

# 语法分析

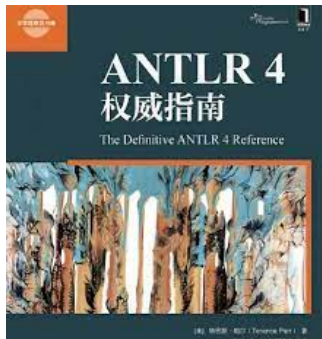
## (3. Adaptive $LL(*)$ 语法分析算法)

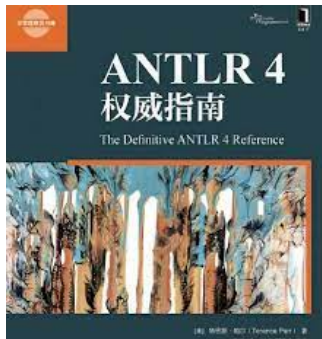
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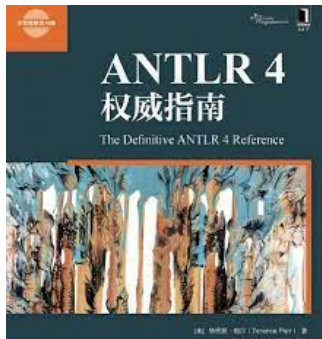
2022 年 11 月 30 日



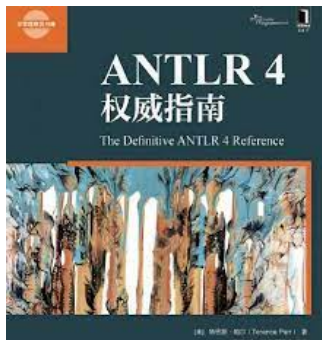




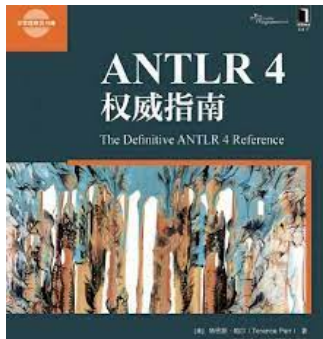
(1) ANTLR 4 自动将类似 `expr` 的左递归规则重写成非左递归形式



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- (2) ANTLR 4 提供优秀的错误报告功能和复杂的错误恢复机制



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- (3) ANTLR 4 使用了一种名为 `Adaptive LL(*)` 的新技术



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- (2) ANTLR 4 提供优秀的错误报告功能和复杂的错误恢复机制
- (3) ANTLR 4 使用了一种名为 Adaptive  $LL(*)$  的新技术
- (4) ANTLR 4 几乎能处理任何文法 (二义性文法✓ 间接左递归✗)

(1995      2011      2014)

## ANTLR: A Predicated- $LL(k)$ Parser Generator

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## $LL(*)$ : The Foundation of the ANTLR Parser Generator

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## Adaptive $LL(*)$ Parsing: The Power of Dynamic Analysis

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ANTLR 4 是如何处理**直接左递归与优先级**的?



parser-allstar/LRExpr.g4

```
stat : expr ';' EOF;
```

```

expr : expr '*' expr
    | expr '+' expr
    | INT
    | ID
    ;

```

## 根本原因:

究竟是在 `expr` 的**当前调用**中匹配下一个运算符,

还是让 `expr` 的**调用者**匹配下一个运算符。

## 根本原因:

究竟是在 `expr` 的**当前调用**中匹配下一个运算符,

还是让 `expr` 的**调用者**匹配下一个运算符。

```
antlr4 LRExpr -Xlog
```

2021-11-25 17:44:23:815 left-recursion LogManager.java:25 expr

```
: ( { } INT<tokenIndex=45>  
  | ID<tokenIndex=51>  
  )  
  (  
    {precpred(_ctx, 4)}?<p=4> '*'<tokenIndex=27> expr<tokenIndex=29,p=5>  
    | {precpred(_ctx, 3)}?<p=3> '+'<tokenIndex=37> expr<tokenIndex=39,p=4>  
  )*  
;
```

2021-11-25 17:44:23:815 left-recursion LogManager.java:25 expr

```
: ( {} INT<tokenIndex=45>  
  | ID<tokenIndex=51>  
  )
```

```
(  
  {precpred(_ctx, 4)}?<p=4> '*'<tokenIndex=27> expr<tokenIndex=29,p=5>  
  | {precpred(_ctx, 3)}?<p=3> '+'<tokenIndex=37> expr<tokenIndex=39,p=4>  
)*
```

```
;
```

```
stat : expr ';' EOF;
```

```
expr : expr '*' expr  
      | expr '+' expr  
      | INT  
      | ID  
      ;
```

```

expr[int _p]
: ( INT
  | ID
  )
  ( {4 >= $_p}? '*' expr[5]
    | {3 >= $_p}? '+' expr[4]
  )*
;

