DEPARTMENT OF COMPUTER SCIENCE
CARLOS III UNIVERSITY OF MADRID

Computer Science
Language Processors

Rules

- The duration of the test is **3.0 hours**
- Questions will not be answered during the test
- One cannot re-enter the classroom after leaving it
- The answers must be written using a pen (not a pencil)

You shall design a translation from a language of arithmetic expressions to either C, Java or Pascal. The characteristics of the language are the following:

- The operands are variables and integers.
- The arithmetic operators are +, -, *, / with their usual meaning.
- Operators return integer results.
- All operators have the same precedence. Expressions are evaluated from left to right.
- Parentheses cannot be used to group expressions (parentheses are used in the iteration construct introduced below).
- The > operator stores the result of evaluating the expression to the left of the operator in the variable to the right of the operator. If there is no variable to the right of the operator, the evaluated value is lost.
- The iteration construct consists of an arithmetic expression enclosed in [], directly followed by an expression enclosed in (), the value of which indicates the number of iterations.
- Variables are initialised to the value 0.

Example:

3>A>[2*A-1+b>b](A)

The value 3 is assigned to the variable A. Then the evaluation of 2*A-1+b returns 5 which is assigned to b. This last operation is repeated 3 times (the value of A), therefore, after evaluating the whole expression, the variable b has a value of 15.

An example of an erroneous expression is:

5>A+2>5+*3

Error

Questions

1. (1 Point) Define the grammar for the language of arithmetic expressions.

2. (2 Points) Construct the LL(1) parsing table for the language.

3. (3 Points) Construct the SLR(1) parsing table for the language.

4. (1 Point) Do your grammars need any semantic checks? If so, describe them.
5. (3 Points) Write the semantic actions necessary to translate the language of arithmetic expressions to either C, Java or Pascal.

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Solution:

1.
The list of tokens of the grammar is: {[,], (,), >, op, id, num}. The token “op” represents every operation (+,-,*,/), can be analyzed as a grammatical symbol because they have the same precedence. The token "id" represents variables and "num" represents numeric constants (it could also return the lexical analyzer a single token for variables and constants). The production rules of the grammar are:

S → E > S | E
E → [S] (E) | P op E | P
P → id | num

The axiom, S, constructs the line of expressions joined with the > operator and the iterations. The non-terminal "E" constructs the arithmetic expressions, set of operands joined by an operator.

After factoring the grammar, we obtain:

S → E S’
S’→ > S | λ
E → [S] (E) | P E’
E’ → op E | λ
P → id | num

2.

Σ_N	First			Follow				
E	Id	num	[	)	>	]	$	
E’	Op	λ		)	>	]	$	
P	Id	num		op	)	>	]	$
S	Id	num	[	]	$			
S’	>	λ		]	$			

Table LL(1)		Σ_T								
		$	**>**	**(**	**)**	**[**	**]**	**id**	**num**	**op**
Σ_N	**E**					E→ [S] (E)		E→ P E’	E→ P E’	
	E’	E’→ λ	E’→ λ		E’→ λ		E’→ λ			E’→ op E
	P							P→ id	P→ num	
	S					S→ E S’		S→ E S’	S→ E S’	
	S’	S’→ λ	S’→ > S				S’→ λ			

3.
1. S_0 → S
2. S → E S’
3. S’→ > S
4. S’→ λ
5. E → [S] (E)
6. E → P E’
7. E’ → op E
8. E’→ λ
9. P → id
10. P →num

