Parallel Algorithms & Programming

theory app

ENGLISH!!!

① lab 20% 50~100 coding

② assignment 30% 100~200 coding

③ midterm 20% take-home 24H

④ final 30%

Why parallel?

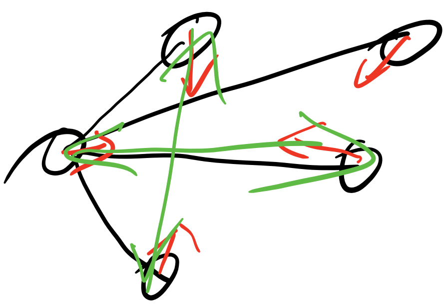
① molecule dynamics simulation

↳ atom coords at t.

↳ calculate force field

↳ more atoms

↳ atom coords at t+1



pairwise cal

indep

protein - drug interaction

↳ no experiments

↳ only MD sim

↳ how?

step → femtosecond 10^{-15} s

length → microsecond 10^{-6} s

\# steps 10^9 steps

calculate force field

↳ n atoms 10^5

↳ n^2 pairs to calculate 10^{10}

slow!!! speed up?

parallel!!!

server 100 cores

100 server 10000 cores

GPU 10000 cores

speed up by parallel

② social network

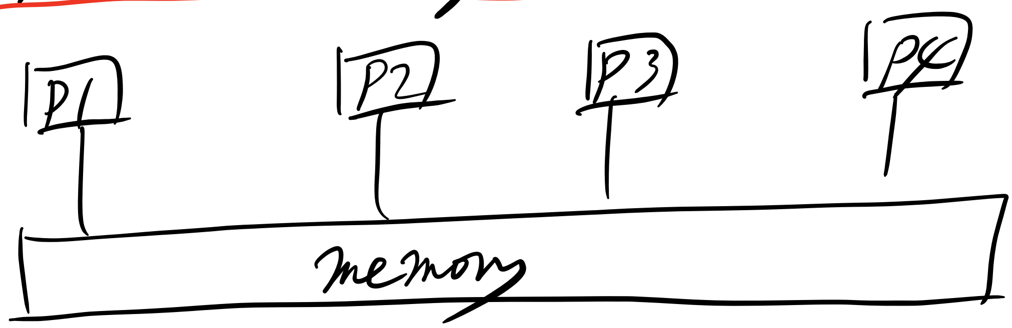
③ weather forecast

④ deep learning / matrix op.

