Swinburne University Of Technology

Faculty of Science, Engineering and Technology

ASSIGNMENT COVER SHEET

Subject Code: COS30023
Subject Title: Languages in Software Development
Assignment number and title: 7, Simple Lambda Calculus Language
Due date: **October 20, 2014, 10:30, on paper**
Lecturer: Dr. Markus Lumpe

Your name:_____

Marker's comments:

Problem	Marks	Obtained
1	2+6+2+7+14+18+19=68	
3	9	
Total	77	

Extension certification:

This assignment has been given an extension and is now due on _____

Signature of Convener:_____

Assignment 7

COS30023 - Languages in Software Development

Daniel Parker - 971328X

October 20, 2014

1. LCLParser (Problems 1 & 2)

1.1. LCLParser.jj

```
options
{
  JDK_VERSION = "1.7";
  static = false;
  OUTPUT_DIRECTORY="parser";
}

PARSER_BEGIN(LCLParser)
package parser;

import java.io.*;
import java.util.*;
import ast.*;

public class LCLParser {
  public static void main( String[] Args ) {
     try {
       LCLParser lParser = new LCLParser( new FileInputStream( Args[0] ) );
       ArrayList<LCLExpression> lExpressions = lParser.CompilationUnit();

      Hashtable< String, LCLExpression > lSymbolTable =
                        new Hashtable< String, LCLExpression >();
       lSymbolTable.put( "succ", new LambdaFunction( "x", new Increment( "x" ) ) );
       lSymbolTable.put( "pred", new LambdaFunction( "x", new Decrement( "x" ) ) );
       lSymbolTable.put( "isZero", new LambdaFunction( "x", new Zero( "x" ) ) );
       lSymbolTable.put( "notZero", new LambdaFunction( "x", new NotZero( "x" ) ) );
```

```
        LCLExpression Result = null;


        for ( LCLExpression e : lExpressions ) {
          Result = e.reduce( lSymbolTable );
        }

        System.out.println( Result );
      } catch (ParseException e) {
        System.out.println("Syntax Error : \n"+ e.toString());
      } catch (FileNotFoundException e) {
        System.out.println( e.toString() );
      }
    }
}
PARSER_END(LCLParser)

ArrayList<LCLExpression> CompilationUnit():
{
  ArrayList<LCLExpression> Result = new ArrayList<LCLExpression>();
  LCLExpression e;
}
{
  (e = LCLExp() { Result.add( e ); })* < EOF >
  { return Result; }
}

LCLExpression LCLExp():
{
  Token t;
  LCLExpression e1;
  LCLExpression e2;
  LCLExpression e3;
}
{
  t = < NUMBER >
  { return new LambdaNumber(t.image); }
|
  t = < VARIABLE >
  { return new LambdaVariable(t.image); }
|
  LOOKAHEAD(2)
```

```
  "(" "define" t = < VARIABLE > e1 = LCLExp() ")"
  { return new LCLDeclaration( t.image, e1 ); }
|
  LOOKAHEAD(2)
  "(" "load" t = < STRING > ")"
  { return new LoadDeclaration( t.image.substring(1, t.image.length() - 1 )); }
|
  LOOKAHEAD(2)
  "(" "if" e1 = LCLExp() e2 = LCLExp() e3 = LCLExp() ")"
  { return new IfThenElse( e1, e2, e3 ); }
|
  LOOKAHEAD(2)
  "(" "lambda" t = < VARIABLE > "." e1 = LCLExp() ")"
  { return new LambdaFunction( t.image, e1 ); }
|
  "(" e1 = LCLExp() e2 = LCLExp() ")"
  { return new LambdaApplication( e1, e2 ); }
}

SKIP :
{
  " "
|
  "\r"
|
  "\t"
|
  "\n"
|
  < "//" (~["\n"])* "\n">
}

TOKEN :
{
  < NUMBER: (["0"-"9"])+ >
|
  < STRING: "\"" (~["\""])* "\"" >
|
  < VARIABLE: ["a" - "z", "A" - "Z"](["a"-"z", "A"-"Z", "0" - "9", "_"])* >
}
```

1.2. ast.LCLExpression

```
package ast;

import java.util.Hashtable;
import java.util.Set;

public abstract class LCLExpression {
  public abstract Set<String> freeNames();

  public abstract LCLExpression substitute( String aVar, LCLExpression aExp );

  public abstract LCLExpression reduce( Hashtable<String, LCLExpression> aSymTable );

  public abstract String toString();
}
```

