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

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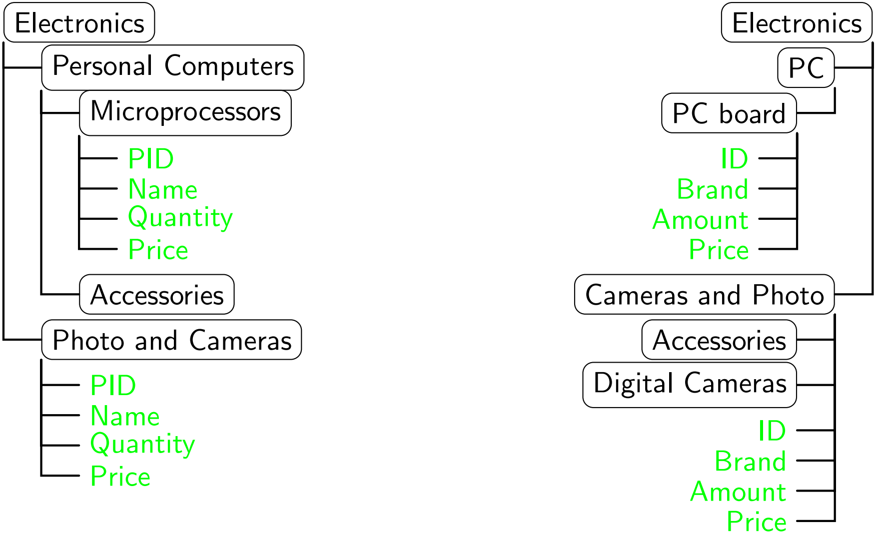
Matching operation

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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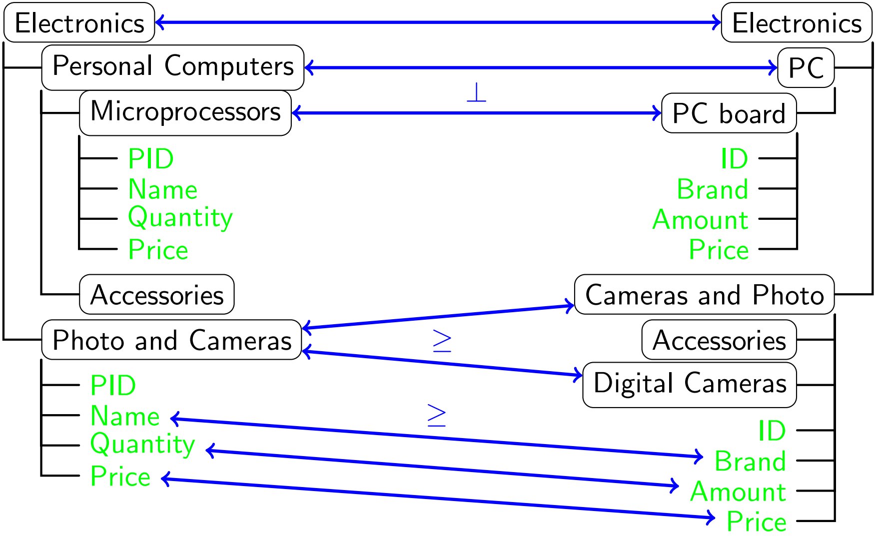

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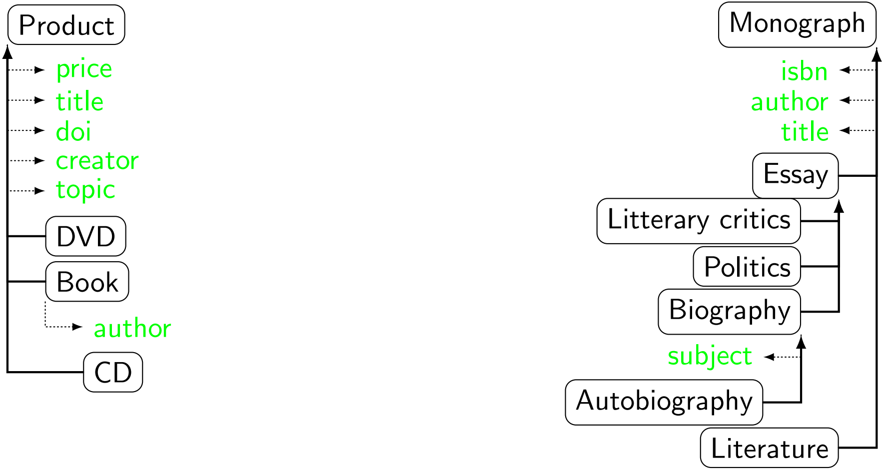

