HAPPY VALENTINE'S DAY
14 Feb 2011
JAIST
Conceptual Graphs and Fuzzy Logic

JAIST, 14 Feb 2011

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Outline

♥ Conceptual graphs and fuzzy logic
♥ Fuzzy conceptual graph programs
♥ Quantified conceptual graphs
♥ Query conceptual graphs
♥ Conclusion
Conceptual graphs


\[ CG = \text{semantic networks} + \text{Peirce's existential graphs} \]
Conceptual graphs

- **1968**: term paper to Marvin Minsky at Harvard
- **1970's**: seriously working on CGs
- **1976**: first paper on CGs
  
  *Conceptual graphs for a database interface*,

- **1981-1982**: meeting with Norman Foo and encountering Charles Peirce's existential graphs (1897)

- **1984**: the book coming out
The cat Tuna is on a mat.
Negated conceptual graphs

PROPOSITION:

CAT: tuna  On  MAT: *

Negated:

¬¬¬¬

Neg

CAT: tuna  On  MAT: *

Negated:

¬¬¬¬
Conceptual graphs as a logic

- A full-fledged first-order typed logic
- Conceptual graph programming
- Smooth mapping to and from natural language
Fuzzy sets

Fuzzy sets

♥ Vagueness:

"Words like **smart**, **tall**, and **fat** are **vague** since in most contexts of use there is no bright line separating them from **not smart**, **not tall**, and **not fat** respectively ..."

The Oxford Companion to Philosophy (1995)
Fuzzy sets

♥ Imprecision vs. Uncertainty:

The bottle is about half-full.

vs.

It is likely to the degree of 0.5 that the bottle is full.
Fuzzy sets

Membership function:

\( \mu_{\text{young}} : U \rightarrow [0, 1] \)
Fuzzy sets

- Membership function:
  - Preference distribution
  - Possibility distribution
  - Family of probability distribution
Multi-valued logic

Truth values are in [0, 1]

Lukasiewicz:

- $\neg a = 1 - a$
- $a \land b = \min(a, b)$
- $a \lor b = \max(a, b)$
- $a \Rightarrow b = \min(1, 1 - a + b)$
Fuzzy logic

\[ \textbf{if} \ x \text{ is } A \ \textbf{then} \ y \text{ is } B \]

\[ x \text{ is } A^* \]

\-----------------------------\]

\[ y \text{ is } B^* \]
Fuzzy logic

\[
\text{if height is tall then shoe-size is large}\\
\text{height is rather tall}\\
\text{----------------------------------------------}\\
\text{shoe-size is ?}
\]
Fuzzy logic

if \( x \) is \( A \) then \( y \) is \( B \)
\( x \) is \( A^* \)

\[ \begin{array}{c}
\hline
\text{R(u, v)} & \equiv & A(u) \rightarrow B(v) \\
A^*(u) & \rightarrow & B^*(v) \\
\hline
\end{array} \]

Viewing a fuzzy rule as a fuzzy relation:
Fuzzy logic

\[ \text{if } x \text{ is } A \text{ then } y \text{ is } B \]
\[ x \text{ is } A^* \]
\[ \text{---------------------------------} \]
\[ y \text{ is } B^* \]

❤ Measuring the similarity of A and A*:

\[ \text{if } x \text{ is } A \text{ then } y \text{ is } B \]
\[ x \text{ is } A^* \]
\[ \text{---------------------------------} \]
\[ B^*(v) = B + \Delta(A/A^*) \]
CG and FL

- Both have the common target of natural language

- CG provides a syntactic structure for smooth mapping to and from natural language
  

- FL provides a semantic processor for approximate reasoning with vagueness in natural language
  
