

Chapter 4

Syntax Analysis

Constructing Parsing Table

Algorithm:

1. Repeat Steps 2 & 3 for each rule $A \rightarrow \alpha$
2. Terminal a in $\text{First}(\alpha)$: Add $A \rightarrow \alpha$ to $M[A, a]$
3. $a \in \text{First}(\alpha)$: Add $A \rightarrow \alpha$ to $M[A, b]$ for all terminals b in $\text{Follow}(A)$.
b) $\epsilon \in \text{First}(\alpha)$ and $\$$ in $\text{Follow}(A)$: Add $A \rightarrow \alpha$ to $M[A, \$]$
4. All undefined entries are errors.

Example 1

Given the production rules:

$S \rightarrow aABb$

$A \rightarrow c \mid \epsilon$

$B \rightarrow d \mid \epsilon$

$\text{First}(S) = \{a\}$

$\text{First}(A) = \{c, \epsilon\}$

$\text{First}(B) = \{d, \epsilon\}$

$\text{Follow}(S) = \{\$ \}$

$\text{Follow}(A) = \{d, b\}$

$\text{Follow}(B) = \{b\}$

	INPUT SYMBOLS				
Non Terminals	a	b	c	d	\$
S	$S \rightarrow aABb$				
A		$A \rightarrow \epsilon$	$A \rightarrow c$	$A \rightarrow \epsilon$	
B		$B \rightarrow \epsilon$		$B \rightarrow d$	

3

Trace of Example 1

STACK	INPUT	OUTPUT
$\$S$	$adb\$$	
$\$bBA\epsilon$	$adb\$$	$S \rightarrow aABb$
$\$bBA$	$db\$$	--- pop
$\$bB$	$db\$$	$A \rightarrow \epsilon$
$\$bd$	$db\$$	$B \rightarrow d$
$\$b$	$b\$$	pop
$\$$	$\$$	pop

Constructing Parsing Table – Example 2

$E \rightarrow TE'$	$\text{First}(E, F, T) = \{ (, id \}$	$\text{Follow}(E, E') = \{), \$ \}$
$E' \rightarrow + TE' \mid \epsilon$	$\text{First}(E') = \{ +, \epsilon \}$	$\text{Follow}(F) = \{ *, +,), \$ \}$
$T \rightarrow FT'$	$\text{First}(T') = \{ *, \epsilon \}$	$\text{Follow}(T, T') = \{ +,), \$ \}$
$T' \rightarrow * FT' \mid \epsilon$		
$F \rightarrow (E) \mid id$		

$E \rightarrow TE'$
 $E' \rightarrow + TE' \mid \epsilon$
 $T \rightarrow FT'$
 $T' \rightarrow * FT' \mid \epsilon$
 $F \rightarrow (E) \mid id$

5

Constructing Parsing Table – Example 2

$E \rightarrow TE'$	$\text{First}(E, F, T) = \{ (, id \}$	$\text{Follow}(E, E') = \{), \$ \}$
$E' \rightarrow + TE' \mid \epsilon$	$\text{First}(E') = \{ +, \epsilon \}$	$\text{Follow}(F) = \{ *, +,), \$ \}$
$T \rightarrow FT'$	$\text{First}(T') = \{ *, \epsilon \}$	$\text{Follow}(T, T') = \{ +,), \$ \}$
$T' \rightarrow * FT' \mid \epsilon$		
$F \rightarrow (E) \mid id$		

Expression Example: $E \rightarrow TE' : \text{First}(TE') = \text{First}(T) = \{ (, id \}$

$M[E, (] : E \rightarrow TE'$
 $M[E, id] : E \rightarrow TE'$

by rule 2

(by rule 2) $E' \rightarrow + TE' : \text{First}(+TE') = + : M[E', +] : E' \rightarrow + TE'$

(by rule 3) $E' \rightarrow \epsilon : \epsilon \text{ in } \text{First}(\epsilon)$	$T' \rightarrow \epsilon : \epsilon \text{ in } \text{First}(\epsilon)$
$M[E',)] : E' \rightarrow \epsilon$ (3.1)	$M[T', +] : T' \rightarrow \epsilon$ (3.1)
$M[E', \$] : E' \rightarrow \epsilon$ (3.2)	$M[T',)] : T' \rightarrow \epsilon$ (3.1)
(Due to Follow(E'))	$M[T', \$] : T' \rightarrow \epsilon$ (3.2)

