Master in Artificial Intelligence

Introduction to Human Language Technologies 9. Syntactic parsing: parsers





- 1 $S \rightarrow NP VP$
- $\mathbf{2}$ NP \rightarrow det n
- $NP \rightarrow n$
- 4 $VP \rightarrow vt NP PP$
- $VP \rightarrow vi$
- **6** $PP \rightarrow with NP$
- 7 $det \rightarrow the |a|$
- 8 $n \rightarrow cat | fish | knife$
- 9 $vt \rightarrow eats$
- 10 $vi \rightarrow eats$

- 1 $S \rightarrow NP VP$
- 2 $NP \rightarrow det \ n$ (A) Convert hybrid rules
- $NP \rightarrow n$
- 4 $VP \rightarrow vt NP PP$
- 5 $VP \rightarrow vi$
- **6** $PP \rightarrow with NP$
- 7 $det \rightarrow the a$
- 8 $n \rightarrow cat|fish|knife$
- $\mathbf{9}$ $vt \rightarrow eats$
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Convert the following CFG to CNF

- 1 $S \rightarrow NP VP$
- $\mathbf{2}$ NP \rightarrow det n
- $NP \rightarrow n$
- 4 $VP \rightarrow vt NP PP$
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- 6 $PP \rightarrow with NP$
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(A) Convert hybrid rules

 $PP \rightarrow A NP$

 $A \rightarrow with$

Convert the following CFG to CNF

- $S \rightarrow NP VP$
- 2 $NP \rightarrow det n$
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(A) Convert hybrid rules

 $PP \rightarrow A NP$

 $A \rightarrow with$

(B) Convert unit productions

Convert the following CFG to CNF

- $S \rightarrow NP VP$
- 2 $NP \rightarrow det n$
- $NP \rightarrow n$
- 4 $VP \rightarrow vt NP PP$
- $VP \rightarrow vi$
- **6** $PP \rightarrow with NP$
- **7** $det \rightarrow the |a|$
- 8 $n \rightarrow cat |fish| knife$
- 9 $vt \rightarrow eats$
- 10 $vi \rightarrow eats$

(A) Convert hybrid rules

 $PP \rightarrow A NP$

 $A \rightarrow with$

(B) Convert unit productions

- 1 $S \rightarrow NP VP$
- 2 $NP \rightarrow det n$
- $NP \rightarrow n$
- 4 $VP \rightarrow vt NP PP$
- 5 $VP \rightarrow vi$
- **6** $PP \rightarrow with NP$
- **7** $det \rightarrow the |a|$
- 8 $n \rightarrow cat | fish | knife$
- 9 $vt \rightarrow eats$
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- (A) Convert hybrid rules $PP \rightarrow A NP$
 - $A \rightarrow with$
- (B) Convert unit productions $NP \rightarrow cat|fish|knife$

$$VP \rightarrow eats$$

Convert the following CFG to CNF

- $S \rightarrow NP VP$
- 2 $NP \rightarrow det n$
- $NP \rightarrow n$
- 4 $VP \rightarrow vt NP PP$
- 5 $VP \rightarrow vi$
- **6** $PP \rightarrow with NP$
- **7** det \rightarrow the a
- 8 $n \rightarrow cat|fish|knife$
- 9 $vt \rightarrow eats$
- 10 $vi \rightarrow eats$

(A) Convert hybrid rules $PP \rightarrow A NP$ $A \rightarrow with$

(B) Convert unit productions $NP \rightarrow cat|fish|knife$ $VP \rightarrow eats$

(C) Convert non-binary rules

Convert the following CFG to CNF

- $S \rightarrow NP VP$
- 2 $NP \rightarrow det n$
- $NP \rightarrow n$
- 4 $VP \rightarrow vt NP PP$
- 5 $VP \rightarrow vi$
- **6** $PP \rightarrow with NP$
- **7** det \rightarrow the a
- 8 $n \rightarrow cat|fish|knife$
- 9 $vt \rightarrow eats$
- 10 $vi \rightarrow eats$

(A) Convert hybrid rules $PP \rightarrow A NP$ $A \rightarrow with$

(B) Convert unit productions $NP \rightarrow cat|fish|knife$ $VP \rightarrow eats$

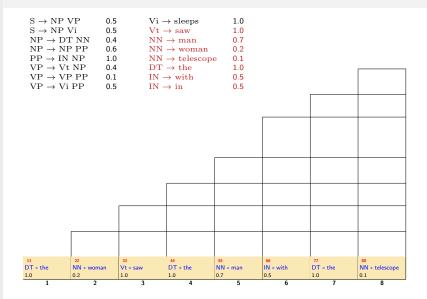
(C) Convert non-binary rules

- $S \rightarrow NP VP$
- 2 $NP \rightarrow det n$
- $NP \rightarrow n$
- 4 $VP \rightarrow vt NP PP$
- 5 $VP \rightarrow vi$
- **6** $PP \rightarrow with NP$
- **7** $det \rightarrow the a$
- $n \rightarrow cat | fish | knife$
- 9 $vt \rightarrow eats$
- 10 $vi \rightarrow eats$

