EDAN20
Language Technology
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Chapter 9: Phrase-Structure Grammars in Prolog

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Constituents

The waiter brought the meal
The waiter brought the meal to the table
The waiter brought the meal of the day

Le serveur a apporté le plat
Le serveur a apporté le plat sur la table
*Le serveur a apporté le plat du jour*

Der Ober hat die Speise gebracht
Der Ober hat die Speise zum Tisch gebracht
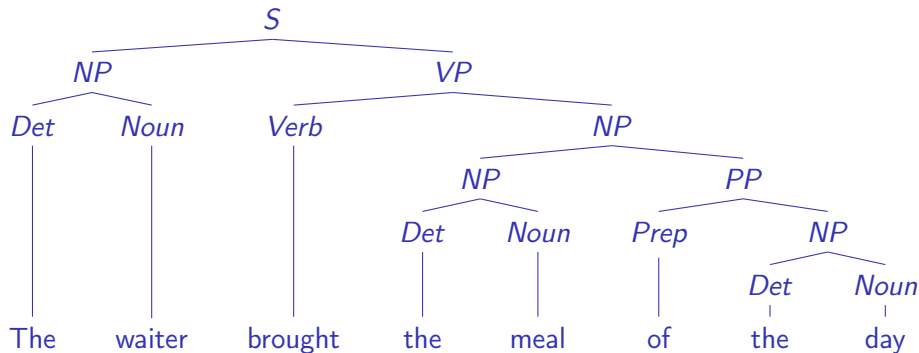*Der Ober hat die Speise des Tages gebracht*

Representing Constituents

The waiter [brought [the meal [to [the table]]]]

The waiter [brought [the meal [of [the day]]]]

Syntactic Trees

```
                              S
            NP                              VP
   Det          Noun      Verb        NP                    PP
                                  Det      Noun      Prep           NP
                                                             Det        Noun

   The         waiter    brought   the      meal       to     the       table
```
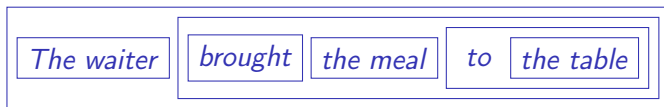
Syntactic Trees

DCG Rules

Nonterminal symbols

```
s --> np, vp, {possible_prolog_preds}.
np --> det, noun.
np --> np, pp.
vp --> verb, np.
vp --> verb, np, pp.
pp --> prep, np.
```

DCG Rules

Terminal symbols

```
det --> [the].
det --> [a].
noun --> [waiter].
noun --> [meal].
noun --> [table].
noun --> [day].
verb --> [brought].
prep --> [to]. % or prep --> [to] ; [of].
prep --> [of].
```

Prolog Search Mechanism

Proves that a sentence is correct

```
?-s([the, waiter, brought, the, meal, to, the, table], []).
yes.
?- s([the, waiter, brought, the, meal, of, the, day], []).
yes.
```

Generates all the solutions

```
?-s(L, []).
L=[the, waiter, brought, the, waiter];
L=[the, waiter, brought, the, meal], etc.
```

