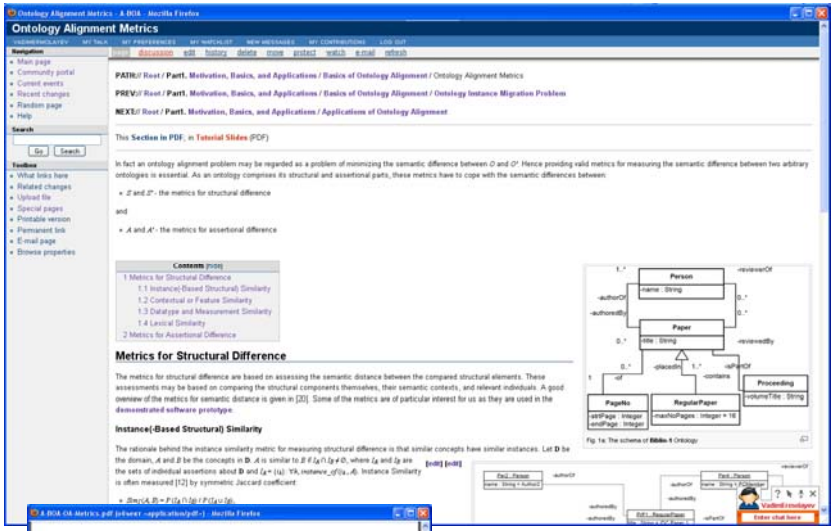
- **Walkthrough Problem and Example**
  - **Ontology Instance Migration Problem**
  - Simple **`Biblio`** ontologies
- **Part 1: Motivation, Basics, and Applications**
  - **What** is **ontology alignment**? and
  - **Why** is the technology needed?
- **Part 2: Theoretical Foundations and Demonstration**
  - Use of agent-based approaches for building ontology alignments - answering "**how**" questions
  - **Demo** of Agent-Based solution for Ontology Instance Migration Problem
- Round the World in 80 … min
  - Some important things will be just mentioned
  - Tasties are left for individual exploration

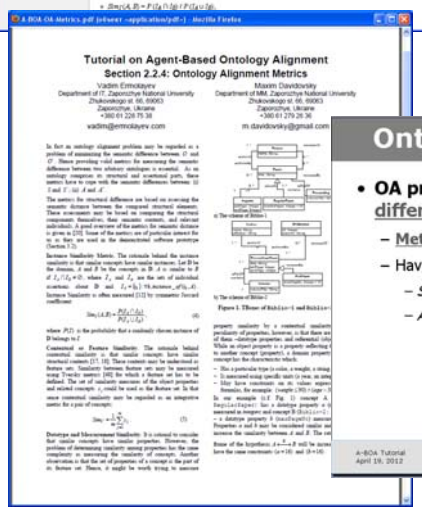
# Workflow

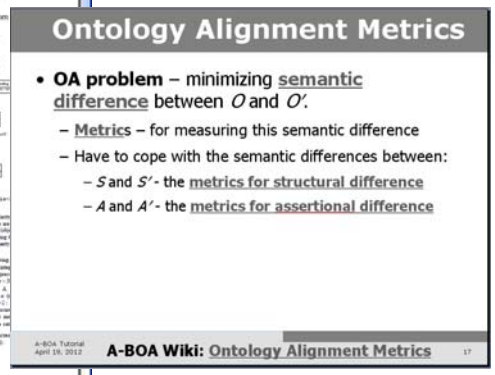

How:
What:
Why:
4
Demo
Requirements Solved by Agent Orientation
Problem Statement and Classification
1
OA
A-BOA
Walkthrough Example and Problem
2
Applications and Requirements

# Support and Questions

- A-BOA Wiki
  - http://isrg.kit.znu.edu.ua/a-boa/
  - Wiki articles to follow the Tutorial
  - Sections in printer friendly form (PDF) – not yet there
  - Tutorial slides corresponding to Wiki articles – not yet there
- Questions and answers anytime
  - Focused: LiveNetLife chat
    - No connection ☹
  - Broader: Oral or Wiki discussion pages
  - After the Tutorial: @Wiki discussion pages answered by e-mail



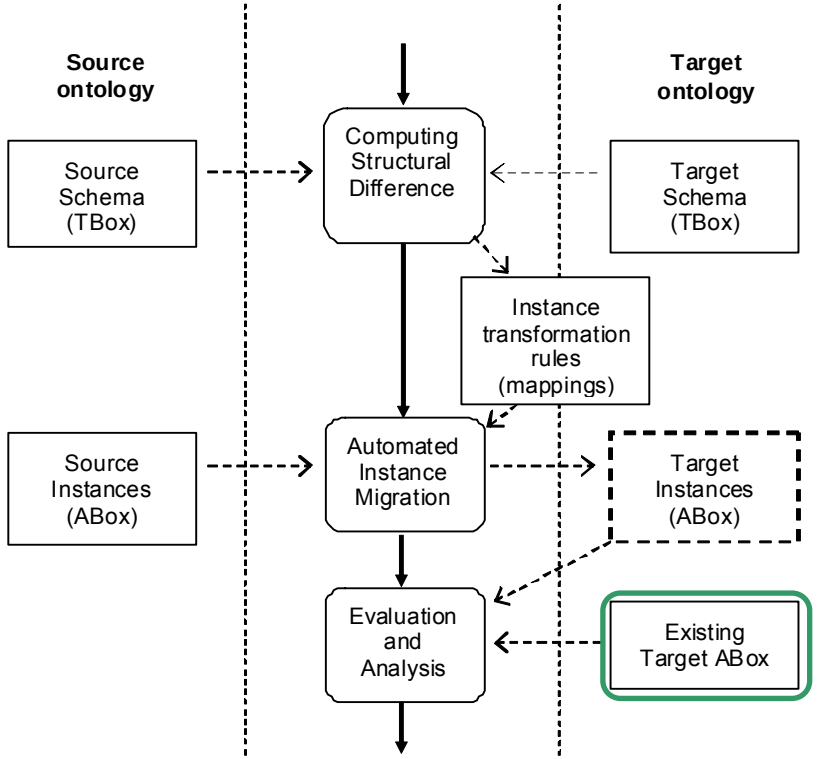



# A Walkthrough Problem and Example

**A-BOA Wiki:** Walkthrough Problem and Example

# Ontology Instance Migration

- When is IM needed:
  - OE – new version developed
    - Schema Changed
    - Instances to be transformed …
  - System Interoperability/Integration
- Simplification:
  - We have the result – for teaching purposes
- How?
  - Different techniques
  - We will show one in the Demo

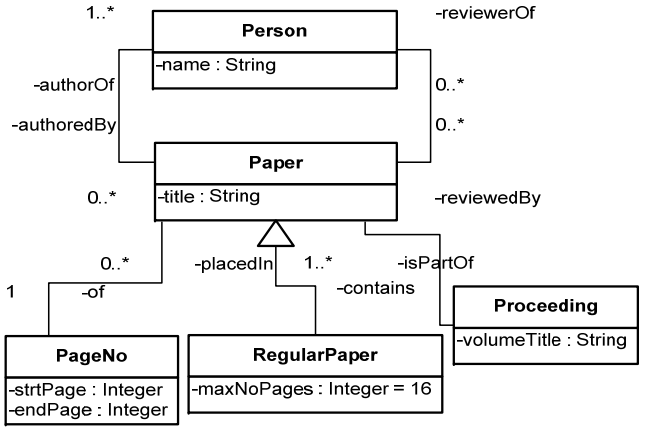


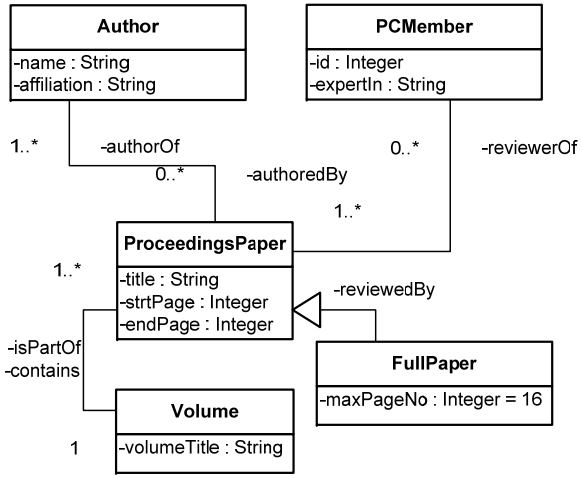
# Example: Biblio Schemas

- Biblio **ontologies** – a VERY simple example
  - Different kowledge representations for the same body of knowledge about conference papers
- Real ontologies are:
  - MORE complex (schema)
  - MUCH MORE bulky (instances)
  - E.g. [10]
- Imagine:
  - Biblio-2 is for a conference management system
  - Biblio-1 is the model for a paper repository at a publisher
  - Papers accepted for a conference have to appear in the publisher's paper repository
  - Publisher's information about the page limits has to be communicated to the conference management system
- Biblio-1 and Biblio-2 have to be aligned

[10] Davidovsky, M., Ermolayev, V., Tolok, V.: Instance Migration Between Ontologies having Structural Differences. International Journal on Artificial Intelligence Tools. Vol. 20, No. 6 (2011) 1127–1156

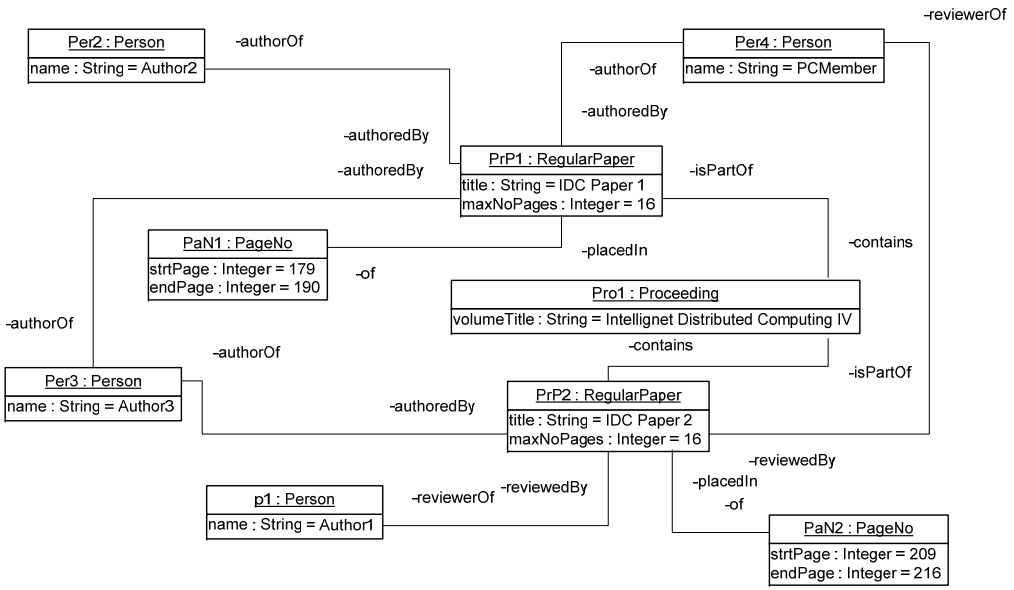
Biblio-1



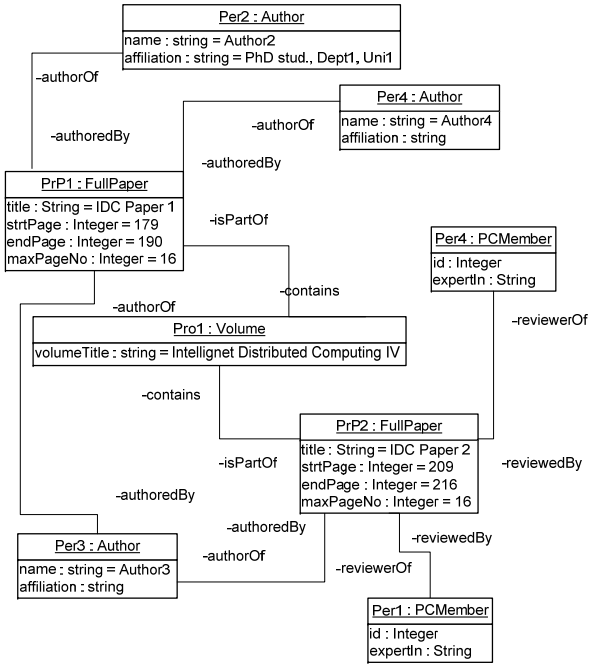




Biblio-2

# Example: Biblio Instances




a) The instances of `Biblio-1`




b) The instances of `Biblio-2`

The result we have to achieve

# Part 1:
# Motivation, Basics, and Applications

**A-BOA Wiki:** Motivation, Basics, and Applications

# Part 1: Structure

- Ontology Alignment in general and at a relatively basic level:
  - Outlines the **motivation** to study OA
  - **WHAT: Denotes** OA and puts the problem into the context of the other knowledge harmonization and integration problems
  - **WHY:** Analyses the **application**s that require aligning knowledge representations, summarizes requirements

# Section 1.1: Motivation to Study Ontology Alignment

*"I find it critical to remember that every ontology is a treaty – a social agreement – among people with some common motive in sharing."*

**Tom Gruber** in the Interview for the Official Quarterly Bulletin of AIS Special Interest Group on Semantic Web and Information Systems, Vol. 1, Issue 3, 2004.

# Are Interpretations the Same?

- In row 1?
- In row 20?

