Graph-Based Question Answering

Diego Mollá-Aliod
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Outline

• Question Answering and AnswerFinder
• Conceptual Graphs
• Graph Comparison

Architecture of AnswerFinder

On-line
  Question
  Question image
  Expected answer type
  Filtering
  Scoring
  Exact Answer

Off-line
  Documents
  Indexing
  Document Image
  Answer(s)

Grammatical Relations

dependent
arg_mod
arg
aux
conj

mod
arg_mod
arg
aux
comp

ncmod
xmod
cmod
detmod
subj_or_dobj

subj
ncsubj
xsubj
csubj
dobj
obj2
obj
xcomp
ccomp
Grammatical Relations

- A man named Richard Sears has been playing a joke on shoppers.
  (detmod _ man a)
  (subj name man _) (dobj name richard_sears _)
  (detmod _ joke a) (subj play man _) (aux _ play have)
  (aux _ play be)
  (ncmod shopper play on) (dobj play joke _)

- Who played a joke on shoppers?
  (subj play who _) (dobj play joke _)
  (ncmod shopper play on) (detmod _ joke a)

Minimal Logical Forms

- Called Minimal Logical forms because they encode the minimum information required for AE
- Flat expressions that use reification

- Example: cp will quickly copy files
  holds(e4), object(cp,o1,[x1]), object(s_command,o2,[x1]),
  evt(s_copy,e4,[x1,x6]), object(s_file,o3,[x6]), prop(quickly,p3,[e4]).

- Example: the man that came ate bananas and apples with a fork
  holds(e1), object(s_man,o2,[x2]), evt(s_come,e4,[x2]), evt(s_eat,e5,[x7]),
  x6@<x7, x8@<x7, object(s_banana,o6,[x6]), object(s_apple,o8,[x8]),
  prop(with,p9,[e5,x11]), object(s_fork,o11,[x11]).

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- Question Answering and AnswerFinder
- Conceptual Graphs
- Graph Comparison
Conceptual Graphs

- Concept Node [Cat:Tom], [Mat]
  - Entities, attributes, or events (actions)
  - Concept nodes have two attributes:
    - Type (e.g. Cat)
    - Referent (e.g. Tom)
- Relation Node (On)
  - The kind of relationship between two concept nodes

Quantification

- Every cat is on a mat

Thematic Roles

- John is going to Boston by Bus

N-Ary Relations

- A person is between a rock and a hard place
Nested Conceptual Graphs

- Tom believes that Mary wants to marry a sailor

How does it Compare with AnswerFinder?

- John is going to Boston by bus

How does it Compare with AnswerFinder?

- A person is between a rock and a hard place

How does it Compare with AnswerFinder?

- Tom believes that Mary wants to marry a sailor
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Comparison of Conceptual Graphs

- Two steps:
  1. Find an overlap
     - Use domain knowledge: thesauri and isa hierarchies
  2. Compute the similarity in function of the overlap

Comparison of Conceptual Graphs

Overlap – The Intuition

Dice Coefficient

\[ S_{D_1, D_2} = \frac{2n(D_1 \cap D_2)}{n(D_1) + n(D_2)} \]

- \( n(D_i) \) = number of terms in \( D_i \)
- \( n(D_i \cap D_j) \) = number of terms that \( D_i \) and \( D_j \) have in common
Applying the Dice Coefficient

- **Conceptual Similarity**
  - \( n(G) \) is the number of concept nodes of graph \( G \)
  
  \[ S_c = \frac{2n(G_c)}{n(G_1) + n(G_2)} \]

- **Relational Similarity**
  - \( m(G) \) is the number of relations of graph \( G \)
  - \( m_{G_1}(G_2) \) is the number of relations in the immediate neighbourhood of \( G_1 \) in \( G_2 \), where \( G_1 \) is a subgraph of \( G_2 \)
  
  \[ S_r = \frac{2m(G_c)}{m_{G_1}(G_2) + m_{G_2}(G_2)} \]

Calculation of Relational Similarity

![Diagram of graphs](image)

\( m_{G_1}(G_2) = 6 \)

\( m_{G_2}(G_2) = 3 \)

\( 2 \times m(G_c) = 4 \)

\[ s_r = \frac{4}{6 + 3} \]

Generalisation of a Conceptual Graph

- **Unrestrict rule:**
  - Replace the type label of a concept with a supertype
  or
  - Replace an individual referent with a generic one

- **Detach rule:**
  - Split a node into two with the same type and referent
  and
  - Distribute the relations of the original node between the two resulting nodes

Projection

- \( \nu \) is a generalisation of \( u \) \( (u \leq \nu) \)
- we can define a projection \( \pi: \nu \rightarrow u \)

![Diagram of projection](image)

\( \nu: \)

- cat \( \rightarrow \) agent \( \rightarrow \) chase \( \rightarrow \) paw \( \rightarrow \) animal

\( u: \)

- cat. jerry \( \rightarrow \) agent \( \rightarrow \) chase \( \rightarrow \) pink \( \rightarrow \) mouse \( \rightarrow \) brown

Fig. 2. Projection mapping \( \pi: \nu \rightarrow u \) (the highlighted area is the projection of \( \nu \) in \( u \)).
Overlap with Graph Generalisations