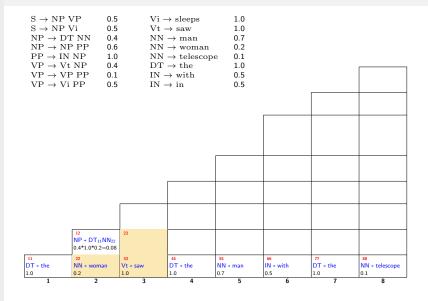
- (A) Convert hybrid rules $PP \rightarrow A NP$ $A \rightarrow with$
- (B) Convert unit productions $NP \rightarrow cat|fish|knife$ $VP \rightarrow eats$
- (C) Convert non-binary rules $VP \rightarrow vtB$ $B \rightarrow NP PP$

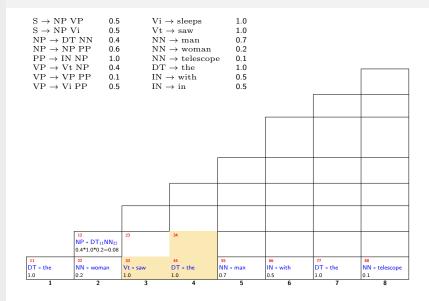
- 1 $S \rightarrow NP VP$
- 2 NP \rightarrow det n
- $NP \rightarrow n$
- 4 $VP \rightarrow vt NP PP$
- $VP \rightarrow vi$
- **6** $PP \rightarrow with NP$
- 7 $det \rightarrow the a$
- 8 $n \rightarrow cat | fish | knife$
- 9 $vt \rightarrow eats$
- 10 $vi \rightarrow eats$

- $S \rightarrow NP VP$
- 2 $NP \rightarrow det n$
- $NP \rightarrow cat|fish|knife$
- 4 $VP \rightarrow vt B$
- $B \to NP PP$
- 6 $VP \rightarrow eats$
- 7 $PP \rightarrow A NP$
- 8 $A \rightarrow with$
- **10** $n \rightarrow cat | fish | knife$
- 11 $vt \rightarrow eats$



$\begin{split} \mathbf{S} &\rightarrow \mathbf{NP} \ \mathbf{VP} \\ \mathbf{S} &\rightarrow \mathbf{NP} \ \mathbf{Vi} \\ \mathbf{NP} &\rightarrow \mathbf{DT} \ \mathbf{NN} \\ \mathbf{NP} &\rightarrow \mathbf{NP} \ \mathbf{PP} \\ \mathbf{PP} &\rightarrow \mathbf{IN} \ \mathbf{NP} \\ \mathbf{VP} &\rightarrow \mathbf{Vt} \ \mathbf{NP} \\ \mathbf{VP} &\rightarrow \mathbf{VP} \ \mathbf{PP} \\ \mathbf{VP} &\rightarrow \mathbf{Vi} \ \mathbf{PP} \\ \mathbf{VP} &\rightarrow \mathbf{Vi} \ \mathbf{PP} \end{split}$	0.5 0.4 0.6 1.0 0.4 0.1	$\begin{array}{l} \text{Vi} \rightarrow \text{sleeps} \\ \text{Vt} \rightarrow \text{saw} \\ \text{NN} \rightarrow \text{man} \\ \text{NN} \rightarrow \text{woman} \\ \text{NN} \rightarrow \text{telescop} \\ \text{DT} \rightarrow \text{the} \\ \text{IN} \rightarrow \text{with} \\ \text{IN} \rightarrow \text{in} \\ \end{array}$	1.0 1.0 0.7 0.2 0.1 1.0 0.5 0.5			
12						
	T ₁₁ NN ₂₂ '0.2=0.08	44	55	66	77	88
DT + the 1.0	1.0	DT + the 1.0	NN → man 0.7	66 IN → with 0.5	DT + the 1.0	NN + telescope 0.1
1	2	3 4	5	6	7	8





$\begin{array}{c} S \rightarrow NP \\ S \rightarrow NP \\ NP \rightarrow D7 \\ NP \rightarrow NH \\ PP \rightarrow IN \\ VP \rightarrow Vt \\ VP \rightarrow Vi \\ VP \rightarrow Vi \end{array}$	Vi 0.5 F NN 0.4 P PP 0.6 NP 1.0 NP 0.4 P PP 0.1	Vt - NN NN NN DT IN -		1.0 1.0 0.7 0.2 0.1 1.0 0.5			
	NP + DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08	23	34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28			
11 DT + the	22 NN + woman	33 Vt → saw	44 DT + the	55 NN → man	66 IN → with	n DT + the	88 NN → telescope
1.0	0.2	1.0	1.0				0.1
1	2	3	4	5	6	7	8

