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|---|---|---|---|---|
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编程语言：***python3.9***

# 实验内容

- 利用PLY实现的Python程序的解析

  本次学习的语法是**函数语句**，需要注意的是本次使用的语法做了一些改进，不是纯粹的python2语法。

  需要结合上次课四则运算的解析程序

  1.示例程序位于example4/

  2.需要进行解析的文件为快速排序

  quick_sort.py

```
def quick_sort(array, left, right){
    if(left >= right){
        return
    }
    low = left
    high = right
    key = array[low]
    while(left < right){
        while(left < right and array[right] > key){
            right -= 1
        }
        array[left] = array[right]
        while(left < right and array[left] <= key){
            left += 1
        }
        array[right] = array[left]
    }
    array[right] = key
    quick_sort(array, low, left - 1)
    quick_sort(array, left + 1, high)
}

a=[1,2,4,3,6,5,7,3]
```

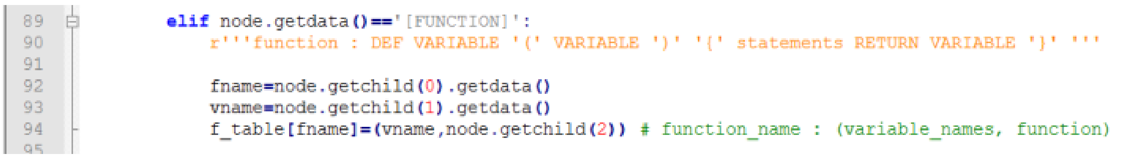
```
quick_sort(a,0,len(a)-1)

print(a)
```

3.解析结果以语法树的形式呈现

- 编程实现语法制导翻译

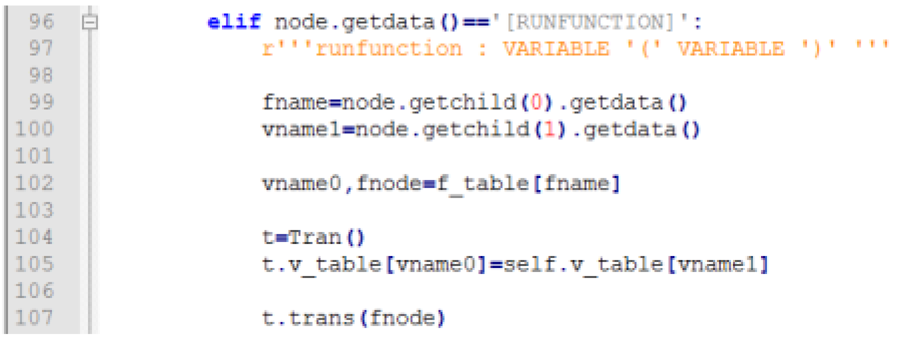
  函数的解析分为2部分：

  1.函数的定义的解析：通过一个函数表来保存每个函数的信息



```
        elif node.getdata()=='[FUNCTION]':
            r'''function : DEF VARIABLE '(' VARIABLE ')' '{' statements RETURN VARIABLE '}' '''

            fname=node.getchild(0).getdata()
            vname=node.getchild(1).getdata()
            f_table[fname]=(vname,node.getchild(2)) # function_name : (variable_names, function)
```

  2.函数的调用：当函数需要调用时，访问函数表，找到相应的函数名，并进行调用



```
        elif node.getdata()=='[RUNFUNCTION]':
            r'''runfunction : VARIABLE '(' VARIABLE ')' '''

            fname=node.getchild(0).getdata()
            vname1=node.getchild(1).getdata()

            vname0,fnode=f_table[fname]

            t=Tran()
            t.v_table[vname0]=self.v_table[vname1]

            t.trans(fnode)
```

# 实验步骤

## 使用lex进行序列标记

在本次实验中要识别的tokens包括以下

```
tokens = ('VARIABLE', 'NUMBER', 'IF', 'WHILE', 'PRINT', 'DEF', 'RETURN', 'AND',
'LEN')

literals = ['=', '+', '-', '*', '(', ')', '{', '}', '<', '>', ',', '[', ']']
```

ply使用"t_"开头的变量来表示规则。如果变量是一个字符串，那么它被解释为一个正则表达式，匹配值是标记的值。 如果变量是函数，则其文档字符串包含模式，并使用匹配的标记调用该函数。该函数可以自由地修改序列或返回一个新的序列来代替它的位置。 如果没有返回任何内容，则忽略匹配。 通常该函数只更改“value”属性，它最初是匹配的文本。

```
def t_NUMBER(t):
    r'[0-9]+'
    return t
def t_PRINT(t):
    r'print'
    return t
def t_IF(t):
    r'if'
    return t
def t_WHILE(t):
    r'while'
    return t
```

```
def t_DEF(t):
    r'def'
    return t
def t_RETURN(t):
    r'return'
    return t
def t_AND(t):
    r'and'
    return t
def t_LEN(t):
    r'len'
    return t
def t_VARIABLE(t):
    r'[a-zA-Z\$_][a-zA-Z\d_]*'
    return t
# Ignored
t_ignore = " \t"
def t_error(t):
    print("Illegal character '%s'" % t.value[0])
    t.lexer.skip(1)
```

