CS 335 Semester 2023–2024-II
Assignment 2

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Problem 1

Givem grammar for this problem:

$$\begin{aligned} \mathit{Function} &\rightarrow \mathit{Type}\ \textbf{id}\ (\mathit{Arguments}) \\ \mathit{Type} &\rightarrow \textbf{id} \mid \mathit{Type}\ \textbf{*} \\ \mathit{Arguments} &\rightarrow \mathit{ArgList} \mid \epsilon \\ \mathit{ArgList} &\rightarrow \mathit{Type}\ \textbf{id}\ \textbf{,}\ \mathit{ArgList} \mid \mathit{Type}\ \textbf{id} \end{aligned}$$

(i)

This grammar is not LL(1) because of following reasons:

(i) The given grammar is left recursive due the production $\mathit{Type} \rightarrow \textbf{id} \mid \mathit{Type}\textbf{*}$ and left recursive grammar can not be LL(1).

(ii) The production $\mathit{ArgList} \rightarrow \mathit{Type}\ \textbf{id,}\mathit{ArgList} \mid \mathit{Type}\ \textbf{id}$ makes this grammar ambiguous because for the both the production of $\mathit{ArgList}$ the initial string is same, which is $\mathit{Type}\textbf{id}$, and that generates an ambiguity while choosing a grammar while parsing.

(ii)

Transformed grammar:

$$\begin{aligned} \mathit{Function} &\rightarrow \mathit{Type}\ \textbf{id}\ (\mathit{Arguments}) \\ \mathit{Type} &\rightarrow \textbf{id}\ T' \\ T' &\rightarrow \textbf{*}\ T' \mid \epsilon \\ \mathit{Arguments} &\rightarrow \mathit{ArgList} \mid \epsilon \\ \mathit{ArgList} &\rightarrow \mathit{Type}\ \textbf{id}\ A' \\ A' &\rightarrow \textbf{,}\ \mathit{ArgList} \mid \epsilon \end{aligned}$$

(iii)

Table 1: FRIST and FOLLOW Sets

FIRST $(Function) = \{\mathbf{id}\}$	FOLLOW $(Function) = \{\mathbf{\$}\}$
FIRST $(Type) = \{\mathbf{id}\}$	FOLLOW $(Type) = \{\mathbf{id}\}$
FIRST $(T') = \{\epsilon, \mathbf{*}\}$	FOLLOW $(T') = \{\mathbf{id}\}$
FIRST $(Arguments) = \{\epsilon, \mathbf{id}\}$	FOLLOW $(Arguments) = \{)\}$
FIRST $(ArgList) = \{\mathbf{id}\}$	FOLLOW $(ArgList) = \{)\}$
FIRST $(A') = \{\epsilon, \mathbf{,}\}$	FOLLOW $(A') = \{)\}$

(iv)

Adding numbers to the productions for the ease of table making:

$$Function \rightarrow Type\ \mathbf{id}\ \mathbf{(}Arguments\mathbf{)} \quad (1)$$
$$Type \rightarrow \mathbf{id}\ T' \quad (2)$$
$$T' \rightarrow \mathbf{*}\ T' \quad (3)$$
$$T' \rightarrow\ \epsilon \quad (4)$$
$$Arguments \rightarrow ArgList\ | \quad (5)$$
$$Arguments \rightarrow\ \epsilon \quad (6)$$
$$ArgList \rightarrow Type\ \mathbf{id}\ A' \quad (7)$$
$$A' \rightarrow \mathbf{,}\ ArgList \quad (8)$$
$$A' \rightarrow\ \epsilon \quad (9)$$

NON-TERMINALS	INPUT SYMBOLS					
	id	**(**	**)**	*****	**,**	**$**
Function	(1)					
Type	(2)					
T'	(4)			(3)		
Arguments	(5)		(6)			
ArgList	(7)					
A'			(9)		(8)	

Table 2: Predictive LL(1) Parsing Table

Problem 2

Given context-free grammar for this problem:

$S \rightarrow LM \mid L\mathbf{p} \mid \mathbf{q}L\mathbf{r} \mid \mathbf{sr} \mid \mathbf{qsp}$	FIRST $(S) = \{q,\ s,\ a,\ t\}$	FOLLOW $(S) = \{\$\}$
$L \rightarrow \mathbf{a}M\mathbf{b} \mid \mathbf{s} \mid \mathbf{t}$	FIRST $(L) = \{s,\ a,\ t\}$	FOLLOW $(L) = \{p,\ r,\ t\}$
$M \rightarrow \mathbf{t}$	FIRST $(M) = \{t\}$	FOLLOW $(M) = \{\$\}$

(i)

The given CFG is not SLR(1) because it has shift-reduce confllict in the below shown parsing table.

