(L) Latency (T_c completion times)

Service time (T_S)

$Sp(n)$ $Sc(n)$

Speedup

$n \rightarrow$ par. degree

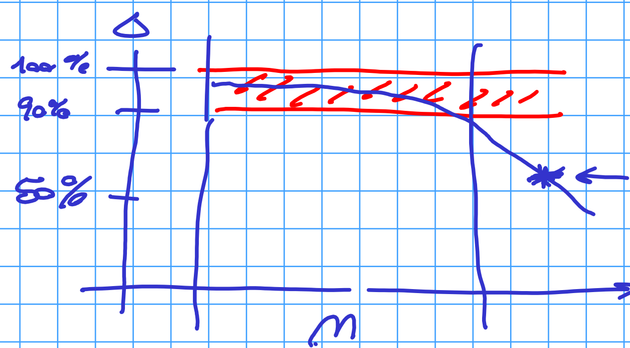
$m \rightarrow$ # tasks

Efficiency $\mathcal{E}(n) = \frac{T_{id}(n)}{T_{par}(n)}$

$$T_{id}(n) = \frac{T_{seq}}{n}$$

$$\mathcal{E}(n) = \frac{T_{seq}/n}{T(n)} = \frac{T_{seq}}{n \cdot T(n)} =$$

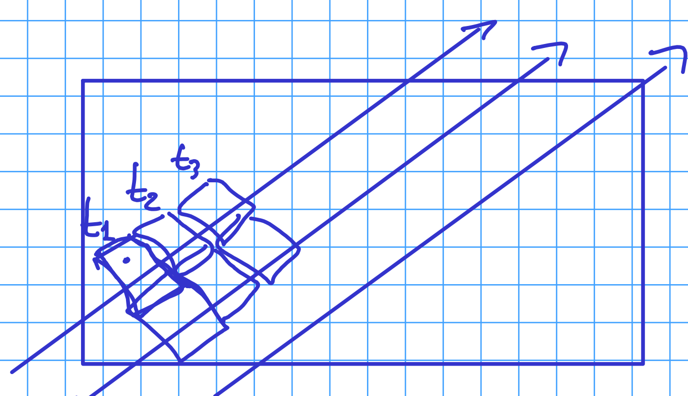
$$\mathcal{E}(n) = \frac{Sp(n)}{n}$$

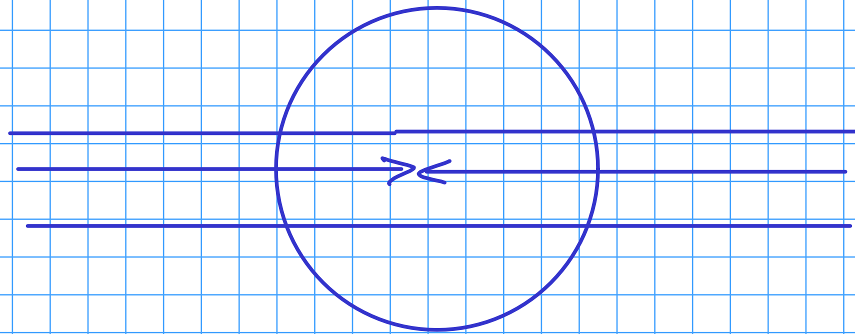


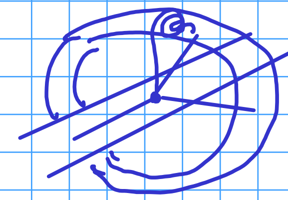
good range for $\mathcal{E}$

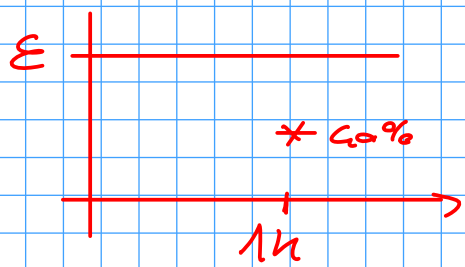
$\forall$ "photo" x

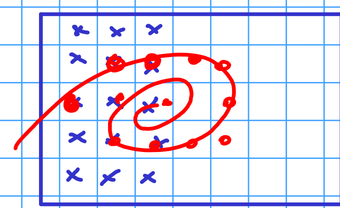
$$\underbrace{F(x)}_{t < (t_i - t_{i-1})}$$

