Chapter 22

**Outline**

- Communication
- Grammar
- Syntactic analysis
- Problems

**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

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

Why utter?

To change the actions of other agents
Speech acts

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

Stages in communication (informing)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
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<tbody>
<tr>
<td>Intention</td>
<td>S wants to inform H that P</td>
</tr>
<tr>
<td>Generation</td>
<td>S selects words W to express P in context C</td>
</tr>
<tr>
<td>Synthesis</td>
<td>S utters words W</td>
</tr>
<tr>
<td>Perception</td>
<td>H perceives W' in context C'</td>
</tr>
<tr>
<td>Analysis</td>
<td>H infers possible meanings P₁,..., Pₙ</td>
</tr>
<tr>
<td>Disambiguation</td>
<td>H infers intended meaning P̂ᵢ</td>
</tr>
<tr>
<td>Incorporation</td>
<td>H incorporates P̂ᵢ into KB</td>
</tr>
</tbody>
</table>

How could this go wrong?
- Insincerity (S doesn’t believe P)
- Speech wreck ignition failure
- Ambiguous utterance
- Differing understanding of current context (C ≠ C' )

Grammar

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

Grammar specifies the compositional structure of complex messages
e.g., speech (linear), text (linear), music (two-dimensional)

A formal language is a set of strings of terminal symbols

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

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

\[ S \rightarrow NP \ VP \]
\[ Article \rightarrow \text{the} \mid \text{a} \mid \text{an} \mid \ldots \]

Here S is the sentence symbol, NP, VP, and Article are nonterminals

Grammar types

Regular: nonterminal → terminal{nonterminal}

\[ S \rightarrow aS \]
\[ S \rightarrow \lambda \]

Context-free: nonterminal → anything

\[ S \rightarrow aSB \]

Context-sensitive: more nonterminals on right-hand side

\[ ASB \rightarrow AAABB \]

Recursively enumerable: no constraints

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

Wumpus lexicon

Nouns → stench | breeze | glitter | nothing
       | wumpus | pit | pits | gold | east | ...
Verbs → is | see | smell | shoot | feel | stinks
       | go | grab | carry | kill | turn | ...
Adjectives → right | left | east | south | back | smelly | ...
Adverbs → here | there | nearby | ahead
       | right | left | east | south | back | ...
Pronouns → me | you | I | it | ...
Names → John | Mary | Boston | UCB | PAJC | ...
Articles → the | a | an | ...
Prepositions → to | in | on | near | ...
Conjunctions → and | or | but | ...

Stages in communication (informing)
classes are small, bounded, change very slowly

I feel a breeze

I feel a breeze and I smell a wumpus

the wumpus is smelly

goes to the east

classes are large, unbounded, change very fast

Open classes are large, unbounded, change very fast

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Digit — 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9

Closed classes are small, bounded, change very slowly

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Noun — stench | breeze | glitter | nothing
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  | go | grab | carry | kill | turn | google
Adjective — right | left | east | south | back | smelly | ...
Adverb — here | there | nearby | ahead
  | right | left | east | south | back | ...
Pronoun — me | you | I | it
Name — John | Mary | Boston | UCB | PAJC | Google ...
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Preposition — to | in | on | near | ...
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Open classes are large, unbounded, change very fast

Wumpus lexicon

Noun — stench | breeze | glitter | nothing
  | wumpus | pit | pits | gold | east | ...
Verb — is | see | smell | shoot | feel | stinks
  | go | grab | carry | kill | turn | false positives
Adjective — right | left | east | south | back | smelly | ...
Adverb — here | there | nearby | ahead
  | right | left | east | south | back | ...
Pronoun — me | you | I | it
Name — John | Mary | Boston | UCB | PAJC | ...
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Grammaticality judgements

Formal language L1 may differ from natural language L2

false positives

false negatives

Adjusting L1 to agree with L2 is a learning problem!

* the gold grab the wumpus
* I smell the wumpus the gold
* I give the wumpus the gold
* I donate the wumpus the gold

Intersubjective agreement somewhat reliable, independent of semantics!
Real grammars 10–500 pages, insufficient even for “proper” English
Parse trees
Exhibit the grammatical structure of a sentence

```
  I    shoot    the    wumpus
```

Parse trees
Exhibit the grammatical structure of a sentence

```
  S
    VP
      NP
        Pronoun
  NP
    VP
      NP
        Pronoun
        Verb
        Article
        Noun
```

Efficient CFG algorithms (e.g., chart parsing, Section 22.3) \(O(n^3)\)
Most view syntactic structure as an essential step towards meaning: 
“Mary hit John” ≠ “John hit Mary”

Nonetheless, ungrammatical sentence may be understood:

“Georgie give Georgie breakfast to dinosaur!! Dinosaur brush teeth!!!”

