

Introduction to Human Language Technologies

9. Syntactic parsing: parsers



UNIVERSITAT POLITÈCNICA DE CATALUNYA
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Exercise 1

Convert the following CFG to CNF

- 1 $S \rightarrow NP VP$
- 2 $NP \rightarrow det\ n$
- 3 $NP \rightarrow n$
- 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 $vi \rightarrow eats$

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3 $NP \rightarrow n$

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(B) Convert unit productions

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(C) Convert non-binary rules

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$$VP \rightarrow eats$$

(C) Convert non-binary rules

$$VP \rightarrow vt B$$

$$B \rightarrow NP PP$$

Exercise 1

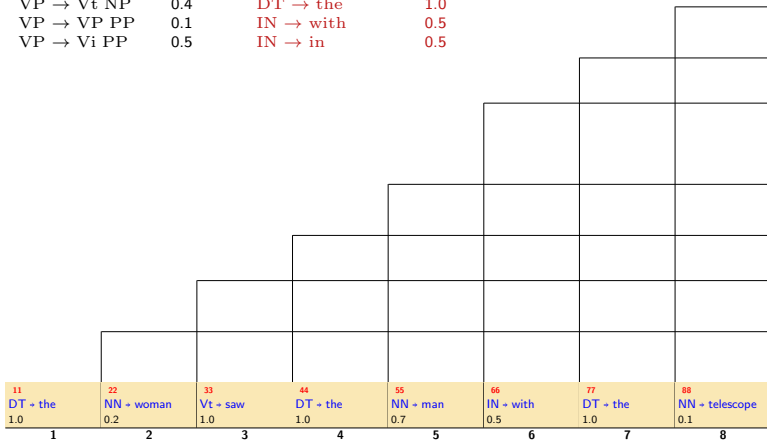
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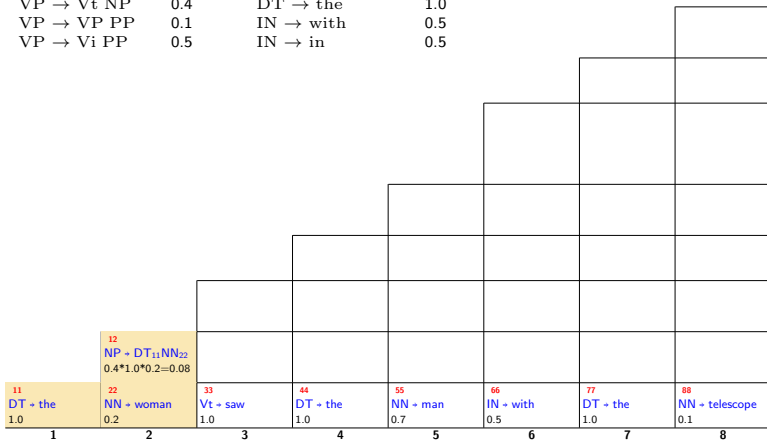
Exercise 2

S → NP VP	0.5	Vi → sleeps	1.0
S → NP Vi	0.5	Vt → saw	1.0
NP → DT NN	0.4	NN → man	0.7
NP → NP PP	0.6	NN → woman	0.2
PP → IN NP	1.0	NN → telescope	0.1
VP → Vt NP	0.4	DT → the	1.0
VP → VP PP	0.1	IN → with	0.5
VP → Vi PP	0.5	IN → in	0.5



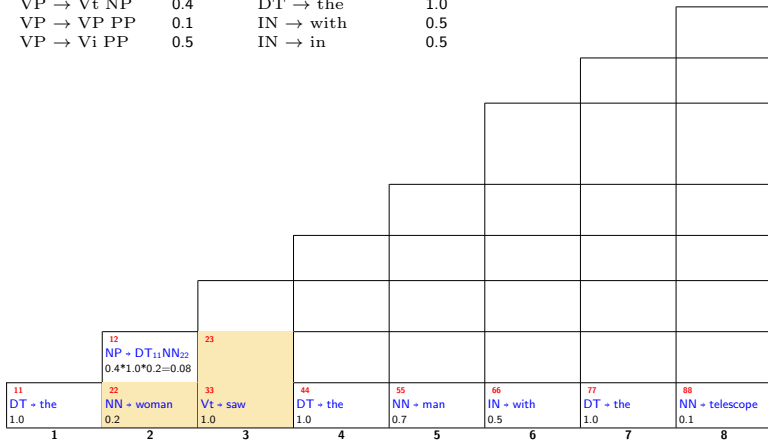
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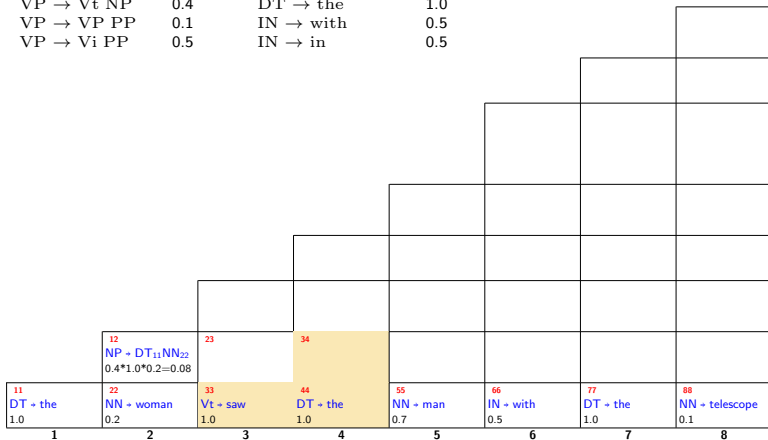
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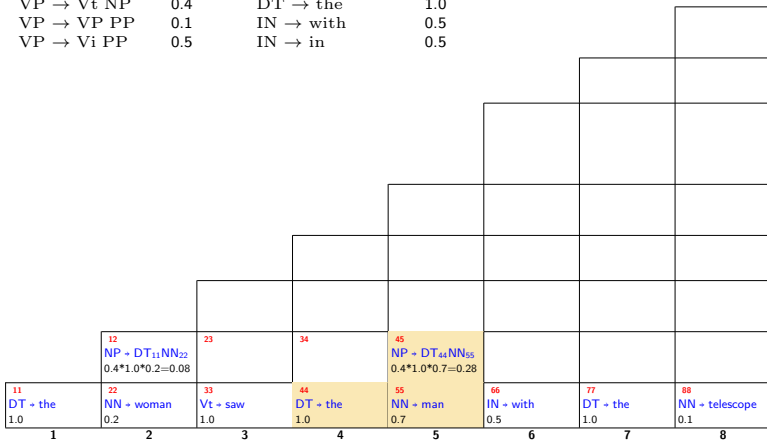
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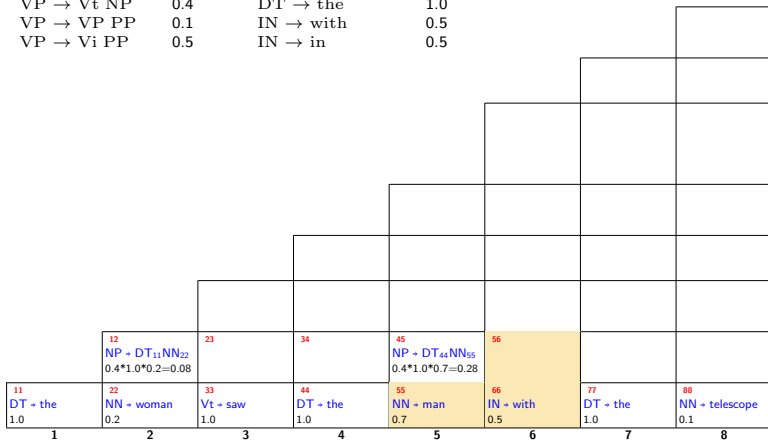
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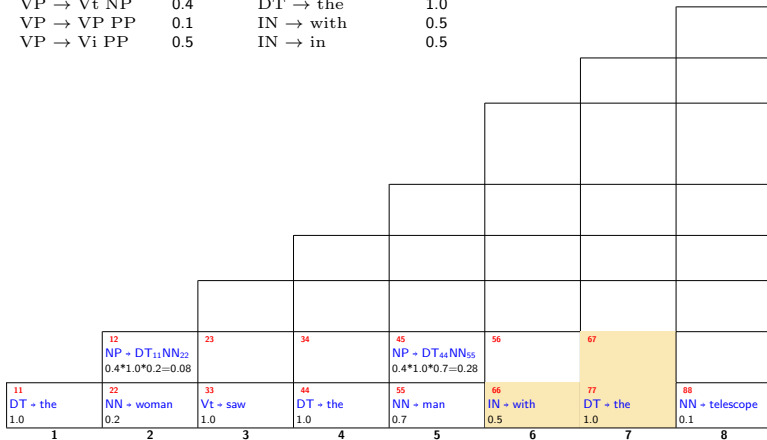
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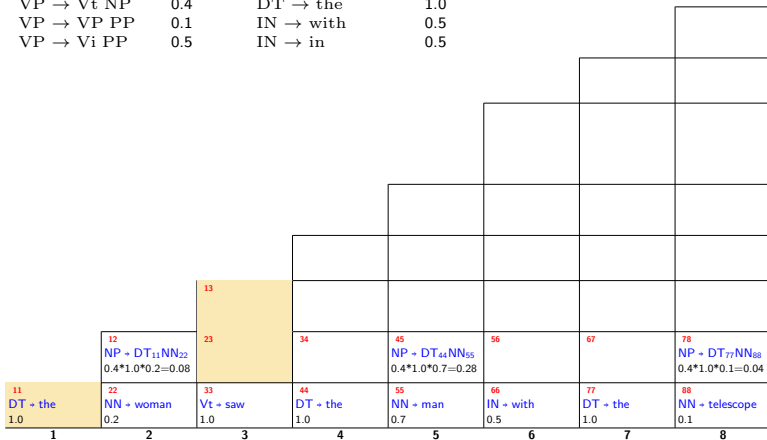
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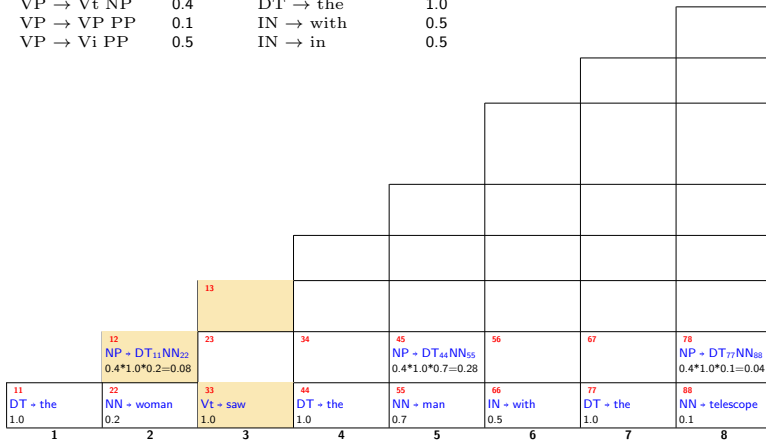
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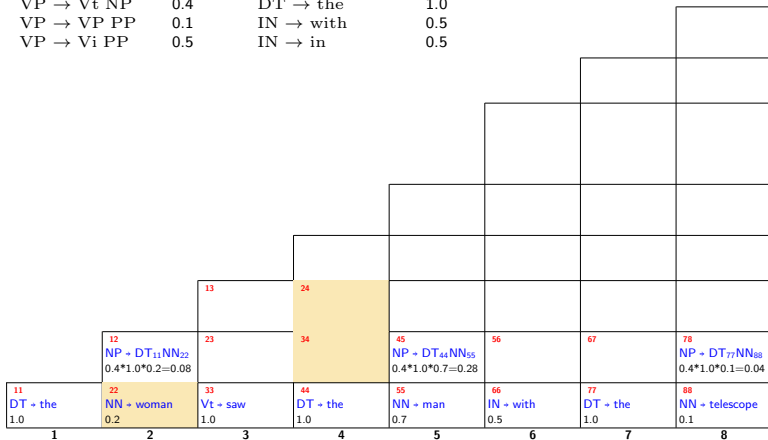
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		13	24				
	12 $NP \rightarrow DT_{11} NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23	34	45 $NP \rightarrow DT_{44} NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	56	67	78 $NP \rightarrow DT_{77} NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$
11 $DT \rightarrow \text{the}$ 1.0	22 $NN \rightarrow \text{woman}$ 0.2	33 $Vt \rightarrow \text{saw}$ 1.0	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1
1	2	3	4	5	6	7	8

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$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
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		13	24	35 $VP \rightarrow Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$			
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Exercise 2

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$NP \rightarrow DT NN$	0.4	$NN \rightarrow \text{man}$	0.7
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$PP \rightarrow IN NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
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$NP \rightarrow DT NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow \text{in}$	0.5

		13	24	35 $VP \rightarrow Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	46	57	68 $PP \rightarrow IN_{66}NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$
	12 $NP \rightarrow DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23	34	45 $NP \rightarrow DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	56	67	78 $NP \rightarrow DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$
11 $DT \rightarrow \text{the}$ 1.0	22 $NN \rightarrow \text{woman}$ 0.2	33 $Vt \rightarrow \text{saw}$ 1.0	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1
1	2	3	4	5	6	7	8

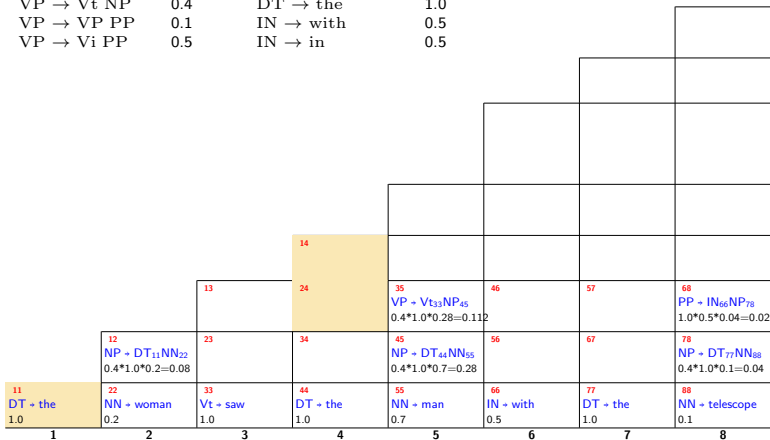
Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow \text{in}$	0.5

		13	24	35 $VP \rightarrow Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	46	57	68 $PP \rightarrow IN_{66}NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$
	12 $NP \rightarrow DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23	34	45 $NP \rightarrow DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	56	67	78 $NP \rightarrow DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$
11 $DT \rightarrow \text{the}$ 1.0	22 $NN \rightarrow \text{woman}$ 0.2	33 $Vt \rightarrow \text{saw}$ 1.0	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1
1	2	3	4	5	6	7	8

Exercise 2

S → NP VP	0.5	Vi → sleeps	1.0
S → NP Vi	0.5	Vt → saw	1.0
NP → DT NN	0.4	NN → man	0.7
NP → NP PP	0.6	NN → woman	0.2
PP → IN NP	1.0	NN → telescope	0.1
VP → Vt NP	0.4	DT → the	1.0
VP → VP PP	0.1	IN → with	0.5
VP → Vi PP	0.5	IN → in	0.5



Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow \text{in}$	0.5

			14				
		13	24	35 $VP \rightarrow Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	46	57	68 $PP \rightarrow IN_{66}NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$
	12 $NP \rightarrow DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23	34	45 $NP \rightarrow DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	56	67	78 $NP \rightarrow DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$
11 $DT \rightarrow \text{the}$ 1.0	22 $NN \rightarrow \text{woman}$ 0.2	33 $Vt \rightarrow \text{saw}$ 1.0	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1
1	2	3	4	5	6	7	8

Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow \text{in}$	0.5

			14				
		13	24	35 $VP \rightarrow Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	46	57	68 $PP \rightarrow IN_{66}NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$
	12 $NP \rightarrow DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23	34	45 $NP \rightarrow DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	56	67	78 $NP \rightarrow DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$
11 $DT \rightarrow \text{the}$ 1.0	22 $NN \rightarrow \text{woman}$ 0.2	33 $Vt \rightarrow \text{saw}$ 1.0	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1
1	2	3	4	5	6	7	8

Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow \text{in}$	0.5

			14	25	36	47	58
		13	24	35 $VP \rightarrow Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	46	57	68 $PP \rightarrow IN_{66}NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$
	12 $NP \rightarrow DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23	34	45 $NP \rightarrow DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	56	67	78 $NP \rightarrow DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$
11 $DT \rightarrow \text{the}$ 1.0	22 $NN \rightarrow \text{woman}$ 0.2	33 $Vt \rightarrow \text{saw}$ 1.0	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1
1	2	3	4	5	6	7	8

Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow \text{in}$	0.5

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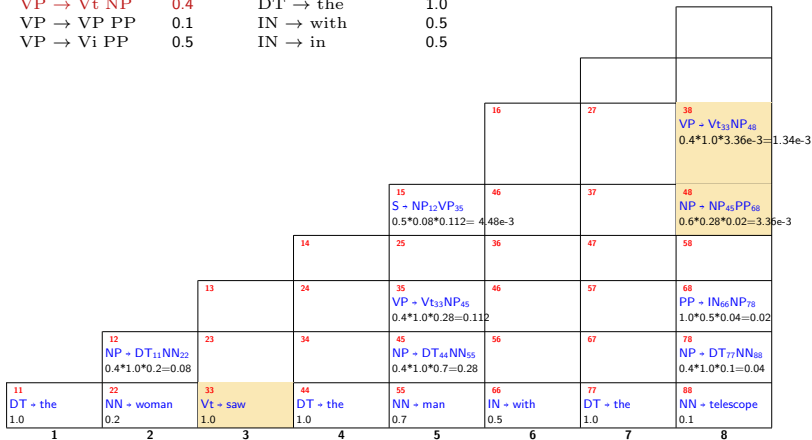
Exercise 2

S → NP VP	0.5	Vi → sleeps	1.0
S → NP Vi	0.5	Vt → saw	1.0
NP → DT NN	0.4	NN → man	0.7
NP → NP PP	0.6	NN → woman	0.2
PP → IN NP	1.0	NN → telescope	0.1
VP → Vt NP	0.4	DT → the	1.0
VP → VP PP	0.1	IN → with	0.5
VP → Vi PP	0.5	IN → in	0.5

				15 S → NP ₁₂ VP ₃₅ 0.5*0.08*0.112=4.48e-3	46	37	48 NP → NP ₄₅ PP ₆₈ 0.6*0.28*0.02=3.36e-3
			14	25	36	47	58
		13	24	35 VP → Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.112	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	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 → woman 0.2	33 Vt → 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

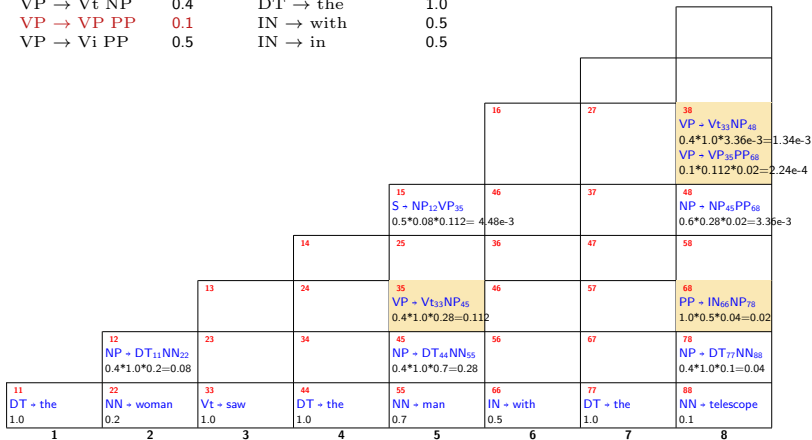
Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow \text{in}$	0.5



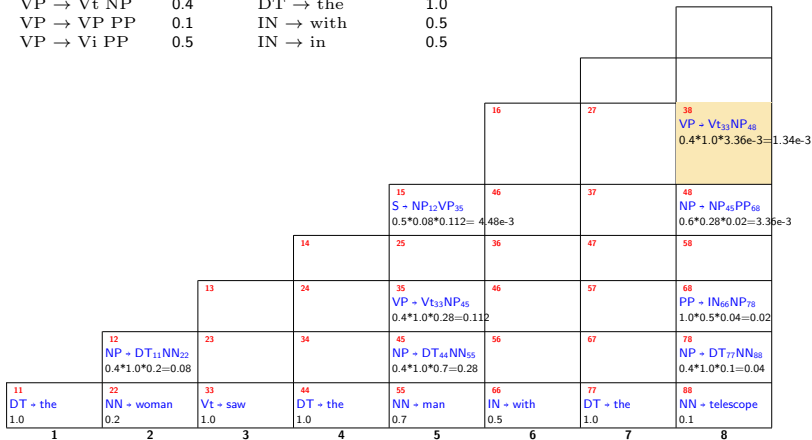
Exercise 2

S → NP VP	0.5	Vi → sleeps	1.0
S → NP Vi	0.5	Vt → saw	1.0
NP → DT NN	0.4	NN → man	0.7
NP → NP PP	0.6	NN → woman	0.2
PP → IN NP	1.0	NN → telescope	0.1
VP → Vt NP	0.4	DT → the	1.0
VP → VP PP	0.1	IN → with	0.5
VP → Vi PP	0.5	IN → in	0.5



Exercise 2

S → NP VP	0.5	Vi → sleeps	1.0
S → NP Vi	0.5	Vt → saw	1.0
NP → DT NN	0.4	NN → man	0.7
NP → NP PP	0.6	NN → woman	0.2
PP → IN NP	1.0	NN → telescope	0.1
VP → Vt NP	0.4	DT → the	1.0
VP → VP PP	0.1	IN → with	0.5
VP → Vi PP	0.5	IN → in	0.5



Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow \text{in}$	0.5

							18 $S \rightarrow NP_{12}VP_{38}$ $0.5 * 0.08 * 1.34e-3 = 5.38e-5$
						17	28
					16	27	38 $VP \rightarrow Vt_{33}NP_{48}$ $0.4 * 1.0 * 3.36e-3 = 1.34e-3$
				15 $S \rightarrow NP_{12}VP_{35}$ $0.5 * 0.08 * 0.112 = 4.48e-3$	46	37	48 $NP \rightarrow NP_{45}PP_{68}$ $0.6 * 0.28 * 0.02 = 3.36e-3$
			14	25	36	47	58
		13	24	35 $VP \rightarrow Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	46	57	68 $PP \rightarrow IN_{66}NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$
	12 $NP \rightarrow DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23	34	45 $NP \rightarrow DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	56	67	78 $NP \rightarrow DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$
11 $DT \rightarrow \text{the}$ 1.0	22 $NN \rightarrow \text{woman}$ 0.2	33 $Vt \rightarrow \text{saw}$ 1.0	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1
1	2	3	4	5	6	7	8

Exercise 2

S → NP VP	0.5	Vi → sleeps	1.0
S → NP Vi	0.5	Vt → saw	1.0
NP → DT NN	0.4	NN → man	0.7
NP → NP PP	0.6	NN → woman	0.2
PP → IN NP	1.0	NN → telescope	0.1
VP → Vt NP	0.4	DT → the	1.0
VP → VP PP	0.1	IN → with	0.5
VP → Vi PP	0.5	IN → in	0.5

Final result

