University of Engineering and Technology
Department of Computer Science

Multi-Process Image Processor

Operating Systems Lab

Submitted By

Name: Rabia Nadeem
Reg#: 2023-CS-705

Name: Abdul Rahman
Reg#: 2023-CS-725

Submitted To

Prof. Mariyam Manzoor

December 08, 2025

Introduction

This project aims to implement a simplified **operating-system-style image processing pipeline** using the C language on a Linux platform. Each image filter (Grayscale, Blur, Sharpen) runs as a **separate process**, while each process uses **POSIX threads** to handle different image chunks concurrently.

The system demonstrates key operating system concepts such as:

- CPU Scheduling simulation
- Process creation using `fork()` and `exec()`
- Thread management using pthreads
- Dynamic memory management
- Inter-Process Communication through Shared Memory
- Process/thread Synchronization with Semaphores Mutex Locks

Problem Statement

Modern operating systems use concurrent processes and threads to speed up multimedia operations. This project simulates that behavior by creating an image-processing pipeline where each stage is isolated in its own process and communicates via shared memory with proper synchronization.

Objectives

- Process images using a pipeline architecture similar to UNIX utilities.
- Demonstrate OS-level concurrency: processes + threads + IPC.
- Implement safe shared memory communication using semaphores/mutexes.
- Simulate CPU scheduling policies inside processing routines.

Methodology

1. Process Architecture

The program will create **five processes**:

1. Loader Process
2. Grayscale Filter Process
3. Blur Filter Process
4. Sharpen Filter Process
5. Output Writer Process

Each process will be created using `fork()`, while filter processes may replace themselves using `exec()` for modularity.

2. Threading Structure

Each process will internally create multiple **pthread worker threads**, each responsible for processing a block of the image.

Example:

- If image has 8 blocks then 8 worker threads per filter.

3. Memory Management

- Image buffers will be dynamically allocated using `malloc()`.
- Each filter will allocate its own chunk buffers.
- Memory will be properly freed to avoid leaks.

4. Inter-Process Communication (IPC)

Shared Memory (shmget, shmat) will be used to exchange image chunks between processes.

- **Loader**: writes raw image to SHM
- **Filters**: read and write processed image blocks
- **Writer**: reads final output from SHM

5. Synchronization

- **Semaphores** to signal ”data ready” between processes.
- **Mutexes** to protect shared memory from race conditions.

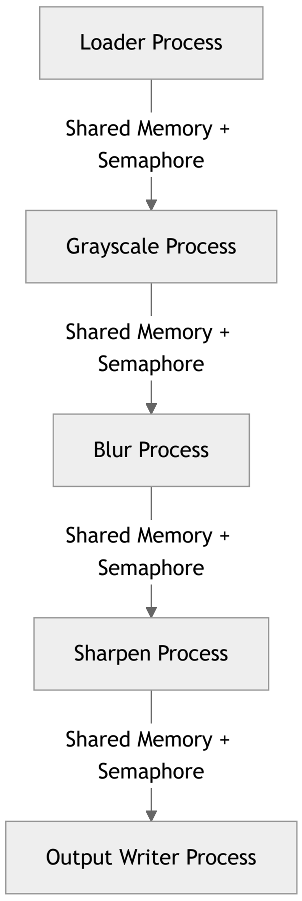
6. CPU Scheduling Simulation

- **Round Robin (RR)** time slices between filter threads
- **Priority Scheduling:** heavy filters (e.g., Sharpen) get higher priority
- **Artificial delay** using `usleep()` to simulate scheduling quantum

Scope

- Multi-process pipeline
- Thread-level concurrency
- Shared memory communication
- Synchronization primitives
- CPU scheduling simulation
- Multiple image filters

System Architecture Diagram


Loader Process
Shared Memory + Semaphore
Grayscale Process
Shared Memory + Semaphore
Blur Process
Shared Memory + Semaphore
Sharpen Process
Shared Memory + Semaphore
Output Writer Process

Expected Outcomes

- Fully functional OS-style pipeline with concurrency.
- Clean, modular C code demonstrating deep OS understanding.
- Clear demonstration of:
  - fork/exec
  - pthreads
  - shared memory
  - semaphores
  - memory management
  - scheduling policies