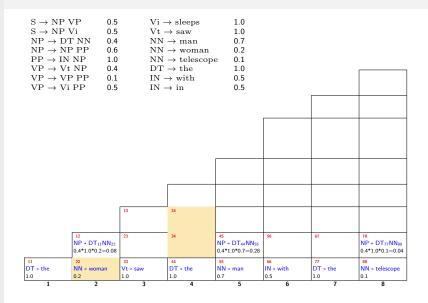
$\begin{split} \mathbf{S} &\to \mathbf{NP} \ \mathbf{VP} \\ \mathbf{S} &\to \mathbf{NP} \ \mathbf{Vi} \\ \mathbf{NP} &\to \mathbf{DT} \ \mathbf{NN} \\ \mathbf{NP} &\to \mathbf{NP} \ \mathbf{PP} \\ \mathbf{PP} &\to \mathbf{IN} \ \mathbf{NP} \\ \mathbf{VP} &\to \mathbf{Vt} \ \mathbf{NP} \\ \mathbf{VP} &\to \mathbf{VP} \ \mathbf{PP} \\ \mathbf{VP} &\to \mathbf{Vi} \ \mathbf{PP} \\ \mathbf{VP} &\to \mathbf{Vi} \ \mathbf{PP} \end{split}$	0.5 0.5 0.4 0.6 1.0 0.4 0.1	$\begin{array}{l} Vi \rightarrow sleeps \\ Vt \rightarrow saw \\ NN \rightarrow man \\ NN \rightarrow woman \\ NN \rightarrow telescope \\ DT \rightarrow the \\ IN \rightarrow with \\ IN \rightarrow in \\ \end{array}$	1.0 1.0 0.7 0.2 0.1 1.0 0.5 0.5			
12 NP + DT 0.4*1.0*0			45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56		
11 22 DT + the NN + wo				66 IN + with	77 DT + the	88 NN → telescope
1 0.2	1.0	1.0	0.7	0.5	7	0.1

$\begin{array}{l} S \rightarrow NP \ VP \\ S \rightarrow NP \ Vi \\ NP \rightarrow DT \ NN \\ NP \rightarrow NP \ PP \\ PP \rightarrow IN \ NP \\ VP \rightarrow Vt \ NP \\ VP \rightarrow VP \ PP \\ VP \rightarrow Vi \ PP \end{array}$	0.5 0.5 0.4 0.6 1.0 0.4 0.1	$\begin{array}{l} \mathrm{Vi} \rightarrow \mathrm{sleeps} \\ \mathrm{Vt} \rightarrow \mathrm{saw} \\ \mathrm{NN} \rightarrow \mathrm{man} \\ \mathrm{NN} \rightarrow \mathrm{woman} \\ \mathrm{NN} \rightarrow \mathrm{telescop} \\ \mathrm{DT} \rightarrow \mathrm{the} \\ \mathrm{IN} \rightarrow \mathrm{with} \\ \mathrm{IN} \rightarrow \mathrm{in} \end{array}$	1.0 1.0 0.7 0.2 0.1 1.0 0.5			
	T ₁₁ NN ₂₂ 0.2=0.08	34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	
11 22 DT + the NN + w 1.0 0.2	oman Vt + sav	v DT + the	55 NN + man 0.7	66 IN → with 0.5	77 DT + the 1.0	88 NN + telescope 0.1
	2	3 4	5	6	7	8

$VP \rightarrow Vt NP$ 0.4 $VP \rightarrow VP PP$ 0.1 $VP \rightarrow Vi PP$ 0.5	IN —	→ with → in	0.5 0.5			
	-					
12	23	34	45	56	67	78
NP + DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08			NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28			NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
DT + the NN + woman \	Vt → saw			66 IN → with	π DT → the	88 NN + telescope
1 0.2 1	3	1.0	0.7 5	0.5	7	0.1

$\begin{array}{c} S \rightarrow NP \\ S \rightarrow NP \\ NP \rightarrow D \\ NP \rightarrow N \\ PP \rightarrow IN \\ VP \rightarrow V \\ VP \rightarrow V \\ VP \rightarrow V \end{array}$	Vi 0.5 T NN 0.4 P PP 0.6 N NP 1.0 t NP 0.4 P PP 0.1	Vt - NN NN NN DT		1.0 1.0 0.7 0.2 0.1 1.0 0.5			
		13					
	NP + DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08		34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
DT + the	NN + woman	33 Vt → saw	44 DT + the			π DT → the	88 NN + telescope
1.0	0.2	1.0	1.0	0.7 5	0.5 6	1.0 7	0.1

$\begin{array}{c} S \rightarrow NP \ V \\ S \rightarrow NP \ V \\ NP \rightarrow DT \\ NP \rightarrow NF \\ PP \rightarrow IN \\ VP \rightarrow Vt \\ VP \rightarrow Vi \\ VP \rightarrow Vi \end{array}$	Vi 0.5 C NN 0.4 C PP 0.6 NP 1.0 NP 0.4 C PP 0.1	Vt - NN NN NN DT IN -	$\begin{array}{l} \rightarrow \text{ sleeps} \\ \rightarrow \text{ saw} \\ \rightarrow \text{ man} \\ \rightarrow \text{ woman} \\ \rightarrow \text{ telescope} \\ \rightarrow \text{ the} \\ \rightarrow \text{ with} \\ \rightarrow \text{ in} \end{array}$	1.0 1.0 0.7 0.2 0.1 1.0 0.5			
				[
		13					
	NP + DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08	23	34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
11 DT + the	22 NN + woman	33 Vt + saw	44 DT + the	55	66 IN → with	π DT → the	88 NN + telescope
1.0	0.2	1.0	1.0				0.1
1	2	3	4	5	6	7	8