```

expr[int \_p]

```

stat : expr ';' EOF;

```

```

expr : expr '*' expr
      | expr '+' expr
      | INT
      | ID
;

```

```

expr[int _p]
: ( INT
  | ID
  )
  ( {4 >= $_p}? '*' expr[5]
    | {3 >= $_p}? '+' expr[4]
  )*
;

```

1 + 2 + 3      1 + 2 \* 3      1 \* 2 + 3

parser-allstar/LRExprParen.g4

```
stat : expr ';' EOF;
```

```
expr : expr '*' expr  
    | expr '+' expr  
    | '(' expr ')'  
    | INT  
    | ID  
    ;
```



parser-allstar/LRExprUS.g4

```
stat : expr ';' EOF;
```

```
expr : '-' expr  
      | expr '!'  
      | expr '+' expr  
      | ID  
      ;
```

```

expr[int _p]
: ( ID
  | '-' expr[4]
)
( {3 >= $_p}? '!'
  | {2 >= $_p}? '+' expr[3]
)*
;

```

$-a!!$        $-a + b!$

```
stat : expr ';' EOF ;  
expr : <assoc = right> expr '^' expr  
      | expr '+' expr  
      | INT  
      ;
```

```

stat : expr ';' EOF ;
expr : <assoc = right> expr '^' expr
      | expr '+' expr
      | INT
      ;

```

```

expr[int _p]
: ( INT )
  ( {3} >= $_p}? '^' expr{3}
    | {2} >= $_p}? '+' expr{3}
  )*
;

```

$1^2^3 + 4$

For *left-associative* operators, the right operand gets **one more** precedence level than the operator itself.

## Adaptive $LL(*)$ Parsing: The Power of Dynamic Analysis

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### Appendix C: Left-recursion Elimination

For *right-associative* operators, the right operand gets **the same** precedence level as the current operand.

# ANTLR 4 是如何进行错误报告与恢复的?



报错、恢复、继续分析



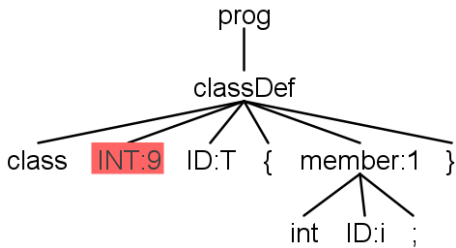
**恐慌/应急 (Panic) 模式:** 假装成功、调整状态、继续进行



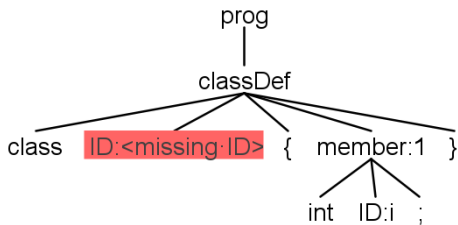
如果**下一个词法单元**符合预期,  
则采用“**单词法符号移除** (single-token deletion)”  
或“**单词法符号补全** (single-token insertion)” 策略

Class.g4

## Class-DeleteToken.txt



## Class-AddToken.txt

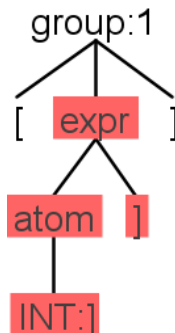
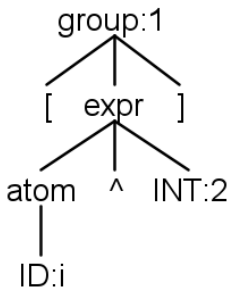


采用“**同步-返回 (sync-and-return)**”策略,  
使用“**重新同步集合 (resynchronization set)**”从**当前规则**中恢复

Group.g4

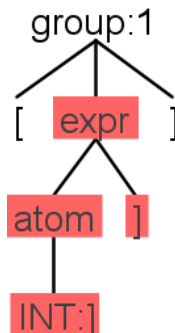
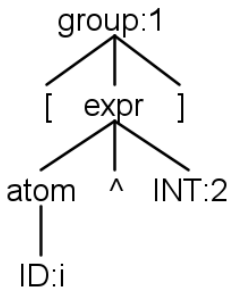
$\text{FOLLOWING}(\{\text{expr}, \text{atom}\}) = \{ ^, ] \}$

