Compiler Design

Today's Class Topics

-Parsing Technique
-Top-down Parsing
-First Function
-Follow Function
-LL(k) Parser and its necessary condition
-How to construct LL(1) Parsing Table
-How to Test LL(1) Grammar etc.

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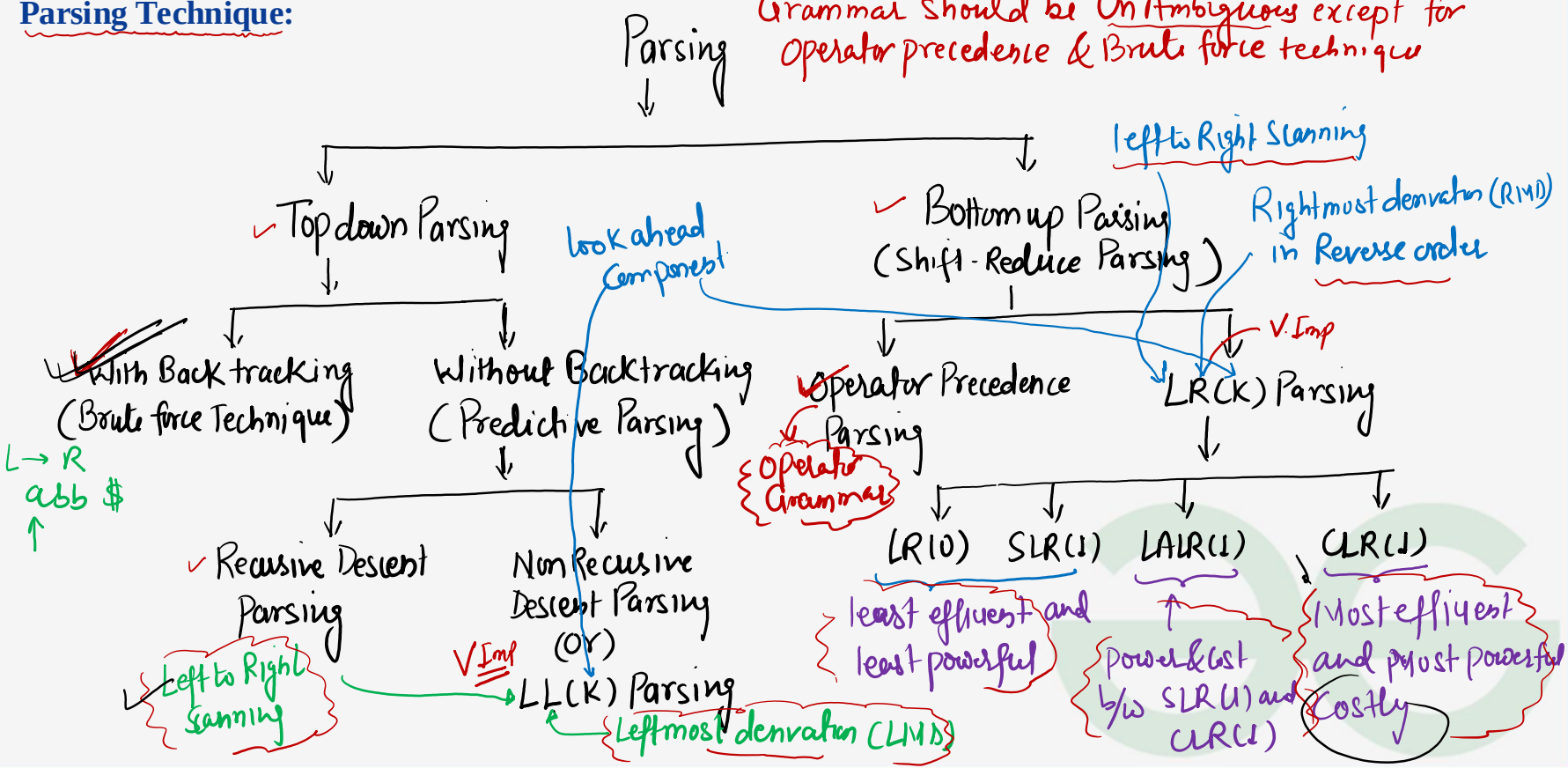
Parsing Technique:



