

# CS 561: Artificial Intelligence

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Lectures: MW 5:00-6:20pm, OHE 122 / DEN

Office hours: By appointment

Class page: <http://www-rcf.usc.edu/~macskass/CS561-Spring2010/>

This class will use <http://www.uscden.net/> and class webpage

- Up to date information
- Lecture notes
- Relevant dates, links, etc.

Course material:

[AIMA] Artificial Intelligence: A Modern Approach,  
by Stuart Russell and Peter Norvig. (2nd ed)

# Communication and Language

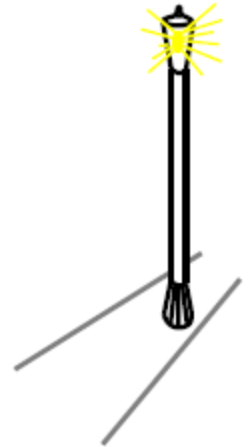
## [AIMA Ch 22]

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- Communication
- Grammar
- Syntactic analysis
- Problems

# Communication

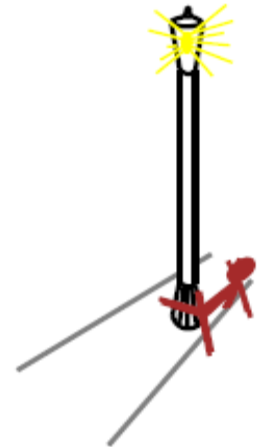
- “Classical” view (pre-1953):
  - language consists of sentences that are true/false (cf. logic)
- “Modern” view (post-1953):
  - language is a form of action
- Wittgenstein (1953) **Philosophical Investigations**
- Austin (1962) **How to Do Things with Words**
- Searle (1969) **Speech Acts**
- Why?



# Communication

- “Classical” view (pre-1953):
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- Wittgenstein (1953) **Philosophical Investigations**
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- Searle (1969) **Speech Acts**
- 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  $W_0$  in context  $C_0$
- **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?
  - Insincerity (S doesn't believe  $P$ )
  - Speech wreck ignition failure
  - Ambiguous utterance
  - Differing understanding of current context ( $C \neq C_0$ )

# 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 | a | an | ...

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

# Grammar types

Regular: nonterminal  $\rightarrow$  terminal[nonterminal]

$$S \rightarrow aS$$

$$S \rightarrow \Lambda$$

Context-free: nonterminal  $\rightarrow$  anything

$$S \rightarrow aSb$$

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 → 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
  
- Divided into **closed** and **open** classes

# Wumpus lexicon

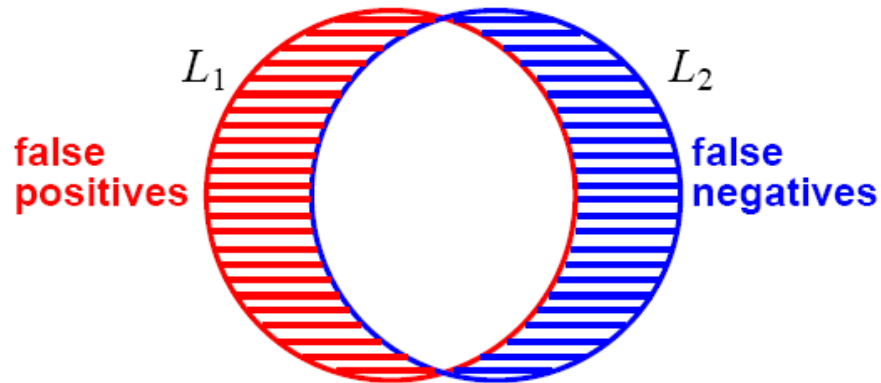
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- Adjective → right | left | east | south | back | smelly | ...
- Adverb → here | there | nearby | ahead  
| right | left | east | south | back | ...
- Pronoun → me | you | I | it | S/HE | Y'ALL | ...
- Name → John | Mary | Boston | UCB | PAJC | ...
- Article → the | a | an | ...
- Preposition → to | in | on | near | ...
- Conjunction → and | or | but | ...
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- 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

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- Exhibit the grammatical structure of a sentence

I

shoot

the

wumpus

# Parse trees

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- Exhibit the grammatical structure of a sentence