$\begin{array}{l} S \rightarrow NP \ VP \\ S \rightarrow NP \ Vi \\ NP \rightarrow DT \ NN \\ NP \rightarrow NP \ PP \\ PP \rightarrow IN \ NP \\ VP \rightarrow Vt \ NP \\ VP \rightarrow VP \ PP \\ VP \rightarrow Vi \ PP \end{array}$	0.5 V 0.4 N 0.6 N 1.0 N 0.4 D 0.1 IN	$\begin{array}{l} i \rightarrow sleeps \\ t \rightarrow saw \\ N \rightarrow man \\ N \rightarrow woman \\ N \rightarrow telescope \\ T \rightarrow the \\ I \rightarrow with \\ I \rightarrow in \end{array}$	1.0 1.0 0.7 0.2 0.1 1.0 0.5 0.5			
	13	24				
NP + DT ₁₁ 0.4*1.0*0.2	=0.08	34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
DT + the NN + woman 1.0 0.2	33 Vt + saw 1.0	DT + the 1.0	55 NN + man 0.7	66 IN + with 0.5	77 DT + the 1.0	88 NN + telescope 0.1
1 2	3	4	5	6	7	8

$\begin{array}{c} S \rightarrow NP \ VP \\ S \rightarrow NP \ Vi \\ NP \rightarrow DT \ NP \\ NP \rightarrow NP \ F \\ PP \rightarrow IN \ NI \\ VP \rightarrow Vt \ NI \\ VP \rightarrow Vi \ PI \\ VP \rightarrow Vi \ PI \end{array}$	0.5 IN 0.4 P 0.6 P 1.0 P 0.4 P 0.1	Vt NN NN NN DT IN		1.0 1.0 0.7 0.2 e 0.1 1.0 0.5 0.5			
		13	24	35			
12		23	34	VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11 45	2 56	67	78
11 22	+ DT ₁₁ NN ₂₂ *1.0*0.2=0.08	33 Vt + saw	44 DT + the	NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28 55 NN + man	66 IN + with	π DT → the	NP → DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04 88 NN → telescope
1.0 0.2	2	1.0	1.0		0.5 6	1.0	0.1

$\begin{array}{c} S \rightarrow NP \ VP \\ S \rightarrow NP \ Vi \\ NP \rightarrow DT \ NN \\ NP \rightarrow NP \ PF \\ PP \rightarrow IN \ NP \\ VP \rightarrow Vt \ NP \\ VP \rightarrow VP \ PF \\ VP \rightarrow Vi \ PP \end{array}$	0.6 1.0 0.4	Vt - NN NN NN DT IN -	$\begin{array}{l} \rightarrow \text{sleeps} \\ \rightarrow \text{saw} \\ \rightarrow \text{man} \\ \rightarrow \text{woman} \\ \rightarrow \text{telescope} \\ \rightarrow \text{the} \\ \rightarrow \text{with} \\ \rightarrow \text{in} \end{array}$	1.0 1.0 0.7 0.2 0.1 1.0 0.5 0.5			
		13	24	35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11	2		
	DT ₁₁ NN ₂₂ 0*0.2=0.08	23	34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
11 22 NN + 1.0 0.2		33 Vt + saw 1.0	44 DT + the 1.0			77 DT + the 1.0	88 NN + telescope 0.1
1	2	3	4	5	6	7	8

$S \rightarrow NP \ Vi$ $NP \rightarrow DT \ NN$ $NP \rightarrow NP \ PP$ $PP \rightarrow IN \ NP$ $VP \rightarrow Vt \ NP$ $VP \rightarrow VP \ PP$	0.5 Vt 0.4 NN 0.6 NN 0.0 NN 0.4 DT 0.1 IN	$\begin{array}{l} \rightarrow \text{ sleeps} \\ \rightarrow \text{ saw} \\ \rightarrow \text{ man} \\ \rightarrow \text{ woman} \\ \rightarrow \text{ telescop} \\ \rightarrow \text{ the} \\ \rightarrow \text{ with} \\ \rightarrow \text{ in} \\ \end{array}$	1.0 1.0 0.7 0.2 e 0.1 1.0 0.5			
	13	24	35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11	46		
NP + DT ₁₁ NN 0.4*1.0*0.2=0		34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
DT + the NN + woman	33 Vt + saw	44 DT + the	55 NN → man	66 IN + with	77 DT → the	88 NN + telescope
1.0 0.2	1.0	1.0	0.7		1.0	0.1
1 2	3	4	5	6	7	8

$\begin{split} S &\rightarrow NP \ VP \\ S &\rightarrow NP \ Vi \\ NP &\rightarrow DT \ NN \\ NP &\rightarrow NP \ PP \\ PP &\rightarrow IN \ NP \\ VP &\rightarrow Vt \ NP \\ VP &\rightarrow VP \ PP \\ VP &\rightarrow VI \ PP \end{split}$	0.5 0.5 0.4 0.6 1.0 0.4 0.1	$\begin{array}{l} Vi \rightarrow sleeps \\ Vt \rightarrow saw \\ NN \rightarrow man \\ NN \rightarrow woman \\ NN \rightarrow telescope \\ DT \rightarrow the \\ IN \rightarrow with \\ IN \rightarrow in \\ \end{array}$	1.0 1.0 0.7 0.2 0.1 1.0 0.5			
	13		35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11	46		
NP + DT ₁ 0.4*1.0*0.		1	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
11 DT + the NN + wom 1.0 0.2	33 Vt → saw 1.0	DT + the 1.0		66 IN + with 0.5	77 DT + the 1.0	88 NN + telescope 0.1