Fuzzy conceptual graphs


It is very true that John is an American man who is young, and it is more or less true that he likes a car whose color is blue.
FCG programs

program $P$:

if

PRODUCT: * $\rightarrow$ ATTR$_1$ $\rightarrow$ DEMAND: *@not high

then

PRODUCT: * $\rightarrow$ ATTR$_2$ $\rightarrow$ PRICE: *@not expensive

if

PRODUCT: * $\rightarrow$ ATTR$_1$ $\rightarrow$ DEMAND: *@not low

then

PRODUCT: * $\rightarrow$ ATTR$_2$ $\rightarrow$ PRICE: *@not cheap

PRODUCT: #36 $\rightarrow$ ATTR$_1$ $\rightarrow$ DEMAND: *@normal

ATTR$_3$ $\rightarrow$ QUALITY: *@quite good
FCG programs

♥ Piece resolution (Salvat, E. 1997):

\[ R_1: \]

\[ G_1 \]

\[ c_1 \]

\[ t_1: *x \]

\[ 1 \]

\[ r_1 \]

\[ 2 \]

\[ t_1: *y \]

\[ G_2 \]

\[ c_3 \]

\[ t_4: * \]

\[ 2 \]

\[ r_4 \]

\[ 1 \]

\[ t_1: *x \]

\[ r_3 \]

\[ 2 \]

\[ t_1: *y \]

\[ c_5 \]

\[ r_5 \]

\[ 2 \]

\[ t_5: * \]

\[ c_6 \]

\[ t_2: m_2 \]

\[ 2 \]

\[ r_2 \]

\[ 1 \]

\[ c_7 \]

\[ Q: \]

\[ t_6: m_6 \]

\[ 2 \]

\[ r_6 \]

\[ 1 \]

\[ t_1: * \]

\[ r_4 \]

\[ 2 \]

\[ t_4: * \]

\[ t_5: * \]

\[ r_5 \]

\[ 2 \]

\[ t_2: m_2 \]

\[ r_2 \]

\[ 2 \]
FCG programs

Annotated fuzzy logic programs (Cao, T.H. 1998):

\[ \text{Obj: } H \leftarrow \text{Obj}_1: B_1 \& \text{Obj}_2: B_2 \& \ldots \& \text{Obj}_n: B_n \]

- \text{buy(John, y): very true} \leftarrow \text{like(John, y): true} \land \text{price(y): not expensive}
- \text{like(John, #36): very true}
- \text{price(#36): fairly cheap.}
Quantified conceptual graphs

Mapping linguistic structure to logical structure:

"Every student likes every course"

\[ \forall x \forall y \ (\text{student}(x) \land \text{course}(y) \rightarrow \text{like}(x, y)) \]

\[ \forall x \in \text{STUDENT} \forall y \in \text{COURSE}: \text{like}(x, y) \]

\[ \text{STUDENT: } \forall \rightarrow \text{Like} \rightarrow \text{COURSE: } \forall \]
Quantified conceptual graphs

♥ Mapping linguistic structure to logical structure:

"Most Swedes are tall"

\[ \text{most} = \Pr(\text{tall}(x) \mid \text{Swede}(x)) \]
Reasoning with relative quantifiers

♥ Generalization:

"Most people who are tall are not fat"

G:

G*:

⇒

"Most people who are tall are not very fat"
Reasoning with relative quantifiers

Specialization:

"About 9% people who are tall are fat"

\[ G: \]

\[
\text{PERSON}: \lambda \xrightarrow{1} \text{ATTR}_1 \xrightarrow{2} \text{HEIGHT}: \bullet \@\text{tall} : \{\} @\text{about 9%} \xrightarrow{1} \text{ATTR}_2 \xrightarrow{2} \text{BODY}: \bullet \@\text{fat}
\]

\[ G^*: \]

\[
\text{PERSON}: \lambda \xrightarrow{1} \text{ATTR}_1 \xrightarrow{2} \text{HEIGHT}: \bullet \@\text{tall} : \{\} @\text{at most about 9%} \xrightarrow{1} \text{ATTR}_2 \xrightarrow{2} \text{BODY}: \bullet \@\text{very fat}
\]

"At most about 9% people who are tall are very fat"
Reasoning with relative quantifiers

- With universal quantifier:

  "All people who are tall are not fat"

  \[ G: \]

  \[
  \begin{array}{c}
  \text{PERSON: } \lambda \\
  \text{ATTR}_1 \\
  \text{HEIGHT: } *@\text{tall} : \{\} @\text{all} \\
  \text{ATTR}_2 \\
  \text{BODY: } *@\text{not fat}
  \end{array}
  \]

  \[ G^*: \]

  \[
  \begin{array}{c}
  \text{MALE: } \lambda \\
  \text{ATTR}_1 \\
  \text{HEIGHT: } *@\text{very tall} : \{\} @\text{all} \\
  \text{ATTR}_2 \\
  \text{BODY: } *@\text{not fat}
  \end{array}
  \]

