```
package parser;

import java.io.BufferedWriter;
import java.io.FileWriter;
import java.io.IOException;
import java.util.ArrayList;
import java.util.List;

import com.sun.org.apache.xpath.internal.operations.Variable;

import scanner.Scanner;
import scanner.Token;
import scanner.Token.TokenType;
import parser.expression.*;
import parser.statement.*;

public class CMinusParser implements Parser
{
   private Scanner scanner;
   // populated after a parse
   private Program parsedProgram = null;

   /*
    * First/Follow Sets
    * The first sub-array is the first set, the following one is the follow set.
    * (Makes sense, right?)
    */
   private TokenType[][] PROGRAM = {
         { TokenType.INT, TokenType.VOID },
         { TokenType.EOF }
   };
   private TokenType[][] DECLARATION_LIST = {
         { TokenType.INT, TokenType.VOID },
         { TokenType.EOF }
   };
   private TokenType[][] DECLARATION = {
         { TokenType.INT, TokenType.VOID },
         { TokenType.INT, TokenType.VOID, TokenType.EOF }
   };
   private TokenType[][] DECLARATION_PRIME = {
         { TokenType.OPEN_PAREN, TokenType.OPEN_BRACKET, TokenType.END_STATEMENT
 },
         { TokenType.INT, TokenType.VOID, TokenType.EOF }
   };
   private TokenType[][] VAR_DECLARATION = {
         { TokenType.INT },
         { TokenType.INT, TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID, Tok
enType.END_STATEMENT, TokenType.OPEN_CBRACE, TokenType.CLOSE_CBRACE, TokenType.I
F, TokenType.WHILE, TokenType.RETURN, TokenType.EPSILON }
   };
   private TokenType[][] VAR_DECLARATION_PRIME = {
         { TokenType.OPEN_BRACKET, TokenType.END_STATEMENT },
         { TokenType.INT, TokenType.VOID, TokenType.EOF }
   };
   private TokenType[][] FUN_DECLARATION_PRIME = {
         { TokenType.OPEN_PAREN },
         { TokenType.INT, TokenType.VOID, TokenType.EOF }
   };
   private TokenType[][] PARAMS = {
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            { TokenType.INT, TokenType.VOID },
            { TokenType.CLOSE_PAREN }
    };
    private TokenType[][] PARAM_LIST = {
            { TokenType.INT },
            { TokenType.CLOSE_PAREN }
    };
    private TokenType[][] PARAM = {
            { TokenType.INT },
            { TokenType.COMMA, TokenType.CLOSE_PAREN }
    };
    private TokenType[][] COMPOUND_STMT = {
            { TokenType.OPEN_CBRACE },
            { TokenType.INT, TokenType.VOID, TokenType.EOF, TokenType.OPEN_PAREN, T
okenType.NUM, TokenType.ID, TokenType.END_STATEMENT, TokenType.OPEN_CBRACE, Toke
nType.IF, TokenType.WHILE, TokenType.RETURN, TokenType.ELSE, TokenType.CLOSE_CBR
ACE }
    };
    private TokenType[][] LOCAL_DECLARATIONS = {
            { TokenType.INT, TokenType.EPSILON },
            { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID, TokenType.END_STAT
EMENT, TokenType.OPEN_CBRACE, TokenType.CLOSE_CBRACE, TokenType.IF, TokenType.WH
ILE, TokenType.RETURN, TokenType.EPSILON }
    };
    private TokenType[][] STATEMENT_LIST = {
            { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID, TokenType.END_STAT
EMENT, TokenType.OPEN_CBRACE, TokenType.IF, TokenType.WHILE, TokenType.RETURN, T
okenType.EPSILON },
            { TokenType.CLOSE_CBRACE }
    };
    private TokenType[][] STATEMENT = {
            { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID, TokenType.END_STAT
EMENT, TokenType.OPEN_CBRACE, TokenType.IF, TokenType.WHILE, TokenType.RETURN },
            { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID, TokenType.END_STAT
EMENT, TokenType.OPEN_CBRACE, TokenType.IF, TokenType.WHILE, TokenType.RETURN, T
okenType.ELSE, TokenType.CLOSE_CBRACE }
    };
    private TokenType[][] EXPRESSION_STMT = {
            { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID, TokenType.END_STAT
EMENT },
            { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID, TokenType.END_STAT
EMENT, TokenType.OPEN_CBRACE, TokenType.IF, TokenType.WHILE, TokenType.RETURN, T
okenType.ELSE, TokenType.CLOSE_CBRACE }
    };
    private TokenType[][] SELECTION_STMT = {
            { TokenType.IF },
            { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID, TokenType.END_STAT
EMENT, TokenType.OPEN_CBRACE, TokenType.IF, TokenType.WHILE, TokenType.RETURN, T
okenType.ELSE, TokenType.CLOSE_CBRACE }
    };
    private TokenType[][] ITERATION_STMT = {
            { TokenType.WHILE },
            { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID, TokenType.END_STAT
EMENT, TokenType.OPEN_CBRACE, TokenType.IF, TokenType.WHILE, TokenType.RETURN, T
okenType.ELSE, TokenType.CLOSE_CBRACE }
    };
    private TokenType[][] RETURN_STMT = {
            { TokenType.RETURN },
            { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID, TokenType.END_STAT
```

