POLITECNICO DI TORINO

(01JEUHT) Formal Languages and Compilers

Laboratory N°4

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Attributes of Symbols

- A set of attributes can be associated to each symbol; attributes can be:
  - **Synthesized**: calculated from the values of the attributes of the node's children in the parse tree,
  - **Inherited**: calculated from the values of the parents / siblings in the parse tree.
- A set of semantic rules, specifying how attributes are calculated, is associated to each production.
- The scanner passes semantic values to the parser which, while recognizing the grammar, updates the nodes of the parse tree

Synthesized attributes

- A grammar whose attributes are all synthesized is denoted as an S-attribute grammar.
- In this case, it is possible to calculate the values of all attributes using a bottom-up strategy, from the leaves to the root of the parse tree.

E ::= E_1 '+' T	**E.value = E_1.value + T.value**
E ::= T	**E.value = T.value**
T ::= number	**T.value = number.value**

Cup & Semantics: the Symbol class

- In Cup, each symbol in the stack is an object of class Symbol (cup/java_cup/runtime/Symbol.java)
- It contains the following information:
  - A number uniquely identifying the symbol
    - public int sym;
  - The state in which the parse is
    - public int parse_state;
  - Two integers that are used to pass the line and column number from the scanner to the parser
    - public int left, right;
  - An object of class Object to handle semantics
    - public Object value;

scanner.jflex

Passing semantic values to the parser

- Symbol and semantic value:

```
[a-zA-Z][a-zA-Z0-9_]*     { return new Symbol(sym.ID, new  String(yytext())); }
```

- Symbol, line number, column number, and semantic value:

```
%{
    private Symbol my_symbol(int type, Object value){
            return new Symbol(type, yyline,yycolumn,value);
    }
%}

%%
[a-zA-Z][a-zA-Z0-9_]*  { return my_symbol(sym.ID, new  String(yytext())); }
```

Symbol Constructors:

```
public Symbol( int sym_id)
public Symbol( int sym_id, int left, int right)
public Symbol( int sym_id, Object o)
public Symbol( int sym_id, int left, int right, Object o)
```

- Or equivalently:

```
[a-zA-Z][a-zA-Z0-9_]*  {
                return new Symbol(sym.ID, yyline, yycolumn, new  String(yytext())); }
```


Cup & Semantic: specifying nodes types

- Cup must know the type of the semantic value of each symbol
- It uses the following definition of terminals and non-terminals:
  - terminal **<Object>** <list_of_terminals> ;
  - non terminal **<Object>** <list_of_not_terminals> ;
- **<Object>** is the class of the object associated to a given symbol

- Example:
  - terminal String ID;
    - An object of class String will be associated to ID.
  - terminal Integer NUM;
  - non terminal MyObject var;

```
class MyObject {
        public String var_name;
        public String var_type;
}
```

Cup & Semantic: using semantic values

- Given a set of productions:

```
E ::=   E PLUS T
      | E MINUS T ;
```

- One can refer to the semantic value of each symbol by adding labels to the symbols of interest:
  - A label is constituted by the ':' character followed by a name

```
E ::= E:n1 PLUS T:n2
    | E:n1 MINUS T:n2 ;
```

- Within each production, the labels can be used normally as objects of the class specified in the definition of terminals and non-terminals:

```
E ::=  E:n1 PLUS T:n2   {: System.out.print(n1 + " + " + n2); :}
     | E:n1 MINUS T:n2  {: System.out.print(n1 + " - " + n2); :}
```


Cup & Semantic: Actions and RESULT

- An action can be associated to each production, (*{: /* Java Code*/ :}*) and is executed every time the corresponding production is reduced
- The action updates the semantic value of each symbol
- For each production, the RESULT object, of class Object, is defined.
- RESULT represents the result of the semanatic rules contained in the action, **and is therefore associated to the symbol in the left hand side of the production**

Calculating synthesized attributes

- Given the algebraic expressions grammar, the following rule assigns to the symbol '**E**' the sum or the subtraction of the values of the addends/subtrahends:

```
non terminal Integer E, T;

E ::=    E:n1 PLUS T:n2
      {: RESULT = n1 + n2; :}
  |    E:n1 MINUS T:n2
      {: RESULT = n1 - n2; :}
;
```

