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Webinar on

Performance Assessment & CPU-OS Simulator

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Agenda

- Performance Assessment
  - *Execution Time*
  - *CPI*
  - *MIPS*
  - *Amdahl's Law*
- Disk Assessment
  - *Access Time, Seek Time, Transfer Time*
- CPU-OS Simulator

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Performance Assessment

Performance Assessment - Summary

- If you were running a program on two different desktop computers, you'd say that the faster one is the desktop computer that gets the job done first.

- Execution time: The total time required for the computer to complete a task, including disk accesses, memory accesses, I/O activities, operating system overhead, CPU execution.

$$\text{Performance}_X = \frac{1}{\text{Execution time}_X}$$

This means that for two computers X and Y, if the performance of X is greater than the performance of Y, we have

$$\text{Performance}_X > \text{Performance}_Y$$

$$\frac{1}{\text{Execution time}_X} > \frac{1}{\text{Execution time}_Y}$$

$$\text{Execution time}_Y > \text{Execution time}_X$$

Example

- Suppose Machine X runs a program in 100 seconds and Machine Y runs the same program in 125 seconds.
  - Which one is faster?
  - How many times its faster?

- $$\frac{Performance\ of\ X}{Performance\ of\ Y} = \frac{Execution\ Time\ of\ Y}{Execution\ Time\ of\ X}$$

- That means machine X is 1.25 times faster than Machine Y.

Performance Assessment – Clock Speed and Instructions per Second

- All computers are governed by a clock that determines when events take place in the hardware.
- These discrete time intervals are called clock cycles.
- The rate of clock pulses is known as the *clock rate*, or clock speed. (e.g., 4 gigahertz, or 4 GHz), which is the inverse of the clock period.

Performance Assessment

CPU Performance and Its Factor

$$\frac{\text{CPU execution time}}{\text{for a program}} = \frac{\text{CPU clock cycles}}{\text{for a program}} \times \text{Clock cycle time}$$

Alternatively, because clock rate and clock cycle time are inverses,

$$\frac{\text{CPU execution time}}{\text{for a program}} = \frac{\text{CPU clock cycles for a program}}{\text{Clock rate}}$$

Instruction Performance

$$\text{CPU clock cycles} = \text{Instructions for a program} \times \frac{\text{Average clock cycles}}{\text{per instruction}}$$

The term clock cycles per instruction, which is the average number of cycles each instruction takes to execute, is often abbreviated as CPI.

Performance Assessment – CPU Performance Equation

$$\text{CPU time} = \text{Instruction count} \times \text{CPI} \times \text{Clock cycle time}$$

or, since the clock rate is the inverse of clock cycle time:

$$\text{CPU time} = \frac{\text{Instruction count} \times \text{CPI}}{\text{Clock rate}}$$

Problem - 1

A compiler designer is trying to decide between two code sequences for a particular machine. Based on the hardware implementation, there are three different classes of instructions: Class A, Class B, and Class C, and they require two, three, and five cycles (respectively). The first code sequence has 5 instructions: 2 of A, 1 of B, and 2 of C The second sequence has 5 instructions: 1 of A, 2 of B, and 2 of C.

What is the CPI for each sequence?
Which code sequence will be faster and How much?

Solution#1

Instruction Class	CPI
A	2
B	3
C	5

Code sequence	IC for instruction Class		
	A	B	C
C1	2	1	2
C2	1	2	2

For Code C1;

Total Cycles = 2*2+1*3+2*5 = 17

Total instructions = 2 + 1 + 2 = 5

CPI = Total cycles / total instructions

= 17/5 = 3.4

Solution#1

Instruction Class	CPI
A	2
B	3
C	5

Code sequence	IC for instruction Class		
	A	B	C
C1	2	1	2
C2	1	2	2

For Code C2;

Total Cycles = 1*2+2*3+2*5 = 18

Total instructions = 1 + 2 + 2 = 5

CPI = Total cycles / total instructions

= 18/5 = 3.6

Solution#1

$$\text{CPU execution time for a program} = \text{CPU clock cycles for a program} \times \text{Clock cycle time}$$

For Code C1;

Total Cycles = 2*2+1*3+2*5 = 17

Total instructions = 2 + 1 + 2 = 5

CPI = Total cycles / total instructions

= 17/5 = 3.4

$$\frac{Performance\ of\ X}{Performance\ of\ Y} = \frac{Execution\ Time\ of\ Y}{Execution\ Time\ of\ X}$$

