Tree Parsing with Synchronous Tree-Adjoining Grammars

Matthias Büchse Mark-Jan Nederhof Heiko Vogler

International Conference on Parsing Technologies

October 2011

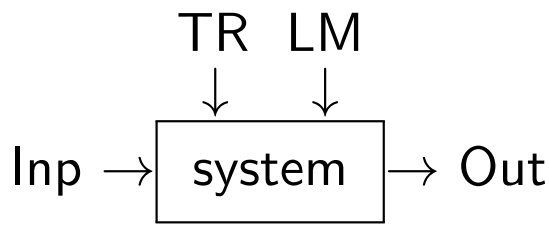
Translation System Example

$\mathsf{TR}\colon \mathsf{Tree} \times \mathsf{Tree} \to \mathbb{R}_{\infty}^{\geq 0}$ translation probabilities (French, English)

$\mathsf{LM}\colon \mathsf{Tree} \to \mathbb{R}_{\infty}^{\geq 0}$ probabilities for English parse trees

$\mathsf{Inp}\colon \mathsf{Tree} \to \mathbb{R}_{\infty}^{\geq 0}$ input weighted tree language

$\mathsf{Out}\colon \mathsf{Tree} \to \mathbb{R}_{\infty}^{\geq 0}$ output weighted tree language



$$\mathsf{Out}(e) = \sum_{f \in \mathsf{Tree}} \mathsf{Inp}(f) \cdot \mathsf{TR}(f, e) \cdot \mathsf{LM}(e)$$

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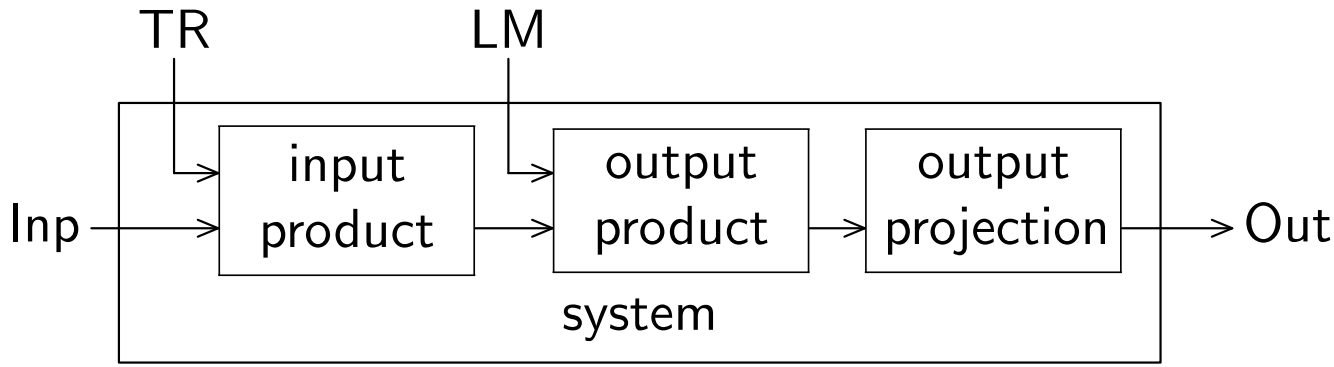

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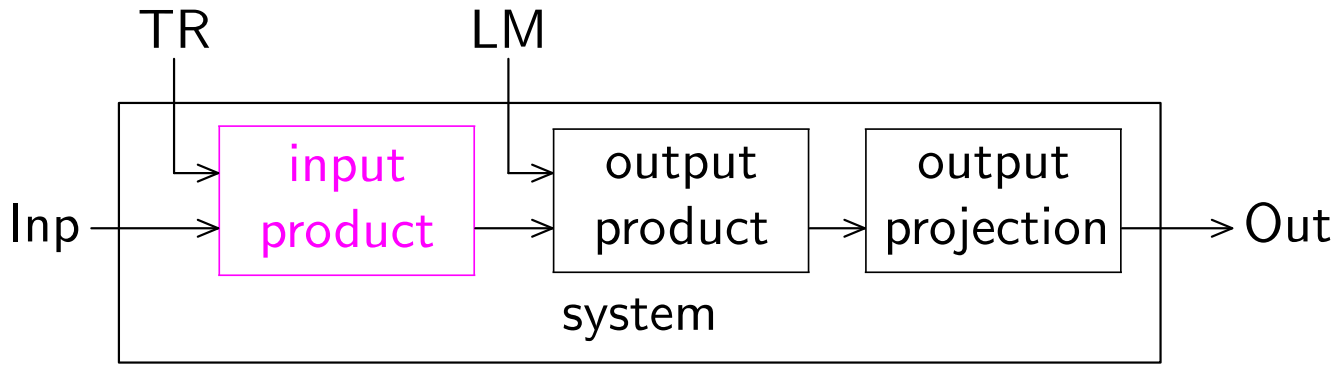

$$\mathsf{Out}(e) = \sum_{f \in \mathsf{Tree}} \mathsf{Inp}(f) \cdot \mathsf{TR}(f, e) \cdot \mathsf{LM}(e)$$

$$= \sum_{f \in \mathsf{Tree}} (\mathsf{Inp} \lhd \mathsf{TR})(f, e) \cdot \mathsf{LM}(e)$$

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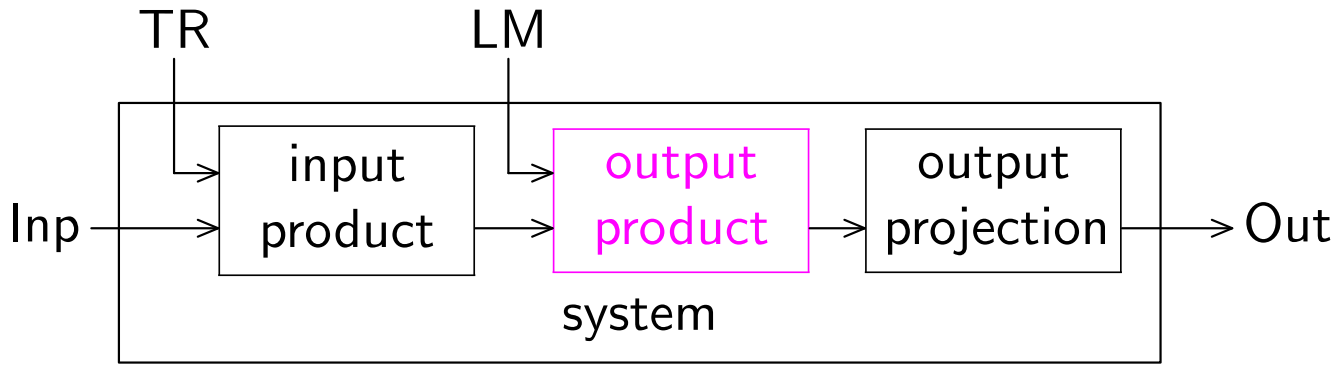

$$\mathrm{Out}(e) = \sum_{f \in \mathrm{Tree}} \mathrm{Inp}(f) \cdot \mathrm{TR}(f, e) \cdot \mathrm{LM}(e)$$

$$= \sum_{f \in \mathrm{Tree}} ((\mathrm{Inp} \lhd \mathrm{TR}) \rhd \mathrm{LM})(f, e)$$

