COMMUNICATION AND LANGUAGE

Chapter 22

Outline

- \Diamond Communication
- ♦ Grammar
- \Diamond Syntactic analysis
- \Diamond Problems

```
"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

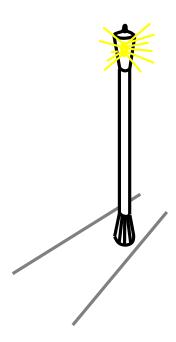
Why?
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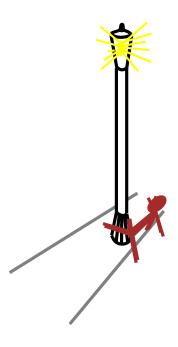


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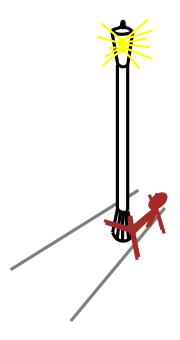
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Why?

To change the actions of other agents



Speech acts

SITUATION

Speaker → **Utterance** → **Hearer**

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)

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 $P_1, \dots P_n$

Disambiguation H infers intended meaning P_i

Incorporation H incorporates P_i into KB

How could this go wrong?

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How could this go wrong?

- Insincerity (S doesn't believe P)
- Speech wreck ignition failure
- Ambiguous utterance
- Differing understanding of current context $(C \neq C')$

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.,

$$S \rightarrow NP \ VP$$

 $Article \rightarrow the \mid a \mid an \mid \dots$

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

Grammar types

Regular: $nonterminal \rightarrow terminal[nonterminal]$

$$S \to aS$$

$$S \to \Lambda$$

Context-free: $nonterminal \rightarrow anything$

$$S \rightarrow \boldsymbol{a} S \boldsymbol{b}$$

Context-sensitive: more nonterminals on right-hand side

$$ASB \rightarrow AAaBB$$

Recursively enumerable: no constraints

Related to Post systems and Kleene systems of rewrite rules

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

Wumpus lexicon

```
Noun \rightarrow stench \mid breeze \mid glitter \mid nothing
                         \mid wumpus \mid \ pit \mid \ pits \mid \ gold \mid \ east \mid \dots
           Verb 
ightarrow is \mid see \mid smell \mid shoot \mid feel \mid stinks
                         \mid go \mid grab \mid carry \mid kill \mid turn \mid \dots
    Adjective \rightarrow right \mid left \mid east \mid south \mid back \mid smelly \mid \dots
       Adverb \rightarrow here \mid there \mid nearby \mid ahead
                         \mid right \mid left \mid east \mid south \mid back \mid \dots
     Pronoun \rightarrow me \mid you \mid I \mid it \mid \dots
         Name \rightarrow John \mid Mary \mid Boston \mid UCB \mid PAJC \mid \dots
       Article \rightarrow the \mid a \mid an \mid \dots
 Preposition \rightarrow to \mid in \mid on \mid near \mid \dots
Conjunction \rightarrow and \mid or \mid but \mid \dots
          Digit \rightarrow \mathbf{0} \mid \mathbf{1} \mid \mathbf{2} \mid \mathbf{3} \mid \mathbf{4} \mid \mathbf{5} \mid \mathbf{6} \mid \mathbf{7} \mid \mathbf{8} \mid \mathbf{9}
```

Divided into closed and open classes

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       Adverb \rightarrow here \mid there \mid nearby \mid ahead
                        \mid right \mid left \mid east \mid south \mid back \mid \dots
     Pronoun \rightarrow me \mid you \mid I \mid it \mid S/HE \mid Y'ALL...
         Name \rightarrow John \mid Mary \mid Boston \mid UCB \mid PAJC \mid \dots
       Article \rightarrow the \mid a \mid an \mid \dots
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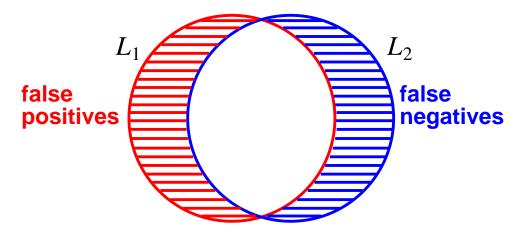
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Wumpus grammar

