JenTab: A Toolkit for Semantic Table Annotations
Nora Abdelmageed, Sirko Schindler
Friedrich Schiller University Jena, Germany
ESWC 2021
# Semantic Table Annotation Tasks

<table>
<thead>
<tr>
<th>Egypt</th>
<th>1,010,408</th>
<th>Cairo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>357,386</td>
<td>Berlin</td>
</tr>
</tbody>
</table>

- wd:Q79 ("Egypt")
- wd:Q183 ("Germany")

<table>
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<th>Cairo</th>
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<tbody>
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</table>

- wd:Q6256 ("country")

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<th>Cairo</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

- wdt:P36 ("capital")

**CEA**
**Cell Entity Annotation**

**CTA**
**Column Type Annotation**

**CPA**
**Column Property Annotation**

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Outlook

1. Semantic Table Annotations
2. Related Work
3. Proposed Technique
4. Datasets
5. Evaluation
6. Results
7. Conclusions & Future work
Related Work

- **SemTab***
  - Multiple data sources
  - Full cell query
- **Approaches**
  - Machine Learning
  - Semantics
  - Limited scope (1 task)
  - Cannot cope with KG changes
- **Benchmarks**
  - Small
  - Some have poor ground truth (Limaye)

*Knowledge Semantic Web Challenge on Tabular Data to Knowledge Graph Matching - SemTab 2019 & 2020*
Proposed Technique

- Preprocessing
- CFS Pattern
- Contexts and annotation modules
- Architecture
Preprocessing

1. **Generic fix**
   - Encoding fixes (ftfy)
   - Special character removal
   - Restore missing spaces (parse errors)

2. **Datatype predication**
   - Types with equivalents in KG
     - `OBJECT`, `QUANTITY`, `DATE`, `STRING`

3. **Type-based cleaning**
   - Extract the relevant part from (`QUANTITY`, `DATE`)
   - 10/12/2020 (10 Dec 2020) → 2020-12-10
   - 1,199 km (745 mi) → 1199
CFS Pattern

• Different KG-lookups using different constraints, assemble all the retrieved information and find a proper solution.

• **Create, Filter and Select** pattern
  1. **Create** all possible candidates for the 3 tasks
  2. **Filter** the initial candidates set by using feedback from other tasks
  3. **Select** the most suitable candidate from the remaining ones

• **Data sources**
  • Lookup services (elastic search tools over KG)
  • SPARQL endpoint (structured queries)
Contexts and Annotation Modules

- 4 contexts used to create/filter annotations

(a) Cell  (b) Column  (c) Row  (d) Row-Column
Contexts and Annotation Modules

- 4 contexts used to create/filter annotations

Plain Cell Value (various strategies)
Contexts and Annotation Modules

- 4 contexts used to create/filter annotations

Semantic Column Type + plain cell value
Assumes all cells in one column belong to the same type
Contexts and Annotation Modules

- 4 contexts used to create/filter annotations

- Bidirectional context
  - Subject cell $\rightarrow$ properties
  - And vice versa

(a) Cell

(c) Row

(d) Row-Column
Contexts and Annotation Modules

• 4 contexts used to create/filter annotations

(a) Cell  (b) Column  (d) Row-Column

Combines b and c conditions
Black Box Example

Annotation Module(s):
• CEA Label Lookup

Do you know what **UK** is?

Ukrainian (Q8798),
United Kingdom (Q145),
University of Kentucky (Q1360303) and more

* For complex cell values, e.g., 1st Global Opinion Leader’s Summit, we try other strategies to create mappings. For example, look for each token in the cell as a standalone query.
CEA Label Lookup

- **4 strategies obtaining queries from cell value** + 2 handling spelling mistakes

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Priority</th>
<th>Method</th>
<th>Cell Example</th>
<th>Queries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Cell</td>
<td>1</td>
<td>Cleaned value as a query</td>
<td>Dainik Bhaskar</td>
<td>{Dainik Bhaskar}</td>
</tr>
<tr>
<td>Selective</td>
<td>2</td>
<td>parts before brackets</td>
<td>Mario’s Super Picross (900 Wii Points)</td>
<td>{Mario’s Super Picross}</td>
</tr>
<tr>
<td>Token</td>
<td>3</td>
<td>tokenize the cell values &amp; exclude stopwords</td>
<td>Lost in Space</td>
<td>{Lost, Space}</td>
</tr>
<tr>
<td>All Token</td>
<td>3</td>
<td>tokenize the cell values, exclude stopwords &amp; concatenate tokens ascending</td>
<td>Little House on the Prairie</td>
<td>{Little, House, Prairie, Little House Prairie, House Prairie}</td>
</tr>
</tbody>
</table>
CEA Label Lookup