$S \rightarrow NP \ VI$ $S \rightarrow NP \ VI$ $NP \rightarrow DT$ $NP \rightarrow NP \ IN \ N$ $VP \rightarrow VI \ N$ $VP \rightarrow VI \ F$ $VP \rightarrow VI \ F$	0.5 NN 0.4 PP 0.6 IP 1.0 IP 0.4 PP 0.1	Vt NN NN NN DT IN		1.0 1.0 0.7 0.2 e 0.1 1.0 0.5 0.5			
		13	24	35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11	46	57	
0	2 P + DT ₁₁ NN ₂₂ 4*1.0*0.2=0.08	23	34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
	N + woman	Vt + saw 1.0	DT + the 1.0	NN → man	IN + with 0.5	DT + the 1.0	NN + telescope 0.1

$\begin{array}{c} S \rightarrow NP \ VP \\ S \rightarrow NP \ Vi \\ NP \rightarrow DT \ N \\ NP \rightarrow NP \ P \\ PP \rightarrow IN \ NF \\ VP \rightarrow Vt \ NI \\ VP \rightarrow VP \ P \\ VP \rightarrow Vi \ PF \end{array}$	P 0.6 P 1.0 P 0.4 P 0.1	Vt - NN NN NN DT	ightarrow sleeps $ ightarrow$ saw $ ightarrow$ man $ ightarrow$ woman $ ightarrow$ telescope $ ightarrow$ the $ ightarrow$ with $ ightarrow$ in	1.0 1.0 0.7 0.2 0.1 1.0 0.5 0.5			
	į	13	24	35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11	46	57	
0.4*	+ DT ₁₁ NN ₂₂ 1.0*0.2=0.08	23	34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
DT + the NN 0.2	+ woman V	3 't + saw .0	DT + the 1.0		66 IN → with 0.5	77 DT + the 1.0	NN + telescope 0.1

$S \rightarrow NP \ VP$ $S \rightarrow NP \ Vi$ $NP \rightarrow DT \ NP$ $NP \rightarrow NP \ F$ $PP \rightarrow IN \ N$ $VP \rightarrow Vt \ N$ $VP \rightarrow Vi \ P$ $VP \rightarrow Vi \ P$	0.5 NN 0.4 PP 0.6 P 1.0 P 0.4 PP 0.1	Vt NI NI NI DI IN		1.0 1.0 0.7 0.2 e 0.1 1.0 0.5			
		13	24	35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11	46	57	68 PP + IN ₆₆ NP ₇₈ 1.0*0.5*0.04=0.02
0.4	+ DT ₁₁ NN ₂₂ *1.0*0.2=0.08	23	34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
DT + the NN 0.2	I + woman	33 Vt + saw 1.0	DT + the 1.0	55 NN + man 0.7	66 IN + with 0.5	77 DT + the 1.0	NN + telescope 0.1

$\begin{array}{c} S \rightarrow NP \ V \\ S \rightarrow NP \ V \\ NP \rightarrow DT \\ NP \rightarrow NP \\ NP \rightarrow NP \\ PP \rightarrow IN \\ VP \rightarrow Vt \\ VP \rightarrow VP \\ VP \rightarrow Vi \end{array}$	7i 0.5 NN 0.4 PP 0.6 NP 1.0 NP 0.4 PP 0.1	Vt NN NN NN DT IN		1.0 1.0 0.7 0.2 e 0.1 1.0 0.5 0.5			
		13	24	35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11	46 2	57	68 PP + IN ₆₆ NP ₇₈ 1.0*0.5*0.04=0.02
	12 NP + DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08	23	34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
	22 NN + woman 0.2	33 Vt → saw 1.0	1.0 44 DT + the		66 IN → with 0.5	7 DT + the 1.0	88 NN → telescope 0.1

$S \rightarrow NP$ $S \rightarrow NP$ $NP \rightarrow D'$ $NP \rightarrow NI$ $PP \rightarrow IN$ $VP \rightarrow VI$ $VP \rightarrow VI$ $VP \rightarrow VI$	Vi 0.5 F NN 0.4 P PP 0.6 NP 1.0 t NP 0.4 P PP 0.1	Vt NN NN NN DT IN		1.0 1.0 0.7 0.2 e 0.1 1.0 0.5			
		13	14	35 VP + Vt33NP45	46	57	68 PP + IN66NP78
11 DT + the	12 NP + DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08 22 NN + woman	23 33 Vt + saw	34 44 DT + the	0.4*1.0*0.28=0.11 45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	2 56 66 IN + with	67 77 DT + the	1.0*0.5*0.04=0.02 78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04 88 NN + telescope
1.0	0.2	1.0	1.0	0.7	0.5 6	1.0	0.1

