Lecture 6

TeaPL语法设计

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大纲

- 一、PEG语法
- 二、TeaPL语法设计
- 三、TeaPL语法解析

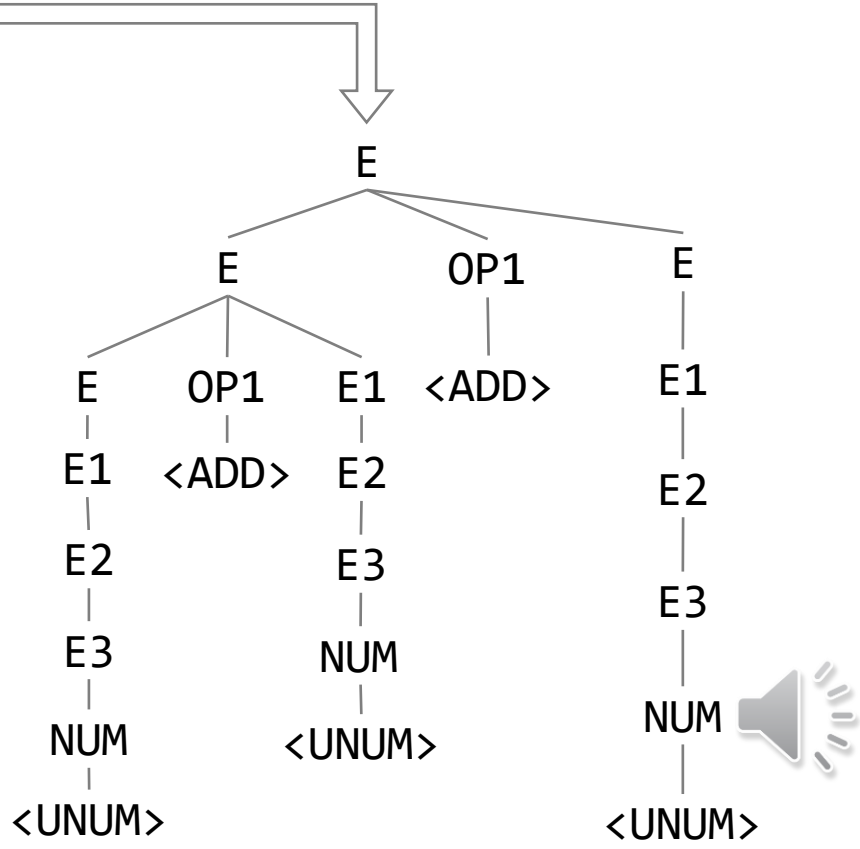
一、PEG语法

CFG的问题

- 语法复杂（避免二义性），易读性差
- 语法解析树复杂

```
[1] E → E OP1 E1
[2]   | E1
[3] E1 → E1 OP2 E2
[4]    | E2
[5] E2 → E3 OP3 E2
[6]    | E3
[7] E3 → NUM
[8]    | <LPAR> E <RPAR>
[9] NUM → <UNUM>
[10]    | <SUB> <UNUM>
[11] OP1 → <ADD>
[12]     | <SUB>
[13] OP2 → <MUL>
[14]     | <DIV>
[15] OP3 → <POW>
```

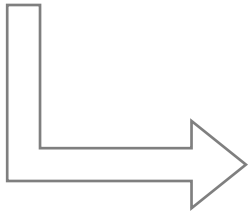
应用：1+2+3的语法解析树



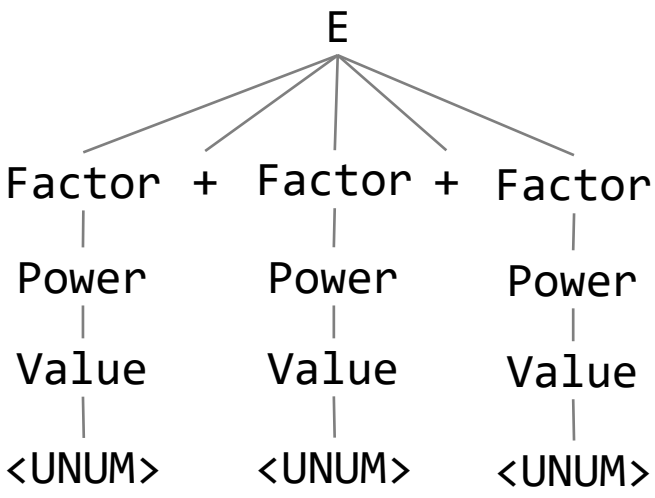
PEG: Parsing Expression Grammar

- 引入更多运算符，简化规则，如：
  - *：闭包
  - /：选择（为前后统一，我们使用|）
  - ''：终结符

```
[1] E → Factor (('+'|'-') Factor)*
[2] Factor → Power (('*'|'/') Power)*
[3] Power → Value ('^' Power)?
[4] Value → <UNUM> | ('-' <UNUM>) | ('(' E ')')
```



