

Tutorial on Ontology Matching

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Goals of the tutorial

- ▶ Illustrate the role of ontology matching
- ▶ Provide an overview of basic matching techniques
- ▶ Demonstrate the use of basic matching techniques in state of the art systems
- ▶ Motivate future research

Outline

Matching problem

Classification

Basic techniques

Matching process

Systems

Conclusions

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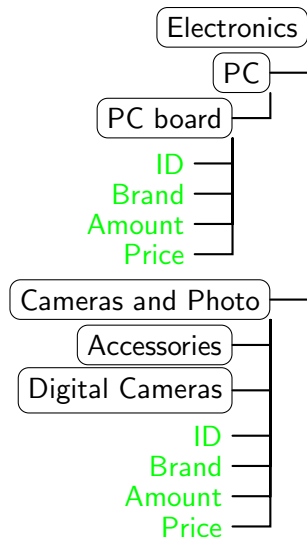
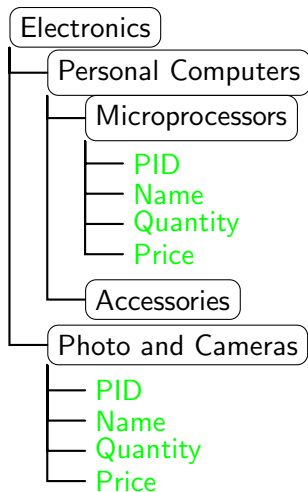
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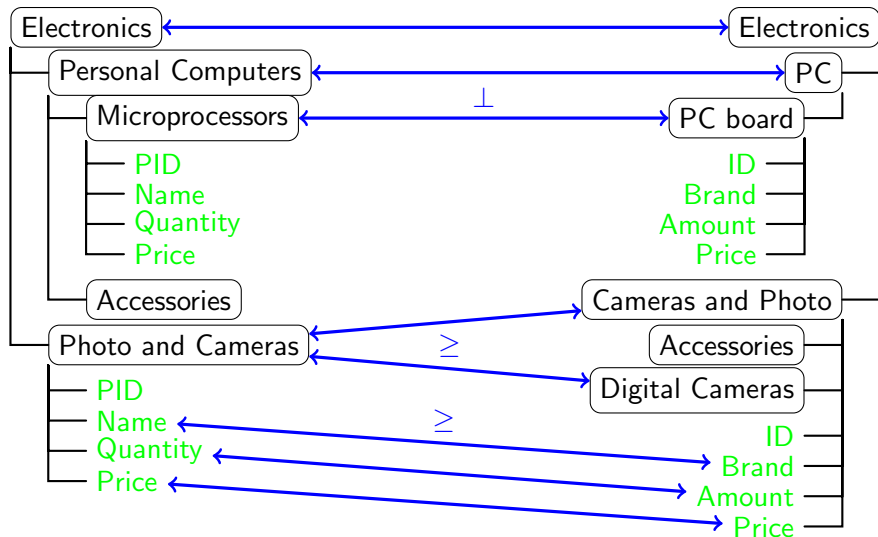
Matching operation

Matching operation takes as input ontologies, each consisting of a set of discrete entities (e.g., tables, XML elements, classes, properties) and determines as output the relationships (e.g., equivalence, subsumption) holding between these entities

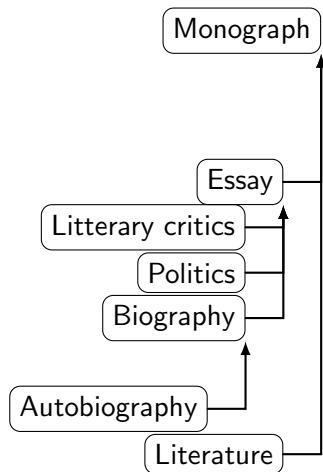
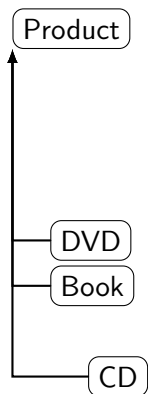
Motivation: two XML schemas



