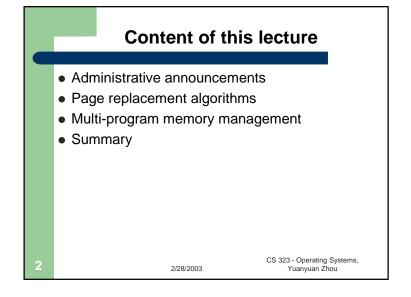
CS323 Operating Systems Memory Management V Yuanyuan Zhou Lecture 17 2/25/2003



Administrative • Quiz2 • MP2 CS 323 - Operating Systems, Yuanyuan Zhou

Midterm1 - Time: 3/10, 7-8pm - Content: 1,2,3, 4 except replacement algorithms - Room: • DCL 1320, first letter in last name: A-L • MSEB 100, first letter in last name: M-Z - Conflict exam

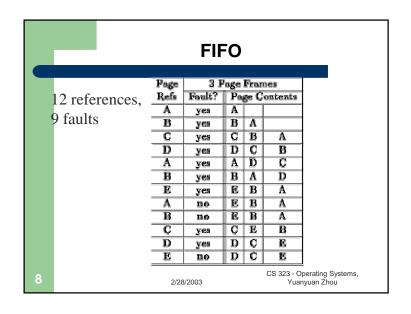
Review Inverted page table Multi-level page table Demand paging Page Replacement Optimal CS 323 - Operating Systems, Yuanyuan Zhou

	Opti	imal	Ex	an	nple	
12 references,	Page		age l			
•	Refs	Fault?	Pag	ge Ca	ontents	
7 faults	A	yes	A			
	В	yes	В	A		
	C	yes	Ç	В	A	
	D	yes	D	В	A	
	A	no	D	В	A	
	В	no	D	В	A	
	E	yes	E	В	A	
	A	no	E	В	A	
	В	no	E	В	A	
	C	yes	C	E	В	
	D	yes	D	C	E	
	E	no	D	C	E	
	2/28	8/2003				Dperating Systems, anyuan Zhou

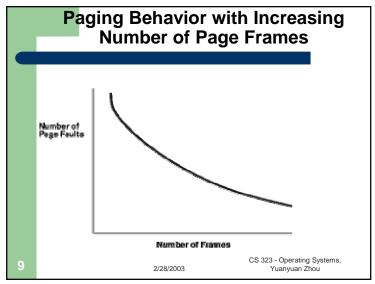
Principal of Optimality Description: Assume that each page can be labeled with the number of instructions that will be executed before that page is first references, i.e., we would know the future reference string for a program. Then the optimal page algorithm would choose the page with the highest label to be removed from the memory. This algorithm provides a basis for comparison with other schemes. Impractical because it needs future references If future references are known should not use demand paging should use pre paging to allow paging to be overlapped with computation.

CS 323 - Operating Systems,

Yuanyuan Zhou



2/28/2003



		Number of Frames							
		CS 323 - Opera 2/28/2003 Yuanyuai							
			L	RU)				
		Page	3 F						
1	2 references,	Refs	Fault?	Pa _i	ge C	ontents			
	0 faults	B	yes yes	B	A				
	o radits	С	yes	C	В	A			
		A	yes	A	Ç D	B C			
		В	yes	В	Ā	D			
		E	yes	E	В	A			
		A	no	A	E	В			
		B	yes	B	A	E A			
		D	yes	D	c	В			

E D

CS 323 - Operating Systems,

Yuanyuan Zhou

yes

2/28/2003

Belady's Anomaly (for FIFO) 4 Page Frames Refs Fault? Page Contents As the number A yes A of page frames В BA yes C C B A yes increase, so D C B A D yes does the fault D C B A A В D C B A rate. E D C B E yes A A E D C yes 12 references. В B A E D C CBAE 10 faults yes D C B A D E E D C B CS 323 - Operating Systems, 2/28/2003 Yuanyuan Zhou

Least Recently Used Issues

- Does not suffer from Belady's anomaly
- How to track "recency"?
 - use time
 - record time of reference with page table entry
 - use counter as clock
 - search for smallest time.
 - use stack
 - remove reference of page from stack (linked list)

CS 323 - Operating Systems,

Yuanyuan Zhou

- push it on top of stack
- both approaches require large processing overhead, more space, and hardware support.

2/28/2003

3

L		and A				ies		
Anomalies	Page Refs	4 F Fault?	enta					
	A	Yes	A	ÇE U	-cutter	211.64		
cannot	В	yes	В	A	\vdash			
occur,	C	yes	C	В	A			
why?	D	yes	D	C	В	Α		
Willy .	A	no	Α	D	C	В		
	В	по	В	Α	D	Ç		
12 references,	E	yes	E	В	A	D		
8 faults	A	no	Α	E	В	D		
o rauris	В	по	В	A	E	D		
	С	yes	C	В	A	E		
	D	yes	D	C	В	Α		
	E	yes	E	D	C	В		
3	2/	28/2003			CS		erating Sy yuan Zhou	

Why does Optimal give the best hit ratio? What is the worst algorithm?

NUR: A LRU Approximation

- NRU: Evict a page that is NOT recently used;
 LRU: evict a page that is LEAST recently used;
- NRU Implementation: simpler than LRU
 - additional reference bits
 - a register is kept per page
 - a one bit is set in the register if the page is referenced
 - the register is shifted by one after some time interval
 - 00110011 would be accessed more recently than 00010111
 - the page with register holding the lowest number is the least recently used.
 - the value may not be unique. use FIFO to resolve conflicts.

CS 323 - Operating Systems, 2/28/2003 Yuanyuan Zhou

Second Chance

- Only one reference bit in the page table entry.
 - 0 initially
 - 1 When a page is referenced
- pages are kept in FIFO order using a circular list.
- Choose "victim" to evict
 - Select head of FIFO
 - If page has reference bit set, reset bit and select next page in FIFO list.
 - keep processing until reach page with zero reference bit and page that one out.
- system v, r4 uses a variant of second chance

CS 323 - Operating Systems, 2/28/2003 Yuanyuan Zhou

	JOHA	Cha	110		λαπ	ipic
	Page	3 F	age I	rance	5	
	Refs	Fault?	Page Contents			
	A	yes	A.			
12 references,	В	yes	B.	A.		
9 faults	C	yes	C*	B.	A.	
9 Tauris	D	yes	D*	C	В	
	A	yes	A.	D.	Ç	
	В	yes	B*	A.	D,	
	E	yes	E*	В	A	
	A	DO	E*	В	A*	
	В	по	E*	B.	A.	
	C	yes	C.	Е	В	
	D	yes	D.	C.	E	
	E	no	D.	C.	E*	

