**Theater Ticket Sales Using Synchronization**

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Abstract – For this project, we decided to simulate the transactions of a movie theater ticket booth. There is a salesman that sells the ticket, and a customer service representative that handles returns. We use semaphores in our version of the producer / consumer problem. The theater starts the day with a certain number of tickets available to sell. The number of tickets sold and returned each day is random, as it is in the real world. The program ends when the tickets are sold out. The use of semaphores is necessary when using shared memory, since we must ensure only one process can modify the data at a time.

1. INTRODUCTION

We chose the topic of this project since we were interested in how semaphores are used in real-world applications. Synchronization is required when using shared memory to ensure that the shared resources are protected from unwanted modification. Theaters make their money by selling tickets and overpriced snacks. Theaters also allow the customer to change their mind and return their purchased tickets. With most real-world applications, synchronization is going to be required. This is especially true in fields such as finance, as well as many other areas. We can accomplish synchronization with the use of semaphores.

At the start of the day, the theater has a set number of tickets that it may sell. To avoid a never-ending program, for this experiment, we will assume that it is a very busy theater, and it will sell out of tickets before the end of the day. At the ticket booth, there is a salesman that sells the tickets to the customer. There is also a customer service representative that is responsible for accepting returns of previously bought tickets. We will use synchronization to ensure that there is no discrepancy in the number of tickets currently available.

We modeled this program after the producer / consumer problem. We will let the salesman represent the consumer process. There is a limit on the number of tickets that can be sold per transaction. When the tickets are sold, the number of tickets available will decrease. We let the customer service representative act as the producer process. There is also a limit on the number of tickets that can be returned per transaction. When the tickets are returned, the number of tickets available will increase.

The program ends when the number of tickets available reaches zero. We use semaphores to ensure that the processes can only access the shared memory segment one at a time. This allows the salesman and the customer service representative to access and modify the shared number of tickets available simultaneously without adversely affecting the other.

1. METHODOLOGY

The algorithm that we used is based on the producer / consumer problem. Semaphores are used to protect the shared variable representing the number of tickets available. We use two separate threads; one is the customer returning the tickets, the other is the buyer.

We wrote this program in C under the Linux environment (Ubuntu 16.04) and it is compiled using GCC (7.2.0) and the required Linux multithreading flags (-lpthread -lrt).

When the program is built and ready to run, the user can run the program without any command line arguments, and it will assume that the maximum number of tickets are available (5000). The user has the option of giving an integer value as a command line argument, and that will be the number of tickets available.

The semaphores are initialized, and the threads are created for each function. The refund function buys the tickets back from the customer if they wish to return them. While there are tickets available for sale, we wait briefly using nanosleep, and choose a random number between 1 and 4 inclusively. If we did not have this condition, the theater would never close, since they could always buy back the tickets. We can think of this as not allowing returns after the movie has already been shown. We protect the critical section of the loop with semaphores. The critical section updates the number of tickets available after the return transaction. We then release the semaphores and exit the thread.

The buy function sells tickets to the customer while there are still tickets available. We wait briefly using nanosleep, and choose a random number between 1 and 8 inclusively. If there are not enough tickets available to complete the transaction, the sale is declined. We protect the critical section of the loop with semaphores. The critical section updates the number of tickets available after the transaction is completed. We then release the semaphores and exit the thread.

After the threads are finished, we delete the semaphores, and end the program. We get random results since the number of sales and returns vary with each run of the program as we will see in the next section.

1. RESULTS

We will show a few runs of our program here. The first run has an argument of 55.

compgeo@compgeo-VirtualBox:~/Downloads/theater-project-Paul$ make

gcc -o theater theater.c -lpthread -lrt

compgeo@compgeo-VirtualBox:~/Downloads/theater-project-Paul$ ./theater 55

Theater Box Office is now open! Tickets available: 55

8 tickets sold Total tickets available = 47

2 tickets sold Total tickets available = 45

4 tickets sold Total tickets available = 41

2 tickets sold Total tickets available = 39

8 tickets sold Total tickets available = 31

3 tickets sold Total tickets available = 28

5 tickets sold Total tickets available = 23

2 tickets sold Total tickets available = 21

6 tickets sold Total tickets available = 15

3 tickets sold Total tickets available = 12

3 tickets returned Total tickets available = 15

3 tickets returned Total tickets available = 18

4 tickets returned Total tickets available = 22

4 tickets returned Total tickets available = 26

3 tickets returned Total tickets available = 29

1 tickets returned Total tickets available = 30

3 tickets returned Total tickets available = 33

1 tickets returned Total tickets available = 34

1 tickets returned Total tickets available = 35

4 tickets returned Total tickets available = 39

4 tickets sold Total tickets available = 35

8 tickets sold Total tickets available = 27

6 tickets sold Total tickets available = 21

7 tickets sold Total tickets available = 14

3 tickets sold Total tickets available = 11

7 tickets sold Total tickets available = 4

4 tickets sold Total tickets available = 0

Tickets Sold Out!

