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**编译原理与技术大作业报告**



**学 院 智能与计算学部**

**专 业 计算机科学与技术**

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# 一.整体概述

## 1.1 整体流程

该编译器的demo的整体流程如下所示

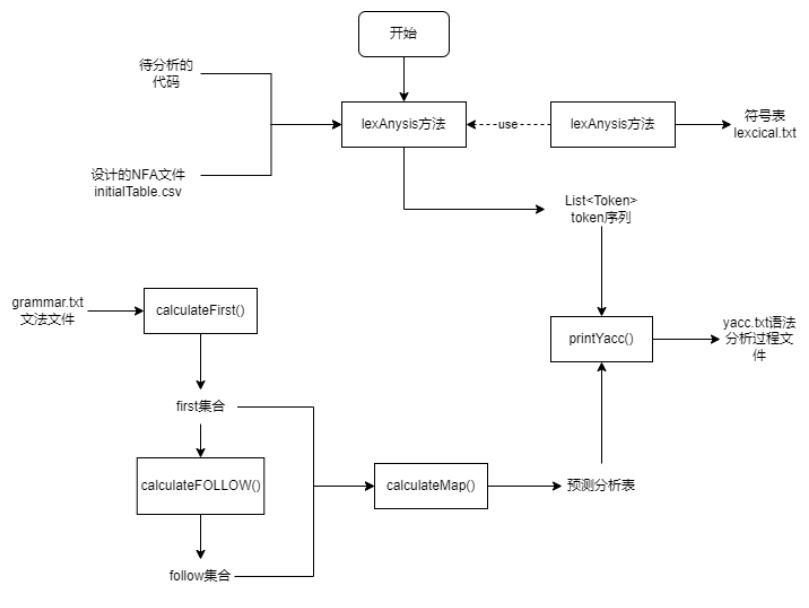


图 1 编译器的demo的整体流程

## 1.2 目录树介绍

项目的目录树如下  
 ├─.idea   
 │ ├─artifacts   
 │ ├─inspectionProfiles   
 │ └─libraries  
 ├─log  
 ├─src  
 │ ├─main  
 │ │ ├─java  
 │ │ └─resources  
 │ └─test  
 │ ├─java  
 │ └─resources  
 └─target

各文件夹的作用如下所示

* .idea: 使用idea的配置文件目录，在本地登录时请删除
* log: 记录错误日志的目录
* src: 源代码和程序所用资源所在的目录
  + main/java: 主体程序源码
  + main/resources: 程序主体所用的资源文件
  + test/java: 测试程序源码
  + test/resources: 测试程序所用的资源文件
* target: 编译后生成文件所在目录

## 1.3 源码结构介绍

主体程序源码结构如下

src  
 ├─lex  
 │ ├─entity  
 │ ├─implement  
 │ └─itf  
 ├─log  
 ├─test  
 ├─utils  
 └─yacc  
 ├─entity  
 ├─implement  
 └─itf

* lex: 词法分析器部分
  + entity：实体类
  + implement: 接口的实现类
  + itf: 对外开放的接口
* log: 日志记录部分
* test: 最终生成的函数入口部分
* utils: 编码时用到的工具
* yacc: 语法分析部分
  + entity：实体类
  + implement: 接口的实现类
  + itf: 对外开放的接口

# 二.词法分析器简介

## 2.1 词法分析器工作流程

词法分析器工作的主要流程由下图所示

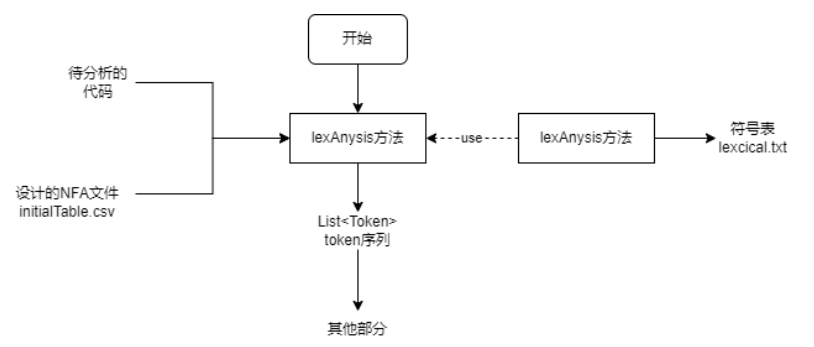


图2-1 词法分析器工作的主要流程图

## 2.2 设计的NFA

NFA的设计图如下所示

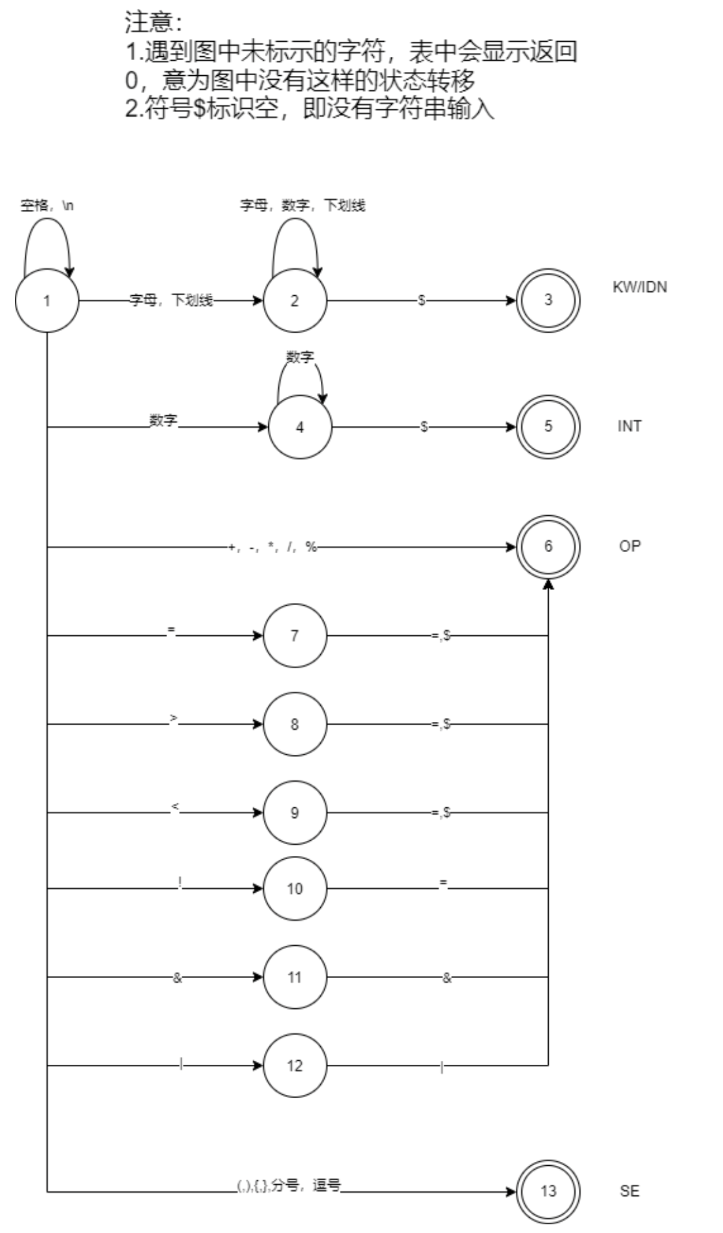


图2-2 NFA的设计图

由此设计出的initialTable如下图所示

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| stateId | start | endSymbol | letter | digit | \_ | + | - | \* | / | % | = | $ | > | < | ! | & | | | ( | ) | { | } | dot | ; |  | \n | others |
| 1 | TRUE | NOT\_END | 2 | 4 | 2 | 6 | 6 | 6 | 6 | 6 | 7 | 0 | 8 | 9 | 10 | 11 | 12 | 13 | 13 | 13 | 13 | 13 | 13 | 1 | 1 | 0 |
| 2 | FALSE | NOT\_END | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | FALSE | KW/IDN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | FALSE | NOT\_END | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | FALSE | INT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | FALSE | OP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | FALSE | NOT\_END | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | FALSE | NOT\_END | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | FALSE | NOT\_END | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | FALSE | NOT\_END | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | FALSE | NOT\_END | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | FALSE | NOT\_END | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | FALSE | SE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 2.3 词法分析器类简介

词法分析器主要类如下

lex  
 ├─entity  
 │ DFA.java  
 │ NFA.java  
 │ State.java  
 │ StateList.java  
 │ Token.java  
 │  
 ├─implement  
 │ LexImpl.java  
 │  
 └─itf  
 Lex.java

### 2.3.1 lex.entity.DFA:

是dfa实体，用来描述一个DFA

重要字段:

|  |
| --- |
| FA //所有状态的集合  private List<State> allStates;  //字母表  private String[] alpha;  // 状态转化表，因为是DFA，所以一个输入字符只会对应一个输出,List的序号对应`状态序号 - 1`  private List<Map<String, Integer>> functionList;  //唯一初态  private State startState;  //终止状态集合  private List<State> endStates;  重要方法:  /\*\*  \* @param :  \* @return DFA 最小化后的DFA  \* @author ZhouXiang  \* @description 将所给的DFA最小化  \* @exception  \*/  public DFA minimizeDFA() |

### 2.3.2 lex.entity.NFA:

NFA实体类,用来描述一个NFA

重要字段:

|  |
| --- |
| //所有状态的集合  private List<State> allStates;  //字母表  private String[] alpha;  //状态转化表，因为是NFA，所以一个输入字符可能对应多个输出  private List<Map<String, Integer[]>> functionList;  //初始状态集合  private List<State> startStates;  //终止状态集合  private List<State> endStates;  重要方法:  /\*\*  \* @param :fileName 初始设计的NFA表文件所在路径  \* @return NFA  \* @author ZhouXiang  \* @description 获取初始的NFA，从文件中获取nfa  \* @exception 文件IO异常  \*/  public static NFA generateNFA(String fileName) throws IOException; |

