Operating System

Lab Two
Threads

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CONTENTS

Summary

Implementing two popular algorithms as multi-threaded ones:

1. Matrix Multiplication
2. Merge Sort

Language Used:

- C/C++ Language.

Libraries used:

1. Library “unistd”.
2. Library “stdio”.
3. Library “pthread”.
4. Library “sys/time”.
5. Library “stdlib”.

Code

I. Matrix Multiplication:

```
#include <stdio.h>
#include <pthread.h>
#include <unistd.h>
#include <stdlib.h>
#include <sys/time.h>

typedef struct {
    int ** mat_one;
    int ** mat_two;
    int ** mat_output;
    int r2;
}threadElement;

typedef struct {
    int i, j;
}indexes;

typedef struct {
    threadElement* myThreadElement;
    indexes* myIndexes;
}threadArgs;

void* elementMultiplication(void* args) {

    threadArgs * myThreadArgs = (threadArgs *) args;
    threadElement* myThread = myThreadArgs->myThreadElement;

    int i = myThreadArgs->myIndexes->i;
    int j = myThreadArgs->myIndexes->j;

    myThread->mat_output[i][j] = 0;

    int k;
    for(k = 0; k < myThread->r2 ; k++)
        myThread->mat_output[i][j] += (myThread->mat_one[i][k] * myThread->mat_two[k][j]);

    pthread_exit(NULL);
}

void* rowMultiplication(void* args) {
    threadArgs * myThreadArgs = (threadArgs *) args;
    threadElement* myThread = myThreadArgs->myThreadElement;

    int i = myThreadArgs->myIndexes->i;

    int k, l;
    for(k = 0; k < myThread->r2; k++) {
        myThread->mat_output[i][k] = 0;
        for (l = 0; l < myThread->r2; ++l) {
            myThread->mat_output[i][k] += (myThread->mat_one[i][l] * myThread->mat_two[l][k]);
        }
    }

    pthread_exit(NULL);
}

int main() {
    int r1, c1, r2, c2, i, j;
    struct timeval start, stop;

    // Opening File Containing inputs
    FILE *fptr = fopen("input.txt", "r");

    // Reading First Matrix
    fscanf(fptr, "%d %d", &r1, &c1);

    int *matrix_one[r1];
    for (i = 0; i < r1; i++)
        matrix_one[i] = (int *)malloc(c1 * sizeof(int));
```

```
        for (i = 0; i <  r1; i++)
            for (j = 0; j < c1; j++)
                fscanf(fptr, "%d", &matrix_one[i][j]);


        // Reading Second Matrix
        fscanf(fptr, "%d %d", &r2, &c2);

        int *matrix_two[r2];
        for (i = 0; i < r2; i++)
            matrix_two[i] = (int *)malloc(c2 * sizeof(int));

        for (i = 0; i <  r2; i++)
            for (j = 0; j < c2; j++)
                fscanf(fptr, "%d", &matrix_two[i][j]);
        fclose(fptr);

        // Printing First Matrix
        printf("First Matrix:\n");
        for (i = 0; i < r1; i++) {
            for (j = 0; j < c1; j++)
                printf("%d ", matrix_one[i][j]);
            printf("\n");
        }

        // Printing Second Matrix
        printf("\nSecond Matrix:\n");
        for (i = 0; i < r2; i++) {
            for (j = 0; j < c2; j++)
                printf("%d ", matrix_two[i][j]);
            printf("\n");
        }

        int *matrix_output[r1];
        for (i = 0; i < r1; i++)
            matrix_output[i] = (int *)malloc(c2 * sizeof(int));

        pthread_t threads[r1][c2];

        threadElement * myThreadElement = malloc(sizeof(threadElement));

        myThreadElement->mat_one = matrix_one;
        myThreadElement->mat_two = matrix_two;
        myThreadElement->mat_output = matrix_output;
        myThreadElement->r2 = r2;

        int error;
        indexes * indexesStruct = (indexes *)malloc(r1 * c1 * sizeof(indexes));
        threadArgs * threadArgsStruct = (threadArgs *)malloc(r1 * c1 * sizeof(threadArgs));

        // Element by Element Algorithm
        // Start checking time
        gettimeofday(&start, NULL);

        for(i = 0; i < r1; i++) {
            for(j = 0; j < c2; j++) {
                indexesStruct[i * c2 + j].i = i;
                indexesStruct[i * c2 + j].j = j;

                threadArgsStruct[i * c2 + j].myThreadElement = myThreadElement;
                threadArgsStruct[i * c2 + j].myIndexes = &indexesStruct[i * c2 + j];

                threads[i][j] = malloc(sizeof(pthread_t));

                error = pthread_create(&threads[i][j], NULL, elementMultiplication, (void *) &threadArgsStruct[i * c2 +
    j]);
                if(error)
                    printf("\nError creating thread... \n");
            }
        }

        for(i = 0; i < r1; i++) {
            for(j = 0; j < c2; j++) {
                pthread_join(threads[i][j], NULL);
```

```
            }
        }
        gettimeofday(&stop, NULL);

        fptr = fopen("output.txt", "w+");

        // Printing Output Matrix
        printf("\nOutput Matrix (Element by Element):\n");
        fprintf(fptr, "Matrix Output 1:\n");

        for (i = 0; i < r1; i++) {
            for (j = 0; j < c2; j++) {
                printf("%d ", matrix_output[i][j]);
                fprintf(fptr, "%d ", matrix_output[i][j]);
            }
            printf("\n");
            fprintf(fptr, "\n");
        }

        printf("\nTime (in micro-seconds) taken for element by element: %lu\nNumber of threads created = %d\n",
    stop.tv_usec - start.tv_usec, r1 * c2);
        fprintf(fptr, "END1\t[%d]\n\n", stop.tv_usec - start.tv_usec);

        // Row by Row Algorithm
        // Start checking time
        gettimeofday(&start, NULL);

        for(i = 0; i < r1; i++) {
            indexesStruct[i].i = i;

            threadArgsStruct[i].myThreadElement = myThreadElement;
            threadArgsStruct[i].myIndexes = &indexesStruct[i];

            error = pthread_create(&threads[i][0], NULL, rowMultiplication, (void *) &threadArgsStruct[i]);
            if(error)
                printf("\nError creating thread... \n");
        }

        for(i = 0; i < r1; i++) {
                pthread_join(threads[i][0], NULL);
        }

        gettimeofday(&stop, NULL);

        // Printing Output Matrix
        printf("\nOutput Matrix (Row by Row):\n");
        fprintf(fptr, "Matrix Output 2:\n");

        for (i = 0; i < r1; i++) {
            for (j = 0; j < c2; j++) {
                printf("%d ", matrix_output[i][j]);
                fprintf(fptr, "%d ", matrix_output[i][j]);
            }
            printf("\n");
            fprintf(fptr, "\n");
        }

        printf("\nTime (in micro-seconds) taken for row by row: %lu\nNumber of threads created = %d\n", stop.tv_usec -
    start.tv_usec, r1);
        fprintf(fptr, "END2\t[%d]", stop.tv_usec - start.tv_usec);

        fclose(fptr);

        return 0;
    }
```