The second run has an argument of 150.

compgeo@compgeo-VirtualBox:~/Downloads/theater-project-Paul$ ./theater 150

Theater Box Office is now open! Tickets available: 150

7 tickets sold Total tickets available = 143

2 tickets sold Total tickets available = 141

4 tickets sold Total tickets available = 137

2 tickets sold Total tickets available = 135

8 tickets sold Total tickets available = 127

3 tickets sold Total tickets available = 124

5 tickets sold Total tickets available = 119

2 tickets sold Total tickets available = 117

6 tickets sold Total tickets available = 111

3 tickets sold Total tickets available = 108

4 tickets sold Total tickets available = 104

3 tickets sold Total tickets available = 101

4 tickets returned Total tickets available = 105

4 tickets returned Total tickets available = 109

3 tickets returned Total tickets available = 112

1 tickets returned Total tickets available = 113

3 tickets returned Total tickets available = 116

1 tickets returned Total tickets available = 117

1 tickets returned Total tickets available = 118

4 tickets returned Total tickets available = 122

1 tickets returned Total tickets available = 123

4 tickets returned Total tickets available = 127

2 tickets returned Total tickets available = 129

3 tickets returned Total tickets available = 132

4 tickets sold Total tickets available = 128

7 tickets sold Total tickets available = 121

4 tickets sold Total tickets available = 117

3 tickets returned Total tickets available = 120

4 tickets returned Total tickets available = 124

2 tickets returned Total tickets available = 126

4 tickets sold Total tickets available = 122

7 tickets sold Total tickets available = 115

3 tickets sold Total tickets available = 112

6 tickets sold Total tickets available = 106

8 tickets sold Total tickets available = 98

2 tickets sold Total tickets available = 96

1 tickets sold Total tickets available = 95

3 tickets returned Total tickets available = 98

3 tickets returned Total tickets available = 101

2 tickets returned Total tickets available = 103

2 tickets returned Total tickets available = 105

2 tickets returned Total tickets available = 107

4 tickets returned Total tickets available = 111

1 tickets returned Total tickets available = 112

4 tickets sold Total tickets available = 108

7 tickets sold Total tickets available = 101

2 tickets returned Total tickets available = 103

4 tickets returned Total tickets available = 107

5 tickets sold Total tickets available = 102

6 tickets sold Total tickets available = 96

7 tickets sold Total tickets available = 89

4 tickets sold Total tickets available = 85

5 tickets sold Total tickets available = 80

5 tickets sold Total tickets available = 75

2 tickets sold Total tickets available = 73

7 tickets sold Total tickets available = 66

3 tickets returned Total tickets available = 69

1 tickets returned Total tickets available = 70

2 tickets returned Total tickets available = 72

2 tickets returned Total tickets available = 74

2 tickets returned Total tickets available = 76

1 tickets returned Total tickets available = 77

3 tickets sold Total tickets available = 74

1 tickets sold Total tickets available = 73

2 tickets sold Total tickets available = 71

7 tickets sold Total tickets available = 64

2 tickets sold Total tickets available = 62

2 tickets sold Total tickets available = 60

2 tickets sold Total tickets available = 58

5 tickets sold Total tickets available = 53

8 tickets sold Total tickets available = 45

7 tickets sold Total tickets available = 38

2 tickets sold Total tickets available = 36

7 tickets sold Total tickets available = 29

4 tickets returned Total tickets available = 33

3 tickets returned Total tickets available = 36

8 tickets sold Total tickets available = 28

4 tickets sold Total tickets available = 24

7 tickets sold Total tickets available = 17

8 tickets sold Total tickets available = 9

1 tickets sold Total tickets available = 8

5 tickets sold Total tickets available = 3

1 tickets returned Total tickets available = 4

1 tickets returned Total tickets available = 5

1 tickets returned Total tickets available = 6

4 tickets returned Total tickets available = 10

4 tickets returned Total tickets available = 14

3 tickets returned Total tickets available = 17

4 tickets returned Total tickets available = 21

1 tickets returned Total tickets available = 22

1 tickets returned Total tickets available = 23

1 tickets returned Total tickets available = 24

1 tickets returned Total tickets available = 25

4 tickets returned Total tickets available = 29

1 tickets returned Total tickets available = 30

3 tickets returned Total tickets available = 33

3 tickets returned Total tickets available = 36

3 tickets returned Total tickets available = 39

4 tickets returned Total tickets available = 43

4 tickets returned Total tickets available = 47

3 tickets sold Total tickets available = 44

3 tickets sold Total tickets available = 41

3 tickets sold Total tickets available = 38

4 tickets sold Total tickets available = 34

2 tickets sold Total tickets available = 32

2 tickets sold Total tickets available = 30

7 tickets sold Total tickets available = 23

6 tickets sold Total tickets available = 17

5 tickets sold Total tickets available = 12

5 tickets sold Total tickets available = 7

5 tickets sold Total tickets available = 2

Sorry, there are only 2 tickets left for sale. We cannot sell you 6 tickets.

