University of Boumerdes

Multi-Class Producer-Consumer Synchronization Using Shared Memory and Semaphores in C

Rapport SE 2

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1. INTRODUCTION

1.1. PROBLEM

In this task, we aim to implement a solution for the multi-class producer-consumer synchronization problem. Four producers (P1, P2, P3, P4) and two consumers (C1, C2) share a common buffer.

The challenge is to synchronize access to the buffer, ensuring adherence to class-specific constraints (P1/P2 in CL1, P3/P4 in CL2, C1/C2 consume messages from their respective classes).

1.2. APPROACH

To address the multi-class producer-consumer synchronization problem, we have implemented a solution using shared memory and semaphores in the C programming language. The approach involves creating shared memory for the buffer and employing semaphores to synchronize access to this shared resource.

Each producer process now reads messages from a messages.txt file and generates messages for its respective class. Each consumer process is responsible for consuming messages from the shared buffer. Semaphores are utilized to coordinate the access of processes to the buffer, preventing conflicts and ensuring that the specified constraints are met.

2. IMPLEMENTATION

2.1. SHARED MEMORY AND DATA STRUCTURES

For inter-process communication, we utilize shared memory with a message buffer and a class integer for the producer.

```c
typedef struct {
    char buffer[256];
    int class; // 1 for CL1, 2 for CL2
} shared_memory;
```

codeSamples/typedef.c

2.2. SEMAPHORE INITIALIZATION

```c
semid = semget(IPC_PRIVATE, 1, IPC_CREAT | 0644);
if (semid == -1) {
    perror("semget");
    exit(1);
}

// Initialize semaphore value
if (semctl(semid, 0, SETVAL, 1) == -1) {
    perror("semctl");
    exit(1);
}
```

codeSamples/semaphore_init.c

2.3. PRODUCER FUNCTION

The producer function now reads messages from a file and generates messages based on the class. It updates the shared memory and utilizes semaphores for synchronization, ensuring mutual exclusion during critical sections.

```c
void producer(int class, int semid, shared_memory* shm) {
    struct sembuf sb;

    while (1) {
        sb.sem_num = 0;
        sb.sem_op = -1;
        sb.sem_flg = 0;
        semop(semid, &sb, 1);

        // Producer logic...

        sb.sem_op = 1;
        semop(semid, &sb, 1);

        sleep(1); // Introduce delay to simulate message
           production
    }
}
```

codeSamples/producer.c

2.4. CONSUMER FUNCTION

The consumer function consumes messages from the shared buffer based on the class. It also utilizes semaphores to ensure proper synchronization.

```c
void consumer(int class, int semid, shared_memory* shm) {
    struct sembuf sb;

    while (1) {
        sb.sem_num = 0;
```

```
        sb.sem_op = -1;
        sb.sem_flg = 0;
        semop(semid, &sb, 1);

        // Consumer logic...

        sb.sem_op = 1;
        semop(semid, &sb, 1);

        sleep(1); // Introduce delay to simulate message
           consumption
    }
}
```

codeSamples/consumer.c

2.5. FORKING PROCESSES

```
for (int i = 1; i <= 4; i++) {
    if (fork() == 0) {
        producer(i <= 2 ? 1 : 2, semid, shm);
        exit(0);
    }
  }

for (int i = 1; i <= 2; i++) {
    if (fork() == 0) {
        consumer(i, semid, shm);
        exit(0);
    }
}
```

codeSamples/fork.c

3. CHALLENGES

During the implementation of the multi-class producer-consumer synchronization system, several challenges were encountered. In this section, we outline the key challenges faced and discuss the strategies employed to address them.

3.1. CHALLENGE 1: SYNCHRONIZATION

One of the primary challenges was achieving effective synchronization among the multiple processes, ensuring that producers and consumers operate correctly without data inconsistencies.

Solution: We implemented semaphore-based synchronization to control access to the shared memory. This approach helped in preventing race conditions and maintaining the integrity of the data.

3.2. CHALLENGE 2: SHARED MEMORY ACCESS

Managing shared memory access and preventing conflicts between processes accessing the shared buffer posed a significant challenge.

Solution: Careful consideration was given to the order of operations, and the use of semaphores was extended to manage access to shared memory. This helped in avoiding conflicts and maintaining the class-based constraints.

3.3. CHALLENGE 3: READING FROM A FILE

Introducing file-based message generation for producers added complexity to the system, requiring adjustments in data flow and synchronization.

Solution: The producer function was modified to read messages from a file and generate messages based on class constraints. Semaphores continued to play a crucial role in ensuring proper synchronization.

4. RESULTS

4.1. SCENARIO 1: CONCURRENT EXECUTION

Observations:

- Producers and consumers worked well together simultaneously.
- No issues observed with messages from the same class.
- The system handled multiple processes without errors.

4.2. SCENARIO 2: STRESS TESTING

Observations:

- The system handled stress conditions effectively.
- No message overflow or system instability during stress tests.

4.3. SCENARIO 3: CLASS-BASED CONSTRAINTS

Observations:

- Producers and consumers respected class constraints.
- Shared memory maintained proper classification.

4.4. SCENARIO 4: ERROR HANDLING

Observations:

- Graceful error handling observed in unexpected events.
- Proper cleanup ensured shared memory release on program termination.

5. CONCLUSION

The multi-class producer-consumer synchronization system successfully met the project requirements. Through testing and observation, several key conclusions can be drawn.

5.1. ACHIEVEMENTS

- The system effectively handled concurrent execution, ensuring proper coordination among producers and consumers.
- Stress testing demonstrated the robustness of the system, with no observable issues under high loads.
- Class-based constraints were maintained, preventing cross-class interactions, and ensuring proper message handling.
- The system adapted seamlessly to reading messages from a file, demonstrating flexibility and expanded functionality.
- The system exhibited graceful error handling, responding well to unexpected events without compromising stability.

5.2. LESSONS LEARNED

This project provided valuable insights into process synchronization and shared memory management. Key takeaways include:

- The importance of using synchronization mechanisms, such as semaphores, to prevent race conditions.
- Proper design considerations for shared memory structures to maintain data integrity.
- The significance of error handling mechanisms for robust system behavior.