MP3: Page Manager I

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CSCE611: Operating System

Assigned Tasks

Main: Completed.

System Design

The main objective of machine problem 3 is the implementation of a demand-paging based virtual memory system where the goal is to initialize the page table for a single process, and therefore, a single address space. This manages kernel frames from 2MB to 4MB and process frames between 4MB and 32MB.

Code Description

During the implementation of this machine problem, I made changes to the following three files:

1. **cont_frame_pool.H**
2. **cont_frame_pool.C**
3. **page_table.C**

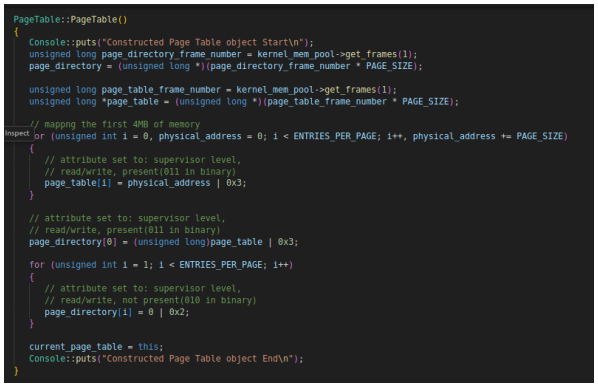
I used the same code that I implemented for MP2. In this machine problem, I implemented the following function definitions in `page_table.C`:

1. **init_paging** : This function is used to initialize static private data members in a class, including the kernel frame pools, memory frame pools, and the shared size for the page table.

```
void PageTable::init_paging(ContFramePool *_kernel_mem_pool,
                            ContFramePool *_process_mem_pool,
                            const unsigned long _shared_size)
{
   // initlizaing basic data structure for paging
   Console::puts("Initialized Paging System Start\n");
   kernel_mem_pool = _kernel_mem_pool;
   process_mem_pool = _process_mem_pool;
   shared_size = _shared_size;
   Console::puts("Initialized Paging System End\n");
}
```

Figure 1: **init_paging**

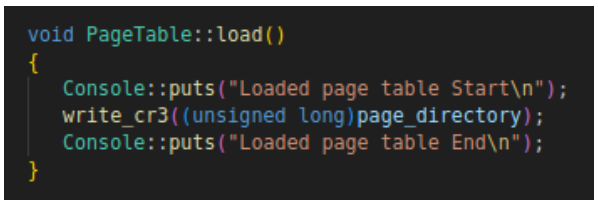
2. **PageTable (Class Constructor)** : The constructor is used to construct the page table object. It initializes the first page directory by assigning the free frame from the kernel frame pool and marking it as valid (present). It also initializes the first page table by assigning the free frame from the kernel frame pool. The first page table is directly mapped to physical memory. The first directory entry holds the first page table, while all the remaining directories are marked as invalid (not present).



```
PageTable::PageTable()
{
    Console::puts("Constructed Page Table object Start\n");
    unsigned long page_directory_frame_number = kernel_mem_pool->get_frames(1);
    page_directory = (unsigned long *)(page_directory_frame_number * PAGE_SIZE);

    unsigned long page_table_frame_number = kernel_mem_pool->get_frames(1);
    unsigned long *page_table = (unsigned long *)(page_table_frame_number * PAGE_SIZE);

    // mappng the first 4MB of memory
    for (unsigned int i = 0, physical_address = 0; i < ENTRIES_PER_PAGE; i++, physical_address += PAGE_SIZE)
    {
        // attribute set to: supervisor level,
        // read/write, present(011 in binary)
        page_table[i] = physical_address | 0x3;
    }

    // attribute set to: supervisor level,
    // read/write, present(011 in binary)
    page_directory[0] = (unsigned long)page_table | 0x3;

    for (unsigned int i = 1; i < ENTRIES_PER_PAGE; i++)
    {
        // attribute set to: supervisor level,
        // read/write, not present(010 in binary)
        page_directory[i] = 0 | 0x2;
    }

    current_page_table = this;
    Console::puts("Constructed Page Table object End\n");
}
```