对quick_sort.py进行测试，输出每一个识别到的token

```
from util import clear_text
text=clear_text(open('quick_sort.py','r').read())
lex.input(text)
for tok in iter(lex.token, None):
    print(repr(tok.type), repr(tok.value))
```

util中的clear_text函数为清除每行的空格

```
def clear_text(text):
    lines=[]
    for line in text.split('\n'):
        line=line.strip()
        if len(line)>0:
            lines.append(line)
    return ' '.join(lines)
```

## 使用yacc进行语法分析

PLY 的解析器适用于lex解析出的序列标记。 它使用 BNF 语法来描述这些标记是如何组装的。

对node进行定义

```
class node:
    def __init__(self, data):
        self._data = data
        self._children = []
        self._value = None
    def getdata(self):
        return self._data
    def setvalue(self, value):
        self._value = value
    def getvalue(self):
        return self._value
    def getchild(self, i):
        return self._children[i]
    def getchildren(self):
        return self._children
    def add(self, node):
        self._children.append(node)
    def print_node(self, prefix):
        print ('  ' * prefix, '+', self._data)
        for child in self._children:
            child.print_node(prefix + 1)
def num_node(data):
    t = node(data)
    t.setvalue(float(data))
    return t
```

定义文法

```
# YACC for parsing Python
def simple_node(t, name):
    t[0] = node(name)
    for i in range(1, len(t)):
        t[0].add(node(t[i]))
    return t[0]
def p_program(t):
    '''program : statements'''
    if len(t) == 2:
        t[0] = node('[PROGRAM]')
        t[0].add(t[1])
def p_statements(t):
    '''statements : statements statement
                  | statement'''
    if len(t) == 3:
        t[0] = node('[STATEMENTS]')
        t[0].add(t[1])
        t[0].add(t[2])
    elif len(t) == 2:
        t[0] = node('[STATEMENTS]')
        t[0].add(t[1])
def p_statement(t):
    ''' statement :
                  | assignment
                  | operation
                  | print
                  | if
                  | while
                  | function
                  | run_function
                  | return'''
    if len(t) == 1:
        t[0] = node('[STATEMENT]')
        t[0].add(node('[NONE]'))
    elif len(t) == 2:
        t[0] = node('[STATEMENT]')
        t[0].add(t[1])
def p_assignment(t):
    '''assignment : VARIABLE '=' NUMBER
                  | VARIABLE '[' expression ']' '=' NUMBER
```

```
                    | VARIABLE '=' VARIABLE
                    | VARIABLE '=' VARIABLE '[' expression ']'
                    | VARIABLE '=' num_list'''
    if len(t) == 4:
        if isinstance(t[3], str):       # NUMBER or VARIABLE
            if ord('0') <= ord(t[3][0]) <= ord('9'):    # NUMBER
                t[0] = node('[ASSIGNMENT]')
                t[0].add(node(t[1]))
                t[0].add(node(t[2]))
                t[0].add(num_node(t[3]))
            else:                                       # VARIABLE
                t[0] = node('[ASSIGNMENT]')
                t[0].add(node(t[1]))
                t[0].add(node(t[2]))
                t[0].add(node(t[3]))
        else:                           # num_list
            t[0] = node('[ASSIGNMENT]')
            t[0].add(node(t[1]))
            t[0].add(node(t[2]))
            t[0].add(t[3])
    elif len(t) == 7:
        if t[2] == '[':                 # NUMBER
            t[0] = node('[ASSIGNMENT]')
            t[0].add(node(t[1]))
            t[0].add(t[3])
            t[0].add(node(t[5]))
            t[0].add(num_node(t[6]))
        else:                           # VARIABLE '[' expression ']'
            t[0] = node('[ASSIGNMENT]')
            t[0].add(node(t[1]))
            t[0].add(node(t[2]))
            t[0].add(node(t[3]))
            t[0].add(t[5])
def p_num_list(t):
    '''num_list : '[' numbers ']' '''
    if len(t) == 4:
        t[0] = node('[NUM_LIST]')
        t[0].add(t[2])
def p_numbers(t):
    '''numbers : NUMBER
           | numbers ',' NUMBER'''
    if len(t) == 2:
        t[0] = node('[NUMBERS]')
        t[0].add(num_node(t[1]))
    elif len(t) == 4:
        t[0] = node('[NUMBERS]')
        t[0].add(t[1])
        t[0].add(num_node(t[3]))
def p_operation(t):
    '''operation : VARIABLE '=' expression
                 | VARIABLE '+' '=' expression
                 | VARIABLE '-' '=' expression
                 | VARIABLE '[' expression ']' '=' expression'''
    if len(t) == 4:
        t[0] = node('[OPERATION]')