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EMENT, TokenType.OPEN_CBRACE, TokenType.IF, TokenType.WHILE, TokenType.RETURN, T
okenType.ELSE, TokenType.CLOSE_CBRACE }
   };
   private TokenType[][] EXPRESSION = {
         { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID },
         { TokenType.END_STATEMENT, TokenType.COMMA, TokenType.CLOSE_PAREN, Toke
nType.CLOSE_BRACKET, TokenType.CLOSE_PAREN }
   };
   private TokenType[][] EXPRESSION_PRIME = {
         { TokenType. ASSIGNMENT, TokenType.OPEN_PAREN, TokenType.OPEN_BRACKET,
TokenType.MULTIPLY, TokenType.DIVIDE, TokenType.PLUS, TokenType.MINUS, TokenType
.EPSILON },
         { TokenType.END_STATEMENT, TokenType.COMMA, TokenType.CLOSE_PAREN, Toke
nType.CLOSE_BRACKET, TokenType.CLOSE_PAREN }
   };
   private TokenType[][] EXPRESSION_PRIME_PRIME = {
         { TokenType. ASSIGNMENT, TokenType.MULTIPLY, TokenType.DIVIDE, TokenTyp
e.PLUS, TokenType.MINUS, TokenType.EPSILON },
         { TokenType.END_STATEMENT, TokenType.COMMA, TokenType.CLOSE_PAREN, Toke
nType.CLOSE_BRACKET, TokenType.CLOSE_PAREN }
   };
   private TokenType[][] VAR = {
         { TokenType.OPEN_BRACKET, TokenType.EPSILON },
         { TokenType.PLUS, TokenType.MINUS, TokenType.MULTIPLY, TokenType.DIVIDE
, TokenType.END_STATEMENT, TokenType.COMMA, TokenType.CLOSE_PAREN, TokenType.CLO
SE_BRACKET, TokenType.CLOSE_PAREN }
   };
   private TokenType[][] SIMPLE_EXPRESSION_PRIME = {
         { TokenType.MULTIPLY, TokenType.DIVIDE, TokenType.PLUS, TokenType.MINUS
, TokenType.LESS_EQUAL_THAN, TokenType.LESS_THAN, TokenType.GREATER_THAN, TokenT
ype.GREATER_EQUAL_THAN, TokenType.EQUALS, TokenType.NOT_EQUALS, TokenType.EPSILO
N },
         { TokenType.END_STATEMENT, TokenType.COMMA, TokenType.CLOSE_PAREN, Toke
nType.CLOSE_BRACKET, TokenType.CLOSE_PAREN }
   };
   private TokenType[][] RELOP = {
         { TokenType.LESS_EQUAL_THAN, TokenType.LESS_THAN, TokenType.GREATER_THA
N, TokenType.GREATER_EQUAL_THAN, TokenType.EQUALS, TokenType.NOT_EQUALS },
         { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID }
   };
   private TokenType[][] ADDITIVE_EXPRESSION = {
         { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID },
         { TokenType.END_STATEMENT, TokenType.COMMA, TokenType.CLOSE_PAREN, Toke
nType.CLOSE_BRACKET, TokenType.CLOSE_PAREN }
   };
   private TokenType[][] ADDITIVE_EXPRESSION_PRIME = {
         { TokenType.MULTIPLY, TokenType.DIVIDE, TokenType.PLUS, TokenType.MINUS
, TokenType.LESS_EQUAL_THAN, TokenType.LESS_THAN, TokenType.GREATER_THAN, TokenT
ype.GREATER_EQUAL_THAN, TokenType.EQUALS, TokenType.NOT_EQUALS, TokenType.EPSILO
N },
         { TokenType.LESS_EQUAL_THAN, TokenType.LESS_THAN, TokenType.GREATER_THA
N, TokenType.GREATER_EQUAL_THAN, TokenType.EQUALS, TokenType.NOT_EQUALS, TokenTy
pe.MULTIPLY, TokenType.DIVIDE, TokenType.END_STATEMENT, TokenType.COMMA, TokenTy
pe.CLOSE_PAREN, TokenType.CLOSE_BRACKET, TokenType.CLOSE_PAREN }
   };
   private TokenType[][] ADDOP = {
         { TokenType.PLUS, TokenType.MINUS },
         { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID }
   };
```

```
   private TokenType[][] TERM = {
         { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID },
         { TokenType.LESS_EQUAL_THAN, TokenType.LESS_THAN, TokenType.GREATER_THA
N, TokenType.GREATER_EQUAL_THAN, TokenType.EQUALS, TokenType.NOT_EQUALS, TokenTy
pe.PLUS, TokenType.MINUS, TokenType.MULTIPLY, TokenType.DIVIDE, TokenType.END_ST
ATEMENT, TokenType.COMMA, TokenType.CLOSE_PAREN, TokenType.CLOSE_BRACKET, TokenT
ype.CLOSE_PAREN }
   };
   private TokenType[][] TERM_PRIME = {
         { TokenType.MULTIPLY, TokenType.DIVIDE, TokenType.EPSILON },
         { TokenType.PLUS, TokenType.MINUS, TokenType.MULTIPLY, TokenType.DIVIDE
, TokenType.END_STATEMENT, TokenType.COMMA, TokenType.CLOSE_PAREN, TokenType.CLO
SE_BRACKET, TokenType.CLOSE_PAREN }
   };
   private TokenType[][] MULOP = {
         { TokenType.MULTIPLY, TokenType.DIVIDE },
         { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID }
   };
   private TokenType[][] FACTOR = {
         { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID },
         { TokenType.LESS_EQUAL_THAN, TokenType.LESS_THAN, TokenType.GREATER_THA
N, TokenType.GREATER_EQUAL_THAN, TokenType.EQUALS, TokenType.NOT_EQUALS, TokenTy
pe.PLUS, TokenType.MINUS, TokenType.MULTIPLY, TokenType.DIVIDE, TokenType.END_ST
ATEMENT, TokenType.COMMA, TokenType.CLOSE_PAREN, TokenType.CLOSE_BRACKET, TokenT
ype.CLOSE_PAREN }
   };
   private TokenType[][] VARCALL = {
         { TokenType.EPSILON, TokenType.OPEN_BRACKET, TokenType.OPEN_PAREN },
         { TokenType.PLUS, TokenType.MINUS, TokenType.MULTIPLY, TokenType.DIVIDE
, TokenType.END_STATEMENT, TokenType.COMMA, TokenType.CLOSE_PAREN, TokenType.CLO
SE_BRACKET, TokenType.CLOSE_PAREN }
   };
   private TokenType[][] CALL = {
         { TokenType.OPEN_PAREN },
         { TokenType.PLUS, TokenType.MINUS, TokenType.MULTIPLY, TokenType.DIVIDE
, TokenType.END_STATEMENT, TokenType.COMMA, TokenType.CLOSE_PAREN, TokenType.CLO
SE_BRACKET, TokenType.CLOSE_PAREN }
   };
   private TokenType[][] ARGS = {
         { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID, TokenType.EPSILON
},
         { TokenType.CLOSE_PAREN }
   };
   private TokenType[][] ARG_LIST = {
         { TokenType.OPEN_PAREN, TokenType.NUM, TokenType.ID },
         { TokenType.CLOSE_PAREN }
   };

   public CMinusParser(Scanner s)
   {
      scanner = s;
   }

   @Override
   public Program parse()
   {
      if (parsedProgram == null)
      {
         parsedProgram = parseProgram();
```

```
      }
      return parsedProgram;
   }

   @Override
   public void printTree(String outFile)
   {
      try
      {
         BufferedWriter bw = new BufferedWriter(new FileWriter(outFile));

         if (parsedProgram != null)
         {
            parsedProgram.print(0, bw);
         }

         bw.flush();
         bw.close();
      }
      catch (IOException e)
      {
         e.printStackTrace();
      }
   }

   /*
    * Matches and consumes the given token.
    * @returns True if matched, false if the next token isn't the one we are loo
king for.
    */
   private boolean matchToken(TokenType t)
   {
      if (scanner.viewNextToken().getType() == t)
      {
         scanner.getNextToken();
         return true;
      }
      return false;
   }

   /**
    * Searches First/Follow Sets
    * @param needle
    * @param haystack
    * @return
    */
   private boolean contains(TokenType needle, TokenType[] haystack)
   {
      for (TokenType straw : haystack)
      {
         if (needle == straw)
            return true;
      }
      return false;
   }

