# Recitation

CFG and CKY

11/12/2020

Param P

#### **CFG**

- Set of nonterminal symbols N
- Set of terminal symbols  $\Sigma$
- A start symbol  $S \in N$
- Set R of productions of the form A → B where A ∈ N and B ∈ (Σ U N)\* ie. B
  is a string of terminals and non-terminals
- Given G is a CFG, language of G is defined as set of all terminal strings that can be derived from the start symbol
- Context free: applicability of a rule depends only on a nonterminal symbol, not on its context

### Regular Grammar

- Set of nonterminal symbols N
- Set of terminal symbols  $\Sigma$
- A start symbol  $S \in N$
- Set R of productions of the form A → aB or A → a where A, B ∈ N and a ∈ Σ
- Can be implemented as finite state automata
- Set of all regular languages is strictly smaller than set of all context-free languages
- Problem: regular languages cannot capture long-distance dependencies

### **CKY Parsing**

- Syntactic parsing is the task of recognizing a sentence and assigning a syntactic structure to it (i.e. adding POS tags).
- The **CKY algorithm** is a bottom-up approach to figuring out if a sentence/sequence of words is in the language/grammar provided, because it starts with the terminals and sees which subtrees it can build, eventually making those subtrees into larger subtrees until you reach S (or don't, in which case it's not in the language).
- To use the CKY algorithm, the CFG must be in CNF.

#### **CNF**

## **Chomsky Normal Form**

- A CFG G=(N, Σ, R, S) is in Chomsky Normal Form (CNF) if the rules take one of the following forms:
  - A  $\rightarrow$  B C, where A  $\in$  N, B  $\in$  N, C  $\in$  N.
  - $A \rightarrow b$ , where  $A \in N$ ,  $b \in \Sigma$ .

Any CFG can be converted to an equivalent grammar in CNF that expresses the same language.

Cannot have null rules and unreachable rules as well

# CNF Example

### CFG -> CNF

- $\bullet S \rightarrow bC$
- $\bullet C \rightarrow B$
- •B → bAE
- $\bullet A \rightarrow bE$
- $\bullet E \rightarrow e$

### CFG -> CNF

- $\bullet S \rightarrow FC$
- •C → FAE
- $\bullet A \rightarrow FE$
- $\bullet E \rightarrow e$
- $\bullet F \rightarrow b$

Replace 'b' by non-terminal 'F' by adding a new rule

Merge B into C since C has only 1 non-terminal On the right side.

### CFG -> CNF

- $\bullet S \rightarrow FC$
- $\bullet C \rightarrow FG$
- $\bullet G \rightarrow AE$
- $\bullet A \rightarrow FE$
- $\bullet E \rightarrow e$
- $\bullet F \rightarrow b$

C had 3 non-terminals on the right. Take the last 3-2 And make a new rule 'G' for them.

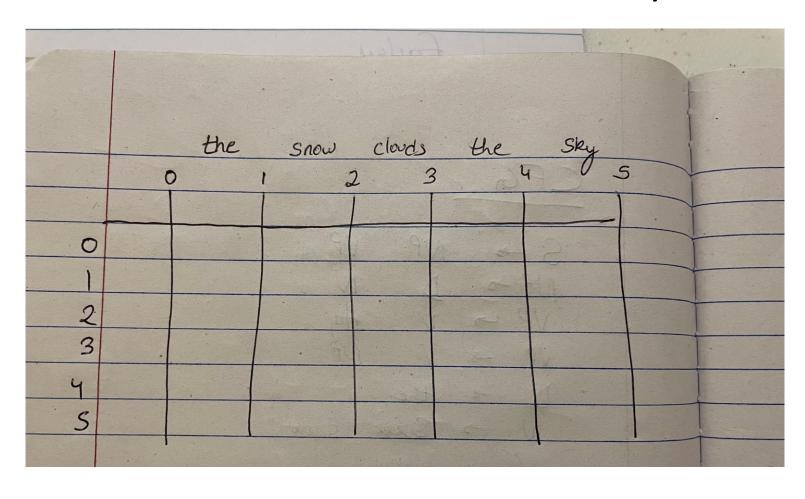
Now each NT has only 2 Non-Terminals on the right or only 1 Terminal.

This is final CNF form

# CKY Example

	and carelly come with	
	CFG	
	S -> NP VP	
	NP > D N VP > V Adj	
7 1 1 1 1 1	VP -3 V NP	
	N -> Brown Snow	
	V = snow  N = clouds	
1	V -> clouds N -> sky	
	Agi -s sky	

## Sentence: the snow clouds the sky



				1
		the	snow clouds the sky	5
P. Commission of the Commissio	0		2	
0	×			
2			· All Land	
4	×	×	× × × ×	
~				

الاستان والمولى الحليد الماد
CFG
S -> NP VP
NP D N
VP -> V Agi
VP -3 V NP
D -3 the
N -> Brow snow
V 3 SNOW
N > clouds
V -> clouds
N -> sky
Adj - Spy
State of the state

		the	Snow	clouds	the	Sky	
	0		1	2 3	04	5	
1:							
0	×	D	9	1 9/		2	
1	×			1		sia -	
2	X					4	
3	X.		. 4		2-		
4	×			the sale		1	
5	X	×	X	X	X	×	
		1		P. William	-		
				Mills			
				short,			
				2.19	4	A PORT	

CFG
S -> NP VP
NP D N
VP -> V Agi
VP -3 V NP
b -3 the
N > Brow Snow
N = clouds
N -3 clouds
N -> sky Adj -> sky
Adj -> Sky

1					
		the	Snow clouds the Sky		
	C	)	1 2 3 4 5		
7					
0	X	D	9/19/14/2		
	×	×	N, V		
_ 2	X	×	X N, V		
3	X.	×	XXD		
- 4	×	X	X X X N, Adj		
5	X	×	XXXX		
,					
			Maria San Cara Cara Cara Cara Cara Cara Cara Ca		
	And the second s				
			The same of the sa		

A HOUR
CFG C
S-> NP VP
NP > D N
VP -> V Adj
VP -3 V NP
) -3 the
N > Brow snow
N > clouds
V -> clouds
N -> sky
Agi -s Sky
and the second second

				,				
		the	Snow	clouds	the	Sky		•
	C		1 2				5	
1								
0	×	D -	> NP	1 9	har &	2		•
. 1	×	×	N,V	X	1	MA I		
2	X	×	X	N,V	X	V		
3	X.	×	*	X	D-	NP N, Adj		
4	X	X	X	×	×	N, Adj		
5	X	×	X	X	X	X	1	
				Was in				-
				Male		4		-
				hall	4			
				1-2	4			
			The said the said			4		

CFG
S -> NP VP
NP > D N
VP -> V Agi
VP -3 V NP
D -3 the
N > Show snow
V = snow
N > clouds
V -> clouds
N > Sky
Agi -> Sky
The state of the s

1	
	the snow clouds the sky
	0 1 2 3 4 5
1	
0	$\times$ D $\rightarrow$ NP $\times$
1	$\times \times \times N, V \times \times$
_ 2	X X X N,V X VP
3	X X X D NP
~ 4	X X X X X X Adj
_ 5	X X X X X X

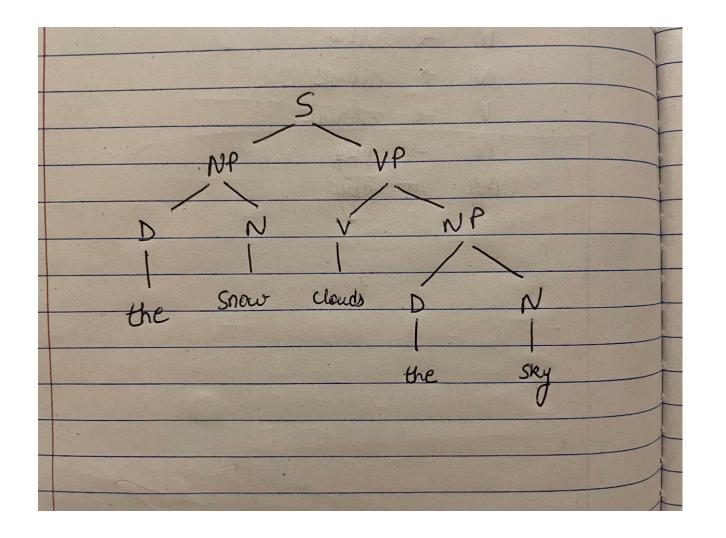
NP VP Adj NP -s the -> Brow Snow 3 SNOW N > clouds -s clouds

				,			
	+	the	Snow	clouds	the	Sky	
	(		1			A	5
0	X	D-	> NP	X	X	2	
1	X	×	N,V	X	X	X	
2	X	×	X	N,V	X	YP ~	
3	X.	×	*	×	D-	NP	
4	X	X	X	X	×	N, Adj	
5	X	×	X	X	X	×	
				Named			
					4		

The same
CFG
S -> NP VP
NP D N
VP -> V Agi
VP -3 V NP
D -3 the
N > Brow Snow
V -s snow
N > clouds
V -> clouds N -> sky
my -, seg
Ag - Spy

			113				
				,			
		the	Snow	clouds	the	Sky	
	C	)	1 2	. 3	ان ا	1 0 5	
1							
0	×	D-	> NP	X	X	5	
1	×	×	N,V	X	X	X	
2	X	×	X	N,V	X	VP	
3	X	×	*	X	D-	NP'	
4	×	X	X	X	X	N, Adj	
5	X	×	X	X	X	X	
					-	M. T. S.	
				i de la			

of the state of
CFG
S -> NP VP
NP D N
VP -> V Adj
VP -3 V NP
D = the
N -> Brown Snow
V - snow
N - clouds
V -> clouds
N > sizy
Age -> Sky
Control of the Contro



-> Brown Snow - snow - clouds -s clouds