Department of Electrical & Computer Engineering
University of California, Davis
EEC 170 – Computer Architecture
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Homework 1

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Question 1 Processor P1 has a clock frequency of 2 GHz, average CPI of 0.9, and executes 1 billion instructions to complete a program. Processor P2 has a clock frequency of 3 GHz, average CPI of 0.8, and executes 2 billion instructions to complete a program.

- Compute the MIPS rating of P1 and P2
- A common fallacy is that a processor with a high clock frequency is better in terms of performance. Check if this is true by comparing the execution times of the two processors.

MIPS OF P1 = (2*10^9)/(0.9*10^6) = 2,222.23

MIPS OF P2 = (3*10^9)/(0.8*10^6) = 3,750.

Execution time = (IC*CPI)/(ClockRate)

Execution time of P1 = (1*10^9*0.9)/(2*10^9) = 0.45s

Execution time of P2 = = (2*10^9*0.8)/(3*10^9) = 0.54s

Turns out that P1 is faster despite the fact that it has a lower clock frequency

Question 2 Consider two different implementations P1 and P2 of the same instruction set architecture. The instructions can be divided into 4 classes according to their CPI (classes A, B, C, and D). P1 has a clock frequency of 2.5GHz and the CPIs of the 4 classes of instructions are 1, 2, 3, and 4. P2 has a clock frequency of 3GHz and the CPIs of the four classes of instructions are 4, 3, 2, and 1. Consider a program with 1 million instructions with 10% instructions of Class A, 20% of class B, 50% of class C and 20% class D.

- Which implementation P1 or P2 is faster? Express your answer as a speed up, i.e. P1 is faster than P2 by X% or vice-versa.
- Now consider making the slower machine faster. That is, supposing you find P2 is slower than P1, what can you do, so that P2 becomes faster than P1, without changing the clock frequency of either processor or the overal instruction count.

Same ISA

P1 Clock rate = 2.5*10^9Hz

Class A 1 = 100,000
Class B 2 = 400,000
Class C 3 = 1,500,000
Class D 4 = 800,000

CPI = Clock Cycles / Instruction count = 2,800,000/1,000,000 = 2.8

CPU 1 = 1,000,000*2.8*(1/2.5*10^9)
CPU 1 time = 0.00112 Seconds

P2 Clock rate = 3*10^9Hz

Class A 4 = 400,000
Class B 3 = 600,000
Class C 2 = 1,000,000
Class D 1 = 200,000

CPI = Clock Cycles / Instruction count = 2,200,000/1,000,000 = 2.2

CPU 2 = 1,000,000*2.2*(1/3*10^9)
CPU 2 time = 0.000734

CPU 1/CPU 2 = P2 is 1.527 times faster than P1 or in other words P2 has a 52.58% increase in performance over P1

IC = 1*10^6

Class A = 0.1 100,000
Class B = 0.2 200,000
Class C = 0.5 500,000
Class D = 0.2 200,000

Inorder for us to make the slower machine faster we need to reduce the amount of cycles per instruction for a particular class, more specifically the one that has the greatest impact. In the case of P1, which is the slower processor, we would need to reduce the amount of clock cycles for class C, as that has the greatest impact on its perfromance.

Question 3
Assume a program requires 50 million floating point (FP) instructions, 100 million integer (INT) instructions, 80 million memory (L/S) operations and 20 million branch instructions.
Assume the clock frequency is 2GHz

Instruction Type	CPI
FP	2
L/S (memory instructions)	4
Branch	2
INT (integer instructions)	1

Part (a)By how much must we improve the CPI of FP instructions if we want the program to run 2 times faster?

Part (b)By how much must we improve the CPI of memory instructions if we want the program to run 2 times faster?

Part (c) By how much is the execution time of the program improved if the CPI of the INT and FP instructions is reduced by 50% and the CPI of the branch instructions is reduced by 30%?

Execution time = Old/New = 2x faster

Average CPI = (50*10^6*X + 4*80*10^6 + 2*20*10^6 + 2*100*10^6)/(250*10^6)
Average CPI = 2.24

Execution time = IC*CPI*Td = 0.28 seconds

Execution Time = 0.28 /New = 2 = 0.14 seconds

A) Cannot be done, we would need negative CPI!

B) The CPI would have to be 0.5 which is OLD/NEW = 4/0.5 = 8X faster than the old CPI

C) The new execution time would be 0.224 which is OLD/NEW = 0.28/0.224 1.25X faster than previously

Question 4 Suppose you have a machine which executes a program consisting of 50% floating point multiply, 20% floating point divide, and the remaining 30% are from other instructions.

- Management wants the machine to run 3 times faster. You can make the divide run at most 2 times faster and the multiply run at most 5 times faster. Can you meet management's goal by making only one improvement, and which one?
- Suppose that we can improve the floating-point instruction performance of machine by a factor of 15 (the same floating-point instructions run 15 times faster on this new machine). What percent of the instructions must be floating point to achieve a Speedup of at least 3?

Using Amdahl's law

Mult = 50s
Div = 20s
other = 30s

Mult new = 10s
Div = 20s
other = 30s

Total = 60s

Mult = 50s
Div new = 10s
other = 30s

Total = 90s

Total Execution time = 100s
Management wants execution time = 33.34 Seconds

No it is not possible to meet mangement requirements under such constraints

Applying Amdahl's law again:

$$Speedup_{overall} = \frac{ExTime_{old}}{ExTime_{new}} = \frac{1}{\left(1 - Fraction_{enhanced}\right) + \frac{Fraction_{enhanced}}{Speedup_{enhanced}}}$$

3 - 3X + X/5 = 1
X = 0.71428

Percent of instructions would have to be 71.42%

Question 5 Assume a 15cm diameter wafer has a cost of $1200, contains 84 dies, and has 0.02 defects/cm^2 and a 20cm diameter wafer has a cost of $1500, contains 100 dies and 0.031 defects/cm^2. Find the cost per die for both wafers.
Which wafer has higher cost and why?

Cost per die for wafer #1 = 1200/(84*(1/(1+(0.02))^2

= $14.862

Cost per die for wafer #2 = 1500/(100*(1/(1+(0.031))^2

= $15.944

The second wafer has a higher cost due to it costing more per wafer and also having a greater amount of defects per area.

Question 6. We would like to reduce the power consumption of a processor by 25% by scaling (reducing) the voltage of operation. Assuming that the frequency of the operation is proportional to the voltage of operation, what should the operating voltage be if the original operating voltage was 3.3V.

Power = 100% = C*V^2*V = (3.3)^3*C
C = 2.786

Power New = 75% = V^3*C

V = 2.99824