- OR: {: RESULT = new Integer(n1.intValue() + n2.intValue()); :}

Calculating synthesized attributes (2)

- It is possible to propagate more than one semantic value through RESULT, in the following way:

```
terminal RO, RC;
terminal String identifier;
terminal Integer Args;
non terminal Object[ ] Func;
non terminal goal;

goal ::= Func:a {:
      System.out.println( "Function name: " + a[0] + "Number of parameters: " + a[1] );
:} ;

Func ::= identifier:a RO Args:b RC {:
            RESULT = new Object[2];
            RESULT[0] = new String(a);
            RESULT[1] = new Integer(b);
:} ;
```

Calculating synthesized attributes (3)

- Alternatively, one can write a class that contains all the required information:

```
action code {:
    class MyFunc {
        public String id;
        public Integer args;
        MyFunc(String id, Integer args) {
            this.id = new String(id);
            this.args = new Integer(args);
    }
}   :}

non terminal MyFunc Func;

goal ::= Func:a {:
    System.out.println( "Function name : " + a.id + "Number of parameters: " + a.args );
:} ;

Func ::= identifier:a RO Args:b RC {: RESULT = new MyFunc( a, b ); :} ;
```


Parser debugging

- A series of option are available in Cup to visualize the parser's internal structures:
  - -dump_grammar : Prints the list of terminals, non-terminals and productions
  - -dump_states : Prints the state graph
  - -dump_table : Prints the ACTION TABLE and the REDUCE TABLE
  - -dump : Prints all information
- The parser can be executed in debug mode (all the actions performed to analyze the input sequence are printed)

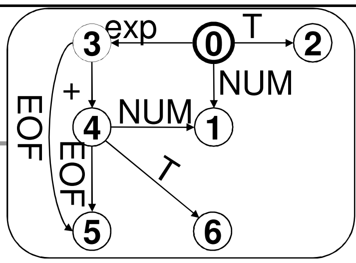
Normal mode:

```
Yylex l = new Yylex(new FileReader(file));
parser p = new parser(l);
Object result = p.parse();
```

Debug mode:

```
Yylex l = new Yylex(new FileReader(file));
parser p = new parser(l);
Object result = p.debug_parse();
```

States



- **-dump_states**

```
==== Viable Prefix Recognizer ====
START lalr_state [0]: {
  [exp ::= (*) T , {EOF PLUS }]
  [exp ::= (*) exp PLUS T , {EOF PLUS
}]
  [T ::= (*) NUMBER , {EOF PLUS }]
  [$START ::= (*) exp EOF , {EOF }]
}
transition on exp to state [3]
transition on T to state [2]
transition on NUMBER to state [1]
-------------------
lalr_state [1]: {
  [T ::= NUMBER (*) , {EOF PLUS }]
}
-------------------
lalr_state [2]: {
  [exp ::= T (*) , {EOF PLUS }]
}
-------------------
lalr_state [3]: {
  [exp ::= exp (*) PLUS T , {EOF PLUS
}]
  [$START ::= exp (*) EOF , {EOF }]
}
transition on EOF to state [5]
transition on PLUS to state [4]
-------------------
lalr_state [4]: {
  [exp ::= exp PLUS (*) T , {EOF PLUS
}]
  [T ::= (*) NUMBER , {EOF PLUS }]
}
transition on T to state [6]
transition on NUMBER to state [1]
-------------------
lalr_state [5]: {
  [$START ::= exp EOF (*) , {EOF }]
}
-------------------
lalr_state [6]: {
  [exp ::= exp PLUS T (*) , {EOF PLUS
}]
}
-------------------
```


Action / Reduce Tables

- **-dump_tables**

```
-------- ACTION_TABLE --------
From state #0
 [term 2:SHIFT(to state 1)]
From state #1
 [term 0:REDUCE(with prod 3)] [term 3:REDUCE(with prod 3)]
From state #2
 [term 0:REDUCE(with prod 2)] [term 3:REDUCE(with prod 2)]
From state #3
 [term 0:SHIFT(to state 5)] [term 3:SHIFT(to state 4)]
From state #4
 [term 2:SHIFT(to state 1)]
From state #5
 [term 0:REDUCE(with prod 0)]
From state #6
 [term 0:REDUCE(with prod 1)] [term 3:REDUCE(with prod 1)]
------------------------------
```

```
-------- REDUCE_TABLE --------
From state #0
 [non term 1->state 3] [non term 2->state 2]
From state #1
From state #2
From state #3
From state #4
 [non term 2->state 6]
From state #5
From state #6
-----------------------------
```