- 4 strategies obtaining queries from cell value + 2 handling spelling mistakes

<table>
<thead>
<tr>
<th>Generic Lookup</th>
<th>Autocorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-computed</td>
<td>On demand</td>
</tr>
<tr>
<td>Executed before the actual pipeline</td>
<td>Invoked in cases of failure by Generic Lookup</td>
</tr>
<tr>
<td>Jaro-Wrinkler distance(^1)</td>
<td>1-edit distance + word2vec ranking(^2)</td>
</tr>
<tr>
<td>Highest priority (0)</td>
<td>Lowest priority (4)</td>
</tr>
</tbody>
</table>

\(^1\) Winkler, W.E.: String comparator metrics and enhanced decision rules in the fellegi-sunter model of record linkage. (1990)

\(^2\) https://www.kaggle.com/cpmpml/spell-checker-using-word2vec
Black Box Example

Annotation Module(s):
• CEA by Column

Do you know what **UK** is?
It is also a **country**

United Kingdom (Q145)

JenTab

KG
Black Box Example

Annotation Module(s):
• CEA by row
• CEA by subject

Do you know what is the thing that has capital named London?

KG

United Kingdom (Q145)

JenTab
Annotations Module Continued …

• **CTA**
  • Collects types for all retrieved cells annotations
Annotations Module Continued …

- **CTA**
  - Collects types for all retrieved cells annotations

- **CPA**
  - Collects properties for all retrieved cells annotations (Object Properties)
  - Fuzzy match properties with values only (Literal Properties)
    - **DATE**: try matching day, month and year parts only, ignore any other parts.
    - **QUANTITY**: support a margin of tolerance e.g., 10%
    - **STRING**: Calculates overlap between KG value and Table value. Consider a match if overlap > threshold.
Annotation Modules … Filter

• **CTA support**
  - Column types < support by cell candidates
  - Affects CTA and CEA candidates

• **CEA by unmatched properties**
  - Cell candidates have no matched properties

• **CEA by property support**
  - A generic form of the above
  - Considers support value

• **CEA by string distance**
  - Cell value vs. KG label value
  - Levenshtein distance > threshold
Annotation Modules ... Select

- Picks the solution!

**CEA**
- **CEA by string similarity**
  - Selects the KG value with the closest Levenshtein distance
- **CEA by column**
  - Looks inside the same column for a similar value and pick its candidate

**CPA**
- **CPA by majority vote**
  - Picks most co-occurred property

**CTA**
- **CTA by LCS vs. CTA by majority**
- **CTA by direct parents**
- **CTA by popularity**

* LCS – Least Common Subsumer
Annotation Modules ... Select

- Finds the solution!

**CEA by string similarity**
- Selects the KG value with the closest Levenshtein distance

**CEA by column**
- Looks inside the same column for a similar value and pick its candidate

**CEA**

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- CPA by majority vote
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**CTA**
- CTA by LCS vs. CTA by majority
  - CTA by direct parents
  - CTA by popularity

* LCS – Least Common Subsumer
Select CTA

- **CTA by majority**

<table>
<thead>
<tr>
<th>CoI0</th>
<th>P31</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spaziano, Florida</td>
<td>Q18146819, Q19692072</td>
</tr>
<tr>
<td>Smith v/ Maryland</td>
<td>Q18146819, Q19692072</td>
</tr>
<tr>
<td>SEC v. Texas Gulf Sulphur Co.</td>
<td>Q2334719</td>
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<td>Reed v. Pennsylvania Railroad Compan</td>
<td></td>
</tr>
<tr>
<td>Building Service Employees International</td>
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<tr>
<td>Union Local 262 v/ Gazzam</td>
<td></td>
</tr>
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<td>Montgomery Building &amp; Construction Trades</td>
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<tr>
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<td></td>
</tr>
<tr>
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<tr>
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<tr>
<td>Labor Relations Board</td>
<td></td>
</tr>
<tr>
<td>Unitee States v. United States Smelting</td>
<td>Q18146819, Q19692072</td>
</tr>
<tr>
<td>Refining</td>
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</tr>
<tr>
<td>Poizzi v. Cowles Magazines</td>
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## Select CTA