State 0	Action	Go To
$S_0 \rightarrow \cdot S$		[0,S]=1
$S \rightarrow \cdot E\ S'$		[0,E]=2
$E \rightarrow \cdot [S](E)$	[0,[ ]=D3	
$E \rightarrow \cdot P\ E'$		[0,P]=4
$P \rightarrow \cdot id$	[0,id]=D5	
$P \rightarrow \cdot num$	[0,num]=D6	
State 1	Action	Go To
$S_0 \rightarrow S\cdot$	[1,$]=ACP	
State 2	Action	Go To
$S \rightarrow E \cdot S'$		[2,S']=7
$S' \rightarrow \cdot > S$	[2,>]=D8	
$S' \rightarrow \lambda$	[2,]]=R4	
	[2,$]=R4	
State 3	Action	Go To
$E \rightarrow [\cdot S](E)$		[3,S]=9
$S \rightarrow \cdot E\ S'$		[3,E]=2
$E \rightarrow \cdot [S](E)$	[3,[ ]=D3	
$E \rightarrow \cdot P\ E'$		[3,P]=4
$P \rightarrow \cdot id$	[3,id]=D5	
$P \rightarrow \cdot num$	[3,num]=D6	
State 4	Action	Go To
$E \rightarrow P \cdot E'$		[4,E']=10
$E' \rightarrow \cdot op\ E$	[4,op]=D11	
$E' \rightarrow \lambda$	[4,>]=R8	
	[4,)]=R8	
	[4,]]=R8	
	[4,$]=R8	
State 5	Action	Go To
$P \rightarrow id\cdot$	[5,op]=R9	
	[5,>]=R9	
	[5,)]=R9	
	[5,]]=R9	
	[5,$]=R9	
State 6	Action	Go To
$P \rightarrow num\cdot$	[6,op]=R10	
	[6,>]=R10	
	[6,)]=R10	
	[6,]]=R10	
	[6,$]=R10	
State 7	Action	Go To
$S \rightarrow E\ S'\cdot$	[7,]]=R2	
	[7,$]=R2	
State 8	Action	Go To
$S' \rightarrow > \cdot S$		[8,S]=12
$S \rightarrow \cdot E\ S'$		[8,E]=2
$E \rightarrow \cdot [S](E)$	[8,[ ]=D3	
$E \rightarrow \cdot P\ E'$		[8,P]=4
$P \rightarrow \cdot id$	[8,id]=D5	
$P \rightarrow \cdot num$	[8,num]=D6	
State 9	Action	Go To
$E \rightarrow [S \cdot](E)$	[9,]]=D13	
State 10	Action	Go To
$E \rightarrow P\ E'\cdot$	[10,>]=R6	
	[10,)]=R6	
	[10,]]=R6	
	[10,$]=R6	
State 11	Action	Go To
$E' \rightarrow op \cdot E$		[11,E]=14
$E \rightarrow P \cdot E'$		[11,E']=10
$E' \rightarrow \cdot op\ E$	[11,op]=D11	
$E' \rightarrow \lambda$	[11,>]=R8	
	[11,)]=R8	
	[11,]]=R8	
	[11,$]=R8	
State 12	Action	Go To
$S' \rightarrow > S\cdot$	[12,]]=R3	
	[12,$]=R3	
State 13	Action	Go To
$E \rightarrow [S] \cdot (E)$	[13,(]=D15	
State 14	Action	Go To
$E' \rightarrow op\ E\cdot$	[14,>]=R7	
	[14,)]=R7	
	[14,]]=R7	
	[14,$]=R7	
State 15	Action	Go To
$E \rightarrow [S] (\cdot E)$		[15,E]=16
$E \rightarrow \cdot [S](E)$	[15,[ ]=D3	
$E \rightarrow \cdot P\ E'$		[15,P]=4
$P \rightarrow \cdot id$	[15,id]=D5	
$P \rightarrow \cdot num$	[15,num]=D6	
State 16	Action	Go To
$E \rightarrow [S] (E \cdot)$	[16,)]=D17	
State 17	Action	Go To
$E \rightarrow [S] (E)\cdot$	[17,>]=R5	
	[17,)]=R5	
	[17,]]=R5	
	[17,$]=R5	

Table SLR(1)		Shift									Go To				
		$	>	(	)	[	]	id	num	op	E'	E	P	S	S'
States	0					D3		D5	D6			2	4	1	
	1	ACP													
	2	R4	D8				R4								7
	3					D3		D5	D6			2	4	9	
	4	R8	R8		R8		R8			D11	10				
	5	R9	R9		R9		R9			R9					
	6	R10	R10		R10		R10			R10					
	7	R2					R2								
	8					D3		D5	D6			2	4	12	
	9						D13								
	10	R6	R6		R6		R6								
	11	R8	R8		R8		R8			D11	10	14			
	12	R3					R3								
	13			D15											
	14	R7	R7		R7		R7								
	15					D3		D5	D6			16	4		
	16				D17										
	17	R5	R5		R5		R5								