Portfolio Milestone: Module 8

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CSC450-1 Programming III

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Introduction

Concurrency is an important concept applicable to many computing scenarios. Applications that require parallel execution benefit significantly. Some common use cases for concurrency include multithreaded applications, parallel computing, networking, game development, and real-time systems. Google Chrome employs concurrency to run separate browser tabs. In Portfolio Project: Part 1, concurrency will be demonstrated using an ascending and descending counter from 0 to 20. Additionally, each count will operate on different threads.

Challenges of Concurrency

Concurrency also has disadvantages, primarily regarding performance. Synchronization overhead occurs when time is spent waiting for another task. Typically, the slowest task dictates the speed of the entire operation (Cornell University, n.d.).

Context switching happens with frequent thread switching. Time is lost as the CPU saves and restores the state. However, context switching will not be a factor in this application since the thread will only switch once.

Race conditions and deadlocks are additional concerns. Race conditions occur when two threads access a shared variable simultaneously, essentially battling to update it. Deadlocks occur when two threads lock different variables at the same time, causing each thread to stop execution while waiting for the other to release the variable (Haiyingyu, 2022).

String Vulnerabilities

String data is a fundamental data type used to represent text. Strings can contain sensitive information such as names, passwords, and birthdates. This high-value data makes it a target for attackers who attempt to exploit information leaks. Some common string vulnerabilities include buffer overflows, format string vulnerabilities, and null terminator issues.

Basic Implementation

In its most basic form, the program will start with separate for loops that increment and decrement to 20. The following for loop increments up:

```
for (int i = 0; i <= 20; ++i) {
std::cout << "increment " << i << std::endl;
}
```

The following for loop decrements down:

```
for (int i = 20; i >= 0; --i) {
std::cout << "decrement " << i << std::endl;
}
```

From these basic FOR-LOOPS additional functions and thread methods will be wrapped. Deadlock protection will be achieved with mutex wrapped in lock_guard. The method is preferred since mutex locking and unlocking will automatically occur. A lock(mtx) object is created to negate the next thread from accessing the resources until release. An alternative would be mtx.lock() and mtx.unlock(). However, if an exception is thrown between the “lock & unlock” a deadlock can occur.

To prevent race conditions unique_lock is employed. Notably, lock_guard and unique_lock are both locks however unique_lock can be controlled manually and in this case can be used with a conditional-variable. Plus, unique_lock is used outside the FOR-LOOP and will notify the ‘increment down’ function that it has authority to proceed on with thread two. Finally, the incDown() uses the conditional variable and function from the C++ standard library in the form of cv.wait(). The cv.wait function accepts two arguments, lock and a lambda function. Cv.wait() is the initiator for thread_2 to start. Thread_2 will only start if the cv.notify() signal is received from thread_1 and the predicate (lambda function) is equal to true, otherwise thread_2 will not be able to lock the mutex and start.

About lambda functions, they are shortened inline anonymous functions that allow specificity. The inline nature makes the code easier to read since the developer does not have

to find the root function in order to discover the function's use. Anonymous lambda functions are mainly used when the function is concise. They are best used in one line applications.

```
Boolean Lock Variable = False
THREAD ONE
for (int i = 0; i <= 20; ++i) {

LOCK_GUARD (Deadlock Protection - auto LOCK/UNLOCK)
std::cout << "increment " << i << std::endl;
}

UNIQUE_LOCK (Race Condition Protection -
SET Boolean Lock Variable = True
THEN notify THREAD TWO)

THREAD TWO
WAIT( Will wait until notified
AND Boolean Lock Variable = True
LOCKS shared Boolean Lock Variable = True (mutex)
THREAD TWO runs
)

for (int i = 20; i >= 0; --i) {
std::cout << "decrement " << i << std::endl;
}
```

Lastly, the code methods are executed in seperate threads t1 and t2. T1 will execute increment up and T2 decrement down. The .join() method orders which thread goes first. In this case t1.join() and t2.join() respectively.

