A DCG for English using gap threading for unbounded dependencies

Detmar Meurers: Intro to Computational Linguistics I
OSU, LING 684.01

Towards a basic DCG for English: X-bar Theory

Generalizing over possible phrase structure rules, one can attempt to specify DCG rules fitting the following general pattern:

$X^2 \rightarrow$ specifier^2 X^1
$X^1 \rightarrow X^1$ modifier^2
$X^1 \rightarrow$ modifier^2 X^1
$X^1 \rightarrow X^0$ complement$^{2}*$

To turn this general X-bar pattern into actual DCG rules,

- X has to be replaced by one of the atoms encoding syntactic categories, and
- the bar-level needs to be encoded as an argument of each predicate encoding a syntactic category.

Noun, preposition, and adjective phrases

```
n(2,Num) --> pronoun(Num).
n(2,Num) --> proper_noun(Num).
n(2,Num) --> det(Num), n(1,Num).
n(2,plur) --> n(1,plur).
n(1,Num) --> pre_mod, n(1,Num).
n(1,Num) --> n(1,Num), post_mod.
n(1,Num) --> n(0,Num).
...

p(2,Pform) --> p(1,Pform).
p(1,Pform) --> adv, p(1,Pform). % slowly past the window
p(1,Pform) --> p(0,Pform), n(2,_).
...

a(2) --> deg, a(1). % very simple
a(1) --> adv, a(1). % commonly used
a(1) --> a(0).
```


Verb phrases and sentences

```
v(2,Vform,Num) --> v(1,Vform,Num).
v(1,Vform,Num) --> adv, v(1,Vform,Num).
v(1,Vform,Num) --> v(1,Vform,Num), verb_postmods.
v(1,Vform,Num) --> v(0,intrans,Vform,Num).
v(1,Vform,Num) --> v(0,trans,Vform,Num), n(2).
v(1,Vform,Num) --> v(0,ditrans,Vform,Num), n(2), n(2).
...

s(Vform) --> n(2,Num), v(2,Vform,Num).
```


From local to non-local dependencies

- A head generally realizes its arguments locally within its head domain, i.e., within a local tree if the X-bar schema is assumed.
- Certain kind of constructions resist this generalization, such as, for example, the wh-questions discussed below.
- How can the non-local relation between a head and such arguments be licensed? How can the properties be captured?

A first example: *Wh*-elements

Wh-elements can have different functions:

(1) a. Who did Hobbs see _ ? — Object of verb
b. Who do you think _ saw the man? — Subject of verb
c. Who did Hobbs give the book to _ ? — Object of prep
d. Who did Hobbs consider _ to be a fool? — Object of obj-control verb

Wh-elements can also occur in subordinate clauses:

(2) a. I asked who the man saw _ .
b. I asked who the man considered _ to be a fool .
c. I asked who Hobbs gave the book to _ .
d. I asked who you thought _ saw Hobbs.

Different categories can be extracted:

(3) a. Which man did you talk to _ ? — NP
b. [To [which man]] did you talk _ ? — PP
c. [How ill] has the man been _ ? — AdjP
d. [How frequently] did you see the man _ ? — AdvP

This sometimes provides multiple options for a constituent:

(4) a. Who does he rely [on _]?
b. [On whom] does he rely _ ?

Unboundedness:

(5) a. Who do you think Hobbs saw _ ?
b. Who do you think Hobbs said he saw _ ?
c. Who do you think Hobbs said he imagined that he saw _ ?

Unbounded dependency constructions

An unbounded dependency construction
- involves constituents with different functions
- involves constituents of different categories
- is in principle unbounded

Two kind of unbounded dependency constructions (UDCs)
- Strong UDCs
- Weak UDCs (*easy*, purpose infinives, ...) → not addressed here

Strong UDCs

An overt constituent occurs in a non-argument position:

Topicalization:
(6) Kim$_i$, Sandy loves _$_i$.

Wh-questions:
(7) I wonder [who$_i$ Sandy loves _$_i$].

Wh-relative clauses:
(8) This is the politician [who$_i$ Sandy loves _$_i$].

It-clefts:
(9) It is Kim$_i$ [who$_i$ Sandy loves _$_i$].

Pseudoclefts:
(10) [What$_i$ Sandy loves _$_i$] is Kim$_i$.

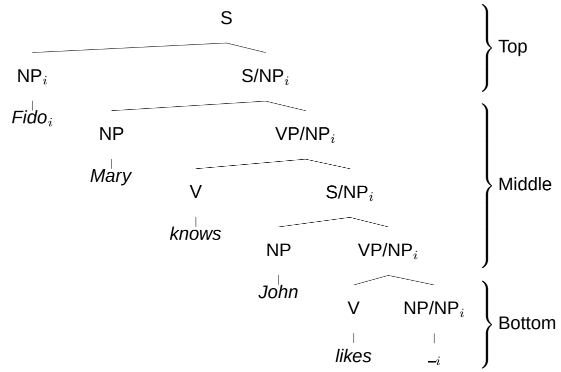
Link from filler to gap needed to identify category

(11) a. Kim$_i$, Sandy trusts $\_{i}$.
     b. [On Kim]$_i$, Sandy depends $\_{i}$.
(12) a. * [On Kim]$_i$, Sandy trusts $\_{i}$.
     b. * Kim$_i$, Sandy depends $\_{i}$.