- \( v \) is a common generalisation of \( u_1 \) and \( u_2 \) iff \( u_1 \leq v \) and \( u_2 \leq v \)
- A set of common generalisations of \( u_1 \) and \( u_2 \) is compatible iff they have projection maps such that the corresponding projections in \( G \), \( u_1 \) and \( u_2 \), do not intersect
- A compatible set of common generalisations \( \{g_1, \ldots, g_n\} \) of \( u_1 \) and \( u_2 \) is maximal iff we cannot add a new common generalisation \( g \leq g_i \) such that \( \{g, \ldots, g_n\} \) is compatible
- A set of common generalisations of \( u_1 \) and \( u_2 \) is an overlap iff it is compatible and maximal

Finding an Overlap

- There may be several overlaps
- Finding an overlap is NP-complete
- Still, workable for small graphs

One Overlap

Another Overlap
**Conceptual Similarity**

\[
S_c = 2 \times \frac{\sum_{c \in G_1} \text{weight}(c) \times \beta(\pi_{G_1} c, \pi_{G_2} c)}{\sum_{c \in G_1} \text{weight}(c) + \sum_{c \in G_2} \text{weight}(c)}
\]

\[
\text{weight}(c) = \begin{cases} W_e & \text{if } c \text{ represents an entity} \\ W_r & \text{if } c \text{ represents an action} \\ W_a & \text{if } c \text{ represents an attribute} \end{cases}
\]

\[
\beta(\pi_{G_1} c, \pi_{G_2} c) = \begin{cases} 1 & \text{if } \text{type}(\pi_{G_1} c) = \text{type}(\pi_{G_2} c) \text{ and } \text{referent}(\pi_{G_1} c) = \text{referent}(\pi_{G_2} c) \\ \frac{\text{depth}(c)}{\text{depth}(c_1) + \text{depth}(c_2)} & \text{if } \text{type}(\pi_{G_1} c) = \text{type}(\pi_{G_2} c) \text{ and } \text{referent}(\pi_{G_1} c) \neq \text{referent}(\pi_{G_2} c) \\ \frac{2d}{d_{c_1} + d_{c_2}} & \text{if } \text{type}(\pi_{G_1} c) \neq \text{type}(\pi_{G_2} c) \end{cases}
\]

**Relational Similarity**

\[
S_r = 2 \times \frac{\sum_{r \in N_{G_1}(G_1)} \text{weight}_{G_1}(r)}{\text{weight}_{G_1}(G_1) + \sum_{r \in N_{G_2}(G_2)} \text{weight}_{G_2}(r)}
\]

\[
N_{G}(G) = \bigcup_{r \in G} (r) \text{, where } N_{G}(G) = \{ r | r \text{ is connected to } c \text{ in } G \}
\]

\[
\text{weight}_{G_1}(r) = \frac{\sum_{c \in N_{G_1}(G_1)} \text{weight}(c)}{|N_{G_1}(G_1)|}, \text{ where } N_{G}(G) = \{ c | c \text{ is connected to } r \text{ in } G \}
\]

**The Similarity Measure**

\[
s = s_c \times (a + b \times s_r)
\]

- The coefficients \( a \) and \( b \) reflect user-specified balance
- \( 0 < a, b < 1 \) and \( a + b = 1 \)

**Example**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Overlap</th>
<th>( s_c )</th>
<th>( s_r )</th>
<th>( s )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a = 0.1, b = 0.9 )</td>
<td>( n_x = w_r = w_y = 1 )</td>
<td>[candidate] \rightarrow [ag] \rightarrow [criticize] \rightarrow [pn] \rightarrow [candidate]</td>
<td>0.86</td>
<td>1</td>
</tr>
<tr>
<td>( a = 0.9, b = 0.1 )</td>
<td>( n_x = w_r = w_y = 1 )</td>
<td>[candidate] \rightarrow [Bush] \rightarrow [criticize] \rightarrow [candidate]</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>( a = 0.5, b = 0.5 )</td>
<td>( n_x = w_r = w_y = 1 )</td>
<td>[candidate] \rightarrow [ag] \rightarrow [criticize] \rightarrow [pn] \rightarrow [candidate]</td>
<td>0.84</td>
<td>1</td>
</tr>
<tr>
<td>( a = 0.5, b = 0.5 )</td>
<td>( n_x = w_r = w_y = 1 )</td>
<td>[candidate] \rightarrow [Bush] \rightarrow [criticize] \rightarrow [candidate]</td>
<td>1.00</td>
<td>0</td>
</tr>
</tbody>
</table>
Example with AnswerFinder

The Similarity

- $W_E = W_V = W_A = 1$:
  \[
  S_e = \frac{2 \times \left( \frac{2 \times 1}{2 + 2} + 1 + 1 \right)}{6 + 4} = 0.7
  \]
  \[
  S_v = \frac{2 \times \left( \frac{2}{2} + \frac{2}{2} + \frac{2}{2} + \frac{2}{2} \right)}{1} = 0.857
  \]
  - $a = b = 0.5$:
    \[
    S = 0.7 \times (0.5 + 0.5 \times 0.857) = 0.65
    \]
  - $a = 0.9, b = 0.1$:
    \[
    S = 0.7 \times (0.9 + 0.1 \times 0.857) = 0.69
    \]
  - $a = 0.1, b = 0.9$:
    \[
    S = 0.7 \times (0.1 + 0.9 \times 0.857) = 0.61
    \]