

## **Cmpsc 473- Programming Assignment 4**

Group Members: Jonathon Dahl, Vibhu Patel, Sanyukta Baluni

Title: Multithreaded Program using Pthreads

### **Assumptions and Decisions:** (refers to pseudocode names, mapped to actual code)

We chose to simulate this problem from the perspective of John Green, or as we refer to in the code as the “Empress.” This means that any information or trading that is done prior to the ship’s arrival is ignored; However, we assumed that the ship arrived at midnight the day prior (ie. the empress arrives day 5, but the merchants’ transactions are checked at the end of day 4). This can be confirmed by the ship checking the merchants’ transactions at this time and any time following the arrival. The merchants arrive, stay for one day, sell their goods, and leave. If any transactions are missed, the ship turns around and returns to the USA. If all three transactions are completed, the ship continues to Canton. At the change of the day, the merchants are all free to trade. Only trades that are done after the ship’s arrival will be valid.

We implemented a shared variable Ready to ensure the synchronization of the merchants. The last merchant to finish execution will signal the Empress to change the day. The merchants simply sell their goods on their day of arrival regardless of the ship’s status. This is reflected in the program with their carefree increments of Transactions. The only time Transactions is checked are at logical times (no omniscient behavior). Ready is reset by the empress, but this does not represent omniscient behavior. This could be relocated to the merchant threads, but this is unnecessarily complex.

Arrive is a shared variable with independent accesses, where each thread has an index of the array. No thread (other than main) changes the variables in Arrive. The values of Arrive are set from a supplied input file.

We implemented semaphores due to their simplicity, efficiency, and readability. Using appropriate names, we created several condition variables and one lock. The lock is held when changing the shared variables. The condition variables either signal the merchants to start the next day or the empress to increment the day. The simplicity stems from the initialization and operations. They are much more efficient than the Pthreads condition variables because they don’t use spin locks (we aren’t sure which system this code will be run on and spin locks are bad for single threaded systems). Finally, readability is key. The variables are all aptly named to easily see their purpose and how they are being used.

### **(i) Pseudocode of the solution:**

Shared variables:        sem\_t lock  
                              sem\_t m\_done (signals empress when the merchants are done trading)  
                              sem\_t m1, m2, m3 (signals the merchants to start the next day)

(All integers below)

Day (time)

Ready (variable that indicates the last merchant to trade)

Transactions (number of merchants that sold goods)

Arrive[] (shared array, each thread accesses their own element)

#### Thread: Main

```
lock = semaphore(1)
m_done = semaphore(0)
m1 = semaphore(0)
m2 = semaphore(0)
m3 = semaphore(0)
Day = Ready = Transactions = 0
Arrive = *FILE*
```

#### Thread: Empress

```
while( Day < 11 ):           // Begin While
    wait( &m_done )
    wait( &lock )           // CS BEGIN - Acquire lock
    Ready = 0               // Shared Variable
    If( Arrive == Day )     // check transactions
    If( Arrive == Day+1 )   // check missed transactions
    Day++                   // Shared Variable
    post( &lock )           // CS END - Release lock
    post( &m1 )             // RM
    post( &m2 )
    post( &m3 )
Done                          // End While
If( Transactions == 3 ) print "Canton"
Else print "USA"
```

#### Thread: Merchant (1, 2, or 3)

```
while( Day < 11 ):
    wait( &lock )           // CS BEGIN - Acquire lock
    If( Arrive == day )     // Shared Variable
        Transactions++
    Ready++                 // Shared Variable
    If( Ready == 3 ) // signal empress
        post( &m_done )
    post( &lock )           // CS END - Release lock
    wait( &m1 ) OR wait( &m2 ) OR wait( &m3 )
Done                         // End While
```

### **(ii) Output for all input files:**

We created a shell script testAllInputs.sh so that the program checks each of the 20 input files and produces an output for each file. After running the script, ./testAllInputs.sh :

```
sanyuktabaluni@ubuntu:~/Cmpsc473/pa4-jrd5595-master$ ./testAllInputs.sh
```

*This script will allow you to test multiple input files at once*

*...Removing old output files...*

*NOTE: The input folder path is ./inputs/*

*NOTE: the files must be in this format: input#*

Enter the last file number:

**20**

**Running: ./inputs/input1**

main: begin thread creation

Merchant (1) creation successful!      Arrival Time: 5

Merchant (3) creation successful!      Arrival Time: 7

Merchant (2) creation successful!      Arrival Time: 1

Merchant (2) sold his goods!      Day: 1, Trans: 1

Empress creation successful!