1.3. ast.LCLDeclaration

```
package ast;

import java.util.Hashtable;
import java.util.Set;

public class LCLDeclaration extends LCLExpression{
  private String fLabel;
  private LCLExpression fExpression;

  public String getVariable() {
    return fLabel;
  }

  public LCLExpression getExpression() {
    return fExpression;
  }

  public LCLDeclaration( String aLabel, LCLExpression aExpression ) {
    fLabel = aLabel;
    fExpression = aExpression;
  }

  @Override
  public Set<String> freeNames() {
```

```
    return fExpression.freeNames();
  }

  @Override
  public LCLExpression substitute(String aVar, LCLExpression aExp) {
    return new LCLDeclaration( fLabel, fExpression.substitute(aVar, aExp));
  }

  @Override
  public String toString() {
    return "(define " + fLabel + " " + fExpression.toString() + ")";
  }

  @Override
  public LCLExpression reduce(Hashtable<String, LCLExpression> aSymTable) {
    LCLExpression lSubExpression = fExpression.reduce(aSymTable);
    aSymTable.put(fLabel, lSubExpression);
    return lSubExpression;
  }
}
```

1.4. ast.LambdaFunction

```
package ast;

import java.util.HashSet;
import java.util.Hashtable;
import java.util.Set;

public class LambdaFunction extends LCLExpression {
  private String fVariable;
  private LCLExpression fBody;

  public String getVariable() {
    return fVariable;
  }

  public LCLExpression getExpression() {
    return fBody;
  }

  public LambdaFunction( String aVariable, LCLExpression aBody) {
    fVariable = aVariable;
```

```
  fBody = aBody;
}

@Override
public Set<String> freeNames() {
  Set<String> Result = new HashSet<String>(fBody.freeNames());
  Result.remove(getVariable());

  return Result;
}

@Override
public LCLExpression substitute(String aVar, LCLExpression aExp) {
  if (getVariable().equals(aVar)) {
    return this;
  } else {
    Set<String> fFrees = aExp.freeNames();

    // Substitution Rule 6
    if ( fFrees.contains( getVariable() ) ) {
      String lFresh = fVariable + "%";
      while ( fFrees.contains( lFresh )){
        lFresh += "%";
      }

      LCLExpression lNewBody = fBody.substitute( fVariable, new LambdaVariable(lFresh));
      lNewBody.substitute(aVar, aExp);
      return new LambdaFunction(lFresh, lNewBody);
    } else {
      // Substitution Rule 5
      return new LambdaFunction( fVariable, fBody.substitute(aVar, aExp));
    }
  }
}

@Override
public String toString() {
  return "(lambda " + fVariable + "." + fBody.toString() + ")";
}

@Override
public LCLExpression reduce(Hashtable<String, LCLExpression> aSymTable) {
  return this;
```

```
  }

}
```

1.5. ast.LambdaNumber

```
package ast;

import java.util.Hashtable;
import java.util.Set;
import java.util.HashSet;

public class LambdaNumber extends LCLExpression {
  private Integer fNumber;

  public Integer getNumber() {
    return fNumber;
  }

  public LambdaNumber( String aNumber ) {
    fNumber = Integer.parseInt( aNumber );
  }

  @Override
  public Set<String> freeNames() {
    return new HashSet<String>();
  }

  @Override
  public LCLExpression substitute(String aVar, LCLExpression aExp) {
    return this;
  }

  @Override
  public String toString() {
    return fNumber.toString();
  }

  @Override
  public LCLExpression reduce(Hashtable<String, LCLExpression> aSymTable) {
    return this;
  }
}
```

1.6. ast.LambdaVariable

```
package ast;

import java.util.HashSet;
import java.util.Hashtable;
import java.util.Set;

public class LambdaVariable extends LCLExpression{
  private String fValue;

  public LambdaVariable( String aVariable ) {
    fValue = aVariable;
  }

  @Override
  public Set<String> freeNames() {
    HashSet<String> Result = new HashSet<String>();
    Result.add(fValue);
    return Result;
  }

  @Override
  public LCLExpression substitute( String aVar, LCLExpression aExp ) {
    if (fValue.equals(aVar)) {
      return aExp;
    } else {
      return this;
    }
  }

  @Override
  public String toString() {
    return fValue;
  }

  @Override
  public LCLExpression reduce(Hashtable<String, LCLExpression> aSymTable) {
    if (aSymTable.containsKey(fValue)) {
      return aSymTable.get(fValue);
    } else {
      throw new RuntimeException("Error reducing " + fValue + ", symbol not found");
    }
```

```
  }
}
```

