CS 465 - Homework 1 – Fall 2021
Prof. Daniel A. Menasce
Department of Computer Science, George Mason University

Team Allowed: maximum of two per team.
State clearly team member names and GMU IDs as comments in source code and each page of submitted report.

IMPORTANT:

(1) Start to work on the homework early.
(2) If you plan to do the homework with a classmate, make a determination early on that your teammate is responsive.
(3) Your MIPS code should be very well documented.
(4) The explanation for your answers in part 3 is required. **You will not get credit without explanation.**

Late submissions are not accepted.

Part I: *MIPS Programming (40 points):*

A factor of a number *n* is a number that divides *n* evenly. Note that 1 and *n* are always factors of *n*. For this task, you will need to write a MIPS program that accepts a positive integer *n* from the standard input in a loop until *n* is zero, at which point the program should stop. For each number *n*, the program should find all positive factors of *n* and report the number of odd and even factors, respectively. You can assume user input is always a non-negative integer within range.

Sample runs (user input in blue, comments starting with # are NOT part of the required output):
Please enter a non-negative int: 6↵
Number of odd factors: 2   #1,3
Number of even factors: 2   #2,6

Please enter a non-negative int: 20↵
Number of odd factors: 2   #1,5
Number of even factors: 4   #2,4,10, 20

Please enter a non-negative int: 27↵
Number of odd factors: 4   #1,3,9,27
Number of even factors: 0   #none

Please enter a non-negative int: 0↵
End of program

Hint: You may need to use div and/or divu MIPS statements.

Deliverable for Part I:

- Your source code: mips1_XXX.asm where XXX is your "last names combined". For example if the last names of the two members in a group are Jones and Smith, your file name should be mips1_JonesSmith.asm. Do not submit PDF of the MIPS programs, just a .asm file!
- The output file of your program named as mips1_XXX.out where XXX is as above.
- As in all programming assignments, your code must be very well commented.

Part II: Exercises:

Question 2.1 (10 points) A computer is able to run a program in 24 seconds and executes $30*10^9$ instructions. The program uses 3 types of instructions (A, B, and C). The percentage of each type of instruction is 35%, 25%, and 40%, respectively. Instructions of type A take 2 cycles, instructions of type B take one cycle, and instructions of type C take 3 cycles.

(a) [5 points] What is the CPI of the program on that machine?

(b) [5 points] What is the clock frequency of the computer in GHz?

Question 2.2 [30 points]: Consider a heterogeneous computer architecture that has two types of processors: a CPU (of which there is only one) and p identical small capacity processors (called small processors heretofore) like in a GPU. Consider that a program P can be broken down into two parts: a sequential part (which is executed by the powerful processor) and a parallelizable part that is processed in parallel by the p small processors. The sequential and parallel parts of the computation start at the same time and the program ends when both parts end (i.e., when the part that takes the longest time ends).

Assume the following notation:

T: total execution time of program P assuming it only uses the CPU (i.e., the program does not do any I/O)
I: total number of instructions executed by P
f: fraction of the instructions of P that have to be executed by the powerful processor, i.e., the sequential part of P's instructions
CPI_s: average CPI of the part of the program executed on the powerful processor
CPI_p: average CPI of the part of the program executed on each small processor
f_s : clock frequency of the powerful processor
f_p : clock frequency of each small processor

(a) [7 points] Give an expression for the CPU time of the sequential part of the program

(b) [7 points] Give an expression for the CPU time of the parallel part of the program

(c) [8 points] Give an expression for the total execution time T

(d) [2 points] Give an expression for T when $f = 0$

(e) [2 points] Give an expression for T when $f = 1$

(f) [12 points] Assume that $I = 2 * 10^{10}$, $f_s = 3.5$ GHz, $f_p = 1.8$ GHz, $CPI_s = 1.5$, $CPI_p = 3.0$. Use Excel to draw a graph of T vs p (the number of small processors). Your graph should show 5 curves for the following values of f: 0, 0.15, 0.25, 0.5, and 1. The values of p should go from 1 to 50 in increments of 5. Use an x-y scatter plot type in Excel. Make sure to properly label the y and x axes.

(g) [4 points] What conclusions do you draw from the graph?

Question 2.3 [18 points]: A program P has a CPI equal to 1.5 when running on a machine that has a clock frequency equal to 2 GHz. The hardware designer was asked to modify the hardware so that the CPU time of P becomes 1/2 of the original CPU time. The machine's ISA should stay the same.

(a) [14 points] What changes should the designer make to the clock frequency to get to the 1/2 CPU time reduction? Assume that that the CPI does not change when the frequency is changed.

(b) [4 points] What was the resulting percentage change in the processor's dynamic power as a result of the change in item (a) above assuming there was no change in the capacitive load and that the voltage had to increase by a factor of 10%.