

```

/*****
Authors : Albert Owusu-Asare , Box 4497, <owusuasa@grinnell.edu>
         : Ezra Edgerton , Box 3503, <edgerton@grinnell.edu>

This document contains answers to questions from CS213 Lab: Threads

Questions:
http://www.cs.grinnell.edu/~weinman/courses/CSC213/2014F/labs/threads.html

modified code has the MODIFIED keyword
Original author is cited below :
* Jerod Weinman
* 21 May 2008
*****/

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

#include "matrix.h"
#include "matrixop.h"

#define SUB2IND(row,col,numcols) (row) * (numcols) + (col)

/* Check the dimensions of three matrices for the sum C=A+B
*
* Returns -1 if there is a dimension mismatch, and zero otherwise. */
int mtxCheckAddDim(const struct matrix_t *a, const struct matrix_t *b,
                  const struct matrix_t *c)
{
    if (a->rows != b->rows || a->rows != c->rows ||
        a->cols != b->cols || a->cols != c->cols ) {
        return -1;
    }

    return 0;
}

/* Matrix addition C = A + B
*
* Preconditions:
*   Matrix parameters a,b and c all have the same dimension
*
* Postconditions:
*   The resulting matrix sum is stored in parameter c
*   Return value of 0 indicates successful completion of the addition
*/
int mtxAdd( const struct matrix_t *a, const struct matrix_t *b,
            struct matrix_t *c) {
    /* Make sure these matrices are "addable" */
    int res = mtxCheckAddDim(a,b,c);

    if (res<0) {
        fprintf(stderr,"Dimension mismatch for matrix add.\n");
        return res;
    }

    int m = a->rows;          /* Dimensions of input matrices */
    int n = a->cols;
    MTX_TYPE *pa, *pb, *pc; /* Pointers to matrix data */

```

```

    pa = a->data;              /* Initialize pointers to beginning of data */
    pb = b->data;
    pc = c->data;

    /* Iterate over every entry in the matrices, adding and storing the result */
    int i,j;
    for (i=0 ; i<m ; i++)
        for (j=0 ; j<n ; j++, pa++,pb++,pc++)
            *pc = *pa + *pb;

    return 0; /* Indicate successful completion */
}

/* MODIFIED : This is an additional piece to the original
* Check the dimensions of three matrices for the sum C=AB
*
* Returns -1 if there is a dimension mismatch, and zero otherwise. */
int mtxCheckMultiplyDim(const struct matrix_t *a, const struct matrix_t *b,
                       const struct matrix_t *c)
{
    if (a->cols != b->rows || a->rows != c->rows
        || b->cols != c->cols ) {
        return -1;
    }

    return 0;
}

/*
* MODIFIED
* Matrix multiplication C = AB
*
* Preconditions:
*   Matrix parameters a,b,c have the required dimension.
*   mtxCheckMultiplyDim(a,b,c) returns >0
*
* Postconditions:
*   The resulting matrix sum is stored in parameter c
*   Return value of 0 indicates successful completion of the multiplication
*/
int mtxMultiplyMin( const struct matrix_t *a, const struct matrix_t *b,
                   struct matrix_t *c)
{
    /* Make sure these matrices are "multiply-able" */
    int res = mtxCheckMultiplyDim(a,b,c);

    if (res<0) {
        fprintf(stderr,"Dimension mismatch for matrix add.\n");
        return res;
    }

    int m = a->rows;          /* Dimensions of input matrices */
    int n = a->cols;
    int p = b->cols;

    MTX_TYPE *pa, *pb, *pc; /* Pointers to matrix data */

    pa = a->data;              /* Initialize pointers to beginning of data */
    pb = b->data;

