

# CS 4650/7650


## Beyond Context-Free Grammars

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# Cross-serial dependencies

(7) ... that we the children Hans the house let help paint  
... das mer d'chind em Hans es huus lönd hülfe aastriiche



The diagram illustrates cross-serial dependencies between the German sentence and its English translation. Brackets connect the words as follows: 'Hans' to 'es', 'huus' to 'huus', 'lönd' to 'hülfe', and 'aastriiche' to 'paint'. These connections show that the relationship between verbs and their objects is signaled by order and case-marking.

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- ▶ Mary likes musicals
- ▶ I loath and detest opears
- ▶ I like and would prefer musicals
- ▶ I dislike, and Mary likes, musicals
- ▶ Introduce Bill to Sue and Harry to George
- ▶ I saw Gilbert arrive and George leave

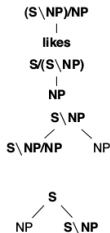


**Lexicon:** $(S \backslash NP) / NP \rightarrow \text{drink}$  $NP \rightarrow I$  $NP \rightarrow \text{coffee}$ **Grammar:** $S \rightarrow NP \ S \backslash NP$  $S \rightarrow S / (S \backslash NP) \ S \backslash NP$  $S \backslash NP \rightarrow (S \backslash NP) / NP \quad NP$  $S \backslash NP \rightarrow (S \backslash NP) / NP \quad (S \backslash NP) \backslash ((S \backslash NP) / NP)$  $S / (S \backslash NP) \rightarrow NP$  $(S \backslash NP) \backslash ((S \backslash NP) / NP) \rightarrow NP$ 

NP S/(S\NP) (S\NP)\((S\NP)/NP)	S/NP	S
	(S\NP)/NP	S\NP
		NP S/(S\NP) (S\NP)\((S\NP)/NP)

## A generative model for CCG

- Given node with category **C**:
  - Is it a **leaf** node?
    - ⇒ Generate **word** **w**:  $P(\mathbf{w} \mid \mathbf{C}, \text{leaf})$
  - Is it a **unary expansion**?
    - ⇒ Generate **head** daughter **H**:  $P(\mathbf{H} \mid \mathbf{C}, \text{unary})$
  - Is it a **binary expansion with head left**?
    - ⇒ Generate **head** daughter **H**:  $P(\mathbf{H} \mid \mathbf{C}, \text{left})$
    - ⇒ Generate **non-head** daughter **D**:  $P(\mathbf{D} \mid \mathbf{C}, \text{left}, \mathbf{H})$
  - Is it a **binary expansion with head right**?
    - ⇒ Generate **head** daughter **H**:  $P(\mathbf{H} \mid \mathbf{C}, \text{right})$
    - ⇒ Generate **non-head** daughter **D**:  $P(\mathbf{D} \mid \mathbf{C}, \text{right}, \mathbf{H})$

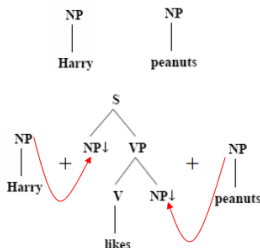


# Tree-adjoining grammar example

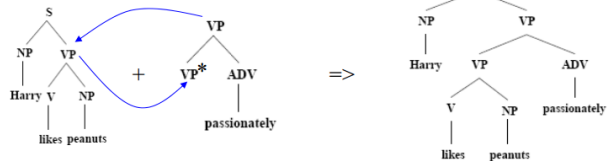
e.g. 'Harry likes peanuts passionately'