   /**
    * Views the next token type (look ahead character)
    * @return
```

```
     */
    private TokenType nextTokenType()
    {
       return scanner.viewNextToken().getType();
    }

    /**
     * Matches (and munches) a Token or throws the passed message
     * @param tt
     * @param msg
     * @return
     */
    private Token matchOrDie(TokenType tt, String msg)
    {
       if (scanner.viewNextToken().getType() != tt)
       {
          throw new RuntimeException(msg + nextTokenType().name());
       }
       return scanner.getNextToken();
    }

    /*
     * Parse methods, BEGIN!
     */

    /**
     * Parses Program
     * @return
     */
    public Program parseProgram()
    {
       ArrayList<Declaration> declList = new ArrayList<Declaration>();

       while (contains(nextTokenType(), DECLARATION[0]))
       {
          declList.add(parseDeclaration());
       }

       if (!matchToken(TokenType.EOF))
       {
          throw new RuntimeException("parseProgram(): illegal token: " + nextTokenType().na
me());
       }

       return new Program(declList);
    }

    /**
     * Parses a Declaration.
     * @return
     */
    public Declaration parseDeclaration()
    {
       Declaration toReturn;
       // strip off the first two tokens
       Token typeSpecifier = scanner.getNextToken();
       Token identifier = scanner.getNextToken();

       if (typeSpecifier.getType() == TokenType.VOID || (typeSpecifier.getType()
```

```
== TokenType.INT && nextTokenType() == TokenType.OPEN_PAREN))
      {
         // declaration -> void ID fun-declaration'
         // OR  decl    -> int ID fun-declaration'
         // this isn't exactly according to the grammar, but it's better coding
practice

         matchOrDie(TokenType.OPEN_PAREN, "parseDeclaration(): parsing function, open paren expec
ted, got ");
         Params params = parseParams();
         matchOrDie(TokenType.CLOSE_PAREN, "parseDeclaration(): parsing function, close paren exp
ected, got ");

         CompoundStatement body = parseCompoundStatement();

         toReturn = new FunctionDeclaration(typeSpecifier.getType(), (String) id
entifier.getData(), params, body);
      }
      else if (typeSpecifier.getType() == TokenType.INT)
      {
         // declaration -> int ID declaration'
         // AND decl'   -> var-declaration'

         if (matchToken(TokenType.OPEN_BRACKET))
         {
            Token number = matchOrDie(TokenType.NUM, "parseDeclaration(): parsing array decla
ration, expected NUM, got ");

            matchOrDie(TokenType.CLOSE_BRACKET, "parseDeclaration(): parsing array declaration,
expected ']', got " + nextTokenType().name());

            toReturn = new VariableDeclaration((String) identifier.getData(), (I
nteger) number.getData());
         }
         else if (nextTokenType() == TokenType.END_STATEMENT)
         {
            toReturn = new VariableDeclaration((String) identifier.getData());
         }
         else
         {
            throw new RuntimeException("parseDeclaration(): parsing variable, '[' or ';' expected, got
" + nextTokenType().name());
         }

         matchOrDie(TokenType.END_STATEMENT, "parseDeclaration(): parsing variable declaration, ';
' expected, got ");

      }
      else
      {
         throw new RuntimeException("parseDeclaration(): type specifier expected, received " + typ
eSpecifier.getType().name());
      }

      return toReturn;
   }

   /**
    * Parses function parameters.
```

```
     * @return
     */
    private Params parseParams()
    {
       List<VariableDeclaration> params = new ArrayList<VariableDeclaration>();

       if (matchToken(TokenType.VOID))
       {
          //do nothing, since there's no parameters
       }
       else if (nextTokenType() == TokenType.INT)
       {
          // grab the first param
          matchOrDie(TokenType.INT, "parseParams(): INT expected, but got ");
          Token id = matchOrDie(TokenType.ID, "parseParams(): identifier expected, got ");
          if (matchToken(TokenType.OPEN_BRACKET))
          {
             params.add(new VariableDeclaration((String) id.getData(), 0));
             matchOrDie(TokenType.CLOSE_BRACKET, "parseParams(): expected ']', but got ");
          }
          else
          {
             params.add(new VariableDeclaration((String) id.getData()));
          }

          // check for other params
          while (nextTokenType() == TokenType.COMMA)
          {
             scanner.getNextToken();

             matchOrDie(TokenType.INT, "parseParams(): INT expected, but got ");
             id = matchOrDie(TokenType.ID, "parseParams(): identifier expected, got ");
             if (matchToken(TokenType.OPEN_BRACKET))
             {
                params.add(new VariableDeclaration((String) id.getData(), 0));
                matchOrDie(TokenType.CLOSE_BRACKET, "parseParams(): expected ']', but got ");
             }
             else
             {
                params.add(new VariableDeclaration((String) id.getData()));
             }
          }
       }
       else
       {
          throw new RuntimeException("parseParams(): expected 'void' or 'int', got " + nextToken
Type().name());
       }

       return new Params(params);
    }

    /**
     * Parses a CompoundStatement.
     * @return
     */
    private CompoundStatement parseCompoundStatement()
    {
       matchOrDie(TokenType.OPEN_CBRACE, "parseCompoundStatement(): expected '{', got ");
```

```
      List<Declaration> decls = new ArrayList<Declaration>();
      List<Statement> stmts = new ArrayList<Statement>();

      while (nextTokenType() == TokenType.INT)
      {
         scanner.getNextToken();
         Token id = matchOrDie(TokenType.ID, "parseCompoundStatement(): parsing variable declaration, expected identifier and got ");

         if (matchToken(TokenType.OPEN_BRACKET))
         {
            Token num = matchOrDie(TokenType.NUM, "parseCompoundStatement(): expected a number, but got ");
            matchOrDie(TokenType.CLOSE_BRACKET, "parseCompoundStatement(): expected ']', but got ");
            matchOrDie(TokenType.END_STATEMENT, "parseCompoundStatement(): expected ';', but got ");
            decls.add(new VariableDeclaration((String) id.getData(), (Integer) num.getData()));
         }
         else if (matchToken(TokenType.END_STATEMENT))
         {
            decls.add(new VariableDeclaration((String) id.getData()));
         }
         else
         {
            throw new RuntimeException("parseCompoundStatement(): expected '[' or ';', got ");
         }
      }

      while (contains(nextTokenType(), STATEMENT_LIST[0]) && nextTokenType() != TokenType.CLOSE_CBRACE)
      {
         stmts.add(parseStatement());
      }

      matchOrDie(TokenType.CLOSE_CBRACE, "parseCompoundStatement(): expected '}', got ");
      return new CompoundStatement(decls, stmts);
   }

   /**
    * Parses Statement
    * @return
    */
   private Statement parseStatement()
   {
      Statement toReturn = null;
      if(nextTokenType() == TokenType.IF)
      {
         //if ( expression ) statement [ else statement ]
         toReturn = parseSelectionStatement();
      }
      else if(nextTokenType() == TokenType.WHILE)
      {
         //while ( expression ) statement
         toReturn = parseIterationStatement();
      }
      else if(nextTokenType() == TokenType.RETURN)
      {
```