### 2.3.3 lex.entity.State

状态的实体类，用来描述状态NFA和DFA中状态的变化

重要字段:

|  |
| --- |
| //状态id  private int stateId;  //是否为起始状态  private boolean start;  //若为结束状态，则为其对应的标识的数组，否则为空数组  private String[] endSymbol;  //状态转换表  private Map<String, Integer[]> moveMap; |

### 2.3.4 lex.entity.StateList

状态集合的实体类，是nfa确定化和dfa最小化的算法中间产生的实体类

重要字段

|  |
| --- |
| //集合中包含的状态  private List<State> states;  //状态集合编号0  private int stateListId;  //标识有没有起始状态  private boolean start;  //若为结束状态，则为其对应的标识的数组，否则为null  private String[] endSymbol;  //key为转移符号，value为转移到的状态集合编号  //注意，这里的状态转移与a弧转换不同，只是简单的将所有状态的状态转移加和，没有算加和的空弧转换  private Map<String, Integer[]> moveMap; |

### 2.3.5 lex.entity.Token

输出Token序列中的Token实体类

重要字段

|  |
| --- |
| //符号种别  private String type;  //符号对应的字符串内容  private String content;  //符号在进行语法分析时的存在形式  private String dealing; |

### 2.3.6 lex.implement.LexImpl

是lex.itf.Lex的实现类，实现了lex.itf.Lex声明的抽象方法

### 2.3.7 lex.itf.Lex

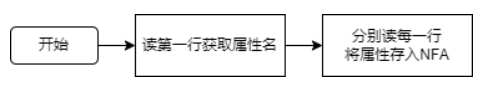
是词法分析器对外声明的接口，声明了词法分析器要实现的两个方法

|  |
| --- |
| /\*\*  \* @param input: 输入的字符串  \* @return List<Token> 识别出的符号表  \* @author ZhouXiang  \* @description 将输入的字符串经过词法分析转为对应的token序列，输出Token序列  \*/  public List<Token> lexAnalysis(String input) throws IOException;  /\*\*  \* @param inputFile: 输入文件名  \* @param outputFile: 输出文件名  \* @return boolean: 是否输出成功  \* @author ZhouXiang  \* @description 对输入文件的语句进行词法分析，结果输出到输出文件中  \*/  public boolean lexAnalysisToFile(String inputFile,String outputFile) throws IOException; |

## 2.4 词法分析器主要算法

### 2.4.1 NFA的获取

从initialTable.csv文件中获取NFA主要步骤如下



具体实现代码在lex.entity.NFA.generateNFA(String fileName)

|  |
| --- |
| public static NFA generateNFA(String fileName) throws IOException {  List<State> stateList = new ArrayList<>();    InputStream in = ClassLoader.getSystemResourceAsStream(fileName);  Scanner scanner = new Scanner(in);  String[] attribute = null; //存所有状态转移表的所有属性，即initialStateTable的第一行  if(scanner.hasNextLine()){  attribute = scanner.nextLine().split(",");  }  while (scanner.hasNextLine()){  String[] line = scanner.nextLine().split(",");  int stateId = -1;  boolean start = false;  String[] endSymbol = new String[0];  //从表中读除了状态转移以外的数据  for (int i = 0; i < line.length; i++){  switch (attribute[i]){  case "stateId":  stateId = Integer.parseInt(line[i]);  break;  case "start":  if(line[i].equals("TRUE")){  start = true;  }  break;  case "endSymbol":  endSymbol = line[i].split("/");  break;  default:  }  }  //取出状态转移的部分  int attributeNum = 3; //State类中除状态转移Map外的属性数  Integer[][] move = new Integer[line.length - attributeNum][];  for(int i = 0; i < move.length; i++){  String[] moveString = line[i + attributeNum].split("/");  Integer[] moveInteger = new Integer[moveString.length];  for(int j = 0; j < moveInteger.length; j++){  moveInteger[j] = Integer.parseInt(moveString[j]);  }  move[i] = moveInteger;  }  Map<String, Integer[]> moveMap = new HashMap<>();  for(int i = 0; i < move.length; i++){  moveMap.put(attribute[i + attributeNum], move[i]);  }  State state = new State(stateId, start, endSymbol, moveMap);  stateList.add(state);  }  return NFA.getNFAInstance(stateList);  } |

### 2.4.2 NFA的确定化

NFA确定化步骤：

1. 求nfa初始状态的闭包，将其放到转换结果List<StateList> result中去
2. 对于result中的每一个StateList，求其a弧转换，加入到result中去
3. 重复2，直到不再有新的StateList加入result
4. 将result转为对应的DFA

具体代码实现在lex.entity.NFA.determineNFA()

|  |
| --- |
| public DFA determineNFA(){  List<StateList> dfa1 = new ArrayList<>();  StateList beginList = new StateList(startStates).moveWithBlank(this);  dfa1.add(beginList);  dfs(beginList, dfa1);  //将StateList转为State  List<State> dfa = new ArrayList<>();  int cnt = 1;  for(StateList stateList: dfa1){  stateList.setStateListId(cnt);  cnt++;  }  for (StateList stateList: dfa1){  dfa.add(stateList.turn2State(dfa1, this));  }  return DFA.getDFAInstance(dfa);  }  //搜索整个nfa  private void dfs(StateList stateList, List<StateList> result){  List<StateList> tempStateList = new ArrayList<>(); //暂存一行中状态转移的StateList  //求该stateList的所有a弧转换  for(String input: alpha){  //排除空弧转换的情况  if(input.equals("$")){  continue;  }  //当a弧转换找到的结果是什么都没有时，不要加入  StateList temp = stateList.moveWithInput(input, this);  if(!temp.getStates().isEmpty()){  tempStateList.add(temp);  }  }  //判断每一个StateList是否已经在收集的![](../../../../../../文档/初始状态转换图.png)结果里了  for(StateList list: tempStateList){  boolean isRepeat = false;  for(StateList stateList1: result){  if(stateList1.equals(list)){  isRepeat = true;  break;  }  }  if(!isRepeat){  result.add(list);  dfs(list, result);  }  }  } |

在本项目中，NFA确定化后的状态转换图为

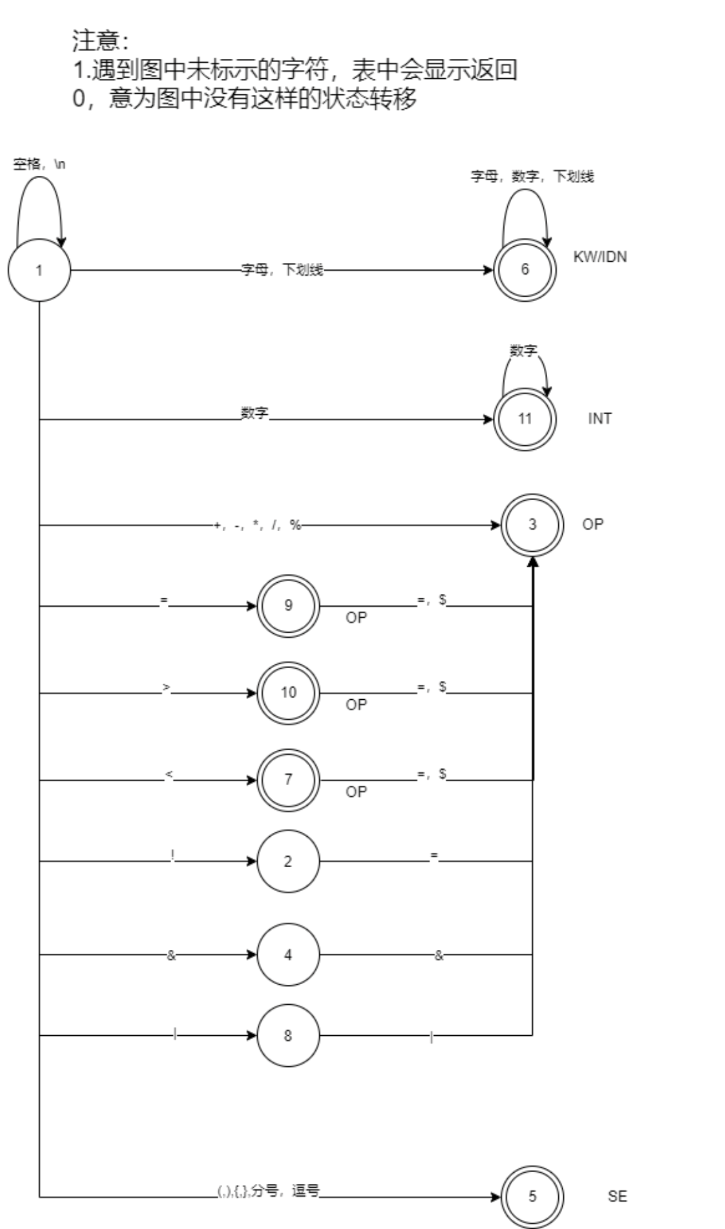


图2-3 NFA确定化后的状态转换图

### 2.4.3 NFA的最小化

NFA最小化步骤：

1. 对NFA中的所有状态，根据endSymbol类型分成不同的组，将分组加入转换结果List<StateList> curList中
2. 对字母表中的每一个字母input，执行划分操作操作：
   1. 将result中的所有StateList加入队列queue中
   2. 从queue中取出一个StateList
   3. 求该StateList中每一个State的a弧转换的结果
   4. 根据每一个State的a弧转换结果是result中的哪一个StateList，将其分为不同的组
   5. 若只有一个分组，将其加入List<StateList> finalList中
   6. 若有多个分组，从curList中删除原分组，加入新分组，并将新分组入队
   7. 重复执行2-5，直到没有新分组入队
3. 对curList进行检查操作:
   1. 存储curList到oldList中，对字母表中的每一个字母input，执行划分操作操作
   2. 比较经过划分操作后的curList和oldList，若相同则进行4，否则继续进行检查操作
4. 将finalList转为对应的DFA

