Parsing Adjuncts

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Overview

- What is an adjunct?
- Two existing models of adjunction
  - Traditional Minimalist Grammar
  - "Syntactic Cartography"
- My model (Minimalist Grammars with Adjunction)
- CKY-like parsing of MGs
- CKY-like parsing of MGAs

Properties of adjuncts to be captured

(1)

a. The (bad) wolf — *optional*

b. The bad wolf — *transparent to selection*

c. The big bad wolf

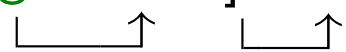
d. *The bad big wolf — *strictly ordered*

e. The Alliance officer shot Kaylee in the cargo hold with a gun

f. The Alliance officer shot Kaylee with a gun in the cargo hold

Unordered

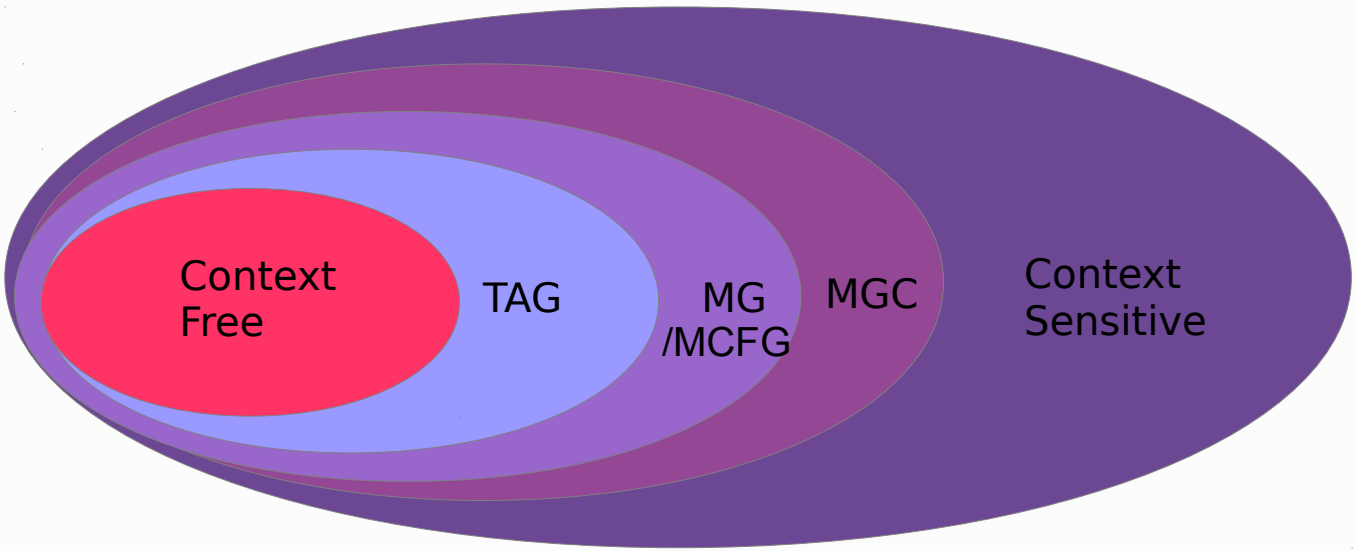
g. [bright blue] balloon — *Adjuncts of adjuncts*



h. Kaylee is clever. — *Selectable*

Minimalist Grammars

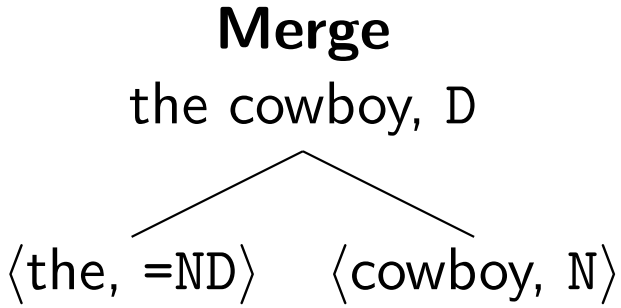
MGs (Stabler, 1997) are weakly and strongly equivalent to Multiple Context Free Grammars, putting them in the right general place for human languages



Minimalist Grammars (Stabler, 1997)

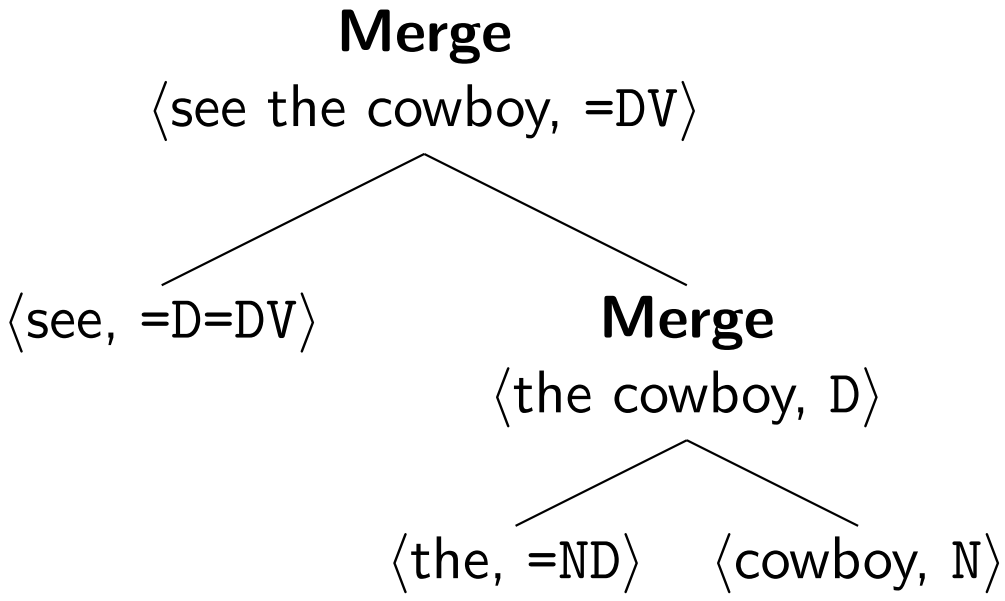
- Features on Lexical Items drive the derivation via **Merge** and **Move**
- **Features**: **sel** (for **Merge**): =X (positive), X (negative)

Example: Merge



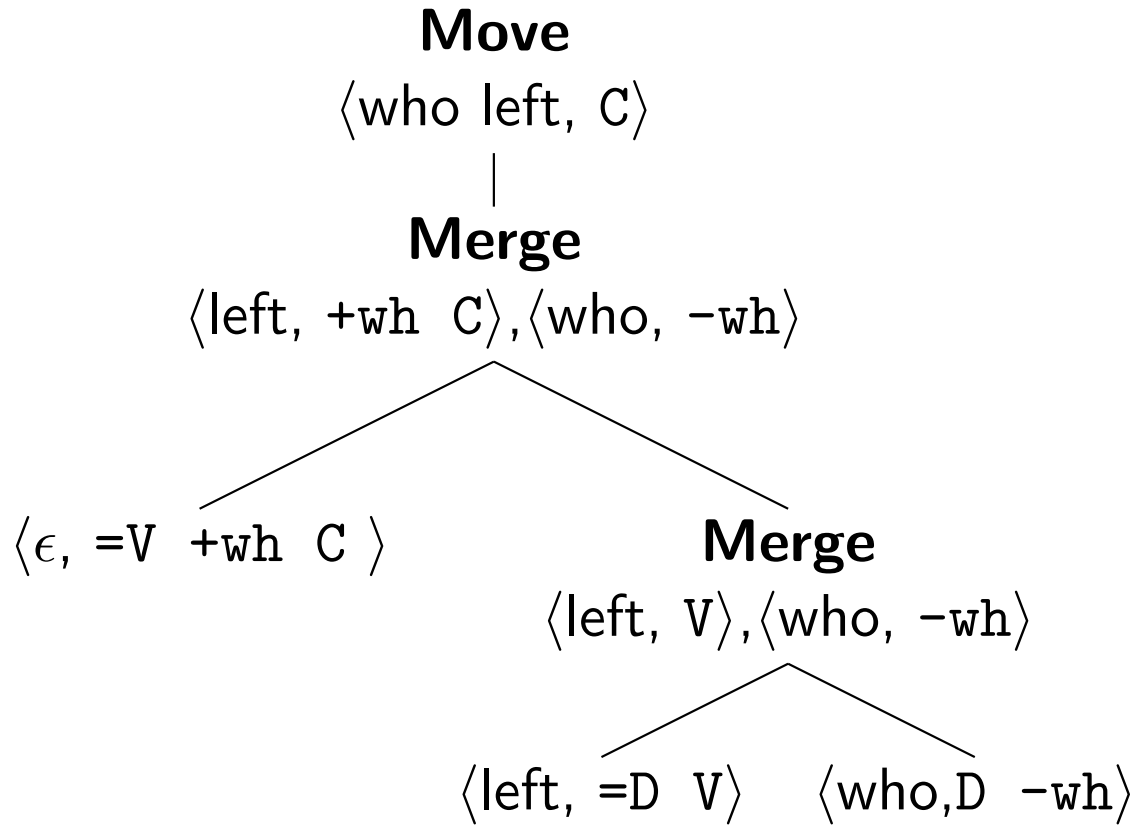
Minimalist Grammars (Stabler, 1997)