```
         //return [expression] ;
         toReturn = parseReturnStatement();
      }
      else if(nextTokenType() == TokenType.OPEN_CBRACE)
      {
         //{ local-declarations statement-list }
         toReturn = parseCompoundStatement();
      }
      else if(contains(nextTokenType(), EXPRESSION[0]))
      {
         //[expression] ;
         toReturn = parseExpressionStatement();
      }
      else
      {
         throw new RuntimeException("parseStatement(): Invalid token for statement, got ");
      }
      return toReturn;
   }

   /**
    * Parses an Expression Statement
    * @return
    */
   private Statement parseExpressionStatement()
   {
      //[expression] ;
      Expression body = null;
      if(contains(nextTokenType(), EXPRESSION[0]))
      {
         body = parseExpression();
      }
      matchOrDie(TokenType.END_STATEMENT, "parseReturnStatement(): Did not recieve ';', got");
      Statement toReturn = new ExpressionStatement(body);
      return toReturn;
   }

   /**
    * Parses a SelectionStatement
    * @return
    */
   private Statement parseSelectionStatement()
   {
      //if ( expression ) statement [ else statement ]
      Statement else_part = null;
      matchOrDie(TokenType.IF,  "parseSelectionStatement(): Did not recieve 'IF', got");
      matchOrDie(TokenType.OPEN_PAREN, "parseSelectionStatement(): Did not recieve '(', got");
      Expression compare = parseExpression();
      matchOrDie(TokenType.CLOSE_PAREN, "parseSelectionStatement(): Did not recieve ')' after '(', go
t");
      Statement body = parseStatement();
      if(nextTokenType() == TokenType.ELSE)
      {
         matchOrDie(TokenType.ELSE, "parseSelectionStatement(): Did not recieve 'else' after 'if', got"
);
         else_part = parseStatement();
      }
      return new SelectionStatement(compare, body, else_part);
   }
```

```
   /**
    * Parses Iteration Statement
    * @return
    */
   private Statement parseIterationStatement()
   {
      //while ( expression ) statement
      matchOrDie(TokenType.WHILE, "parseIterationStatement(): Did not receive WHILE token, got ");
      matchOrDie(TokenType.OPEN_PAREN, "parseIterationStatement(): Did not recieve '(', got ");
      Expression compare = parseExpression();
      matchOrDie(TokenType.CLOSE_PAREN, "parseIterationStatement(): Did not recieve ')' after '(', got
");
      Statement body = parseStatement();

      return new IterationStatement(compare, body);
   }

   /**
    * Parses Return Statement
    * @return
    */
   private Statement parseReturnStatement()
   {
      //return [expression] ;
      Expression body = null;
      matchOrDie(TokenType.RETURN, "parseReturnStatement(): Did not recieve 'RETURN', got");
      if(contains(nextTokenType(), EXPRESSION[0]))
      {
         body = parseExpression();
      }
      matchOrDie(TokenType.END_STATEMENT, "parseReturnStatement(): Did not recieve ';', got");
      return new ReturnStatement(body);
   }

   /**
    * Parses an additive-expression'.
    * @param lhs
    * @return
    */

   /**
    * Parses Additive-Expression and Additive-Expression'
    * @param lhs
    * @return
    */
   private Expression parseAdditiveExpression(Expression lhs)
   {
      Expression term = null;
      if(lhs == null)
      {
         term = parseTerm(null);
      }
      else
      {
         term = parseTerm(lhs);
      }
```

```
      while (contains(nextTokenType(), ADDOP[0]))
      {
         if (nextTokenType() == TokenType.PLUS||nextTokenType() == TokenType.MIN
US)
         {
            term = new BinaryExpression(term, scanner.getNextToken().getType(),
parseTerm(null));
         }
         else
         {
            throw new RuntimeException("parseTerm(): '*' or '/' expected, but got ");
         }
      }

      return term;
   }



   /**
    * Parses term and  term'.
    * @param term
    * @return
    */
   private Expression parseTerm(Expression term)
   {
      if(term == null)
      {
         term = parseFactor();
      }

      while (contains(nextTokenType(), MULOP[0]))
      {
         if (nextTokenType() == TokenType.MULTIPLY||nextTokenType() == TokenType
.DIVIDE)
         {
            term = new BinaryExpression(term, scanner.getNextToken().getType(),
parseFactor());
         }
         else
         {
            throw new RuntimeException("parseTerm(): '*' or '/' expected, but got ");
         }
      }

      return term;
   }


   /**
    * Parses a Factor.
    * @return
    */
   private Expression parseFactor()
   {
      Expression toReturn;

      if (matchToken(TokenType.OPEN_PAREN))
```

```
      {
         // factor -> ( expression )
         toReturn = parseExpression();

         matchOrDie(TokenType.CLOSE_PAREN, "parseFactor(): No ')' found, got ");
      }
      else if (nextTokenType() == TokenType.NUM)
      {
         // factor -> NUM
         toReturn = new NumberExpression((Integer)(scanner.getNextToken().getDat
a()));
      }
      else if (nextTokenType() == TokenType.ID)
      {
         // factor -> ID varcall
         Token id = scanner.getNextToken();

         if (matchToken(TokenType.OPEN_PAREN))
         {
            // varcall -> call -> ( args )
            List<Expression> args = parseArgs();

            toReturn = new CallExpression((String) id.getData(), args);

            matchOrDie(TokenType.CLOSE_PAREN, "parseFactor(): No ')' found after args in function
call, got ");
         }
         else if (matchToken(TokenType.OPEN_BRACKET))
         {
            // varcall -> var -> [ expression ]
            Expression xpr = parseExpression();
            toReturn = new VariableExpression((String) id.getData(), xpr);

            matchOrDie(TokenType.CLOSE_BRACKET, "parseFactor(): No ']' found after '[', got");
         }
         else if (contains(nextTokenType(), VARCALL[1]))
         {
            // next token is in $varcall
            // varcall -> var -> EPSILON
            toReturn = new VariableExpression((String) id.getData());
         }
         else
         {
            throw new RuntimeException("parseFactor(): Illegal token after ID!");
         }
      }
      else
      {
         throw new RuntimeException("parseFactor(): Illegal token for factor, got " + nextTokenT
ype().name());
      }

      return toReturn;
   }


   /**
    * Parses Expression, Expression', and Expression''
    * @return
```

```
    */

   private Expression parseExpression()
   {
      Expression toReturn = null;

      if(matchToken(TokenType.OPEN_PAREN))
      {
         //Expression -> ( expression ) simple-expression'
         Expression compare = parseExpression();
         matchOrDie(TokenType.CLOSE_PAREN, "parseExpression(): No ')' found after '(', got ");
         toReturn = parseSimpleExpression(compare);
      }
      else if(nextTokenType() == TokenType.ID)
      {
         Token ID = scanner.getNextToken();

