CS 350 Notes

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1 Paging

1.1 Page Replacement

Definition 1.1.1. Locality *is a property of the page reference string.*

Temporal *pages that are used will likely be used again.*

Spacial *pages "close" to those that have been used will probably be used.*

- A page that has been recently used will probably be used in the near future.
- Frequency-based page replacement
  - Look at the pages that are used the most, don't remove them and remove pages used less.
  - Not practical since the MMU would need to increment some counter, which it can't do.
  - Old references are never forgotten
  - New pages may be paged out soon after since the counts for old pages are higher
- Least Recently Used
  - Based on principle of temporal locality. Replace page that hasn't been used in a long time
  - TO implement, it is necessary to track each page's recency.
  - Although LRU and variants have many applications, it is not considered practical for virtual memory. (This is because the MMU still needs to keep track of what was used.) It is inefficient to keep track of LRU.
- The *use bit* or *reference bit* is a bit found in the TLB

  - It is set by the MMU each time the page is used
  - Can be read and modified by OS
  - OS copies information into page table
- What if the MMU doesn't have a use bit?
  - The kernel can emulate the bit at the cost of extra exceptions.
    1. When a page is loaded, mark it as invalid.
    2. If a program attempts to access the page, an exception will occur.
    3. In its exception handler, the OS sets the page's simulated use bit to true, and marks the page valid.
  - This technique requires that the OS maintain extra information for each page.
- Clock Replacement Algorithm
  - The clock algorithm is one of the simplest algorithms to exploit the use bit
  - Identical to FIFO except that a page is skpped if its use bit is set.
  - Can be visualized as a victim pointer that cycles through the page frames. The pointer moves whenever a replacement is necessary.
- Enchanced Second Chance Algorithm
  - prefer to unload pages that are not recently used and not modified.
  - If there are no such pages, look for not recently used but modified.
  - If there are no such pages, another run through the algorithm will find one because we reset the use bits as we're going through.

1.2 Page Cleaning

Definition 1.2.1. *Cleaning*

Cleaning a page means copying the page to secondary storage.

Synchronous happens at the time the page is replaced, during fault handling. Page is first cleaned by copying it to secondary storage then a new page is brought in to replace it.

Asynchronous happens before a page is replaced, so that page fault handling can be faster.

- Asynchronous cleaning may be implemented by dedicated OS page cleaning threads that sweep through in-memory pages cleaning modified pages.