Data Cleaning for Data Integration

--- Entity Resolution ---

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Courtesy and Creation: Ekaterini Ioannou

Problem overview

Data integration:

- Combine data from various sources/applications
- Merge into a single database
- Requires a unified view over the data → cleaning

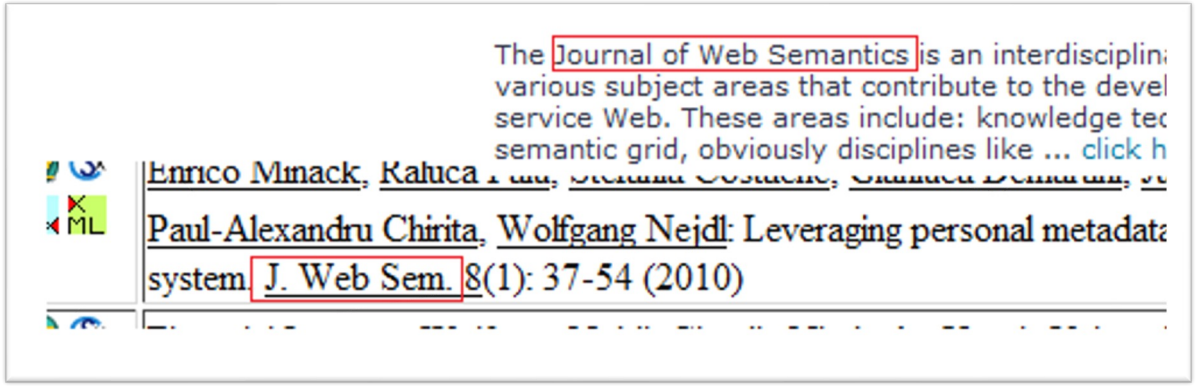
Challenges:

- Handling the various incoming schemata
- Dealing with the missing data values
- **Entity Resolution**

  → combine the various descriptions or references for the same real world objects

Reasons for Various Descriptions

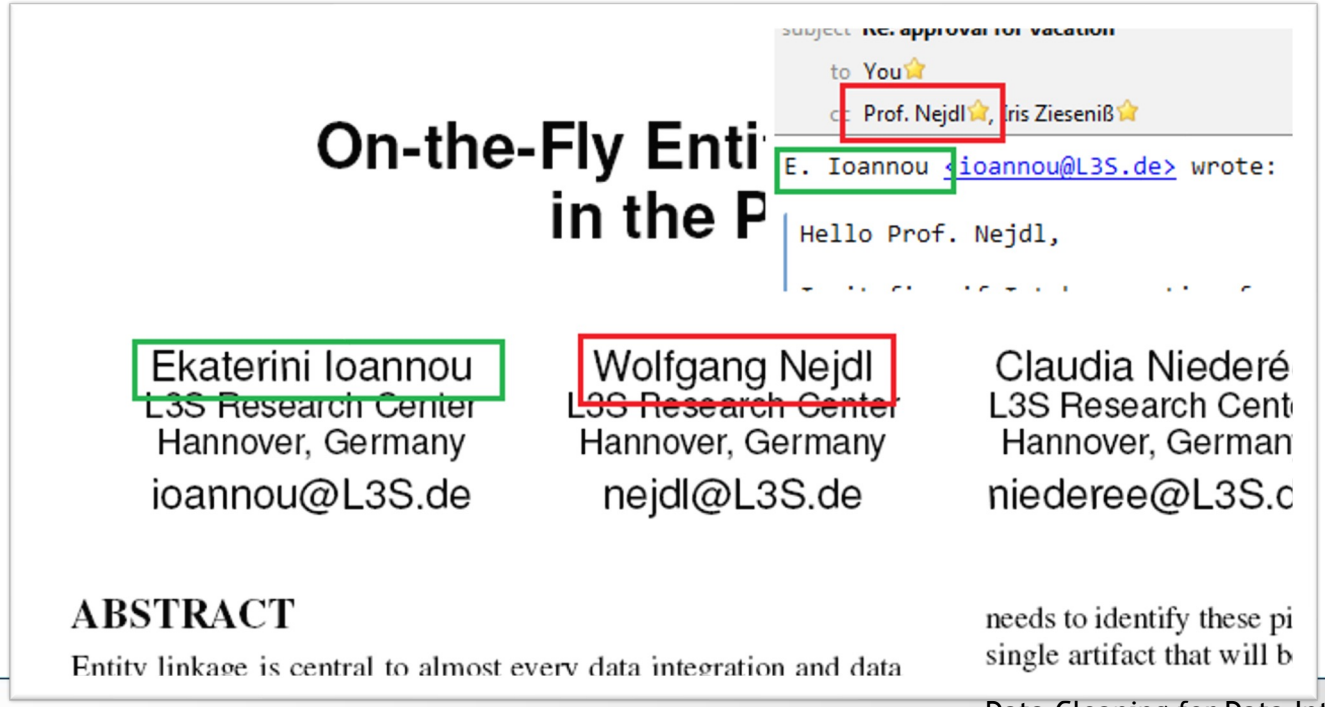
- Text variations:
  - Misspellings
  - Acronyms
  - Transformations
  - Abbreviations
  - etc.



Reasons for Various Descriptions

- Text variations
- Local knowledge:
  - Each source uses different formats

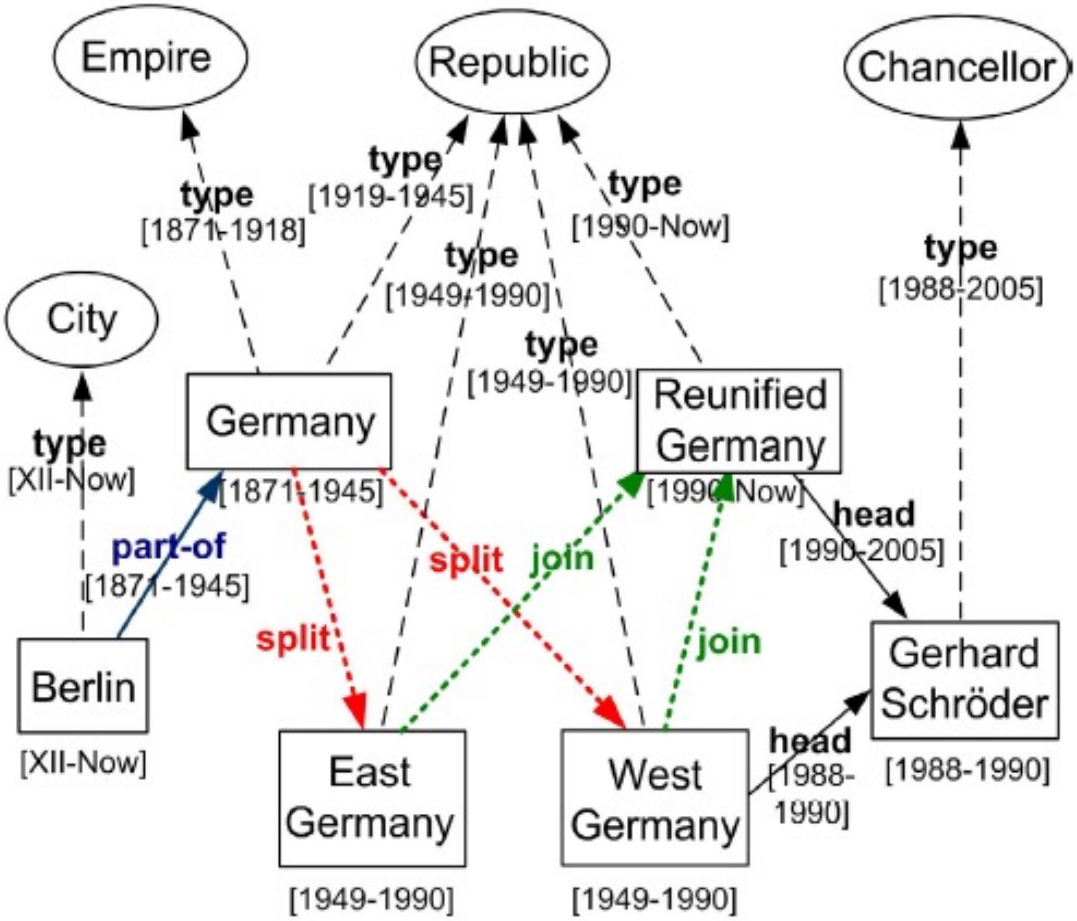
    e.g., person from publication vs. person from email
  - Lack of global coordination for identifier assignment