Conversion in Prolog

```
s --> np, vp.
```

is translated into

```
s(L1, L) :- np(L1, L2), vp(L2, L).
```

Alternative translation:

```
s(L) :- np(L1), vp(L2), append(L1, L2, L).
% not used
```
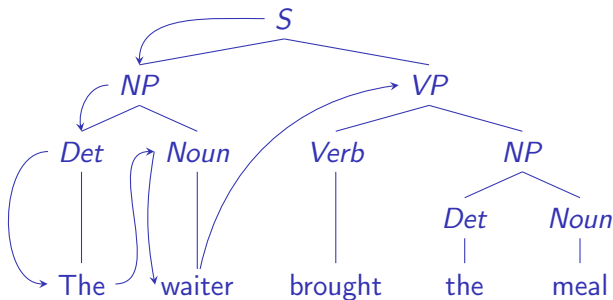
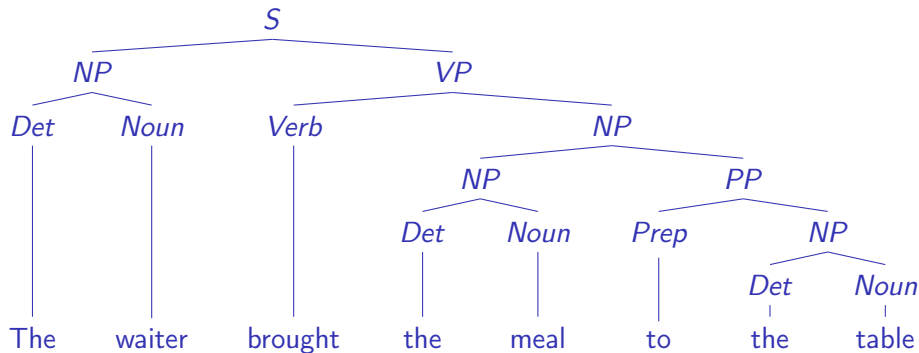Terminal vocabulary:

```
det --> [the]
```

is translated into

```
det(L1, L) :- c(L1, the, L).
```

The Prolog Search

Ambiguity

Left-Recursive Rules

```
np --> np, pp.
```

The sentence:

  * The brings the meal to the table

traps the parser in an infinite recursion.

```
npx --> det, noun.
np --> npx.
np --> npx, pp.
```

Variables

```
np --> det, noun.
det --> [le] ; [la].
noun --> [garçon] ; [fille].
```

With variables:

```
np(Gender) --> det(Gender), noun(Gender).
det(m) --> [le]. det(f) --> [la].
noun(m) --> [garçon]. noun(f) --> [fille].
```

Getting the Syntactic Structure

```prolog
s(s(NP, VP)) --> np(NP), vp(VP).
np(np(D, N)) --> det(D), noun(N).
vp(vp(V, NP)) -->  verb(V), np(NP).

det(det(the)) --> [the].
det(det(a)) --> [a].
noun(noun(waiter)) --> [waiter].
noun(noun(meal)) --> [meal].
noun(noun(table)) --> [table].
noun(noun(tray)) --> [tray].
verb(verb(bring)) --> [brought].
```

Getting the Syntactic Structure

```
?-s(S, L, []).
```

Yields:

```
S = s(np(det(the), noun(waiter)),
      vp(verb(bring), np(det(the), noun(waiter)))),
L = [the, waiter, brought, the, waiter] ;
```

Semantic Parsing

Converts sentences to first-order logic or predicate-argument structures
Example:

> *Mr. Schmidt called Bill*
                                                                        to

```
called('Mr. Schmidt', 'Bill').
```

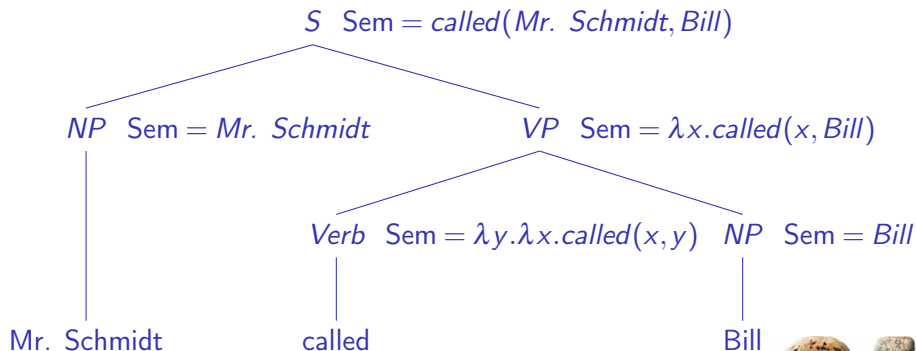Assumption: We can compose sentence fragments (phrases) into logical
forms while parsing
This corresponds to the compositionality principle

Semantic Composition

Semantic composition can be viewed as a parse tree annotation

S Sem $=$ *called*(*Mr. Schmidt*, *Bill*)