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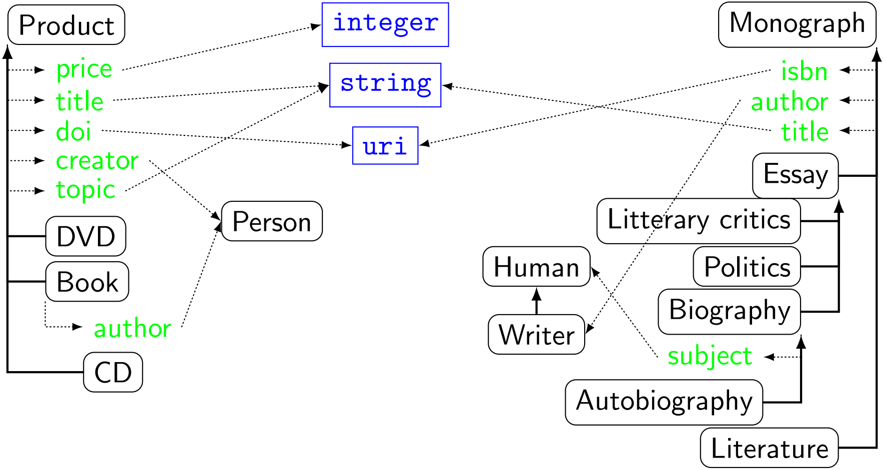

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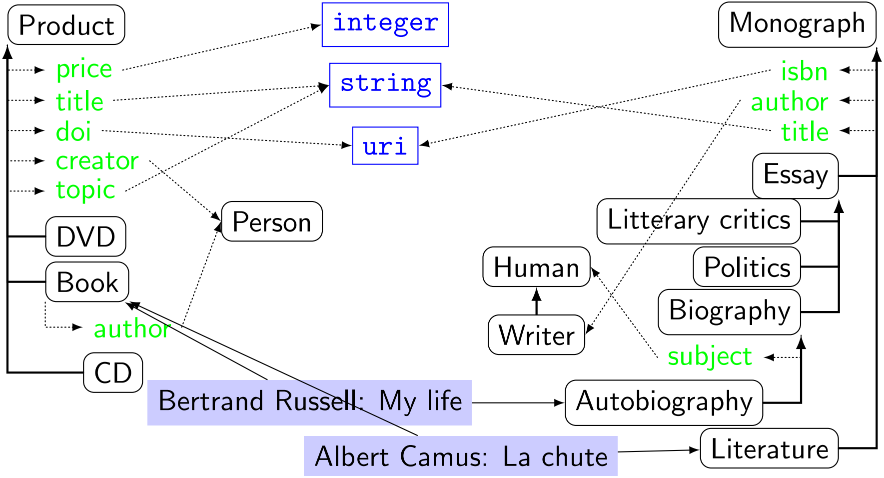

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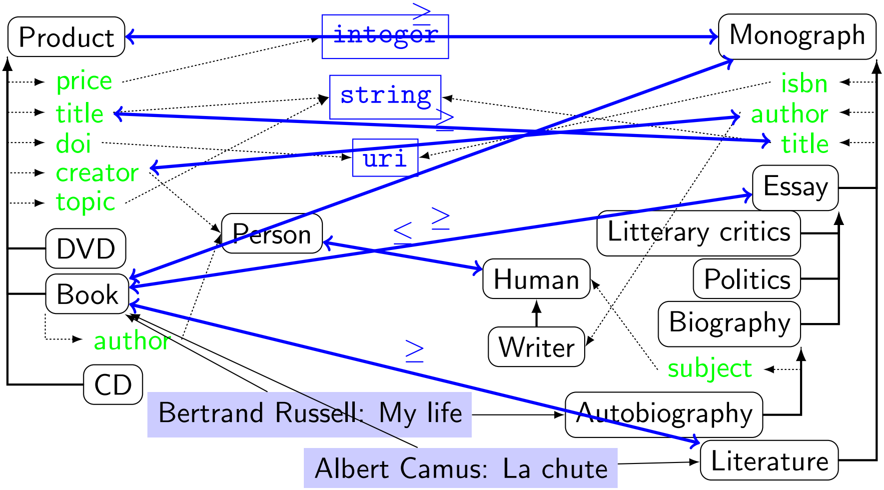

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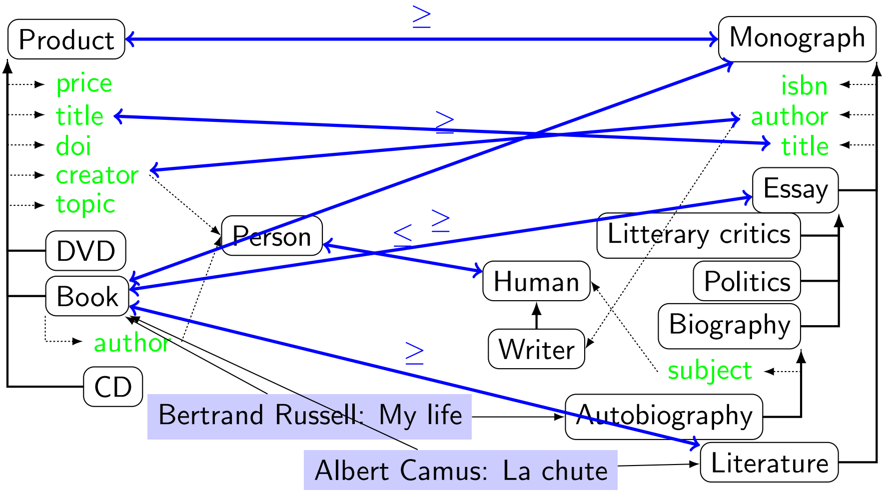