Reasons for Various Descriptions

figure from [RVMB09]

- Text variations
- Local knowledge
- Evolving nature of data:
  - Entity alternative names appearing in time
  - Updates in entity data



Jacqueline Lee Bouvier

Alternate Names: Jackie Bouvier | Jackie Kennedy | Mrs. John F. Kennedy | Jackie Onassis | Jacqueline Kennedy Onassis | Jacqueline Onassis

Reasons for Various Descriptions

- Text variations
- Local knowledge
- Evolving nature of data
- New functionality:
  - Web page extraction

    e.g., Calais, Cogito
  - Import data collections from various applications

    e.g., Wikipedia data used in Freebase
  - Mashups for easy and fast integration from various source

    e.g., yahoo pipes

Required Process

Entity Resolution typical methodology:

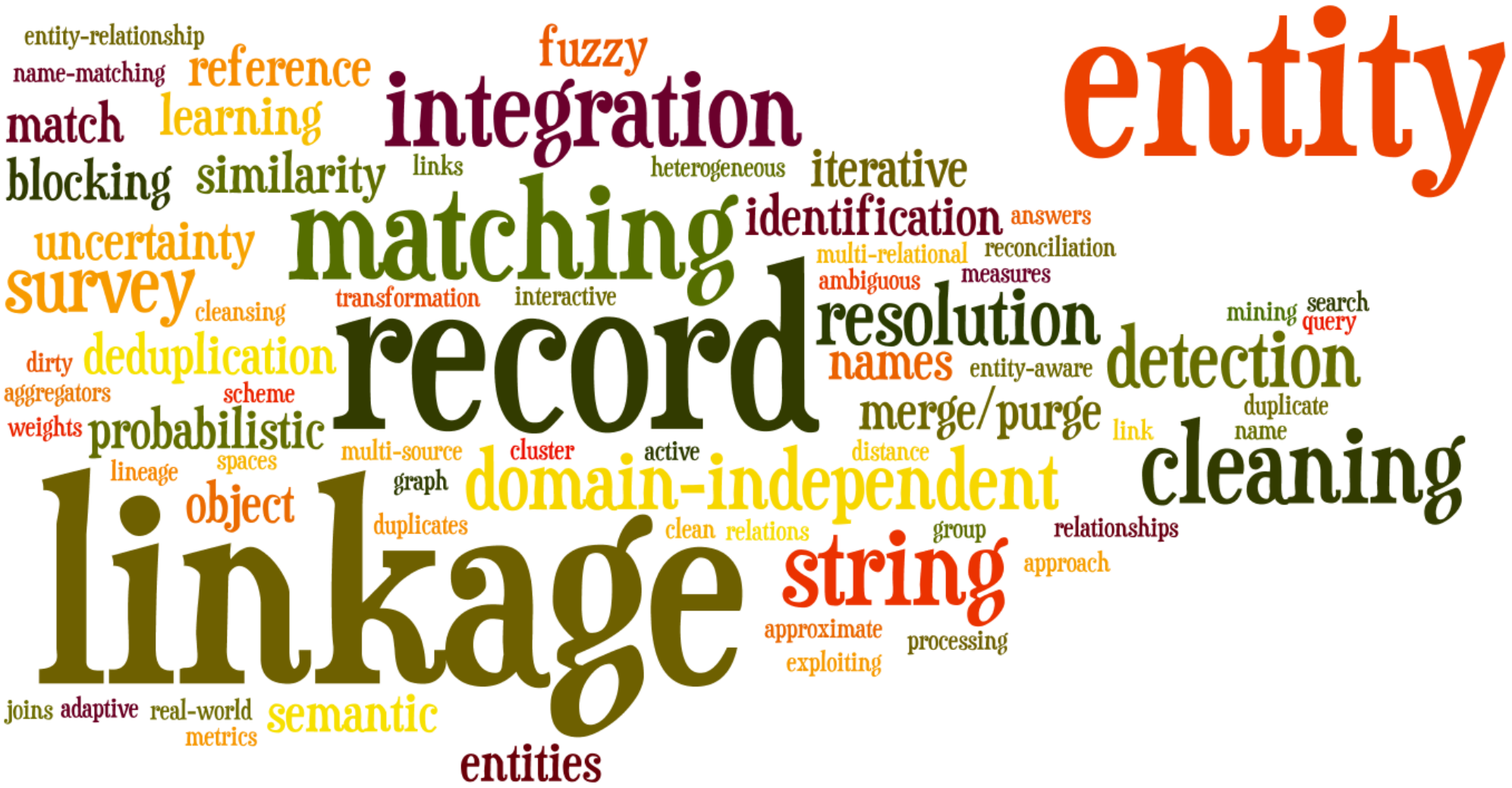
- Indentify data describing the same real-world objects
- Decide how to merge the data
- Update the data collection

Solutions following various directions

We present them through four categories:

1. Atomic similarity methods
2. Similarity methods for sets
3. Facilitating inner-relationships
4. Methods in uncertain data

Alternative names for Entity Resolution



Outline

1. Motivation: Entity Resolution
2. **Atomic similarity methods**
3. Similarity methods for sets
4. Facilitating inner-relationships
5. Methods in uncertain data
6. Conclusions

