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?
Newspaper Example

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

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

- $S$ 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. $(S\backslash NP)/(S\backslash NP)$, effectively has a variable feature: $(S[X]\backslash NP)/(S[X]\backslash NP)$, which unifies with the feature on the argument and transfers to the result
Activation of the CD28 surface receptor provides a major costimulatory signal for T cell activation resulting in enhanced production of interleukin-2 and cell proliferation.

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

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

<table>
<thead>
<tr>
<th>A form of asbestos</th>
<th>once</th>
<th>used</th>
<th>to make Kent cigarettes</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP</td>
<td>(NP\NP)(NP\NP)</td>
<td>(NP\NP)(S[to]\NP)</td>
<td>S[to]\NP</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>A form of asbestos</th>
<th>once</th>
<th>used</th>
<th>to make Kent cigarettes</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP</td>
<td>(S\NP)(S\NP)</td>
<td>(S[pss]\NP)(S[to]\NP)</td>
<td>S[to]\NP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S[pss]\NP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NP\NP</td>
</tr>
</tbody>
</table>

- 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:

\[
\begin{array}{cccccccc}
\text{That} & \text{finished} & \text{the job} & \text{that} & \text{Captain Chandler} & \text{had} & \text{begun} \\
\text{NP} & (S[dcl]\text{\}/NP)/NP & \text{NP} & (NP\text{\}/NP)/(S[dcl]\text{\}/NP) & \text{NP} & (S[dcl]\text{\}/NP)/(S[pt]\text{\}/NP) & (S[pt]\text{\}/NP)/NP \\
\end{array}
\]

• Question with an object extraction:

\[
\begin{array}{cccccccc}
\text{What} & \text{books} & \text{did} & \text{he} & \text{author} & \text{?} \\
(S[wq]/(S[q]/NP))/N & N & (S[q]/(S[b]\text{\}/NP))/NP & NP & (S[b]\text{\}/NP)/NP & - \\
\end{array}
\]

• Subject extraction from an embedded clause:

\[
\begin{array}{cccccccc}
\text{the revolution} & \text{which} & \text{he} & \text{pretended} & \text{did} & \text{not} & \text{exist} \\
NP & (NP\text{\}/NP)/(S[dcl]\text{\}/NP) & \text{NP} & ((S[dcl]\text{\}/NP)/NP)/(S[dcl]\text{\}/NP) & (S[dcl]\text{\}/NP)/(S[b]\text{\}/NP) & (S[\text{NP}]\text{\}/NP) & (S[\text{NP}]\text{\}/NP) \\
\end{array}
\]
### Real Coordination Example

<table>
<thead>
<tr>
<th>children</th>
<th>were</th>
<th>more</th>
<th>apt</th>
<th>to</th>
<th>avoid</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP</td>
<td>(S[dcl]/NP)/(S[adj]/NP)</td>
<td>(S\NP)/(S\NP)</td>
<td>(S[adj]/NP)/(S[to]/NP)</td>
<td>(S[to]/NP)/(S[b]/NP)</td>
<td>(S[b]/NP)/NP</td>
</tr>
<tr>
<td>or</td>
<td>conj</td>
<td>be</td>
<td>shocked</td>
<td>by</td>
<td>nudity</td>
</tr>
<tr>
<td>NP</td>
<td>(S[b]/NP)/(S[pss]/NP)</td>
<td>S[pss]/NP</td>
<td>((S\NP)/(S\NP))/NP</td>
<td>NP</td>
<td></td>
</tr>
</tbody>
</table>

• Data and models for statistical parsing with Combinatory Categorial Grammar, Julia Hockenmaier, PhD thesis, Edinburgh, 2003