Page Frame Reclaiming Algorithms

Swapping Algorithms

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Swapping (1)

- What happens if we run out of physical memory (RAM)?
- We need to move some pages from physical memory to disk
  - Swap space – space on disk reserved for moving pages back and forth.
- This is called swapping pages between physical memory and disk
- Allows the OS to support the illusion of a large virtual memory for multiple concurrently-running processes
- If physical memory is full, a page in physical memory needs to be evicted when we access a page that is on disk

Swapping (2)

- Accessing a page that is on disk is slower than accessing a page from physical memory
  - Disk is slower than physical memory
  - The swapping process takes time
- Page hit
  - The page we want to access is already in physical memory, no need for swapping
- Page miss
  - The page we want to access resides on disk, we need to swap it for another page in physical memory
- We want as many page hits as possible as this requires less work

How to Choose Which Page to Evict?

- We do not want to evict a page that will soon be used again
  - Then we would have to place it in memory soon again
- We want to evict a page that will not be used for long
- There are different policies to decide what page to evict

Random Policy

- Evict a random page
- Pros:
  - Simple!
- Cons:
  - Luck based - can lead to us evicting a page that will be used soon again in the future => wasted time

Optimal Policy

- Replaces the page that will be accessed furthest in the future
- Leads to the fewest number of misses overall
- Problem: We do not know which pages will be accessed in the future!
    - Therefore, this policy cannot be used on practice
    - But we can simulate it and use the result to compare other policies' performance

FIFO Policy

- Pages are placed in a queue when they enter the system
- When replacement occurs, the page at the tail of the queue is evicted
  - This is the page that first entered the system, the “first-in” page
- Pros:
  - Easy to implement
- Cons:
  - Bad hit-rate as it cannot determine the importance of blocks
  - Bad performance with looping-sequential workload

Least Recently Used (LRU)

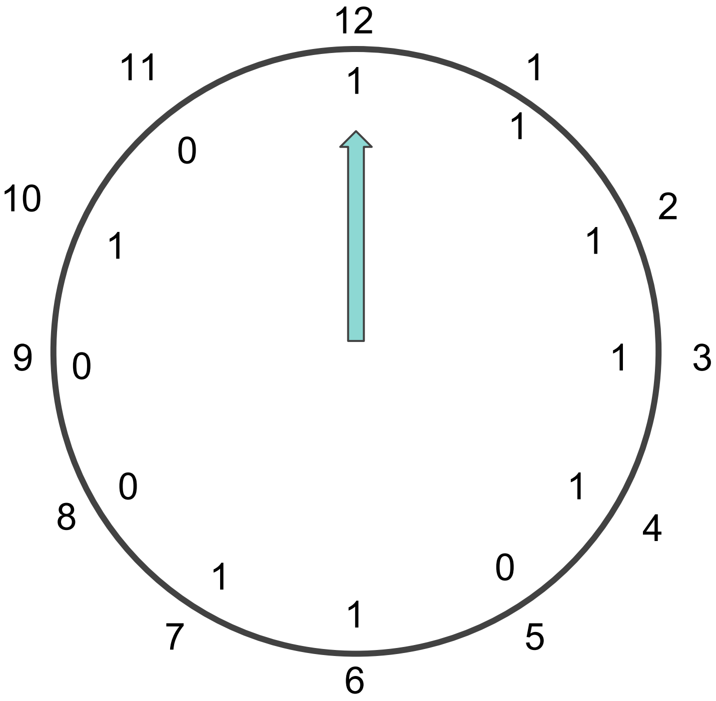
- Use history to predict the future
- If a program has accessed a page in the near past, it is likely to access it again in the near future
- LRU replaces the least recently used page
  - I.e. the page that hasn't been used for the longest time
- Pros:
  - Better hit-rate as it is likely to keep "hot pages" in memory
- Cons:
  - Complicated to implement
  - Computational performance heavy
  - Bad performance with looping-sequential workload

Clock Algorithm

- Approximation of LRU
- Arranges the pages in a circular structure
- Uses one bit to determine if the page has been accessed since the last iteration of the circle
- Kick out the first page that has not been accessed since last iteration
- Performs almost as well as LRU, but with better computational performance and less complicated implementation

