Problem Set 7: Loop optimizations (Solutions)

Consider the following code:

1: READ(x);
2: READ(y);
3: READ(b);
L1  4: if (x > 100) goto L4
  5:   b = y + 7;
  6:   z = y + 2;
  7:   x = x + z;
  8:   goto L1;
L4  9: WRITE(b)
10: WRITE(x)
11: halt

1. Which line(s) are loop invariant? Explain.
   Lines 5 and 6 are loop invariant (y is only defined outside the loop)

2. Which line(s) can be moved outside of the loop? Explain.
   Line 6 can be moved outside the loop (only one definition of z, not live before or after the loop). Line 5 cannot be moved outside the loop (b is live at a loop exit that line 5 does not dominate – note that WRITE(b) in line 9 may not see the definition of b in line 5.)

Consider the following code:

1: READ(x);
2: READ(y);
3: READ(z);
L1  4: w = y * x + 5;
  5:   WRITE(w);
  6:   x = x + z;
  7: if (x < 200) goto L1
  8:   halt;

1. What are the induction variable(s)? What are the mutual induction variable(s)?
   Induction variable: x (increments by a loop-invariant amount each iteration); mutual induction variable: w (linear function of x, and y is loop invariant)

2. Perform strength reduction on any mutual induction variables.
1: READ(x);
2: READ(y);
3: READ(z);
   \[ w' = y \times x + 5; \]
L1 4: \[ w = w'; \]
5: WRITE(w);
6: \[ x = x + z; \]
   \[ w' = w' + y \times z; \]
7: if (x < 200) goto L1
8: halt;

3. Perform linear test replacement if possible.

1: READ(x);
2: READ(y);
3: READ(z);
   \[ w' = y \times x + 5; \]
L1 4: \[ w = w'; \]
5: WRITE(w);
6: \[ x = x + z; \]
   \[ w' = w' + y \times z; \]
7: if \( w' < 200 \times y + 5 \) goto L1
8: halt;

at which point, the increment of x in line 6 is no longer necessary.