        t[0].add(node(t[1]))
        t[0].add(node(t[2]))
        t[0].add(t[3])
    elif len(t) == 5:
        t[0] = node('[OPERATION]')
        t[0].add(node(t[1]))
        t[0].add(node(t[2] + t[3]))
        t[0].add(t[4])
    elif len(t) == 7:
        t[0] = node('[OPERATION]')
        t[0].add(node(t[1]))
        t[0].add(t[3])
        t[0].add(node(t[5]))
        t[0].add(t[6])
def p_expression(t):
    '''expression : expression '+' term
                  | expression '-' term
                  | term
                  | LEN '(' factor ')' '''
    if len(t) == 4:
        t[0] = node('[EXPRESSION]')
        t[0].add(t[1])
        t[0].add(node(t[2]))
        t[0].add(t[3])
    elif len(t) == 2:
        t[0] = node('[EXPRESSION]')
        t[0].add(t[1])
    elif len(t) == 5:
        t[0] = node('[EXPRESSION]')
        t[0].add(node('[LEN]'))
        t[0].add(t[3])
def p_term(t):
    '''term : term '*' factor
            | term '/' factor
            | factor'''
    if len(t) == 4:
        t[0] = node('[TERM]')
        t[0].add(t[1])
        t[0].add(node(t[2]))
        t[0].add(t[3])
    elif len(t) == 2:
        t[0] = node('[TERM]')
        t[0].add(t[1])
def p_factor(t):
    '''factor : NUMBER
              | VARIABLE
              | VARIABLE '[' expression ']'
              | '(' expression ')' '''
    if len(t) == 2:
        if ord('0') <= ord(t[1][0]) <= ord('9'):       # NUMBER
            t[0] = node('[FACTOR]')
            t[0].add(num_node(t[1]))
        else:                                           # VARIABLE
            t[0] = node('[FACTOR]')
            t[0].add(node(t[1]))
    elif len(t) == 4:
        t[0] = node('[FACTOR]')
        t[0].add(t[2])
    elif len(t) == 5:
        t[0] = node('[FACTOR]')
        t[0].add(node(t[1]))
```

```python
        t[0].add(t[3])
def p_print(t):
    '''print : PRINT '(' VARIABLE ')' '''
    if len(t) == 5:
        t[0] = node('[PRINT]')
        t[0].add(node(t[3]))
def p_if(t):
    '''if : IF '(' condition ')' '{' statements '}' '''
    if len(t) == 8:
        t[0] = node('[IF]')
        t[0].add(t[3])
        t[0].add(t[6])
def p_while(t):
    '''while : WHILE '(' conditions ')' '{' statements '}' '''
    if len(t) == 8:
        t[0] = node('[WHILE]')
        t[0].add(t[3])
        t[0].add(t[6])
def p_conditions(t):
    '''conditions : condition
                  | condition AND condition'''
    if len(t) == 2:
        t[0] = node('[CONDITIONS]')
        t[0].add(t[1])
    elif len(t) == 4:
        t[0] = node('[CONDITIONS]')
        t[0].add(t[1])
        t[0].add(t[3])
def p_condition(t):
    '''condition : factor '>' factor
                 | factor '<' factor
                 | factor '<' '=' factor
                 | factor '>' '=' factor'''
    if len(t) == 4:
        t[0] = node('[CONDITION]')
        t[0].add(t[1])
        t[0].add(node(t[2]))
        t[0].add(t[3])
    elif len(t) == 5:
        t[0] = node('[CONDITION]')
        t[0].add(t[1])
        t[0].add(node(t[2] + t[3]))
        t[0].add(t[4])
def p_function(t):
    '''function : DEF VARIABLE '(' variables ')' '{' statements '}' '''
    if len(t) == 9:
        t[0] = node('[FUNCTION]')
        t[0].add(node(t[2]))
        t[0].add(t[4])
        t[0].add(t[7])
def p_run_function(t):
    '''run_function : VARIABLE '(' expressions ')' '''
    if len(t) == 5:
        t[0] = node('[RUN_FUNCTION]')
        t[0].add(node(t[1]))
        t[0].add(t[3])
def p_variables(t):
    '''variables :
```

```
                   | VARIABLE
                   | variables ',' VARIABLE'''
    if len(t) == 1:
        t[0] = node('[VARIABLES]')
        t[0].add(node('[NONE]'))
    elif len(t) == 2:
        t[0] = node('[VARIABLES]')
        t[0].add(node(t[1]))
    elif len(t) == 4:
        t[0] = node('[VARIABLES]')
        t[0].add(t[1])
        t[0].add(node(t[3]))
def p_expressions(t):
    '''expressions : expression
                   | expressions ',' expression'''
    if len(t) == 2:
        t[0] = node('[EXPRESSIONS]')
        t[0].add(t[1])
    elif len(t) == 4:
        t[0] = node('[EXPRESSIONS]')
        t[0].add(t[1])
        t[0].add(t[3])
def p_return(t):
    '''return : RETURN variables'''
    if len(t) == 3:
        t[0] = node('[RETURN]')
        t[0].add(t[2])
def p_error(t):
    print("Syntax error at '%s'" % t.value)
yacc.yacc()
```