Grammar

- **-dump_grammar**

exp → exp PLUS T
exp → T
T → NUMBER

===== Terminals =====
[0]EOF [1]error [2]NUMBER [3]PLUS
===== Non terminals =====
[0]$START [1]exp [2]T
===== Productions =====
[0] $START ::= exp EOF
[1] exp ::= exp PLUS T
[2] exp ::= T
[3] T ::= NUMBER

Debugging

- **debug_parse()**

Input string: 3+5

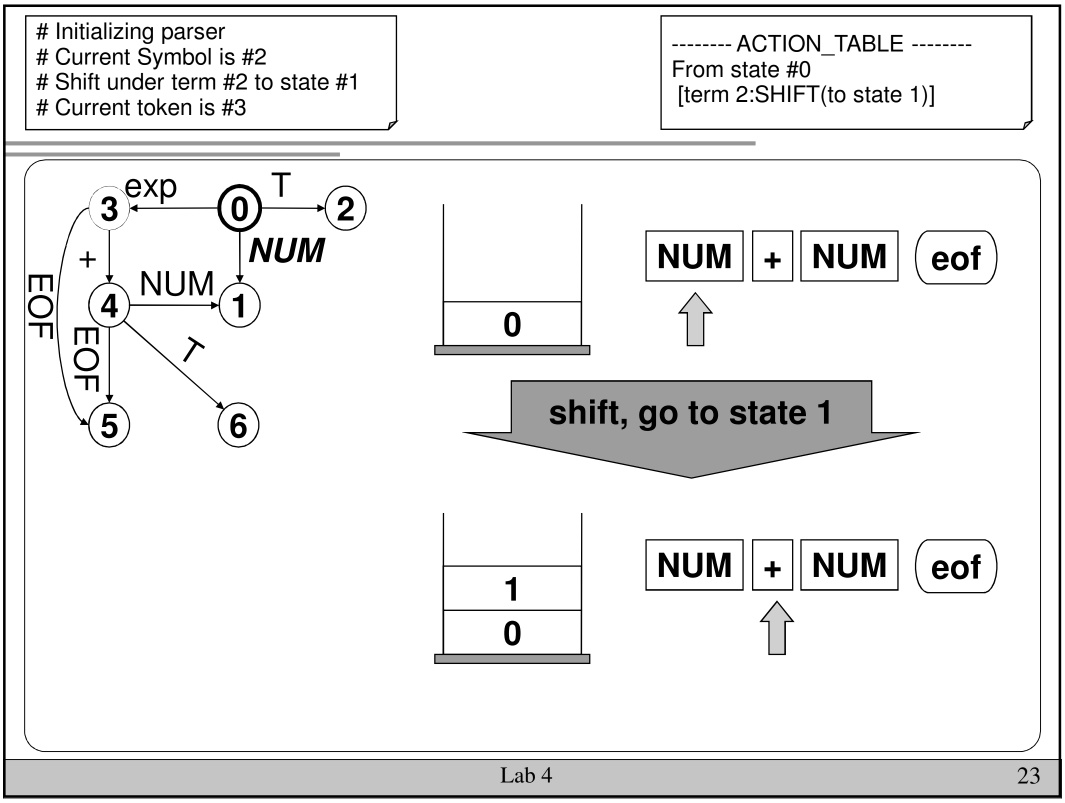
```
# Initializing parser
FOUND: 3
# Current Symbol is #2
# Shift under term #2 to state #1
FOUND: +
# Current token is #3
# Reduce with prod #3 [NT=2, SZ=1]
# Reduce rule: top state 0, lhs sym 2 -> state 2
# Goto state #2
# Reduce with prod #2 [NT=1, SZ=1]
# Reduce rule: top state 0, lhs sym 1 -> state 3
# Goto state #3
# Shift under term #3 to state #4
FOUND: 5
# Current token is #2
# Shift under term #2 to state #1
# Current token is #0
# Reduce with prod #3 [NT=2, SZ=1]
# Reduce rule: top state 4, lhs sym 2 -> state 6
# Goto state #6
Found expression
# Reduce with prod #1 [NT=1, SZ=3]
# Reduce rule: top state 0, lhs sym 1 -> state 3
# Goto state #3
----------------------------------------------------------------
# Shift under term #0 to state #5
# Current token is #0
# Reduce with prod #0 [NT=0, SZ=2]
# Reduce rule: top state 0, lhs sym 0 -> state -1
# Goto state #-1
```

