SEM. 7

3.b)

$E \to E + T$

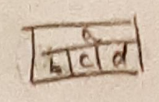
$E \to T$

$T \to T * F$

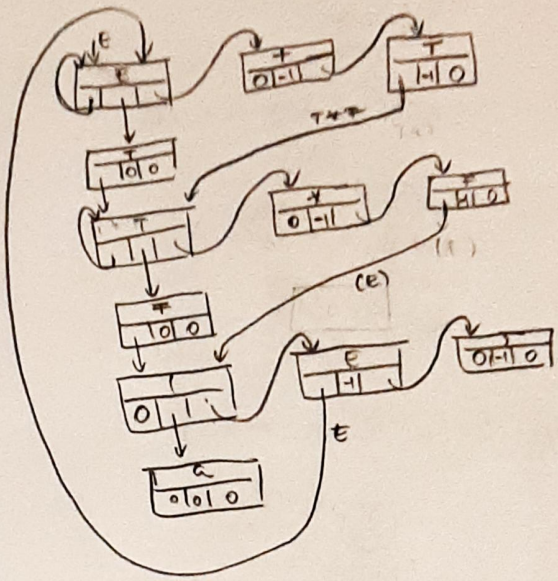
$T \to F$

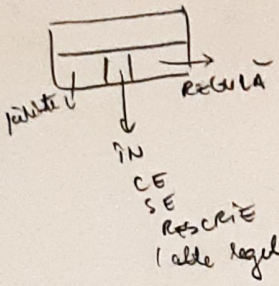
$F \to (E)$

$F \to a$



TRIPLE | LINIEA LIST





SEM. 8

$M_F = (Q, \Sigma, \delta, q_0, F)$

$M_{PD} = (Q, \Sigma, \Gamma, \delta, q_0, Z_0, F)$

$\delta(q_0, w, Z_0) \vdash (q_1, \underbrace{A}_{\Gamma^*})$

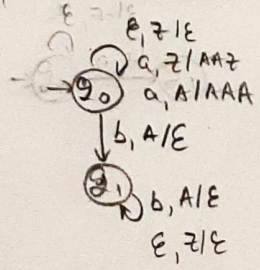
$q_0 \xrightarrow{w, Z_0 / A} q_1$

$L_\varepsilon = (s, \varepsilon, \varepsilon)$ CRITERIUL STIVEI VIDE

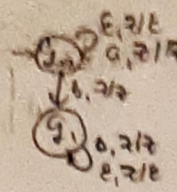
$L_f = (q_f, \varepsilon, Z)$

$q_f \in F$

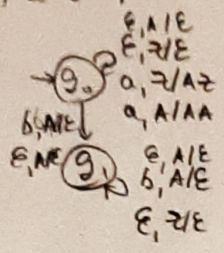
① a) $L = \{a^m b^{2m} \mid m \geq 0\}$



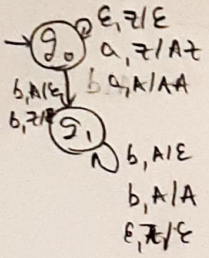
b) $L = \{a^n b^m \mid n, m \geq 0\}$



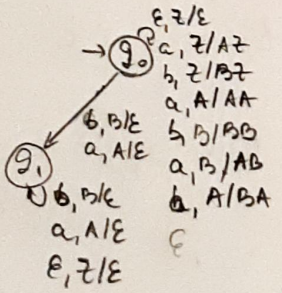
c) $L = \{a^n b^m \mid n \geq m \geq 0\}$



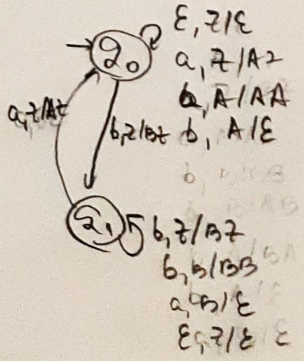
d) $L = \{a^m b^n \mid m \geq n \geq 0\}$



e) $L = \{w w^r \mid w^r$ inv. lui $w\}$

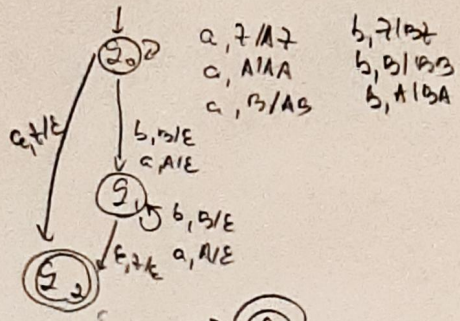


f) $L = \{w \mid w \in \{a,b\}^*, nr_a(w) = nr_b(w)\}$

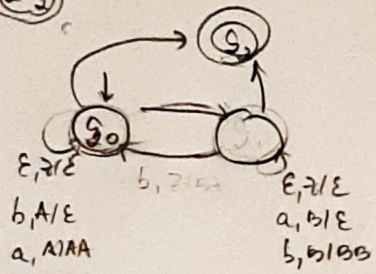


③

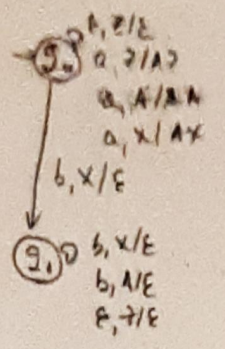
e)


a, Z/AZ
a, A/AA
a, B/AB
b, Z/BZ
b, B/BB
b, A/BA
a, Z/ε
b, B/ε
a, A/ε
b, B/ε
a, A/ε
ε, Z/ε

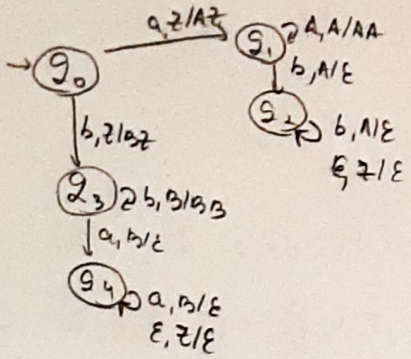
f)


ε, Z/ε
b, A/ε
a, A/AA
ε, Z/ε
a, B/ε
b, B/BB

g) $L = \{a^{2n} b^{n} \mid n \geq 0\}$



h) $L = \{a^{m} b^{n} \mid m \geq 0\} \cup \{b^{n} a^{m} \mid m \geq 0\}$



2)

$S \to \varepsilon$

$S \to aSb$

$S \to bSa$

$S \to SS$

$G = (N, \Sigma, P, S)$

$M = (Q, \Sigma, \Gamma, \delta, q_0, Z_0, F)$

$Q = \{q\}$

$\Sigma = \Sigma$

$\Gamma = N \cup \Sigma$

$q_0 = q$

$Z_0 = S$

$F = \emptyset$

L_ε

$A \to \alpha$

$\delta(q, \varepsilon, A) = \{(q, \alpha)\}$

$\delta(q, a, a) = \{(q, \varepsilon)\}$

		a	b	ε
q	S			(q, aSb) (q, bSa) (q, ε) (q, SS)
	a	(q, ε)		
	b		(q, ε)	

Varsayılan Alfabetik Sırası

$(q, baab, S) \vdash (q, \underline{b}aab, \underline{b}Sa) \vdash$

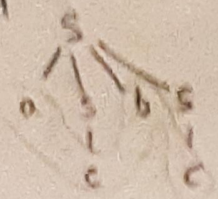
$\vdash (q, \underline{a}ab, Sa) \vdash (q, aab, \underline{a}Sba) \vdash (q, ab, Sba)$

1)

1) $(q,1,\varepsilon,S) \vdash (q,1,S_1,aSbS) \vdash (q,1,S_1a,SbS) \vdash (q,1,S_1aS_1,aSbSbS)$

$\vdash (r,1,S_1aS_1,aSbSbS) \vdash (q,1,S_1aS_1,SbS) \vdash (q,1,S_1aS_1,aSbS)$

$|acbc| = 4$



$\vdash (r,1,S_1aS_1,aSbS) \vdash (q,1,S_1a,SbS) \vdash (q,1,S_1aS_3,cbS)$

$\vdash (q,1,S_1aS_3c,bS) \vdash (q,1,S_1aS_3cb,S) \vdash$

$\vdash (q,1,S_1aS_3cbS_1,aSbS) \vdash (r,1,S_1aS_3cbS_1,aSbS) \vdash$

$S \to aSbS$ (1) $\vdash (q,1,S_1aS_3cb,S) \vdash (q,1,S_1aS_3cbS_3,aS) \vdash$

$S \to aS$ (2) $\vdash (r,1,S_1aS_3cbS_3,aS) \vdash (q,1,S_1aS_3cb,S) \vdash$

$S \to c$ (3) $\vdash (q,1,S_1aS_3cbS_3,c) \vdash (q,1,S_1aS_3cbS_3c,\varepsilon) \vdash$

$\vdash (f,1,S_1aS_3cbS_3c,\varepsilon)$

$\boxed{acbc \in L(G)}$

$|cb| = 2$

$(q,1,\varepsilon,S) \vdash (q,1,S_1,aSbS) \vdash (r,1,S_1,aSbS) \vdash (q,1,\varepsilon,S) \vdash (q,1,S_2,cS) \vdash$

$\vdash (r,1,S_2,cS) \vdash (q,1,\varepsilon,S) \vdash (q,1,S_3,c) \vdash (q,2,S_3c,\varepsilon) \vdash (r,2,S_3c,\varepsilon) \vdash$

$\vdash (r,1,S_3,c) \vdash (r,1,\varepsilon,S) \vdash (e,1,\varepsilon,S)$

$cb \notin L(G)$

---

2)

$S \to +SS$ (S_1)

$S \to -SS$ (S_2)

$S \to a$ (S_3)

$|+a-aa| = 5$

$(q,1,\varepsilon,S) \vdash (q,1,S_1,+SS) \vdash (q,2,S_1+,SS) \vdash$

$\vdash (q,2,S_1+S_1,+SSS) \vdash (r,2,S_1+S_1,+SSS) \vdash$

$\vdash (q,2,S_1+,SS) \vdash (q,2,S_1+S_2,-SSS) \vdash (r,2,S_1+S_2,-SSS)$

$\vdash (q,2,S_1+,SS) \vdash (q,2,S_1+S_3,aS) \vdash (q,3,S_1+S_3a,S) \vdash$

$\vdash (q,3,S_1+S_3aS_1,+SS) \vdash (r,3,S_1+S_3aS_1,+SS) \vdash (q,3,S_1+S_3a,S) \vdash$

$\vdash (q,3,S_1+S_3aS_2,-SS) \vdash (q,4,S_1+S_3aS_2-,SS) \vdash (q,4,S_1+S_3aS_2-S_1,+SS)$

$\vdash (r,4,S_1+S_3aS_2-S_1,+SSS) \vdash (q,4,S_1+S_3aS_2-,SS) \vdash (q,4,S_1+S_3aS_2-S_2,-S$

$\vdash (r,4,S_1+S_3aS_2-S_2,-SSS) \vdash (q,4,S_1+S_3aS_2-,SS) \vdash (q,4,S_1+S_3aS_2-S_3,aS$

$\vdash (q,5,S_1+S_3aS_2-S_3a,S) \vdash (q,5,S_1+S_3aS_2-S_3aS_1,+SS) \vdash (r,5,S_1+S_3aS_2-S_3aS_1,+$

