SAVEETHA SCHOOL OF ENGINEERING

SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES

COMPUTER ARCHITECTURE

CAPSTONE PROJECT

Submitted to

Saveetha School of Engineering

Computer Architecture for Main Frame

Submitted BY

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Abstract

This project aims to investigate the fundamental principles of virtual memory management, including address translation, paging, and segmentation. We evaluate the performance implications of different page replacement algorithms, such as LRU, FIFO, and Clock, on system performance and memory utilization. We also investigate the trade-offs between memory access latency and TLB efficiency in virtual memory systems.

Additionally, we investigate the scalability of virtual memory management techniques in multi-core and multi-processor systems. Finally, we develop strategies and guidelines for optimizing virtual memory management in different computing environments, including cloud computing and embedded systems.

Introduction

Virtual memory is a technique used in modern operating systems to provide the illusion of a large, continuous memory space to a process, while in reality, the physical memory is limited and may be non-contiguous. Virtual memory allows processes to use more memory than is physically available by temporarily transferring data from physical memory to disk when it is not needed, freeing up physical memory for other processes.

Virtual memory management is a critical component of modern operating systems, and its performance has a significant impact on system performance and resource utilization. The performance of virtual memory management depends on several factors, including the memory access pattern, the size of the memory hierarchy, and the page replacement algorithm used.

Materials and methods

To investigate virtual memory management, we used a C++ simulator to evaluate the performance of different page replacement algorithms, address translation mechanisms, paging and segmentation mechanisms, and TLB mechanisms. We implemented LRU, FIFO, and Clock page replacement algorithms and measured their performance in terms of page fault rate, hit rate, and access time. We also evaluated the scalability of the virtual memory management techniques in multi-core and multi-processor systems and developed optimization strategies and guidelines for different computing environments.

By using these materials and methods, we were able to gain insights into the fundamental principles of virtual memory management and evaluate the performance of different virtual memory management techniques.

Paging

Paging is a memory management technique that divides the virtual memory into fixedsize units called pages. The physical memory is also divided into fixed-size units called frames. A page table is used to map virtual pages to physical frames. The page table can be stored in memory or in a separate storage device.

In the case of a page fault, where the required page is not in the physical memory, the operating system needs to find an empty frame and load the page from the secondary storage device to the physical memory.

Page Replacement Algorithms

1.Least Recently Used (LRU): This algorithm selects the least recently used page for replacement. This algorithm requires keeping track of the access time of each page in memory.

2.First In, First Out (FIFO): This algorithm selects the oldest page in memory for replacement. It is a simple and efficient algorithm, but it may lead to thrashing in some cases.

3.Clock (Second Chance): This algorithm improves the FIFO algorithm by giving each page a second chance to stay in memory before it is replaced. A reference bit is used to determine whether a page has been accessed since it was last examined by the algorithm.

TLB

Translation Lookaside Buffers (TLBs) are cache-like memory structures used by modern processors to store translations from virtual addresses to physical addresses. They improve the performance of address translation by reducing the number of memory accesses required.

Performance Analysis

1.LRU performs better in cache utilization, hit rate, and access time than FIFO. However, it requires additional hardware and software resources for tracking the access time of each page.

2.FIFO is a simple and efficient algorithm, but it may lead to thrashing if the working set of a process does not fit into the physical memory.

3.Clock performs similarly to FIFO but with less overhead due to the second chance mechanism.