Exercise

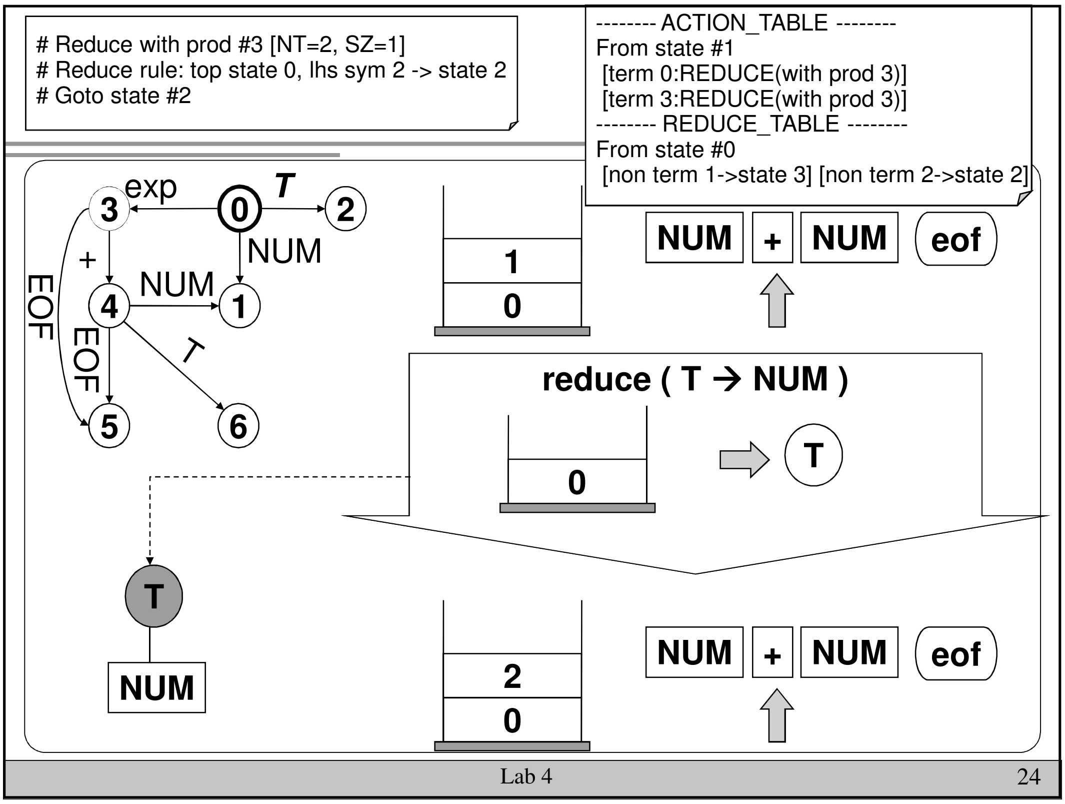
```
Salad 2.10;
Wine 12.00;
Pasta 1.50;
Bread 0.40;
%
Stefano : 2 Pasta, 1 Wine;
Giulia : 1 Salad, 1 Bread, 1 Pasta;

/* OUTPUT:
Stefano: 15.0 EURO
Giulia: 4.0 EURO
*/
```