应用：1+2+3的语法解析树



二、TeaPL语法设计

使用PEG定于TeaPL：程序组成

```
program ⟼  (varDeclStmt | structDef | fnDeclStmt
            | fnDef | macro | comment)*
```

varDeclStmt	全局变量声明
structDef	数据结构定义
fnDeclStmt	函数声明
fnDef	函数定义
macro	宏
comment	注释

变量声明形式

```
let a:int;
let a:int = 0;
let a;
let a = 0;
let a[5]:int;
let a[n]:int;
let a[n];
let a[2]:int = {0};
let a[2]:int = {1, 2};
```

变量声明

声明时初始化

类型可省略

支持数组类型

数组声明时初始化

暂不支持：

- 二维数组：let a[m][n];
- 一条语句同时声明多个变量：let i,j;

变量声明

```
 varDeclStmt ⟼ let (varDecl | varDef) ';'

     varDecl ⟼ id (':' type)?
     varDecl ⟼ id '[' (id | num) ']' (':' type)?

      varDef ⟼ id (':' type)? '=' rightval
      varDef ⟼ id '[' (id | num) ']' (':' type)? '=' '{' num '}'

        type ⟼ primitiveType | structType | ptrType
primitiveType ⟼ int | bool | char | long | float | double
  structType ⟼ id
     ptrType ⟼ '*' type

   structDef ⟼ struct id '{' varDecl (, varDecl)* '}'
```

右值表达式

```
 rightVal ⟼ arithExpr | boolExpr
arithExpr ⟼ factor (('+' | '-') factor)*
   factor ⟼ power (('*' | '/') power)*
    power ⟼ value ('^' power)?
    value ⟼ num | id | fnCall | deref | addr | string | '(' rightVal ')'
    value ⟼ id '.' id | id '[' (id | num) ']'
      num ⟼ unum | ('-' unum)
    deref ⟼ '*' id
     addr ⟼ '&' id
   string ⟼ '"' (num|id)* '"'
```

函数声明和定义

```
fn foo(a:int, b:int)->int;

fn foo(a:int, b:int)->int {
    return a + b;
}
```

函数声明

函数定义

```
fnDeclStmt  ⟼ fn fnSign ';'
    fnSign  ⟼ id '(' params ')'
    fnSign  ⟼ id '(' params ')' '->' type
    params  ⟼ (id ':' type (',' id ':' type)*) | ϵ
     fnDef  ⟼ fn fnSign codeBlock
 codeBlock  ⟼ '{' (stmt | codeBlock)* '}'
```

基本语句

```
        stmt  ⟼ varDeclStmt | assignStmt | callStmt | retStmt |
                ifStmt | whileStmt | breakStmt | continueStmt
                forStmt | matchStmt

   breakStmt  ⟼ break ';'
continueStmt  ⟼ continue ';'

  assignStmt  ⟼ leftVal '=' rightVal ';'
     leftVal  ⟼ id | deref | id '[' (num | id) ']' | id '.' id

    callStmt  ⟼ fnCall ';'
      fnCall  ⟼ id '(' (rightVal (, rightVal)*) | ϵ ')'
     retStmt  ⟼ ret (rightVal|ϵ) ';'

      ifStmt  ⟼ if '(' boolExpr ')' codeBlock (else codeBlock)?
   whileStmt  ⟼ while '(' boolExpr ')' codeBlock
```

条件表达式

```
boolExpr  ⟼ andExpr ('||' andExpr)*
 andExpr  ⟼ notExpr ('&&' notExpr)*
 notExpr  ⟼ '!'? (bitVal | '(' boolExpr ')')
  bitVal  ⟼ rightVal ('>' | '>=' | '<' | '<=' | '==' | '!=') rightVal
```

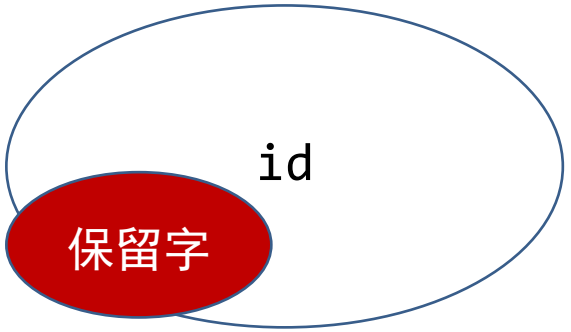
定义常量和标识符

$$
\begin{aligned}
\texttt{digits} &\longmapsto \texttt{[0-9]}^{+} \\
\texttt{fraction} &\longmapsto \texttt{.digits} \mid \epsilon \\
\texttt{unum} &\longmapsto \texttt{digits fraction}
\end{aligned}
$$

$$
\begin{aligned}
\texttt{letter} &\longmapsto \texttt{[a-zA-Z]} \\
\texttt{id} &\longmapsto \texttt{letter (letter | digits)*}
\end{aligned}
$$

