



CKY Parsing

A worked example



The grammar: Binary, no epsilons,

$S \rightarrow NP VP$	0.9	$N \rightarrow people$	0.5
$S \rightarrow VP$	0.1	$N \rightarrow fish$	0.2
$VP \rightarrow V NP$	0.5	$N \rightarrow tanks$	0.2
$VP \rightarrow V$	0.1	$N \rightarrow rods$	0.1
$VP \rightarrow V @VP_V$	0.3	$V \rightarrow people$	0.1
$VP \rightarrow V PP$	0.1	$V \rightarrow fish$	0.6
$@VP_V \rightarrow NP PP$	1.0	$V \rightarrow tanks$	0.3
$NP \rightarrow NP NP$	0.1	$P \rightarrow with$	1.0
$NP \rightarrow NP PP$	0.2		
$NP \rightarrow N$	0.7		
$PP \rightarrow P NP$	1.0		

	fish	1	people	2	fish	3	tanks	4
0	score[0][1]	score[0][2]	score[0][3]	score[0][4]				
1		score[1][2]	score[1][3]	score[1][4]				
2			score[2][3]	score[2][4]				
3				score[3][4]				
4								

$S \rightarrow NP VP$	0.9	0	fish	1	people	2	fish	3	tanks	4
$S \rightarrow VP$	0.1									
$VP \rightarrow V NP$	0.5									
$VP \rightarrow V$	0.1									
$VP \rightarrow V @VP_V$	0.3	1								
$VP \rightarrow V PP$	0.1									
$@VP_V \rightarrow NP PP$	1.0									
$NP \rightarrow NP NP$	0.1									
$NP \rightarrow NP PP$	0.2									
$NP \rightarrow N$	0.7	2								
$PP \rightarrow P NP$	1.0									
$N \rightarrow people$	0.5									
$N \rightarrow fish$	0.2									
$N \rightarrow tanks$	0.2									
$N \rightarrow rods$	0.1									
$V \rightarrow people$	0.1									
$V \rightarrow fish$	0.6									
$V \rightarrow tanks$	0.3									
$P \rightarrow with$	1.0									

3

for i=0; i<#(words); i++
 for A in nonterms
 if A -> words[i] in grammar
 score[i][i+1][A] = P(A -> words[i]);

4

$S \rightarrow NP VP$	0.9
$S \rightarrow VP$	0.1
$VP \rightarrow V NP$	0.5
$VP \rightarrow V$	0.1
$VP \rightarrow V @VP_V$	0.3
$VP \rightarrow V PP$	0.1
$@VP_V \rightarrow NP PP$	1.0
$NP \rightarrow NP NP$	0.1
$NP \rightarrow NP PP$	0.2
$NP \rightarrow N$	0.7
$PP \rightarrow P NP$	1.0
$N \rightarrow people$	0.5
$N \rightarrow fish$	0.2
$N \rightarrow tanks$	0.2
$N \rightarrow rods$	0.1
$V \rightarrow people$	0.1
$V \rightarrow fish$	0.6
$V \rightarrow tanks$	0.3
$P \rightarrow with$	1.0

	fish	1	people	2	fish	3	tanks	4
0	N \rightarrow fish 0.2 V \rightarrow fish 0.6							
1			N \rightarrow people 0.5 V \rightarrow people 0.1					
2				N \rightarrow fish 0.2 V \rightarrow fish 0.6				
							N \rightarrow tanks 0.2 V \rightarrow tanks 0.1	

```
// handle unaries
boolean added = true
while added
  added = false
  for A, B in nonterms
    if score[i][i+1][B] > 0 && A->B in grammar
      prob = P(A->B)*score[i][i+1][B]
      if(prob > score[i][i+1][A])
        score[i][i+1][A] = prob
        back[i][i+1][A] = B
        added = true
```

		fish	1	people	2	fish	3	tanks	4
$S \rightarrow NP VP$	0.9	0 N \rightarrow fish 0.2 V \rightarrow fish 0.6 NP \rightarrow N 0.14 VP \rightarrow V 0.06 S \rightarrow VP 0.006	1						
$S \rightarrow VP$	0.1								
$VP \rightarrow V NP$	0.5								
$VP \rightarrow V$	0.1								
$VP \rightarrow V @VP_V$	0.3								
$VP \rightarrow V PP$	0.1	2		N \rightarrow people 0.5 V \rightarrow people 0.1 NP \rightarrow N 0.35 VP \rightarrow V 0.01 S \rightarrow VP 0.001					
$@VP_V \rightarrow NP PP$	1.0								
$NP \rightarrow NP NP$	0.1								
$NP \rightarrow NP PP$	0.2								
$NP \rightarrow N$	0.7								
$PP \rightarrow P NP$	1.0	3			N \rightarrow fish 0.2 V \rightarrow fish 0.6 NP \rightarrow N 0.14 VP \rightarrow V 0.06 S \rightarrow VP 0.006				
$N \rightarrow people$	0.5								
$N \rightarrow fish$	0.2								
$N \rightarrow tanks$	0.2								
$N \rightarrow rods$	0.1								
$V \rightarrow people$	0.1	4					N \rightarrow tanks 0.2 V \rightarrow tanks 0.1 NP \rightarrow N 0.14 VP \rightarrow V 0.03 S \rightarrow VP 0.003		
$V \rightarrow fish$	0.6								
$V \rightarrow tanks$	0.3								
$P \rightarrow with$	1.0								

- $S \rightarrow NP VP$ 0.9
- $S \rightarrow VP$ 0.1
- $VP \rightarrow V NP$ 0.5
- $VP \rightarrow V$ 0.1
- $VP \rightarrow V @VP_V$ 0.3
- $VP \rightarrow V PP$ 0.1
- $@VP_V \rightarrow NP PP$ 1.0
- $NP \rightarrow NP NP$ 0.1
- $NP \rightarrow NP PP$ 0.2
- $NP \rightarrow N$ 0.7
- $PP \rightarrow P NP$ 1.0
- $N \rightarrow people$ 0.5
- $N \rightarrow fish$ 0.2
- $N \rightarrow tanks$ 0.2
- $N \rightarrow rods$ 0.1
- $V \rightarrow people$ 0.1
- $V \rightarrow fish$ 0.6
- $V \rightarrow tanks$ 0.3
- $P \rightarrow with$ 1.0

	fish	1	people	2	fish	3	tanks	4
0								
1	<div>N → fish 0.2 V → fish 0.6 NP → N 0.14 VP → V 0.06 S → VP 0.006</div>		<div>NP → NP NP 0.0049 VP → V NP 0.105 S → NP VP 0.00126</div>					
2			<div>N → people 0.5 V → people 0.1 NP → N 0.35 VP → V 0.01 S → VP 0.001</div>	<div>NP → NP NP 0.0049 VP → V NP 0.007 S → NP VP 0.0189</div>				
3				<div>N → fish 0.2 V → fish 0.6 NP → N 0.14 VP → V 0.06 S → VP 0.006</div>		<div>NP → NP NP 0.00196 VP → V NP 0.042 S → NP VP 0.00378</div>		
4						<div>N → tanks 0.2 V → tanks 0.1 NP → N 0.14 VP → V 0.03 S → VP 0.003</div>		

//handle unaries
boolean added = true
while added
 added = false
 for A, B in nonterms
 prob = P(A->B)*score[begin][end][B];
 if prob > score[begin][end][A]
 score[begin][end][A] = prob
 back[begin][end][A] = B
 added = true

```
//handle unaries
boolean added = true
while added
  added = false
  for A, B in nonterms
    prob = P(A->B)*score[begin][end][B];
    if prob > score[begin][end][A]
      score[begin][end][A] = prob
      back[begin][end][A] = B
  added = true
```

- $S \rightarrow NP VP$ 0.9
- $S \rightarrow VP$ 0.1
- $VP \rightarrow V NP$ 0.5
- $VP \rightarrow V$ 0.1
- $VP \rightarrow V @VP_V$ 0.3
- $VP \rightarrow V PP$ 0.1
- $@VP_V \rightarrow NP PP$ 1.0
- $NP \rightarrow NP NP$ 0.1
- $NP \rightarrow NP PP$ 0.2
- $NP \rightarrow N$ 0.7
- $PP \rightarrow P NP$ 1.0
- $N \rightarrow people$ 0.5
- $N \rightarrow fish$ 0.2
- $N \rightarrow tanks$ 0.2
- $N \rightarrow rods$ 0.1
- $V \rightarrow people$ 0.1
- $V \rightarrow fish$ 0.6
- $V \rightarrow tanks$ 0.3
- $P \rightarrow with$ 1.0

	fish	1	people	2	fish	3	tanks	4	
0									
1	N → fish 0.2 V → fish 0.6 NP → N 0.14 VP → V 0.06 S → VP 0.006	NP → NP NP 0.0049 VP → V NP 0.105 S → VP 0.0105							
2		N → people 0.5 V → people 0.1 NP → N 0.35 VP → V 0.01 S → VP 0.001		NP → NP NP 0.0049 VP → V NP 0.007 S → NP VP 0.0189					
3				N → fish 0.2 V → fish 0.6 NP → N 0.14 VP → V 0.06 S → VP 0.006		NP → NP NP 0.00196 VP → V NP 0.042 S → VP 0.0042			
4	<div>for split = begin+1 to end-1 for A,B,C in nonterms prob=score[begin][split][B]*score[split][end][C]*P(A->BC) if prob > score[begin][end][A] score[begin][end][A] = prob back[begin][end][A] = new Triple(split,B,C)</div>					N → tanks 0.2 V → tanks 0.1 NP → N 0.14 VP → V 0.03 S → VP 0.003			

```

for split = begin+1 to end-1
  for A,B,C in nonterms
    prob=score[begin][split][B]*score[split][end][C]*P(A->BC)
    if prob > score[begin][end][A]
      score[begin][end][A] = prob
      back[begin][end][A] = new Triple(split,B,C)

```


$S \rightarrow NP VP$	0.9
$S \rightarrow VP$	0.1
$VP \rightarrow V NP$	0.5
$VP \rightarrow V$	0.1
$VP \rightarrow V @VP_V$	0.3
$VP \rightarrow V PP$	0.1
$@VP_V \rightarrow NP PP$	1.0
$NP \rightarrow NP NP$	0.1
$NP \rightarrow NP PP$	0.2
$NP \rightarrow N$	0.7
$PP \rightarrow P NP$	1.0
$N \rightarrow people$	0.5
$N \rightarrow fish$	0.2
$N \rightarrow tanks$	0.2
$N \rightarrow rods$	0.1
$V \rightarrow people$	0.1
$V \rightarrow fish$	0.6
$V \rightarrow tanks$	0.3
$P \rightarrow with$	1.0

	fish	1	people	2	fish	3	tanks	4
0								
1	$N \rightarrow fish\ 0.2$ $V \rightarrow fish\ 0.6$ $NP \rightarrow N\ 0.14$ $VP \rightarrow V\ 0.06$ $S \rightarrow VP\ 0.006$		$NP \rightarrow NP\ NP$ 0.0049 $VP \rightarrow V\ NP$ 0.105 $S \rightarrow VP$ 0.0105		$NP \rightarrow NP\ NP$ 0.0000686 $VP \rightarrow V\ NP$ 0.00147 $S \rightarrow NP\ VP$ 0.000882			
2			$N \rightarrow people\ 0.5$ $V \rightarrow people\ 0.1$ $NP \rightarrow N\ 0.35$ $VP \rightarrow V\ 0.01$ $S \rightarrow VP\ 0.001$		$NP \rightarrow NP\ NP$ 0.0049 $VP \rightarrow V\ NP$ 0.007 $S \rightarrow NP\ VP$ 0.0189		$NP \rightarrow NP\ NP$ 0.0000686 $VP \rightarrow V\ NP$ 0.000098 $S \rightarrow NP\ VP$ 0.01323	
3					$N \rightarrow fish\ 0.2$ $V \rightarrow fish\ 0.6$ $NP \rightarrow N\ 0.14$ $VP \rightarrow V\ 0.06$ $S \rightarrow VP\ 0.006$		$NP \rightarrow NP\ NP$ 0.00196 $VP \rightarrow V\ NP$ 0.042 $S \rightarrow VP$ 0.0042	
4							$N \rightarrow tanks\ 0.2$ $V \rightarrow tanks\ 0.1$ $NP \rightarrow N\ 0.14$ $VP \rightarrow V\ 0.03$ $S \rightarrow VP\ 0.003$	

```

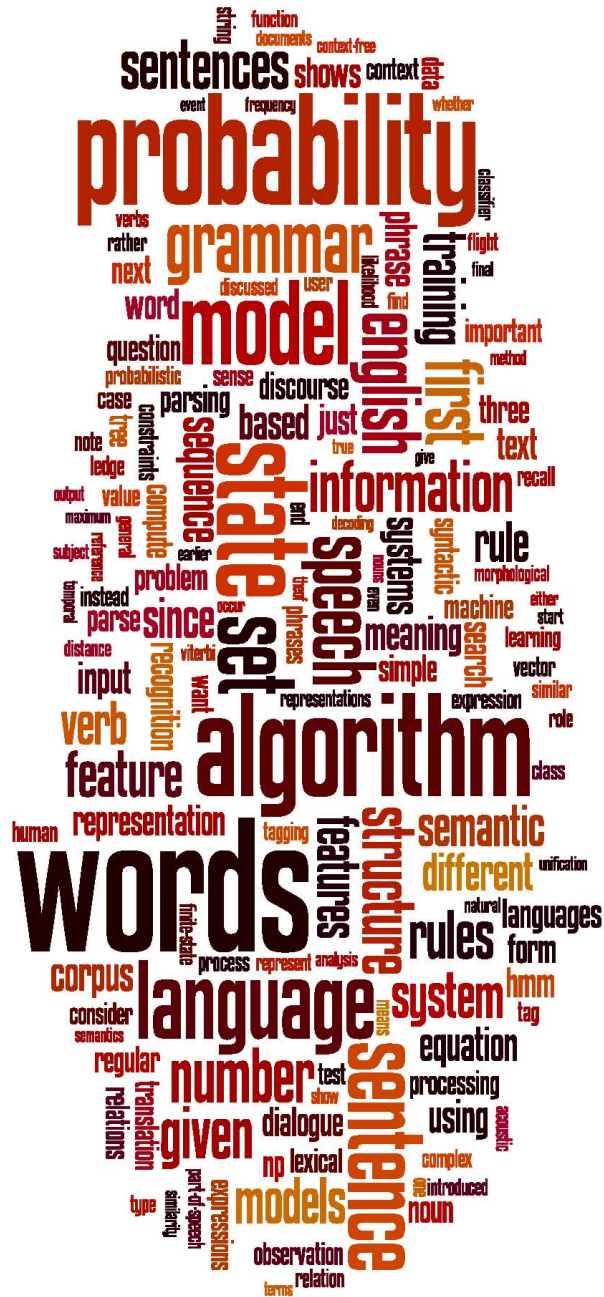
for split = begin+1 to end-1
  for A,B,C in nonterms
    prob=score[begin][split][B]*score[split][end][C]*P(A->BC)
    if prob > score[begin][end][A]
      score[begin][end][A] = prob
      back[begin][end][A] = new Triple(split,B,C)

```

- $S \rightarrow NP VP$ 0.9
- $S \rightarrow VP$ 0.1
- $VP \rightarrow V NP$ 0.5
- $VP \rightarrow V$ 0.1
- $VP \rightarrow V @VP_V$ 0.3
- $VP \rightarrow V PP$ 0.1
- $@VP_V \rightarrow NP PP$ 1.0
- $NP \rightarrow NP NP$ 0.1
- $NP \rightarrow NP PP$ 0.2
- $NP \rightarrow N$ 0.7
- $PP \rightarrow P NP$ 1.0
- $N \rightarrow people$ 0.5
- $N \rightarrow fish$ 0.2
- $N \rightarrow tanks$ 0.2
- $N \rightarrow rods$ 0.1
- $V \rightarrow people$ 0.1
- $V \rightarrow fish$ 0.6
- $V \rightarrow tanks$ 0.3
- $P \rightarrow with$ 1.0

	0	1	2	3	4
	fish	people	fish	tanks	
0	$N \rightarrow fish$ 0.2 $V \rightarrow fish$ 0.6 $NP \rightarrow N$ 0.14 $VP \rightarrow V$ 0.06 $S \rightarrow VP$ 0.006	$NP \rightarrow NP NP$ 0.0049 $VP \rightarrow V NP$ 0.105 $S \rightarrow VP$ 0.0105	$NP \rightarrow NP NP$ 0.0000686 $VP \rightarrow V NP$ 0.00147 $S \rightarrow NP VP$ 0.000882	$NP \rightarrow NP NP$ 0.0000009604 $VP \rightarrow V NP$ 0.00002058 $S \rightarrow NP VP$ 0.00018522	
1		$N \rightarrow people$ 0.5 $V \rightarrow people$ 0.1 $NP \rightarrow N$ 0.35 $VP \rightarrow V$ 0.01 $S \rightarrow VP$ 0.001	$NP \rightarrow NP NP$ 0.0049 $VP \rightarrow V NP$ 0.007 $S \rightarrow NP VP$ 0.0189	$NP \rightarrow NP NP$ 0.0000686 $VP \rightarrow V NP$ 0.000098 $S \rightarrow NP VP$ 0.01323	
2			$N \rightarrow fish$ 0.2 $V \rightarrow fish$ 0.6 $NP \rightarrow N$ 0.14 $VP \rightarrow V$ 0.06 $S \rightarrow VP$ 0.006	$NP \rightarrow NP NP$ 0.00196 $VP \rightarrow V NP$ 0.042 $S \rightarrow VP$ 0.0042	
3				$N \rightarrow tanks$ 0.2 $V \rightarrow tanks$ 0.1 $NP \rightarrow N$ 0.14 $VP \rightarrow V$ 0.03 $S \rightarrow VP$ 0.003	
4					

Call buildTree(score, back) to get the best parse



CKY Parsing

A worked example