(ii)

The given CFG is an LALR(1) grammar since it doesn't have any conflict the in the parsiing table.

(Explanation of Conflicts)

When we create SLR parsing table it, does shows up with shift-reduce conflicts when it is at state I_4 and the next input token is r. Similar conflicts also rise for states of I_{11}.

$$
\begin{aligned}
I_0 &= Closure(S' \to \bullet S) \\
&= \{S' \to \bullet\ S, \\
&\quad S \to\ \bullet LM, \\
&\quad S \to\ \bullet Lp, \\
&\quad S \to\ \bullet qLr, \\
&\quad S \to\ \bullet sr, \\
&\quad S \to\ \bullet qsp, \\
&\quad L \to\ \bullet aMb, \\
&\quad L \to\ \bullet s, \\
&\quad L \to\ \bullet t\}
\end{aligned}
$$

$$
\begin{aligned}
I_5 &= Goto(I_0\ , a) \\
&= \{L \to\ a \bullet Mb, \\
&\quad M \to\ \bullet t\}
\end{aligned}
$$

$$
\begin{aligned}
I_9 &= Goto(I_2\ , t) \\
&= \{M \to\ t\bullet\}
\end{aligned}
$$

$$
\begin{aligned}
I_{10} &= Goto(I_3\ , L) \\
&= \{S \to\ qL \bullet r\}
\end{aligned}
$$

$$
\begin{aligned}
I_{16} &= Goto(I_{13}\ , b) \\
&= \{L \to\ aMb\bullet\}
\end{aligned}
$$

$$
\begin{aligned}
I_1 &= Goto(I_0\ , S) \\
&= \{S' \to\ S\bullet\}
\end{aligned}
$$

$$
\begin{aligned}
I_2 &= Goto(I_0\ , L) \\
&= \{S \to\ L \bullet M, \\
&\quad S \to\ L \bullet p, \\
&\quad M \to\ \bullet t\}
\end{aligned}
$$

$$
\begin{aligned}
I_6 &= Goto(I_0\ , t) \\
&= \{L \to\ t\bullet\}
\end{aligned}
$$

$$
\begin{aligned}
I_7 &= Goto(I_2\ , M) \\
&= \{S \to\ LM\bullet\}
\end{aligned}
$$

$$
\begin{aligned}
I_{11} &= Goto(I_3\ , s) \\
&= \{S \to\ qs \bullet p, \\
&\quad L \to\ s\bullet\ \}
\end{aligned}
$$

$$
\begin{aligned}
I_{14} &= Goto(I_{10}\ , r) \\
&= \{S \to\ qLr\bullet\}
\end{aligned}
$$

$$
I_5 = Goto(I_3\ , a)
$$

$$
I_9 = Goto(I_5\ , t)
$$

$$
\begin{aligned}
I_3 &= Goto(I_0\ , q) \\
&= \{S \to\ q \bullet Lr, \\
&\quad S \to\ q \bullet sp, \\
&\quad L \to\ \bullet aMb, \\
&\quad L \to\ \bullet s, \\
&\quad L \to\ \bullet t\}
\end{aligned}
$$

$$
\begin{aligned}
I_4 &= Goto(I_0\ , s) \\
&= \{S \to\ s \bullet r, \\
&\quad L \to\ s\bullet\}
\end{aligned}
$$

$$
\begin{aligned}
I_8 &= Goto(I_2\ , p) \\
&= \{S \to\ Lp\bullet\}
\end{aligned}
$$

$$
\begin{aligned}
I_{12} &= Goto(I_4\ , r) \\
&= \{S \to\ sr\bullet\}
\end{aligned}
$$

$$
\begin{aligned}
I_{13} &= Goto(I_5\ , M) \\
&= \{L \to\ aM \bullet b\}
\end{aligned}
$$

$$
\begin{aligned}
I_{15} &= Goto(I_{11}\ , p) \\
&= \{S \to\ qsp\bullet\}
\end{aligned}
$$

