

CSEE W3827  
Fundamentals of Computer Systems  
Homework Assignment 6

Prof. Martha A. Kim  
Columbia University

Due December 2, 2014 at **10:10**.

Write your name **and UNI** on your solutions

Show your work for each problem; we are more interested in how you get the answer than whether you get the right answer.

Many of the problems in this assignment will involve analysis of the execution of this implementation of `countLocalMinima`. It is derived from the HW#4 solution, modified slightly to use only instructions supported by our MIPS CPU implementations.

```
i0:      addi  $a1, $a1, -1
i1:      add   $a1, $a1, $a1
i2:      add   $a1, $a1, $a1
i3:      add   $a1, $a1, $a0
i4:      addi  $a0, $a0, 4
i5:      add   $v0, $0, $0
i6:      addi  $t3, $0, 2
i7_top:  beq   $a0, $a1, i19_done
i8:      lw    $t0, -4($a0)
i9:      lw    $t1, 0($a0)
i10:     lw    $t2, 4($a0)
i11:     slt  $t0, $t1, $t0
i12:     slt  $t2, $t1, $t2
i13:     add  $t0, $t0, $t2
i14:     beq  $t0, $t3, i17_inc
i15_adv: addi  $a0, $a0, 4
i16:     beq  $0, $0, i7_top
i17_inc: addi  $v0, $v0, 1
i18:     beq  $0, $0, i15_adv
i19_done:
```

1. (20 pts.) Imagine how `countLocalMinima` would execute on a fully bypassed 5-stage MIPS pipeline (i.e., branches resolved in D, forwarding from W-E, M-E, and M-D). List all pairs of instructions between which one or more bubbles would occur. If a bubble occurs between `i3` and `i4`, then you should write `i3 → i4`. (HINT: Think systematically through all scenarios that result in an empty slot in the pipeline.)

2. (20 pts.) Now list where in the program (still count local minima on the fully bypassed 5-stage pipe) data operands would be forwarded, and which forwarding path would be used. If i3 forwards the future value of \$a0 to i4 using the M-E forwarding path, write \$a0, i3 → i4, M-E, per the example below. (HINT: Think through the values consumed by each instruction systematically.)
- \$a1 for i0, as producer unknown, assuming no forward
  - **\$a1, i0 → i1, M-E**

3. (15 pts.) Assuming a very large array such that the repeating loop body dominates the execution of the code snippet, what is the CPI of `countLocalMinima` code? Assume that the `beq` in `i14` is taken 20% of the time.

4. (10 pts.) Assuming an array of length 6 found at address `0x0000C0D8`, list the stream of addresses referenced by `countLocalMinima`.



6. (15 pts.) Assuming the address references to an initially empty 2-level cache hierarchy with Cache A as the L1 and Cache B as the L2, fill in the table below indicating the set for each reference and whether it resulted in a hit or a miss. If there is no access, just mark the squares with a “-”.

| Address    | L1 (Cache A) |        | L2 (Cache B) |        |
|------------|--------------|--------|--------------|--------|
|            | Set          | Result | Set          | Result |
| 0x0000C0DE |              |        |              |        |
| 0x0000C0E2 |              |        |              |        |
| 0x0000C0E6 |              |        |              |        |
| 0x0000C0EC |              |        |              |        |
| 0x0000C0DE |              |        |              |        |
| 0x0000C0E2 |              |        |              |        |



7. (5 pts.) Assume that Cache A's access time is 10ns with a miss rate of 10%, Cache B's access time is 500ns with a miss rate of 20%, and Memory's access time is 5000ns. What is the expected access time for the overall cache hierarchy?