The Neural Basis of Thought and Language

Week 12

Metaphor and Automatic Reasoning, plus Grammars
Schedule

• Assignment 8 due Thursday

• Last Week
  – Event Structure Metaphor
  – Bayes nets

• This Week
  – Inference, KARMA: Knowledge-based Action
    Representations for Metaphor and Aspect
  – Grammar

• Next Week
  – More grammar
Questions

1. How are the source and target domains represented in KARMA?

2. How does the source domain information enter KARMA? How should it?

3. What is chart parsing? Using a plausible CFG grammar, what is the parse of “Pat ate the kiwi”?

4. How well can CFGs represent English? What are some mechanisms for improvement?

5. What is unification?
KARMA

- DBN to represent target domain knowledge

- Metaphor maps link target and source domain

- X-schema to represent source domain knowledge
Metaphor Maps

• map entities and objects between embodied and abstract domains

• invariently map the aspect of the embodied domain event onto the target domain
  
  by setting the evidence for the status variable based on controller state (event structure metaphor)

• project x-schema parameters onto the target domain
DBN for the target domain

- Economic State: [recession, nogrowth, lowgrowth, highgrowth]
- Policy: [Liberalization, Protectionism]
- Goal: [free trade, protection]
- Outcome: [success, failure]
- Difficulty: [present, absent]
Let’s try a different domain

- I didn’t quite catch what he was saying
- His slides are packed with information
- He sent the audience a clear message

When we can get a good flow of information from the streets of our cities across to, whether it is an investigating magistrate in France or an intelligence operative in the Middle East, and begin to assemble that kind of information and analyze it and repackage it and send it back out to users, whether it's a policeman on the beat or a judge in Italy or a Special Forces Team in Afghanistan, then we will be getting close to the kind of capability we need to deal with this kind of problem. That's going to take a couple, a few years.
Target domain belief net (T-1)

Target domain belief net (T) (communication frame)

- Speaker
- Addressee
- Action
- Outcome
- Degree of understanding

Metaphor Map (conduit metaphor)

- Send is talk
- Receive is hear
- Ideas are objects
- Words are containers
- Senders are speakers
- Receivers are addressees

Source domain f-structs (transfer)

- Sender
- Receiver
- Means
- Force
- Rate

X-Schema representation

- Transfer
- Send
- Receive
- Pack
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How do the source domain f- structs get parameterized?

- In the KARMA system, they are hand-coded.
- In general, you need analysis of sentences:
  - syntax
  - semantics

Syntax captures:
- constraints on word order
- constituency (units of words)
- grammatical relations
  (e.g. subject, object)
- subcategorization & dependency
  (e.g. transitive, intransitive, subject-verb agreement)
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Grammar

• A grammar is a set of rules defining a formal language
• an example is right-regular grammar
• a more common example is Context-Free Grammar
  \[ \alpha \rightarrow \beta \]

\forall \alpha : single non-terminal

• \( \beta \) : any combination of terminals and non-terminals

  \[
  \begin{align*}
  S &\rightarrow NP \ VP \\
  NP &\rightarrow \text{Det Noun} \mid \text{ProperNoun} \\
  VP &\rightarrow \text{Verb NP} \mid \text{Verb PP} \\
  PP &\rightarrow \text{Preposition NP}
  \end{align*}
  \]

  \[
  \begin{align*}
  \text{Noun} &\rightarrow \text{kiwi} \mid \text{orange} \mid \text{store} \\
  \text{ProperNoun} &\rightarrow \text{Pat} \mid \text{I} \\
  \text{Det} &\rightarrow \text{a} \mid \text{an} \mid \text{the} \\
  \text{Verb} &\rightarrow \text{ate} \mid \text{went} \mid \text{shop} \\
  \text{Preposition} &\rightarrow \text{to} \mid \text{at}
  \end{align*}
  \]
Sentence generation: *Pat ate the kiwi*

- start from S and apply all applicable rules
- forward expansion

**Diagram:**

- **S**: root node
- **NP VP**: non-terminal node
- **Det Noun VP**
- **ProperNoun VP**
- **a Noun VP**
- **an Noun VP**
- **the Noun VP**
- **a kiwi VP**
- **a orange VP**
- **a store VP**

**Grammar Rules:**

- **S → NP VP**
- **NP → Det Noun | ProperNoun**
- **VP → Verb NP | Verb PP**
- **PP → Preposition NP**
- **Noun → kiwi | orange | store**
- **ProperNoun → Pat | I**
- **Det → a | an | the**
- **Verb → ate | went | shop**
- **Preposition → to | at**
Chart parsing

• On board
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Notice the ungrammatical and/or odd sentences that we can generate?

- *Pat ate a orange
- *Pat shop at the store
- *Pat went a store
- ?Pat ate a store
- ?The kiwi went to an orange

need to capture agreement, subcategorization, etc

you could make many versions of verbs, nouns, dets ➔ cumbersome
Unification Grammar

- Basic idea: capture these agreement features for each non-terminal in feature structures

\[
\begin{align*}
I & \quad \text{agreement} \quad \text{number : SG} \quad \text{person : 1st} \\
\text{Went} & \quad \text{agreement} \\
\text{Pat} & \quad \text{agreement} \quad \text{number : SG} \quad \text{person : 3rd} \\
\text{Shop} & \quad \text{agreement} \quad \text{number :} \quad \text{person : 1st}
\end{align*}
\]

Enforce constraints on these features using unification rules

- \( VP \rightarrow \text{Verb} \ \text{NP} \)
- \( \text{VP.agreement} \leftrightarrow \text{Verb.agreement} \)
- \( S \rightarrow \text{NP} \ \text{VP} \)
- \( \text{NP.agreement} \leftrightarrow \text{VP.agreement} \)
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Unification

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