Atomic String Similarity

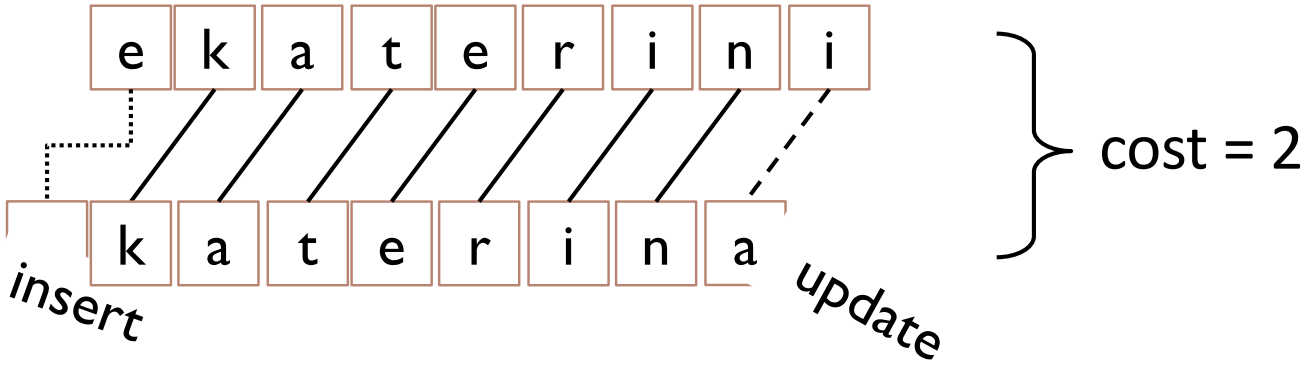
Examples of targeting cases:

- Publication authors: "John D. Smith" vs. "J. D. Smith"
- Journal names: "Transactions on Knowledge and Data Engineering" vs. "Trans. Knowl. Data Eng."

Edit Distance:

- Number of operations to convert from 1st to 2nd string
- Operations in Levenstein distance [Lev66]

  → delete, insert, and update a character with cost 1

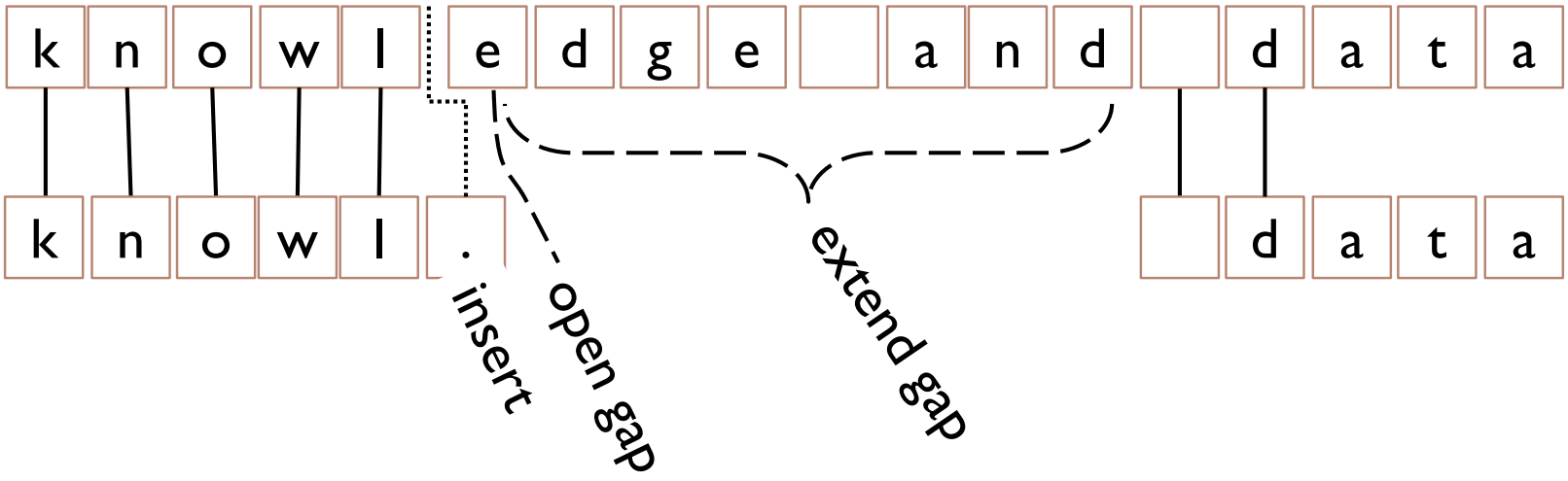


Atomic String Similarity

Gap Distance:

- Overcome limitation of edit distance with shortened strings
- Considers two extra operations [Nav01]

  → open gap, and extend gap (with small cost)



cost = 1 + o + 8e

Atomic String Similarity

Jaro similarity [Jar89]:

- Small string, e.g., first and last names

$$\text{JaroSim}(s_1, s_2) = \frac{1}{3}\left(\frac{C}{|s_1|} + \frac{C}{|s_2|} + \frac{C-T}{C}\right)$$

C → common characters in s_1 and s_2

T → transpositions/2 transposition is a *k* in which $s_1[k] != s_2[k]$

Example: "DEIS"vs. "DESI"

$$C=4,\ T=2/2,\ \text{JaroSim} = \frac{1}{3}\left(\frac{4}{4} + \frac{4}{4} + \frac{4-1}{4}\right) = 0.9167$$

Jaro-Winkler similarity [Win99]:

- Extension that gives higher weight to matching prefix
- Increasing it's applicability to names

Atomic String Similarity

Soundex:

- Coverts each word into a phonetic encoding by assigning the same code to the string parts that sound the same
- Similarity between the corresponding phonetic encodings

Remarks:

- Surveys: [CRF03], [Win06]
- Existing API with these methods:
  - SecondString: http://secondstring.sourceforge.net/
  - SimMetrics: http://www.dcs.shef.ac.uk/~sam/simmetrics.html

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Similarity methods for sets

Database community:

- Each relation is an entity
- A simple example:

	Name	Email	Journal
e1	John D. Smith	smith@uni.edu	Transactions on Knowledge and Data Engineering
e2	Smith, J.	smith@uni.edu	IEEE Trans. Knowl. Data Eng.

