Natural Language Processing
(Spring 2023)

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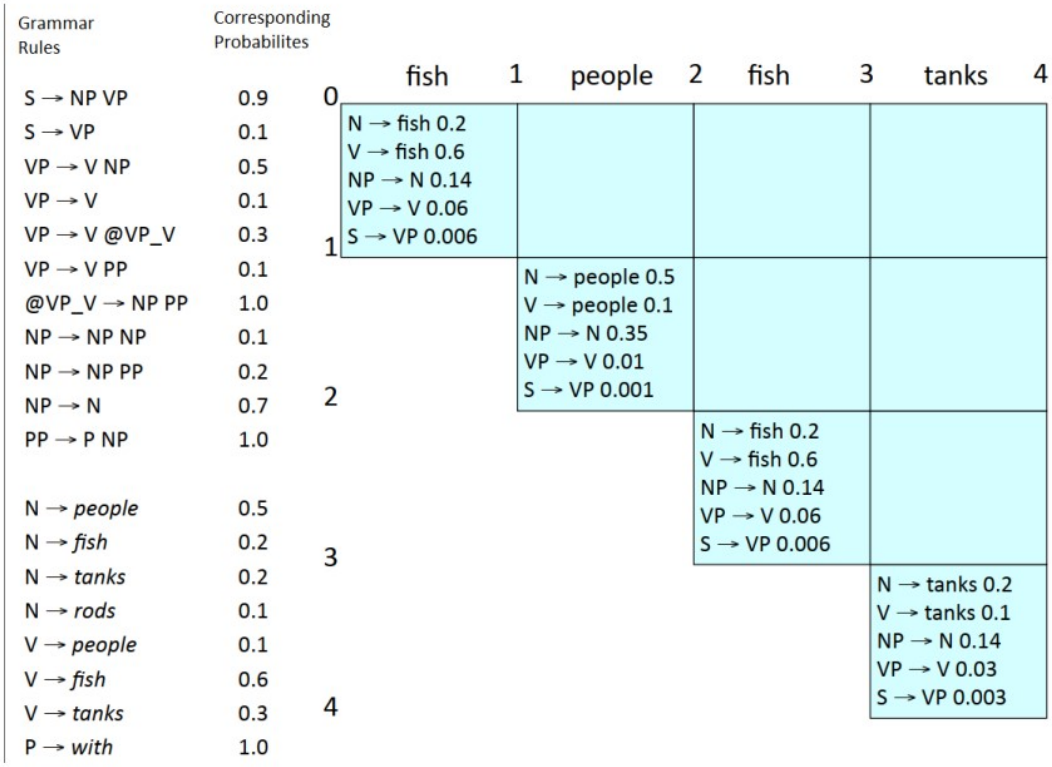
Contents

1 Question 1

Use the CKY algorithm to generate the parse tree for the sentence "fish people fish tanks". 8 marks The probabilistic context free grammar in CNF with unarys is given in the figure below. When the start position is 0 and end position is 1, the sentence is "fish". Looking at the grammar, we see that there are two rules that generate "fish" directly: N → fish with probability 0.2, and V → fish with probability 0.6. We place these two transitions in the location 0 to 1 corresponding to fish. There is a rule NP → N with probability 0.7 that can combine with N → fish with probability 0.2 to generate fish from NP with probability 0.7 × 0.2 = 0.14. Similarly, all the single word entries are pre-filled in the table. Fill the remaining entries in the table and generate the desired parse tree if possible from the grammar.



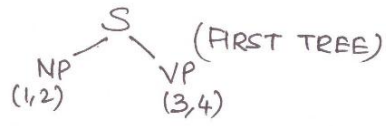
Grammar Rules	Corresponding Probabilites
S → NP VP	0.9
S → VP	0.1
VP → V NP	0.5
VP → V	0.1
VP → V @VP_V	0.3
VP → V PP	0.1
@VP_V → NP PP	1.0
NP → NP NP	0.1
NP → NP PP	0.2
NP → N	0.7
PP → P NP	1.0
N → *people*	0.5
N → *fish*	0.2
N → *tanks*	0.2
N → *rods*	0.1
V → *people*	0.1
V → *fish*	0.6
V → *tanks*	0.3
P → *with*	1.0

Figure 1:

See the solution below.

	FISH	PEOPLE	FISH	TANKS
FISH	N→fish (0.2) V→fish (0.6) NP→N (0.7×0.2=0.14) VP→V (0.6×0.1=0.06) S→VP (0.06×0.1=0.006)	VP→V NP (0.6×0.35×0.5=0.105)✓✓ NP→NP NP (0.14×0.35×0.1=0.0049) S→NP VP // S→VP (0.0105)✓✓ (0.14×0.01×0.9=0.00126)	VP→V NP max(0.6×0.0049×0.5) = 0.00147 NP→NP NP (0.0049×0.14×0.1) = 0.0000686 S→NP VP (0.9×0.14×0.007=0.0002646	
PEOPLE	*	N→people (0.5) V→people (0.1) NP→N (0.5×0.7=0.35) VP→V (0.1×0.1=0.01) S→VP (0.1×0.1=0.001)	VP→V NP (0.1×0.14×0.5=0.007)✗ NP→NP NP (0.35×0.14×0.1=0.0049)✓✓ S→NP VP // S→VP (0.0007)✗ (0.35×0.06×0.9=0.0189)✓✓	
FISH	*	*	COPY N→fish (0.2) V→fish (0.6) NP→N (0.14) VP→V (0.06) S→VP (0.006)	VP→V NP (0.6×0.14×0.5=0.042)✓✓ NP→NP NP (0.14×0.14×0.1=0.00196) S→NP VP // S→VP (0.0042)✓✓ (0.14×0.03×0.9=0.00378)
TANKS	*	*	*	N→tanks (0.2) V→tanks (0.3) NP→N (0.2×0.7=0.14) VP→V (0.3×0.1=0.03) S→VP (0.03×0.1=0.003)

	FISH	PEOPLE	FISH	TANKS
FISH	N → fish (0.2) V → fish (0.6) NP → N (0.7×0.2=0.14) VP → V (0.6×0.1=0.06) S → VP (0.06×0.1=0.006)	VP → V NP (0.6×0.35×0.5=0.105)✓ NP → NP NP (0.14×0.35×0.1=0.0049) S → NP VP // S → VP (0.0105)✓ (0.14×0.01×0.9=0.00126)	VP → V NP Max (0.6×0.0049×0.5) = 0.00147 NP → NP NP (0.0049×0.14×0.1) = 0.0000686 S → NP VP (0.9×0.14×0.007=0.0002646	
PEOPLE	*	N → people (0.5) V → people (0.1) NP → N (0.5×0.7=0.35) VP → V (0.1×0.1=0.01) S → VP (0.1×0.1=0.001)	VP → V NP (0.1×0.14×0.5=0.007)✗ NP → NP NP (0.35×0.14×0.1=0.0049)✓ S → NP VP // S → VP (0.0007)✗ (0.35×0.06×0.9=0.0189)✓	VP → V NP (0.1×0.00196×0.5=0.000098) NP → NP NP (0.35×0.00196×0.1=0.0000686) S → NP VP (0.35×0.042×0.9=0.0001323
FISH	*	*	COPY N → fish (0.2) V → fish (0.6) NP → N (0.14) VP → V (0.06) S → VP (0.006)	VP → V NP (0.6×0.14×0.5=0.042)✓✓ NP → NP NP (0.14×0.14×0.1=0.00196) S → NP VP // S → VP (0.0042)✓✓ (0.14×0.03×0.9=0.00378)
TANKS	*	*	*	N → tanks (0.2) V → tanks (0.3) NP → N (0.2×0.7=0.14) VP → V (0.3×0.1=0.03) S → VP (0.03×0.1=0.003)



(3)

Selected cells for
$S \rightarrow NP\ VP$
(1,2) (3,4)

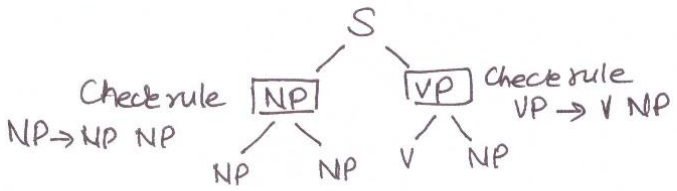
	1 FISH	2 PEOPLE	3 FISH	4 TANKS
1 FISH	N→fish (0.2) V→fish (0.6) NP→N (0.7×0.2=0.14) VP→V (0.6×0.1=0.06) S→VP (0.06×0.1=0.006)	VP→V NP ●● (0.6×0.35×0.5=0.105) ✓ NP→NP NP (0.14×0.35×0.1=0.0049) S→NP VP // S→VP (0.0105) ✓ (0.14×0.01×0.9=0.00126)	VP→V NP Max(0.6×0.0049×0.5) = 0.00147 NP→NP NP (0.0049×0.14×0.1) = 0.0000686 S→NP VP (0.9×0.14×0.007=0.0002646)	VP→V NP (0.6×0.0000686×0.5 =0.00002058) NP→NP NP (0.14×0.0000686×0.1= (0.0049×0.00196×0.1= } 0.000009604 (0.0000686×0.14×0.1=) S→NP VP (0.14×0.000098×0.9) ✗
2 PEOPLE	*	N→people (0.5) V→people (0.1) NP→N (0.5×0.7=0.35) VP→V (0.1×0.1=0.01) S→VP (0.1×0.1=0.001)	VP→V NP (0.1×0.14×0.5=0.007) ✗ NP→NP NP (0.35×0.14×0.1=0.0049) ✓ S→NP VP // S→VP (0.0007) ✗ (0.35×0.06×0.9= 0.0189) ✓	VP→V NP (0.1×0.00196×0.5 =0.000098) NP→NP NP (0.35×0.00196×0.1 =0.0000686) S→NP VP (0.35×0.042×0.9=0.0001323)
3 FISH	*	*	COPY N→fish (0.2) V→fish (0.6) NP→N (0.14) VP→V (0.06) S→VP (0.006)	VP→V NP ●● (0.6×0.14×0.5=0.042) ✓ NP→NP NP (0.14×0.14×0.1=0.00196) S→NP VP // S→VP (0.0042) ✓ (0.14×0.03×0.9=0.00378)
4 TANKS	*	*	*	N→tanks (0.2) V→tanks (0.3) NP→N (0.2×0.7=0.14) VP→V (0.3×0.1=0.03) S→VP (0.03×0.1=0.003)

(0.0049 × 0.0042 × 0.9 ✓ = 0.00018522)

(0.0000686 × 0.03 × 0.9 = 0.0000018)

4

SECOND TREE



THIRD TREE