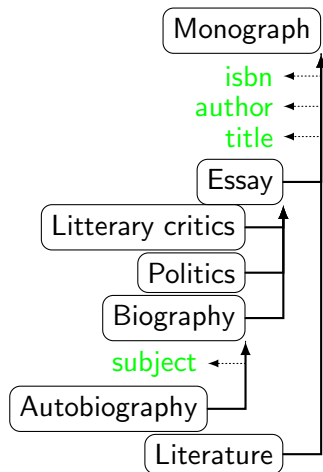
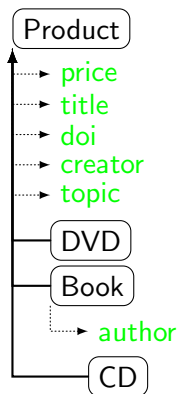
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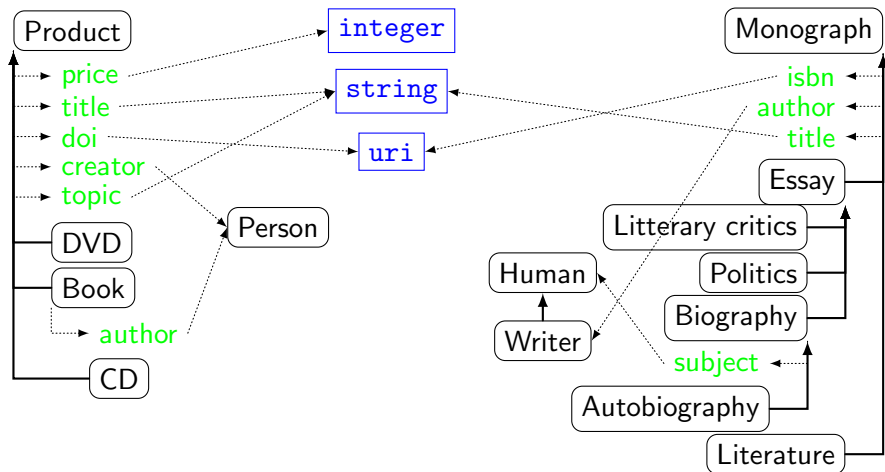
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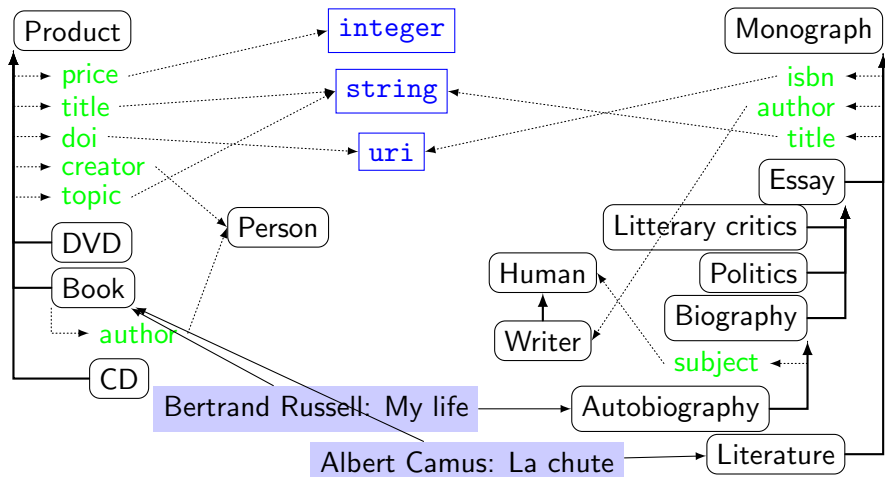
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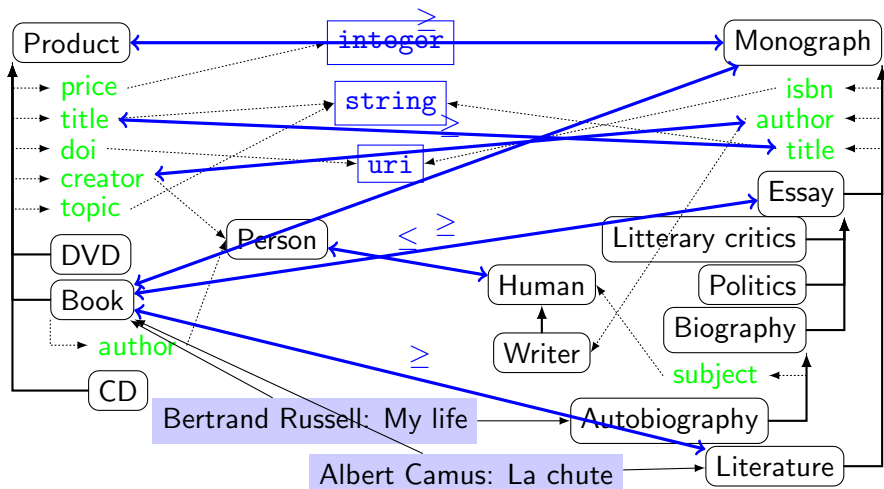
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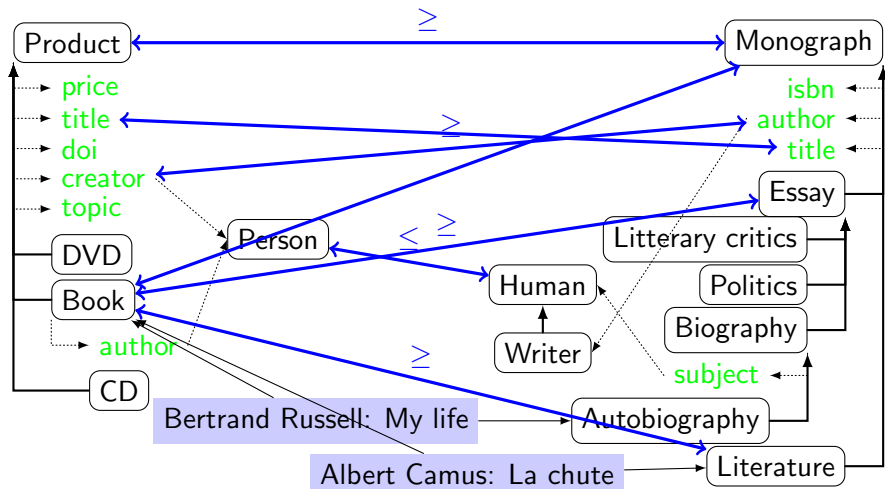
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Schema matching vs. ontology matching: differences

- ▶ Schemas often do not provide explicit semantics for their data
 - ▶ Relational schemas provide no generalization

Schema matching vs. ontology matching: differences

- ▶ Schemas often do not provide explicit semantics for their data
 - ▶ Relational schemas provide no generalization
- ▶ Ontologies are logical systems that constrain the meaning
 - ▶ Ontology definitions as a set of logical axioms

Schema matching vs. ontology matching: commonalities

- ▶ Schemas and ontologies provide a vocabulary of terms that describes a domain of interest

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Techniques developed for both problems are of a mutual benefit

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Heterogeneity between ontologies can occur when

- ▶ different languages are used
- ▶ different terminologies are used
- ▶ different modeling is used
- ▶ ...

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Correspondence

Definition (Correspondence)

Given two ontologies O and O' , a **correspondence** M between O and O' is a 5-uple: $\langle id, e, e', R, n \rangle$ such that:

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- ▶ n is a **confidence measure** in some mathematical structure (typically in the $[0,1]$ range)

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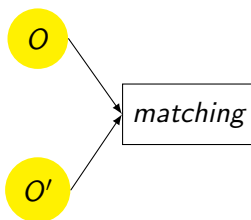
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- ▶ some additional metadata (method, date, properties, etc.)

