High Performance Computing (2019/2020), Exercise 01

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Monday 28th October, 2019

1 Task

(a) The CDC 6600 was able to perform three megaFLOPS ($3 * 10^6$ floating point operations) per second and therefore was the worlds fastest computer from 1964 to 1969.

Source:
Wikipedia: CDC 6600

(b) The currently fastest supercomputer known to public is the Summit (or OLCF-4). Its fastest measured performance using the 'LINPACK Benchmarks suite' was 148.6 petaFLOPs (10^15 FLOPs). Its theoretical maximum peak performance is 200.795 petaFLOPs.

Source: Numbers taken from:
Wikipeia, Summit Wikipedia, TOP500

(c) The 'LINPACK Benchmarks' tool was used to determine the peak performance of the Summit supercomputer. The tool measures a systems floating point computing power by measureing how fast the system measures a 'dense n by n system of linear equations'.

Source:
Wikipedia, TOP500 LINPACK Benchmarks

(d) The fastest german supercomputer (the SuperMUC) has reacently fallen on place number 8 on the TOP500 list.

Source: Wikipedia, TOP500

(e) Other possible rankings depend on the criteria that are looked at. For measuring pure performance FLOPs are a very good system. Possible other rankings could involve power usage per FLOPs. Since supercomputers tend to drain a lot of power a ranking like this could promote more efficient architecture desing.

2 Task

(a) The peak performance of a system is categorized by the total usage of all availabe ressources the system has to offer. At this point the systems only limitation are of physical limitations
(example: time information needs to "travel" between different compartments of the system)

(b) Operations per clock cycle (OPC)
Operations per second (OPS)
Parallel processors (PP)
FLoating point operations (FPO)
processor clock time (PCT)
Number of x (#x)

$$\begin{aligned} OPC &= \#PP * \#ALU(perPP) * \#FPO(perALU) \\ &= 512 * 8 * 3 \\ &= 12288 \end{aligned}$$

$\rightarrow$ 12288 Operations per clock cycle

$$\begin{aligned} OPS &= \#OPC * PCT \\ &= 12288 * 10^9 * \frac{1}{s} \\ &= 12.288 * 10^{12} \end{aligned}$$

$\rightarrow 12.288 * 10^{12}$ operations per second

(c) It is almost impossible to archieve peak performace on any system. Reasons include the lack of perfect parallelization, dependencies between different operations (operation B needs to wait on operation A to finish, etc), waiting times between calculations (a processor needs to wait for information that is needed to continue a process; expl. cash fault) and many more.

3 Task

(a) 14.2 ms are linear
$\rightarrow$ 57.6ms can be parellized
$\frac{57.6}{32} = 1.8ms$ (since 32 processors are used)
$\rightarrow 14.2ms + 1.8ms = 16ms$ are needed to solve the problem

$\frac{72ms}{16ms} = 4$
$\rightarrow$ Speedup is 4

(b)

$$\begin{aligned}
32 &= 72 * x + 0.25 * 72 * (1 - x) \\
32 &= 72 * (x + 0.25 * (1 - x)) \\
32 &= 72 * (x + 0.25 - 0.25x) \\
32 &= 72 * (0.75x + 0.25) \\
32 &= 48x + 16 \\
16 &= 48x \\
x &= \frac{1}{3}
\end{aligned}$$

1/3 der Gesamtzeit (24ms) wird zum initialisieren benoetigt

(c) maximum speedup with infinite amouts of processors (S_{max})
(infinite perfectly parallel working processors reduce the parallel runntime to effectively zero)

$$\begin{aligned}
S_{max} &= \frac{\text{normal runtime}}{(\text{initialization time} + \text{paralellized time})} \\
&= \frac{72}{(24 + lim_{x \to 0} x)} = \frac{72}{(24 + 0)} = 3
\end{aligned}$$

if an infinite number of processors run perfecly parallel then only the initialization time remains. Therefore the minimal runtime of the program is 24 ms

(d)

$$\begin{aligned}
x &= 72 * \frac{1}{6} + \frac{1}{32} * 72 * \frac{5}{6} \\
&= 72 * (\frac{1}{6} + \frac{5}{192}) \\
&= 72 * (\frac{32}{192} + \frac{5}{192}) \\
&= 72 * (\frac{37}{192}) \\
&= \frac{2664}{192} \\
&= 13.875
\end{aligned}$$

$\rightarrow$ With the new algorithm the program fnishes in less then 14 ms and the company is saved!