

# Language Technology

<http://cs.lth.se/edan20/>  
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*

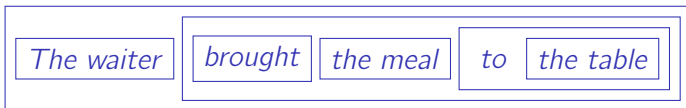
*Der Ober hat die Speise gebracht*

*Der Ober hat die Speise zum Tisch gebracht*

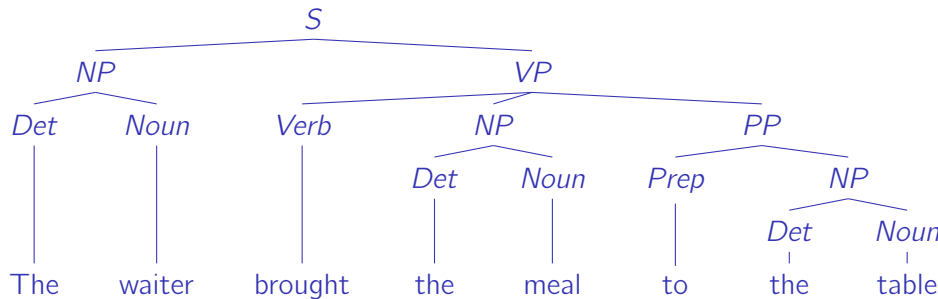
*Der Ober hat die Speise des Tages gebracht*



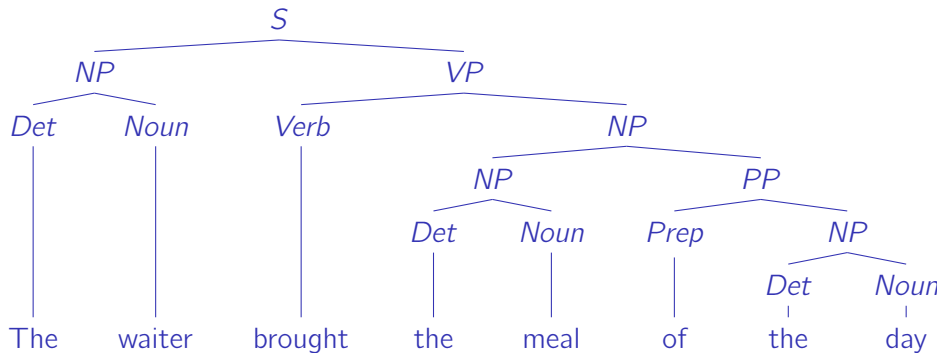
# Representing Constituents



# Syntactic Trees



# 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:

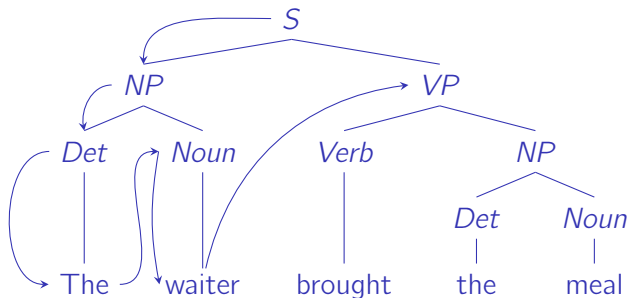
`det --> [the]`

is translated into

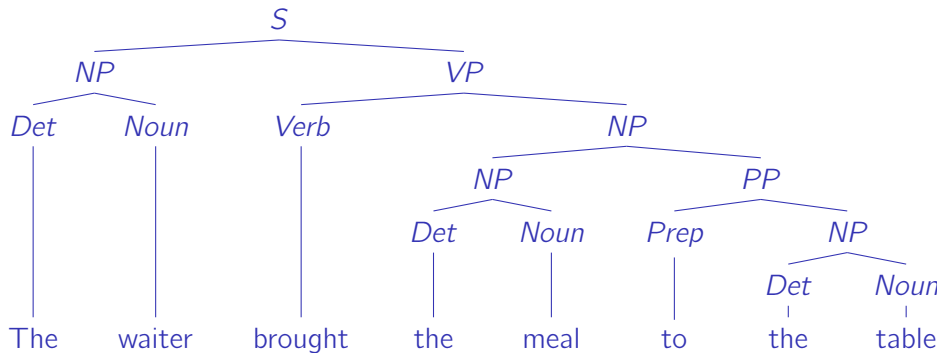
```
det(L1, L) :- c(L1, the, L).
```



# The Prolog Search



# Ambiguity



# Left-Recursive Rules

$np \rightarrow np, pp.$

The sentence:

\* *The brings the meal to the table*

traps the parser in an infinite recursion.