Figure 2: **PageTable (Class Constructor)**

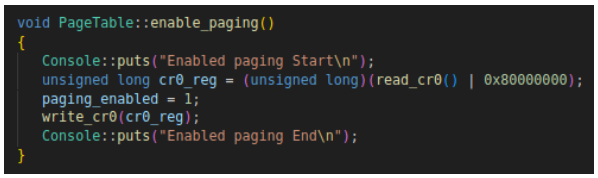
3. **load** : This function loads the current page directory into register CR3 using `write_cr3()`. The page table is loaded.



```
void PageTable::load()
{
    Console::puts("Loaded page table Start\n");
    write_cr3((unsigned long)page_directory);
    Console::puts("Loaded page table End\n");
}
```

Figure 3: **load**

4. **enable_paging** : This function is used to enable paging by setting the paging bit (bit 31) of CR0 to 1 using `read_cr0` to read the contents of CR0 and `write_cr0` to write the contents to CR0. Also, we set the boolean `paging_enabled` to true. Before enabling the paging, the page directory and page table should be set up and loaded correctly.



```
void PageTable::enable_paging()
{
    Console::puts("Enabled paging Start\n");
    unsigned long cr0_reg = (unsigned long)(read_cr0() | 0x80000000);
    paging_enabled = 1;
    write_cr0(cr0_reg);
    Console::puts("Enabled paging End\n");
}
```

Figure 4: **enable_paging**

5. **handle_fault** : This function is utilized to handle raised faults. It examines the error code received from the register through bit manipulation. Subsequently, it retrieves the faulty address from CR2 register using the `read_cr0` function. Additionally, it reads the current page directory from CR3 using the `read_cr3` function. If the current page directory is an invalid page directory entry, the function first obtains a free frame from the kernel frame pool, assigns it to the current page directory, and marks it as 'present.' Following this, it obtains another free frame from the kernel frame pool and assigns it to the new page table, initializing all its entries as invalid. Simultaneously, the address pointing to that page location is assigned a free frame from the process frame pool and marked as 'valid' (present). If the page directory is valid, the function employs an existing page table and assigns a free frame from the process frame pool, marking it as 'valid' (present). In the event of a different scenario than the aforementioned two, the function halts execution with a message stating that 'something went wrong'.

```
void PageTable::handle_fault(REGS *_r)
{
    Console::puts("handle_fault Start\n");
    unsigned long err_code = _r->err_code;
    if ((err_code & 0x1) == 0x0)
    {
        Console::puts("handle_fault err occuured\n");
        unsigned long faulty_address = (unsigned long)(read_cr2());
        unsigned long *page_directory_list = (unsigned long *)(read_cr3());
        unsigned long directory_location = (faulty_address & 0xFFC00000) >> 22;
        unsigned long page_location = (faulty_address & 0x003FF000) >> 12;
        bool page_table_fault = false;

        if ((page_directory_list[directory_location] & 0x1) == 0x0)
        {
            Console::puts("directory issue and new page table");
            Console::puts("\n");
            unsigned long new_page_table_frame_number = kernel_mem_pool->get_frames(1);
            unsigned long *new_page_table = (unsigned long *)((new_page_table_frame_number * PAGE_SIZE));

            // attribute set to: supervisor level,
            // read/write, not present(010 in binary)
            page_directory_list[directory_location] = (unsigned long)new_page_table | 0x3;

            // initializing the page table enteries
            for (unsigned int i = 0; i < ENTRIES_PER_PAGE; i++)
            {
                // attribute set to: supervisor level,
                // read/write, not present(010 in binary)
                new_page_table[i] = 0 | 0x2;
            }
```

```
            // initializing the page table enteries
            for (unsigned int i = 0; i < ENTRIES_PER_PAGE; i++)
            {
                // attribute set to: supervisor level,
                // read/write, not present(010 in binary)
                new_page_table[i] = 0 | 0x2;
            }

            unsigned long physical_frame_number = process_mem_pool->get_frames(1);
            new_page_table[page_location] = (unsigned long)(physical_frame_number * PAGE_SIZE) | 0x3;
        }
        else
        {
            Console::puts("existing page table issue");
            Console::puts("\n");
            unsigned long *existing_page_table = (unsigned long *)(page_directory_list[directory_location] & 0xFFFFF000);
            unsigned long physical_frame_number = process_mem_pool->get_frames(1);
            existing_page_table[page_location] = (unsigned long)(physical_frame_number * PAGE_SIZE) | 0x3;
        }

        Console::puts("resolved page fault\n");
    }
    else
    {
        Console::puts("Something went wrong\n");
        assert(false);
    }
    Console::puts("handle_fault End\n");
}
```

Figure 5: **handle_fault**

Testing

During the development of the code, I wrote several `Console:puts()` and `Console:putui()` statements to identify where my code was breaking and to understand if the logic was incorrect or not performing as expected. During testing, the execution was running infinitely while running the program. Also, during testing, test case 0 was failing. After making changes and understanding the console debug logs, the code ran successfully. I removed all Console statements and changed back the Kernel.C to the original one.