         //Expression -> ID expression'
         if(matchToken(TokenType.ASSIGNMENT))
         {
            //expression' -> = expression
            VariableExpression var = new VariableExpression((String)ID.getData()
);
            toReturn = new AssignExpression(var, parseExpression());
         }
         else if(matchToken(TokenType.OPEN_PAREN))
         {
            //expression' -> ( args ) simple-expression'
            List<Expression> args = parseArgs();
            Expression func = new CallExpression((String)ID.getData(), args);
            matchOrDie(TokenType.CLOSE_PAREN, "parseExpression(): No ')' found after '(', got ")
;
            toReturn = parseSimpleExpression(func);
         }
         else if(matchToken(TokenType.OPEN_BRACKET))
         {
            //expression' -> [ expression ] expression''

               Expression internalExpr = parseExpression();

               matchOrDie(TokenType.CLOSE_BRACKET, "parseExpression(): No ']' found after '[',
got ");
               Expression varExpression = new VariableExpression((String)ID.getD
ata(), internalExpr);

               if(matchToken(TokenType.ASSIGNMENT))
               {
                  //expression'' -> = expression
                  toReturn = new AssignExpression((VariableExpression) varExpres
sion, parseExpression());
               }
               else if(contains(nextTokenType(), SIMPLE_EXPRESSION_PRIME[0]))
               {
                  //expression'' -> simple-expression'
                  toReturn = parseSimpleExpression(varExpression);
               }
               else if(contains(nextTokenType(), SIMPLE_EXPRESSION_PRIME[1]))
               {
                  // expression'' -> simple-expression' -> epsilon
```

```
                toReturn = varExpression;
             }
             else
             {
                throw new RuntimeException("parseExpression(): Illegal token following ]!");
             }
          }
          else if(contains(nextTokenType(), SIMPLE_EXPRESSION_PRIME[0]) || contai
ns(nextTokenType(), SIMPLE_EXPRESSION_PRIME[1]))
          {
             //expression' -> simple-expression'
             Expression temp = new VariableExpression((String) ID.getData());
             toReturn = parseSimpleExpression(temp);
          }
          else
          {
             throw new RuntimeException("parseExpression(): Illegal token following " + ID.getT
ype().name() + ":" + ID.getData() + ", got " + nextTokenType());
          }
       }
       else if(nextTokenType() == TokenType.NUM)
       {
          //Expression -> NUM simple-expression'
          Token num = scanner.getNextToken();
          Expression Num = new NumberExpression((Integer)num.getData());
          toReturn = parseSimpleExpression(Num);
       }
       else
       {
          throw new RuntimeException("parseExpression(): Illegal token for Expression, got " + next
TokenType());
       }
       return toReturn;
    }

    /**
     * Parses Simple-Expression'
     * @param lhs
     * @return
     */

    private Expression parseSimpleExpression(Expression lhs) {
       Expression toReturn = null;
       Expression left = parseAdditiveExpression(lhs);

       if(contains(nextTokenType(), RELOP[0]))
       {
          //match Relop
          TokenType opp = scanner.getNextToken().getType();

          Expression right = parseAdditiveExpression(null);
          toReturn = new BinaryExpression(left, opp, right);
       }
       else
       {
          toReturn = left;
       }

       return toReturn;
```

```
    }

    /**
     * Parses Args and Arg-list
     * @return
     */

    private List<Expression> parseArgs()
    {
       List<Expression> args = new ArrayList<Expression>();

       while (nextTokenType() != TokenType.CLOSE_PAREN)
       {
          args.add(parseExpression());

          if (nextTokenType() != TokenType.CLOSE_PAREN)
          {
             matchOrDie(TokenType.COMMA, "parseArgs(): We didn't match the comma?? Instead we fo
und a ");
          }
       }

       return args;
    }
}
```

```
package parser;

import java.io.BufferedWriter;
import java.io.IOException;

public abstract class Declaration
{
   public abstract void print(int indent, BufferedWriter out) throws IOException
;
}
```

```
package parser;

import java.io.BufferedWriter;
import java.io.IOException;

import parser.statement.CompoundStatement;
import scanner.Token.TokenType;

public class FunctionDeclaration extends Declaration
{
   private TokenType returnType;
   private Params parameters;
   private String name;
   private CompoundStatement body;

   public FunctionDeclaration(TokenType returnType, String functionName, Params
params, CompoundStatement body)
   {
      this.returnType = returnType;
      parameters = params;
      name = functionName;
      this.body = body;
   }

   public String getName()
   {
      return name;
   }

   public Params getParams()
   {
      return parameters;
   }

   public CompoundStatement getBody()
   {
      return body;
   }

   @Override
   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for (int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<FunctionDeclaration>\n");

      out.write(prefix + "\t<Name>" + name + "</Name>\n");
      out.write(prefix + "\t<ReturnType>" + returnType.name() + "</ReturnType>\n");

      parameters.print(indent + 1, out);

      body.print(indent + 1, out);
      out.write(prefix + "</FunctionDeclaration>\n");
   }
}
```

```
package parser;

import java.io.BufferedWriter;
import java.io.IOException;
import java.util.List;

public class Params
{
   List<VariableDeclaration> paramList;

   public Params(List<VariableDeclaration> list)
   {
      paramList = list;
   }

   public List<VariableDeclaration> getParameters()
   {
      return paramList;
   }

   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for (int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<Params>\n");

      for (VariableDeclaration varDec : paramList)
      {
         varDec.print(indent + 1, out);
      }

      out.write(prefix + "</Params>\n");
   }
}
```

```
package parser;

public interface Parser
{
   public void printTree(String outFile);
   public Program parse();
}
```

```
package parser;

import java.io.BufferedWriter;
import java.io.IOException;
import java.util.ArrayList;
import java.util.List;

public class Program
{
   private List<Declaration> declarations;

   public Program(List<Declaration> decls)
   {
      declarations = decls;
   }

   public List<Declaration> getProgram()
   {
      return declarations;
   }

   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for (int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<Program>\n");

      for (Declaration decl : declarations)
         decl.print(indent + 1, out);

      out.write(prefix + "</Program>\n");
   }
}
```

```
package parser;

import java.io.BufferedWriter;
import java.io.BufferedReader;
import java.io.FileReader;
import java.io.FileWriter;
import java.io.IOException;

import scanner.CMinusScanner;
import scanner.Scanner;
import scanner.Token;
import scanner.Token.TokenType;

/**
* @author Mitch Birti
* @author Seth Yost
* @version 1.0
* File: Tester.java
* Created: Feb 2014
* Â©Copyright the authors. All rights reserved.
*
* Description: Tests CMinusScanner.java
*/

public class Tester
{

   public static void main(String[] args)
   {
      try
      {
         // set up the scanner and the output file
         String baseName = "TestFile";
         Scanner s = new CMinusScanner(new BufferedReader(new FileReader("tests/"
+ baseName + ".cm")));