Pseudocode - C++

START

DECLARE MUTEX mtx

DECLARE CONDITION_VARIABLE cv

DECLARE BOOLEAN firstThreadDone **SET** TO FALSE

```
FUNCTION threadSwitch()
    DISPLAY "THREAD SWITCH"
END FUNCTION


FUNCTION incUp()
    FOR i FROM 0 TO 20 DO
        LOCK mtx
        DISPLAY "Count Up: " + i
        UNLOCK mtx
    ENDFOR
    LOCK mtx
    SET firstThreadDone TO TRUE
    NOTIFY cv
    UNLOCK mtx
END FUNCTION
FUNCTION incDown()
    LOCK mtx
    WAIT ON cv UNTIL firstThreadDone IS TRUE
    UNLOCK mtx


    CALL threadSwitch()


    FOR i FROM 20 TO 0 DO
        DISPLAY "Count Down: " + i
    ENDFOR
```

END FUNCTION

MAIN()

START THREAD t1 RUNNING incUp()

START THREAD t2 RUNNING incDown()

WAIT FOR t1 TO FINISH

WAIT FOR t2 TO FINISH

END

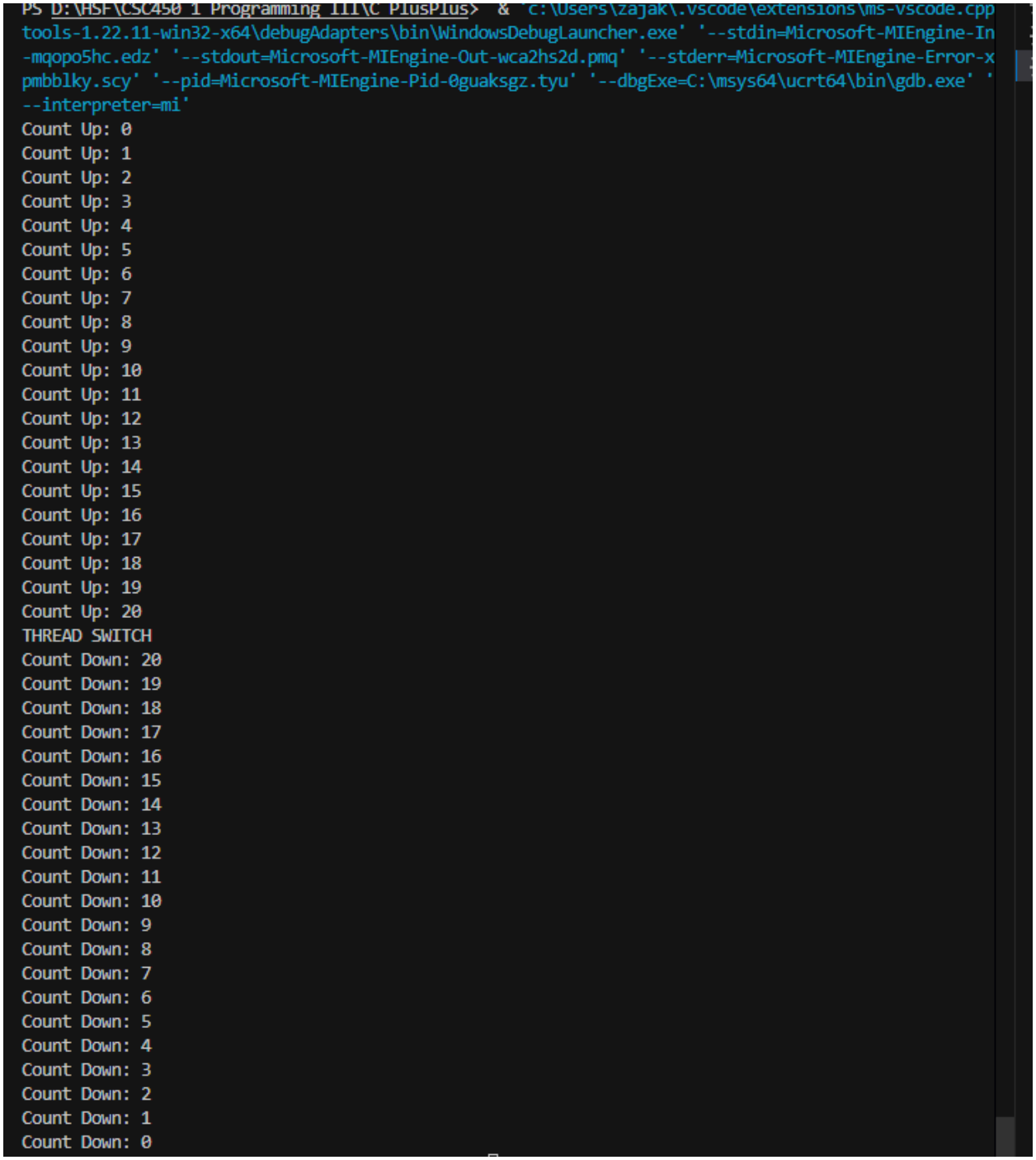
Code - C++

```cpp
#include <iostream>
#include <thread>
#include <mutex>
#include <condition_variable>


std::mutex mtx;
std::condition_variable cv;
bool firstThreadDone = false;

//Simple notification that a thread switch has occured.
void threadSwitch(){
    std::cout << "THREAD SWITCH" << std::endl;
}

//FOR-LOOP UpThread
void incUp() {
    for (int i = 0; i <= 20; ++i) {
        //deadlock protection. automatic lock/unlock via lock(mtx)
        std::lock_guard<std::mutex> lock(mtx);
        //print statement
        std::cout << "Count Up: " << i << std::endl;
    }

    //Race condition protection. notify incDown after completion
```

```
    std::unique_lock<std::mutex> lock(mtx);
    firstThreadDone = true;
    cv.notify_one(); // Notify the second thread to start
}

//FOR-LOOP downThread
void incDown() {
    //authority from incUp (thread one) to proceed
    std::unique_lock<std::mutex> lock(mtx);

    //conditional variable. waits as locked until notified true via cv.notify_one
()
    cv.wait(lock, [] { return firstThreadDone; });

    //shows thread two is in operation after unique lock is removed.
    threadSwitch();

    //no further thread safeguards needed since this is the last operation.
    for (int i = 20; i >= 0; --i) {
        std::cout << "Count Down: " << i << std::endl;
    }
}


int main() {
    std::thread t1(incUp);
    std::thread t2(incDown);

    t1.join();
    t2.join();

    return 0;
}
```

