ECE 468 & 573

Problem Set 5: Dataflow analysis and Loop transformations

Loop transformations

For the following problems, consider the code below:

```
1.   X = 2;
2.   Y = 10;
3.   Y = X * Y;
4.   A = Y * X - 2 * Y;
5.   B = X / 2 + Y;
6.   Z = 10;
7.   if (B < Z) goto 12
8.   D = Y - Z * Y;
9.   Q = Y - 8;
10.  Z = Z - Q;
11.  goto 7;
12.  X = X + A*Y;
13.  if (X < Z*100) goto 4;
14.  Y = D;
15.  halt;
```

1. Draw the CFG for the code above. Identify the loops in the code.

2. Which statements are loop invariant? Can they be moved outside their enclosing loop? Show the code that results after hoisting any loop invariant code outside the loop.

3. Identify the induction variables in this code. Show the code that results after performing any possible strength reduction.

4. Show the code after performing any possible linear test replacement.

5. Draw the iteration space graph for the following piece of code (be careful about the index expressions and the loop order!):

   ```
   for (j = 0; j < 5; j++)
     for (i = 0; i < 5; i++)
       A[j+2][i+1] = A[j-1][i+1] + A[j+1][i+2];
   ```

6. What are the distance vectors? The direction vectors?

7. Can the loops be interchanged? Why or why not?

8. Can the following two loops be fused? Why or why not? Explain your answer in terms of dependences between the loops.

```
for (i = 1; i < 10; i++)
  A[i - 1] = B[i + 1]

for (i = 1; i < 10; i++)
  A[i + 2] = A[i]
```

9. Show the results of running an *available expressions* analysis on the following piece of code: for each line of code, show which expressions are available in that line of code.

```
    1: x = 4;
    2: y = 7;
L1  3: if (x > c) goto L4
    4:   if (y > 3) goto L2
    5:     c = x + 1;
    6:     b = a + x;
    7:     goto L3
L2  8:     a = a + x;
    9:     b = x + 1;
L3 10:   y = a + x;
   11:   goto L1;
L4 12: c = a + x
   13: halt
```