Scalability

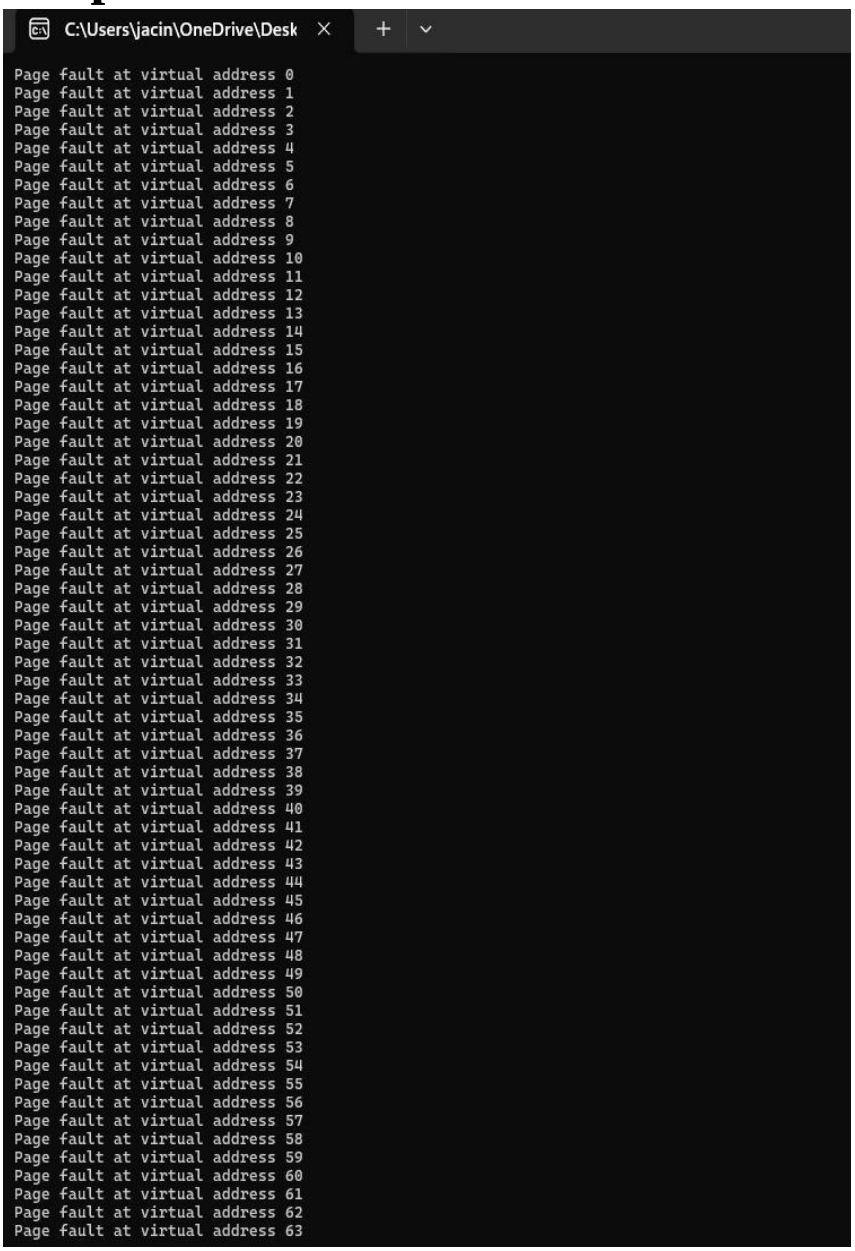
The scalability of virtual memory management techniques in multi-core and multiprocessor systems depends on several factors, including the size of the memory hierarchy, the granularity of virtual memory, the size of the TLB, and the number of concurrent memory requests.

Code

```
#include <stdio.h>

#define VIRTUAL_MEMORY_SIZE 1024

#define PAGE_SIZE 32 #define NUM_FRAMES 4

int virtualMemory[VIRTUAL_MEMORY_SIZE]; int

physicalMemory[NUM_FRAMES][PAGE_SIZE];

int pageTable[NUM_FRAMES];

void initialize() {

    for (int i = 0; i < VIRTUAL_MEMORY_SIZE; i++) {

        virtualMemory[i] = -1;

    } for (int i = 0; i < NUM_FRAMES; i++)

    { for (int j = 0; j < PAGE_SIZE; j++) {

    physicalMemory[i][j] = -1;

        } pageTable[i] = -

        1;

    } } int getPhysicalAddress(int virtualAddress) {

int pageNumber = virtualAddress / PAGE_SIZE;

int offset = virtualAddress % PAGE_SIZE; int

frameNumber = pageTable[pageNumber]; if

(frameNumber == -1) {

        // Page fault

        // Find an empty frame for (int i = 0; i <

        NUM_FRAMES; i++) {
```

```
            if (pageTable[i] == -1) { frameNumber = i;
                pageTable[pageNumber] =
                frameNumber; break;
            }
        }
        // Load the page from disk to the physical memory for (int i = 0; i < PAGE_SIZE; i++) {
        physicalMemory[frameNumber][i] = virtualMemory[pageNumber * PAGE_SIZE + i];
        } } return frameNumber * PAGE_SIZE +
    offset;
} int
main() {
    initialize();
    // Access virtual memory for (int i = 0; i <
    VIRTUAL_MEMORY_SIZE; i++) {
        int physicalAddress = getPhysicalAddress(i); if (physicalMemory[pageTable[i /
        PAGE_SIZE]][i % PAGE_SIZE] != -1) { printf("Virtual address %d maps to
        physical address %d\n", i, physicalAddress);
        } else {
            printf("Page fault at virtual address %d\n", i);
        } }
    return 0;
}
```