# Motivation - Abstract

- The World is multi-faceted and **polysemic**
  => Many different views or interpretations by different individuals or groups
- Reflected in different **knowledge representations** **of the same** reality
- We do many things across several facets or even across **subject domain**s
  => Several knowledge representations (ontologies) have to be harmonized or aligned
  – To enable proper **communication**, **coordination** or information processing

# Motivation - Utility

- An **alignment** is essentially:
  - A **result** of applying a set of formal transformations to a knowledge representation – to its schema and individuals
- An alignment allows:
  - Interpreting knowledge that is external to the interpreter
  - In the same way the interpreter views his own knowledge schema and assertions
- E.g., given that a bi-directional alignment of `Biblio-2` to `Biblio-1` exists:
  - A publisher (`Biblio-1`) – seamlessly imports the assertions about the accepted papers to its production repository
  - A conference organizer (`Biblio-2`) – gets publisher's information about publication constraints, like page limits
  - Common motive in sharing is satisfied
- Many kinds of important applications require OA

# Section 1.2: Basics of Ontology Alignment

**A-BOA Wiki:** Basics of Ontology Alignment

# Section 1.2: Structure

- **Basic Definitions and Generic Problem Statement**
  - Denotes an **ontology**, **ontology schema**, **assertional part**, **mapping**, and **ontology matching process**
  - Based on these a definition of **ontology alignment** is given
- **Classification of Ontology Alignment Problems**
  - Several features of participating ontologies
  - The span of the aligned ontology elements across ontologies
- **Ontology Instance Migration Problem**
  - A **walkthrough problem** with a little bit of more formal detail
- **Ontology Alignment Metrics**
  - Not all of them, but those important for solving Ontology Instance Migration Problem – structural and assertional

# Section 1.2.1: Basic Definitions and Generic Problem Statement

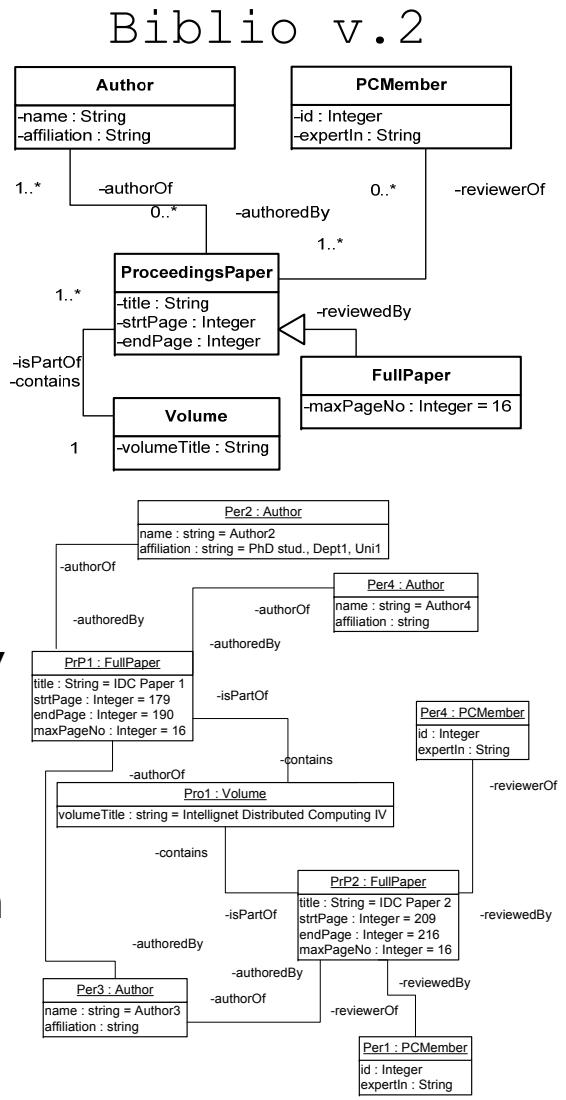
**A-BOA Wiki:** Basic Definitions and Generic Problem Statement

# Basic Definitions: Ontology

- **Ontology** (c.f. [22]) – a tuple:

$$O = (C, P, I, T, V, \leq, \perp, \in, =)$$

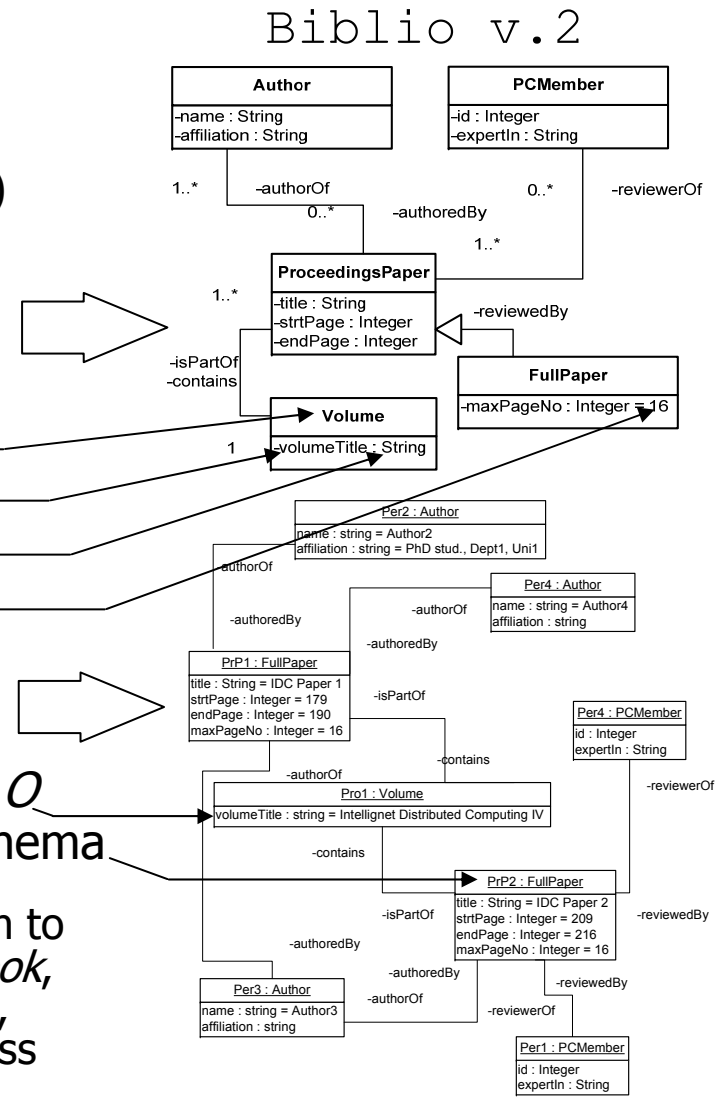
- where the sets $C$, $P$, $I$, $T$, $V$ are pair-wise disjoint and:
  - $C$ – set of **concepts** (or classes)
  - $P$ – set of **properties** (object and datatype properties)
  - $I$ – set of **individuals** (or instances)
  - $T$ – set of **datatypes**
  - $V$ – set of **values**
  - $\leq$ – reflexive, anti-symmetric, and transitive relation on $(C \times C) \cup (P \times P) \cup (T \times T)$ called **specialization**, (**subsumption**) that form partial orders on:
    - $C$ – concept hierarchy; and
    - $P$ – property hierarchy
  - $\perp$ – irreflexive and symmetric relation on $(C \times C) \cup (P \times P) \cup (T \times T)$ called **exclusion**
  - $\in$ – relation over $(I \times C) \cup (I \times V)$ called **instantiation**
  - $=$ – relation over $I \cup P \cup (I \times V)$ called **assignment**




[22] Euzenat J. and Shvaiko P. 2007. *Ontology Matching*, Berlin Heidelberg (DE), Springer-Verlag

# Basic Definitions: TBox and ABox

- An **ontology** (c.f. [36]) *O* comprises:
  - Schema *S* and its assertional part *A*
  - *O* = (*S*, *A*); *S* = (*C*, *P*, *T*, ...); *A* = (*I*, *V*, ...)
- **Ontology schema** *S* (or a terminological component, TBox) contains statements describing:
  - The concepts from *C* of *O*,
  - The properties from *P* of those *C*
  - The datatypes *T* for the elements of *P*
  - The axioms over the elements of *C*, *P*, *T*
- The **set of individuals** *A* (or assertional component, ABox) contains:
  - Ground statements about the instances of *O*
  - Attribution of the instances of *O* to the schema




[36] Nardi D. and Brachman R. J. 2007. An Introduction to Description Logics. In *The Description Logic Handbook*, F. Baader, D. Calvanese, D. L. McGuinness, D. Nardi, P. F. Patel-Schneider, Eds. Cambridge University Press New York, NY, USA

# Basic Definitions: Mapping

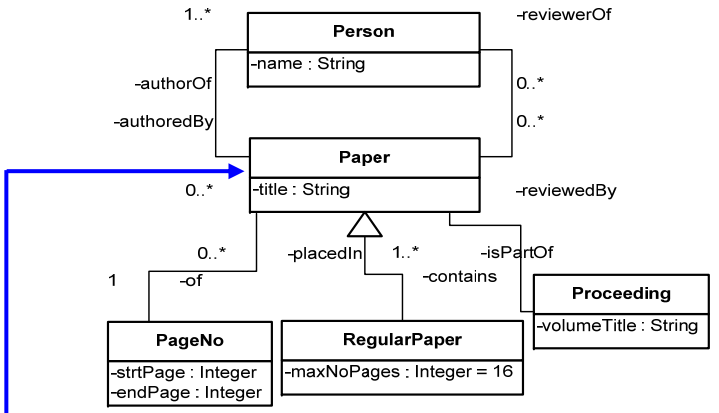
- A **Mapping** (or a **Mapping Rule**, c.f. [22]) is a tuple

$$m = (e, e', \mathbf{R}, n),$$

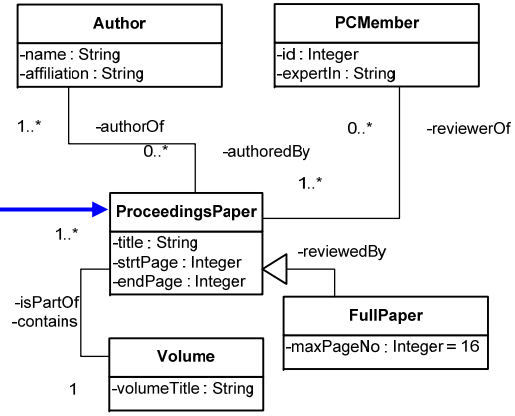
where:

- $e$, $e'$ are the elements of $C$, $P$, $I$, $T$, $V$ of the respective ontologies $O$ and $O'$
- **R** is a set of relations
- $n$ is a confidence value (typically in the range of [0, 1])

TBox: Biblio v.1




$m = (\text{Paper} \in C, \text{ProceedingsPaper} \in C', \Leftrightarrow, 1)$

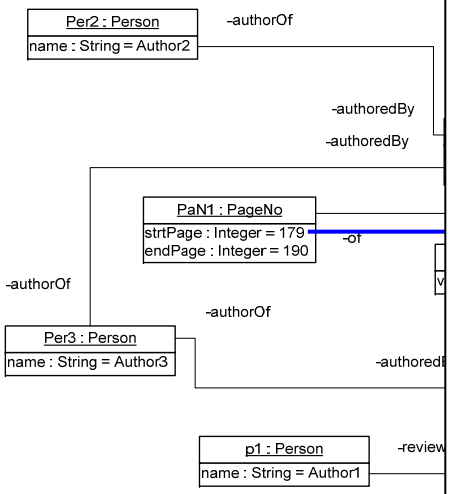



TBox: Biblio v.2


[22] Euzenat J. and Shvaiko P. 2007. *Ontology Matching*, Berlin Heidelberg (DE), Springer-Verlag

# Basic Definitions: Mapping

- A more complex Mapping:
  - *m* = (<PaN1.strtPage=179> ∈ *V*, <PrP1.strtPage> ∈ *V'*, *migrate* , 1)



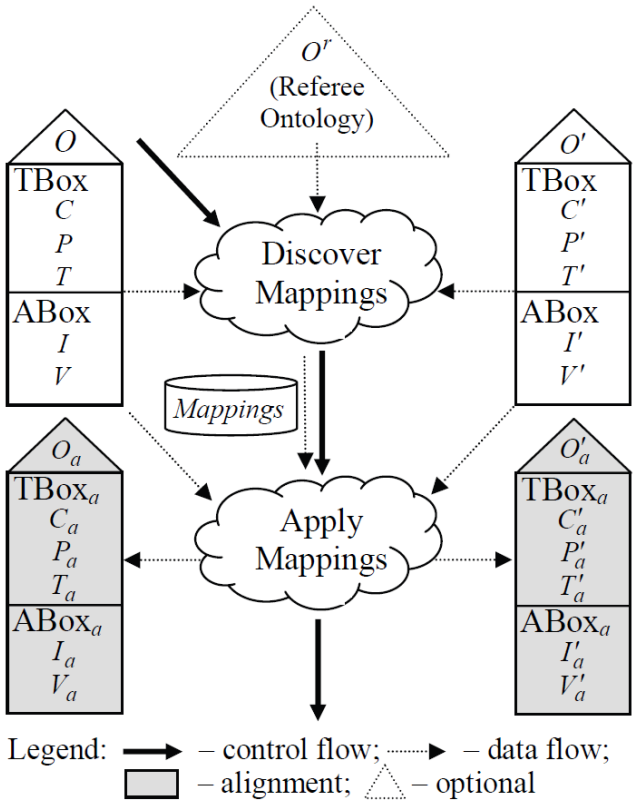

a) The instances of Biblio-1

```
...
<concept concept_name="http://www.somewhere.com/ontologies/2011/1/
                       BibliographicOntology_1.owl#RegularPaper">
    <rename>FullPaper</rename>
    <removeProperty>maxNoPages</removeProperty>
    <addProperty data_type="integer" value="16">maxPageNo</addProperty>
</concept>
<concept concept_name="http://www.somewhere.com/ontologies/2011/1/
                       BibliographicOntology_1.owl#Paper">
    <rename>ProceedingsPaper</rename>
    <addProperty>strtPage
        <condition>
            <valueFrom domain="PageNo" property="pageRange">%sup condition%</valueFrom>
            <supplementaryCondition type="relation" name="PageNo-of-Paper"
             range="ProceedingPaper">%current individual%</supplementaryCondition>
        </condition>
     </addProperty>
     <addProperty>endPage
        <condition>
             <valueFrom domain="PageNo" property="pageRange">%sup condition%</valueFrom>
             <supplementaryCondition type="relation" name="PageNo-of-Paper"
             range="ProceedingPaper">%current individual%</supplementaryCondition>
                       </condition>
             </addProperty>
             ...
</concept>
...
```

# Basic Defs: Ontology Matching

- **Ontology matching** (c.f. [22]) – a **process** of **discovering** the **mappings** between the elements *e* and *e′* of different ontologies *O* and *O′*