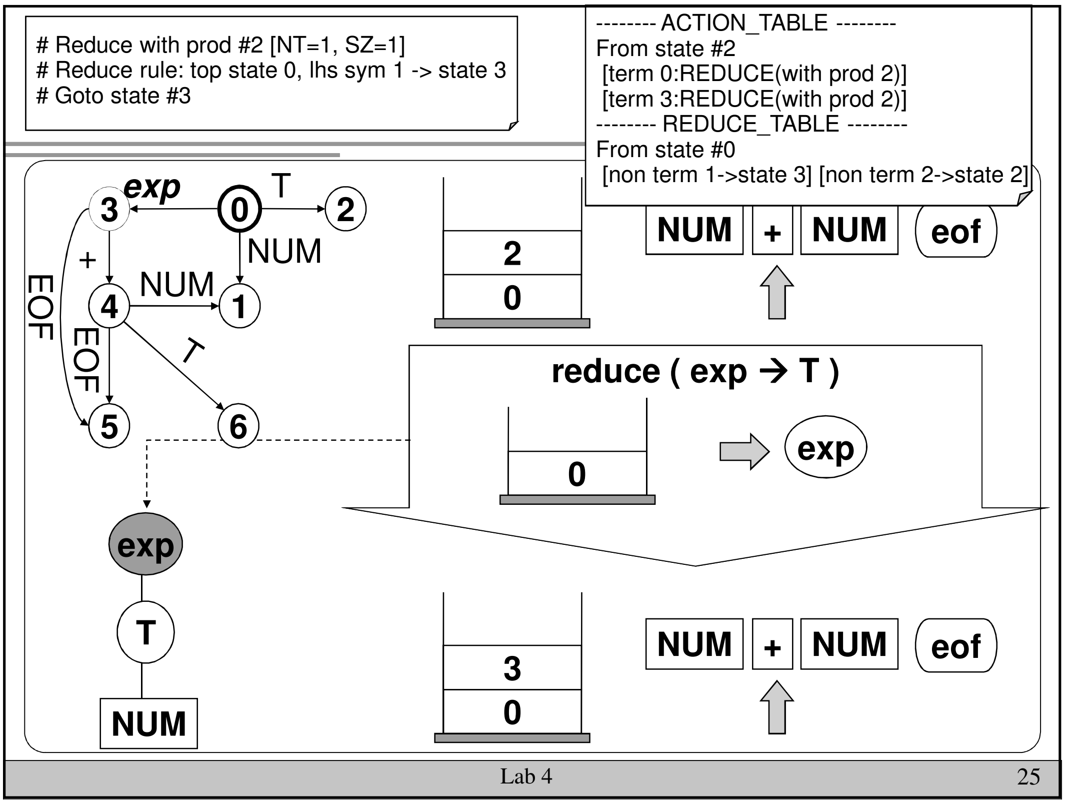

OTHER SLIDES



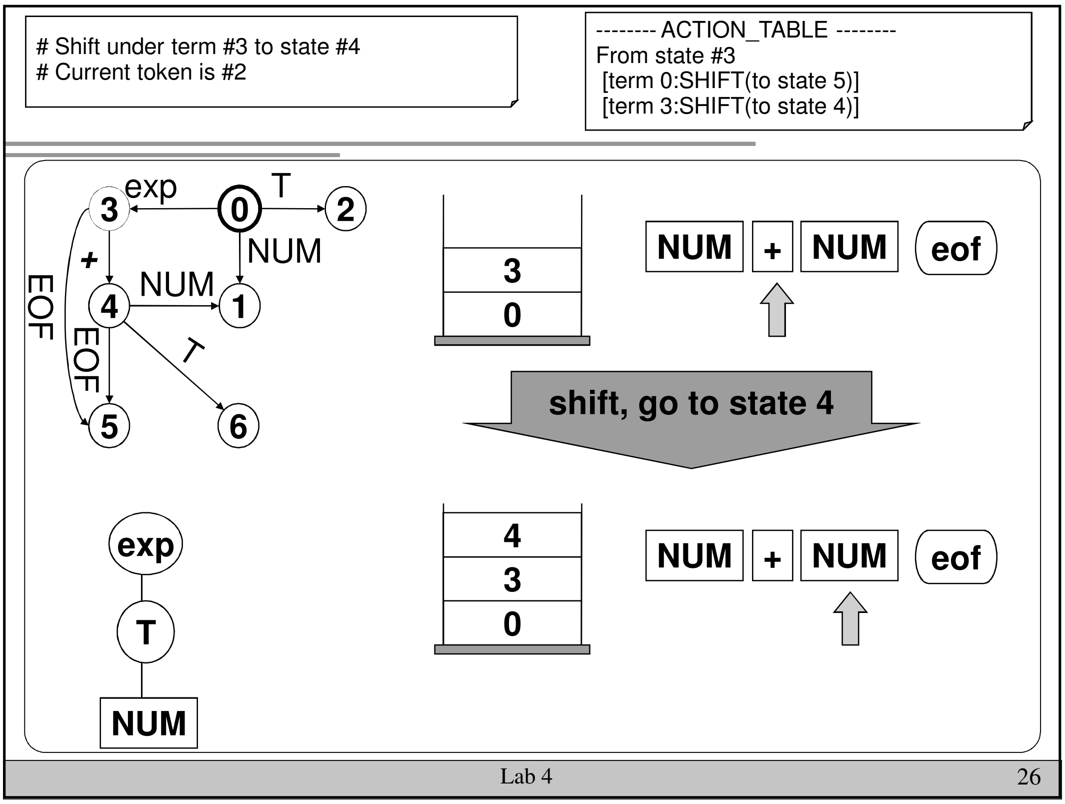
Initializing parser
Current Symbol is #2
Shift under term #2 to state #1
Current token is #3
-------- ACTION_TABLE --------
From state #0
[term 2:SHIFT(to state 1)]
exp
T
NUM
+
NUM
EOF
EOF
T
0
1
2
3
4
5
6
0
NUM + NUM eof
shift, go to state 1
1
0
NUM + NUM eof
Lab 4
23



