

# FOLLOW Sets

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# Objectives

- ▶ Compute the FOLLOW sets for the nonterminal symbols of a grammar.

## FOLLOW Sets

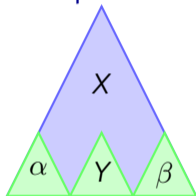
- ▶ Given a non terminal symbol  $S$ , what terminal symbols could come after strings that are derived from  $S$ ?

The algorithm:

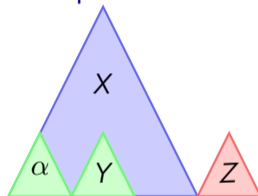
1. Put  $\$$  in  $FOLLOW(S)$ , where  $S$  is the start symbol.  
 $\$$  represents the “end of input.”
2. If there is a production  $X \rightarrow \alpha Y \beta$ , then add  $FIRST(\beta)$  (but not  $\epsilon$ ) to  $FOLLOW(Y)$ .
3. If there is a production  $X \rightarrow \alpha Y$ , or if there is a production  $X \rightarrow \alpha Y \beta$ , where  $\epsilon \in FIRST(\beta)$  then add  $FOLLOW(X)$  to  $FOLLOW(Y)$ .

# Diagram

## Example 1



## Example 2



1. If there is a production  $X \rightarrow \alpha Y \beta$ , then add  $FIRST(\beta)$  (but not  $\epsilon$ ) to  $FOLLOW(Y)$ .
2. If there is a production  $X \rightarrow \alpha Y$ , or if there is a production  $X \rightarrow \alpha Y \beta$ , where  $\epsilon \in FIRST(\beta)$  then add  $FOLLOW(X)$  to  $FOLLOW(Y)$ .

## Small Examples

### Example 1

$$S \rightarrow x A y$$

FOLLOW set of  $A$  is  $\{y\}$ .

### Example 2

$$A \rightarrow q B$$

FOLLOW set of  $B$  is also  $\{y\}$ .

### Example 3

$$B \rightarrow C E D$$
$$FIRST(D) = \{a, b\}$$

FOLLOW set of  $D$  is  $\{y\}$ .

FOLLOW set of  $E$  is  $\{a, b\}$ .

### Example 4

$$B \rightarrow C E D$$
$$FIRST(D) = \{a, b, \epsilon\}$$

FOLLOW set of  $D$  is  $\{y\}$ .

FOLLOW set of  $E$  is  $\{a, b, y\}$ .

# FOLLOW Set Example

## Grammar

$S \rightarrow \text{if } E \text{ then } S ;$

$S \rightarrow \text{print } E;$

$E \rightarrow E + E$

$E \rightarrow P \text{ id } P$

$P \rightarrow * P$

$P \rightarrow \epsilon$

## Result

$S = \{ \$ \}$

$E = \{ \}$

$P = \{ \}$

## Action

Make a chart, add \$ to S.

## FOLLOW Set Example

### Grammar

$S \rightarrow \text{if } E \text{ then } S ; \leftarrow$

$S \rightarrow \text{print } E ;$

$E \rightarrow E + E$

$E \rightarrow P \text{ id } P$

$P \rightarrow * P$

$P \rightarrow \epsilon$

### Result

$S = \{ \$, ; \}$

$E = \{ \text{then} \}$

$P = \{ \}$

### Action

Check productions: add `then` to  $FOLLOW(E)$ , and `;` to  $FOLLOW(S)$ .

## FOLLOW Set Example

### Grammar

$S \rightarrow \text{if } E \text{ then } S ;$

$S \rightarrow \text{print } E ; \leftarrow$

$E \rightarrow E + E \leftarrow$

$E \rightarrow P \text{ id } P$

$P \rightarrow * P$

$P \rightarrow \epsilon$

### Result

$S = \{ \$, ; \}$

$E = \{ \text{then}, ;, + \}$

$P = \{ \}$

### Action

Check productions: add ; and + to  $FOLLOW(E)$ .



## FOLLOW Set Example

### Grammar

$S \rightarrow \text{if } E \text{ then } S ;$

$S \rightarrow \text{print } E ;$

$E \rightarrow E + E$

$E \rightarrow P \text{ id } P \leftarrow$

$P \rightarrow * P$

$P \rightarrow \epsilon$

### Result

$S = \{ \$, ; \}$

$E = \{ \text{then}, ,, + \}$

$P = \{ \text{id} \}$

### Action

Check productions: add `id` to  $FOLLOW(P)$ .

## FOLLOW Set Example

### Grammar

$S \rightarrow \text{if } E \text{ then } S ;$

$S \rightarrow \text{print } E ;$

$E \rightarrow E + E$

$E \rightarrow P \text{ id } P \leftarrow$

$P \rightarrow * P$

$P \rightarrow \epsilon$

### Result

$S = \{\$, ;\}$

$E = \{\text{then}, ,, +\}$

$P = \{\text{id}, \text{then}, ,, +\}$

### Action

Check endings:  $P$  ends this rule, so add  $FOLLOW(E)$  to  $FOLLOW(P)$ .