Merge-purge [HS95],[HS98]:

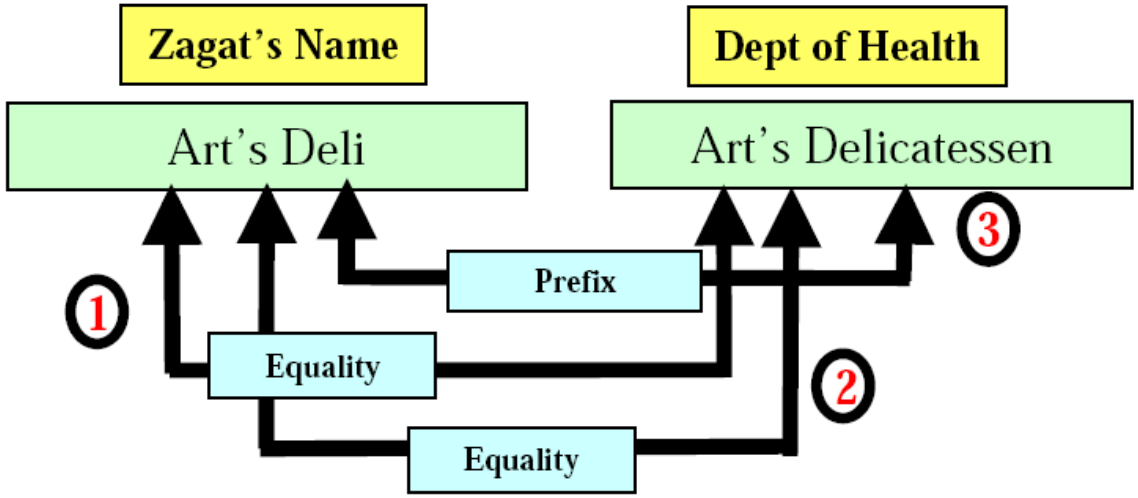
- Idea: same entities with share information
- Create a key for each relation (e.g., email)
- Sort relations according to key
- Compare only a limited set of relations in each iteration

Similarity methods for sets

Using transformations [TKM02]:

1. Analyze data to generate transformations

- Unary transform:
  - Equality, Stemming, Soundex, Abbreviation (e.g., 3rd or third)
- N-ary transformations:
  - Initial, Prefix, Suffix, Substring Acronym, Abbreviation, Drop



2. Calculate transformation weights
3. Apply on candidate mappings

Similarity methods for sets

Group Linkage [OKLS07]:

- Considers groups of relational records
  - not individual relational records
- Groups match when:
  1. High similarity between data of individual records
  2. Large fraction of matching records, i.e., no. 1

Some additional methods

→ [DLLH03]

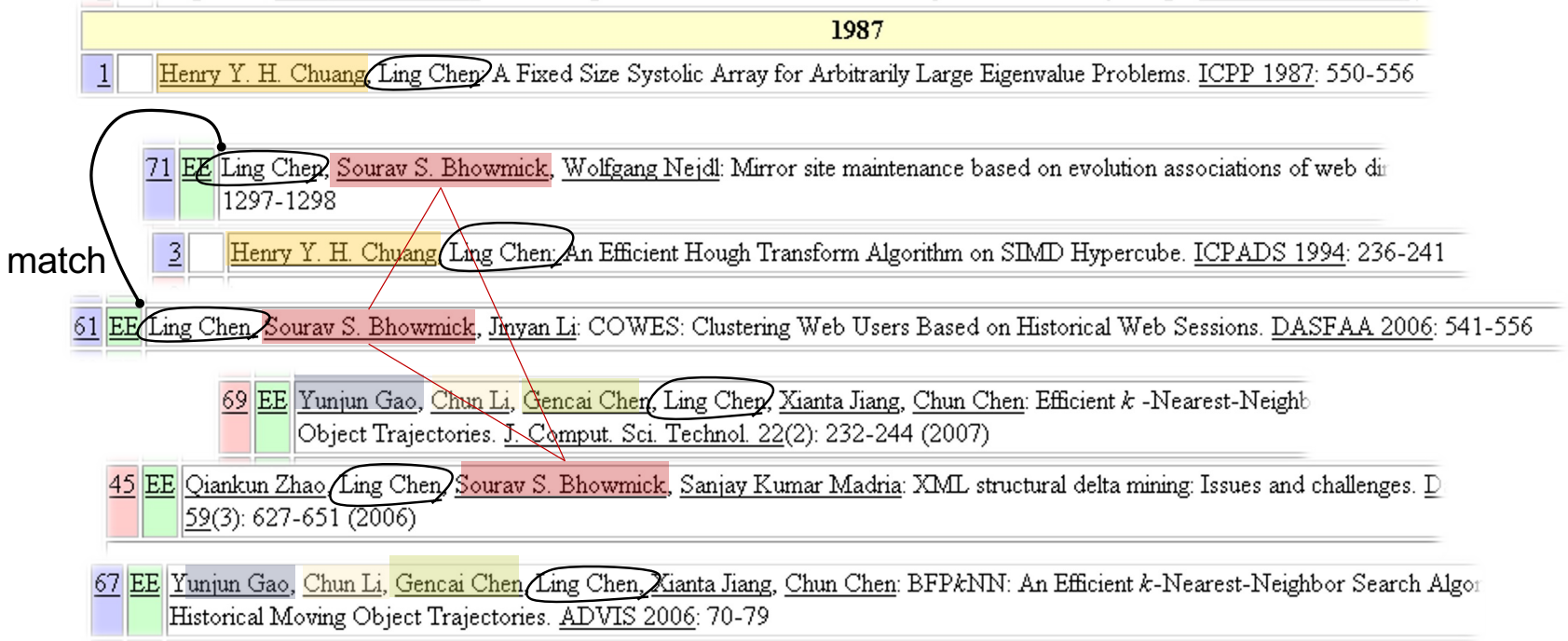
Surveys for methods in this category

→ [DH05], [EIV07], [OS99]

Similarity methods for sets

Remarks:

- Methods do not consider semantics of data
- Currently used as a first step of Entity Resolution



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Facilitating inner-relationships