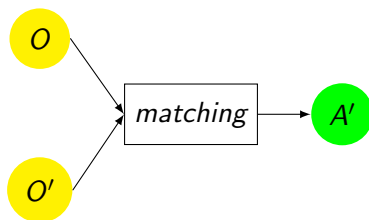
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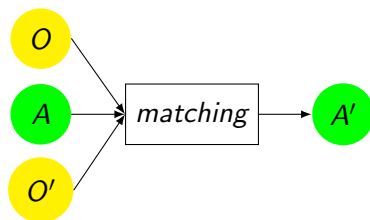
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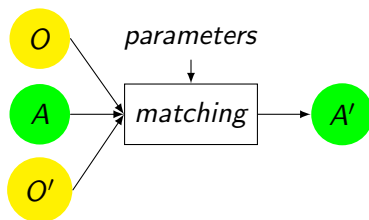
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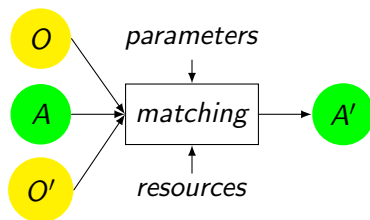
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Application domains

- ▶ **Traditional**
 - ▶ Ontology evolution
 - ▶ Schema integration
 - ▶ Catalog integration
 - ▶ Data integration

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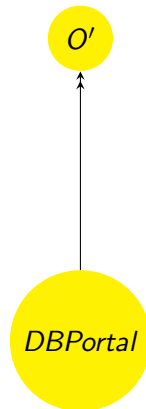
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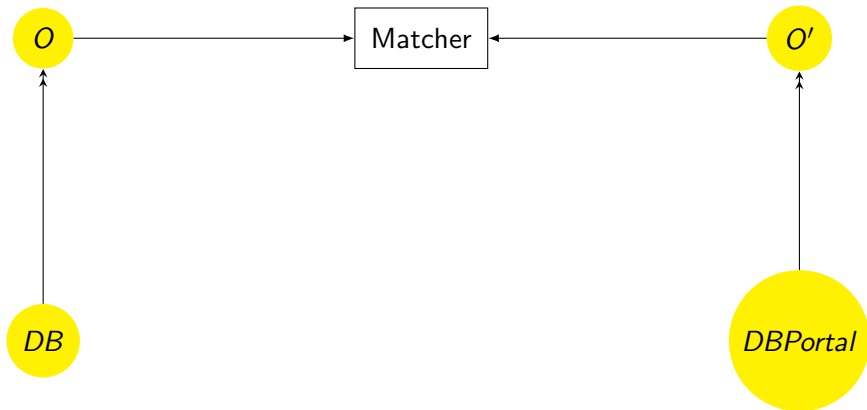
▶ **Emergent**

- ▶ P2P information sharing
- ▶ Agent communication
- ▶ Web service composition
- ▶ Query answering on the web

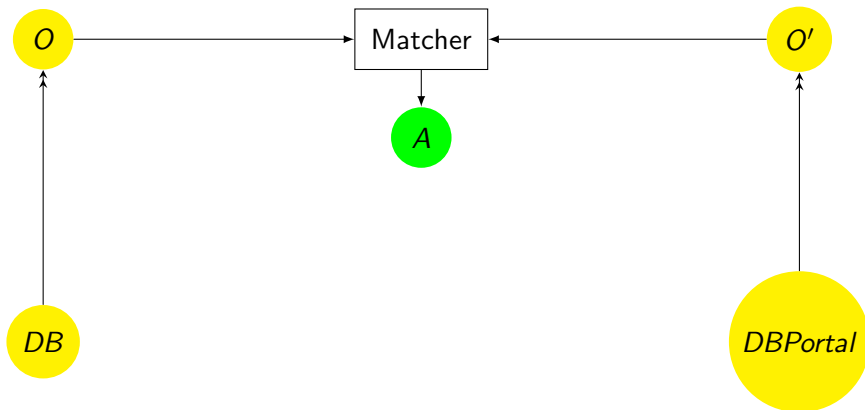
Application: catalog integration (simplified)