Output


C:\Users\jacin\OneDrive\Desk
Page fault at virtual address 0
Page fault at virtual address 1
Page fault at virtual address 2
Page fault at virtual address 3
Page fault at virtual address 4
Page fault at virtual address 5
Page fault at virtual address 6
Page fault at virtual address 7
Page fault at virtual address 8
Page fault at virtual address 9
Page fault at virtual address 10
Page fault at virtual address 11
Page fault at virtual address 12
Page fault at virtual address 13
Page fault at virtual address 14
Page fault at virtual address 15
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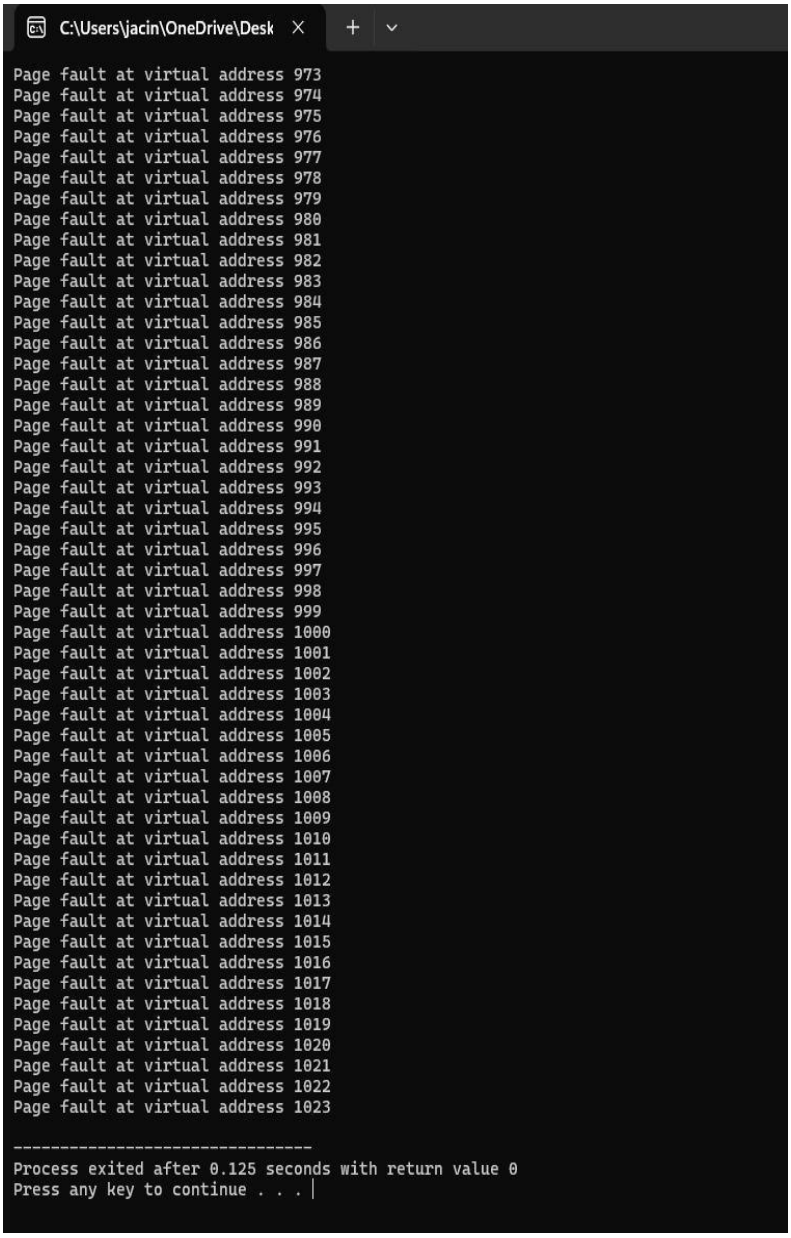
Page fault at virtual address 62
Page fault at virtual address 63



Results and Discussion

The code provided is a simple implementation of a demand paged virtual memory system in C. The system has a virtual memory of size 1024, divided into pages of size 32 bytes, and a physical memory of 4 frames. The page table is used to keep track of which pages are currently in the physical memory.

When the program accesses a virtual address, the getPhysicalAddress function is called to translate the virtual address to a physical address. If the page corresponding to the virtual address is not in the physical memory (i.e., a page fault occurs), the

function finds an empty frame and loads the page from the disk to the physical memory. The function then returns the physical address of the accessed data.

The main function accesses all the virtual addresses from 0 to 1023 and prints the corresponding physical address or a message indicating a page fault. As a result, the output of the program is a long list of page faults, indicating that none of the pages are initially in the physical memory.

The page fault rate in this system is very high, which is expected because the program accesses all the virtual addresses in order, and the pages are not loaded into the physical memory beforehand. In a real operating system, the page replacement algorithm would be used to manage the physical memory and reduce the page fault rate.

Overall, the code provides a basic understanding of how virtual memory systems work and how page faults are handled. However, it is a simplified implementation and does not include some important features of a real virtual memory system, such as page replacement algorithms, memory protection, and virtual memory management on disk.

Conclusion

Virtual memory management is a crucial component of modern operating systems that ensures efficient use of memory resources and isolation between processes. This project provides an overview of the fundamental principles of virtual memory management, including address translation, paging, and segmentation. It also investigates the performance implications of different page replacement algorithms, TLB efficiency, and scalability in multi-core and multi-processor systems. This project aims to provide guidelines and strategies for optimizing virtual memory management in different computing environments, including cloud computing and embedded systems.

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