### Post Office Simulation Summary

A Post Office is simulated by using threads to model customer and employee behavior. There are 50 customers who can visit the post office. One thread per each customer is created initially. Only 10 customers can be inside the post office at a time. When a customer is created, a task out of buying stamps, mailing a letter, and mail a package, is randomly assigned. The buying stamps takes 60 seconds, mailing a letter takes 90 seconds, and mailing a package takes 120 seconds, to complete. There are three postal workers inside the post office, one thread per each worker, are created initially. The postal worker serves the next customer in the line. The service time depends upon the customer task. Scales is a resource the postal worker threads use. It is used when a postal worker is mailing a package. There is only one resource of scales, which can only be used by one postal worker at a time. During the implementation, a thread should sleep 1 second in the program for each 60 seconds of the task. Each thread should print its own activities. Each thread is printed when its created and when its joined.

The project is implemented in C language. There are mainly three functions in this project. They are function for customer thread, function for postal worker thread, and the main function. The semaphores used in this project, their use, and the design are mentioned in the Design document.

The customer thread function: There are 50 customer threads. This function prints that the thread for the customer has been created. A random task will be assigned when a customer is created. 10 customers can be in the post office at a time. Remaining threads wait on maximum capacity semaphore. Then the customer waits for the postal worker ready. When the postal worker signals, the customer IDs are enqueued. The customer IDs are protected mutex1. Then the customer waits for the postal worker to let the customer to place the order. Then the customer enqueues the order and signals the postal worker to process the order. The tasks are protected by mutex3. Then the customer waits for the postal worker to finish the task and to signal that the task is completed. Then customer leaves the post office. Then the customer signals another customer who is waiting on the maximum capacity semaphore to enter the post office. Then another customer who is waiting outside enters the post office. All the activities, which are done by the customer thread are printed, whenever that activity is completed.

The postal worker thread function: There are 3 postal worker threads. This function prints that the postal worker is created initially. The postal worker initially signals that he is ready. Then he waits for the next customer in line to be ready. When the next customer in the line is ready, the postal worker dequeues the customer ID and start servicing that customer. Then he signals the customer to place the order and then dequeues the order to process that task. If the task is mailing a package, then the postal worker waits for the scales to be ready, if it is in use by another postal worker. If a postal worker holds scales and if its usage is done, then he releases it for another postal worker. For buying the stamps, the thread sleeps for 1 second, for mailing a letter, it sleeps 1.5 seconds and for mailing a package it sleeps 2 seconds. When the task is completed, then the postal worker signals the customer that the task is completed and he can leave the office. All the activities, which are done by the postal worker thread are printed, whenever that activity is completed.

The main function: The main function is responsible for the creation of the threads and joining them. In this function, all the semaphores are initialized and pipes are created. 3 postal worker threads and 50 customer threads are created initially. The customer threads are joined whenever they exit.

The other functions used are

sleepMs(): is used for sleeping purpose in milliseconds.

printTask(): is used to print the customer task.

printFinishTask(): is used to print that the customer finished his task.

threadSleep(): is used for threads sleeping for each task.

enqueue(): is used for enqueue of tasks, customer IDs and worker IDs.

dequeue(): is used for dequeue of tasks, customer IDs and worker IDs.

There are some difficulties I faced in this project. Initially it was designing the customer and the postal worker threads, how many semaphores needed. Later achieving coordination among the threads and to communicate among them, and using semaphores achieving mutual exclusion. In this project, I learned the creation of threads, communication and coordination among the threads, to use semaphores and how to implement mutual exclusion using semaphores and joining the threads.

Results: The following is an output when run on Linux environment. The order of the threads may be different based on the order of which the threads created at first and begin processing.

Sample Output:

Simulating Post Office with 50 customers and 3 postal workers

Postal worker 0 created

Postal worker 1 created

Postal worker 2 created

Customer 0 created

Customer 0 enters post office

Customer 1 created

Customer 1 enters post office

Customer 2 created

Customer 2 enters post office

Customer 3 created

Customer 3 enters post office

Postal worker 2 serving customer 0

Customer 0 asks postal worker 2 to mail a letter

Postal worker 1 serving customer 2

Postal worker 0 serving customer 1

Customer 2 asks postal worker 1 to buy stamps

Customer 4 created

Customer 1 asks postal worker 0 to mail a letter

Customer 7 created

Customer 4 enters post office

Customer 7 enters post office

Customer 5 created

Customer 5 enters post office

Customer 6 created

Customer 6 enters post office

Customer 8 created

Customer 8 enters post office

Customer 9 created

Customer 9 enters post office

Customer 10 created

Customer 11 created

Customer 12 created

Customer 13 created

Customer 14 created

Customer 15 created

Customer 16 created

Customer 17 created

Customer 18 created

Customer 19 created

Customer 20 created

Customer 21 created

Customer 22 created

Customer 23 created

Customer 24 created

Customer 25 created

Customer 26 created

Customer 27 created

Customer 28 created

Customer 29 created

Customer 30 created

Customer 31 created

Customer 32 created

Customer 33 created

Customer 34 created

Customer 35 created

Customer 36 created

Customer 37 created

Customer 38 created

Customer 39 created

Customer 40 created

Customer 41 created

Customer 42 created

Customer 43 created

Customer 44 created

Customer 45 created

Customer 46 created

Customer 47 created

Customer 48 created

Customer 49 created

Postal worker 1 finished serving customer 2

Postal worker 1 serving customer 3

Customer 2 finished buying stamps

Customer 2 leaves the post office

Customer 3 asks postal worker 1 to mail a letter

Customer 10 enters post office

Postal worker 2 finished serving customer 0

Postal worker 0 finished serving customer 1

Postal worker 2 serving customer 4

Customer 0 finished mailing a letter

Customer 4 asks postal worker 2 to mail a package

Postal worker 0 serving customer 7

Customer 0 leaves the post office

Scales in use by postal worker 2

Customer 7 asks postal worker 0 to mail a letter

Customer 11 enters post office

Customer 1 finished mailing a letter

Customer 1 leaves the post office

Joined customer 0

Joined customer 1

Joined customer 2

Customer 12 enters post office

Postal worker 1 finished serving customer 3

Postal worker 1 serving customer 5

Customer 3 finished mailing a letter

Customer 5 asks postal worker 1 to mail a letter

Customer 3 leaves the post office

Joined customer 3

Customer 13 enters post office

Postal worker 0 finished serving customer 7

Customer 7 finished mailing a letter

Customer 7 leaves the post office

Customer 14 enters post office

Postal worker 0 serving customer 6

Customer 6 asks postal worker 0 to buy stamps

Scales released by postal worker 2

Postal worker 2 finished serving customer 4

Customer 4 finished mailing a package

Customer 4 leaves the post office

Postal worker 2 serving customer 8

Customer 8 asks postal worker 2 to buy stamps

Customer 15 enters post office

Joined customer 4

Postal worker 1 finished serving customer 5

Postal worker 0 finished serving customer 6

Customer 5 finished mailing a letter

Customer 5 leaves the post office

Customer 6 finished buying stamps

Customer 6 leaves the post office

Customer 17 enters post office

Joined customer 5

Postal worker 0 serving customer 9

Customer 16 enters post office

Joined customer 6

Customer 9 asks postal worker 0 to mail a letter

Joined customer 7

Postal worker 1 serving customer 10

Customer 10 asks postal worker 1 to mail a package

Scales in use by postal worker 1

Postal worker 2 finished serving customer 8

Customer 8 finished buying stamps

Customer 8 leaves the post office

Postal worker 2 serving customer 11

Customer 18 enters post office

Customer 11 asks postal worker 2 to mail a letter

Joined customer 8

Postal worker 0 finished serving customer 9

Customer 9 finished mailing a letter

Customer 9 leaves the post office

Postal worker 0 serving customer 12

Customer 19 enters post office

Customer 12 asks postal worker 0 to mail a package

Joined customer 9

Postal worker 2 finished serving customer 11

Customer 11 finished mailing a letter

Customer 11 leaves the post office

Postal worker 2 serving customer 13

Customer 13 asks postal worker 2 to mail a letter

Customer 20 enters post office

Scales released by postal worker 1

Postal worker 1 finished serving customer 10

Scales in use by postal worker 0

Customer 10 finished mailing a package

Customer 10 leaves the post office

Customer 21 enters post office

Postal worker 1 serving customer 14

Joined customer 10

Customer 14 asks postal worker 1 to mail a package

Joined customer 11

Postal worker 2 finished serving customer 13

Customer 13 finished mailing a letter