- **CTA by LCS**

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<tr>
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* LCS – Least Common Subsumer
Select CTA

- **CTA by direct parents** (flatten leaves and parents + majority voting)

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</table>

![CTA Diagram](image)
Sequence of Modules

- **Create**
  - Plus
  - Red

- **Filter**
  - Triangle
  - Green

- **Select**
  - Circle
  - Yellow

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Sequence of Modules

- **Group 1**
  - Core Pipeline
  - No selection
- **Group 9**
  - Last resort
  - Backup solutions are invoked if failure of the previous methods
Architecture

- Distributed system
- Manager central point
- Isolated services
- Scalable
  - Fits large scale datasets
- Easily exchange
  - Data sources (KG substitution)
  - Approach

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Datasets

- Automatically Generated
- Tough Tables
- 130K tables

<table>
<thead>
<tr>
<th>Round</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tables #</td>
<td>34,294</td>
<td>12,173</td>
<td>62,614</td>
<td>22,390</td>
</tr>
<tr>
<td>Avg. Rows # (± Std Dev.)</td>
<td>7 ± 4</td>
<td>7 ± 7</td>
<td>7 ± 5</td>
<td>109 ± 11,120</td>
</tr>
<tr>
<td>Avg. Columns # (± Std Dev.)</td>
<td>5 ± 1</td>
<td>5 ± 1</td>
<td>4 ± 1</td>
<td>4 ± 1</td>
</tr>
<tr>
<td>Avg. Cells # (± Std Dev.)</td>
<td>36 ± 20</td>
<td>36 ± 18</td>
<td>23 ± 18</td>
<td>342 ± 33,362</td>
</tr>
<tr>
<td>Target Cells # (CEA)</td>
<td>985,110</td>
<td>283,446</td>
<td>768,324</td>
<td>1,662,164</td>
</tr>
<tr>
<td>Target Columns # (CTA)</td>
<td>34,294</td>
<td>26,726</td>
<td>97,585</td>
<td>32,461</td>
</tr>
<tr>
<td>Target Columns Pairs # (CPA)</td>
<td>135,774</td>
<td>43,753</td>
<td>166,633</td>
<td>56,475</td>
</tr>
</tbody>
</table>
Dataset Challenges

a) Missing metadata  
b) Spelling mistakes  
c) Ambiguity  
d) Missing spaces  
e) Inconsistent format  
f) Nested pieces of information in Quantity fields  
g) Redundant columns  
h) Encoding issues  
i) Noisy data  
j) Missing values (nulls, empty strings and special characters)  
k) Tables of excessive length
Evaluation

• **CEA & CPA metrics**

\[ P = \frac{|\text{correct annotations}|}{|\text{annotated cells}|}, \quad R = \frac{|\text{correct annotations}|}{|\text{target cells}|}, \quad F1 = \frac{2 \times P \times R}{P + R} \]

• **CTA metrics**

\[ \text{c} \text{score}(\alpha) = \begin{cases} 
1, & \text{if } \alpha \text{ is in GT}, \\
0.8^{d(\alpha)}, & \text{if } \alpha \text{ is an ancestor of the GT}, \\
0.7^{d(\alpha)}, & \text{if } \alpha \text{ is a descendant of the GT}, \\
0, & \text{otherwise} 
\end{cases} \]

\[ AP = \frac{\sum \text{c} \text{score}(\alpha)}{|\text{annotated cells}|}, \quad AR = \frac{\sum \text{c} \text{score}(\alpha)}{|\text{target cells}|}, \quad A\text{F}1 = \frac{2 \times AP \times AR}{AP + AR} \]

* GT is the ground truth
* AP Approximate Precision
Experiments

• 3 Modes of CTA
  • Which one has the best scores?

