Objectives

Objectives

First Sets

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First Sets

Objectives

- Be able to explain the purpose of a first set.
- Be able to compute the first set.

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The Problem

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- Given a grammar for a language *L*, how can we recognize a sentence in *L*?
- Solution: Divide and Conquer: Given a symbol *E.*..
 - What symbols indicate that the symbol *E* is just starting? (First Set)
 - What symbols should we expect to see after we have finished parsing an *E*?

Misleadingly simple example:
$$S \rightarrow xEy$$
 First(E) = $\{z, q\}$
 $E \rightarrow zE$ Follow(E)= $\{y\}$
 $E \rightarrow q$

• Important because a parser can see only a few tokens at once.

First Sets

Algorithm

We can compute the FIRST set by a simple iterative algorithm. For each symbol X.

- \bullet if *X* is a terminal, then $First(X) = \{X\}$
- \bullet if there is a production $X \to \epsilon$, then add ϵ to First(X).
- **1** if there is a production $X \to Y_1 Y_2 \cdots Y_n$, then add $First(Y_1 Y_2 \cdots Y_n)$ to First(X):
 - If $First(Y_1)$ does not contain ϵ , then $First(Y_1Y_2\cdots Y_n)=First(Y_1)$.
 - Otherwise, $First(Y_1 Y_2 \cdots Y_n) = First(Y_1)/\epsilon \cup First(Y_2 \cdots Y_n)$
 - If all of $Y_1, Y_2, \ldots Y_n$ have ϵ then add ϵ to First(X).

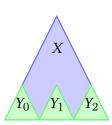
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Diagram

Small Examples

 $X \rightarrow Y_0 Y_1 Y_2$



- if there is a production $X \to Y_1 Y_2 \cdots Y_n$, then add $First(Y_1 Y_2 \cdots Y_n)$ to First(X):
 - If $First(Y_1)$ does not contain ϵ , then $First(Y_1 Y_2 \cdots Y_n) = First(Y_1)$.

First Sets

- Otherwise, $First(Y_1 Y_2 \cdots Y_n) = First(Y_1)/\epsilon \cup First(Y_2 \cdots Y_n)$
- If all of $Y_1, Y_2, \dots Y_n$ have ϵ then add ϵ to First(X).

Example 1

 $S \rightarrow x A B$

First set of *S* is $\{x\}$

Example 3

 $B \rightarrow A q$

 $B \rightarrow r$

First set of *B* is $\{y, z, q, r\}$

Example 2

 $A \rightarrow \epsilon$

 $A \rightarrow y$

 $A \rightarrow z q$

First set of *A* is $\{y, z, \epsilon\}$

Example 4

 $C \rightarrow A A$

 $C \rightarrow B$

First set of *C* is $\{y, z, q, r, \epsilon\}$

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First Set Example

First Set Example

Grammar

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

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

E
ightarrow Pid

 $P \rightarrow *P$

 $P \rightarrow \epsilon$

Result

 $S={}$ $E={}$

P={}

Grammar

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

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

 $E \rightarrow E + E$

E
ightarrow P id

 $P \rightarrow * P \Leftarrow$

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 $P \rightarrow \epsilon \Leftarrow$

Result

S={if, print}

 $E={}$

 $P = \{\epsilon, *\}$

Action

Step 1: Create a list of symbols.

Action

Step 2: Add terminals starting productions, and all ϵ .

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First Set Example

First Set Example

Grammar

 $P \rightarrow *P$

 $P \rightarrow \epsilon$

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

Result

 $S = \{if, print\}$ $E=\{*, id\}$ $P=\{\epsilon, *\}$

First Sets

Grammar

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

Result

 $S = \{if, print\}$ $E=\{*, id\}$ $P=\{\epsilon, *\}$

Action

Step 3: Check productions. Add First(Pid) to First(E).

Action

Step 4: Check productions: $E \rightarrow E + E$ adds nothing. We're done.

