L4: Syntax II - Encoding grammar with features

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September 17, 2015

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We developed a (simplified) CFG fragment of English.

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3. Sentence meaning:
   #The tree climbed up George.

Outline

Agreement

Subject-verb agreement

. . . in Person and Number

(1) a. [$_{NP}$George] likes to travel by plane.

b. [$_{NP}$Cats] like to travel by plane.

Subject-verb agreement

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(1) a. [$_{NP}$George] likes to travel by plane.

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(2) a. Does [$_{NP}$this cat] like to travel by plane?

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(3) a. *[$_{NP}$Cats] likes to travel by plane.

b. *Do [$_{NP}$George] likes to travel by plane?

Main verb and auxiliary verb

. . . agree for Tense in English.

(4) a. Many flights stoped in Chicago.

b. Many flights did stop in Chicago.

c. Did any flights stop in Chicago?

d. Did George stop in Chicago?

Case

In Kambera the verb agrees with both subject and object.

(5) a.

[I Ama]$_s$ na$_s$-kei-ya$_o$ [na rí muru]$_o$
the father 3sg,nom-buy-3sg,acc the vegetable green
"Father buys the green vegetables."

b.

Na$_s$-kei-ya$_o$
3sg,nom-buy-3sg,acc
"He/she buys it."

(Tallerman, 2011), p.159

Case

English pronouns behave similarly. . .

(6) a. She$_{nom}$ met her$_{acc}$.

b. *She$_{nom}$ met he$_{nom}$.

c. *Him$_{acc}$ met she$_{nom}$.

Gender

Object-verb gender in Arabic

(7) a. uhibbuka
I love you - said to a male.

b. uhibbuki
I love you - said to a female.

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Subject-verb agreement in Portuguese

(8) a. Muito obrigado.
I am very grateful - said by a male.

b. Muito obrigada.
I'm very grateful - said by a female.

Gender

Determiner-adjective-noun agreement in German

(9) a. der Krach
the noise

b. der laute Krach
the loud noise

c. ein lauter Krach
a loud noise

d. lauter Krach
loud noise

Gender

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Interaction with Case

(10) a. die kluge starke Frau
the clever strong woman (nom)

b. der klugen starken Frau
the clever strong woman (gen)

Quantifiers

(11) a. Many letters have arrived.

b. *Much letters have arrived.

c. Not much post has arrived.

d. *Not many post has arrived.

Why natural languages have agreement?

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Marking grammatical relations between constituents.

From Northern Sotho, a Bantu language (Tallerman, 2011), p.160:

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Mpša e-lomile ngwana.
dog subj-bit child
"The dog bit a/the child."

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"As for the child, the dog bit him/her."

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"As for the child, the dog bit him/her."

c.

Mpša ngwana e-mo-lomile.
dog child subj-obj-bit
"As for the dog, it bit the child."

How to represent agreement - a solution?

Encode the agreement information in CFG rules.

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(14) a. TP $\rightarrow$ NP3sg T3sg VPNon3sg

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c. T3sg $\rightarrow$ does | has | ...

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g. NP3sg $\rightarrow$ (D) (AP+) N3sg (PP+)

h. NPNon3sg $\rightarrow$ (D) (AP+) NNon3sg (PP+)

i. N3sg $\rightarrow$ George | tree | he | she | it | ...

j. NNon3sg $\rightarrow$ I | you | we | they | cats | trees ...

Sub-categorisation

The categories of verbs

Currently, our VP rule is very general...

(15) VP $\rightarrow$ (AdvP+) V (NP) ({NP/CP}) (AdvP+) (PP+) (AdvP+)

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But not every verb is compatible with every phrase that the rule generates.

(16) a. *George sleeps the birds.

b. *George bought that Lydia sang an aria.

Different kinds of lexical incompatibility

(17) a. #George typed a neutrino.

b. #The apple is eating the colourless green cat furiously.

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c. *George said.

d. *George kissed Lydia Simon.

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3. A theme argument: un-accusative verbs
   [$_{NP}$George] fell.
   Remember: sentences have to have subjects!
4. An agent and a theme argument: transitive verbs
   [$_{NP}$George] kissed [$_{NP}$ Lydia] again.

5. An agent, a theme, and a goal argument

   [$_{NP}$George] gave [$_{NP}$Lydia] [$_{NP}$a present].