```
S \rightarrow NP VP
                         \mathsf{I} + \mathsf{feel} a breeze
               S Conjunction S I feel a breeze + and + I smell a wumpus
      NP \rightarrow Pronoun
                                    pits
               Noun
               Article\ Noun \hspace{1cm} {\it the} + {\it wumpus}
               Digit Digit
                                    3 4
               NP PP
                                   the wumpus + to the east
               NP \ RelClause the wumpus + that is smelly
       VP \rightarrow Verb
                                    stinks
               VP NP feel + a breeze
               VP \ Adjective is +  smelly
                        \mathsf{turn} + \mathsf{to} \mathsf{the} \mathsf{east}
               VP PP
               VP \ Adverb go + ahead
      PP \rightarrow Preposition NP to + the east
RelClause \rightarrow that VP that + is smelly
```

Grammaticality judgements

Formal language L_1 may differ from natural language L_2



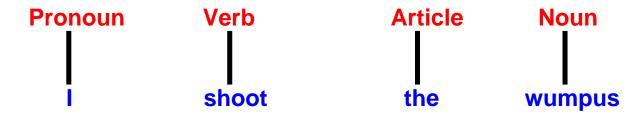
Adjusting L_1 to agree with L_2 is a learning problem!

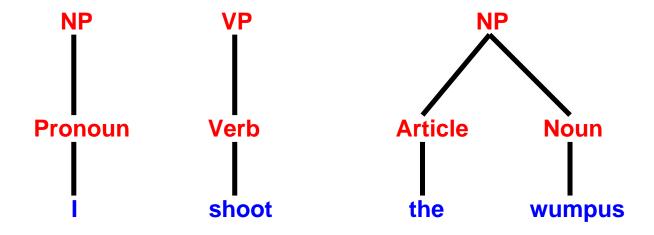
- * the gold grab the wumpus
- * I smell the wumpus the gold I give the wumpus the gold
- * I donate the wumpus the gold

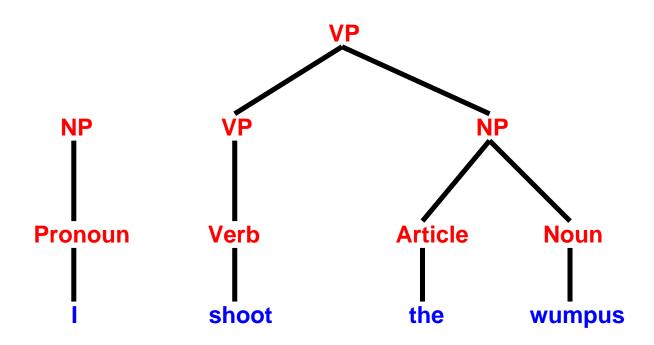
Intersubjective agreement somewhat reliable, independent of semantics! Real grammars 10–500 pages, insufficient even for "proper" English

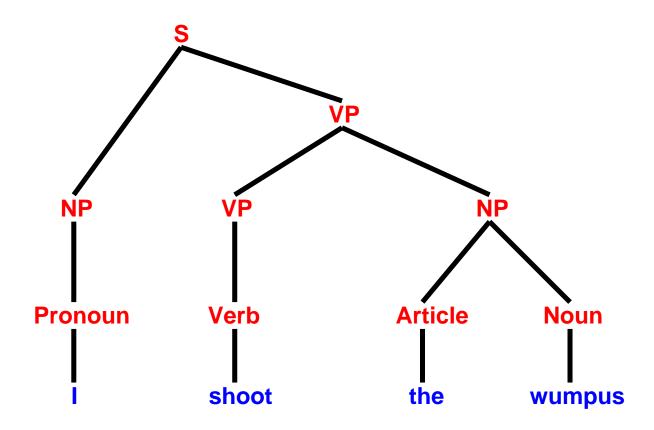
Exhibit the grammatical structure of a sentence

I shoot the wumpus









Syntax in NLP

Most view syntactic structure as an essential step towards meaning; "Mary hit John" \neq "John hit Mary"

"And since I was not informed—as a matter of fact, since I did not know that there were excess funds until we, ourselves, in that checkup after the whole thing blew up, and that was, if you'll remember, that was the incident in which the attorney general came to me and told me that he had seen a memo that indicated that there were no more funds."

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"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 Chips, as well as after Chips?"

Context-free parsing

Bottom-up parsing works by replacing any substring that matches RHS of a rule with the rule's LHS

Efficient algorithms (e.g., chart parsing, Section 22.3) $O(n^3)$ for context-free, run at several thousand words/sec for real grammars

Context-free parsing \equiv Boolean matrix multiplication (Lee, 2002) \Rightarrow unlikely to find faster practical algorithms

Logical grammars

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

$$X \to YZ$$
 becomes $Y(s_1) \wedge Z(s_2) \Rightarrow X(Append(s_1, s_2))$
 $X \to \boldsymbol{word}$ becomes $X(["\boldsymbol{word}"])$
 $X \to Y \mid Z$ becomes $Y(s) \Rightarrow X(s) \mid Z(s) \Rightarrow X(s)$

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

Logical grammars contd.

Now it's easy to augment the rules

$$NP(s_1) \wedge EatsBreakfast(Ref(s_1)) \wedge VP(s_2)$$

 $\Rightarrow NP(Append(s_1, ["who"], s_2))$

$$NP(s_1) \wedge Number(s_1, n) \wedge VP(s_2) \wedge Number(s_2, n)$$

 $\Rightarrow S(Append(s_1, s_2))$

Parsing is reduced to logical inference:

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

Generation simply requires a query with uninstantiated variables:

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

Ask(
$$KB$$
, $S(x, At(Robot, [1, 1])$)

Real language

Real human languages provide many problems for NLP:

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

Squad helps dog bite victim

Squad helps dog bite victim Helicopter powered by human flies

Squad helps dog bite victim Helicopter powered by human flies American pushes bottle up Germans

Squad helps dog bite victim
Helicopter powered by human flies
American pushes bottle up Germans
I ate spaghetti with meatballs

Squad helps dog bite victim
Helicopter powered by human flies
American pushes bottle up Germans
I ate spaghetti with meatballs
salad

Squad helps dog bite victim
Helicopter powered by human flies
American pushes bottle up Germans
I ate spaghetti with meatballs
salad
abandon

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Squad helps dog bite victim
Helicopter powered by human flies
American pushes bottle up Germans
I ate spaghetti with meatballs
salad
abandon
a fork
```

