# Natural Language Understanding

- We want to communicate with computers using natural language (spoken and written).
  - unstructured natural language — allow any statements, but make mistakes or failure.
  - controlled natural language — only allow unambiguous statements that can be interpreted (e.g., in supermarkets or for doctors).
- There is a vast amount of information in natural language.
- Understanding language to extract information or answering questions is more difficult than getting extracting gestalt properties such as topic, or choosing a help page.
- Many of the problems of AI are explicit in natural language understanding. "AI complete".

# Syntax, Semantics, Pragmatics

- Syntax describes the form of language (using a grammar).
- Semantics provides the meaning of language.
- Pragmatics explains the purpose or the use of language (how utterances relate to the world).

Examples:

- *This lecture is about natural language.*
- *The green frogs sleep soundly.*
- *Colorless green ideas sleep furiously.*
- *Furiously sleep ideas green colorless.*

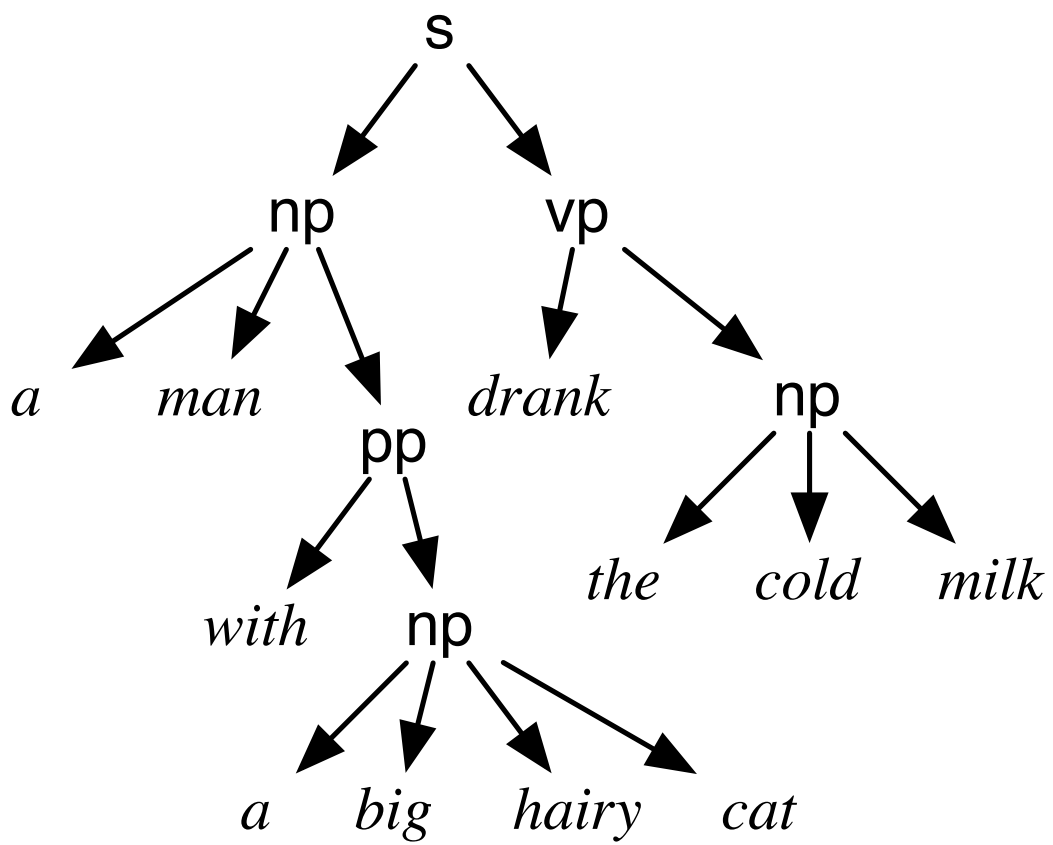
# Beyond N-grams

- *A man with a big hairy cat drank the cold milk.*
- Who or what drank the milk?