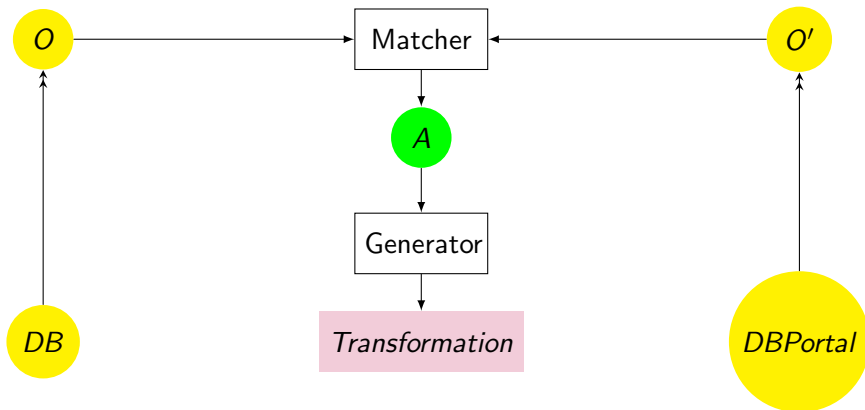
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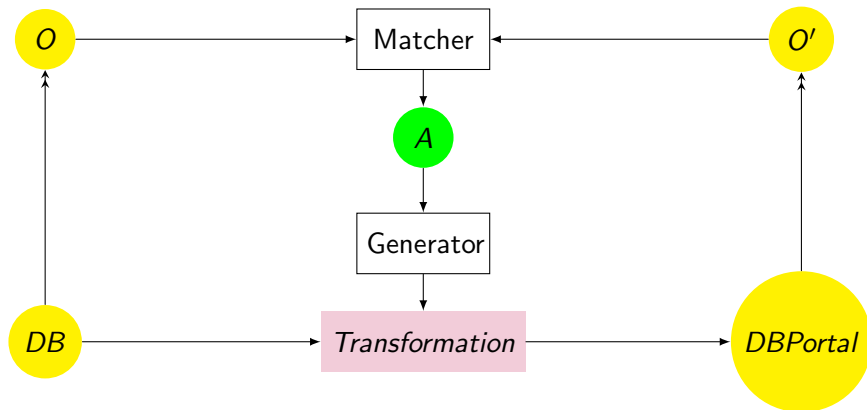
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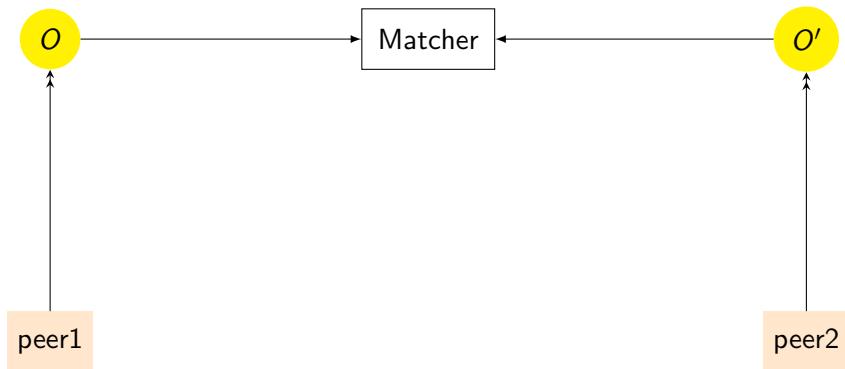
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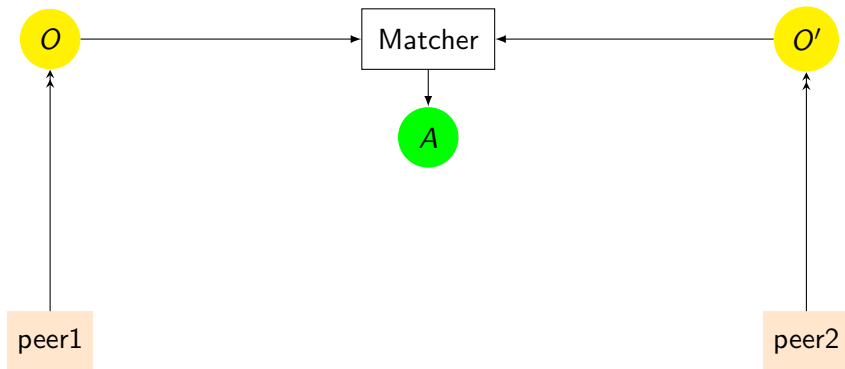
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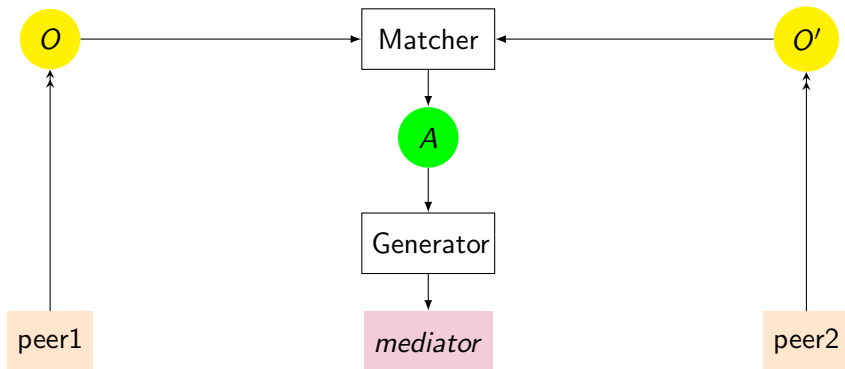
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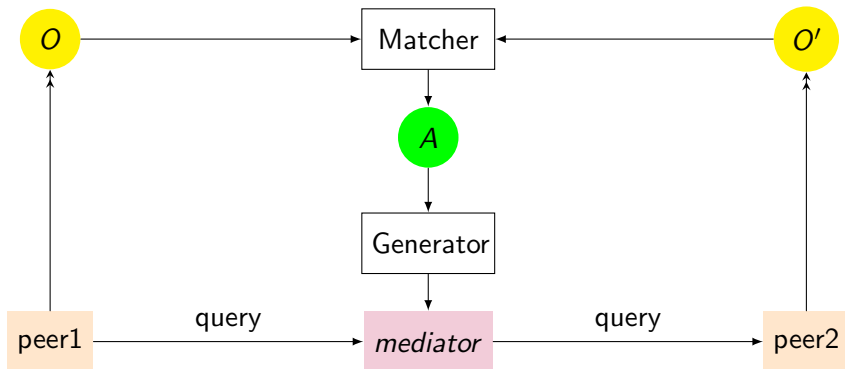
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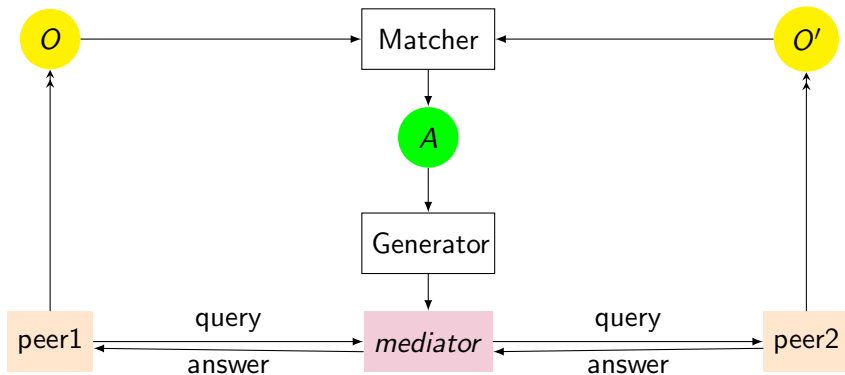
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Applications: summary