1 tickets sold Total tickets available = 1

Sorry, there are only 1 tickets left for sale. We cannot sell you 7 tickets.

Sorry, there are only 1 tickets left for sale. We cannot sell you 2 tickets.

Sorry, there are only 1 tickets left for sale. We cannot sell you 2 tickets.

3 tickets returned Total tickets available = 4

1 tickets returned Total tickets available = 5

4 tickets returned Total tickets available = 9

2 tickets sold Total tickets available = 7

2 tickets sold Total tickets available = 5

Sorry, there are only 5 tickets left for sale. We cannot sell you 8 tickets.

1 tickets returned Total tickets available = 6

2 tickets returned Total tickets available = 8

4 tickets returned Total tickets available = 12

2 tickets returned Total tickets available = 14

4 tickets returned Total tickets available = 18

2 tickets returned Total tickets available = 20

4 tickets returned Total tickets available = 24

4 tickets returned Total tickets available = 28

1 tickets returned Total tickets available = 29

2 tickets returned Total tickets available = 31

2 tickets returned Total tickets available = 33

6 tickets sold Total tickets available = 27

6 tickets sold Total tickets available = 21

3 tickets sold Total tickets available = 18

4 tickets sold Total tickets available = 14

4 tickets sold Total tickets available = 10

1 tickets sold Total tickets available = 9

1 tickets sold Total tickets available = 8

8 tickets sold Total tickets available = 0

Tickets Sold Out!

The third run uses the default max value of 5000. Although 5000, is unrealistic for the number of tickets a theater will sell, it is used for demonstrative purposes only.

compgeo@compgeo-VirtualBox:~/Downloads/theater-project-Paul$ ./theater

Theater Box Office is now open! Tickets available: 5000

8 tickets sold Total tickets available = 4992

2 tickets sold Total tickets available = 4990

4 tickets sold Total tickets available = 4986

2 tickets sold Total tickets available = 4984

8 tickets sold Total tickets available = 4976

3 tickets sold Total tickets available = 4973

5 tickets sold Total tickets available = 4968

2 tickets sold Total tickets available = 4966

6 tickets sold Total tickets available = 4960

3 tickets sold Total tickets available = 4957

4 tickets sold Total tickets available = 4953

3 tickets sold Total tickets available = 4950

4 tickets sold Total tickets available = 4946

4 tickets sold Total tickets available = 4942

7 tickets sold Total tickets available = 4935

5 tickets sold Total tickets available = 4930

3 tickets sold Total tickets available = 4927

5 tickets sold Total tickets available = 4922

1 tickets sold Total tickets available = 4921

4 tickets sold Total tickets available = 4917

1 tickets sold Total tickets available = 4916

3 tickets returned Total tickets available = 4919

2 tickets returned Total tickets available = 4921

8 tickets sold Total tickets available = 4913

3 tickets returned Total tickets available = 4916

3 tickets returned Total tickets available = 4919

3 tickets sold Total tickets available = 4916

4 tickets sold Total tickets available = 4912

8 tickets sold Total tickets available = 4904

2 tickets sold Total tickets available = 4902

3 tickets sold Total tickets available = 4899

7 tickets sold Total tickets available = 4892

3 tickets sold Total tickets available = 4889

6 tickets sold Total tickets available = 4883

8 tickets sold Total tickets available = 4875

2 tickets sold Total tickets available = 4873

1 tickets sold Total tickets available = 4872

4 tickets sold Total tickets available = 4868

3 tickets sold Total tickets available = 4865

6 tickets sold Total tickets available = 4859

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1 tickets sold Total tickets available = 87

1 tickets returned Total tickets available = 88

1 tickets returned Total tickets available = 89

4 tickets sold Total tickets available = 85

8 tickets sold Total tickets available = 77

5 tickets sold Total tickets available = 72

3 tickets returned Total tickets available = 75

1 tickets returned Total tickets available = 76

2 tickets returned Total tickets available = 78

5 tickets sold Total tickets available = 73

7 tickets sold Total tickets available = 66

3 tickets sold Total tickets available = 63

8 tickets sold Total tickets available = 55

5 tickets sold Total tickets available = 50

4 tickets sold Total tickets available = 46

5 tickets sold Total tickets available = 41

7 tickets sold Total tickets available = 34

2 tickets sold Total tickets available = 32

7 tickets sold Total tickets available = 25

6 tickets sold Total tickets available = 19

1 tickets sold Total tickets available = 18

4 tickets sold Total tickets available = 14

6 tickets sold Total tickets available = 8

8 tickets sold Total tickets available = 0

Tickets Sold Out!

1. CONCLUSION

It can be seen that every time the program is run, the number of tickets sold and returned vary. It is also noted that they are quite often sold and returned in chunks, rather than interspersed throughout the others.