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States: n_1 n_2 n_3 n_4

Note:

1) $n_1 = n_2 = n_3 \leq n_4$

2) No. of Shift entries of in $LR(0) = SLR(1) = LALR(1) \leq CLR(1)$

3) No of Reduce entries $LR(0) \geq SLR(1) \geq LALR(1) \geq CLR(1)$

4) Power of $LR(0) < SLR(1) < LALR(1) < CLR(1)$

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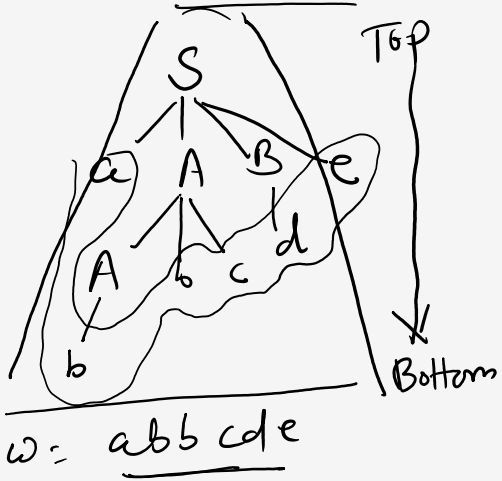
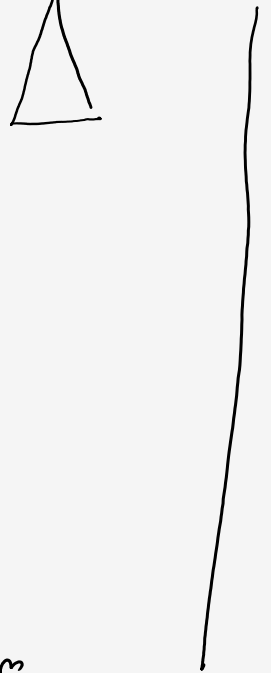
Top down Passing (LMD)

G: S → aABe
A → Abc | b
B → d

w = abbcde

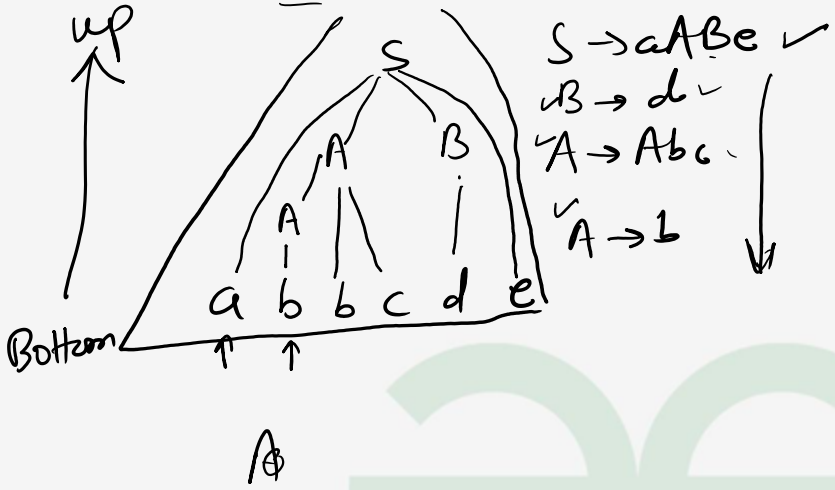


w = abbcde



Bottom up passing (RMD in Reverse order)