Application	instances	run time	automatic	correct	complete	operation
Ontology evolution	✓			✓	✓	transformation
Schema integration	✓			✓	✓	merging
Catalog integration	✓			✓	✓	data translation
Data integration	✓			✓	✓	query answering
P2P information sharing		✓				query answering
Web service composition		✓	✓	✓		data mediation
Multi agent communication		✓	✓	✓	✓	data translation
Query answering	✓	✓				query reformulation

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Matching dimensions

- ▶ **Input dimensions**
 - ▶ Underlying models (e.g., XML, OWL)
 - ▶ Schema-level vs. Instance-level

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- ▶ Equivalence vs. Diverse relations (e.g., subsumption)
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Three layers

- ▶ The upper layer
 - ▶ Granularity of match
 - ▶ Interpretation of the input information

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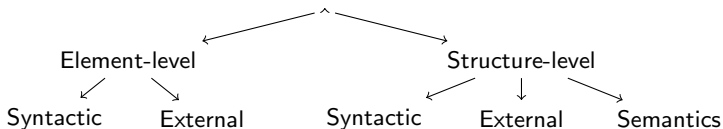
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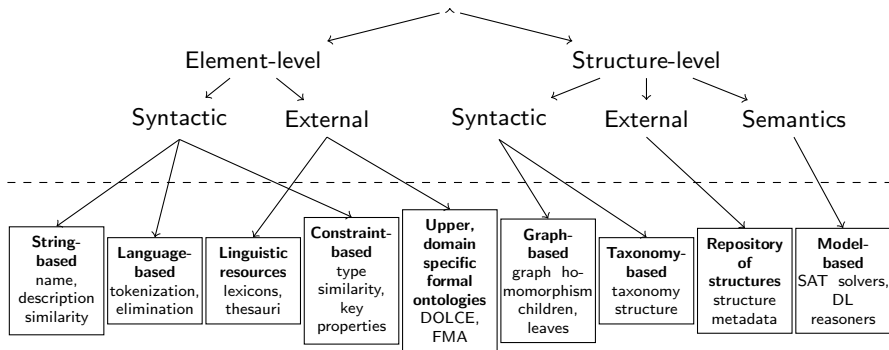
- ▶ The upper layer
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- ▶ The middle layer represents classes of elementary (basic) matching techniques
- ▶ The lower layer is based on the kind of input which is used by elementary matching techniques

Classification of schema-based techniques (simplified)

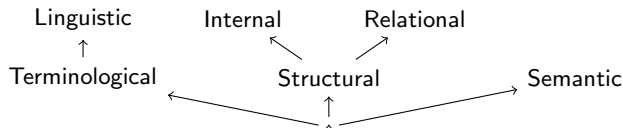
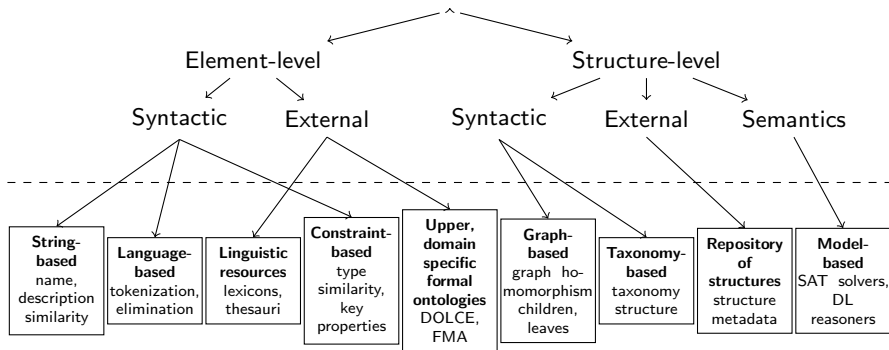
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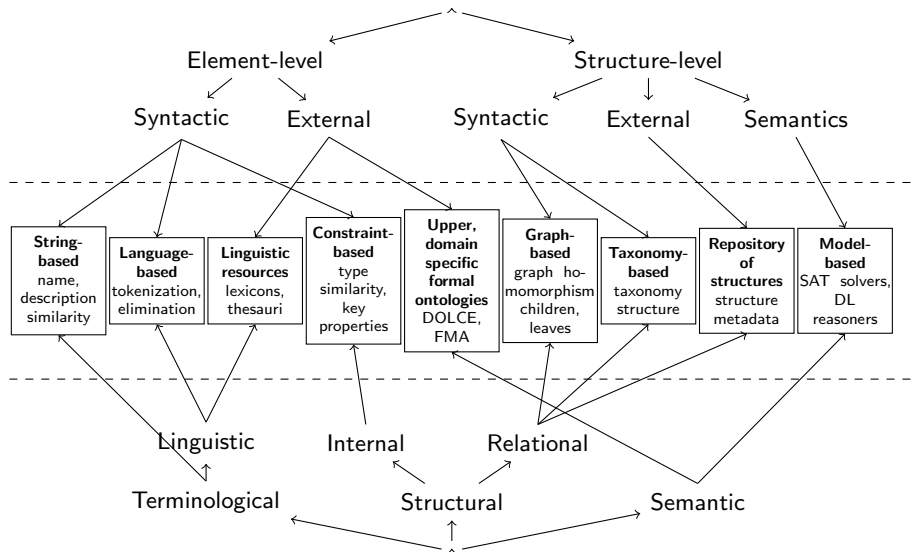
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Element-level techniques: String-based

▶ Prefix

- ▶ takes as input two strings and checks whether the first string starts with the second one
- ▶ **net** = **network**; but also **hot** = **hotel**

(e.g., COMA, SF, S-Match, OLA)

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▶ Suffix

- ▶ takes as input two strings and checks whether the first string ends with the second one
- ▶ **ID** = **PID**; but also **word** = **sword**

(e.g., COMA, SF, S-Match, OLA)

Element-level techniques: String-based

▶ Edit distance

- ▶ takes as input two strings and calculates the number of edition operations, (e.g., **insertions**, **deletions**, **substitutions**) of characters required to transform one string into another, normalized by length of the maximum string
- ▶ $\text{EditDistance}(\text{NKN}, \text{Nikon}) = 0.4$