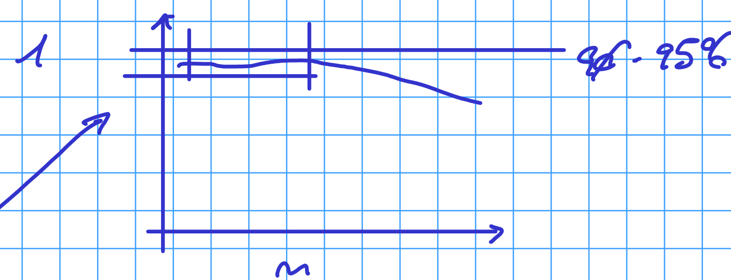




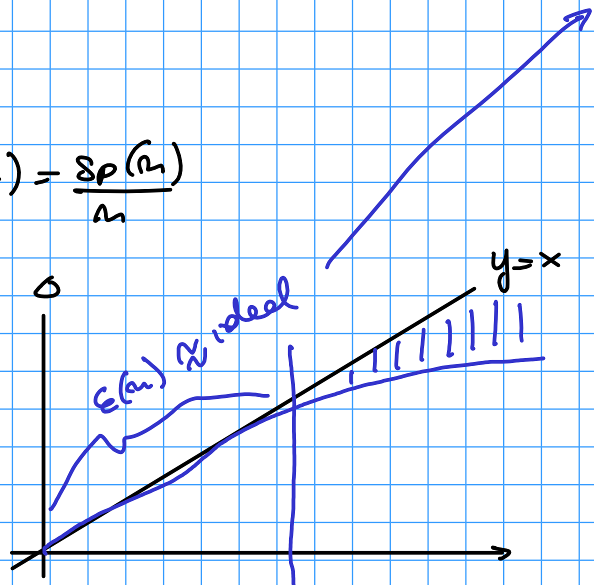








$$\mathcal{E}(n) = \frac{Sp(n)}{n}$$

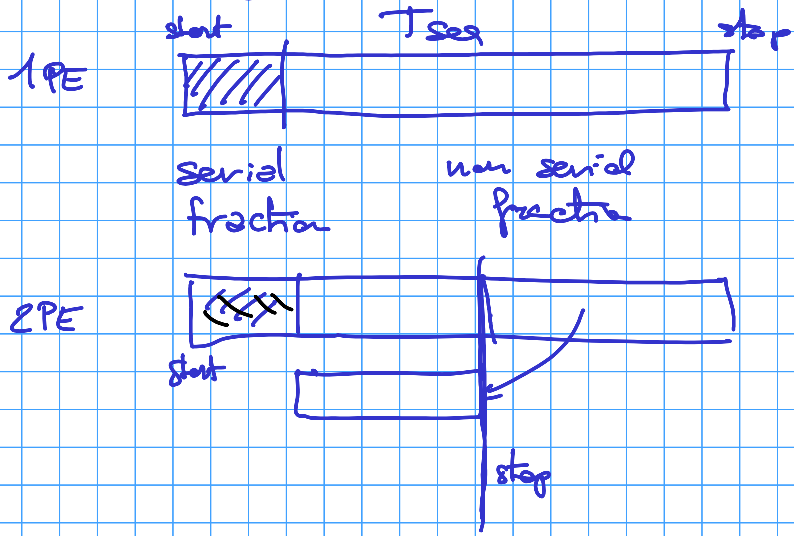


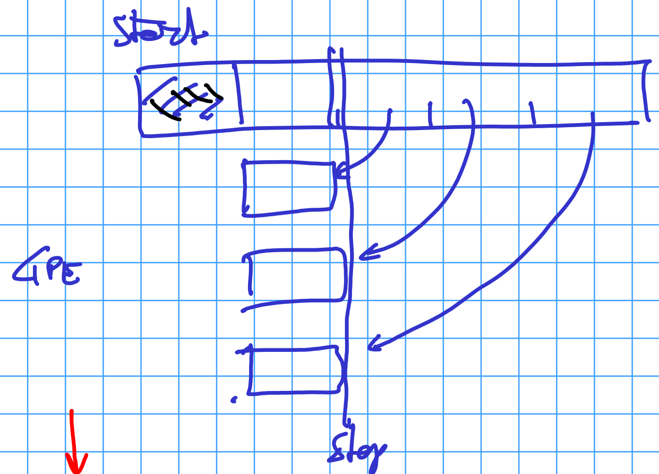
$$Sp(n) = \frac{T_{seq}}{T(n)}$$

$\binom{k}{p}$ FLOPS

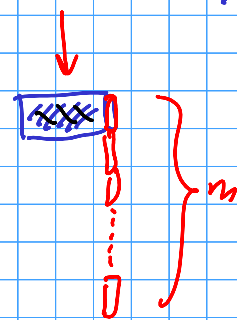
FLOPS/WATT

AMDAHL '60