Example: Merge



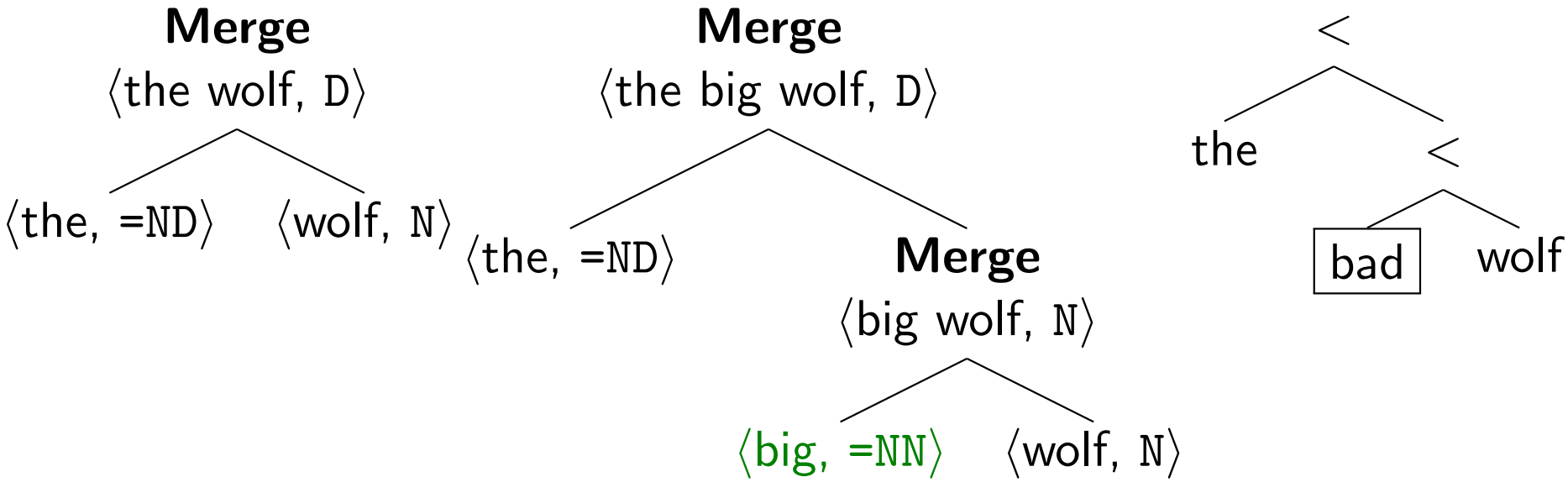
Minimalist Grammars (Stabler, 1997)

Example: Move



Traditional MG/Categorial Grammar approach

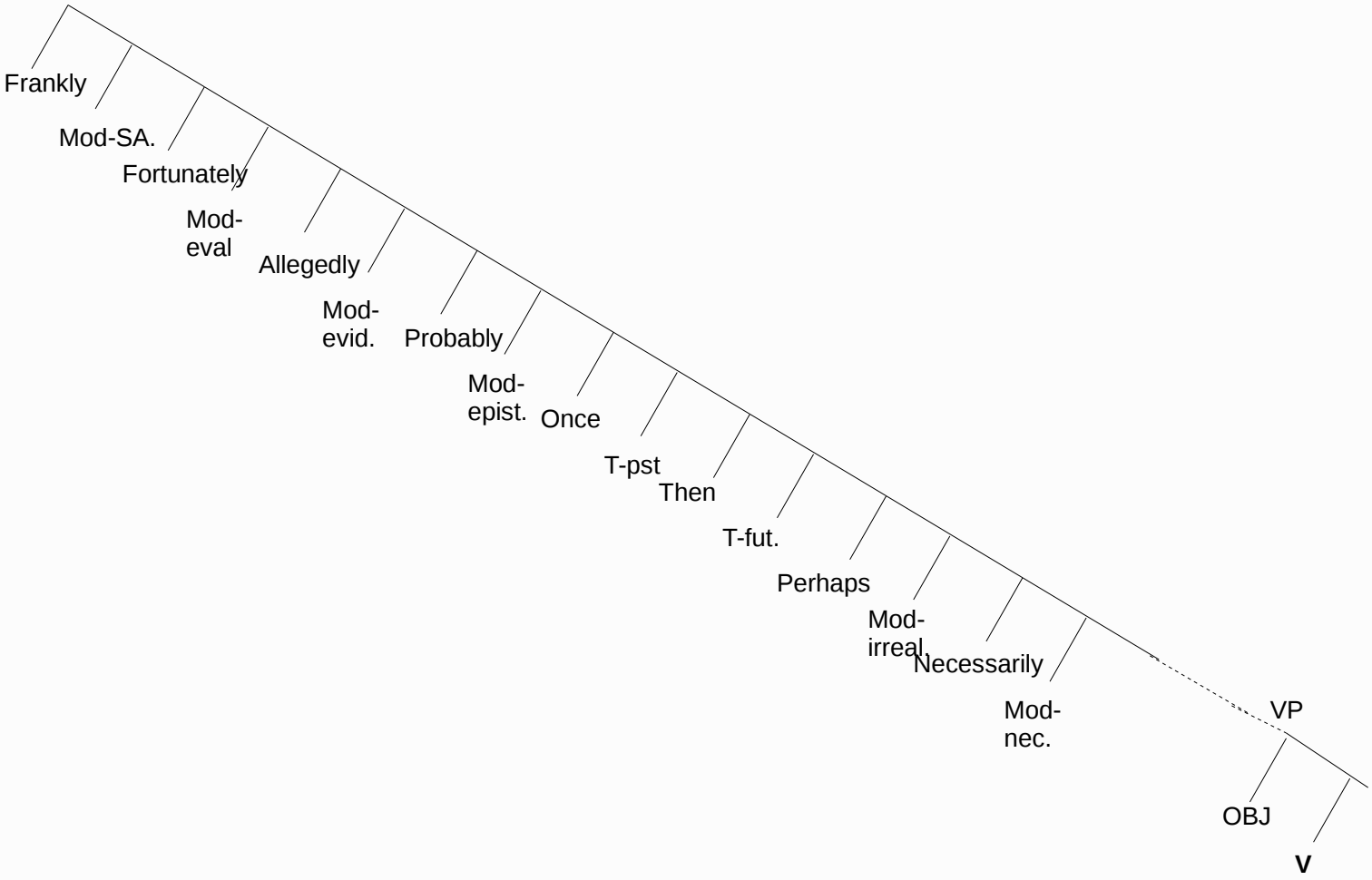
- X-Modifier features: (Categorial Grammar: X/X or X\ X) =XX; Verbal modifier: =VV; Nominal modifier: =NN etc.
- ✓Optionality
- ✗ Ordering
- ✗ Transparent to selection



Traditional MG/Categorial Grammar approach

	Trad. (=XX)	Cart. (=A_5A_6)	MGAs ([X,i,j])
Optionality	✓		
Selector selects expected category	✓		
Adjunct does not become head	✗		
Unordered adjuncts possible	✓		
Ordered adjuncts possible	✗		
Adjuncts of adjuncts	✗		
Selectability	✗		

Cartography: adverbs

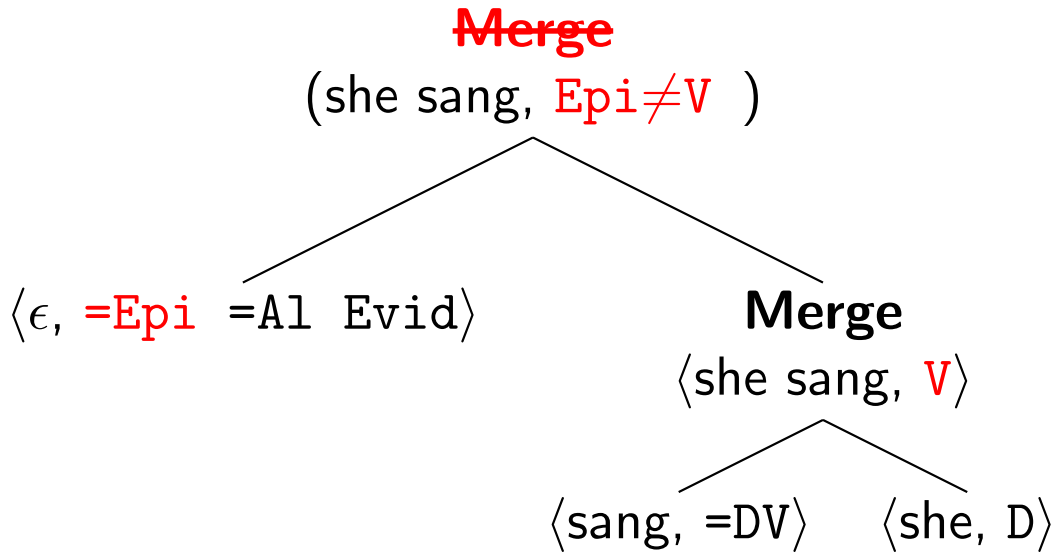


Problem

Allegedly, she sang

Lexicon:

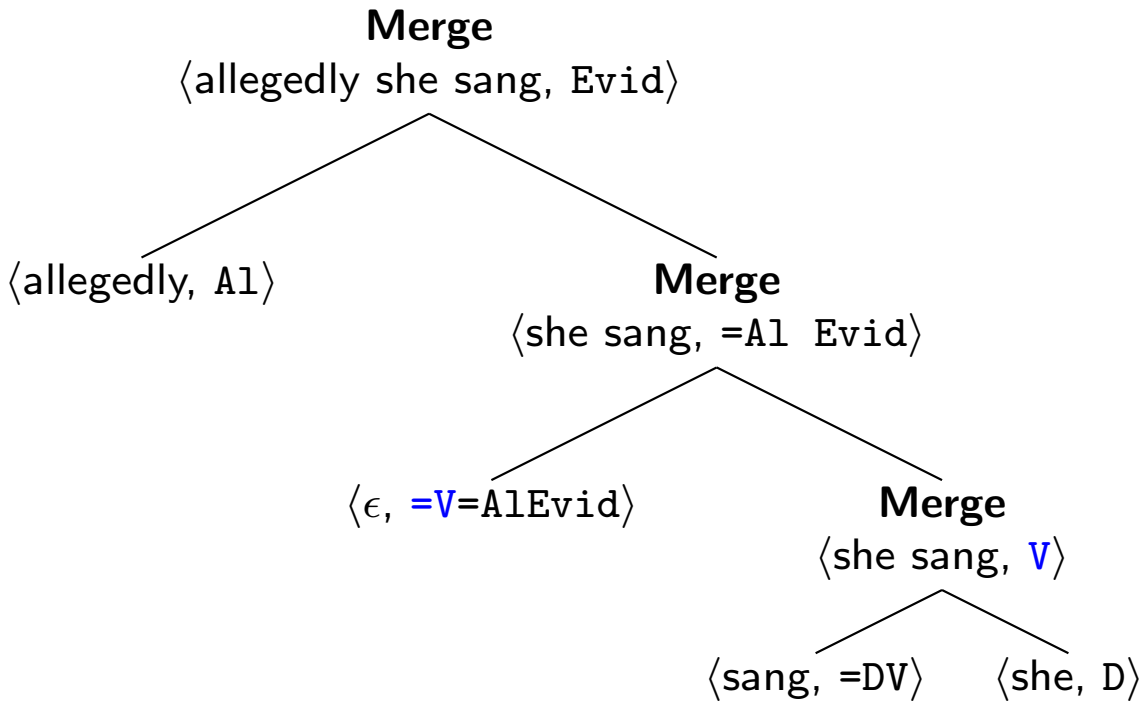
- (Allegedly, Al)
- (ϵ, =Epi =Al Evid)
- (probably, Pr)
- (ϵ, $=T_{pst}$ =Pr T_{fut})
- ...
- (ϵ, =V =Compl Asp_{compl})
- (she, D)
- (sang, =D V)



Solution 1: multiplication of the lexicon

Lexicon:

- (Allegedly, `Al`)
- (ϵ, `=Epi =Al Evid`)
- (ϵ, `=T`$_{\texttt{pst}}$ `=Al Evid`)
- (ϵ, `=T`$_{\texttt{fut}}$ `=Al Evid`)
- (ϵ, `=Per =Al Evid`)
- (ϵ, `=Nec =Al Evid`)
- (ϵ, `=Pos =Al Evid`)
- ...about 20 more...
- (ϵ, `=V =Al Evid`)
- (she, `D`)
- (sang, `=D V`)



Solution 2: silent, meaningless LIs

Lexicon:

- (allegedly, ⟦allegedly⟧, Al)
- (ϵ, ⟦evid⟧, =Epi =Al Evid)
- (ϵ, **id**, =Epi Evid)
- (ϵ, ⟦prob⟧, $=T_{pst}$=Prob Epi)
- (ϵ, **id**, $=T_{pst}$Epi)
- (ϵ, ⟦past⟧, $=T_{fut}T_{pst}$)
- (ϵ, **id**, $=T_{fut}T_{pst}$)
- ...
- (ϵ, ⟦compl⟧, =V=Compl Asp_{Compl})
- (ϵ, **id**, =V Asp_{Compl})
- (she, D)
- (sang, =D V)

Cartography – Properties

	Trad. (=XX)	Cart. (=A_5A_6)	MGAs ([X,i,j])
Optionality	✓	✗	
Selector selects expected category	✓	✗	
Adjunct does not become head	✗	✗	
Unordered adjuncts possible	✓	✗	
Ordered adjuncts possible	✗	✓	
Adjuncts of adjuncts	✗	✗	
Selectability	✗	✗	

Cartography: summary

If we want to keep:

- Merge driven by features
- Adjunct ordering is syntactic
- Just Merge and Move

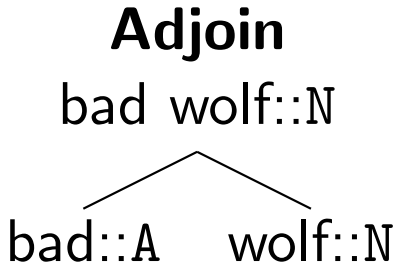
Then we need either:

- Lots of versions of each functional head (or adjunct) OR
- Silent, meaningless, non-specifier-selecting versions of each functional head, yielding a full Cinque hierarchy in every sentence

Minimalist Grammars with Adjunction (MGAs)

Proposal

Adjoin is optional $\rightarrow$ Add an optional operation **Adjoin** that applies to full phrases. Resulting phrase has the category of the adjoined-to phrase.



MGAs

Wait! Adjunction doesn't occur between just any to phrases $\rightarrow$ add to the grammar a set of adjuncts for each category

$\textbf{Ad} : \textbf{sel} \rightarrow \mathcal{P}(\textbf{sel})$

eg $\textbf{Ad}(\texttt{N}) = \{\texttt{A}, \texttt{P}, \texttt{C}\}$

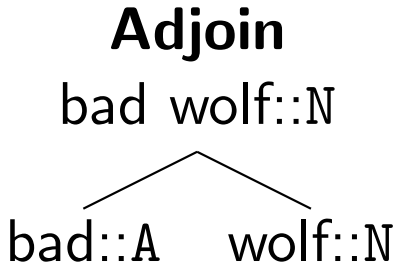
MGAs

Merge $s\cdot{=}\mathtt{X}\alpha \quad t\cdot\mathtt{Y}\beta$ iff $\mathtt{X} = \mathtt{Y}$

Move $s : {+}\mathtt{f}\alpha \quad t : {-}\mathtt{g}\beta$ iff $\mathtt{f} = \mathtt{g}$

Adjoin $s\cdot\mathtt{X}\alpha \quad t\cdot\mathtt{Y}\beta$ iff $\mathtt{Y} \in \textbf{Ad}(\mathtt{X})$

MGAs



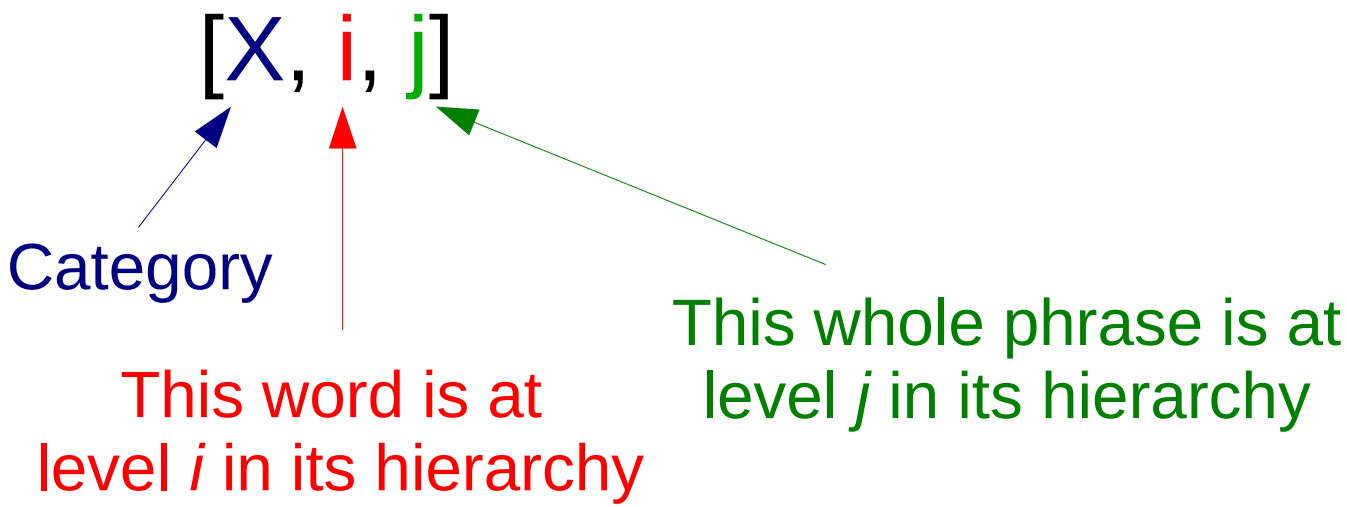
- Optional
- Category-preserving
- Applies to complete phrases
- Specifies which phrases can adjoin to which phrases
- Adjuncts have their own categories ($\rightarrow$ selectable, adjoin-able, intuitive)

MGAs

Wait! What about adjunct ordering?