(e.g., S-Match, OLA, Anchor-Prompt)

Element-level techniques: Language-based

▶ Tokenization

- ▶ parses names into tokens by recognizing punctuation, cases
- ▶ **Hands-Free_Kits** → **< hands, free, kits >**

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▶ Lemmatization

- ▶ analyses morphologically tokens in order to find all their possible basic forms
- ▶ **Kits** → **Kit**

(e.g., COMA, Cupid, S-Match, OLA)

Element-level techniques: Language-based

▶ Elimination

- ▶ discards “empty” tokens that are articles, prepositions, conjunctions . . .
- ▶ **a, the, by, type of, their, from**

(e.g., Cupid, S-Match)

Element-level techniques: Linguistic resources

► Sense-based: WordNet

- $A \sqsubseteq B$ if A is a hyponym or meronym of B
 - Brand \sqsubseteq Name
- $A \sqsupseteq B$ if A is a hypernym or holonym of B
 - Europe \sqsupseteq Greece
- $A = B$ if they are synonyms
 - Quantity = Amount
- $A \perp B$ if they are antonyms or the siblings in the part of hierarchy
 - Microprocessors \perp PC Board

(e.g., Artemis, CtxMatch, S-Match)

Element-level techniques: Linguistic resources

▶ Gloss-based: WordNet gloss comparison

- ▶ The number of the same words occurring in both input glosses increases the similarity value. The equivalence relation is returned if the resulting similarity value exceeds a given threshold
- ▶ **Maltese dog** is a **breed** of toy dogs having a **long** straight **silky** white **coat**
Afghan hound is a tall graceful **breed** of hound with a **long silky** coat

(e.g., S-Match)

Structure-level techniques: Taxonomy-based

Ontologies are viewed as graph-like structures containing terms and their inter-relationships.

- ▶ **Bounded path matching**

- ▶ These take two paths with links between classes defined by the hierarchical relations, compare terms and their positions along these paths, and identify similar terms

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- ▶ **Super(sub)-concepts rules**

- ▶ If super-concepts are the same, the actual concepts are similar to each other

(e.g., Anchor-Prompt, NOM, QOM)

Structure-level techniques: Tree-based

▶ Children

- ▶ Two non-leaf schema elements are structurally similar if their immediate children sets are highly similar

(e.g., Cupid, COMA)

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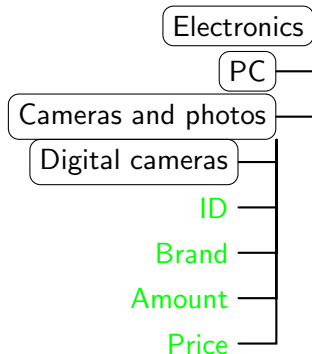
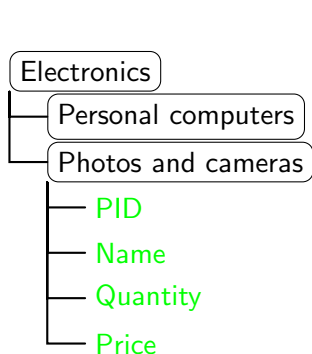
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▶ Leaves

- ▶ Two non-leaf schema elements are structurally similar if their leaf sets are highly similar, even if their immediate children are not

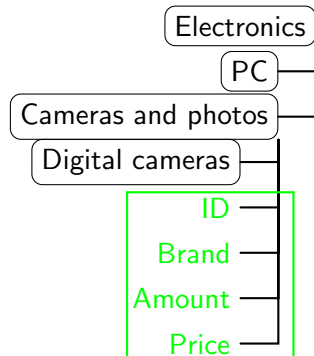
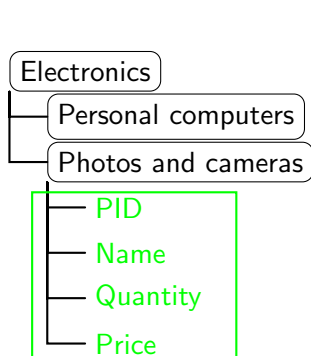
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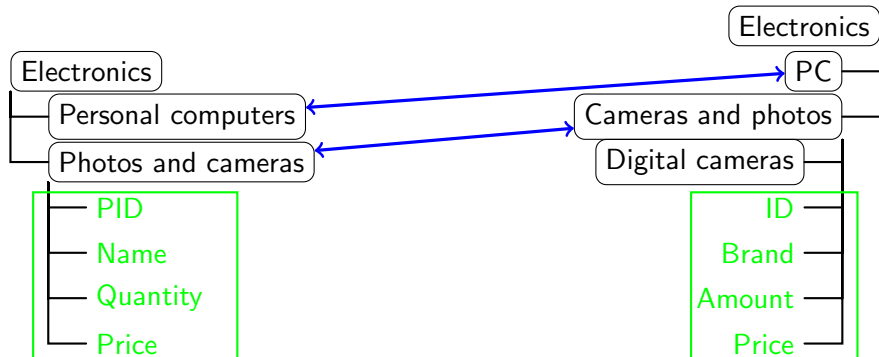
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Structure-level techniques: Model-based

► Propositional satisfiability (SAT)

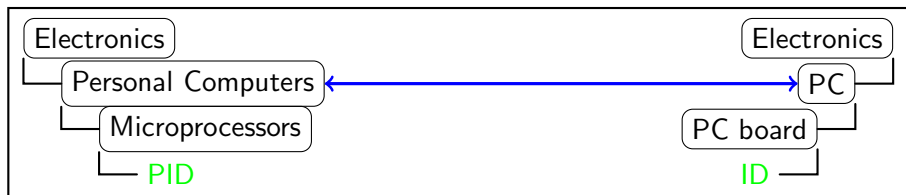
$Axioms \rightarrow rel(context_1, context_2)$

(e.g., CtxMatch, S-Match)

