Compiler Construction

Chapter 5(Normal Forms)

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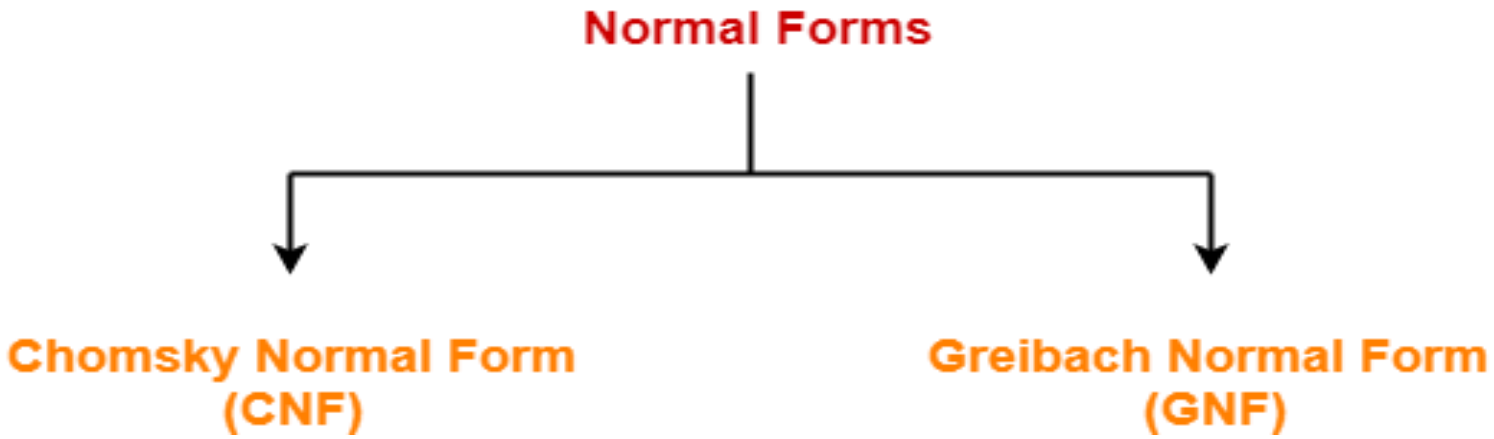
Chapter 5- Normal Forms

Types of Normal Forms

The most frequently used normal forms are



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Restriction for Normal Form

* nonrecursive start symbol.
* **Elimination of Lambda Rules**
* **Elimination of Chain Rules**
* **Useless Symbols**

nonrecursive start symbol.

Example:

G: $S \to aS \mid AB \mid AC$

$A \to aA \mid \lambda$

$B \to bB \mid bS$

$C \to cC \mid \lambda$

G′: $S' \to S$

$S \to aS \mid AB \mid AC$

$A \to aA \mid \lambda$

$B \to bB \mid bS$

$C \to cC \mid \lambda$

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Elimination of Lambda Rules

Example:

$$S \rightarrow SaB \mid aB$$
$$B \rightarrow bB \mid \lambda.$$

$$S \rightarrow SaB \mid Sa \mid aB \mid a$$
$$B \rightarrow bB \mid b$$

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Elimination of Chain Rules

$$A \rightarrow aA \mid a \mid B$$

$$B \rightarrow bB \mid b$$

$$A \rightarrow aA \mid a \mid B$$

$$B \rightarrow bB \mid b$$

$$A \rightarrow aA \mid a \mid bB \mid b$$

$$B \rightarrow bB \mid b$$

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Useless Symbols

G: $S \rightarrow AC \mid BS \mid B$

$A \rightarrow aA \mid aF$

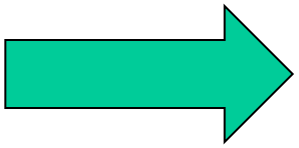
$B \rightarrow CF \mid b$

$C \rightarrow cC \mid D$

$D \rightarrow aD \mid BD \mid C$

$E \rightarrow aA \mid BSA$

$F \rightarrow bB \mid b.$



G: $S \rightarrow AC \mid BS \mid B$

$A \rightarrow aA \mid aF$

$B \rightarrow CF \mid b$

$C \rightarrow cC \mid D$

$D \rightarrow aD \mid BD \mid C$

$E \rightarrow aA \mid BSA$

$F \rightarrow bB \mid b.$

Iteration	TERM	PREV
0	$\{B, F\}$	
1	$\{B, F, A, S\}$	$\{B, F\}$

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G: $S \rightarrow AC \mid BS \mid B$

$A \rightarrow aA \mid aF$

$B \rightarrow CF \mid b$

$C \rightarrow cC \mid D$

$D \rightarrow aD \mid BD \mid C$

$E \rightarrow aA \mid BSA$

$F \rightarrow bB \mid b.$

Iteration	TERM	PREV
0	$\{B, F\}$	
1	$\{B, F, A, S\}$	$\{B, F\}$
2	$\{B, F, A, S, E\}$	$\{B, F, A, S\}$

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Iteration	TERM	PREV
0	$\{B, F\}$	
1	$\{B, F, A, S\}$	$\{B, F\}$
2	$\{B, F, A, S, E\}$	$\{B, F, A, S\}$
3	$\{B, F, A, S, E\}$	$\{B, F, A, S, E\}$

G: $S \rightarrow AC \mid BS \mid B$

$A \rightarrow aA \mid aF$

$B \rightarrow CF \mid b$

$C \rightarrow cC \mid D$

$D \rightarrow aD \mid BD \mid C$

$E \rightarrow aA \mid BSA$

$F \rightarrow bB \mid b.$

$S \rightarrow BS \mid B$

$A \rightarrow aA \mid aF$

$B \rightarrow b$

$E \rightarrow aA \mid BSA$

$F \rightarrow bB \mid b.$

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Chomsky Normal Form

From here, we infer- To be in CNF, all the productions must derive either two non-terminals or a single terminal.

CNF restricts the number of symbols on the right side of a production to be two.

The two symbols must be non-terminals or a single terminal.

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Chomsky Normal Form

A context free grammar is said to be in chomsky normal form (CNF) if all its productions are of the form-

A → **BC** or **A** → **a**

where A, B, C are non-terminals and a is a terminal

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Example-

$S \rightarrow AB$
$A \rightarrow a$
$B \rightarrow b$

This context free grammar is in chomsky normal form.

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Example1 :

Convert the following grammar to Chomsky normal form

$G: S \rightarrow aAB / a\,A / b\,B$
$A \rightarrow a\,Ab / aB / a$
$B \rightarrow bA / b$

Solution

Step 1 :

The productions already in chomsky normal form are:

$A \rightarrow a$
$B \rightarrow b$

These productions will remain as they are.

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Step 2 :

The productions not in chomsky normal form are-

G: S → aAB / a A / b B
A → a Ab / aB
B → bA

We will convert these productions in chomsky normal form

Step 3:
Replace the terminal symbols a and b by new variables T_1 and T_2

This is done by introducing the following two new productions in the grammar:
$T_1 \rightarrow a$
$T_2 \rightarrow b$

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$G: S \rightarrow aAB / a\,A / b\,B$
$A \rightarrow a\,Ab / aB / a$
$B \rightarrow bA / b$

Now, the productions $S \rightarrow a\,A$ modifies to $S \rightarrow T_1\,A$

the productions $S \rightarrow b\,B$ modifies to $S \rightarrow T_2\,B$

the productions $A \rightarrow a\,B$ modifies to $A \rightarrow T_1\,B$

the productions $B \rightarrow b\,A$ modifies to $B \rightarrow T_2\,A$

the productions $A \rightarrow a\,Ab$ modifies to $A \rightarrow aAT_2$

$G: S \rightarrow aAB / T_1\,A / T_2\,B$
$A \rightarrow a\,AT_2 / T_1\,B / a$
$B \rightarrow T_2\,A / b$
$T_1 \rightarrow a$
$T_2 \rightarrow b$

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$G: S \rightarrow aAB / T_1 A / T_2 B$
$A \rightarrow a AT_2 / T_1 B / a$
$B \rightarrow T_2 A / b$
$T_1 \rightarrow a$
$T_2 \rightarrow b$

Step 3:

Replace AB and AT_2 by new variables T_3 and T_4 respectively.

This is done by introducing the following two new productions in the grammar:

$T_3 \rightarrow AB$
$T_4 \rightarrow AT_2$

Now, the productions S → aAB , and A → a AT2 modifies to:
$S \rightarrow T_1 T_3$
$A \rightarrow T_1 T_4$

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Finally:

$G: S \rightarrow aAB / a\,A / b\,B$
$A \rightarrow a\,Ab / aB / a$
$B \rightarrow bA / b$

Chomsky normal form:

$G: S \rightarrow T_1\,T_3 / T_1\,A / T_2\,B$
$A \rightarrow A \rightarrow T_1\,T_4 / T_1\,B / a$
$B \rightarrow T_2\,A / b$
$T_1 \rightarrow a$
$T_2 \rightarrow b$
$T_3 \rightarrow AB$
$T_4 \rightarrow AT_2$

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Greibach Normal Form

A context-free grammar $G = (V, \Sigma, P, S)$ is in **Greibach normal form** if each rule has one of the following forms:

i) $A \rightarrow aA_1A_2 \ldots A_n$

ii) $A \rightarrow a$

iii) $S \rightarrow \lambda$,

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Example 2: Convert the following grammar to Greibach normal form

$G: S \rightarrow aAB / a\,A / b\,B$
$A \rightarrow a\,Ab / aB / a$
$B \rightarrow bA / b$

Solution

Step 1 :

The productions already in Greibach normal form are:

$G: S \rightarrow aAB / a\,A / b\,B$
$A \rightarrow aB / a$
$B \rightarrow bA / b$

These productions will remain as they are

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Step 2 :

The productions not in Greibach normal form are-

$A \rightarrow a\,Ab$

We will convert this production in Greibach normal form

Step 3:

Replace the terminal symbol b by new variables T_1

$T_1 \rightarrow b$

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Finally :

Greibach normal form

$G: S \rightarrow aAB / a\,A / b\,B$

$A \rightarrow a\,AT_1 / aB / a$

$B \rightarrow bA / b$

$T_1 \rightarrow b$

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Example 3:
Convert the following grammar to Greibach normal form

$G: S \rightarrow aAB / a\,A / B\,b$
$A \rightarrow a\,Ab / aB / a$
$B \rightarrow bA / b$

Solution

Step 1 :

The productions already in Greibach normal form are:

$G: S \rightarrow aAB / a\,A$
$A \rightarrow aB / a$
$B \rightarrow bA / b$

These productions will remain as they are

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Step 2 :

The productions not in Greibach normal form are-

$S \rightarrow B\ b$
$A \rightarrow a\ Ab$

We will convert this production in Greibach normal form

Step 3:
Replace the terminal symbol b by new variables T_1

$T_1 \rightarrow b$

$S \rightarrow B\ b$ *?????*

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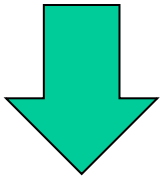
$G: S \rightarrow aAB / a\,A / B\,b$
$A \rightarrow a\,AT_1 / aB / a$
$B \rightarrow bA / b$
$T_1 \rightarrow b$

$S \rightarrow B\ b$

$B \rightarrow bA / b$

$S \rightarrow bA\,b / b\,b$

$G: S \rightarrow aAB / a\,A / bA\,b / bb$
$A \rightarrow a\,AT_1 / aB / a$
$B \rightarrow bA / b$
$T_1 \rightarrow b$



$G: S \rightarrow aAB / a\,A / bA\ T_1 / bT_1$
$A \rightarrow a\,AT_1 / aB / a$
$B \rightarrow bA / b$
$T_1 \rightarrow b$