Seminar 2 - LL(1)

LL(K)
- L (first): sequence read from left to right
- L (second): uses leftmost derivations
- K: predictions of length K

LL(K) parser: at each moment of parsing an action is uniquely determined

LL(1) Parser

→ uses predictions of length 1

Steps
1) build FIRST & FOLLOW
2) build LL(1) parse table
3) analyse sequence based on moves and table

$\boxed{\text{FIRST}}$

Let $\alpha \in (N \cup \Sigma)^*$, then $FIRST_K$ means first K terminal symbols that can be generated by α

Notation $FIRST_1 = FIRST$

Example:

$S \to Bb \mid Cd$
$B \to aB \mid \varepsilon$
$C \to cC \mid \varepsilon$

	F_0	F_1	F_2
S	$\emptyset$	a, ε, c, d	a, ε, c, d
B	a, ε	a, ε	a, ε
C	c, ε	c, ε	c, ε

REBEL DOT LEADING THE LINE

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Ex1 Compute FIRST for:

$S \to BA$ 1
$A \to +BA$ 2
$A \to \varepsilon$ 3
$B \to DC$ 4
$C \to *DC$ 5
$C \to \varepsilon$ 6
$D \to (S)$ 7
$D \to a$ 8

	F_0	F_1	F_2	F_3
S	$\emptyset$	$\emptyset$	(, a	(, a
A	+, ε	+, ε	+, ε	+, ε
B	$\emptyset$	(, a	(, a	(, a
C	*, ε	*, ε	*, ε	*, ε
D	(, a	(, a	(, a	(, a

FIRST(S) = { (, a }
FIRST(A) = { +, ε }
FIRST(B) = { (, a }
FIRST(C) = { *, ε }
FIRST(D) = { (, a }

FOLLOW

→ the next symbol generated after/following A

Rules: (FOLLOW(A) for example)
we look for A in the right side of all productions

- if A is at the end of production we add (union) FOLLOW (left side of prod.)
- if after A is a terminal, that terminal is the FOLLOW
- ! if after A is another non-terminal, let's say B, then FOLLOW(A) = FIRST(B) and if FIRST(B) contains ε then we also add FOLLOW(left-side) !

example

$S \to Bb \mid Cd$
$B \to aB \mid \varepsilon$
$C \to cC \mid \varepsilon$

	L_0	L_1	L_2
S	ε	ε	ε
B	$\emptyset$	b	b
C	$\emptyset$	d	d

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Algorithm FOLLOW

INPUT: G, FIRST(X), $\forall X \in N \cup \Sigma$

OUTPUT: FOLLOW(A), $\forall A \in N$

for $A \in N - \{S\}$ **do** {init}

  $L_0(A) = \Phi$;

endFor;

$L_0(S) = \{\varepsilon\}$; {init}

$i = 0$;

repeat

 $i = i+1$;

 for $B \in N$ **do**

  for $A \to \alpha B y \in P$ **do**

   for $\forall a \in FIRST(y)$ **do**

    if $a = \varepsilon$ **then** $F_i(B) = F_i(B) \cup F_{i-1}(A)$

     else $F_i(B) = F_{i-1}(B) \cup First(y)$

    endif

   endFor

  endFor

 endfor

until $Fi(X) = Fi\text{-}1(X)$, $\forall X \in N$

$FOLLOW(X) = Fi(X)$, $\forall X \in N$

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7. Rule for L_0

$L_0(S) = \{\varepsilon\}$

$L_0(X) = \emptyset \ \forall \ X \in N - \{S\}$

Ex 2

Compute FOLLOW for the grammar from EX1

	L_0	L_1	L_2	L_3	L_4
S	ε	ε,)	ε,)	ε,)	ε,)
A	∅	ε	ε,)	ε,)	ε,)
B	∅	+, ε	+, ε,)	+, ε,)	+, ε,)
C	∅	∅	+, ε	+, ε,)	+, ε,)
D	∅	*, ε	*, ε, +	*, ε, +,)	*, ε, +,)

