San Francisco Bay University

EE488 - Computer Architecture
Homework Assignment #1

Due day: 5/25/2024

Instruction:
1. Push the answer sheet to Github in Word file.
2. Overdue homework submission could not be accepted.
3. Takes academic honesty and integrity seriously (Zero Tolerance of Cheating & Plagiarism)

1. **Assuming that a web server with the architecture spends 20% on processing, 30% on disk access, and 50% on network transfer, you have a base system consisting of a 500MHz processor and a disk with 20Mbytes/sec data transfer rate. This system costs $5K and can support 10,000 average web page accesses/sec. Considering the following three options to enhance system performance:**

   a. **Option-1: replacing the existing disk with a disk supporting 40Mbytes/sec data transfer rate with an additional (compared to the base) cost of $1,000.**

   b. **Option-2: replacing the processor with an 800MHz processor with an additional (compared to the base) cost of $800.**

   c. **Option-3: using the two enhancements indicated in Option-1 & Option-2 together with an additional (compared to the base) cost of $1,500.**

   (1) **Determine what will be the new performance (in terms of average web page access per second) with each of the enhancement options.**
   (2) **By doing a cost-performance analysis, determine which option will be cost-effective to go for and why.**

<u>Answer:</u>
Given data,

Processing Time: 20%
Disk Access Time: 30%
Network Transfer Time: 50%
Processor = 500 MHz
Data transfer rate of disk = 20 Mbytes/sec
System cost = $5,000.00
Performance = 10,000 web page accesses/sec

<u>In option 1:</u>

New Disk Transfer Rate = 40 Mbytes/sec
Additional Cost = $1,000.00
Total Cost = $5,000.00 + $1,000.00 = $6,000.00

In option 2:

New Processor Speed = 800 MHz
Additional Cost = $800.00
Total Cost = $5,000.00 + $800.00 = $5,800.00

In option 3:

New Disk Transfer Rate = 40 Mbytes/sec
New Processor Speed = 800 MHz
Additional Cost = $1,500.00
Total Cost = $5,000.00 + $1,500.00 = $6,500.00

Performance Calculation according to given data:

(1)Option 1: Enhanced Disk
Processing time, f = 0.3
Speed up factor, k = (40 Mbytes/sec) / (20 Mbytes/sec) = 2
Speed = 1 / ((1-f) +(f/k)) =1 / (0.7+0.15) = 1.1765
Average web page accesses = 1.176*10000 = 11,760 web page accesses/sec

(2)Web page access cost performance analysis:
Performance = 11,765 web accesses/sec
Cost = $6,000
Cost-Performance Ratio = 6,000 / 11,765 = 0.50998 $\approx$ 0.51

(1)Option 2: Enhanced Processor
Processing time, f = 0.2
Speed up factor, k = (800 MHz) / (500 MHz) = 1.6
Speed = 1 / ((1-f) +(f/k)) = 1 / (0.8+0.2/1.6)= 1.0811
Average web page accesses = 1.081*10000 = 10,810 web page accesses/sec

(2)Web page access cost performance analysis:
Performance = 10,810 web accesses/sec
Cost = $5,800
Cost-Performance Ratio = 5,800 / 10,810 = 0.53654 $\approx$ 0.54

(1) Option 3: Enhanced Disk and Processor
By combining option 1 & option 2,
Processing time, f = 0.3 + 0.2 = 0.5
$f/k = (f/k)_{\text{option 1}} + (f/k)_{\text{option 2}} = (0.3/2) + (0.2/1.6) = 0.275$
Speed = 1 / ((1-f) + (f/k)) = 1/ ((1-0.5) + 0.275 =1.2903
Average web page access = 1.2903*10000 = 12,903 web page accesses/sec

(2)Web page access cost performance analysis:
Performance = 12,903 web accesses/sec
Cost = $6,500
Cost-Performance Ratio = 6,500 / 12,903 = 0.50375 $\approx$ 0.50

Why: Option 3 is the most cost-effective, offering the lowest cost-performance ratio (0.50) compared to Option 1 (0.51) and Option 2 (0.54). Thus, combining both enhancements (Option 3) provides the best performance improvement for the additional cost.

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2. **The Amdahl's law is based on the assumption that when an enhancement is performed to some part of the system, the enhancement doesn't have any negative impact on the non-enhanced part. However, in real life, it could lead to negative impact on these parts. Thus, Amdahl's law can be modified to take care of this situation.**

   Consider a computer system with two components, A and B, which can be enhanced. There is interdependency between these components. And enhancement in one component affects the other. There are three options for enhancement as suggested below. All options involve the same amount of cost.

   a. **Option-A: Let us assume that f_A, the fraction of instructions using component A, can be sped up by 10 times. However, due to the dependency of A on B, another fraction $2f_A$ will be get slowed down by 5 times.**
   b. **Option-B: The instructions using component B, fraction f_B, can be sped up by 20 times. The dependency forces another fraction $0.5f_B$ to get slow down by 2 times.**
   c. **Option-C: A fraction f_A of instructions using the component A, can be sped up by a factor of 4. Unfortunately, the dependency forces another fraction f_A to get slowed down by 1.8 times.**

   (1) Derive the parameterized speed-up equations (in terms of f_A, f_B) for each of the above three options.

   (2) As a beginner architect, which option will be preferred and why? Give convincing reasoning. Assuming for a reasonable enhancement, you need to have $f_A > 0$ and $f_B > 0$

Answer:

Option A:

Speed-up of A, $S_A = 1 / ((1-f_A)+(f_A/10))$
Slow-down for dependency on B, $S_{depB} = 1 / (1+(2f_A/5))$
Combined Speed-up, $S_{total(A)} = 1 / ((1-f_A)+(f_A/10)+(2f_A/5))$
$= 1 / (1- f_A+0.1f_A +0.4f_A)$
$= 1 / (1-0.5f_A)$

Analyzing:
The significant negative impact due to the slowdown of $2f_A$ makes this option less stable for reasonable values of $f_A>0$.

Option B:

Speed-up of B, $S_B = 1 / ((1-f_B)+(f_B/20))$
Slow-down for dependency on B, $S_{depB} = 1 / (1+(0.5f_B/2))$
Combined Speed-up, $S_{total(B)} = 1 / ((1-f_B)+(f_B/20)+(0.25f_B/2))$
$= 1 / (1- f_B+0.05f_B +0.125f_B)$
$= 1 / (1-0.825f_B)$

Analyzing:
The substantial negative impact due to the slowdown of $0.5f_B$ leads to a significant reduction in overall performance for reasonable values of $f_B>0$

Option C:

Speed-up of A, $S_A = 1 / ((1-f_A)+(f_A/4))$
Slow-down for dependency on A, $S_{depA} = 1 / (1+(f_A/1.8))$
Combined Speed-up, $S_{total(C)} = 1 / ((1-f_A)+(f_A/4)+(f_A/1.8))$
$= 1 / (1- f_A+0.25f_A +0.5556f_A)$
$= 1 / (1-0.1944f_A)$

Analyzing:
This option provides a more balanced and stable performance improvement, as the slowdown factor is much less severe.

Why: Option C is the preferred choice because it provides a balanced and stable improvement in performance. The negative impact of the slowdown is less severe compared to Options A and B. For reasonable values of f_A and f_B, Option C maintains a manageable slowdown, ensuring a more reliable and consistent enhancement to the system.

Therefore, as a beginner architect, Option C is the best option to choose because it optimizes the system's performance without introducing significant instability or negative impacts on the other components.

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3. A set of three systems are being evaluated to be used in a laboratory environment. This environment uses three types of programs with a relative usage of 45% (Program 1), 35% (Program 2), and 20% (Program 3) respectively. Each of these three programs has been benchmarked on these three systems individually and their execution times are shown as follows.

Programs	System 1	System 2	System 3
Programs 1	1.0 sec	2.0 sec	1.5 sec
Programs 2	10.0 sec	7.0 sec	5.0 sec
Programs 3	5.0 sec	3.0 sec	4.0 sec

a. **Determine which of the above three systems will provide the best performance for the laboratory.**

b. **The three systems cost as follows: \$8,000 (System 1), \$5,000 (System 2), and \$6,500 (System 3). By doing a cost-performance analysis, indicate which one of these systems you will choose and why.**

Answer:
a. Performance Analysis:

We calculate the weighted execution time for each system based on the relative usage of the programs.

Weighted Average Execution Time Calculation:

Weighted Average Execution Time = (Time for Program 1×0.45)+(Time for Program 2×0.35)+(Time for Program 3×0.20)

System 1:

$$= (1.0\times0.45)+(10.0\times0.35)+(5.0\times0.20)$$
$$= 0.45+3.5+1.0$$
$$= 4.95\text{sec}$$

System 2:

$$= (2.0\times0.45)+(7.0\times0.35)+(3.0\times0.20)$$
$$= 0.9+2.45+0.6$$
$$=3.95 \text{ sec}$$

System 3:

$$= (1.5\times0.45)+(5.0\times0.35)+(4.0\times0.20)$$
$$= 0.675+1.75+0.8$$
$$= 3.225 \text{ sec}$$

For best performance:

System 3 has the lowest weighted average execution time of 3.225 seconds, indicating it will provide the best performance in the laboratory environment.

b. Cost-Performance Analysis

We divide the cost by the weighted execution time:

Cost-Performance Ratio = (Cost / Weighted average execution time)

System 1:

$$= (8000/4.95)$$
$$= 1616.16$$

System 2:

$$= (5000/3.95)$$
$$=1265.82$$

System 3:

$$= (6500/3.225)$$
$$=2015.50$$

Cost-Performance Analysis:

System 2 has the lowest cost-performance ratio of 1265.82, indicating it provides the best value for money.

Final Decision:

Based on the cost-performance analysis, System 2 is the preferred choice despite System 3 having the best performance. System 2 offers the best value considering both performance and cost.

Summary:

Best Performance: System 3 with 3.225 seconds
Best Value: System 2 with a cost-performance ratio of 1265.82
This analysis indicates that while System 3 performs best, System 2 is the most cost-effective solution for the laboratory environment.

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