Homework 01: Exercise 1

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13. 09. 2004

Problem: If today's workstations execute at 10^8 operations per second, and performance increases at a rate of 25 percent per year, how long will it be before we have workstations capable of 10^9 operations per second? 10^{12}?

A climate model requires 10^{16} floating point operations for a ten-year simulation. How long would this computation take at 10^7 floating point operations per second (10 Mflops)?

A climate model generates 10^{11} bytes of data in a ten-day simulation. How fast must data be transferred to secondary storage? What transfer rate is required if we are to search this data in ten minutes?

Solution: Let x be the number of years that is needed to reach the specified magnitude of operations per second. Since the performance increases at 25 percent per year, after one year $10^8 \cdot 1.25$ ops are possible. After two years we would have $10^8 \cdot 1.25 \cdot 1.25$ ops. So after x years, we have $10^8 \cdot 1.25^x$ ops, what leads us to the following equations:

$$\begin{aligned} 10^8 \cdot 1.25^x &= 10^9 \\ 1.25^x &= 10 \\ x &= \log_{1.25} 10 \end{aligned}$$

for 10^9 ops and

$$\begin{aligned} 10^8 \cdot 1.25^x &= 10^{12} \\ 1.25^x &= 10^4 \\ x &= \log_{1.25} 10^4 \end{aligned}$$

for 10^{12} ops.

If 10^{16} flops are required for some simulation and the machines used perform 10^7 flops, it would take $\frac{10^{16}}{10^7} = 10^9$ seconds to finish the computations. 10^9 seconds are nearly 32 years what leads us to the conclusion that such a simulation would be useless because the time needed to obtain any result exceeds the time covered by the simulation. (Even if we could pause the computations each time the hardware would be improved and replace the processors but that is impossible.)

If 10^{11} bytes are to be transferred to mass storage in ten days (that is 864000 seconds), we would need a transfer rate of

$$\frac{10^{11}}{864 \cdot 10^3} = \frac{10^8}{864} = 115.\overline{740} \cdot 10^3$$

bytes per second (roughly 115 KB per second). If we wanted to search the data in 10 minutes, that is, in 600 seconds, we would need a transfer rate of

$$\frac{10^{11}}{6 \cdot 10^2} = \frac{10^9}{6} = 1.\overline{6} \cdot 10^8$$

bytes per second (roughly 160 MB per second).