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

$FOLL(A) = FOLL(S) \cup FOLL(A)$

$FOLL(B) = FIRST(A) \underbrace{\cup FOLL(S) \cup FOLL(B)}_{\text{because } FIRST(A) \text{ contains } \varepsilon}$

$FOLL(C) = FOLL(B) \cup FOLL(C)$

$FOLL(D) = FIRST(C) \underbrace{\cup FOLL(B) \cup FOLL(C)}_{\text{because } FIRST(C) \text{ contains } \varepsilon}$

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LL(1) TABLE

$M(A, a) = (\alpha, i) \ \forall \ a \in FIRST(\alpha), a \neq \varepsilon, A \to \alpha$

production with number i

$M(A, b) = (\alpha, i)$ if $\varepsilon \in FIRST(\alpha), \forall b \in FOLLOW(A)$,

$A \to \alpha$ production with number i

$M(a, a) = pop, \forall a \in \Sigma$ ($\Leftarrow$ terminal + terminal = pop)

$M(\$, \$) = acc$

$M(x, a) = err$

example: for example FIRST & example FOLLOW

	a	b	c	d	\$
S	Bb, 1	Bb, 1	Cd, 2	Cd, 2	
B	aB, 3	ε, 4			
C			cC, 5	ε, 6	
a	pop				
b		pop			
c			pop		
d				pop	
\$					acc

$conf(\alpha, \beta, \pi)$

input stack, workin stack, output

init: $(w\$, S\$, \varepsilon)$

end: $(\$, \$, \pi)$

$w = aab \in L(G)$?

$(aab\$, S\$, \varepsilon) \xrightarrow{push} (aab\$, Bb\$, 1) \xrightarrow{push} (aab\$, aBb\$, 13)$
$\xrightarrow{pop} (ab\$, Bb\$, 13) \xrightarrow{push} (ab\$, aBb\$, 133) \xrightarrow{pop} (b\$, Bb\$, 133)$
$\vdash (b\$, \varepsilon b\$, 1334) \xrightarrow{pop} (\$, \$, 1334)$ ✓

Ex 3

Build the LL(1) table for ex 1 & 2

	+	*	(	)	a	$
S			BA,1		BA,1	
A	+BA,2			ε,3		
B			DC,4		DC,4	
C	ε,6	*DC,5		ε,6		
D			(S),7		a,8	
+	pop					
*		pop				
(			pop			
)				pop		
a					pop	
$						acc

$w = a * (a + a) \ ? \ L(G)$

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$D \rightarrow a^8$

› (a*(a+a)$,S$, ε)⊢ (a∗(a+a)$, BA$, 1) ⊢(a*(a+a)$, DCA$, 14)
⊢(a*(a+a)$, aCA$,148) ⊢(*(a+a)$, CA$,148) ⊢((*(a+a)$,*DCA$,1485)
⊢ ((a + a)$, DCA$, 1485) ⊢((a+a)$, (S)CA$,14857)
⊢(a+a)$,S)CA$,14857) ⊢(a+a)$, BA)CA$, 148571) ⊢(a+a)$, DCA)CA$,
1485714) ⊢(a+a)$, aCA)CA$, 14857148) ⊢(+a)$, CA)CA$, 14857148)
⊢(+a)$,εA)CA$, 148571486) ⊢(+a)$, +BA)CA$, 1485714862) ⊢(a)$,
BA)CA$, 1485714862) ⊢(a)$, DCA)CA$,14857148624) ⊢ (a)$,
aCA)CA$,148571486248) ⊢()$, CA)CA$, 148571486248) ⊢ ()$,
εA)CA$, 1485714862486) ⊢ ()$, ε)CA$, 14857148624863) ⊢($, CA$,
14857148624863) ⊢($,εA$, 148571486248636) ⊢ ($,ε$,
1485714862486363) ⊢ ($,$, 1485714862486363) ⊢acc

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