And this link has to be established for an unbounded length:

(13) a. Kim$_i$, Chris knows Sandy trusts $\_{i}$.
     b. [On Kim]$_i$, Chris knows Sandy depends $\_{i}$.
(14) a. * [On Kim]$_i$, Chris knows Sandy trusts $\_{i}$.
     b. * Kim$_i$, Chris knows Sandy depends $\_{i}$.
(15) a. Kim$_i$, Dana believes Chris knows Sandy trusts $\_{i}$.
     b. [On Kim]$_i$, Dana believes Chris knows Sandy depends $\_{i}$.
(16) a. * [On Kim]$_i$, Dana believes Chris knows Sandy trusts $\_{i}$.
     b. * Kim$_i$, Dana believes Chris knows Sandy depends $\_{i}$.

An example for a strong UDC



A small DCG (dcg/udc/dcg_basis.pl)

```
np --> [mary]
      ;[john]
      ;[fido].

p  --> [to].
pp -->  p,
        np.

vt --> [loves].
vd --> [gives].
vs --> [knows].
```

```
s -->   np,
        vp.

vp -->  vt,
        np.

vp -->  vd,
        np,
        pp.

vp -->  vs,
        s.
```


A mini grammar with gaps (dcg/udc/dcg_gaps1.pl)

```
% 1) Top of UDC: realizing filler
s(nogap) --> np(nogap), s(gap).

% 2) Middle of UDC: passing info
s(GapInfo)  --> np(nogap), vp(GapInfo). % no subject gaps
vp(GapInfo) --> vt,        np(GapInfo).

% 3) Bottom of UDC
np(gap)   --> [].

% "Lexicon"
np(nogap) --> [mary];[john];[fido].

vt --> [loves].
```


Towards different kinds of gaps (dcg/udc/dcg_gaps2.pl)

```
% 1) Top of UDC: realizing filler
s(nogap) --> np(nogap), s(gap).

s(nogap) --> pp(nogap), s(gap).

% 2) Middle of UDC: passing info
s(GapInfo) --> np(nogap), vp(GapInfo).  % no subject gaps

vp(GapInfo) --> vt, np(GapInfo).
vp(GapInfo) --> vd, np(GapInfo), pp(nogap).
vp(GapInfo) --> vd, np(nogap),   pp(GapInfo).

pp(GapInfo) --> p,  np(GapInfo).
```



```
% 3) Bottom of UDC
np(gap)   --> [].
pp(gap)   --> [].

% "Lexicon"
np(nogap) --> [mary];[john];[fido].
p  --> [to].
vt --> [loves].
vd --> [gives].
```


Different kinds of gaps (dcg/udc/dcg_gaps3.pl)

```
% 1) Top of UDC: realizing filler
s(nogap) --> np(nogap), s(gap(np)).

s(nogap) --> pp(nogap), s(gap(pp)).

% 2) Middle of UDC: passing info
s(GapInfo) --> np(nogap), vp(GapInfo).   % no subject gaps

vp(GapInfo) --> vt, np(GapInfo).
vp(GapInfo) --> vd, np(GapInfo), pp(nogap).
vp(GapInfo) --> vd, np(nogap),   pp(GapInfo).

pp(GapInfo) --> p, np(GapInfo).
```



```
% 3) Bottom of UDC
np(gap(np)) --> [].
pp(gap(pp)) --> [].

% "Lexicon"
np(nogap) --> [mary];[john];[fido].
p  --> [to].
vt --> [loves].
vd --> [gives].
```


From hardcoded gap percolation to gap threading

Two problems of current encoding:

- Two rules are needed to license ditransitive VPs.
- In sentences without topicalization, two identical analyses arise for ditransitive VPs.

Idea:

- Use difference-list encoding to thread occurrence of gaps through the tree (“gap threading”).

An encoding using gap threading (dcg/udc/dcg_gaps4.pl)

```
% 1) Top of UDC: realizing filler

s([],[]) --> np([],[]), s([gap(np)],[]).
s([],[]) --> pp([],[]), s([gap(pp)],[]).

% 2) Middle of UDC: passing info

s(G0,G) --> np([],[]), vp(G0,G).

vp(G0,G) --> vt, np(G0,G).
vp(G0,G) --> vd, np(G0,G1), pp(G1,G).
pp(G0,G) --> p,  np(G0,G).
```



```
% 3) Bottom of UDC
np([gap(np)],[]) --> [].
pp([gap(pp)],[]) --> [].

% "Lexicon"
np(X,X) --> [mary];[john];[fido].
p  --> [to].
vt --> [loves].      vd --> [gives].
```


Reading assignment

Read the following chapters from the lecture notes:

- Chapter 4: *DCGs as a Grammar Formalism*
- Chapter 5: *Unbounded Dependencies in DCGs*