$$
I_6 = Goto(I_3\ , t)
$$

Table 3: LR(0) canonical collection sets

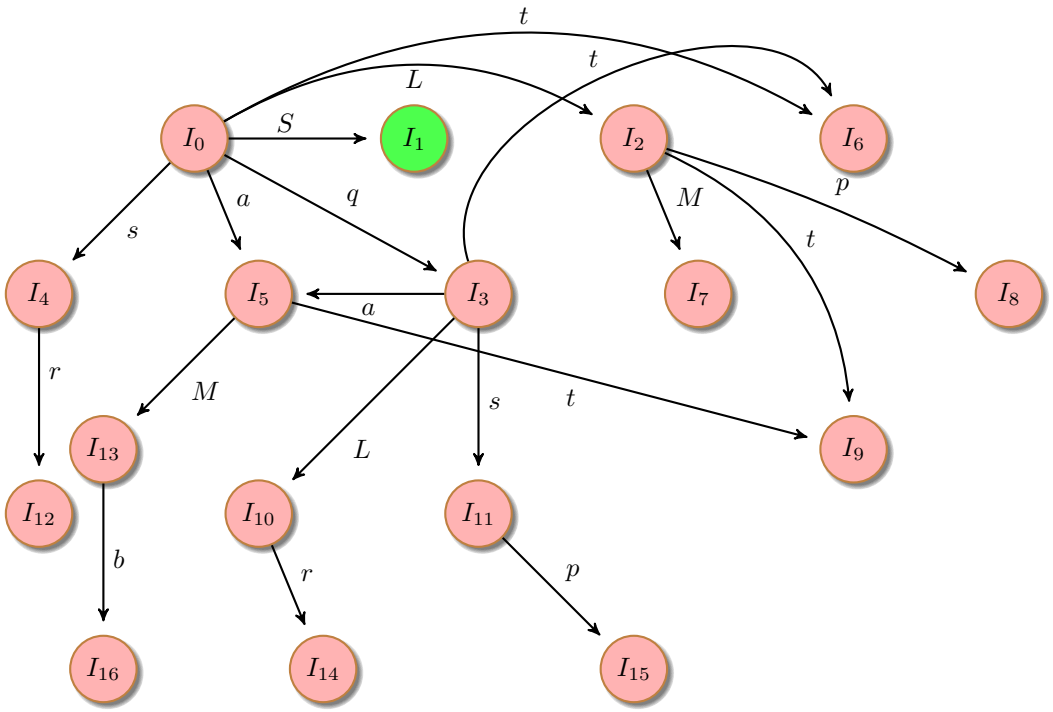

Figure 1: LR(0) Automaton

Adding numbers to the productions for the ease of table making:

$$S \to LM \quad (2)$$
$$S \to Lp \quad (3)$$
$$S \to qLr \quad (4)$$
$$S \to sr \quad (5)$$
$$S \to qsp \quad (6)$$
$$L \to aMb \quad (7)$$
$$L \to s \quad (8)$$
$$L \to t \quad (9)$$
$$M \to t \quad (10)$$

STATE	ACTION								GOTO		
	a	**b**	**p**	**q**	**r**	**s**	**t**	**$**	S	L	M
I_0	s5			s3		s4	s6		1	2	
I_1								Accept			
I_2			s8				s9				7
I_3	s5					s11	s6			10	
I_4			r8		s12 r8		r8				
I_5							s9				13
I_6			r9		r9		r9				
I_7								r2			
I_8								r3			
I_9		r10						r10			
I_{10}					s14						
I_{11}			s15 r8		r8		r8				
I_{12}								r5			
I_{13}		s16									
I_{14}								r4			
I_{15}								r6			
I_{16}			r7		r7		r7				