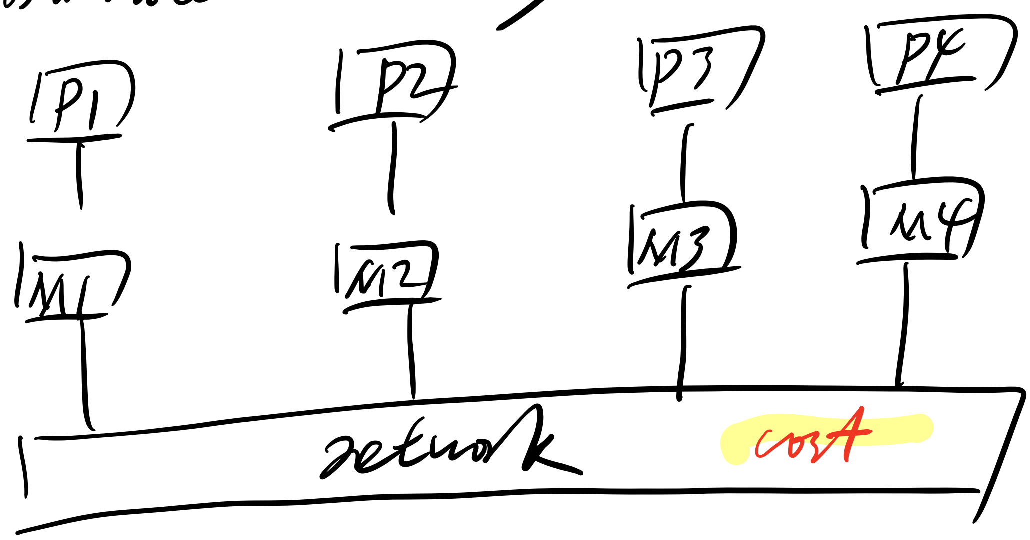
let's parallel

Parallel Model before midterm

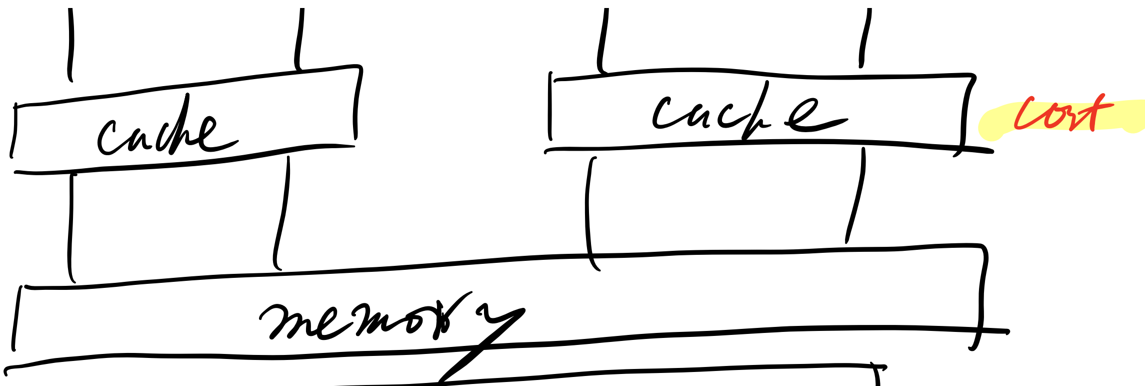
① shared memory server



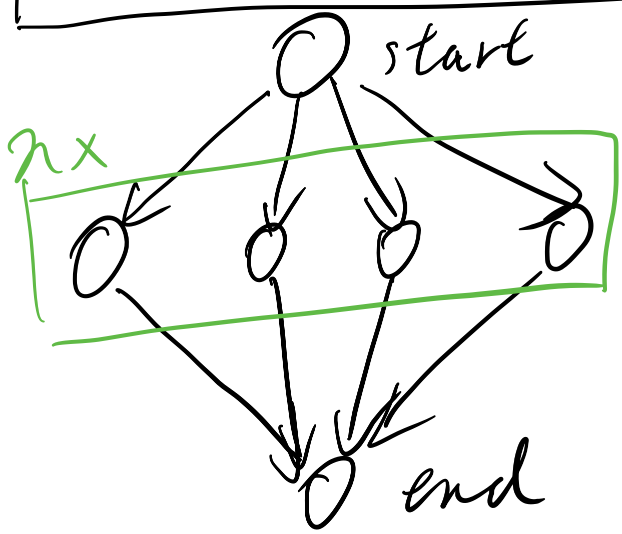
② distributed memory cluster



③ tow-level memory GPU



Directed Acyclic Graph (DAG)



Asumptions:

① same speed for cores

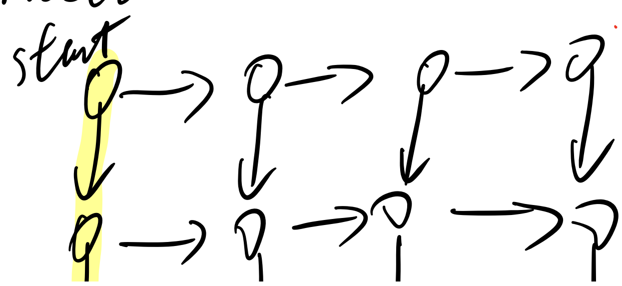
② same time for ops

③ no time for deps.