Add indicies to track hierarchy level of most recent adjunct.

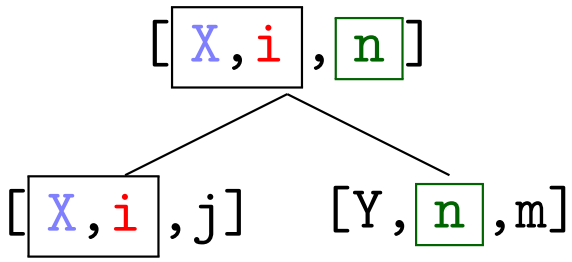
Categories

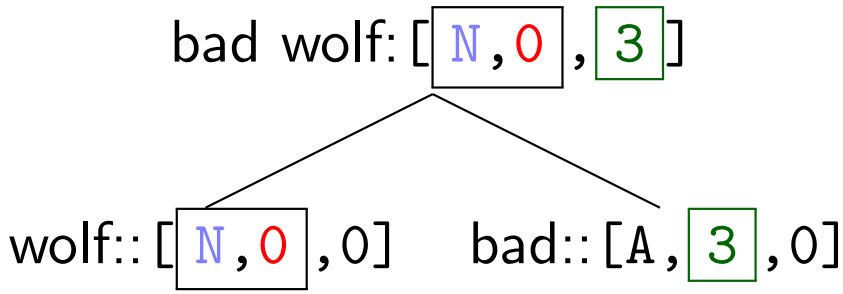


big::A →big::[A,5,0]

bad::A →bad::[A,3,0]]

Example





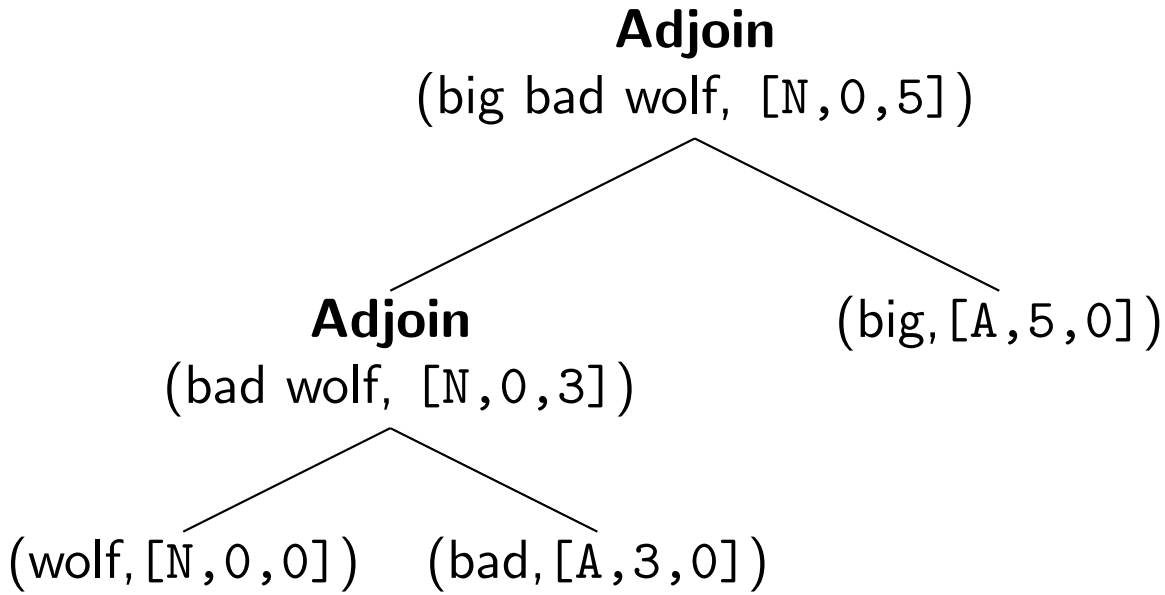
Adjoin example

big bad wolf

ad(N) = {A, P, C}

Lexicon:

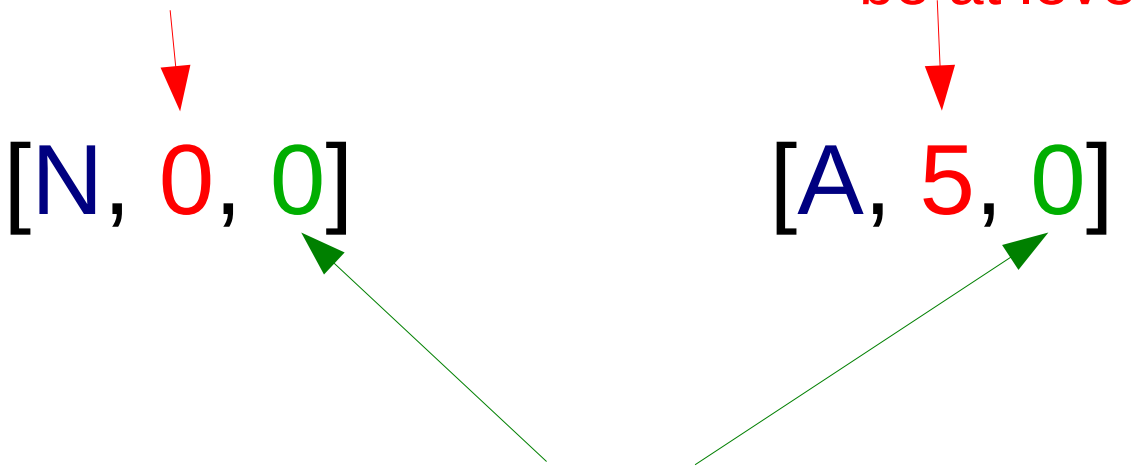
- ⟨bad, [A,3,0]⟩
- ⟨big, [A,5,0]⟩
- ⟨the, =N[D,0,0]⟩
- ⟨wolf, [N,0,0]⟩



Adjoin

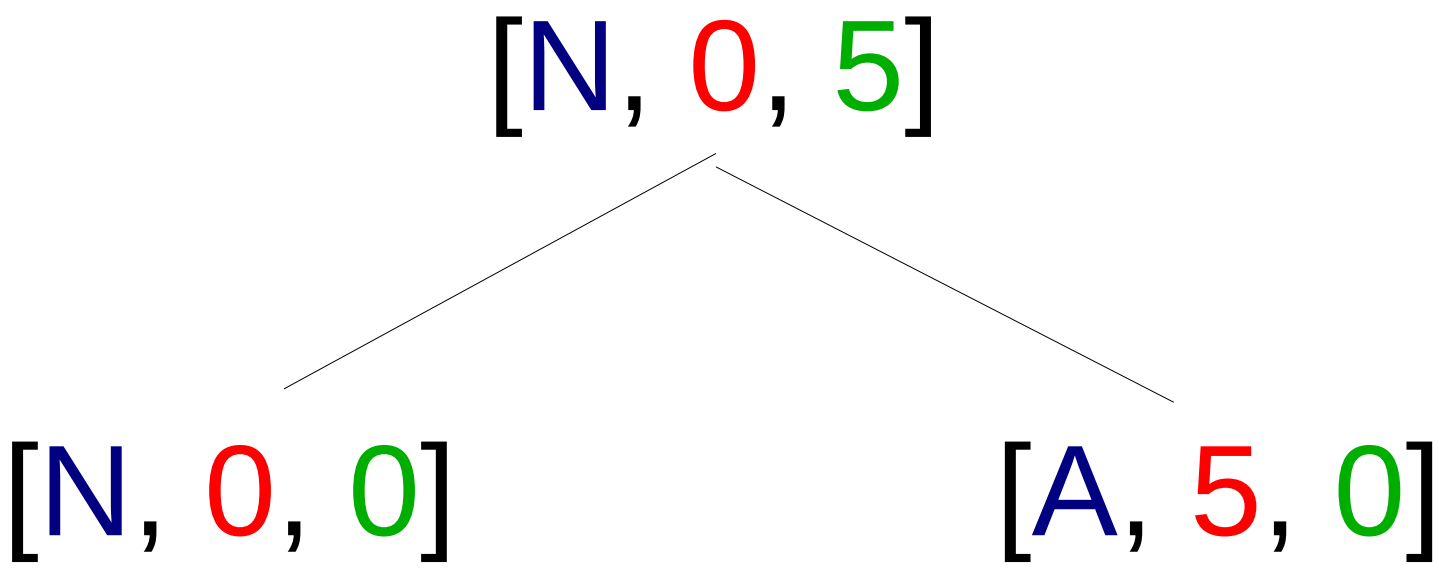
If NP adjoins to some XP, XP must be at level 0, and the resulting XP will remain at level 0

When AP adjoins to NP, NP must be at level 5 or lower, and the resulting NP will be at level 5