         Parser parser = new CMinusParser(s);

         parser.parse();
         parser.printTree("tests/" + baseName + ".xml");
      }
      catch (Exception e)
      {
         e.printStackTrace();
      }
   }


}
```

```
package parser;

import java.io.BufferedWriter;
import java.io.IOException;

public class VariableDeclaration extends Declaration
{
   private String id;
   // -1 indicates this isn't an array
   private int arraySize;

   /**
    * Makes a variable of type int.
    * @param id
    */
   public VariableDeclaration(String id)
   {
      this.id = id;
      arraySize = -1;
   }

   /**
    * Makes an array of type int.
    * @param id
    * @param size
    */
   public VariableDeclaration(String id, int size)
   {
      this.id = id;
      arraySize = size;
   }

   public String getId()
   {
      return id;
   }

   /**
    * Gets the size of this variable array.
    * -1 indicates it is not an array.
    * @return
    */
   public int arraySize()
   {
      return arraySize;
   }

   @Override
   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for (int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<VariableDeclaration>\n");

      out.write(prefix + "\t<Name>" + id + "</Name>\n");
      out.write(prefix + "\t<Type>" + "INT" + "</Type>\n");
```

```
      if (arraySize != -1)
         out.write(prefix + "\t<Size>" + arraySize + "</Size>\n");

      out.write(prefix + "</VariableDeclaration>\n");
   }
}
```

```
package parser.expression;

import java.io.BufferedWriter;
import java.io.IOException;

public class AssignExpression extends Expression
{
   private VariableExpression variable;
   private Expression rightSide;

   public AssignExpression(VariableExpression var, Expression rhs)
   {
      variable = var;
      rightSide = rhs;
   }

   public VariableExpression getVariableExpr()
   {
      return variable;
   }

   public Expression getRightSide()
   {
      return rightSide;
   }

   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for (int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<AssignExpression>\n");

      out.write(prefix + "\t<Variable>\n");
      variable.print(indent + 2, out);
      out.write(prefix + "\t</Variable>\n");

      out.write(prefix + "\t<Value>\n");
      rightSide.print(indent + 2, out);
      out.write(prefix + "\t</Value>\n");

      out.write(prefix + "</AssignExpression>\n");
   }
}
```

```
package parser.expression;

import java.io.BufferedWriter;
import java.io.IOException;

import scanner.Token.TokenType;

public class BinaryExpression extends Expression
{
   private Expression leftSide;
   private Expression rightSide;
   private TokenType operand;

   public BinaryExpression(Expression lhs, TokenType op, Expression rhs)
   {
      leftSide = lhs;
      operand = op;
      rightSide = rhs;
   }

   public Expression getLeftSide()
   {
      return leftSide;
   }

   public Expression getRightSide()
   {
      return rightSide;
   }

   public TokenType getOperand()
   {
      return operand;
   }

   @Override
   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for (int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<BinaryExpression>\n");

      out.write(prefix + "\t<Operand>" + operand.name() + "</Operand>\n");

      out.write(prefix + "\t<LeftSide>\n");
      leftSide.print(indent + 2, out);
      out.write(prefix + "\t</LeftSide>\n");

      out.write(prefix + "\t<RightSide>\n");
      rightSide.print(indent + 2, out);
      out.write(prefix + "\t</RightSide>\n");

      out.write(prefix + "</BinaryExpression>\n");
   }
}
```

```
package parser.expression;

import java.io.BufferedWriter;
import java.io.IOException;
import java.util.List;

public class CallExpression extends Expression
{
   String functionName;
   List<Expression> arguments;

   public CallExpression(String funcName, List<Expression> args)
   {
      functionName = funcName;
      arguments = args;
   }

   public String getFunctionName()
   {
      return functionName;
   }

   public List<Expression> getArgs()
   {
      return arguments;
   }

   @Override
   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for (int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<CallExpression>\n");

      out.write(prefix + "\t<FunctionName>" + functionName + "</FunctionName>\n");

      out.write(prefix + "\t<Arguments>\n");

      for (Expression arg : arguments)
         arg.print(indent + 2, out);

      out.write(prefix + "\t</Arguments>\n");
      out.write(prefix + "</CallExpression>\n");
   }
}
```

```
package parser.expression;

import java.io.BufferedWriter;
import java.io.IOException;

public abstract class Expression
{
   public abstract void print(int indent, BufferedWriter out) throws IOException
;
}
```

```
package parser.expression;

import java.io.BufferedWriter;
import java.io.IOException;

public class NumberExpression extends Expression
{
   private int value;

   public NumberExpression(int val)
   {
      value = val;
   }

   public int getValue()
   {
      return value;
   }

   @Override
   public void print(int index, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for (int i = 0; i < index; i++)
         prefix += "\t";

      out.write(prefix + "<NumberExpression>" + value + "</NumberExpression>\n");
   }
}
```

```
package parser.expression;

import java.io.BufferedWriter;
import java.io.IOException;

public class VariableExpression extends Expression
{
   private String identifier;
   private Expression index;

   public VariableExpression(String id)
   {
      identifier = id;
      index = null;
   }

   public VariableExpression(String id, Expression index)
   {
      identifier = id;
      this.index = index;
   }

   public String getIdentifier()
   {
      return identifier;
   }

   /**
    * Gets the index expression for this array.
    * If null, this isn't an array variable.
    * @return
    */
   public Expression getIndex()
   {
      return index;
   }

   @Override
   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for (int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<VariableExpression>\n");

      out.write(prefix + "\t<Identifier>" + identifier + "</Identifier>\n");
      if(index != null)
      {
         out.write(prefix + "\t<Index>\n");
         index.print(indent + 2, out);
         out.write(prefix + "\t</Index>\n");
      }

      out.write(prefix + "</VariableExpression>\n");
   }
}
```

```
package parser.statement;

import parser.*;

import java.io.BufferedWriter;
import java.io.IOException;
import java.util.List;

public class CompoundStatement extends Statement
{
   private List<Declaration> locals;
   private List<Statement> body;

   public CompoundStatement(List<Declaration> locals, List<Statement> body)
   {
      this.locals = locals;
      this.body = body;
   }

   public List<Declaration> getLocals()
   {
      return locals;
   }

   public List<Statement> getBody()
   {
      return body;
   }

   // to keep Statement happy in the meantime
   @Override
   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for (int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<CompoundStatement>\n");
      out.write(prefix + "\t<Declarations>\n");
      for (Declaration decl : locals)
      {
         decl.print(indent+2, out);
      }
      out.write(prefix + "\t</Declarations>\n");
      out.write(prefix + "\t<Statments>\n");
      for (Statement temp : body)
      {
         temp.print(indent+2, out);
      }
      out.write(prefix + "\t</Statments>\n");
      out.write(prefix + "</CompoundStatement>\n");
   }
}
```

