Parsing Lab

Step by step solutions

Exercise 1

Given this grammar and lexicon

Lexicon

Det → that | this | the | a
Noun → book | flight | meal | money
Verb → book | include | prefer
Pronoun → I | she | me
Proper-Noun → Houston | NWA
Aux → does
Preposition → from | to | on | near | through

$\mathcal{L}_1$ in CNF

S → NP VP
S → X1 VP
X1 → Aux NP
S → book | include | prefer
S → Verb NP
S → X2 PP
S → Verb PP
S → VP PP
NP → I | she | me
NP → TWA | Houston
NP → Det Nominal
Nominal → book | flight | meal | money
Nominal → Nominal Noun
Nominal → Nominal PP
VP → book | include | prefer
VP → Verb NP
VP → X2 PP
X2 → Verb NP
VP → Verb PP
VP → VP PP
PP → Preposition NP

Exercise 1

Parse the following sentence

Book	the	flight	through	Houston

Solution 1 – step 1

For cell (1, 1), look for rules of the form *-> *book*

Book	the	flight	through	Houston
Cell (1,1)				

Solution 1 – step 1.1

S -> book

Book	the	flight	through	Houston
S				

Solution 1 – step 1.2

Nominal -> book

Book	the	flight	through	Houston
S, **Nominal**				

Solution 1 – step 1.3

VP -> book

Book	the	flight	through	Houston
S, Nominal, **VP**				

Solution 1 – step 1.4

Noun -> book

Book	the	flight	through	Houston
S, Nominal, VP, **Noun**				

Solution 1 – step 1.5

Verb -> book

Book	the	flight	through	Houston
S, Nominal, VP, Noun, **Verb**				

Solution 1 – step 2

For cell (2, 2), look for rules of the form ** -> the*

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb				
	Cell (2,2)			

Solution 1 – step 2.1

Det -> the

Book	<u>the</u>	flight	through	Houston
S, Nominal, VP, Noun, Verb				
	Det			

Solution 1 – step 3

For cell (3, 3), look for rules of the form * -> flight

Book	the	<u>flight</u>	through	Houston
S, Nominal, VP, Noun, Verb				
	Det			
		Cell (3, 3)		

Solution 1 – step 3.1

Nominal -> flight

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb				
	Det			
		Nominal		

Solution 1 – step 3.2

Noun -> flight

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb				
	Det			
		Nominal, **Noun**		

Solution 1 – step 4

For cell (4, 4), Look for rules of the form * -> through

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb				
	Det			
		Nominal, Noun		
			Cell (4, 4)	

Solution 1 – step 4.1

Preposition -> through

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb				
	Det			
		Nominal, Noun		
			Preposition	

Solution 1 – step 5

For cell (5, 5), look for rules of the form * -> Houston

Book	the	flight	through	<u>Houston</u>
S, Nominal, VP, Noun, Verb				
	Det			
		Nominal, Noun		
			Preposition	
				Cell (5, 5)

Solution 1 – step 5.1

NP -> Houston

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb				
	Det			
		Nominal, Noun		
			Preposition	
				NP

Solution 1 – step 5.2

Proper-Noun -> Houston

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb				
	Det			
		Nominal, Noun		
			Preposition	
				NP, **Proper-Noun**

Solution 1 – step 6

For cell (1, 2), check cells (1,1) and (2,2)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	Cell (1,2)			
	Det			
		Nominal, Noun		
			Preposition	
				NP, Proper-Noun

Solution 1 – step 6.1

No rule found! Eg, There is no rule of the form * -> S Det

Book	the	flight	through	Houston
<u>S, Nominal, VP, Noun, Verb</u>	**---**			
	<u>Det</u>			
		Nominal, Noun		
			Preposition	
				NP, Proper-Noun

Solution 1 – step 7

For cell (2, 3), check cells (2,2) and (3,3)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---			
	Det	Cell (2, 3)		
		Nominal, Noun		
			Preposition	
				NP, Proper-Noun

Solution 1 – step 7.1

NP -> Det Nominal

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---			
	Det	**NP**		
		Nominal, Noun		
			Preposition	
				NP, Proper-Noun

Solution 1 – step 8

For cell (3, 4), check cells (3,3) and (4,4)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---			
	Det	NP		
		Nominal, Noun	Cell (3, 4)	
			Preposition	
				NP, Proper-Noun

Solution 1 – step 8.1

No rule found! Eg, no rule like * -> Nominal Preposition

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---			
	Det	NP		
		<u>Nominal, Noun</u>	**---**	
			<u>Preposition</u>	
				NP, Proper-Noun

Solution 1 – step 9

For cell (4, 5), check cells (4,4) and (5,5)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---			
	Det	NP		
		Nominal, Noun	---	
			<u>Preposition</u>	Cell (4,5)
				<u>NP, Proper-Noun</u>

Solution 1 – step 9.1

PP -> Preposition NP

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---			
	Det	NP		
		Nominal, Noun	---	
			Preposition	**PP**
				NP, Proper-Noun

Solution 1 – step 10

For cell (1, 3), first check (1,1) and (2,3)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	Cell (1,3)		
	Det	NP		
		Nominal, Noun	---	
			Preposition	PP
				NP, Proper-Noun

then check (1,2) and (3,3)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	Cell (1,3)		
	Det	NP		
		Nominal, Noun	---	
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 10.1

S -> Verb NP

Book	the	flight	through	Houston
<u>S, Nominal, VP, Noun, Verb</u>	---	**S**		
	Det	<u>NP</u>		
		Nominal, Noun	---	
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 10.2

VP -> Verb NP

Book	the	flight	through	Houston
<u>S, Nominal, VP, Noun, Verb</u>	---	S, **VP**		
	Det	<u>NP</u>		
		Nominal, Noun	---	
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 10.3

X2 -> Verb NP

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, **X2**		
	Det	NP		
		Nominal, Noun	---	
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 10.4

No rule found when we check (1,2) and (3,3)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2		
	Det	NP		
		Nominal, Noun	---	
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 11

For cell (2, 4), first check (2, 2) and (3,4)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2		
	Det	NP	Cell (2,4)	
		Nominal, Noun	---	
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 11

then check (2, 3) and (4,4)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2		
	Det	NP	Cell (2,4)	
		Nominal, Noun	---	
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 11.1

No rule found when we check (2,2) and (3,4)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2		
	<u>Det</u>	NP	---	
		Nominal, Noun	<u>---</u>	
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 11.2

No rule found when we check (2,3) and (4,4)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2		
	Det	NP	---	
		Nominal, Noun	---	
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 12

For cell (3,5), first check (3,3) and (4,5)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2		
	Det	NP	---	
		<u>Nominal, Noun</u>	---	Cell (3,5)
			Preposition	<u>PP</u>
				NP, Proper-Noun

Solution 1 – step 12

then check (3,4) and (5,5)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2		
	Det	NP	---	
		Nominal, Noun	<u>---</u>	Cell (3,5)
			Preposition	PP
				<u>NP, Proper-Noun</u>

Solution 1 – step 12.1

Nominal -> Nominal PP

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2		
	Det	NP	---	
		Nominal, Noun	---	**Nominal**
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 12.2

No rule found when we check (3,4) and (5,5)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2		
	Det	NP	---	
		Nominal, Noun	<u>---</u>	Nominal
			Preposition	PP
				<u>NP, Proper-Noun</u>

Solution 1 – step 13

For cell (1,4), first check (1,1) and (2,4)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	Cell (1,4)	
	Det	NP	---	
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

then check (1,2) and (3,4)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	Cell (1,4)	
	Det	NP	---	
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 13

then check (1,3) and (4,4)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	<u>S, VP, X2</u>	Cell (1,4)	
	Det	NP	---	
		Nominal, Noun	---	Nominal
			<u>Preposition</u>	PP
				NP, Proper-Noun

Solution 1 – step 13.1

Check (1,1) and (2,4). No rule found!

Book	the	flight	through	Houston
<u>S, Nominal, VP, Noun, Verb</u>	---	S, VP, X2	**---**	
	Det	NP	<u>---</u>	
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 13.2

Check (1,2) and (3,4). No rule found!

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	**---**	
	Det	NP	---	
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 13.3

Check (1,3) and (4,4). No rule found!

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	<u>S, VP, X2</u>	**---**	
	Det	NP	---	
		Nominal, Noun	---	Nominal
			<u>Preposition</u>	PP
				NP, Proper-Noun

For cell (2,5), first check (2,2) and (3,5)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	
	Det	NP	---	Cell (2,5)
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 14

then check (2,3) and (4,5)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	
	Det	<u>NP</u>	---	Cell (2,5)
		Nominal, Noun	---	Nominal
			Preposition	<u>PP</u>
				NP, Proper-Noun

then check (2,4) and (5,5)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	
	Det	NP	==	Cell (2,5)
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 14.1

Check (2,2) and (3,5). NP -> Det Nominal

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	
	<u>Det</u>	NP	---	**NP**
		Nominal, Noun	---	<u>Nominal</u>
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 14.2

Check (2,3) and (4,5). No rule found!

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 14.3

Check (2,4) and (5,5). No rule found!

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	
	Det	NP	<u>--</u>	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				<u>NP, Proper-Noun</u>

For cell (1,5), first check (1,1) and (2,5)

Book	the	flight	through	Houston
<u>S, Nominal, VP, Noun, Verb</u>	---	S, VP, X2	---	Cell (1,5)
	Det	NP	---	<u>NP</u>
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

then check (1,2) and (3,5)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	Cell (1,5)
	Det	NP	---	NP
		Nominal, Noun	---	<u>Nominal</u>
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 15

then check (1,3) and (4,5)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	Cell (1,5)
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

then check (1,4) and (5,5)

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	==	Cell (1,5)
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 15.1

Check (1,1) and (2,5). S -> Verb NP

Book	the	flight	through	Houston
<u>S, Nominal, VP, Noun, Verb</u>	---	S, VP, X2	---	**S1**
	Det	NP	---	<u>NP</u>
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 15.2

Check (1,1) and (2,5). VP -> Verb NP

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	S1, **VP**
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 15.3

Check (1,1) and (2,5). X2 -> Verb NP

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	S1, VP, **X2**
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 15.4

Check (1,2) and (3,5). No rule found!

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	S1, VP, X2
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 15.5

Check (1,3) and (4,5). S -> VP PP

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	S1, VP, X2, **S2**
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 15.6

Check (1,3) and (4,5). VP -> VP PP

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	S1, VP, X2, S2, **VP2**
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 15.7

Check (1,3) and (4,5). S -> X2 PP

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	---	S1, VP, X2, S2, VP2, **S3**
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Solution 1 – step 15.8

Check (1,3) and (4,5). VP -> X2 PP

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	<u>S, VP, X2</u>	---	S1, VP, X2, S2, VP2, S3, **VP3**
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	<u>PP</u>
				NP, Proper-Noun

Solution 1 – step 15.9

Check (1,4) and (5,5). No rule found!

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	<u>--</u>	S1, VP, X2, S2, VP2, S3, VP3
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				<u>NP, Proper-Noun</u>

Solution 1 – final

The three S in (1,5) form three different parse trees.

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	==	**S1**, VP, X2, **S2**, VP2, **S3**, VP3
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				NP, Proper-Noun

Exercise 2

Retrieve the three parse trees from S1, S2 and S3

Book	the	flight	through	Houston
S, Nominal, VP, Noun, Verb	---	S, VP, X2	<u>---</u>	**S1**, VP, X2, **S2**, VP2, **S3**, VP3
	Det	NP	---	NP
		Nominal, Noun	---	Nominal
			Preposition	PP
				<u>NP, Proper-Noun</u>

Solution 2 – S1 – step 1

S1

S1
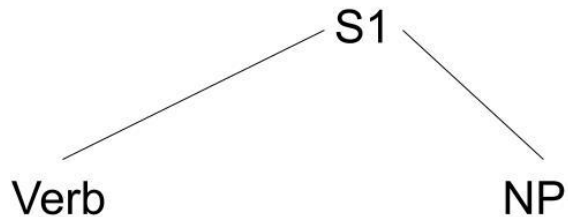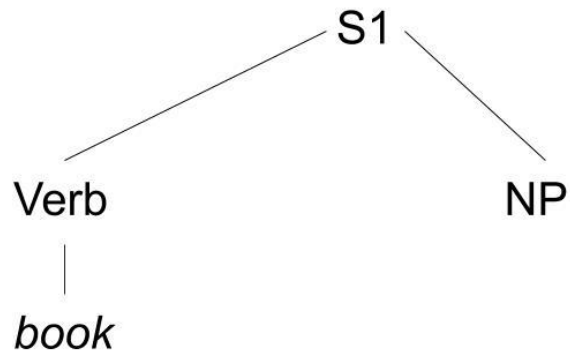
Verb

NP

S -> Verb   NP
      (1,1)   (2,5)

S1
Verb   NP
|
book

Verb -> book

S1

Verb

book

NP

Det

Nominal

NP -> Det   Nominal
       (2,2)   (3,5)

S1

Verb

book

NP

Det

the

Nominal

Det -> the

S1
Verb
book
NP
Det
the
Nominal
Nominal
PP

Nominal -> Nominal   PP
              (3,3)   (4,5)

Nominal -> flight

S1
Verb — book
NP
  Det — the
  Nominal
    Nominal — flight
    PP
      Preposition
      NP

PP -> Preposition   NP
         (4,4)   (5,5)
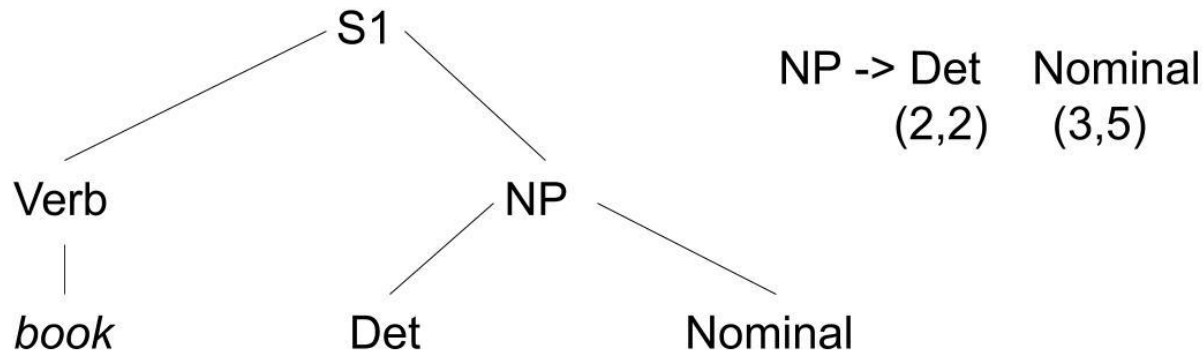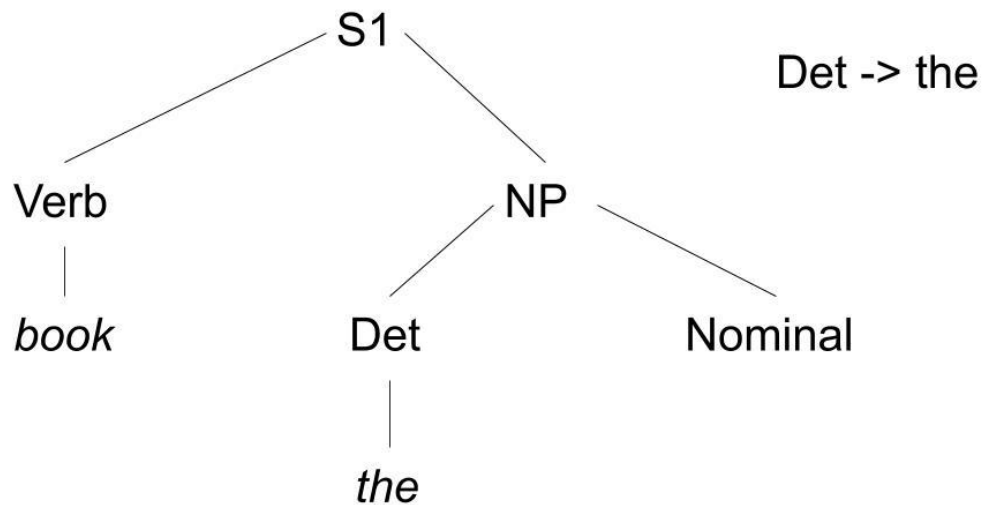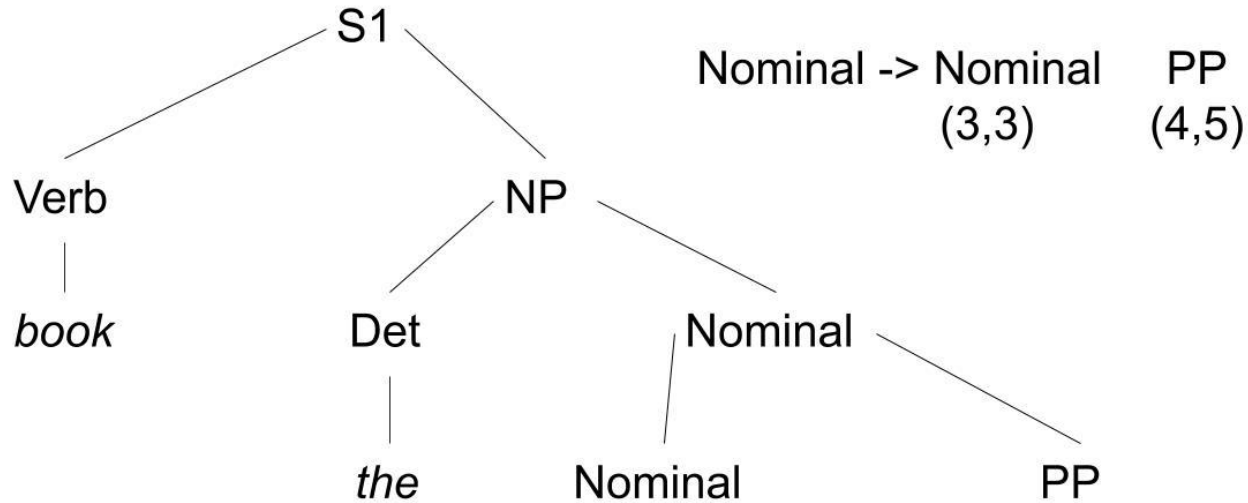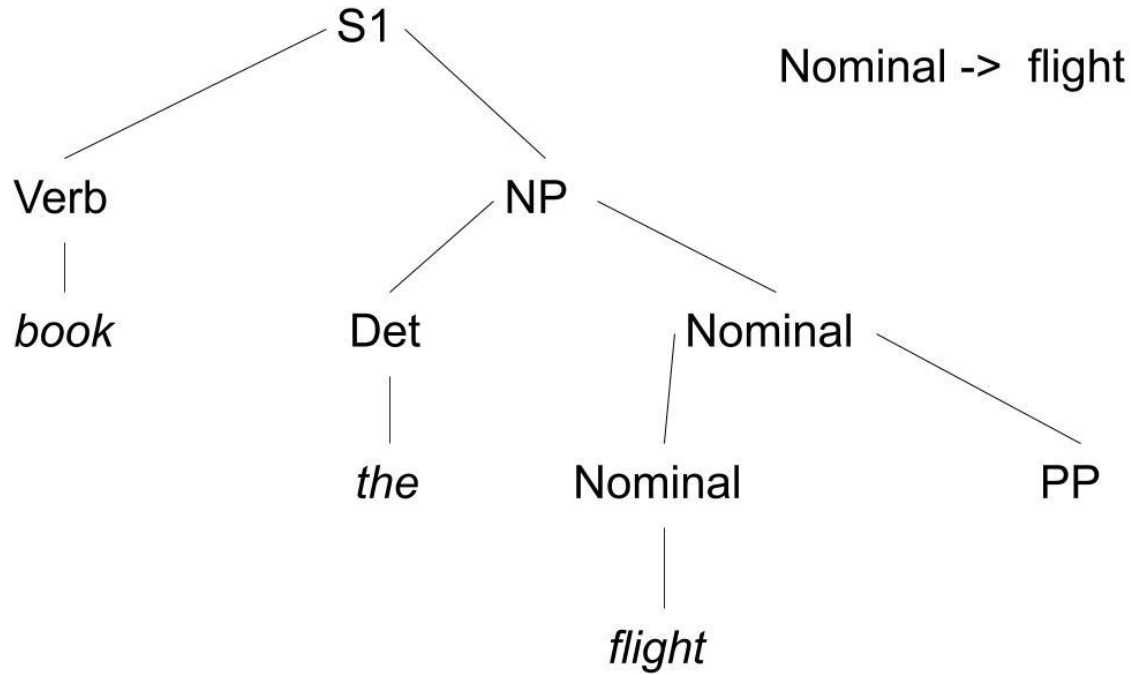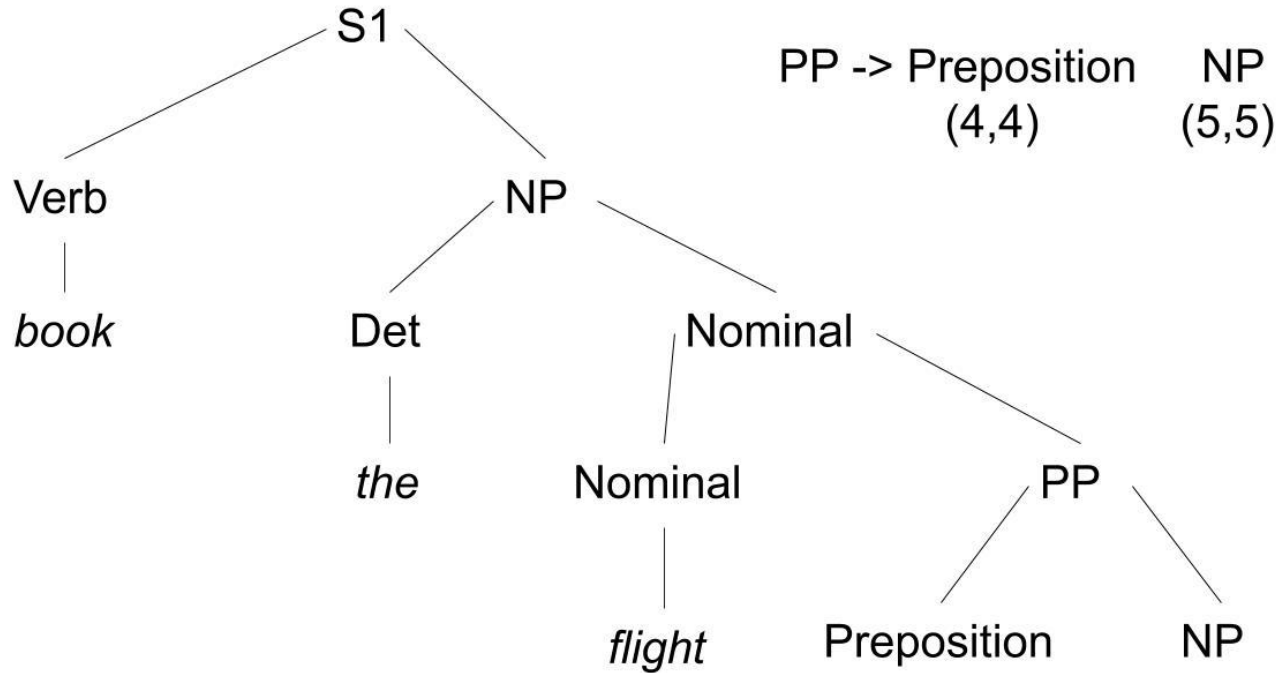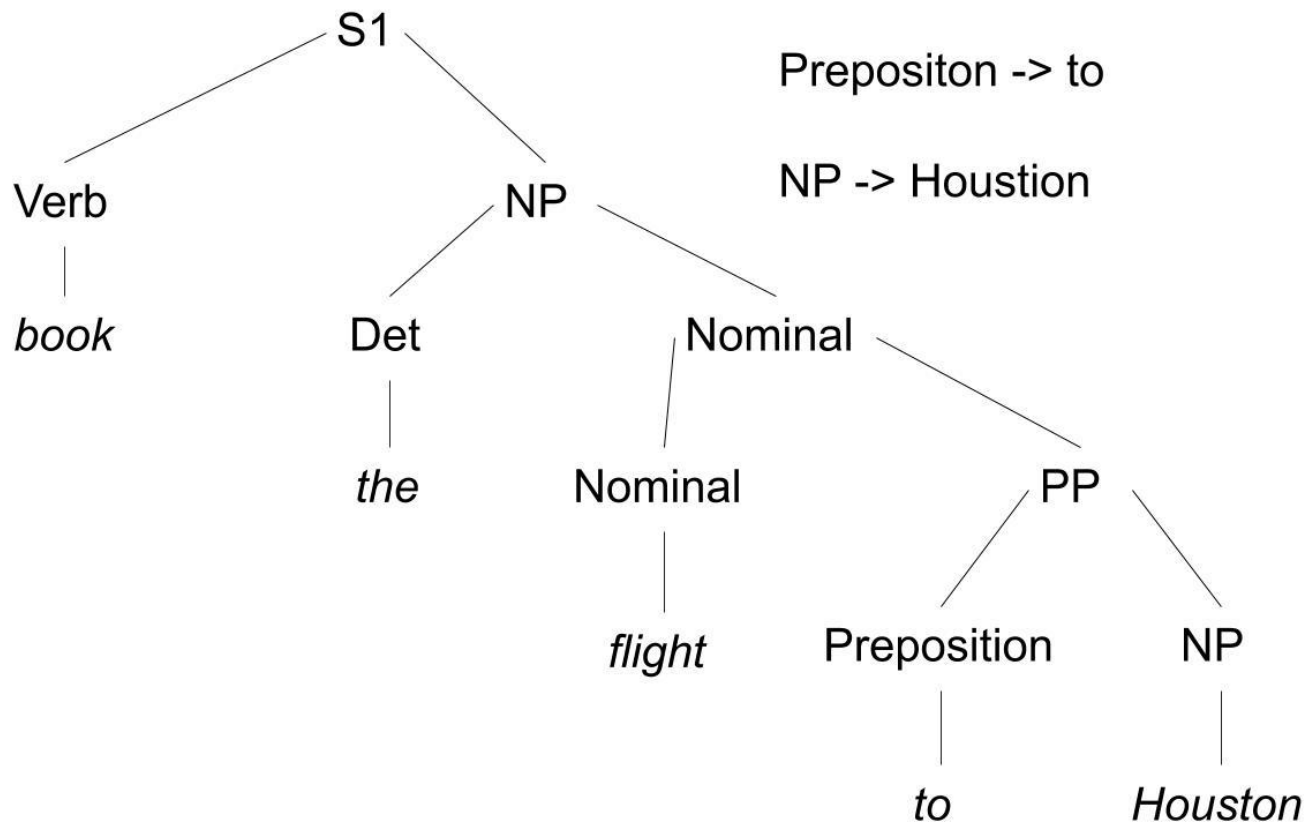
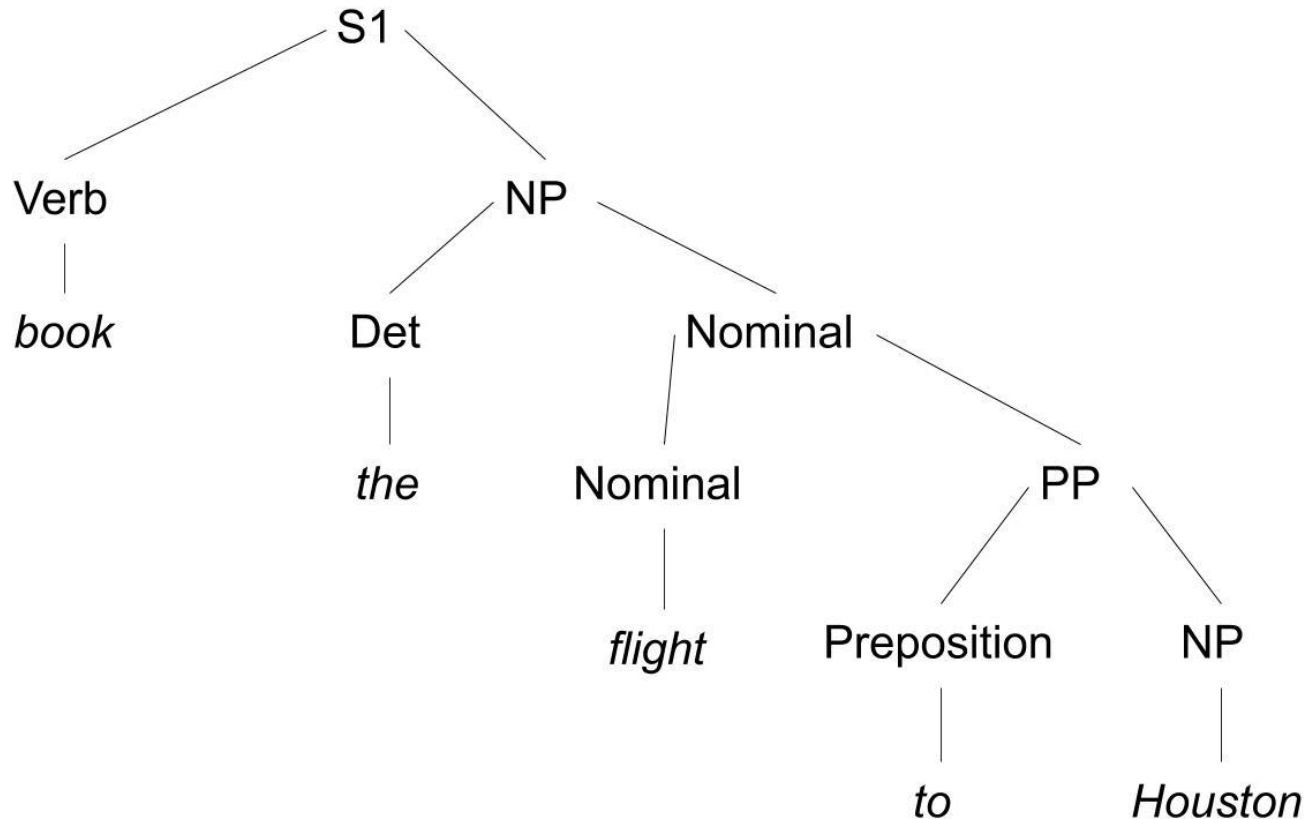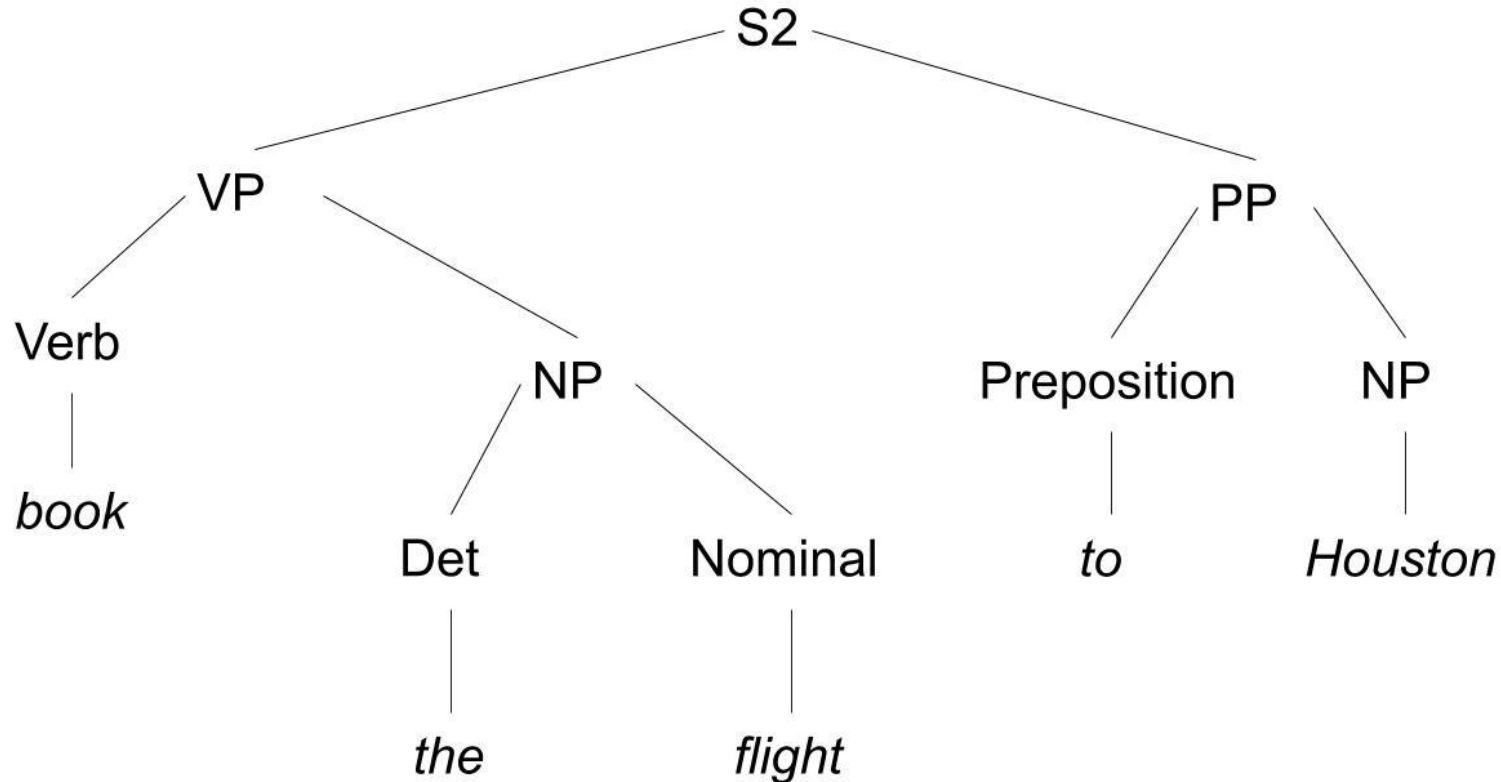# Solution 2 – S1 – step 9

Solution 2 – S1 – final

Solution 2 – S2 – final

Solution 2 – S3 – final
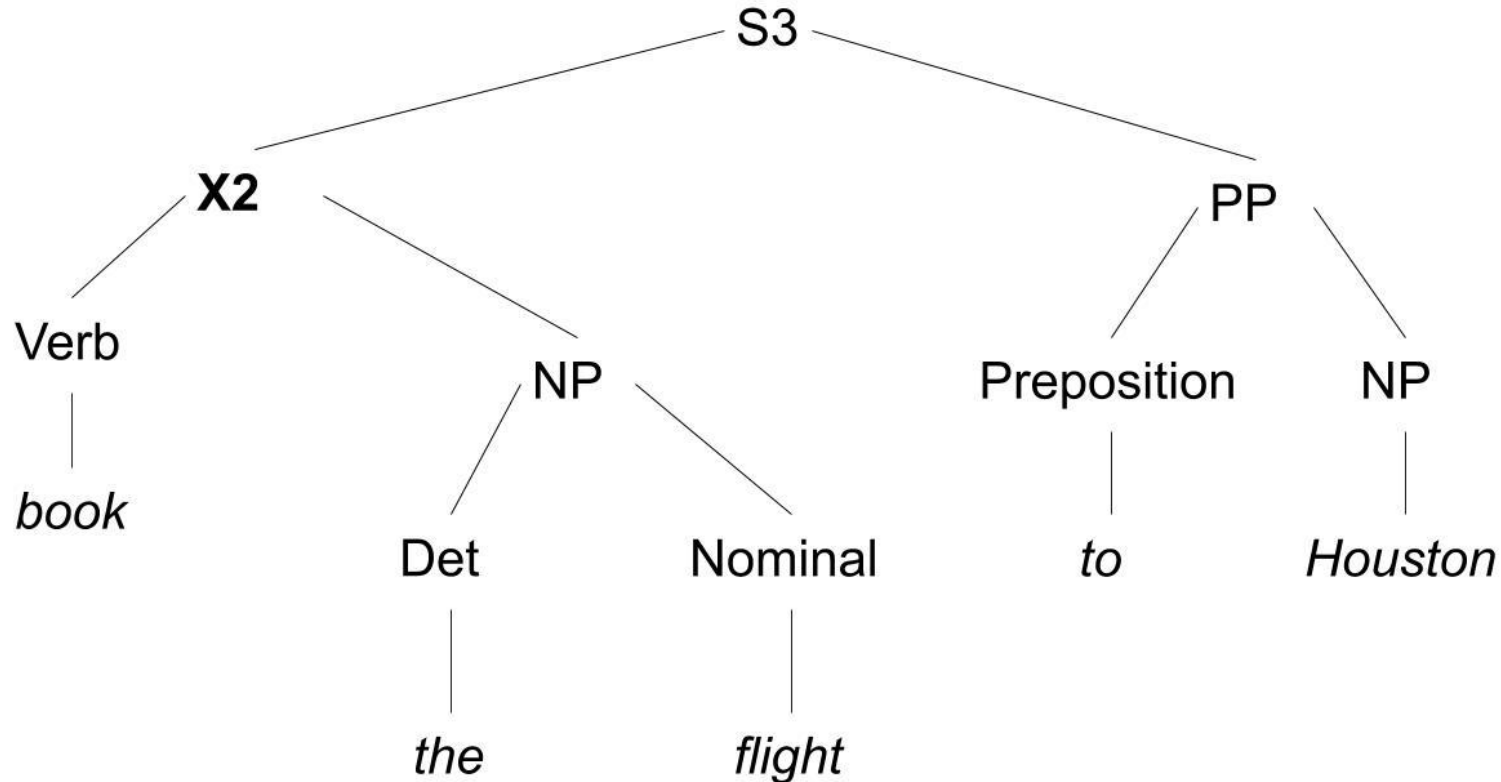
Exercise 3

Given this corpus, show its complete PCFG:

```
( (S
  (NP-SBJ (DT The) (NN move))
  (VP (VBD followed)
    (NP
      (NP (DT a) (NN round))
      (PP (IN of)
        (NP
          (NP (JJ similar) (NNS increases))
          (PP (IN by)
            (NP (JJ other) (NNS lenders)))
          (PP (IN against)
            (NP (NNP Arizona) (JJ real) (NN estate) (NNS loans))))))
    (, ,)
    (S-ADV
      (NP-SBJ (-NONE- *))
      (VP (VBG reflecting)
        (NP
          (NP (DT a) (VBG continuing) (NN decline))
          (PP-LOC (IN in)
            (NP (DT that) (NN market)))))))
  (. .)))
```

$T =$

$N =$

$S =$

$R =$

$q =$

Solution 3

T = {the, move, followed, a, round, of, similar, increases, by, other, lenders, against, arizona, real, estate, loans, **,** , *, reflecting, continuing, decline, in, that, market, **.**}

N = {NP-SBJ, DT, NN, VP, VBD, NP, PP, IN, JJ, NNS, NNP, **,** ,S-ADV, -NONE-, VBG, PP-LOC, . }

S = {S}

Solution 3

R = {(root -> S .), (S -> NP-SBJ VP), (NP-SBJ -> DT NN), (DT -> the), (NN -> move),

(VP -> VBD NP , S-ADV), (VBD -> followed), (NP -> NP PP), (NP -> DT NN), (DT -> a),

(NN -> round), (PP -> IN NP), (IN -> of), (NP -> NP PP PP), (NP -> JJ NNS),

(JJ -> similar), (NNS -> increases), (IN -> by), (JJ -> other), (NNS -> lenders),

(IN -> against), (NP -> NNP JJ NN NNS), (NNP -> Arizona), (JJ -> real), (NN -> estate),

(NNS -> loans), (, -> ,), (S-ADV -> NP-SBJ VP), (NP-SBJ -> -NONE-), (-NONE- -> *),

(VP -> VBG NP), (VBG -> reflecting), (NP -> NP PP-LOC), (NP -> DT VBG NN),

(VBG -> continuing), (NN -> decline), (PP-LOC -> IN NP), (IN -> in), (DT -> that),

(NN -> market), (. -> .)}

Solution 3

For q,

$$P(NP \rightarrow JJ\ NNS) = \frac{count(NP \rightarrow JJ\ NNS)}{count(NP)} = 2/9$$

Solution 3

q = { P(root -> S .) = 1, P(S -> NP-SBJ VP) = 1, P(NP-SBJ -> DT NN) = ½ , P(DT -> the) = ¼ , P(NN -> move) = ⅕ ,

P(VP -> VBD NP , S-ADV) = ½ , P(VBD -> followed) = 1, P(NP -> NP PP) = 1/9, P(NP -> DT NN) = 2/9, P(DT -> a)= 2/4,

P(NN -> round) = ⅕ , P(PP -> IN NP) = 3/3, P(IN -> of) = ⅓ , P(NP -> NP PP PP) = 1/9, P(NP -> JJ NNS) = 2/9,

P(JJ -> similar) = ⅓ , P(NNS -> increases) = ⅓ , P(IN -> by) = ⅓ , P(JJ -> other) = ⅓ , P(NNS -> lenders) = ⅓ ,

P(IN -> against) = ⅓ , P(NP -> NNP JJ NN NNS) = 1/9 , P(NNP -> Arizona) = 1, P(JJ -> real) = ⅓ ,

P(NN -> estate) = ⅕ , P(NNS -> loans) = ⅓ , P(, -> ,) = 1, P(S-ADV -> NP-SBJ VP) = 1, P(NP-SBJ -> -NONE-) = ½ ,

P(-NONE- -> *) = 1, P(VP -> VBG NP) = ½ ,P(VBG -> reflecting) = ½ , P(NP -> NP PP-LOC) = 1/9,

P(NP -> DT VBG NN) = 1/9, P(VBG -> continuing)= ½ , P(NN -> decline) = ⅕ , P(PP-LOC -> IN NP) = 1, P(IN -> in) = ⅓ ,

P(DT -> that) = ¼ , P(NN -> market) = ⅕ , P(. -> .) = 1 }

Exercise 4 – The CKY algorithm for PCFG

Example by Michael Collins

Given the grammar:

S	⇒	NP	VP	1.0
VP	⇒	Vi		0.4
VP	⇒	Vt	NP	0.4
VP	⇒	VP	PP	0.2
NP	⇒	DT	NN	0.3
NP	⇒	NP	PP	0.7
PP	⇒	IN	NP	1.0

Vi	⇒	sleeps	1.0
Vt	⇒	saw	1.0
NN	⇒	man	0.7
NN	⇒	woman	0.2
NN	⇒	telescope	0.1
DT	⇒	the	1.0
IN	⇒	with	0.5
IN	⇒	in	0.5

Generate the best parse tree for the sentence:

The woman saw the man with the telescope

Generate the best parse tree for the sentence:

The woman saw the man with the telescope

Solution 4

The	woman	saw	the	man	with	the	telescope

Solution 4 – step 1

The	woman	saw	the	man	with	the	telescope
DT (1.0)							

DT -> the (1.0)

Solution 4 – step 2

The	woman	saw	the	man	with	the	telescope
DT (1.0)							
	NN (0.2)						

NN -> woman (0.2)

Solution 4 – step 3

The	woman	saw	the	man	with	the	telescope
DT (1.0)							
	NN (0.2)						
		Vt (1.0)					

Vt -> saw (1.0)

Solution 4 – step 4

The	woman	saw	the	man	with	the	telescope
DT (1.0)							
	NN (0.2)						
		Vt (1.0)					
			DT (1.0)				

DT -> the (1.0)

Solution 4 – step 5

The	woman	saw	the	man	with	the	telescope
DT (1.0)							
	NN (0.2)						
		Vt (1.0)					
			DT (1.0)				
				NN (0.7)			

NN -> man (0.7)

The	woman	saw	the	man	with	the	telescope
DT (1.0)							
	NN (0.2)						
		Vt (1.0)					
			DT (1.0)				
				NN (0.7)			
					IN (0.5)		

IN -> with (0.5)

The	woman	saw	the	man	with	the	telescope
DT (1.0)							
	NN (0.2)						
		Vt (1.0)					
			DT (1.0)				
				NN (0.7)			
					IN (0.5)		
						DT (1.0)	

DT -> the (1.0)

The	woman	saw	the	man	with	the	telescope
DT (1.0)							
	NN (0.2)						
		Vt (1.0)					
			DT (1.0)				
				NN (0.7)			
					IN (0.5)		
						DT (1.0)	
							NN (0.1)

NN -> telescope (0.1)

Solution 4 – step 9

The	woman	saw	the	man	with	the	telescope
DT (1.0)	**NP (0.06)**						
	NN (0.2)						
		Vt (1.0)					
			DT (1.0)				
				NN (0.7)			
					IN (0.5)		
						DT (1.0)	
							NN (0.1)

NP -> DT NN (0.3)

π(1,2) = 0.3 x 1.0 x 0.2 = 0.06

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)						
	NN (0.2)	---					
		Vt (1.0)					
			DT (1.0)				
				NN (0.7)			
					IN (0.5)		
						DT (1.0)	
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)						
	NN (0.2)	---					
		<u>Vt (1.0)</u>	**---**				
			<u>DT (1.0)</u>				
				NN (0.7)			
					IN (0.5)		
						DT (1.0)	
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)						
	NN (0.2)	---					
		Vt (1.0)	---				
			DT (1.0)	NP (0.21)			
				NN (0.7)			
					IN (0.5)		
						DT (1.0)	
							NN (0.1)

NP -> DT NN (0.3)

π(4,5) = 0.3 x 1.0 x 0.7 = 0.21

Solution 4 – step 13

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)						
	NN (0.2)	---					
		Vt (1.0)	---				
			DT (1.0)	NP (0.21)			
				NN (0.7)	---		
					IN (0.5)		
						DT (1.0)	
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)						
	NN (0.2)	---					
		Vt (1.0)	---				
			DT (1.0)	NP (0.21)			
				NN (0.7)	---		
					IN (0.5)	---	
						DT (1.0)	
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)						
	NN (0.2)	---					
		Vt (1.0)	---				
			DT (1.0)	NP (0.21)			
				NN (0.7)	---		
					IN (0.5)	---	
						DT (1.0)	NP (0.03)
							NN (0.1)

NP -> DT NN (0.3)

$\pi(7,8) = 0.3 \times 1.0 \times 0.1 = 0.03$

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	==					
		Vt (1.0)	---				
			DT (1.0)	NP (0.21)			
				NN (0.7)	---		
					IN (0.5)	---	
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	---					
		Vt (1.0)	---				
			DT (1.0)	NP (0.21)			
				NN (0.7)	---		
					IN (0.5)	---	
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 17.1

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	---	---				
		Vt (1.0)	---				
			DT (1.0)	NP (0.21)			
				NN (0.7)	---		
					IN (0.5)	---	
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 17.2

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	==	---				
		Vt (1.0)	---				
			DT (1.0)	NP (0.21)			
				NN (0.7)	---		
					IN (0.5)	---	
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 18.1

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	---	---				
		Vt (1.0)	---	**VP (0.084)**			
			DT (1.0)	NP (0.21)			
				NN (0.7)	---		
					IN (0.5)	---	
						DT (1.0)	NP (0.03)
							NN (0.1)

VP -> Vt NP (0.4)
π(3,5) = 0.4 x 1.0 x 0.21 = 0.084

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	---	---				
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)			
				NN (0.7)	---		
					IN (0.5)	---	
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	---	---				
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)	**---**		
				NN (0.7)	<u>--</u>		
					IN (0.5)	---	
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	---	---				
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)	**---**		
				NN (0.7)	---		
					IN (0.5)	---	
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 20.1

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	---	---				
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	---	---	
					IN (0.5)	==	
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	---	---				
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	≡≡	---	
					IN (0.5)	---	
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	---	---				
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	---	---	
					IN (0.5)	---	**PP (0.015)**
						DT (1.0)	NP (0.03)
							NN (0.1)

PP -> IN NP (1.0)

π(6,8) = 1.0 x 0.5 x 0.03 = 0.015

Solution 4 – step 21.2

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---					
	NN (0.2)	---	---				
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	---	---	
					IN (0.5)	==	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	**---**				
	NN (0.2)	---	==				
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	---	---	
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	**---**				
	NN (0.2)	---	---				
		Vt (1.0)	<u>---</u>	VP (0.084)			
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	---	---	
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	==	**---**				
	NN (0.2)	---	---				
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	---	---	
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	---	---	---			
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	---	---	
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	==	---	---			
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	---	---	
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 23.3

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	---	==	---			
		Vt (1.0)	---	VP (0.084)			
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	---	---	
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 24.1

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	---	---	---			
		Vt (1.0)	---	VP (0.084)	**---**		
			DT (1.0)	NP (0.21)	<u>--</u>		
				NN (0.7)	---	---	
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	---	---	---			
		Vt (1.0)	==	VP (0.084)	---		
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	==	---	
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 24.3

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	---	---	---			
		Vt (1.0)	---	<u>VP (0.084)</u>	**---**		
			DT (1.0)	NP (0.21)	---		
				NN (0.7)	---	---	
					<u>IN (0.5)</u>	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	---	---	---			
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	---	==	
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 25.2

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	---	---	---			
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	---	---	
					IN (0.5)	==	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 25.3

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	---	---	---			
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	==	---	
				NN (0.7)	---	---	
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	---	---	---			
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	---	---	---			
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	==	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 26.3

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---				
	NN (0.2)	---	---	---			
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	---	==	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	**---**			
	NN (0.2)	---	---	==			
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	**S (.00504)**			
	NN (0.2)	---	---	---			
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

S -> NP VP (1.0)
π(1,5) = 1.0 x 0.06 x 0.084 = 0.00504

Solution 4 – step 27.3

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	<u>==</u>	---	S (.00504)			
	NN (0.2)	---	---	---			
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	<u>NP (0.21)</u>	---	---	
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 27.4

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	==	S (.00504)			
	NN (0.2)	---	---	---			
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 28.1

	The	woman	saw	the	man	with	the	telescope
	DT (1.0)	NP (0.06)	---	---	S (.00504)			
		NN (0.2)	---	---	---	**---**		
			Vt (1.0)	---	VP (0.084)	<u>---</u>		
				DT (1.0)	NP (0.21)	---	---	
					NN (0.7)	---	---	---
						IN (0.5)	---	PP (0.015)
							DT (1.0)	NP (0.03)
								NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)			
	NN (0.2)	==	---	---	---		
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	==	---	
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)			
	NN (0.2)	---	==	---	---		
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	==	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)			
	NN (0.2)	---	---	==	---		
		Vt (1.0)	---	VP (0.084)	---		
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 29.1

	The	woman	saw	the	man	with	the	telescope
	DT (1.0)	NP (0.06)	---	---	S (.00504)			
		NN (0.2)	---	---	---	---		
			Vt (1.0)	---	VP (0.084)	---	**---**	
				DT (1.0)	NP (0.21)	---	==	
					NN (0.7)	---	---	---
						IN (0.5)	---	PP (0.015)
							DT (1.0)	NP (0.03)
								NN (0.1)

No rule found!

Solution 4 – step 29.2

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)			
	NN (0.2)	---	---	---	---		
		Vt (1.0)	==	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	---	==	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)			
	NN (0.2)	---	---	---	---		
		Vt (1.0)	---	<u>VP (0.084)</u>	---	**---**	
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	---	---	---
					IN (0.5)	<u>==</u>	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)			
	NN (0.2)	---	---	---	---		
		Vt (1.0)	---	VP (0.084)	<u>--</u>	**---**	
			DT (1.0)	NP (0.21)	---	---	
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						<u>DT (1.0)</u>	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 30.1

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)			
	NN (0.2)	---	---	---	---		
		Vt (1.0)	---	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	---	---	---
				NN (0.7)	---	---	==
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)			
	NN (0.2)	---	---	---	---		
		Vt (1.0)	---	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	---	---	**NP (.002205)**
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

NP -> NP PP (0.7)

$\pi(4,8)$ = .7 x .21 x 0.015 = 0.002205

Solution 4 – step 30.3

	The	woman	saw	the	man	with	the	telescope
	DT (1.0)	NP (0.06)	---	---	S (.00504)			
		NN (0.2)	---	---	---	---		
			Vt (1.0)	---	VP (0.084)	---	---	
				DT (1.0)	NP (0.21)	<u>==</u>	---	NP (.002205)
					NN (0.7)	---	---	---
						IN (0.5)	---	PP (0.015)
							DT (1.0)	<u>NP (0.03)</u>
								NN (0.1)

No rule found!

Solution 4 – step 30.4

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)			
	NN (0.2)	---	---	---	---		
		Vt (1.0)	---	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	---	==	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 31.1

The	woman	saw	the	man	with	the	telescope
<u>DT (1.0)</u>	NP (0.06)	---	---	S (.00504)	**---**		
	NN (0.2)	---	---	---	<u>==</u>		
		Vt (1.0)	---	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 31.2

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	---	---	---		
		Vt (1.0)	---	VP (0.084)	==	---	
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	==	---	S (.00504)	---		
	NN (0.2)	---	---	---	---		
		Vt (1.0)	---	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	==	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 31.4

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	==	S (.00504)	**---**		
	NN (0.2)	---	---	---	---		
		Vt (1.0)	---	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	==	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	---	---	---		
		Vt (1.0)	---	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	---	---	---	**---**	
		Vt (1.0)	---	VP (0.084)	---	==	
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	==	---	---	---	---	
		Vt (1.0)	---	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	---	==	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	==	---	---	---	
		Vt (1.0)	---	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	==	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	---	==	---	---	
		Vt (1.0)	---	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	==	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	---	---	==	---	
		Vt (1.0)	---	VP (0.084)	---	---	
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	---	---	---	---	
		Vt (1.0)	---	VP (0.084)	---	---	**VP (.000882)**
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

VP -> Vt NP (0.4)

$\pi(3,8) = .4 \times 1 \times .002205 = 0.000882$

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	---	---	---	---	
		Vt (1.0)	<u>--</u>	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	<u>--</u>
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	---	---	---	---	
		Vt (1.0)	---	<u>VP (0.084)</u>	---	---	VP (.000882) **VP (.000252)**
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	<u>PP (0.015)</u>
						DT (1.0)	NP (0.03)
							NN (0.1)

VP -> VP PP (0.2)

π(3,8) = .2 x .084 x .015 = 0.000252

Solution 4 – step 33.3

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	---	---	---	---	
		Vt (1.0)	---	<u>VP (0.084)</u>	---	---	**VP (.000882)** ~~**VP (.000252)**~~
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	<u>PP (0.015)</u>
						DT (1.0)	NP (0.03)
							NN (0.1)

0.000252 < 0.000882
So we keep the earlier VP (and its backpointers)

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	---	---	---	---	
		Vt (1.0)	---	VP (0.084)	<u>---</u>	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	<u>NP (0.03)</u>
							NN (0.1)

No rule found!

Solution 4 – step 33.5

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---		
	NN (0.2)	---	---	---	---	---	
		Vt (1.0)	---	VP (0.084)	---	==	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 34.1

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	**---**	
	NN (0.2)	---	---	---	---	==	
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 34.2

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	**---**	
	NN (0.2)	---	---	---	---	---	
		Vt (1.0)	---	VP (0.084)	---	<u>==</u>	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 34.3

	The	woman	saw	the	man	with	the	telescope
	DT (1.0)	NP (0.06)	==	---	S (.00504)	---	**---**	
		NN (0.2)	---	---	---	---	---	
			Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
				DT (1.0)	NP (0.21)	---	==	NP (.002205)
					NN (0.7)	---	---	---
						IN (0.5)	---	PP (0.015)
							DT (1.0)	NP (0.03)
								NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	==	S (.00504)	---	**---**	
	NN (0.2)	---	---	---	---	---	
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	==	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	---	
	NN (0.2)	---	---	---	---	---	
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	==	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	==	**---**	
	NN (0.2)	---	---	---	---	---	
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 35.1

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	---	
	NN (0.2)	---	---	---	---	---	**---**
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 35.2

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	---	
	NN (0.2)	==	---	---	---	---	---
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	---	
	NN (0.2)	---	==	---	---	---	---
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	==
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	---	
	NN (0.2)	---	---	==	---	---	---
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 35.5

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	---	
	NN (0.2)	---	---	---	==	---	---
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 35.6

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	---	
	NN (0.2)	---	---	---	---	==	---
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 36.1

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	---	---
	NN (0.2)	---	---	---	---	---	==
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	---	**S (.00005292**
	NN (0.2)	---	---	---	---	---	---
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

S -> NP VP (1.0)

$\pi(1,8) = 1 \times .06 \times .000882 = .00005292$

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	==	---	S (.00504)	---	---	S (.00005292)
	NN (0.2)	---	---	---	---	---	---
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	==	S (.00504)	---	---	S (.00005292)
	NN (0.2)	---	---	---	---	---	---
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	==
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 36.5

	The	woman	saw	the	man	with	the	telescope
	DT (1.0)	NP (0.06)	---	---	S (.00504)	---	---	S (.00005292)
		NN (0.2)	---	---	---	---	---	---
			Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
				DT (1.0)	NP (0.21)	---	---	NP (.002205)
					NN (0.7)	---	---	---
						IN (0.5)	---	PP (0.015)
							DT (1.0)	NP (0.03)
								NN (0.1)

No rule found!

Solution 4 – step 36.6

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	═	---	S (.00005292)
	NN (0.2)	---	---	---	---	---	---
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – step 36.7

The	woman	saw	the	man	with	the	telescope
DT (1.0)	NP (0.06)	---	---	S (.00504)	---	==	S (.00005292)
	NN (0.2)	---	---	---	---	---	---
		Vt (1.0)	---	VP (0.084)	---	---	VP (.000882)
			DT (1.0)	NP (0.21)	---	---	NP (.002205)
				NN (0.7)	---	---	---
					IN (0.5)	---	PP (0.015)
						DT (1.0)	NP (0.03)
							NN (0.1)

No rule found!

Solution 4 – final

Exercise 5

- Given the hyp and ref parse trees below, compute recall, precision and f-measure
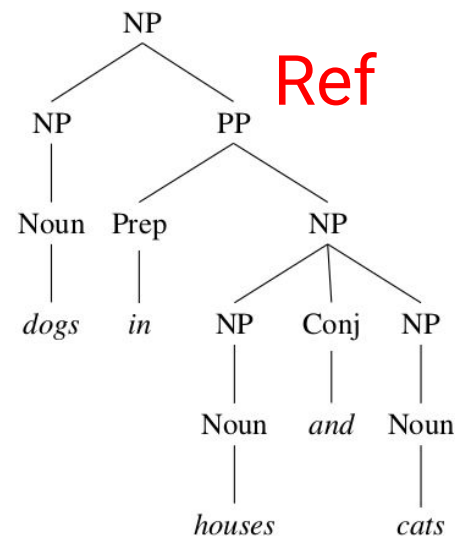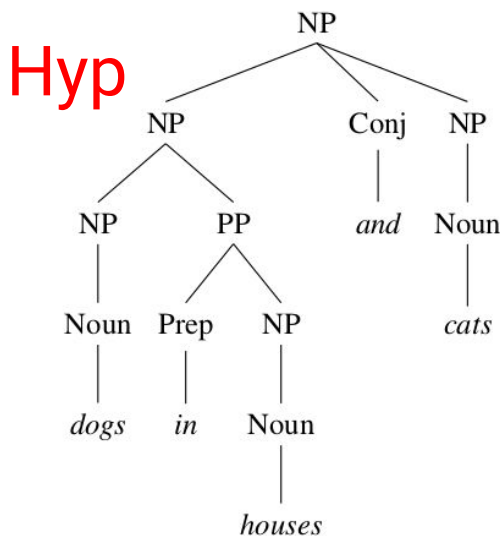
Hyp

Ref
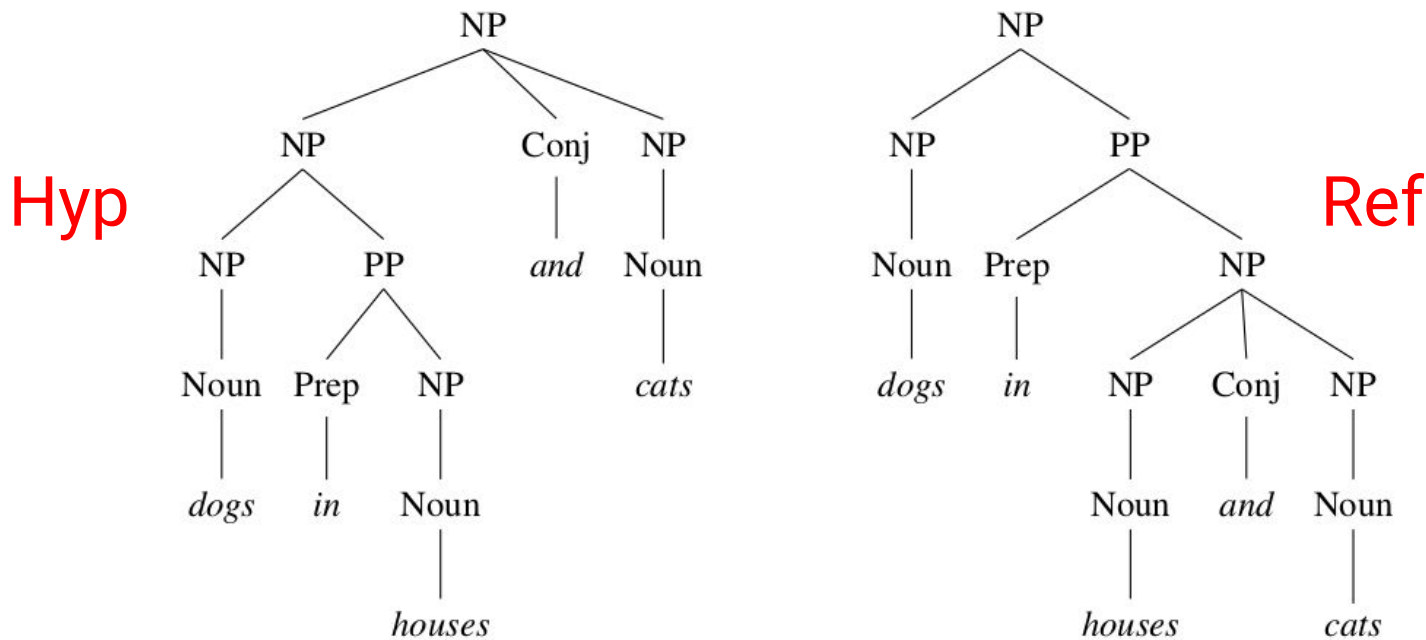
Solution 5

Hypothesis
NP: dogs
NP: houses
PP: in houses
NP: dogs in houses
NP: cats
NP: dogs in houses and cats
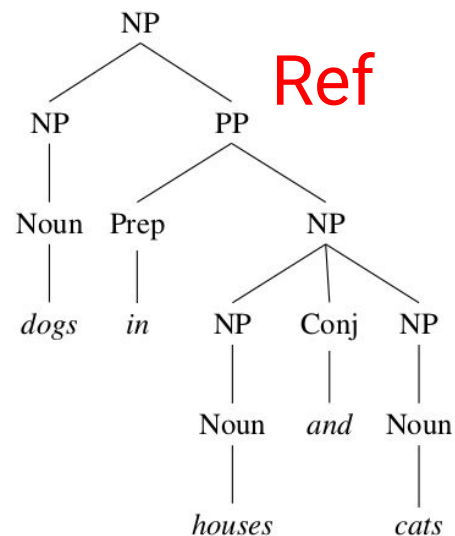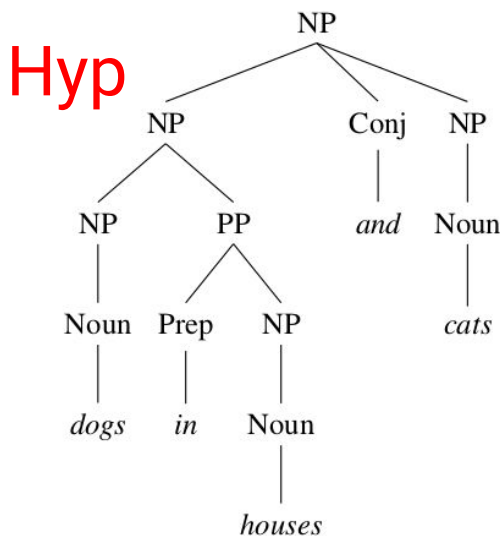
Reference
NP: dogs
NP: houses
PP: in houses and cats
NP: cats
NP: houses and cats
NP: dogs in houses and cats

Solution 5 – precision

Hypothesis

NP: **dogs**
NP: **houses**
PP: in houses
NP: dogs in houses
NP: **cats**
NP: **dogs in houses and cats**
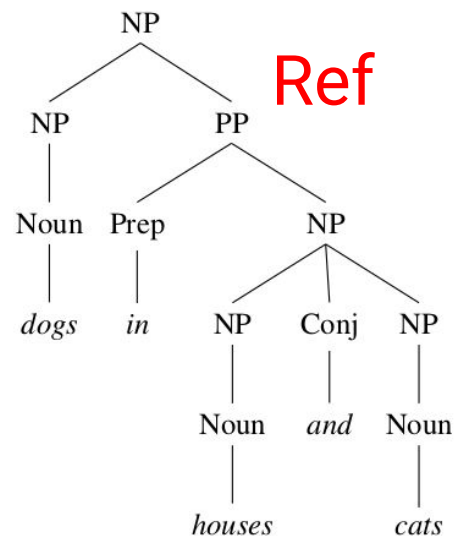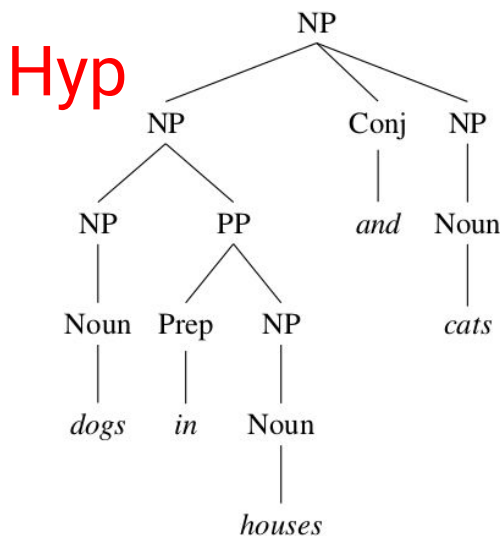
Reference

NP: dogs
NP: houses
PP: in houses and cats
NP: cats
NP: houses and cats
NP: dogs in houses and cats

Hyp

Ref

Precision = **4** / 6

Solution 5 – recall

Hypothesis

NP: dogs
NP: houses
PP: in houses
NP: dogs in houses
NP: cats
NP: dogs in houses and cats
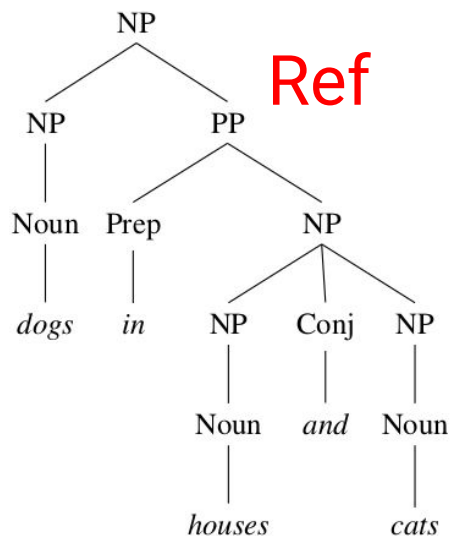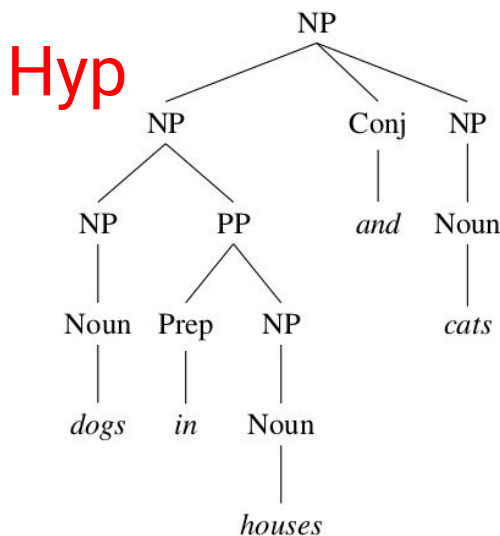
Reference

NP: **dogs**
NP: **houses**
PP: in houses and cats
NP: **cats**
NP: houses and cats
NP: **dogs in houses and cats**

Recall = **4** / 6

Solution 5 – F-measure

Hypothesis
NP: dogs
NP: houses
PP: in houses
NP: dogs in houses
NP: cats
NP: dogs in houses and cats

Reference
NP: dogs
NP: houses
PP: in houses and cats
NP: cats
NP: houses and cats
NP: dogs in houses and cats

Hyp

Ref

$$\text{F-measure} = \frac{2(4/6)(4/6)}{4/6 + 4/6} = 4/6$$

Exercise 6 – Lexicalised CFG

Given the following CFG grammar, convert it into a LCFG

S → NP VP

VP → V NP

VP → VP PP

PP → P NP

P → with

V → saw

NP → NP PP

NP → astronomers

NP → ears

NP → saw

NP → stars

NP → telescope

Solution 6

Different solutions are possible. Here is one. For terminals,

NP(astronomers) → astronomers

NP(ears) → ears

NP(saw) → saw

P(with) → with

NP(stars) → stars

V(saw) → saw

NP(telescope) → telescope

Solution 6

For non-terminals,

S(v) $\longrightarrow_2$ NP(n) VP(v) $\forall$ n and v

NP(n) $\longrightarrow_1$ NP(n) PP(p) $\forall$ n and p

VP(v) $\longrightarrow_1$ V(v) NP(n) $\forall$ n and v

VP(v) $\longrightarrow_1$ VP(v) PP(p) $\forall$ n and v

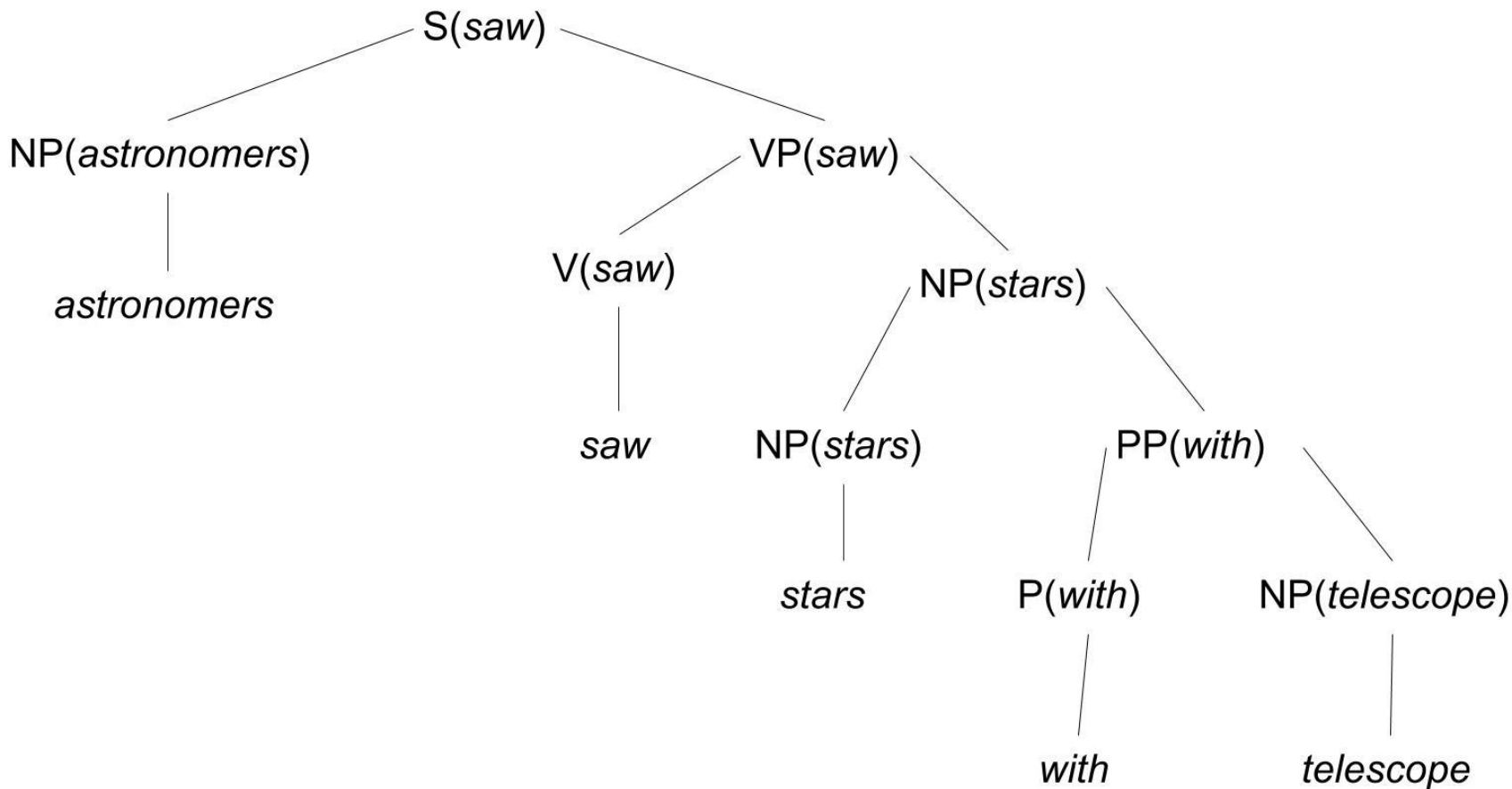PP(p) $\longrightarrow_1$ P(p) NP(n) $\forall$ n and p

Solution 6 – example
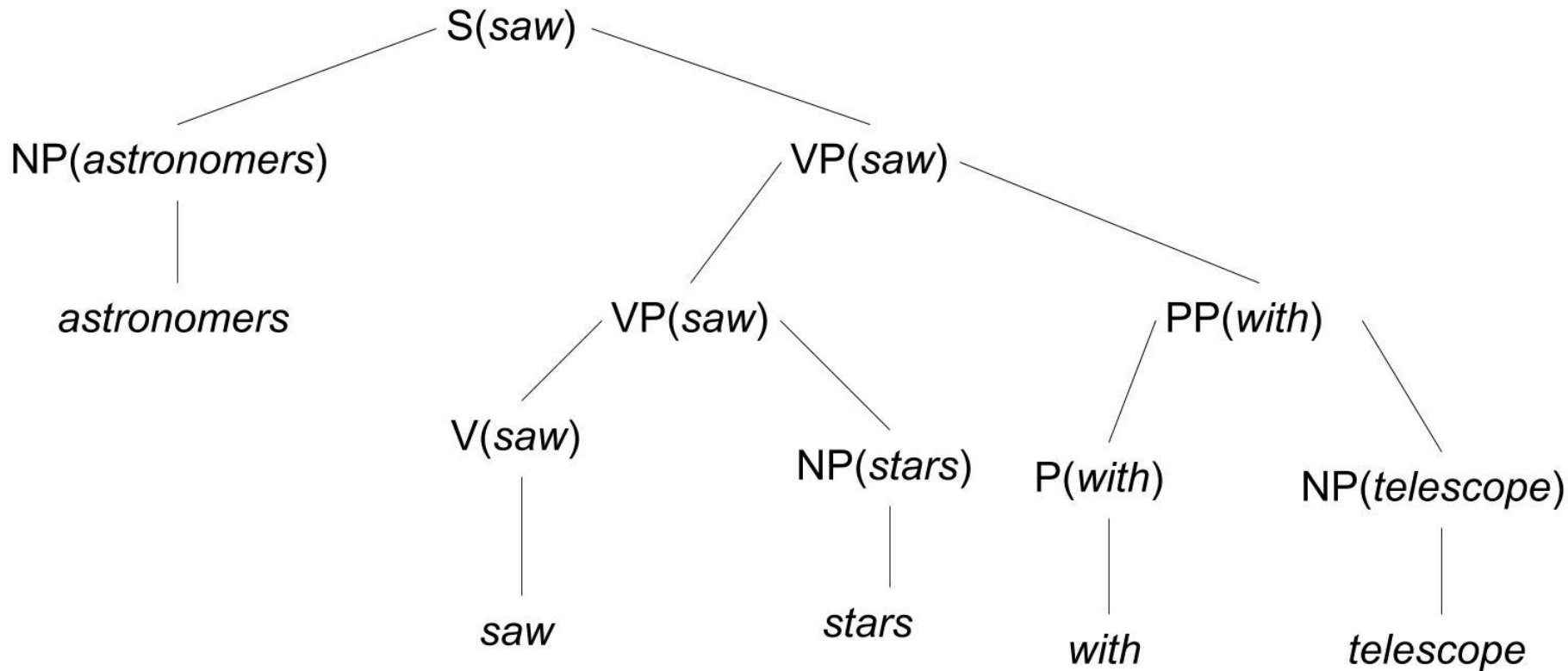
astronomers saw stars with telescope

Solution 6 – example

We get two parse trees according to LCFG

Solution 6 – example – 1

Solution 6 – example – 2

Solution 6 – example

If we have a Probabilistic LCFG, then we can identify which of the two solutions is the most probable using the same dynamic programming algorithm used in Exercise 4.