SIT315 – Programming Paradigms

TaskM2.T1P: Parallel Matrix Multiplication

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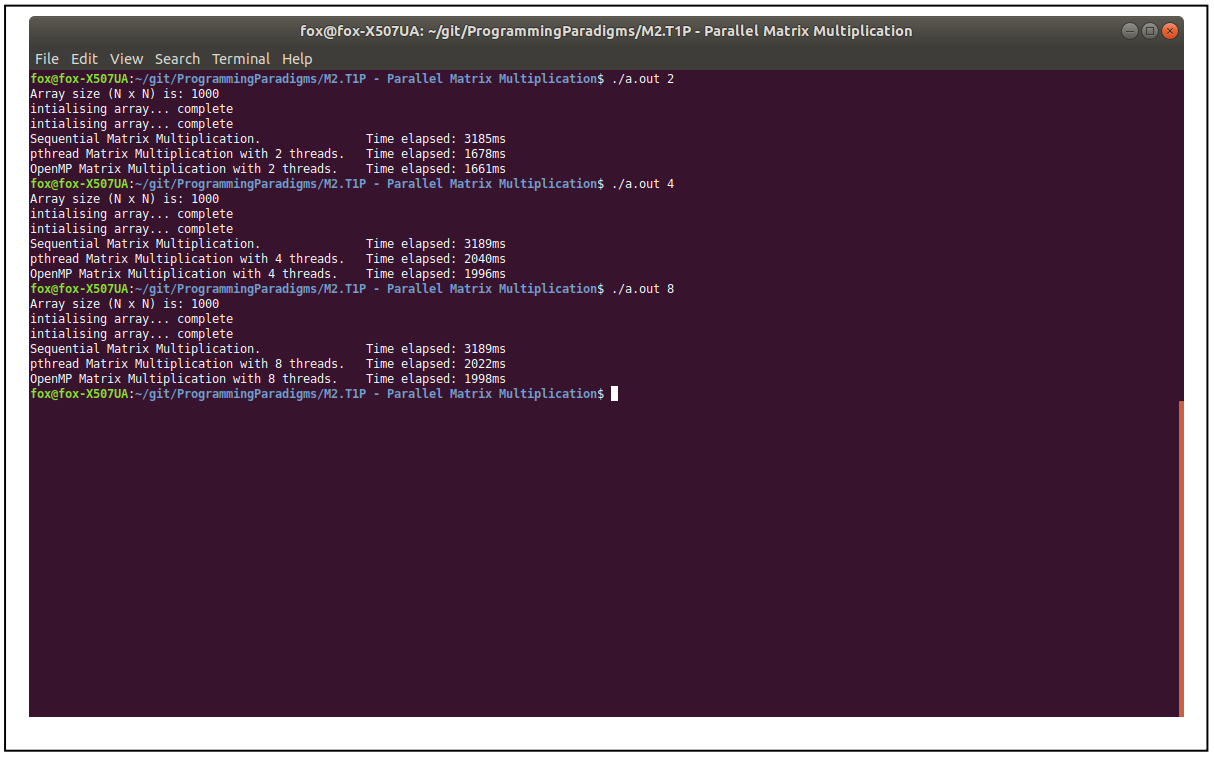
1. Implement a sequential matrix multiplication program in C or C++.

Written in C++.

https://github.com/gregorymcintyre/ProgrammingParadigms/tree/master/M2.T1P%20-%20Parallel%20Matrix%20Multiplication

or See Appendix B for a static version

2. At the end of the program, please print the execution time.



3. Once you have completed and tested the program, please review your code and develop a roadmap to parallelise your code.

To parallelise my code, I would like to have the following loop happen in parallel:

```
void SequentialMatrixMultiplication()
{
	int value;
	for (int i = 0; i < N; i++)
	{
//code
```

I will implement it to perform the column functions independently, as results are not dependent on each other I should not need to implement mutex with this method, but I will assess as the program develops.

