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 utter?

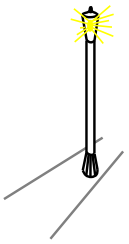
Communication

"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?



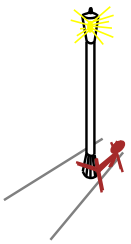
Communication

"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?



Communication

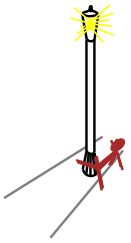
"Classical" view (pre-1953):
language consists of sentences that are true/false (cf. logic)

"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)

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	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?
- 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.,

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

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

Grammar types

Regular: $nonterminal \rightarrow \textbf{\textit{terminal}}[nonterminal]$

$S \rightarrow \textbf{\textit{a}}S$
$S \rightarrow \Lambda$

Context-free: $nonterminal \rightarrow anything$

$S \rightarrow \textbf{\textit{a}}S\textbf{\textit{b}}$

Context-sensitive: more nonterminals on right-hand side

$ASB \rightarrow AA\textbf{\textit{a}}BB$

Recursively enumerable: no constraints

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

Wumpus lexicon

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

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*** | ...
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**

Closed classes are small, bounded, change very slowly

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*** | ~~***thou***~~ | ***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**

Closed classes are small, bounded, change very slowly

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*** | ...
Name → ***John*** | ***Mary*** | ***Boston*** | ***UCB*** | ***PAJC*** | ...
Article → ***the*** | ***a*** | ***an*** | ...
Preposition → ***to*** | ***in*** | ***on*** | ***near*** | ...
Conjunction → ***and*** | ***or*** | ***but*** | ...

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*** | *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* ...
Article → ***the*** | ***a*** | ***an*** | ...
Preposition → ***to*** | ***in*** | ***on*** | ***near*** | ...
Conjunction → ***and*** | ***or*** | ***but*** | ...

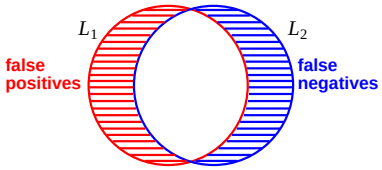
Open classes are large, unbounded, change very fast

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

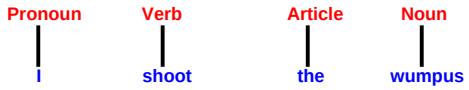
Exhibit the grammatical structure of a sentence

Pronoun Verb Article Noun

I shoot the wumpus

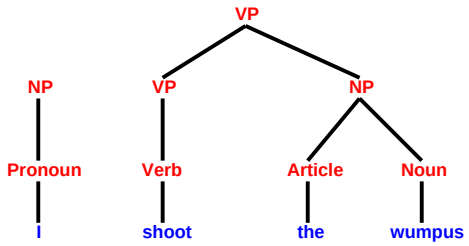
Parse trees

Exhibit the grammatical structure of a sentence



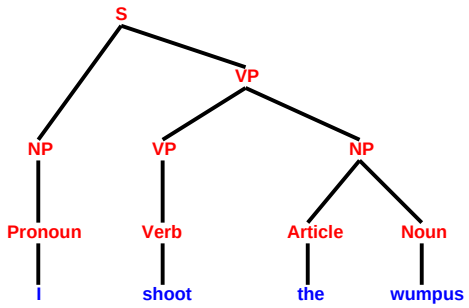
Parse trees

Exhibit the grammatical structure of a sentence



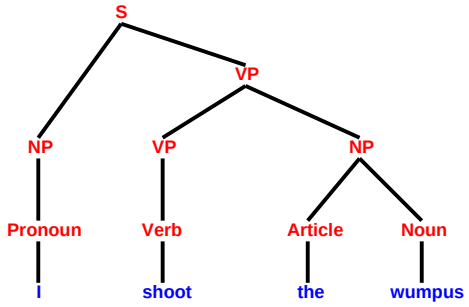
Parse trees

Exhibit the grammatical structure of a sentence



Parse trees

Exhibit the grammatical structure of a sentence



Efficient CFG algorithms (e.g., chart parsing, Section 22.3) $O(n^3)$

Syntax in NLP

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

Nonetheless, ungrammatical sentence may be understood:

Syntax in NLP

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

Nonetheless, ungrammatical sentence may be understood:

"Georgie give Georgie breakfast dinosaur!! Dinosaur brush teeth!!!"

Syntax in NLP

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

Nonetheless, ungrammatical sentence may be understood:

"Georgie give Georgie breakfast to dinosaur!! Need teeth brush!!!"

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 Chips, as well as after Chips?"

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 $Y(s_1) \wedge Z(s_2) \Rightarrow X(Append(s_1, s_2))$
$X \rightarrow \textbf{\textit{word}}$ becomes $X([\text{"}\textbf{\textit{word}}\text{"}])$
$X \rightarrow Y \mid Z$ 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
the car that I saw
* the car who I saw
the chimp who I saw
* the cockroach who I saw

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

John eats
* John eat
Penguins eat

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

Logical grammars contd.

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

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

Logical grammars contd.

Parsing is reduced to logical inference:
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:
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, $S(x, At(Robot, [1, 1]))$)
$Yes, \{x =$ "The robot is at [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
Eighth Army push bottles up Germans

Ambiguity

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

Ambiguity

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

Ambiguity

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

Ambiguity

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

Ambiguity

Squad helps dog bite victim
Helicopter powered by human flies
Eighth Army push bottles up Germans
I ate spaghetti with meatballs
salad
abandon
a fork
a friend

Ambiguity

Squad helps dog bite victim
Helicopter powered by human flies
Eighth Army push bottles 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.

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

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**

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.

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

basketball shoes

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

basketball shoes
baby shoes

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

basketball shoes
baby shoes
alligator shoes

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

basketball shoes
baby shoes
alligator shoes
designer shoes

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book
red pen

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book
red pen
red hair

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book
red pen
red hair
red herring

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book
red pen
red hair
red herring

small moon

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

basketball shoes
baby shoes
alligator shoes
designer shoes
brake shoes

red book
red pen
red hair
red herring

small moon
large molecule

Noncompositionality

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

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

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

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

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

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

Meaning of $Word_1\,Word_2$ composed from meanings of $Word_1$, $Word_2$?

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
artificial grass