NP Sem $=$ *Mr. Schmidt*

VP Sem $= \lambda x.called(x, Bill)$

$Verb$ Sem $= \lambda y.\lambda x.called(x, y)$ NP Sem $= Bill$

Mr. Schmidt

called

Bill

Getting the Semantic Structure

<div align="center">

Bill rushed   `rushed('Bill').`

</div>

The verb *rushed* is represented as a lambda expression: $\lambda x.rushed(x)$
Beta reduction: $\lambda x.rushed(x)(Bill) = rushed(Bill)$
Lambda expressions are represented in Prolog as `X^rushed(X)`.

<div align="center">

The patron ordered a meal	`ordered(patron, meal)`
ordered a meal	`X^ordered(X, meal)`
ordered	`Y^X^ordered(X, Y)`

</div>

Getting the Semantic Structure

```
s(Semantics) --> np(Subject), vp(Subject^Semantics).
np(X) --> det, noun(X).
vp(Subject^Predicate) --> verb(Subject^Predicate).
vp(Subject^Predicate) -->
verb(Object^Subject^Predicate), np(Object).
noun(waiter) --> [waiter].
noun(patron) --> [patron].
noun(meal) --> [meal]. det --> [a].
det --> [the].

verb(X^rushed(X)) --> [rushed].
verb(Y^X^ordered(X, Y)) --> [ordered].
verb(Y^X^brought(X, Y)) --> [brought].

?- s(Semantics, [the, patron, ordered, a, meal], []).
Semantics = ordered(patron, meal)
```

An Example from Persona

I'd like to hear something composed by Mozart.

```
like1 (+Modal +Past +Futr)
  Dsub: i1 (+Pers1 +Sing)
  Dobj: hear1
        Dsub: i1
          Dobj: something1 (+Indef +Exis +Pers3 +Sing)
          Prop: compose1
            Dsub: mozart1 (+Sing)
            Dobj: something1
```

Simpler Sentences

I would like something
I would like some Mozart

```
s(Sem) --> np(Sub), vp(Sub^Sem).

npx(SemNP) --> pro(SemNP).
npx(SemNP) --> noun(SemNP).
npx(SemNP) --> det, noun(SemNP).

np(SemNP) --> npx(SemNP).

noun(SemNP) --> proper_noun(SemNP).
```

The Verb Phrase

```
verb_group(SemVG) --> verb(SemVG).
verb_group(SemVG) --> aux(SemAux), verb(SemVG).

vp(SemVP) --> verb_group(SemVP).
vp(SemVP) --> verb_group(Obj^SemVP), np(Obj).

verb(Obj^Sub^like(Sub, Obj)) --> [like].
verb(Obj^Sub^hear(Sub, Obj)) --> [hear].
```

The Vocabulary

```
aux(would) --> [would].
pro('I') --> ['I'].
pro(something) --> [something].
proper_noun('Mozart') --> ['Mozart'].
det --> [some].

?- s(Sem, ['I', would, like, some, 'Mozart'], []).
Sem = like('I', 'Mozart')
```

More Complex Sentences

I would like to hear something
I would like to hear some Mozart

```
vp_inf(SemVP) --> [to], vp(SemVP).

vp(SemVP) --> verb_group(Obj^SemVP), vp_inf(Obj).

?- s(Sem, ['I', would, like, to, hear, some, 'Mozart'], []).
Sem = like('I', X^hear(X, 'Mozart'))
```

And Finally

```prolog
np(SemNP) --> npx(SemVP^SemNP), vp_passive(SemVP).

vp_passive(SemVP) --> verb(Sub^SemVP) , [by], np(Sub).

verb(Sub^Obj^compose(Sub, Obj)) --> [composed].

pro(Modifier^something(Modifier)) --> [something].

?- s(Sem, ['I', would, like, to, hear, something,
  composed, by, 'Mozart'], []).
Sem = like('I', X^hear(X, Y^something(compose('Mozart', Y))))
```