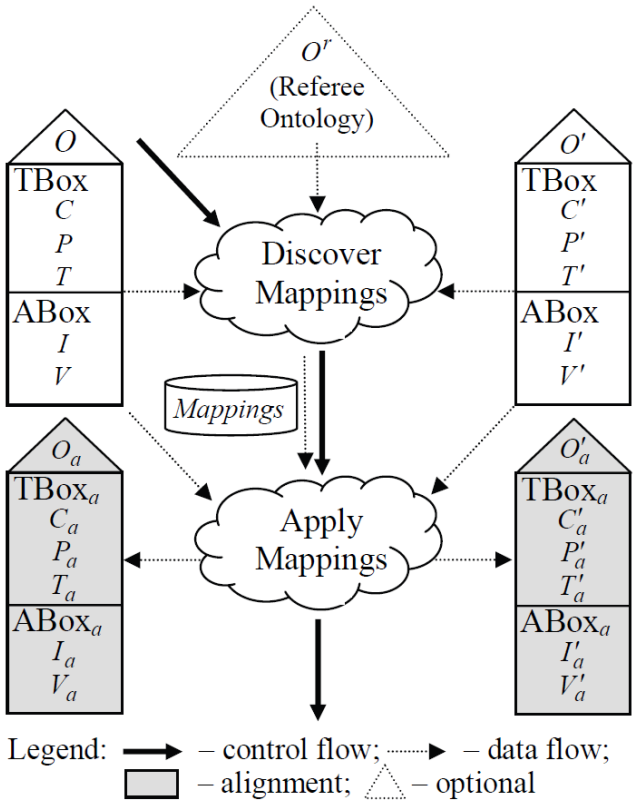
- A generic ontology matching process
  - **Discover Mappings**




[22] Euzenat J. and Shvaiko P. 2007. *Ontology Matching*, Berlin Heidelberg (DE), Springer-Verlag

# Basic Defs: Ontology Alignment

- **Ontology Alignment**
  – the **result** of **applying** the discovered set of **mappings** to the respective **ontologies**
- A Generic Ontology Alignment Problem
  – Build alignments following a **Generic Ontology Alignment process**
    – **Discover Mappings**
    – **Apply Mappings**
    – Could be interweaved
    – Result: **Alignment** – shaded gray
- Several kinds of OA problems …



# Section 1.2.2: Classification of Ontology Alignment Problems

**A-BOA Wiki:** Classification of Ontology Alignment Problems

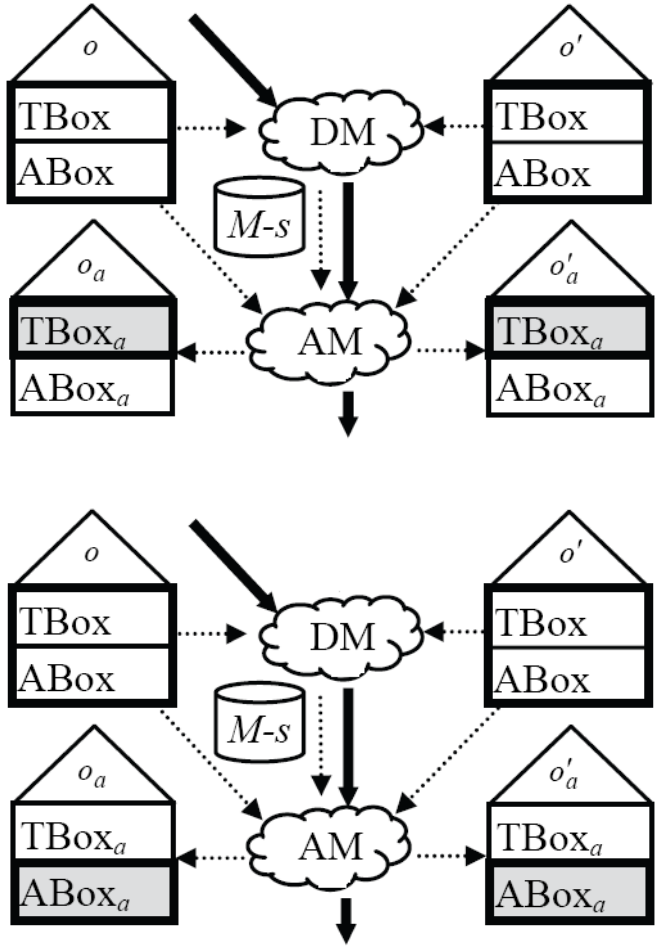
# **Classification:** Dimensions

- Let:
  - $O = (C, P, I, T, V, ...)$, $e$ belongs to $O$
  - $O' = (C', P', I', T', V', ...)$, $e'$ belongs to $O'$
- **Ontology Alignment Problems** are classified based on:
  - The features of participating ontologies $O$, $O'$; and
  - The span of $e$, $e'$ across $C$, $P$, $I$, $T$, $V$-s of $O$, $O'$
- Classification dimensions:
  - **Span** – **C**omplete, **S**tructural, or **A**ssertional alignment
  - **Dynamicity** – **S**tatic versus **D**ynamic aligned ontologies
  - **Direction** – **B**i-directional versus **U**ni-directional alignment
  - **Distribution** – Fully **D**istributed settings versus the use of a **C**entral referee ontology
- Additionally we differentiate:
  - **One-Shot** versus **Iterative** Alignment approaches

| C\|S\|A |
|---|
| S\|D |
| B\|U |
| D\|C |

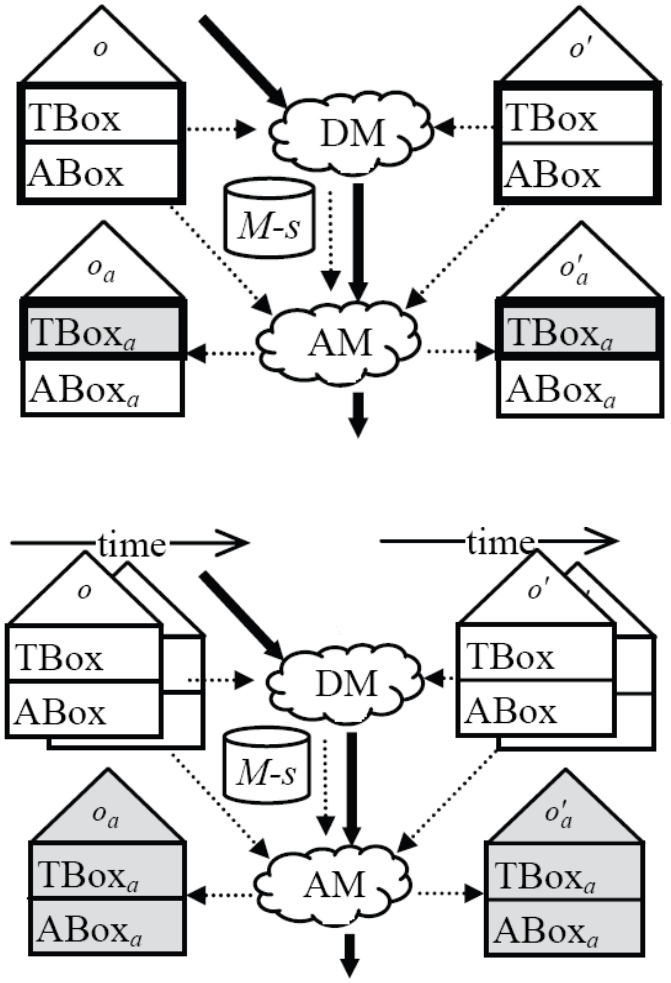
# Classification: Span

- By the **span** of aligned elements Ontology Alignment Problems are classified as:
  - **Complete** - if alignments span across TBox-es and ABox-es of *O*, *O′*
  - **Structural** - if alignments cover only the TBox-es of *O*, *O′*
  - **Assertional** - if alignments cover only the ABox-es of *O*, *O′*



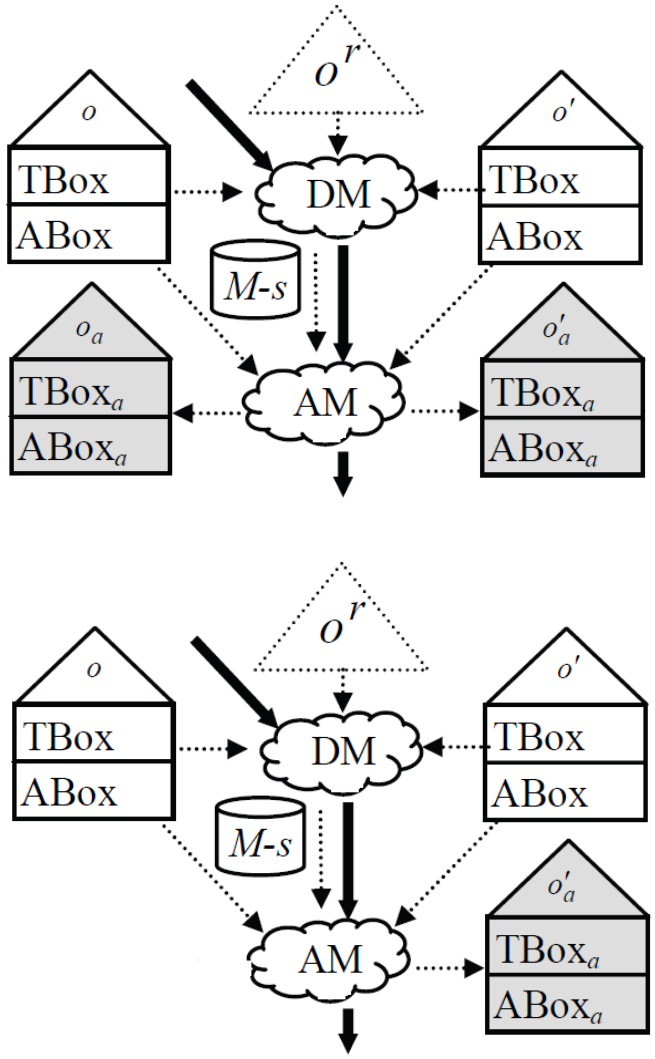
# Classification: Dynamicity

- Wrt **dynamicity** of aligned elements Ontology Alignment Problems are classified as:
  - **Static** – *e*, *e′* of *O*, *O′* are considered unchanged
    - At least for the time of alignment
  - **Dynamic** – *e* and *e′* may be changed while DM or AM phase is executed
    - Potential invalidity of mappings and alignments
    - Additional revision may be required



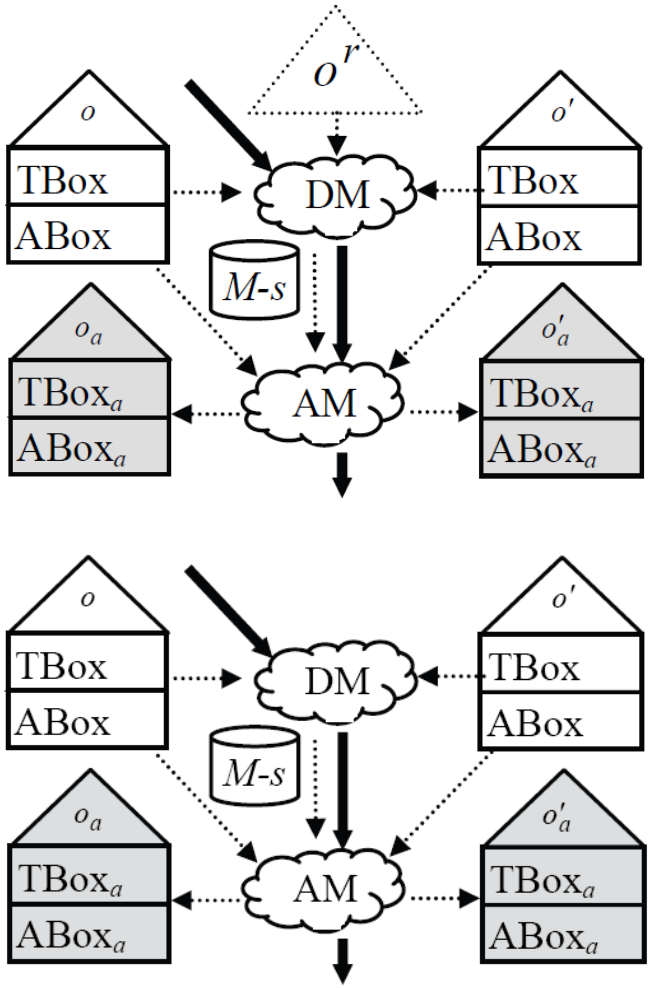
# Classification: Direction

- By **direction** of alignments Ontology Alignment Problems are classified as:
  - **Bi-directional** – *e* and *e′* of both ontologies (*O* and *O′*) are aligned
  - **Uni-directional** – alignments are applied to only one ontology – either *O* or *O′*



# Classification: Distribution

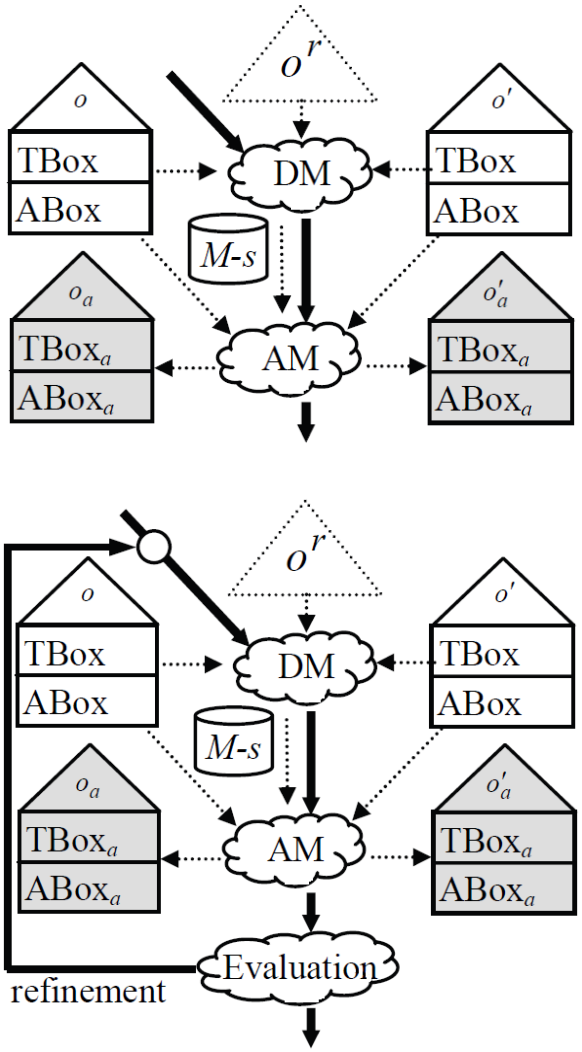
- By the degree of **distribution** in their settings Ontology Alignment Problems are classified as:
  - **Centralized** – rely on a central **Referee Ontology** $O^r$ as a bridge for constructing correct mappings
    - Not always possible
      - E.g. competitors
      - E.g. appropriate referee ontology is not available
  - **Distributed** – without a central referee



