ACS Syntax and Semantics of Natural Language

Lecture 3: CCG – More Combinatory Rules

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Generalised Forward Composition

- Some linguistic phenomena suggest the need for additional combinatory rules, eg:

I offered, and may give, a flower to a policeman

- Need to coordinate *offered* and *may give*, which means we need to make *may give* a constituent:

$$(S\backslash NP)/(S\backslash NP) \;\; ((S\backslash NP)/PP)/NP \;\; \Rightarrow \;\; ((S\backslash NP)/PP)/NP \;\; ?$$

Generalised Forward Composition

$$X/Y \quad (\ldots(Y/Z)/W)/\ldots \Rightarrow_{\mathbf{B}^n} (\ldots(X/Z)/W)/\ldots$$

- Can now combine *may* and *give*:

$$\dfrac{\dfrac{may}{(S\backslash NP)/VP} \quad \dfrac{give}{(VP/PP)/NP}}{((S\backslash NP)/PP)/NP}{>}\mathbf{B}^n$$

where $VP = S\backslash NP$

[full derivation for *I offered, and may give, a flower to a policeman* left as an exercise for the reader]

Argument Cluster Coordination

give a teacher an apple and a policemen a flower

- Looks like we need to coordinate *a teacher an apple* and *a policeman a flower*
- Can *a teacher an apple* really be a constituent?!
- Yes, if we allow backward type-raising and composition rules (once we allow these the derivation drops out)

Type-Raising (Forward and Backward)

$$X \Rightarrow_{\mathbf{T}} T/(T\backslash X) \qquad \text{forward}$$

$$X \Rightarrow_{\mathbf{T}} T\backslash(T/X) \qquad \text{backward}$$

- Now we have another derivation for a sentence like *John likes beer* (next slide)

Example Derivation for Backward Type-Raising

$$
\begin{array}{ccc}
John & likes & beer \\
\hline NP & \hline (S\backslash NP)/NP & \hline NP \\
 & & \overline{VP\backslash(VP/NP)}^{<\mathbf{T}} \\
 & \multicolumn{2}{c}{\overline{\qquad S\backslash NP \qquad}^{<}} \\
\multicolumn{3}{c}{\overline{\qquad\qquad S \qquad\qquad}^{<}}
\end{array}
$$

where $VP = S\backslash NP$

- This is an unproductive use of backward type-raising (leading to a “spurious” ambiguity)

$$
\begin{array}{cccccc}
give & a\ teacher & an\ apple & and & a\ policeman & a\ flower \\
\hline DTV & \overline{NP} & \overline{NP} & \overline{conj} & \overline{NP} & \overline{NP} \\
 & \overline{TV\backslash DTV}^{<\mathbf{T}} & \overline{VP\backslash TV}^{<\mathbf{T}} & & \overline{TV\backslash DTV}^{<\mathbf{T}} & \overline{VP\backslash TV}^{<\mathbf{T}}
\end{array}
$$

where $VP = S\backslash NP$, $TV = (S\backslash NP)/NP$, $DTV = ((S\backslash NP)/NP)/NP$

- Now we need a rule to combine $TV\backslash DTV$ and $VP\backslash TV$

$$\dfrac{\textit{give}}{DTV} \quad \dfrac{\textit{a teacher}}{\dfrac{NP}{TV\backslash DTV}{<}\mathbf{T}} \quad \dfrac{\textit{an apple}}{\dfrac{NP}{VP\backslash TV}{<}\mathbf{T}} \quad \dfrac{\textit{and}}{conj} \quad \dfrac{\textit{a policeman}}{\dfrac{NP}{TV\backslash DTV}{<}\mathbf{T}} \quad \dfrac{\textit{a flower}}{\dfrac{NP}{VP\backslash TV}{<}\mathbf{T}}$$

where $VP = S\backslash NP$, $TV = (S\backslash NP)/NP$, $DTV = ((S\backslash NP)/NP)/NP$

- Now we need a rule to combine $TV\backslash DTV$ and $VP\backslash TV$
- Backward Composition $(< \mathbf{B})$:

$$Y\backslash Z \quad X\backslash Y \quad \Rightarrow_{\mathbf{B}} \quad X\backslash Z$$

Full Derivation for Argument Cluster Coordination

$$
\begin{array}{cccccc}
\textit{give} & \textit{a teacher} & \textit{an apple} & \textit{and} & \textit{a policeman} & \textit{a flower} \\
\hline
DTV & NP & NP & conj & NP & NP \\
\cline{2-3}\cline{5-6}
 & TV\backslash DTV \;{<}\mathbf{T} & VP\backslash TV \;{<}\mathbf{T} & & TV\backslash DTV \;{<}\mathbf{T} & VP\backslash TV \;{<}\mathbf{T} \\
\cline{2-3}\cline{5-6}
 & \multicolumn{2}{c}{VP\backslash DTV \;{<}\mathbf{B}} & & \multicolumn{2}{c}{VP\backslash DTV \;{<}\mathbf{B}} \\
\cline{2-6}
 & \multicolumn{5}{c}{VP\backslash DTV \;{<}\Phi{>}} \\
\hline
\multicolumn{6}{c}{VP \;{<}}
\end{array}
$$

where $VP = S\backslash NP$, $TV = (S\backslash NP)/NP$, $DTV = ((S\backslash NP)/NP)/NP$

Backward Crossed Composition

I shall buy today and cook tomorrow some mushrooms

- *buy today* and *cook tomorrow* need to be constituents
- *buy* has category $(S\backslash NP)/NP$ and *today* has category $(S\backslash NP)\backslash(S\backslash NP)$
- No rule so far allows us to combine these; but this one will:

$$Y/Z \;\; X\backslash Y \quad \Rightarrow_{\mathbf{B}} \quad X/Z \qquad (< \mathbf{B}_x)$$

$$VP/NP \;\; VP\backslash VP \quad \Rightarrow_{\mathbf{B}} \quad VP/NP$$

How do we decide what rules are allowed?

- Steedman (2000) has extensive discussion of this issue
- Various constraints are proposed on linguistic grounds, in order to prevent excessive overgeneration
- Multi-modal CCG (Baldridge) provides a principled mechanism for applying constraints (although we won't cover this extenstion of CCG in this course)
- From a practical perspective we're less concerned about overgeneration, since we have a probability model to rule out unlikely constituents
  - although putting constraints on when certain rules can apply can have a large impact on efficiency [give example from C&C parser]

References

- The Syntactic Process, Mark Steedman, 2000, MIT Press
- Combinatory Categorial Grammar, Steedman and Baldridge, 2007, available from Mark's webpage