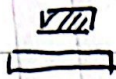


inclusive =  $\frac{1}{2}$  cache  
exclusive



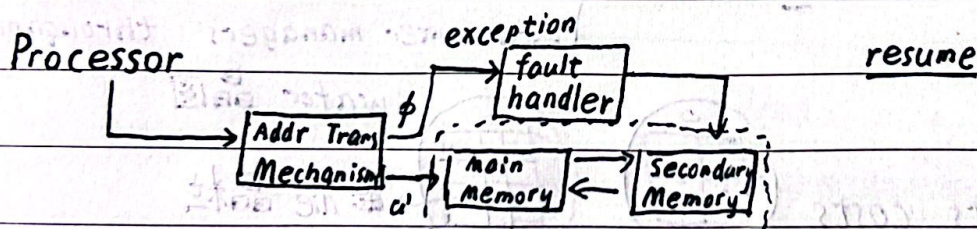
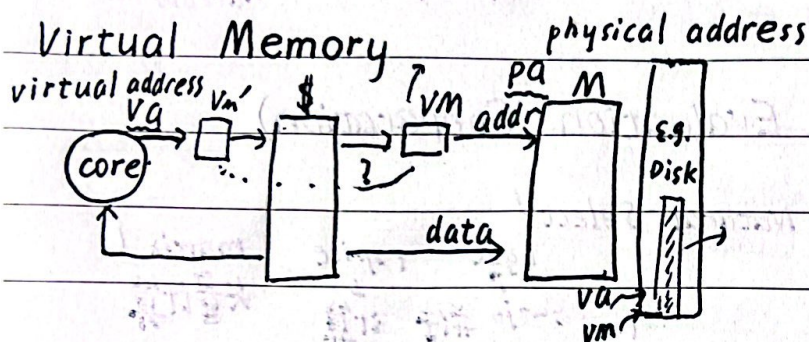
## Major Categories of Cache Misses

Compulsory Misses

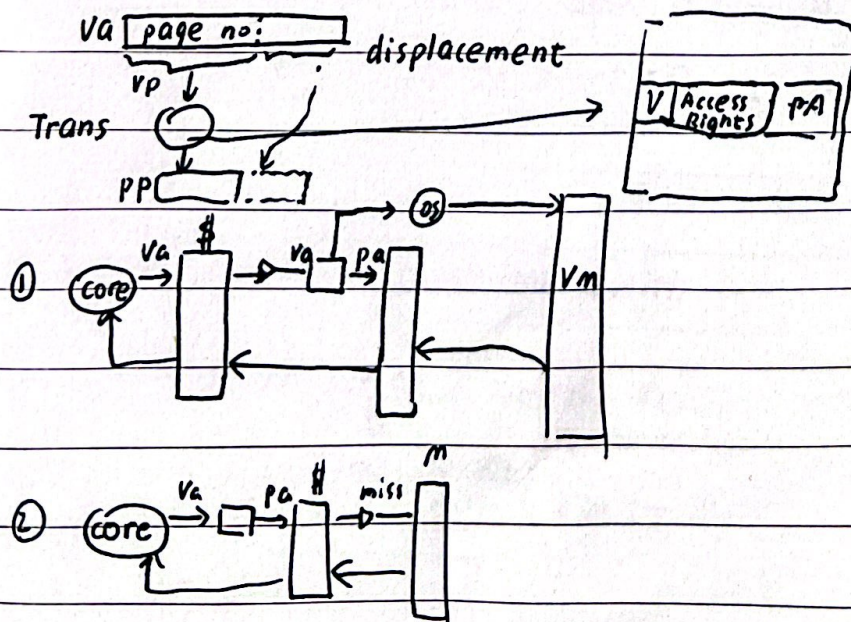
Amdahl vs Brooks

Capacity Misses increase cache size

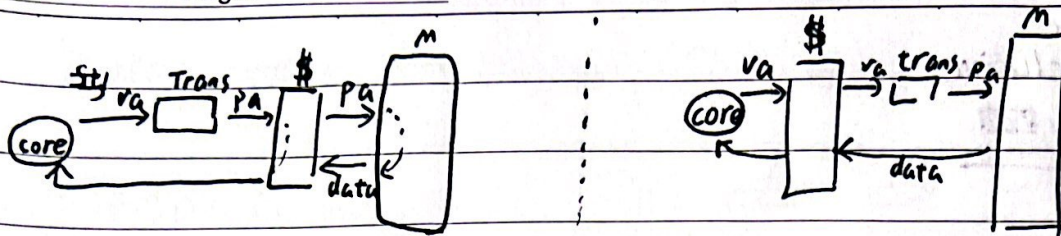
Conflict Misses increase cache size/associative



