Natural Language for Communication

Chapter 23
Next week’s schedule (Nov. 19, 21)

• Tuesday (Nov. 19) – Hao will continue discussion of Ch. 23

• Thursday (Nov. 21) – Hao will lead a tour of Parker’s Distributed Intelligence Lab (MK629)
  – 11:10-11:45: Undergrads go to MK629 for tour
  – 11:50-12:25: Grads go to MK629 for tour
Communication

Classical" view (pre-1953): language consists of sentences that are true/false (cf. logic)

Modern" view (post-1953): language is a form of action

Why?

Searle (1969) Speech Acts
Austin (1962) How to Do Things with Words
Wittgenstein (1953) Philosophical Investigations

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Communication

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Language is a form of action

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Communication

Classical view (pre-1953): language consists of sentences that are true/false (cf. logic).

Modern view (post-1953): language is a form of action.

Why?

Wittgenstein (1953) Philosophical Investigations
Austin (1962) How to Do Things with Words
Searle (1969) Speech Acts
Communication

To change the actions of other agents

Why?

Wittgenstein (1953) Philosophical Investigations
Austin (1962) How to Do Things with Words
Searle (1969) Speech Acts

Modern view (post-1953):
Language is a form of action

Classical view (pre-1953):
Language consists of sentences that are true/false (cf. logic)

Chapter 22
Speech acts achieve the speaker's goals:

- **Inform**
  - "There's a pit in front of you"
- **Query**
  - "Can you see the gold?"
- **Command**
  - "Pick it up"
- **Promise**
  - "I'll share the gold with you"
- **Acknowledge**
  - "OK"

Speech act planning requires knowledge of:

- Hearer's goals, knowledge base, and rationality
- Semantic and syntactic conventions
- Situation

Speech acts achieve the speaker's goals:
Stages in communication (informing)

- **Intention**
  - S wants to inform H that $P$

- **Generation**
  - S selects words $W$ to express $P$ in context $C$

- **Synthesis**
  - S utters words $W$

- **Perception**
  - H perceives $W'$ in context $C'$

- **Analysis**
  - H infers possible meanings $P_1, \ldots, P_n$

- **Disambiguation**
  - H infers intended meaning $P_i$

- **Incorporation**
  - H incorporates $P_i$ into KB

How could this go wrong?
Stages in Communication (Informing)

Intention
- P wants to inform H that $P \neq C$

Generation
- S selects words $W$ to express $P$ in context $C$

Synthesis
- S utters words $W$ into KB
- S infers intended meaning $P_i$
- S infers possible meanings $P_1, \ldots, P_n$

Perception
- H perceives $W$ in context $C$
- H infers intended meaning $P_i$
- H incorporates $P_i$ into KB

Analysis
- H infers possible meanings $P_1, \ldots, P_n$

Disambiguation
- H infers intended meaning $P_i$

Incorporation
- H incorporates $P_i$ into KB

How could this go wrong?
- In sincerity (S doesn't believe $P$)
- Speech wreck (ignition failure)
- Ambiguous utterance
- Insignificant ($S$ doesn't believe $P$)

Stages in Communication (Informing)
Grammar

Vervet monkeys, antelopes etc. use isolated symbols for sentences of a restricted set of communicable propositions, no generative capacity (Chomsky 1957)

A formal language is a set of strings of terminal symbols

A grammar specifies the compositional structure of complex messages.

(Chomsky (1957): Syntactic Structures)

Each string in the language can be analyzed/generated by the grammar.

A formal language is a set of strings of terminal symbols.

The grammar is a set of rewrite rules, e.g.,

```
S → NP V
NP → Articulate an the
```

Here is the sentence symbol, and nonterminals are denoted with a uppercase letter, e.g., S, V, N, P.

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```
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```

Chapter 22
Natural languages probably context-free, parsable in real time!