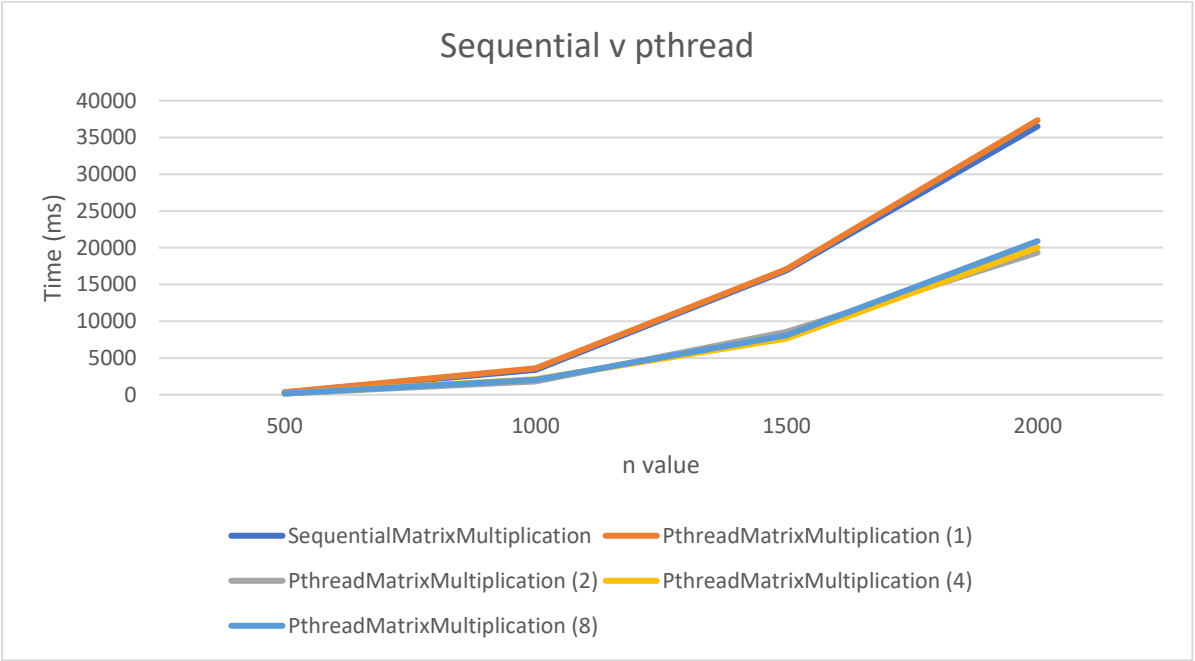
The array values are independent of each other and should be able to be implemented parallel. This would mean that all array values would be calculated concurrently, this should improve the performance of the program significantly.

4. Implement your parallel algorithm in C or C++ using pthread library

Same Git

https://github.com/gregorymcintyre/ProgrammingParadigms/tree/master/M2.T1P%20-%20Parallel%20Matrix%20Multiplication

5. Evaluate the performance of your program



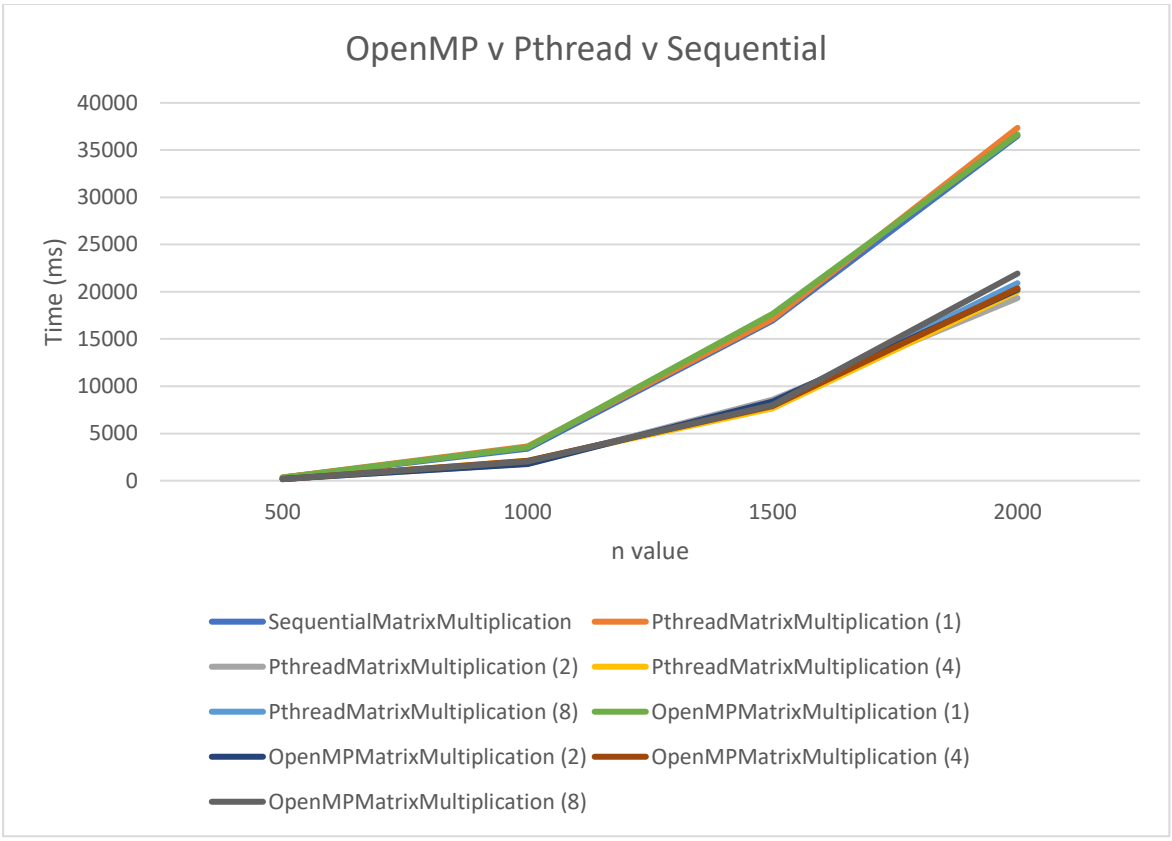
Program performed well, I expected to see a more variable result when adding more threads, but results show that the systems did not improve significantly in runtime when using more than 2 threads.