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Another First Set Example

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Another First Set Example

Grammar

 $S \rightarrow Ax$ $S \rightarrow By$ $S \rightarrow z$ $A \rightarrow 1CB$ A o 2BB
ightarrow 3B

 $B \rightarrow C$

 $C \rightarrow 4$

 $C \rightarrow \epsilon$

Result

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

Grammar

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

Result

 $S = \{z\}$ $A = \{ 1, 2 \}$ $B = {3}$ $C = \{ \epsilon, 4 \}$

Action

Create a chart.

Action

Add initial terminals and ϵ s.

Result

 $S = \{z, 1, 2\}$

 $A=\{1, 2\}$

 $C = \{\epsilon, 4\}$

 $B = {3}$

Another First Set Example

Another First Set Example

Grammar

$$S \rightarrow A x \Leftarrow$$

$$S \rightarrow By$$

$$S \rightarrow z$$

$$A \rightarrow 1CB$$

$$A o$$
 2 B

$$B o$$
 3 B

$$B\to C$$

$$C \rightarrow 4$$

$$C \rightarrow \epsilon$$

Grammar

$$S \to Ax$$

 $S \to By \Leftarrow$

$$A \rightarrow 1CB$$

$$A \rightarrow 2B$$

$$B o$$
 3 B

$$B\to C$$

$$C \rightarrow 4$$

$$C \rightarrow \epsilon$$

Result

$$S = \{z, 1, 2, 3\}$$

$$A = \{1, 2\}$$

$$B = \{3\}$$

$$C = \{\epsilon, 4\}$$

Action

Add First(Ax) to First(S).



Action

Add *First*(*By*) to *First*(*S*). Note that there is still more to be added to *First*(*B*)! We will have to revisit this step later.

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First Sets

Another First Set Example

Another First Set Example

Grammar

$$S \to A \mathbf{x}$$

$$S o B$$
y

$$S \rightarrow z$$

$$A \rightarrow 1CB$$

$$A o$$
 2 B

$$B o$$
 3 B

$$B \rightarrow C \Leftarrow$$

$$C \rightarrow 4$$

 $C \rightarrow \epsilon$

Result

$$S = \{z, 1, 2, 3\}$$

$$A=\{1, 2\}$$

$$B = \{3, \mathbf{4}, \boldsymbol{\epsilon}\}$$

$$C = \{\epsilon, 4\}$$

Grammar

$$S \rightarrow Ax \Leftarrow$$

$$S \rightarrow By$$

$$S \rightarrow z$$

$$A \rightarrow 1CB$$

$$A \rightarrow 1CB$$

 $A \rightarrow 2B$

$$B \rightarrow 3B$$

$$B \rightarrow C$$

$$C \rightarrow 4$$

$$C \rightarrow \epsilon$$

Result

$$S = \{z, 1, 2, 3\}$$

First Sets

$$A = \{1, 2\}$$

B =
$$\{3, 4, \epsilon\}$$

$$C = \{\epsilon, 4\}$$

Action

Add First(C) to First(B). At this point we should iterate again to see if anything changes.

Action

Add First(Ax) to First(S) again. Nothing happens...

Another First Set Example

Another First Set Example

Grammar

$$S \rightarrow Ax$$

$$S o B$$
y \Leftarrow

$$S \rightarrow z$$

$$A \rightarrow 1CB$$

$$A
ightarrow$$
 2 B

$$B\to C$$

$$C \rightarrow \epsilon$$

Result

$$S = \{z, 1, 2, 3, 4, y\}$$

$$A = \{1, 2\}$$

B =
$$\{3, 4, \epsilon\}$$

$$C = \{\epsilon, 4\}$$

Grammar

$$S \rightarrow Ax$$

$$S \rightarrow By$$

$$S o \mathsf{z}$$

$$A \rightarrow 1CB$$

$$A o$$
 2 B

$$B o$$
 3 B

$$B \rightarrow C \Leftarrow$$

$$C \rightarrow \epsilon$$

Result

$$S = \{z, 1, 2, 3, 4, y\}$$

$$A = \{1, 2\}$$

B =
$$\{3, 4, \epsilon\}$$

$$C = \{\epsilon, 4\}$$

Action

Add First(By) to First(S) again. The 4 gets propagated. Since B could be ϵ we need to add y.

Action

Add First(C) to First(B) again. We are done.