# 实现语法制导翻译

定义变量存储函数

```
f_table={}
```

定义Tran类来进行翻译

v_table 存储变量

update_v_table函数对变量表进行更新

```
class Tran:
    def __init__(self):
        self.v_table = {}  # variable table
    def update_v_table(self, name, value):
        self.v_table[name] = value
```

ASSIGNMENT的文法

$$ASSIGENMENT:$$
$$VARIABLE = NUMBER$$
$$|VARIABLE[expression] = NUMBER$$
$$|VARIABLE = VARIABLE$$
$$|VARIABLE = VARIABLE[expression]|VARIABLE = num\_list$$

```
def trans(self, node):
    # Translation
    # Assignment
    if node.getdata() == '[ASSIGNMENT]':
        r'''assignment : VARIABLE '=' NUMBER
                       | VARIABLE '[' expression ']' '=' NUMBER
                       | VARIABLE '=' VARIABLE
                       | VARIABLE '=' VARIABLE '[' expression ']'
                       | VARIABLE '=' num_list'''
        if len(node.getchildren()) == 3:
            if ord('0') <= ord(node.getchild(2).getdata()[0]) <= ord('9'):  #
NUMBER
                value = node.getchild(2).getvalue()
                # update v_table
                self.update_v_table(node.getchild(0).getdata(), value)
            elif node.getchild(2).getdata() == '[NUM_LIST]':  # num_list
                self.trans(node.getchild(2))
                value = node.getchild(2).getvalue()
                # update v_table
                self.update_v_table(node.getchild(0).getdata(), value)
            else:  # VARIABLE
                value = self.v_table[node.getchild(2).getdata()]
                # update v_table
                self.update_v_table(node.getchild(0).getdata(), value)
        elif len(node.getchildren()) == 4:
            if node.getchild(2).getdata() == '=':  # NUMBER
                arg = self.v_table[node.getchild(0).getdata()]
                self.trans(node.getchild(1))
                index = int(node.getchild(1).getvalue())
                value = node.getchild(3).getvalue()
                # update VARIABLE
                arg[index] = value
            elif node.getchild(1).getdata() == '=':  # VARIABLE '[' expression
']'
                arg1 = self.v_table[node.getchild(2).getdata()]
                self.trans(node.getchild(3))
                index = int(node.getchild(3).getvalue())
                value = arg1[index]
                # update v_table
                self.update_v_table(node.getchild(0).getdata(), value)
```

Num_list

$num\_list:$

$[numebers]$

```
elif node.getdata() == '[NUM_LIST]':
    '''num_list : '[' numbers ']' '''
    if len(node.getchildren()) == 1:
        self.trans(node.getchild(0))
        value = [float(x) for x in node.getchild(0).getvalue().split()]
        node.setvalue(value)
```

Numbers

$$numbers:$$

$$NUMBER$$

$$|numbers, NUMBER$$

```
elif node.getdata() == '[NUMBERS]':
    '''numbers : NUMBER
               | numbers ',' NUMBER'''
    if len(node.getchildren()) == 1:
        value = str(node.getchild(0).getvalue())
        node.setvalue(value)
    elif len(node.getchildren()) == 2:
        self.trans(node.getchild(0))
        value0 = node.getchild(0).getvalue()
        value1 = str(node.getchild(1).getvalue())
        value = value0 + ' ' + value1
        node.setvalue(value)
```

Operation

$$operation:$$

$$VARIABLE = expression$$

$$|VARIABLE+ = expression$$

$$|VARIABLE- = expression$$

$$|VARIABLE[expression] = expression$$

```
elif node.getdata() == '[OPERATION]':
    '''operation : VARIABLE '=' expression
                 | VARIABLE '+' '=' expression
                 | VARIABLE '-' '=' expression
                 | VARIABLE '[' expression ']' '=' expression'''
    if len(node.getchildren()) == 3:
        if node.getchild(1).getdata()[0] == '=':  # '='
            self.trans(node.getchild(2))
            value = node.getchild(2).getvalue()
            node.getchild(0).setvalue(value)
            # update v_table
            self.update_v_table(node.getchild(0).getdata(), value)
        elif node.getchild(1).getdata()[1] == '=':  # '+=' or '-='
            arg1 = self.v_table[node.getchild(0).getdata()]
            self.trans(node.getchild(2))
            arg2 = node.getchild(2).getvalue()
            op = node.getchild(1).getdata()[0]
            if op == '+':
                value = arg1 + arg2
            elif op == '-':
                value = arg1 - arg2
            node.getchild(0).setvalue(value)
            # update v_table
            self.update_v_table(node.getchild(0).getdata(), value)
    elif len(node.getchildren()) == 4:
        arg = self.v_table[node.getchild(0).getdata()]
        self.trans(node.getchild(1))
        index = int(node.getchild(1).getvalue())
        self.trans(node.getchild(3))
        value = node.getchild(3).getvalue()
        # update VARIABLE
        arg[index] = value
```