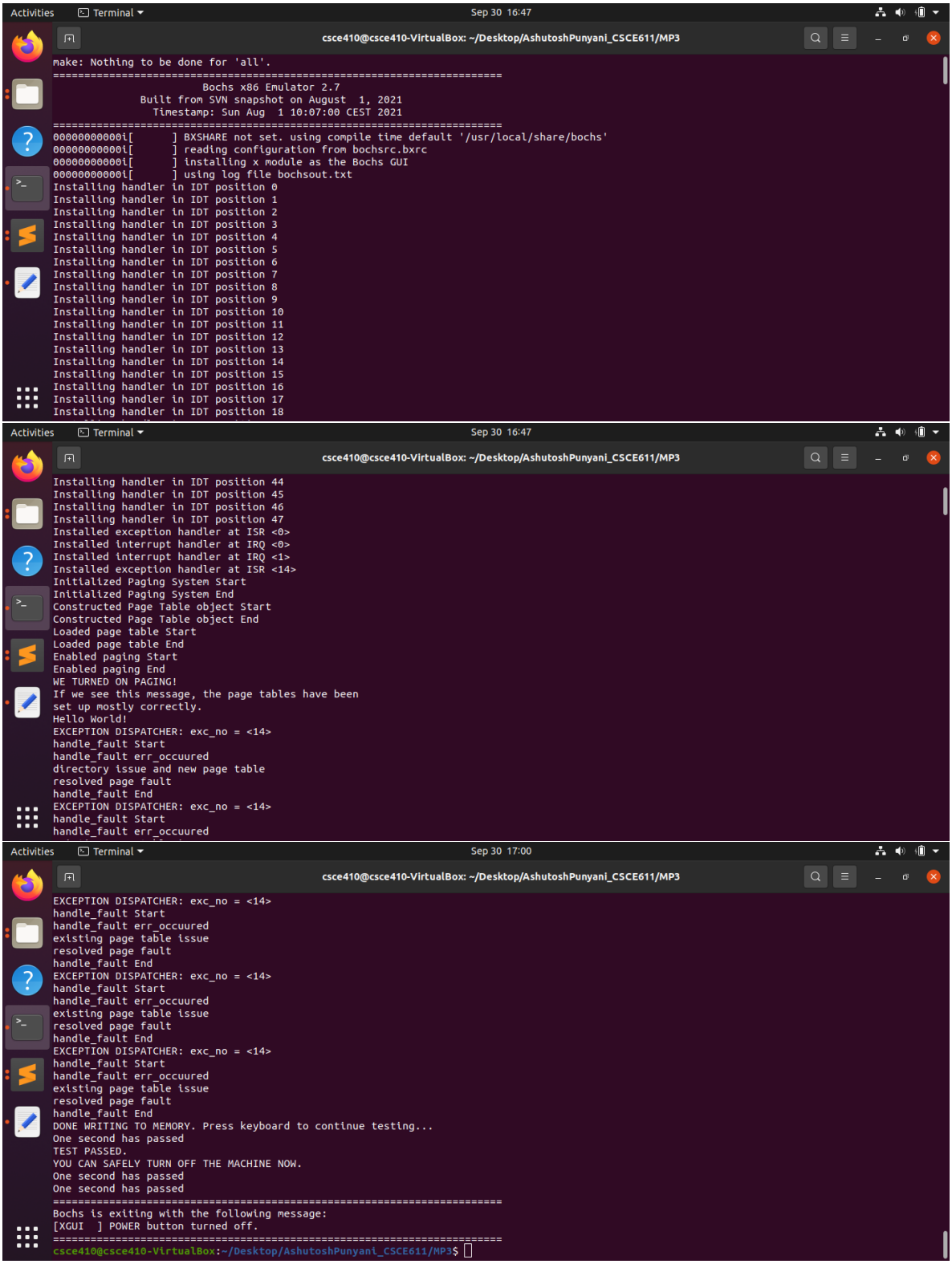


Figure 6: **Testing**