# Similarity Search in Large Databases

## Course Organisation and Demo

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## A Problem at Our Municipality of Bozen

- Given:
  - realty owners DB (name and address of the realty)
  - residents DB (name and residential address)
  - both DBs cover the same geographic area (the city of Bozen)

Owners (dataset $A$)

| | |
|---|---|
| Peter | Gilmstrasse 1 |
| Arturas | Gilmstrasse 3 |
| Linas | Marieng. 1/A |
| Markus | Cimitero 4 |
| Michael | Gilmstrasse 5 |
| Igor | Friedensplatz 2/A/1 |
| Andrej | Friedensplatz 3 |
| Francesco | Untervigil 1 |
| Johann | Cimitero 6/B |
| Igor | Friedensplatz 2/A/2 |
| Nikolaus | Cimitero 6/A |

Residents (dataset $B$)

| | |
|---|---|
| Rosa | Siegesplatz 3/-/3 |
| Dario | Friedhofplatz 4 |
| Romans | Untervigli 1 |
| Adriano | Mariengasse 1 |
| Maria | Siegesplatz 3/-/2 |
| Arturas | Hermann-von-Gilm-Str. 3/A |
| Peter | Hermann-von-Gilm-Str. 1 |
| Markus | Siegesplatz 2/A |
| Juozas | Hermann-von-Gilm-Str. 3/B |
| Andrej | Siegesplatz 3/-/1 |
| Luigi | Friedhofplatz 6 |
| Anita | Herman-von-Gilm-Str. 6 |

- Query: Give me owner and resident for each apartment in Bozen!



## Assumptions for the Solutions in this Course

- Large data volumes
  - cannot be done by hand
  - solution must be efficient
- Data-driven, not process-driven
  - Sometimes it is better to change the world, e.g., force people to adhere to coding conventions, instead of fixing the errors later.
  - We cannot change the world.
- No domain-specific solution (e.g., address standardization)
- No training phase (e.g., supervised learning)
- No expensive configuration (e.g., define dictionaries, rules)
- Tuning parameters (like weights) are OK



## The Objects

- Many objects can be represented as sets:
  - text document as the set of its words
  - social network user as the set of group memberships or friends
  - sales as the set of product categories
  - user interaction as the set of visited links
- Strings are everywhere:
  - deduplicate product names retrieved by a wrapper
  - integration of customer records
  - cluster medical records by free text description
- Hierarchical data are represented as trees:
  - JSON or XML data
  - abstract syntax trees for code analysis
  - RNA secondary structures in biology

## Outline


1. Course Organisation
2. Demo: Similarity Join on Residential Addresses
3. Conclusion






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## All Information about Lecture and Lab

`https://dbresearch.uni-salzburg.at/teaching/2024ws/ssdb/`





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## Back to Our Initial Example

- Given:
  - realty owners DB (name and address of the realty)
  - residents DB (name and residential address)
  - both DBs cover the same geographic area (the city of Bozen/Italy)

Owners (dataset $A$)

| | |
|---|---|
| Peter | Gilmstrasse 1 |
| Arturas | Gilmstrasse 3 |
| Linas | Marieng. 1/A |
| Markus | Cimitero 4 |
| Michael | Gilmstrasse 5 |
| Igor | Friedensplatz 2/A/1 |
| Andrej | Friedensplatz 3 |
| Francesco | Untervigil 1 |
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Residents (dataset $B$)

| | |
|---|---|
| Rosa | Siegesplatz 3/-/3 |
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| Luigi | Friedhofplatz 6 |
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- Give me owner and resident for each apartment in Bozen!





