Department of Computer Science
National Tsing Hua University
CS4100 Computer Architecture
Spring, 2022, Homework 1
Due date: 3/10/2022

1. (50 points) Install and use AndeSight™ for RISC-V program development.
   (1) See AndeSight_STD_v3.2.0_Installation_Guide.pdf to install AndeSight™.
   (2) Create a new Andes C project:
      (i) Project name: "ADD_recursive".
      (ii) Chip profile: "NX25F".
      (iii) Project type: Andes Executable -> Hello World
      (iv) Tool chains: nds64le-elf-mculib-v5d.
      (v) All the others remain the same.
   (3) Replace ADD_recursive.c in the project with the one on EECLASS.
   (4) Press the button "Build 'Debug' for project 'ADD_recursive'" in the toolbar.
   (5) Press the button "Profile" in the toolbar.
   (6) Profile as "Application Program".
   (7) Press the button "Resume" in the debug window.
   (8) Do the same for project "ADD_iterative".
   Use default optimization setting -Og and answer the following questions.
   (a) (6 points) Record the results for the two programs using CycC and InsC for "add_recur" function of "ADD_recursive" and for "add_iter" function of "ADD_iterative". Based on your understanding of the characteristics of the two programs, compare the differences in their profiles.
   (b) (6 points) RISC-V has 32 general purpose registers, whereas X86 (a CISC architecture) only has 8. Why does RISC have more registers than CISC? When executing "ADD_iterative", which register stores the return value for add_iter function? (You can select  debug icon to view the contents of all registers. Note that you should set breakpoints at the right spots.)
   (c) (6 points) What are the average CPI for "add_recur" function in ADD_recursive.c and "add_iter" function in ADD_iterative.c, respectively?
   (d) (6 points) What are the CPU execution time for "add_recur" function in ADD_recursive.c and "add_iter" function in ADD_iterative.c, respectively, on a processor with a clock rate of 1GHz?
   (e) (6 points) Assume we execute ADD_iterative.c in (d) but with a 4-core multiprocessor instead and also employ parallelization techniques on add_iter function to equally allocate computation to each core. But, the parallelization increases 50 communication cycles on the multiprocessor. What is the program execution time now? (Hint: Only add_iter can be parallelized.)
   (f) (20 points) Compiler will affect program performance. Compile ADD_recursive.c and ADD_iterative.c with two optimization levels, -O0 and -O1, respectively. Compare the performance of "add_recur" and "add_iter" function in ADD_recursive.c and ADD_iterative.c for different optimization levels (-O0 and -O1). You should report CycC, InsC and CPI and explain the differences in their profiles. (To change optimization level, see Fig. 1.)