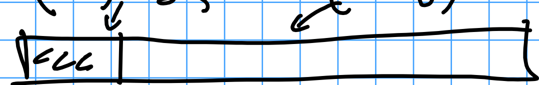
$n \to \infty$



f serial fraction
% of T_{seq}
$\in [0, 1]$

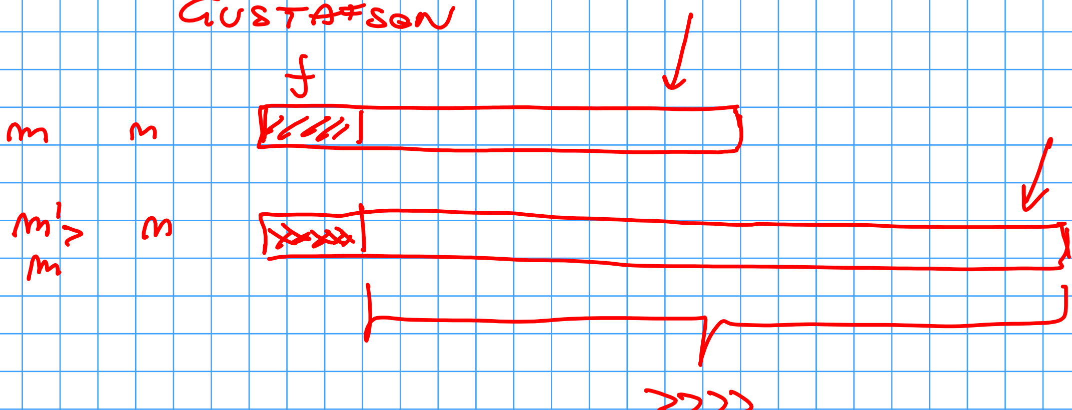
$$sp(n) = \frac{T_{seq}}{f\,T_{seq} + \frac{(1-f)T_{seq}}{n}}$$

$$T_{seq} = (f)\,T_{seq} + (1-f)\,T_{seq}$$



$$\lim_{n \to \infty} sp(n) = \frac{\cancel{T_{seq}}}{f\,\cancel{T_{seq}}} = \frac{1}{f}$$