# One-Shot vs Iterative

- **One-Shot** techniques – align *e*, *e′* of *O*, *O′* in one iteration
  - Shortcomings:
    - **Dynamicity**: *e*, *e′* may change – invalid alignment
    - **Bad quality** revealed in subsequent evaluation

- **Iterative** approaches
  - Add **evaluation** step in the loop
  - Iterate in the **refinement loop** until the quality of alignment is not sufficient



# Section 1.2.3: Ontology Instance Migration Problem

**A-BOA Wiki:** Ontology Instance Migration Problem

# Ontology Instance Migration

- Let:
  - $O^s = (S^s, A^s)$ - a **source** ontology
  - $O^t = (S^t, A^t)$ - a **target** ontology
  - $O^s$, $O^t$ conceptualize the semantics of the same Universe of Discourse $U$
    - E.g. the same **`Biblio`** domain
  - $U$ regarded as a collection of ground facts: $U = \{f\}$
  - Essentially, $O^s$ and $O^t$ are the interpretations of $U$
    - E.g. Marylin vs Albert

- $O^s$ and $O^t$ would be considered identical iff:
  - $\forall f \in U$ $\text{int}_I{}^s(f) \equiv \text{int}_I{}^t(f)$
  - E.g. Either Marylin OR Albert
    - $\text{int}_I(f)$ is the interpretation of the fact $f$ by the individuals from $I$ of ontology $O$

# Ontology Instance Migration

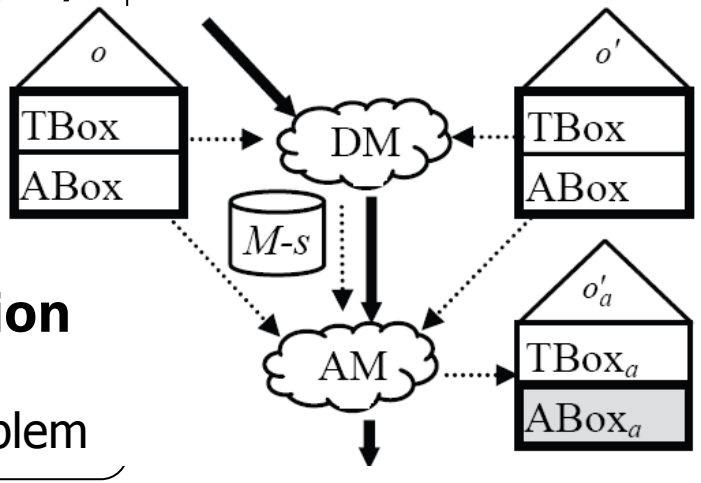
- Let *idiff* ($U$, $O^s$, $O^t$):
  - An **abstract metric of interpretation difference**
  - *idiff* = **0** for identical ontologies
  - *idiff* increases monotonically to **1** with the increase of the number of $f \in U$ such that
    $$(\neg\ (\ \text{int}_I{}^s(f) \equiv \text{int}_I{}^t(f)\ )$$
  - *idiff* = **1** iff $\forall f \in U\ (\neg\ (\ \text{int}_I{}^s(f) \equiv \text{int}_I{}^t(f)\ )$

- (1 – *idiff*) may further be interpreted as **balanced F-measure** in evaluation of **semantic distance**

A
S
U
D

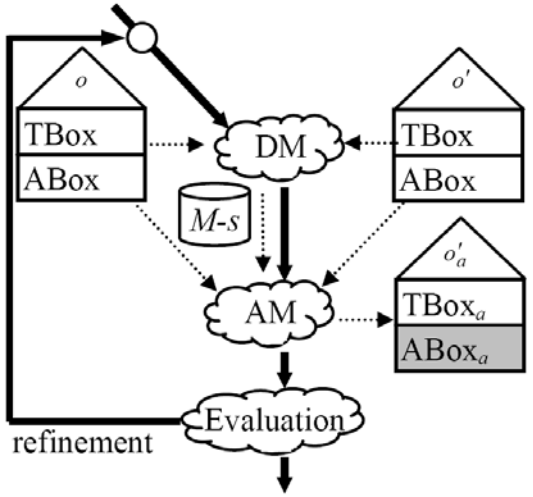
# Ontology Instance Migration

- $O^s$ and $O^t$ are **structurally different** if $S^s \neq S^t$
  - Structural difference – a transformation T: $S^s \rightarrow S^t$
  - T may be sought in the form of a set of nested transformation rules
- Let:
  - **ABox** of $O^s$ contains individuals ($I^s \neq \varnothing$), while
  - **ABox** of $O^t$ is empty ($I^t = \varnothing$)
- The problem of minimizing $idiff(U, O^s, O^t)$ by:
  - (**1**) Taking the individuals from $I^s$
  - (**2**) Transforming them correspondingly to the structural difference between $O^s$ and $O^t$ using T; and
  - (**3**) Adding them to $I^t$
- is denoted as **Ontology Instance Migration** problem
  - Classified as **ASUD** Ontology Alignment Problem



# Ontology Instance Migration

- Theoretically can be solved in one shot
- In practice each of the sub-tasks (**1**-**3**) may result in the loss of **assertions** [10]
  - **Iterative refinement** could yield results with a lower resulting *idiff* value




- An iterative solution:
  - Develops a sequence of $O^s$ states $O^s_{st_i}$ to minimize the $idiff(U, O^s, O^t)$ in a way that:

$$idiff(U, O^s_{st_i}, O^t) < idiff(U, O^s_{st_j}, O^t) \rightarrow i < j$$

where: $O^s_{st_i}$ is $O^s$ in the state after accomplishing iteration $i$

# Section 1.2.4: Ontology Alignment Metrics

*"... I would contend that analysts frequently should not seek a single measure and will never find a perfect measure. ... It is time to stop acting embarrassed about the supposed surplus of measures and instead make fullest possible use of their diversity."*

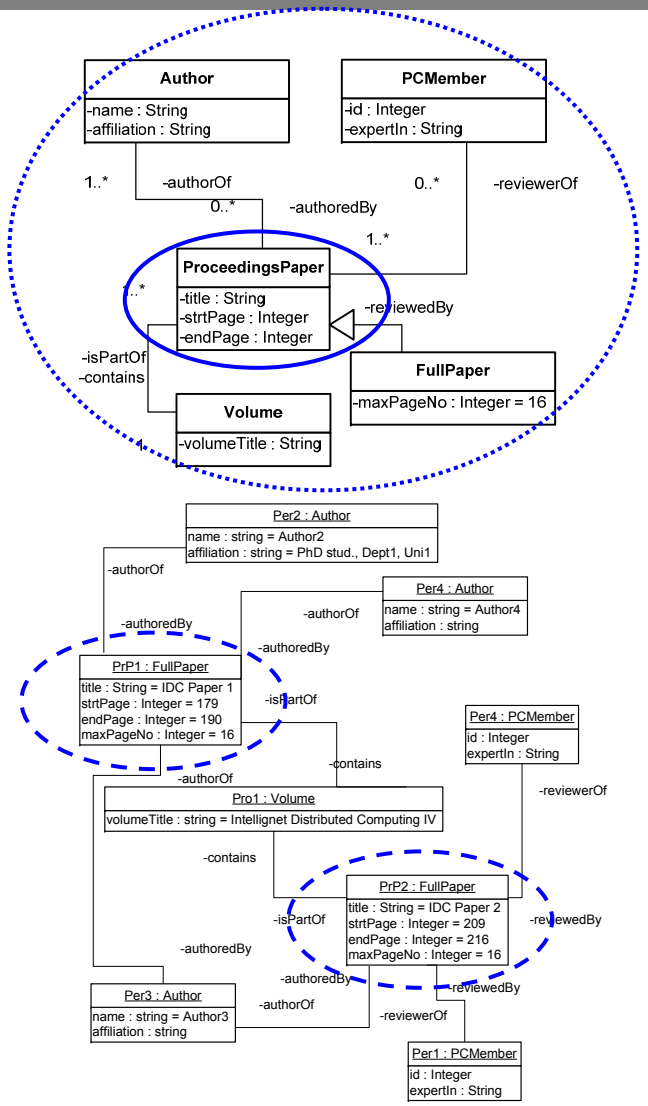
**Herbert F. Weisberg:** American Political Science Review 68 (1974) 1638-1655

# Ontology Alignment Metrics

- **OA problem** – minimizing **semantic difference** between *e* and *e′* of *O* and *O′*
  - **Metrics** – for measuring this semantic difference
  - *O* = (*S*, *A*)
  - Have to cope with the semantic differences between:
    - *S* and *S′* - the **metrics for Structural Difference**
    - *A* and *A′* - the **metrics for Assertional Difference**

# Metrics for Structural Difference

- Based on assessing the **semantic distance** between the structural elements, comparing:
  - **Structural Elements** themselves
  - The **semantic contexts** of the Structural Components
  - The **individuals** relevant to the Structural Components
- A good overview - in **[20]**
  - Not all discussed here





**[20]** Euzenat, J. et al.: State of the Art on Ontology Alignment. KnowledgeWeb project deliverable D2.2.3, v.1.2. August 2, 2004

# Instance(-Based Structural) Similarity

- **Rationale**: similar structural elements (e.g. concepts) have similar instances
- Let:
  - **D** a domain
  - $A$ and $B$ – the concepts in **D**
- $A$ is (somewhat) similar to $B$ if $I_A \cap I_B \neq \emptyset$
  - $I_A$ and $I_B$ are the sets of individual assertions about **D**; and
  - $I_A = \{i_k\}: \forall k, \mathit{instance\_of}(i_k, A)$
- Instance Similarity is often measured [12] by a **symmetric Jaccard coefficient**:

$$Sim_I(A, B) = P(I_A \cap I_B) / P(I_A \cup I_B)$$

  - $P(I)$ is the probability that a randomly chosen instance of **D** belongs to $I$

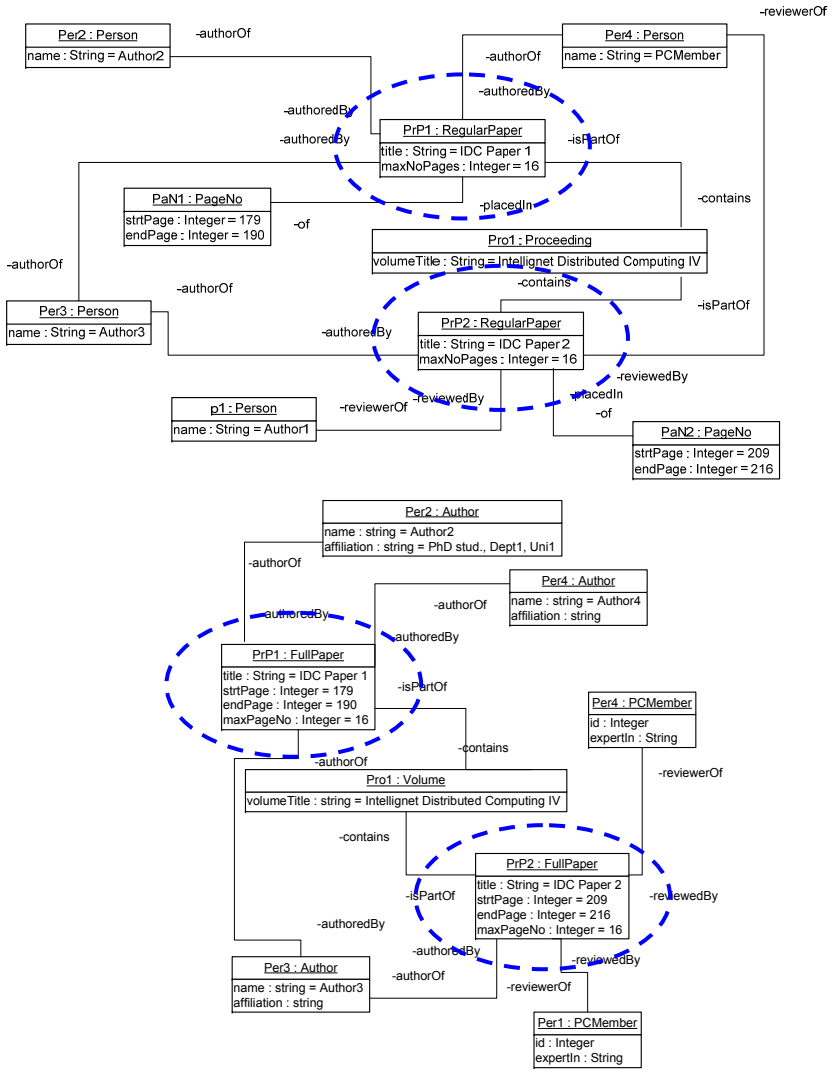
[12] Doan, A., Madhavan, J., Domingos, P., Halevy, A.: Learning to Match Ontologies on the Semantic Web. Int. J. Very Large Data Bases, 12(4) (2003) 303-319

# Instance(-Based Structural) Similarity

$Sim_I(A, B) = P(I_A \cap I_B) / P(I_A \cup I_B)$

- Concepts
  - A=`Biblio-1:RegularPaper`; and
  - B=`Biblio-2:FullPaper`

  have the same set of instances
- So:
  - $I_A \cap I_B = I_A \cup I_B$; and
  - It is very probable that $P(I_A \cap I_B) = P(I_A \cup I_B)$
- Hence: $Sim_I(A, B)$ is close to 1.0