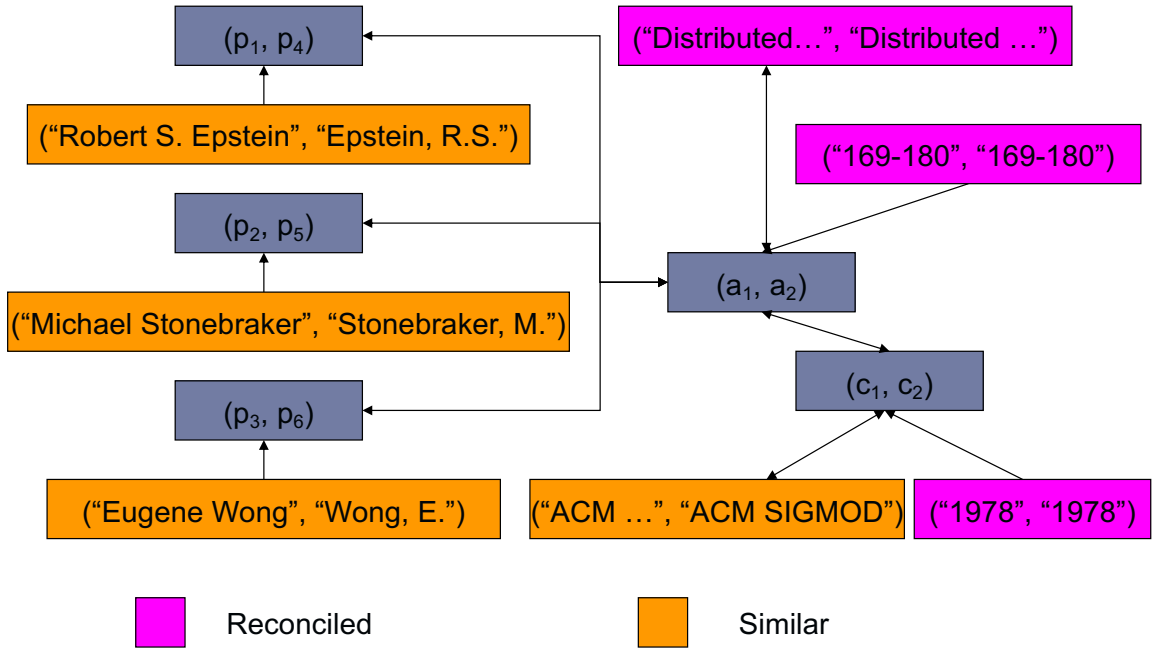
General idea

- Heterogeneous data
  - Lack of schema information
  - Variations in entity descriptions
  - Incomplete or missing values
- Improve effectiveness by considering data semantics
- Example → Reference Reconciliation

Facilitating inner-relationships

Reference Reconciliation [DHM05]

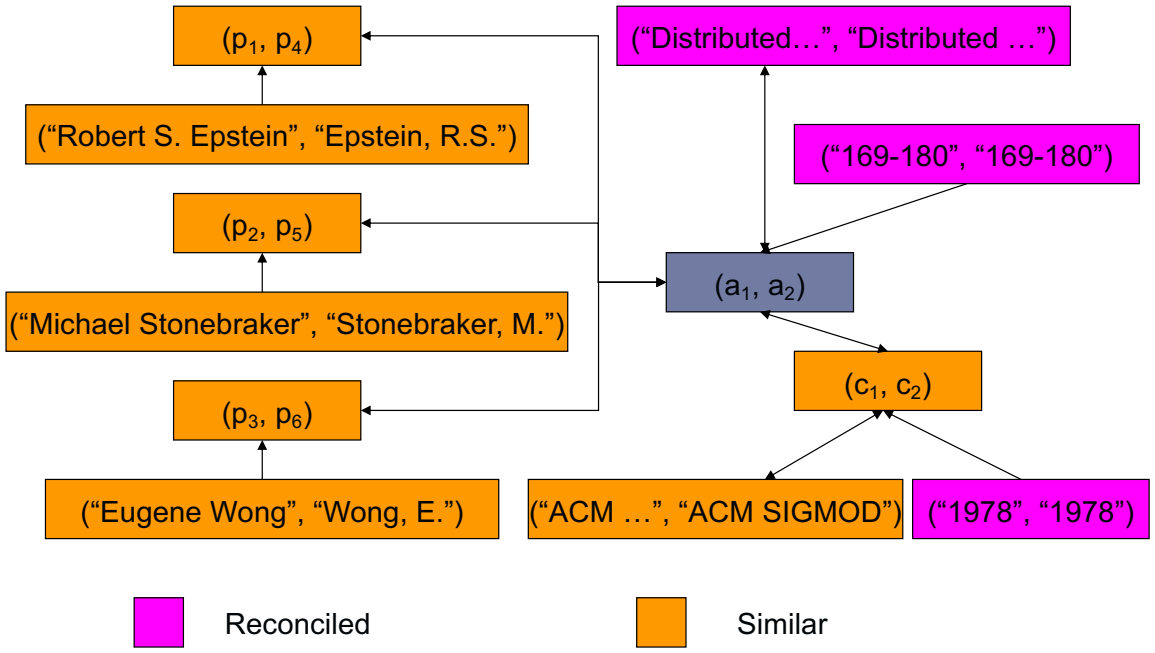
1. Build a dependency graph



Facilitating inner-relationships

Reference Reconciliation [DHM05]

1. Build a dependency graph
2. Exploit information and relationships



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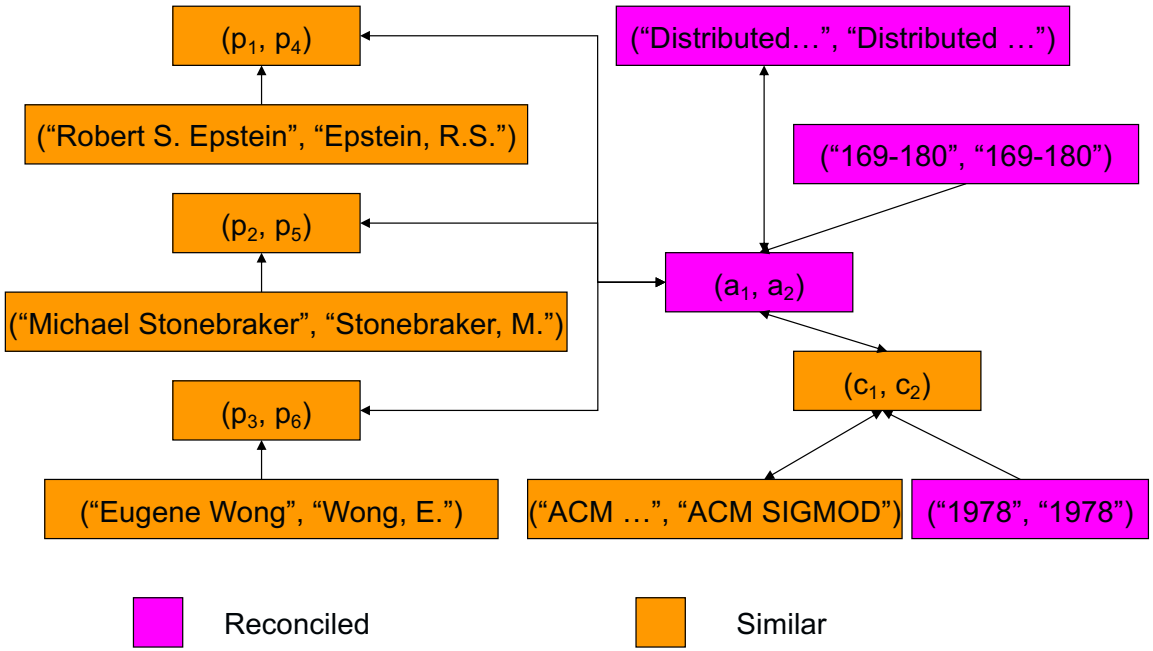

