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

Why?

Language is used to affect 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

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Stages in communication (informing)

- **Intention**
  S wants to inform H that $P$
- **Generation**
  S selects words $W$ to express $P$
- **Synthesis**
  S utters words $W$
- **Perception**
  H perceives $W'$
- **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 situation
Grammar

Grammar specifies the structure of messages.

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.,

\[
S \rightarrow NP \ VP
\]

\[
Article \rightarrow \text{the} | \text{a} | \text{an} | \ldots
\]

Here \( S \) is the sentence symbol, \( NP \) and \( VP \) are non-terminals.

Wumpus lexicon

\[
\text{Noun} \rightarrow \text{stench} | \text{breeze} | \text{glitter} | \text{nothing} \\
| \text{wumpus} | \text{pit} | \text{pits} | \text{gold} | \text{east} | \ldots
\]

\[
\text{Verb} \rightarrow \text{is} | \text{see} | \text{smell} | \text{shoot} | \text{feel} | \text{stinks} \\
| \text{go} | \text{grab} | \text{carry} | \text{kill} | \text{turn} | \ldots
\]

\[
\text{Adjective} \rightarrow \text{right} | \text{left} | \text{east} | \text{south} | \text{back} | \text{smelly} | \ldots
\]

\[
\text{Adverb} \rightarrow \text{here} | \text{there} | \text{nearby} | \text{ahead} \\
| \text{right} | \text{left} | \text{east} | \text{south} | \text{back} | \ldots
\]

\[
\text{Pronoun} \rightarrow \text{me} | \text{you} | \text{I} | \text{it} | \ldots
\]

\[
\text{Name} \rightarrow \text{John} | \text{Mary} | \text{Boston} | \text{UCB} | \text{PAJC} | \ldots
\]

\[
\text{Article} \rightarrow \text{the} | \text{a} | \text{an} | \ldots
\]

\[
\text{Preposition} \rightarrow \text{to} | \text{in} | \text{on} | \text{near} | \ldots
\]

\[
\text{Conjunction} \rightarrow \text{and} | \text{or} | \text{but} | \ldots
\]

\[
\text{Digit} \rightarrow 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
\]
Wumpus grammar

\[
S \rightarrow \ NP \ VP \quad \text{I + feel a breeze}
\]
\[
\quad | \ S \ Conjunction \ S \quad \text{I feel a breeze + and + I smell a wumpus}
\]

\[
NP \rightarrow \ Pronoun \quad \text{I}
\]
\[
\quad | \ Noun \quad \text{pits}
\]
\[
\quad | \ Article \ Noun \quad \text{the + wumpus}
\]
\[
\quad | \ Digit \ Digit \quad 3 \ 4
\]
\[
\quad | \ NP \ PP \quad \text{the wumpus + to the east}
\]
\[
\quad | \ NP \ RelClause \quad \text{the wumpus + that is smelly}
\]

\[
VP \rightarrow \ Verb \quad \text{stinks}
\]
\[
\quad | \ VP \ NP \quad \text{feel + a breeze}
\]
\[
\quad | \ VP \ Adjective \quad \text{is + smelly}
\]
\[
\quad | \ VP \ PP \quad \text{turn + to the east}
\]
\[
\quad | \ VP \ Adverb \quad \text{go + ahead}
\]

\[
PP \rightarrow \ Preposition \ NP \quad \text{to + the east}
\]

\[
\text{RelClause} \rightarrow \ that \ VP \quad \text{that + is smelly}
\]

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

Real grammars are 10–500 pages, insufficient even for “proper” English.
Parsing

A parse tree exhibits the grammatical structure of a sentence.

Syntax in NLP

Most view syntactic structure as an essential step towards meaning;

“Mary hit John” ≠ “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.”
Context-free parsing

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

Efficient algorithms (e.g., chart parsing, Ch. 23) are $O(n^3)$ for context-free grammars and run at several thousand words/sec for real grammars.

Context-free parsing $\equiv$ Boolean matrix multiplication (Lee, 2002)
$\rightarrow$ faster practical algorithms are unlikely.

Logical grammars

BNF notation for grammars makes it difficult:
- to add “side conditions” (number agreement, etc.)
- to connect syntax to semantics

Idea: express grammar rules as logic

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

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

$X \rightarrow Y | Z$ becomes $Y(s) \rightarrow X(s)$ and $Z(s) \rightarrow X(s)$

Here, $X(s)$ means string $s$ can be interpreted as an $X$. 
Logical grammars contd.

Now it’s easier to augment the rules:
\[ NP(s_1) \land Agent(Ref(s_1)) \land VP(s_2) \rightarrow NP(Append(s_1, ["who"], s_2)) \]
\[ NP(s_1) \land Number(s_1, n) \land VP(s_2) \land Number(s_2, n) \rightarrow S(Append(s_1, s_2)) \]

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

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

Extra arguments can be added to return/construct the parse tree and semantics.

Real language

Real human languages provide many problems for NLP:
- ambiguity
- anaphora
- indexicality
- vagueness
- noncompositionality
- discourse structure
- metonymy
- metaphor
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

Indexicality

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

I am over here

Why did you do that?
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

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:

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

basketball shoes    red book    small moon
baby shoes         red pen     large molecule
alligator shoes    red hair    mere child
designer shoes     red herring alleged murderer
brake shoes        real leather artificial grass