$\begin{array}{c} S \rightarrow NP \ V \\ S \rightarrow NP \ V \\ NP \rightarrow DT \\ NP \rightarrow NF \\ PP \rightarrow NF \\ VP \rightarrow VF \\ VP \rightarrow VF \\ VP \rightarrow VF \\ VP \rightarrow VF \\ \end{array}$	Vi 0.5 C NN 0.4 C PP 0.6 NP 1.0 NP 0.4 C PP 0.1	Vt - NN NN NN DT IN -		1.0 1.0 0.7 0.2 0.1 1.0 0.5 0.5			
		13	14	35	46	57	68
	12 NP + DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08	23	34	$\begin{array}{c} VP + V_{133}NP_{45} \\ 0.4*1.0*0.28{=}0.11 \\ \hline 45 \\ NP + DT_{44}NN_{55} \\ 0.4*1.0*0.7{=}0.28 \\ \end{array}$	56	67	PP + IN ₆₆ NP ₇₈ 1.0*0.5*0.04=0.02 78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
DT + the 1.0	NN + woman 0.2	33 Vt + saw 1.0	DT + the 1.0		66 IN + with 0.5	77 DT + the 1.0	NN + telescope 0.1

$S \rightarrow NP$	VP 0.	5	Vi –	→ sleeps	1.0			
$S \rightarrow NP$				→ saw	1.0			
$NP \rightarrow I$ $NP \rightarrow N$				\rightarrow man \rightarrow woman	0.7 0.2			
$PP \rightarrow II$				\rightarrow woman \rightarrow telescop				
$VP \rightarrow V$				→ the	1.0			
$VP \rightarrow V$	/P PP 0.	1	IN -	→ with	0.5			
$VP \rightarrow V$	/i PP 0.	5	IN -	→ in	0.5			
				14				
		13		24	35	46	57	68
					VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11			PP + IN ₆₆ NP ₇₈ 1.0*0.5*0.04=0.02
	12	23		34	45	56	67	78
	NP + DT ₁₁ NN ₂	2			NP + DT ₄₄ NN ₅₅			NP + DT ₇₇ NN ₈₈
	0.4*1.0*0.2=0.0	8			0.4*1.0*0.7=0.28			0.4*1.0*0.1=0.04
DT + the	NN + woman	33 Vt → saw		A4 DT + the	55 NN → man	66 IN + with	77 DT → the	88 NN + telescope
1.0	0.2	1.0		1.0		0.5	1.0	0.1
1	2	3	1	4	5	6	7	8

$S \rightarrow NP$ $S \rightarrow NP$	Vi 0.5	V	$f i \to sleeps$ $f t \to saw$	1.0 1.0			
$NP \rightarrow D$ $NP \rightarrow N$ $PP \rightarrow IN$ $VP \rightarrow V$	P PP 0.6 I NP 1.0	N N	$N \rightarrow man$ $N \rightarrow woman$ $N \rightarrow telescop$ $N \rightarrow the$	0.7 0.2 e 0.1 1.0			
$VP \rightarrow V$ $VP \rightarrow V$			$N \to \text{with}$ $N \to \text{in}$	0.5 0.5			
			14	25	36	47	58
		13	24	35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11	46	57	68 PP + IN ₆₆ NP ₇₈ 1.0*0.5*0.04=0.02
	NP + DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08	23	34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
DT + the 1.0	NN + woman 0.2	33 Vt + saw 1.0	44 DT → the 1.0		66 IN + with 0.5	77 DT + the 1.0	88 NN + telescope 0.1
1	2	3	4	5	6	7	8

$\begin{array}{c} S \rightarrow N \\ NP \rightarrow \\ NP \rightarrow \\ PP \rightarrow \\ VP \rightarrow \\ VP \rightarrow \end{array}$	NP VP NP Vi DT NN NP PP IN NP Vt NP VP PP	0.5 0.5 0.4 0.6 1.0 0.4 0.1	Vt NN NN NN DT IN		1.0 1.0 0.7 0.2 0.1 1.0 0.5 0.5			
					15 S → NP ₁₂ VP ₃₅ 0.5*0.08*0.112= 4	.48e-3		
				14	25	36	47	58
			13	24	35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11	46	57	68 PP + IN ₆₆ NP ₇₈ 1.0*0.5*0.04=0.02
	NP + DT ₁ 0.4*1.0*0.2	1NN ₂₂	23	34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
11 DT + the 1.0	22 NN + wom 0.2	nan '	33 √t → saw 1.0	44 DT + the 1.0	55 NN + man 0.7	66 IN → with 0.5	77 DT + the 1.0	88 NN → telescope 0.1
1	2		3	4	5	6	7	8