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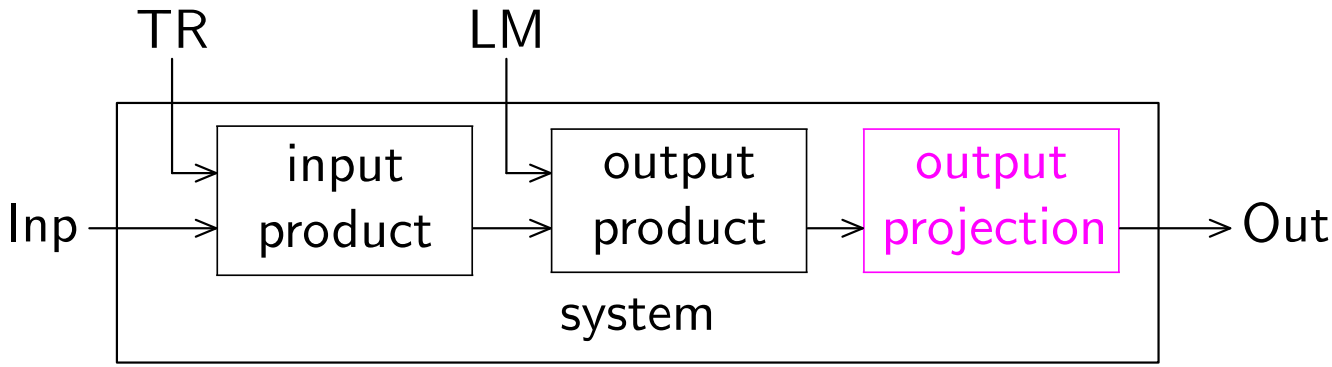

$$\mathsf{Out}(e) = \sum_{f \in \mathsf{Tree}} \mathsf{Inp}(f) \cdot \mathsf{TR}(f, e) \cdot \mathsf{LM}(e)$$

$$= \mathsf{Proj}((\mathsf{Inp} \lhd \mathsf{TR}) \rhd \mathsf{LM})(e)$$

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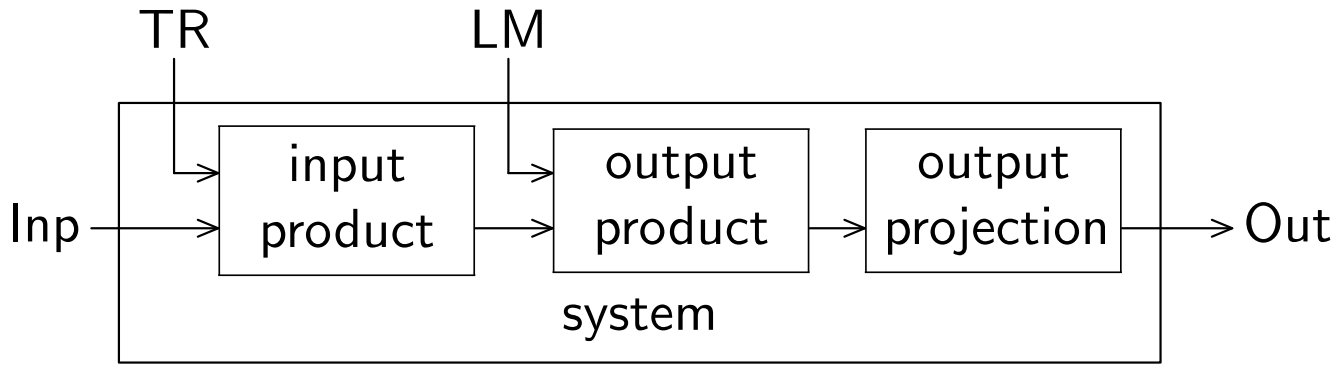

$$\mathrm{Out} = \mathrm{Proj}((\mathrm{Inp} \lhd \mathrm{TR}) \rhd \mathrm{LM})$$

Translation System Example

$\mathrm{TR}\colon \mathrm{Tree} \times \mathrm{Tree} \to \mathbb{R}_{\infty}^{\geq 0}$ synchronous tree-adjoining grammar

$\mathrm{LM}\colon \mathrm{Tree} \to \mathbb{R}_{\infty}^{\geq 0}$ regular tree grammar

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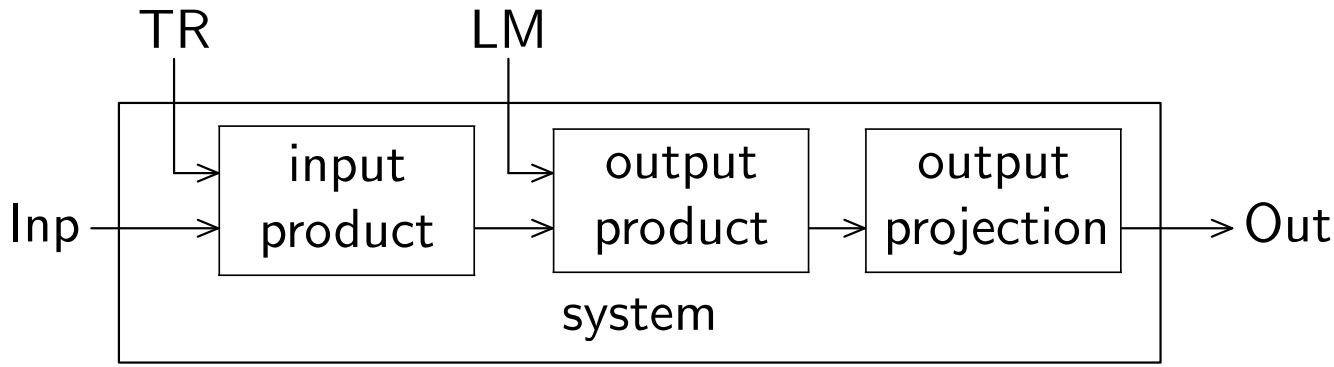

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Finitely representable?