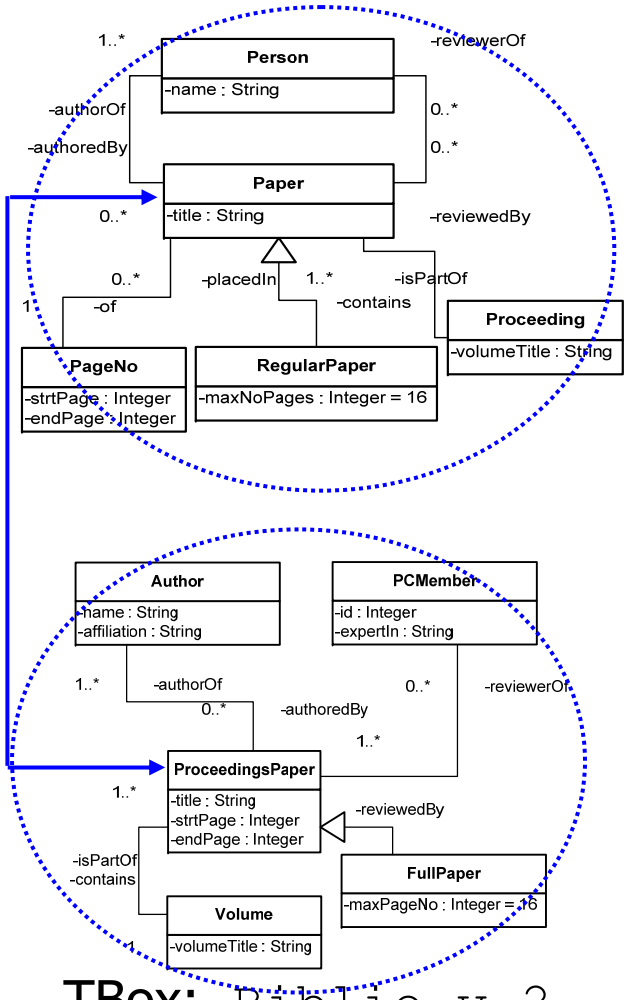
# Contextual or Feature Similarity

- **Rationale**: similar structural elements (e.g. Concepts) have similar structural contexts [17, 18]
- Contexts may be understood as feature sets
- Hence, Contextual Similarity may be measured using **Tversky metrics** [48]
  - A feature set has to be defined
  - E.g. the set of similarity measures of the object properties and related concepts $s_j$

$$Sim_C = 1/m \sum s_j$$

  - In that sense contextual similarity may be regarded as an integrative metric for a pair of concepts

TBox: Biblio v.1




TBox: Biblio v.2

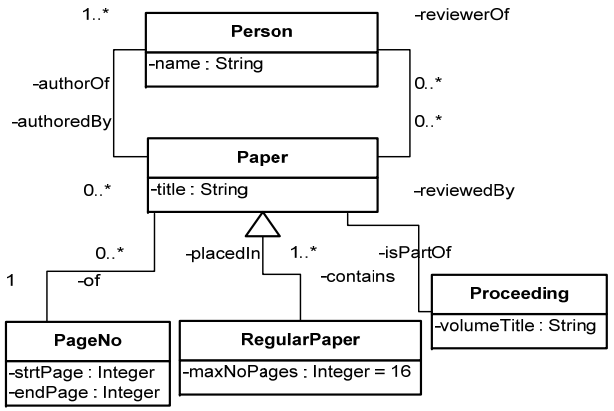

[18] Ermolayev, V., Ruiz, C., Tilly, M., Jentzsch, E., Gomez-Perez, G. M., Matzke, W.-E. 2010. A Context Model for Knowledge Workers. In: CIAO 2010, CEUR-WS, vol. 626

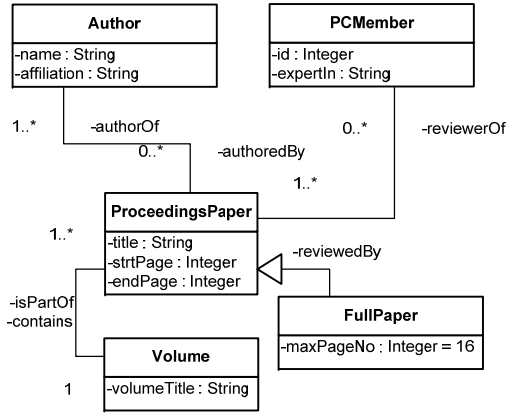
[48] Tversky, A.: Features of Similarity. Psychological Review, 84(4), 327-352, July 1977

# Datatype and Measurement Similarity

- **Rationale**: similar structural elements (e.g. Concepts) have similar properties
- **Shortcoming**: the problem of determining similarity among properties has the same complexity as measuring the similarity of concepts
- **Hint**: the set of properties of a concept is the part of its feature set
  - Measure **property similarity** using a **contextual similarity** metric
- **Complication**: different types of properties, e.g.:
  - Datatype properties
    - Reflect that a concept has a characteristic which:
      - Has a particular **type** (a *color*, a *weight*, a *string*, …)
      - Is measured using specific **unit**s (a *year*, an *integer*, …)
      - May have **constraint**s on its **value**s expressed as logical formulas, e.g.: (*weight* ≤ 90) ^ (*age* ≤ 30)
  - Referential (object) properties
    - Reflect a relationship to another concept (property)

TBox: Biblio v.1



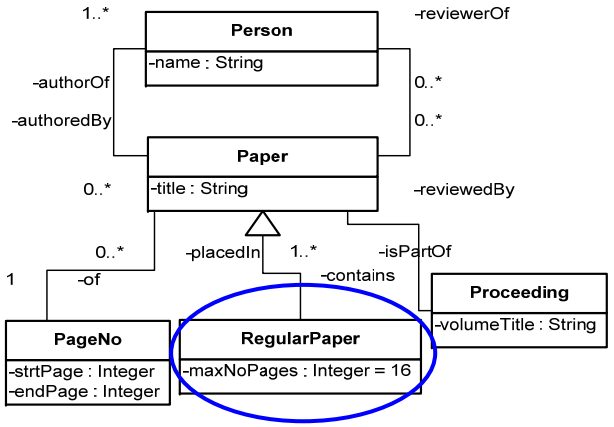



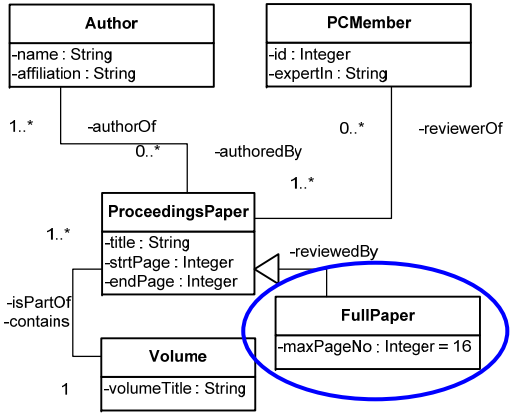

TBox: Biblio v.2

# Datatype and Measurement Similarity

- `Biblio` example:
- *A* =`Biblio-1:RegularPaper`
  - Has a datatype property *a* =`maxNoPages`
  - Measured in *integer* s
- *B* = `Biblio-2:FullPaper`
  - Has a datatype property *b* =`maxPageNo`
  - Measured in *integer* s
- Properties *a* and *b* may be considered **similar**
  - Hypothesis *similar_to (A, B)*
  - $Sim_M$ between *A* and *B* increased
- $Sim_M$ will be even higher if *a* and *b* have the same constraints/values:
  - (*a* = 16) and (*b* = 16)

TBox: `Biblio v.1`




TBox: `Biblio v.2`

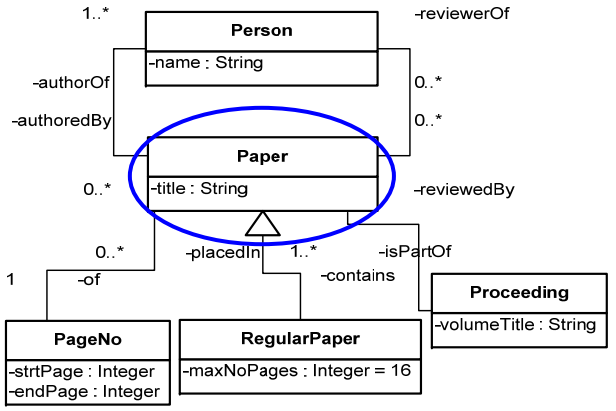
# Lexical Similarity

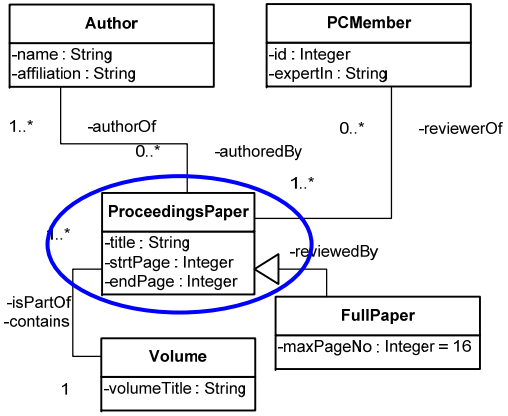
- **Rationale**: similar structural elements have similar identifiers
  - E.g. lexical roots are the same
  - May of course lead to confusion
  - However, a good hint for supposing similarity
- Lexical **heuristic**s work if supported by other evidence:
  - E.g. **instance** or **feature similarity** for a pair of concepts is high
- The following lexical metric $Sim_L$ is often used
  - Let $R_A$, $R_B$ be the sets of roots of the words which constitute the names of concepts $A$ and $B$ respectively, then:

$$Sim_L = |(R_A \cap R_B)| \; / \; |(R_A \cup R_B)|$$

- `Biblio` example:
  - $A$ = `Biblio-1:RegularPaper`
  - $B$ = `Biblio-2:FullPaper`
  - $Sim_L(A, B) = 0.33$

TBox: `Biblio v.1`




TBox: `Biblio v.2`

# Metrics for Assertional Difference

- Have a slightly different nature
- Are often based on measuring the fraction of aligned individuals in terms of:
  - Recall
  - Precision, or
  - A combination of those
    - E.g. *balanced F-measure*
- For the **ontology instance migration** problem:
  - *Precision* (*P*) is the fraction of migrated individuals that are relevant
  - *Recall* (*R*) is the fraction of relevant individuals that are migrated

# Metrics for Assertional Difference

- For the **ontology instance migration** problem:
  - ***Precision*** (*P*) is the fraction of migrated individuals that are relevant
    $P = tp / (tp + fp)$;
  - ***Recall*** (*R*) is the fraction of relevant individuals that are migrated
    $R = tp / (tp + fn)$
  - Additionally - ***Accuracy*** (*A*)
    $A = (tp + tn) / (tp + fp + tn + fn)$

| | **Relevant** | **Irrelevant** |
|---|---|---|
| **Migrated** | True positives (*tp*) | False positives (*fp*) |
| **Not Migrated** | False negatives (*fn*) | True negatives (*tn*) |

- An ideal migration outcome corresponds to $P = R = 1$
- Neither *P* nor *R* separately fully reflects the correctness of migration results
- ***F-measure*** (*F*) could be of interest as it brings *P* into correlation with *R* as a harmonic mean

$$F = \frac{1}{\alpha / P + (1-\alpha) / R} = \frac{(\beta^2 + 1)PR}{\beta^2 P + R} \qquad \beta^2 = (1-\alpha)/\alpha$$

- Balanced F-measure equally weights P and R: $\alpha = 1/2 \Rightarrow \beta = 1$

# Section 1.3: Applications of Ontology Alignment

**A-BOA Wiki:** Applications of Ontology Alignment

# Section 1.3: Structure

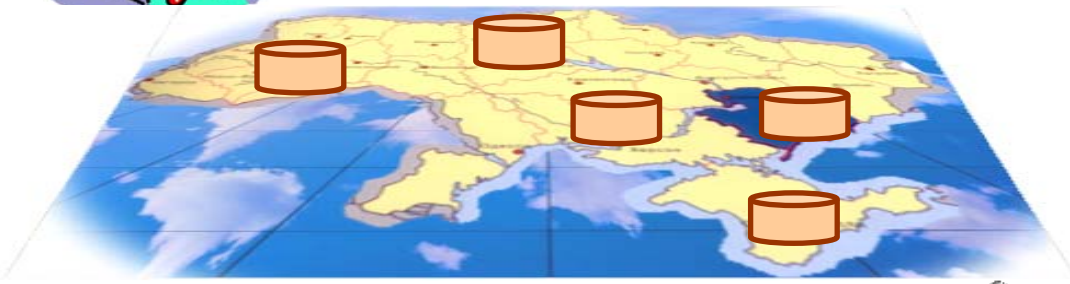
- A few (1 ☺) selected categories of applications
  - A broader spectrum is surveyed in [11]
- Focus on the requirements to ontology alignment that are posed by the applications in a category
  - A particular **ontology alignment problem**
  - Why is an **agent-based solution** appropriate?
- Categories of applications:
  - **Distributed Information Retrieval**
  - **Human-Machine Dialogues**
  - **Ontology Evolution, Versioning, Refinement**
  - **Service Composition**
- The **requirements** to ontology alignment technology are finally summarized

[11] Davidovsky, M., Ermolayev, V., and Tolok, V. 2012. A survey on agent-based ontology alignment. In *Proc ICAART'12*, 355-361

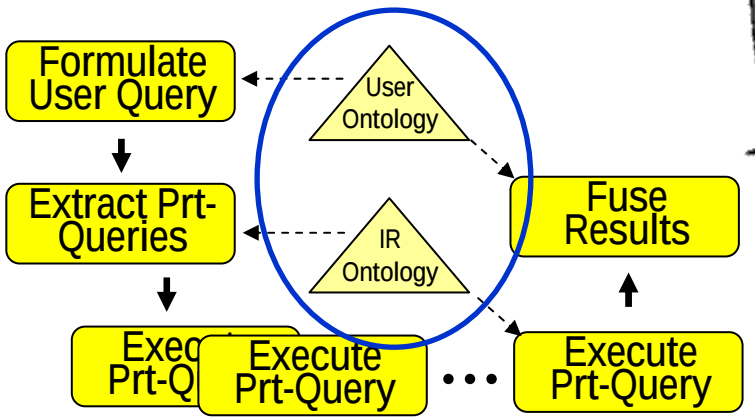
# Distributed Info Retrieval

- DIR applications assist retrieving and fusing information from heterogeneous, distributed, and independent IR
- **Ontologies** in DIR are used for:
  - **Transforming** user queries and system responses
  - **Representing** Structures and Semantics of IR
- Ontology **alignment**s are required:
  - At Query Transformation step
  - At Result Fusion step