Schema matching vs. ontology matching: differences

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  - Relational schemas provide no generalization

Schema matching vs. ontology matching: differences

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  - 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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- different terminologies are used
- different modeling is used
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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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- R is a relation (e.g., equivalence ($=$), more general ($\sqsupseteq$), disjointness ($\perp$))
- n is a confidence measure in some mathematical structure (typically in the [0,1] range)

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Given two ontologies O and O', an **alignment (A)** between O and O':

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

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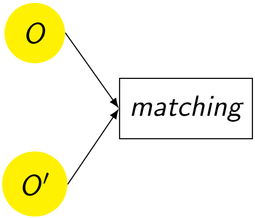

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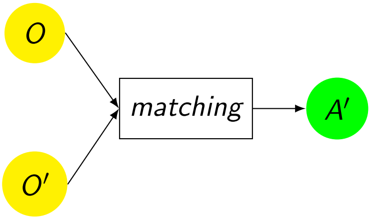

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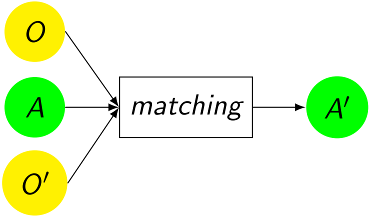

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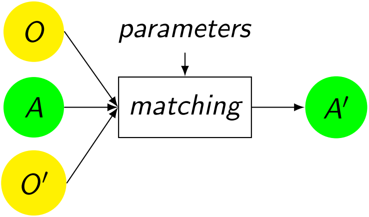

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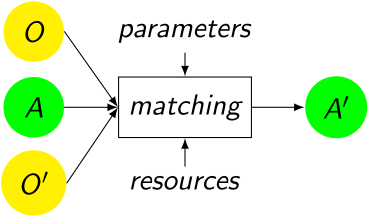

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- **Traditional**
  - Ontology evolution
  - Schema integration
  - Catalog integration
  - Data integration

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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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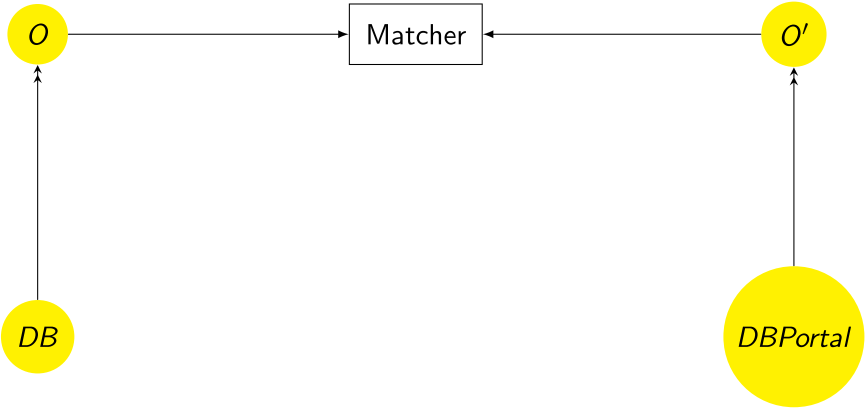

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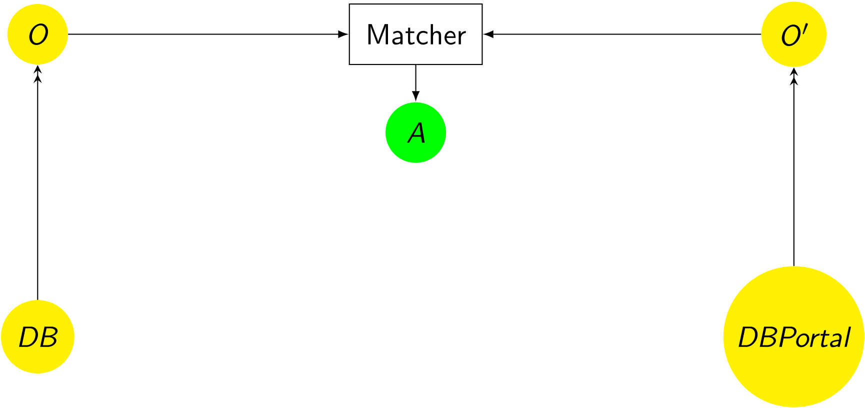