具体代码实现在lex.entity.DFA.minimizeDFA()中

|  |
| --- |
| public DFA minimizeDFA(){  List<StateList> curList = new ArrayList<>();  //根据endSymbol的不同，对State进行第一次划分  //因为java对String[]的比较未重写，所以要将String[]转为String  Map<State, String> map =new HashMap<>();  for (State state: this.allStates){  StringBuilder sb = new StringBuilder();  for(String str: state.getEndSymbol()){  sb.append(str + "\_");  }  map.put(state, sb.toString());  }  Set<String> set = new HashSet<>(map.values());  for(String str: set){  List<State> list = new ArrayList<>();  for(Map.Entry<State, String> entry: map.entrySet()){  State key = entry.getKey();  String value = entry.getValue();  if(value.equals(str)){  list.add(key);  }  }  curList.add(new StateList(list));  }  for(String input: alpha){  if(input.equals("$")){  continue;  }  curList = separate(curList, input);  }  List<StateList> result = check(curList);  //将StateList转为State  List<State> dfa = new ArrayList<>();  int cnt = 1;  for(StateList stateList: result){  stateList.setStateListId(cnt);  cnt++;  }  for (StateList stateList: result){  dfa.add(stateList.turn2State(result, this));  }  return DFA.getDFAInstance(dfa);  }  //检查，直到不发生改变  private List<StateList> check(List<StateList> curList){  List<StateList> oldList = curList;  for(String input: alpha){  if(input.equals("$")){  continue;  }  curList = separate(curList, input);  }  if(!oldList.equals(curList)){  check(curList);  }  return oldList;  }  //使用某字母对目前的dfa(List<StateList>)进行一次划分,返回划分后的结果  private List<StateList> separate(List<StateList> curList, String input){  List<StateList> finalStateList = new ArrayList<>();  Queue<StateList> queue = new LinkedList<>();  for (StateList list: curList){  queue.offer(list);  }  List<StateList> oldList = new ArrayList<>(curList);  while (!queue.isEmpty()){  StateList tempStateList = queue.poll();  //调试用  // if(tempStateList.getStates().size() == 4){  // int a = 0;  // }  //根据a弧转换，对tempStateList中的状态进行分类  //tempStateList中的每一个State，会对应到一个StateList  //取StateList为key，若不用划分，应只有一个键值对，否则，就要根据value划分成不同的StateList  Map<StateList, List<State>> map = new HashMap<>();  for(State state: tempStateList.getStates()){  StateList next = state.getMove(this, input);  Pair<StateList, List<State>> pair = personalGetOrDefault(map, next, new ArrayList<>());  List<State> list = pair.getValue();  list.add(state);  map.put(pair.getKey(), list);  }  if(map.size() == 1){//包含在oldList里面，说明是最终分组  finalStateList.add(tempStateList);  }else {//不包含在oldList里面，删除原来的分组，创建新分组，将新分组入队  oldList.remove(tempStateList);  for(List<State> stateList: map.values()){  StateList stateList1 = new StateList(stateList);  oldList.add(stateList1);  queue.add(stateList1);  }  }  }  return finalStateList;  }  //实现getOrDefault功能，用api的无法比较StateList是否相同  private static Pair<StateList, List<State>> personalGetOrDefault(Map<StateList, List<State>> map, StateList testKey, List<State> defaultResult){  for(Map.Entry<StateList, List<State>> entry: map.entrySet()){  StateList key = entry.getKey();  List<State> value = entry.getValue();  if(testKey.equals(key)){  return new Pair<>(key, value);  }  }  return new Pair<>(testKey, defaultResult);  } |

在本项目中，DFA确定化后的状态转换图如下

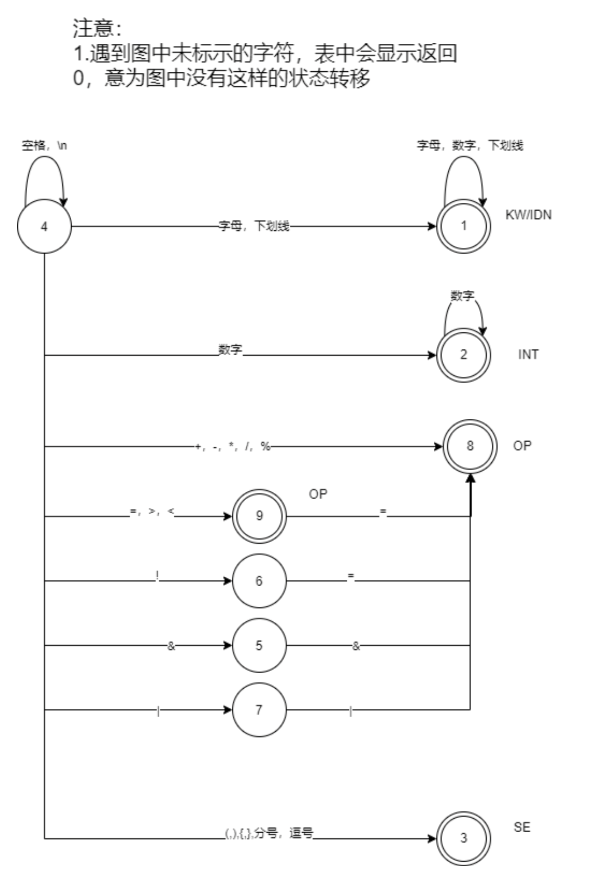


图2-4 DFA确定化后的状态转换图

### 2.4.4 Token序列的生成

根据最小化的DFA，获取待分析代码的Token序列的主要步骤如下:

1. 初始化当前状态为起始状态，初始化firstLetter，curLetter指针为第一个读入的字符，初始创建一个空的List<Token> result
2. 判断curLetter是否超过了input的长度，若超过了，跳到9；若没有，则从curLetter的位置读取一个字符
3. 对读入的字符进行预处理
4. 根据当前状态和遇到的字符，看还有没有下一个状态
5. 若有，则将curLetter + 1，然后跳转到2继续执行
6. 若没有，则判断当前状态是否是终结状态
7. 若是终结状态，读取firstLetter和curLetter之间的部分作为一个Token的content内容，目前State的endSymbol作为Token的type，将firstLetter指针移到curLetter位置，curLetter + 1，然后跳转到2继续执行
8. 若不是终结状态，说明代码存在错误，使用Log.errorLog()记录错误，退出程序
9. 遍历result，根据后面是INT，前面是null || KW || INT || { || (的原则找到要将-和INT合并成INT的位置
10. 遍历result，计算每一个Token的dealing，同时在要合并的地方对-和INT进行合并

具体实现代码在lex.implement.LexImp中

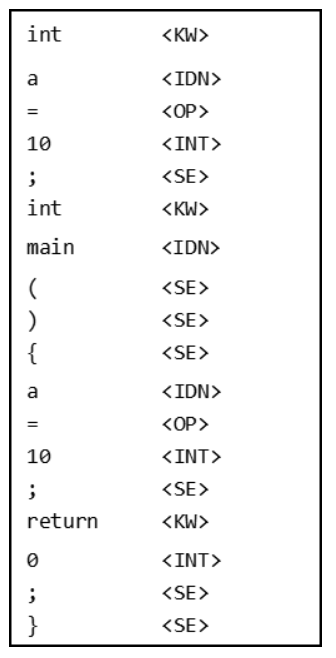
|  |
| --- |
| public List<Token> lexAnalysis(String input) throws IOException {  List<Token> tokens = new ArrayList<>();  //加空格是为了保证能读取最后的token  //当最后的字符的currentState为起始状态时，证明最后是由空格和\n组成的符号串，不该加入tokens，加入" "无影响  //当最后的字符的currentState为非终结状态时，证明到最后了还没读到可判断断词的字符，说明出现错误，加入" "无影响  //当最后的字符的currentState为终结状态时，因为所有终结状态遇到" "都会断词，且不会将最后一个" "读进，加入" "能帮助断词，否则该词就无法读进了  input = input + " ";  //获取dfa  // String fileName = "D:\\大学\\课程\\编译原理\\My大作业\\C--Complier\\complier\\src\\main\\resources\\initialStateTable.csv";  // String fileName = "./src/main/resources/config/initialStateTable.csv";  //generateNFA是静态方法，用的是ClassLoader.getSystemResourceAsStream(fileName)获取输入流，前面不加/  String fileName = "config/initialStateTable.csv";  NFA nfa = NFA.generateNFA(fileName);  DFA dfa = nfa.determineNFA();  dfa = dfa.minimizeDFA();  State currentState = dfa.getStartState(); //字符当前所处的状态  int currentNum = 0; //当前识别到哪一个字符  int startNum = 0; //每个token内容的开始字符  int endNum = 0; //每个token内容的结束字符  while (currentNum < input.length()){  //字符预处理  char currentChar = input.charAt(currentNum);  String currentLetter = "";  if(Character.isDigit(currentChar)){  currentLetter = "digit";  }else if(Character.isLetter(currentChar)){  currentLetter = "letter";  }else if(currentChar == ','){  currentLetter = "dot";  }else {  currentLetter = String.valueOf(currentChar);  }  if(!Arrays.asList(dfa.getAlpha()).contains(currentLetter)){  currentLetter = "others";  }  //找开始位置,会将空格，\n都去除  if(currentState.isStart()){  startNum = currentNum;  }  // if(currentChar == '}'){  // int a = 1;  // }  //找结束位置  State nextState = dfa.move(currentState, currentLetter);  if(nextState == null){  if(currentState.isEnd()){  endNum = currentNum;  String content = input.substring(startNum, endNum);  String type = "";  if(currentState.getEndSymbol().length == 1){  type = currentState.getEndSymbol()[0];  }else {  if(content.equals("int") || content.equals("void") || content.equals("return") || content.equals("const")){  type = "KW";  }else {  type = "IDN";  }  }  Token token = new Token(type, content);  tokens.add(token);  currentState = dfa.getStartState();  }else {  String errorInfo = currentLetter + "不能被识别，它是输入的第" + currentNum + "个字符";  Log.errorLog(errorInfo, logger);  System.exit(1);  }  }else {  currentState = nextState;  //后移currentNum  currentNum++;  }  }  //处理负数  //找到应该合并的位置  List<Integer> list = new ArrayList<>();  for(int i = 0; i < tokens.size(); i++){  Token before = null;  if(i != 0){  before = tokens.get(i - 1);  }  Token cur = tokens.get(i);  Token after = null;  if(i != tokens.size() - 1){  after = tokens.get(i + 1);  }  if(cur.getContent().equals("-") && after != null && after.getType().equals("INT")){  if(before == null || before.getType().equals("KW") || before.getType().equals("OP")){  list.add(new Integer(i));  }else {  if(before.getContent().equals("(") || before.getContent().equals("{")){  list.add(new Integer(i));  }  }  }  }  List<Token> result = new ArrayList<>();  int skip = 0;  for(int i = 0; i < tokens.size() - list.size(); i++){  if(list.contains(i + skip)){  String content = tokens.get(i + skip).getContent() + tokens.get(i + skip + 1).getContent();  Token token = new Token("INT", content);  //加入结果前要计算其在语法分析中的dealing  token.calculateDealing();  result.add(token);  skip++;  }else {  Token token = tokens.get(i + skip);  //加入结果前要计算其在语法分析中的dealing  token.calculateDealing();  result.add(token);  }  }  return result;  } |

