CMSC430 Spring 2009 Midterm 2

Instructions

- You have until 4:45pm to complete the midterm.
- Feel free to ask questions on the midterm.
- One sentence answers are sufficient for the ``essay" questions.
- Use only the following 3-address code and Java stack code instructions for answering code generation questions.

3-addr Instruction	Effect
load R1 x	R1 ← x
store x R1	x ← R1
add R1 R2 R3	R1 ← R2 + R3
sub R1 R2 R3	R1 ← R2 - R3
mult R1 R2 R3	R1 ← R2 * R3

Java Stack Code	Effect
nop	none
ldc_int c	push constant *c* onto stack
iload index(x)	push local variable X onto stack
istore index(x)	pop stack, store in local variable X
iadd	pop 2 elems off stack, add, push
isub	pop 2 elems, subtract top from 2nd, push
imult	pop 2 elems off stack, multiply, push
ineg	pop stack, negate, push
goto L	jump to handle L
ifeq L	pop stack, jump to handle L if zero
if_icmpeq L	pop 2 elems, jump to L if equal
if_icmpgt L	pop 2 elems, jump to L if 1st greater
dup	duplicate top of stack
pop	pop top of stack
swap	swap top two positions of stack

1. (15 pts) Intermediate representations.

   Consider the arithmetic expression:

   a - (b - c)

   a. Translate it into an AST
   b. Translate it into 3-address code
   c. Translate it into Java stack code
   d. Name an advantage of using 3-address code instead of stack code.

2. (16 pts) Code generation.
   You are generating code for a Java stack machine.
   You are given the following grammar attributes and helper functions:

Attribute	**Holds**
AstNode.code	list of instructions
Function	**Effect**
genInst(X)	create new instruction X returns handle to instruction
append(...)	concatenates lists of instructions

   a. A Ruby-style UPTO loop iterates (exp$_2$-exp$_1$+1) number of times. For example, *5 upto (2+6) do ... end* would iterate 4 times. Write syntax-directed actions needed to generate code for a UPTO loop for the following grammar production. Note you can only use the Java instructions provided at the beginning of the exam.

      stmt → *exp*$_1$ *UPTO exp*$_2$ *DO { stmtList } END*
      {: stmt.code = ?? :}

   b. The logical operator NAND is false only if BOTH of its operands are true. Write syntax-directed actions needed to generate code for a NAND expression in the following production. Your code should leave a 1 or 0 on the stack, depending on whether the resulting expression is true or false. Make sure you apply short circuiting.

      exp → *exp*$_1$ *NAND exp*$_2$
      {: exp.code = ?? :}

3. (8 pts) Compiling and optimizing high-level languages
   Object-oriented programming languages such as C++ and Java use classes and inheritance to improve programmer productivity. Remember that inheritance allows objects of one class to be used in place of objects in a parent class.

   a. How are objects and classes implemented in the run-time environment?
   b. What compiler-generated code is need to support inheritance?
   c. What is prefixing?

4. (6 pts) Compiler optimizations

   a. Give an example of a machine-independent optimization, and explain why it is machine-independent
   b. Give an example of a machine-dependent optimization, and explain why it is machine-dependent
   c. Why would a compiler writer decide not to implement a particular optimization?

5. (6 pts) Directed acyclic graphs

   Consider the following code.

   (1) a := b + c
   (2) b := b + c
   (3) c := b + c

   a. Perform renaming for the code
   b. Build a DAG for the renamed code
   c. How do DAGs support optimizations?

6. (6 pts) Control flow analysis

   For the following problems, consider this code:

```
<S1>          a := b
<S2>    L1:   b := c
<S3>          if (...) goto L2
<S4>          c := d
<S5>          if (...) goto L1
<S6>    L2:   d := a
```

   a. What are the basic blocks?
   b. What is the control flow graph
   c. What is a reverse Postorder numbering of the basic blocks?
   d. Why do compilers use basic blocks?

7. (6 pts) Local information

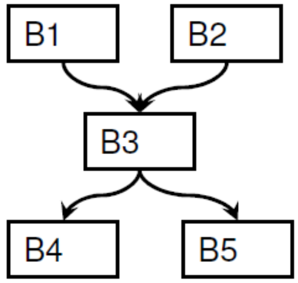
   Consider the following basic block for live variables:

```
b = a
d = b
a = c
e = d
a = e
```

   a. What is GEN for the basic block?
   b. What is KILL for the basic block?

8. (6 pts) Data-flow analysis

Consider the following control flow graph:

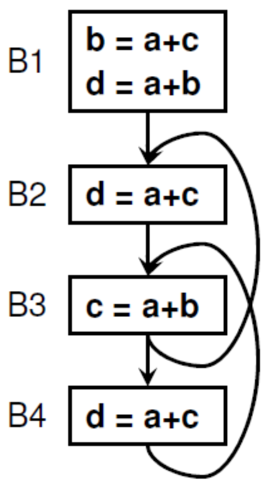


Assume you are given IN/OUT for B1,B2,B4,B5, and GEN/KILL for B3. Show the data-flow equations for IN/OUT for B3 (e.g., IN(B3) = OUT(B1)).

a. For forward data-flow problems
b. For backwards data-flow problems?

9. (20 pts) Available expressions

Consider the following control flow graph for available expressions:



a. Calculate GEN/KILL for each basic block
b. Solve available expressions, showing IN/OUT for each pass

10. (12 pts) Data-flow analysis frameworks

Recall that $\wedge$ is used in data-flow iterative analysis to combine information where paths merge.

a. Using properties of the $\wedge$ operator, prove $a \leq b$ and $b \leq a$ imply $a = b$.
b. For reaching definitions, pick values for a, b, c for which $a > b$ and $b > c$.
c. For very busy expressions, pick values for a, b for which neither $a \leq b$ or $b \leq a$ are true?
d. How is $\perp$ defined in terms of the $\wedge$ operator?
e. What is monotonicity and why is it important for iterative data-flow problems?