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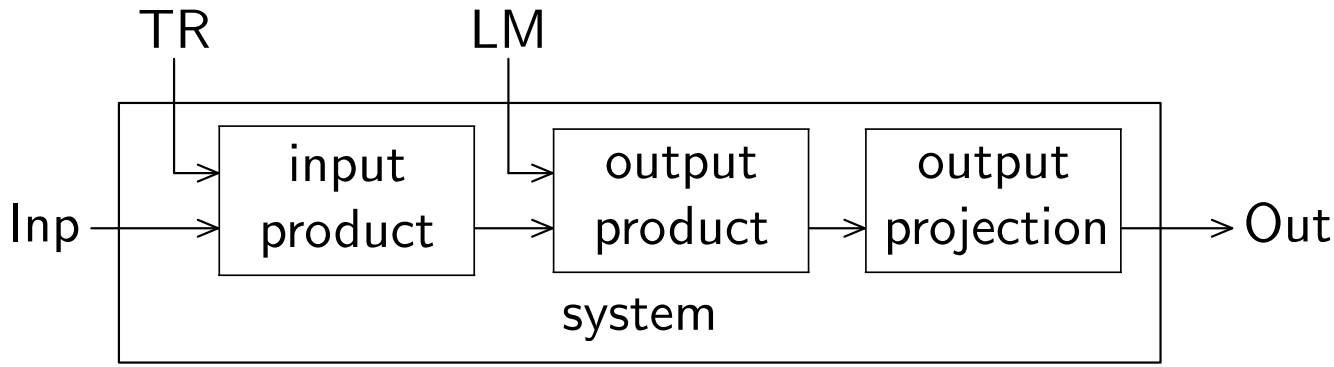

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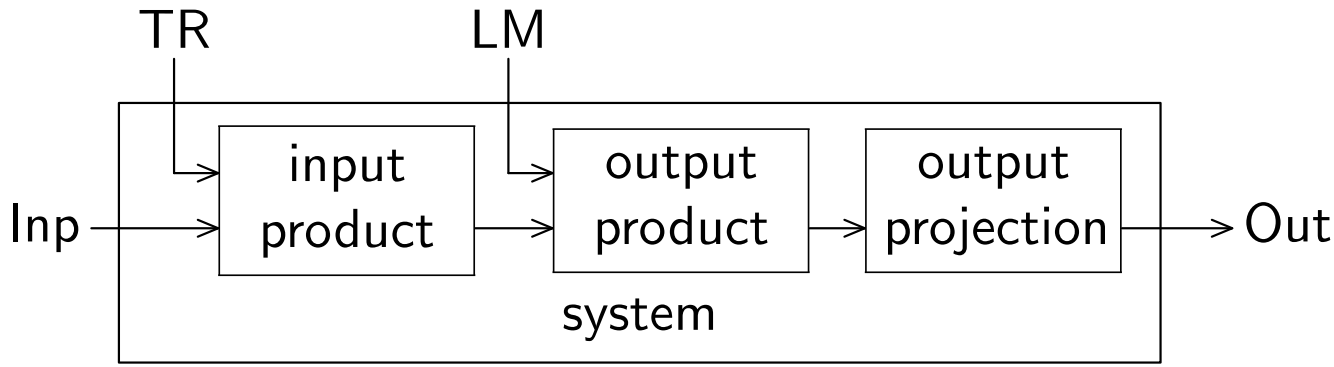

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Small selection of grammar types?

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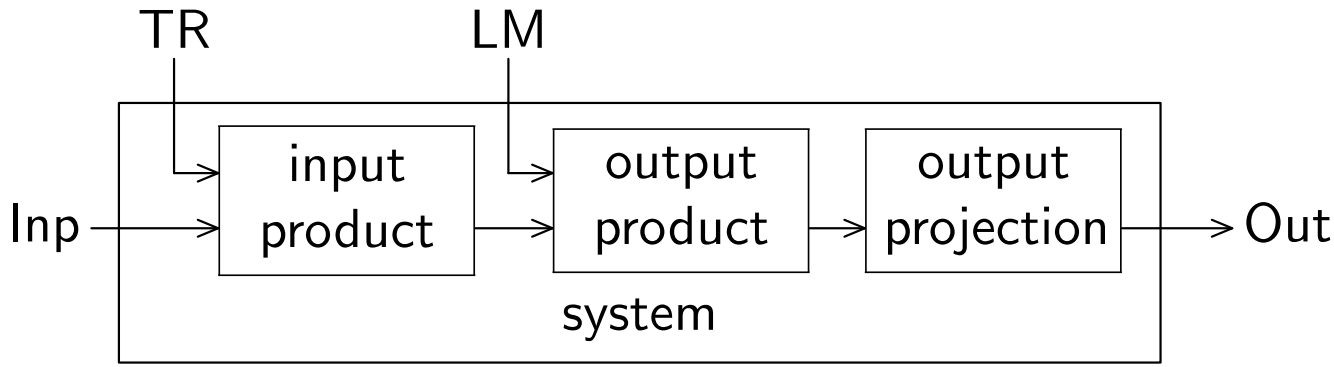

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Finitely representable?
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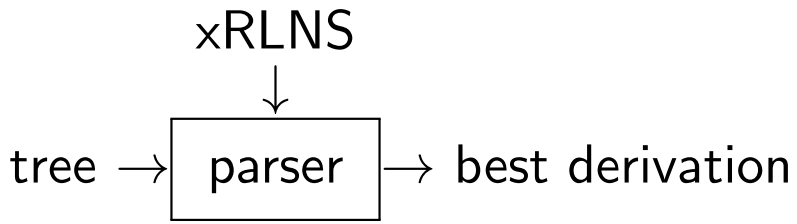
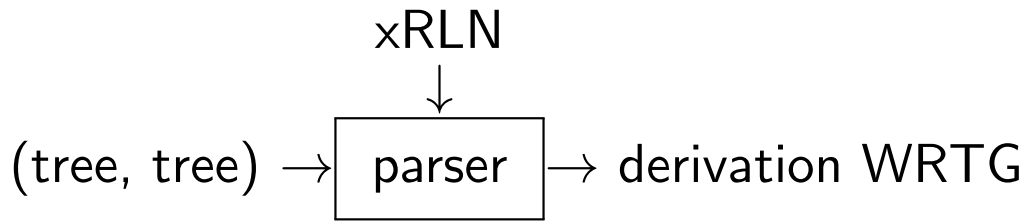
Small selection of grammar types?
$\rightsquigarrow$ Toolbox