G: S → aABe
A → Abc | b
B → d



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Brute Force Technique: ✗

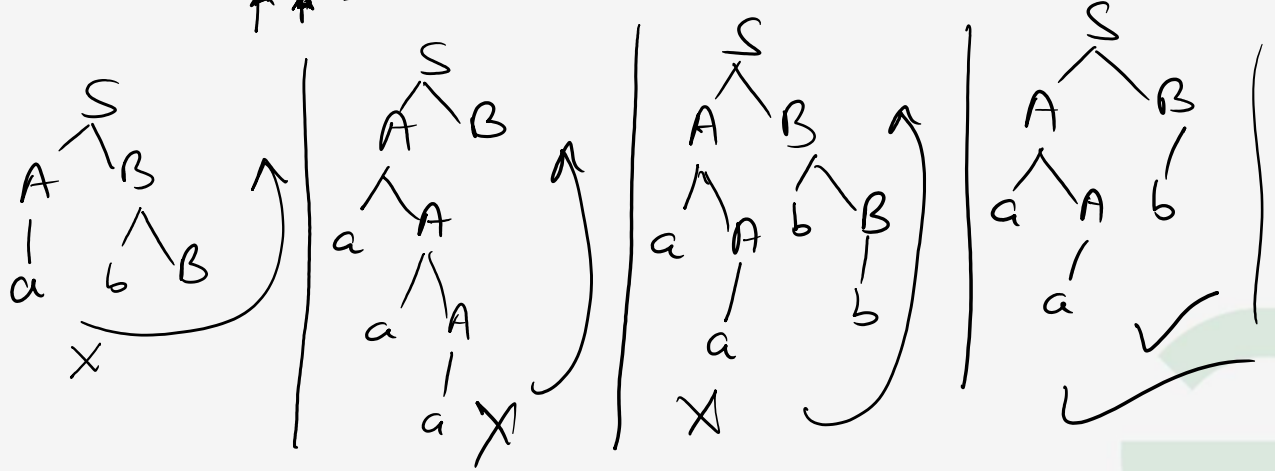
10000

100000

$G = \{S \to AB,\ A \to aA \mid a,\ B \to bB \mid b\}$

$\omega = aaab\$$

aab



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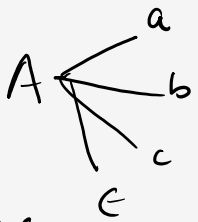
First and Follow Function:

First Function: First(A) is the set of terminals that are the first symbols (Terminal Symbol) on the right side of the arrow in every production of A

$A \rightarrow a\_ \mid b\_\_ \mid c\_\_ \mid \epsilon$



First(A) = {a, b, c, ϵ}

Ex: $A \rightarrow aA \mid bb \mid cB$

First(A) = {a, b, c}

Ex: $A \rightarrow aA \mid \epsilon$

First(A) = {a, ϵ}

$A \rightarrow aA \mid BC$

First(A) = {a, First(BC)}

First(A) = First(B) − ϵ

Ex: $A \rightarrow BCD$

$B \rightarrow bB \mid \epsilon$

$C \rightarrow c \mid \epsilon$

$D \rightarrow d \mid \epsilon$

First(A) = {b, c, d, ϵ}

First(B) = {b, ϵ}

First(C) = {c, ϵ}

First(D) = {d, ϵ}

First(A) : First(BCD) = First(B)

= {b}

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Procedure:

1. First(a) = {a}
2. if $A \to a \Rightarrow First(A) = \{a\}$
3. if $A \to \epsilon \Rightarrow First(A) = \{\epsilon\}$
4. if $A \to BC \Rightarrow First(A) = First(B)$ iff First(B) does not Contain ϵ
5. if $A \to BC \Rightarrow First(A) = (First(B) - \{\epsilon\}) \cup First(C)$

Ex: G: $S \to ABC$, $A \to a$, $B \to bB \mid a$, $C \to \epsilon$

First(S) = First(ABC) = First(A) = {a}
First(A) = {a}
First(B) = {a, b}
First(C) = {ε}

First(S) = First(ABC)
= {a, ✗} ∪ {a, b}
= {a, b}

Ex:
G: $S \to ABC$ First(S) = {a, b}
$A \to aA \mid \epsilon$ First(A) = {a, ε}
$B \to bB \mid a$ First(B) = {b, a}
$C \to cC \mid a$ First(C) = {c, a}

6. $A \to BCD$
First(A) = (First(B) − {ε}) ∪ (First(C) − {ε}) ∪ First(D)

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Ex: $S \to A\,b\,(C)$ — First(S) = {a, b, c, ∈} ✓