$\vdash (q,5,S_1+S_3aS_2-S_3a,S) \vdash^* (f,6,S_1+S_3aS_2-S_3aS_3a,\varepsilon)$ $+a-aa \in L(G)$

②

1) $S \to abA$

$S \to \varepsilon$

$A \to Saa$

$A \to b$

$FIRST_1(S) = \{a, \varepsilon\}$

$FIRST_1(A) = \{a, b\}$

$FOLLOW_1(S) = \{\$, a\}$

$FOLLOW_1(A) = \{\$, a\}$

	F_0	F_1	F_2
S	a, ε	a, ε	a, ε
A	b	b, a	b, a

$F_1 = F_2 = FIRST_1$

	$First_1$	$Follow_1$
S	a, ε	$\$, a$
A	b, a	$\$, a$

③

1) $S \to aSc$

$S \to aSbSc$

$S \to i$

$LL(1) \to FIRST_1(\alpha_i) \cap FIRST_1(\alpha_j) = \emptyset$

$i \neq j$

$S \to cA$
$S \to cB$ $\Big\} \not\to LL(1)$

$\varepsilon \in First(\alpha_i)$

$\downarrow$

$FOLLOW(A) \cap FIRST(\alpha_j) = \emptyset$

a) $FIRST_1(aSc) = \{a\}$
$FIRST_1(aSbSc) = \{a\}$ $\Big\} \to FIRST_1(aSc) \cap FIRST_1(aSbSc) = \{a\} \neq \emptyset$

$\Rightarrow$ nu e $LL(1)$

$S \to aSS_1$

$S \to i$

$S_1 \to c$

$S_1 \to bSc$

	$FIRST_1$	$FOLLOW_1$
S	a, i	$\$, c, b$
S_1	c, b	$\$, c, b$

$FIRST_1(aSS_1) = \{a\}$

$FIRST_1(i) = \{i\}$

$FIRST_1(c) = \{c\}$

$FIRST_1(bSc) = \{b\}$

$\cap = \emptyset \to$ e $LL(1)$

ADR - analizator descendent cu retroacere

(s, i, α, β)

s → q → regulat
r/b → retrocedare/back
e → eroare
t → terminat

s = stare

$1 \le i \le n+1$

β = stiva de intrare (neprelucrate)

α = stiva ieșire

$(q, i, \ldots, A\beta) \vdash (q, i, \ldots A_i, \alpha; \beta)$ EXPANDARE

A_i = regula de producție

$(q, i, \ldots, a\beta) \vdash (q, i+1, \ldots a, \beta)$

$\vdash (r, i, \ldots, a\beta)$

$(r, i, \ldots, a\beta) \vdash (r, i-1, \ldots \ldots)$

$(q, n+1, t, \varepsilon) \vdash (t, i+1, \ldots, \varepsilon)$
accept

$r \vdash r, i-1, \ldots c, \ldots$

$q, i, \ldots \alpha_{i+1}$

$e, i=1, \beta = s$ (eroare)

$r, i, \ldots, A\beta)$

$\left.\begin{array}{l} \text{FIRST}_k \\ \text{FOLLOW}_k \end{array}\right\} \Rightarrow$

	a	b	c	i	$
S	aSS_1			i, 2	
S_1		bSS_1	c, 3		
a	pop				
b		pop			
c			pop		
i				pop	
$					acc

$S \to aSS_1$ (1)
$S \to i$ (2)
$S_1 \to c$ (3)
$S_1 \to bSc$ (4)

(β, π, τ) acceptare

aaibicc

(α, β, τ)

banda de intrare $w\$$

stiva de lucru

șirul regulilor aplicate

$(a\$, S\$, \varepsilon) \vdash$

$(aaibicc\$, S\$, \varepsilon) \vdash (aaibicc\$, aSS_1\$, 1) \vdash (aibicc\$, SS_1\$, 1) \vdash$
$\vdash (aibicc\$, aSS_1S_1\$, 11) \vdash (ibicc\$, SS_1S_1\$, 11) \vdash (ibicc\$, iS_1S_1\$, 112) \vdash$
$\vdash (bicc\$, S_1S_1\$, 112) \vdash (bicc\$, bScS_1\$, 1123) \vdash (icc\$, ScS_1\$, 1123) \vdash$
$\vdash (icc\$, icS_1\$, 11232) \vdash (cc\$, cS_1\$, 11232) \vdash (c\$, S_1\$, 11232) \vdash (c\$, c\$, 112323)$
$\vdash (\$, \$, 112323) \Rightarrow aaibicc \in L(G)$

2)

$S \to aS$
$S \to aSbS$
$S \to i$

$FIRST_1(aS) = \{a\}$
$FIRST_1(aS) = \{a\}$

$FOLLOW_1(S_1) = \{\$, b\}$
$FIRST_1(bS) = \{b\}$

$S \to aSS_1$ (1)
$S \to i$ (2)
$S_1 \to \varepsilon$ (3)
$S_1 \to bS$ (4)

	$FIRST_1$	$FOLLOW_1$
S	a, i	$, b
S_1	ε, b	$, b

	a	b		i	$
S	aSS_1			$i,2$	
S_1			$bS,4$ / $\varepsilon,3$		$\varepsilon,3$
a	pop				
b		pop			
i				pop	
$					acc

CONFLICT, NU E LL(1)

$$(aaibi\$,\ S\$,\ \varepsilon) \vdash (aaibi\$,\ aSS_1\$,\ 1) \vdash$$

$$\vdash (aibi\$,\ SS_1\$,\ 1) \vdash (aibi\$,\ aSS_1S_1\$,\ 11) \vdash (ibi\$,\ SS_1S_1\$,\ 11) \vdash$$

$$\vdash (ibi\$,\ iS_1S_1\$,\ 112) \vdash (bi\$,\ S_1S_1\$,\ 112) \vdash (bi\$,\ bSS_1\$,\ 1124) \vdash$$

$$\vdash (i\$,\ SS_1\$,\ 1124) \vdash (i\$,\ iS_1\$,\ 11242) \vdash (\$,\ S_1\$,\ 11242) \vdash$$

$$\vdash (\$,\ \$,\ 112423) \Rightarrow aaibi \in L(G)$$

Seria 10

② LL(1)

3.

a) $E \to T+E$
$E \to T$
$T \to T*F$
$T \to F$
$F \to (E)$
$F \to a$

	FIRST	FOLLOW
E	(, a	$,)
T	(, a	+, $, *,)
F	(, a	+, $, *,)

b) $E \to TE'$ (1)
$E' \to +E$ (2)
$E' \to \varepsilon$ (3)
$T \to FT'$ (4)
$T' \to *T$ (5)
$T' \to \varepsilon$ (6)
$F \to (E)$ (7)
$F \to a$ (8)

OBS $T*T = T*F$

	FIRST	FOLLOW
E	(, a	$,)
E'	+, ε	$,)
T	(, a	+, $,)
T'	*, ε	+, $,)
F	(, a	*, +, $,)

$FIRST_1(+E) \cap FIRST_1(\varepsilon) = \emptyset$
$FIRST_1(+E) \cap FOLLOW_1(E') = \emptyset$ | → este LL(1)

	+	*	a	(	)	$
E			TE', 1	TE', 1		
E'	+E', 2				ε, 3	ε, 3
T			FT', 4	FT', 4		
T'	ε, 6	*T, 5			ε, 6	ε, 6
F			a, 8	(E), 7		
+	pop					
*		pop				
a			pop			
(				pop		
)					pop	
$						acc

← OBS ⇒ ε in FIRST

e) $(a+a\$, E\$, \varepsilon) \vdash (a+a\$, TE'\$, 1) \vdash (a+a\$, FT'E'\$, 14) \vdash$
$\vdash (a+a\$, aT'E'\$, 148) \vdash (+a\$, T'E'\$, 148) \vdash (+a\$, E'\$, 1486) \vdash$
$\vdash (+a\$, +E'\$, 14862) \vdash (a\$, E'\$, 14862) \vdash (a\$, TE'\$, 148621) \vdash$
$\vdash (a\$, FT'E'\$, 1486214) \vdash (a\$,$

$\Rightarrow$ acc

1) List $\to$ id
List $\to$ id sep List

	FIRST	FOLLOW
List	id	\$

$FIRST(id) \cap FIRST(id\ sep\ List) = \{id\} \neq \emptyset$
$\Rightarrow$ nu este LL(1)

List $\to$ id List' (1)
List' $\to$ sep List (2)
List' $\to \varepsilon$ (3)

	FIRST	FOLLOW
List	id	\$
List'	sep, ε	\$

	id	sep	\$
List	id List'		
List'		sep List	ε, 3
id	pop		
sep		pop	
\$			acc

$\Rightarrow$ nu sunt conflicte $\Rightarrow$ este LL(1)

③

S → begin Slist end
S → stmt
Slist → S
Slist → S; Slist

S → b SLe
S → s
SL → S
SL → S; SL

	FIRST₁	FOLLOW₁
S	b, s	$, e, ;
SL	b, s	e

FIRST₁(S) ∩ FIRST₁(S; SL) = {b, s} ≠ ∅

⇒ nu e LL(1)

S → b SLe (1)
S → s (2)
SL → SS' (3)
S' → ; SL (4)
S' → ε (5)

	FIRST₁	FOLLOW₁
S	b, s	$, ;, e
S'	ε, ;	e
SL	b, s	e

	b	e	s	;	$
S	bSLe, 1		s, 2		
SL	SS', 3		SS', 3		
S'		ε, 5		;SL, 4	
b	pop				
e		pop			
s			pop		
;				pop	
$					acc

OBS: lăsăt ε

6)

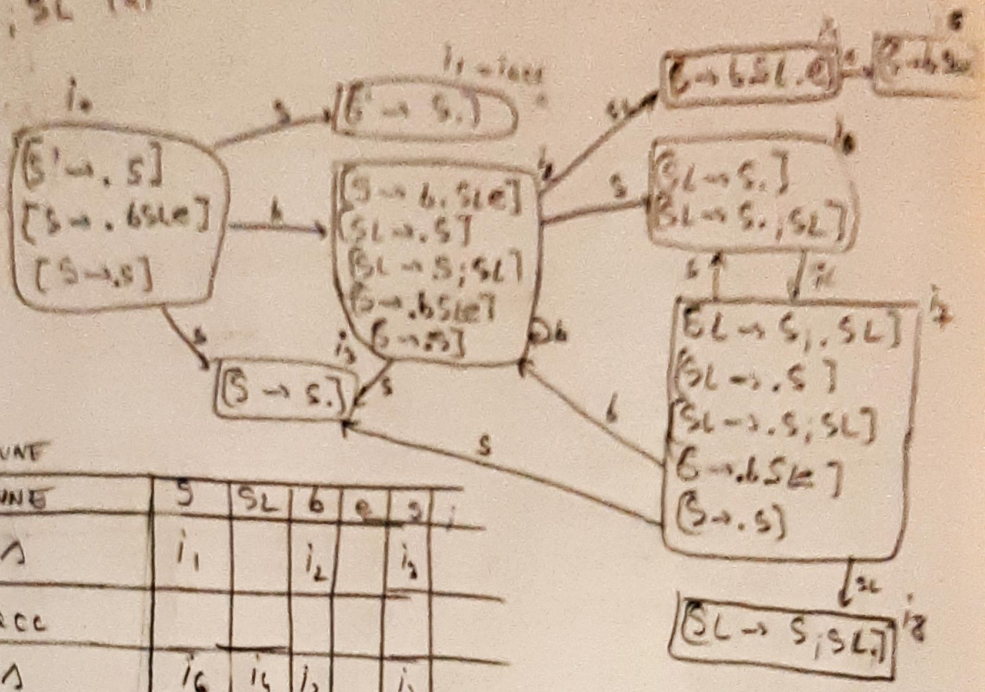
a) $S' \to S$ (0)

