**Operating Systems – Project 1**  
- Simple Scheduling -

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**Abstract.** Most modern operating systems have extended the concept of the process to allow having multiple threads of execution and thus to perform more than one task at a time (*Silberschatz et al., 2014*). While allowing this multi-threaded concept, there are some issues to consider in designing it: Synchronization (Concurrency Control). In this paper, we will discuss the concept of the multi-thread, synchronization examples, and their solutions, especially on producer and consumer problems. Also, we will implement the example case of producer and consumer problems with a multi-threaded word count program and evaluate it.

**Keywords:** Concurrency Control, Multi-Thread, Mutex, Producer and Consumer, Semaphore, Synchronization, Reader and Write

# Introduction

In a single-processor computer system, only one process can run at a single time. Other processes must wait until the CPU resources are free and can be rescheduled. A process is executed until it must wait, typically for the completion of the I/O request. However, in multiprogramming, some process runs at all time, to maximize CPU utilization. Multiprogramming tries to use the waiting time productively. Some process is loaded into the memory at one time, and when one process has to wait, the operating system takes the CPU resources away from the process and gives the CPU resources to another process. The following progress continues, every time one process has to wait, while another process takes over the use of the CPU resources.

Scheduling the following progress is a fundamental operating system function. Almost all the computer resources are scheduled before use. Since the CPU is one of the primary computer resources, CPU scheduling is central to the operating system design.

In this paper, we will first explain the concepts of process, process scheduling, Inter-process communication (IPC), and CPU scheduling. By applying these concepts, we will explain how we implemented the simple scheduling program and its results for different algorithms, such as first-come-first-served (FCFS), shortest job first (SJF), round-robin (RR), and completely fair safe (CFS). Also, we will show the performance of each algorithm based on the features discussed in a later section. At the end of the paper, we will present the result of the execution of the different scheduling algorithms and compare them.