## 2.5 词法分析器输出格式说明

### 2.5.1 符号表lexical.txt说明

输出格式为

[待测代码中的单词符号] [TAB] [单词符号种别]



其中，单词符号种别为 KW（关键字）、OP（运算符）、SE（界符）、IDN（标识符）INT（整形数）；单词符号内容第一个维度为其种别，第二个维度为其属性。[TAB]为一个制表符‘\t’

### 2.5.2 Token序列说明

Token序列是一个Token组成的List，即List<Token>，它是lexAnalysis(String input)方法的返回值，将作为参数，传入语法分析器中。

# 三. 语法分析器简介

## 3.1 语法分析器工作流程

语法分析器工作流程如下

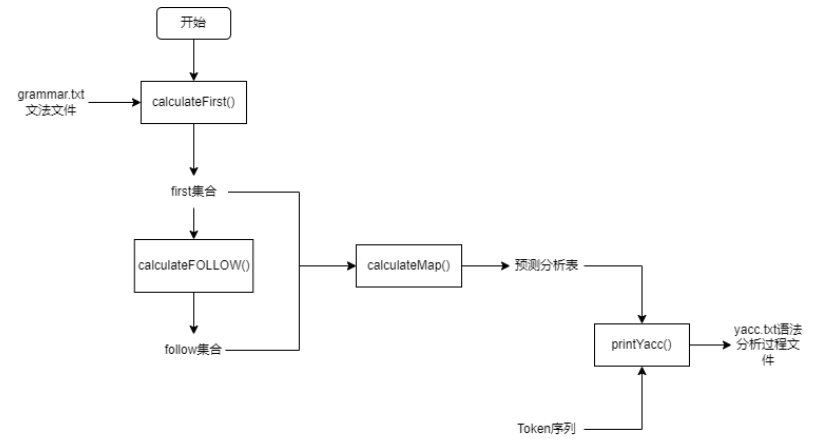


图 3-1 语法分析器工作流程

## 3.2 文法文件与预测分析表

### 3.2.1文法文件

文法文件grammar.txt由助教给出，具体如下：

|  |
| --- |
| program -> compUnit  compUnit -> decl compUnit  compUnit -> funcDef compUnit  compUnit -> $  decl -> constDecl  decl -> varDecl  constDecl -> const bType constDef argConst ;  argConst -> , constDef argConst  argConst -> $  constDef -> IDN = constInitVal  constInitVal -> constExp  constExp -> assignExp  varDecl -> bType varDef argVarDecl ;  argVarDecl -> , varDef argVarDecl  argVarDecl -> $  varDef -> IDN argVarDef  argVarDef -> = initVal  argVarDef -> $  initVal -> exp  bType -> int  funcDef -> funcType IDN ( funcFParams ) block  funcType -> void  funcFParams -> funcFParam argFunctionF  funcFParams -> $  argFunctionF -> , funcFParam argFunctionF  argFunctionF -> $  funcFParam -> bType IDN  block -> { blockItem }  blockItem -> decl blockItem  blockItem -> stmt blockItem  blockItem -> $  stmt -> exp ;  stmt -> ;  stmt -> block  stmt -> return argExp ;  callFunc -> ( funcRParams )  callFunc -> $  funcRParam -> exp  funcRParams -> funcRParam argFunctionR  funcRParams -> $  argFunctionR -> , funcRParam argFunctionR  argFunctionR -> $  argExp -> exp  argExp -> $  exp -> assignExp  assignExp -> eqExp assignExpAtom  assignExpAtom -> = eqExp assignExpAtom  assignExpAtom -> $  eqExp -> relExp eqExpAtom  eqExpAtom -> == relExp eqExpAtom  eqExpAtom -> != relExp eqExpAtom  eqExpAtom -> $  relExp -> addExp relExpAtom  relExpAtom -> < addExp relExpAtom  relExpAtom -> > addExp relExpAtom  relExpAtom -> <= addExp relExpAtom  relExpAtom -> >= addExp relExpAtom  relExpAtom -> $  addExp -> mulExp addExpAtom  addExpAtom -> + mulExp addExpAtom  addExpAtom -> - mulExp addExpAtom  addExpAtom -> $  mulExp -> unaryExp mulExpAtom  mulExpAtom -> \* unaryExp mulExpAtom  mulExpAtom -> / unaryExp mulExpAtom  mulExpAtom -> % unaryExp mulExpAtom  mulExpAtom -> $  number -> INT  unaryExp -> number  unaryExp -> IDN callFunc |