6. Modify your sequential program to use OpenMP to achieve parallelism

Same Git

https://github.com/gregorymcintyre/ProgrammingParadigms/tree/master/M2.T1P%20-%20Parallel%20Matrix%20Multiplication

7. Evaluate the performance of the OpenMP implementation vs pthread implementation vs the sequential program



The OpenMP Did not yield a decrease in runtime, it was much simpler to implement. But implementing a `#pragma omp for` yielded the no improvement on the pthread method.

8. Submit your task as detailed on the submission details section above to OnTrack

Submitted

Appendix A: Raw Data

	500	1000	1500	2000
SequentialMatrixMultiplication	334	3378	16949	36512
PthreadMatrixMultiplication (1)	341	3613	17104	37353
PthreadMatrixMultiplication (2)	172	1808	8584	19338
PthreadMatrixMultiplication (4)	173	2106	7652	20028
PthreadMatrixMultiplication (8)	172	2023	8087	20910
OpenMPMatrixMultiplication (1)	331	3544	17654	36649
OpenMPMatrixMultiplication (2)	193	1757	8385	20226
OpenMPMatrixMultiplication (4)	162	2110	7893	20362
OpenMPMatrixMultiplication (8)	169	2027	8000	21932

Appendix B: Source

```
/* SequentialMatrixMultiplication.cpp
 * Greg McIntyre
 * 8/4/19
 *
 * This program creates 2 random arrays of n size and multiplies them together in a
sequential, pthread and OpenMP method.
 */
#include "pch.h"

#include <stdio.h>
#include <iostream>
#include <sys/time.h>
#include <time.h>
#include <pthread.h>
#include <omp.h>

using namespace std;

#define N 2000
//#define NUM_THREADS 2
//int N;
int NUM_THREADS;

pthread_mutex_t mutx;

int inputArray1[N][N];
int inputArray2[N][N];
int outputArray[N][N];

void intialiseArray(int array[N][N]) {
	cout<<"intialising array... ";
	for (int i = 0; i < N; i++)
	{
		for (int j = 0; j < N; j++)
		{
			array[i][j] = rand() % ((100 - 1) + 1) + 1;
		}
	}
	cout<<"complete"<<endl;
}		//intialises array with random values, uses the N global variable

void printArrays(int array[N][N]){
	cout <<"[";
	for (int i = 0; i < N; i++) {
		cout << "[";
		for (int j = 0; j < N; j++) {
			cout << array[i][j];
			std::cout << " ";
		}
		std::cout << "]\n";
	}
	std::cout << "]\n\n";
}		//prints array to console

void SequentialMatrixMultiplication()
{
	int value;
	for (int i = 0; i < N; i++)
	{
```

```
		for (int j = 0; j < N; j++)
		{
			value = 0;
			for (int k = 0; k < N; k++)
			{
				value += inputArray1[i][k] * inputArray2[k][j];
			}
			outputArray[i][j] = value;

		}
	}
}		//performs a sequential matrix mutiplication

void *pthreadMatrixMultiplication(void *threadid)
{
	long tid = (long)threadid;
	long value;

	int range = N/NUM_THREADS;
	int start = tid * range;
	int end = start + range;

	//pthread_mutex_lock(&mutx);
	//cout<<tid<<":"<<start<<"-"<<end<<endl;
	//pthread_mutex_unlock(&mutx);

	for (int i = start ; i < end ; i++)
	{
		for (int j = 0; j < N; j++)
		{
			value = 0;
			for (int k = 0; k < N; k++)
			{
				value += inputArray1[i][k] * inputArray2[k][j];
			}

			//pthread_mutex_lock(&mutx);
			outputArray[i][j] = value;
			//pthread_mutex_unlock(&mutx);
		}
	}
	//cout<<"Done"<<endl;
	pthread_exit(NULL);