# Requirements

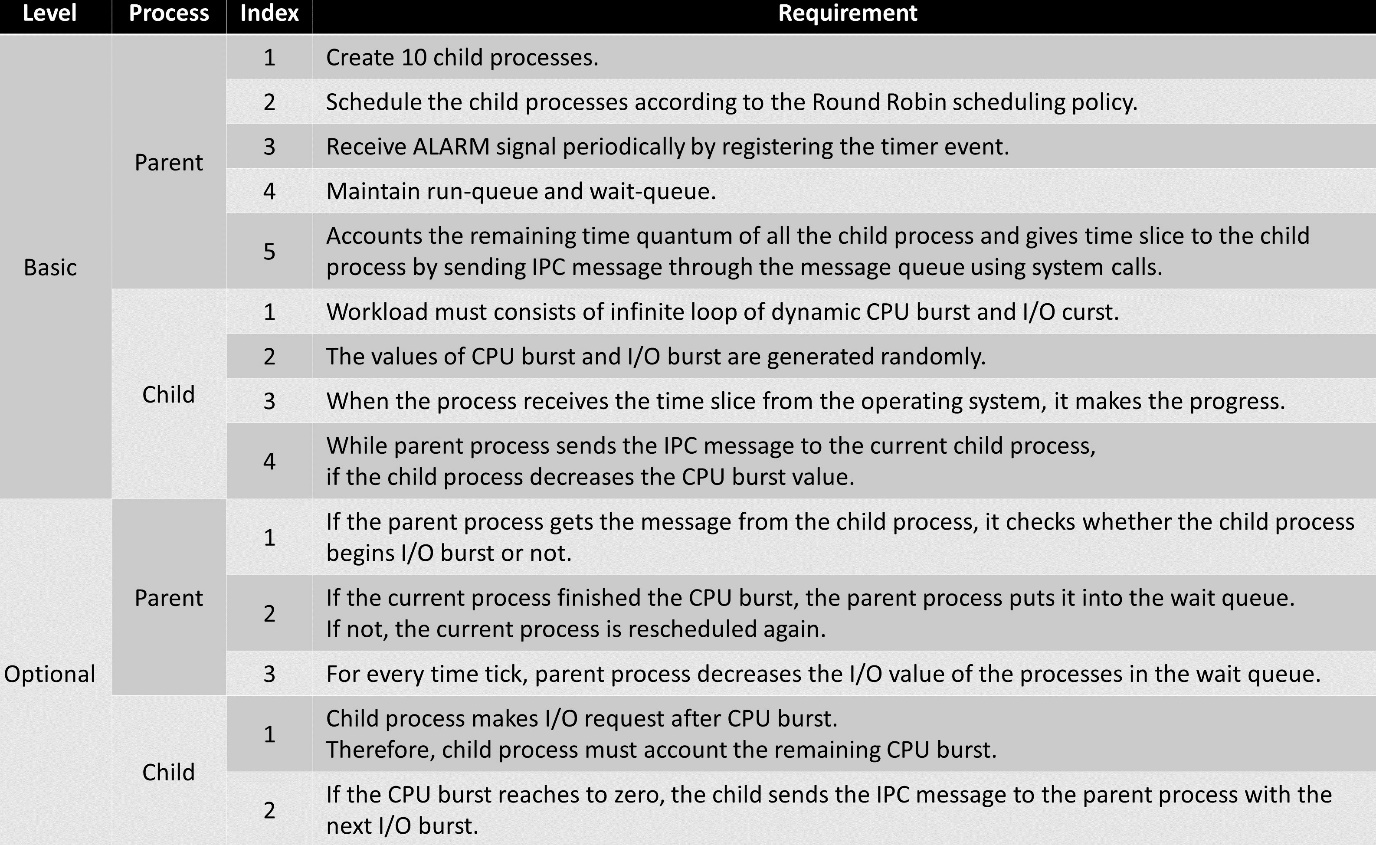


Figure 1 - Requirement Specification

Figure 1 shows the requirements for a simple scheduling program. The implementations for these requirements will be described in detail afterwards.

# Concepts

## Process

The normal process model implies that a process is a program that performs a single thread of execution. For example, when a process is running a word-processor program, a single thread of the instructions is being executed. This single thread of control allows the process to perform only one task at a time (*Silberschatz et al., 2014*). On the systems that supports thread, the process control block (PCB) is expanded to include the information for the thread. Other changes throughout the system are also needed to support the threads.

## Process State

The normal process model implies that a process is a program that performs a single thread of execution. For example, when a process is running a word-processor program, a single thread of the instructions is being executed. This single thread of control allows the process to perform only one task at a time (*Silberschatz et al., 2014*). On the systems that supports thread, the process control block (PCB) is expanded to include the information for the thread.

## Process Control Block

The normal process model implies that a process is a program that performs a single thread of execution. For example, when a process is running a word-processor program, a single thread of the instructions is being executed.

## Process Scheduling

In this paper, we will focus on applying the concept of multi-threaded programming, and the solutions for resolving the presented challenges in the word count program. These challenges will also be described in detail, in a section on the optimization of the implemented program.

## Scheduling Queues

In this paper, we will focus on applying the concept of multi-threaded programming, and the solutions for resolving the presented challenges in the word count program. These challenges will also be described in detail, in a section on the optimization of the implemented program.

## Scheduler

In this paper, we will focus on applying the concept of multi-threaded programming, and the solutions for resolving the presented challenges in the word count program. These challenges will also be described in detail, in a section on the optimization of the implemented program.

## Inter-Process Communication (IPC)

There are several solutions for the following situation that satisfies the requirements above. In this paper, we will present two main solutions for resolving the critical-section problem, which is mutex and semaphore. The details of the mutex and semaphore will be presented in the later sections.

## Message Passing

There are several solutions for the following situation that satisfies the requirements above. In this paper, we will present two main solutions for resolving the critical-section problem, which is mutex and semaphore. The details of the mutex and semaphore will be presented in the later sections.

## Message Queue Naming

There are several solutions for the following situation that satisfies the requirements above. In this paper, we will present two main solutions for resolving the critical-section problem.

## Message Queue Synchronization

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## Message Queue Buffering

There are several solutions for the following situation that satisfies the requirements above. In this paper, we will present two main solutions for resolving the critical-section problem, which is mutex and semaphore. The details of the mutex and semaphore will be presented in the later sections.

## CPU Scheduling

In this paper, we will focus on applying the concept of multi-threaded programming, and the solutions for resolving the presented challenges in the word count program. These challenges will also be described in detail, in a section on the optimization of the implemented program.

## Scheduling Criteria

In this paper, we will focus on applying the concept of multi-threaded programming, and the solutions for resolving the presented challenges in the word count program. These challenges will also be described in detail, in a section on the optimization of the implemented program.

