

# ACS Syntax and Semantics of Natural Language

## Lecture 5: CCG Applied to Real Text



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*Pierre Vinken, 61 years old, will join the board as a non-executive director Nov. 29.*

*Activation of the CD28 surface receptor provides a major costimulatory signal for T cell activation resulting in enhanced production of interleukin-2 (IL-2) and cell proliferation.*

*The Trust's symbol, a sprig of oak leaves and acorns, is thought to have been inspired by a carving in the cornice of the Alfriston Clergy House.*

- Can we really move from simple “linguistic” examples to sentences like these found in the real world?

Pierre|N/N Vinken|N ,|, 61|N/N years|N old|(S[adj]\NP)\NP  
,|, will|(S[dcl]\NP)/(S[b]\NP) join|((S[b]\NP)/PP)/NP  
the|NP/N board|N as|PP/NP a|NP/N nonexecutive|N/N  
director|N Nov.|((S\NP)\(S\NP))/N 29|N .|. .

- Needs an  $N \rightarrow NP$  rule
- $S[adj]\backslash NP$  is for predicative adjectives, e.g. *the man is old*
- We need a *unary type-changing rule*:  $S[adj]\backslash NP \rightarrow NP\backslash NP$
- We need special rules in the parser to deal with punctuation
- Only need application in this example (no composition or type-raising)

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- $S$  category often has a grammatical feature which indicates the kind of sentence or verb phrase
    - $S[dcl]$  declarative sentence
    - $S[q]$  yes/no questions
    - $S[b]$  bare infinitives
    - $S[to]$  to infinitives
    - $S[pss]$  past participles in passive mode
    - $S[pt]$  past participles in active mode
    - $S[ng]$  present participles
    - ...
  - See p.59 of Julia's thesis for full list
  - $S$  in adverbial modifiers, e.g.  $(S \setminus NP) / (S \setminus NP)$ , effectively has a variable feature:  $(S[X] \setminus NP) / (S[X] \setminus NP)$ , which unifies with the feature on the argument and transfers to the result

Activation|N of|(NP\NP)/NP the|NP/N CD28|N/N surface|N/N  
receptor|N provides|(S[dc1]\NP)/NP a|NP/N major|N/N  
costimulatory|N/N signal|N for|(NP\NP)/NP T|(N/N)/(N/N)  
cell|N/N activation|N resulting|(S[ng]\NP)/PP in|PP/NP  
enhanced|N/N production|N of|(NP\NP)/NP interleukin-2|N  
( |( IL-2|N ) | ) and|conj cell|N/N proliferation|N .|. .

- Needs a unary type-changing rule:  $S[ng]\backslash NP \rightarrow (S\backslash NP)\backslash(S\backslash NP)$
- Need special rules to deal with brackets
- Still only needs application

The|NP/N Trust|N 's|(NP/N)\NP symbol|N ,|, a|NP/N sprig|N  
of|(NP\NP)/NP oak|N/N leaves|N and|conj acorns|N ,|,  
is|(S[decl]\NP)/(S[pss]\NP) thought|(S[pss]\NP)/(S[to]\NP)  
to|(S[to]\NP)/(S[b]\NP) have|(S[b]\NP)/(S[pt]\NP)  
been|(S[pt]\NP)/(S[pss]\NP) inspired|S[pss]\NP  
by|((S\NP)\(S\NP))/NP a|NP/N carving|N in|(NP\NP)/NP  
the|NP/N cornice|N of|(NP\NP)/NP the|NP/N  
Alfriston|(N/N)/(N/N) Clergy|N/N House|N .|.

- Still only need application
- No unary type-changing rules in this example

- Without type-changing rules (notice that the category for *used* is non-standard and the category for *once* changes also):

<i>A form of asbestos</i>	<i>once</i>	<i>used</i>	<i>to make Kent cigarettes</i>
$NP$	$(NP \backslash NP) / (NP \backslash NP)$	$(NP \backslash NP) / (S[to] \backslash NP)$	$S[to] \backslash NP$

- With type-changing rules (uses standard categories for *used* and *once*):

<i>A form of asbestos</i>	<i>once</i>	<i>used</i>	<i>to make Kent cigarettes</i>
$NP$	$(S \backslash NP) / (S \backslash NP)$	$(S[pss] \backslash NP) / (S[to] \backslash NP)$	$S[to] \backslash NP$
	$S[pss] \backslash NP$		
	$NP \backslash NP$		

- Type-changing rules increase the compactness of the lexicon (capturing generalisations) and reduce the number of categories assigned to modifiers such as *once*

- Object extraction from a relative clause, using type-raising and forward composition:

$$\frac{\text{That}}{NP} \quad \frac{\text{finished}}{(S[dcl] \backslash NP) / NP} \quad \frac{\text{the job}}{NP} \quad \frac{\text{that}}{(NP \backslash NP) / (S[dcl] / NP)} \quad \frac{\text{Captain Chandler}}{NP} \quad \frac{\text{had}}{(S[dcl] \backslash NP) / (S[pt] \backslash NP)} \quad \frac{\text{begun}}{(S[pt] \backslash NP) / NP}$$

- Question with an object extraction:

$$\frac{\text{What}}{(S[wq] / (S[q] / NP)) / N} \quad \frac{\text{books}}{N} \quad \frac{\text{did}}{(S[q] / (S[b] \backslash NP)) / NP} \quad \frac{\text{he}}{NP} \quad \frac{\text{author}}{(S[b] \backslash NP) / NP} \quad ?$$

- Subject extraction from an embedded clause:

$$\frac{\text{the revolution}}{NP} \quad \frac{\text{which}}{(NP \backslash NP) / (S[dcl] / NP)} \quad \frac{\text{he}}{NP} \quad \frac{\text{pretended}}{((S[dcl] \backslash NP) / NP) / (S[dcl] \backslash NP)} \quad \frac{\text{did}}{(S[dcl] \backslash NP) / (S[b] \backslash NP)} \quad \frac{\text{not}}{(S \backslash NP) \backslash (S \backslash NP)} \quad \frac{\text{exist}}{S[b] \backslash NP}$$



# Real Coordination Example

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*children*                      *were*                      *more*                      *apt*                      *to*                      *avoid*  
 $\frac{NP}{(S[dcl]\backslash NP)/(S[adj]\backslash NP)} \quad \frac{(S\backslash NP)/(S\backslash NP)}{(S[adj]\backslash NP)/(S[to]\backslash NP)} \quad \frac{(S[to]\backslash NP)/(S[b]\backslash NP)}{(S[b]\backslash NP)/NP}$

*or*                      *be*                      *shocked*                      *by*                      *nudity*  
 $\frac{conj}{(S[b]\backslash NP)/(S[pss]\backslash NP)} \quad \frac{S[pss]\backslash NP}{((S\backslash NP)\backslash (S\backslash NP))/NP} \quad \frac{NP}{NP}$

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- CCGbank: A Corpus of CCG Derivations and Dependency Structures Extracted from the Penn Treebank. Julia Hockenamier and Mark Steedman. Computational Linguistics. 2007
  - Data and models for statistical parsing with Combinatory Categorical Grammar, Julia Hockenmaier, PhD thesis, Edinburgh, 2003