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 hälfe aastriiche

The relationship between verbs and their objects is signaled by order and case-marking (Shieber 1985).

CCG Examples

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CCG Examples

- 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\NP)/NP → drink

NP → I

NP → coffee

Grammar:

S → NP S\NP

S → S/(S\NP) S\NP

S\NP → (S\NP)/NP NP

S\NP → (S\NP)/NP (S\NP)\((S\NP)/NP)

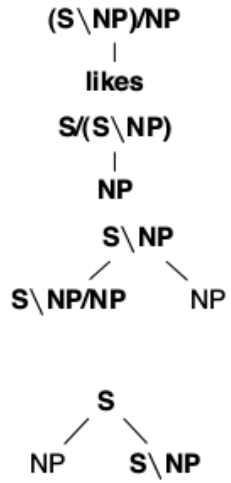
S/(S\NP) → NP

(S\NP)\((S\NP)/NP) → 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)**

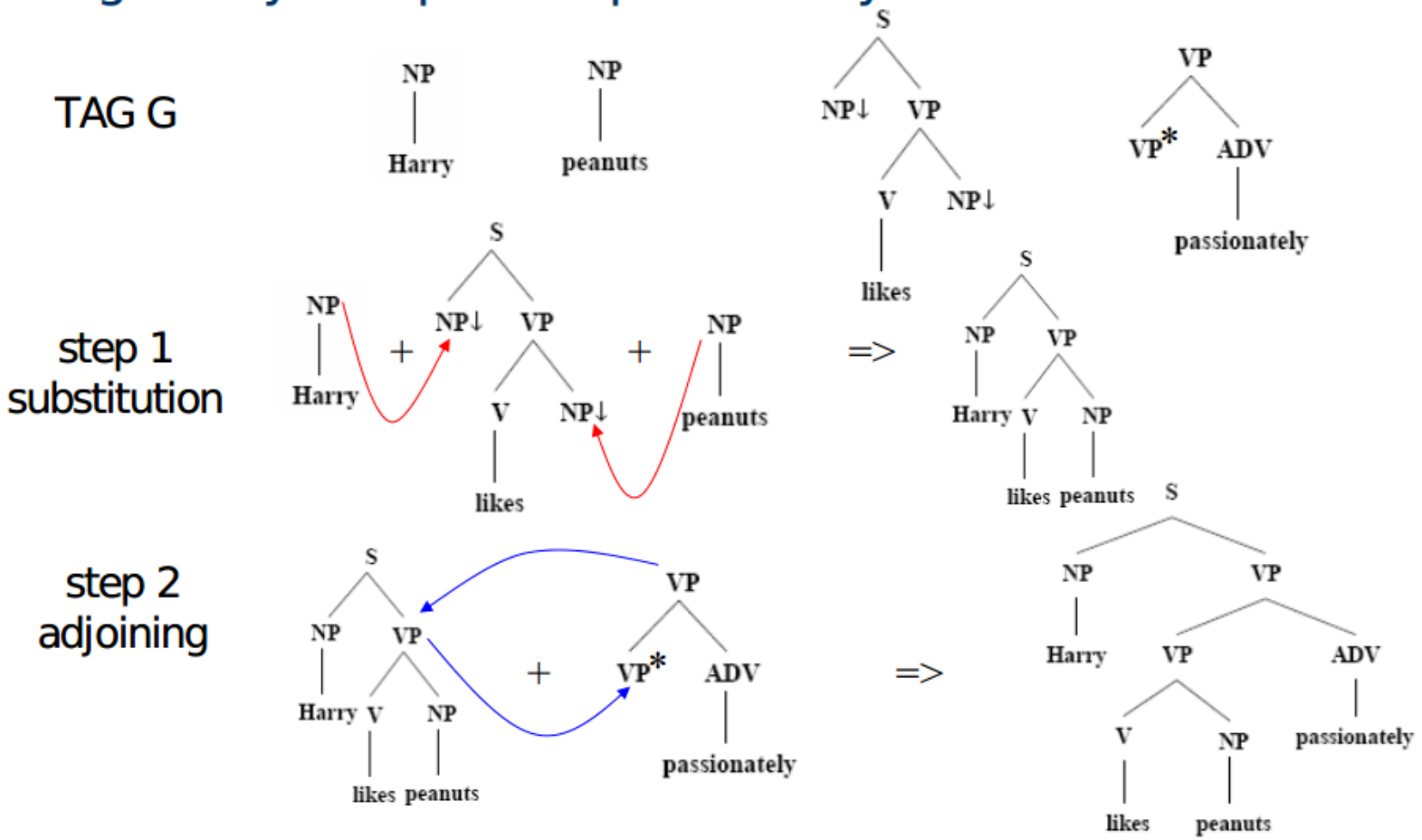
A generative model for CCG

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

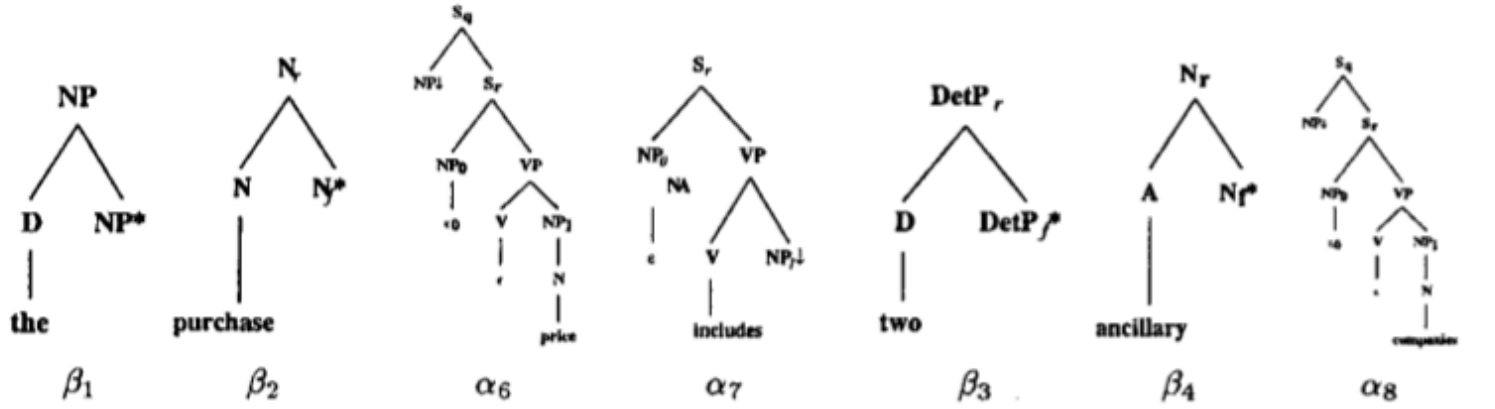


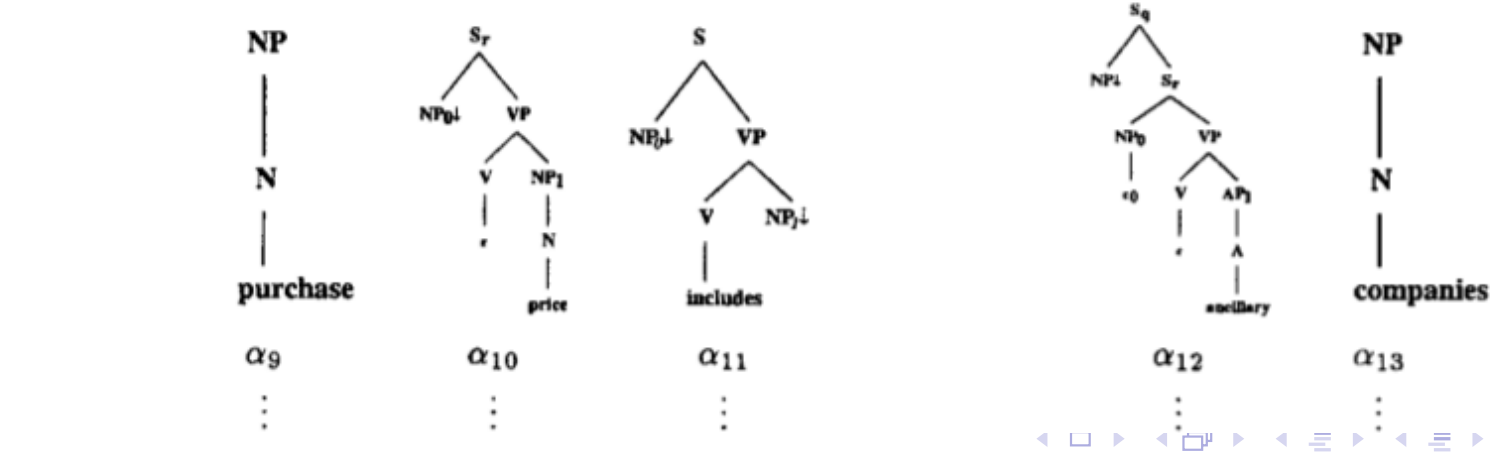
Tree-adjoining grammar example

e.g. 'Harry likes peanuts passionately'