### 3.2.2 预测分析表

程序分析过程中产生的预测分析表超链接为：

<程序分析过程中产生的预测分析表.xlsx>

具体内容如下所示：

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | == | <= | void | const | % | ( | ) | \* | + | , | - | INT | int | / | IDN | ; | { | != | < | = | } | return | > | >= |
| argFunctionR |  |  |  |  |  |  | argFunctionR -> $ |  |  | argFunctionR -> , funcRParam argFunctionR |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| eqExpAtom | eqExpAtom -> == relExp eqExpAtom |  |  |  |  |  | eqExpAtom -> $ |  |  | eqExpAtom -> $ |  |  |  |  |  | eqExpAtom -> $ |  | eqExpAtom -> != relExp eqExpAtom |  | eqExpAtom -> $ |  |  |  |  |
| decl |  |  |  | decl -> constDecl |  |  |  |  |  |  |  |  | decl -> varDecl |  |  |  |  |  |  |  |  |  |  |  |
| constInitVal |  |  |  |  |  |  |  |  |  |  |  | constInitVal -> constExp |  |  | constInitVal -> constExp |  |  |  |  |  |  |  |  |  |
| constDef |  |  |  |  |  |  |  |  |  |  |  |  |  |  | constDef -> IDN = constInitVal |  |  |  |  |  |  |  |  |  |
| compUnit |  |  | compUnit -> funcDef compUnit | compUnit -> decl compUnit |  |  |  |  |  |  |  |  | compUnit -> decl compUnit |  |  |  |  |  |  |  |  |  |  |  |
| funcRParam |  |  |  |  |  |  |  |  |  |  |  | funcRParam -> exp |  |  | funcRParam -> exp |  |  |  |  |  |  |  |  |  |
| addExp |  |  |  |  |  |  |  |  |  |  |  | addExp -> mulExp addExpAtom |  |  | addExp -> mulExp addExpAtom |  |  |  |  |  |  |  |  |  |
| program |  |  | program -> compUnit | program -> compUnit |  |  |  |  |  |  |  |  | program -> compUnit |  |  |  |  |  |  |  |  |  |  |  |
| addExpAtom | addExpAtom -> $ | addExpAtom -> $ |  |  |  |  | addExpAtom -> $ |  | addExpAtom -> + mulExp addExpAtom | addExpAtom -> $ | addExpAtom -> - mulExp addExpAtom |  |  |  |  | addExpAtom -> $ |  | addExpAtom -> $ | addExpAtom -> $ | addExpAtom -> $ |  |  | addExpAtom -> $ | addExpAtom -> $ |
| relExp |  |  |  |  |  |  |  |  |  |  |  | relExp -> addExp relExpAtom |  |  | relExp -> addExp relExpAtom |  |  |  |  |  |  |  |  |  |
| mulExpAtom | mulExpAtom -> $ | mulExpAtom -> $ |  |  | mulExpAtom -> % unaryExp mulExpAtom |  | mulExpAtom -> $ | mulExpAtom -> \* unaryExp mulExpAtom | mulExpAtom -> $ | mulExpAtom -> $ | mulExpAtom -> $ |  |  | mulExpAtom -> / unaryExp mulExpAtom |  | mulExpAtom -> $ |  | mulExpAtom -> $ | mulExpAtom -> $ | mulExpAtom -> $ |  |  | mulExpAtom -> $ | mulExpAtom -> $ |
| funcRParams |  |  |  |  |  |  | funcRParams -> $ |  |  |  |  | funcRParams -> funcRParam argFunctionR |  |  | funcRParams -> funcRParam argFunctionR |  |  |  |  |  |  |  |  |  |
| argVarDecl |  |  |  |  |  |  |  |  |  | argVarDecl -> , varDef argVarDecl |  |  |  |  |  | argVarDecl -> $ |  |  |  |  |  |  |  |  |
| initVal |  |  |  |  |  |  |  |  |  |  |  | initVal -> exp |  |  | initVal -> exp |  |  |  |  |  |  |  |  |  |
| number |  |  |  |  |  |  |  |  |  |  |  | number -> INT |  |  |  |  |  |  |  |  |  |  |  |  |
| argConst |  |  |  |  |  |  |  |  |  | argConst -> , constDef argConst |  |  |  |  |  | argConst -> $ |  |  |  |  |  |  |  |  |
| eqExp |  |  |  |  |  |  |  |  |  |  |  | eqExp -> relExp eqExpAtom |  |  | eqExp -> relExp eqExpAtom |  |  |  |  |  |  |  |  |  |
| funcFParams |  |  |  |  |  |  | funcFParams -> $ |  |  |  |  |  | funcFParams -> funcFParam argFunctionF |  |  |  |  |  |  |  |  |  |  |  |
| block |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | block -> { blockItem } |  |  |  |  |  |  |  |
| mulExp |  |  |  |  |  |  |  |  |  |  |  | mulExp -> unaryExp mulExpAtom |  |  | mulExp -> unaryExp mulExpAtom |  |  |  |  |  |  |  |  |  |
| argExp |  |  |  |  |  |  |  |  |  |  |  | argExp -> exp |  |  | argExp -> exp | argExp -> $ |  |  |  |  |  |  |  |  |
| exp |  |  |  |  |  |  |  |  |  |  |  | exp -> assignExp |  |  | exp -> assignExp |  |  |  |  |  |  |  |  |  |
| constExp |  |  |  |  |  |  |  |  |  |  |  | constExp -> assignExp |  |  | constExp -> assignExp |  |  |  |  |  |  |  |  |  |
| funcType |  |  | funcType -> void |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| assignExp |  |  |  |  |  |  |  |  |  |  |  | assignExp -> eqExp assignExpAtom |  |  | assignExp -> eqExp assignExpAtom |  |  |  |  |  |  |  |  |  |
| relExpAtom | relExpAtom -> $ | relExpAtom -> <= addExp relExpAtom |  |  |  |  | relExpAtom -> $ |  |  | relExpAtom -> $ |  |  |  |  |  | relExpAtom -> $ |  | relExpAtom -> $ | relExpAtom -> < addExp relExpAtom | relExpAtom -> $ |  |  | relExpAtom -> > addExp relExpAtom | relExpAtom -> >= addExp relExpAtom |
| constDecl |  |  |  | constDecl -> const bType constDef argConst ; |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| assignExpAtom |  |  |  |  |  |  | assignExpAtom -> $ |  |  | assignExpAtom -> $ |  |  |  |  |  | assignExpAtom -> $ |  |  |  | assignExpAtom -> = eqExp assignExpAtom |  |  |  |  |
| callFunc | callFunc -> $ | callFunc -> $ |  |  | callFunc -> $ | callFunc -> ( funcRParams ) | callFunc -> $ | callFunc -> $ | callFunc -> $ | callFunc -> $ | callFunc -> $ |  |  | callFunc -> $ |  | callFunc -> $ |  | callFunc -> $ | callFunc -> $ | callFunc -> $ |  |  | callFunc -> $ | callFunc -> $ |
| bType |  |  |  |  |  |  |  |  |  |  |  |  | bType -> int |  |  |  |  |  |  |  |  |  |  |  |
| unaryExp |  |  |  |  |  |  |  |  |  |  |  | unaryExp -> number |  |  | unaryExp -> IDN callFunc |  |  |  |  |  |  |  |  |  |
| argVarDef |  |  |  |  |  |  |  |  |  | argVarDef -> $ |  |  |  |  |  | argVarDef -> $ |  |  |  | argVarDef -> = initVal |  |  |  |  |
| funcFParam |  |  |  |  |  |  |  |  |  |  |  |  | funcFParam -> bType IDN |  |  |  |  |  |  |  |  |  |  |  |
| varDef |  |  |  |  |  |  |  |  |  |  |  |  |  |  | varDef -> IDN argVarDef |  |  |  |  |  |  |  |  |  |
| blockItem |  |  |  | blockItem -> decl blockItem |  |  |  |  |  |  |  | blockItem -> stmt blockItem | blockItem -> decl blockItem |  | blockItem -> stmt blockItem | blockItem -> stmt blockItem | blockItem -> stmt blockItem |  |  |  | blockItem -> $ | blockItem -> stmt blockItem |  |  |
| argFunctionF |  |  |  |  |  |  | argFunctionF -> $ |  |  | argFunctionF -> , funcFParam argFunctionF |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| varDecl |  |  |  |  |  |  |  |  |  |  |  |  | varDecl -> bType varDef argVarDecl ; |  |  |  |  |  |  |  |  |  |  |  |
| stmt |  |  |  |  |  |  |  |  |  |  |  | stmt -> exp ; |  |  | stmt -> exp ; | stmt -> ; | stmt -> block |  |  |  |  | stmt -> return argExp ; |  |  |
| funcDef |  |  | funcDef -> funcType IDN ( funcFParams ) block |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

## 3.3 语法分析器类简介

语法分析器主要的类如下

yacc  
├─entity  
│ Analysis.java  
│ Grammar.java  
│ Rool.java  
│  
├─implement  
│ YaccImpl.java  
│  
└─itf  
 Yacc.java

### 3.3.1 yacc.entity.Analysis

使用预测分析表分析时每一条分析的实体类

主要字段如下

|  |
| --- |
| //操作序号  private String no;  //使用的规则序号  private String roolNo;  //栈顶符号  private String stackSym;  //面对的输入符号  private String faceSym;  //进行的动作  private String action; |

### 3.3.2 yacc.entity.Rool

每一条从grammar.txt中获取的规则的实体类

主要字段如下

|  |
| --- |
| //规则序号  private String no;  //规则左部  private String left;  //规则右部  private String right; |

### 3.3.3 yacc.entity.Grammar

语法实体，一个文法文件对应一个Grammar实体，采用构造工厂模式，只能用getGrammarInstance()方式构建实例

主要字段如下

|  |
| --- |
| //非终结符集合  private List<String> nonEndSymbol;  //终结符集合，此处将$也算在了终结符中  private List<String> endSymbol;  //开始符号  private String startSymbol;  //一条一条单个的规则  private List<Rool> rools;  //一个非终结符对应的一组规则  private Map<String,Set<String>> newRools;  //单个符号的first集合  private Map<String, List<String>> first;  //非终结符的follow集合  private Map<String, Set<String>> nonFollow;  // 存储在查找FOLLOW集合时非终结符的状态,仅在本类中使用  private Map<String, Integer> status;  //预测分析表，第一个String是非终结符，第二个是终结符  private Map<String,Map<String, Rool>> predictMap; |

主要方法如下

|  |
| --- |
| /\*\*  \* @param :  \* @return Map<String,List<String>>  \* @author ZhouXiang  \* @description 计算本语法终结符与非终结符的First集  \*/  private Map<String,List<String>> calculateFirst();    /\*\*  \* @param :  \* @return void  \* @author ZhouXiang  \* @description 计算Fowllow集合  \*/  private void calculateFOLLOW();  /\*\*  \* @param :  \* @return void  \* @author ZhouXiang  \* @description 计算预测分析表  \*/  private void calculateMap(); |

### 3.3.4 yacc.implement.YaccImpl

是yacc.itf.Yacc的实现类，实现了yacc.itf.Yacc中声明的抽象方法

### 3.3.5 yacc.itf.Yacc

是语法分析器对外声明的接口，声明了语法分析器要实现的方法

|  |
| --- |
| /\*\*  \* @param tokens: 词法分析产生的序列  \* @param filePath: 语法分析产生文件的路径  \* @return boolean 语法分析是否成功  \* @author ZhouXiang  \* @description 根据词法分析的结果，产生语法分析的结果，输入到文件中  \*/  public boolean printYacc(List<Token> tokens, String filePath) throws IOException; |

## 3.4 语法分析器主要算法

### 3.4.1 Rool序列的获取

获取Rool序列的方法是按行读取grammar.txt文件，解析出每一条Rool的左部和右部

具体实现在yacc.entity.Grammar.getGrammarByFile()方法

|  |
| --- |
| public static Grammar getGrammarByFile(String filePath,String start) throws IOException {  List<Rool> rools = new ArrayList<>();  List<String> nonEndSymbols = new ArrayList<>();  List<String> endSymbols = new ArrayList<>();  String roolStr = "";  InputStream in = ClassLoader.getSystemResourceAsStream(filePath);  Scanner scanner = new Scanner(in);  int cnt = 1; //用于记录规则号  while (scanner.hasNextLine()){  roolStr = scanner.nextLine();  if(roolStr.equals("")){  continue;  }  //获取规则  Rool rool = new Rool();  String roolNo = String.valueOf(cnt);  cnt++;  String content = roolStr;  String left = content.split("->",2)[0].trim();  String right = content.split("->",2)[1].trim();  rool.setNo(roolNo);  rool.setLeft(left);  rool.setRight(right);  rools.add(rool);  //获取非终结符，出现在左边的全是非终结符，且非终结符只会在左边出现  if(!nonEndSymbols.contains(left)){  nonEndSymbols.add(left);  }  //获取终结符，先将右边的符号都放进去，后面进行对右边的符号分割，去除终结符的操作  if(!endSymbols.contains(right)){  endSymbols.add(right);  }  }  //对终结符，进行分割，去除终结符的操作  List<String> realEndSymbols = new ArrayList<>();  Iterator<String> it = endSymbols.iterator();  while (it.hasNext()){  String endSymbol = it.next();  if(endSymbol.equals("{ blockItem }")){  int a = 3;  }  //如果它是非终结符，不用加入  if(nonEndSymbols.contains(endSymbol)){;  continue;  }  String[] endSymbolStr = endSymbol.split(" ");  //进行分割，找终结符  if(endSymbolStr.length != 1){  for(int j = 0;j < endSymbolStr.length;j++){  if(!nonEndSymbols.contains(endSymbolStr[j]) && !realEndSymbols.contains(endSymbolStr[j])){  realEndSymbols.add(endSymbolStr[j]);  }  }  it.remove();  }else {  realEndSymbols.add(endSymbol);  }  }  endSymbols = realEndSymbols;  //对非终结符与终结符去重  Set<String> set = new HashSet<>(nonEndSymbols);  nonEndSymbols.clear();  nonEndSymbols.addAll(set);  set = new HashSet<>(endSymbols);  endSymbols.clear();  endSymbols.addAll(set);  Grammar grammar = new Grammar(nonEndSymbols,endSymbols,start,rools);  return grammar;  } |