$S \to b\,SL\,e$ (1)

$S \to s$ (2)

$SL \to S$ (3)

$SL \to S\,;\,SL$ (4)



ACȚIUNE

	ACȚIUNE	S	SL	b	e	s	
i_0	s	i_1		i_2		i_3	
i_1	acc						
i_2	s	i_6	i_4	i_2		i_3	
i_3	r - regula 2						
i_4	s				i_5		
i_5	r - regula 1						
i_6	r - regula 3 / s						i_7
i_7	s	i_6	i_8	i_2		i_3	
i_8	r - regula 4						

nu e LR(0)

SLR [nucleu, predicție]

	FIRST	FOLLOW
S	b, s	$, i, e
SL	b, s	e

1)

a) $S' \to S$ (0)

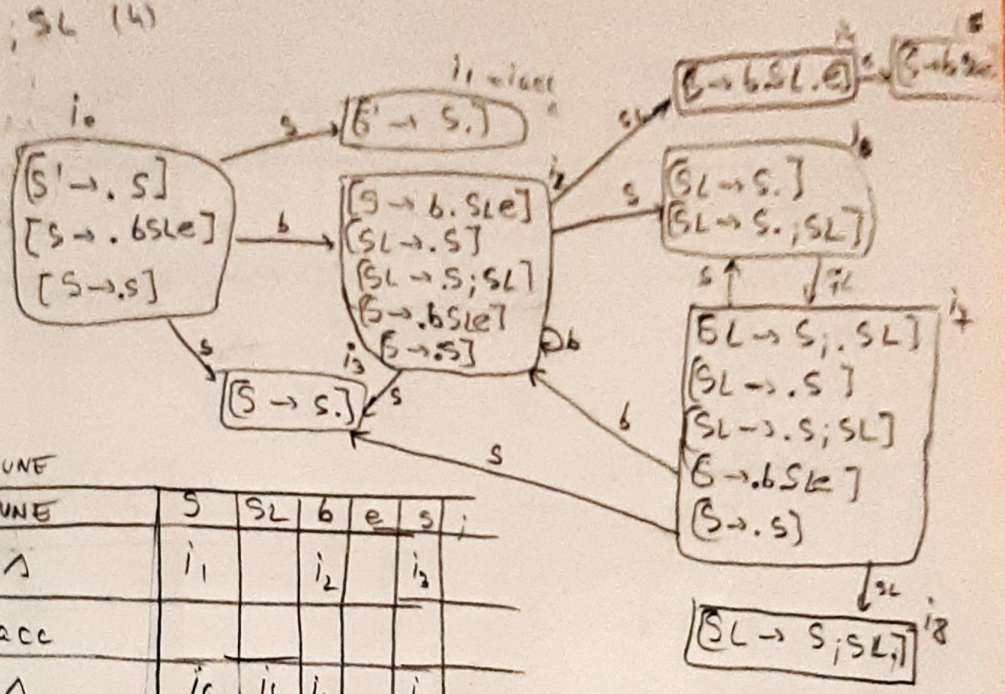
$S \to b\,SL\,e$ (1)

$S \to s$ (2)

$SL \to S$ (3)

$SL \to S\,;\,SL$ (4)

(LR(0))



ACTIUNE

	ACTIUNE	S	SL	b	e	s	;
i_0	s	i_1		i_2		i_3	
i_1	acc						
i_2	s	i_6	i_4	i_2		i_3	
i_3	r - regula 2						
i_4	s				i_5		
i_5	r - regula 1						
i_6	r - regula 3 / s						i_7
i_7	s	i_6	i_8	i_2		i_3	
i_8	r - regula 4						

nu e LR(0) ⇐ i_6

SLR [muchie, predicție]

	FIRST	FOLLOW
S	b, s	$, ;, e
SL	b, s	e

SEM 11

① LR(k)

6. (0) S' → S
(1) S → b SL e
(2) S → λ
(3) SL → S
(4) SL → S ; SL

a) shift conflicts in table
b) SLR

	FIRST	FOLLOW
S'	b, λ	$
S	b, λ	$, ;, e
SL	b, λ	e

i_0: [S' → .S, $]
[S → .bSLe, $/;/e]
[S → .λ, $/;/e]

$\xrightarrow{S}$ [S' → S., $] $i_1 = i_{acc}$

$\xrightarrow{b}$ i_2: [S → b.SLe, $/;/e]
[SL → .S, e]
[SL → .S ; SL, e]
[S → .bSLe, $/;/e]
[S → .λ, $/;/e]

$\xrightarrow{\lambda}$ i_3: [S → λ., $/;/e]

$\xrightarrow{SL}$ i_4: [S → bSL.e, $/;/e]

$\xrightarrow{e}$ i_6: [S → bSLe., $/;/e]

$\xrightarrow{S}$ i_5: [SL → S., e]
[SL → S.; SL, e]

$\xrightarrow{;}$ i_7: [SL → S; .SL, e]
[SL → .S, e]
[SL → .S ; SL, e]
[S → .bSLe, $/;/e]
[S → .λ, $/;/e]

$\xrightarrow{SL}$ i_8: [SL → S; SL., e]

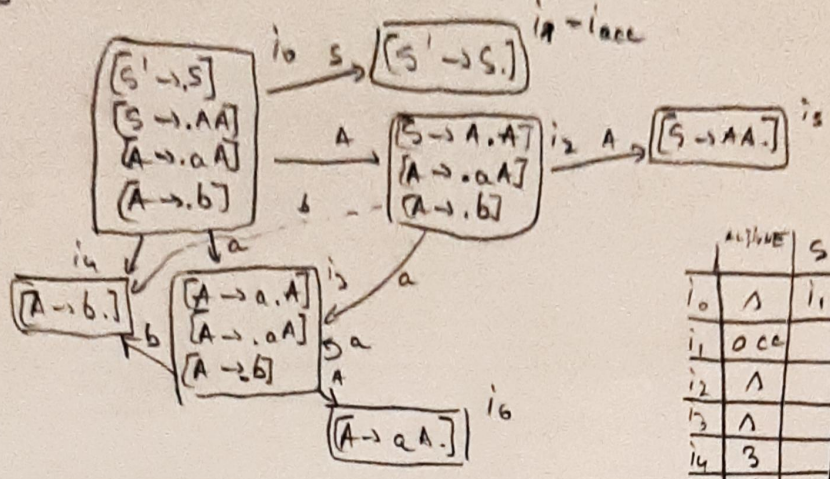
	S	SL	b	e	λ	;	$
i_0	S_1		S_2		S_3		
i_1							acc
i_2	S_5	S_4	S_2		S_3		
i_3				R_2		R_2	R_2 → regula 2
i_4				S_6			
i_5				R_3	S_7		R_1
i_6				R_1		R_1	R_1
i_7	S_5	S_8	S_2		S_3	S_3	
i_8				R_4			

shift $0	bλ;λe$, ε
shift $0b2	λ;λe$, ε
reduce $0b2λ3	;λe$, ε
shift $0b2S5	;λe$, 2
shift $0b2S5;7	λe$, 2
reduce $0b2S5;7λ3	e$, 2
shift $0b2S5;7S5	e$, 22
$0b2S5;7SL8	e$, 322

$0b2SL4	e$, 4322
$0b2SL4eb	$, 4322
$0S1	$, 14322
acc	

→ bλ;λe ∈ L(G)

1. a) (0) $S' \to S$
(1) $S \to AA$
(2) $A \to aA$
(3) $A \to b$

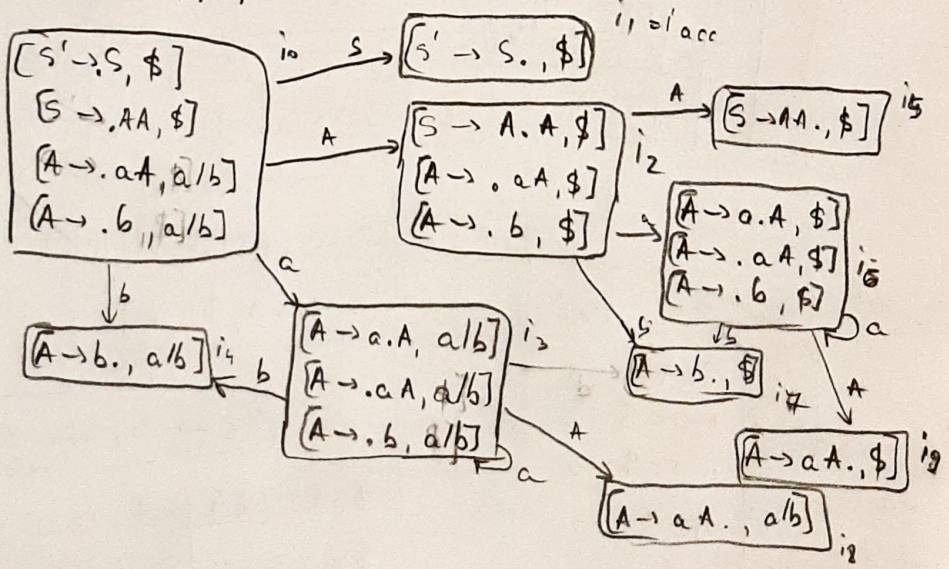


	ACTIONE	S	A	a	b
i_0	s	i_1	i_2	i_3	i_4
i_1	acc				
i_2	s		i_5	i_3	i_4
i_3	s		i_6	i_3	i_4
i_4	3				
i_5	1				
i_6	2				

=> este LR(0)

b)

	PRIMI	FOLLOW
S'	a, b	$
S	a, b	$
A	a, b	$, a, b

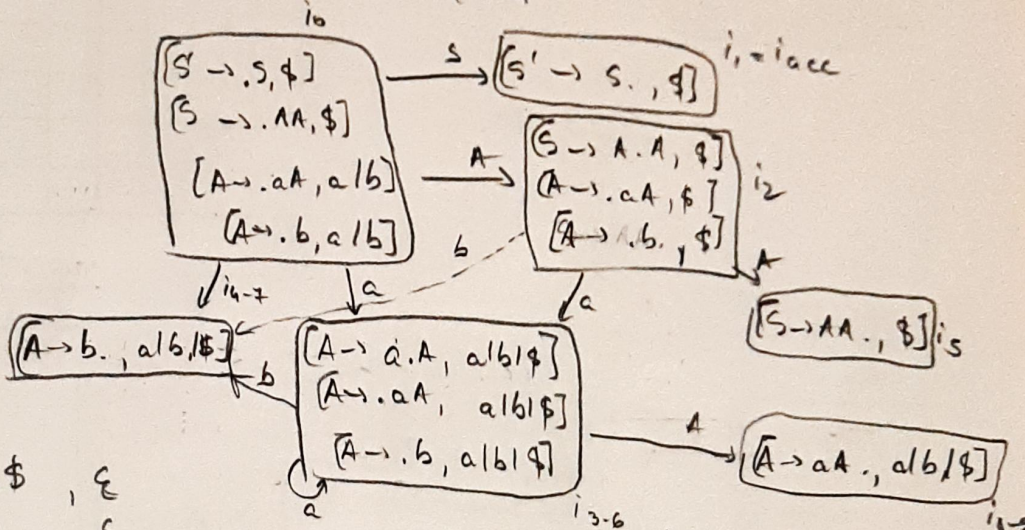


	S	A	a	b	$
i_0	S_1	S_2	S_3	S_4	
i_1					acc
i_2		g_5	S_6	S_7	
i_3		g_8	S_3	S_4	
i_4			r_3	r_3	
i_5		g_9	S_3	S_4	r_1
i_6		g_9	S_6	S_7	
i_7					r_3
i_8			r_2	r_2	
i_9					r_2