Supertagging in LTAG parsing





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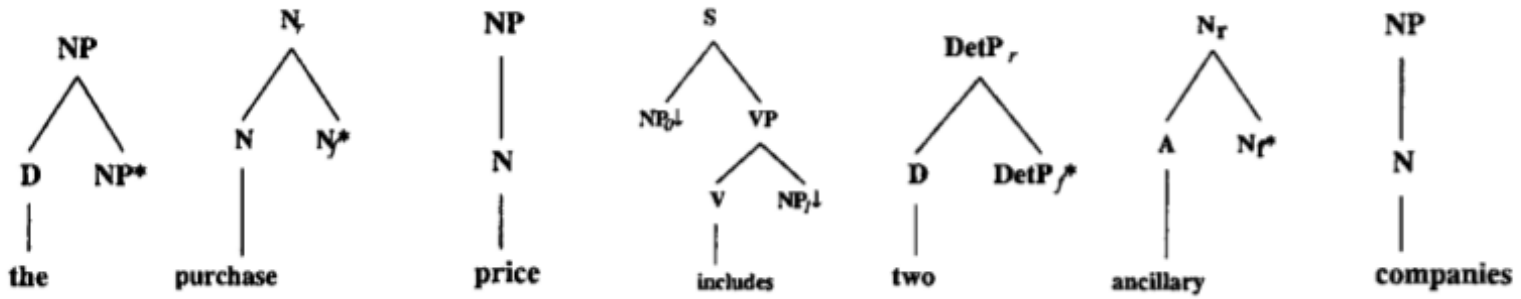

Sent:	the	purchase	price	includes	two	ancillary	companies.
Initial Assignment	β_1	α_1 β_2 α_9 ⋮	α_2 α_6 α_{10} ⋮	α_3 α_7 α_{11} ⋮	β_3	α_4 β_4 α_{12} ⋮	α_5 α_8 α_{13} ⋮
Final Assignment	β_1	β_2	α_2	α_{11}	β_3	β_4	α_{13}

Semantics in CCG

- Forward and backward application correspond to function application.

$$X/Y : f \;\; Y : a \Rightarrow X : fa \tag{1}$$

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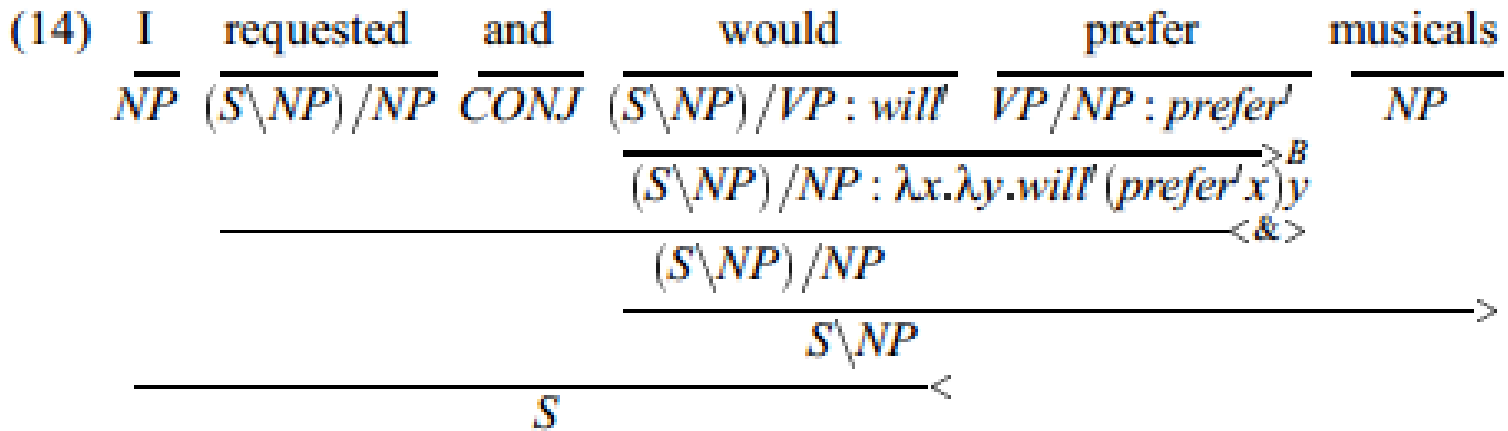
- Composition corresponds to function composition.

$$X/Y : fY/Z : g \Rightarrow X/Z : \lambda x.f(gx) \tag{2}$$



Type-raising semantics

$$NP : a \Rightarrow T/(T\backslash NP) : \lambda f.fa \tag{3}$$

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

$$NP : a \quad \Rightarrow \quad \mathrm{T}/(\mathrm{T}\backslash NP) : \lambda f.f\ a$$

(16)