$S \to NP$		0.5	$\mathrm{Vi} \to \mathrm{sleeps}$	1.0			
$S \rightarrow NP$		0.5	$Vt \rightarrow saw$	1.0			
$NP \rightarrow D$		0.4	$NN \rightarrow man$	0.7			
$NP \rightarrow N$		0.6	NN → woman				
$PP \rightarrow II$ $VP \rightarrow V$		1.0 0.4	$NN \rightarrow telesco$ $DT \rightarrow the$	pe 0.1 1.0			
$VP \rightarrow V$ $VP \rightarrow V$		0.4	$DI \rightarrow tne$ $IN \rightarrow with$				
$VP \rightarrow V$ $VP \rightarrow V$				0.5			
$VP \rightarrow V$	1 PP	0.5	$IN \rightarrow in$	0.5			
						37	
				15 S → NP ₁₂ VP ₃₅	46	37	48 NP → NP ₄₅ PP ₆₈
				0.5*0.08*0.112= 4	.48e-3		0.6*0.28*0.02=3.3
			14	25	36	47	58
		13	24	35 VP → Vt33NP45	46	57	68 PP → IN66NP78
				0.4*1.0*0.28=0.11	2		1.0*0.5*0.04=0.02
	12	23	34	45	56	67	78
	NP + DT ₁₁ N			NP + DT ₄₄ NN ₅₅			NP + DT ₇₇ NN ₈₈
	0.4*1.0*0.2=	0.08		0.4*1.0*0.7=0.28			0.4*1.0*0.1=0.04
11	22	33	44	55	66	77	88
DT + the	NN + womai 0.2	n Vt → sa 1.0	w DT + the		IN + with 0.5	DT + the 1.0	NN → telescope 0.1
1.0							

$S \rightarrow NF$	VP	0.5	$Vi \rightarrow sleeps$	1.0			
$S \rightarrow NF$	Vi Vi	0.5	$Vt \rightarrow saw$	1.0			
$NP \rightarrow I$	OT NN	0.4	$NN \rightarrow man$	0.7			
$NP \rightarrow 1$	NP PP	0.6	$NN \rightarrow woman$	n 0.2			
$PP \rightarrow I$	N NP	1.0	$NN \rightarrow telesco$	ре 0.1			
$VP \rightarrow V$	√t NP	0.4	$DT \rightarrow the$	1.0			
$VP \rightarrow V$	/P PP	0.1	$IN \rightarrow with$	0.5			
$VP \rightarrow V$	Vi PP	0.5	$IN \rightarrow in$	0.5			
					16	27	38
							VP - Vt ₃₃ NP ₄₈
							0.4*1.0*3.36e-3=1.3
				15	46	37	48
				S + NP ₁₂ VP ₃₅			NP + NP ₄₅ PP ₆₈
				0.5*0.08*0.112= 4	48e-3		0.6*0.28*0.02=3.36e-3
			14	25	36	47	58
		13	24	35	46	57	68
				VP + Vt ₃₃ NP ₄₅			PP + IN ₆₆ NP ₇₈
				0.4*1.0*0.28=0.11	2		1.0*0.5*0.04=0.02
	12	23	34	45	56	67	78
	NP + DT ₁₁ N 0.4*1.0*0.2=			NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28			NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
DT + the	NN → womai	33 Vt → sav	v DT → the	55 NN → man	66 IN → with	TOT + the	88 NN → telescope
1.0	0.2	1.0	1.0		0.5	1.0	0.1
1	2	2.0	3 4	5	6	7	8

1	2	3	4	5	6	7	- 8
.0	0.2	1.0	1.0		0.5	1.0	0.1
II OT + the	NN + woman		DT + the		66 IN + with	TOT + the	88 NN + telescope
	0.4*1.0*0.2=0	0.08		0.4*1.0*0.7=0.28			0.4*1.0*0.1=0.04
	12 NP + DT ₁₁ NI	23	34	45 NP + DT ₄₄ NN ₅₅	56	67	78 NP + DT ₇₇ NN ₈₈
		13	24	35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11	46 2	57	68 PP + IN ₆₆ NP ₇₈ 1.0*0.5*0.04=0.02
		-					
			14	25	36	47	58
				S - NP ₁₂ VP ₃₅ 0.5*0.08*0.112= 4	.48e-3		NP + NP ₄₅ PP ₆₈ 0.6*0.28*0.02=3.3
				15	46	37	48
							VP - VP ₃₅ PP ₆₈ 0.1*0.112*0.02=1
							0.4*1.0*3.36e-3=
					16	27	38 VP → Vt ₃₃ NP ₄₈
$\mathrm{VP} \to \mathrm{V}$	Vi PP	0.5	$IN \rightarrow in$	0.5			
$VP \rightarrow V$			$DI \rightarrow the$ $IN \rightarrow with$	0.5			
$PP \rightarrow I$ $VP \rightarrow V$			$NN \rightarrow telescop$ $DT \rightarrow the$	pe 0.1 1.0			
$NP \rightarrow N$			NN → woman				
$NP \rightarrow I$			$NN \rightarrow man$	0.7			
$S \rightarrow NF$	77;	0.5	$Vt \rightarrow saw$	1.0			