Not all grammatical sentences are easy to understand:

“Wouldn’t the sentence ‘I want to put a hyphen between the words Fish and And and And and Chips in my Fish-And-Chips sign’ have been clearer if quotation marks had been placed before Fish, and between Fish and and, and and and And, and And and and, and and and And, and And and and, and and and and, and and and Chips, as well as after Chips?”

BNF notation for grammars too restrictive:
– difficult to add “side conditions” (number agreement, etc.)
– difficult to connect syntax to semantics

Idea: express grammar rules as logic

$X \rightarrow YZ$ becomes $Y(s_1) \land Z(s_2) \Rightarrow X(Append(s_1, s_2))$

$X \rightarrow \text{word}$ becomes $X([\text{"word"}])$

$X \rightarrow Y \mid Z$ becomes $Y(s) \Rightarrow X(s) \land Z(s) \Rightarrow X(s)$

Here, $X(s)$ means that string $s$ can be interpreted as an $X$

Now it’s easy to augment the rules

* the car that I saw
  * the car who I saw
  * the chimp who I saw
  * the cockroach who I saw

$NP(s_1) \land EatsBreakfast(Ref(s_1)) \land VP(s_2)
\Rightarrow NP(Append(s_1, [\text{"who"}]), s_2))$

John eats
  * John eat
  Penguins eat

$NP(s_1) \land Number(s_1, n) \land VP(s_2) \land Number(s_2, n)
\Rightarrow S(Append(s_1, s_2))$

Parsing is reduced to logical inference:

Ask($KB, S([\text{"I am an "} \text{"wumpus"}])$)

(Can add extra arguments to return the parse structure, semantics)

Generation simply requires a query with uninstantiated variables:

Ask($KB, S(x)$)

If we add arguments to nonterminals to construct sentence semantics, NLP generation can be done from a given logical sentence:

Ask($KB, S(x, At([\text{Robot}, [1, 1]])$)
Parsing is reduced to logical inference:
\[
\text{Ask}(KB, S(["I\ "am\ "a\ "wumpus"]))
\]

(Can add extra arguments to return the parse structure, semantics)

Generation simply requires a query with uninstantiated variables:
\[
\text{Ask}(KB, S(x))
\]

If we add arguments to nonterminals to construct sentence semantics, NLP generation can be done from a given logical sentence:
\[
\text{Ask}(KB, S(x; At(Robot, [1,1])))
\]
\[
\text{Yes,}\ \{x = "The robot is at [1,1]"\}
\]

Real human languages provide many problems for NLP:

- ambiguity
- anaphora
- indexicality
- vagueness
- discourse structure
- metonymy
- metaphor
- noncompositionality

Squad helps dog bite victim
Helicopter powered by human flies
Eighth Army push bottles up Germans
I ate spaghetti with meatballs
Ambiguity

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Helicopter powered by human flies
Eighth Army push bottles up Germans
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Ambiguity can be lexical (polysemy), syntactic, semantic, referential

Chapter 22

Ambiguity

Squad helps dog bite victim
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Chapter 22

Anaphora

Using pronouns to refer back to entities already introduced in the text

After Mary proposed to John, they found a preacher and got married.
Anaphora

Using pronouns to refer back to entities already introduced in the text

After Mary proposed to John, they found a preacher and got married.

For the honeymoon, they went to Hawaii

They saw a ring through the window and asked John for it

They threw a rock at the window and broke it

Indexicality

Indexical sentences refer to utterance situation (place, time, S/H, etc.)

I am over here

Why did you do that?

Metonymy

Using one noun phrase to stand for another

I’ve read Shakespeare

Chrysler announced record profits

The ham sandwich on Table 4 wants another beer

Metaphor

“Non-literal” usage of words and phrases, often systematic:

I’ve tried killing the process but it won’t die. Its parent keeps it alive.
Noncompositionality

Meaning of Word₁, Word₂ composed from meanings of Word₁, Word₂?

basketball shoes
baby shoes
alligator shoes

Noncompositionality

Meaning of Word₁, Word₂ composed from meanings of Word₁, Word₂?

basketball shoes
baby shoes
alligator shoes
designer shoes

Noncompositionality

Meaning of Word₁, Word₂ composed from meanings of Word₁, Word₂?

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes
red book
Noncompositionality

Meaning of Word₁, Word₂ composed from meanings of Word₁, Word₂?

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes
red book
red pen
red hair
red herring

Noncompositionality

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basketball shoes
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brake shoes
red book
red pen
red hair
red herring
small moon
large molecule

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red book
red pen
red hair
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small moon
large molecule
mere child
Noncompositionality

Meaning of Word₁ Word₂ composed from meanings of Word₁, Word₂?

basketball shoes
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alligator shoes
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brake shoes
red book
red pen
red hair
red herring
small moon
large molecule
mere child
alleged murderer

Noncompositionality

Meaning of Word₁ Word₂ composed from meanings of Word₁, Word₂?

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artificial grass