Constructing LL(1) Parsing Tables

- Two functions are used in the construction of LL(1) parsing tables:
  - FIRST FOLLOW

- **FIRST(α)** is a set of the terminal symbols which occur as first symbols in strings derived from α where α is any string of grammar symbols.
- if α derives to ε, then ε is also in FIRST(α) .

- **FOLLOW(A)** is the set of the terminals which occur immediately after (follow) the *non-terminal A* in the strings derived from the starting symbol.
  - a terminal a is in FOLLOW(A) if $S \stackrel{*}{\Rightarrow} \alpha A a \beta$
  - \$ is in FOLLOW(A) if $S \stackrel{*}{\Rightarrow} \alpha A$

Compute FIRST for Any String X

- If X is a terminal symbol ➔ FIRST(X)={X}
- If X is a non-terminal symbol and $X \rightarrow \varepsilon$ is a production rule
  ➔ ε is in FIRST(X).
- If X is a non-terminal symbol and $X \rightarrow Y_1 Y_2 .. Y_n$ is a production rule
  ➔ if a terminal **a** in FIRST(Y_i) and ε is in all FIRST(Y_j) for j=1,...,i-1 then **a** is in FIRST(X).
  ➔ if ε is in all FIRST(Y_j) for j=1,...,n then ε is in FIRST(X).
- If X is ε ➔ FIRST(X)={ε}
- If X is $Y_1 Y_2 .. Y_n$
  ➔ if a terminal **a** in FIRST(Y_i) and ε is in all FIRST(Y_j) for j=1,...,i-1 then **a** is in FIRST(X).
  ➔ if ε is in all FIRST(Y_j) for j=1,...,n then ε is in FIRST(X).

FIRST Example

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

$\mathrm{FIRST}(F) = \{(, id\}$
$\mathrm{FIRST}(T') = \{*, \varepsilon\}$
$\mathrm{FIRST}(T) = \{(, id\}$
$\mathrm{FIRST}(E') = \{+, \varepsilon\}$
$\mathrm{FIRST}(E) = \{(, id\}$

$\mathrm{FIRST}(TE') = \{(, id\}$
$\mathrm{FIRST}(+TE') = \{+\}$
$\mathrm{FIRST}(\varepsilon) = \{\varepsilon\}$
$\mathrm{FIRST}(FT') = \{(, id\}$
$\mathrm{FIRST}(*FT') = \{*\}$
$\mathrm{FIRST}(\varepsilon) = \{\varepsilon\}$
$\mathrm{FIRST}((E)) = \{(\}$
$\mathrm{FIRST}(id) = \{id\}$

Compute FOLLOW (for non-terminals)

- If S is the start symbol ➔ \$ is in FOLLOW(S)

- if $A \rightarrow \alpha B \beta$ is a production rule
  ➔ everything in FIRST(β) is FOLLOW(B) except ε

- If ($A \rightarrow \alpha B$ is a production rule) or
  ($A \rightarrow \alpha B \beta$ is a production rule and ε is in FIRST(β))
  ➔ everything in FOLLOW(A) is in FOLLOW(B).

We apply these rules until nothing more can be added to any follow set.

FOLLOW Example

$E \rightarrow TE'$
$E' \rightarrow +TE' \ | \ \varepsilon$
$T \rightarrow FT'$
$T' \rightarrow *FT' \ | \ \varepsilon$
$F \rightarrow (E) \ | \ id$

$FOLLOW(E) = \{ \$,) \}$

$FOLLOW(E') = \{ \$,) \}$

$FOLLOW(T) = \{ +,), \$ \}$

$FOLLOW(T') = \{ +,), \$ \}$

$FOLLOW(F) = \{+, *,), \$ \}$

LL(1) Parser

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

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

Practice Examples

$S \rightarrow ABCDE$

$A \rightarrow a \mid \varepsilon$

$B \rightarrow b \mid \varepsilon$

$C \rightarrow c$

$D \rightarrow d \mid \varepsilon$

$E \rightarrow e \mid \varepsilon$

$S \rightarrow Bb \mid Cd$

$B \rightarrow aB \mid e$

$C \rightarrow cC \mid \varepsilon$