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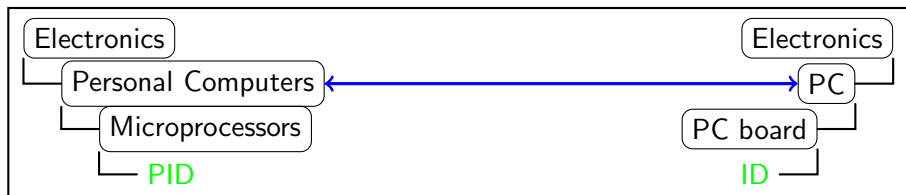


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$$\begin{array}{c}
 \text{Axioms} \\
 \overbrace{(Electronics_1 \leftrightarrow Electronics_2) \wedge (Personal\ Computers_1 \leftrightarrow PC_2)} \\
 \text{context}_1 \qquad \qquad \qquad \text{context}_2 \\
 \overbrace{(Electronics_1 \wedge Personal\ Computers_1)} \leftrightarrow \overbrace{(Electronics_2 \wedge PC_2)}
 \end{array}
 \rightarrow$$

(e.g., CtxMatch, S-Match)

Structure-level techniques: Model-based

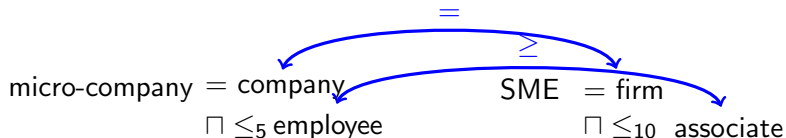
Description logics (DL)-based

micro-company = company
 $\sqcap \leq_5$ employee

SME = firm
 $\sqcap \leq_{10}$ associate

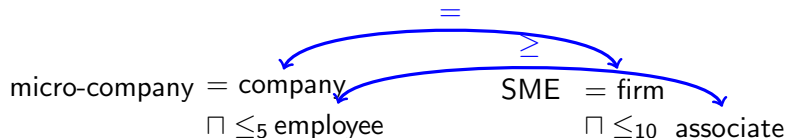
Structure-level techniques: Model-based

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Structure-level techniques: Model-based

Description logics (DL)-based



$\text{company} = \text{firm}$; $\text{associate} \sqsubseteq \text{employee}$

Structure-level techniques: Model-based

Description logics (DL)-based



$\text{company} = \text{firm}$; $\text{associate} \sqsubseteq \text{employee}$

$\text{micro-company} \sqsubseteq \text{SME}$

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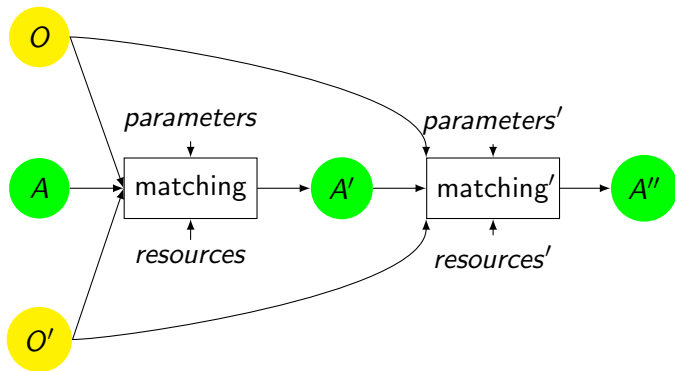
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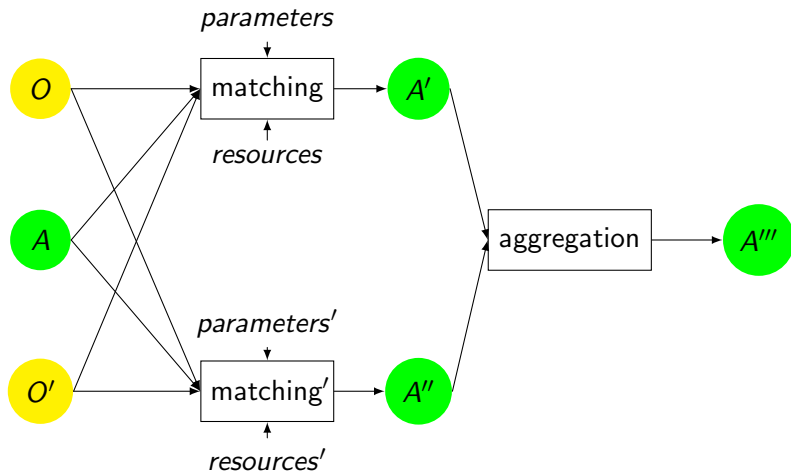
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Sequential composition



Parallel composition



Selecting the final alignment

- ▶ Ranking strategies
 - ▶ Thresholds
 - ▶ MaxDelta

Selecting the final alignment

- ▶ Ranking strategies
 - ▶ Thresholds
 - ▶ MaxDelta
- ▶ Cardinalities
 - ▶ 1-1, 1-*, *-*

Selecting the final alignment

- ▶ Ranking strategies
 - ▶ Thresholds
 - ▶ MaxDelta
- ▶ Cardinalities
 - ▶ 1-1, 1-*, *-*
- ▶ Optimization
 - ▶ stable marriage
 - ▶ maximal weight match

Selecting the final alignment

- ▶ Ranking strategies
 - ▶ Thresholds
 - ▶ MaxDelta
- ▶ Cardinalities
 - ▶ 1-1, 1-*, *-*
- ▶ Optimization
 - ▶ stable marriage
 - ▶ maximal weight match
- ▶ Directionality
 - ▶ $O \rightarrow O', O' \rightarrow O$ (SmallLarge, LargeSmall)
 - ▶ $O \rightarrow O'$ and $O' \rightarrow O$ (Both)