$A \to aA \mid B$ — First(A) = {a, b, ∈} ✓

$B \to bB \mid \in$ — First(B) = {b, ∈} ✓

$C \to cC \mid b \mid \in$ — First(C) = {b, c, ∈} ✓

$A \to Ae$

$A \to \in \cdot a$

$A \to c$

$B \to Ca$

$B \to a$

$B \to C$ ✗

$B \to Ca$

Ex: $S \to aA \mid BC$, First(S) = {a, b, c}

$A \to Aa \mid \in$ — First(A) = {∈, a}

$B \to Ca \mid bB$ — First(B) = {b, c, a}

$C \to cA \mid \in$ — First(C) = {c, ∈}

Ans

First(S) = First(aA) ∪ First(BC)

= {a} ∪ {a, b, c}

= {a, b, c}

First(B) = First(Ca) ∪ First(bB)

= First(c, a) ∪ {b}

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Ex:

$S \to ACB \mid CbA \mid Ba$

$A \to da \mid BC$

$B \to g \mid \epsilon$

$C \to h \mid \epsilon$

$first(S) = \{d, g, h, \epsilon, b, a\}$

$first(A) = \{d, g, h, \epsilon\}$

$first(B) = \{g, \epsilon\}$

$first(C) = \{h, \epsilon\}$

Ex:

$S \to AaB \mid bC$

$A \to BC \mid bA$

$B \to aB \mid \epsilon$

$C \to SA \mid a$

$first(S) = \{a, b\}$

$first(A) = \{b, a\}$

$first(B) = \{a, \epsilon\}$

$first(C) = \{a, first(S)\}$

$= \{a, b\}$

$first(S) = first(AaB) \cup first(bC)$

$first(A) = first(BC) \cup first(bA)$

$= \{b, a, first(C)\}$

$first(C) = first(SA) \cup first(a)$

$= \{a, first(S)\}$ — (1)

$first(S) = \{b, first(A)\}$

$= \{b, b, a, first(C)\}$ — (2)

$= \{a, b, first(C)\}$

$first(C) = \{a, b, first(C)\}$

$\{a, b, first(C)\}$'s

$\{a, b\}$ - fin

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G: $E \to E+T \mid T$

$T \to T*F \mid F$

$F \to (E) \mid id$

id

$First(E) = First(T) = First(F) = \{(, id\}$

$First(T) = \{(, id\}$

$First(F) = \{(, id\}$

$E \to TE'$

$E' \to +TE' \mid \in$, $First(E') = \{+, \in\}$

$T \to FT'$

$T' \to *FT' \mid \in$, $First(T') = \{*, \in\}$

$F \to (E) \mid id$

$First(E) = First(T) = First(F) = \{(, id\}$

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Follow Function: Follow(A) is the set of terminals that present immediately to the right side of A wherever A is on the RHS of the arrow → A ( )

$ S $

Procedure:

1- follow(S) = {$} if S is the start symbol

2- if A → αBβ ⇒ follow(B) = first(β) iff First(β) does not contain ∈

3- if A → αBβ ⇒ follow(B) = (first(β) − {∈}) ∪ follow(A) , if β contain ∈

4- if A → αB. ⇒ follow(B) = follow(A)

first(β) = {a ∈}

A $)

αB. $

follow(B) = first(β) =

A → αBa

{c,

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$G = \{ S \to AaAb \mid BbBa,\ A \to cA \mid a,\ B \to bB \mid b \}$

follow(S) = {$}

follow(A) = {a, b}

follow(B) = {a, b}

S →	AaAb | BbBa
A →	cA | a
B →	bB | b

$B \to bB \mid b$

$S \Rightarrow BbBa$

$A \to cA$

$B \to bB$

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Ex: $S \to AaBb \mid AC$

$A \to aB \mid b$

$B \to a$

$C \to c$

$S \to A$

$A \to cA$ follow(A) = follow(A)

follow(S) = {$}

follow(A) = {a, first(C)} = {a, c}

follow(B) = {b, follow(A)} = {a, b, c}

follow(C) = {follow(S)} = {$}

Ex:

$S \to ABC$

$A \to aA \mid \epsilon$

$B \to bB \mid \epsilon$

$C \to cC \mid \epsilon$

follow(S) = {$} = {$}

follow(A) = {b, c, follow(S)} = {b, c, $}

follow(B) = {c, follow(S)} = {c, $}

follow(C) = {follow(S)} = {$}

first(B) = {b, ε}

first(C) = {c, ε}

first(A) = {a, ε}

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$G = \{ S \xrightarrow{S \to S} SAB \mid \epsilon,\ A \to AB \mid \epsilon,\ B \to BC \mid Ca,\ C \to cCb \mid a \}$

$S \to SAB \mid \epsilon$

$A \to AB \mid \epsilon$

$B \to BC \mid Ca$

$C \to cCb \mid a$

$first(S) = \{\epsilon, a, c\}$

$first(A) = \{\epsilon, a, c\}$

$first(B) = \{a, c\}$

$first(C) = \{a, c\}$

$follow(S) = \{\$, first(AB)\} = \{\$, a, c\}$

$follow(A) = \{first(B)\} = \{a, c\}$

$follow(B) = \{first(C), follow(A), follow(S)\}$

$follow(C) = \{b, follow(B), a\}$

$follow(B) = \{a, c, \$\}$

$follow(C) = \{a, b, c, \$\}$

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$E \rightarrow TE'$

$E' \rightarrow +TE' \mid \epsilon$

$T \rightarrow FT'$

$T' \rightarrow *FT' \mid \epsilon$

$F \rightarrow (E) \mid id$

$First(E) = First(T) = First(F) = \{(, id\}$

$First(E') = \{+, \epsilon\}$

$First(T') = \{*, \epsilon\}$

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

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

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

$Follow(T) = \{+, Follow(E)\} = \{+,), \$\}$

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

$Follow(F) = \{*, Follow(T)\} = \{*, +,), \$\}$

Ans

$T \rightarrow FT'$

$T \rightarrow F(*)$

$T \rightarrow F$

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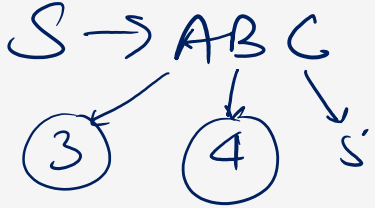
Q.1: Consider the following Production $S \rightarrow ABC$, of the no. of elements in First(A), First(B), and First(C) are 3,4,5 elements respectively and all these First sets contain 'ϵ' and the remaining all symbols are different. Then find no. of elements in First(S)? — ?

Soln:



$First(S) = \{First(A) - \epsilon\} \cup \{First(B) - \epsilon\} \cup \{First(C)\}$

$= 2 + 3 + 5 \Rightarrow 10$

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Question: Consider the following Production $S \rightarrow ABC$, if the no. of elements in First(A), First(B) and First(C) are 3, 4, 5 elements respectively and all these First sets Contains $\{a, \epsilon\}$ and the remaining all symbols are different. Then find no. of elements in First(S)?

Soln:

$S \rightarrow A\ B\ C$

3 4 5

4_{-3}

First(A) = {a, ∈, ---- }

First(B) = {a, ∈, ___ }

First(C) = {a, ∈, ___ }

5 minute Break

$$First(S) = (First(A) - \epsilon) \cup (First(B) - \epsilon) \cup First(C)$$

$$= 2 + 2 + 4 \Rightarrow 8$$

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Top down parser:

LL(1) Parser

- LL(1) Grammar
- LL(1) Table Construction
- LL(1) Parsing
- LL(1) Grammar Testing

Left to Right Scanning → LL(K) ← Leftmost derivation

LookAhead Component

$x \to y$

if x Then y

LL(0) LL(1) LL(2) ... LL(K)

Predictive Parsing

LL(1): It is a CFG ✓

1. It is UnAmbiguous ✓
2. It is non left recursive ✓
3. It is Left factored (Deterministic CFG) ✓

a a s

$A \to A\alpha \mid \beta$

$A \to \beta A'$

$A' \to \alpha A' \mid \epsilon$

$x \to y \;\&\; vy \to vx$

$x \to y \neq y \to x$

(Left Recursive ∨ left factor ∨ Ambiguous) → LL(1)