   [$_{NP}$George] gave [$_{NP}$a present] [$_{PP}$to Lydia].

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Arguments are of types: Theta/θ-roles

Thematic roles

(18) Agent, Theme, Goal...

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Sub-categorisation frame/valency: a collection of arguments/theta roles associated with a verb:

(19) give(Agent,Theme,Goal)

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Theta-hierarchy

(20) Agent $<$ Experiencer $<$ Goal/Source/Location $<$ Theme

(21) a. Captain Alex sank the ship.

b. The ship sank.

Arguments are of types: Theta/θ-roles

A single verb can have different subcat-frames:

(22) a. George found a snake.

b. George found me a good song on iTunes.

Sub-categorisation resources for NLP

FrameNet: an annotated lexical resource of linguistic predicates (frames) and their arguments (frame elements).

http://framenet.icsi.berkeley.edu
http://spraakbanken.gu.se/eng/swefn

Communication

Core frame elements:

1. Communicator: He finds it hard to communicate. . .
2. Medium: Opinions are usually communicated over the telephone. . .
3. Message: How do you communicate to them that you really like them?
4. Topic: Had someone communicated to the capital about the disregard of the religious law?
5. Addressee: The company must be able to communicate to potential customers. . .
6. Amount of information: He never really fully communicated his intentions.
7. Duration, frequency, manner, means, place, purpose, time. . .

Nouns as predicates

(23) a. [NP a student [PPof linguistics]
[PPwith long hair]].

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e. [NPthe one [PPwith short hair]]

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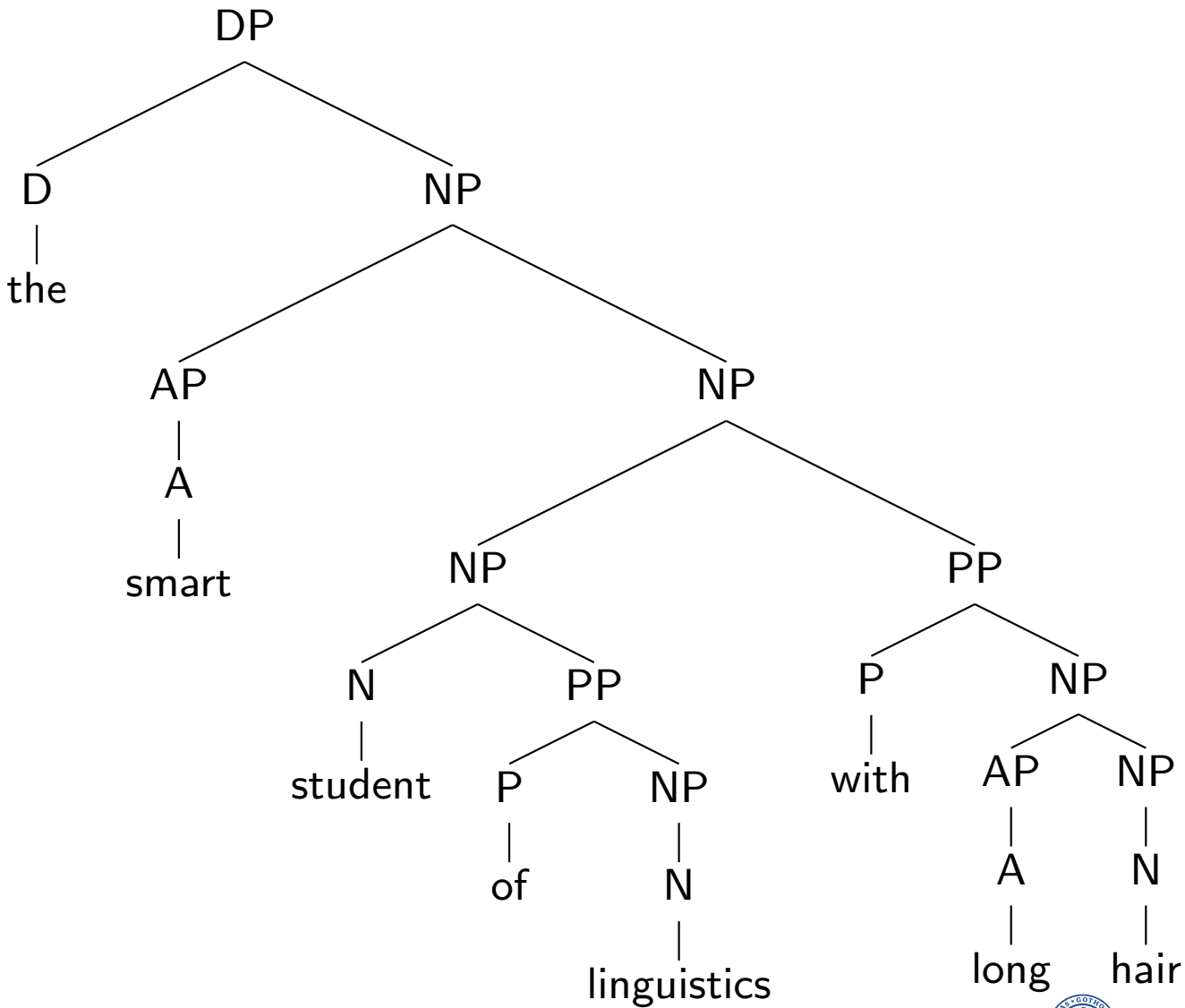
Sub-categorisation arguments (Complements) are obligatory, other modifiers are optional (Adjuncts).

