Event Causal Relationship Retrieval

Takushoku Univ.
Yasunobu Sumikawa
Background | The importance of history

- *History does not repeat itself, but rhythms repeat themselves*
- Analyzing and knowing history is important
  - Understanding how the present shape
  - Using historical knowledge in the present
  - Many countries have classes for learning history from elementary school
- Practice and research in history learning supporting
  - Understanding history → Developing Thinking Skills → Utilization of the ability of using historical knowledge [1]
  - Research on learning environments that support the ability to use history in school education[2]

[1]: MEXT (2018): government course (curriculum) guidelines
Related works | Focusing on Causal Relationships

● We can use the knowledge of the past for the present and future.

● Promoting historical analogies [3]
  ○ Card-game-based learning material for finding similar causal relationships between past and present
  ○ Learners manually constructs the causal relationship
  ○ Theme is fixed by the research

Related works | Focusing on Causal Relationships

- We can use the knowledge of the past for the present and future.

- Predicting future events [4~5]
  - Learning relationship A → B from texts
  - Predicting of A' → o using the learned relationships

Objective of this study

- **Measure similarity** between causal relationships
  - Assumption: Event graph is given
Usage | Future work

- Searching past/present events with the same/similar cause
  - for history education
Outline

● Definition
● Proposed algorithm (ECM)
  ○ Event Causal relationship Measurement
● Experimental evaluation
● Conclusion
A causal relationship is a list of events.
Bipartite graph construction

To compare two causal relationships A and B, ECM constructs a bipartite graph \( G = (A, B) \):

- \( A, B \): lists of events
- A weight \( w \) of \( e = (a_i, b_j) \): similarity between two events \( a_i \) and \( b_j \)

※ some edges are omitted for ease presentation
Algorithm | Theory

- Maximum weight matching problem on Bipartite graph
- We extend the general problem by adding
  - no intersection points on the edges that are the solutions to the problem

Red: solutions of the extended problem
Blue: solutions of the general problem
Algorithm | Implementation as a dynamic programming

- **Green**: Selected edges as solutions
- **Red**: An edge ECM is analyzing
- **Blue**: Edges ECM will analyze future
Algorithm | Implementation as a dynamic programming

Green: Selected edges as solutions
Red: An edge ECM is analyzing
Blue: Edges ECM will analyze future
Tables used in DP

\[
\begin{array}{cccc}
W & b_1 & b_2 & b_3 & b_4 \\
\hline
a_1 & 2 & 0 & 0 & 4 \\
a_2 & 0 & 10 & 0 & 0 \\
a_3 & 0 & 0 & 1 & 0 \\
\end{array}
\]

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\begin{array}{cccc}
DP & 0 & 0 & 0 & 0 \\
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0 & \hline
0 & \hline
\end{array}
\]
Tables used in DP

<table>
<thead>
<tr>
<th>W</th>
<th>$b_1$</th>
<th>$b_2$</th>
<th>$b_3$</th>
<th>$b_4$</th>
</tr>
</thead>
<tbody>
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<td>$a_1$</td>
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<td>0</td>
<td>4</td>
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<tr>
<td>$a_2$</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$a_3$</td>
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<td>1</td>
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Tables used in DP

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
W & $b_1$ & $b_2$ & $b_3$ & $b_4$ \\
\hline
$a_1$ & 2 & 0 & 0 & 4 \\
\hline
$a_2$ & 0 & 10 & 0 & 0 \\
\hline
$a_3$ & 0 & 0 & 1 & 0 \\
\hline
\end{tabular}
\end{table}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
DP & 0 & 0 & 0 & 0 \\
\hline
0 & 2 & & & \\
\hline
0 & & 12 & & \\
\hline
0 & & & & \\
\hline
\end{tabular}
\end{table}
Tables used in DP

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<tr>
<th>W</th>
<th>b₁</th>
<th>b₂</th>
<th>b₃</th>
<th>b₄</th>
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<tbody>
<tr>
<td>a₁</td>
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<td>a₂</td>
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</tbody>
</table>
Tables used in DP

\[ \begin{align*}
| & W & b_1 & b_2 & b_3 & b_4 | \\
| a_1 & 2 & 0 & 0 & 4 | \\
| a_2 & 0 & 10 & 0 & 0 | \\
| a_3 & 0 & 0 & 1 & 0 | \\
\end{align*} \]

\[ \begin{align*}
| & DP & 0 & 0 & 0 & 0 | \\
| 0 & 2 & 2 & 2 & 6 | \\
| 0 & 2 & 12 & 12 & 12 | \\
| 0 & 2 & 12 & 13 & 13 | \\
\end{align*} \]
Experimental evaluation | Dataset

