# Exercise 1

## 1.1 Reading

## 1.2 Moore's Law

### 1.2.1

Apply Moore's Law to currently fastest Supercomputer to extrapolate time until exa scale performance is achieved.

1. Consider derived law stating that computing power doubles every 18 months:

$$P_{\text{compute}}(t) = N_0 2^{\frac{1}{18}t} \tag{1}$$

   where $N_0$ is the computing power at time 0 and $t$ the time in months.

2. Set $P_{\text{compute}}$ to $1 \times 10^{18}$ flop/s.
3. Set $N_0$ to current max performance of $415\,530 \times 10^{12}$ flop/s (*Supercomputer Fugaku*)[1].
4. Solving for $t$ yields a time of $\approx 23$ months (see figure 1).

⇒ extrapolating from current performance using a derived Moore's law Exa scale computing power will be achieved in approximately 23 months or almost two years.

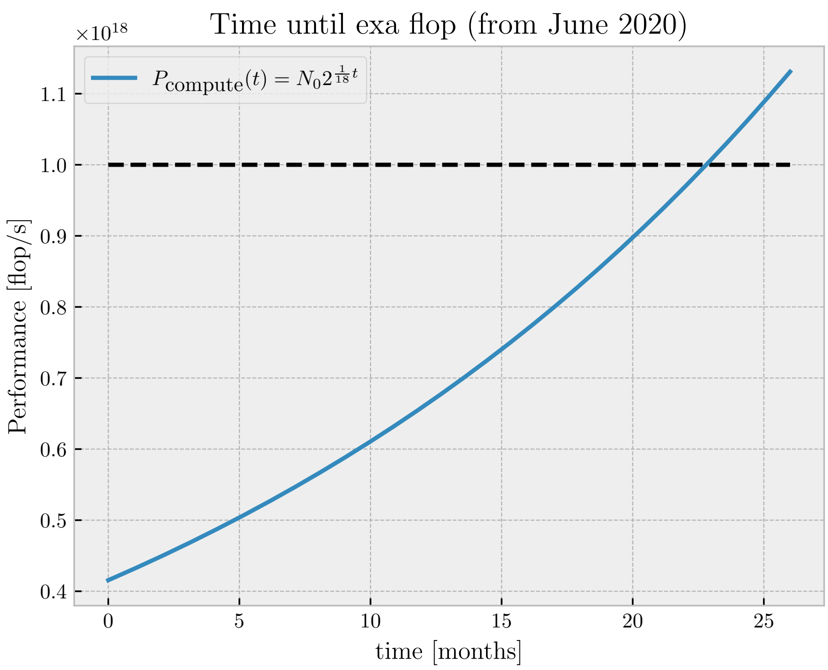


Figure 1: Extrapolating time until exaflop from derived Moore's law

[1] https://top500.org/lists/top500/2020/06/

### 1.2.2

Determine time until exa scale from growth rate from TOP500 list

1. Use data from 2007 and 2011
2. Linear fit (on log scale) yields that exaflop performance should have been reached around 2018 (see figure 2)

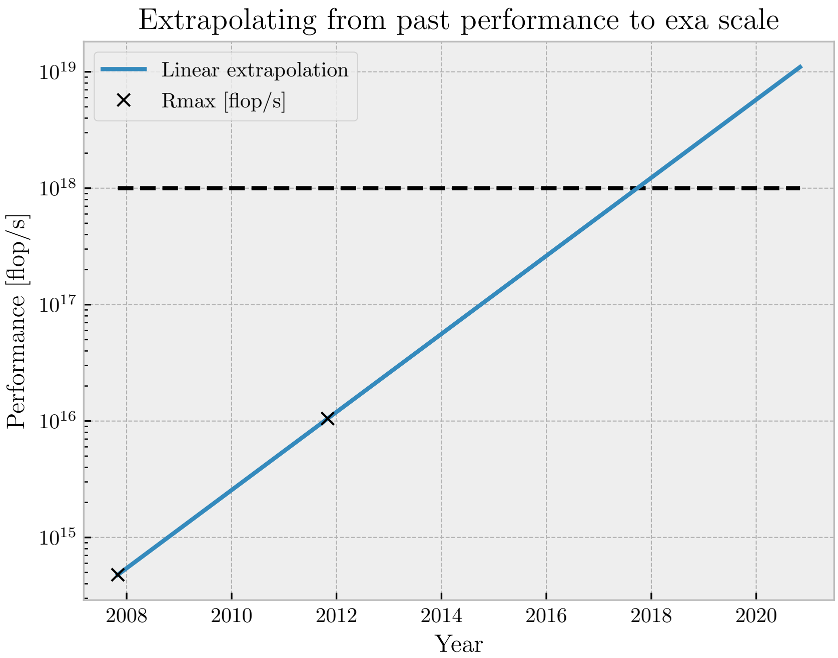


Figure 2: Extrapolating time until exaflop from TOP500 data using linear fit

⇒ Extrapolating from past performance exaflop performance should have been achieved around 2018, which is evidently not the case. Note however that extrapolation from two data points is not very robust.

## 1.3 Amdahl's Law

### 1.3.1

- new CPU 10 times faster
- old CPU spent 40% of execution time on calculations
- remaining time was for IO

$$S := 60\% \tag{2}$$
$$P := 40\% \tag{3}$$
$$N := 10 \tag{4}$$

$$Speedup = \frac{1}{.6 + \frac{.4}{10}} = 1.563 \tag{5}$$

⇒ We would expect a 56% performance improvement from the new CPU.

### 1.3.2

- 20% of compute time is used for squaere roots
- possibilities:
  - improve floating point square root calculations by factor of 10
  - improve all fp operations by 1.6
- 50% of operation is spent on FP

$$S_1 = \frac{1}{(1 - (0.5 \cdot 0.2)) + \frac{0.5 \cdot 0.2}{10}} \tag{6}$$
$$= 1.099 \tag{7}$$

$$S_2 = \frac{1}{(1 - 0.5) + \frac{0.5}{1.6}} \tag{8}$$
$$= 1.231 \tag{9}$$

⇒ By accelerating all FP operations by a facctor of 1.6 a speedup of 23% can be observed and therefore is the optimal solution (in contrast to only 9.9% when only speeding up FPSQRT).

### 1.3.3

$$100 = \frac{1}{(1 - P) + \frac{P}{128}} \tag{10}$$
$$\Leftrightarrow P = 0.9978 \tag{11}$$
$$\Rightarrow S \leq 0.22\% \tag{12}$$