

CSc 360

Operating Systems

Page Replacement

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Review

- Virtual memory
 - on-demand paging
 - reference
 - if invalid, trap
 - page in
 - to a free frame
- No free frame?!

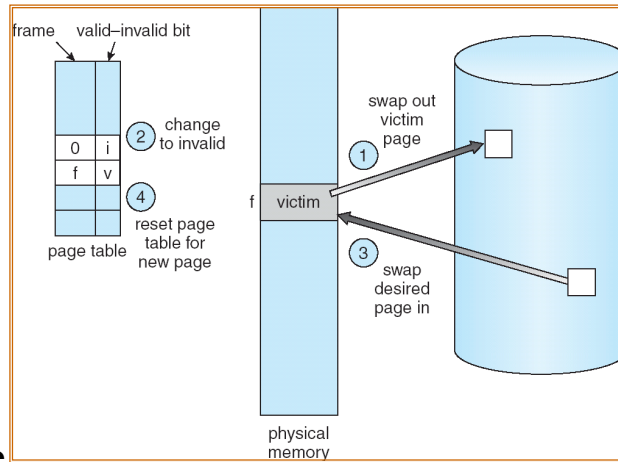
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Basic page replacement

- Page in
 - no free frame?
 - choose a victim
 - swap out
 - dirty bit
- Algorithms
 - allocation
 - replacement
- Reduce fault rate



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First-in-first-out (FIFO)

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

- 3 frames

1	1	4	5
2	2	1	3
3	3	2	4

9 page faults

- 4 frames

1	1	5	4
2	2	1	5
3	3	2	
4	4	3	

10 page faults

- Belady's Anomaly
 - more frames: more page faults!⁴

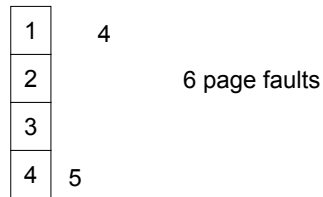
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Optimal algorithm

- Replace the page will not be used for the longest period of time
 - how do you know the future?!
 - if history is of any indication ...



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Least recently used (LRU)

- Replace the least recently used
- Counter implementation
 - copy timestamp
 - search to replace
- Stack implementation
 - move to top
 - replace the bottom

1	1	1	1	5
2	2	2	2	2
3	5	5	4	4
4	4	3	3	3

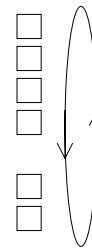
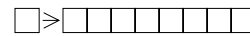
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LRU approximation algorithms

- Additional-reference-bits algorithm
 - set reference bit on reference
 - shift into a history byte on timer
 - least-recently-used one has lowest history byte
- Second-chance algorithm
 - if 0, replace
 - if 1, change to 0 and check the next page
 - circular queue



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Counting-based algorithms

- Counter
 - number of references
- Least frequently used (LFU)
 - replace the one with the smallest counter
 - aging necessary
- Most frequently used (MFU)
 - new page has small counter
 - and might be referenced soon

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This lecture

- Page replacement algorithms
 - FIFO
 - optimal
 - LRU
 - approximation
- Explore further
 - another reference string
7,0,1,2,0,3,0,4,2,3,0,3,2,1,2,0,1,7,0,1

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Next lecture

- More on page allocation and replacement
 - read OSC7Ch9

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