Tree Parsing Results

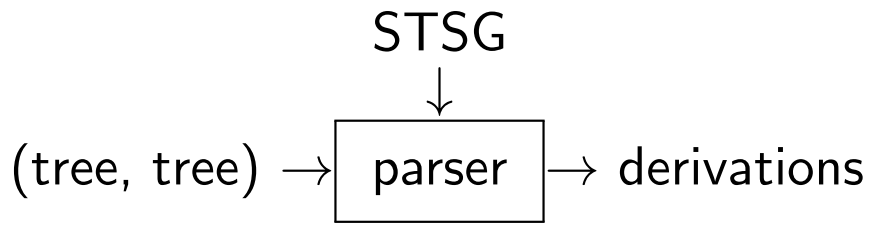
Huang et al. (2006)



Graehl et al. (2008)

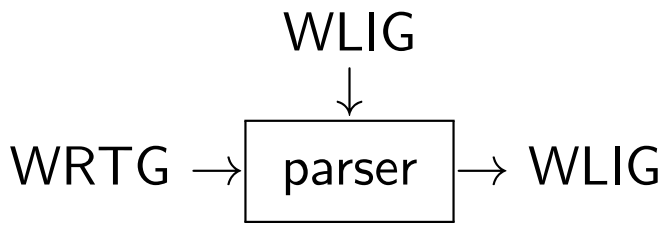


Eisner (2003)

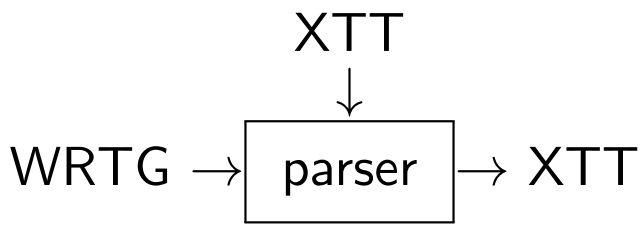


Tree Parsing Results

Nederhof (2009)



Maletti (2010)



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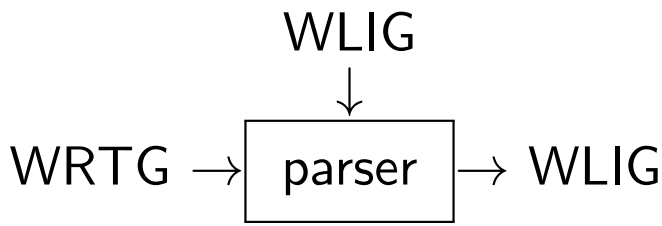

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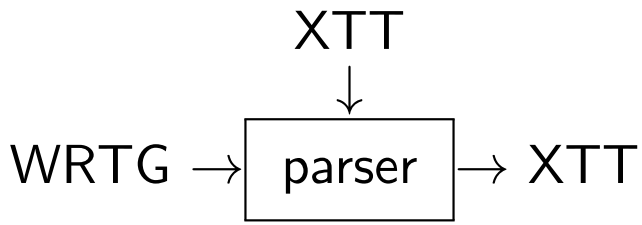
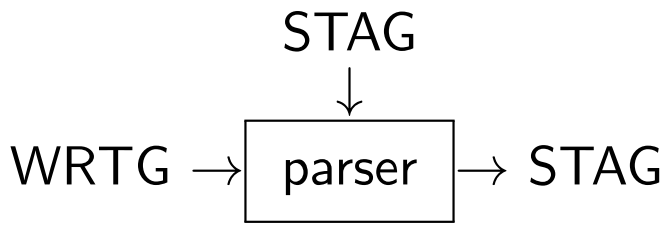


this talk



Outline

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Weighted Regular Tree Grammar (WRTG)

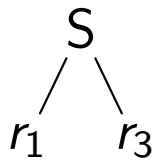
$$\rho_1: \quad r_0 \to \overset{\mathsf{S}}{\underset{r_1 \quad r_3}{/ \ \backslash}} \qquad \# \ p(\rho_1)$$

$$\rho_2: \quad r_1 \to \overset{\mathsf{Adv}}{\underset{r_2}{|}} \qquad \# \ p(\rho_2)$$

$$\rho_3: \quad r_2 \to \mathsf{yesterday} \qquad \# \ p(\rho_3)$$

$$\vdots$$

Weighted Regular Tree Grammar (WRTG)

ρ_1 : $r_0 \to$ 

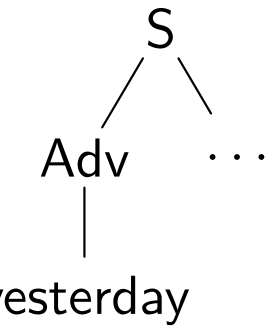
$\#\ p(\rho_1)$

ρ_2 : $r_1 \to$ 

$\#\ p(\rho_2)$

ρ_3 : $r_2 \to$ yesterday $\#\ p(\rho_3)$

$\vdots$

tree t 

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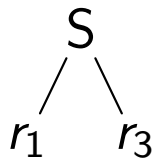
ρ_1 : $r_0 \to$ 

$\#\ p(\rho_1)$

ρ_2 : $r_1 \to$ 

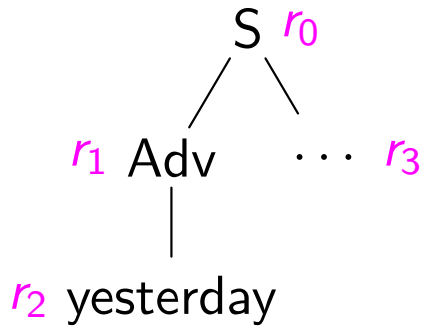
$\#\ p(\rho_2)$

ρ_3 : $r_2 \to$ yesterday $\#\ p(\rho_3)$

$\vdots$

tree t

run κ



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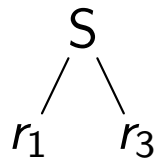
ρ_1 : $r_0 \to$ 