I have a query to all of you in terms (and in language) that I understand

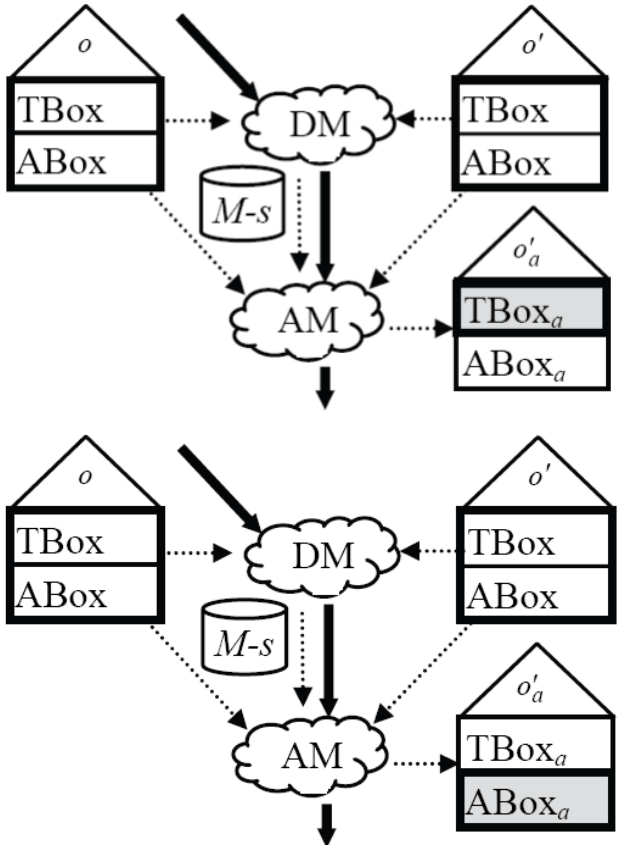


We provide IR-s annotated in terms suitable for us. Normally, we do not care about the others



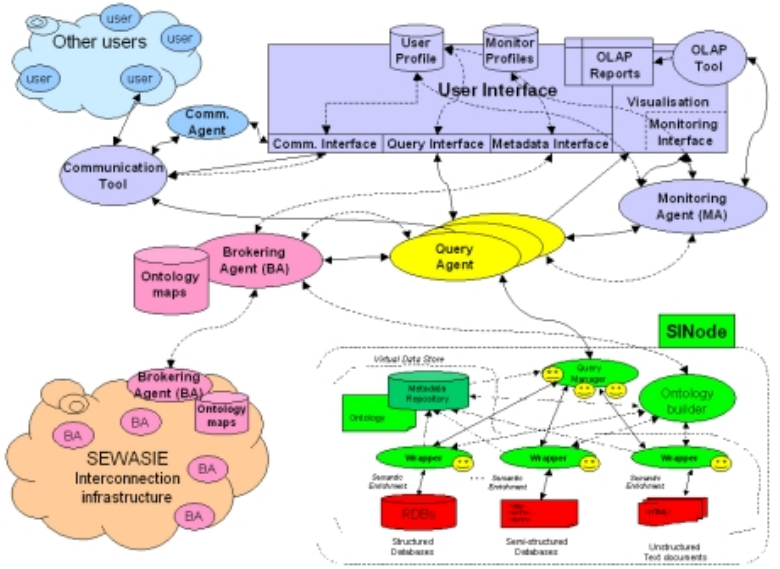
# Distributed Info Retrieval

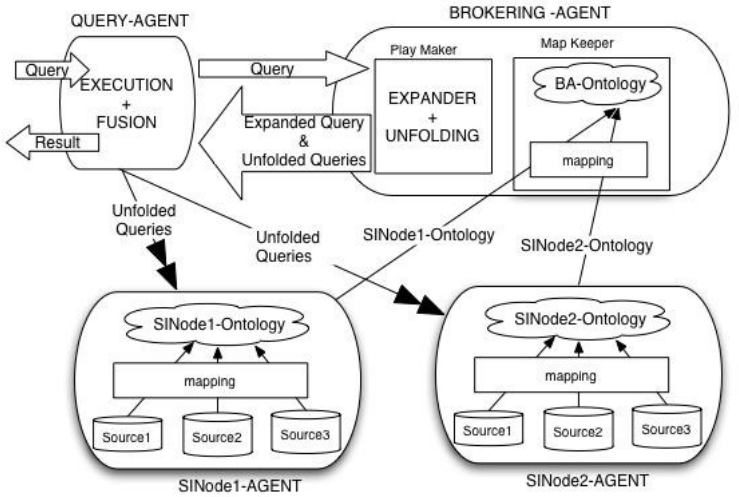
- Ontology alignments are required:
  - At Query Transformation (**QT**) – for:
    - Correlating query structure and semantics with different information resource schemas
    - Building respective partial queries
  - At Result Fusion (**RF**) – for:
    - Transforming and putting together the retrieved information instances
- **QT** Requirement: a solution for a **Structural Static Uni-directional Distributed** (SSUD) OA problem
- **RF** Requirements:
  - A solution for an **Assertional Static Uni-directional Distributed** (ASUD) OA problem
  - **High recall** – important not to miss any potentially relevant information; irrelevant can be filtered out using other techniques
- **General** requirement: **scalability** wrt the complexity and number of aligned ontologies



# Agents in DIR

- E.g. SEWASIE project [13]:
  - A multi-agent system for querying heterogeneous data sources integrated using ontologies
  - http://www.sewasie.org/




[13] Dongilli P., Fillottrani P.R., Franconi E., and Tessaris S. 2005. A multi-agent system for querying heterogeneous data sources with ontologies. In Proce 13th Italian Symposium on Advanced Database Systems, SEBD-2005

# Requirements to Onto Alignment

| Application Category | Requirements | | | | | | Ontology Alignment Problems | | | | | | | | | Method | | Agent Capabilities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Span | | | Dyna-mics | | Direc-tion | | Distri-bution | | | | | | | | |
| | Recall | Precision | Run-time Solution | Semantic contexts | Integrativity | Scalability | Complete | Structural | Assertional | Static | Dynamic | Bi-directional | Uni-directional | Cetntal Referee | Distributed | One-shot | Iterative | Reasoning | Behavior Adaptability | Negotiation | Collaboration | Planning |
| | | | | | | | C | S | A | S | D | B | U | C | D | | | | | | | |
| Distributed Information Retrieval | + | | ~ | + | | + | | + | + | + | | | + | +- | + | +- | +- | + | | + | + | |
| Human-Machine Dialogues | | | + | | + | + | | + | | +- | ~ | + | | +- | ~ | +- | + | + | + | | + | |
| Ontology Engineering and Management | + | + | | + | | | + | + | + | + | | + | + | + | + | | + | + | | + | + | |
| Service Composition | + | + | + | | | + | ~ | | + | + | ~ | + | | +- | ~ | + | ~ | + | | | | + |

**Legend**: +- – minimal requirement/basic solution; ~ – desired; + – required.

- **Instance Migration** (ASUD, Iterative):
  - Required:
    - Distributed Information Retrieval
    - Ontology Engineering and Management (Evolution, Versioning, Refinement)
  - Good to have:
    - Service Composition (ASBD)



**A-BOA Wiki: Requirements to OA**

# Part 2:
# Theoretical Foundations and Demonstration

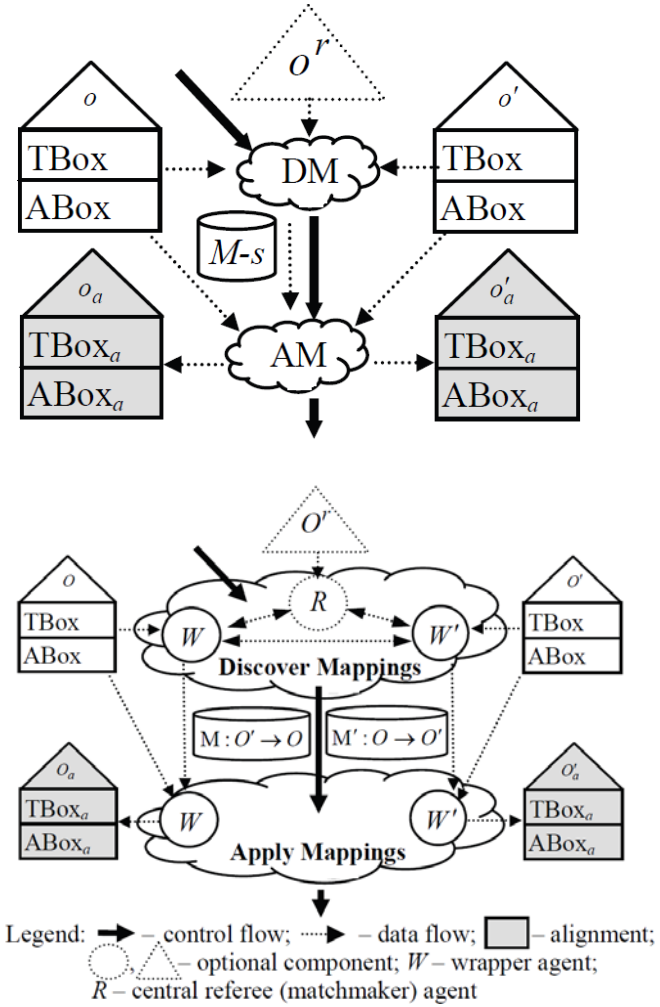
**A-BOA Wiki:** Theoretical Foundations and Demonstration

# Part 2: Structure

- Answers the **"how"** group of questions
  - A more advanced material
  - More focused on agent-based approaches for building ontology alignments
- Overviews selected **agent-based frameworks** for ontology alignment:
  - **Information Flow Theory based approaches**
  - **Argumentation based frameworks**
  - **Semantic Contexts and Propositional Substitutions**
- Offers, as a **practical reinforcement** for the overview
  - **Demonstration of the Agent-Based Software Prototype**
    - **A very brief one** – showing the results, not the process
  - The tool for solving one particular problem of Ontology Alignment - **Ontology Instance Migration Problem**

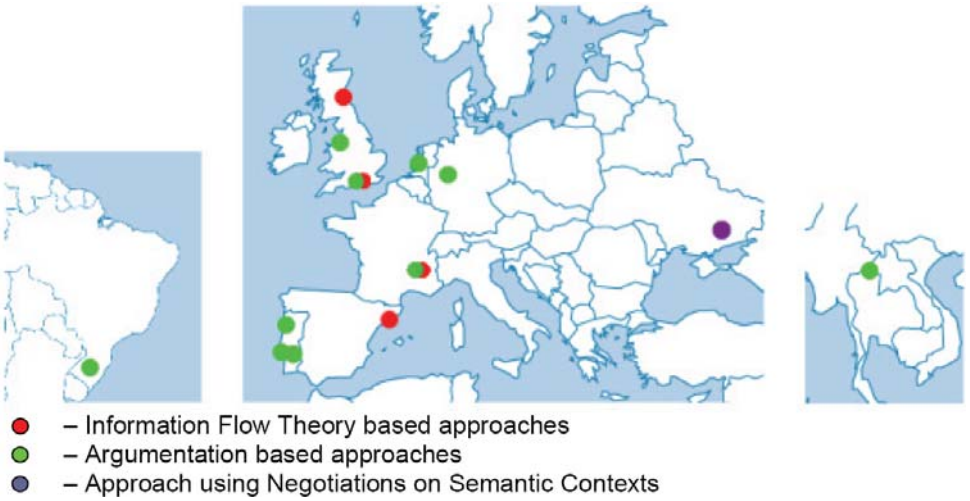
# Theoretical Foundations

- Agent-based approach for solving a **generic ontology alignment problem**
- **Discover Mappings**
  - *W* and *W′* are the **wrapper agents** for ontologies *O* and *O′*
  - Agent *R* wraps the central referee ontology $O^r$ and helps *W* and *W′* finding the proper mappings *M* and *M′* using $O^r$ (a **matchmaker** function)
  - *W* and *W′* produce their own sets of mappings *M* and *M′*:
    - In collaboration with each other (a fully distributed problem setting); or
    - Also in collaboration with *R* (the problem setting with a central referee ontology)
- **Apply Mappings**
  - *M* and *M′* are autonomously applied by *W* and *W′* to *O* and *O′*
- Problem: **How** do the agents collaborate and develop these mappings?



# Theoretical Foundations

- Substantial attention in the literature
- **Mainstream**: use of (different flavors of) negotiation techniques as the most natural and well-proven mechanism for reaching agreements



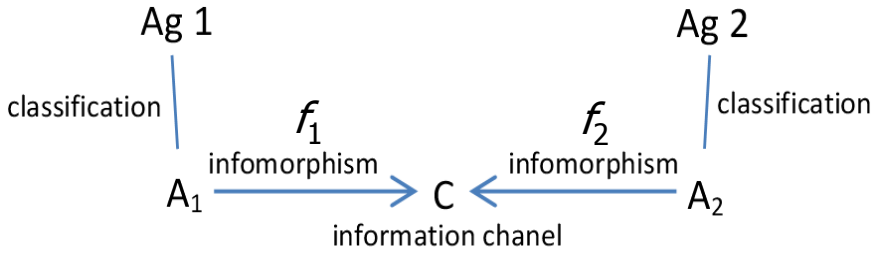

- Several fundamental theoretical approaches with different expressive power
  - Most widely used formalism is the Dung's **Argumentation Framework or its derivatives**
  - The formalism used in our software (demo):
    - Negotiations on propositional substitutions in semantic contexts
    - Based on the Type Theory

# Section 2.1: Information Flow Theory Based Approaches

**A-BOA Wiki:** Information Flow Theory Based Approaches

# Information Flow Theory

- A formal foundation by Schorlemmer et al. [42]
  - **Ontology Alignment** – a product of **meaning negotiation** between software agents
  - Focus: introduction of **general alignment interaction models**




- The approach
  - Is grounded on Barwise and Seligman's **theory of information** [2]
  - Uses their notion of **information flow** (**IF**) as a basic formalism

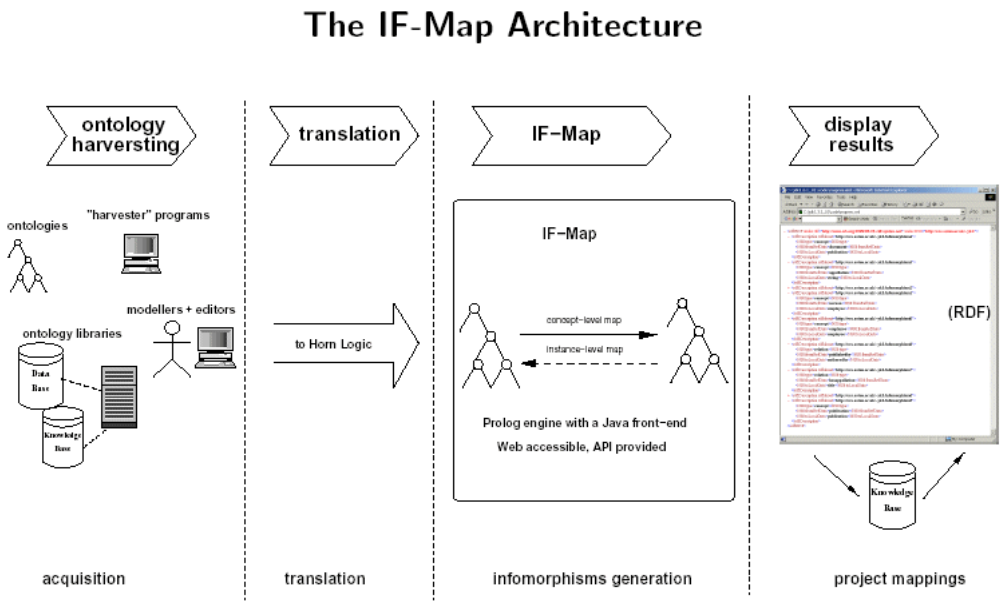
- Alignment is:
  - Defined as a system of **classifications** and **infomorphisms**
  - Obtained via **meaning coordination** between agents $Ag_1$ and $Ag_2$ through the information channel:
    - $C$ is the classification determined by the meaning coordination done before
    - $A_1$, $A_2$ – respective classifications
    - $f_1$, $f_2$ – respective infomorphisms


[42] Schorlemmer, M., Kalfoglou, Y., and Attencia, M. 2007. A formal foundation for ontology-alignment interaction models. *International Journal on Semantic Web and Information Systems*, 3(2), 50–68.