P31

2 Hops

Multiple Hops

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Results

• Preprocessing
  • Type Prediction
  • Accuracy 99.0%
Results

• Generic Lookup
  • High coverage
  • Computationally expensive

<table>
<thead>
<tr>
<th>Rounds</th>
<th>Unique Labels Matched (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>252,329</td>
</tr>
<tr>
<td>R2</td>
<td>132,948</td>
</tr>
<tr>
<td>R3</td>
<td>361,313</td>
</tr>
<tr>
<td>R4</td>
<td>533,015</td>
</tr>
</tbody>
</table>

https://github.com/fusion-jena/JenTab_precomputed_lookup

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Results

- Audit statistics for CEA
- Reflects our priorities
- Various strategies capture a wide range of information inside cells

Creation Strategies
Results

- Audit statistics for CEA
- String similarity is the dominant method
- Solves 38% more than column similarity
- The need of a backup method
- Some cells failed to have an annotation or annotation was removed by filter function
Results

• Audit statistics for CTA
• Majority vote is the dominant
• Backup solutions are frequently used

Mode: P31
Results

- Audit statistics for CTA
- LCS is the dominant
- Backup solutions are less frequently used
- LCS is more effective than Majority vote
Results

- JenTab among the
  - Top 5 systems (CEA & CTA)
  - Top 3 systems (CPA)
- No Wikidata dump
- No generic search engines
  - SearX
Results

• JenTab among the
  • Top 5 systems (CEA & CTA)
  • Top 3 systems (CPA)
• No Wikidata dump
• No generic search engines
  • SearX
• Poor performance on 2T dataset
  • P31 is insufficient for hard cases

<table>
<thead>
<tr>
<th>System</th>
<th>Automatically Generated Dataset</th>
<th>Tough Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CEA</td>
<td>CTA</td>
</tr>
<tr>
<td>JenTab (P31)</td>
<td>0.974</td>
<td>0.974</td>
</tr>
<tr>
<td>JenTab (2 Hops)</td>
<td>0.973</td>
<td>0.974</td>
</tr>
<tr>
<td>JenTab (Multiple Hops)</td>
<td>0.947</td>
<td>0.949</td>
</tr>
<tr>
<td>MTab4Wikidata</td>
<td>0.993</td>
<td>0.993</td>
</tr>
<tr>
<td>bbw</td>
<td>0.978</td>
<td>0.984</td>
</tr>
<tr>
<td>LinkingPark</td>
<td>0.985</td>
<td>0.985</td>
</tr>
<tr>
<td>DAGOBAH</td>
<td>0.984</td>
<td>0.985</td>
</tr>
<tr>
<td>SSL</td>
<td>0.833</td>
<td>0.833</td>
</tr>
</tbody>
</table>
Results

- JenTab among the
  - Top 5 systems (CEA & CTA)
  - Top 3 systems (CPA)
- No Wikidata dump
- No generic search engines
  - SearX
- Multiple Hops
  - Too generic solutions
  - Lower scores

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<tr>
<td>SSL</td>
<td>0.833</td>
<td>0.833</td>
</tr>
</tbody>
</table>
Results

- Execution Time
  - Time scoped
  - Faster convergence
  - R4 50% reduction

<table>
<thead>
<tr>
<th>Mode</th>
<th>R1 Days Runners</th>
<th>R1 Runners</th>
<th>R2 Days Runners</th>
<th>R2 Runners</th>
<th>R3 Days Runners</th>
<th>R3 Runners</th>
<th>R4 Days Runners</th>
<th>R4 Runners</th>
</tr>
</thead>
<tbody>
<tr>
<td>P31</td>
<td>0.5</td>
<td>4</td>
<td>2.5</td>
<td>4</td>
<td>1.5</td>
<td>6</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2 Hops</td>
<td>1</td>
<td>4</td>
<td>1.2</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>1.1</td>
<td>8</td>
</tr>
<tr>
<td>Multi Hops</td>
<td>1</td>
<td>4</td>
<td>1.5</td>
<td>4</td>
<td>2.5</td>
<td>6</td>
<td>3.5</td>
<td>6</td>
</tr>
</tbody>
</table>
Conclusions

- JenTab toolkit*
  - Publicly available KG data sources
  - CFS pattern
  - 3 experiments of CTA
  - Detailed analysis of the 3 modes

* https://github.com/fusion-jena/JenTab
Future Work

• Optimize certain components that take substantial resources
  • Generic lookup
  • SPARQL queries
• Dig deeper into Tough Table dataset
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