### 3.4.2 First集合的计算

计算First集合的规则是：

* 如果x是终结符，FIRST(x)为{x}。
* 如果x是空串，FIRST(x)为{空串}。
* 如果x是非终结符，x->Y1Y2Y3...，逐步地从Y1计算起，如果Y1的FIRST集包含空串，将FIRST(Y1)-空串加入到FIRST(X)，继续计算FIRST(Y2)，... ，如果计算到某个符号Yn不包含空串，就结束计算。如果计算到最后一个符号也包含空串，也就是说Y1Y2Y3...->空串，则加入最后一个符号的FIRST集。

计算某一个符号的First集合的主要步骤如下：

1. 对单个终结符，其First集合是它自身，返回自身所形成的List<String>
2. 对单个非终结符a
   1. 初始化其First集合List<String> result为空
   2. 遍历文法的Rool，找到rool.right中包含a的所有rool.right
   3. 求这些rool.right的First集合，将其加入到result中
   4. 返回result
3. 对所有不止一个的符号S，将S用空格分割成String[] patterns，初始化其First集合List<String> result为空
   1. 若paterns[0]是终结符，result.add(patterns[0])，返回result
   2. 若patterns[0]不是终结符，遍历整个patterns，遍历过程中执行下面的操作
      1. 计算patterns[i]的First集合patternsFirst
      2. 判断patternsFirst是否包含空(在本程序中用$替代)
      3. 若不包含，执行result.addAll(patternsFirst)，结束遍历
      4. 若包含，判断是否是最后一个符号(即i == patterns.length - 1)
      5. 若是最后一个符号，执行result.addAll(patternsFirst)
      6. 若不是最后一个符号，将patternsFirst去掉$，执行result.addAll(patternsFirst)
   3. 返回result

具体代码实现在yacc.entity.Grammar.calculateFirst()中

|  |
| --- |
| private Map<String,List<String>> calculateFirst(){  Map<String,List<String>> result = new HashMap<>();  //终结符，first集合是他本身  for(String endSymbol : this.endSymbol){  List<String> first = new ArrayList<>();  first.add(endSymbol);  result.put(endSymbol,first);  }  //非终结符，first集合要递归地计算  for(String nonSymbol : this.nonEndSymbol){  // if(nonSymbol.equals("querySpecification unionStatements")){  // System.out.println("error");  // }  result.put(nonSymbol,getFirstBySingle(nonSymbol));  }  return result;  }  private List<String> getFirstBySingle(String symbol){  Set<String> result = new HashSet<>();  if(this.endSymbol.contains(symbol)){ //单个终结符，first集合是自身  result.add(symbol);  } else if(this.nonEndSymbol.contains(symbol)){ //单个非终结符，其First集合是其所在的，所有产生该非终结符的规则的右部，的first集合之和  Set<String> rights = this.newRools.get(symbol);  for(String right : rights){  result.addAll(this.getFirstBySingle(right));  }  }else {//处理有几个符号的情况  String[] patterns = symbol.split(" ");  if(this.endSymbol.contains(patterns[0])){  //第一个符号是终结符，其first集合就是这个终结符  result.add(patterns[0]);  } else {  for(int i = 0;i < patterns.length;i++){  List<String> patternsFirst = this.getFirstBySingle(patterns[i]);  if(!patternsFirst.contains("$")){  result.addAll(patternsFirst);  break;  } else {  if(i == patterns.length - 1){  result.addAll(patternsFirst);  }else {  patternsFirst.remove("$");  result.addAll(patternsFirst);  }  }  }  }  }  List<String> realResult = new ArrayList<>(result);  return realResult;  } |

### 3.4.3 Follow集合的计算

计算Follow集合，按以下方式进行处理:

* 对于开始符号S，先将界符加入到其FOLLOW集中。
* 对于A->aBp，如果p不能推导出空串，就将FIRST(p)加入到B的FOLLOW集。
* 如果p能推导出空串，就将FIRST(p)-空串和FOLLOW(A)加入到B的FOLLOW集。

具体的实现在yacc.entity.grammar中

|  |
| --- |
| private void calculateFOLLOW(){  status = new HashMap<>();  nonFollow = new HashMap<>();  for (String character : this.nonEndSymbol) {  // 初始化非终结符的状态  // 状态1表示还没找过  // 状态2表示正在查找  // 状态3表示已经结束查找  status.put(character, 1);  nonFollow.put(character, new HashSet<>());  }  // 首先在开始符号的FOLLOW集中加入界符  Set<String> startFollow = new HashSet<>();  startFollow.add("#");  this.nonFollow.put(this.startSymbol, startFollow);  for (String character : this.nonEndSymbol){  // 如果已经查找完，就跳过  if (status.get(character) == 3){  continue;  }  FOLLOWx(character);  }  }  private Set<String> FOLLOWx(String x){  // 首先置当前查找的非终结符的状态为正在查找  status.put(x, 2);  // 在产生式中搜索所有非终结符出现的位置  for (String character : this.nonEndSymbol){  Set<String> rightSet = this.newRools.get(character);  String[] rightItems = rightSet.toArray(new String[rightSet.size()]);  RightItemLoop:for (String item : rightItems){  // 获取符号列表  List<String> cList = this.disassemble(item);  // 接下来，搜索当前查找的非终结符的位置  for (int i=0; i<cList.size(); i++){  String nonEndChar = cList.get(i);  if (nonEndChar.equals(x)){  // 判断是否处于最右的位置  if (i < cList.size() - 1){  // 如果没在最右边的位置  // 下面循环判断后一个符号是否是非终结符  for (int j=i+1; j<cList.size(); j++){  String nextChar = cList.get(j);  if (this.nonEndSymbol.contains(nextChar)){  // 如果是非终结符，查看其FIRST集是否包含空串  Set<String> nextFirst = this.first.get(nextChar).stream().collect(Collectors.toSet());  // 如果包含空串，并且此时这个符号是最后一个符号  // 就要将其FIRST除去空串的集合加入FOLLOW集，且左部的FOLLOW集加入FOLLOW集  if (nextFirst.contains("$")){  // 判断是否是最后一个符号  if (j == cList.size() - 1){  // 这里首先判断一下要递归查找的非终结符的状态  // 如果为正在查找，就会陷入死循环  // 所以要略过这一条产生式  // 在略过产生式之前，因为直接略过会遗漏掉之前正在查找的非终结符的FOLLOW集中的元素，所以要加上  if (status.get(character) == 2){  Set<String> follow = this.nonFollow.get(character);  if (follow.size() != 0){  addCharsToFOLLOW(follow, x);  }  continue RightItemLoop;  }  Set<String> leftFOLLOW = FOLLOWx(character);  Set<String> nextFirstExceptNULL = new HashSet<>(nextFirst);  nextFirstExceptNULL.remove("$");  addCharsToFOLLOW(leftFOLLOW, x);  addCharsToFOLLOW(nextFirstExceptNULL, x);  } else{  // 如果不是最后一个符号，将FIRST集合加入  Set<String> nextFirstExceptNULL = new HashSet<>(nextFirst);  nextFirstExceptNULL.remove("$");  addCharsToFOLLOW(nextFirstExceptNULL, x);  }  } else{  // 如果不包含空串加入FIRST之后跳出循环  addCharsToFOLLOW(nextFirst, x);  break;  }  } else{  // 如果不是非终结符，把此符号加入到当前查找的非终结符的FOLLOW集中  addCharToFOLLOW(nextChar, nonEndChar);  break;  }  }  }  // 如果在最右边，将FOLLOW（左部）加入到当前非终结符的FOLLOW集合  else{  // 这里首先判断一下要递归查找的非终结符的状态  // 如果为正在查找，就会陷入死循环  // 所以要略过这一条产生式  // 在略过产生式之前，因为直接略过会遗漏掉之前正在查找的非终结符的FOLLOW集中的元素，所以要加上  if (status.get(character) == 2){  Set<String> follow = this.nonFollow.get(character);  if (follow.size() != 0){  addCharsToFOLLOW(follow, x);  }  continue RightItemLoop;  }  Set<String> leftFOLLOW = FOLLOWx(character);  addCharsToFOLLOW(leftFOLLOW, x);  }  }  }  }  }  // 如果return，说明已经查找完  status.put(x, 3);  return this.nonFollow.get(x);  } |

### 3.4.5 预测分析表的计算

计算步骤如下：

1. 将预测分析表M的所有位置置为errorRool
2. 遍历所有的Rool，执行2，3步
3. 求rool.right的First集合，对其中的每一个终结符a，把M[rool.left, a]置为rool
4. 若rool.right的First集合中有$(空)，对rool.left的Follow集合中的每一个终结符b，把M[rool.left, b]置为rool

具体实现在yacc.entity.Grammar.calculateMap()中

|  |
| --- |
| private void calculateMap(){  this.predictMap = new HashMap<>();  Rool error = new Rool("error","error","error");  //初始化，置为error  for (String nonEnd : this.nonEndSymbol){  Map<String,Rool> map = new HashMap<>();  for(String end : this.endSymbol){  if(end.equals("$")){  continue;  }  map.put(end,error);  }  this.predictMap.put(nonEnd,map);  }  //遍历rool来看预测分析表  for (Rool rool : this.rools){  List<String> first = this.getFirstBySingle(rool.getRight()); //右边的first集合  Set<String> follow = this.nonFollow.get(rool.getLeft()); //左边的follow集合，左边必定是非终结符  String non = rool.getLeft();  //在终结符中加#,此时$还包含在endSymbol中  List<String> newSym = new ArrayList<>(this.endSymbol);  newSym.add("#");  if(!first.contains("$")){  for(String end : newSym){  //去掉endSymbol中的$的影响  if(end.equals("$")){  continue;  }  if(first.contains(end)){  editPredictMap(non,end,rool);  }  }  }else {  for(String end : newSym){  if(end.equals("$")){  continue;  }  if(first.contains(end)){  editPredictMap(non,end,rool);  }  }  for(String endB : newSym){  if (endB.equals("$")){  continue;  }  if(follow.contains(endB)){  editPredictMap(non,endB,rool);  }  }  }  }  } |