Table 4: SLR Parsing Table

$$
\begin{aligned}
I_0 &= Closure(S' \to \bullet S, \$) \\
&= \{S' \to \bullet\ S,\ \$, \\
&\quad S \to\ \bullet LM,\ \$, \\
&\quad S \to\ \bullet Lp,\ \$, \\
&\quad S \to\ \bullet qLr,\ \$, \\
&\quad S \to\ \bullet sr,\ \$, \\
&\quad S \to\ \bullet qsp,\ \$, \\
&\quad L \to\ \bullet aMb,\ t/p, \\
&\quad L \to\ \bullet s,\ t/p, \\
&\quad L \to\ \bullet t,\ t/p\}
\end{aligned}
$$

$$
\begin{aligned}
I_5 &= Goto(I_0\ , a) \\
&= \{L \to\ a \bullet Mb,\ r/t/p, \\
&\quad M \to\ \bullet t,\ b\}
\end{aligned}
$$

$$
\begin{aligned}
I_9 &= Goto(I_2\ , t) \\
&= \{M \to\ t\bullet,\ b/\$\}
\end{aligned}
$$

$$
\begin{aligned}
I_{10} &= Goto(I_3\ , L) \\
&= \{S \to\ qL \bullet r,\ \$\}
\end{aligned}
$$

$$
\begin{aligned}
I_{16} &= Goto(I_{13}\ , b) \\
&= \{L \to\ aMb\bullet,\ r/t/p\}
\end{aligned}
$$

$$
\begin{aligned}
I_1 &= Goto(I_0\ , S) \\
&= \{S' \to\ S\bullet,\ \$\}
\end{aligned}
$$

$$
\begin{aligned}
I_2 &= Goto(I_0\ , L) \\
&= \{S \to\ L \bullet M,\ \$ \\
&\quad S \to\ L \bullet p,\ \$ \\
&\quad M \to\ \bullet t,\ \$\}
\end{aligned}
$$

$$
\begin{aligned}
I_6 &= Goto(I_0\ , t) \\
&= \{L \to\ t\bullet,\ r/t/p\}
\end{aligned}
$$

$$
\begin{aligned}
I_7 &= Goto(I_2\ , M) \\
&= \{S \to\ LM\bullet,\ \$\}
\end{aligned}
$$

$$
\begin{aligned}
I_{11} &= Goto(I_3\ , s) \\
&= \{S \to\ qs \bullet p,\ \$ \\
&\quad L \to\ s\bullet,\ r\}
\end{aligned}
$$

$$
\begin{aligned}
I_{14} &= Goto(I_{10}\ , r) \\
&= \{S \to\ qLr\bullet,\ \$\}
\end{aligned}
$$

$$
\begin{aligned}
I_5 &= Goto(I_3\ , a) \\
&\quad 6 \\
I_9 &= Goto(I_5\ , t)
\end{aligned}
$$

$$
\begin{aligned}
I_3 &= Goto(I_0\ , q) \\
&= \{S \to\ q \bullet Lr,\ \$ \\
&\quad S \to\ q \bullet sp,\ \$ \\
&\quad L \to\ \bullet aMb,\ r \\
&\quad L \to\ \bullet s,\ r \\
&\quad L \to\ \bullet t,\ r\}
\end{aligned}
$$

$$
\begin{aligned}
I_4 &= Goto(I_0\ , s) \\
&= \{S \to\ s \bullet r,\ \$ \\
&\quad L \to\ s\bullet,\ t/p\}
\end{aligned}
$$

$$
\begin{aligned}
I_8 &= Goto(I_2\ , p) \\
&= \{S \to\ Lp\bullet,\ \$\}
\end{aligned}
$$

$$
\begin{aligned}
I_{12} &= Goto(I_4\ , r) \\
&= \{S \to\ sr\bullet,\ \$\}
\end{aligned}
$$

$$
\begin{aligned}
I_{13} &= Goto(I_5\ , M) \\
&= \{L \to\ aM \bullet b,\ r/t/p\}
\end{aligned}
$$

$$
\begin{aligned}
I_{15} &= Goto(I_{11}\ , p) \\
&= \{S \to\ qsp\bullet,\ \$\}
\end{aligned}
$$