Merchant (1) sold his goods!      Day: 5, Trans: 2

Empress arrived on day 6

Alas, we were too late.. We missed some merchants!

Time to turn back to the US..

Merchant 1 rejoined!      Merchant 2 rejoined!      Merchant 3 rejoined!

Empress rejoined!

main: exiting

Execution of ./inputs/input1 complete!

**Running: ./inputs/input2**

main: begin thread creation

Merchant (3) creation successful!      Arrival Time: 2

Merchant (2) creation successful!      Arrival Time: 6

Merchant (1) creation successful!      Arrival Time: 7

Empress creation successful!

Merchant (3) sold his goods!      Day: 2, Trans: 1

Merchant (2) sold his goods!      Day: 6, Trans: -2

Empress arrived on day 6

Alas, we were too late.. We missed some merchants!

Merchant 1 rejoined!      Merchant 2 rejoined!      Merchant 3 rejoined!

Time to turn back to the US..

Empress rejoined!

main: exiting

Execution of ./inputs/input2 complete!

**Running: ./inputs/input3**

main: begin thread creation

Merchant (3) creation successful!      Arrival Time: 9

Merchant (2) creation successful!      Arrival Time: 4

Merchant (1) creation successful!      Arrival Time: 2

Empress creation successful!

Merchant (1) sold his goods!      Day: 2, Trans: 1

Merchant (2) sold his goods!      Day: 4, Trans: -2

Empress arrived on day 4

*Alas, we were too late.. We missed some merchants!*  
*Time to turn back to the US..*  
*Merchant 1 rejoined! Merchant 2 rejoined! Merchant 3 rejoined!*  
*Empress rejoined!*  
*main: exiting*  
*Execution of ./inputs/input3 complete!*

***Running: ./inputs/input4***

*main: begin thread creation*  
*Merchant (3) creation successful! Arrival Time: 4*  
*Merchant (2) creation successful! Arrival Time: 4*  
*Merchant (1) creation successful! Arrival Time: 2*  
*Empress creation successful!*  
*Merchant (1) sold his goods! Day: 2, Trans: 1*  
*Empress arrived on day 3*  
*Alas, we were too late.. We missed some merchants!*  
*Merchant 1 rejoined! Merchant 2 rejoined! Merchant 3 rejoined!*  
*Time to turn back to the US..*  
*Empress rejoined!*  
*main: exiting*  
*Execution of ./inputs/input4 complete!*

***Running: ./inputs/input5***

*main: begin thread creation*  
*Merchant (3) creation successful! Arrival Time: 7*  
*Merchant (2) creation successful! Arrival Time: 6*  
*Merchant (1) creation successful! Arrival Time: 9*  
*Empress creation successful!*  
*Empress arrived on day 4*  
*Merchant (2) sold his goods! Day: 6, Trans: 1*  
*We bought some goods!*  
*Merchant (3) sold his goods! Day: 7, Trans: 2*  
*We bought some goods!*  
*We bought some goods!*  
*Merchant (1) sold his goods! Day: 9, Trans: 3*  
*We met everyone by day 9*  
*Merchant 1 rejoined! Merchant 2 rejoined! Merchant 3 rejoined!*  
*Good Job! We met everyone, time to go to Canton!*  
*Empress rejoined!*  
*main: exiting*  
*Execution of ./inputs/input5 complete!*

**Running: ./inputs/input6**

main: begin thread creation

Merchant (3) creation successful!      Arrival Time: 6

Merchant (2) creation successful!      Arrival Time: 6

Merchant (1) creation successful!      Arrival Time: 1

Merchant (1) sold his goods!      Day: 1, Trans: 1

Empress creation successful!

Empress arrived on day 2

Alas, we were too late.. We missed some merchants!

Merchant 1 rejoined!    Merchant 2 rejoined!    Merchant 3 rejoined!

Time to turn back to the US..

Empress rejoined!

main: exiting

Execution of ./inputs/input6 complete!

**Running: ./inputs/input7**

main: begin thread creation

Empress creation successful!

Merchant (3) creation successful!      Arrival Time: 7

Merchant (2) creation successful!      Arrival Time: 3

Merchant (1) creation successful!      Arrival Time: 2

Merchant (1) sold his goods!      Day: 2, Trans: 1

Merchant (2) sold his goods!      Day: 3, Trans: 2

Empress arrived on day 4

Alas, we were too late.. We missed some merchants!

Time to turn back to the US..

Merchant 1 rejoined!    Merchant 2 rejoined!    Merchant 3 rejoined!

Empress rejoined!

main: exiting

Execution of ./inputs/input7 complete!