Code

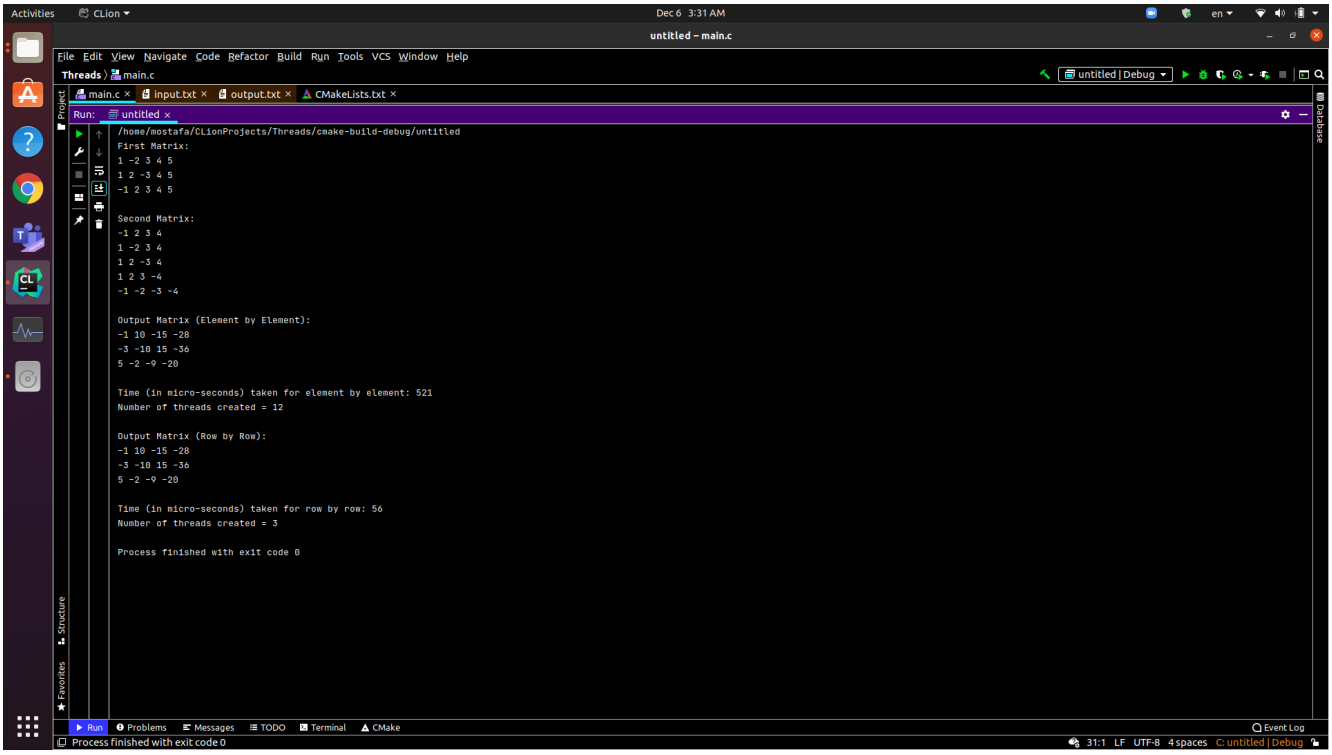
II. Merge Sort:

```
#include <stdlib.h>
#include <stdio.h>
#include <pthread.h>

typedef struct {
    int* arr;
    int l;
    int r;
} mergeArgs;

void merge(int * arr, int l, int m, int r) {
    int i, j, k;
    int n1 = m - l + 1;
    int n2 = r - m;

    /* create temp arrays */
    int L[n1], R[n2];

    /* Copy data to temp arrays L[] and R[] */
    for (i = 0; i < n1; i++)
        L[i] = arr[l + i];
    for (j = 0; j < n2; j++)
        R[j] = arr[m + 1 + j];

    i = 0;
    j = 0;
    k = l;
    while (i < n1 && j < n2) {
        if (L[i] <= R[j]) {
            arr[k] = L[i];
            i++;
        }
        else {
            arr[k] = R[j];
            j++;
        }
        k++;
    }

    while (i < n1) {
        arr[k] = L[i];
        i++;
        k++;
    }

    while (j < n2) {
        arr[k] = R[j];
        j++;
        k++;
    }
}

void mergeSort(int* arr, int l, int r) {
    if (l < r) {

        int m = l + (r - l) / 2;

        mergeSort(arr, l, m);
        mergeSort(arr, m + 1, r);

        merge(arr, l, m, r);
    }
}

void* mergeSortThread(void * args) {
    mergeArgs* myArgs = (mergeArgs *) args;

    int * arr = &myArgs->arr[0];

    int l = myArgs->l;
```

```
        int r = myArgs->r;

        if (l < r) {
            pthread_t * firstThread = malloc(sizeof(pthread_t));
            pthread_t * secondThread = malloc(sizeof(pthread_t));
            mergeArgs * myArgsOne = malloc(sizeof(mergeArgs));
            mergeArgs * myArgsTwo = malloc(sizeof(mergeArgs));

            int m = l + (r - l) / 2;

            myArgsOne->arr = &arr[0];
            myArgsOne->l = l;
            myArgsOne->r = m;

            pthread_create(&firstThread, NULL, mergeSortThread, myArgsOne);

            myArgsTwo->arr = &arr[0];
            myArgsTwo->l = m + 1;