- W2E[6]: Wikipedia-based causal relationship dataset
  a. Every causal relationship has a category
  b. Num. of causal relationship: 322
  c. Num. of events: 1,041
  d. Num. of categories: 10
  e. Ave. num. of events per causal relationship: 3.23

## Experimental evaluation | Dataset

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>AA</th>
<th>BE</th>
<th>ST</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave. Num. of events</td>
<td>2.92</td>
<td>3.26</td>
<td>3.85</td>
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<tr>
<td>Num. of topics</td>
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<td>73</td>
<td>7</td>
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<td>3</td>
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<td>Ave. Num. of tokens</td>
<td>29.44</td>
<td>27.15</td>
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<td>23.25</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>LC</th>
<th>PE</th>
<th>IR</th>
<th>DA</th>
<th>HM</th>
</tr>
</thead>
<tbody>
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<td>Ave. Num. of events</td>
<td>3.06</td>
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<td>3.11</td>
<td>4.66</td>
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<tr>
<td>Num. of topics</td>
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<td>57</td>
<td>45</td>
<td>6</td>
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<td>Ave. Num. of tokens</td>
<td>34.53</td>
<td>31.87</td>
<td>38.20</td>
<td>29.54</td>
<td>28.25</td>
</tr>
</tbody>
</table>

- S: Sports
- AA: Armed conflict and Attack
- BE: Business and Economy
- ST: Science and Technology
- AC: Arts and Culture
- LC: Law and Crime
- PE: Politics and Election
- IR: International relations
- DA: Disaster and Accident
- HM: Health and medicine
### Examples of W2E

<table>
<thead>
<tr>
<th>Category</th>
<th>TOPIC ID Event texts</th>
<th>TOPIC ID Event texts</th>
</tr>
</thead>
</table>
| Politics and elections | 2016-07-13 The new Prime Minister of the United Kingdom Theresa May begins forming her ministry following the end of the Second Cameron ministry.                                                                 | TOPIC-1780

2016-06-29 The process to elect a new leader of the Conservative Party to replace outgoing Prime Minister David Cameron begins in the United Kingdom.                                                                 |

2016-07-14 Elizabeth Truss is named Secretary of State for Justice and first ever female Lord Chancellor of the United Kingdom as former chancellor Michael Gove is ousted from the cabinet.  

2016-07-05 Home Secretary Theresa May gets 165 votes after the first ballot of Conservative members of parliament to select a new Leader and the next Prime Minister.  

2016-07-11 Prime Minister David Cameron announces he will step down on Wednesday, July 13. |
Baselines

1. BM25:
   Bag-of-words-based ranking function

2. TF-IDF + dynamic time warping (DTW)
   DTW evaluates the similarity between data considering time series
Bipartite graph construction

Each node is constructed by TF-IDF vector.

Each weight of an edge is a result of cosine similarity.

<table>
<thead>
<tr>
<th></th>
<th>TF-IDF</th>
<th>LSA</th>
<th>LDA</th>
<th>Doc2Vec</th>
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<tbody>
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<td>CosSim</td>
<td>59.8%</td>
<td>48.8%</td>
<td>26.4%</td>
<td>14.3%</td>
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<td>Euclid</td>
<td>17.7%</td>
<td>11.2%</td>
<td>20.2%</td>
<td>15.0%</td>
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<td>JS</td>
<td>14.0%</td>
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Results | Prediction distribution

S: Sports
AA: Armed conflict and Attack
BE: Business and Economy
ST: Science and Technology
AC: Arts and Culture
LC: Law and Crime
PE: Politics and Election
IR: International relations
DA: Disaster and Accident
HM: Health and medicine
## Error Analysis | Correct ratio per category

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<th>50.0%</th>
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<th>21.8%</th>
<th>66.6%</th>
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Whole average
- Jaccard: 0.12
- Mutual information: 0.12
Conclusion

We proposed an algorithm to evaluate the similarity of causal relationships.

- Goal: measuring the similarity of events with a focus on causality to facilitate historical analogies
- Proposed algorithm: using DP to calculate similarity between two relationships

Future works

- Using the proposed algorithm in history learning tool to evaluate how the algorithm is useful to enhance historical analogy