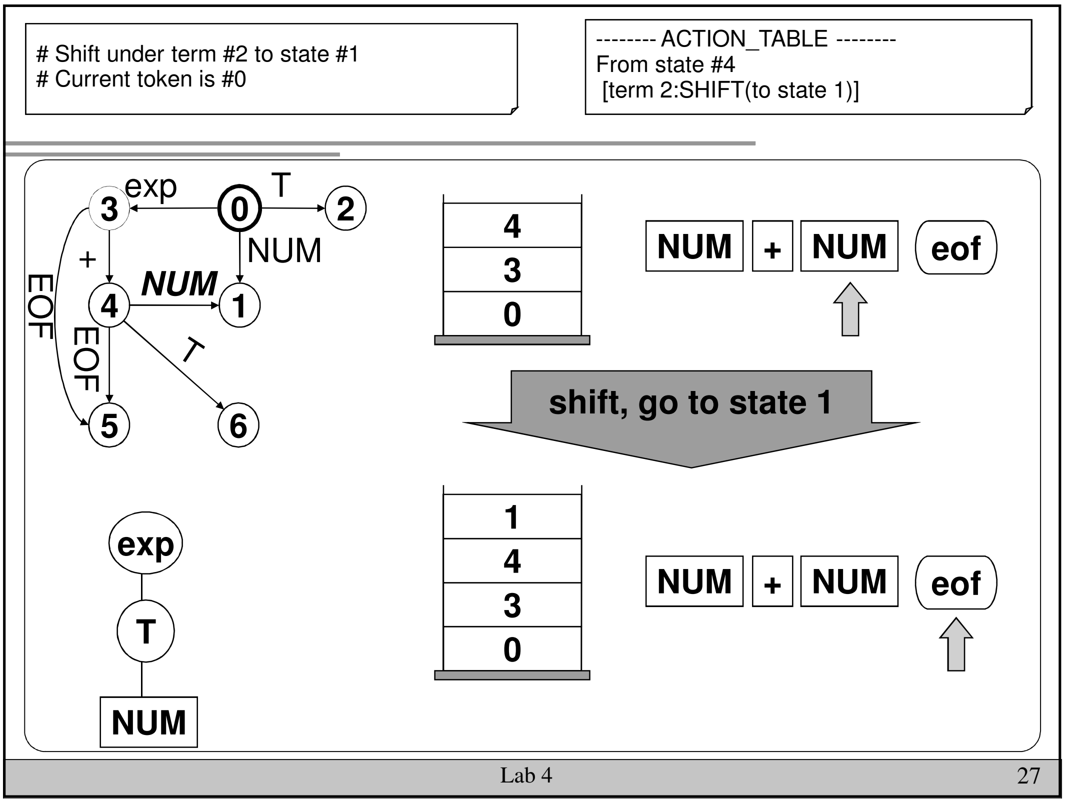
Reduce with prod #3 [NT=2, SZ=1]
Reduce rule: top state 0, lhs sym 2 -> state 2
Goto state #2
-------- ACTION_TABLE --------
From state #1
[term 0:REDUCE(with prod 3)]
[term 3:REDUCE(with prod 3)]
-------- REDUCE_TABLE --------
From state #0
[non term 1->state 3] [non term 2->state 2]
exp
T
NUM
+
NUM
EOF
EOF
T
0
1
2
3
4
5
6
1
0
NUM + NUM eof
reduce (T → NUM)
0
T
T
NUM
2
0
NUM + NUM eof
Lab 4
24