## Database Representation

Owners

A

| strID | name | num | entr | apt |
|---|---|---|---|---|
| $\alpha_1$ | Gilmstrasse | 1 | | |
| $\alpha_1$ | Gilmstrasse | 3 | | |
| $\alpha_1$ | Gilmstrasse | 5 | | |
| $\alpha_2$ | Friedensplatz | 2 | A | 1 |
| $\alpha_2$ | Friedensplatz | 2 | A | 2 |
| $\alpha_2$ | Friedensplatz | 3 | | |
| $\alpha_3$ | Cimitero | 4 | | |
| $\alpha_3$ | Cimitero | 6 | A | |
| $\alpha_3$ | Cimitero | 6 | B | |
| $\alpha_4$ | Untervigil | 1 | | |
| $\alpha_5$ | Marieng. | 1 | A | |

Residents

B

| strID | name | num | entr | apt |
|---|---|---|---|---|
| $\beta_2$ | Hermann-von-Gilm-Str. | 1 | | |
| $\beta_2$ | Hermann-von-Gilm-Str. | 3 | A | |
| $\beta_2$ | Hermann-von-Gilm-Str. | 3 | B | |
| $\beta_2$ | Hermann-von-Gilm-Str. | 6 | | |
| $\beta_3$ | Siegesplatz | 2 | A | |
| $\beta_3$ | Siegesplatz | 3 | - | 1 |
| $\beta_3$ | Siegesplatz | 3 | - | 2 |
| $\beta_3$ | Siegesplatz | 3 | - | 3 |
| $\beta_1$ | Friedhofplatz | 4 | | |
| $\beta_1$ | Friedhofplatz | 6 | | |
| $\beta_5$ | Untervigli | 1 | | |
| $\beta_4$ | Mariengasse | 1 | | |





## String Similarity

- **Observation 1:** Some street names are similar.

| dataset $A$ | dataset $B$ |
|---|---|
| Gilmstrasse | Friedhofplatz |
| Friedensplatz | Hermann-von-Gilm-Str. |
| Cimitero | Siegesplatz |
| Untervigil | Mariengasse |
| Marieng. | Untervigli |

- We match:
  - Untervigil ↔ Untervigli
  - Marieng. ↔ Mariengasse
  - Gilmstrasse ↔ Hermann-von-Gilm-Str.
- But what to do with the others?
  - Friedensplatz was renamed to Siegesplatz, but one database was not updated
  - Cimitero is the Italian name for Friedhofplatz (German name)
- Problem: Friedensplatz looks more like Friedhofplatz than like Siegesplatz!





## Demo: String Similarity

- Street name tables:

| strID | name |
|---|---|
| $\alpha_1$ | Gilmstrasse |
| $\alpha_2$ | Friedensplatz |
| $\alpha_3$ | Cimitero |
| $\alpha_4$ | Untervigil |
| $\alpha_5$ | Marieng. |

| strID | name |
|---|---|
| $\beta_1$ | Friedhofplatz |
| $\beta_2$ | Hermann-von-Gilm-Str. |
| $\beta_3$ | Siegesplatz |
| $\beta_4$ | Mariengasse |
| $\beta_5$ | Untervigli |

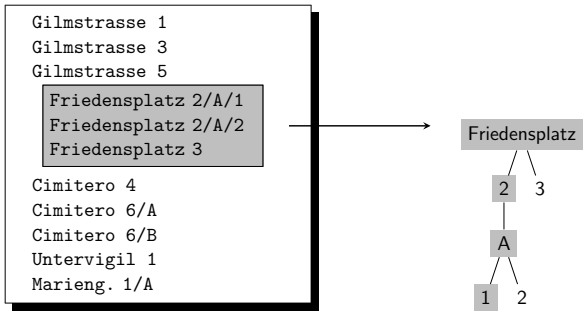
- Distance matrix for the $q$-gram distance between strings:

| | $\beta_1$ | $\beta_2$ | $\beta_3$ | $\beta_4$ | $\beta_5$ |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0 | 0.8333 | 1.0 | 0.6923 | 1.0 |
| $\alpha_2$ | 0.3333 | 1.0 | 0.5714 | 0.9286 | 1.0 |
| $\alpha_3$ | 1.0 | 1.0 | 1.0 | 1.0 | 0.9091 |
| $\alpha_4$ | 1.0 | 0.9429 | 1.0 | 1.0 | 0.3333 |
| $\alpha_5$ | 0.92 | 0.9394 | 1.0 | 0.3913 | 1.0 |