## Scheduling Algorithms

In this paper, we will focus on applying the concept of multi-threaded programming, and the solutions for resolving the presented challenges in the word count program. These challenges will also be described in detail, in a section on the optimization of the implemented program.

## Algorithm Evaluation

In this paper, we will focus on applying the concept of multi-threaded programming, and the solutions for resolving the presented challenges in the word count program.

# Simple Scheduling

## Signal and Handler

Figure 4 shows the solution code that uses mutex lock to resolve the critical section problem. The acquire function acquires the lock, and the release function releases the lock. A mutex has a Boolean variable whose value indicates whether the lock is available or not. If the lock is available, the acquire function succeeds, and the lock is then considered to be unavailable. A thread that attempts to acquire an unavailable lock is blocked until the lock is released.

The main disadvantage of the implementation of the mutex lock is that it acquires busy waiting. While a process or thread is in its critical section, any other process that tries to enter its critical section must loop continuously in the call of acquiring function. This continual looping becomes a problem in the multi-programming system because it wastes the CPU cycle that some other processes and threads might be able to use productively. In the aspect of continuously looping for the busy wait, the mutex lock is also called a spinlock because the thread spins while waiting for the lock to become available.

## Message Passing in POSIX

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## First-Come First-Served Algorithm (FCFS)

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## Shortest Job First Algorithm (SJF)

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## Round Robin Algorithm (RR)

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## Completely Fair Safe Algorithm (CFS)

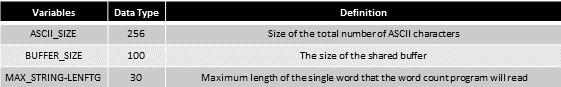
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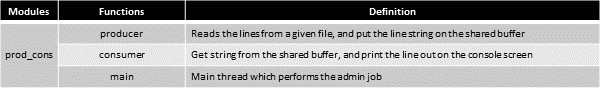
## Program Definition

Before implementing the multi-threaded word count program, we will state the additional program definition that will be used in the real implementation.

* Global Variables



* Modules and Functions



# Implementation

## Queue Header

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## Heap Header

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## Inter-Process Control (IPC) Message Passing Header

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## Main

Figure 4 shows the solution code that uses mutex lock to resolve the critical section problem. The acquire function acquires the lock, and the release function releases the lock. A mutex has a Boolean variable whose value indicates whether the lock is available or not. If the lock is available, the acquire function succeeds, and the lock is then considered to be unavailable. A thread that attempts to acquire an unavailable lock is blocked until the lock is released.

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# Build Environment

* Build Environment:

1. Linux Environment -> Vi editor, GCC Complier
2. Program is built by using the Makefile.

* Build Command:

1. $make prod\_cons -> build the execution program for prod\_cons from version 1 to 4.
2. $make clean -> clean all the object files that consists of the prod\_cons programs.

* Execution Command:

1. . /Prod\_cons\_v1 {$readfile}   
   -> Execute the producer and consumer version 1 program.
2. . /Prod\_cons\_v2.1 {$readfile} #Producer #Consumer  
   -> Execute the producer and consumer version 2.1 program.
3. . /Prod\_cons\_v2.2 {$readfile} #Producer #Consumer  
   -> Execute the producer and consumer version 2.2 program.
4. . /Prod\_cons\_v2.3 {$readfile} #Producer #Consumer  
   -> Execute the producer and consumer version 2.3 program.
5. . /Prod\_cons\_v3 {$readfile} #Producer #Consumer  
   -> Execute the producer and consumer version 3 program.
6. . /Prod\_cons\_v4 {$readfile} #Producer #Consumer  
   -> Execute the producer and consumer version 4 program.

# Results

* Producer and Consumer Version 1 reading LICENSE file.

# Evaluation

Figures 35 and 36 show the graph result of execution time per number of the threads for the producer and consumer program versions 2.3 that reads the file of FeeBSD9-Orig.tar and the android.tar. The following program is implemented by applying the methods that are presented previously. As we can see from the figures, the execution time decreases as the number of threads increases. In short, the producer and consumer program version 2.3 show the ideal and faster result of execution time among the other programs.

# Conclusion

By understanding this paper, we can understand the basic concepts of thread and multi-threaded programming. Also, we can understand the problems and the solutions that occur by applying the following concept, which is about data dependency and synchronization.

# Citations

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