6

Example 2

$E \rightarrow TE'$
 $E' \rightarrow + TE' \mid \epsilon$
 $T \rightarrow FT'$
 $T' \rightarrow * FT' \mid \epsilon$
 $F \rightarrow (E) \mid id$



Table M

Non-terminal	INPUT SYMBOL					
	id	+	*	()	\$
E	$E \rightarrow TE'$			$E \rightarrow TE'$		
E'		$E' \rightarrow + TE'$			$E' \rightarrow \epsilon$	$E' \rightarrow \epsilon$
T	$T \rightarrow FT'$			$T \rightarrow FT'$		
T'		$T' \rightarrow \epsilon$	$T' \rightarrow * FT'$		$T' \rightarrow \epsilon$	$T' \rightarrow \epsilon$
F	$F \rightarrow id$			$F \rightarrow (E)$		

7

Trace of Example 2

STACK	INPUT	OUTPUT
SE	id + id * id\$	
SE'T	id + id * id\$	$E \rightarrow TE'$
SE'T'F	id + id * id\$	$T \rightarrow FT'$
SE'T'id	id + id * id\$	$F \rightarrow id$
SE'T'	+ id * id\$	
SE'	+ id * id\$	$T' \rightarrow \epsilon$
SE'T+	+ id * id\$	$E' \rightarrow + TE'$
SE'T	id * id\$	
SE'T'F	id * id\$	$T \rightarrow FT'$
SE'T'id	id * id\$	$F \rightarrow id$
SE'T'	* id\$	
SE'T'F*	* id\$	$T' \rightarrow * FT'$
SE'T'F	id\$	
SE'T'id	id\$	$F \rightarrow id$
SE'T'	\$	
SE'	\$	$T' \rightarrow \epsilon$
\$	\$	$E' \rightarrow \epsilon$

Motivation Behind First & Follow

First: Is used to help find the appropriate production to follow given the top-of-the-stack non-terminal and the current input symbol.

Example: If $A \rightarrow \alpha$, and a is in $\text{First}(\alpha)$, then when $a = \text{input}$, replace A with α (in the stack).

(a is one of first symbols of α , so when A is on the stack and a is input, POP A and PUSH α .)

Follow: Is used when First has a conflict, to resolve choices, or when First gives no suggestion. When $\alpha \rightarrow \epsilon$ or $\alpha \xRightarrow{*} \epsilon$, then what follows A dictates the next choice to be made.

Example: If $A \rightarrow \alpha$, and b is in $\text{Follow}(A)$, then when $\alpha \xRightarrow{*} \epsilon$ and b is an input character, then we expand A with α , which will eventually expand to ϵ , of which b follows!

($\alpha \xRightarrow{*} \epsilon$: i.e., $\text{First}(\alpha)$ contains ϵ .)

9

Example 3

$E \rightarrow TX$
 $X \rightarrow +E$
 $X \rightarrow \epsilon$
 $T \rightarrow \text{int } Y$
 $T \rightarrow (E)$
 $Y \rightarrow *T$
 $Y \rightarrow \epsilon$

Symbol	First	Follow
((N/A
))	
+	+	
*	*	
int	int	
Y	$\epsilon, *$), \$, +
X	$\epsilon, +$), \$
T	int, (), \$, +
E	int, (), \$

	INPUT SYMBOLS					
Non Terminals	+	*	()	int	\$
E			$E \rightarrow TX$		$E \rightarrow TX$	
X	$X \rightarrow +E$			$X \rightarrow \epsilon$		$X \rightarrow \epsilon$
T			$T \rightarrow (E)$		$T \rightarrow \text{int } Y$	
Y	$Y \rightarrow \epsilon$	$Y \rightarrow *T$		$Y \rightarrow \epsilon$		$Y \rightarrow \epsilon$