Figure 1

Concurrency Output - C++



Note. terminal output *VS Code,* by Isaiah Jackson

Java

The Java program starts similar to C++ with FOR-LOOPS that increment and decrement to 20.

The following for-loop increments up:

```
for (int i = 0; i <= 20; i++) {
      System.out.println("Count Up: " + i);
}
```

The following for-loop decrements down:

```
for (int i = 20; i >= 0; i--) {
      System.out.println("Count Down: " + i);
}
```

Next, additional methods and threading mechanisms will be wrapped. Deadlock protection is achieved with ReentrantLock wrapped in lock(). The method is preferred since locking and unlocking will automatically occur in a try-finally block. A lock.lock() call prevents another thread from accessing the resource until it is released. An alternative would be using synchronized, but ReentrantLock provides more flexibility.

To prevent race conditions, Condition is used with await() and signal(). Notably, lock.lock() and condition.await() both manage synchronization, but await() will suspend the second thread until it receives a signal. Additionally, condition.signal() is used outside the for-loop to notify the decrement function that it has authority to proceed.

Finally, countDown() uses Condition from the Java standard library in the form of await(). The await() function suspends execution of thread two until signal() is received from thread one and firstThreadDone is set to true. Otherwise, thread two will not be able to proceed.

Pseudocode - Java

START

DECLARE LOCK lock

DECLARE CONDITION condition

DECLARE BOOLEAN firstThreadDone **SET** TO FALSE

FUNCTION threadSwitch()

```
    DISPLAY "THREAD SWITCH"
END FUNCTION

FUNCTION countUp()
    FOR i FROM 0 TO 20 DO
        LOCK lock
        DISPLAY "Count Up: " + i
        UNLOCK lock
    ENDFOR
    LOCK lock
    SET firstThreadDone TO TRUE
    NOTIFY condition
    UNLOCK lock
END FUNCTION
FUNCTION countDown()
    LOCK lock
    WAIT ON condition UNTIL firstThreadDone IS TRUE
    UNLOCK lock
    CALL threadSwitch()
    FOR i FROM 20 TO 0 DO
        DISPLAY "Count Down: " + i
    ENDFOR
END FUNCTION

MAIN()
START THREAD t1 RUNNING countUp()
```

START THREAD t2 RUNNING countDown()

WAIT FOR **t1** TO FINISH

WAIT FOR **t2** TO FINISH

END

Lastly, the code methods are executed in separate threads t1 and t2. t1 executes the increment function, while t2 executes the decrement function. The .join() method ensures thread t1 starts first, followed by t2.

Code Java

```java
import java.util.concurrent.locks.Condition;
import java.util.concurrent.locks.Lock;
import java.util.concurrent.locks.ReentrantLock;

public class ConcurrencyCounter {
    //constructors for the lock instance
    private static final Lock lock = new ReentrantLock();
    private static final Condition condition = lock.newCondition();
    //intial condition for race condition
    private static boolean firstThreadDone = false;

    public static void main(String[] args) {
        //thread constructors
        Thread t1 = new Thread(ConcurrencyCounter::incUp);
        Thread t2 = new Thread(ConcurrencyCounter::incDown);

        //thread starts
        t1.start();
        t2.start();

        //tries thread join
        try {
            t1.join();
            t2.join();

        //print error occurs via e as message
```

```
        } catch (InterruptedException e) {
            e.printStackTrace();
        }
    }

    //simple function that shows thread switch
    public static void threadSwitch(){
        System.out.println("THREAD SWITCH");
    }

    //increment function
    public static void incUp() {
        for (int i = 0; i <= 20; i++) {
            //lock instance
            lock.lock();
            //incrememement with deadlock protection
            try {
                System.out.println("Count Up: " + i);
            } finally {
                //unlock deadlock condition
                lock.unlock();
            }
        }
        lock.lock(); //race condition lock
        try {
            firstThreadDone = true;
            condition.signal(); // similar to c++ cv.notify_one()
        } finally {
            lock.unlock(); //unlock race condition
        }
    }

    public static void incDown() {
        lock.lock(); //race condition lock
        try {
            while (!firstThreadDone) { //while not true
                condition.await(); // Wait until incUp completes
            }
        } catch (InterruptedException e) {
```

```
            e.printStackTrace(); //exception via e message
        } finally {
            lock.unlock(); // unlocks when firstThreadDone is Ture
        }

        threadSwitch(); //simple middle point

        for (int i = 20; i >= 0; i--) {
            lock.lock(); //same other instances
            try {
                System.out.println("Count Down: " + i);
            } finally {
                lock.unlock(); //same as other instance
            }
        }
    }
}
```