$\Rightarrow$ ste LR(1)

LALR $\rightarrow$ $i_3 + i_6$

$i_4 + i_7$



$0	abab$	, ε
$0a3-6	bab$	, ε
$0a3-6b4-7	ab$	, ε
$0a3-6a8-9	ab$	, 3
$0A2	ab$	, 23
$0A2a3-6	b$	, 23
$0A2a3-6b4-7	$	, 23
$0A2a3-6A2	$	, 323
$0A2		

	S	A	a	b	$
i_0	S_1	S_2	S_{3-6}	S_{4-7}	
i_1					acc
i_2		S_5	S_{3-6}	S_{4-7}	
i_{3-6}		S_{8-9}	S_{3-6}	S_{4-7}	
i_{4-7}			R_3	R_3	R_3
i_5					R_1
i_{8-9}			R_2	R_2	R_2

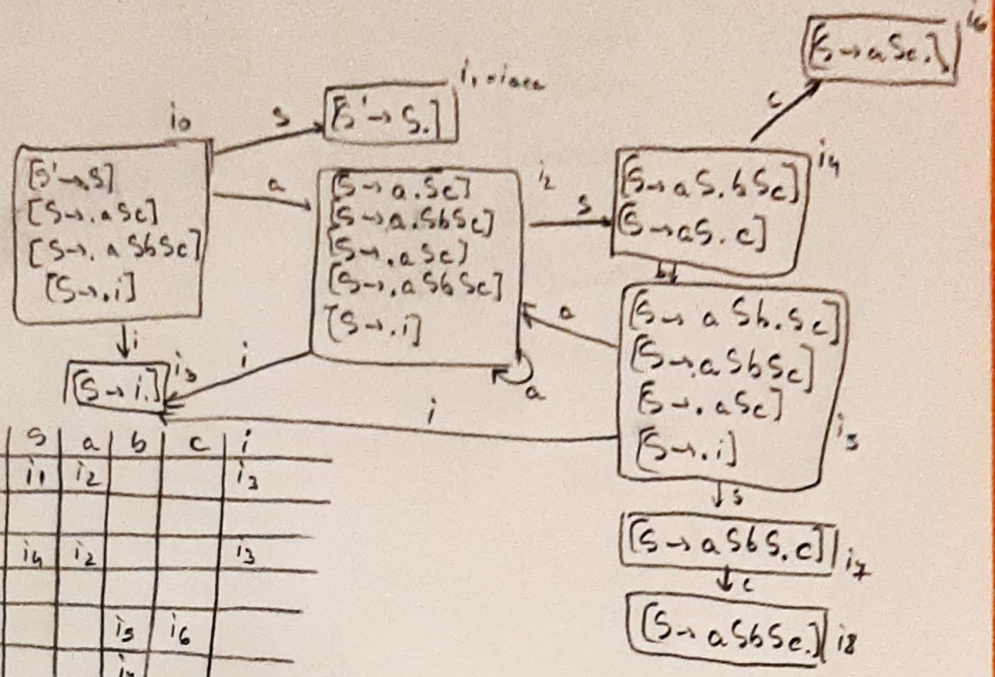
$\rightarrow$ ente LALR

2) $S' \to S$ (0)

a) $S \to aSc$ (1)

$S \to aSbSc$ (2)

$S \to i$ (3)

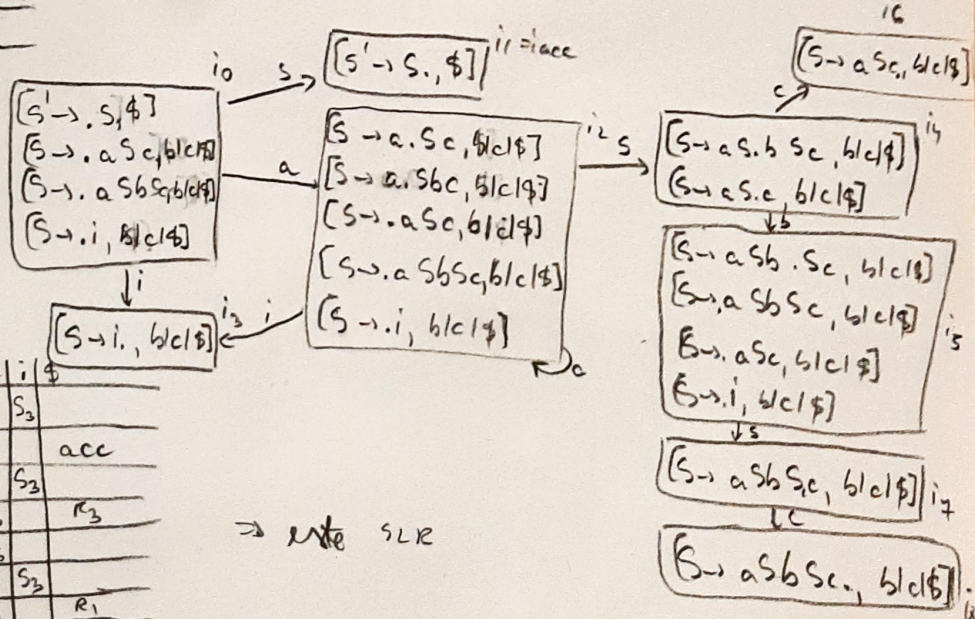


	ACTIVNE	S	a	b	c	i
i_0	1	i_1	i_2			i_3
i_1	acc					
i_2	1	i_4	i_2			i_3
i_3	3					
i_4	1			i_5	i_6	
i_5	1			i_7		
i_6	1					
i_7	1				i_8	
i_8	2					

$\Rightarrow$ este LR(0)

b)

	FIRST	FOLLOW
S'	a, i	$, c
S	a, i	b, c, $



	S	a	b	c	i	$
i_0	S_1	S_2			S_3	
i_1						acc
i_2	S_4	S_2			S_3	
i_3			R_3	R_3		R_3
i_4			S_5	S_6		
i_5	S_7	S_2			S_3	
i_6			R_1	R_1		R_1
i_7				S_8		
i_8			R_2	R_2		R_2

$\Rightarrow$ este SLR

c) este SLR $\Rightarrow$ este LR(1)

$a aibicc

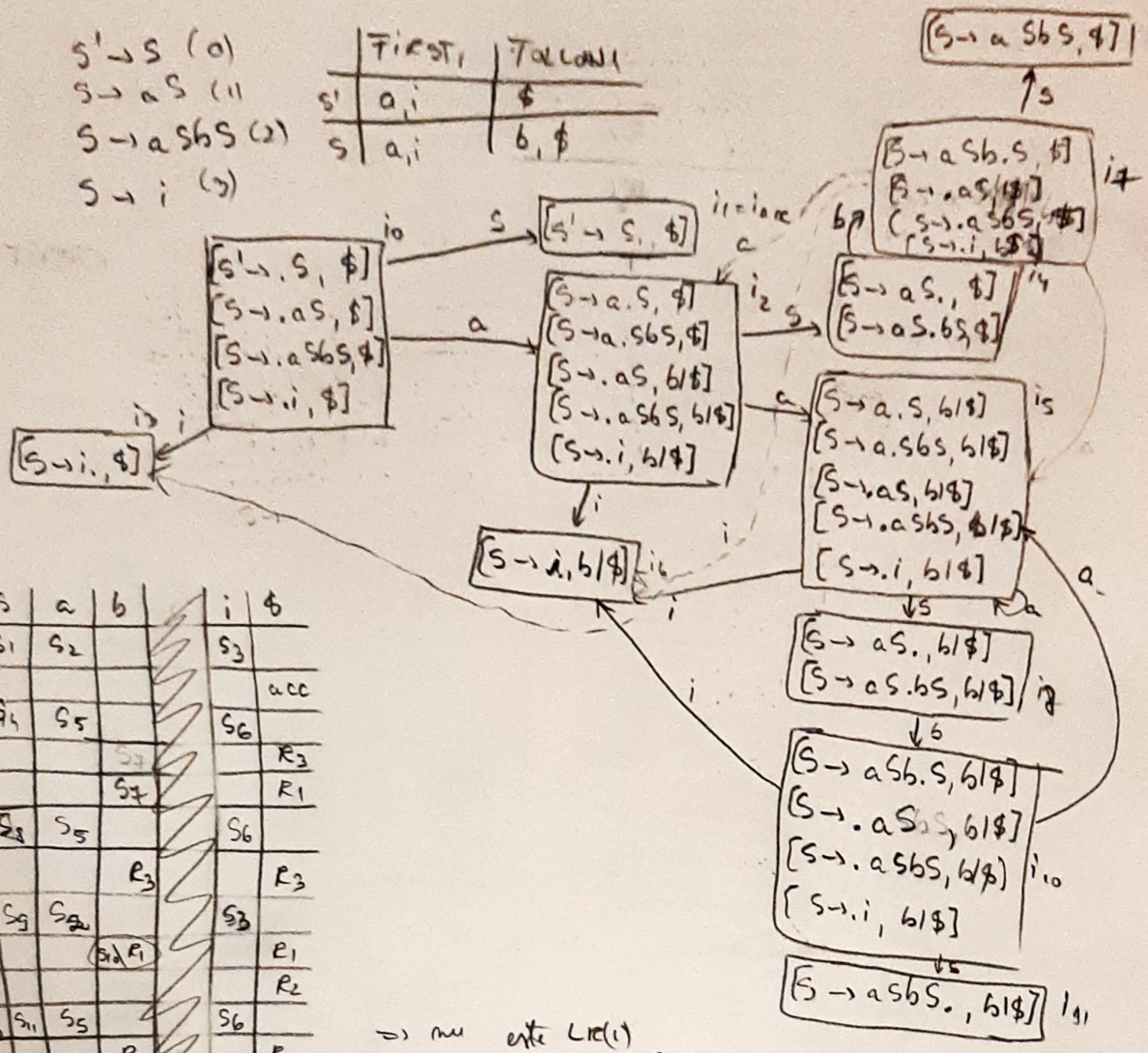
$0a2	aaibicc$	ε
$0a2	aibicc$	ε
$0a2a2	ibicc$	ε
$0a2a2i3	bicc$	ε
$0a2a$3	bicc$	3
$0a2a2$4b4	icc$	3

$0a2a2$5bbi

a)

$S' \to S$ (0)
$S \to aS$ (1)
$S \to aSbS$ (2)
$S \to i$ (3)

