**Performance of a computer Continued ...**

Most processors execute instructions in a synchronous manner using a clock that runs at a constant *clock rate* or *frequency f*.

• Clock cycle time *C* is the reciprocal of the clock rate *f*:

*C = 1 / f*

• The clock rate *f* depends on two factors:

a) The implementation technology used.

b) The CPU organization used.

A micro-operation is an elementary hardware operation that can be

carried out in one clock cycle.

– Register transfer operations, arithmetic and logic operations, etc.

• Thus a single machine instruction may take one or more CPU cycles tocomplete.

– We can characterize an instruction by *Cycles Per Instruction* (CPI).

• Average CPI of a program:

– Average CPI of all instructions executed in the program on a given processor.

– Different instructions can have different CPIs.

For a given program compiled to run on a specific machine, we can define the following parameters:

a) The total number of instructions executed or *instruction count* (IC).

b) The average number of *cycles per instruction* (CPI).

*c) Clock cycle time* (C) of the machine.

• The total execution time can be computed as:

***Execution Time XT = IC x CPI x C***

• How do we evaluate and compare the performances of several machines?

One of the easiest methods to make the comparison.

• We measure the execution times of a program on two machines (A and B), as XTA and XTB.

• Performance can be defined as the reciprocal of execution time:

PerfA = 1 / XTA

PerfB = 1 / XTB

• We can estimate the speedup of machine A over machine B as:

Speedup = PerfA / PerfB = XTB / XTA

A program is run on three different machines A, B and C and execution times of 10, 25 and 75 are noted.

– A is 2.5 times faster than B

– A is 7.5 times faster than C

– B is 3.0 times faster than C

A program is running on a machine with the following parameters:

– Total number of instructions executed = 50,000,000

–Average CPI for the program = 2.7

– CPU clock rate = 2.0 GHz (i.e. C = 0.5 x 10-9 sec)

• Execution time of the program:

XT = 50,000,000 x 2.7 x 0.5 x 10-9 = 0.0675 sec

Suppose that a machine A executes a program with an average CPI of 2.3. Consider another machine B that executes the same program with 20% less instructions and with a CPI of 1.7 at 1.2 GHz.

What should be the clock rate of A so that the two machines have the same performance?

We must have: IC x CPIA x CA = 0.8\*IC x CPIB x CB

Hence: 2.3 x CA = 0.80 x 1.7 x (1 / (1.2 x 109))

We get: CA = 0.49 x 10-9 sec

Thus, clock rate of A = 1 / CA = 2.04 GHz

Consider the earlier example with IC = 50,000,000; average CPI = 2.7, and clock rate = 2.0 GHz.

Suppose we use a new compiler on the same program, for which:

– New IC = 40,000,000

– New CPI = 3.0 (i.e. the new compiler is using more complex instructions)

– Also we have a faster CPU implementation, with clock rate = 2.4 GHz.

Speedup = XTold / XTnew

= (50,000,000 x 2.7 x 0.5 x 10-9) / (40,000,000 x 3.0 x 0.4167 x 10-9)

= 1.35 à 35% faster

Amadahl’s law demonstrates the law of diminishing returns.

• An example:

– Suppose we are improving a part of the computer system that affects only 25% of the overall task.

– The improvement can be very little or extremely large.

– With “infinite” speedup, the 25% of the task can be done in “zero” 4me.

– Maximum possible speedup = XTorig / XTnew = 1 / (1 – 0.25) = 1.33

100% - program

45% -

55%

Execution time before improvement: (1 – F) + F = 1

• Execution time after improvement: (1 – F) + F / S

• Speedup obtained:

1/((1 – F) + F / S)

• As S tends ∞, Speedup à 1 / (1 – F)

– The fraction F limits the maximum speedup that can be obtained.

We make 10% of a program 90X faster, speedup = 1 / (0.9 + 0.1 / 90) = 1.11

– We make 90% of a program 10X faster, speedup = 1 / (0.1 + 0.9 / 10) = 5.26

– We make 25% of a program 25X faster, speedup = 1 / (0.75 + 0.25 / 25) = 1.32

– We make 50% of a program 20X faster, speedup = 1 / (0.5 + 0.5 / 20) = 1.90

– We make 90% of a program 50X faster, speedup = 1 / (0.1 + 0.9 / 50) = 8.47

The execution time of a program on a machine is found to be 50 seconds, out of which 42 seconds is consumed by multiply operations. It is required to make the program run 5 times faster. By how much must the speed of the multiplier be improved?

– Here, F = 42 / 50 = 0.84

– According to Amadahl’s law,

5 = 1 / (0.16 + 0.84 / S)

or, 0.80 + 4.2 / S = 1

or, S = 21

out of which 42 seconds is consumed by multiply operations. It is required to make the program run 8 times faster. By how much must the speed of themultiplier be improved?

– Here, F = 42 / 50 = 0.84

– According to Amadahl’s law,

8 = 1 / (0.16 + 0.84 / S)

or, 1.28 + 6.72 / S = 1

or, S = – 24

**Reference: Materials from IIT kharagpur and NIT,Megalaya**



C