## address mapping







core slow 100 cycle + 1 cycle  
page table in M

pros Fast

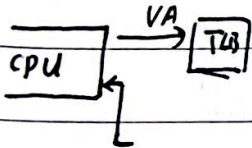
solution: TLB solution

partes PTE, in TLB

other solution  
CR3

full association wide

TLB's entry



PTE narrow

## SPEC (System Performance Evaluation Cooperation)

Whetstone (float) Synth → Natural Select

Dhrystone (int)

gcc rspice matrix  
94-96 并行 计算 向量计算

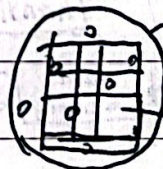
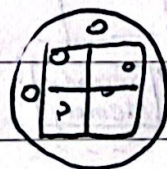
$$performance_x = \frac{1}{Execution\ time_x}$$

如何评估 performance  $\sum w_i p_i$  mean

good-product

pc user response time  
data center managers throughput

Integrated Circuits costs.



wafer 晶圆

die 晶粒

微型机

工作站/s

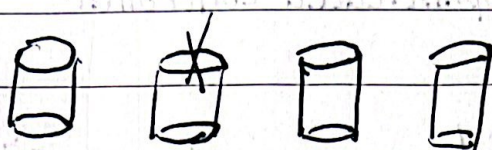
PC



RAID (Redundant Arrays of (Inexpensive) Disks) { dependability  
performance

RAID 1 ~~mirror~~ Disk Mirroring / Shadowing | 热备份

RAID 3: Parity Disk



disk array

throughput ↑  
latency ↔

Striping: spreading data over multiple disks  
num devices ↑ reliability ↓

How to improve dependability?

↳ add redundant disks → tolerate faults

a disk fail → reconstruct (V)  
↑  
redundant information  
(disk) fail

only danger: mean time to ~~fail~~ repair (MTTR) hours  
mean time to fail (MTTF) years

the ability to recover

RAID { higher throughput

Pros

~~Cons~~

Cons

RAID 0 a bunch of disks

No space overhead  
no parity calculation

No protection

RAID 1 mirroring/shadowing

storage overhead

RAID 3 higher-level disk interfaces understand the health of a disk

$N$  data block  $\wedge$  one parity block  $= 0$

figure out which disk fail

Probs

Low check overhead; high bandwidth

Cons:

small, random reads/writes

RAID 4 small write need read every disks to calculate parity

two disks { write @ disk; what bits changed  
parity disk



RAID 5 RAID 4 read/write the same check disk.

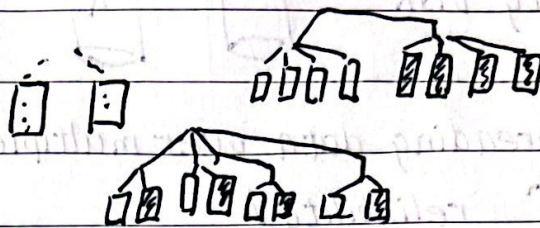
↓ distribute the parity information across all disks.

the most sophisticated controller

RAID 10 vs RAID 01

先 mirror 再 strip

先 strip 再 mirror



RAID 6 Beyond a Single Disk Failure (RAID-PP)

| Data  | disk 0  | disk 1  | disk 2  | disk 3  | Row parity  | Diagonal parity  |
|---|---|---|---|---|---|--|
| <div style="border: 1px solid black; padding: 2px;">0</div> | <div style="border: 1px solid black; padding: 2px;">0</div> | <div style="border: 1px solid black; padding: 2px;">1</div> | <div style="border: 1px solid black; padding: 2px;">2</div> | <div style="border: 1px solid black; padding: 2px;">3</div> | <div style="border: 1px solid black; padding: 2px;">4</div> | <div style="border: 1px solid black; padding: 2px;">10</div> |
| <div style="border: 1px solid black; padding: 2px;">1</div> | <div style="border: 1px solid black; padding: 2px;">1</div> | <div style="border: 1px solid black; padding: 2px;">2</div> | <div style="border: 1px solid black; padding: 2px;">3</div> | <div style="border: 1px solid black; padding: 2px;">4</div> | <div style="border: 1px solid black; padding: 2px;">0</div> | <div style="border: 1px solid black; padding: 2px;">11</div> |
| <div style="border: 1px solid black; padding: 2px;">2</div> | <div style="border: 1px solid black; padding: 2px;">2</div> | <div style="border: 1px solid black; padding: 2px;">3</div> | <div style="border: 1px solid black; padding: 2px;">4</div> | <div style="border: 1px solid black; padding: 2px;">0</div> | <div style="border: 1px solid black; padding: 2px;">1</div> | <div style="border: 1px solid black; padding: 2px;">2</div>  |
| <div style="border: 1px solid black; padding: 2px;">3</div> | <div style="border: 1px solid black; padding: 2px;">3</div> | <div style="border: 1px solid black; padding: 2px;">4</div> | <div style="border: 1px solid black; padding: 2px;">0</div> | <div style="border: 1px solid black; padding: 2px;">1</div> | <div style="border: 1px solid black; padding: 2px;">2</div> | <div style="border: 1px solid black; padding: 2px;">3</div>  |

先 Diagonal 再 Row