	FIRST	FOLLOW
S'	a, i	$
S	a, i	b, $



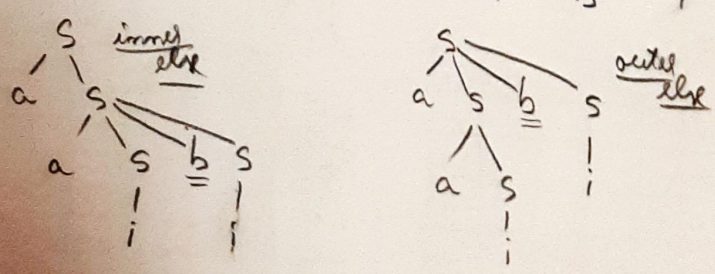
	S	a	b	i	$
i_0	s_1	s_2		s_3	
i_1					acc
i_2	s_4	s_5		s_6	
i_3			s_7		R_3
i_4			s_7		R_1
i_5	s_8	s_5		s_6	
i_6			R_3		R_3
i_7	s_9	s_{10}		s_3	
i_8			s_7 / R_1		R_1
i_9					R_2
i_{10}	s_{11}	s_5		s_6	
i_{11}			R_2		R_2

⇒ nu este LR(1)

avem conflict shift/reduce

4) if a then if a then stmt else stmt

a a i b i



$S' \to S$
$S \to aASbAS$
$A \to aA$
$A \to \varepsilon$

4) (0) $S' \to S$
(1) $S \to aS$
(2) $S \to aAbS$
(3) $S \to i$
(4) $A \to aAbA$
(5) $A \to i$

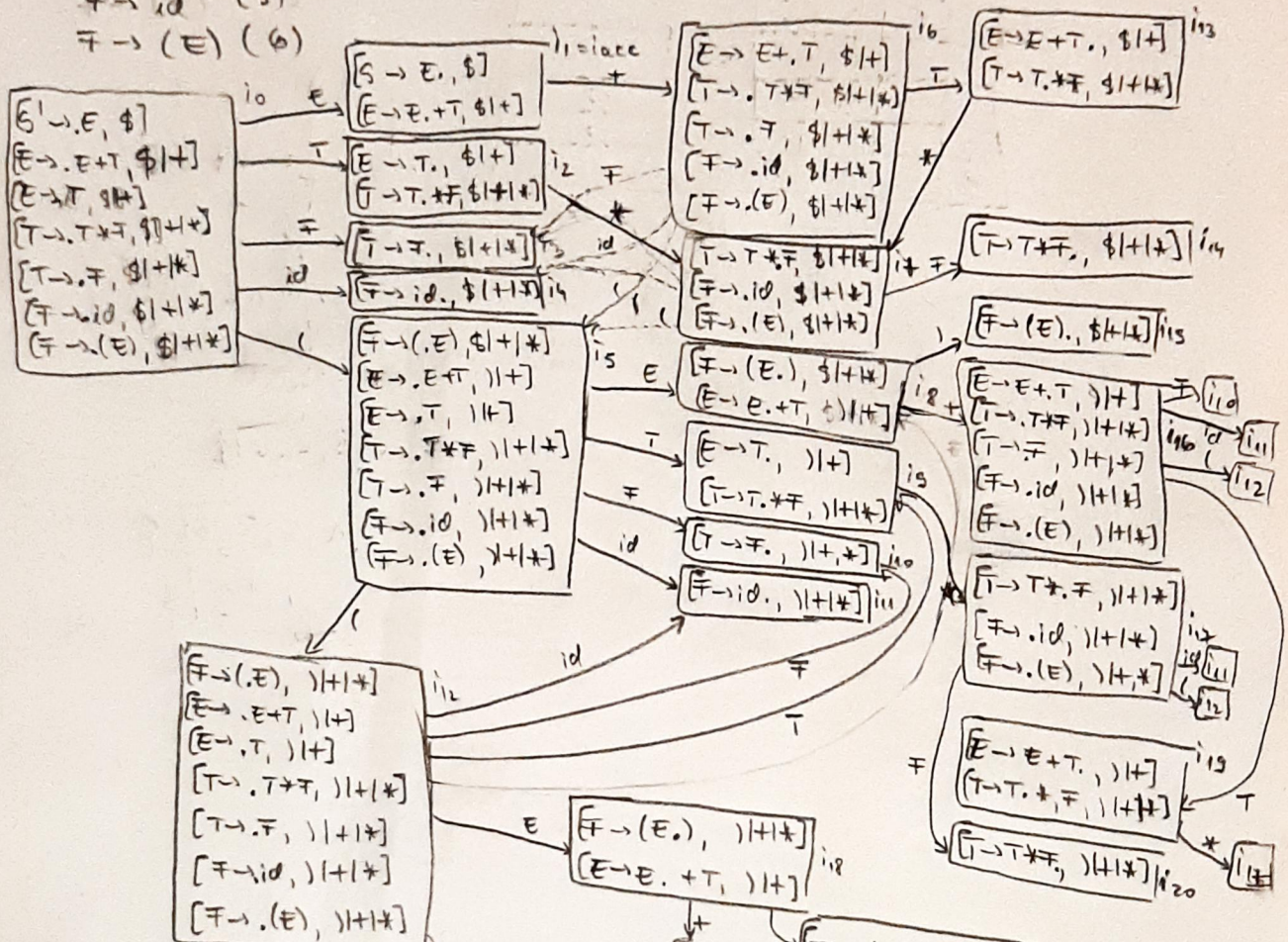
	FIRST	FOLLOW
S'	a, i	$
S	a, i	$, b
A	a, i	b, $

[S' → S, $]

5)

$S' \to E$ (0)
$E \to E+T$ (1)
$E \to T$ (2)
$T \to T*F$ (3)
$T \to F$ (4)
$F \to id$ (5)
$F \to (E)$ (6)

	FIRST	FOLLOW
S'	id, (	$
E	id, (	$, +,)
T	id, (	$, +,), *
F	id, (	$, +,), *



	E	T	F	+	*	id	(	)	$
i0	S_1	S_2	S_3			S_4	S_5		
i1				S_6					acc
i2				R_2	S_7				R_2
i3				R_4	R_4				R_4
i4				R_5	R_5				R_5
i5	S_8	S_9	S_{10}			S_{11}	S_{12}		
i6	S_8	S_9	S_{10}	S_4		S_4	S_5		
i7			S_{14}			S_4	S_5		
i8				S_{16}				S_{15}	
i9				R_2	S_{17}			R_2	
i10				R_4	R_4			R_4	
i11				R_5	R_5			R_5	

	E	T	F	+	*	id	(	)	$
i12	S_{18}	S_8	S_{10}			S_{11}	S_{12}		
i13				R_1	S_7				R_1
i14				R_3	R_3				R_3
i15				R_6	R_6				R_6
i16		S_{19}	S_{10}			S_{11}	S_{12}		
i17			S_{20}			S_{11}	S_{12}		
i18				S_{16}				S_{21}	
i19				R_1	S_{17}			R_1	
i20				R_3	R_3			R_3	
i21				R_6	R_6			R_6	

⇒ este LR(1)

6

$\$ a\ cc\ b\ \$ \Rightarrow \$ a\ S\ cb \$ \Rightarrow \$ a\ SSb \$ \Rightarrow \$ S \$$

$\Rightarrow acc \in L(G)$

acc

	S	a	b	c	$
S	≐	<·	≐	<·	
a	≐	<·		<·	
b		·>	·>	·>	·>
c		·>	·>	·>	·>
$		<·		<·	

$S \to aSSb$

$S \to c$

$\$ \lessdot acccb\$$

$\$ \lessdot a \lessdot ccb\$$

$\$ \lessdot a \lessdot c \gtrdot cb\$$

$\$ \lessdot a \doteq S \lessdot cb\$$

$\$ \lessdot a \doteq S \lessdot c \gtrdot b\$$

$\$ \lessdot a \doteq S \lessdot c \gtrdot b \gtrdot \$$

$\$ \lessdot a \doteq S \doteq S \doteq b \gtrdot \$$

$\$ \lessdot S \gtrdot \$$

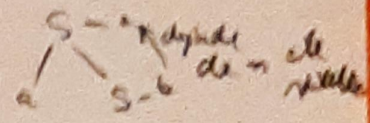
SEM 14

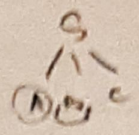
$G = (N, \Sigma, P, S)$

A

R

$$\frac{S_1 \to aS_1 \qquad S_0.N_a \leftarrow 3}{S \to b}$$

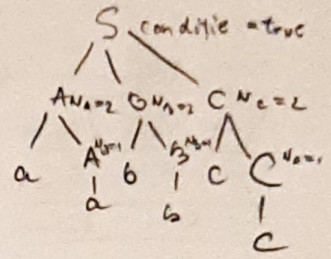




① $L = \{a^n b^m c^m \mid m$ - natural$\}$

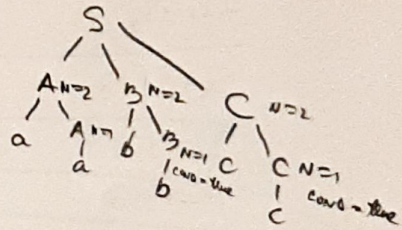
$S \to ABC$	$S.condiție \leftarrow A.N_a = B.N_b = C.N_c$
$A \to a$	$A.N_a \leftarrow 1$
$A_0 \to aA_1$	$A_0.N_a \leftarrow A_1.N_a + 1$
$B \to b$	$B.N_b \leftarrow 1$
$B_0 \to bB_1$	$B_0.N_b \leftarrow B_1.N_b + 1$
$C \to c$	$C.N_c \leftarrow 1$
$C_0 \to cC_1$	$C_0.N_c \leftarrow C_1.N_c + 1$

$A = \{N_a, N_b, N_c, condiție\}$



$S \to ABC$	$B.N \leftarrow A.N$ $C.N \leftarrow A.N$
$A \to a$	$A.N \leftarrow 1$
$A_0 \to aA_1$	$A_0.N \leftarrow A_1.N + 1$
$B \to b$	$B.CONDIȚIE \leftarrow B.N == 1$
$B_0 \to bB_1$	$B_1.N \leftarrow B_0.N - 1$
$C \to c$	$C.CONDIȚIE \leftarrow C.N == 1$
$C_0 \to cC_1$	$C_1.N \leftarrow C_0.N - 1$

$A = \{N, condiție\}$



②

$E_0 \to E_1 T +$	$E_0.val \leftarrow E_1.val + T.val$
$E \to T$	$E.val \leftarrow T.val$
$T_0 \to T_1 F *$	$T_0.val \leftarrow T.val * F.val$
$T \to F$	$T.val \leftarrow F.val$
$F \to CONST$	$F.val \leftarrow CONST.val$
$CONST \to 5$	$CONST.val \leftarrow 5$
$CONST \to 6$	$CONST.val \leftarrow 6$
$F \to E$	$F.val \leftarrow E.val$

(b)

a+b*c

a b c * a +

$A = \{out\}$

$E_0 \to E_1 + T$	$E_0.out \leftarrow E_1.out \| T_1.out \| +$
$E \to T$	$E.out \leftarrow T.out$
$T_0 \to T_1 * F$	$T_0.out \leftarrow T_1.out \| F.out \| *$
$T \to F$	$T.out \leftarrow F.out$
$F \to id$	$F.out \leftarrow id.out$
$F \to E$	$F.out \leftarrow E.out$
$id \to a$	$id.out \leftarrow a$
$id \to b$	$id.out \leftarrow b$
$id \to c$	$id.out \leftarrow c$