$\#\ p(\rho_1)$

ρ_2 : $r_1 \to$ 

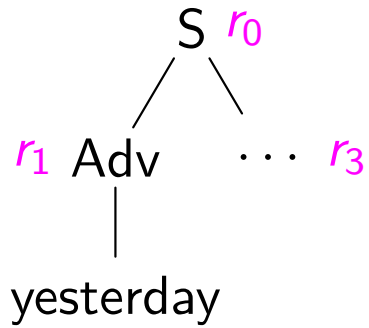
$\#\ p(\rho_2)$

ρ_3 : $r_2 \to$ yesterday $\#\ p(\rho_3)$

$\vdots$

tree t

run κ



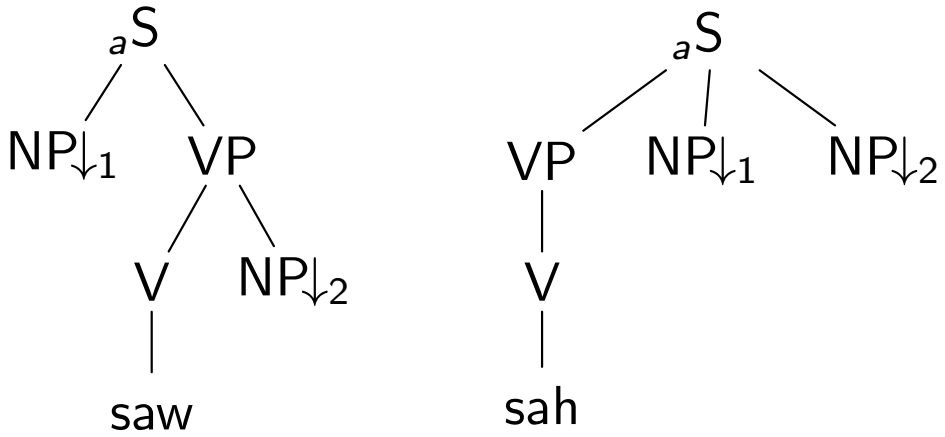
weight of κ $\quad p(\rho_1) \cdot p(\rho_2) \cdot p(\rho_3) \cdot \ldots$

weight of t $\quad \sum_\kappa p(\kappa)$

Synchronous Tree-Adjoining Grammar

following DeNeefe and Knight (2009)

ρ_1:



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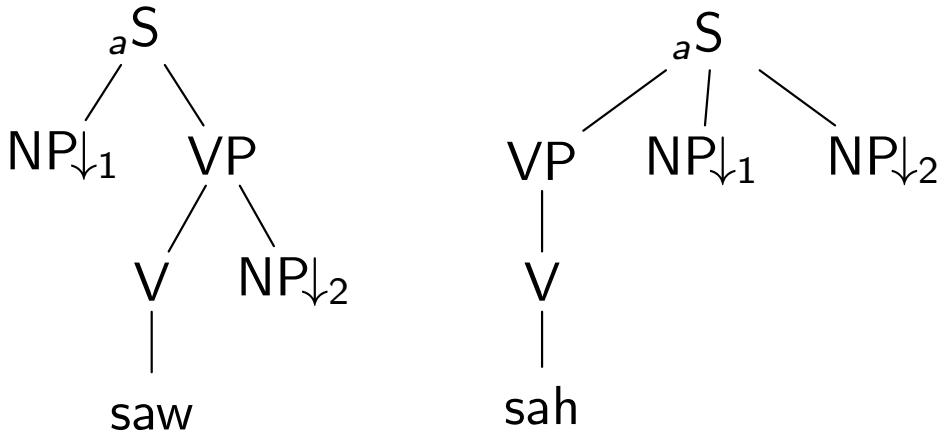
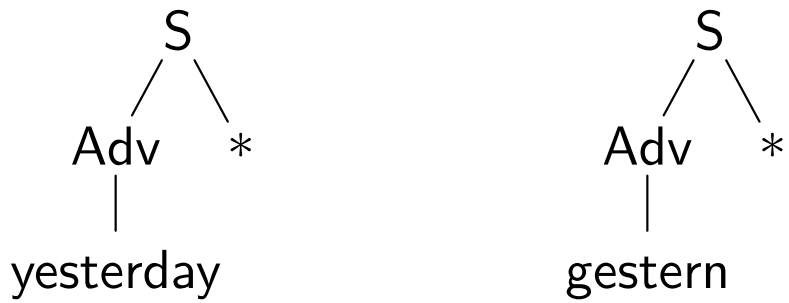


ρ_5:



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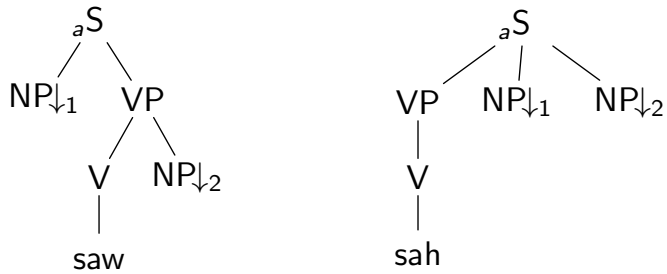

ρ_2 :

ρ_3 :

ρ_4 :

ρ_5 :

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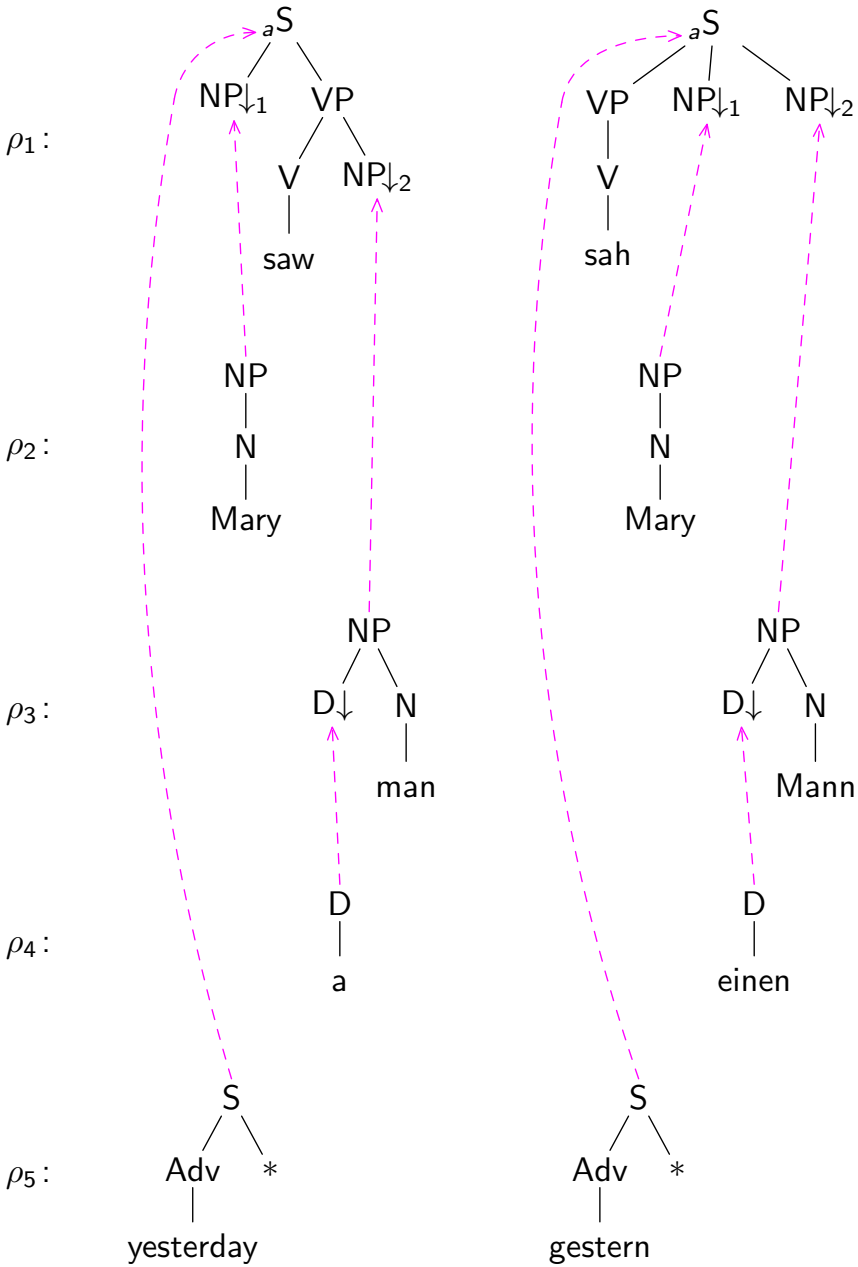