Related to Post systems and Kleene systems of rewaite rules

Recursively enumerable: no constraints

\[ A \alpha B \rightarrow A \alpha A \beta B \]

Context-sensitive: more nonterminals on right-hand side

\[ q \alpha p \rightarrow S \]

Context-free: nonterminal 

\[ V \rightarrow S \]

\[ S \alpha p \rightarrow S \]

Regular: nonterminal \[ \rightarrow \] terminal [nonterminal]
Divided into closed and open classes

Wumpus Lexicon
<table>
<thead>
<tr>
<th>Digit</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conjunction</td>
<td>and</td>
<td>or</td>
<td>but</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Preposition</td>
<td>to</td>
<td>in</td>
<td>on</td>
<td>near</td>
<td></td>
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<tr>
<td>Article</td>
<td>the</td>
<td>a</td>
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<tr>
<td>Name</td>
<td>John</td>
<td>Mary</td>
<td>Boston</td>
<td>UCB</td>
<td>PAIC</td>
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<tr>
<td>Pronoun</td>
<td>me</td>
<td>you</td>
<td>I</td>
<td>it</td>
<td>S/HE</td>
<td>Y'ALL</td>
<td></td>
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<tr>
<td>Adverb</td>
<td>here</td>
<td>there</td>
<td>nearby</td>
<td>ahead</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Adjective</td>
<td>right</td>
<td>left</td>
<td>east</td>
<td>south</td>
<td>back</td>
<td></td>
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<tr>
<td>Verb</td>
<td>is</td>
<td>see</td>
<td>smell</td>
<td>feel</td>
<td>shoot</td>
<td>VERB</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Noun</td>
<td>stench</td>
<td>breeze</td>
<td>pit</td>
<td>pits</td>
<td>gold</td>
<td>east</td>
<td>nothing</td>
<td>glitter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syntax</td>
<td>Description</td>
<td></td>
<td></td>
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<tr>
<td><strong>RelClause</strong></td>
<td>that + is smelly to the east</td>
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<tr>
<td><strong>RelClause</strong></td>
<td>rel_ahead turn to the east is + smelly feel + a breeze stinks the wumpus + that is smelly the wumpus + to the east 34 the wumpus + wumpus pits</td>
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</table>
Real grammars 10-500 pages, insufficient even for "proper" English. Inter-subjective agreement somewhat reliable, independent of semantics. Inter-subjective agreement somewhat reliable, independent of semantics.

Adjusting $L_1$ to agree with $L_2$ is a learning problem!

Adjusting $L_1$ to agree with $L_2$ is a learning problem!

Real grammar $L_1$ may differ from natural language $L_2$.

Grammaticality judgments
Exhibit the grammatical structure of a sentence
Exhibit the grammatical structure of a sentence.
Exhibit the grammatical structure of a sentence through parse trees.
Exhibit the grammatical structure of a sentence.
Exhibit the grammatical structure of a sentence.
Parse tree for “Every wumpus smells”
Most views syntactic structure as an essential step towards meaning:

“Mary hit John” ≠ “John hit Mary”
Most views syntactic structure as an essential step towards meaning.

Syntax in NLP
Bottom-up parsing works by replacing any substring that matches the RHS of a rule with the rule’s LHS. Efficient algorithms (e.g., chart parsing, Section 22.3) run at several thousand words/sec for real grammars, unlikely to find faster practical algorithms (Lee, 2002).

Boolean matrix multiplication \( \in O(n^3) \) for context-free, context-free parsing \( \equiv \) Boolean matrix multiplication (Lee, 2002)
Exercise 1

- An HMM grammar is essentially a standard HMM whose state variable is \( N \) (nonterminal, with values such as *Adjective*, *Noun*, etc.) and whose evidence variable is \( W \) (word, with values such as *is*, *duck*, etc.). The HMM model includes a prior \( P(No) \), a transition model \( P(N_{t+1} | N_t) \), and a sensor model \( P(W_t | N_t) \).
- Show that every HMM grammar can be written as a PCFG.
Exercise 2: Consider the following PCFG for simple verb phrases

0.1: VP → Verb
0.2: VP → Copula Adjective
0.5: VP → Verb the Noun
0.2: VP → VP Adverb
0.5: Verb → is
0.5: Verb → shoots
0.8: Copula → is
0.2: Copula → seems
0.5: Adjective → unwell
0.5: Adjective → well
0.5: Adverb → well
0.5: Adverb → badly
0.6: Noun → duck
0.4: Noun → well

What is the probability of generating “is well well”?
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0.5: Adverb → badly
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Which of the following have nonzero probability as a VP?

i. shoots the duck well well well
ii. seems the well well
iii. shoots the unwell well badly