Clock Algorithm

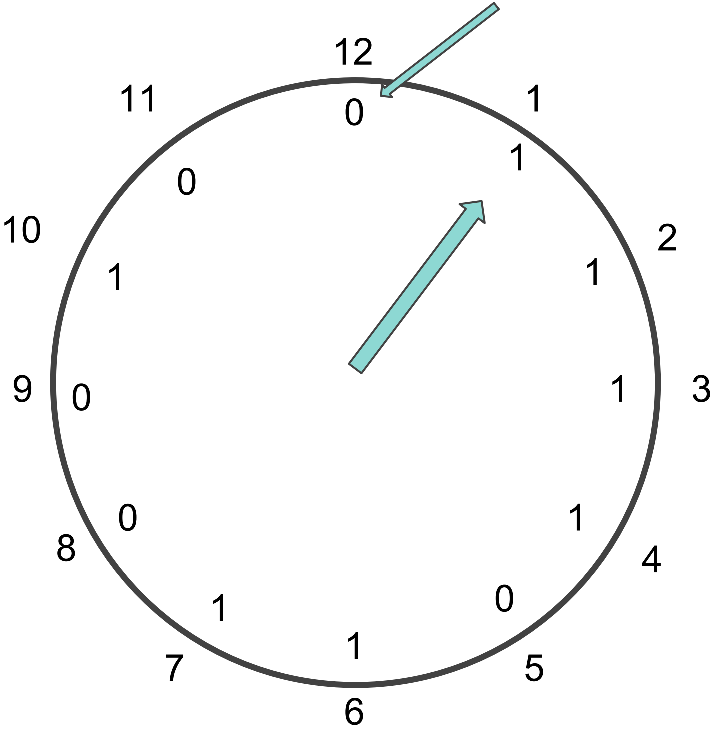
We need to swap in page 13!



Clock Algorithm

We need to swap in page 13!

Update to 0 as we move to the next entry



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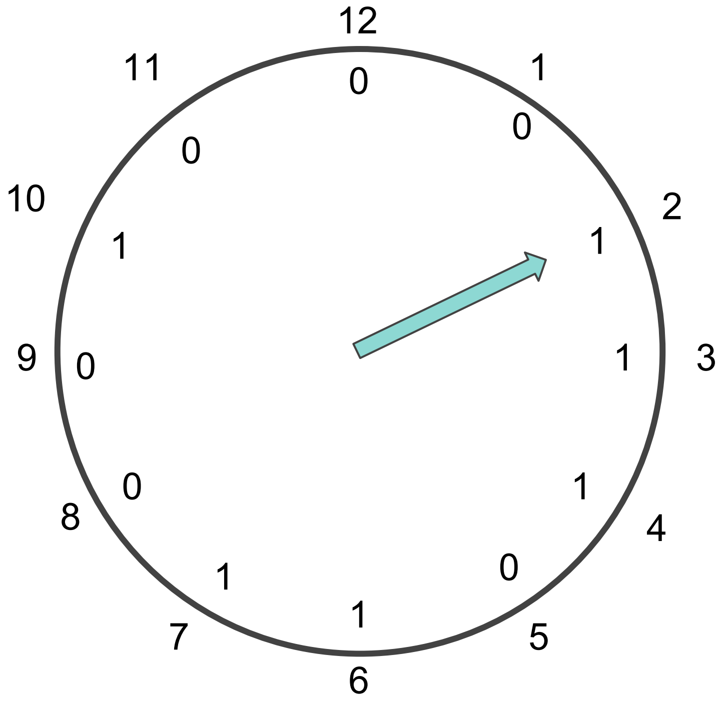

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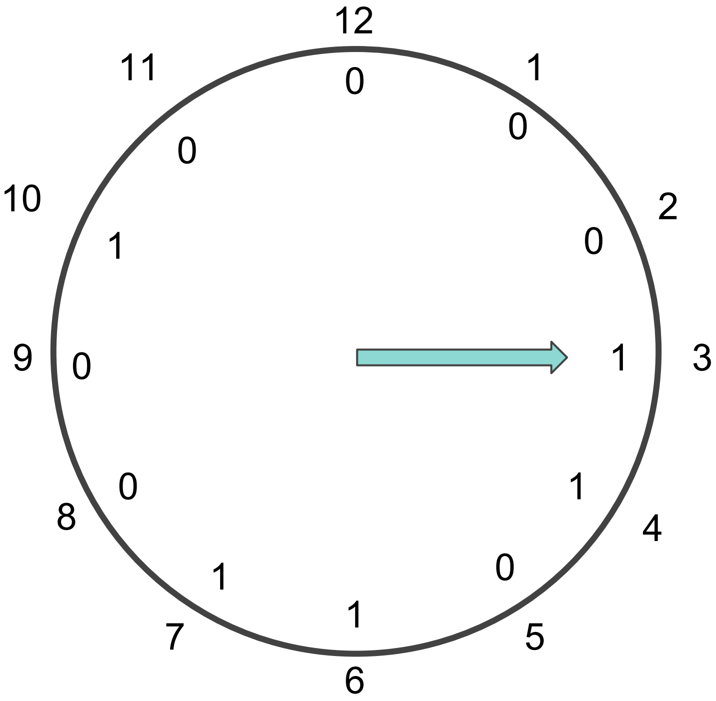