### 3.4.5 语法分析过程文件的生成

根据Token序列和预测分析表来生成语法分析过程文件yacc.txt的过程如下：

1. 初始化一个stack，将#和开始符号入栈，在Token序列末端加上#，初始化token序列的指针i
2. 判断stack是否为空
3. 若为空，执行14
4. 若不为空，从栈中取出(不移除)栈顶元素now，从token中取出token[i]为face
5. 若now与face相同，判断是不是#，
6. 若都为#，则操作为accept，执行
7. 若不是#，则操作为move，移除栈顶元素，i++
8. 若now与face不同，查找M[now, face]的rool
9. 若rool为error，则说明语法分析遇到错误，记日志，退出程序
10. 若rool不为error，则操作为reduction，如果rool.right是不是为$(空)
11. 若rool.right为$(空)，从stack中移除栈顶元素
12. 若rool.right不为$(空)，从stack中移除栈顶元素，将rool右边的元素入栈
13. 执行2
14. 遍历储存的analysis信息
15. 将每一条analysis信息输出到语法分析过程文件yacc.txt中

具体实现在yacc.implement.YaccImpl.printYacc()中

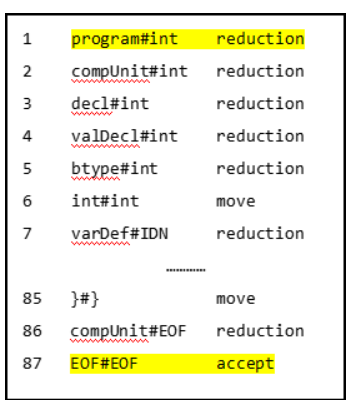
|  |
| --- |
| public boolean printYacc(List<Token> tokens, String filePath) throws IOException {  String grammarFile = "config/grammar.txt";  Grammar grammar = Grammar.getGrammarByFile(grammarFile, "program");  Stack<String> stack = new Stack<>();  Map<String,Map<String, Rool>> table = grammar.getPredictMap();  stack.push("#");  stack.push(grammar.getStartSymbol());  List<Analysis> analysises = new ArrayList<>();  Token endToken = new Token("#","#");  endToken.calculateDealing();  tokens.add(endToken);  int i = 0;  Integer analysisNo = 1;  while (!stack.empty()){  Token token = tokens.get(i);  Analysis analysis = new Analysis();  analysis.setNo(analysisNo.toString());  analysis.setStackSym(stack.peek());  analysis.setFaceSym(token.getDealing());  String now = analysis.getStackSym();  String face = analysis.getFaceSym();  //调试使用  // if(now.equals("compUnit") && !face.equals("void")){  // int a = 3;  // }  if(now.equals(face)){  if(now.equals("#")){  analysis.setAction("accept");  analysis.setRoolNo("/");  analysises.add(analysis);  break;  }else {  analysis.setAction("move");  analysis.setRoolNo("/");  analysises.add(analysis);  stack.pop();  i++;  }  } else {  Rool rool = this.dictionary(now,face,table);  if(rool.getNo() == "error"){  analysis.setAction("error");  analysis.setRoolNo("/");  analysises.add(analysis);  String info = "语法分析遇到错误, 非终结符: " + now + ", 面临的终结符: " + face;  Log.errorLog(info, logger);  break;  // System.exit(401);  // stack.pop();  // i++;  } else {  analysis.setAction("reduction");  analysis.setRoolNo(rool.getNo());  analysises.add(analysis);  if(rool.getRight().equals("$")){  stack.pop();  }else {  stack.pop();  String[] rights = rool.getRight().split(" ");  for(int j = rights.length - 1; j >= 0; j--){  stack.push(rights[j]);  }  }  }  }  analysisNo++;  }  File file = new File(filePath);  if(!file.exists()){  file.createNewFile();  }  FileWriter fw = new FileWriter(file,false);  BufferedWriter bw = new BufferedWriter(fw);  for(Analysis analysis : analysises){  //将"#"转为EOF  if(analysis.getFaceSym().equals("#")){  analysis.setFaceSym("EOF");  }  if(analysis.getStackSym().equals("#")){  analysis.setStackSym("EOF");  }  String content = "";  content = content + analysis.getStackSym() + "#" + analysis.getFaceSym() + "\t" + analysis.getAction() + "\n";  bw.write(content);  }  bw.close();  return true;  } |

## 3.5 语法分析器输出格式说明

### 3.5.1 语法分析过程文件yacc.txt格式说明

输出格式为

[栈顶符号]#[面临输入符号][TAB][执行动作]



# 四. 程序检测

本程序使用junit进行单元检测，执行mvn test命令会自动执行检测单元，生成检测报告在target/surefire-reports下。

## 4.1 实现代码

检测的实现的代码如下所示。

以下是词法分析器部分的检测：

|  |
| --- |
| public class LexImplTest {   @Test  public void lexAnalysisToFile() throws IOException {  String dir = "./src/test/resources";  Lex lex = new LexImpl();  for(int i = 0; i < 5; i++){  String inputFile = dir + "/" + i + "/" + i + ".txt";  String testFile = dir + "/" + i + "/lexical.txt";  String expectedFile = dir + "/" + i + "/" + i + "\_lexical.txt";   lex.lexAnalysisToFile(inputFile, testFile);   Scanner sc = new Scanner(new File(testFile));  StringBuilder testBuilder = new StringBuilder();  while (sc.hasNext()){  String line = sc.nextLine();  testBuilder.append(line + System.lineSeparator());  }  String test = testBuilder.toString();   sc = new Scanner(new File(expectedFile));  StringBuilder expectedBuilder = new StringBuilder();  while (sc.hasNext()){  String line = sc.nextLine();  expectedBuilder.append(line + System.lineSeparator());  }  String expected = expectedBuilder.toString();  assertEquals(expected, test);  }  } } |

以下是语法分析器检测的实现代码

|  |
| --- |
| public class YaccTest {   @Test  public void printYacc() throws IOException {  String dir = "D:\\大学\\课程\\编译原理\\My大作业\\C--Complier\\complier\\src\\test\\resources";  Lex lex = new LexImpl();  Yacc yacc = new YaccImpl();   for(int i = 0; i < 4; i++){  String inputFile = dir + "\\" + i + "\\" + i + ".txt";  String testFile = dir + "\\" + i + "\\grammar.txt";  String expectedFile = dir + "\\" + i + "\\" + i + "\_grammar.txt";   String input = Util.readFile(inputFile);  List<Token> tokens = lex.lexAnalysis(input);  yacc.printYacc(tokens, testFile);   String expected = Util.readFile(expectedFile);  String test = Util.readFile(testFile);   Assert.assertEquals(expected, test);  }  } } |

## 4.2 检测结果

使用助教给的样例的检测结果如下所示

### 4.2.1 测试用例00

用例的输入文件00.txt

|  |
| --- |
| void main(){  return 3;  } |

产生的38lex.txt

|  |
| --- |
| void <KW>  main <IDN>  ( <SE>  ) <SE>  { <SE>  return <KW>  3 <INT>  ; <SE>  } <SE> |

产生的38gra.txt

|  |
| --- |
| program#void reduction  compUnit#void reduction  funcDef#void reduction  funcType#void reduction  void#void move  IDN#IDN move  (#( move  funcFParams#) reduction  )#) move  block#{ reduction  {#{ move  blockItem#return reduction  stmt#return reduction  return#return move  argExp#INT reduction  exp#INT reduction  assignExp#INT reduction  eqExp#INT reduction  relExp#INT reduction  addExp#INT reduction  mulExp#INT reduction  unaryExp#INT reduction  number#INT reduction  INT#INT move  mulExpAtom#; reduction  addExpAtom#; reduction  relExpAtom#; reduction  eqExpAtom#; reduction  assignExpAtom#; reduction  ;#; move  blockItem#} reduction  }#} move  compUnit#EOF reduction  EOF#EOF accept |

### 4.2.2 测试用例01

用例的输入文件01.txt

|  |
| --- |
| int a = 3;  int b = 5;  void main(){  int a = 5;  return a + b;  } |

产生的38lex.txt

|  |
| --- |
| int <KW>  a <IDN>  = <OP>  3 <INT>  ; <SE>  int <KW>  b <IDN>  = <OP>  5 <INT>  ; <SE>  void <KW>  main <IDN>  ( <SE>  ) <SE>  { <SE>  int <KW>  a <IDN>  = <OP>  5 <INT>  ; <SE>  return <KW>  a <IDN>  + <OP>  b <IDN>  ; <SE>  } <SE> |