[2] Barwise, J. and Seligman, J. 1997. *Information Flow: The Logic of Distributed Systems*. Cambridge University Press

# Information Flow Theory

- The **IF**-based approach has been implemented as the **IF-Map** method for automated ontology mapping [29]




http://www.aktors.org/technologies/ifmap/

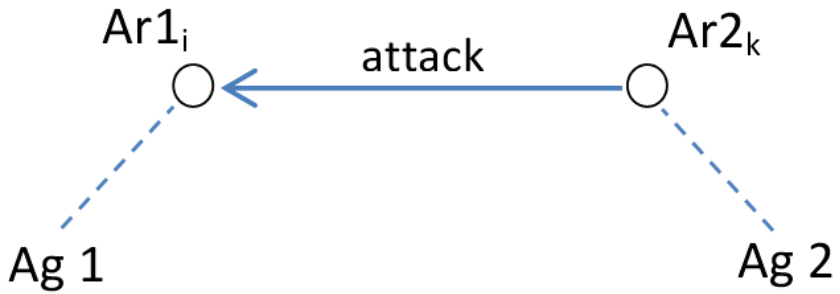

[29] Kalfoglou, Y. and Schorlemmer M. 2002. IF-Map: an ontology-mapping method based on Information-Flow Theory. In *Proceedings of the 1st Int. Conf. Ontologies, Databases and Application of Semantics (ODBASE'02)*, Irvine, CA, USA

# Section 2.2: Argumentation Based Frameworks

**A-BOA Wiki:** Argumentation based frameworks

# Argumentation Frameworks

- Abstract **Argumentation Framework** (**AF**) introduced by Dung [14] as a pair:
  $AF = \langle AR, attacks \rangle$
  - *AR* – a set of arguments
  - *attacks* – a binary relation on *AR* ; and
  - *attacks* (*A*, *B* ) signifies that argument *A* attacks argument *B*




- **Different flavors of AF** used for ontology alignment by agents to determine acceptable **mappings** in **negotiations**

[14] Dung, P. 1995. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artificial Intelligence,* 77(2), 321-357

# Argumentation Frameworks

- **Different flavors of AF** used for ontology alignment:
  - **Value-Based Argumentation Framework (VAF)** by Bench-Capon [3]
    $AF = \langle AR, attacks, V, val, P \rangle$
    - $V$ – a non-empty set of values
    - $val$ – a function which maps the elements of $AR$ to the elements of $V$
    - $P$ – the set of possible **audience**s
  - **Voting-based VAF** (**V-VAF**) and a **Strength VAF** (**S-VAF**) by Isaac et al. [28]
    - **S-VAF** extends **VAF** with a strength function $S : AR \rightarrow [0, 1]$
    - **V-VAF** is defined by adding a notion of *support*
      - A reflexive binary relation over $AR$ disjoint to *attacks*
      - Allows counting arguments as **defenders** (or **co-attackers**) within a particular attack


[3] Bench-Capon, T.J.M. 2003. Persuasion in practical argument using Value-based Argumentation Frameworks. *J Logic Computation*, 13 (2003), 429-448

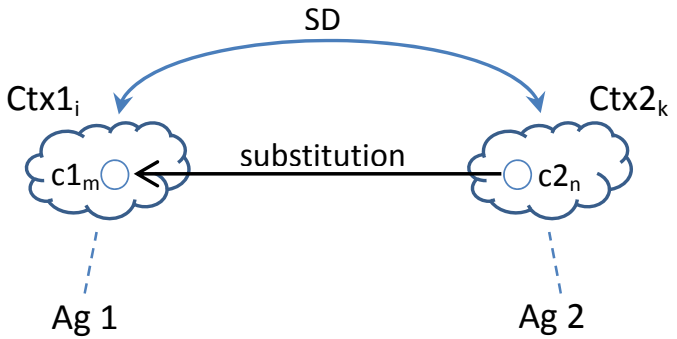
[28] Isaac, A., Trojahn, C., Wang, S., and Quaresma, P. 2008. Using quantitative aspects of alignment generation for argumentation on mappings. In *Proceedings of ISWC'08 Workshop on Ontology Matching*, Karlsruhe, Germany

# Section 2.3: Semantic Contexts and Propositional Substitutions

**A-BOA Wiki:** Propositional Substitutions

# Propositional Substitutions

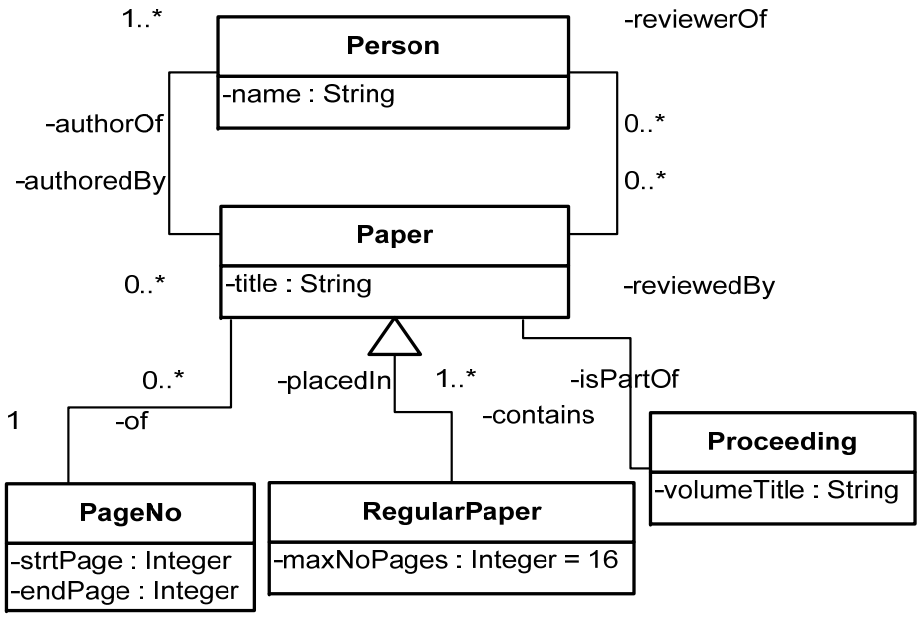
- Given $O^s$ and $O^t$
- Choose a **center of gravity**
  - A pair of "central" concepts with high similarity
- Discover mappings for a **structural context** by
  - Exchanging **hypotheses** (propositions)
  - Trying **substitutions** of own statements by received propositions
  - Measuring **similarity improvement** (several metrics)
- Accepting good propositions (conceding)
- Exclude the pair from the negotiation set



# Propositional Substitutions

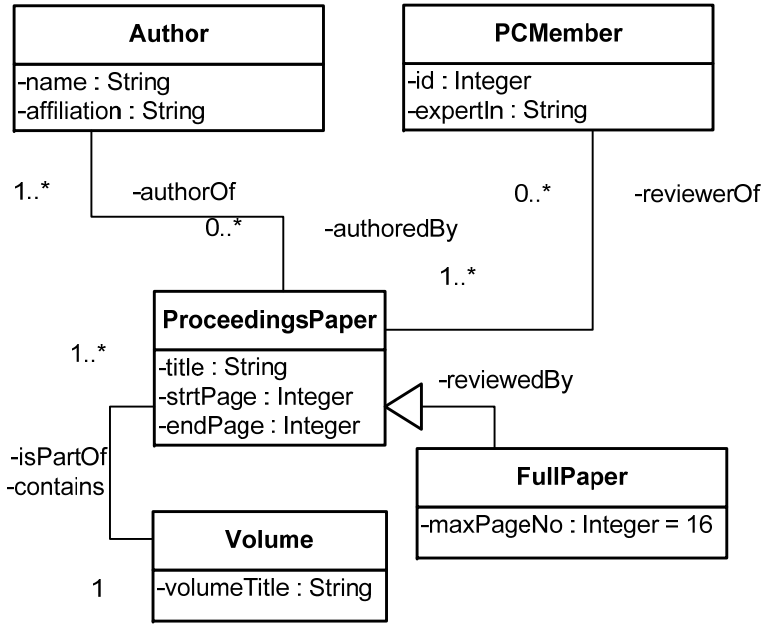
- Center of Gravity: `Paper ↔ ProceedingsPaper`

Publisher




TBox: `Biblio v.1` ($O^s$)

Conf MS

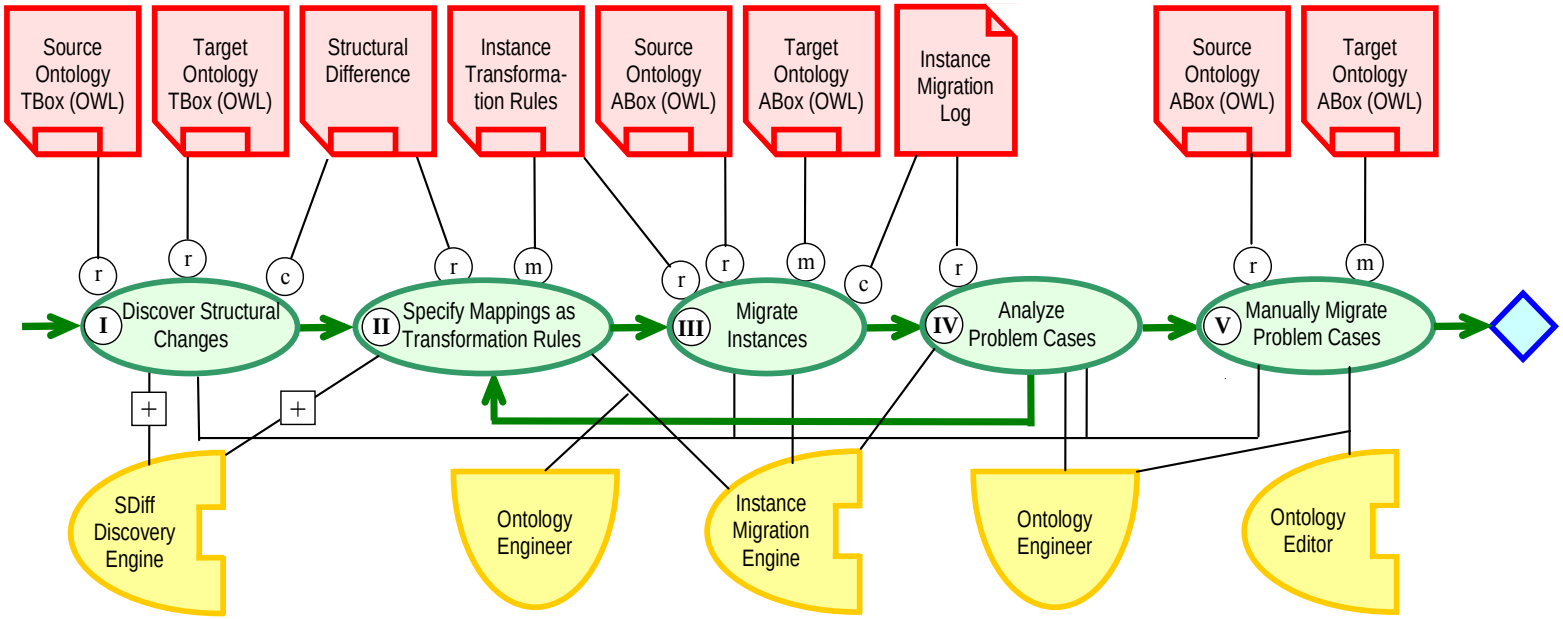



TBox: `Biblio v.2` ($O^t$)

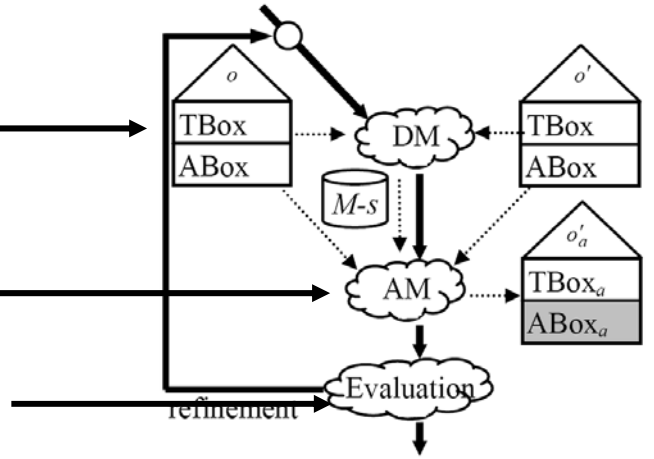
# Section 2.4: Demonstration of A-BOA Solution for Instance Migration