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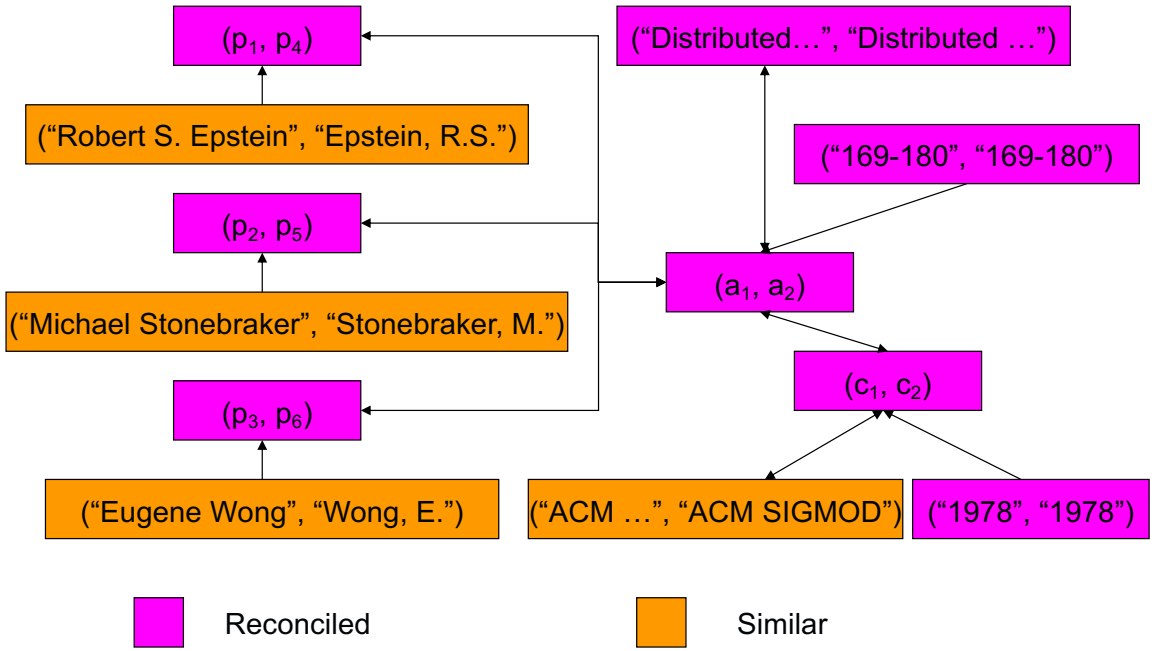
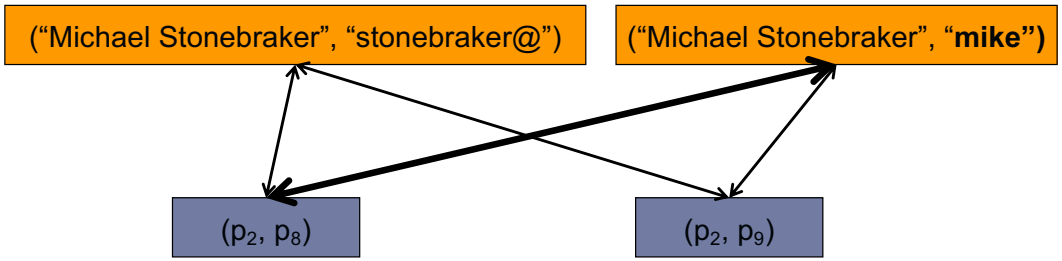


Facilitating inner-relationships

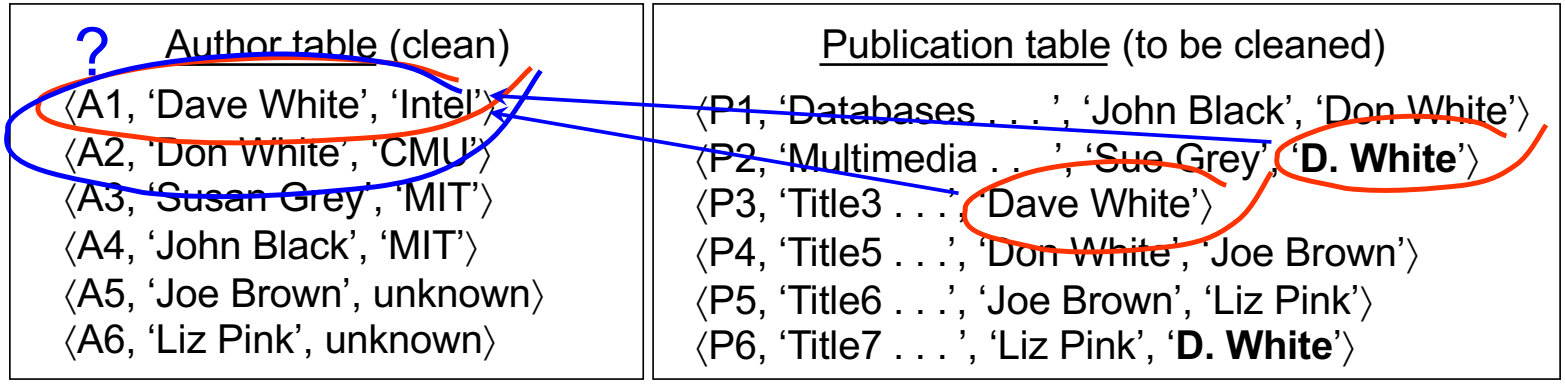
Reference Reconciliation [DHM05]

1. Build a dependency graph
2. Exploit information and relationships
3. Propagate information → enrich relationships



Facilitating inner-relationships

Analysis of entity-relationship graph [KM06], [KMC05]:

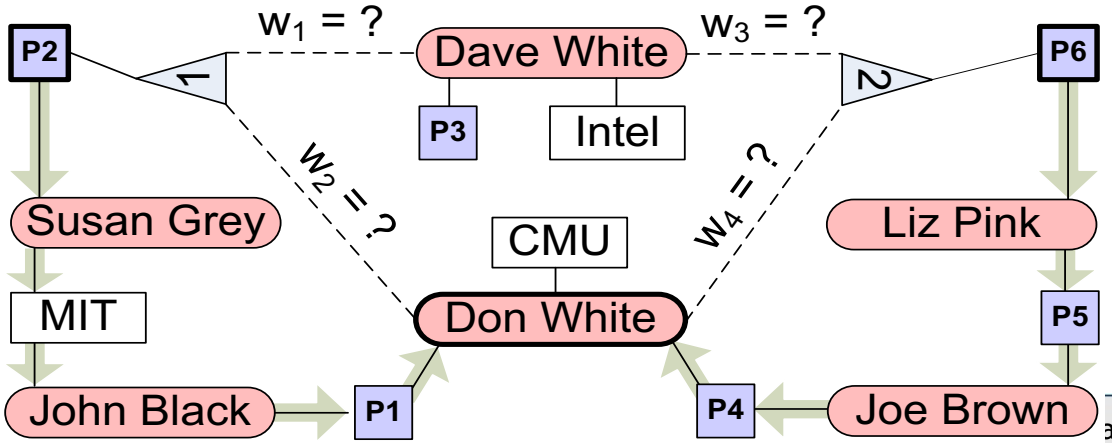


Facilitating inner-relationships

Analysis of entity-relationship graph [KM06], [KMC05]:

1. Dataset modeled as a graph

? Author table (clean)	Publication table (to be cleaned)
⟨A1, 'Dave White', 'Intel'⟩	⟨P1, 'Databases . . . ', 'John Black', 'Don White'⟩
⟨A2, 'Don White', 'CMU'⟩	⟨P2, 'Multimedia . . . ', 'Sue Grey', **'D. White'**⟩
⟨A3, 'Susan Grey', 'MIT'⟩	⟨P3, 'Title3 . . .', 'Dave White'⟩
⟨A4, 'John Black', 'MIT'⟩	⟨P4, 'Title5 . . .', 'Don White', 'Joe Brown'⟩
⟨A5, 'Joe Brown', unknown⟩	⟨P5, 'Title6 . . .', 'Joe Brown', 'Liz Pink'⟩
⟨A6, 'Liz Pink', unknown⟩	⟨P6, 'Title7 . . . ', 'Liz Pink', **'D. White'**⟩



Facilitating inner-relationships

Analysis of entity-relationship graph [KM06], [KMC05]:

1. Dataset modeled as a graph
2. Data more strongly connected when sharing relationships

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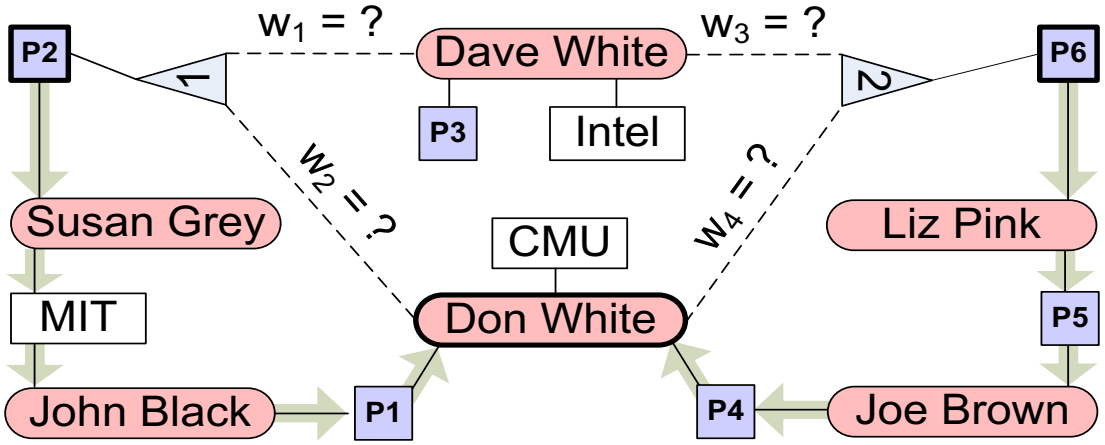

Facilitating inner-relationships

Analysis of entity-relationship graph [KM06], [KMC05]:

1. Dataset modeled as a graph
2. Data more strongly connected when sharing relationships
3. Measure the connection strengths (details in paper)

? Author table (clean)	Publication table (to be cleaned)
⟨A1, 'Dave White', 'Intel'⟩	⟨P1, 'Databases . . . ', 'John Black', 'Don White'⟩
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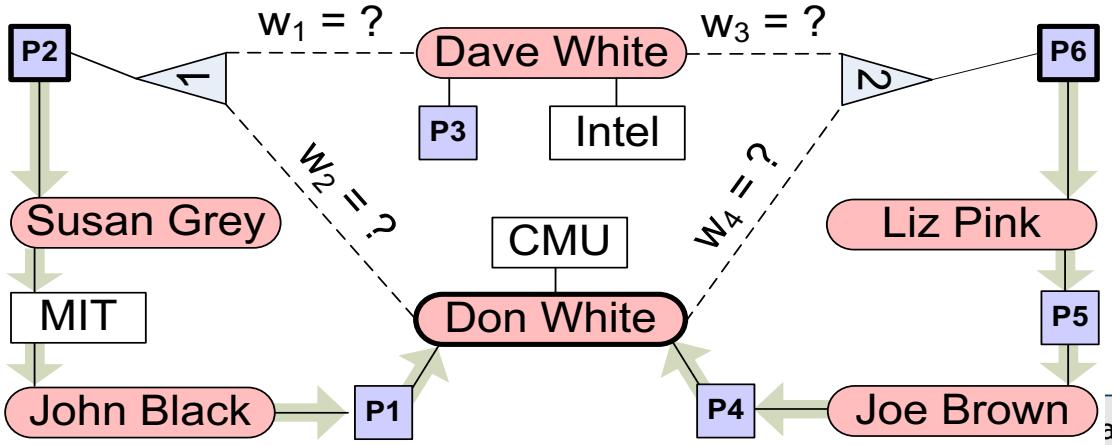

Facilitating inner-relationships

Some additional methods:

- Relationship-based clustering [BG04a], [BG04b]:
  - Common references for a match increase our belief
  - For this we need to identify common references
  - Iterative process: common matches → identifying additional matches
- Incremental & adaptive [INN08], [MPC+10]:
  - Targets data that are constantly changing and evolving
  - Bayesian network to model entities, relationships, and evidences (possible linkages)
  - Enables flexible update of the network

Surveys for methods in this category

→ [GD05], [KSS06]

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Methods in uncertain data

General idea:

- Keep conflicting relations, e.g., [AFM06], [RDS07], [DS07a], [DHY07]
  - Lack of resolution rules to correctly resolve and merge relations
  - No merging, but maintain results in the database
  - Relation are alternative representations of the same real world object
- Entity representation with probability – indicates…
  - Reliability of the source
  - Output of the matching process
  - Etc.

customer

	custId	name	income	prob
s_1	c1	John	\$120K	0.9
s_2	c1	John	\$80K	0.1
s_3	c2	Mary	\$140K	0.4
s_4	c2	Marion	\$40K	0.6

Methods in uncertain data

Clean answers over dirty databases [AFM06]:

- Dirty database represents several possible databases
- Result set for queries should include the entity resolution results
- Query rewriting mechanism with

  efficient computation of probability for each answer

order	id	orderId	custFk	clIdFk	quantity	prob
t_1	o1	11	m1	c1	3	1
t_2	o2	12	m2	c1	2	0.5
t_3	o2	13	m3	c2	5	0.5

customer	id	custId	name	balance	prob
t_4	c1	m1	John	\$20K	0.7
t_5	c1	m2	John	\$30K	0.3
t_6	c2	m3	Mary	\$27K	0.2
t_7	c2	m4	Marion	\$5K	0.8

$$
\begin{aligned}
D_1^{cd} &= \{t_1, t_2, t_4, t_6\} \\
D_2^{cd} &= \{t_1, t_2, t_4, t_7\} \\
D_3^{cd} &= \{t_1, t_2, t_5, t_6\} \\
D_4^{cd} &= \{t_1, t_2, t_5, t_7\} \\
D_5^{cd} &= \{t_1, t_3, t_4, t_6\} \\
D_6^{cd} &= \{t_1, t_3, t_4, t_7\} \\
D_7^{cd} &= \{t_1, t_3, t_5, t_6\} \\
D_8^{cd} &= \{t_1, t_3, t_5, t_7\}
\end{aligned}
$$