For Code C2;

Total Cycles = 1*2+2*3+2*5 = 18

Total instructions = 1 + 2 + 2 = 5

CPI = Total cycles / total instructions

= 18/5 = 3.6

What is the CPI for each sequence? C1= 3.4 and C2 = 3.6

Which code sequence will be faster and How much? ------C1 1.05 times

Performance Assessment – Millions of Instructions per Second (MIPS) Rate

- The rate at which instructions are executed.

$$\text{MIPS} = \frac{\text{Instruction count}}{\text{Execution time} \times 10^6}$$

$$\text{MIPS} = \frac{\text{Instruction count}}{\dfrac{\text{Instruction count} \times \text{CPI}}{\text{Clock rate}} \times 10^6} = \frac{\text{Clock rate}}{\text{CPI} \times 10^6}$$

Problem - 2

- A benchmark program is run on a 40 MHz processor. The executed program consists of 100,000 instruction executions, with the following instruction mix and clock cycle count.

Instruction Type	Instruction Count	Cycles per Instruction
Integer arithmetic	45000	1
Data transfer	32000	2
Floating point	15000	2
Control transfer	8000	2

- Determine the effective CPI, MIPS rate, and execution time for this program.

Solution #2

Instruction Type	Instruction Count	Cycles Per Instruction	Cycles in Instruction
Integer Arithmetic	45000	1	45000
Data Transfer	32000	2	64000
Floating Point	15000	2	30000
Control Transfer	8000	2	16000
	100000		**155000**

CPI = Total cycles / total instructions = 155000 / 100000 = 1.55

MIPS = clock rate / (CPI *10^6) = 40*10^6 / (1.55 * 10^6) = 25.8

Execution Time = Total cycles * cycle time = Total cycles / cycle rate

= 155000 / 40 * 10^6 = 3.87 * 10^-3 sec

Problem - 3

- A new microprocessor was designed and tested for performance. This microprocessor requires 2, 4 or 8 machine cycles to perform various operations. 45% of its instructions take 2 machine cycles, 40% take 4 machine cycles and 15% take 8 machine cycles.

- (a) Compute the average CPI for the microprocessor.
- (b) What is the clock frequency required for the microprocessor to be a 500 MIPS processor?

Solution #3

Instruction Count	Cycles Per Instruction	Cycles in Instruction
45	2	90
40	4	160
15	8	120
100		**370**

CPI = Total cycles / total instructions = 370 / 100 = 3.7

MIPS = clock rate / (CPI *10^6)

Clock rate = MIPS * CPI * 10^6

= 500 * 3.7 * 10^6 = 1850 MHz

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Amdahl's Law

Amdahl's Law
Use to predict system speed up

$$\text{Speedup} = \frac{\text{Performance after enhancement}}{\text{Performance before enhancement}} = \frac{\text{Execution time before enhancement}}{\text{Execution time after enhancement}}$$

$$S = \frac{1}{(1-f) + \frac{f}{k}}$$

- S=Speedup,
- f=fraction of time enhancement,
- k=speedup of the faster component

Problem - 4

- Let a program have 40percent of its code enhanced to run 2.3 times faster. What is the overall system speedup S?

$$S = \frac{1}{(1\text{-}f) + \frac{f}{k}}$$

$$S = \frac{1}{(1-0.4)+0.4/2.3} = 1.29$$

Problem - 5

- Floating point instructions are improved to run twice as fast, but only 10% of the time was spent on these instructions originally. How much faster is the new machine?

$$S = \frac{1}{(1-f) + \frac{f}{k}}$$

$$S = \frac{1}{(1-0.1)+0.1/2} = 1.05$$

Problem - 6

- Let a program have a portion of its code enhanced to run 4 times faster to yield a system speedup 3.3 times faster. What is the fraction of the code enhanced?

$$S = \frac{1}{(1-f) + \frac{f}{k}}$$

$$3.3 = \frac{1}{(1-f)+f/4}$$

$$1 - 3f/4 = \frac{1}{3.3} \qquad f = 0.93$$

Problem - 7

- You need to design a data analytics server. You have 2 options available:
  - a) A matrix computation module unit with a speedup of 2.5 which processes 60% of calculations
  - b) A statistical computation module unit with a speedup of 1.5 which processes 40% of calculations.
- Which option is a better method to design and justify your answer.