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Ambiguity can be lexical (polysemy), syntactic, semantic, referential

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

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

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

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

Mary 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.

basketball shoes

basketball shoes baby shoes

basketball shoes baby shoes alligator shoes

basketball shoes baby shoes alligator shoes designer shoes

basketball shoes baby shoes alligator shoes designer shoes brake shoes

basketball shoes baby shoes alligator shoes designer shoes brake shoes

red book

basketball shoes baby shoes alligator shoes designer shoes brake shoes

red book red pen

basketball shoes baby shoes alligator shoes designer shoes brake shoes

red book red pen red hair

basketball shoes baby shoes alligator shoes designer shoes brake shoes

red book red pen red hair red herring

basketball shoes baby shoes alligator shoes designer shoes brake shoes

red book red pen red hair red herring

small moon

basketball shoes baby shoes alligator shoes designer shoes brake shoes

red book red pen red hair red herring

small moon large molecule

basketball shoes baby shoes alligator shoes designer shoes brake shoes

red book red pen red hair red herring

small moon large molecule mere child

basketball shoes baby shoes alligator shoes designer shoes brake shoes

red book red pen red hair red herring

small moon large molecule mere child alleged murderer

basketball shoes baby shoes alligator shoes designer shoes brake shoes

red book red pen red hair red herring

small moon large molecule mere child alleged murderer real leather

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red book red pen red hair red herring

small moon large molecule mere child alleged murderer real leather artificial grass