NP and AP are at level 0
so any adjunct may adjoin to them

Adjoin



if $\mathtt{A} \in \mathbf{Ad}(\mathtt{N})$

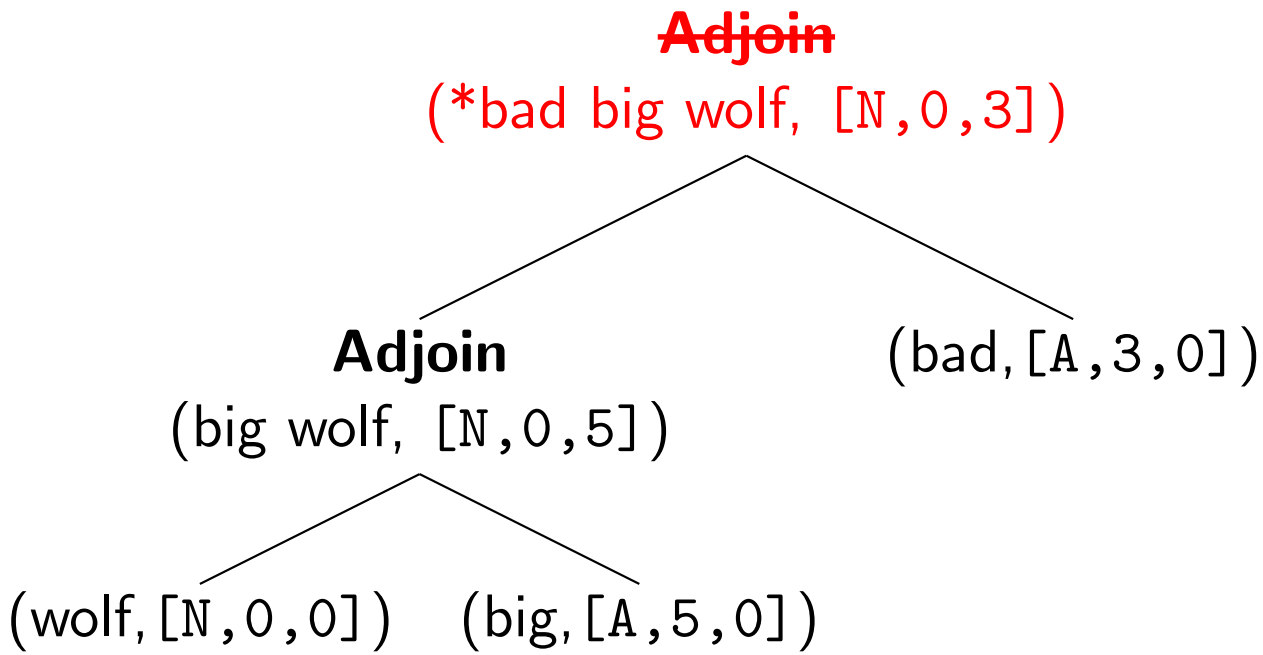
Failed example: bad adjunct order

*The bad big wolf

$\textbf{ad}(\texttt{N}) = \{\texttt{A}, \texttt{P}, \texttt{C}\}$

Lexicon:

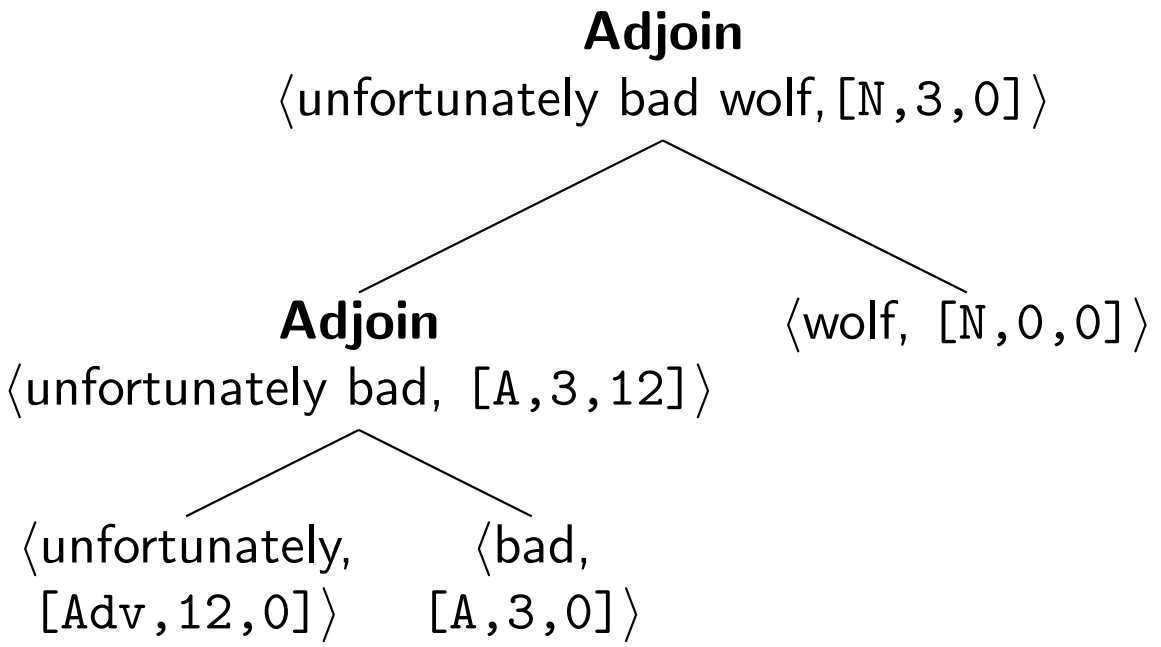
- ⟨bad, [A,3,0]⟩,
- ⟨big, [A,5,0]⟩,
- ⟨the, =N[D,0,0]⟩,
- ⟨wolf, [N,0,0]⟩,



Adjuncts of adjuncts

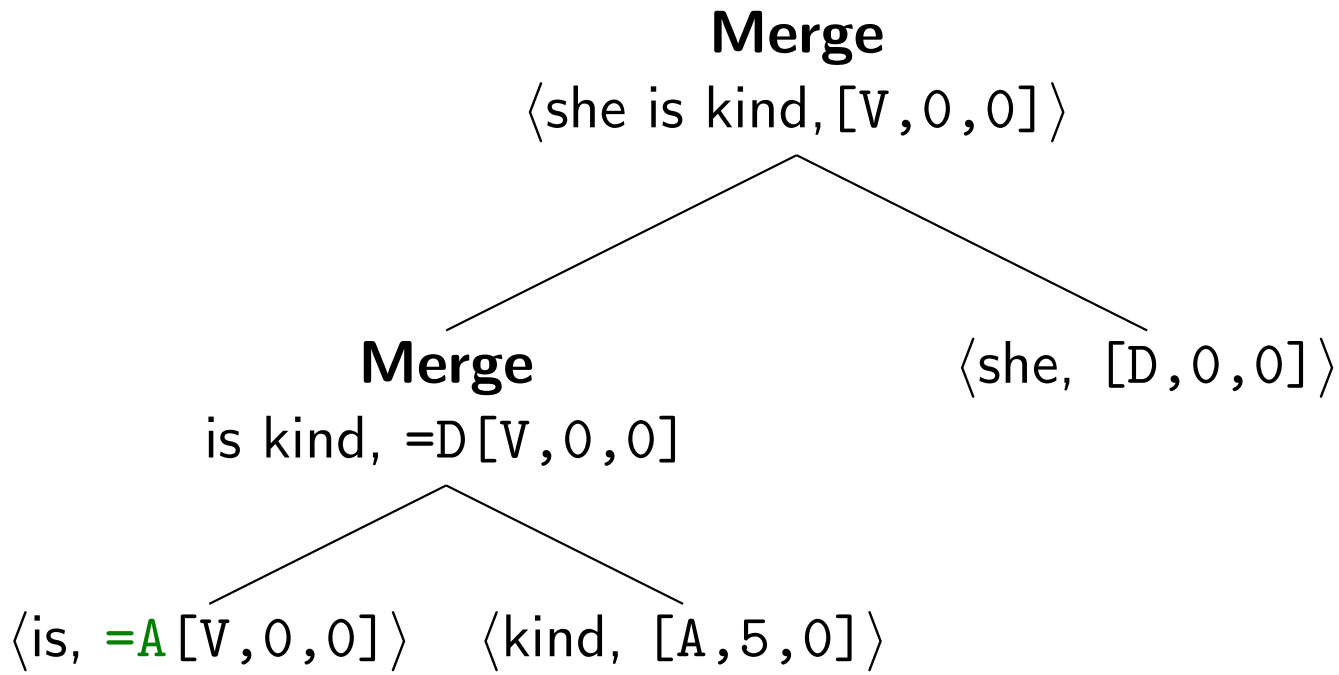
ad(N) = {A, P, C}
ad(V) = {Adv, P, C}
ad(A) = {Adv}

- ⟨frankly, [Adv, 12, 0]⟩
- ⟨unfortunately, [Adv, 11, 0]⟩
- ⟨allegedly, [Adv, 10, 0]⟩
- ⟨bad, [A, 3, 0]⟩
- ⟨wolf, [N, 0, 0]⟩