Expression

$$expr:$$
$$expression + term$$
$$|expression - term$$
$$|term$$
$$|LEN(factor)$$

```
elif node.getdata() == '[EXPRESSION]':
    '''expr : expression '+' term
            | expression '-' term
            | term
            | LEN '(' factor ')' '''
    if len(node.getchildren()) == 3:
        self.trans(node.getchild(0))
        arg0 = node.getchild(0).getvalue()
        self.trans(node.getchild(2))
        arg1 = node.getchild(2).getvalue()
        op = node.getchild(1).getdata()
        if op == '+':
            value = arg0 + arg1
        elif op == '-':
            value = arg0 - arg1
        node.setvalue(value)
    elif len(node.getchildren()) == 1:  # term
        self.trans(node.getchild(0))
        value = node.getchild(0).getvalue()
        node.setvalue(value)
    elif len(node.getchildren()) == 2:
        self.trans(node.getchild(1))
        value = len(node.getchild(1).getvalue())
        node.setvalue(value)
```

Term

$$term:$$
$$term * factor$$
$$|term/factor$$
$$|factor$$

```
elif node.getdata() == '[TERM]':
    '''term : term '*' factor
            | term '/' factor
            | factor'''
    if len(node.getchildren()) == 3:
        self.trans(node.getchild(0))
        arg0 = node.getchild(0).getvalue()
        self.trans(node.getchild(2))
        arg1 = node.getchild(2).getvalue()
        op = node.getchild(1).getdata()
        if op == '*':
            value = arg0 + arg1
        elif op == '/':
            value = arg0 - arg1
        node.setvalue(value)
    elif len(node.getchildren()) == 1:
        self.trans(node.getchild(0))
        value = node.getchild(0).getvalue()
        node.setvalue(value)
```

factor

$$
\begin{gathered}
factor: \\
NUMBER \\
|VARIABLE \\
|VARIABLE[expression] \\
|(expression)
\end{gathered}
$$

```
elif node.getdata() == '[FACTOR]':
    '''factor : NUMBER
              | VARIABLE
              | VARIABLE '[' expression ']'
              | '(' expression ')' '''
    if len(node.getchildren()) == 1:
        if ord('0') <= ord(node.getchild(0).getdata()[0]) <= ord('9'):  # NUMBER
            value = node.getchild(0).getvalue()
            node.setvalue(value)
        elif node.getchild(0).getdata() == '[EXPRESSION]':              # '('
expr ')'
            self.trans(node.getchild(0))
            value = node.getchild(0).getvalue()
            node.setvalue(value)
        else:                                                           #
VARIABLE
            value = self.v_table[node.getchild(0).getdata()]
            node.setvalue(value)
    elif len(node.getchildren()) == 2:
        arg = self.v_table[node.getchild(0).getdata()]
        self.trans(node.getchild(1))
        index = int(node.getchild(1).getvalue())
        value = arg[index]
        node.setvalue(value)
```

print

$$
\begin{gathered}
print: \\
PRINT(VARIABLE)
\end{gathered}
$$

```
elif node.getdata() == '[PRINT]':
    '''print : PRINT '(' VARIABLE ')' '''
    arg0 = self.v_table[node.getchild(0).getdata()]
    print(arg0)
```

If

$$if : \\ IF(condition)\{statements\}$$

```
elif node.getdata() == '[IF]':
    r'''if : IF '(' condition ')' '{' statements '}' '''
    children = node.getchildren()
    self.trans(children[0])
    condition = children[0].getvalue()
    if condition:
        for c in children[1:]:
            value = self.trans(c)
            if isinstance(value, list) and value[0] == '[RETURN]':
                return value
```

Whlie

$$while : \\ WHILE(conditions)\{statements\}$$

```
elif node.getdata() == '[WHILE]':
    r'''while : WHILE '(' conditions ')' '{' statements '}' '''
    children = node.getchildren()
    while self.trans(children[0]):
        for c in children[1:]:
            self.trans(c)
```

Conditions

$$conditions : \\ condition \\ |condition AND condition$$

```
elif node.getdata() == '[CONDITIONS]':
    '''conditions : condition
                  | condition AND condition'''
    if len(node.getchildren()) == 1:
        self.trans(node.getchild(0))
        value = node.getchild(0).getvalue()
        node.setvalue(value)
    elif len(node.getchildren()) == 2:
        self.trans(node.getchild(0))
        arg0 = node.getchild(0).getvalue()
        self.trans(node.getchild(1))
        arg1 = node.getchild(1).getvalue()
        value = arg0 and arg1
        node.setvalue(value)
```

