**Summary**

**Simulation**

In this project, the simulation of post office was implemented by semaphore and threads. The project programmed in JAVA and Eclipse neon.2 IDE. The java JDK used is 1.8. I created three java classes as following: a main class “PO” where the main method and the execution first starts, and another two class “PWorker” and “Customer” simulate postal behavior of a worker and a customer, respectively. PWorker and Customer implements Runnable interface. Both instances of PWorker and Customer is created in main class PO. When a new instance is created, then a new thread of PWorker or Customer is started. Instances of PWoker and Customer can interact with each other to perform simulated behavior like in post office, all of their behaviors will be displayed as result of println function on the console. To ensure the rules of this post office that there will be at most 10 customers in the post office at one time, there are three workers in the post office and each worker can serve only on customer, and there is only one scaler in the post office where can be occupied by only one worker at one time, different semaphores are created. Semaphores are also applied to enforce mutual exclusion between postal worker and customer.

In the run method of Customer Class, an instance of Customer class is created while less than 10 customers is the post office and the customer number is less than 50. A created customer wait signal for available room in the post office (10 at most). Then a customer enters the post office, wait for static variables in PO class available (customer number, worker number, and service type). Then get static information from PO class. Then signal worker with corresponding worker number to start to acquire static information (customer number and service type). Wait until worker successfully get static information and allows worker to begin working on that service. Signal to static variables for next customer and assign new workers. After getting the signal from worker that the service is done, notice worker that this customer leaves post office and allows one more customer to enter the post office.

In the run method of PWorker class, after a new worker is created, wait for next available customer. When receive signal of corresponded semaphore from an available customer, get information of that customer (customer number and service type) and notice that customer. Then wait for permission to start service from customer. After permission acquired, start service based on requested type. If the service type is mailing a package, first to wait until the scaler is available. After receiving the available signal, start mailing that package. When service is done, worker signal the customer to leave. Then wait until that customer leave and then allow the post office can have one more customer entered.

**Difficulties**

The biggest problems that I have encountered is to enforce mutual exclusion. At first time, I fail create mutex semaphores to protect the static variables and make a tie between one customer and one worker. In that case, the output is always messed up. The output is like a worker serve many customers at one time, and a customer also be serve by multiple worker at one time. Another difficulty in this project is to decide the right order of signal and wait functions of semaphores, fails to have a proper order may also fail to achieve mutual exclusion.

**Learned from this project**

From this project, I learned a great deal in how to place semaphore to enforce mutual exclusion and multi-threading interaction. The project helped me learn deeply what is mutex semaphore and how it works. Also the I learned a lot in how to do multithreading programming and enforce concurrency in JAVA.

**Result**

Simulating Post Office with 50 customers and 3 postal workers

Customer 0 created

Customer 1 created

Customer 2 created

Customer 3 created

Customer 4 created

Customer 5 created

Customer 6 created

Customer 7 created

Customer 8 created

Customer 9 created

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 0 created.

Postal worker 1 created.

Postal worker 2 created.