**Pronoun**

|

**I**

**Verb**

|

**shoot**

**Article**

|

**the**

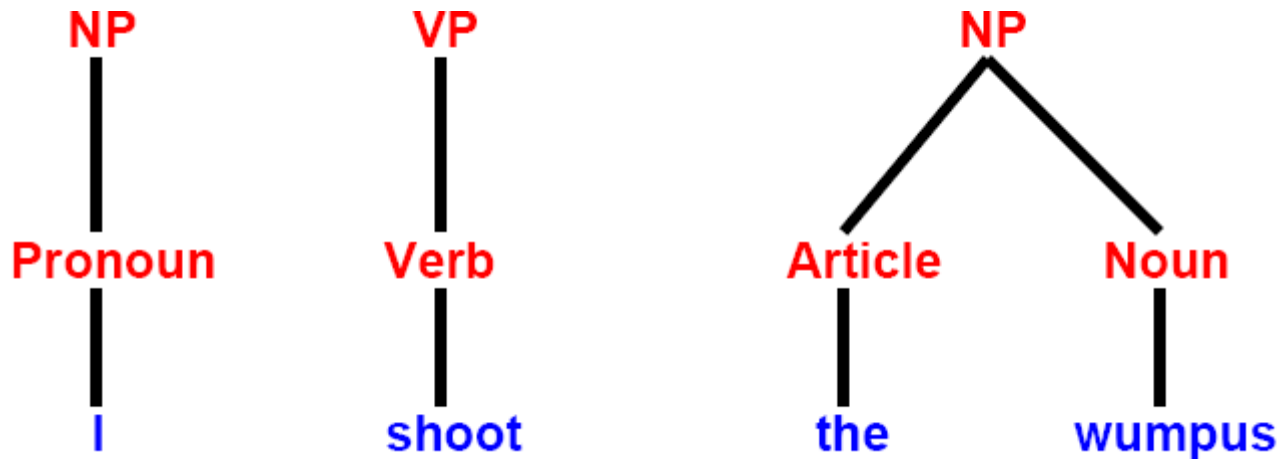
**Noun**

|

**wumpus**

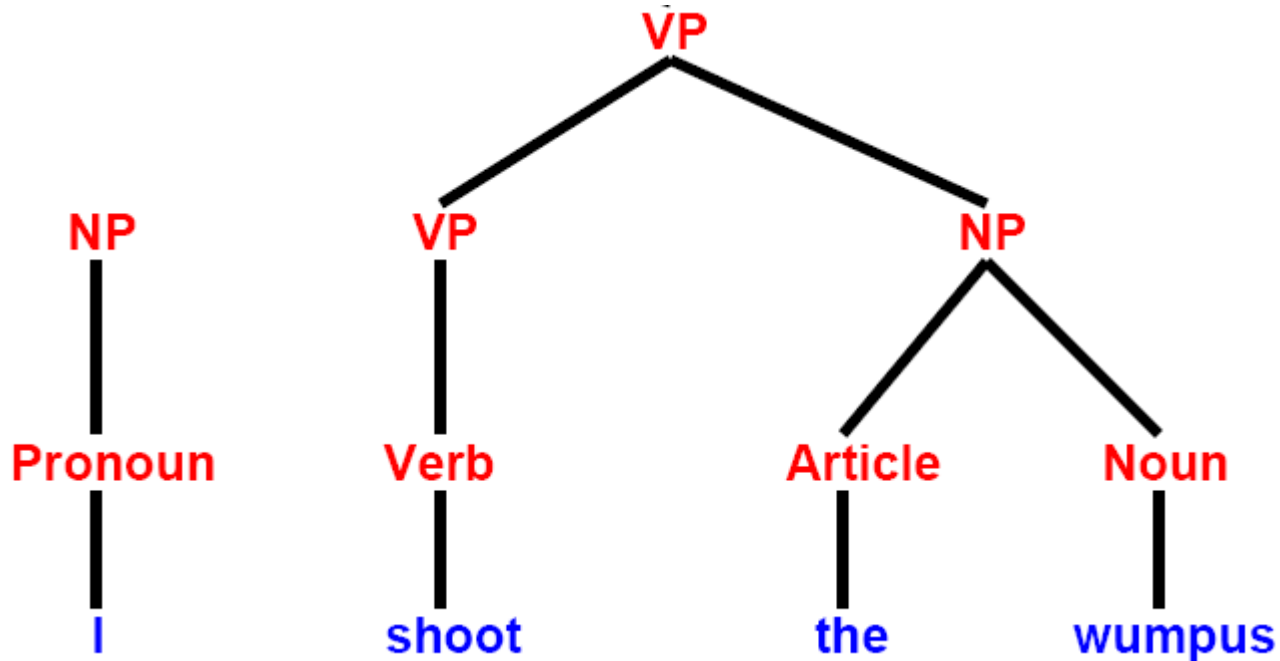
# Parse trees

- Exhibit the grammatical structure of a sentence



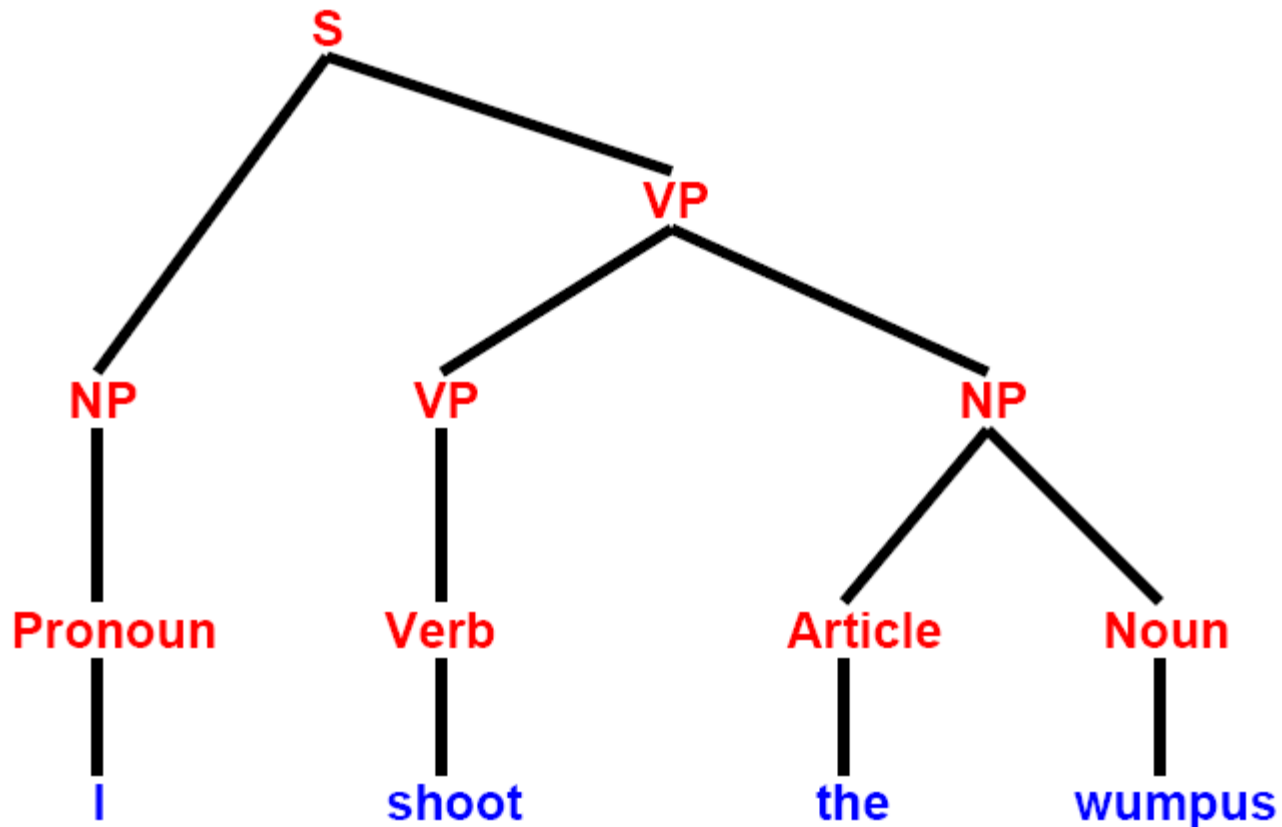
# Parse trees

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# Parse trees

- Exhibit the grammatical structure of a sentence



# 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.”

“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

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- 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 Boolean matrix multiplication (Lee, 2002)
  - ⇒ 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  $Y(s_1) \wedge Z(s_2) \Rightarrow X(\text{Append}(s_1; s_2))$
  - $X \rightarrow \text{word}$  becomes  $X([\text{“word”}])$
  - $X \rightarrow Y \mid Z$  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 cont'd

Now it's easy to augment the rules

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

Parsing is reduced to logical inference:

$$\text{Ask}(\text{KB}, \text{S}([\text{"I"} \text{"am"} \text{"a"} \text{"wumpus"}]))$$

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

Generation simply requires a query with uninstantiated variables:

$$\text{Ask}(\text{KB}, \text{S}(x))$$

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

$$\text{Ask}(\text{KB}, \text{S}(x, \text{At}(\text{Robot}, [1, 1])))$$

# Real language

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Real human languages provide many problems for NLP:

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

# Ambiguity

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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
  - a friend
- Ambiguity can be lexical (polysemy), syntactic, semantic, referential

# Anaphora

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- 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

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- Indexical sentences refer to utterance situation (place, time, S/H, etc.)
- **I am over here**
- Why did **you** do **that**?

# Metonymy

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- 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

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- “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

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- 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
- artificial grass