- Matches with the global greedy algorithm:
  $\{(\alpha_1, \beta_2), (\alpha_2, \beta_1), (\alpha_3, \beta_3), (\alpha_4, \beta_5), (\alpha_5, \beta_4), \}$

## Tree Similarity

- **Observation 2**: Different streets have different addresses.
- Build *address tree*:



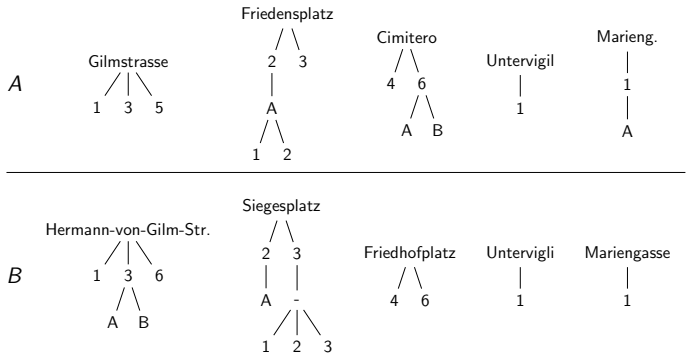

- Address is path from root to leaf.
- Example: Shaded path is the address `Friedensplatz 2/A/1` (house number `2`, entrance `A`, apartment `1`).





## Tree Similarity

- Address trees of our example:




- Ignore root labels for distance computation.
- Trees of `Siegesplatz` and `Friedensplatz` are similar :-)
- Trees of `Cimitero` and `Friedhofplatz` are similar :-)
- But: `Untervigil` and `Mariengasse` have identical address trees in dataset $B$.





## Demo: Tree Similarity

- Street name tables:

| *strID* | *name* |
|---|---|
| $\alpha_1$ | `Gilmstrasse` |
| $\alpha_2$ | `Friedensplatz` |
| $\alpha_3$ | `Cimitero` |
| $\alpha_4$ | `Untervigil` |
| $\alpha_5$ | `Marieng.` |

| *strID* | *name* |
|---|---|
| $\beta_1$ | `Friedhofplatz` |
| $\beta_2$ | `Hermann-von-Gilm-Str.` |
| $\beta_3$ | `Siegesplatz` |
| $\beta_4$ | `Mariengasse` |
| $\beta_5$ | `Untervigli` |

- Distance matrix for the *pq*-gram distance between trees:

| | $\beta_1$ | $\beta_2$ | $\beta_3$ | $\beta_4$ | $\beta_5$ |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0 | 0.7143 | 1.0 | 0.6667 | 0.6667 |
| $\alpha_2$ | 1.0 | 1.0 | 0.5758 | 1.0 | 1.0 |
| $\alpha_3$ | 0.4118 | 0.9167 | 1.0 | 1.0 | 1.0 |
| $\alpha_4$ | 1.0 | 0.7647 | 1.0 | 0.0 | 0.0 |
| $\alpha_5$ | 1.0 | 0.9 | 1.0 | 0.4545 | 0.4545 |

- Matches with the global greedy algorithm:
  $\{(\alpha_1, \beta_2), (\alpha_2, \beta_3), (\alpha_3, \beta_1), (\alpha_4, \beta_4), (\alpha_5, \beta_5)\}$





## Combining String and Tree Distance

- Use strings *and* trees!
- String distance $s$, tree distance $t$
- Weight $\omega \in [0..1]$
  - $\omega = 0 \rightarrow$ only trees
  - $\omega = 1 \rightarrow$ only strings
- overall distance $d$ (using weighted Euclidean distance):

$$d = \sqrt{\omega s^2 + (1-\omega)t^2}$$

## Demo: Combining String and Tree Distance

- Computed with $w = 0.5$ from string and tree matrices:

| | $\beta_1$ | $\beta_2$ | $\beta_3$ | $\beta_4$ | $\beta_5$ |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0 | 0.7761 | 1.0 | 0.6796 | 0.8498 |
| $\alpha_2$ | 0.7454 | 1.0 | 0.5736 | 0.9649 | 1.0 |
| $\alpha_3$ | 0.7647 | 0.9592 | 1.0 | 1.0 | 0.9556 |
| $\alpha_4$ | 1.0 | 0.8584 | 1.0 | 0.7071 | 0.2357 |
| $\alpha_5$ | 0.9608 | 0.9199 | 1.0 | 0.4241 | 0.7767 |