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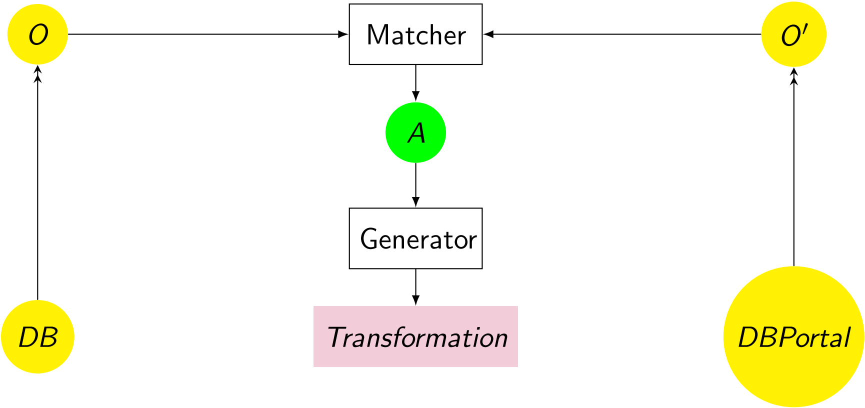

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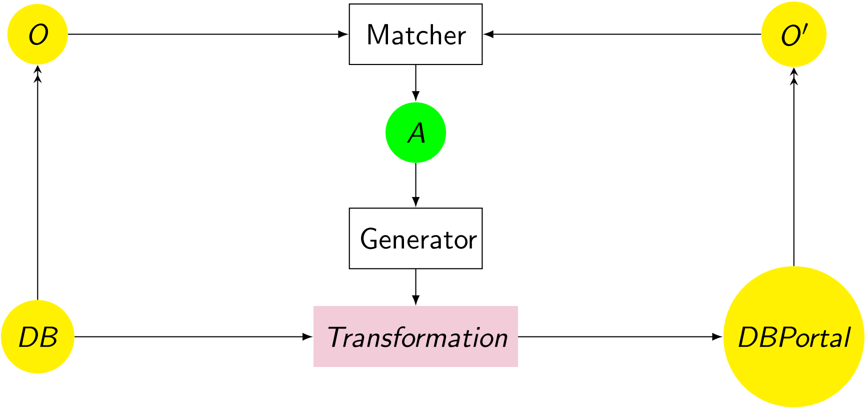

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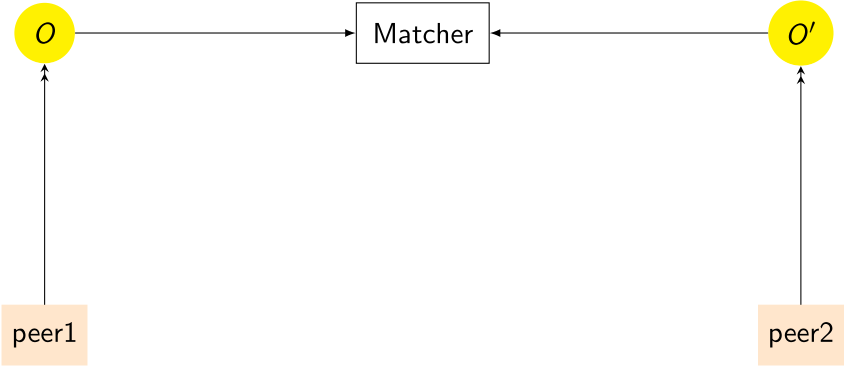

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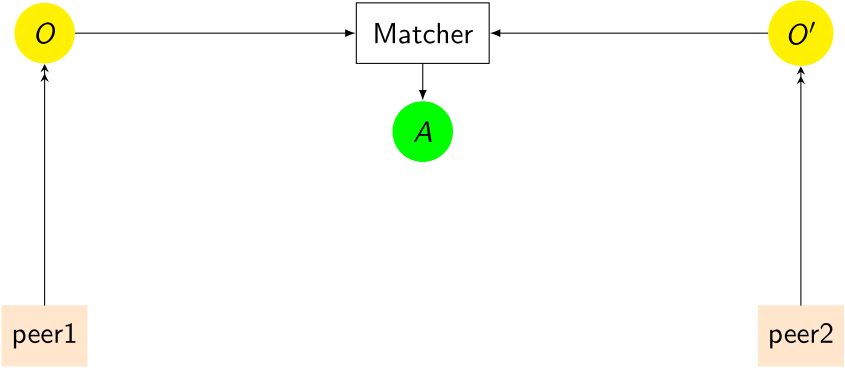

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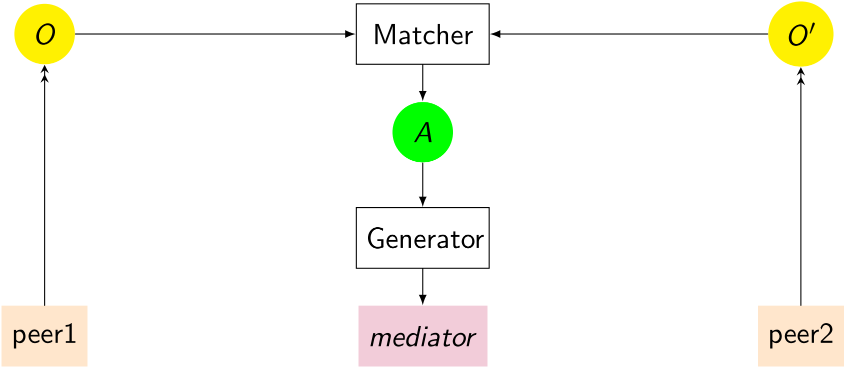