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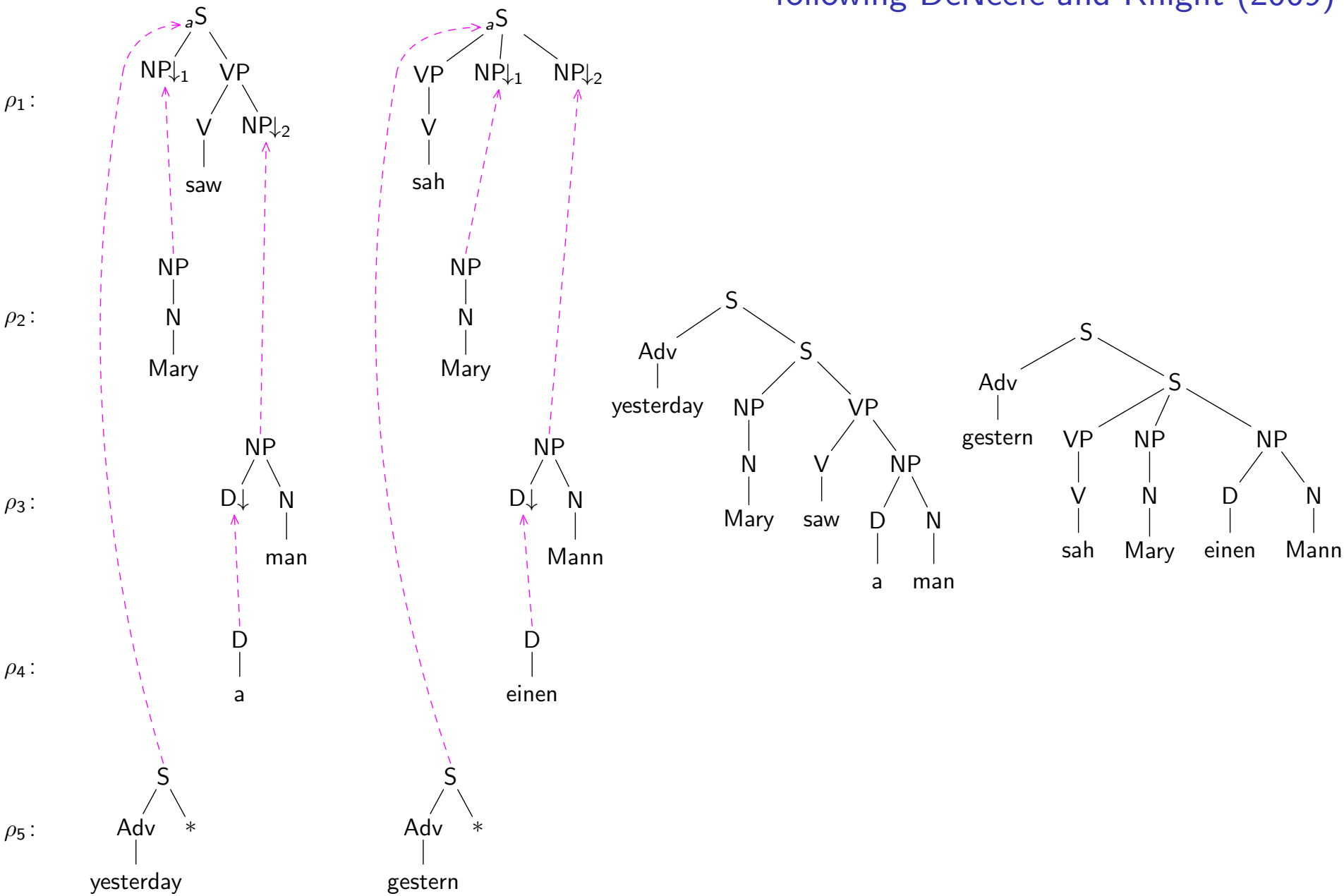

Outline

Example Revisited

ρ_1: $q_S \to \left\langle \begin{array}{c} z_1 \\ S \\ x_1 \quad VP \\ \quad V \quad x_2 \\ \quad saw \end{array} \quad \begin{array}{c} z_1 \\ S \\ VP \quad x_1 \quad x_2 \\ V \\ sah \end{array} , q_{NP}\, q_{NP}, f_S \right\rangle \quad \# \quad 1.0$

ρ_2: $q_{NP} \to \left\langle \begin{array}{c} NP \\ N \\ Mary \end{array} \quad \begin{array}{c} NP \\ N \\ Mary \end{array} , \varepsilon, \varepsilon \right\rangle \quad \# \quad 0.6$

ρ_3: $q_{NP} \to \left\langle \begin{array}{c} NP \\ x_1 \quad N \\ \quad man \end{array} \quad \begin{array}{c} NP \\ x_1 \quad N \\ \quad Mann \end{array} , q_D, \varepsilon \right\rangle \quad \# \quad 0.4$

ρ_4: $q_D \to \left\langle \begin{array}{c} D \\ a \end{array} \quad \begin{array}{c} D \\ einen \end{array} , \varepsilon, \varepsilon \right\rangle \quad \# \quad 1.0$

ρ_5: $f_S(*) \to \left\langle \begin{array}{c} S \\ Adv \quad * \\ yesterday \end{array} \quad \begin{array}{c} S \\ Adv \quad * \\ gestern \end{array} , \varepsilon, \varepsilon \right\rangle \quad \# \quad 1.0$

