Problems on Process Coordination - 1

Group Members
Rahul Padhy (2022201003)
Arun Das (2022201021)
Praddyumn Shukla (2022201001)
Vaibhav Saxena (202220)

Supervisor
Nikhil

Problem 1: The Editors Reporters Problem

- Given the number of editors n and the number of articles m, we have to assign the articles to the editors.
- Each editor will randomly pick an article and then accept or reject it.
- Each editor requires exactly one second to read an article. While reading no other editor can read the same article.
- If an editor is reading an article, other editors should not wait on the same article.
- If an editor accepts an article, no other editor can read it.
- Program ends when there is no article that can be accepted by any editor. Some articles may not be accepted by anyone.

Solution

- Create a semaphore for each article.
- Each editor is run as a different thread.
- Whenever an editor tries to access an article, first lock the semaphore for the article.
- While the article is locked other editors can’t access the article.
- After reading the article, the semaphore is unlocked.
- A list is maintained keeping track of open articles and the articles accepted by the editors.

Preventing Waiting on an Article

- Before accessing the article, first check if the semaphore is already locked.
- This is done using the sem_getvalue function.
- If the article is already locked, pick a different random article.

```
int num = available[rand()%available.size()];
int *buffer = (int *)malloc(sizeof(int));
sem_getvalue(&semaphores[num], buffer);
if(*buffer == 0)
    continue;
```

Results

- Logs are printed to show the actions of the editors.
- The output contains the number of articles picked up by each editor and the indices of the articles picked.
- There are no race conditions or deadlock as semaphores are used and only one editor is allowed to read the article at a time.
- No starvation because a new random article is picked whenever an article is locked.

```
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out 3 6
Editor 1 picked up article 3
Editor 2 picked up article 4
Editor 0 picked up article 0
Editor 0 ACCEPTED article 0
Editor 1 REJECTED article 3
Editor 1 picked up article 5
Editor 2 ACCEPTED article 4
Editor 2 picked up article 3
Editor 0 picked up article 1
Editor 1 ACCEPTED article 5
Editor 1 picked up article 2
Editor 2 ACCEPTED article 3
Editor 0 REJECTED article 1
Editor 2 picked up article 1
Editor 0 has finished its job
Editor 1 ACCEPTED article 2
Editor 2 ACCEPTED article 1
Editor 1 has finished its job
Editor 2 has finished its job
1
1
2
3 6
3
2 4 5
```

Problem 2: The Dish Washing Problem

- There are n taps and n-1 scrubs (one between each consecutive taps).
- There are m students. A student has to wash three utensils in order - his plate, glass and spoon.
- A student should acquire a free tap first and will continue to occupy the same spot until he has washed all utensils. If a person is waiting for a tap, he continues to wait.
- Once a person has found a tap he will look for a free scrubber next to his tap. He must coordinate with his neighbors to finish washing his utensils as fast as possible.
- A plate takes 4 seconds to scrub and 5 seconds to wash.
- A glass takes 3 seconds to scrub and 3 seconds to wash.
- A spoon takes 2 seconds to scrub and 1 second to wash.
- While a person is washing his utensils, his neighbor can scrub his utensils.

Solution

- Create semaphores for each tap and semaphores for each scrubber.
- Each student is a different thread and is randomly assigned a tap at the start.
- A student randomly picks up a scrubber from the left or right side and locks the semaphore.
- After picking up the scrubber sleep is used to simulate the scrubbing.
- After scrubbing unlock the semaphore and start washing.
- While the student is washing a neighbour a neighbour can pick up the unlocked scrubber.
- All three utensils are washed this way.
- A student who waits on a tap keeps waiting until his turn.