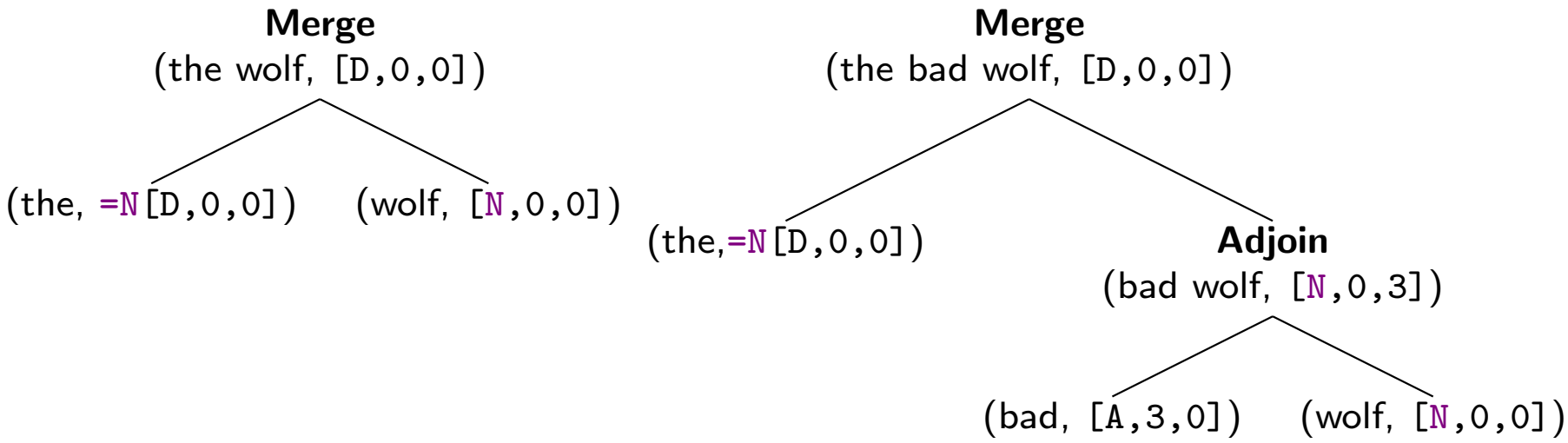
Selecting adjuncts

She is kind



MGA – properties

Optional
Transparent to selection



Comparison

	Trad. (=XX)	Cart. (=A_5A_6)	MGAs ([X,i,j])
Optionality	✓	✗	✓
Selector selects expected category	✓	✗	✓
Adjunct does not become head	✗	✗	✓
Unordered adjuncts possible	✓	✗	✓
Ordered adjuncts possible	✗	✓	(✓)
Adjuncts of adjuncts	✗	✗	✓
Selectability	✗	✗	✓

MGA – formal properties

- Not strongly equivalent to traditional MGs: has an extra function
- Weakly equivalent to traditional MGs
- **Proof outline:**
  - $L(MG) \subseteq L(MGA)$ since you can just take out **Adjoin** and remove the indicies, and you're left with an MG
  - $L(MG) \subseteq L(MCFG) = L(MGA)$:
    - Convert each featural instance of Adjoin and Merge to a set of Multiple Context Free rules

MGA – weak equivalence to MGs

Merge$(\langle s, =\mathtt{X}\alpha\rangle :: \text{mvrs}_s, \langle t, [\mathtt{X}, \mathtt{m}, \mathtt{n}]\rangle :: \text{mvrs}_t) = \langle st, \alpha\rangle :: \text{mvrs}_s \cdot \text{mvrs}_t$

$\text{mvrs}_1 = \langle\langle s_1, \delta_1\rangle, \langle s_2, \delta_2\rangle, \ldots, \langle s_i, \delta_i\rangle\rangle$
$\text{mvrs}_2 = \langle\langle t_1, \gamma_1\rangle, \langle t_2, \gamma_2\rangle, \ldots, \langle t_j, \gamma_j\rangle\rangle$

$\langle \alpha, \delta_1, ..., \delta_i, \gamma_1, ...\gamma_j\rangle(st, s_1, ..., s_i, t_1, ..., t_j)$

:- $\langle = \mathtt{X}\alpha, \delta_1, ..., \delta_i\rangle(s, s_1, ..., s_i)\ \langle[\mathtt{X}, \mathtt{m}, \mathtt{n}], \gamma_1, ...\gamma_j\rangle(t, t_1, ..., t_j)$

$\forall \mathtt{X} \in \textbf{sel}$,
$\forall \alpha, \in \mathit{Suf}(\mathit{Lex})$,
$\forall \delta_1, \ldots, \delta_i, \gamma_1, \ldots, \gamma_j \in \mathit{Suf}(\mathit{Lex}) \cap -\mathit{lic}^*$,
$\forall \mathtt{n}, \mathtt{m} \leq h$
for h the maximal hierarchy depth in the grammar

MGA – weak equivalence to MGs

Adjoin-and-stay rules:

$$\forall \mathtt{X}, \mathtt{Y} \in \textbf{sel} \;\; s.t. \;\; \mathtt{Y} \in \textbf{Ad}(\mathtt{X}), \forall \mathtt{k}, \mathtt{l}, \mathtt{n}, \mathtt{m} \leq h \;\; s.t. \;\; \mathtt{n} \geq \mathtt{k}$$
$$\langle [\mathtt{X}, \mathtt{m}, \mathtt{n}], \delta_1, ..., \delta_i, \gamma_1, ...\gamma_j \rangle (s_0 t_0, s_1, ..., s_i, t_1, ..., t_j)$$
$$\text{:-} \; \langle [\mathtt{X}, \mathtt{m}, \mathtt{k}], \delta_1, ..., \delta_i \rangle (s_0, ..., s_i) \; \langle [\mathtt{Y}, \mathtt{n}, \mathtt{l}], \gamma_1, ...\gamma_j \rangle (t_0, ..., t_j)$$

Adjoin-and-move rules:

$$\forall \mathtt{X}, \mathtt{Y} \in \textbf{sel} \;\; s.t. \;\; \mathtt{Y} \in \textbf{Ad}(\mathtt{X}), \forall \mathtt{k}, \mathtt{l}, \mathtt{n}, \mathtt{m} \leq h \;\; s.t. \;\; \mathtt{n} \geq \mathtt{k}$$
$$\langle [\mathtt{X}, \mathtt{m}, \mathtt{n}], \beta, \delta_1, ..., \delta_i, \gamma_1, ...\gamma_j \rangle (s_0, t_0, s_1, ..., s_i, t_1, ..., t_j)$$
$$\text{:-} \; \langle [\mathtt{X}, \mathtt{m}, \mathtt{k}], \delta_1, ..., \delta_i \rangle (s_0, ..., s_i) \; \langle [\mathtt{Y}, \mathtt{n}, \mathtt{l}] \beta, \gamma_1, ...\gamma_j \rangle (t_0, ..., t_j)$$

Interim Summary

- MGAs capture linguistic properties of adjuncts
- Generate same sentences as an MG, but more efficiently, capturing more generalisations
- Can be expanded to capture unordered adjuncts, functional heads, and obligatory adjuncts

CKY recogniser for CFGs

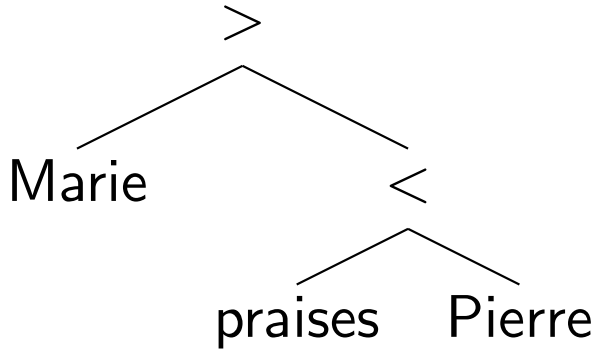
- S→DP VP
- DP→D N
- D→the
- N→cat
- VP→slept

(2) $_0$ the $_1$ cat $_2$ slept $_3$

	0	1	2	3
0		D	DP	S
1			N	
2				VP
3				

CKY parsing of MGs (Harkema, 2001)

Marie::D
Pierre::D
praises::=D=DV



$_0$ Marie $_1$ praises $_2$ Pierre $_3$

	0	1	2	3
0		$_L$ D		V
1			$_L$ =D=DV	=DV
2				$_L$ D
3				

CKY parsing of MGs

Marie::D-nom
Pierre::D
praises::=D=DV
ϵ::=V+nomT

$_0$ Marie $_1$ praises $_2$ Pierre $_3$

	0	1	2	3
0	$_L$=V+nomT	$_L$D-nom		T
1		$_L$=V+nomT	$_L$=D=DV	=DV V;(0,1):-nom +nomT;(0,1):-nom
2			$_L$=V+nomT	$_L$D
3				$_L$=V+nomT

CKY parsing of MGAs

the::=N[D,0,0] wolf::[N,0,0] big::[A,5,0] bad::[A,3,0]

$_0$ the $_1$ big $_2$ bad $_3$ wolf $_4$

	0	1	2	3	4
0		$_L$=N[D,8,8]			[D,0,0]
1			$_L$[A,5,0]		[N,0,5]
2				$_L$[A,3,0]	[N,0,3]
3					$_L$[N,0,0]
4					

CKY parsing of MGAs

When you have a `[X,i,j]`α,

- Look to the right for something to adjoin to, `Y`. Check **Ad**(`Y`) and indicies.
- Look left for adjunct. Check **Ad**(`X`) and indicies.
- Look anywhere for moving adjunct. Check **Ad**(`X`) and indicies. Keep mover just like with Merge.

Conclusions

- To preserve both traditional observations of adjuncts (optionality etc) and modern observations (ordering) I propose a new function, Adjoin, that applies optionally, restricted by both adjunct categories and hierarchy
- MGAs are weakly equivalent to MGs
- MGAs can be (fairly efficiently) parsed with a CKY-like chart parser

References

Aho, Alfred V, and Jeffrey D Ullman. 1972. *The theory of parsing, translation, and compiling*. Prentice-Hall, Inc.

