Homework #4: CMPT-379

- Only submit answers for questions marked with †.
- Download the files for this homework:
  `wget http://www.cs.sfu.ca/~msiahban/personal/teaching/CMPT-379-Spring-2016/hw4.tgz`
- Put your solution programs in the `hw4/answer` directory. Use the `makefile` provided. There are strict filename requirements. Read the file `readme.txt` in the `hw4` directory for details.
- Create a file called `HANDLE` in your `hw4` directory which contains your group handle (no spaces).
- The `hw4/testcases` directory contains useful test cases; you will need to consult `readme.txt` for the mapping between the homework questions and test cases and instructions on how to run the auto check program.
- Reading for this homework includes Chp 5 of the Dragon book. We will be using the LLVM Compiler Infrastructure for code generation and code optimization: `http://llvm.org`.

1. **Global variables**

   Add support for global variables. The following rules in **`Decaf`** are the ones that involve the use of global variables.

$$
\begin{array}{rcl}
\langle \text{program} \rangle & \rightarrow & \langle \text{extern-defn} \rangle^{\,*}\ \ \textbf{class id `\{'}\ \langle \text{field-decl} \rangle^{\,*}\ \langle \text{method-decl} \rangle^{\,*}\ \textbf{`\}'} \\
\langle \text{field-decl} \rangle & \rightarrow & \langle \text{type} \rangle \left\{ \textbf{id} \mid \left\{ \textbf{id `[' intConstant `]'} \right\} \right\}^{+}\textbf{,`;'} \\
 & \mid & \langle \text{type} \rangle\ \textbf{id `='}\ \langle \text{constant} \rangle\ \textbf{`;'} \\
\langle \ell\text{-value} \rangle & \rightarrow & \textbf{id} \\
 & \mid & \textbf{id `['}\ \langle \text{expr} \rangle\ \textbf{`]'} \\
\langle \text{expr} \rangle & \rightarrow & \textbf{id} \\
 & \mid & \textbf{id `['}\ \langle \text{expr} \rangle\ \textbf{`]'}
\end{array}
$$

2. **Control-flow and loops**

   The following fragment of **`Decaf`** syntax adds control flow (**if** statements) and loops (**while** and **for** statements) to **`Decaf`**.

$$
\begin{array}{rcl}
\langle \text{statement} \rangle & \rightarrow & \textbf{if `('}\ \langle \text{expr} \rangle\ \textbf{`)'}\ \langle \text{block} \rangle \left[\textbf{else}\ \langle \text{block} \rangle \right] \\
 & \mid & \textbf{while `('}\ \langle \text{expr} \rangle\ \textbf{`)'}\ \langle \text{block} \rangle \\
 & \mid & \textbf{for `('} \left\{ \langle \text{assign} \rangle \right\}^{+}\textbf{,`;'}\ \langle \text{expr} \rangle\ \textbf{`;'} \left\{ \langle \text{assign} \rangle \right\}^{+}\textbf{,`)'}\ \langle \text{block} \rangle \\
 & \mid & \textbf{return} \left[\textbf{`('} \left[ \langle \text{expr} \rangle \right] \textbf{`)'} \right] \textbf{`;'} \\
 & \mid & \textbf{break `;'} \\
 & \mid & \textbf{continue `;'}
\end{array}
$$

   Your program must implement short-circuit evaluation for boolean expressions.

3. **Semantic checks**

   Perform at least the following semantic checks for any syntactically valid input **Decaf** program:

   (a) A method called **main** has to exist in the **Decaf** program.

   (b) Find all cases where there is a type mismatch between the definition of the type of a variable and a value assigned to that variable. e.g. `bool x; x = 10;` is an example of a type mismatch.

   (c) Find all cases where an expression is well-formed, where binary and unary operators are distinguished from relational and equality operators. e.g. `true + false` is an example of a mismatch but `true != true` is not a mismatch.

   (d) Check that all variables are defined in the proper scope before they are used as an lvalue or rvalue in a **Decaf** program (see below for hints on how to do this).

   (e) Check that the return statement in a method matches the return type in the method definition. e.g. `bool foo() { return(10); }` is an example of a mismatch.

   Raise a semantic error if the input **Decaf** program does not pass any of the above semantic checks.

   Your program should take a syntactically valid **Decaf** program as input and perform all the semantic checks listed above. You can optionally include any other semantic checks that seem reasonable based on your analysis of the language. Provide a readme file with a description of any additional semantic checks.

4. **Code Optimization using LLVM**

   Implement at least the following optimization passes:

   (a) Convert stack allocation usage (alloca) into register usage (mem2reg)

   (b) Simple "peephole" optimization (instruction combining pass)

   (c) Re-associate expresssions

   (d) Eliminate common sub-expressions (GVN)

   (e) Simplify the control flow graph (CFG simplification)

   You should modify the source code in your yacc program using the `FunctionPassManager` LLVM API call.

   You can even write your own LLVM pass using the documentation in `http://llvm.org/docs/WritingAnLLVMPass.html`.

5. † **The `Decaf` compiler**

   Create a yacc/lex program that accepts any syntactically valid **Decaf** program as defined in the **Decaf** specification and produces LLVM assembly language output. Your program should reject any syntactically invalid **Decaf** program and provide a helpful error message (the quality of the error reporting is up to you – at least report the line and character number where the syntax error is thrown). Your program should also perform the semantic checks defined in the **Decaf** specification and the code optimizations defined in Q. 4 above. Make sure that `make` will compile your program. Provide the details of your implementation in the readme file (it is essential for marking this assignment).