# FOLLOW Set Example

## Grammar

$$S \rightarrow \text{if } E \text{ then } S ;$$
$$S \rightarrow \text{print } E;$$
$$E \rightarrow E + E$$
$$E \rightarrow P \text{ id } P$$
$$P \rightarrow * P$$
$$P \rightarrow \epsilon$$

## Result

$$S = \{\$, ;\}$$
$$E = \{\text{then}, ,, +\}$$
$$P = \{\text{id}, \text{then}, ,, +\}$$

## Action

Done.

## Another FOLLOW Set Example

### Grammar

$S \rightarrow Ax$   
 $S \rightarrow By$   
 $S \rightarrow z$   
 $A \rightarrow 1CB$   
 $A \rightarrow 2B$   
 $B \rightarrow 3B$   
 $B \rightarrow C$   
 $C \rightarrow 4$   
 $C \rightarrow \epsilon$

### Result

$S = \{ \$ \}$   
 $A = \{ \}$   
 $B = \{ \}$   
 $C = \{ \}$

### Action

Create a table, and add \$ to  $FOLLOW(S)$ .

## Another FOLLOW Set Example

### Grammar

$S \rightarrow Ax$  ←

$S \rightarrow By$

$S \rightarrow z$

$A \rightarrow 1CB$

$A \rightarrow 2B$

$B \rightarrow 3B$

$B \rightarrow C$

$C \rightarrow 4$

$C \rightarrow \epsilon$

### Result

$S = \{ \$ \}$

$A = \{ x \}$

$B = \{ \}$

$C = \{ \}$

### Action

Add  $x$  to  $FOLLOW(A)$ .

## Another FOLLOW Set Example

### Grammar

$$S \rightarrow Ax$$
$$S \rightarrow By \leftarrow$$
$$S \rightarrow z$$
$$A \rightarrow 1CB$$
$$A \rightarrow 2B$$
$$B \rightarrow 3B$$
$$B \rightarrow C$$
$$C \rightarrow 4$$
$$C \rightarrow \epsilon$$

### Result

$$S = \{ \$ \}$$
$$A = \{ x \}$$
$$B = \{ y \}$$
$$C = \{ \}$$

### Action

Add  $y$  to  $FOLLOW(B)$ .

## Another FOLLOW Set Example

### Grammar

$$S \rightarrow Ax$$
$$S \rightarrow By$$
$$S \rightarrow z \leftarrow$$
$$A \rightarrow 1CB$$
$$A \rightarrow 2B$$
$$B \rightarrow 3B \leftarrow$$
$$B \rightarrow C$$
$$C \rightarrow 4 \leftarrow$$
$$C \rightarrow \epsilon \leftarrow$$

### Result

$$S = \{ \$ \}$$
$$A = \{ x \}$$
$$B = \{ y \}$$
$$C = \{ \}$$

### Action

These productions add nothing.

## Another FOLLOW Set Example

### Grammar

 $S \rightarrow Ax$  $S \rightarrow By$  $S \rightarrow z$  $A \rightarrow 1CB \leftarrow$  $A \rightarrow 2B$  $B \rightarrow 3B$  $B \rightarrow C$  $C \rightarrow 4$  $C \rightarrow \epsilon$ 

### Result

 $S = \{ \$ \}$  $A = \{ x \}$  $B = \{ y \}$  $C = \{ 3, 4 \}$ 

### Action

Add  $FIRST(B)$  to  $FOLLOW(C)$ .



## Another FOLLOW Set Example

### Grammar

$$S \rightarrow Ax$$
$$S \rightarrow By$$
$$S \rightarrow z$$
$$A \rightarrow 1CB \leftarrow$$
$$A \rightarrow 2B \leftarrow$$
$$B \rightarrow 3B$$
$$B \rightarrow C$$
$$C \rightarrow 4$$
$$C \rightarrow \epsilon$$

### Result

$$S = \{ \$ \}$$
$$A = \{ x \}$$
$$B = \{ x, y \}$$
$$C = \{ 3, 4 \}$$

### Action

Add  $FOLLOW(A)$  to  $FOLLOW(B)$ .

## Another FOLLOW Set Example

### Grammar

 $S \rightarrow Ax$  $S \rightarrow By$  $S \rightarrow z$  $A \rightarrow 1CB \leftarrow$  $A \rightarrow 2B$  $B \rightarrow 3B$  $B \rightarrow C$  $C \rightarrow 4$  $C \rightarrow \epsilon$ 

### Result

 $S = \{ \$ \}$  $A = \{ x \}$  $B = \{ x, y \}$  $C = \{ x, 3, 4 \}$ 

### Action

$B$  can become  $\epsilon$ , so add  $FOLLOW(A)$  to  $FOLLOW(C)$ .

## Another FOLLOW Set Example

### Grammar

 $S \rightarrow Ax$  $S \rightarrow By$  $S \rightarrow z$  $A \rightarrow 1CB$  $A \rightarrow 2B$  $B \rightarrow 3B$  $B \rightarrow C \leftarrow$  $C \rightarrow 4$  $C \rightarrow \epsilon$ 

### Result

 $S = \{ \$ \}$  $A = \{ x \}$  $B = \{ x, y \}$  $C = \{ x, y, 3, 4 \}$ 

### Action

Add  $FOLLOW(B)$  to  $FOLLOW(C)$ . Now we're done.