Example Revisited

ρ_1: $q_S \to \left\langle \begin{array}{c} z_1 \\ S \\ x_1 \quad VP \\ \quad V \quad x_2 \\ \quad saw \end{array} \quad \begin{array}{c} z_1 \\ S \\ VP \quad x_1 \quad x_2 \\ V \\ sah \end{array} , q_{NP}\ q_{NP}, f_S \right\rangle$ # 1.0

x_1 x_2 z_1

ρ_2: $q_{NP} \to \left\langle \begin{array}{c} NP \\ N \\ Mary \end{array} \quad \begin{array}{c} NP \\ N \\ Mary \end{array} , \varepsilon, \varepsilon \right\rangle$ # 0.6

ρ_3: $q_{NP} \to \left\langle \begin{array}{c} NP \\ x_1 \quad N \\ \quad man \end{array} \quad \begin{array}{c} NP \\ x_1 \quad N \\ \quad Mann \end{array} , q_D, \varepsilon \right\rangle$ # 0.4

ρ_4: $q_D \to \left\langle \begin{array}{c} D \\ a \end{array} \quad \begin{array}{c} D \\ einen \end{array} , \varepsilon, \varepsilon \right\rangle$ # 1.0

ρ_5: $f_S(*) \to \left\langle \begin{array}{c} S \\ Adv \quad * \\ yesterday \end{array} \quad \begin{array}{c} S \\ Adv \quad * \\ gestern \end{array} , \varepsilon, \varepsilon \right\rangle$ # 1.0

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x_1 x_2 z_1

ρ_2: $q_{NP} \to \left\langle \begin{array}{c} NP \\ N \\ Mary \end{array} \quad \begin{array}{c} NP \\ N \\ Mary \end{array} , \varepsilon, \varepsilon \right\rangle$ # 0.6

ρ_3: $q_{NP} \to \left\langle \begin{array}{c} NP \\ x_1 \quad N \\ \quad man \end{array} \quad \begin{array}{c} NP \\ x_1 \quad N \\ \quad Mann \end{array} , q_D, \varepsilon \right\rangle$ # 0.4

ρ_4: $q_D \to \left\langle \begin{array}{c} D \\ a \end{array} \quad \begin{array}{c} D \\ einen \end{array} , \varepsilon, \varepsilon \right\rangle$ # 1.0

ρ_5: $f_S(*) \to \left\langle \begin{array}{c} S \\ Adv \quad * \\ yesterday \end{array} \quad \begin{array}{c} S \\ Adv \quad * \\ gestern \end{array} , \varepsilon, \varepsilon \right\rangle$ # 1.0

derivation tree WRTG:

$D(\rho_1)$:	$q_S \to \rho_1(q_{NP}, q_{NP}, f_S)$	# 1.0
$D(\rho_2)$:	$q_{NP} \to \rho_2()$	# 0.6
$D(\rho_3)$:	$q_{NP} \to \rho_3(q_D)$	# 0.4
$D(\rho_4)$:	$q_D \to \rho_4()$	# 1.0
$D(\rho_5)$:	$f_S \to \rho_5()$	# 1.0

Example Revisited

ρ_1: $q_S \to \left\langle \begin{array}{c} z_1 \\ S \\ x_1 \quad VP \\ \quad V \quad x_2 \\ \quad saw \end{array} \quad \begin{array}{c} z_1 \\ S \\ VP \quad x_1 \quad x_2 \\ V \\ sah \end{array} , q_{NP}\ q_{NP}, f_S \right\rangle$ # 1.0

(x_1 x_2 z_1)

ρ_2: $q_{NP} \to \left\langle \begin{array}{c} NP \\ N \\ Mary \end{array} \quad \begin{array}{c} NP \\ N \\ Mary \end{array} , \varepsilon, \varepsilon \right\rangle$ # 0.6

ρ_3: $q_{NP} \to \left\langle \begin{array}{c} NP \\ x_1 \quad N \\ \quad man \end{array} \quad \begin{array}{c} NP \\ x_1 \quad N \\ \quad Mann \end{array} , q_D, \varepsilon \right\rangle$ # 0.4

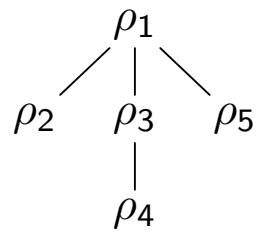
ρ_4: $q_D \to \left\langle \begin{array}{c} D \\ a \end{array} \quad \begin{array}{c} D \\ einen \end{array} , \varepsilon, \varepsilon \right\rangle$ # 1.0

ρ_5: $f_S(*) \to \left\langle \begin{array}{c} S \\ Adv \quad * \\ yesterday \end{array} \quad \begin{array}{c} S \\ Adv \quad * \\ gestern \end{array} , \varepsilon, \varepsilon \right\rangle$ # 1.0

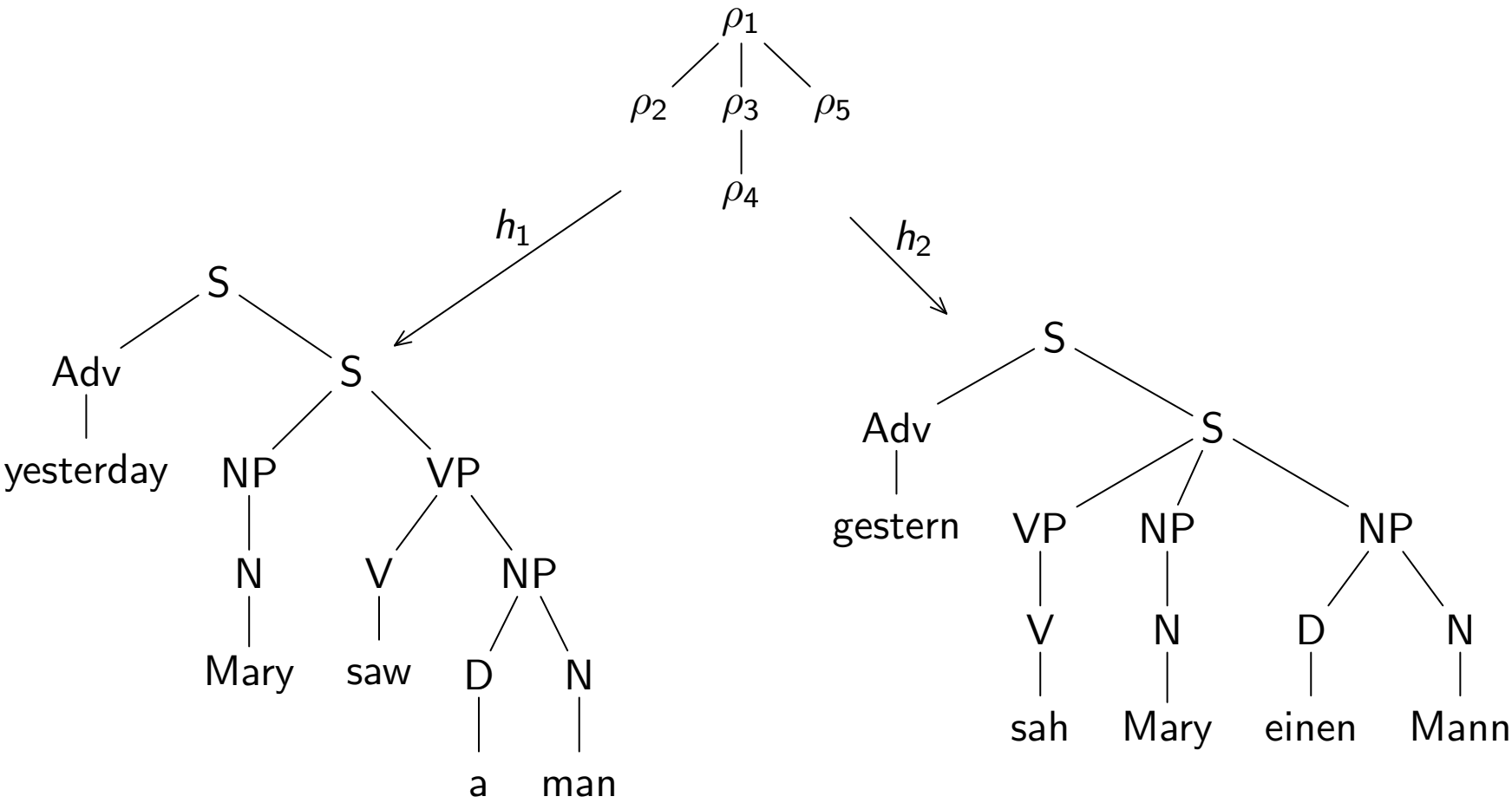
derivation tree WRTG:

$D(\rho_1)$:	$q_S \to \rho_1(q_{NP}, q_{NP}, f_S)$	# 1.0
$D(\rho_2)$:	$q_{NP} \to \rho_2()$	# 0.6
$D(\rho_3)$:	$q_{NP} \to \rho_3(q_D)$	# 0.4
$D(\rho_4)$:	$q_D \to \rho_4()$	# 1.0
$D(\rho_5)$:	$f_S \to \rho_5()$	# 1.0

derivation tree:



Bimorphism Semantics



Input Product Construction

WSTAG	WRTG	product WSTAG
$q \to \left\langle \begin{array}{c} \mathsf{A} \\ \mid \\ z_1 \\ \mid \\ \mathsf{A} \\ \mid \\ x_1 \end{array}, q, f \right\rangle \quad \# \quad 0.2$		
$q \to \langle \mathsf{a}, \varepsilon, \varepsilon \rangle \quad \# \quad 0.8$		
$f(*) \to \left\langle \begin{array}{ccc} & \mathsf{B} & \\ / & & \backslash \\ \mathsf{b} & & * \end{array}, \varepsilon, \varepsilon \right\rangle \quad \# \quad 0.1$		
$f(*) \to \langle *, \varepsilon, \varepsilon \rangle \quad \# \quad 0.9$		

Input Product Construction

WSTAG	WRTG	product WSTAG
$q \to \left\langle \begin{array}{c} \mathsf{A} \\ \mid \\ z_1 \\ \mid \\ \mathsf{A} \\ \mid \\ x_1 \end{array}, q, f \right\rangle$ # 0.2	$r_0 \to \begin{array}{c} \mathsf{A} \\ \mid \\ r_0 \end{array}$ # 0.1	
$q \to \langle \mathsf{a}, \varepsilon, \varepsilon \rangle$ # 0.8	$r_0 \to \begin{array}{ccc} & \mathsf{B} & \\ / & & \backslash \\ r_0 & & r_1 \end{array}$ # 0.5	
$f(*) \to \left\langle \begin{array}{ccc} & \mathsf{B} & \\ / & & \backslash \\ \mathsf{b} & & * \end{array}, \varepsilon, \varepsilon \right\rangle$ # 0.1	$r_0 \to \mathsf{b}$ # 0.4	
$f(*) \to \langle *, \varepsilon, \varepsilon \rangle$ # 0.9	$r_1 \to \begin{array}{c} \mathsf{A} \\ \mid \\ r_1 \end{array}$ # 0.5	
	$r_1 \to \mathsf{a}$ # 0.5	

Input Product Construction

WSTAG

$q \to \left\langle \begin{array}{c} \mathrm{A} \\ | \\ z_1 \\ | \\ \mathrm{A} \\ | \\ x_1 \end{array}, q, f \right\rangle \quad \# \quad 0.2$

$q \to \langle \mathrm{a}, \varepsilon, \varepsilon \rangle \quad \# \quad 0.8$

$f(*) \to \left\langle \begin{array}{c} \mathrm{B} \\ / \quad \backslash \\ \mathrm{b} \quad * \end{array}, \varepsilon, \varepsilon \right\rangle \quad \# \quad 0.1$

$f(*) \to \langle *, \varepsilon, \varepsilon \rangle \quad \# \quad 0.9$

WRTG

$r_0 \to \begin{array}{c} \mathrm{A} \\ | \\ r_0 \end{array} \quad \# \quad 0.1$

$r_0 \to \begin{array}{c} \mathrm{B} \\ / \quad \backslash \\ r_0 \quad r_1 \end{array} \quad \# \quad 0.5$

$r_0 \to \mathrm{b} \quad \# \quad 0.4$

$r_1 \to \begin{array}{c} \mathrm{A} \\ | \\ r_1 \end{array} \quad \# \quad 0.5$

$r_1 \to \mathrm{a} \quad \# \quad 0.5$

product WSTAG

$qr_0 \to \left\langle \begin{array}{c} \mathrm{A} \\ | \\ z_1 \\ | \\ \mathrm{A} \\ | \\ x_1 \end{array}, qr_0, fr_0 r_0 \right\rangle \quad \# \quad 0.002$

$fr_0 r_0(*) \to \langle *, \varepsilon, \varepsilon \rangle \quad \# \quad 0.9$

$qr_0 \to \left\langle \begin{array}{c} \mathrm{A} \\ | \\ z_1 \\ | \\ \mathrm{A} \\ | \\ x_1 \end{array}, qr_1, fr_0 r_1 \right\rangle \quad \# \quad 0.01$

$fr_0 r_1(*) \to \left\langle \begin{array}{c} \mathrm{B} \\ / \quad \backslash \\ \mathrm{b} \quad * \end{array}, \varepsilon, \varepsilon \right\rangle \quad \# \quad 0.002$

$qr_1 \to \langle \mathrm{a}, \varepsilon, \varepsilon \rangle \quad \# \quad 0.4$

Outline