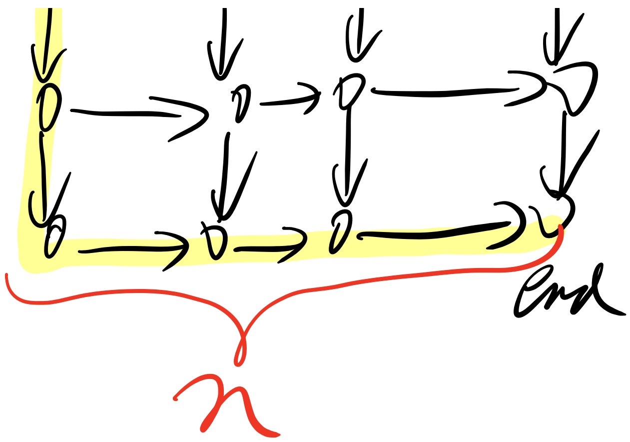
complexity:

- work $T_1 \to$ # vertices $\quad n+2$
- span $T_\infty \to$ longest path $\quad 3$
  critical path.

practice 1:

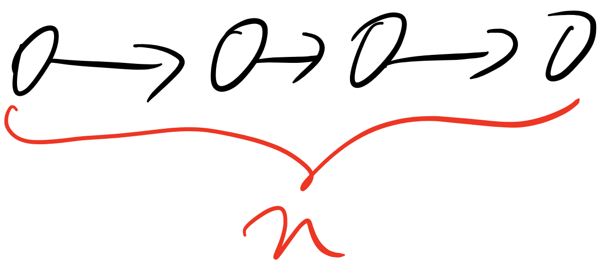


$T_1 = n^2$



$T_\infty = 2n-1$

practice 2



$T_1 = n$

$T_\infty = n$

parallel is not for all algs!!!

example 1: map $n \to n$

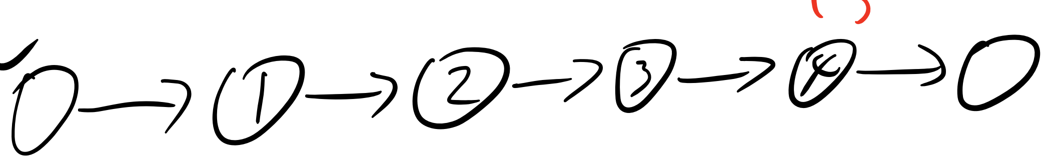
square

input $1 \quad 2 \quad 3 \quad 4$

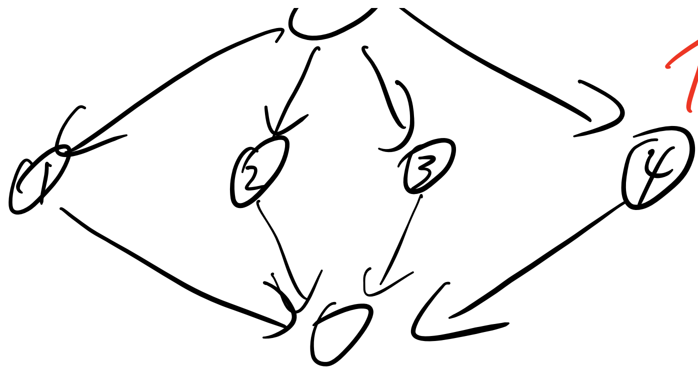
output $1^2 \quad 2^2 \quad 3^2 \quad 4^2$