```
package parser.statement;

import java.io.BufferedWriter;
import java.io.IOException;

import parser.expression.*;

public class ExpressionStatement extends Statement{

   private Expression data;

   public ExpressionStatement(Expression data)
   {
      this.data = data;
   }

   public Expression getData()
   {
      return data;
   }

   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for(int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<ExpressionStatement>\n");
      data.print(indent+1, out);
      out.write(prefix + "</ExpressionStatement>\n");
   }

}
```

```
package parser.statement;

import java.io.BufferedWriter;
import java.io.IOException;

import parser.expression.*;

public class IterationStatement extends Statement{

   private Expression compare;
   private Statement body;

   public IterationStatement(Expression compare, Statement body)
   {
      this.compare = compare;
      this.body = body;
   }

   public Expression getCompare()
   {
      return compare;
   }

   public Statement getBody()
   {
      return body;
   }

   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for(int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<IterationStatement>\n");
      out.write(prefix + "\t<Expression>\n");
      compare.print(indent+2, out);
      out.write(prefix + "\t</Expression>\n");
      out.write(prefix + "\t<Then>\n");
      body.print(indent+2, out);
      out.write(prefix + "\t</Then>\n");
      out.write(prefix + "</IterationStatement>\n");
   }
}
```

```
package parser.statement;

import java.io.BufferedWriter;
import java.io.IOException;

import parser.expression.*;

public class ReturnStatement extends Statement{

   private Expression body;

   public ReturnStatement(Expression body)
   {
      this.body = body;
   }

   public Expression getBody()
   {
      return body;
   }

   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for(int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<ReturnStatement>");
      if (body != null)
      {
         out.write("\n" + prefix + "\t<Expression>\n");
         body.print(indent+2, out);
         out.write(prefix + "\t</Expression>\n" + prefix);
      }
      out.write("</ReturnStatement>\n");
   }
}
```

```
package parser.statement;

import java.io.BufferedWriter;
import java.io.IOException;

import parser.statement.*;
import parser.expression.*;

public class SelectionStatement extends Statement{

   private Expression compare;
   private Statement body;
   private Statement else_part;

   public SelectionStatement(Expression compare, Statement body, Statement else_
part)
   {
      this.compare = compare;
      this.body = body;
      this.else_part = else_part;
   }

   public Expression getCompare() {
      return compare;
   }

   public Statement getBody() {
      return body;
   }

   public Statement getElse_part() {
      return else_part;
   }

   public void print(int indent, BufferedWriter out) throws IOException
   {
      String prefix = "";
      for (int i = 0; i < indent; i++)
         prefix += "\t";

      out.write(prefix + "<SelectionStatement>\n");

      out.write(prefix + "\t<Expression>\n");
      compare.print(indent+2, out);
      out.write(prefix + "\t</Expression>\n");

      out.write(prefix + "\t<Then>\n");
      body.print(indent+2, out);
      out.write(prefix + "\t</Then>\n");

      if(else_part != null)
      {
         out.write(prefix + "\t<Else>\n");
         else_part.print(indent+2, out);
         out.write(prefix + "\t</Else>\n");
      }

      out.write(prefix + "</SelectionStatement>\n");
   }
```

```
}
```

```
package parser.statement;

import java.io.BufferedWriter;
import java.io.IOException;

public abstract class Statement
{
   public abstract void print(int indent, BufferedWriter out) throws IOException
;
}
```

```
void test(void){
  int a;
  int b;
  a = 0;
  b = 1;
  a = b = 0;
  if(a > b){
    b = b - 1;
  }
  else{
    b = 2;
    while( b == 2){
      b = 2;
      if(b == 2){
        b = b + 1;
      }
      else{
        b = 1;
        while(b == 1){
          b = b + 2;
        }
      }
    }
  }
  if(a == b){
    while (a == b){
      while(a == b){
        a = b  - 1;
      }
    }
  }
  b = 3;
  return;
}
```

```
<Program>
   <FunctionDeclaration>
      <Name>test</Name>
      <ReturnType>VOID</ReturnType>
      <Params>
      </Params>
      <CompoundStatement>
         <Declarations>
            <VariableDeclaration>
               <Name>a</Name>
               <Type>INT</Type>
            </VariableDeclaration>
            <VariableDeclaration>
               <Name>b</Name>
               <Type>INT</Type>
            </VariableDeclaration>
         </Declarations>
         <Statments>
            <ExpressionStatement>
               <AssignExpression>
                  <Variable>
                     <VariableExpression>
                        <Identifier>a</Identifier>
                     </VariableExpression>
                  </Variable>
                  <Value>
                     <NumberExpression>0</NumberExpression>
                  </Value>
               </AssignExpression>
            </ExpressionStatement>
            <ExpressionStatement>
               <AssignExpression>
                  <Variable>
                     <VariableExpression>
                        <Identifier>b</Identifier>
                     </VariableExpression>
                  </Variable>
                  <Value>
                     <NumberExpression>1</NumberExpression>
                  </Value>
               </AssignExpression>
            </ExpressionStatement>
            <ExpressionStatement>
               <AssignExpression>
                  <Variable>
                     <VariableExpression>
                        <Identifier>a</Identifier>
                     </VariableExpression>
                  </Variable>
                  <Value>
                     <AssignExpression>
                        <Variable>
                           <VariableExpression>
                              <Identifier>b</Identifier>
                           </VariableExpression>
                        </Variable>
                        <Value>
                           <NumberExpression>0</NumberExpression>
                        </Value>
```

```
                </AssignExpression>
             </Value>
          </AssignExpression>
       </ExpressionStatement>
       <SelectionStatement>
          <Expression>
             <BinaryExpression>
                <Operand>GREATER_THAN</Operand>
                <LeftSide>
                   <VariableExpression>
                      <Identifier>a</Identifier>
                   </VariableExpression>
                </LeftSide>
                <RightSide>
                   <VariableExpression>
                      <Identifier>b</Identifier>
                   </VariableExpression>
                </RightSide>
             </BinaryExpression>
          </Expression>
          <Then>
             <CompoundStatement>
                <Declarations>
                </Declarations>
                <Statments>
                   <ExpressionStatement>
                      <AssignExpression>
                         <Variable>
                            <VariableExpression>
                               <Identifier>b</Identifier>
                            </VariableExpression>
                         </Variable>
                         <Value>
                            <BinaryExpression>
                               <Operand>MINUS</Operand>
                               <LeftSide>
                                  <VariableExpression>
                                     <Identifier>b</Identifier>
                                  </VariableExpression>
                               </LeftSide>
                               <RightSide>
                                  <NumberExpression>1</NumberExpression>
                               </RightSide>
                            </BinaryExpression>
                         </Value>
                      </AssignExpression>
                   </ExpressionStatement>
                </Statments>
             </CompoundStatement>
          </Then>
          <Else>
             <CompoundStatement>
                <Declarations>
                </Declarations>
                <Statments>
                   <ExpressionStatement>
                      <AssignExpression>
                         <Variable>
                            <VariableExpression>
```

