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?

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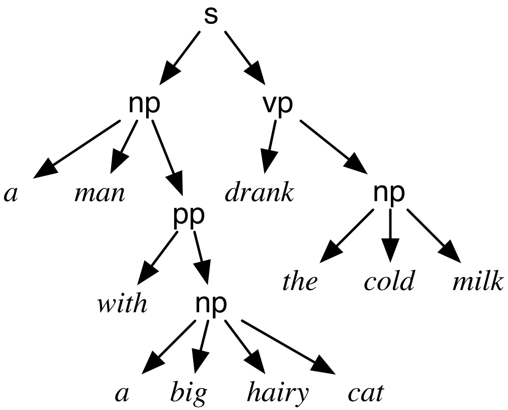
Simple syntax diagram:



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:

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

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- "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:

$$\begin{aligned} & sentence(T_0, T_2) \leftarrow \\ & \quad noun\_phrase(T_0, T_1) \land \\ & \quad verb\_phrase(T_1, T_2). \end{aligned}$$

$$\overbrace{\underbrace{T_0 \qquad\qquad\qquad}_{noun\_phrase} \underbrace{T_1 \qquad\qquad\qquad}_{verb\_phrase}}^{sentence} T_2$$

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:

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

using the interpretation

$$\overbrace{\underbrace{T_0 \qquad}_{b_1} \underbrace{T_1 \qquad}_{b_2} T_2 \cdots \underbrace{T_{n-1} \qquad}_{b_n}}^{h} T_n$$

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?

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

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What will the following query return?

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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:

$$
\begin{aligned}
& \mathit{sentence}(T_0, T_2, s(NP, VP)) \leftarrow \\
& \qquad \mathit{noun\_phrase}(T_0, T_1, NP) \wedge \\
& \qquad \mathit{verb\_phrase}(T_1, T_2, VP).
\end{aligned}
$$

Enforcing Constraints

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

$$
\begin{aligned}
& sentence(T_0, T_2, Num, s(NP, VP)) \leftarrow \\
& \qquad noun\_phrase(T_0, T_1, Num, NP) \wedge \\
& \qquad verb\_phrase(T_1, T_2, Num, VP).
\end{aligned}
$$

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

$$
\begin{aligned}
& noun\_phrase(T, T, Num, no\_np). \\
& noun\_phrase(T_0, T_4, Num, np(Det, Num, Mods, Noun, PP)) \leftarrow \\
& \qquad det(T_0, T_1, Num, Det) \wedge \\
& \qquad modifiers(T_1, T_2, Mods) \wedge \\
& \qquad noun(T_2, T_3, Num, Noun) \wedge \\
& \qquad pp(T_3, T_4, PP).
\end{aligned}
$$

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...

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