- Matches with the global greedy algorithm:
  $\{(\alpha_4, \beta_5), (\alpha_5, \beta_4), (\alpha_2, \beta_3), (\alpha_3, \beta_1), (\alpha_1, \beta_2)\}$
- All matches are correct :-)

```
   Gilmstrasse ↔ Hermann-von-Gilm-Str.
 Friedensplatz ↔ Siegesplatz
      Cimitero ↔ Friedhofplatz
    Untervigil ↔ Untervigli
      Marieng. ↔ Mariengasse
```

map_A_B

| *idA* | *idB* |
|---|---|
| $\alpha_4$ | $\beta_5$ |
| $\alpha_5$ | $\beta_4$ |
| $\alpha_2$ | $\beta_3$ |
| $\alpha_3$ | $\beta_1$ |
| $\alpha_1$ | $\beta_2$ |





## Experiments: Results for Real World Data

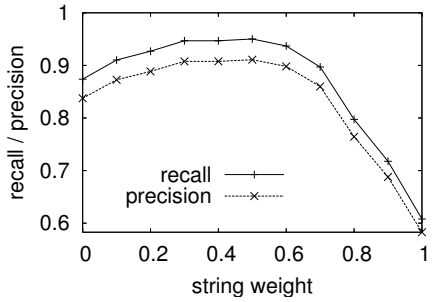
- Similarity join on three real databases:
  - electricity company (elec) – German street names, 45k addresses
  - registration office (reg) – Italian street names, 43k addresses
  - census database (cens) – German street names, 11k addresses
- Measure precision and recall
  - Precision: correctly computed matches to total number of computed matches
  - Recall: correctly computed matches to total number of correct matches





## Experiments: Results for Real World Data

- Similarity join with global greedy matching
- String weight $\omega$ varies from 0 (only trees) to 1 (only strings)
- Measure precision and recall (high is good)




elec (German) ↔ reg (Italian)





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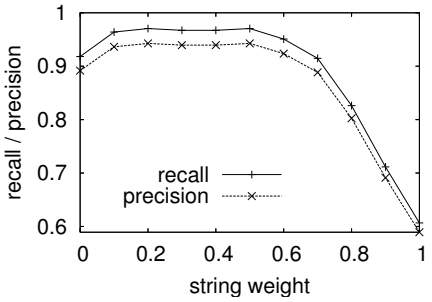


reg (Italian) ↔ cens (German)

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- Similarity join with global greedy matching
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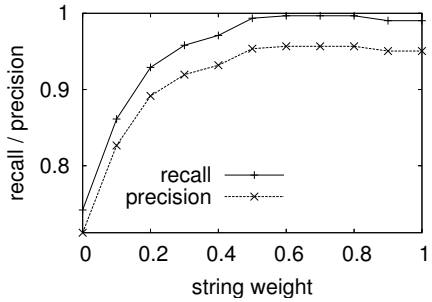


elec (German) $\leftrightarrow$ reg (German)





## Experiments: Results for Real World Data

Summary of the experimental results:

- High string weight $\omega$ good for German-German, bad for German-Italian
- String weight $\omega = 0.5$ good for both German-German and German-Italian
- Precision and recall very high ($\omega = 0.5$):
  - more than 90% even for German-Italian
  - recall almost 100%, precision 95% for German-German ($\omega = 0.5$)





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## Conclusion

- Scope:
  - general, data-centric solutions
  - focus on efficiency
- Data types: sets, strings, trees
- Street matching demo:
  - leverage string and tree matching