**A-BOA Wiki:** Demonstration of the Agent-Based Software Prototype

# Workflow and Tools

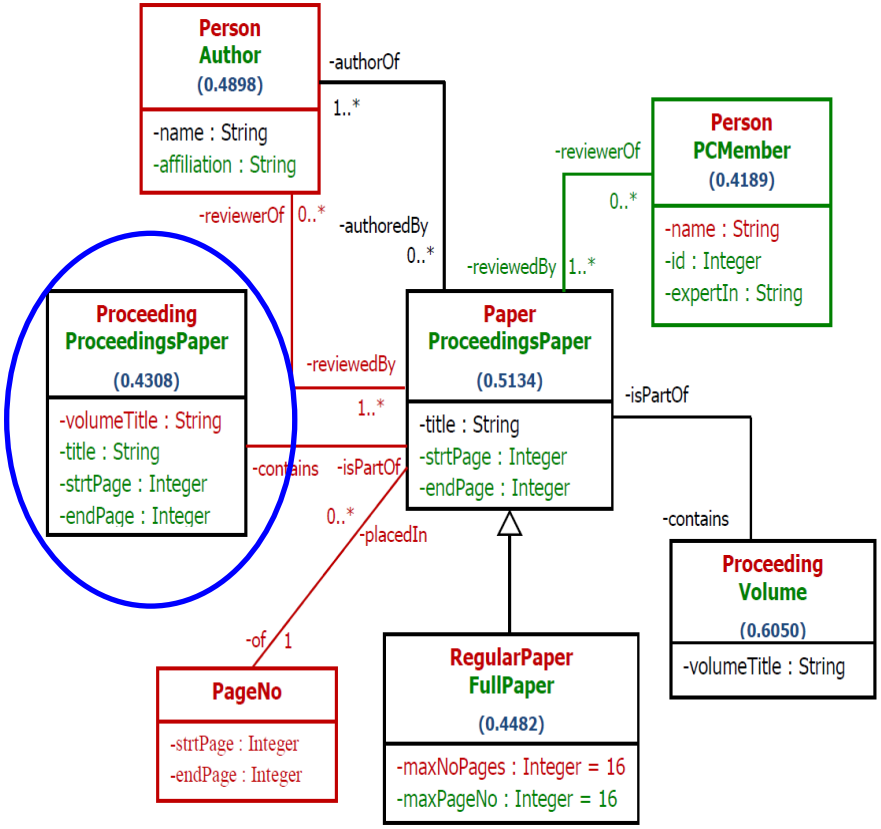



- (I) SDiff Discovery Engine (SDDE)
  - Compared to manual
- (II) SDiff Discovery Engine (SDDE)
- (III) Instance Migration Engine (IME)
- (IV) Knowledge Engineer

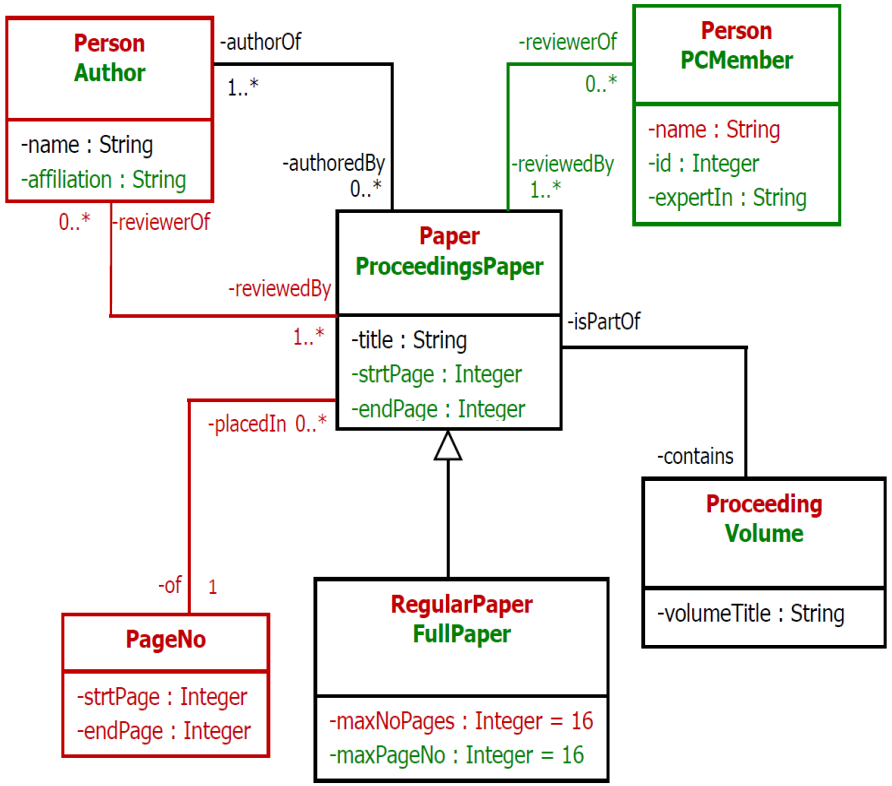


# (I) Discover Structural Changes

- Structural Diff Discovery Engine

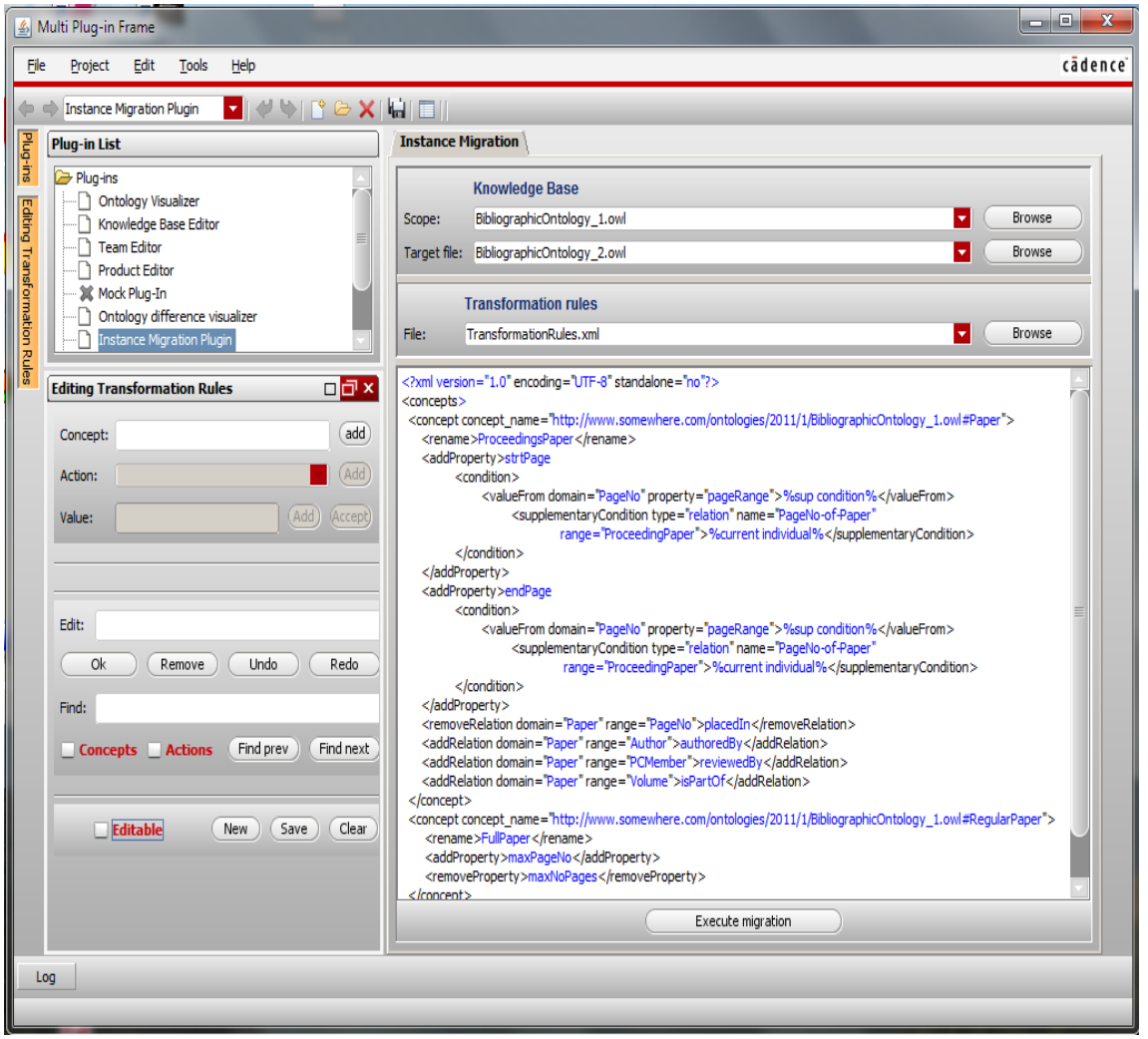



- Done manually



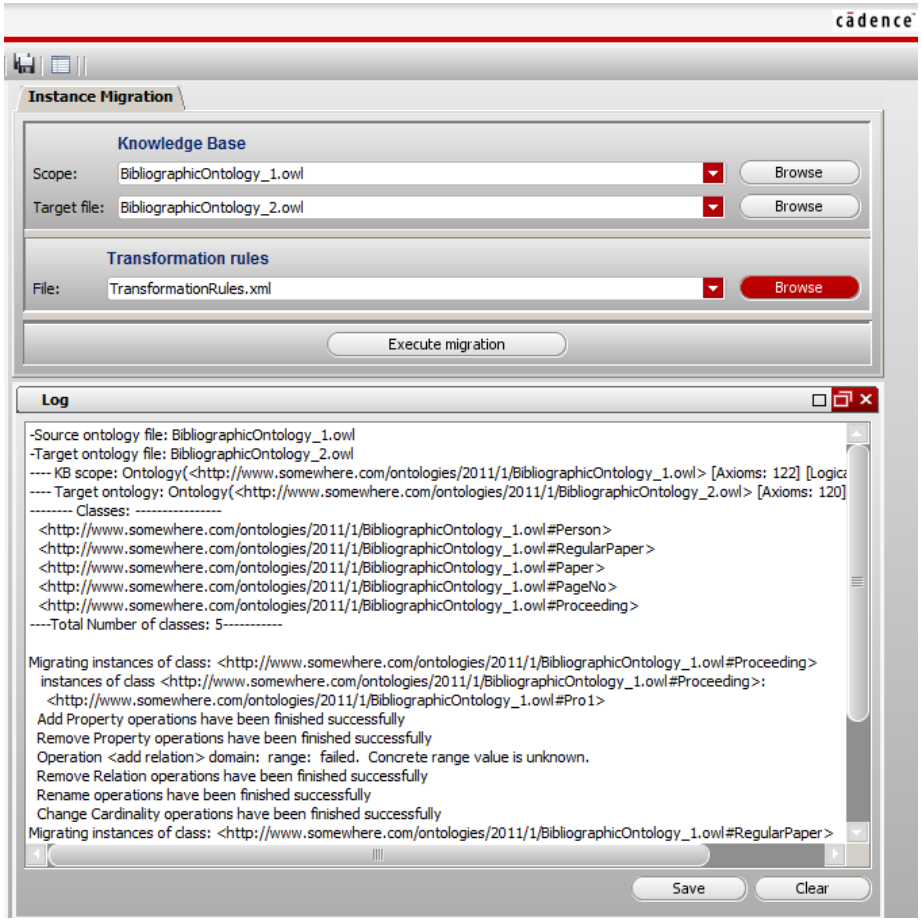
# (II) Generate Transformation Rules

- Generated by the Structural Diff Discovery Engine
- Imported by the Instance Migration Engine



# (III) Migrate Instances

- Instance Migration Engine [10]
  - Generates Migration Log




[10] Davidovsky, M., Ermolayev, V., and Tolok, V. 2011. Instance migration between ontologies having Structural Differences. International Journal on Artificial Intelligence Tools. 20, 6 (Dec. 2011), 1127–1156, DOI=10.1142/S0218213011000553

# (IV) Evaluate Migration Log

- Manual – by a Knowledge Engineer
- Decision to be made about a need to refine …

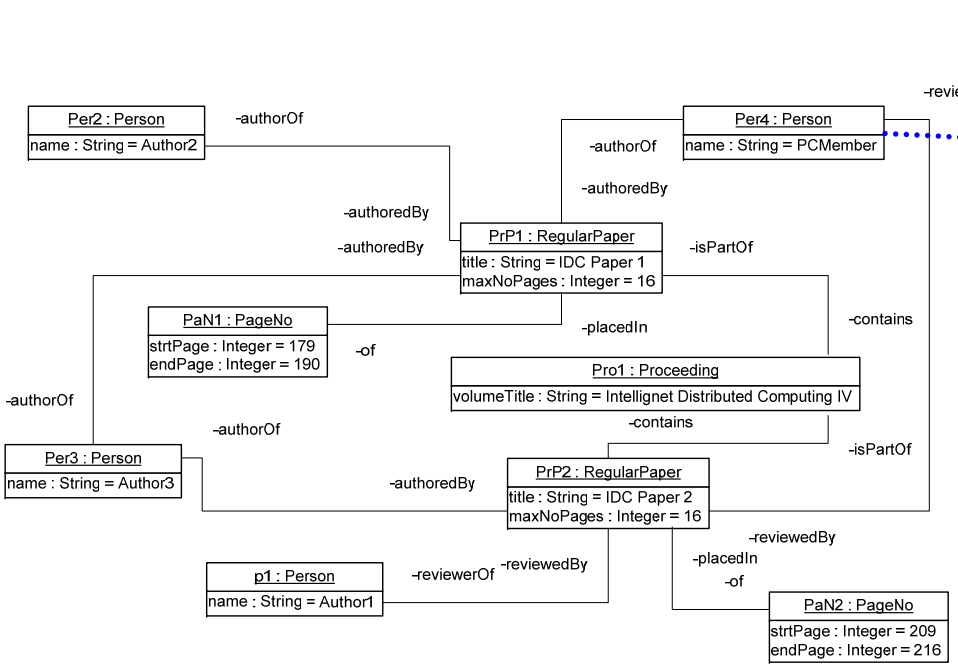
**Migration Log**

```
…
Migrating instances of class: <http://www.somewhere.com/ontologies/2011/1/
BibliographicOntology_1.owl#Person>
To
<http://www.somewhere.com/ontologies/2011/1/BibliographicOntology_1.owl#PCMember>
    The initial set of instances:
        <http:
        <http:
        <http:
        <http:
    Migrated i
        <http:
        <http:
        <http:
…
```

**New Condition to Transformation Rule (added manually)**

```
…
<concept concept_name="http://www.somewhere.com/ontologies/2011/1/
BibliographicOntology_1.owl#Person">
    <condition>
        <supplementaryCondition type="concept" name=" PCMember"/>
    </condition>
    <rename>PCMember</rename>
                <removeProperty>name</removeProperty>
    <addProperty datatype=”integer”>id</addProperty>
    <addProperty datatype=”string”>expertIn</addProperty>
  </concept>
…
```

# Example: Biblio Instances




a) The instances of `Biblio-1`




b) The instances of `Biblio-2`

The result we have to achieve

# Final Questions Please

http://isrg.kit.znu.edu.ua/a-boa/