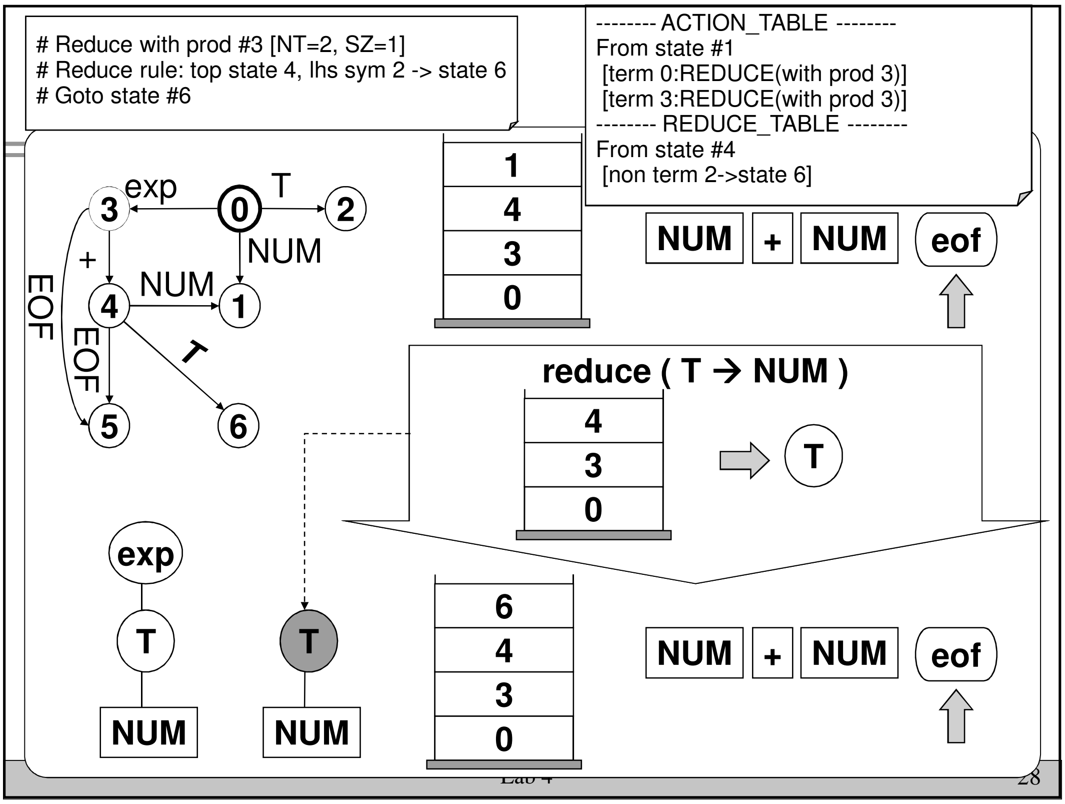


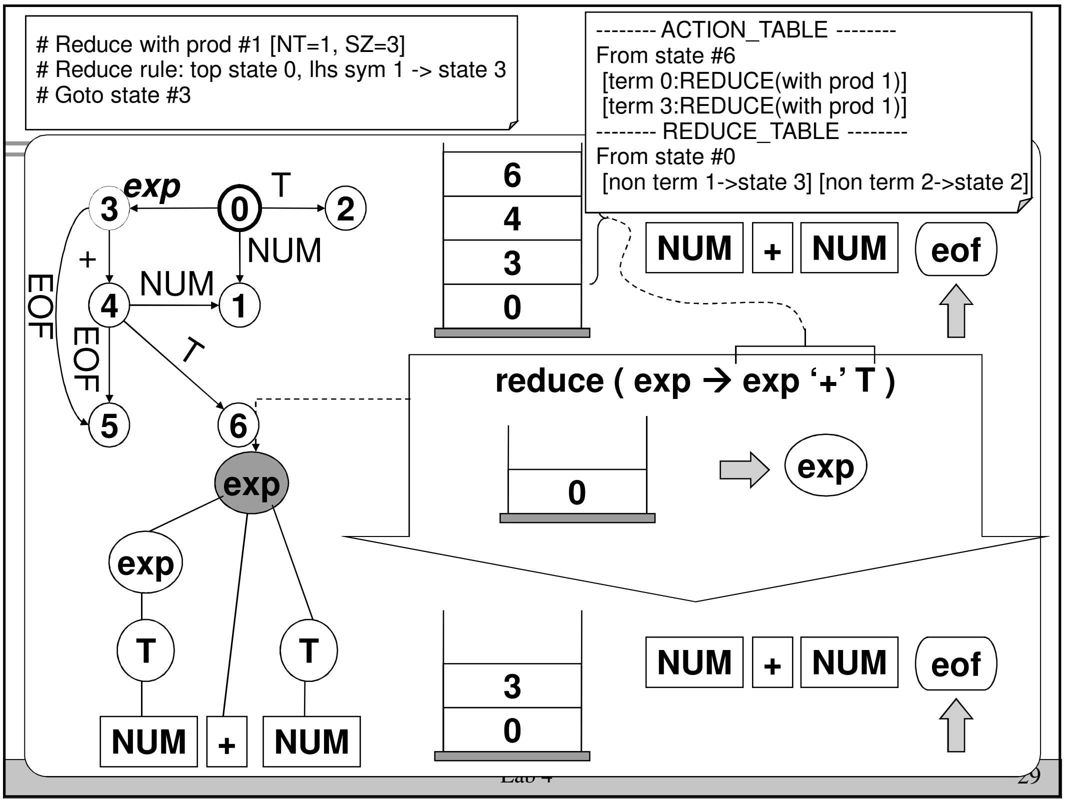
Reduce with prod #2 [NT=1, SZ=1]
Reduce rule: top state 0, lhs sym 1 -> state 3
Goto state #3
-------- ACTION_TABLE --------
From state #2
[term 0:REDUCE(with prod 2)]
[term 3:REDUCE(with prod 2)]
-------- REDUCE_TABLE --------
From state #0
[non term 1->state 3] [non term 2->state 2]
exp
T
NUM
EOF
+
reduce (exp → T)
NUM + NUM eof
Lab 4
25



Shift under term #3 to state #4
Current token is #2
-------- ACTION_TABLE --------
From state #3
[term 0:SHIFT(to state 5)]
[term 3:SHIFT(to state 4)]
exp
T
NUM
EOF
+
shift, go to state 4
NUM + NUM eof
Lab 4
26


Shift under term #2 to state #1
Current token is #0
-------- ACTION_TABLE --------
From state #4
[term 2:SHIFT(to state 1)]
exp
T
NUM
+
NUM
EOF
EOF
T
3
0
2
4
1
5
6
4
3
0
