Page Tables and Replacement Algorithms

Introduction

You will simulate the operation of page tables and page replacement.

You have two tasks in this assignment, which will be based on a virtual memory simulator. The first task is to implement virtual-to-physical address translation and demand paging using a two-level page table. The second task is to implement four different page replacement algorithms: FIFO, Clock, exact LRU, and OPT.

Setup

Compile the trace programs and generate the traces.

You may have noticed while doing the Exercise that the traces generated by Valgrind are enormous since they contain every memory reference from the entire execution. We have provided a program, fastslim.py to reduce the traces by removing repeated references to the same page that occur within a small window of each other while preserving the important characteristics for virtual memory simulation. (For example, a sequence of references to pages A and B such as "ABABABABAB..AB" are reduced to just "AB") The runit script pipes the output of valgrind through this program to create the reduced trace. If you wish, you can experiment with fastslim.py to try omitting the instruction references from the trace or using a smaller or larger window (fastslim.py --help).

Task 1 -Address Translation and Paging

Implement virtual-to-physical address translation and demand paging using a two-level pagetable.

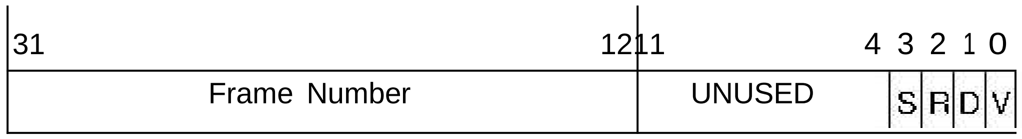
The main driver for the memory simulator, sim.c, read memory reference traces in the format produced by the fastslim.py that corresponds to the given virtual address by calling find_physpage, and then reads from that location. If the access type is a write (“M” for modify or “S” for store), it will also write to the location. You should sim.c so that you understand how it works.

The simulator is executed as ./sim -f <trace-file> -m <memory size> -s <swap-file size> -a <replacement algorithm> where memory size and swa-pfile size are the number of frames of simulated physical memory and the number of pages that can be stored in the swap file, respectively. The swap-file size should as long as the number of unique virtual pages in the trace, which you should be able to determine easily.

There are four main date structures that are used:

1. char *physmem: This is the space for our simulated physical memory. We define a simulated page size (and hence frame size) of SIMPAGESIZE and allocate SIMPAGESIZE * “memory size” bytes for physmem.
2. struct frame *coremap: The coremap array represents the state of (simulated) physical memory. Each element of the array represents a physical page frame. It records if the physical frame is in use and, if so, a pointer to the page table entry for the virtual page that is using it.
3. pgdir_entry_t pgdir[PTRSPER_PGDIR]: We are using a two-level page table design; the top level is referred to as the page directory, which is represented by array. Each page directory entry (pde_t) holds a pointer to a second level page table (which we refer to simply as page tables, for short). We use the low-order bit in this pointer to record whether the entry is valid or not. The page tables are array s of page table entries (pte_t), which consist of a frame number if the page

is in (simulated) physical memory and an offset into the swap file if the page has been written out to swap. The format of a page table is shown here:



V: PG_VALID, D: PG_DIRTY, R: PG_REF, S: PG_ONSWAP

Note that the frame number and status bits share a word, with the low-order PAGE_SHIFT bits (12 in our implementation) used for status (only 4 status bits but can add more if you find it useful). Thus, for a given physical fram number (e.g., 7), remember to shift it over to leave room for the status bits (7 << PAGE_SHIFT) when storing into the pte and to shift it back when retrieving a frame number from a pte (e.g., p->frame >> PAGE_SHIFT).

4. memory swap.c: The swap-file functions are all implemented in this file, along with bitmap functions to track free and used space in the swap file, and to move virtual pages between the swapfile and (simulated) physical memory. The swap_pagein and swap_pageaut functions take a frame number and a swap offset as arguments*. Be careful not to pass the frame field from* a *page table entry (pte_t) directly, since that would include the extra status bits.* The simulator code creates a temporary file in the current directory where it is executed to use as the swapfile and removes this file as part of the cleanup when it completes. It does not, however, remove the temporary file if the simulator crashes or exits early due to a detected error. *You must manually remove the swapfiLe.XXXXXX files in this* case.

To complete this task, you will have to write code in pagetable.c. Read the code and comments in this file-- it should be clear where implementation work is needed and what it needs to do. The rand replacement algorithm is already implemented for you, so you can test your translation and paging functionality independently of implementing the replacement algorithms.

Task2

Using the starter code, implement each of *the four different page replacement algorithms: FIFO, exact LRU, CLOCK (with one ref-bit), OPT.*

You will find that you want to add fields to the struct frame for the different page replacement algorithms. You can add them in pagetable.h, but please label them clearly. You may NOT modify the pgtbl_entry_t or pgdir_entry_t structures.

Once you're done implementing the algorithms, run all three programs from the provided traceprogs, plus a fourth program of your choosing with interesting memory reference behavior, using each of your algorithms (include rand as well). For each algorithm, run the programs on memory sizes 50, 100, 150, and 200. Use the data from these runs to create a set of tables that include the following columns. (Please label your columns in the following order,)

- Hit rate
- Hit count
- Miss count
- Overall eviction count
- Clean eviction count
- Dirty eviction count

Efficiency: Page replacement algorithms must be fast, since page replacement operations can be critical to performance. Consequently, you must implement these policies with efficiency in mind. For example, we will give you the expected complexities for some of the policies:

- FIFO: init, evict, ref: 0(1) in time and space
- LRU: evict, ref: 0(1) in time and space; init: O(M) in time and space, where M = size of memory
- CLOCK: init, ref: 0(1) in time and space; evict: O(M) in time, 0(1) in space, where M =size of memory