$\text{FOLLOWING}(\{\text{expr}\}) = \{ ] \}$



$\text{FOLLOWING}(\{\text{expr}, \text{atom}\}) = \{ ^, ] \}$

$\text{FOLLOWING}(\{\text{expr}\}) = \{ ] \}$



注意 FOLLOW (静态) 集合与 FOLLOWING (动态) 集合的区别

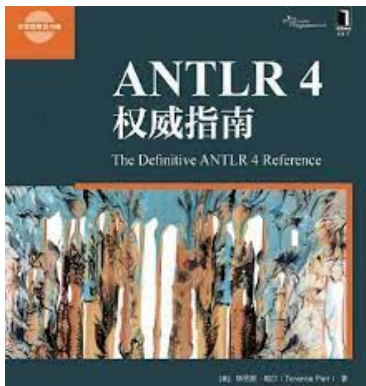
## 如何从子规则中优雅地恢复出来？

Class.g4 (`member+`)

Class-Subrule-Start.txt (“`单词法符号`移除”)

Class-Subrule-Loop.txt (“`另一次 member` 迭代”)

Class-Subrule-End.txt (“`退出当前 classDef` 规则”)



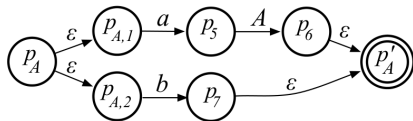
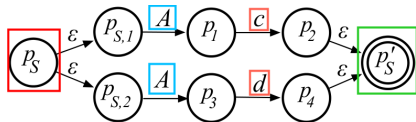
## 第 9 章: 错误报告与恢复



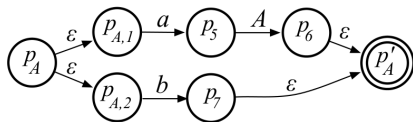
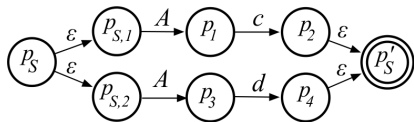
$$P = \{S \rightarrow Ac \mid Ad, A \rightarrow aA \mid b\}$$

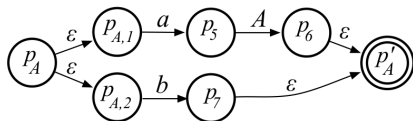
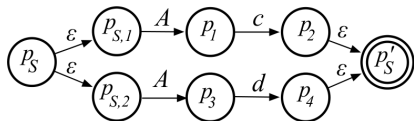
不是  $LL(1)$  文法，也不是  $LL(k)$  文法 ( $\forall k \geq 1$ )

$$P = \{S \rightarrow Ac \mid Ad, A \rightarrow aA \mid b\}$$

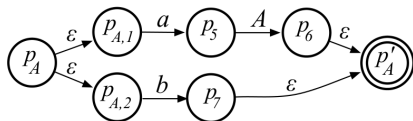
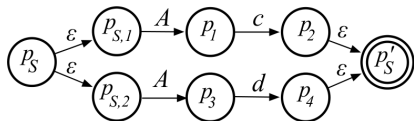


ATN: Augmented Transition Network

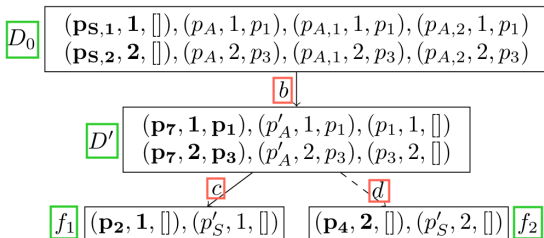


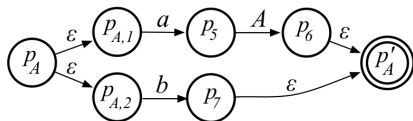
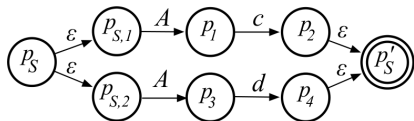


Incrementally and dynamically build up a *lookahead DFA* that map lookahead phrases to predicated productions.

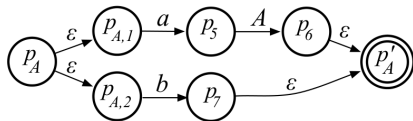
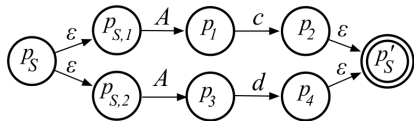


Incrementally and dynamically build up a *lookahead DFA* that map lookahead phrases to predicated productions.