$npx \rightarrow det, noun.$

$np \rightarrow npx.$

$np \rightarrow npx, pp.$



# 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

```
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

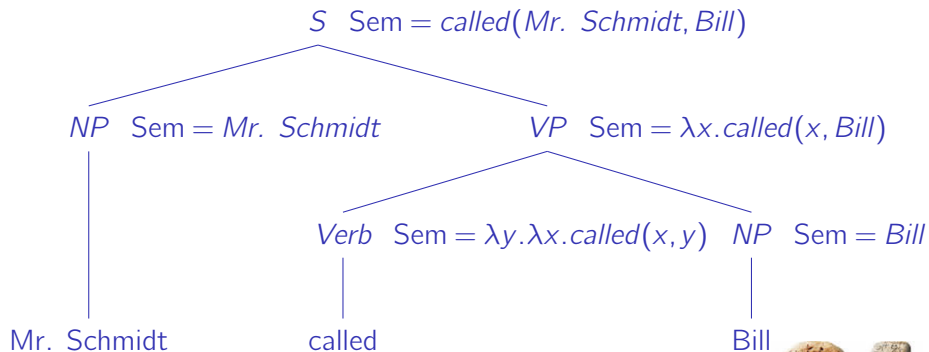
This corresponds to the compositionality principle





# Semantic Composition

Semantic composition can be viewed as a parse tree annotation



# Getting the Semantic Structure

*Bill rushed*    `rushed('Bill').`

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  $X^rushed(X)$ .

*The patron ordered a meal*    `ordered(patron, meal)`

*ordered a meal*    `X^ordered(X, meal)`

*ordered*    `Y^X^ordered(X, Y)`



# 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)
```



# Persona System Architecture

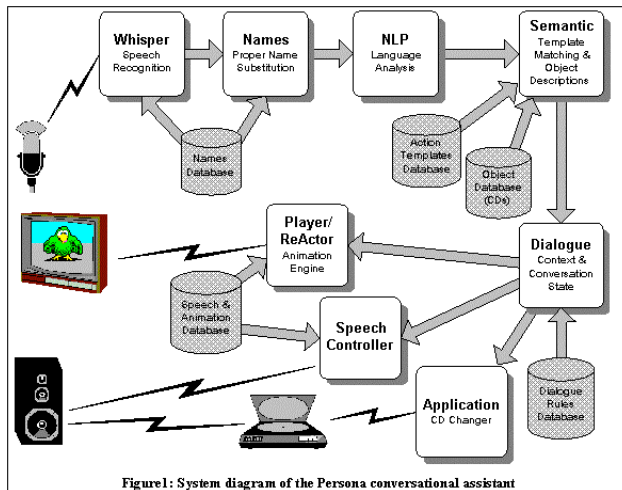


Figure 1: System diagram of the Persona conversational assistant

Source: <http://research.microsoft.com/research/pubs/view.aspx?pubid=439>

[//research.microsoft.com/research/pubs/view.aspx?pubid=439](http://research.microsoft.com/research/pubs/view.aspx?pubid=439)

# Semantic Analysis

A command like:

*Play before you accuse me by Clapton*

is transformed into:

*Play track1 by artist1.*

The procedure is:

- 1 Produce a logical form from the parse tree:  
verb(subject, object)  
*I would like to hear something* → like(i, hear(i, something));
- 2 The logical form is transformed into the task graph:  
like(i, hear(i, something)) →  
verbPlay(you, objectTrack)  
*You play (verbPlay) a track (objectTrack)*



# 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*

$s(\text{Sem}) \rightarrow np(\text{Sub}), vp(\text{Sub}^{\wedge}\text{Sem}).$

$np_x(\text{SemNP}) \rightarrow pro(\text{SemNP}).$

$np_x(\text{SemNP}) \rightarrow noun(\text{SemNP}).$

$np_x(\text{SemNP}) \rightarrow det, noun(\text{SemNP}).$

$np(\text{SemNP}) \rightarrow np_x(\text{SemNP}).$

$noun(\text{SemNP}) \rightarrow proper\_noun(\text{SemNP}).$



# 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

```
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))))
```