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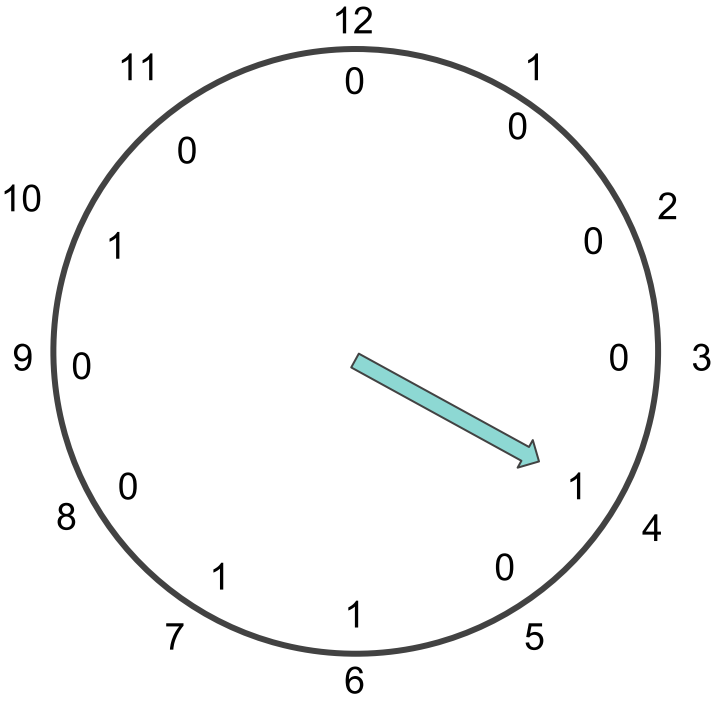

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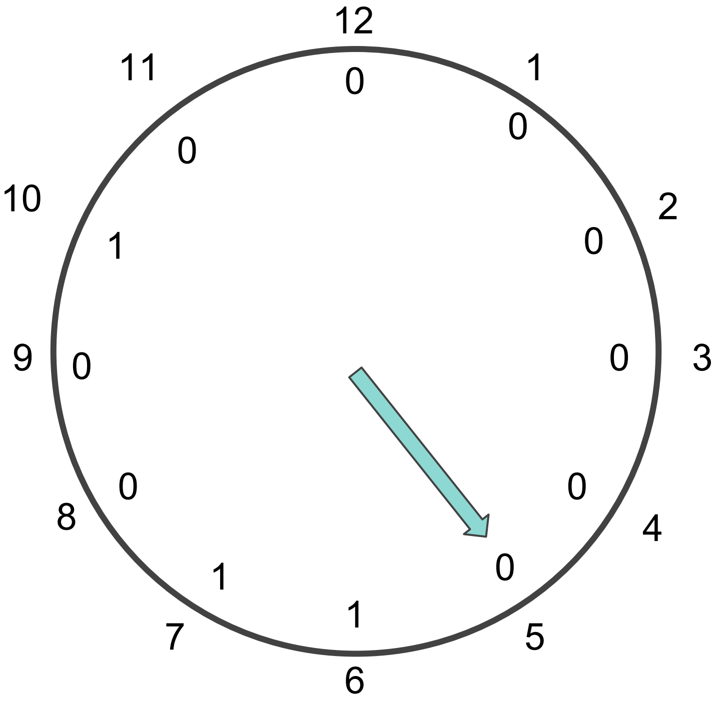

