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

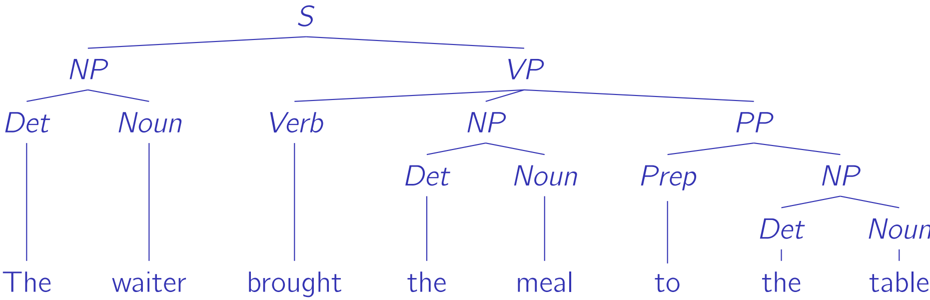
Der Ober hat die Speise gebracht
Der Ober hat die Speise zum Tisch gebracht
Der Ober hat die Speise des Tages gebracht

Representing Constituents

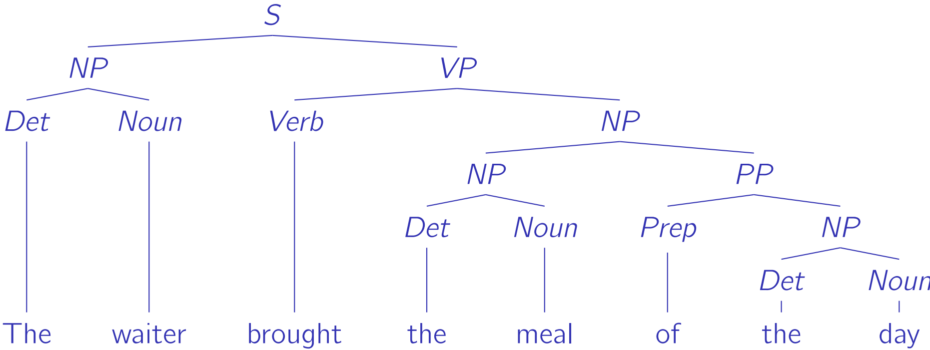
The waiter *brought* *the meal* *to* *the table*

The waiter *brought* *the meal* *of* *the day*

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
```

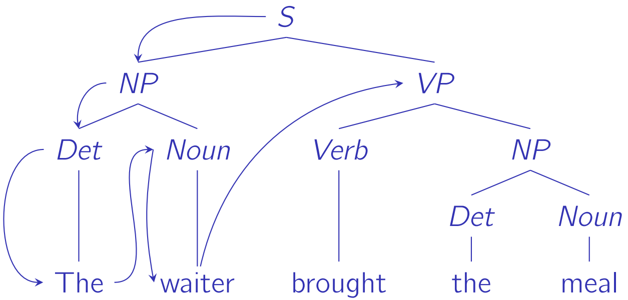
Terminal vocabulary:

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

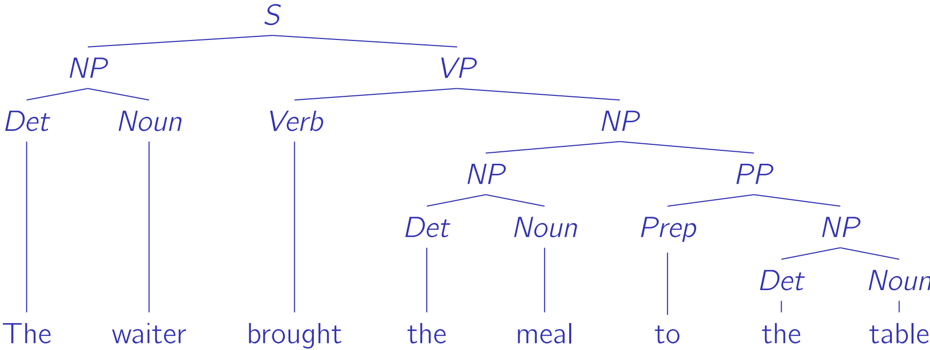
is translated into

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

The Prolog Search



Ambiguity


S
NP
VP
Det
Noun
Verb
NP
NP
PP
Det
Noun
Prep
NP
Det
Noun
The
waiter
brought
the
meal
to
the
table

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

```
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 $= Mr.\ Schmidt$
  - Mr. Schmidt
- VP Sem $= \lambda x.called(x, Bill)$
  - $Verb$ Sem $= \lambda y.\lambda x.called(x, y)$
    - called
  - NP Sem $= Bill$
    - Bill

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

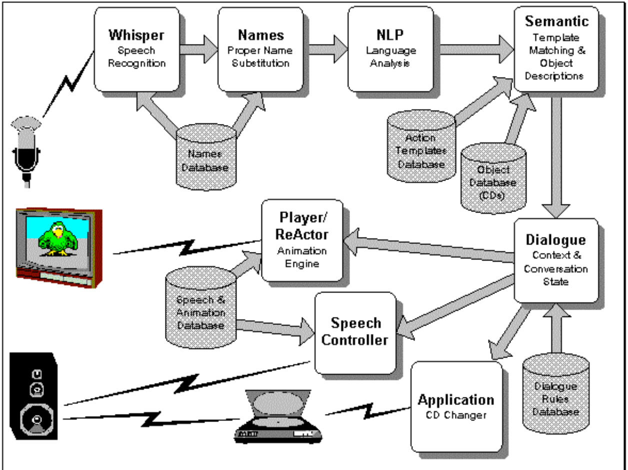


Figure1: System diagram of the Persona conversational assistant

Source: 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(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

```
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))))
```