Cinque, Gugliemo. 1999. *Adverbs and functional heads: a cross-linguistic perspective*. Oxford studies in comparative syntax. Oxford: Oxford University Press.

Harkema, Hendrik. 2001. Parsing minimalist languages. Doctoral Dissertation, Citeseer.

Shieber, Stuart M, Yves Schabes, and Fernando CN Pereira. 1995. Principles and implementation of deductive parsing. *The Journal of logic programming* 24:3–36.

Sportiche, Dominique. 2005. Division of labor between merge and move: Strict locality of selection and apparent reconstruction paradoxes. *LingBuzz* .

Stabler, Edward. 1997. Derivational minimalism. *Logical Aspects of Computational Linguistics* 68–95.

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- UCLA linguistics department
- Thomas Graf, Kathleen O'Flynn, Floris van Vugt, Jesse Zymet, Lisa Travis

Cartography: default adjunct orders

- Using the same architecture, how can we capture ordering?

(3) a. Wear the enormous ugly green hat
Wear the hat that is enormous, ugly, and green
b. #Wear the ugly enormous green hat
Of your enormous green hats, wear the ugly one.

Cartography (Cinque, 1999)

(4)

a. The small ancient triangular green Irish pagan metal artifact was lost.

b. *The metal green small artifact was lost. **Adjectives**

c. Frankly, John probably once usually arrived early.

d. *Usually, John early frankly once arrived probably. **Adverbs**

e. [Il premio Nobel]$_{\text{top}}$, [a chi]$_{\text{wh}}$ lo daranno?
[the prize Nobel]$_{\text{top}}$, [to whom]$_{\text{wh}}$ it give.fut
'The Nobel Prize, to whom will they give it?' **Left periphery**

f. DP zhe [NumP yi [ClP zhi [NP bi]]]
DP this [NumP one [ClP Cl [NP pen]]]
'this pen' **Functional DP projections**

Adjoin: formal definition

Definition (Adjoin)

Let $s, t \in \Sigma$ be strings, $\mathtt{Y}, \mathtt{X} \in$ **sel** be categories, $i, j, n, m \in \mathbb{N}$, $mvrs \in (\Sigma^* \times F)^*$ be a mover list, and $\alpha, \beta \in F^*$.

$$\textbf{Adjoin}(\langle s, [\mathtt{X}, \mathtt{i}, \mathtt{j}]\alpha :: mvrs\rangle, \langle t, [\mathtt{Y}, \mathtt{n}, \mathtt{m}]\beta\rangle) =$$
$$\begin{cases} \langle ts, [\mathtt{X}, \mathtt{i}, \mathtt{n}]\alpha\rangle :: mvrs & \text{if } \mathtt{n} \geq \mathtt{j} \;\&\; \mathtt{Y} \in \textbf{Ad}(\mathtt{X}) \;\&\; \beta = \epsilon \\ \langle s, [\mathtt{X}, \mathtt{i}, \mathtt{n}]\alpha\rangle :: \langle t, \beta\rangle :: mvrs & \text{if } \mathtt{n} \geq \mathtt{j} \;\&\; \mathtt{Y} \in \textbf{Ad}(\mathtt{X}) \;\&\; \beta \neq \epsilon \end{cases}$$

Merge: new formal definition

Definition (Merge)

For $\alpha, \beta \in F^*$; s, t strings:
Merge$(\langle s, =\mathtt{X}\alpha\rangle :: \text{mvrs}_s, \langle t, [\mathtt{X}, \mathtt{i}, \mathtt{j}]\beta\rangle :: \text{mvrs}_t) =$

$$\begin{cases} \langle st, \alpha\rangle :: \text{mvrs}_s \cdot \text{mvrs}_t & \text{if } \beta = \epsilon \\ \langle s, \alpha\rangle :: \langle t, \beta\rangle :: \text{mvrs}_s \cdot \text{mvrs}_t & \text{if } \beta \neq \epsilon \end{cases}$$

Context Free CKY recogniser

- S→DP VP
- DP→D N
- D→the, every
- N→cat, dog
- VP→slept, V DP
- V→saw

(5) $_0$ the $_1$ cat $_2$ slept $_3$

	1	2	3
0	D	DP	S
1		N	
2			VP

CKY

- Cocke, Kasami, and Younger
- aka CYK parsing
- a type of chart parsing
- sound and complete (Shieber et al., 1995)
- for sentence length n, maximum number of steps is proportional to n^3 (Aho and Ullman, 1972)
- Efficient enough? Disagreement in the literature.

CKY

For string $s = w_0 w_1 ... w_n$ and for $i, j, k \leq n$, we use the following rules:

- $(i-1, i) : w_i$ (AXIOMS)
- $\frac{(i,j) : w}{(i,j) \ : \ A}$(REDUCE1) if A→w
- $\frac{(i,j) : B \quad (j,k) : C}{(i,k) \ : \ A}$(REDUCE2) if A→B C

$s \in L$ iff the closure of the axioms under the inference rules is $(0, n) : S$

CKY

- Fill in the chart in every way possible
- Top right corner has start category: grammatical
- relative efficiency comes from the fact that ambiguities get merged whereever possible

CKY parsing of MGs

$$\frac{}{(i,j) :: \gamma} \text{ for each } w \in [i,j] \text{ s.t. } w :: \gamma$$

$$\frac{(i,j) :: =\mathtt{X}\gamma \qquad (j,k) \cdot \mathtt{X}; mvr_1; \ldots; mvr_n}{(i,k) : \gamma; mvr_1; \ldots; mvr_n} (\textsc{merge1})$$

$$\frac{(j,k) : =\mathtt{X}\gamma; mvr_{11}; \ldots; mvr_{1n} \qquad (i,j) \cdot \mathtt{X}; mvr_{21}; \ldots; mvr_{2m}}{(i,k) : \gamma; ; mvr_{11}; \ldots; mvr_{1n}; mvr_{21}; \ldots; mvr_{2m}} (\textsc{merge2})$$

$$\frac{(i,j) \cdot =\mathtt{X}\gamma; mvr_{11}; \ldots; mvr_{1n} \qquad (k,l) \cdot \mathtt{X}\beta; mvr_{21}; \ldots; mvr_{2m}}{(i,j) : \gamma; ; mvr_{11}; \ldots; mvr_{1n}; (\mathbf{k},\mathbf{l}) : \beta; mvr_{21}; \ldots; mvr_{2m}} (\textsc{merge3})$$

$$\frac{(j,k) \cdot +\mathtt{f}\gamma; mvr_1; \ldots; mvr_{x-1}; (i,j) \cdot +\mathtt{f}; mvr_{x+1}; \ldots; mvr_m}{(i,k) : \gamma; mvr_1; \ldots; mvr_{x-1}; mvr_{x+1}; \ldots; mvr_m} (\textsc{move1})$$

$$\frac{(i,j) \cdot +\mathtt{f}\gamma; mvr_1; \ldots; mvr_{x-1}; (i,j) \cdot +\mathtt{f}\beta; mvr_{x+1}; \ldots; mvr_m}{(i,j) : \gamma; mvr_1; \ldots; mvr_{x-1}; (k,l) : \beta; mvr_{x+1}; \ldots; mvr_m} (\textsc{move2})$$

CKY parsing of MGs

In the worst case, this kind of MG recognition requires no more than $\mathcal{O}n^{4k+4}$ steps, where k is the number of licensors and n is the length of the input

CKY parsing of MGAs: Merge

Add SMC!

$$\frac{}{(i,j) :: \gamma} \text{ for each } w \in [i,j] \text{ s.t. } w :: \gamma$$

$$\frac{(i,j) :: {=}\mathtt{X}\gamma \qquad (j,k) \cdot [\mathtt{X}, \mathsf{a}, \mathsf{b}]; mvr_1; \ldots; mvr_n}{(i,k) : \gamma; mvr_1; \ldots; mvr_n}(\textsc{merge1})$$

$$\frac{(j,k) : {=}\mathtt{X}\gamma; mvr_{11}; \ldots; mvr_{1n} \qquad (i,j) \cdot [\mathtt{X}, \mathsf{a}, \mathsf{b}]; mvr_{21}; \ldots; mvr_{2m}}{(i,k) : \gamma; ; mvr_{11}; \ldots; mvr_{1n}; mvr_{21}; \ldots; mvr_{2m}}(\textsc{merge2})$$

$$\frac{(i,j) \cdot {=}\mathtt{X}\gamma; mvr_{11}; \ldots; mvr_{1n} \qquad (k,l) \cdot [\mathtt{X}, \mathsf{a}, \mathsf{b}]\beta; mvr_{21}; \ldots; mvr_{2m}}{(i,j) : \gamma; ; mvr_{11}; \ldots; mvr_{1n}; (\mathbf{k},\mathbf{l}) : \beta; mvr_{21}; \ldots; mvr_{2m}}(\textsc{merge3})$$