$$S = \frac{1}{(1-f) + \frac{f}{k}}$$

$$S1 = \frac{1}{(1-0.6)+0.6/2.5} = 1.56$$

$$S2 = \frac{1}{(1-0.4)+0.4/1.5} = 1.15$$

Problem - 8

- A programmer has parallelized 99% of a program, but there is no value in increasing the problem size, i.e., the program will always be run with the same problem size regardless of the number of processors or cores used. What is the expected speedup on 20 processors?

$$S = \frac{1}{(1-f) + \frac{f}{k}}$$

$$S = \frac{1}{(1-0.99)+0.99/20} = 16.81$$

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Disk Assessment

Problem - 9

Consider a disk pack with the following specifications- 16 surfaces, 128 tracks per surface, 256 sectors per track and 512 bytes per sector.

Answer the following questions-

a) What is the capacity of disk pack?
b) What is the number of bits required to address the sector?
c) What is the average access time with a seek time of 11.5 msec, if the disk is rotating at 3600 RPM?

Problem - 9

Given Data:

Number of surfaces = 16
Number of tracks per surface = 128
Number of sectors per track = 256
Number of bytes per sector = 512 bytes

Disk Capacity = No. of Surfaces x No. of tracks per surface x No. of sectors per track x No. of bytes per sector

= 16 x 128 x 256 x 512
= 2^4 x 2^7 x 2^8 x 2^9
= 2^28
= 256 MB

Problem - 9

Consider a disk pack with the following specifications- 16 surfaces, 128 tracks per surface, 256 sectors per track and 512 bytes per sector.

Answer the following questions-

a) What is the capacity of disk pack?
b) What is the number of bits required to address the sector?
c) What is the average access time with a seek time of 11.5 msec, if the disk is rotating at 3600 RPM?

Problem - 9

Given Data:

Number of surfaces = 16
Number of tracks per surface = 128
Number of sectors per track = 256

Total Sectors = No. of Surfaces x No. of tracks per surface x No. of sectors per track
= 16 x 128 x 256
= 2^4 x 2^7 x 2^8
= 2^19

Bits required to access sectors are --→ 19 bits

Problem - 9

Consider a disk pack with the following specifications- 16 surfaces, 128 tracks per surface, 256 sectors per track and 512 bytes per sector.

Answer the following questions-

a) What is the capacity of disk pack?
b) What is the number of bits required to address the sector?
c) What is the average access time with a seek time of 11.5 msec, if the disk is rotating at 3600 RPM?

Problem - 9

Given Data:

Rotating Rate = 3600 RPM

Seek Time = 11.5 ms

Sector = 256 and bytes per sector = 512 bytes

Taccess= Tavgseek + Tavgrotation + Tavgtransfer

Tavgrotation = 1/2r = 1/(2*60) = 8.33 ms

Tavgtransfer = b/rN

= 512 / (60*256*512)

= 0.06 ms

Hence Taccess= 11.5 + 8.33 + 0.06 = 19.9 ms

CPU-OS Simulator

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How to write a new Program

- Start CPU simulator and explain how to create a program.
- How to execute a program?
- Where we can check the stored result?

Example - CPU Simulator

- Program to compute average of two numbers
  - MOV #10, R00
  - MOV #20, R01
  - ADD R00, R01
  - DIV #02, R01
  - HLT

How to Simulate and Run the program

Simulator Teaching Language (STL)

```
program LinearSearch
    var a array(50) byte

    for n = 0 to 10
        a(n) = n
    next

    key = 10
    found = 0

    for n = 0 to 20
        temp = a(n)
        if temp = key then
            found = 1
            writeln("Key Found",temp)
            break
        end if
    next
    if found <> 1 then
        writeln("Key Not Found")
    end if
end
```

How to Simulate and Run the program

a) Execute the above program by setting block size to 2, 4, 8, 16 and 32 for cache size = 8, 16 and 32. Record the observation in the following table.

Block Size	Cache size	# Hits	# Misses	% Miss Ratio	%Hit Ratio
2	8				
4					
8					
2	16				
4					
8					

b) Plot a single graph of Cache hit ratio Vs Block size with respect to cache size = 8, 16 and 32. Comment on the graph that is obtained.

Q&A

Thankyou