TAG G

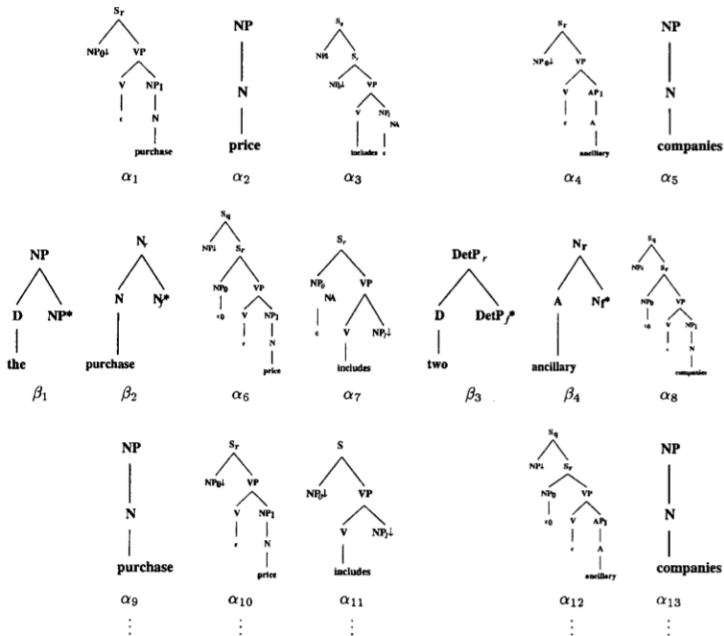
step 1  
substitution



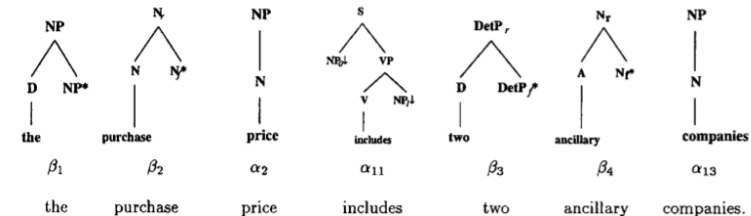
step 2  
adjoining



# Supertagging in LTAG parsing



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Sent:            the   purchase   price   includes   two   ancillary   companies.

Initial		$\alpha_1$	$\alpha_2$	$\alpha_3$		$\alpha_4$	$\alpha_5$
Assignment	$\beta_1$	$\beta_2$	$\alpha_6$	$\alpha_7$	$\beta_3$	$\beta_4$	$\alpha_8$
		$\alpha_9$	$\alpha_{10}$	$\alpha_{11}$		$\alpha_{12}$	$\alpha_{13}$
		$\vdots$	$\vdots$	$\vdots$		$\vdots$	$\vdots$

Final							
Assignment	$\beta_1$	$\beta_2$	$\alpha_2$	$\alpha_{11}$	$\beta_3$	$\beta_4$	$\alpha_{13}$

# Semantics in CCG

- ▶ Forward and backward application correspond to function application.

$$X/Y : f \ Y : a \Rightarrow X : fa \quad (1)$$

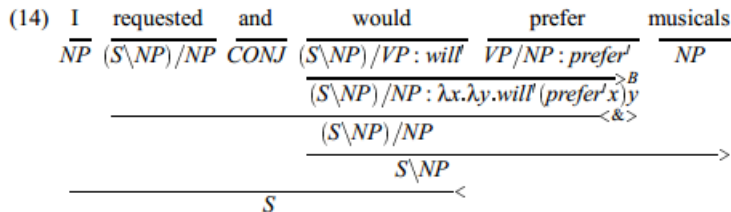
# Semantics in CCG

- Forward and backward application correspond to function application.

$$X/Y : f \quad Y : a \Rightarrow X : fa \quad (1)$$

- Composition corresponds to function composition.

$$X/Y : f \quad Y/Z : g \Rightarrow X/Z : \lambda x.f(gx) \quad (2)$$



# Type-raising semantics

$$NP : a \Rightarrow T / (T \setminus NP) : \lambda f.fa \quad (3)$$

(15) *Subject Type-raising: ( $>T$ )*

$$NP : a \Rightarrow T / (T \setminus NP) : \lambda f.f a$$

(16)

I	dislike	and	Mary	likes	musicals
$\overline{NP}$	$\overline{(S \setminus NP) / NP}$	$\overline{CONJ}$	$\overline{NP}$	$\overline{(S \setminus NP) / NP}$	$\overline{NP}$
			$: mary'$	$: \lambda x.\lambda y.like' xy$	
$\overline{S / (S \setminus NP)}^{>T}$			$\overline{S / (S \setminus NP)}^{>T}$		
			$: \lambda f.f mary'$		
$\overline{S / NP}^{>B}$			$\overline{S / NP}^{>B}$		
			$: \lambda x.like' x mary'$		
$\overline{S / NP}^{<\&>}$					
$\overline{S}^{>}$					