Outline

Matching problem

Classification

Basic techniques

Matching process

Systems

Conclusions

State of the art systems

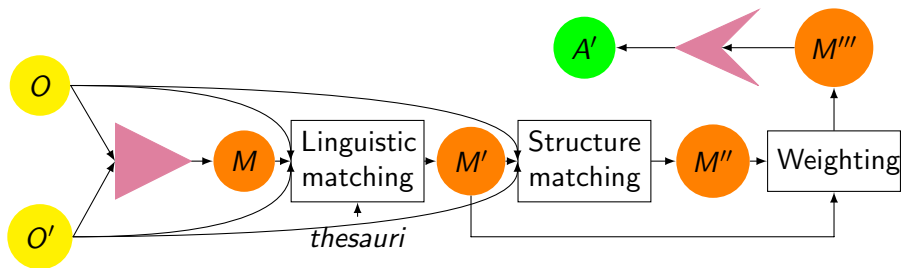
~50 matching systems exist, ... we consider some of them

- ▶ Cupid (U. of Washington, Microsoft Corporation and U. of Leipzig)
- ▶ Falcon-AO (China Southwest U.)
- ▶ OLA (INRIA Rhône-Alpes and U. de Montréal)
- ▶ S-Match (U. of Trento)
- ▶ ...

Cupid

- ▶ Schema-based
- ▶ Computes **similarity coefficients** in the $[0, 1]$ range
- ▶ Performs **linguistic** and **structure** matching
- ▶ Sequential system

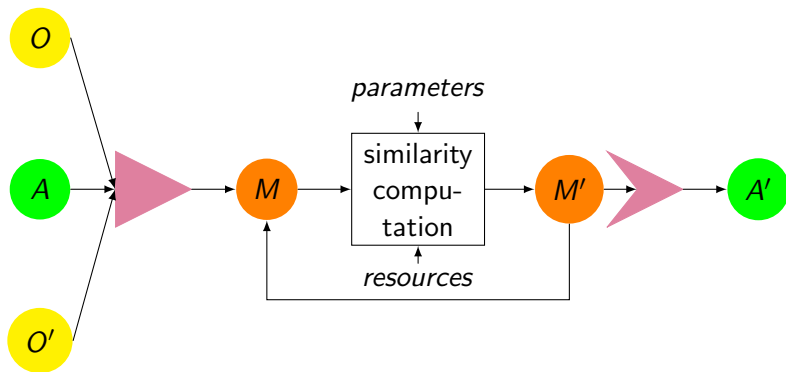
Cupid architecture



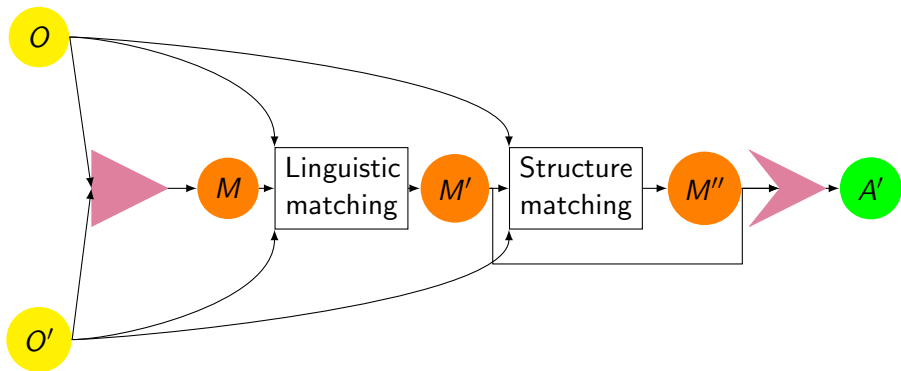
OLA

- ▶ Schema- and Instance-based
- ▶ Computes dissimilarities + extracts alignments (equivalences in the $[0\ 1]$ range)
- ▶ Based on terminological (including linguistic) and structural (internal and relational) distances
- ▶ Neither sequential nor parallel

OLA architecture



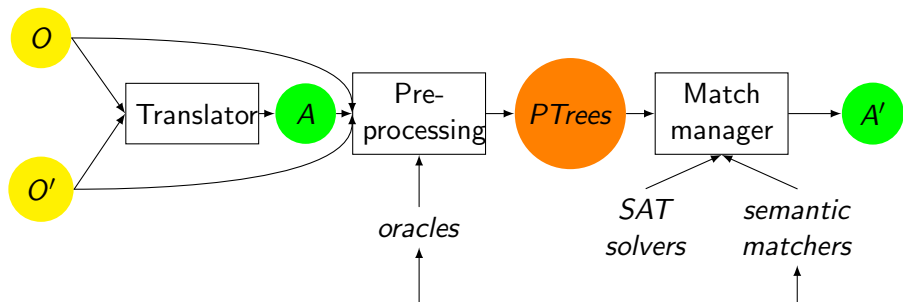
Falcon-OA architecture



S-Match

- ▶ Schema-based
- ▶ Computes **equivalence** ($=$), **more general** (\sqsupseteq), **less general** (\sqsubseteq), **disjointness** (\perp)
- ▶ Analyzes the **meaning** (concepts, not labels) which is codified in the elements and the structures of ontologies
- ▶ Sequential system with a composition at the element level

S-Match architecture



Outline

Matching problem

Classification

Basic techniques

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Summary

- ▶ We have discussed the ontology matching problem and its application domains
- ▶ We have provided classificatory elements for approaching ontology matching techniques
- ▶ We have presented a number of basic matching techniques as well as different strategies for building the matching process
- ▶ We have reviewed some existing matching systems

Uses of classification

- ▶ It provides a common conceptual basis, and hence, can be used for comparing (analytically) different existing ontology matching systems
- ▶ It can help in designing a new matching system, or an elementary matcher, taking advantages of state of the art solutions
- ▶ It can help in designing systematic benchmarks, e.g., by discarding features one by one from ontologies, namely, what class of basic techniques deals with what feature

Challenges

- ▶ Missing background knowledge
- ▶ Performance of systems
- ▶ Interactive approaches
- ▶ Explanations of matching
- ▶ Social aspects of ontology matching
- ▶ Large-scale evaluation
- ▶ Infrastructures
- ▶ ...

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...coming up soon



Thank you
for your attention and interest!

Questions?

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