$$
I_6 = Goto(I_3\ , t)
$$

Table 5: LALR collection sets

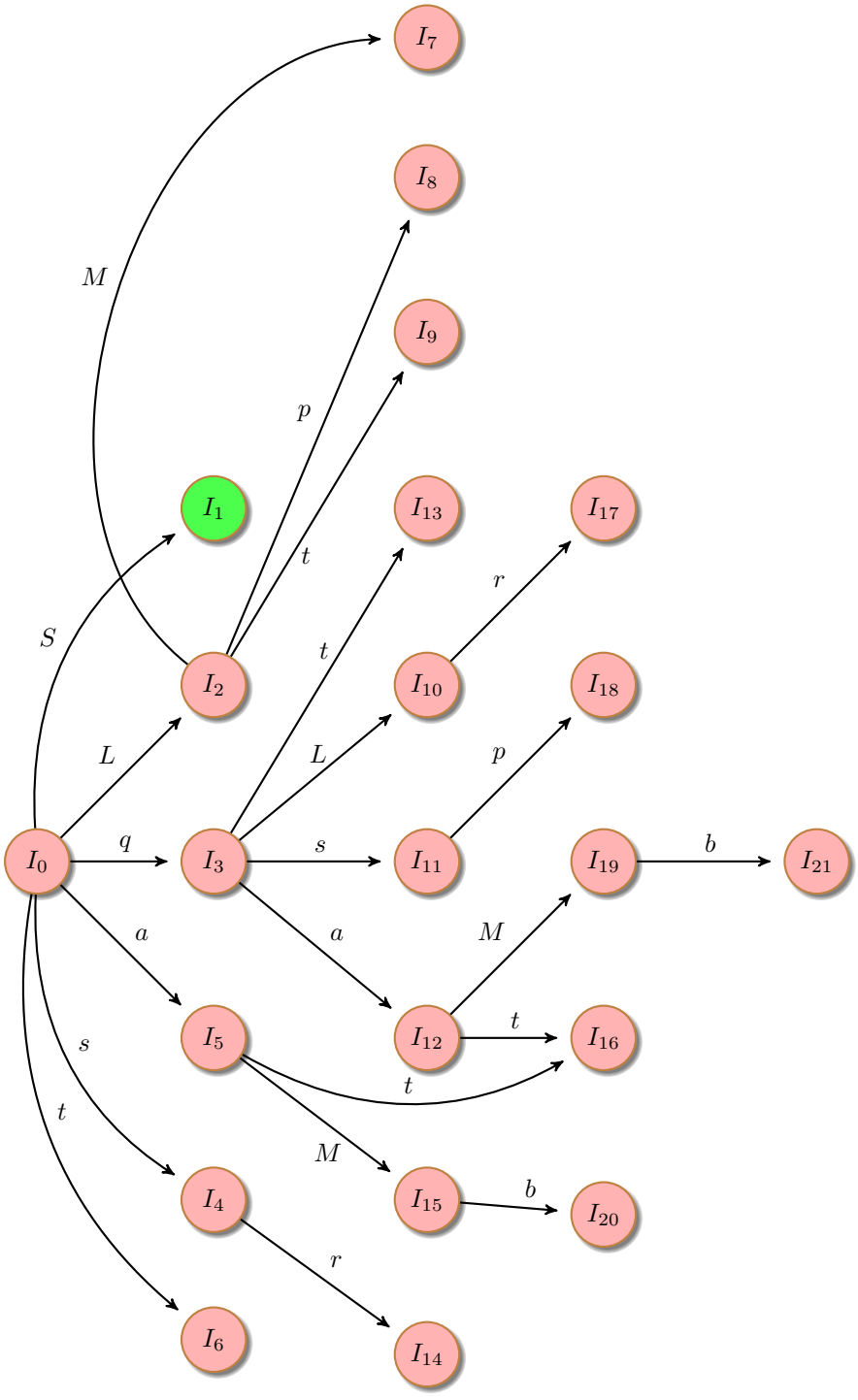

Figure 2: LR(1) Automaton

STATE	ACTION								GOTO		
	a	**b**	**p**	**q**	**r**	**s**	**t**	**$**	S	L	M
I_0	s5			s3		s4	s6		1	2	
I_1								Accept			
I_2			s8				s9				7
I_3	s5					s11	s6			10	
I_4			r8		s12		r8				
I_5							s9				13
I_6			r9		r9		r9				
I_7								r2			
I_8								r3			
I_9		r10						r10			
I_{10}					s14						
I_{11}			s15		r8						
I_{12}								r5			
I_{13}		s16									
I_{14}								r4			
I_{15}								r6			
I_{16}			r7		r7		r7				

Table 6: LALR(1) Parsing Table

Problem 3

The directory `problem3` has three files `parser.y` , `parser.l` and the `Makefile` . The following instruction will compile the codes and will generate an executable named `parser`.

```
make
```

Now, to execute the parser for any `testcase1`, run the following command:

```
./parser < testcase1
```

and at last the following command will remove the newly created files:

```
make clean
```