Complements and adjuncts structurally



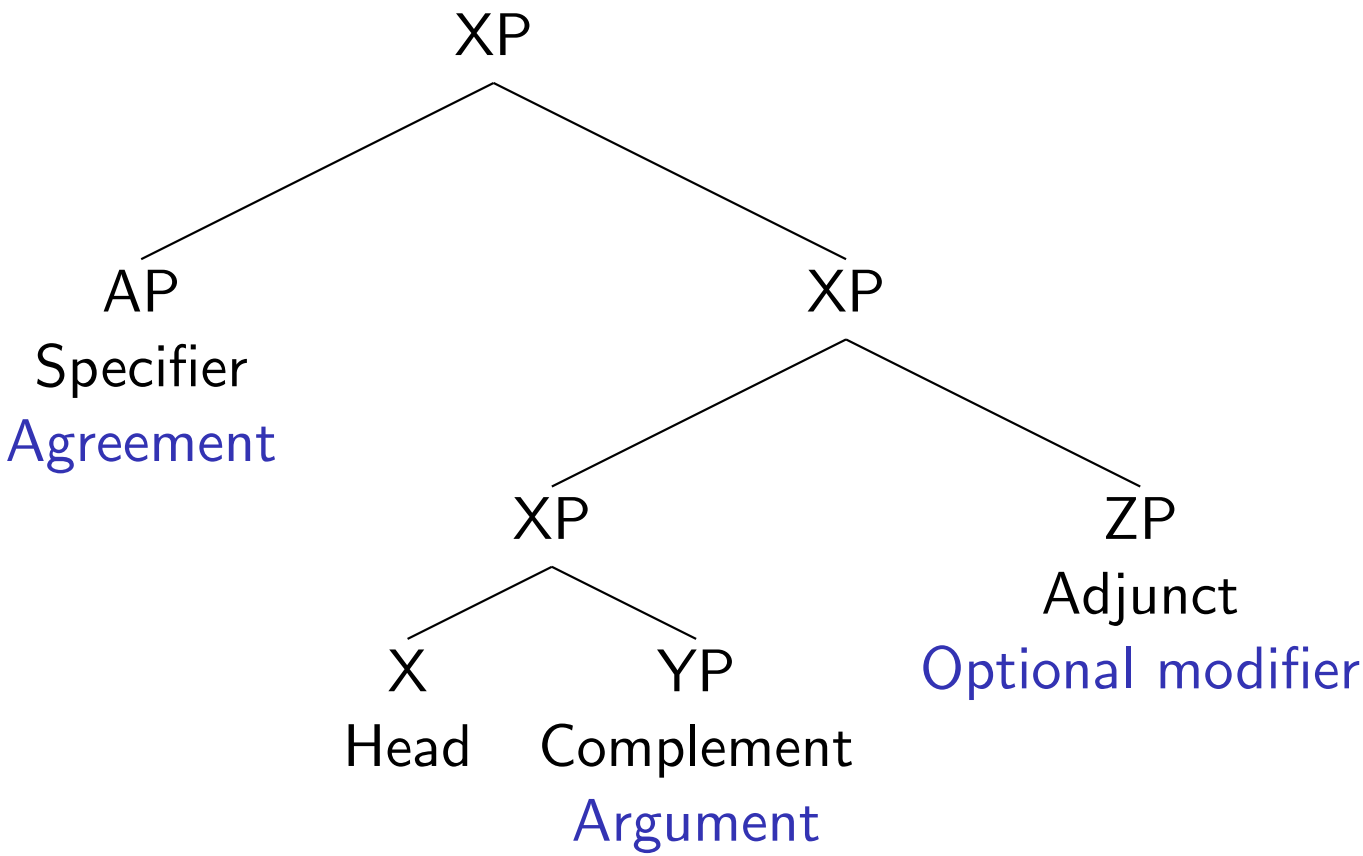
Complements and adjuncts structurally

Sentences (TPs) make a similar tree.

What takes the D's place?

What takes the AP's and PP's place?

Can structural relations be generalised?



The X-bar theory

The X-bar theory (Chomsky, 1970; Jackendoff, 1977):

(24) a. XP $\rightarrow$ Spec; $\overline{X}$

b. ($\overline{X} \rightarrow \overline{X}$; ZP)

c. $\overline{X} \rightarrow$ X; YP

Representing sub-categorisation in CFG

- A new rule for each predicate category?
  1. $\text{VP}_{intran} \rightarrow \text{NP V}_{intran}$
  2. $\text{VP}_{tran} \rightarrow \text{NP V}_{tran}\ \text{NP}$
  3. ...

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- Parametrise each node in the tree with feature structures.

Representing constraints: features and unification

Feature structures and unification

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Feature structures and unification

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(25) S $\rightarrow$ NP VP
The number of the NP is equal to the number of the VP.

Feature structures as attribute-value matrices (AVMs)

$$\begin{bmatrix} \text{Cat} & \text{np} \\ \text{Number} & \text{sg} \\ \text{Person} & 3 \end{bmatrix} \quad \begin{bmatrix} \text{Cat} & \text{np} \\ \text{Agreement} & \begin{bmatrix} \text{Number} & \text{sg} \\ \text{Person} & 3 \end{bmatrix} \end{bmatrix}$$

- Lists of feature=value pairs
- Features/attributes: atoms
- Values: atoms or feature structures
- Feature path: a list of features through a FS leading to a value: ⟨Agreement Person⟩