(4)

$E \to AA_1$	$E.val \leftarrow A_0.val + A_1.val$ $A = \{val\}$
$A_0 \to 0A_1 1$	$A_0.val \leftarrow A_1.val + 1$
$A_0 \to 1A_1 0$	$A_0.val \leftarrow A_1.val + 1$
$A \to \varepsilon$	$A.val \leftarrow 0$

(5)

$A = \{val_0, val_1\}$

$S_0 \to S_1 S_2$	$S_0.val_0 \leftarrow S_1.val_0 + S_2.val_0$, $S_0.val_1 \leftarrow S_1.val_1 + S_2.val_1$
$S_0 \to P S_1$	$S_0.val_0 \leftarrow P.val_0 + S_1.val_0$, $S_1.val_1 \leftarrow P.val_1 + S_1.val_1$
$S_0 \to i_0 S_1 i_1$	$S_0.val_1 \leftarrow i_0.val_1 + i_1.val_1 + S_1.val_1$, $S_0.val_0 \leftarrow i_0.val_0 + i_1.val_0 + S_1.val_0$
$P \to 00$	$P.val_1 = 0$, $P.val_0 = 2$
$P \to 11$	$P.val_1 = 2$, $P.val_0 = 0$
$i \to 01$	$i.val_0 \leftarrow 1$, $i.val_1 \leftarrow 1$
$i \to 10$	$i.val_0 \leftarrow 1$, $i.val_1 \leftarrow 1$

COD INTERMEDIAR

(1) $A := B + C * D$

$B := B + C * D$

$D := B + C * D$

a) reglas modelo

OPERATOR	ARG1	ARG2	REZULTAT
*	C	D	T_1
+	B	T_1	T_2
:=	T_2		A
*	C	D	T_3
+	B	T_3	T_4
:=	T_4		B
*	C	D	T_5
+	B	T_5	T_6
:=	T_6		D

b) reglas reinplute

	OPERATOR	ARG1	ARG2
(1)	*	C	D
(2)	+	B	(1)
(3)	:=	A	(2)
(4)	*	C	D
(5)	+	B	(4)
(6)	:=	B	(5)
(7)	*	C	D
(8)	+	B	(7)
(9)	:=	D	(8)

② g OPERATOR

goto

a := 0

for i := 1 to 5 do begin

a := a+1;

i := i+1;

end

	OPERATOR	ARG 1	ARG 2	REZULTAT
	:=	0		a
	:=	1		i
L3:	<	i	5	T1
	g	T1	false	L1
	goto			L2
L1:	+	a	1	T2
	:=	T2		a
	+	i	1	T3
	:=	T3		i
	goto			L3
L2:				

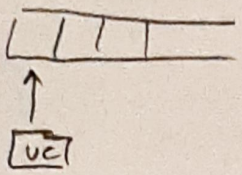
b) a = 5

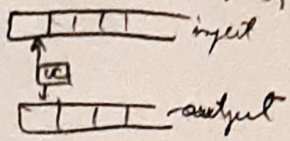
i = 6

SEM 14. TRANSLATOARE

AF: $M = (Q, \Sigma, \delta, q_0, F)$ $\Rightarrow$ $M(Q, \Sigma, \Delta, \delta, q_0, F)$

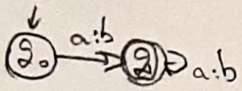
alfabet de ieșire





① $T(M) = \{(a^n, b^n) \mid n \geq 1\}$

$M = (\{q_0, q_1\}, \{a\}, \{b\}, \delta, q_0, \{q_1\})$



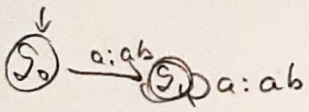
$\delta(q, \varepsilon, \sigma)$

$\in F$

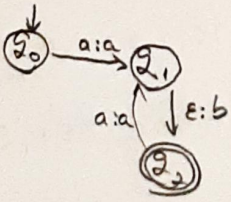
$(q_0, \underset{\text{se consumă}}{\underline{a}}aa, \varepsilon) \vdash (q_1, \underline{a}a, \underset{\text{nou}}{\underline{b}}) \vdash (q_1, \underline{a}, b\underset{\text{nou}}{\underline{b}}) \vdash (q_1, \varepsilon, b\underline{b})$

$(aaa, bbb) \in T(M)$

② $T(M) = \{(a^n, (ab)^n) \mid n \geq 1\}$



SAU



$M = (\{q_0, q_1, q_2\}, \{a\}, \{a, b\}, \delta, q_0, \{q_2\})$

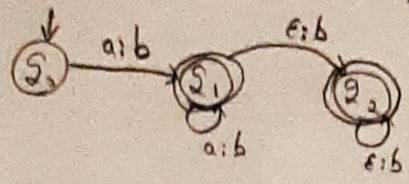
$\delta(q_0, a) = \{(q_1, a)\}$

$\delta(q_1, \varepsilon) = \{(q_2, b)\}$

$\delta(q_2, a) = \{(q_1, a)\}$

$\delta(\ldots, \ldots) = \emptyset$

③ $T(M) = \{(a^m, b^m) \mid m \geq m \geq 1\}$



$M = (\{q_0, q_1, q_2\}, \{a\}, \{b\}, \delta, q_0, \{q_1, q_2\})$

$\delta(q_0, a) = \{(q_1, b)\}$

$\delta(q_1, a) = \{(q_1, b)\}$

$\delta(q_1, \varepsilon) = \{(q_2, b)\}$

$\delta(q_2, \varepsilon) = \{(q_2, b)\}$

$\delta(\ldots, \ldots) = \emptyset$

④

APD

$M = (Q, \Sigma, \Gamma, \delta, q_0, Z_0, F) \Rightarrow M = (Q, \Sigma, \Gamma, \Delta, \delta, q_0, Z_0, F)$

⑤ $+a*aa \Rightarrow aaa*+$

$E \to +EE$

$E \to *EE$

$E \to a$

$M = (\{q\}, \{a, *, +\}, \{E, +, *\}, \{a, +, *\}, \delta, q, E, \emptyset)$

$\delta(q, +a*aa, E, \varepsilon) \vdash (q, a*aa, EE+, \varepsilon) \vdash (q, *aa,$

$\delta(q, \underset{\text{im}}{+}, \underset{\text{vârful}}{E}) = \{(q, \underset{\text{out}}{EE+}, \underset{\text{vârful}}{\varepsilon})\}$

$\delta(q, a, E) = \{(q, \varepsilon, a)\}$

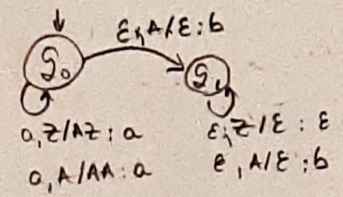
$\delta(q, *, E) = \{(q, EE*, \varepsilon)\}$

$\delta(q, \varepsilon, *) = \{(q, \varepsilon, *)\}$

$\delta(q, \varepsilon, +) = \{(q, \varepsilon, +)\}$

$\delta(\ldots, \ldots, \ldots) = \emptyset$

⑤ $T(n) = \{(a^n, a^m b^m) \mid m \geq 1\}$



$(q_0, aa, Z, \varepsilon) \vdash (q_0, a, \underset{\text{nou}}{AZ}, a) \vdash (q_0, \varepsilon, \underset{\text{nou}}{AAZ}, aa) \vdash (q_1, \varepsilon, AZ, aab) \vdash (q_1, \varepsilon, Z, aab$

$\vdash (q_1, \varepsilon, \varepsilon, aabb$

$\Rightarrow (aa, aabb)$

$M = (\{q_0, q_1\}, \{a\}, \{Z, A\}, \{a, b\}, \delta, q_0, \emptyset)$

$\delta(q_0, a, Z) = \{(q_0, AZ, a)\}$

$\delta(q_0, a, A) = \{(q_0, AA, a)\}$

$\delta(q_0, \varepsilon, A) = \{(q_1, \varepsilon, b)\}$

$\delta(q_1, \varepsilon, Z) = \{(q_1, \varepsilon, \varepsilon)\}$

$\delta(q_1, \varepsilon, A) = \{(q_1, \varepsilon, b)\}$

$\delta(\ldots, \ldots, \ldots) = \emptyset$

$S \to AB$ (1)

$A \to a$ (2)

$B \to b$ (3)

$G' = (N \cup \{S'\}, \Sigma, P \cup \{S' \to S\}, S')$

$S' \notin N$

$S \xrightarrow[dr]{*} \alpha A w \xrightarrow[dr]{} \boxed{\alpha\beta} w$

orice prefix al lui $\boxed{\alpha\beta}$ s.n. <u>prefix viabil</u>

<u>element de analiză LR(k)</u>

$[A \to \alpha . \beta, u]$ unde $A \to \alpha\beta$, $u \in \Sigma^k$ ($|u| \le k$)

<u>element de analiză valid</u>

$[A \to \alpha . \beta, u]$ valid pentru <u>prefixul viabil</u> $\gamma\alpha$ dacă:

$S \xrightarrow[dr]{*} \gamma A w \xrightarrow[dr]{} \gamma\alpha\beta w$

$u = FIRST_k(w)$

<u>colecția canonică LR(k)</u>

$C = \{I_i$ - elemente de analiză pt. un prefix viabil$\}$

- în I_0 avem un prim element de analiză
- cel puțin un element în I_j => adug cu funcția Closure
- o mulțime I_j => construiesc goto(I_i, X)

I_i corespunde unei stări a automatonului

<u>C</u> Σ = mulțimea elementelor de analiză

$I_0 \Rightarrow [S' \to .S, \ldots]$

$I_0 = \text{Closure}([S' \to .S, \ldots])$

$C = \{I_0\}$

repetă

pentru toți I_i din C, $X \in N \cup \Sigma$ execută

$C = C \cup \text{goto}(I_i, X)$

sf. pentru

până când C nu se mai modifică

$\left.\begin{array}{l} k=0 \\ LR(k) \end{array}\right] \Rightarrow LR(0)$

i_0 este $[S' \to .S]$

<u>Closure pt LR(0)</u>

$Closure : Set(E) \to Set(E)$

$e \in E$, dacă $e = [A \to \alpha . B\beta]$ atunci $\forall B \to \gamma \in P$, $[B \to .\gamma] \in Closure(e)$

<u>goto pt LR(0)</u>

$goto : Set(E) \times NUZ \to Set(E)$

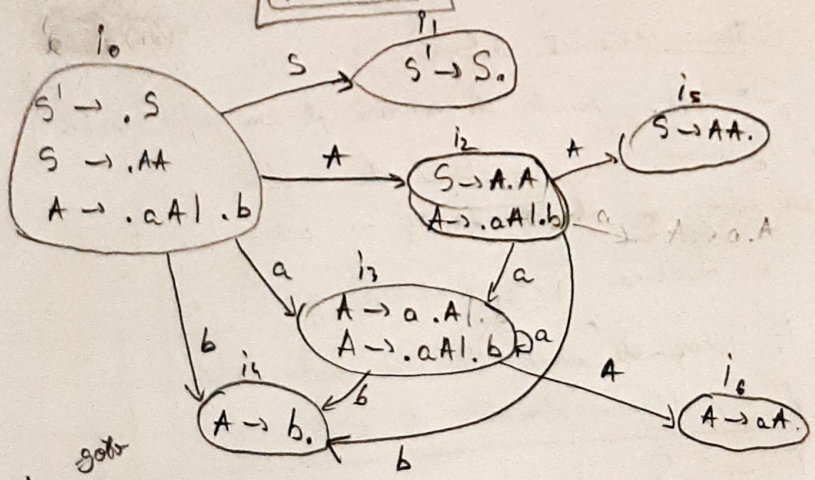
$goto(i, X) = Closure(\{A \to \alpha \underbrace{X}_{} . \beta] \mid [A \to \alpha . X\beta] \in i\})$