其它保留字词法定义

```
    let  ⟼  'let'
     if  ⟼  'if'
   else  ⟼  'else'
  while  ⟼  'while'
    int  ⟼  'int'
   long  ⟼  'long'
  float  ⟼  'float'
   bool  ⟼  'bool'
   char  ⟼  'char'
     fn  ⟼  'fn'
    ret  ⟼  'ret'
 struct  ⟼  'struct'
  break  ⟼  'break'
continue ⟼  'continue'
```



注释

- 注释内部的单词无需识别为单独的标签

```
comment  ⟼  '//' (!newline)* newline
comment  ⟼  '/*' (!'*/')* '*/'
newline  ⟼  \r\n
```

三、语法解析

PEG解析方法

- 方法一：基于Flex和Bison，需要进行改写和适配
- 方法二：手写解析代码
- 方法三：专用PEG解析算法或工具，如Packrat parser

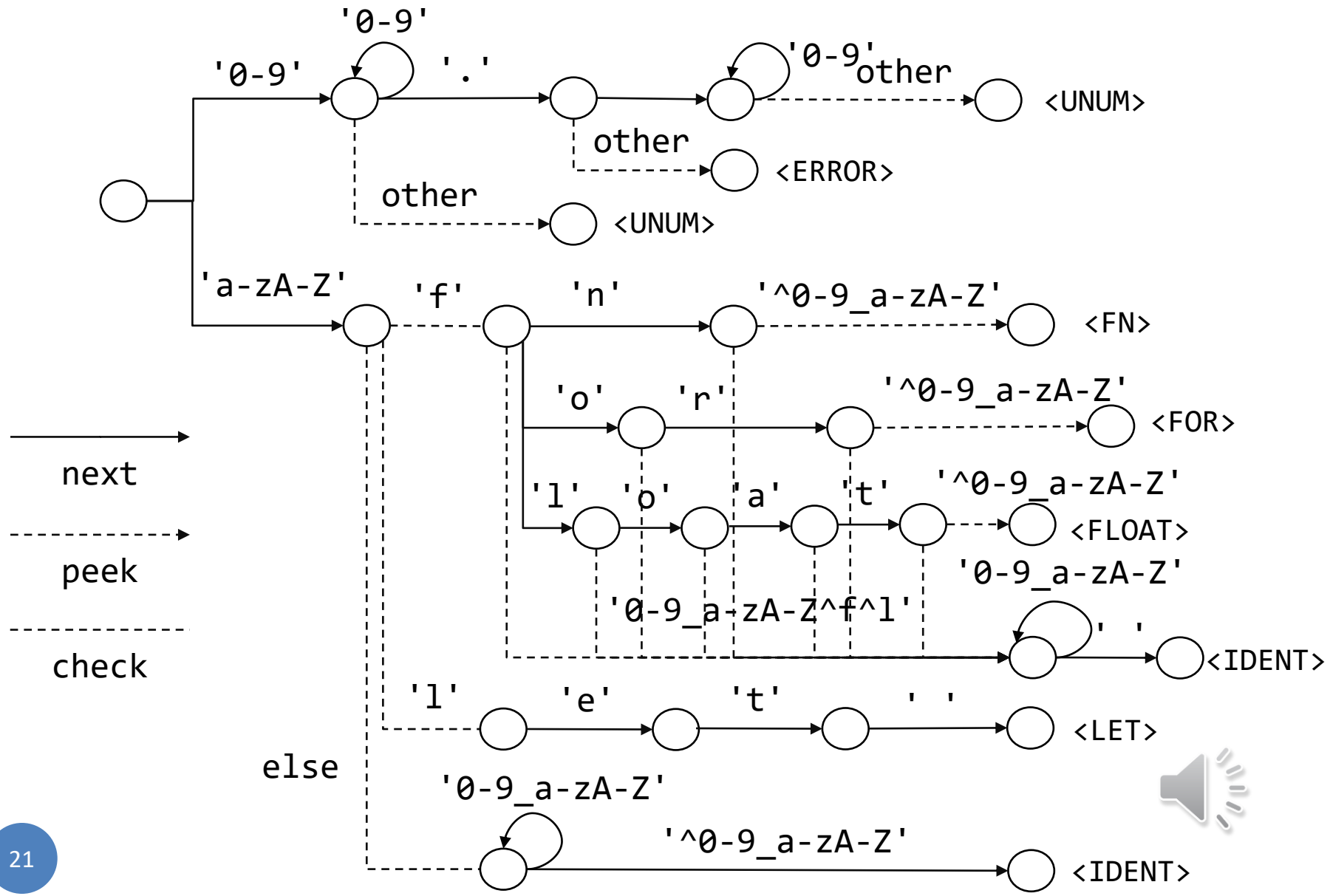
词法分析的冲突处理

- 多种匹配方案时，选择最长的匹配，如
  - '<='不应识别为'<'和'='，'ifabc'不应识别为<IF>和<IDENT>
  - Flex默认采用的规则
- 保留字优先级高于标识符，如
  - 'if'应识别为<IF>，非<IDENT>
  - Flex默认优先匹配先定义的标签