$T_s = O(n)$

serial



prallel



$T_\infty = O(1)$

example 2: reduce $n \to 1$

sum input 1 2 3 4

output 10

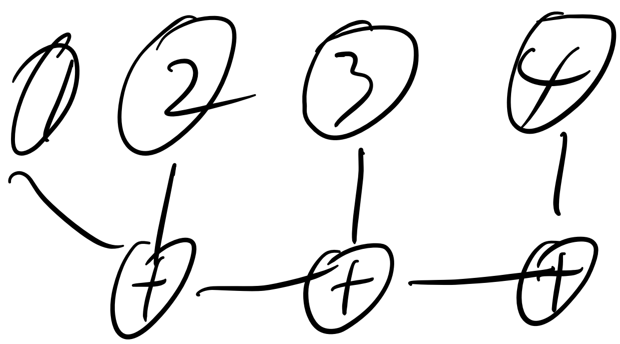
→ associative

$(A+B)+C = A+(B+C)$

int ? OK

float ? relax

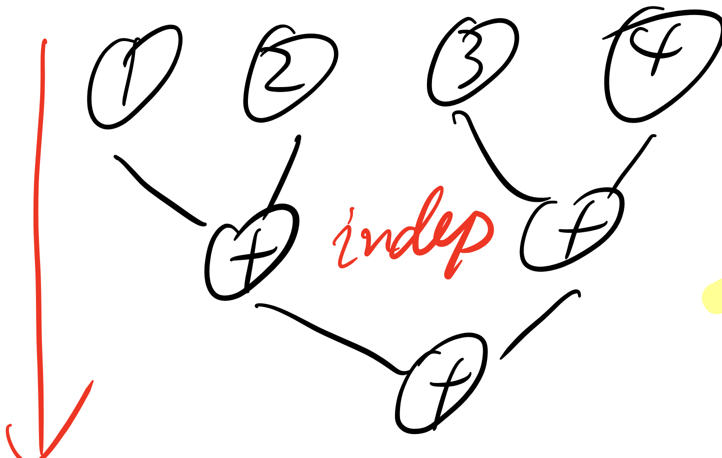
serial



$T_s = n$

parallel

level



$T_1 = n$

$T_\infty = \log n$

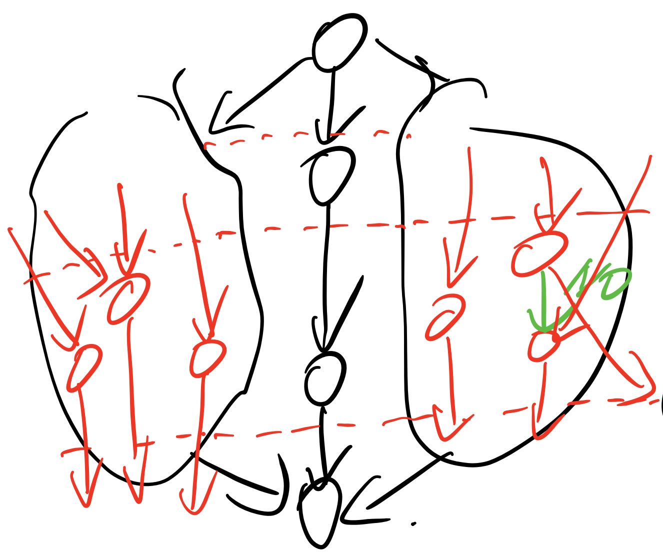
T_1 & T_∞, what about T_p?

① span law $T_p \geq T_\infty$

② work law $T_p \geq \lceil T_1 / p \rceil$

③ Brent's Theorem

DAG → phases.



① one critical vertex per phase

② non-critical vertices are indep.

③ every vertex in one phase

$\sum W_k = W$

phase k analysis

$$t_k = \left\lceil \frac{W_k}{p} \right\rceil \leq \frac{W_k - 1}{p} + 1$$

$$T_p = \sum_{i=1}^{k} T_k = \sum_{k=1}^{k} \left\lceil \frac{W_k}{p} \right\rceil$$

$$\leq \sum^{k} \frac{W_k - 1}{\ } + 1$$

$$\le \sum_{k=1} \frac{W_k - 1}{p} + 1$$

$$\le \frac{\sum W_k - k}{p} + k$$

$$\le \frac{W - k}{p} + k$$

$$\le \frac{T_1 - T_\infty}{p} + T_\infty$$

$$\underset{T_1/p}{\overset{T_\infty}{MAX}} \le T_p \le \frac{T_1 - T_\infty}{p} + T_\infty$$

$\boxed{\text{ideal goal of parallel alg.}}$

① speed-up. $S = T_s^* / T_p = \Theta(p)$

② work optimality $T_s^* = T_1$

③ weak scalibility $\frac{T_1}{p} = \Omega(T_\infty)$

$T_\infty = O(\log^k n)$

practice

PAlg 1 v.s. PAlg 2

$T_1 = n^2 \log n$ $T_1 = n^2$

$T_\infty = \log n$ $T_\infty = n$

open, it depends.