

CS162 – Section # 8, 03/18/2003

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Announcements

Initial design document for phase 2 due today.

Midterm will be handed back by the end of section.

Design reviews: go to class web page, “Online design review signup”

Times: Wednesday Morning, Wednesday Afternoon, Thursday Afternoon

Must be Wednesday or Thursday

Readings:

Silberchatz: Chapter 10, Virtual Memory

H. M. Levy and P. H. Lipman. [Virtual Memory Management in the VAX/VMS Operating Systems](#). *IEEE Computer*, 15(3), March 1982, pp. 35-41.

(can be found at http://inst.eecs.berkeley.edu/~cs162/hand-outs/vax_vms.pdf)

TLB, Caching, Demand Paging

TLB – Caching of Address Translations

Direct Mapped: each virtual page uses one slot

N-Way associative: each virtual page uses N-slots (N separate banks)

Fully Associative: can use any entry

Important issues: consistency, what to do in context switch

Hardware Caches – Caching of memory contents (different than translations)

Virtually Addressed – between CPU and TLB

Physically Addressed – between TLB and main memory

Demand Paging: use main memory as a cache for the disk

Only a portion of the Virtual Address space is kept in memory

Why do Caches work?

Temporal locality

Spatial locality

Cache (effective) access time:

$$P(\text{hit}) \times t_{\text{hit}} + P(\text{miss}) \times t_{\text{miss}}$$

Miss Types:

Compulsory

Capacity

Policy

Conflict

Page Replacement Policies

For the different caching situations, there is a common decision: which item to replace when there is no available slot?

Random

FIFO: replace the page that has been in memory the longest

LRU: replace the page that has been referenced farthest in the past

MIN: replace the page that will be referenced farthest in the future

CLOCK:

Approximation to LRU.

Algorithm:

1. keep used bit, set on each reference
2. on page fault,
 - a. advance clock hand
 - b. if (use bit = 1): set to 0, repeat else, replace page

Example:

What is the number of page faults for the following policies, with fully associative caches with 3 and 4 memory slots, for the reference string below?

	3	4	obs
FIFO	9	10	Notice Belady's anomaly!
LRU	10	8	
MIN	7	6	

Reference string
4,3,2,1,4,3,5,4,3,2,1,5

FIFO, 3

	4*	3*	2*	1*	4*	3*	5*	4	3	2*	1*	5
SI1	4			1			5					
SI2		3			4					2		
SI3			2			3					1	

FIFO, 4

	4*	3*	2*	1*	4	3	5*	4*	3*	2*	1*	5*
SI1	4						5				1	
SI2		3						4				5
SI3			2						3			
SI4				1						2		

LRU, 3

	4*	3*	2*	1*	4*	3*	5*	4	3	2*	1*	5*
SI1	4			1			5			2		
SI2		3			4			"			1	
SI3			2			3			"			5

LRU, 4

	4*	3*	2*	1*	4	3	5*	4	3	2*	1*	5*
SI1	4				"			"				5
SI2		3				"			"			
SI3			2				5				1	
SI4				1						2		

MIN, 3

	4*	3*	2*	1*	4	3	5*	4	3	2*	1*	5
SI1	4									2		
SI2		3									1	
SI3			2	1			5					

MIN, 4

	4*	3*	2*	1*	4	3	5*	4	3	2	1*	5
SI1	4											
SI2		3										
SI3			2								1	
SI4				1			5					

CLOCK -> actually, it was pretty fun. If you didn't go to section, you missed it, but we had five volunteers be the pages, and one be the clock hand. Three chairs were the memory locations, and the use bit was represented by the "pages" either sitting down or standing.