手写词法分析程序

```
cur = cstream.next();
match (cur.value) {
    '+' => tstream.add(SymToken::new(ADD,cur.pos));
    '-' => {
        if cstream.peek(1) == '>' {
            tstream.add(SymToken::new(RARROW, cur.pos));
            cur = cstream.next ();
        } else tstream.add(SymToken::new(SUB, cur.pos));
    'a'-'z' || 'A'-'Z' => {
        pos = cur.pos;
        char value[256];
        if (cur.value == 'f') {
                value[0] = 'f';
                if (cstream.peek(1) == 'n') {
                    if (!isAlphanum(cstream.peek(2))) {
                        tstream.add(SymToken::new(FN,cur.pos));
                } else if (cstream.peek(1) == 'o') { ...//for
                } else {
                    int i = 1;
                    ch = cstream.next().value;
                    while (isAlphanum(ch)) {
                        value[i] = ch;
                        ch = cstream.peek(++i).value
                    }
                    tstream.add(IdentTok::new(value,pos));
                }
    ...
```

识别数字和标识符


'0-9'
'0-9'
'.'
'0-9'
other
<UNUM>
other
<ERROR>
other
<UNUM>
'a-zA-Z'
'f'
'n'
'^0-9_a-zA-Z'
<FN>
'o'
'r'
'^0-9_a-zA-Z'
<FOR>
'l'
'o'
'a'
't'
'^0-9_a-zA-Z'
<FLOAT>
'0-9_a-zA-Z'
'0-9_a-zA-Z^f^l'
' '
<IDENT>
'l'
'e'
't'
' '
<LET>
else
'0-9_a-zA-Z'
'^0-9_a-zA-Z'
<IDENT>
next
peek
check

Token对象应记录哪些信息

```
enum Token {
    SymTok,
    IdentTok,
    UnumTok
}
```

```
struct Pos {
    line:int,
    col:int
}
```

```
struct SymTok {
    type : int, //1:ADD, 2:SUB,...
    pos : Pos
}
```

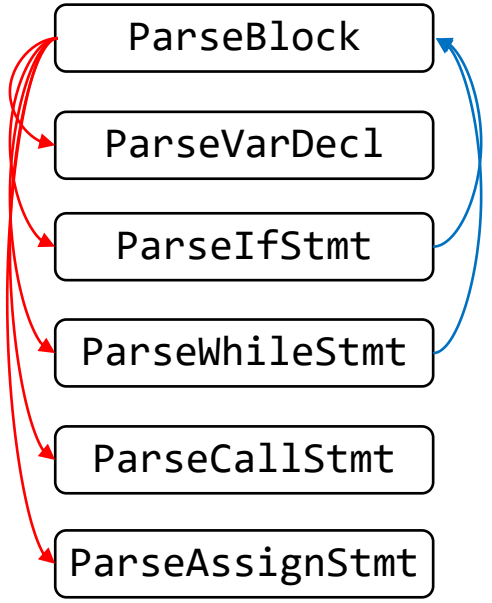
```
struct IdentTok {
    ident : *char,
    pos : Pos
}
```

```
struct UnumTok {
    unum : *char,
    pos : Pos
}
```

手写句法分析程序思路

- 递归下降LL(K)
  - 表达式解析可使用操作符优先级解析算法

```
ParseBlock(tstream) -> Node {
    cur = tstream.next();
    while (cur != tok::RBRACE) {
        match (cur.type) {
            tok::LET => ParseVarDecl(tstream);
            tok::IF => ParseIfStmt(tstream);
            tok::WHILE => ParseWhileStmt(tstream);
            tok::IDENT => {
                if(tstream.peek() == tok::LPAREN) {
                    ParseCallStmt(tstream);
                }
                else ...//
            }
        }
        cur = tstream.next();
    }
}
```



语法解析树节点类型

```
program  ⟼   (varDeclStmt | structDef | fnDeclStmt | fnDef | comment | ';')*
```

```
enum Node {
    varDeclStmt,
    structDef,
    fnDeclStmt,
    fnDef,
    ...
}
```

```
varDeclStmt ⟼ let (varDecl | varDef) ';'
```

```
struct varDeclStmt {
    let : *SymTok,
    var : *varDeNode,
    colon : *SymTok
}
```

```
enum varDNode {
    varDecl,
    varDef
}
```