}		//performs a threaded matrix multiplication using the global NUM_THREADS
value

void OpenmpMatrixMultiplication()
{
	#pragma omp parallel
	{
		//cout<<omp_get_thread_num()<<endl;
		int value;
		#pragma omp for
		for (int i = 0; i < N; i++)
		{
			for (int j = 0; j < N; j++)
			{
				value = 0;
				for (int k = 0; k < N; k++)
				{
					value += inputArray1[i][k] * inputArray2[k][j];
				}
```

```
                                        outputArray[i][j] = value;

                                }
                        }
                }
}               //performs a threaded matrix multiplication using OpenMP

int main(int argc, char *argv[]){

        NUM_THREADS = atoi(argv[1]);              //pull argv value for threads
        //N = atoi(argv[2]);

        struct timeval timecheck;

        pthread_t threads[NUM_THREADS];
        pthread_mutex_init(&mutx, NULL);

        omp_set_num_threads(NUM_THREADS);

        cout<<"Array size (N x N) is: "<<N<<endl;
        intialiseArray(inputArray1);
        intialiseArray(inputArray2);

        //cout << "Input Array"<<endl;
        //printArrays(inputArray1);

        //cout << "Input Array"<<endl;
        //printArrays(inputArray2);

        //cout << "Output Array"<<endl;
        //printArrays(outputArray);

        cout<<"Sequential Matrix Multiplication.\t\tTime elapsed: ";

        gettimeofday(&timecheck, NULL);

        long timeofday_start = (long)timecheck.tv_sec * 1000 + (long)timecheck.tv_usec
/1000;

        SequentialMatrixMultiplication();

        gettimeofday(&timecheck, NULL);
        long timeofday_end = (long)timecheck.tv_sec * 1000 + (long)timecheck.tv_usec
/1000;

        double time_elapsed = timeofday_end - timeofday_start;
        cout<<time_elapsed<<"ms"<<endl;
        //cout << "Output Array"<<endl;
        //printArrays(outputArray);

        cout<<"pthread Matrix Multiplication with " << NUM_THREADS << " threads.\tTime
elapsed: ";

        gettimeofday(&timecheck, NULL);

        timeofday_start = (long)timecheck.tv_sec * 1000 + (long)timecheck.tv_usec
/1000;

        for (long tid = 0 ; tid < NUM_THREADS;tid++){
                pthread_create(&threads[tid], NULL, pthreadMatrixMultiplication, (void
*)tid);
        }
```

```
	for (long tid = 0 ; tid < NUM_THREADS;tid++){
		pthread_join(threads[tid], NULL);
	}

	gettimeofday(&timecheck, NULL);
	timeofday_end = (long)timecheck.tv_sec * 1000 + (long)timecheck.tv_usec /1000;

	time_elapsed = timeofday_end - timeofday_start;
	cout<<time_elapsed<<"ms"<<endl;
	//cout << "Output Array"<<endl;
	//printArrays(outputArray);

	cout<<"OpenMP Matrix Multiplication with " << NUM_THREADS << " threads.\tTime
elapsed: ";

	gettimeofday(&timecheck, NULL);

	timeofday_start = (long)timecheck.tv_sec * 1000 + (long)timecheck.tv_usec
/1000;

	OpenmpMatrixMultiplication();

	gettimeofday(&timecheck, NULL);
	timeofday_end = (long)timecheck.tv_sec * 1000 + (long)timecheck.tv_usec /1000;

	time_elapsed = timeofday_end - timeofday_start;
	cout<<time_elapsed<<"ms"<<endl;
	//cout << "Output Array"<<endl;
	//printArrays(outputArray);

	return 0;
}
```