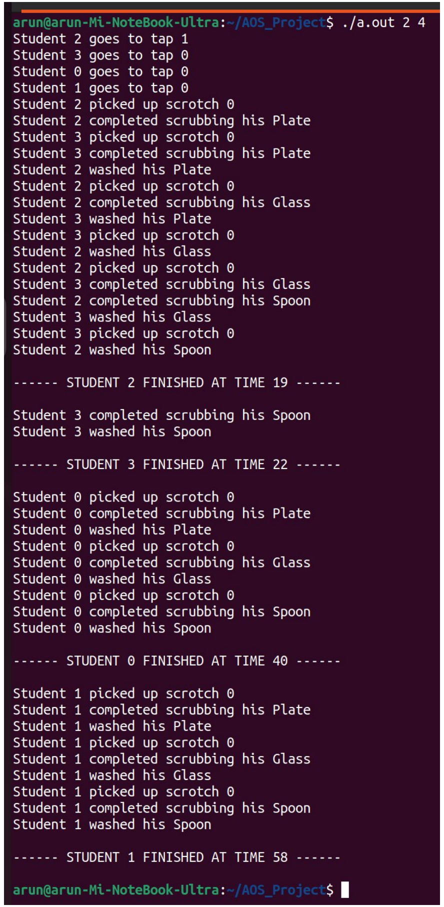
Continually Checking the Left and Right Scrubber

- While waiting for an empty scrubber a student shouldn’t wait on the scrubber on only a particular side.
- Similar to previous question use sem_getvalue to check if the scrubber on one side is locked. If it is, then check the other side and continue while an empty scrubber is not found.

```
if(tap_number != n)
    sem_getvalue(&scrotch[tap_number], buffer);
if(*buffer == 0){
    if(tap_number != 0)
        sem_getvalue(&scrotch[tap_number-1], buffer);
    if(*buffer != 0){
        sem_wait(&scrotch[tap_number-1]);
        acquired_scrotch_number = tap_number-1;
        break;
    }
}
```

Results

- The actions of each student and their finishing times are logged.
- No starvation occurs as all students are randomly assigned a tap at the start and scrubbers are checked continually on both sides.
- There are no deadlocks or race conditions as semaphores are used to acquire a scrubber.



```
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out 2 4
Student 2 goes to tap 1
Student 3 goes to tap 0
Student 0 goes to tap 0
Student 1 goes to tap 0
Student 2 picked up scrotch 0
Student 2 completed scrubbing his Plate
Student 3 picked up scrotch 0
Student 3 completed scrubbing his Plate
Student 2 washed his Plate
Student 2 picked up scrotch 0
Student 2 completed scrubbing his Glass
Student 3 washed his Plate
Student 3 picked up scrotch 0
Student 2 washed his Glass
Student 2 picked up scrotch 0
Student 3 completed scrubbing his Glass
Student 2 completed scrubbing his Spoon
Student 3 washed his Glass
Student 3 picked up scrotch 0
Student 2 washed his Spoon

------ STUDENT 2 FINISHED AT TIME 19 ------

Student 3 completed scrubbing his Spoon
Student 3 washed his Spoon

------ STUDENT 3 FINISHED AT TIME 22 ------

Student 0 picked up scrotch 0
Student 0 completed scrubbing his Plate
Student 0 washed his Plate
Student 0 picked up scrotch 0
Student 0 completed scrubbing his Glass
Student 0 washed his Glass
Student 0 picked up scrotch 0
Student 0 completed scrubbing his Spoon
Student 0 washed his Spoon

------ STUDENT 0 FINISHED AT TIME 40 ------

Student 1 picked up scrotch 0
Student 1 completed scrubbing his Plate
Student 1 washed his Plate
Student 1 picked up scrotch 0
Student 1 completed scrubbing his Glass
Student 1 washed his Glass
Student 1 picked up scrotch 0
Student 1 completed scrubbing his Spoon
Student 1 washed his Spoon

------ STUDENT 1 FINISHED AT TIME 58 ------

arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$
```

Problem 3 : Concurrent Merge Sort

- Given a number n and n numbers, sort the numbers using Merge Sort.
- Recursively make two child processes, one for the left half, one for the right half. If the number of elements in the array for a process is less than 5, perform a selection sort.
- The parent of the two children then merges the result and returns back to the parent and so on.
- Compare the performance of the merge sort with a normal merge sort implementation and make a report.
- You must use the shmget, shmat functions as taught in the tutorial.
- (Bonus) Use threads in place of processes for Concurrent Merge Sort. Add the performance comparison to the above report.