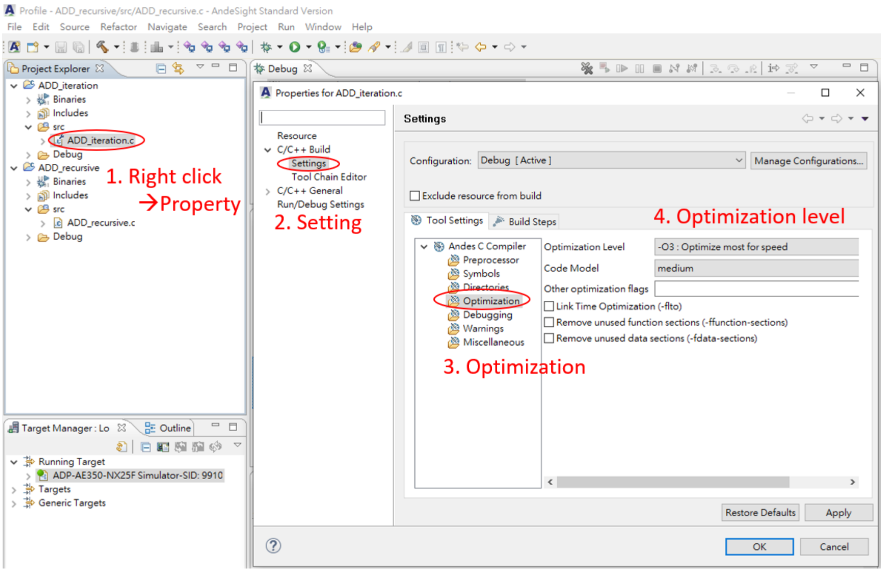

Fig. 1

2. (20 points) Go to **SPEC Benchmarks** website and search for the benchmarks of the following systems:
   - Intel DH87MC Motherboard (Intel Core i3-4340)
   - Intel DH87MC Motherboard (Intel Core i5-4430)
   - Intel DH87MC Motherboard (Intel Core i7-4770)

   Step 1. Click the SPEC Website URL: https://www.spec.org/cgi-bin/osgresults?conf=cint2006 and then choose the options as shown in Fig. 2.

SPECint2006 Results -- Query

This configuration is specific to the SPECint2006 results, including access to all of the individual benchmark component results.

Simple Request

Fetch just the summary information for all results.

- Optional: Return only those results where
  - 1. Hardware Vendor Matches 2. Intel ☐ Case-Sensitive

3. Execute Simple Fetch

Fig. 2

Step 2. Choose PDF to get the result table of Intel Core i3-4340, Intel Core i5-4430 and Intel Core i7-4770.

Results (Download as CSV)

Found 245 results (out of 9550 records).

CINT2006

Hardware Vendor	System	# Cores	# Chips	# Cores Per Chip	Result	Baseline	Published	Disclosure
Intel Corporation	ASUS H97M-PLUS Motherboard (Intel Celeron G1840)	2	1	2	39.3	37.8	Jul-2014	HTML CSV PDF PS Text Config
Intel Corporation	ASUS H97M-PLUS Motherboard (Intel Core i3-4150)	2	1	2	51.7	49.9	Jul-2014	HTML CSV PDF PS Text Config
Intel Corporation	ASUS H97M-PLUS Motherboard (Intel Core i3-4360)	2	1	2	55.2	53.3	Aug-2014	HTML CSV PDF PS Text Config
Intel Corporation	ASUS H97M-PLUS Motherboard (Intel Core i5-4460)	4	1	4	52.7	50.9	Aug-2014	HTML CSV PDF PS Text Config
Intel Corporation	ASUS H97M-PLUS Motherboard (Intel Core i5-4590)	4	1	4	56.4	54.5	Aug-2014	HTML CSV PDF PS Text Config
Intel Corporation	ASUS H97M-PLUS Motherboard (Intel Core i5-4690)	4	1	4	59.0	56.9	Jul-2014	HTML CSV PDF PS Text Config
Intel Corporation	ASUS H97M-PLUS Motherboard (Intel Pentium G3240)	2	1	2	44.3	42.6	Aug-2014	HTML CSV PDF PS Text Config
Intel Corporation	ASUS H97M-PLUS Motherboard (Intel Pentium G3258)	2	1	2	45.6	43.8	Aug-2014	HTML CSV PDF PS Text Config
Intel Corporation	ASUS H97M-PLUS Motherboard (Intel Pentium G3440)	2	1	2	47.4	45.6	Aug-2014	HTML CSV PDF PS Text Config
Intel Corporation	ASUS Z97-A motherboard (Intel Core i5-4690K)	4	1	4	60.2	58.2	Jun-2014	HTML CSV PDF PS Text Config