Java and C++ comparisons

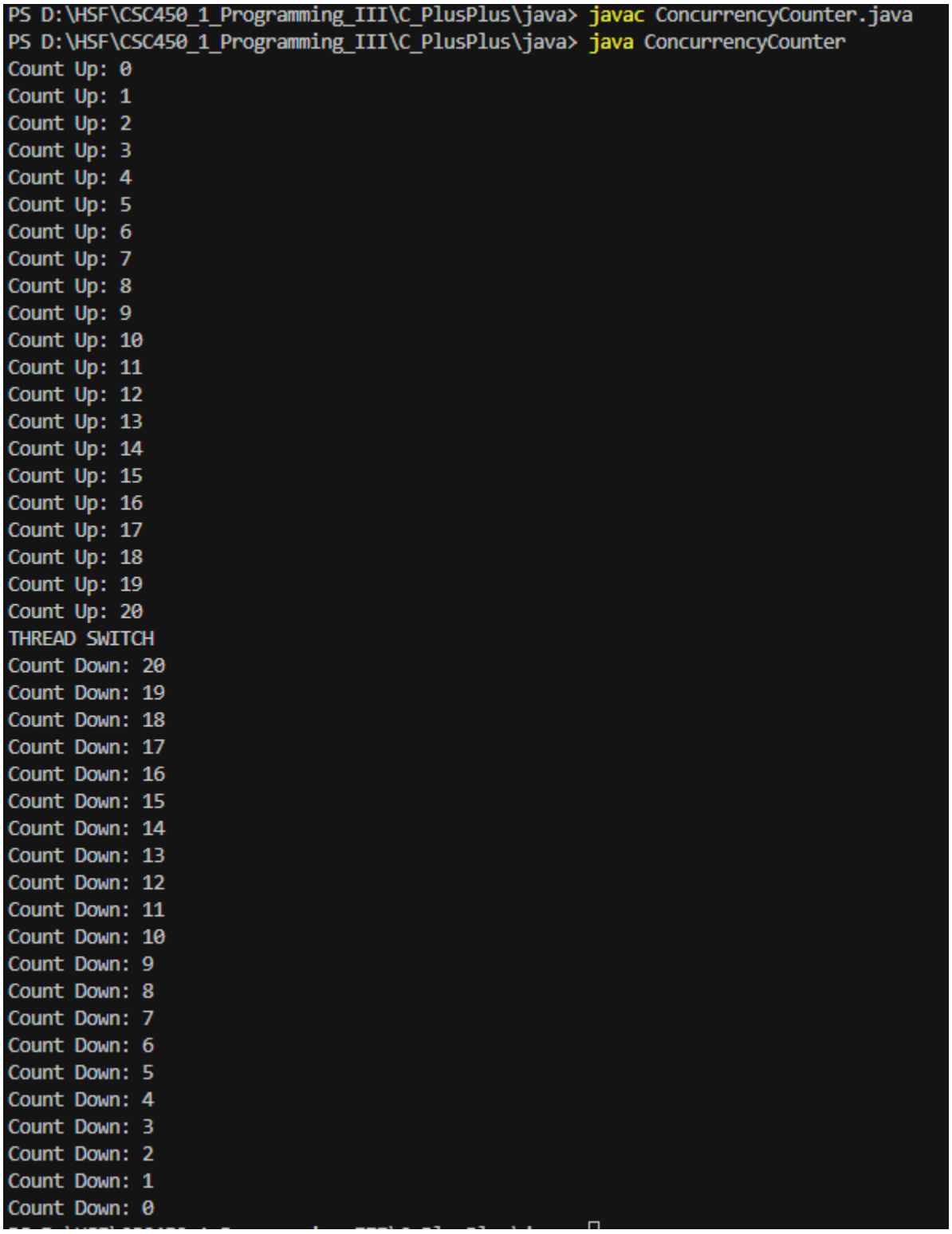
Java exhibits more thread vulnerabilities. Threads are potentially more opportunities to misplace a lock and unlock statement. At the very least an exception will be thrown. However, if coupled with a TRY-CATCH block there is a possibility to induce an unwanted deadlock or race condition.

C++ has the greater potential for string vulnerabilities. These risks come in the form of buffer overflows, memory leaks and pointer errors which are typical of C++. Java has auto memory management and garbage collection to mitigate these risks.

Although C++ offers more control, Java is generally more secure regarding data types. Specifically, Java's String primitive is immutable. Java does not let the developer access the memory with pointers reducing the chances of memory corruption. In general Java's data types are more secure since memory is handled by Java.

Figure 2

Concurrency Output - Java



Github Link

See Files: MP7_8.cpp and MP7_8.exe

See Files: ConcurrencyCounter.java and ConcurrenctCounter.class

https://github.com/zajakson/CSC450_Programming_III

References

Cornell University. (n.d.). Synchronization Overhead. Cornell University. https://cvw.cac.cornell.edu/parallel/efficiency/synchronization-overhead#:~:text=Any%20time%20a%20task%20spends,and%20computing%20the%20next%20timestep.

Haiyingyu,. Simonxjx. (2022). Race conditions and deadlocks. Microsoft . https://learn.microsoft.com/en-us/troubleshoot/developer/visualstudio/visual-basic/language-compilers/race-conditions-deadlocks