Solution - using normal merge sort

- Firstly, a generic version normal merge sort is implemented, i.e., without any threads or processes.
  - If a partition size is observed to be less than 5, then Selection Sort is applied for that.
- Its observed that this version of merge sort works well enough for input sizes upto 2 * 10^8.

```
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ g++ Q3_Normal_Merge_Sort.cpp
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
1000
Time elapsed : 0 seconds.
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
10000
Time elapsed : 0.003 seconds.
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
100000
Time elapsed : 0.013 seconds.
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
100000000
Time elapsed : 19.349 seconds.
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$
```

Solution - using concurrent merge sort

- Now, a concurrent version of merge sort is implemented.
- The **shmget()** system call allocates a System V shared memory segment and returns the identifier of the memory segment.
- The **shmat()** system call attaches to the shared memory segment specified by the shmget() call above and returns the address of the shared memory segment.
- At each merge_sort step, wherein left and right partitions are made, 2 separate processes are spawned to work upon the corresponding partitions.
    - The restriction being that if a certain partition contains less than 5 elements, then Selection Sort is applied to that partition and for this, no new process is spawned.
- At the end, verification is done using another vector, as to whether the array is actually sorted or not.

Solution - using concurrent merge sort (continued...)

- Beyond a certain limit, this process fails since the system-imposed limit on the total number of processes under execution (which is configuration-dependent) is exceeded.
- The maximum input size for which concurrent merge sort gets executed successfully is :-
  - ~ **2.36 * 10^3** on **OSX M1**.
  - ~ **6.1 * 10 ^ 4** on **Ubuntu 22.04 LTS**.

Solution - using concurrent merge sort (continued...)

```
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ g++ Q3_Concurrent_Merge_Sort.cpp
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
1000

Time elapsed : 0.03 seconds.
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
10000

Time elapsed : 0.685 seconds.
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
20000
Error in Fork for leftChild!!
Error in Fork for rightChild!!
Error in Fork for rightChild!!
Error in Fork for leftChild!!
Error in Fork for rightChild!!
```

Solution using multithreaded merge sort

- In this case, at each merge_sort step, 2 threads are created for sorting the left and right partitions.
    - With the restriction being that, if the partition size is less than 5, then selection sort is used to sort that partition.
- But it can be noted that beyond a certain input size, this method fails too due to the restriction on the number of threads that can be spawned.
- The maximum input size for which this procedure executes properly is :
    - ~ **2.1 * 10^4** on **OSX M1**.
    - ~ **10^5** on **Ubuntu 22.04 LTS**.

Solution using multithreaded merge sort

```
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ g++ Q3_Multithreaded_Merge_Sort.cpp
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
1000

Time elapsed : 0.021 seconds.
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
10000

Time elapsed : 0.072 seconds.
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
20000

Time elapsed : 0.141 seconds.
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
40000

Time elapsed : 0.285 seconds.
arun@arun-Mi-NoteBook-Ultra:~/AOS_Project$ ./a.out
100000
Unable to create thread for left child!!Unable to create thread for right child!!Unable to create thread for right child!!
Unable to create thread for left child!!
```

Learnings from the project

- While its definitely worthwhile to try out multiprocessing and multithreading in order to speed-up applications, but there is a limit on the maximum number of processes or threads that can be spawned in a given system.
    - Increasing the number of threads or processes beyond a certain limit can decrease the performance due to too many context switches and process synchronisations.
- Care must be taken to ensure that sempahores must be used properly when shared memory comes into the picture, so as not to get ambiguous results.

Github Link for source codes and Readmes

- https://github.com/JimHalpert26/AOS_Project

THANK YOU!!!