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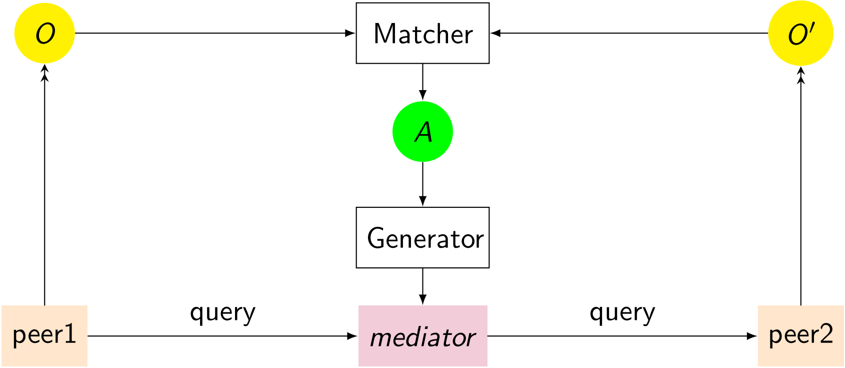

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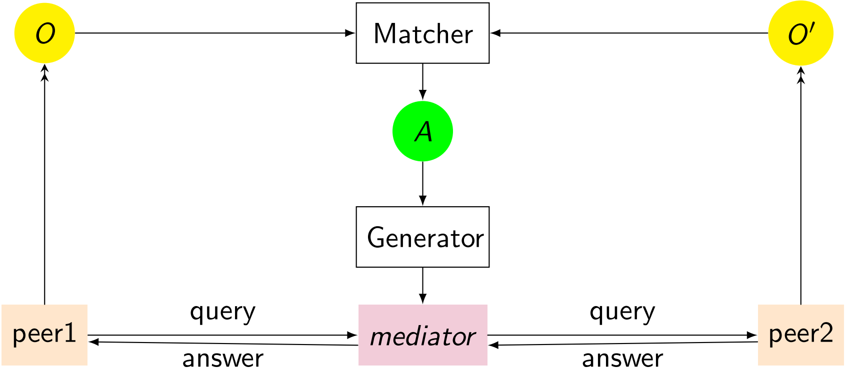

Applications: summary

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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  - Underlying models (e.g., XML, OWL)
  - Schema-level vs. Instance-level

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- The lower layer is based on the kind of input which is used by elementary matching techniques

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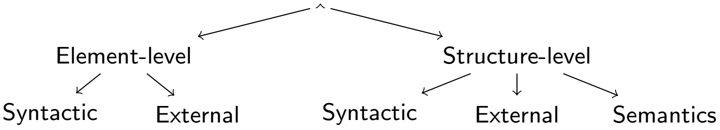

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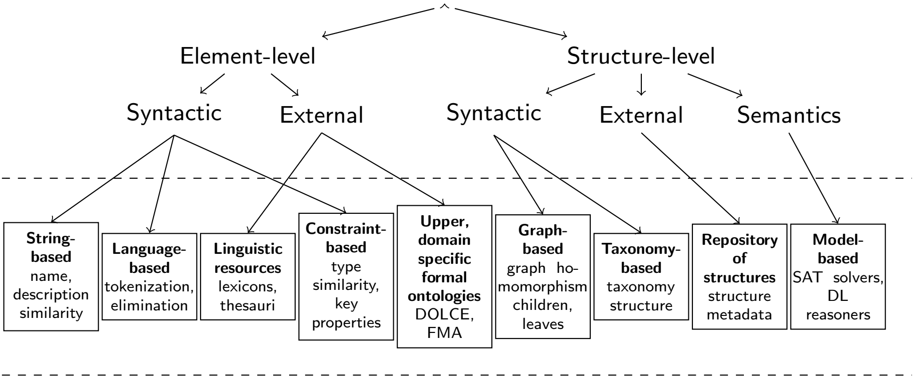

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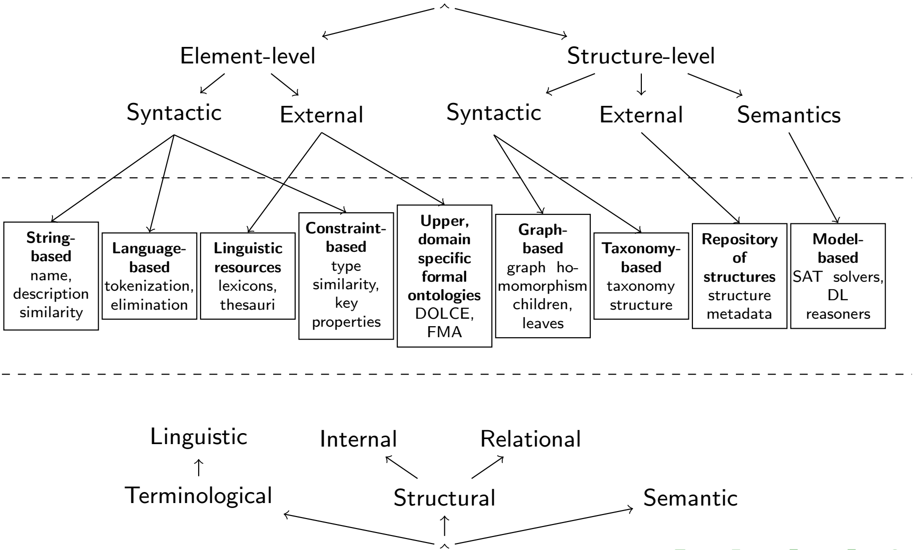