SHIFT deja X

$S \to AA$

$A \to aA \mid b$

$\Rightarrow$ $\boxed{S' \to S \;\; \boxed{S \to AA \;\; A \to aA \mid b}}$ augmented gramma



	action			goto	
	a	b	$	A	S
0	S_3	S_4		2	1
1			acc		
2	S_3	S_4		5	
3	S_3	S_4		6	
4	R_3	R_3	R_3		
5	R_1	R_1	R_1		
6	R_2	R_2	R_2		

R - reduce

S - shift

SLR: conflitti le produzioni comune

$S' \to S$	0
$S \to A$	1
$S \to xb$	2
$A \to aAb$	3
$A \to B$	4
$B \to x$	5

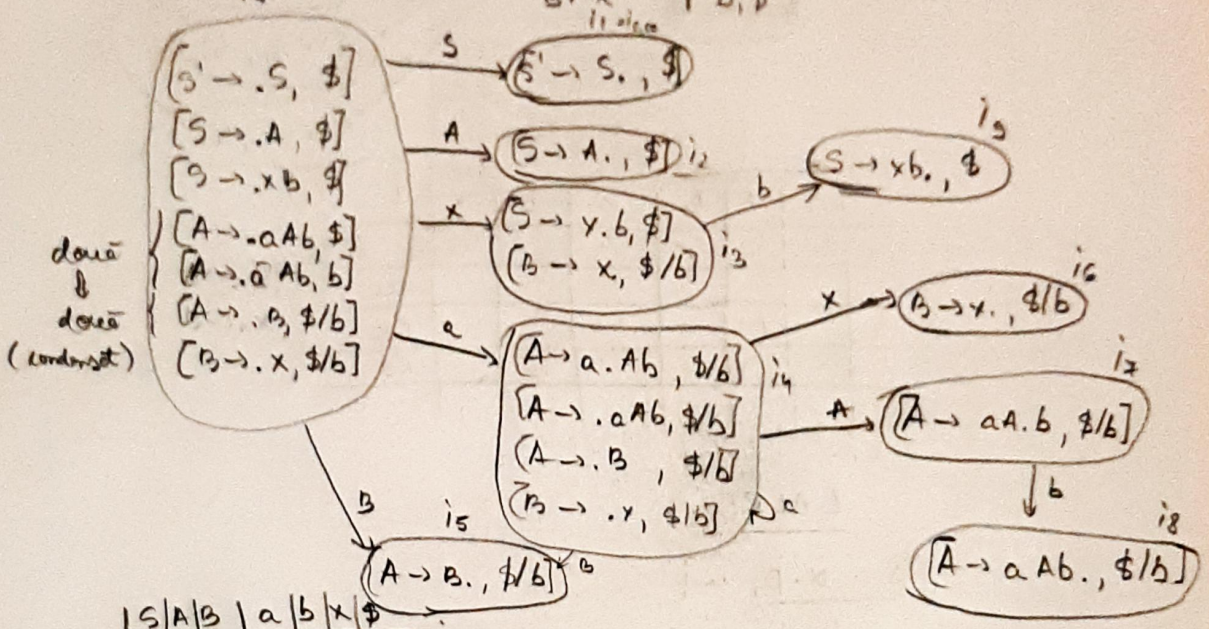
SLR = riduzione LR

$[A \to \alpha.\beta, a]$

a ∈ FOLLOW(A)

|w| = 1

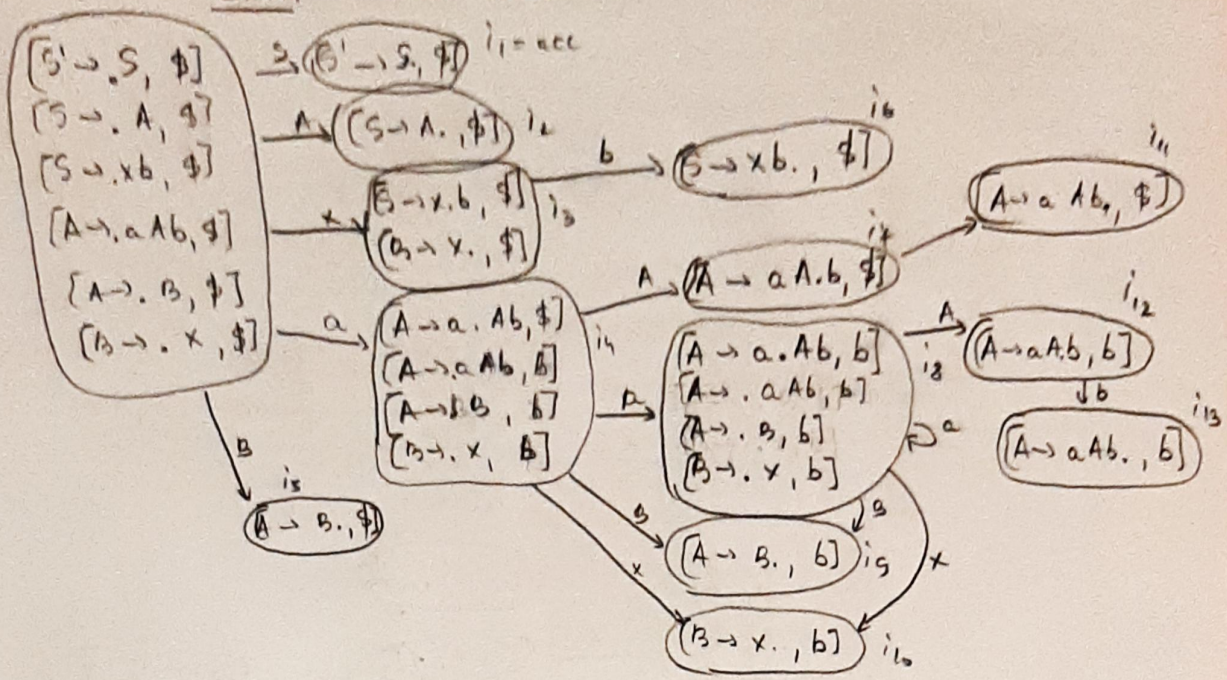
	FIRST	FOLLOW
S'	x, a	$
S	x, a	$
A	a, x	$, b
B	x	b, $



	S	A	B	a	b	x	$
i_0	S_1	S_2	S_5	S_4		S_3	
i_1							acc
i_2							R_1
i_3						S_9 / R_9	R_5
i_4		S_7	S_5	S_4			S_6
i_5						R_4	R_4
i_6						R_5	R_5
i_7						S_8	
i_8						R_3	R_3
i_9							R_2

CONFLICT, non esiste SLR

LR(1) → multe stări



	S	A	B	a	b	x	$
i_0	S1	S2	S5	S4		S3	
i_1							acc
i_2		R1					R1
i_3					S6		R5

...

LALR

[A → α.β, u]

nucleu

- se unesc elementele de condiție neconflictuale cu nucleu comun

$0	xb$	ε,
$0x3	b$	ε,
$0x3b4	$	ε,
$0S1	$	ε,

GRAMATICĂ DE PRECEDENȚĂ

$S \to aSSb$

$S \to c$

$a \doteq S$

$S \doteq S$

$S \doteq b$

$S \lessdot a$

$S \lessdot c$

$a \lessdot a$

$a \lessdot c$

$X \doteq Y$: $A \to \alpha X Y \gamma \in P$

$X \lessdot Y$: $A \to \alpha X B \beta \in P$, $B \xrightarrow{+} Y\delta$

$X \gtrdot a$: $A \to \alpha B Y \beta \in P$, $B \xrightarrow{+} \delta X$, $Y \xrightarrow{+} a\gamma$

$\$ \lessdot X$: $S \xrightarrow{+} X\alpha$

$X \gtrdot \$$: $S \xrightarrow{+} \alpha X$

$R_{\lessdot} \subset (N \cup \Sigma \cup \{\$\}) \times (N \cup \Sigma \cup \{\$\})$

$R_{\doteq} \subset (N \cup \Sigma) \times (N \cup \Sigma)$

$R_{\gtrdot} \subset (N \cup \Sigma \cup \{\$\}) \times (\Sigma \cup \{\$\})$

	S	a	b	c	$
S	$\doteq$	$\lessdot$	$\doteq$	$\lessdot$	
a	$\doteq$	$\lessdot$		$\lessdot$	
b		$\gtrdot$	$\gtrdot$	$\gtrdot$	$\gtrdot$
c		$\gtrdot$	$\gtrdot$	$\gtrdot$	$\gtrdot$
$		$\lessdot$		$\lessdot$	

$$\$ \underset{\lessdot}{a} \underset{\lessdot}{c} \underset{\lessdot}{c} \underset{\gtrdot}{b} \$ \Rightarrow \$ \underset{\lessdot}{a} \underset{\doteq}{S} \underset{\lessdot}{c} \underset{\gtrdot}{b} \$ \Rightarrow \$ \underset{\lessdot}{a} \underset{\doteq}{S} \underset{\doteq}{S} \underset{\doteq}{b} \underset{\gtrdot}{\$} \Rightarrow \$ S \$$$

<u>OBS</u>: relații de precedență a operatorilor

GRAMATICĂ DE ATRIBUTE

$G = (N, \Sigma, P, S)$ g. l.c.