            myArgsTwo->r = r;

            pthread_create(&secondThread, NULL, mergeSortThread, myArgsTwo);

            pthread_join(firstThread, NULL);
            pthread_join(secondThread, NULL);

            merge(arr, l, m, r);
        }
        pthread_exit(NULL);
    }

    void main() {
        FILE *fptr = fopen("input.txt", "r");

        int i, size;
        mergeArgs myArgs;

        // Reading Array
        fscanf(fptr, "%d", &size);

        int * array = malloc(size * sizeof(int));
        int * arrayThread = malloc(size * sizeof(int));

        for(i = 0; i < size; i++) {
            fscanf(fptr, "%d", &array[i]);
            arrayThread[i] = array[i];
        }

        // Printing Unsorted Array
        printf("Unsorted Array:\n");
        for(i = 0; i < size; i++)
            printf("%d ", array[i]);

        mergeSort(array, 0, size - 1);

        // Printing Sorted Array
        printf("\n\nSorted Array (no threads):\n");
        for(i = 0; i < size; i++)
            printf("%d ", array[i]);
        fclose(fptr);

        pthread_t * myThread = malloc(sizeof(pthread_t));

        myArgs.arr = arrayThread;
        myArgs.l = 0;
        myArgs.r = size - 1;

        pthread_create(&myThread, NULL, mergeSortThread, (void *) &myArgs);
        pthread_join(myThread, NULL);

        // Printing Sorted Array
        printf("\n\nSorted Array (with threads):\n");
        for(i = 0; i < size; i++)
            printf("%d ", arrayThread[i]);
    }
```

Sample Runs

Matrix Multiplication:



Input file (input.txt)

3 5
1 -2 3 4 5
1 2 -3 4 5
-1 2 3 4 5
5 4
-1 2 3 4
1 -2 3 4
1 2 -3 4
1 2 3 -4
-1 -2 -3 -4

Output file (output.txt)

Matrix Output 1:
-1 10 -15 -28
-3 -10 15 -36
5 -2 -9 -20
END1 [521]

Matrix Output 2:
-1 10 -15 -28
-3 -10 15 -36
5 -2 -9 -20
END2 [56]

Sample Runs

Merge Sort: