Tutorial - 2

Performance metrics

Introduction

Amdhal's Law: In computer architecture ,Amdahl's law (or Amdahl's Argument) is a formula which gives the theoretical speedup in latency of the execution of a task at fixed workload that can be expected of a system whose resources are improved .It is named after the computer scientist Gene Amdahl.

The speedup formula is given by ,

$$\text{speedup} = \frac{\text{Execution time without enhancement}}{\text{Execution Time with enhancement}} = \frac{\text{Execution Time}_{old}}{\text{Execution Time}_{new}}$$

$$\text{Execution Time}_{new} = \text{Execution Time}_{old} \times ((1 - \text{Fraction}_{enhanced}) + (\text{Fraction}_{Enhanced} / \text{Speedup}_{Enhanced}))$$

$$\text{Overall speedup} = 1/((1 - \text{Fraction}_{enhanced}) + (\text{Fraction}_{Enhanced} / \text{Speedup}_{Enhanced}))$$

Example problems

a)Given, $Speedup_{enhanced}$ =20

$Fraction_{enhanced}$ =0.5

overall speedup =?

overall speedup = 1/((1-0.5) + 0.5/20) = 1.905

b)Given, $Speedup_{enhanced}$ =16

$Fraction_{enhanced}$=0.6

overall speedup = ?

overall speedup =1/((1-0.6) + 0.6/16)=2.286.

Question-1

A program is executed for **1** sec, on a processor with a clock cycle of **25** nsec and Throughput = **20 MIPS**.

a) How many cycles are used by an instruction for the program?

b) Let us assume that, given some optimization techniques, the throughput of the program is optimized. In the new case, **20%** of the program instructions are executed with **CPI=1**, while a fraction of remaining instructions is executed with the same CPI.

How much is the Speed Up in the program exec, given the optimization in cpi?

How much is the new Throughput expressed in MIPS?

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a) Given , Execution time of program = 1 sec

Clock cycle time =25 nsec

=> clock rate=1/25 nsec=0.04Ghz=40 Mhz

Throughput =20 MIPS

cpi= ?

We know Throughput in MIPS = (Clock rate)/(CPI x 10^6)

cpi=clock rate /(throughput x 10^6)

=40 x 10^6 / 20 x 10^6=2.

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b)Given , For 20% of program CPI =1.
80% of program CPI =2
initial throughput =20 MIPS
Speedup from initial to enhanced cpi=?
Throughput after optimization =?
fraction of instructions (fraction enhancement) whose cpi is enhanced =20/100=0.2

Enhanced CPI=1, for 20% instructions

Speedup enhanced in CPI for 20% instructions = old cpi /new cpi = 2/1=2.

Overall speedup in program execution is given by Amdahl's law

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b) Let us assume that, given some optimization techniques, the throughput of the program is optimized. In the new case, **20%** of the program instructions are executed with **CPI=1**, while a fraction of remaining instructions is executed with the same CPI.

How much is the Speed Up in the program exec, given the optimization in cpi?

How much is the new Throughput expressed in MIPS?

b) contd...

Speedup=1/((1- fraction enhanced) + fraction enhanced/speedup)

Speedup=1/((1- 0.2) +0.2/2) =1.11.

Enhanced throughput=speedup x original throughput=1.11 x 20 =22.2.

Question-2

Q2. A program consisting **10 million** instructions in total is executed, on a processor with a clock cycle of **50 nsec** with a **CPI = 1.25.**

a) How much is the Throughput expressed in MIPS, and exec time of the program?

b) Let us assume that, given some optimization techniques, **25%** of program instructions is executed with CPI =1, while a fraction of remaining instructions is executed with the same cpi.

How much is the Throughput expressed in MIPS?

How much is the speedup from initial to the enhanced state?

Question-2

Q2. A program consisting 10 million instructions in total is executed ,on a processor with a clock cycle of **50 nsec** with a **CPI1 = 1.25.**

a) How much is the Throughput expressed in MIPS, and exec time of the program?

b) Let us assume that, given some optimization techniques, **25%** of the program instructions is executed with CPI =1 , while a fraction of remaining instructions is executed with the same CPI.

HOW much is the Throughput expressed in MIPS?

How much is the speedup from initial to the enhanced state?

b) Fraction of instructions for which CPI is enhanced (Fraction Enhanced)= 25/100 = 0.25 .

Enhanced cpi=1

Speedup in CPI=CPI_{old} /CPI_{new} =1.25 /1=1.25

Overall speedup from initial to enhanced

State using (Amdahl's law)

=1/((1-0.25)+ 0.25/1.25) = 1.053

Overall speedup is given by speedup =enhanced throughput/initial throughput

enhanced throughput = speedup x initial throughput =1.053 x 16= 16.85.

Question-2

Q2. A program consisting 10 million instructions in total is executed ,on a processor with a clock cycle of **50 nsec** with a **CPI1 = 1.25.**

a) How much is the Throughput expressed in MIPS, and exec time of the program?

b) Let us assume that, given some optimization techniques, **25%** of the program instructions is executed with CPI =1 , while the fraction of remaining instructions is executed with the same cpi.

HOW much is the Throughput expressed in MIPS?

How much is the speedup from initial to the enhanced state?

a)Given, No. of instructions in the program is 10 million.

clock cycle time=50 nsec.

=>clock rate =20 MHz

cpi=1.25.

Throughput= ?

we know Throughput in MIPS =(Clock rate)/(CPI x 10^6)

=>Throughput = (20 x 10^6)/1.25 x 10^6

= 20/1.25 =16 MIPS

Execution time of the program= no of instructions in the program/ throughput

=10 X 10^6 / 16 x 10^6 = 0.625 seconds

Question-3

Q3.

a) A program is executed for **1 sec**, on a processor with a clock cycle of **25 nsec** and Throughput=**30 MIPS**. How much is the CPI for this program?

b) Let us consider a computer executing the following mix of instructions:

Instructions	Frequency	Clock cycles
ALU	75	1
LOAD	10	8
STORE	10	4
BRANCH	5	3

Question-3

. b) contd

i)How much is the CPI average assuming a clock period of **3 nsec** ?

How much is the Throughput expressed in MIPS ,for the given clock period?

ii)How much is the speedup assuming that, introducing an optimized data cache, load instructions require **2 clock cycles** ?

iii)How much is the Speedup assuming that, introducing an optimized branch unit,branch instructions require **1 clock cycle**?

iv)How much is the speedup assuming to introduce **8 ALUs** working in parallel ?

v)How much is the speedup assuming to introduce all together the above optimizations?

Question-3

b) Let us consider a computer executing the following mix of instructions:

Instructions	Frequency	Clock cycles
ALU	75	1
LOAD	10	8
STORE	10	4
BRANCH	5	3

i)How much is the average CPI assuming a clock period of 3 nsec ?

How much is the Throughput expressed in MIPS , for the given clock period?

b) Given , clock period=3 nsec

=> clock rate=333 MHz.

i. Average cpi=75/100 * 1 + 10/100 * 8 + 10/100 * 4+ 5/100 * 3=2.1.

Throughput(MIPS)=clock rate / (cpi x 10^6)

=(333 * 10^6)/ (2.1* 10^6)

=158.57 MIPS

Question-3

a) A program is executed for **1 sec**, on a processor with a clock cycle of **25 nsec** and Throughput = **30 MIPS**.

How much is the CPI for this program?

a)Given, execution time of program =1 sec.

Throughput=30 MIPS

cct=25nsec

=>clock rate=40 MHz

cpi_1= ?

cpi=clock rate / (MIPS x 10^6)

cpi=40 x 10^6 /(30 x 10^6)=1.33.

ALU	75	1
LOAD	10	8
STORE	10	4
BRANCH	5	3

speedup = cpi_1 / cpi_2=2.1/1.5
=1.4

ii) How much is the speedup assuming that,introducing an optimized data cache, load instructions require 2 clock cycles?

Question-3

b) Let us consider a computer executing the following mix of instructions:

Instructions	Frequency	Clock cycles
ALU	75	1
LOAD	10	8
STORE	10	4
BRANCH	5	3

iv.) How much is the speedup assuming to introduce 8 ALUs working in parallel ?

iv) $cpi_4 = 0.09375 * 1 + 0.1 * 8 + 0.1 * 4 + 0.05 * 3$

$= 1.44375$

$cpi_1 = 2.1$

$speedup = CPI_1/CPI_4 = 2.1/1.44 = 1.46$

Question-3

b) Let us consider a computer executing the following mix of instructions:

Instructions	Frequency	Clock cycles
ALU	75	1
LOAD	10	8
STORE	10	4
BRANCH	5	3

iii)How much is the SpeedUP assuming that,introducing an optimized branch unit, branch instructions require 1 clock cycles?

iii)$cpi_3 = 0.75*1 + 0.1 * 8 + 0.1 * 4 + 0.05 * 1 = 2$

$cpi_1 = 2.1$

speedup $= cpi_1/cpi_3 = 2.1/2 = 1.05$

Question-3

b) Let us consider a computer executing the following mix of instructions:

Instructions	Frequency	Clock cycles
ALU	75	1
LOAD	10	8
STORE	10	4
BRANCH	5	3

v) How much is the speedup assuming to introduce all together the previous optimizations?

v) $cpi_5 = 0.09375 * 1 + 0.1 * 2 + 0.1 * 4 + 0.05 * 1$

$=0.744$

$cpi_1=2.1.$

$speedup=CPI_1/CPI_5=2.1/0.744=2.82.$

Additional exercise problems

Question 1) You have a system that contains a special processor for doing floating-point operations. You have determined that **50%** of your computations can use the floating-point processor . The speedup of the floating point processor is **8**.

a)Compute the overall speedup achieved by using the floating-point processor.

b)Compute the overall speedup achieved if you modify the compiler so that **62%** of the computations can use the floating-point processor.

Question 2) What is the speedup that could be achieved according to Amdahl's Law if infinite number of processors are utilized for optimizing the program execution, given the fact that **5%** of a program is sequential and the remaining part is ideally parallel?