Condition

$$\begin{aligned} condition :& \\ factor > factor& \\ |factor < factor& \\ |factor <= factor& \\ |factor >= factor& \end{aligned}$$

```python
elif node.getdata() == '[CONDITION]':
    '''condition : factor '>' factor
                 | factor '<' factor
                 | factor '<' '=' factor
                 | factor '>' '=' factor'''
    self.trans(node.getchild(0))
    arg0 = node.getchild(0).getvalue()
    self.trans(node.getchild(2))
    arg1 = node.getchild(2).getvalue()
    op = node.getchild(1).getdata()
    if op == '>':
        node.setvalue(arg0 > arg1)
    elif op == '<':
        node.setvalue(arg0 < arg1)
    elif op == '<=':
        node.setvalue(arg0 <= arg1)
    elif op == '>=':
        node.setvalue(arg0 >= arg1)
```

Function

$$function : DEFVARIABLE(variables)\{statements\}$$

```python
elif node.getdata() == '[FUNCTION]':
    '''function : DEF VARIABLE '(' variables ')' '{' statements '}' '''
    fname = node.getchild(0).getdata()
    self.trans(node.getchild(1))
    vname = node.getchild(1).getvalue()
    f_table[fname] = (vname, node.getchild(2))  # function_name :
(variable_names, function)
```

Run_function

$$run\_function : VARIABLE(expressions)$$

```python
elif node.getdata() == '[RUN_FUNCTION]':
    '''run_function : VARIABLE '(' expressions ')' '''
    fname = node.getchild(0).getdata()
    self.trans(node.getchild(1))
    vname1 = node.getchild(1).getvalue()
    vname0, fnode = f_table[fname]
    t = Tran()
    for i in range(len(vname1)):
        t.v_table[vname0[i]] = vname1[i]
    value = t.trans(fnode)
    if isinstance(value, list):
        node.setvalue(value[1])
    print(t.v_table)
```

Variables

$$variables :$$
$$VARIABLE$$
$$|variables, VARIABLE$$

```
elif node.getdata() == '[VARIABLES]':
    '''variables :
                 | VARIABLE
                 | variables ',' VARIABLE'''
    if len(node.getchildren()) == 1:
        if node.getchild(0).getdata() == '[NONE]':  # NONE
            value = []
            node.setvalue(value)
        else:                                        # VARIABLE
            value = [node.getchild(0).getdata()]
            node.setvalue(value)
    elif len(node.getchildren()) == 2:
        self.trans(node.getchild(0))
        value0 = node.getchild(0).getvalue()
        value = [node.getchild(1).getdata()]
        value.extend(value0)
        node.setvalue(value)
```

Expressions

$$expressions :$$
$$expression$$
$$|expression, expression$$

```
elif node.getdata() == '[EXPRESSIONS]':
    '''expressions : expression
                   | expressions ',' expression'''
    if len(node.getchildren()) == 1:
        self.trans(node.getchild(0))
        value = [node.getchild(0).getvalue()]
        node.setvalue(value)
    elif len(node.getchildren()) == 2:
        self.trans(node.getchild(0))
        value0 = node.getchild(0).getvalue()
        self.trans(node.getchild(1))
        value = [node.getchild(1).getvalue()]
        value.extend(value0)
        node.setvalue(value)
```

Return

$$return : RETURNvariables$$

```
elif node.getdata() == '[RETURN]':
    '''return : RETURN variables'''
    return ['[RETURN]', node.getchild(0).getvalue()]
else:
    for c in node.getchildren():
        value = self.trans(c)
        if isinstance(value, list) and value[0] == '[RETURN]':
            return value
return node.getvalue()
```

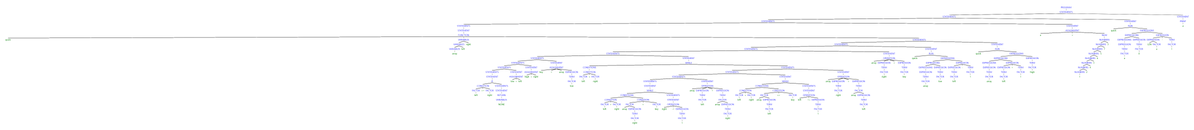
# 实验结果

## 主程序代码

```
def translation(filename):
    text = clear_text(open(filename, 'r').read())
    def put2str(node):
        global res
        if node:
            data = str(node._data)
            data = data.replace("[", "").replace("]", "").replace("/'", "")
            res += data
        if node._children:
            for i in node._children:
                res += "["
                put2str(i)
                res += "]"
    # syntax parse
    root = yacc.parse(text)
    root.print_node(0)
    # translation
    t = Tran()
    t.trans(root)
    print(t.v_table)

    put2str(root)
    print("["+res+"]")
if __name__ == '__main__':
    res = ""
    translation("quick_sort.py")
```

