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- Understanding language to answer questions is more difficult than extracting gestalt properties such as topic, or choosing a web page.
- Many of the problems of AI are explicit in natural language understanding. “AI complete”.

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Examples:

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- *The green frogs sleep soundly.*
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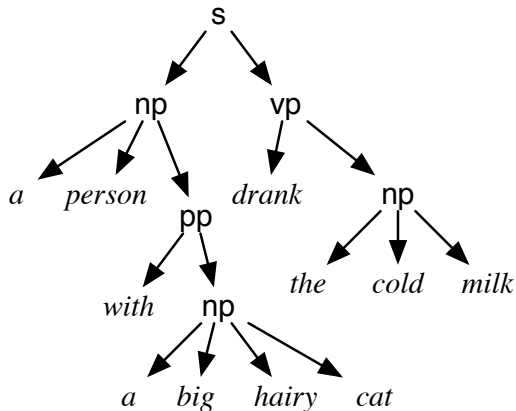
Beyond N-grams

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Simple parse tree:



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sentence \mapsto *noun_phrase, verb_phrase*

verb_phrase \mapsto *verb, noun_phrase*

verb \mapsto [“*drank*”]

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$sentence \mapsto noun_phrase, verb_phrase$

$verb_phrase \mapsto verb, noun_phrase$

$verb \mapsto ["drank"]$

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

$sentence(S) \leftarrow noun_phrase(N), verb_phrase(V), append(N, V, S).$

$verb_phrase(P) \leftarrow verb(V), noun_phrase(N), append(V, N, P).$

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
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- “the student” is a noun phrase:

noun_phrase([" the", " student", " passed", " the", " course"],
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- “the student” is a noun phrase:

*noun_phrase(["the", "student", "passed", "the", "course"],
["passed", "the", "course"])*

- The words “drank” and “passed” are verbs:

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

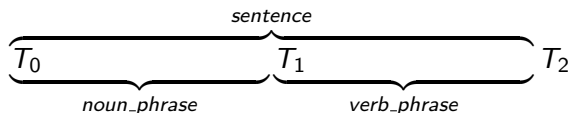
verb(["passed" | W], W).

Definite clause grammar

The grammar rule

$$\textit{sentence} \mapsto \textit{noun_phrase}, \textit{verb_phrase}$$

represented as: 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 :

$$\begin{aligned} \textit{sentence}(T_0, T_2) \leftarrow \\ \textit{noun_phrase}(T_0, T_1) \wedge \\ \textit{verb_phrase}(T_1, T_2). \end{aligned}$$


Definite clause grammar rules

The rewriting rule

$$h \mapsto b_1, b_2, \dots, b_n$$

says that h is b_1 followed by b_2, \dots , followed by b_n :

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

using the interpretation

$$\underbrace{\underbrace{T_0}_{b_1} \underbrace{T_1}_{b_2} T_2 \cdots T_{n-1}}_h T_n$$

Terminal Symbols

Non-terminal h gets mapped to the terminal symbols, t_1, \dots, t_n :

$$h([t_1, \dots, t_n \mid T], T)$$

using the interpretation

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

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

Context Free Grammar Example

see

https:

```
//artint.info/3e/resources/ch15/geography_CFG.pl
```

(also load https:

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What will the following query return?

```
noun_phrase(["a", "country", "that", "borders", "Chile"], L3).
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What will the following query return?

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```

How many answers does the following query have?

```
noun_phrase(["a", "Spanish", "speaking", "country",  
            "that", "borders", "Chile"], L3).
```

Example

```
% a noun phrase is a determiner followed by adjectives
% followed by a noun followed by a prepositional phrase.
noun_phrase(L0,L4) :-
    det(L0,L1),
    adjectives(L1,L2),
    noun(L2,L3),
    pp(L3,L4).

% dictionary for determiners
det(L,L).
det(["a"|L],L).
det(["the"|L],L).

% adjectives is a sequence of adjectives
adjectives(L,L).
adjectives(L0,L2) :-
    adj(L0,L1),
    adjectives(L1,L2).
```

Clicker Question

If the query for the grammar rule

```
noun_phrase([the, cat, on, the, mat, sat, on, the, hat], R).
```

returns with substitution $R=[\text{sat, on, the, hat}]$

What is the noun-phrase it found?

- A the cat
- B the mat
- C the cat on the mat
- D sat on the hat
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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!

- How can we get from natural language directly to the answer?
- Goal: map natural language to a query that is asked of a knowledge base.
- Add arguments representing the individual

noun_phrase(T_0, T_1, O)

means

- ▶ $T_0 - T_1$ is a difference list forming a noun phrase.
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- Can be implemented by the parser directly calling the knowledge base.

Example natural language to query

see

https://artint.info/3e/resources/ch15/geography_QA.pl

Noun Phrases

```
% A noun phrase is a determiner followed by adjectives followed  
% by a noun followed by an optional modifying phrase.  
% They all refer to the same individual.  
noun_phrase(L0, L4, Ind) :-  
    det(L0, L1, Ind),  
    adjectives(L1, L2, Ind),  
    noun(L2, L3, Ind),  
    omp(L3, L4, Ind).
```

Adjectives provide properties

```
% adj(T0,T1,Entity) is true if T0-T1
% is an adjective that is true of Entity
adj(["large" | L], L, Ind) :- large(Ind).
adj([LangName, "speaking" | L], L, Ind) :-
    language(Ind, Lang), name(Lang, LangName).
```

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% adjectives(T0,T1,Entity) is true if
% T0-T1 is a sequence of adjectives that true of Entity
adjectives(T0,T2,Entity) :-
    adj(T0,T1,Entity),
    adjectives(T1,T2,Entity).
adjectives(T,T,_).
```

Verbs and prepositions provide relations

reln(*T0*, *T1*, *Subject*, *Object*)

- *T0* – *T1* is a verb or preposition that provides
- a relation that true between *Subject* and *Object*

```
reln(["borders" | L], L, Sub, Obj) :- borders(Sub, Obj).
reln(["bordering" | L], L, Sub, Obj) :- borders(Sub, Obj).
reln(["next", "to" | L], L, Sub, Obj) :- borders(Sub, Obj).
reln(["the", "capital", "of" | L], L, Sub, Obj) :-
    capital(Obj, Sub).
reln(["the", "name", "of" | L], L, Sub, Obj) :-
    name(Obj, Sub).
```

Verbs and prepositions provide relations

```
% A modifying phrase / relative clause is either  
% a relation (verb or preposition)  
% followed by a noun_phrase or  
% 'that' followed by a relation then a noun_phrase
```

```
mp(L0, L2, Subject) :-  
    reln(L0, L1, Subject, Object),  
    aphrase(L1, L2, Object).
```

```
mp(["that" | L0], L2, Subject) :-  
    reln(L0, L1, Subject, Object),  
    aphrase(L1, L2, Object).
```

```
% An optional modifying phrase is either a modifying phrase
```

```
omp(L0,L1,E) :-  
    mp(L0,L1,E).  
omp(L, L, _).
```

Real-world queries

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- And other tricky and subtle aspects of English?
 - program them
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- 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.

Building a list of constraints on the entity (geography_QA_query.pl)

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 - ▶ *L4* is an ending of *L0*

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- $C0$ is a list such that $C4$ is an ending of $C0$ and $C0 - C4$ contains the constraints imposed by the noun phrase

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```
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    noun(L2,L3,Entity,C2,C3),  
    mp(L3,L4,Entity,C3,C4).
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