# Beyond N-grams

- *A man with a big hairy cat drank the cold milk.*
- Who or what drank the milk?

Simple syntax diagram:



# Context-free grammar

- A terminal symbol is a word (perhaps including punctuation).
- A non-terminal symbol can be rewritten as a sequence of terminal and non-terminal symbols, e.g.,

$$sentence \longmapsto noun\_phrase, verb\_phrase$$

$$verb\_phrase \longmapsto verb, noun\_phrase$$

$$verb \longmapsto [drank]$$

- Can be written as a logic program, where a sentence is a sequence of words:

$$sentence(S) \leftarrow noun\_phrase(N), verb\_phrase(V), append(N, V, S).$$

To say word "drank" is a verb:

$$verb([drank]).$$

# Difference Lists

- Non-terminal symbol $s$ becomes a predicate with two arguments, $s(T_1, T_2)$, meaning:
  - $T_2$ is an ending of the list $T_1$
  - all of the words in $T_1$ before $T_2$ form a sequence of words of the category $s$.
- Lists $T_1$ and $T_2$ together form a difference list.
- "the student" is a noun phrase:

$$noun\_phrase([the, student, passed, the, course], [passed, the, course])$$

# Difference Lists

- Non-terminal symbol $s$ becomes a predicate with two arguments, $s(T_1, T_2)$, meaning:
  - $T_2$ is an ending of the list $T_1$
  - all of the words in $T_1$ before $T_2$ form a sequence of words of the category $s$.
- Lists $T_1$ and $T_2$ together form a difference list.
- "the student" is a noun phrase:

$$noun\_phrase([the, student, passed, the, course], [passed, the, course])$$

- The word "drank" is a verb:

$$verb([drank|W], W).$$

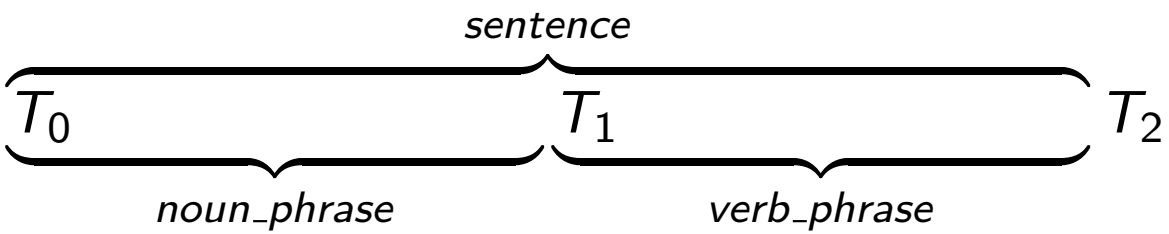
# Definite clause grammar

The grammar rule

$$sentence \longmapsto noun\_phrase, verb\_phrase$$

means that there is a sentence between $T_0$ and $T_2$ if there is a noun phrase between $T_0$ and $T_1$ and a verb phrase between $T_1$ and $T_2$:

$$sentence(T_0, T_2) \leftarrow$$
$$noun\_phrase(T_0, T_1) \wedge$$
$$verb\_phrase(T_1, T_2).$$



# Definite clause grammar rules

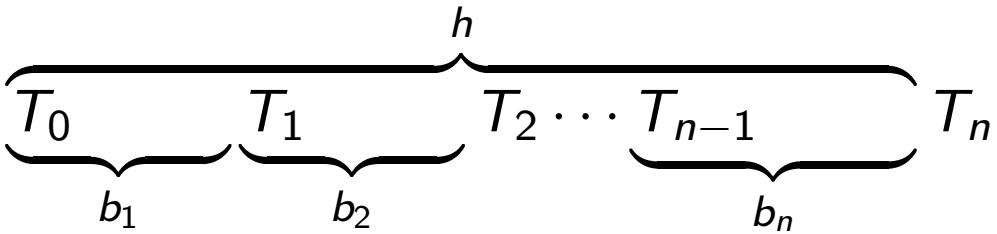
The rewriting rule

$$h \longmapsto b_1, b_2, \ldots, b_n$$

says that $h$ is $b_1$ then $b_2$, ..., then $b_n$:

$$h(T_0, T_n) \leftarrow$$
$$b_1(T_0, T_1) \wedge$$
$$b_2(T_1, T_2) \wedge$$
$$\vdots$$
$$b_n(T_{n-1}, T_n).$$

using the interpretation



# Terminal Symbols

Non-terminal $h$ gets mapped to the terminal symbols, $t_1, ..., t_n$:

$$h([t_1, \cdots, t_n | T], T)$$

using the interpretation

$$\overbrace{t_1, \cdots, t_n}^{h} T$$

Thus, $h(T_1, T_2)$ is true if $T_1 = [t_1, ..., t_n | T_2]$.

# Complete Context Free Grammar Example

see
`http://artint.info/code/Prolog/ch12/cfg_simple.pl`

What will the following query return?

$noun\_phrase([the, student, passed, the, course, with, a, computer], R).$

# Complete Context Free Grammar Example

see
`http://artint.info/code/Prolog/ch12/cfg_simple.pl`

What will the following query return?

$noun\_phrase([the, student, passed, the, course, with, a, computer], R).$

How many answers does the following query have?

$sentence([the, student, passed, the, course, with, a, computer], R).$

# Augmenting the Grammar

Two mechanisms can make the grammar more expressive:

- extra arguments to the non-terminal symbols
- arbitrary conditions on the rules.

We have a Turing-complete programming language at our disposal!

# Building Structures for Non-terminals

Add an extra argument representing a parse tree:

$$sentence(T_0, T_2, s(NP, VP)) \leftarrow$$
$$noun\_phrase(T_0, T_1, NP) \wedge$$
$$verb\_phrase(T_1, T_2, VP).$$

# Enforcing Constraints

Add an argument representing the number (singular or plural), as well as the parse tree:

$$sentence(T_0, T_2, Num, s(NP, VP)) \leftarrow$$
$$noun\_phrase(T_0, T_1, Num, NP) \wedge$$
$$verb\_phrase(T_1, T_2, Num, VP).$$

The parse tree can return the determiner (definite or indefinite), number, modifiers (adjectives) and any prepositional phrase:

$$noun\_phrase(T, T, Num, no\_np).$$
$$noun\_phrase(T_0, T_4, Num, np(Det, Num, Mods, Noun, PP)) \leftarrow$$
$$det(T_0, T_1, Num, Det) \wedge$$
$$modifiers(T_1, T_2, Mods) \wedge$$
$$noun(T_2, T_3, Num, Noun) \wedge$$
$$pp(T_3, T_4, PP).$$

# Complete Example

see
`http://artint.info/code/Prolog/ch12/nl_numbera.pl`

# Question-answering

- How can we get from natural language to a query or to logical statements?
- Goal: map natural language to a query that can be asked of a knowledge base.
- Add arguments representing the individual and the relations about that individual. E.g.,

$$noun\_phrase(T_0, T_1, O, C_0, C_1)$$

means

  - $T_0 - T_1$ is a difference list forming a noun phrase.
  - The noun phrase refers to the individual $O$.
  - $C_0$ is list of previous relations.
  - $C_1$ is $C_0$ together with the relations on individual $O$ given by the noun phrase.

# Example natural language to query

see
`http://artint.info/code/Prolog/ch12/nl_interface.pl`

# Context and world knowledge

*The student took many courses. Two computer science courses and one mathematics course were particularly difficult.* The mathematics course. . .

# Context and world knowledge

*The student took many courses. Two computer science courses and one mathematics course were particularly difficult.* The mathematics course. . .

*Who was the captain of the Titanic?*
*Was she tall?*