

### 3.1.4 Performance Measurement

There are several ways of making quantitative performance comparisons. Consider the comparison of two different ways of driving a car between two points. It can be made in terms of speed (“I averaged 34 miles per hour going the old route, and 46 miles per hour going the new route.”), or in terms of time (“it took me 96 minutes taking the old route, and only 71 minutes taking the new route.”).

When comparing speeds, or *rates*, the old speed is compared with the new speed by dividing new by old. In the example above:

$$\text{Speedup} = \frac{\text{Speed going the new way}}{\text{Speed going the old way}} = \frac{S_{\text{old}}}{S_{\text{new}}} = \frac{46}{34} = 1.35 \quad [\text{Eq. 3.1}]$$

for an improvement of 0.35 or 35% to two significant digits. One can calculate the % improvement, or speedup, directly by using the equation

$$\% \text{Speedup} = \frac{S_{\text{new}} - S_{\text{old}}}{S_{\text{old}}} \times 100 = \frac{46 - 34}{34} \times 100 = \frac{12}{34} \times 100 = 35\% \quad [\text{Eq. 3.2}]$$

For comparisons in terms of time rather than speed, or rate, recall that time is the reciprocal of speed:

$$\frac{\text{Miles}}{\text{Hour}} = \frac{1}{\frac{\text{Hours}}{\text{Mile}}}; \quad \text{or } S = \frac{1}{T} \quad [\text{Eq. 3.3}]$$

Thus

$$\begin{aligned} \% \text{Speedup} &= \frac{S_{\text{new}} - S_{\text{old}}}{S_{\text{old}}} \times 100 \\ &= \frac{\frac{1}{T_{\text{new}}} - \frac{1}{T_{\text{old}}}}{\frac{1}{T_{\text{old}}}} \times 100 \\ &= \frac{T_{\text{old}} - T_{\text{new}}}{T_{\text{new}}} \times 100 \end{aligned} \quad [\text{Eq. 3.4}]$$

In the present case,

$$\% \text{Speedup} = \frac{T_{\text{old}} - T_{\text{new}}}{T_{\text{new}}} \times 100 = \frac{96 - 71}{71} \times 100 = 35\% \quad [\text{Eq. 3.5}]$$

We box this equation because it will be used frequently throughout the text.

workload

benchmark

**Estimating Computing System Performance** Estimates of machine performance vary from the qualitative (“It takes 16 seconds to load Microsoft Word 6.0”) to fairly careful tests using software suites designed specifically to measure a particular aspect of system performance. Generally, the performance testing is begun by defining a *workload*, that is, a suite of programs that can be run and whose execution time can be measured. Ideally, the workload should consist of exactly those programs that customers will want to run on their machines. The impracticality of satisfying the ideal for all users and all time leads to the selection of a set of *benchmark* programs that are intended to approximate the real workload. These benchmark programs are generally chosen so as to provide a program mix that exercises a system feature that the tester wishes to evaluate.

▶ **Example 3.1 Estimating Performance**

A certain computer system takes 125 ms to render a certain graphic image, and this time is reduced to 100 ms when a graphics processor card is added to the system. What is the speedup?

$$\text{Speedup} = \frac{T_{\text{old}}}{T_{\text{new}}} = \frac{125}{100} = 1.25, \text{ or a 25\% speedup}$$



program execution,  
or wall clock time

**Execution Time, Clock Speed, and Clocks per Instruction (CPI)** Computer system performance is usually measured by the time to execute a program or program mix, rather than the speed with which it executes programs. A computer system that completes a given program faster than another computer performs better on that workload. The *program execution time*, or *wall clock time*, is made up of many factors. We ignore factors such as waits for I/O that do not depend on processor speed for the moment. The processor-related time is given by

$$\text{Execution time} = T = IC \times CPI \times$$

**[Eq. 3.6]**

IC is the instruction count, CPI is the average number of system clock periods to execute an instruction, and is the duration of a clock period. Once again we box this equation because of the importance it will assume during later chapters. A computer with a faster system clock, with fewer clocks per instruction, or taking fewer instructions to do the job will better performance.

▶ **Example 3.2 Speedup due to a Clock Frequency Increase**

The master clock in a certain computer system is increased in frequency from 700 MHz to 1.2 GHz. What is the speedup due to this improvement if no other factors in the computer system change?

Ans:

Since according to the problem definition neither IC nor CPI changed, and since the clock period,  $t_{clk}$ , is proportional to the reciprocal of clock frequency,

$$\text{Speedup} = \frac{(\text{IC} \times \text{CPI} \times t_{clk})_{\text{old}}}{(\text{IC} \times \text{CPI} \times t_{clk})_{\text{new}}} = \frac{1/700}{1/1200} = \frac{1200}{700} = 1.71, \text{ or } 71\% \text{ speedup}$$