**Running: ./inputs/input8**

main: begin thread creation

Merchant (3) creation successful!      Arrival Time: 1

Merchant (3) sold his goods!      Day: 1, Trans: 1

Merchant (2) creation successful!      Arrival Time: 9

Merchant (1) creation successful!      Arrival Time: 8

Empress creation successful!

Empress arrived on day 1

We bought some goods!

We bought some goods!

We bought some goods!

We bought some goods!

We bought some goods!  
We bought some goods!  
We bought some goods!  
Merchant (1) sold his goods! Day: 8, Trans: 2  
We bought some goods!  
Merchant (2) sold his goods! Day: 9, Trans: 3  
We met everyone by day 9  
Good Job! We met everyone, time to go to Canton!  
Merchant 1 rejoined! Merchant 2 rejoined! Merchant 3 rejoined!  
Empress rejoined!  
main: exiting  
Execution of ./inputs/input8 complete!

**Running: ./inputs/input9**

main: begin thread creation  
Empress creation successful!  
Merchant (3) creation successful! Arrival Time: 5  
Merchant (2) creation successful! Arrival Time: 10  
Merchant (1) creation successful! Arrival Time: 3  
Merchant (1) sold his goods! Day: 3, Trans: 1  
Merchant (3) sold his goods! Day: 5, Trans: 2  
Empress arrived on day 7  
Alas, we were too late.. We missed some merchants!  
Time to turn back to the US..  
Merchant 1 rejoined! Merchant 2 rejoined! Merchant 3 rejoined!  
Empress rejoined!  
main: exiting  
Execution of ./inputs/input9 complete!

**Running: ./inputs/input10**

main: begin thread creation  
Merchant (3) creation successful! Arrival Time: 10  
Merchant (2) creation successful! Arrival Time: 10  
Merchant (1) creation successful! Arrival Time: 5  
Empress creation successful!  
Empress arrived on day 3  
Merchant (1) sold his goods! Day: 5, Trans: 1  
We bought some goods!  
We bought some goods!  
We bought some goods!  
We bought some goods!  
We bought some goods!  
Merchant (2) sold his goods! Day: 10, Trans: 2  
Merchant (3) sold his goods! Day: 10, Trans: 3

We met everyone by day 10  
Merchant 1 rejoined! Merchant 2 rejoined! Merchant 3 rejoined!  
Good Job! We met everyone, time to go to Canton!  
Empress rejoined!  
main: exiting  
Execution of ./inputs/input10 complete!

**Running: ./inputs/input11**

main: begin thread creation  
Merchant (3) creation successful! Arrival Time: 10  
Merchant (2) creation successful! Arrival Time: 1  
Merchant (2) sold his goods! Day: 1, Trans: 1  
Merchant (1) creation successful! Arrival Time: 8  
Empress creation successful!  
Empress arrived on day 5  
Alas, we were too late.. We missed some merchants!  
Merchant 1 rejoined! Merchant 2 rejoined! Merchant 3 rejoined!  
Time to turn back to the US..  
Empress rejoined!  
main: exiting  
Execution of ./inputs/input11 complete!

**Running: ./inputs/input12**

main: begin thread creation  
Merchant (3) creation successful! Arrival Time: 9  
Merchant (2) creation successful! Arrival Time: 7  
Merchant (1) creation successful! Arrival Time: 7  
Empress creation successful!  
Merchant (2) sold his goods! Day: 7, Trans: 1  
Merchant (1) sold his goods! Day: 7, Trans: 2  
Merchant (3) sold his goods! Day: 9, Trans: 3  
Empress arrived on day 10  
Alas, we were too late.. We missed some merchants!  
Time to turn back to the US..  
Merchant 1 rejoined! Merchant 2 rejoined! Merchant 3 rejoined!  
Empress rejoined!  
main: exiting  
Execution of ./inputs/input12 complete!

**Running: ./inputs/input13**

main: begin thread creation  
Merchant (3) creation successful! Arrival Time: 1

Merchant (3) sold his goods! Day: 1, Trans: 1  
Merchant (2) creation successful! Arrival Time: 7  
Merchant (1) creation successful! Arrival Time: 1  
Merchant (1) sold his goods! Day: 1, Trans: 2  
Empress creation successful!  
Merchant (2) sold his goods! Day: 7, Trans: 3  
Empress arrived on day 8  
Alas, we were too late.. We missed some merchants!  
Time to turn back to the US..  
Merchant 1 rejoined! Merchant 2 rejoined! Merchant 3 rejoined!  
Empress rejoined!  
main: exiting  
Execution of ./inputs/input13 complete!