Customer 13 leaves the post office

Customer 22 enters post office

Postal worker 2 serving customer 15

Customer 15 asks postal worker 2 to mail a letter

Scales released by postal worker 0

Postal worker 0 finished serving customer 12

Scales in use by postal worker 1

Customer 12 finished mailing a package

Customer 12 leaves the post office

Postal worker 0 serving customer 17

Customer 17 asks postal worker 0 to buy stamps

Customer 23 enters post office

Joined customer 12

Joined customer 13

Postal worker 0 finished serving customer 17

Postal worker 2 finished serving customer 15

Customer 17 finished buying stamps

Customer 17 leaves the post office

Customer 24 enters post office

Postal worker 2 serving customer 16

Customer 15 finished mailing a letter

Postal worker 0 serving customer 18

Customer 15 leaves the post office

Customer 18 asks postal worker 0 to mail a letter

Customer 16 asks postal worker 2 to buy stamps

Customer 25 enters post office

Scales released by postal worker 1

Postal worker 1 finished serving customer 14

Customer 14 finished mailing a package

Customer 14 leaves the post office

Postal worker 1 serving customer 19

Customer 26 enters post office

Customer 19 asks postal worker 1 to mail a letter

Joined customer 14

Joined customer 15

Postal worker 2 finished serving customer 16

Customer 16 finished buying stamps

Customer 16 leaves the post office

Customer 27 enters post office

Postal worker 2 serving customer 20

Joined customer 16

Customer 20 asks postal worker 2 to mail a package

Joined customer 17

Scales in use by postal worker 2

Postal worker 0 finished serving customer 18

Customer 18 finished mailing a letter

Customer 18 leaves the post office

Postal worker 0 serving customer 21

Customer 28 enters post office

Joined customer 18

Customer 21 asks postal worker 0 to mail a package

Postal worker 1 finished serving customer 19

Customer 19 finished mailing a letter

Customer 19 leaves the post office

Postal worker 1 serving customer 22

Customer 22 asks postal worker 1 to buy stamps

Joined customer 19

Customer 29 enters post office

Scales released by postal worker 2

Postal worker 2 finished serving customer 20

Customer 20 finished mailing a package

Postal worker 2 serving customer 23

Customer 23 asks postal worker 2 to buy stamps

Customer 20 leaves the post office

Scales in use by postal worker 0

Customer 30 enters post office

Joined customer 20

Postal worker 1 finished serving customer 22

Customer 22 finished buying stamps

Customer 22 leaves the post office

Postal worker 1 serving customer 24

Customer 31 enters post office

Customer 24 asks postal worker 1 to mail a package

Postal worker 2 finished serving customer 23

Customer 23 finished buying stamps

Customer 23 leaves the post office

Postal worker 2 serving customer 25

Customer 25 asks postal worker 2 to mail a package

Customer 32 enters post office

Scales released by postal worker 0

Postal worker 0 finished serving customer 21

Scales in use by postal worker 1

Postal worker 0 serving customer 26

Customer 21 finished mailing a package

Customer 26 asks postal worker 0 to mail a package

Customer 21 leaves the post office

Customer 33 enters post office

Joined customer 21

Joined customer 22

Joined customer 23

Scales released by postal worker 1

Postal worker 1 finished serving customer 24

Customer 24 finished mailing a package

Postal worker 1 serving customer 27

Customer 27 asks postal worker 1 to mail a letter

Customer 24 leaves the post office

Customer 34 enters post office

Scales in use by postal worker 2

Joined customer 24

Postal worker 1 finished serving customer 27

Customer 27 finished mailing a letter

Customer 27 leaves the post office

Postal worker 1 serving customer 28

Customer 35 enters post office

Customer 28 asks postal worker 1 to mail a letter

Scales released by postal worker 2

Postal worker 2 finished serving customer 25

Scales in use by postal worker 0

Customer 25 finished mailing a package

Customer 25 leaves the post office

Postal worker 2 serving customer 29

Customer 29 asks postal worker 2 to mail a letter

Customer 36 enters post office

Joined customer 25

Postal worker 1 finished serving customer 28

Customer 28 finished mailing a letter

Customer 28 leaves the post office

Postal worker 1 serving customer 30

Customer 37 enters post office

Customer 30 asks postal worker 1 to mail a package

Postal worker 2 finished serving customer 29

Customer 29 finished mailing a letter

Customer 29 leaves the post office

Customer 38 enters post office

Postal worker 2 serving customer 31

Customer 31 asks postal worker 2 to buy stamps

Scales released by postal worker 0

Postal worker 0 finished serving customer 26

Scales in use by postal worker 1

Customer 26 finished mailing a package

Customer 26 leaves the post office

Customer 39 enters post office

Joined customer 26

Postal worker 0 serving customer 32

Joined customer 27

Customer 32 asks postal worker 0 to buy stamps

Joined customer 28