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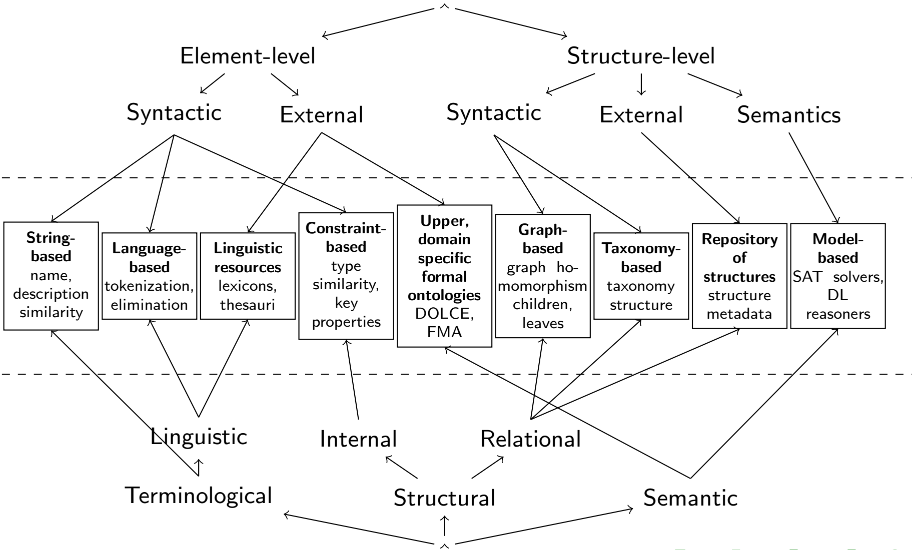

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Element-level techniques: String-based

- 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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  - net = network; but also hot = hotel
- Suffix
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  - 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
  - EditDistance(NKN,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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  - parses names into tokens by recognizing punctuation, cases
  - Hands-Free_Kits → ⟨ hands, free, kits ⟩
- 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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- 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
- 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)

Structure-level techniques: Tree-based

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

(e.g., Cupid, COMA)

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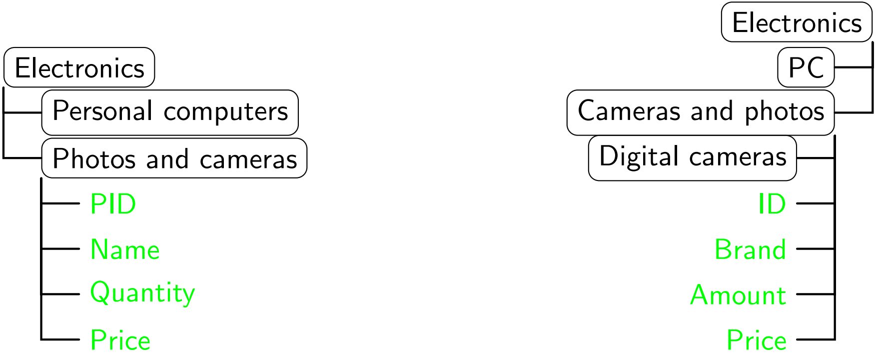

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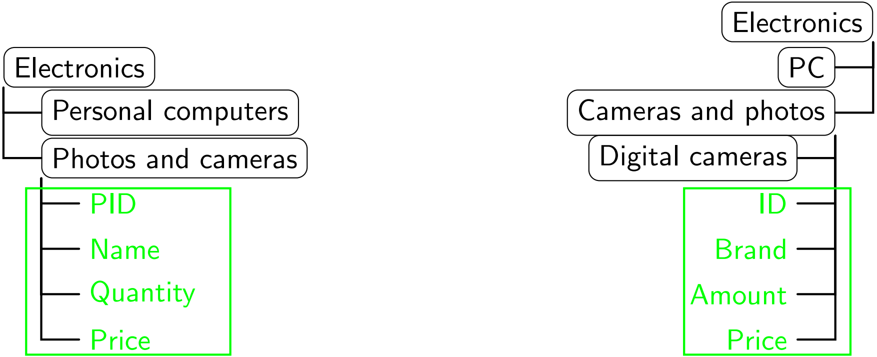