Fig. 3

Results Table

Benchmark	Base						Peak					
	Seconds	Ratio	Seconds	Ratio	Seconds	Ratio	Seconds	Ratio	Seconds	Ratio	Seconds	Ratio
400.perlbench	316	30.9	**316**	**31.0**	315	31.0	258	37.9	**259**	**37.8**	259	37.8
401.bzip2	459	21.0	**449**	**21.5**	438	22.0	436	22.1	**439**	**22.0**	446	21.7
403.gcc	294	27.4	293	27.5	**294**	**27.4**	275	29.2	276	29.1	**276**	**29.2**
429.mcf	155	58.8	**155**	**58.9**	154	59.3	155	58.8	**155**	**58.9**	154	59.3
445.gobmk	422	24.9	**422**	**24.9**	422	24.9	**399**	**26.3**	399	26.3	399	26.3
456.hmmer	164	57.0	**163**	**57.1**	163	57.2	164	57.0	**163**	**57.1**	163	57.2
458.sjeng	419	28.9	417	29.0	**418**	**28.9**	419	28.9	417	29.0	**418**	**28.9**
462.libquantum	39.9	519	**39.9**	**519**	40.2	515	39.9	519	**39.9**	**519**	40.2	515
464.h264ref	**380**	**58.2**	382	57.9	380	58.3	350	63.3	348	63.5	**349**	**63.4**
471.omnetpp	287	21.8	286	21.8	**287**	**21.8**	270	23.1	278	22.5	**275**	**22.7**
473.astar	271	25.9	**271**	**25.9**	270	26.0	271	25.9	**271**	**25.9**	270	26.0
483.xalancbmk	147	46.9	146	47.3	**147**	**47.0**	147	46.9	146	47.3	**147**	**47.0**

Results appear in the order in which they were run. Bold underlined text indicates a median measurement.

Fig. 4

We want to compare the performance of the three computer systems using different methods to normalize the performance.

(a) (5 points) Compare the hardware and software specifications of these three motherboards and identify their differences.

(b) (5 points) Consider the three benchmarks: 464.h264ref, 471.omnetpp, and 473.astar in the results table. Please use the first column of "seconds" (check Fig. 4) to calculate the relative performance of the three computer systems based on the three benchmarks. Fill out the following table, which uses each of the three computers as the reference for comparison. Summarize the performance results with the arithmetic mean of the performance ratios of the three benchmark programs. Please show the calculation procedure.

Reference	Performance ratio		
	Intel Core i3-4340	Intel Core i5-4430	Intel Core i7-4770
Intel Core i3-4340	1		
Intel Core i5-4430		1	
Intel Core i7-4770			1

Note:

$$Performance\ ratio = \frac{the\ execution\ time\ of\ the\ reference\ machine}{the\ execution\ time\ of\ the\ test\ machine}$$

You should do this problem according to this formula.

(c) (5 points) Repeat (b) with the geometric mean of the performance ratios of the three benchmark programs.

(d) (5 points) Which observations can you make from (b) and (c)? How are these results compared with SPECint_base2006 ratio?

3. (10 points) Assume a program requires the execution of 90×10^6 FP instructions, 110×10^6 INT instructions, 100×10^6 L/S instructions, and 25×10^6 branch instructions. The CPI for each type of instruction is 2, 1, 5, and 2, respectively. Assume that the processor has a 4GHz clock rate.

(a) (5 points) By how much must we improve the CPI of FP instructions if we want the program to run two times faster? Please show the calculation procedure.

(b) (5 points) By how much is the execution time of the program improved if the CPI of INT and FP instructions is reduced by 31% and the CPI of L/S and Branch is reduced by 77%? Please show the calculation procedure.

4. (10 points) Processor P1 has a clock rate of 5GHz and a voltage of 1.25V. Assume that, on average, it consumes 60W of static power and 90W of dynamic power. Assume that the dynamic power and static power are respectively calculated by the following equations:

    dynamic power = 1/2 × capacitive load × volatge^2 × clock frequency

    static power = voltage × leakage current

    (a) (2 points) Find the average capacitive load.
    (b) (2 points) Find the percentage of the total dissipated power comprised by dynamic power and the ratio of static power to dynamic power.
    (c) (6 points) If the total dissipated power is to be reduced by 35%, how much should the voltage be reduced to maintain the same leakage current?

5. (10 points) Assume that a 25 cm diameter wafer has a cost of 15, contains 120 dies, and has 0.02 defects/cm^2.
    (a) (3 points) Find the yield for this wafer using the equation on page 50 of the Lecture 1-1.
    (b) (3 points) Find the cost per die for this wafer.
    (c) (4 points) If the number of dies per wafer is increased by 20% and the defects per area unit increases by 35%, find the die area and yield.