LL(1) → (Left Recursive ∨ Left factor ∨ Ambiguous)'

LL(1) → (Non left Recursive ∧ Left factored ∧ UnAmbiguous)

(Non left Recursive ∧ Left factored ∧ UnAmbiguous) → LL(1)

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CFG

CFG to LL(1) Grammar:

Step1: Take any CFG

↓ Remove Ambiguity → No Algo. Exist (Undecidable)

Step2: Convert to UnAmbiguous CFG

↓ Elimination of Left Recursion (Algo. Exist)

Step3: Non Left Recursive CFG

↓ Left factoring Algo

Step4: Left factored CFG

↓

Step5: LL(1) Grammar

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$B \to bB \mid \epsilon$, $First(B) = \{b, \epsilon\}$

Construction of LL(1) Parsing Table:

We consider every Production of the form $A \to \alpha$ and Proceed as follows

i) We write $A \to \alpha$ in $M[A, x]$ where $x \in First(\alpha)$

ii) if $First(\alpha) = \{\epsilon\}$ then Add $A \to \alpha$ in $M[A, y]$ where $y \in follow(A)$

iii) The Unfilled entries will be Considered as Syntax error

iv) if all the entries in the table are single then the Grammar is LL(1). Otherwise not LL(1)

$B \to \epsilon$

$M[B, follow(B)]$

$B \to \epsilon$

Size of Table $= |V| * (|T| + 1)$

Ex: Construct LL(1) Parsing Table.

$G = \{ S \to AB,\ A \to aA \mid b,\ B \to bB \mid \epsilon \}$

$first(S) = \{a, b\}$

$first(A) = \{a, b\}$

$First(B) = \{b, \epsilon\}$

$follow(S) = \{\$\}$

$follow(A) = \{b, \$\}$

$follow(B) = \{\$\}$

$M[S, x]$ $x \in first(AB)$

$S \to AB$

$V = 3$

$T = 2$

$|V| * (|T| + 1)$

$3 * 2 \to 9$

M

	a	b	$
S	S→AB	S→AB	error
A	A→aA	A→b	error
B	error	B→bB	B→ε

G:

$E \to TE'$

$E' \to +TE' \mid \epsilon$

$T \to FT'$

$T' \to *FT' \mid \epsilon$

$F \to (E) \mid id$

First(E) = {(, id}

First(E') = {+, ε}

First(T) = {(, id}

First(T') = {*, ε}

First(F) = {(, id}

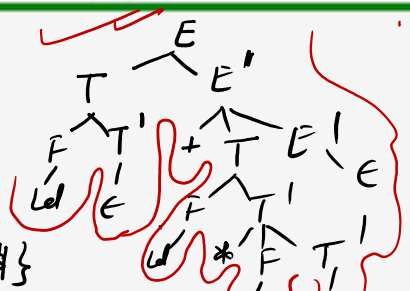
Follow(E) = {), $}

Follow(E') = {), $}

Follow(T) = {+,), $}

Follow(T') = {+,), $}

Follow(F) = {+, *,), $}



int a, b, c;

int a, b, c

id + id * id

LL(1) Parsing Table (M)

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

id + * id

ω = id + id * id

STACK	Input	output
$E	id + id * id $	$E \to TE'$
$E'T	id + id * id $	$T \to FT'$
$E'T'F	id + id * id $	$F \to id$
$E'T' id	id + id * id $	$T' \to \epsilon$
$E'	+ id * id $	$E' \to +TE'$
$E'T+	+ id * id $	$T \to FT'$
$E'T	id * id $	$F \to id$
$E'T'F	id * id $	$T' \to *FT'$
$E'T' id	id * id $	$F \to id$
$E'T'	* id $	$T' \to \epsilon$
$E'T'F*	* id $	$E' \to \epsilon$
$E'T'F	id $	
$E'T' id	id $	
$E'	$	
$	$	