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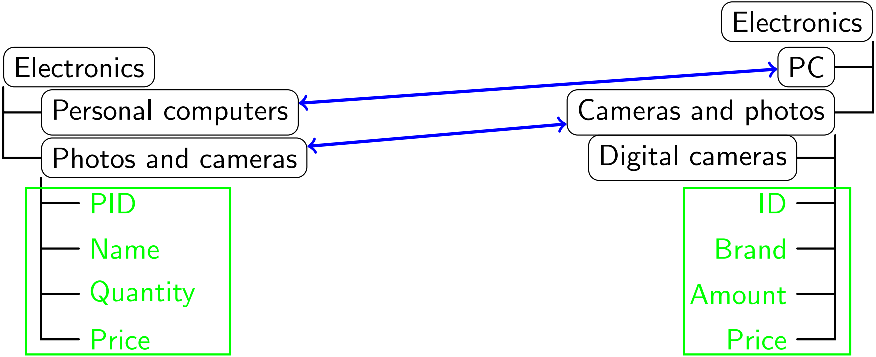

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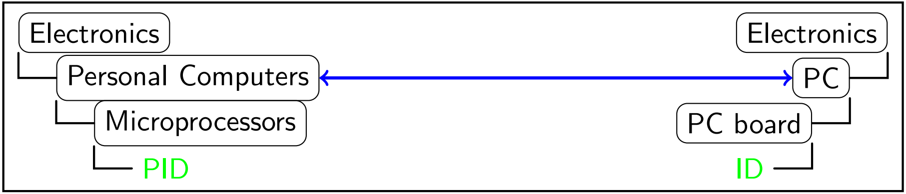

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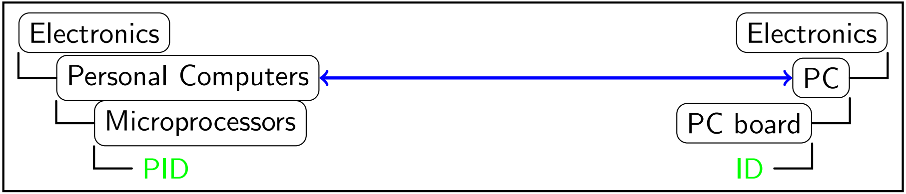

$$\overbrace{(Electronics_1 \leftrightarrow Electronics_2) \wedge (Personal\ \ Computers_1 \leftrightarrow PC_2)}^{Axioms} \rightarrow$$

$$\overbrace{(Electronics_1 \wedge Personal\ \ Computers_1)}^{context_1} \leftrightarrow \overbrace{(Electronics_2 \wedge PC_2)}^{context_2}$$

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

Structure-level techniques: Model-based

Description logics (DL)-based

$$\text{micro-company} = \text{company} \sqcap \leq_5 \text{employee}$$

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

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$=$

$\geq$

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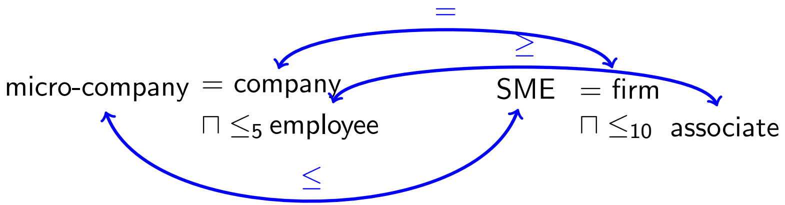

$$\text{company} = \text{firm} \; ; \; \text{associate} \sqsubseteq \text{employee}$$

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

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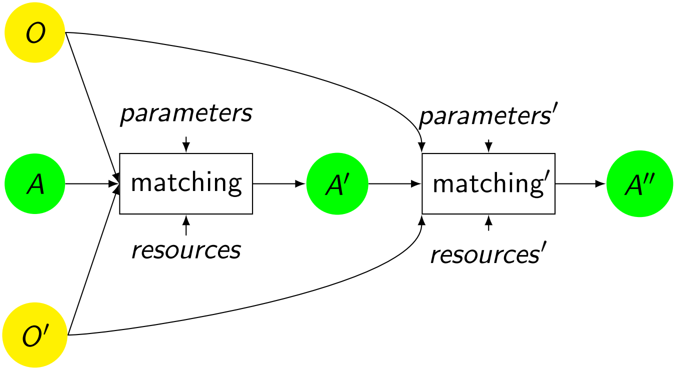
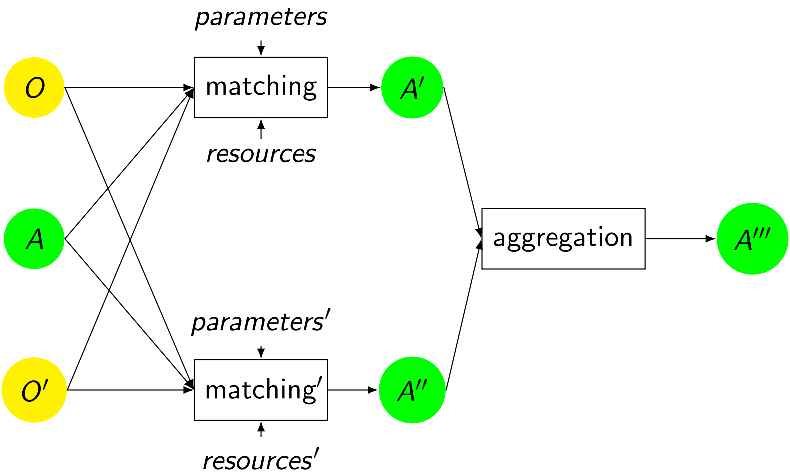
Sequential composition