1.7. ast.LoadDeclaration

```
package ast;

import java.io.FileInputStream;
import java.io.FileNotFoundException;
import java.util.ArrayList;
import java.util.HashSet;
import java.util.Hashtable;
import java.util.Set;

import parser.LCLParser;
import parser.ParseException;

public class LoadDeclaration extends LCLExpression {
  private String fUnitName;

  public String getUnitName() {
    return fUnitName;
  }

  public LoadDeclaration( String aUnitName ) {
    fUnitName = aUnitName;

    if ( !fUnitName.endsWith( ".lam" )) {
      fUnitName += ".lam";
    }
  }

  @Override
  public Set<String> freeNames() {
    return new HashSet<String>();
  }

  @Override
  public LCLExpression substitute(String aVar, LCLExpression aExp) {
    return this;
  }

  @Override
```

```
  public String toString() {
    return "(load \"" + fUnitName + "\")";
  }

  @Override
  public LCLExpression reduce(Hashtable<String, LCLExpression> aSymTable) {
    try {
      LCLParser lParser = new LCLParser(new FileInputStream(fUnitName));
      ArrayList<LCLExpression> LCLExpressions = lParser.CompilationUnit();

      LCLExpression lastExpression = null;

      for ( LCLExpression e: LCLExpressions ) {
        lastExpression = e.reduce(aSymTable);
      }

      return lastExpression;

    } catch (FileNotFoundException e) {
      throw new RuntimeException("The file '" + fUnitName + "' was not found.");
    } catch ( ParseException e ) {
      throw new RuntimeException("Syntax Error : \n"+ e.toString());
    }
  }
}
```

1.8. ast.LambdaApplication

```
package ast;

import java.util.Hashtable;
import java.util.Set;
import java.util.HashSet;

public class LambdaNumber extends LCLExpression {
  private Integer fNumber;

  public Integer getNumber() {
    return fNumber;
  }

  public LambdaNumber( String aNumber ) {
    fNumber = Integer.parseInt( aNumber );
```

```
  }

  @Override
  public Set<String> freeNames() {
    return new HashSet<String>();
  }

  @Override
  public LCLExpression substitute(String aVar, LCLExpression aExp) {
    return this;
  }

  @Override
  public String toString() {
    return fNumber.toString();
  }

  @Override
  public LCLExpression reduce(Hashtable<String, LCLExpression> aSymTable) {
    return this;
  }
}
```

1.9. ast.IfThenElse

```
package ast;

import java.util.Hashtable;
import java.util.Set;
import java.util.HashSet;

public class IfThenElse extends LCLExpression {

  private LCLExpression fCondition;
  private LCLExpression fThen;
  private LCLExpression fElse;

  public IfThenElse( LCLExpression aCondition, LCLExpression aThen, LCLExpression aElse ){
    fCondition = aCondition;
    fThen = aThen;
    fElse = aElse;
  }
```

```
public LCLExpression getCondition() {
  return fCondition;
}

public LCLExpression getThen() {
  return fThen;
}

public LCLExpression getElse() {
  return fElse;
}

@Override
public Set<String> freeNames() {
  Set<String> Result = new HashSet<String>( fCondition.freeNames() );
  Result.addAll( fThen.freeNames() );
  Result.addAll( fElse.freeNames() );

  return Result;
}

@Override
public LCLExpression substitute(String aVar, LCLExpression aExp) {
  return new IfThenElse( fCondition.substitute( aVar, aExp ),
              fThen.substitute(aVar, aExp),
              fElse.substitute(aVar, aExp));
}

@Override
public String toString() {
  return "(if " + fCondition.toString() + " " + fThen.toString() + " " + fElse.toString()
}

@Override
public LCLExpression reduce(Hashtable<String, LCLExpression> aSymTable) {
  LambdaNumber lConditionReduced;

  if (!(fCondition.reduce(aSymTable) instanceof LambdaNumber)) {
    throw new RuntimeException("Condition is not an instance of LambdaNumber");
  } else {
    lConditionReduced = (LambdaNumber)fCondition.reduce(aSymTable);
  }
```

```
    if (lConditionReduced.getNumber() != 0) {
      return fThen.reduce(aSymTable);
    } else {
      return fElse.reduce(aSymTable);
    }
  }
}
```