CKY parsing of MGAs: Move

$$\frac{(j,k)\cdot \texttt{+f}\gamma;\ mvr_1;\ldots;mvr_{x-1};(i,j)\cdot \texttt{+f};\ mvr_{x+1};\ldots;mvr_m}{(i,k):\gamma;\ mvr_1;\ldots;mvr_{x-1};mvr_{x+1};\ldots;mvr_m}(\textsc{move}1)$$

$$\frac{(i,j)\cdot \texttt{+f}\gamma;\ mvr_1;\ldots;mvr_{x-1};(i,j)\cdot \texttt{+f}\beta;\ mvr_{x+1};\ldots;mvr_m}{(i,j):\gamma;\ mvr_1;\ldots;mvr_{x-1};(k,l):\beta;\ mvr_{x+1};\ldots;mvr_m}(\textsc{move}2)$$

CKY parsing of MGAs: Adjoin

$$\frac{(j,k) : [\mathtt{X},\mathtt{a},\mathtt{b}]\gamma; mvr_{11}; \ldots; mvr_{1n} \qquad (i,j) \cdot [\mathtt{Y},\mathtt{c},\mathtt{d}]; mvr_{21}; \ldots; mvr_{2m}}{(i,k) : [\mathtt{X},\mathtt{a},\mathtt{c}]\gamma; ; mvr_{11}; \ldots; mvr_{1n}; mvr_{21}; \ldots; mvr_{2m}} (\textsc{adjoin1})$$

if $\mathtt{Y} \in Ad(\mathtt{X})$ and $\mathtt{c} \geq \mathtt{b}$

$$\frac{(i,j) \cdot [\mathtt{X},\mathtt{a},\mathtt{b}]\gamma; mvr_{11}; \ldots; mvr_{1n} \qquad (k,l) \cdot [\mathtt{Y},\mathtt{c},\mathtt{d}]\beta; mvr_{21}; \ldots; mvr_{2m}}{(i,j) : [\mathtt{X},\mathtt{a},\mathtt{c}]\gamma; ; mvr_{11}; \ldots; mvr_{1n}; (\mathbf{k},\mathbf{l}) : \beta; mvr_{21}; \ldots; mvr_{2m}} (\textsc{adjoin2})$$

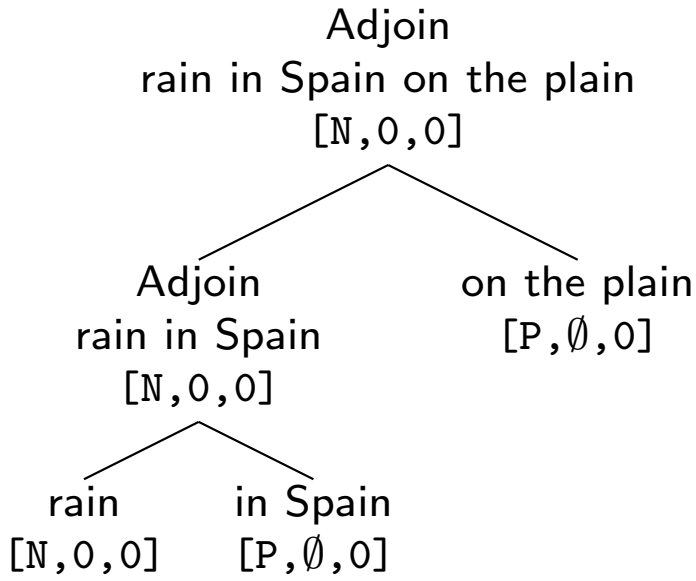
Unordered adjuncts

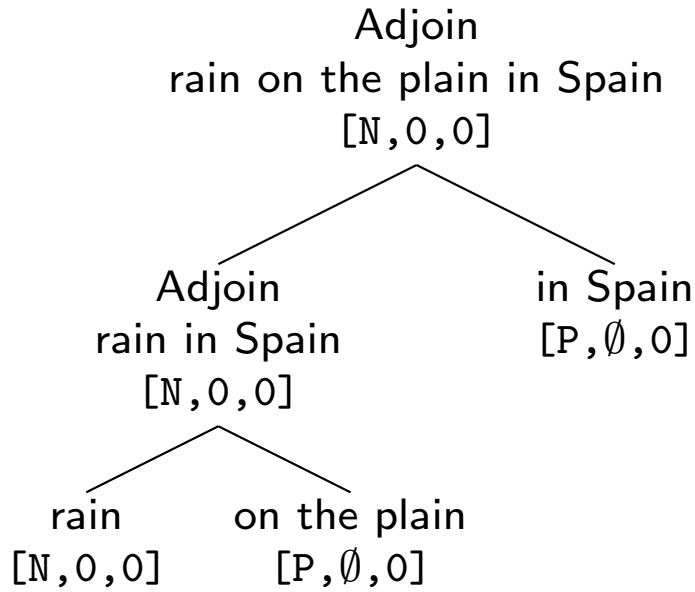
? Unordered

- Could make them all one level
- Or at every level
- Better: expand index set to include non-number, $\emptyset$
  - When **Adjoin** sees $\emptyset$, *asymmetrically* checks features
  - Hierarchy level of phrase doesn't change

Unordered adjuncts

✓**Unordered**





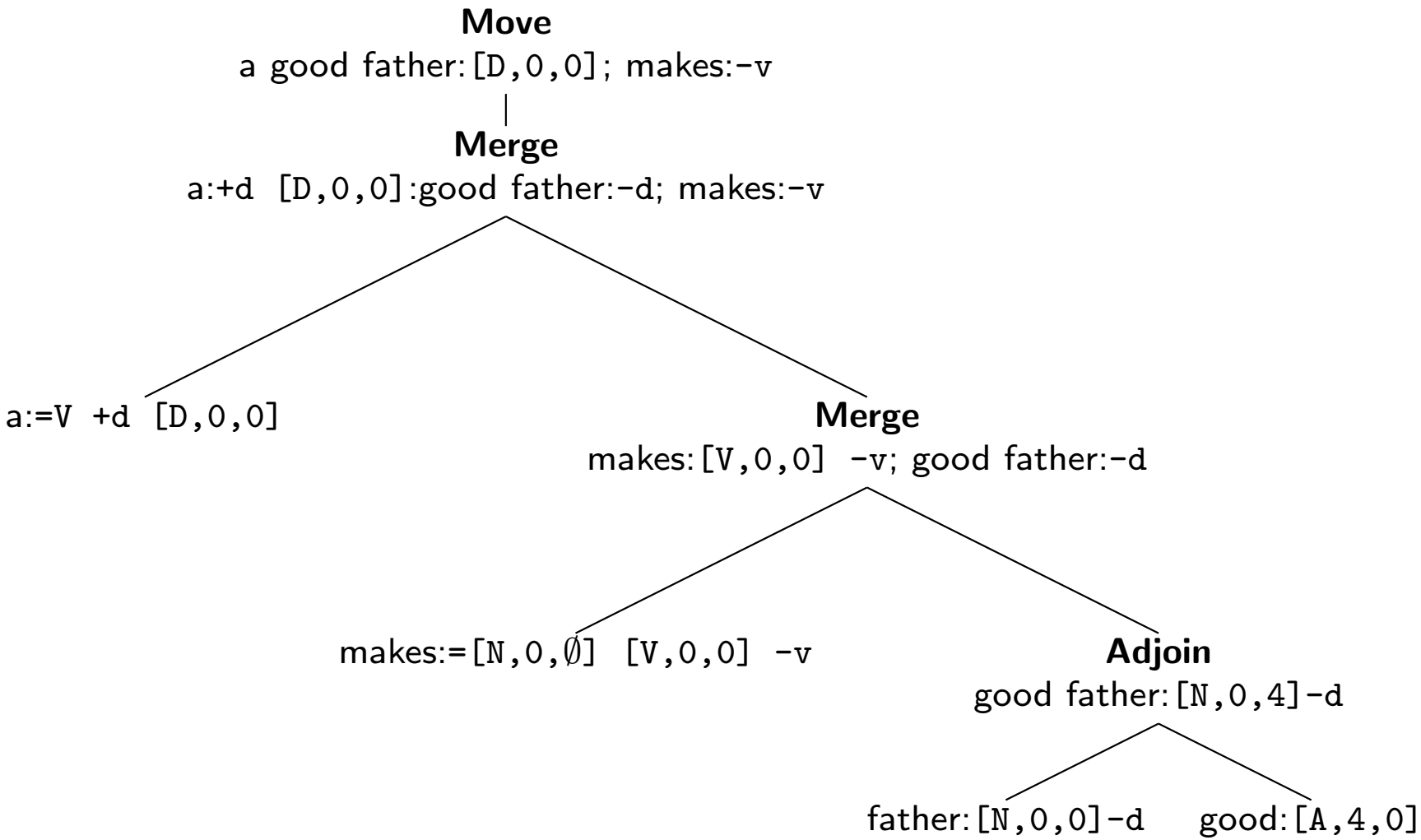
✓**Adjuncts on either side of head**

Obligatory adjuncts

(6) a. He makes a **good** father.
b. *He makes a father.

- Noun with no adjuncts: `[N,0,0]`
- Noun with adjunct: `[N,0,3]`
- →Expand Merge to require last element to be non-zero
- =`[N,0,∅]` can Merge with `[N,i,j]` for `j>0`

Obligatory adjuncts



Note: Sportiche (2005) proposes that verbs select NPs, and the NPs move to their Ds, which are functional heads on the spine.