  "All males who are very tall are not fat"
Reasoning with absolute quantifiers

Generalization:

"Few people who are tall are fat"

\[ G:\]

\[
\text{PERSON: } \lambda \rightarrow \text{ATTR}_1 \rightarrow \text{HEIGHT: } *@tall : \{\} @\text{few} \rightarrow \text{ATTR}_2 \rightarrow \text{BODY: } *@\text{fat}
\]

\[ G^*:\]

\[
\text{PERSON: } \lambda \rightarrow \text{ATTR}_1 \rightarrow \text{HEIGHT: } *@\text{fairly tall} : \{\} @\text{at least few} \rightarrow \text{ATTR}_2 \rightarrow \text{BODY: } *@\text{fairly fat}
\]

"At least few people who are fairly tall are fairly fat"
Reasoning with absolute quantifiers

Specialization:

"Few people who are tall are fat"

\[
G:
\begin{array}{c}
\text{PERSON: } \lambda \\
\rightarrow \text{ATTR}_1 \\
\rightarrow \text{HEIGHT: } ^*\text{@tall} : \{\}^*\text{@few} \\
\rightarrow \text{ATTR}_2 \\
\rightarrow \text{BODY: } ^*\text{@fat}
\end{array}
\]

\[
G^*:
\begin{array}{c}
\text{PERSON: } \lambda \\
\rightarrow \text{ATTR}_1 \\
\rightarrow \text{HEIGHT: } ^*\text{@very tall} : \{\}^*\text{@at most few} \\
\rightarrow \text{ATTR}_2 \\
\rightarrow \text{BODY: } ^*\text{@very fat}
\end{array}
\]

"At most few people who are very tall are very fat"
Jeffrey's rule (1965)

♥ The conditional probability on a property of a specific object of a class is equal to that of the whole class.

"Most birds can fly"

⇒ "The probability that Tweet can fly given that it is a bird is most"
Jeffrey's rule (1965)

The conditional probability on a property of a specific object of a class is equal to that of the whole class.

"Most people who are tall are not fat"

\[ G: \]

\[ G^*: \]

\[ H^*: \]

"The probability that John is not fat is \( p \)"
Jeffrey's rule (1965)

\[ p = (\text{at least } (\text{most.} \varepsilon_\pi)) \cap (\text{at most } (\text{most.} \varepsilon_\pi + (1 - \varepsilon_\pi))) \]

Probabilistic FCG projection:

\[ \varepsilon_\pi = \Pr(\text{tall} \mid \text{fairly tall}) \]
Query conceptual graphs

Connective query:

"What international leaders sent or gave congratulations?"
Query conceptual graphs

♥ Superlative query:

"What’s the tallest building in New York City?"
Query conceptual graphs

Counting query:

"How many languages has *Harry Potter and the Goblet of Fire* been translated to?"

```
COUNT

BOOK: *Harry Potter and the Goblet of Fire* → TRANSLATED TO

1

2

LANGUAGE: ?
```
Query conceptual graphs

♥ A syntax-free approach for understanding natural language queries:
Query conceptual graphs

1. Recognizing specified entities
2. Recognizing unspecified entities
3. Extracting relational phrases
4. Extracting adjectives
5. Splitting a connective query
6. Determining the type of queried entities
7. Unifying identical entities
8. Discovering implicit relations
9. Determining the types of relations
10. Removing improper relations
11. Modifying concepts with adjectives
12. Constructing the final CG
Query conceptual graphs

Experiment on TREC 2002 dataset:

<table>
<thead>
<tr>
<th>Query Type</th>
<th>Number of Queries</th>
<th>Correct CGs</th>
<th>M-errors</th>
<th>O-errors</th>
<th>Q-errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connective</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Superlative adjective</td>
<td>35</td>
<td>16</td>
<td>0</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>How many</td>
<td>17</td>
<td>13</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>What</td>
<td>184</td>
<td>170</td>
<td>3</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Which</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Where</td>
<td>62</td>
<td>61</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Who</td>
<td>57</td>
<td>54</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>When</td>
<td>38</td>
<td>33</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>How</td>
<td>22</td>
<td>20</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>21</td>
<td>18</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>440</strong></td>
<td><strong>389</strong></td>
<td><strong>4</strong></td>
<td><strong>44</strong></td>
<td><strong>3</strong></td>
</tr>
<tr>
<td></td>
<td>(100%)</td>
<td>(88.41%)</td>
<td>(0.91%)</td>
<td>(10%)</td>
<td>(0.68%)</td>
</tr>
</tbody>
</table>
Query conceptual graphs

 Experiment on TREC 2007 dataset:

<table>
<thead>
<tr>
<th>Query Type</th>
<th>Number of Queries</th>
<th>Correct CGs</th>
<th>M-errors</th>
<th>O-errors</th>
<th>Q-errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connective</td>
<td>11</td>
<td>6</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Superlative adjective</td>
<td>21</td>
<td>4</td>
<td>0</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>How many</td>
<td>49</td>
<td>31</td>
<td>2</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>What</td>
<td>217</td>
<td>177</td>
<td>2</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>Which</td>
<td>23</td>
<td>18</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Where</td>
<td>13</td>
<td>11</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Who</td>
<td>56</td>
<td>45</td>
<td>0</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>When</td>
<td>12</td>
<td>10</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>How</td>
<td>15</td>
<td>10</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>28</td>
<td>25</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>445 (100%)</td>
<td>337 (75.73%)</td>
<td>4 (0.90%)</td>
<td>89 (20%)</td>
<td>15 (3.37%)</td>
</tr>
</tbody>
</table>
VN-KIM system

VN-KIM Front-End
Applications Interface

Semantic LUCENE
Semantic Web Document Repository

VN-KIM IE
Semantic Annotation

Fuzzy SESAME
Ontology and Knowledge Base

A KB of over 200,000 popular entities in Vietnamese news

Plug-ins
S-Search
S-Editor
VN-KIM entity recognition
VN-KIM search

Clusters

All Results (100)
- internationalorganization (63)
  - yugoslavia, pakistan (24)
  - rabin, treaty (11)
  - cambodia, korea (22)
  - king, hussein (6)
  - ocean (8)
  - man (25)
  - locationgeneralkey (4)

Set clustering parameters  Re-cluster

1. Peter Foster - Telegraph Blogs
   Latest Posts, September 6th, 2010 10:54. Is China ready for cagefighting?
   Cage-fighting in Yankton, South Dakota, USA (Photo: David Howells). Cage-fighting...
   http://blogs.telegraph.co.uk/news/author/peterfoster/
   Cached

2. BBC News - History of failed peace talks
   Facebook, reddit, StumbleUpon, Twitter, Email, Print. History of failed peace talks. Peace between Israel and the Palestinians has proved elusive...
   http://www.bbc.co.uk/news/world-middle-east-111053745
   Cached

3. BBC News - World's press guarded as Middle East peace talks begin
   Twitter, Email, Print. World's press guarded as Middle East peace talks begin. The opening day of US-brokered peace talks between Israel...
   http://www.bbc.co.uk/news/world-middle-east-111762547?print=true
   Cached

4. BBC News - World's press guarded as Middle East peace talks begin
   Twitter, Email, Print. World's press guarded as Middle East peace talks begin. The opening day of US-brokered peace talks between Israel...
   http://www.bbc.co.uk/news/world-middle-east-111762564
   Cached

5. BBC News - Obstacles to Middle East peace: Borders and settlements
   reddit, StumbleUpon, Twitter, Email, Print. Obstacles to Middle East peace: Borders and settlements. By Martin Asser, BBC News. Without fixed borders, Israel...
   http://www.bbc.co.uk/news/world-middle-east-111026967?print=true
   Cached

6. Burma news, all the latest and breaking Burmese news - Telegraph
VN-KIM search
Artificial intelligence needs a knowledge representation language that approaches natural language
Conclusion

♥ "Form without content is empty. Content without form is so indeterminate that it cannot be grasped as an object of knowledge."

John Hibben, Hegel’s Logic: An Essay in Interpretation

♥ CG+FL is just an attempt.
Thanks for your attention