```
                                    <Identifier>b</Identifier>
                                 </VariableExpression>
                              </Variable>
                              <Value>
                                 <NumberExpression>2</NumberExpression>
                              </Value>
                           </AssignExpression>
                        </ExpressionStatement>
                        <IterationStatement>
                           <Expression>
                              <BinaryExpression>
                                 <Operand>EQUALS</Operand>
                                 <LeftSide>
                                    <VariableExpression>
                                       <Identifier>b</Identifier>
                                    </VariableExpression>
                                 </LeftSide>
                                 <RightSide>
                                    <NumberExpression>2</NumberExpression>
                                 </RightSide>
                              </BinaryExpression>
                           </Expression>
                           <Then>
                              <CompoundStatement>
                                 <Declarations>
                                 </Declarations>
                                 <Statments>
                                    <ExpressionStatement>
                                       <AssignExpression>
                                          <Variable>
                                             <VariableExpression>
                                                <Identifier>b</Identifier>
                                             </VariableExpression>
                                          </Variable>
                                          <Value>
                                             <NumberExpression>2</NumberExpressi
on>

                                          </Value>
                                       </AssignExpression>
                                    </ExpressionStatement>
                                    <SelectionStatement>
                                       <Expression>
                                          <BinaryExpression>
                                             <Operand>EQUALS</Operand>
                                             <LeftSide>
                                                <VariableExpression>
                                                   <Identifier>b</Identifier>
                                                </VariableExpression>
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```
int a;

int addThem(int d, int e) {
  int f;
  f = d + e;

  return f;
}

int main (void) {

  int b;
  int c;
  int g;
  int h;
  int i;

  b = 5;

  if (b == 5) {
    a = 3;
  }
  else {
    a = 4;
  }

  g = 0;
  i = 1;
  while (i <= 8) {
    g = g + i;
    i = i+1;
  }
  h = g / 3;
  g = h * 4;

  c = addThem(a, b);
  putchar (c+g);
  putchar (10);

  return 0;
}
```

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```
int a;

int addThem(int d, int e) {
  int f;
  f = d + e;

  return f;
}

void putDigit(int s) {
   putchar(48+s);
}

void printInt(int r) {
  int t;
  int found;

  found = 0;

  if (r >= 10000) {
      /* print -1) */
    putchar(45);
    putDigit(1);
    return;
  }
  else {
    if (r >= 1000) {
       t = r / 1000;
       putDigit(t);
       r = r - t * 1000;
       found=1;
    }

    if (r >= 100) {
       t = r / 100;
       putDigit(t);
       r = r - t * 100;
       found=1;
    }
    else if (found == 1) {
       putDigit(0);
    }

    if (r >= 10) {
       t = r / 10;
       putDigit(t);
       r = r - t * 10;
    }
    else if (found == 1) {
       putDigit(0);
    }

    putDigit(r);
  }

}

int main (void) {
```

```
  int b;
  int c;
  int g;
  int h;
  int i;

  b = c = 5;

  if (b == 5) {
    a = 3;
  }
  else {
    a = 4;
  }

  g = 0;
  i = 1;
  while (i <= 8) {
    g = g + i;
    i = i+1;
  }
  h = g / 3;
  g = h * 4;

  c = addThem(a, b);
  putchar (56);
  putchar (61);
  putchar (c+g);
  putchar (10);

  i = 0;
  while (i < 10) {
    putchar(48+i);
    i = i+1;
  }
  putchar(10);
  putchar(67);
  putchar(83);
  printInt(3510);
  putchar(10);

  b = 0;
  c = 1;
  g = 1;
  h = 0;
  i = 0;

  if (b == 0) {
    if (c==0) {
      i = 1;
    }
    else if (g == 0) {
      i = 2;
    }
    else if (h == 0) {
      i = 10;
    }
    else {
      i = 3;
```

```
    }
  }
  else {
    i = 0;
  }


  if (i == 10) {
    putchar(99);
    putDigit(0);
    putDigit(0);
    putchar(108);
  }
  else {
    putchar(98);
    putchar(97);
    putchar(100);
    putchar(61);
    printInt(i);
  }
  putchar(10);

  return 0;
}
```

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                           </Arguments>
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```

```
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                              </VariableExpression>
                           </Arguments>
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   </CompoundStatement>
</FunctionDeclaration>
</Program>
```

```
int fact( int x )
/* recursive factorial function */
{ if (x > 1)
   return x * fact(x−1);
else
    return 1;
}

void main (void)
{
   int x;
    x = read();
   if(x > 0) write (fact(x));
}
```

```
<Program>
   <FunctionDeclaration>
      <Name>fact</Name>
      <ReturnType>INT</ReturnType>
      <Params>
         <VariableDeclaration>
            <Name>x</Name>
            <Type>INT</Type>
         </VariableDeclaration>
      </Params>
      <CompoundStatement>
         <Declarations>
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         <Statments>
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                     <LeftSide>
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                           <Identifier>x</Identifier>
                        </VariableExpression>
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                     <RightSide>
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                              </VariableExpression>
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                                       <LeftSide>
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                                          </VariableExpression>
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                        </BinaryExpression>
                     </Expression>
                  </ReturnStatement>
```

```
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               </ReturnStatement>
            </Else>
         </SelectionStatement>
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   </CompoundStatement>
</FunctionDeclaration>
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   <ReturnType>VOID</ReturnType>
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   <CompoundStatement>
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            <Type>INT</Type>
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                  </VariableExpression>
               </Variable>
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                     <Arguments>
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                  </CallExpression>
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                     </VariableExpression>
                  </LeftSide>
                  <RightSide>
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                  </RightSide>
               </BinaryExpression>
            </Expression>
            <Then>
               <ExpressionStatement>
                  <CallExpression>
                     <FunctionName>write</FunctionName>
```

```
                        <Arguments>
                           <CallExpression>
                              <FunctionName>fact</FunctionName>
                              <Arguments>
                                 <VariableExpression>
                                    <Identifier>x</Identifier>
                                 </VariableExpression>
                              </Arguments>
                           </CallExpression>
                        </Arguments>
                     </CallExpression>
                  </ExpressionStatement>
               </Then>
            </SelectionStatement>
         </Statments>
      </CompoundStatement>
   </FunctionDeclaration>
</Program>
```

```
a2ps -R -s1 --media=letter --columns=1 --rows=1 --chars-per-line=80 --major=rows
 --border=no --tabsize=3 src/parser/* src/parser/expression/* src/parser/stateme
nt/* tests/* print.sh -o - | ps2pdf - Program.pdf
pdfunite write-ups/Project2WriteUp.pdf Grammar-MkII.pdf First-Follow-MkII.pdf Pr
ogram.pdf Printout.pdf
```