Clock Algorithm

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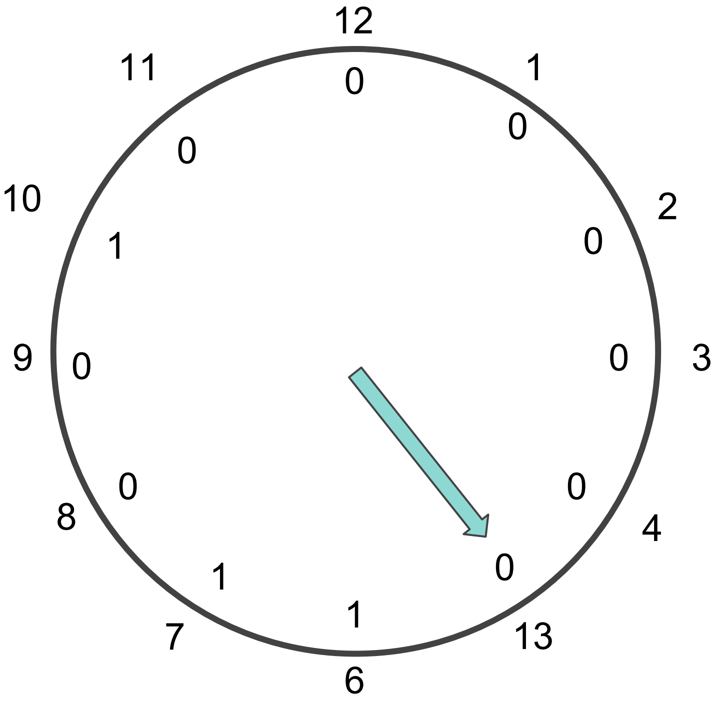
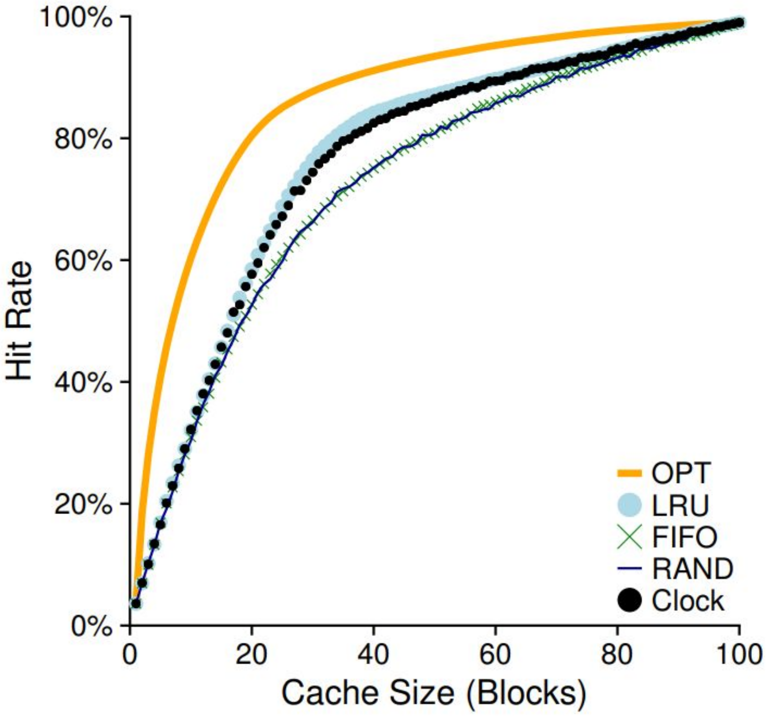
Found page to evict!



Performance Comparison



From: Operating Systems: Three Easy Pieces by Remzi H. Arpaci-Dusseau and Andrea C. Arpaci-Dusseau

2017-08-21

Below is a extract from a program that implements Least Recently Used (**LRU**). The code shows why LRU is expensive to implement and why one probably instead choose to approximate this strategy. What is the code doing and when is it executed?

```
if(entry->present == 1) {

    if(entry->next != NULL) {

        if(first == entry) {
            first = entry->next;
        } else {
            entry->prev->next = entry->next;
        }
        entry->next->prev = entry->prev;

        entry->prev = last;
        entry->next = NULL;

        last->next = entry;
        last = entry;
    }
} else {
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  :
```

Answer: The code unlinks an entry and places it last in a list that should be updated with the least used pages first. This operation must be done every time a page is referenced.

2017-01-14

When implementing the ***clock algorithm*** it is sucient to have the list single linked i.e. there is no need for a double linked list. Why can we manage with a single linked list?

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Answer: We never remove an element at random but always from the current position of the dial. We can easily keep track of its position and its immediate predecessor.

2017-01-14

In an experiment we have a virtual memory of 100 pages and simulate a memory of up to 100 frames. The experiment simulate a sequence of memory operations with temporal locality

In the diagram below you should plot justiable graphs for the following three strategies:

- **RND**: *evict the page by random*
- **OPT**: *evict the page that won't be used for the longest time*
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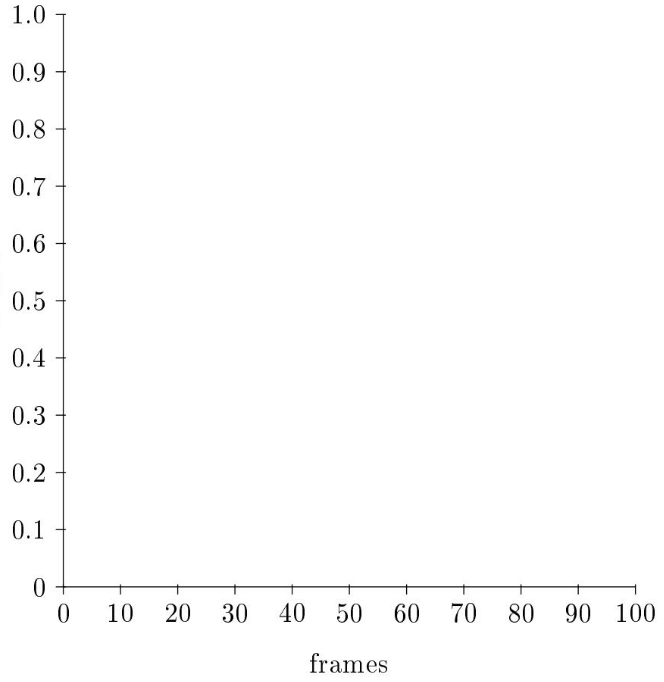

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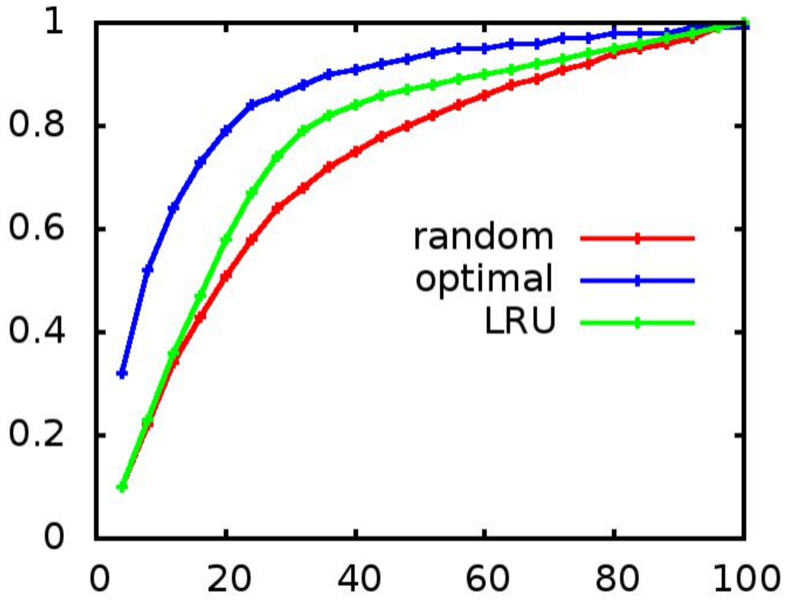

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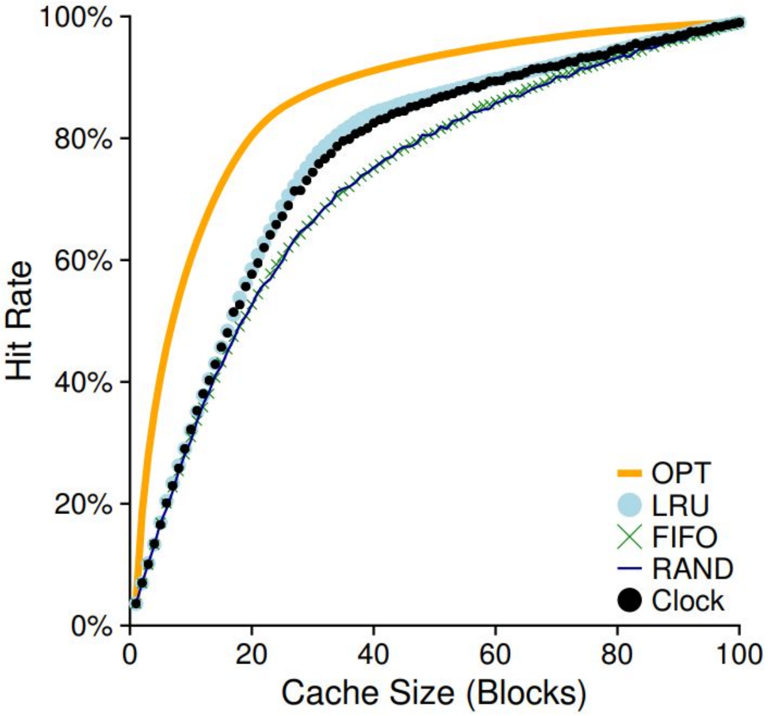

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