GUSTAFSON



APPL → code, problem

$\xrightarrow[\text{BASIC CONCEPTS}]{\text{tools}}$

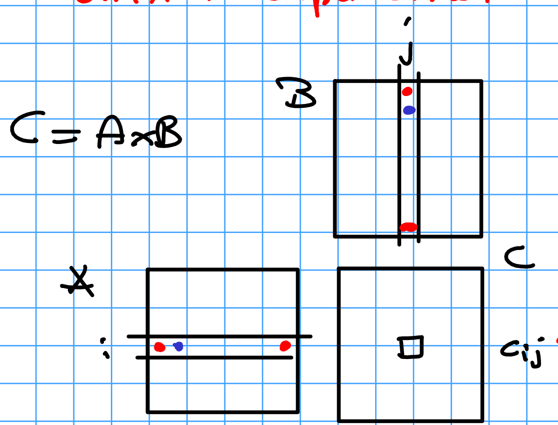
PAR/DISTR APPL → code, par probl

find what we can (usefully) do in parallel/distributed to "improve" → implementation
- concurrent activities { threads, processes
- communication
- synchronization

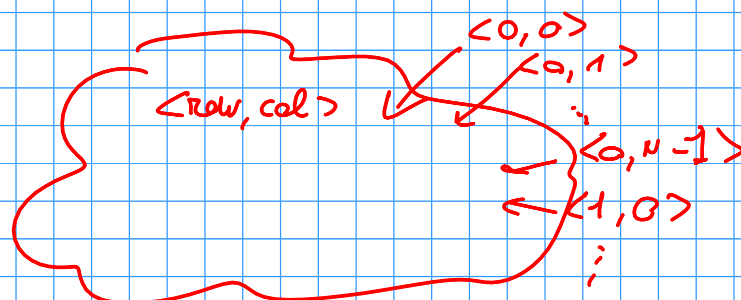
Can I do $c_{ij} = \Sigma \dots$ relatively to $\langle i, j \rangle$ and $\langle i', j' \rangle$ $i' \neq i$ $j' \neq j$ concurrently?

Matrix Multiplication

$C = A \times B$



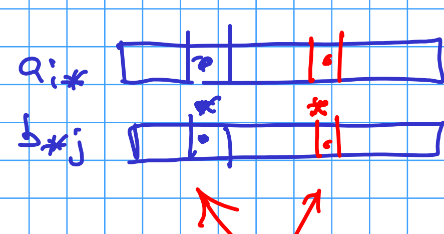
$\cdot \times \cdot + \cdot \times \cdot + \dots \cdot \times \cdot$



$$c_{ij} = \sum_{k=0}^{N-1} a_{ik} \cdot b_{kj}$$

Computation of each c_{ij} may be done concurrently (write $c_{i'j'}$)

$$c_{ij} = \sum_{k} a_{ik} \cdot b_{kj}$$



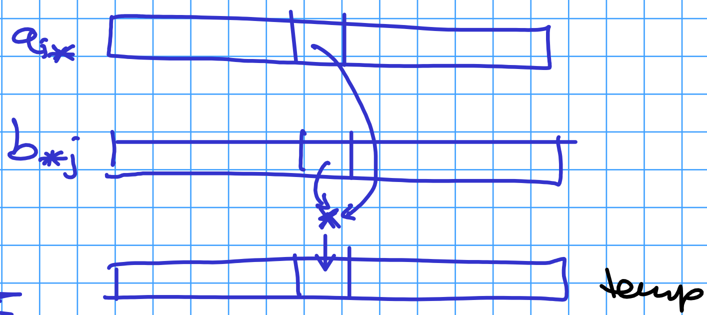
may be concurrent?

act_i $\quad R(act_i) = \{\text{data read by } i\}$

act_j $\quad W(act_i) = \{\text{data written by } i\}$

YES!

$$\left.\begin{array}{l} R(act_i) \cap W(act_j) = \emptyset \\ W(act_i) \cap R(act_j) = \emptyset \\ W(act_i) \cap W(act_j) = \emptyset \end{array}\right\} \Rightarrow \text{conc. activities}$$