Methods in uncertain data

Clean answers over dirty databases [AFM06]:

- Query rewriting

$$\texttt{select } A_1,\ldots,A_n \quad \texttt{from } R_1,\ldots,R_m \quad \texttt{where } \mathcal{W}$$

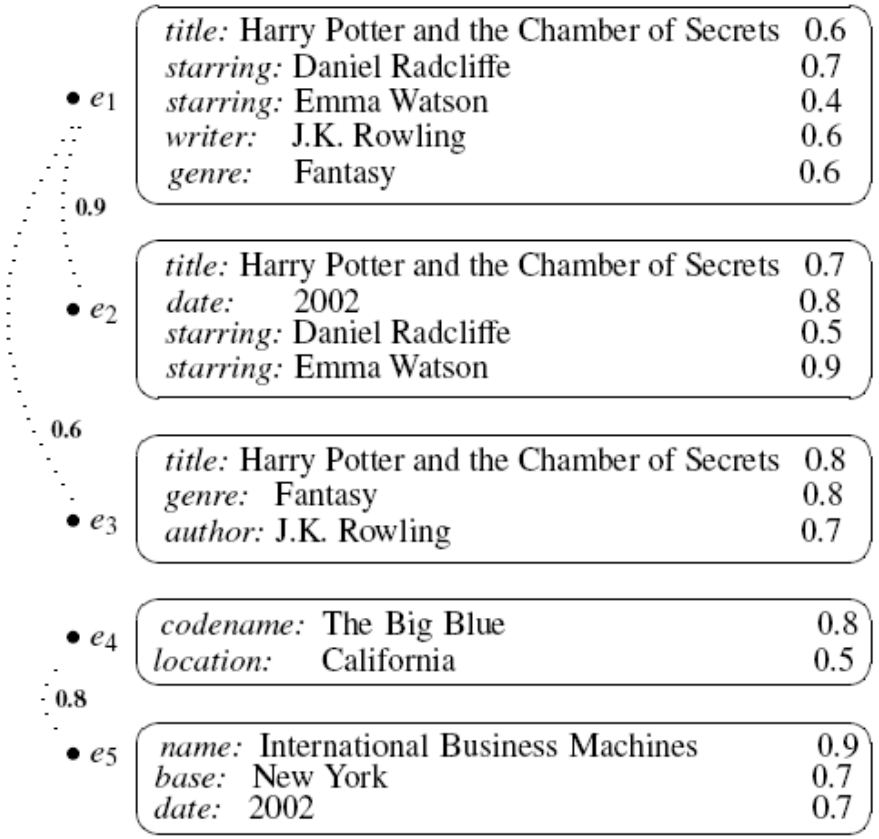
$$\rightarrow \texttt{select } A_1,\ldots,A_n,\texttt{sum}(R_1.\texttt{prob}.*\ldots.*R_m.\texttt{prob}) \quad \texttt{from } R_1,\ldots,R_m \quad \texttt{where } \mathcal{W} \quad \texttt{group by } A_1,\ldots,A_n$$

- Groups the result by the attributes
- For each group: sums the product of relation probabilities
- (applicable only to rewritable queries)

Methods in uncertain data

Entity-Aware querying over prob. linkages [INNV10]:

- Not merging the entities using threshold
- Keep probabilistic linkages alongside the original data
- Use them during query processing



Query:

- "J. K. Rowling" movies in "2002"

Assume no linkages:

- zero results

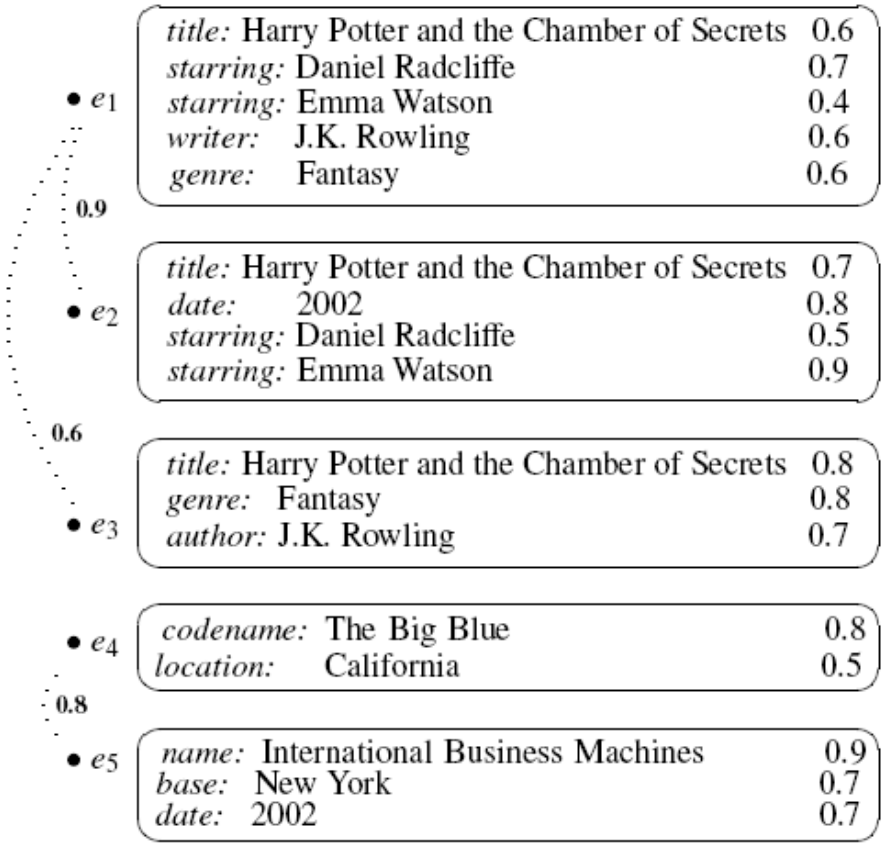
Possible answer with linkages:

- merge(e_1, e_2)
- merge(e_1, e_2, e_3)

Methods in uncertain data

Entity-Aware querying over prob. linkages [INNV10]:

- Linkage prob. represent several possible l-worlds
- Attribute prob. represent several possible worlds
- Efficient query processing:
  - Analyze query conditions
  - Identify the required entity merges
  - Decide useful possible l-worlds
  - Generate possible worlds
  - Compute probability



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Conclusions

Discussed methods entity resolution

Four categories of methods

Not presented:

- Blocking mechanisms:
  - Split data into blocks and compare inner-block data
  - Improves efficiency for large-size datasets
  - Examples: [WMK+09], [PINF11]
- Active learning approaches:
  - Use a subset of the data to learn matching rules
  - Apply the rules to remaining data
  - Examples: [SB02], [CR01]
- Similarity Joins [GIJ+1]
- Schema matching
- ….

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