**Running: ./inputs/input14**

main: begin thread creation  
Merchant (3) creation successful! Arrival Time: 7  
Merchant (2) creation successful! Arrival Time: 3  
Merchant (1) creation successful! Arrival Time: 7  
Empress creation successful!  
Merchant (2) sold his goods! Day: 3, Trans: 1  
Empress arrived on day 6  
Alas, we were too late.. We missed some merchants!  
Merchant 1 rejoined! Merchant 2 rejoined! Merchant 3 rejoined!  
Time to turn back to the US..  
Empress rejoined!  
main: exiting  
Execution of ./inputs/input14 complete!

**Running: ./inputs/input15**

main: begin thread creation  
Empress creation successful!  
Merchant (2) creation successful! Arrival Time: 2  
Merchant (3) creation successful! Arrival Time: 5  
Merchant (1) creation successful! Arrival Time: 5  
Merchant (2) sold his goods! Day: 2, Trans: 1  
Empress arrived on day 4  
Alas, we were too late.. We missed some merchants!  
Time to turn back to the US..  
Merchant 1 rejoined! Merchant 2 rejoined! Merchant 3 rejoined!  
Empress rejoined!  
main: exiting  
Execution of ./inputs/input15 complete!



**Running: ./inputs/input16**

main: begin thread creation

Merchant (3) creation successful!      Arrival Time: 2

Merchant (2) creation successful!      Arrival Time: 9

Merchant (1) creation successful!      Arrival Time: 10

Empress creation successful!

Merchant (3) sold his goods!      Day: 2, Trans: 1

Empress arrived on day 5

Alas, we were too late.. We missed some merchants!

Merchant 1 rejoined!    Merchant 2 rejoined!    Merchant 3 rejoined!

Time to turn back to the US..

Empress rejoined!

main: exiting

Execution of ./inputs/input16 complete!

**Running: ./inputs/input17**

main: begin thread creation

Merchant (3) creation successful!      Arrival Time: 9

Merchant (2) creation successful!      Arrival Time: 1

Merchant (2) sold his goods!      Day: 1, Trans: 1

Merchant (1) creation successful!      Arrival Time: 2

Empress creation successful!

Merchant (1) sold his goods!      Day: 2, Trans: 2

Empress arrived on day 3

Alas, we were too late.. We missed some merchants!

Merchant 1 rejoined!    Merchant 2 rejoined!    Merchant 3 rejoined!

Time to turn back to the US..

Empress rejoined!

main: exiting

Execution of ./inputs/input17 complete!

**Running: ./inputs/input18**

main: begin thread creation

Merchant (3) creation successful!      Arrival Time: 10

Merchant (2) creation successful!      Arrival Time: 5

Merchant (1) creation successful!      Arrival Time: 1

Merchant (1) sold his goods!      Day: 1, Trans: 1

Empress creation successful!

Merchant (2) sold his goods!      Day: 5, Trans: 2

Merchant (3) sold his goods!      Day: 10, Trans: -1

Empress arrived on day 10

Alas, we were too late.. We missed some merchants!

Merchant 1 rejoined!    Merchant 2 rejoined!    Merchant 3 rejoined!  
Time to turn back to the US..  
Empress rejoined!  
main: exiting  
Execution of ./inputs/input18 complete!

**Running: ./inputs/input19**

main: begin thread creation  
Merchant (3) creation successful!      Arrival Time: 2  
Merchant (2) creation successful!      Arrival Time: 3  
Merchant (1) creation successful!      Arrival Time: 2  
Empress creation successful!  
Merchant (1) sold his goods!      Day: 2, Trans: 1  
Merchant (3) sold his goods!      Day: 2, Trans: 2  
Merchant (2) sold his goods!      Day: 3, Trans: 3  
Empress arrived on day 6  
Alas, we were too late.. We missed some merchants!  
Merchant 1 rejoined!    Merchant 2 rejoined!    Merchant 3 rejoined!  
Time to turn back to the US..  
Empress rejoined!  
main: exiting  
Execution of ./inputs/input19 complete!

**Running: ./inputs/input20**

main: begin thread creation  
Merchant (3) creation successful!      Arrival Time: 9  
Merchant (2) creation successful!      Arrival Time: 2  
Merchant (1) creation successful!      Arrival Time: 5  
Empress creation successful!  
Merchant (2) sold his goods!      Day: 2, Trans: 1  
Merchant (1) sold his goods!      Day: 5, Trans: 2  
Empress arrived on day 8  
Alas, we were too late.. We missed some merchants!  
Merchant 1 rejoined!    Merchant 2 rejoined!    Merchant 3 rejoined!  
Time to turn back to the US..  
Empress rejoined!  
main: exiting  
Execution of ./inputs/input20 complete!