COMMUNICATION AND LANGUAGE

CHAPTER 22
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?
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Why utter?

To change the actions of other agents
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)

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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
⇒ 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.,

\[ S \rightarrow NP \; VP \]
\[ Article \rightarrow the \mid a \mid an \mid \ldots \]

Here \( S \) is the sentence symbol, \( NP \), \( VP \), and \( Article \) are nonterminals
Grammar types

Regular: \( \text{nonterminal} \rightarrow \text{terminal}[\text{nonterminal}] \)

\[
S \rightarrow aS \\
S \rightarrow \Lambda
\]

Context-free: \( \text{nonterminal} \rightarrow \text{anything} \)

\[
S \rightarrow aSb
\]

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

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

Adjective $\rightarrow$ right | left | east | south | back | smelly | ...

Adverb $\rightarrow$ here | there | nearby | ahead
| right | left | east | south | back | ...

Pronoun $\rightarrow$ me | you | I | it | thou | y'all...

Name $\rightarrow$ John | Mary | Boston | UCB | PAJC | ...

Article $\rightarrow$ the | a | an | ...

Preposition $\rightarrow$ to | in | on | near | ...

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Open classes are large, unbounded, change very fast
Wumpus lexicon

**Noun** → stench | breeze | glitter | nothing  
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  | go | grab | carry | kill | turn | google...  

**Adjective** → right | left | east | south | back | smelly | ...  

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**Preposition** → to | in | on | near | ...  

**Conjunction** → and | or | but | ...  

Open classes are large, unbounded, change very fast
Wumpus grammar

\[
S \rightarrow NP \ VP \quad \text{l + feel a breeze}
\]
\[
S \rightarrow S \ Conjunction \ S \quad \text{l feel a breeze + and + l smell a wumpus}
\]
\[
NP \rightarrow Pronoun \quad \text{l}
\]
\[
NP \rightarrow Noun \quad \text{pits}
\]
\[
NP \rightarrow Article \ Noun \quad \text{the + wumpus}
\]
\[
NP \rightarrow Digit \ Digit \quad \text{3 4}
\]
\[
NP \rightarrow NP \ PP \quad \text{the wumpus + to the east}
\]
\[
NP \rightarrow NP \ RelClause \quad \text{the wumpus + that is smelly}
\]
\[
VP \rightarrow Verb \quad \text{stinks}
\]
\[
VP \rightarrow VP \ NP \quad \text{feel + a breeze}
\]
\[
VP \rightarrow VP \ Adjective \quad \text{is + smelly}
\]
\[
VP \rightarrow VP \ PP \quad \text{turn + to the east}
\]
\[
VP \rightarrow VP \ Adverb \quad \text{go + ahead}
\]
\[
PP \rightarrow Preposition \ NP \quad \text{to + the east}
\]
\[
RelClause \rightarrow that \ VP \quad \text{that + is smelly}
\]
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

```
I shoot the wumpus
```

- **Pronoun**: I
- **Verb**: shoot
- **Article**: the
- **Noun**: wumpus
Parse trees

Exhibit the grammatical structure of a sentence

I shoot the wumpus

NP
Pronoun
I

VP
Verb
shoot

NP
Article
the
Noun
wumpus
Parse trees

Exhibit the grammatical structure of a sentence

I shoot the wumpus

NP VP NP
Pronoun Verb Article Noun
I shoot the wumpus
Parse trees

Exhibit the grammatical structure of a sentence

S

NP

Pronoun

I

VP

Verb

shoot

NP

Article

the

Noun

wumpus
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” ≠ “John hit Mary”

Nonetheless, ungrammatical sentence may be understood:
Syntax in NLP

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“Mary hit John” ≠ “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” ≠ “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 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

\[ X \rightarrow YZ \quad \text{becomes} \quad Y(s_1) \land Z(s_2) \Rightarrow X(Append(s_1, s_2)) \]
\[ X \rightarrow \text{word} \quad \text{becomes} \quad X([\text{“word”}]) \]
\[ X \rightarrow Y \mid Z \quad \text{becomes} \quad Y(s) \Rightarrow X(s) \quad Z(s) \Rightarrow X(s) \]

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

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

John eats
* John eat
Penguins eat

\[ NP(s_1) \land Number(s_1, n) \land VP(s_2) \land Number(s_2, n) \]
\[ \Rightarrow S(Append(s_1, s_2)) \]
Logical grammars contd.

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:
\[
\text{Ask}(KB, S(x, At(Robot, [1, 1])))
\]
Logical grammars contd.

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

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 $Word_1 \text{ } Word_2$ 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
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alligator shoes
designer shoes
brake shoes

red book
red pen
red hair
red herring

small moon
large molecule
mere child
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artificial grass