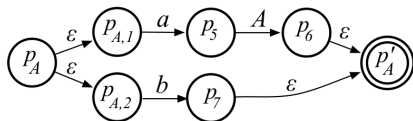
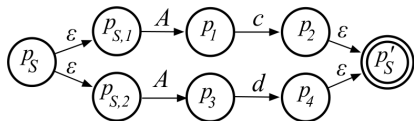




- Launch subparsers at a decision point, one per alternative productions.

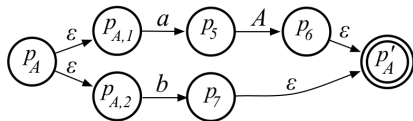
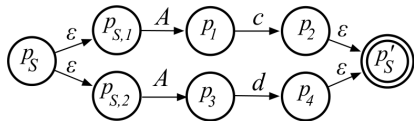


- ▶ Launch subparsers at a decision point, one per alternative productions.
- ▶ These subparsers run in pseudo-parallel to explore all possible paths.

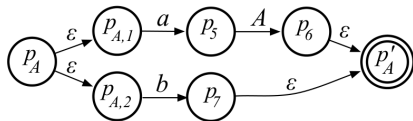
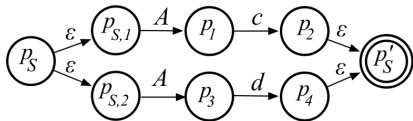


- ▶ Launch subparsers at a decision point, one per alternative productions.
- ▶ These subparsers run in pseudo-parallel to explore all possible paths.
- ▶ Subparsers die off as their paths fail to match the remaining input.

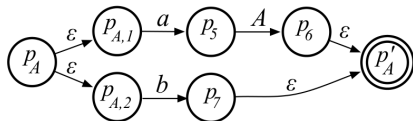
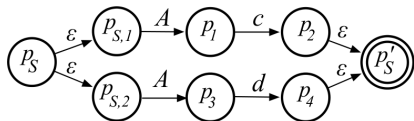


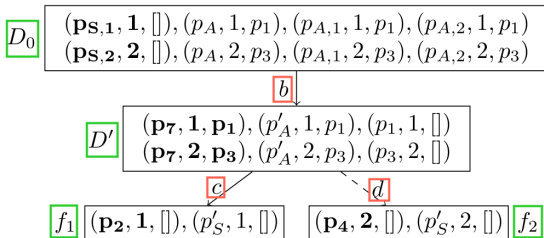
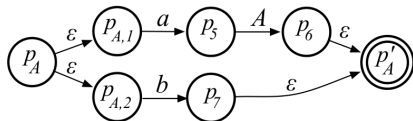
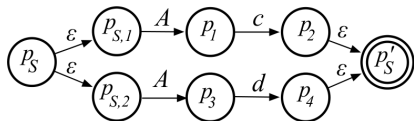


- ▶ Launch subparsers at a decision point, one per alternative productions.
- ▶ These subparsers run in pseudo-parallel to explore all possible paths.
- ▶ Subparsers die off as their paths fail to match the remaining input.
- ▶ Ambiguity: Multiple subparsers coalesce together or reach EOF.

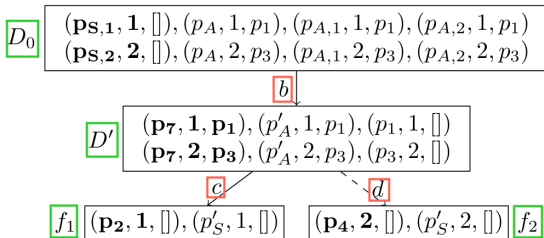
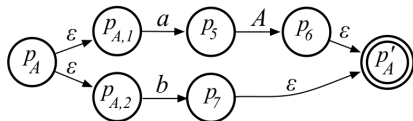
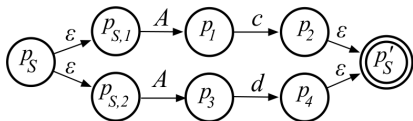


- ▶ Launch subparsers at a decision point, one per alternative productions.
- ▶ These subparsers run in pseudo-parallel to explore all possible paths.
- ▶ Subparsers die off as their paths fail to match the remaining input.
- ▶ Ambiguity: Multiple subparsers coalesce together or reach EOF.
- ▶ Resolution: The first production associated with a surviving subparser.





Upon  $bc$  and then  $bd$



Upon  $bc$  and then  $bd$

**move-closure!!!**

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Thank  
You!



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