## 结果

字符串形式的语法树



输出

```
+ [PROGRAM]
  + [STATEMENTS]
    + [STATEMENTS]
      + [STATEMENTS]
```

```
        + [STATEMENTS]
          + [STATEMENT]
            + [FUNCTION]
              + quick_sort
              + [VARIABLES]
                + [VARIABLES]
                  + [VARIABLES]
                    + array
                  + left
                + right
              + [STATEMENTS]
                + [STATEMENTS]
                  + [STATEMENTS]
                    + [STATEMENTS]
                      + [STATEMENTS]
                        + [STATEMENTS]
                          + [STATEMENTS]
                            + [STATEMENTS]
                              + [STATEMENT]
                                + [IF]
                                  + [CONDITION]
                                    + [FACTOR]
                                      + left
                                    + >=
                                    + [FACTOR]
                                      + right
                                  + [STATEMENTS]
                                    + [STATEMENT]
                                      + [RETURN]
                                        + [VARIABLES]
                                          + [NONE]
                            + [STATEMENT]
                              + [ASSIGNMENT]
                                + low
                                + =
                                + left
                          + [STATEMENT]
                            + [ASSIGNMENT]
                              + high
                              + =
                              + right
                        + [STATEMENT]
                          + [ASSIGNMENT]
                            + key
                            + =
                            + array
                            + [EXPRESSION]
                              + [TERM]
                                + [FACTOR]
                                  + low
                      + [STATEMENT]
                        + [WHILE]
                          + [CONDITIONS]
                            + [CONDITION]
                              + [FACTOR]
                                + left
                              + <
                              + [FACTOR]
```

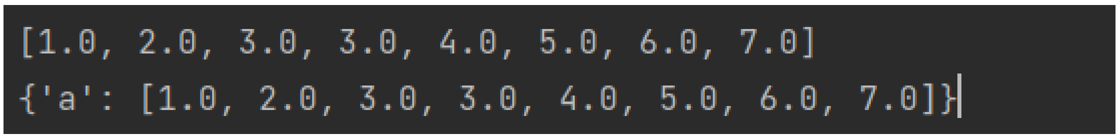
```
      + right
+ [STATEMENTS]
  + [STATEMENTS]
    + [STATEMENTS]
      + [STATEMENTS]
        + [STATEMENT]
          + [WHILE]
            + [CONDITIONS]
              + [CONDITION]
                + [FACTOR]
                  + left
                + <
                + [FACTOR]
                  + right
              + [CONDITION]
                + [FACTOR]
                  + array
                  + [EXPRESSION]
                    + [TERM]
                      + [FACTOR]
                        + right
                + >
                + [FACTOR]
                  + key
            + [STATEMENTS]
              + [STATEMENT]
                + [OPERATION]
                  + right
                  + -=
                  + [EXPRESSION]
                    + [TERM]
                      + [FACTOR]
                        + 1
      + [STATEMENT]
        + [OPERATION]
          + array
          + [EXPRESSION]
            + [TERM]
              + [FACTOR]
                + left
          + =
          + [EXPRESSION]
            + [TERM]
              + [FACTOR]
                + array
                + [EXPRESSION]
                  + [TERM]
                    + [FACTOR]
                      + right
    + [STATEMENT]
      + [WHILE]
        + [CONDITIONS]
          + [CONDITION]
            + [FACTOR]
              + left
            + <
            + [FACTOR]
              + right
```

```
                  + [CONDITION]
                    + [FACTOR]
                      + array
                      + [EXPRESSION]
                        + [TERM]
                          + [FACTOR]
                            + left
                    + <=
                    + [FACTOR]
                      + key
                + [STATEMENTS]
                  + [STATEMENT]
                    + [OPERATION]
                      + left
                      + +=
                      + [EXPRESSION]
                        + [TERM]
                          + [FACTOR]
                            + 1
          + [STATEMENT]
            + [OPERATION]
              + array
              + [EXPRESSION]
                + [TERM]
                  + [FACTOR]
                    + right
              + =
              + [EXPRESSION]
                + [TERM]
                  + [FACTOR]
                    + array
                    + [EXPRESSION]
                      + [TERM]
                        + [FACTOR]
                          + left
  + [STATEMENT]
    + [OPERATION]
      + array
      + [EXPRESSION]
        + [TERM]
          + [FACTOR]
            + right
      + =
      + [EXPRESSION]
        + [TERM]
          + [FACTOR]
            + key
+ [STATEMENT]
  + [RUN_FUNCTION]
    + quick_sort
    + [EXPRESSIONS]
      + [EXPRESSIONS]
        + [EXPRESSIONS]
          + [EXPRESSION]
            + [TERM]
              + [FACTOR]
                + array
        + [EXPRESSION]
```

```
                              + [TERM]
                                + [FACTOR]
                                  + low
                          + [EXPRESSION]
                            + [EXPRESSION]
                              + [TERM]
                                + [FACTOR]
                                  + left
                            + -
                            + [TERM]
                              + [FACTOR]
                                + 1
                  + [STATEMENT]
                    + [RUN_FUNCTION]
                      + quick_sort
                      + [EXPRESSIONS]
                        + [EXPRESSIONS]
                          + [EXPRESSIONS]
                            + [EXPRESSION]
                              + [TERM]
                                + [FACTOR]
                                  + array
                          + [EXPRESSION]
                            + [EXPRESSION]
                              + [TERM]
                                + [FACTOR]
                                  + left
                            + +
                            + [TERM]
                              + [FACTOR]
                                + 1
                        + [EXPRESSION]
                          + [TERM]
                            + [FACTOR]
                              + high
          + [STATEMENT]
            + [ASSIGNMENT]
              + a
              + =
              + [NUM_LIST]
                + [NUMBERS]
                  + [NUMBERS]
                    + [NUMBERS]
                      + [NUMBERS]
                        + [NUMBERS]
                          + [NUMBERS]
                            + [NUMBERS]
                              + [NUMBERS]
                                + 1
                              + 2
                            + 4
                          + 3
                        + 6
                      + 5
                    + 7
                  + 3
        + [STATEMENT]
          + [RUN_FUNCTION]
```