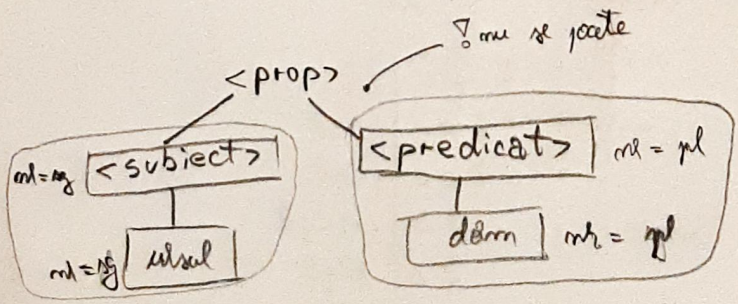
$A = \bigcup_{X \in N \cup \Sigma} A(X)$ → fiecărui simbol al gramaticii i se asociază o sau mai multe atribute

<prop> → <subiect><predicat>
<subiect> → ursul
<subiect> → urșii
<predicat> → doarme
<predicat> → dorm

$A = \{nr\}$
↳ asociat tuturor terminalelor și neterminalelor
→ $nr \in \{sg, pl\}$

<subiect>.nr = <predicat>.nr = <prop>.nr

<predicat> → doarme	<predicat>.nr ← doarme.nr doarme.nr ← sg
<predicat> → dorm	<predicat>.nr ← dorm.nr dorm.nr ← pl
<subiect> → ursul	<subiect>.nr ← ursul.nr ursul.nr ← sg
<subiect> → urșii	<subiect>.nr ← urșii.nr urșii.nr ← pl



Esempio

$S \to A$
$A \to Aa$
$A \to b$

$\mathcal{A} = \{a, b, x, y\}$

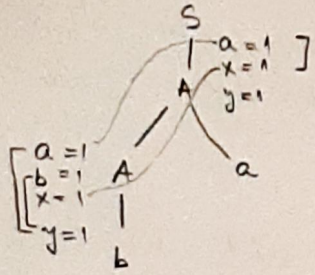
$A(A) = \{a, b, x, y\}$

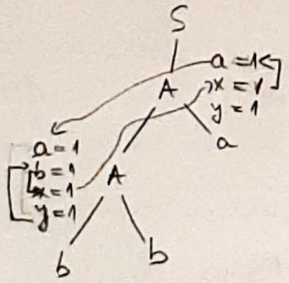
$S \to A \quad \{A.a = A.x$

$A_0 \to A_1 a \quad \begin{cases} A_1.a = A_0.a \\ A_1.b = A_1.y \\ A_0.x = A_1.x \\ A_0.y = 1 \end{cases}$

$A \to b \quad \begin{cases} A.y = A.a \\ A.x = 1 \end{cases}$

$A \to bb \quad \begin{cases} A.x = A.b \\ A.y = 1 \end{cases}$

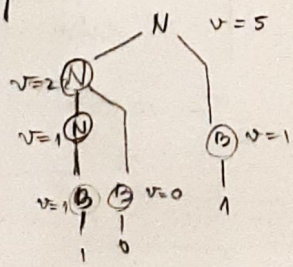




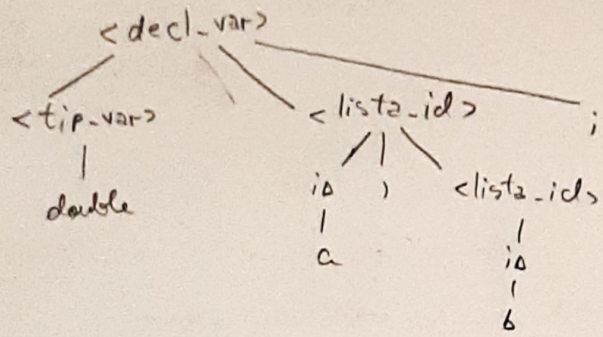
$N_0 \to N_1 B$	$N_0.v = N_1.v * 2 + B.v$
$N \to B$	$N.v = B.v$
$B \to 0$	$B.v = 0$
$B \to 1$	$B.v = 1$

$\mathcal{A} = \{v\}$

$A(N) = A(B) = \{v\}$



<decl_var> → <tip_var> <lista_id>;	<lista_id>.tip ← <tip_var>.tip
<tip_var> → double	<tip_var>.tip ← real
<tip_var> → char	<tip_var>.tip ← ch
<lista_id>$_0$ → id, <lista_id>$_1$	id.tip ← <lista_id>$_0$.tip <lista_id>$_1$.tip ← <lista_id>$_0$.tip
<lista_id> → id	id.tip ← <lista_id>.tip
id → a	a.tip ← id.tip
id → b	b.tip ← id.tip
id → c	c.tip ← id.tip



$A = \{tip\}$

$tip \in \{real, ch\}$

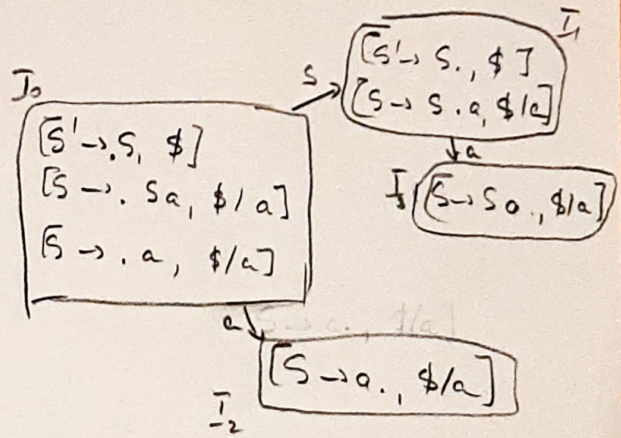
OBS:

$S' \to S$

$S \to Sa$

$S \to a$

	FIRST	FOLLOW
S'	a	$
S	a	$, a



STĂRI	
$\$_0$	aaa $
$\$_0 a_2$	aa $
$\$_0 S_1$	aa $
$\$_0 S_1 a_3$	a $
$\$_0 S_1$	a $
$\$_0 S_1 a_3$	$
$\$_0 S_1$	$
	acc

MAȘINA CU REGIȘTRI

A+B ⇒ load A, r0
load B, r1
add r0, r1, r2

load, add, sub, mul, div

MAȘINA CU STIVĂ

push, pop, add, sub, mul, div — operații

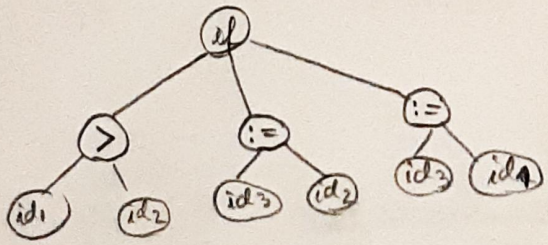
B+C−D ⇒ BC+D− ⇒ push B
push C
add
push D
sub

ALTELE

- mașine cu acumulator
- mașine cu stivă și acumulator

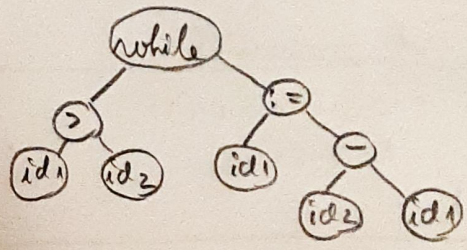
ARBORE SINTACTIC ABSTRACT

if id1 > id2 then id3 := id2
else id3 := id1



while id1 > id2 do

id1 := id2 − id1



COD INTERMEDIAR CU 3 ADRESE

<rezultat> := <arg1> <operator> <arg2>

Ex:

A := B*(C+D)

REPREZENTARE CUADRUPLETE

operator	arg1	arg2	rezultat
...	...	...	...
+	C	D	T_1
*	B	T_1	T_2
:=	T_2		A

REPREZENTARE TRIPLETE

	operator	arg1	arg2
..	...	...	...
(51)	+	C	D
(52)	*	B	(51)
(53)	:=	A	(52)

if a>b then m:=a
else m:=b

a)

	>	a	b	T1
	gt	T1	true	L1
	:=	b		m
	goto			L2
L1	:=	a		m
L2				

OPTIMIZARE COD INTERMEDIAR

① P = 2 * 3.14 * 2 => calcule la mom. compilării

② A := B + C*D;
B := B + C*D;
C := B + C*D;
=> elim. of redundante / exp. comune

③ if true then
...
else
⊠
=> elim. cod inaccesibil

⑤ for (i=0; i<n; i++){
A = 7+5*13;
}

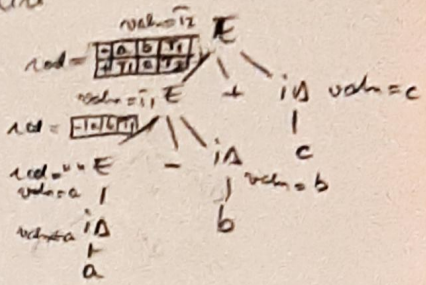
④ int x[10];
int i;
while ((i<10) && (x[i]>0))
i++;
=> multiplexarea operațiilor logice (lazy evaluation)

GENERAREA CODULUI INTERMEDIAR

- vom atribuie gramatica ce descrie structurile sintactice

Atributele:

- numele de variabile (pt. expresii)
- cod (cele cu 3 adrese)
- numele de etichete



$T_1 := a - b$

$T_2 := T_1 + c$

$E_0 \to E_1 + iΔ$	$E_0.val = newVal(Name()); E_0.cod = E_1.val + iΔ.val$ $\quad A = \{cod, val\}$
$E_0 \to E_1 - iΔ$	$E_0.val = newVal(Name()); E_0.cod = E_1.val - iΔ.val$
$E \to iΔ$	$E.cod \leftarrow$ " "; $E.val \leftarrow iΔ.val$
$iΔ \to a$	$iΔ.val \leftarrow a$
$iΔ \to b$	$iΔ.val \leftarrow b$
$iΔ \to c$	$iΔ.val \leftarrow c$

$<instr_if> \to if \; <cond> \; then \; <atrib>_1 \; else \; <atrib>_2$

$<cond> \to iΔ_1 > iΔ_2$

$<atrib> \to iΔ_1 := iΔ_2$

$<cond>.val \leftarrow newVal(Name())$

$<cond>.cod \leftarrow$ | > | $iΔ_1.val$ | $iΔ_2.val$ | $<cond>.val$ |

$<atrib>.cod \leftarrow$ | := | $iΔ_2.val$ | | $iΔ_1.val$ |

$iΔ \to mat$ $\quad iΔ.val \leftarrow mat$

$iΔ \to a$ $\quad iΔ.val \leftarrow a$

$iΔ \to b$ $\quad iΔ.val \leftarrow b$

$<instr_if>.et_then \leftarrow newLabel()$

$<instr_if>.et_after \leftarrow newLabel()$

$<instr_if>.cod \leftarrow$

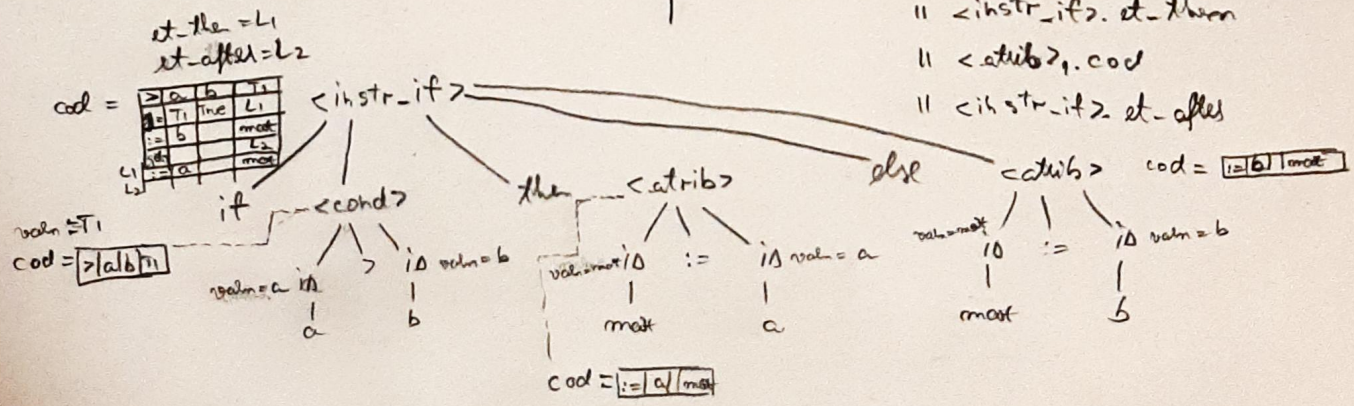
$<cond>.cod$ ||

j=	$<cond>.val$	True	$<instr_if>.et_else$

$||<atrib>_1.cod$

|| | goto | | $<instr_if>.et_after$ |

|| $<instr_if>.et_then$

|| $<atrib>_1.cod$

|| $<instr_if>.et_after$