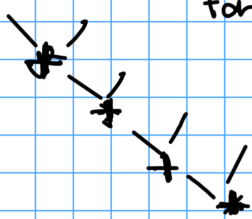


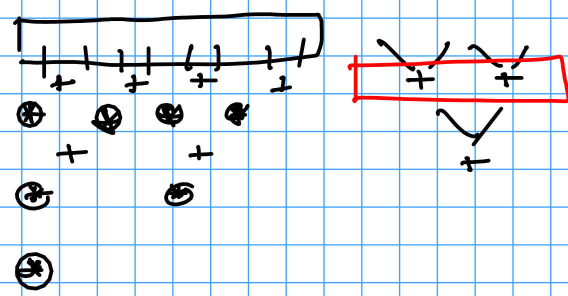
$+$: $(a+b)+c = a+(b+c)$

$(a+b) = (b+c)$

Σ

```
sum = 0;
for(i=0 ; i<N ; i++)
    sum = sum + temp[i];
```





Solve linear system

$$\begin{cases} a_{00}x_0 + a_{01}x_1 \cdots + a_{0n-1}x_{n-1} = b_0 \\ a_{10}x_0 + \qquad + \qquad = b_1 \\ \vdots \\ a_{n-10}x_0 + \qquad \cdots \qquad = b_{n-1} \end{cases}$$

$$\boxed{\begin{matrix} a_{00} & \cdots & a_{0n-1} & b_0 \\ \vdots & & & \\ a_{n-10} & \cdots & a_{n-1n-1} & b_{n-1} \end{matrix}}$$

$a_{00} \quad \cdots \quad b_0$

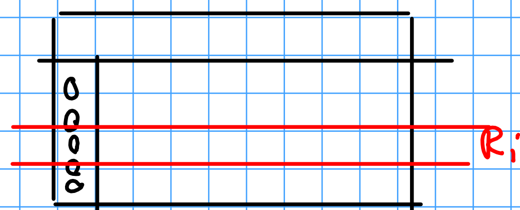
a_{01}

R_0

$R_1 = R_1 - \left(\frac{a_{01}}{a_{00}}\right) R_0$

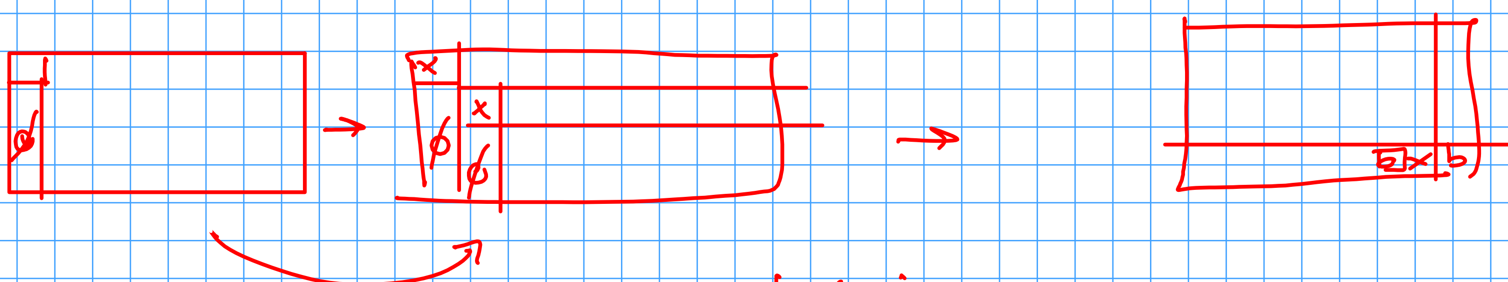
$a_{00} \quad \cdots \quad b_0$

$\emptyset \quad a'_{11} \quad \cdots \quad b'_1$



$R = \{R_0, R_i\}$

$W = \{R_i\}$



$i \neq j$

$R_i = \{R_0, R_i\}$ $\quad$ $\{R_0, R_j\}$

$W_j = \{R_j\}$ $\quad$ $\{R_j\}$

$R_i \cap W_j$

$W_i \cap R_j$

$W_i \cap W_j$