Trace of Example 3

STACK	INPUT	OUTPUT
\$ E	int * int \$	—
\$ XT	int * int \$	$E \rightarrow TX$
\$ XY int	int + int \$	$T \rightarrow int Y$
\$ XY	* int \$	pop
\$ XT *	* int \$	$Y \rightarrow XT$
\$ XT	int \$	pop
\$ XY int	int \$	$T \rightarrow int Y$
\$ XY	\$	pop
\$ X	\$	$Y \rightarrow E$
\$	\$	$X \rightarrow E$

Example 4

- $S \rightarrow A a$ $\text{First}(S) = \{b, d, a\}$ $\text{Follow}(S) = \{\$ \}$
- $A \rightarrow B D$ $\text{First}(A) = \{b, d, \epsilon\}$ $\text{Follow}(A) = \{a\}$
- $B \rightarrow b$ $\text{First}(B) = \{b, \epsilon\}$ $\text{Follow}(B) = \{d, a\}$
- $B \rightarrow \epsilon$ $\text{First}(D) = \{d, \epsilon\}$ $\text{Follow}(D) = \{a\}$
- $D \rightarrow d$
- $D \rightarrow \epsilon$

	INPUT SYMBOLS			
Non Terminals	a	b	d	\$
S	$S \rightarrow Aa$	$S \rightarrow Aa$	$S \rightarrow Aa$	
A	$A \rightarrow BD$	$A \rightarrow BD$	$A \rightarrow BD$	
B	$B \rightarrow \epsilon$	$B \rightarrow b$	$B \rightarrow \epsilon$	
D	$D \rightarrow \epsilon$		$D \rightarrow d$	

Trace of Example 4

STACK	INPUT	OUTPUT
\$ S	b d a \$	
\$ a A	b d a \$	$S \rightarrow A a$
\$ a D B	b d a \$	$A \rightarrow B D$
\$ a D b	b d a \$	$B \rightarrow b$
\$ a D	d a \$	Pop
\$ a d	d a \$	$D \rightarrow d$
\$ a	a \$	Pop .
\$	\$	—

Trace of Example 4

STACK	INPUT	OUTPUT
\$ S	a \$	
\$ a A	a \$	$S \rightarrow A a$
\$ a D B	a \$	$A \rightarrow B D$
\$ a D	a \$	$B \rightarrow \epsilon$
\$ a	a \$	$D \rightarrow \epsilon$
\$	\$	Pop .

Constructing Parsing Table – Example 5

$S \rightarrow i E t S S' \mid a$	$\text{First}(S) = \{ i, a \}$	$\text{Follow}(S) = \{ e, \$ \}$
$S' \rightarrow e S \mid \epsilon$	$\text{First}(S') = \{ e, \epsilon \}$	$\text{Follow}(S') = \{ e, \$ \}$
$E \rightarrow b$	$\text{First}(E) = \{ b \}$	$\text{Follow}(E) = \{ t \}$

15

Constructing Parsing Table – Example 5

$S \rightarrow i E t S S' \mid a$	$\text{First}(S) = \{ i, a \}$	$\text{Follow}(S) = \{ e, \$ \}$
$S' \rightarrow e S \mid \epsilon$	$\text{First}(S') = \{ e, \epsilon \}$	$\text{Follow}(S') = \{ e, \$ \}$
$E \rightarrow b$	$\text{First}(E) = \{ b \}$	$\text{Follow}(E) = \{ t \}$

 $S \rightarrow i E t S S'$ $S \rightarrow a$ $E \rightarrow b$ $\text{First}(i E t S S') = \{ i \}$ $\text{First}(a) = \{ a \}$ $\text{First}(b) = \{ b \}$ $S' \rightarrow e S$ $S \rightarrow \epsilon$ $\text{First}(e S) = \{ e \}$ $\text{First}(\epsilon) = \{ \epsilon \}$ $\text{Follow}(S') = \{ e, \$ \}$

Non-terminal	INPUT SYMBOL					
	a	b	e	i	t	\$
S	<u>$S \rightarrow a$</u>			<u>$S \rightarrow i E t S S'$</u>		
S'			<u>$S' \rightarrow \epsilon$</u> <u>$S' \rightarrow e S$</u>			<u>$S' \rightarrow \epsilon$</u>
E		<u>$E \rightarrow b$</u>				

16