1.10. ast.Increment

```
package ast;

import java.util.Set;
import java.util.HashSet;
import java.util.Hashtable;

public class Increment extends LCLExpression {
  private String fVariable;

  public String getVariable() {
    return fVariable;
  }

  public Increment( String aVariable ) {
    fVariable = aVariable;
  }

  public Set<String> freeNames() {
    return new HashSet<String>();
  }

  public LCLExpression reduce( Hashtable<String,LCLExpression> aSymTable ) {
    return this;
  }

  public LCLExpression substitute( String aVar, LCLExpression aExp ) {
    if ( getVariable().equals( aVar ) ) {
      if ( aExp instanceof LambdaNumber ) {
        Integer lNumber = ((LambdaNumber)aExp).getNumber() + 1;
        return new LambdaNumber( lNumber.toString() );
      } else {
        throw new ArithmeticException( "Illegal argument: " + aExp );
      }
```

```
    } else {
      return this;
    }
  }

  public String toString() {
    return "incr(" + fVariable + ")";
  }
}
```

1.11. ast.Decrement

```
package ast;

import java.util.HashSet;
import java.util.Hashtable;
import java.util.Set;

public class Decrement extends LCLExpression {
  private String fVariable;

  public String getVariable() {
    return fVariable;
  }

  public Decrement( String aVariable ) {
    fVariable = aVariable;
  }

  @Override
  public Set<String> freeNames() {
    return new HashSet<String>();
  }

  @Override
  public LCLExpression reduce(Hashtable<String, LCLExpression> aSymTable) {
    return this;
  }

  @Override
  public LCLExpression substitute(String aVar, LCLExpression aExp) {
    if ( getVariable().equals(aVar) ) {
      if ( aExp instanceof LambdaNumber ) {
```

```
        Integer lNumber = ((LambdaNumber)aExp).getNumber() - 1;
        return new LambdaNumber( lNumber.toString() );
      } else {
        throw new ArithmeticException("Illegal argument: " + aExp);
      }
    } else {
      return this;
    }
  }

  @Override
  public String toString() {
    return "decr(" + fVariable + ")";
  }
}
```

1.12. ast.Zero

```
package ast;

import java.util.HashSet;
import java.util.Hashtable;
import java.util.Set;

public class Zero extends LCLExpression {
  private String fVariable;

  public String getVariable() {
    return fVariable;
  }

  public Zero( String aVariable ) {
    fVariable = aVariable;
  }

  @Override
  public Set<String> freeNames() {
    return new HashSet<String>();
  }

  @Override
  public LCLExpression reduce(Hashtable<String, LCLExpression> aSymTable) {
    if ( aSymTable.contains( getVariable() )) {
```

```
      if ( aSymTable.get( getVariable() ) instanceof LambdaNumber ) {
        LambdaNumber lNumber = (LambdaNumber)aSymTable.get(getVariable());
        if (lNumber.getNumber() == 0) {
          return new LambdaNumber("1");
        } else {
          return new LambdaNumber("0");
        }
      } else {
        throw new ArithmeticException("Variable not a number" + getVariable());
      }
    } else {
      throw new RuntimeException("No symbol mapping for " + getVariable());
    }
  }

  @Override
  public LCLExpression substitute(String aVar, LCLExpression aExp) {
    return this;
  }

  @Override
  public String toString() {
    return "zero(" + fVariable + ")";
  }

}
```

1.13. ast.NotZero

```
package ast;

import java.util.HashSet;
import java.util.Hashtable;
import java.util.Set;

public class NotZero extends LCLExpression {
  private String fVariable;

  public String getVariable() {
    return fVariable;
  }

  public NotZero( String aVariable ) {
```

```
    fVariable = aVariable;
  }

  @Override
  public Set<String> freeNames() {
    return new HashSet<String>();
  }

  @Override
  public LCLExpression reduce(Hashtable<String, LCLExpression> aSymTable) {
    if ( aSymTable.contains( getVariable() )) {
      if ( aSymTable.get( getVariable() ) instanceof LambdaNumber ) {
        LambdaNumber lNumber = (LambdaNumber)aSymTable.get(getVariable());
        if (lNumber.getNumber() == 0) {
          return new LambdaNumber("0");
        } else {
          return new LambdaNumber("1");
        }
      } else {
        throw new ArithmeticException("Variable not a number" + getVariable());
      }
    } else {
      throw new RuntimeException("No symbol mapping for " + getVariable());
    }
  }

  @Override
  public LCLExpression substitute(String aVar, LCLExpression aExp) {
    return this;
  }

  @Override
  public String toString() {
    return "notZero(" + fVariable + ")";
  }

}
```

2. Notes

Though I tried to, I still wasn't able to get the reduction to completely collapse to the point where the answer to ((plus 1) 1) was 2. Instead I am only able to get the following answer.

```
(lambda f.( (lambda x.( f (lambda y.( ( x x ) y )) ))
            (lambda x.( f (lambda y.( ( x x ) y )) )) ))
```