- Feature paths as directed acyclic graphs (DAGs).

Shared or reentrant feature structures

$$\begin{bmatrix} \text{Cat} & \text{tp} \\ \text{Head} & \begin{bmatrix} \text{Agreement } \boxed{1} & \begin{bmatrix} \text{Number} & \text{sg} \\ \text{Person} & 3 \end{bmatrix} \\ \text{Subject} & \begin{bmatrix} \text{Agreement } \boxed{1} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Unifying FSs

- Unification ($\sqcup$): combine two FSs so that the resulting FS contains all the information from the original two, nothing more.
- Partial operation: may be undefined (unlike union of sets).

F1: $\begin{bmatrix} \text{Cat} & \text{np} \\ \text{Agreement} & \begin{bmatrix} \text{Number sing} \end{bmatrix} \end{bmatrix}$ F2: $\begin{bmatrix} \text{Cat} & \text{np} \\ \text{Agreement} & \begin{bmatrix} \text{Person 3} \end{bmatrix} \end{bmatrix}$

F1 $\sqcup$ F2 $=$

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F1 $\sqcup$ F2 = F3: $\begin{bmatrix} \text{Cat} & \text{np} \\ \text{Agreement} & \begin{bmatrix} \text{Number} & \text{sing} \\ \text{Person} & 3 \end{bmatrix} \end{bmatrix}$

Examples of unification

F4: $\begin{bmatrix} \text{Cat} & \text{np} \end{bmatrix}$

F5: $\begin{bmatrix} \text{Cat} & \text{vp} \end{bmatrix}$

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F7: $\begin{bmatrix} \text{Cat} & \text{np} \end{bmatrix}$ F8: $\begin{bmatrix} \text{Cat} & [] \end{bmatrix}$

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F7 $\sqcup$ F8 = F9: $\begin{bmatrix} \text{Cat} & \text{np} \end{bmatrix}$

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F10: []