NUM
+
NUM
eof
shift, go to state 1
1
4
3
0
exp
T
NUM
NUM
+
NUM
eof
Lab 4
27


Reduce with prod #3 [NT=2, SZ=1]
Reduce rule: top state 4, lhs sym 2 -> state 6
Goto state #6
-------- ACTION_TABLE --------
From state #1
[term 0:REDUCE(with prod 3)]
[term 3:REDUCE(with prod 3)]
-------- REDUCE_TABLE --------
From state #4
[non term 2->state 6]
exp
T
NUM
+
NUM
EOF
EOF
T
1
4
3
0
NUM
+
NUM
eof
reduce (T → NUM)
4
3
0
T
exp
T
NUM
T
NUM
6
4
3
0
NUM
+
NUM
eof
28


Reduce with prod #1 [NT=1, SZ=3]
Reduce rule: top state 0, lhs sym 1 -> state 3
Goto state #3
-------- ACTION_TABLE --------
From state #6
[term 0:REDUCE(with prod 1)]
[term 3:REDUCE(with prod 1)]
-------- REDUCE_TABLE --------
From state #0
[non term 1->state 3] [non term 2->state 2]
exp
T
NUM
+
EOF
reduce (exp → exp '+' T)
NUM
+
NUM
eof
exp
Lab 4
29