CprE 308 Homework 2

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Problem 1. Address translation (5 points)

Suppose we are given a virtual address 16390. If we are using paging and the page size is 4KB, what are the *virtual page number* and *offset* of the given virtual address? Suppose virtual page numbers start with 0.

Note: 2^{10}=1024, 2^{11}=2048, 2^{12}=4096, 2^{13}=8192, 2^{14}=16384, 2^{15}=32768, 2^{16}=65536.

➔ Virtual Address – 16390
Page Size – 4KB

So, 4KB = 2^12 bytes = 4096 bytes

Now, we know that; page number = virtual address / page size

= 16390 / 1024
= 4

Therefore, Page Number = **4**

Now, we know that; offset = virtual address **mod** page size
= 16390 **mod** 4096
= 6

Therefore, Offset = **6**

Problem 2. Multi-level page table (5 points)

Suppose a program has a 64-bit virtual address space, and the system uses a three-level page table. The virtual address has a 10-bit top level page table field (i.e., index for page global directory), 16-bit second level page table field (i.e., index for page middle directory), and 22-bit third level page table field, and an offset.

a) What is the page size?
b) What is the max number of virtual pages for this program?

➔ The virtual address is split into 10-bit, 16-bit and 22-bit level pages.

Now, we know that the program has a 64-bit virtual address space.

So , the offset = (64) – (10+16+22)
= 64 – 48
= 16 bits

a) Page Size = $2^{16} = 2^{6}2^{10}$ = 64K

b) Max Number of Virtual Pages = (Virtual memory size / page size)

$$= 2^{64} / 2^{16} = 2^{48}$$

Problem 3. Page Replacement Algorithms (10 points)

Suppose the physical memory has four page frames and they are occupied by four pages (0 - 3). The following table shows the timestamp when each page is loaded to the frame (i.e., the "Loaded" column), the timestamp when each page is last referenced (i.e., the "Last Ref." column), the recently referenced bit R in the corresponding page table entry.

Page	Loaded	Last Ref.	R
0	126	280	0
1	230	265	0
2	140	270	1
3	110	285	1

Suppose a page fault happens and the system needs to replace a page.

a) If the system uses First-In-First-Out (FIFO) algorithm, which page is replaced?

➔ Based on the table above, page 3 will be loaded first with the time stamp "110". Hence, if the system uses First-In-First-Out algorithm, page 3 will be replaced.

b) If the system uses Least-Recently-Used (LRU) algorithm, which page is replaced?

➔ Based on the table above, page 1 is the page with the lowest last reference with the time stamp "265". Hence, if the system uses Least-Recently-Used algorithm, page 1 will be replaced.

c) If the system uses Clock algorithm, and the pages are organized in a circular list of 0-->1-->2-->3->0, the clock hand currently points to page 1, which page is replaced?

➔ Since the clock hand currently points to page 1, and its recently referenced bit is 0, page 1 will be replaced if the system uses the Clock algorithm.

d) If the system uses Clock algorithm, and the pages are organized in a circular list of 0-->1-->2-->3->0, the clock hand currently points to page 2, which page is replaced?

➔ Since the clock hand currently points to page 2, and its recently referenced bit is 1, due to the clock algorithm, the clock hand will now point to page 3, and will replace the recent reference bit of page 2 to 0. Now, the recently referenced bit for page 3 is also 1, and so the clock hand will move to page 0 and will replace the recent reference bit of page 3 to 0. Now, since the recently referenced bit of page 0 is 0, page 0 will be replaced.