Customer 0 asks postal worker 1 to mail a package

Customer 1 asks postal worker 0 to buy stamps

scale in use by postal worker 1

Customer 2 asks postal worker 2 to buy stamps

Postal worker 0 finished serving customer 1

Customer 1 leaves post office

Customer 3 asks postal worker 0 to mail a letter

Postal worker 2 finished serving customer 2

Customer 2 leaves post office

Customer 4 asks postal worker 2 to buy stamps

scale released by postal worker 1

Postal worker 2 finished serving customer 4

Postal worker 1 finished serving customer 0

Customer 4 leaves post office

Customer 6 asks postal worker 2 to mail a package

Customer 0 leaves post office

Customer 7 asks postal worker 1 to mail a letter

scale in use by postal worker 2

Joined customer 0

Joined customer 1

Joined customer 2

Postal worker 0 finished serving customer 3

Customer 3 leaves post office

Customer 5 asks postal worker 0 to mail a package

Joined customer 3

Joined customer 4

Postal worker 1 finished serving customer 7

Customer 7 leaves post office

Customer 8 asks postal worker 1 to buy stamps

scale released by postal worker 2

Postal worker 2 finished serving customer 6

scale in use by postal worker 0

Customer 6 leaves post office

Customer 9 asks postal worker 2 to buy stamps

Postal worker 1 finished serving customer 8

Customer 8 leaves post office

Customer 11 asks postal worker 1 to mail a letter

Postal worker 2 finished serving customer 9

Customer 9 leaves post office

Customer 10 asks postal worker 2 to mail a package

scale released by postal worker 0

Postal worker 0 finished serving customer 5

scale in use by postal worker 2

Customer 5 leaves post office

Customer 12 asks postal worker 0 to buy stamps

Joined customer 5

Joined customer 6

Joined customer 7

Joined customer 8

Joined customer 9

Postal worker 1 finished serving customer 11

Customer 11 leaves post office

Customer 13 asks postal worker 1 to buy stamps

Postal worker 1 finished serving customer 13

Postal worker 0 finished serving customer 12

Customer 13 leaves post office

Customer 12 leaves post office

Customer 14 asks postal worker 1 to mail a letter

Customer 15 asks postal worker 0 to buy stamps

scale released by postal worker 2

Postal worker 2 finished serving customer 10

Postal worker 0 finished serving customer 15

Customer 10 leaves post office

Customer 15 leaves post office

Joined customer 10

Joined customer 11

Joined customer 12

Joined customer 13

Customer 17 asks postal worker 2 to buy stamps

Customer 16 asks postal worker 0 to mail a package

scale in use by postal worker 0

Postal worker 1 finished serving customer 14

Customer 14 leaves post office

Customer 18 asks postal worker 1 to buy stamps

Joined customer 14

Joined customer 15

Postal worker 2 finished serving customer 17

Customer 17 leaves post office

Customer 19 asks postal worker 2 to mail a package

Postal worker 1 finished serving customer 18

Customer 18 leaves post office

Customer 21 asks postal worker 1 to mail a package

scale released by postal worker 0

Postal worker 0 finished serving customer 16

Customer 16 leaves post office

scale in use by postal worker 2

Joined customer 16

Joined customer 17

Joined customer 18

Customer 20 asks postal worker 0 to mail a letter

Postal worker 0 finished serving customer 20

Customer 20 leaves post office

Customer 22 asks postal worker 0 to buy stamps

scale released by postal worker 2

Postal worker 2 finished serving customer 19

scale in use by postal worker 1

Customer 19 leaves post office

Customer 23 asks postal worker 2 to mail a letter

Joined customer 19

Joined customer 20

Postal worker 0 finished serving customer 22

Customer 22 leaves post office

Customer 24 asks postal worker 0 to buy stamps

Postal worker 0 finished serving customer 24

Customer 24 leaves post office

Customer 27 asks postal worker 0 to buy stamps

Postal worker 2 finished serving customer 23

Customer 23 leaves post office

Customer 26 asks postal worker 2 to mail a letter

scale released by postal worker 1

Postal worker 1 finished serving customer 21

Customer 21 leaves post office

Joined customer 21

Customer 28 asks postal worker 1 to mail a package

Joined customer 22

scale in use by postal worker 1

Joined customer 23

Joined customer 24

Postal worker 0 finished serving customer 27

Customer 27 leaves post office

Customer 25 asks postal worker 0 to buy stamps

Postal worker 2 finished serving customer 26

Customer 26 leaves post office

Customer 31 asks postal worker 2 to buy stamps

Postal worker 0 finished serving customer 25

Customer 25 leaves post office

Customer 32 asks postal worker 0 to mail a letter

Joined customer 25

Joined customer 26

Joined customer 27

scale released by postal worker 1

Postal worker 1 finished serving customer 28

Customer 28 leaves post office

Joined customer 28

Customer 30 asks postal worker 1 to mail a letter

Postal worker 2 finished serving customer 31

Customer 31 leaves post office

Customer 33 asks postal worker 2 to buy stamps

Postal worker 0 finished serving customer 32

Customer 32 leaves post office

Customer 29 asks postal worker 0 to mail a package

scale in use by postal worker 0

Postal worker 2 finished serving customer 33

Customer 33 leaves post office

Customer 34 asks postal worker 2 to buy stamps

Postal worker 1 finished serving customer 30

Customer 30 leaves post office

Customer 36 asks postal worker 1 to mail a package

Postal worker 2 finished serving customer 34

Customer 34 leaves post office

Customer 35 asks postal worker 2 to mail a package

scale released by postal worker 0

Postal worker 0 finished serving customer 29

scale in use by postal worker 1

Customer 29 leaves post office

Customer 37 asks postal worker 0 to mail a letter

Joined customer 29

Joined customer 30

Joined customer 31

Joined customer 32

Joined customer 33

Joined customer 34

Postal worker 0 finished serving customer 37

Customer 37 leaves post office

Customer 38 asks postal worker 0 to buy stamps

scale released by postal worker 1

Postal worker 1 finished serving customer 36

scale in use by postal worker 2

Customer 36 leaves post office

Customer 39 asks postal worker 1 to mail a letter

Postal worker 0 finished serving customer 38

Customer 38 leaves post office

Customer 40 asks postal worker 0 to mail a letter

Postal worker 1 finished serving customer 39

Customer 39 leaves post office

Customer 41 asks postal worker 1 to buy stamps

scale released by postal worker 2

Postal worker 2 finished serving customer 35

Customer 35 leaves post office

Joined customer 35

Postal worker 0 finished serving customer 40

Customer 40 leaves post office

Joined customer 36

Customer 42 asks postal worker 2 to mail a letter

Joined customer 37

Joined customer 38

Joined customer 39

Joined customer 40

Customer 43 asks postal worker 0 to mail a letter

Postal worker 1 finished serving customer 41

Customer 41 leaves post office

Joined customer 41

Customer 44 asks postal worker 1 to buy stamps

Postal worker 2 finished serving customer 42

Postal worker 0 finished serving customer 43

Customer 42 leaves post office

Customer 43 leaves post office

Customer 47 asks postal worker 2 to mail a letter

Joined customer 42

Joined customer 43

Customer 48 asks postal worker 0 to buy stamps

Postal worker 1 finished serving customer 44

Customer 44 leaves post office

Customer 45 asks postal worker 1 to buy stamps

Joined customer 44

Postal worker 0 finished serving customer 48

Customer 48 leaves post office

Customer 46 asks postal worker 0 to buy stamps

Postal worker 1 finished serving customer 45

Customer 45 leaves post office

Customer 49 asks postal worker 1 to buy stamps

Joined customer 45

Postal worker 2 finished serving customer 47

Customer 47 leaves post office

Postal worker 0 finished serving customer 46

Customer 46 leaves post office

Joined customer 46

Joined customer 47

Joined customer 48

Postal worker 1 finished serving customer 49

Customer 49 leaves post office

Joined customer 49