Parallel composition



Selecting the final alignment

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- Cardinalities
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- Optimization
  - stable marriage
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- Directionality
  - $O \rightarrow O'$, $O' \rightarrow O$ (SmallLarge, LargeSmall)
  - $O \rightarrow O'$ and $O' \rightarrow O$ (Both)

Outline

State of the art systems

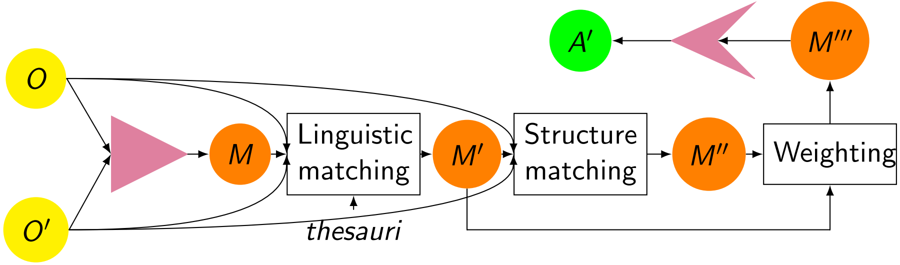
~50 matching systems exist, . . . we consider some of them

- 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

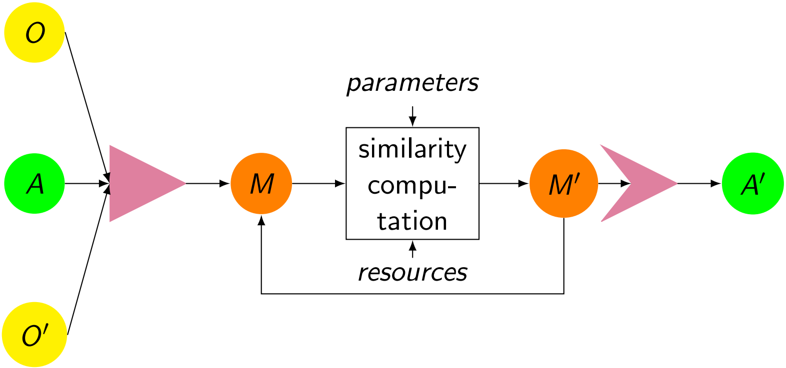
Cupid architecture



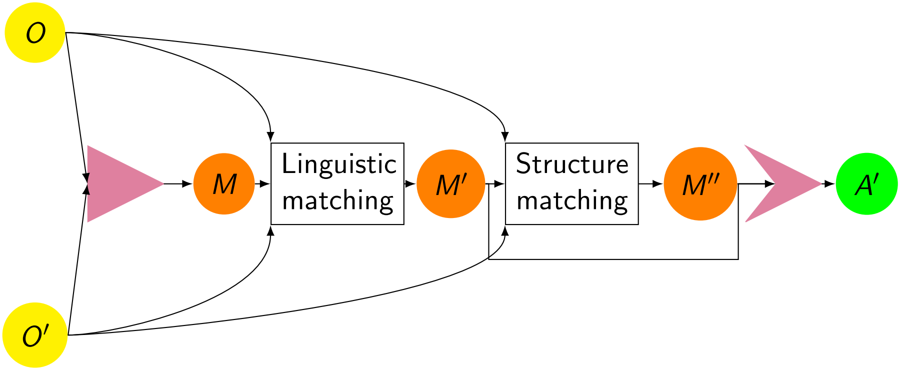
OLA

- 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



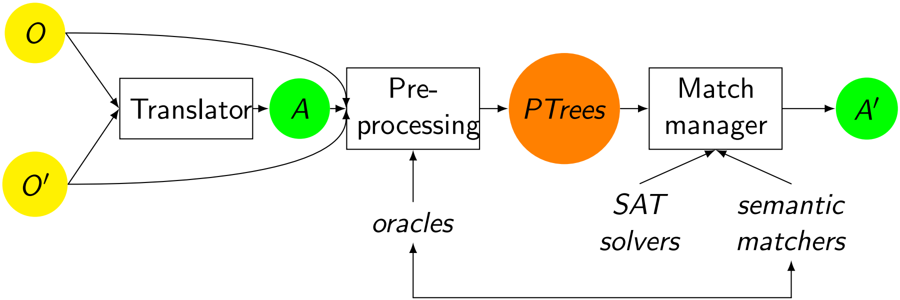
Falcon-OA architecture



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

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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