F7 $\sqcup$ F10 =

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F7 $\sqcup$ F8 = F9: $\begin{bmatrix} \text{Cat} & \text{np} \end{bmatrix}$

F10: []

F7 $\sqcup$ F10 = F7 = $\begin{bmatrix} \text{Cat} & \text{np} \end{bmatrix}$

Examples of unification

F11: $\begin{bmatrix} \text{Agreement} & \begin{bmatrix} \text{Number} & \text{sing} \end{bmatrix} \\ \text{Subject} & \begin{bmatrix} \text{Agreement} & \begin{bmatrix} \text{Number} & \text{sing} \\ \text{Person} & 3 \end{bmatrix} \end{bmatrix} \end{bmatrix}$

F12: $\begin{bmatrix} \text{Agreement} & \boxed{1} \begin{bmatrix} \text{Number} & \text{sing} \end{bmatrix} \\ \text{Subject} & \begin{bmatrix} \text{Agreement} & \boxed{1} \end{bmatrix} \end{bmatrix}$

F11 $\sqcup$ F12 $=$

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F11 $\sqcup$ F12 = F13:
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Agreement in unification grammar

(26) a. George likes planes.

b. Cats like planes.

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$\langle$NP Agreement$\rangle$ = $\langle$VP Agreement$\rangle$
(Jurafsky and Martin, 2009) and (Shieber, 1986)

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```
S -> NP[AGR=?n] VP[AGR=?n]
```

?n in FS is a variable!

Terminal nodes

Propagating features from terminals to heads

```
V[AGR=[NUM=pl]] -> 'like'
V[AGR=[NUM=sg,PERS=3]] -> 'likes'
V[AGR=[]] -> 'liked'
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V[AGR=[]] -> 'liked'

N[AGR=[NUM=sg]] -> 'George'
N[AGR=[NUM=pl]] -> 'planes' | 'cats'
N[AGR=[]] -> 'sheep' | 'fish'
```

Propagating features from heads to phrases

Head features: features of a head that get propagated to the phrase

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```
VP[AGR=?agr] -> V[AGR=?agr] NP
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```
VP[AGR=?agr] -> V[AGR=?agr] NP
```

All head features can be grouped under the head FS and then propagated with a rule like

```
X[HEAD=[CAT=v,AGR=[NUM=sg,PERS=3]],...]
XP[HEAD=?head] -> ... X[HEAD=?head] ...
```

Sub-categorisation in unification grammar

(27) a. [$_{NP}$George] intended [$_{TP}$to climb a tree].

b. [$_{NP}$George] saw [$_{NP}$Lydia].

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Add a subcat feature to predicates in the lexicon.

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V[HEAD=[...],SUBCAT=to_clause] -> intended
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V[HEAD=[...],SUBCAT=to_clause] -> intended
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VP[HEAD=?head,SUBCAT=trans] ->
   V[HEAD=?head,SUBCAT=trans] NP
VP[HEAD=?head,SUBCAT=to_clause] ->
   V[HEAD=?head,SUBCAT=to_clause] TP[-TENSE]
```

More examples in NLTK

nltk_data/grammars/book_grammars/

feat0.fcfg, feat1.fcfg and german.fcfg

Further reading

- (Allen, 1995): Chapters 4.1 (Feature systems and augmented grammars), 4.2 (Some basic feature systems for English) and 4.3 (A simple grammar using features)
- (Bird, Klein, and Loper, 2009): Chapter 9 Building Feature Based Grammars.
- (Jurafsky and Martin, 2009): Chapter 15.1 (Feature Structures), 15.2 (Unification feature structures), 15.3 (Feature structures in the grammar) and 15.4 (Implementation of Unification)
- (Shieber, 1986): http://dash.harvard.edu/handle/1/11576719

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Chomsky, Noam. 1970. Remarks on nominalization. In Roderick A. Jacobs and Peter S. Rosenbaum, editors, *Readings in English Transformational Grammar*. Ginn, Boston, pages 184–221.

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Jurafsky, Dan and James H. Martin. 2009. *Speech and language processing: an introduction to natural language processing, computational linguistics, and speech recognition*. Pearson Prentice Hall, Upper Saddle River, N.J., 2nd ed edition.

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Tallerman, Maggie. 2011. *Understanding syntax*. Understanding language series. Hodder Arnold, London, 3rd edition.