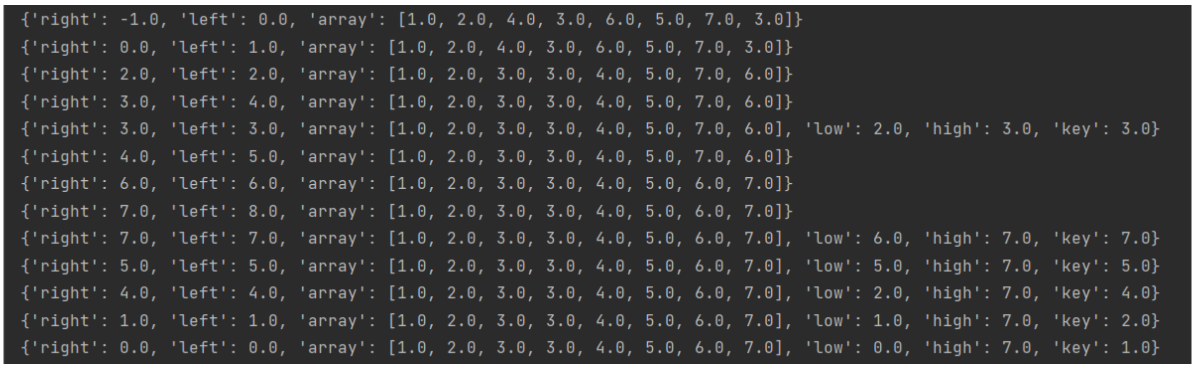
```
            + quick_sort
            + [EXPRESSIONS]
              + [EXPRESSIONS]
                + [EXPRESSIONS]
                  + [EXPRESSION]
                    + [TERM]
                      + [FACTOR]
                        + a
                + [EXPRESSION]
                  + [TERM]
                    + [FACTOR]
                      + 0
              + [EXPRESSION]
                + [EXPRESSION]
                  + [LEN]
                  + [FACTOR]
                    + a
                + -
                + [TERM]
                  + [FACTOR]
                    + 1
      + [STATEMENT]
        + [PRINT]
          + a
```

翻译结果



```
[1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 6.0, 7.0]
{'a': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 6.0, 7.0]}
```

每次调用函数，函数局部变量的结果



```
{'right': -1.0, 'left': 0.0, 'array': [1.0, 2.0, 4.0, 3.0, 6.0, 5.0, 7.0, 3.0]}
{'right': 0.0, 'left': 1.0, 'array': [1.0, 2.0, 4.0, 3.0, 6.0, 5.0, 7.0, 3.0]}
{'right': 2.0, 'left': 2.0, 'array': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 7.0, 6.0]}
{'right': 3.0, 'left': 4.0, 'array': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 7.0, 6.0]}
{'right': 3.0, 'left': 3.0, 'array': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 7.0, 6.0], 'low': 2.0, 'high': 3.0, 'key': 3.0}
{'right': 4.0, 'left': 5.0, 'array': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 7.0, 6.0]}
{'right': 6.0, 'left': 6.0, 'array': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 6.0, 7.0]}
{'right': 7.0, 'left': 8.0, 'array': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 6.0, 7.0]}
{'right': 7.0, 'left': 7.0, 'array': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 6.0, 7.0], 'low': 6.0, 'high': 7.0, 'key': 7.0}
{'right': 5.0, 'left': 5.0, 'array': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 6.0, 7.0], 'low': 5.0, 'high': 7.0, 'key': 5.0}
{'right': 4.0, 'left': 4.0, 'array': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 6.0, 7.0], 'low': 2.0, 'high': 7.0, 'key': 4.0}
{'right': 1.0, 'left': 1.0, 'array': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 6.0, 7.0], 'low': 1.0, 'high': 7.0, 'key': 2.0}
{'right': 0.0, 'left': 0.0, 'array': [1.0, 2.0, 3.0, 3.0, 4.0, 5.0, 6.0, 7.0], 'low': 0.0, 'high': 7.0, 'key': 1.0}
```