Communication and Language

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?

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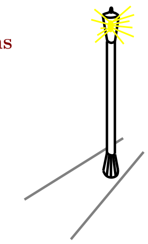
Why?



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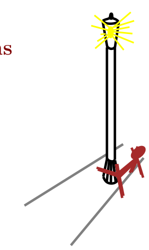

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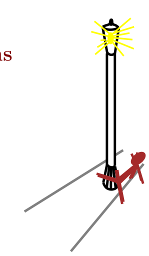
Why?

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 $P_1, \ldots P_n$
Disambiguation	H infers intended meaning P_i
Incorporation	H incorporates P_i into KB

How could this go wrong?

Stages in communication (informing)

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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
$\Rightarrow$ 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.,

$S \rightarrow NP\ VP$
$Article \rightarrow \boldsymbol{the} \mid \boldsymbol{a} \mid \boldsymbol{an} \mid \ldots$

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

Grammar types

Regular: $nonterminal \rightarrow \boldsymbol{terminal}[nonterminal]$

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

Context-free: $nonterminal \rightarrow anything$

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

Context-sensitive: more nonterminals on right-hand side

$ASB \rightarrow AA\boldsymbol{a}BB$

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

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

Divided into closed and open classes

Wumpus lexicon

Noun → ***stench*** | ***breeze*** | ***glitter*** | ***nothing***
| ***wumpus*** | ***pit*** | ***pits*** | ***gold*** | ***east*** | . . .
Verb → ***is*** | ***see*** | ***smell*** | ***shoot*** | ***feel*** | ***stinks***
| ***go*** | ***grab*** | ***carry*** | ***kill*** | ***turn*** | . . .
Adjective → ***right*** | ***left*** | ***east*** | ***south*** | ***back*** | ***smelly*** | . . .
Adverb → ***here*** | ***there*** | ***nearby*** | ***ahead***
| ***right*** | ***left*** | ***east*** | ***south*** | ***back*** | . . .
Pronoun → ***me*** | ***you*** | ***I*** | ***it*** | ***S/HE*** | ***Y'ALL*** . . .
Name → ***John*** | ***Mary*** | ***Boston*** | ***UCB*** | ***PAJC*** | . . .
Article → ***the*** | ***a*** | ***an*** | . . .
Preposition → ***to*** | ***in*** | ***on*** | ***near*** | . . .
Conjunction → ***and*** | ***or*** | ***but*** | . . .
Digit → **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9**

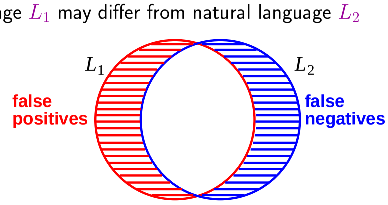
Divided into closed and open classes

Wumpus grammar

S →	*NP VP*	I + feel a breeze
|	*S Conjunction S*	I feel a breeze + and + I smell a wumpus
NP →	*Pronoun*	I
|	*Noun*	pits
|	*Article Noun*	the + wumpus
|	*Digit Digit*	3 4
|	*NP PP*	the wumpus + to the east
|	*NP RelClause*	the wumpus + that is smelly
VP →	*Verb*	stinks
|	*VP NP*	feel + a breeze
|	*VP Adjective*	is + smelly
|	*VP PP*	turn + to the east
|	*VP Adverb*	go + ahead
PP →	*Preposition NP*	to + the east
RelClause →	***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

Parse trees

Exhibit the grammatical structure of a sentence

I shoot the wumpus

Parse trees

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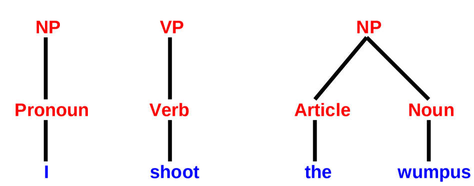

Parse trees

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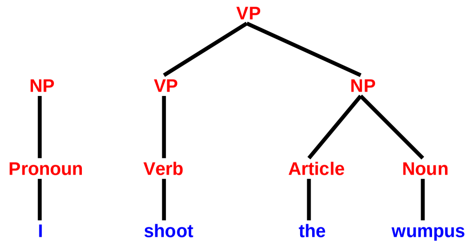

Parse trees

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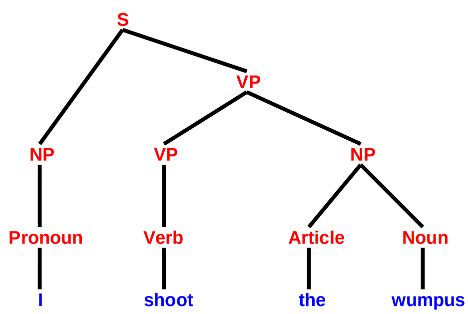

Syntax in NLP

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

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

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

Logical grammars contd.

Now it's easy to augment the rules

$$NP(s_1) \wedge EatsBreakfast(Ref(s_1)) \wedge VP(s_2) \Rightarrow NP(Append(s_1, [\text{“}\boldsymbol{who}\text{”}], s_2))$$

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

Parsing is reduced to logical inference:
$\textsc{Ask}(KB,\ S([\text{“}\boldsymbol{I}\text{” “}\boldsymbol{am}\text{” “}\boldsymbol{a}\text{” “}\boldsymbol{wumpus}\text{”}]))$
(Can add extra arguments to return the parse structure, semantics)

Generation simply requires a query with uninstantiated variables:
$\textsc{Ask}(KB,\ S(x))$

If we add arguments to nonterminals to construct sentence semantics, NLP generation can be done from a given logical sentence:
$\textsc{Ask}(KB,\ S(x, At(Robot, [1,1])))$

Real language

Real human languages provide many problems for NLP:

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

Ambiguity

Squad helps dog bite victim

Ambiguity

Squad helps dog bite victim
Helicopter powered by human flies

Ambiguity

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

Ambiguity

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

Ambiguity

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

Ambiguity

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

Ambiguity

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

Ambiguity

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

Ambiguity

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

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.

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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**

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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.

Noncompositionality

basketball shoes

Noncompositionality

basketball shoes
baby shoes

Noncompositionality

basketball shoes
baby shoes
alligator shoes

Noncompositionality

basketball shoes
baby shoes
alligator shoes
designer shoes

Noncompositionality

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

Noncompositionality

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book

Noncompositionality

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book
red pen

Noncompositionality

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book
red pen
red hair

Noncompositionality

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book
red pen
red hair
red herring

Noncompositionality

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book
red pen
red hair
red herring

small moon

Noncompositionality

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book
red pen
red hair
red herring

small moon
large molecule

Noncompositionality

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book
red pen
red hair
red herring

small moon
large molecule
mere child

Noncompositionality

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

Noncompositionality

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

Noncompositionality

basketball shoes
baby shoes
alligator shoes
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brake shoes

red book
red pen
red hair
red herring

small moon
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