$S \rightarrow NP$ $S \rightarrow NP$		0.5 0.5	$Vi \rightarrow sleeps$ $Vt \rightarrow saw$	1.0 1.0			
$NP \rightarrow D$		0.4	$NN \rightarrow man$	0.7			
$NP \rightarrow N$		0.6	$NN \rightarrow woman$				
$PP \rightarrow II$		1.0	NN → telesco				
$VP \rightarrow V$		0.4	$DT \rightarrow the$	1.0			
$VP \rightarrow V$ $VP \rightarrow V$		0.1 0.5	IN → with	0.5			
$VP \rightarrow V$	1 PP	0.5	$IN \rightarrow in$	0.5			
				1	16	27	38
							VP - Vt ₃₃ NP ₄₈
							0.4*1.0*3.36e-3=1.3
				15	46	37	48
				S + NP ₁₂ VP ₃₅ 0.5*0.08*0.112= 4	40- 2		NP + NP ₄₅ PP ₆₈ 0.6*0.28*0.02=3.36e-3
			14	25	46E-3	47	58
			14	25	36	47	58
		13	24	35 VP + Vt33NP45	46	57	68 PP → IN ₆₆ NP ₇₈
				0.4*1.0*0.28=0.11	2		1.0*0.5*0.04=0.02
	12	23	34	45	56	67	78
	NP + DT ₁₁ N			NP + DT ₄₄ NN ₅₅			NP + DT ₇₇ NN ₈₈
	0.4*1.0*0.2=	0.08		0.4*1.0*0.7=0.28			0.4*1.0*0.1=0.04
II DT + the	22 NN → woman	33 Vt → saw	DT + the	55 NN → man	66 IN → with	77 DT → the	88 NIN and an and
1.0	0.2	1.0	1.0		0.5	1.0	NN + telescope 0.1
1	2		3 4	5	6	7	8

1	2	3	4	5	6	7	8
.0	0.2	1.0	1.0	0.7	0.5	1.0	0.1
II OT + the	NN + woman	33 Vt → saw	44 DT → the	55 NN + man	66 IN → with	77 DT → the	88 NN → telescope
	0.4*1.0*0.2=0			0.4*1.0*0.7=0.28			0.4*1.0*0.1=0.04
	NP + DT ₁₁ NI			NP + DT ₄₄ NN ₅₅			NP + DT ₇₇ NN ₈₈
	12	23	34	45	56	67	78
				0.4*1.0*0.28=0.1	ık		1.0*0.5*0.04=0.02
		13	24	35 VP + Vt33NP45	46	57	68 PP + IN66NP78
			14	25	36	47	58
				S + NP ₁₂ VP ₃₅ 0.5*0.08*0.112=	1.0 2		NP + NP ₄₅ PP ₆₈ 0.6*0.28*0.02=3.36
				15	46	37	48
							0.4*1.0*3.36e-3=
							VP - Vt ₃₃ NP ₄₈
					16	27	38
						17	28
$\mathrm{VP} \to \mathrm{Vi}\;\mathrm{PP}$		0.5	$IN \rightarrow in$	0.5			0.5*0.08*1.34e-3=5
$VP \rightarrow V$	P PP	0.1	$IN \rightarrow with$	0.5			18 S → NP ₁₂ VP ₃₈
$VP \rightarrow V$	t NP		$DT \rightarrow the$	1.0			
$PP \rightarrow IN$			NN → telesco				
$NP \rightarrow D$			$NN \rightarrow man$ $NN \rightarrow woman$				
$S \rightarrow NP$ $NP \rightarrow D$			$Vt \rightarrow saw$ $NN \rightarrow man$	0.7			
		0.5		1.0			

$\begin{array}{c} S \rightarrow NP \\ S \rightarrow NP \\ NP \rightarrow D' \\ NP \rightarrow NI \\ PP \rightarrow IN \\ VP \rightarrow V' \\ VP \rightarrow V' \\ VP \rightarrow V' \end{array}$	Vi 0.5 T NN 0.4 P PP 0.6 I NP 1.0 t NP 0.4 P PP 0.1	5 1 5 0 1	$\begin{array}{l} \text{Vi} \rightarrow \text{sleeps} \\ \text{Vt} \rightarrow \text{saw} \\ \text{NN} \rightarrow \text{man} \\ \text{NN} \rightarrow \text{woman} \\ \text{NN} \rightarrow \text{telescope} \\ \text{DT} \rightarrow \text{the} \\ \text{IN} \rightarrow \text{with} \\ \text{IN} \rightarrow \text{in} \end{array}$	1.0 1.0 0.7 0.2 e 0.1 1.0 0.5 0.5			18 S - NP ₁₂ VP ₃₈	
Final result							0.5*0.08*1.34e-3=5	i.38e-5
						17	28	
					16	27	38 VP + Vt ₃₃ NP ₄₈ 0.4*1.0*3.36e-3=1	1.34e-3
				S + NP ₁₂ VP ₃₅ 0.5*0.08*0.112= 4	46 1.48e-3	37	48 NP + NP ₄₅ PP ₆₈ 0.6*0.28*0.02=3.36	ie-3
			14	25	36	47	58	
		13	24	35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.11	46	57	68 PP + IN ₆₆ NP ₇₈ 1.0*0.5*0.04=0.02	
	12 NP + DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08		34	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP - DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04	
11 DT → the	22 NN - woman	33 Vt → saw	44 DT → the	55 NN → man	66 IN → with	77 DT - the	88 NN → telescope	
1.0	0.2	1.0	1.0	0.7	0.5	1.0	0.1	
1	2	3	4	5	6	7	8	