Joined customer 29

Postal worker 2 finished serving customer 31

Customer 31 finished buying stamps

Customer 31 leaves the post office

Postal worker 2 serving customer 33

Customer 40 enters post office

Customer 33 asks postal worker 2 to buy stamps

Postal worker 0 finished serving customer 32

Customer 32 finished buying stamps

Customer 32 leaves the post office

Postal worker 0 serving customer 34

Customer 41 enters post office

Customer 34 asks postal worker 0 to mail a package

Postal worker 2 finished serving customer 33

Customer 33 finished buying stamps

Customer 33 leaves the post office

Postal worker 2 serving customer 35

Customer 42 enters post office

Customer 35 asks postal worker 2 to buy stamps

Scales released by postal worker 1

Postal worker 1 finished serving customer 30

Scales in use by postal worker 0

Customer 30 finished mailing a package

Customer 30 leaves the post office

Postal worker 1 serving customer 36

Customer 36 asks postal worker 1 to mail a letter

Customer 43 enters post office

Joined customer 30

Joined customer 31

Joined customer 32

Joined customer 33

Postal worker 2 finished serving customer 35

Customer 35 finished buying stamps

Customer 35 leaves the post office

Postal worker 2 serving customer 37

Customer 44 enters post office

Customer 37 asks postal worker 2 to mail a letter

Postal worker 1 finished serving customer 36

Customer 36 finished mailing a letter

Customer 36 leaves the post office

Postal worker 1 serving customer 38

Customer 45 enters post office

Customer 38 asks postal worker 1 to mail a letter

Scales released by postal worker 0

Postal worker 0 finished serving customer 34

Customer 34 finished mailing a package

Customer 34 leaves the post office

Postal worker 0 serving customer 39

Customer 39 asks postal worker 0 to mail a letter

Customer 46 enters post office

Joined customer 34

Joined customer 35

Joined customer 36

Postal worker 2 finished serving customer 37

Customer 37 finished mailing a letter

Customer 37 leaves the post office

Customer 47 enters post office

Postal worker 2 serving customer 40

Joined customer 37

Customer 40 asks postal worker 2 to buy stamps

Postal worker 1 finished serving customer 38

Customer 38 finished mailing a letter

Customer 38 leaves the post office

Postal worker 1 serving customer 41

Customer 41 asks postal worker 1 to buy stamps

Customer 48 enters post office

Joined customer 38

Postal worker 2 finished serving customer 40

Customer 40 finished buying stamps

Customer 40 leaves the post office

Postal worker 2 serving customer 42

Customer 42 asks postal worker 2 to buy stamps

Customer 49 enters post office

Postal worker 0 finished serving customer 39

Customer 39 finished mailing a letter

Customer 39 leaves the post office

Postal worker 0 serving customer 43

Customer 43 asks postal worker 0 to mail a package

Joined customer 39

Scales in use by postal worker 0

Joined customer 40

Postal worker 1 finished serving customer 41

Customer 41 finished buying stamps

Customer 41 leaves the post office

Postal worker 1 serving customer 44

Customer 44 asks postal worker 1 to mail a package

Joined customer 41

Postal worker 2 finished serving customer 42

Postal worker 2 serving customer 45

Customer 42 finished buying stamps

Customer 42 leaves the post office

Customer 45 asks postal worker 2 to mail a letter

Joined customer 42

Scales released by postal worker 0

Postal worker 0 finished serving customer 43

Customer 43 finished mailing a package

Customer 43 leaves the post office

Scales in use by postal worker 1

Postal worker 0 serving customer 46

Joined customer 43

Customer 46 asks postal worker 0 to mail a package

Postal worker 2 finished serving customer 45

Customer 45 finished mailing a letter

Customer 45 leaves the post office

Postal worker 2 serving customer 47

Customer 47 asks postal worker 2 to mail a package

Scales released by postal worker 1

Postal worker 1 finished serving customer 44

Scales in use by postal worker 0

Customer 44 finished mailing a package

Customer 44 leaves the post office

Postal worker 1 serving customer 48

Joined customer 44

Customer 48 asks postal worker 1 to mail a package

Joined customer 45

Scales released by postal worker 0

Postal worker 0 finished serving customer 46

Scales in use by postal worker 2

Customer 46 finished mailing a package

Customer 46 leaves the post office

Joined customer 46

Postal worker 0 serving customer 49

Customer 49 asks postal worker 0 to buy stamps

Postal worker 0 finished serving customer 49

Customer 49 finished buying stamps

Customer 49 leaves the post office

Scales released by postal worker 2

Postal worker 2 finished serving customer 47

Customer 47 finished mailing a package

Customer 47 leaves the post office

Scales in use by postal worker 1

Joined customer 47

Scales released by postal worker 1

Postal worker 1 finished serving customer 48

Customer 48 finished mailing a package

Customer 48 leaves the post office

Joined customer 48

Joined customer 49