产生的38gra.txt

|  |
| --- |
| program#int reduction  compUnit#int reduction  decl#int reduction  varDecl#int reduction  bType#int reduction  int#int move  varDef#IDN reduction  IDN#IDN move  argVarDef#= reduction  =#= move  initVal#INT reduction  exp#INT reduction  assignExp#INT reduction  eqExp#INT reduction  relExp#INT reduction  addExp#INT reduction  mulExp#INT reduction  unaryExp#INT reduction  number#INT reduction  INT#INT move  mulExpAtom#; reduction  addExpAtom#; reduction  relExpAtom#; reduction  eqExpAtom#; reduction  assignExpAtom#; reduction  argVarDecl#; reduction  ;#; move  compUnit#int reduction  decl#int reduction  varDecl#int reduction  bType#int reduction  int#int move  varDef#IDN reduction  IDN#IDN move  argVarDef#= reduction  =#= move  initVal#INT reduction  exp#INT reduction  assignExp#INT reduction  eqExp#INT reduction  relExp#INT reduction  addExp#INT reduction  mulExp#INT reduction  unaryExp#INT reduction  number#INT reduction  INT#INT move  mulExpAtom#; reduction  addExpAtom#; reduction  relExpAtom#; reduction  eqExpAtom#; reduction  assignExpAtom#; reduction  argVarDecl#; reduction  ;#; move  compUnit#void reduction  funcDef#void reduction  funcType#void reduction  void#void move  IDN#IDN move  (#( move  funcFParams#) reduction  )#) move  block#{ reduction  {#{ move  blockItem#int reduction  decl#int reduction  varDecl#int reduction  bType#int reduction  int#int move  varDef#IDN reduction  IDN#IDN move  argVarDef#= reduction  =#= move  initVal#INT reduction  exp#INT reduction  assignExp#INT reduction  eqExp#INT reduction  relExp#INT reduction  addExp#INT reduction  mulExp#INT reduction  unaryExp#INT reduction  number#INT reduction  INT#INT move  mulExpAtom#; reduction  addExpAtom#; reduction  relExpAtom#; reduction  eqExpAtom#; reduction  assignExpAtom#; reduction  argVarDecl#; reduction  ;#; move  blockItem#return reduction  stmt#return reduction  return#return move  argExp#IDN reduction  exp#IDN reduction  assignExp#IDN reduction  eqExp#IDN reduction  relExp#IDN reduction  addExp#IDN reduction  mulExp#IDN reduction  unaryExp#IDN reduction  IDN#IDN move  callFunc#+ reduction  mulExpAtom#+ reduction  addExpAtom#+ reduction  +#+ move  mulExp#IDN reduction  unaryExp#IDN reduction  IDN#IDN move  callFunc#; reduction  mulExpAtom#; reduction  addExpAtom#; reduction  relExpAtom#; reduction  eqExpAtom#; reduction  assignExpAtom#; reduction  ;#; move  blockItem#} reduction  }#} move  compUnit#EOF reduction  EOF#EOF accept |

### 4.2.3 测试用例02

用例的输入文件02.txt

|  |
| --- |
| void main(){  int a, b0, \_c;  a = 1;  b0 = 2;  \_c = 3;  return b0 + \_c;  } |

产生的38lex.txt

|  |
| --- |
| void <KW>  main <IDN>  ( <SE>  ) <SE>  { <SE>  int <KW>  a <IDN>  , <SE>  b0 <IDN>  , <SE>  \_c <IDN>  ; <SE>  a <IDN>  = <OP>  1 <INT>  ; <SE>  b0 <IDN>  = <OP>  2 <INT>  ; <SE>  \_c <IDN>  = <OP>  3 <INT>  ; <SE>  return <KW>  b0 <IDN>  + <OP>  \_c <IDN>  ; <SE>  } <SE> |

产生的38gra.txt

|  |
| --- |
| program#void reduction  compUnit#void reduction  funcDef#void reduction  funcType#void reduction  void#void move  IDN#IDN move  (#( move  funcFParams#) reduction  )#) move  block#{ reduction  {#{ move  blockItem#int reduction  decl#int reduction  varDecl#int reduction  bType#int reduction  int#int move  varDef#IDN reduction  IDN#IDN move  argVarDef#, reduction  argVarDecl#, reduction  ,#, move  varDef#IDN reduction  IDN#IDN move  argVarDef#, reduction  argVarDecl#, reduction  ,#, move  varDef#IDN reduction  IDN#IDN move  argVarDef#; reduction  argVarDecl#; reduction  ;#; move  blockItem#IDN reduction  stmt#IDN reduction  exp#IDN reduction  assignExp#IDN reduction  eqExp#IDN reduction  relExp#IDN reduction  addExp#IDN reduction  mulExp#IDN reduction  unaryExp#IDN reduction  IDN#IDN move  callFunc#= reduction  mulExpAtom#= reduction  addExpAtom#= reduction  relExpAtom#= reduction  eqExpAtom#= reduction  assignExpAtom#= reduction  =#= move  eqExp#INT reduction  relExp#INT reduction  addExp#INT reduction  mulExp#INT reduction  unaryExp#INT reduction  number#INT reduction  INT#INT move  mulExpAtom#; reduction  addExpAtom#; reduction  relExpAtom#; reduction  eqExpAtom#; reduction  assignExpAtom#; reduction  ;#; move  blockItem#IDN reduction  stmt#IDN reduction  exp#IDN reduction  assignExp#IDN reduction  eqExp#IDN reduction  relExp#IDN reduction  addExp#IDN reduction  mulExp#IDN reduction  unaryExp#IDN reduction  IDN#IDN move  callFunc#= reduction  mulExpAtom#= reduction  addExpAtom#= reduction  relExpAtom#= reduction  eqExpAtom#= reduction  assignExpAtom#= reduction  =#= move  eqExp#INT reduction  relExp#INT reduction  addExp#INT reduction  mulExp#INT reduction  unaryExp#INT reduction  number#INT reduction  INT#INT move  mulExpAtom#; reduction  addExpAtom#; reduction  relExpAtom#; reduction  eqExpAtom#; reduction  assignExpAtom#; reduction  ;#; move  blockItem#IDN reduction  stmt#IDN reduction  exp#IDN reduction  assignExp#IDN reduction  eqExp#IDN reduction  relExp#IDN reduction  addExp#IDN reduction  mulExp#IDN reduction  unaryExp#IDN reduction  IDN#IDN move  callFunc#= reduction  mulExpAtom#= reduction  addExpAtom#= reduction  relExpAtom#= reduction  eqExpAtom#= reduction  assignExpAtom#= reduction  =#= move  eqExp#INT reduction  relExp#INT reduction  addExp#INT reduction  mulExp#INT reduction  unaryExp#INT reduction  number#INT reduction  INT#INT move  mulExpAtom#; reduction  addExpAtom#; reduction  relExpAtom#; reduction  eqExpAtom#; reduction  assignExpAtom#; reduction  ;#; move  blockItem#return reduction  stmt#return reduction  return#return move  argExp#IDN reduction  exp#IDN reduction  assignExp#IDN reduction  eqExp#IDN reduction  relExp#IDN reduction  addExp#IDN reduction  mulExp#IDN reduction  unaryExp#IDN reduction  IDN#IDN move  callFunc#+ reduction  mulExpAtom#+ reduction  addExpAtom#+ reduction  +#+ move  mulExp#IDN reduction  unaryExp#IDN reduction  IDN#IDN move  callFunc#; reduction  mulExpAtom#; reduction  addExpAtom#; reduction  relExpAtom#; reduction  eqExpAtom#; reduction  assignExpAtom#; reduction  ;#; move  blockItem#} reduction  }#} move  compUnit#EOF reduction  EOF#EOF accept |

### 4.2.1 测试用例07

用例的输入文件07.txt

|  |
| --- |
| void main(){  const int a = 10, b = 5;  return b;  } |

产生的38lex.txt

|  |
| --- |
| void <KW>  main <IDN>  ( <SE>  ) <SE>  { <SE>  const <KW>  int <KW>  a <IDN>  = <OP>  10 <INT>  , <SE>  b <IDN>  = <OP>  5 <INT>  ; <SE>  return <KW>  b <IDN>  ; <SE>  } <SE> |

产生的38gra.txt

|  |
| --- |
| program#void reduction  compUnit#void reduction  funcDef#void reduction  funcType#void reduction  void#void move  IDN#IDN move  (#( move  funcFParams#) reduction  )#) move  block#{ reduction  {#{ move  blockItem#const reduction  decl#const reduction  constDecl#const reduction  const#const move  bType#int reduction  int#int move  constDef#IDN reduction  IDN#IDN move  =#= move  constInitVal#INT reduction  constExp#INT reduction  assignExp#INT reduction  eqExp#INT reduction  relExp#INT reduction  addExp#INT reduction  mulExp#INT reduction  unaryExp#INT reduction  number#INT reduction  INT#INT move  mulExpAtom#, reduction  addExpAtom#, reduction  relExpAtom#, reduction  eqExpAtom#, reduction  assignExpAtom#, reduction  argConst#, reduction  ,#, move  constDef#IDN reduction  IDN#IDN move  =#= move  constInitVal#INT reduction  constExp#INT reduction  assignExp#INT reduction  eqExp#INT reduction  relExp#INT reduction  addExp#INT reduction  mulExp#INT reduction  unaryExp#INT reduction  number#INT reduction  INT#INT move  mulExpAtom#; reduction  addExpAtom#; reduction  relExpAtom#; reduction  eqExpAtom#; reduction  assignExpAtom#; reduction  argConst#; reduction  ;#; move  blockItem#return reduction  stmt#return reduction  return#return move  argExp#IDN reduction  exp#IDN reduction  assignExp#IDN reduction  eqExp#IDN reduction  relExp#IDN reduction  addExp#IDN reduction  mulExp#IDN reduction  unaryExp#IDN reduction  IDN#IDN move  callFunc#; reduction  mulExpAtom#; reduction  addExpAtom#; reduction  relExpAtom#; reduction  eqExpAtom#; reduction  assignExpAtom#; reduction  ;#; move  blockItem#} reduction  }#} move  compUnit#EOF reduction  EOF#EOF accept |

# 五. 编译使用说明

## 5.1 编译说明

本项目是maven项目，只要在安装了maven的情况下，在工程根目录(pom.xml所在目录)下执行mvn package，文件将自动编译并打包，编译后的文件都会输出到target文件夹下

## 5.2 使用说明

在打包完成后，进入target文件夹，其中的complier-1.0-SNAPSHOT-jar-with-dependencies.jar就是带所有依赖的jar包，此时执行java -jar ./complier-1.0-SNAPSHOT-jar-with-dependencies.jar即可执行程序。

# 六. 贡献说明

|  |  |
| --- | --- |
| 任务 | 贡献者 |
| 词法分析器 | 周翔 卢锐 |
| 语法分析器 | 周翔 向旭 |
| junit单元检测 | 周翔 向旭 |
| 联合调试 | 周翔 吕鹏程 |
| 开发文档 | 周翔 吕鹏程 |
| PPT制作 | 卢锐 |