```

```

pc = c->data;

/* Iterate over every entry in the matrices, adding and storing the result */
int i,j,k, l;

/* initialise elements of matrix c to 0*/

for (l = 0; l < (m*p); l++, pc++)
{
    *pc = 0;
}
pc = c->data; // point back to start of c matrix

for (i = 0; i < m; i++, pc += SUB2IND(1,0,p), pb = b->data)
//i loops through the rows of a and the rows of c
{
    for (k = 0; k < n; k++, pa++, pc = pc - p)
        //k loops through the columns of a and the rows of b
        {
            for (j = 0; j < p; j++,pb++,pc++)
                //the columns of b and the columns of c
                {
                    *pc += *pa * *pb;
                }
            }
        }

    }

return 0; /* Indicate successful completion */
}
/*
 * MODIFIED
 * Does the matrix multiplication work for one thread
 * preconditions: none
 * postconditions : matrix c is modified such that each of its values agrees with m
atrix
 * multiplication of c = a * b.
 *
 * much of the code involving the creation and running of threads was taken from th
e POSIX
 * Threads Programming tutorial:
 * https://chhttps://computing.llnl.gov/tutorials/pthreads/#Joining
 * computing.llnl.gov/tutorials/pthreads/#PassingArguments
 */

void* threadMtxMultiplyMin(void *multParam)
{
    struct matrixThreadParam_t *data;
    data = ( struct matrixThreadParam_t *) multParam ;

    /* Dimensions of input matrices */
    int m = data->a->rows;
    int n = data->a->cols;
    int p = data->b->cols;

    int stride = data->numThreads;
    int ID = data->threadId;

    /* Pointers to matrix data */
    MTX_TYPE *pa, *pb, *pc;

    /* Initialize pointers to beginning of data */
    pa = data->a->data;
    pb = data->b->data;
    pc = data->c->data;

```

```

/* Iterate over every entry in the matrices, adding and storing the result */
int i,j,k;

pc += SUB2IND(ID, 0, p);
pa += SUB2IND(ID, 0, n);

for (i = ID; i < m;
     i= i + stride, pc += SUB2IND(stride, 0, p), pb = data->b->data,
     pa += SUB2IND(stride-1, 0 , n))
//i loops through the rows of a and the rows of c
{
    for (k = 0; k < n; k++, pa++, pc = pc - p)
        //k loops through the columns of a and the rows of b
        {
            for (j = 0; j < p; j++,pb++,pc++)
                //the columns of b and the columns of c
                {
                    *pc += *pa * *pb;
                }
            }
        }

    return NULL; /* Indicate successful completion */
}

/*
 * MODIFIED
 * Computes the threaded concurrent matrix product.
 * preconditions: none
 * postconditions : matrix c is modified such that each of its values agrees with m
atrix
 * multiplication of c = a * b.
 *
 * much of the code involving the creation and running of threads was taken from th
e POSIX
 * Threads Programming tutorial:
 * https://chhttps://computing.llnl.gov/tutorials/pthreads/#Joining
 * computing.llnl.gov/tutorials/pthreads/#PassingArguments
 */

int parMtxMultiply( const struct matrix_t *a,
                    const struct matrix_t *b,
                    struct matrix_t *c,
                    int numThreads)
{
    //checks to see if matrixes are multipliable
    int res = mtxCheckMultiplyDim(a,b,c);

    if (res<0) {
        fprintf(stderr,"Dimension mismatch for matrix add.\n");
        return res;
    }

    /* initialise elements of matrix c to 0*/
    int l;
    MTX_TYPE *pc;
    pc = c->data;

    for (l = 0; l < (a->rows * b->cols); l++, pc++)
    {
        *pc = 0;
    }
    pc = c->data; // point back to start of c matrix

```

```
//creates threads according to numThreads
int t;
int rc; //gets return value when thread is created and when thread is joined
struct matrixThreadParam_t thread_matrix_array[numThreads];
pthread_t threads[numThreads];

pthread_attr_t attr;
void *status;

//initialization of attr to make threads joinable
pthread_attr_init(&attr);
pthread_attr_setdetachstate(&attr, PTHREAD_CREATE_JOINABLE);

for (t = 0; t < numThreads; t++)
{
    //set elements of thread_array[t]
    thread_matrix_array[t].a = a;
    thread_matrix_array[t].b = b;
    thread_matrix_array[t].c = c;
    thread_matrix_array[t].numThreads = numThreads;
    thread_matrix_array[t].threadId = t;
    rc = pthread_create(&threads[t], &attr, threadMtxMultiplyMin,
                       (void *) &thread_matrix_array[t]);

    if (rc) {
        fprintf(stderr, "Could not create thread %d\n", t);
        return EXIT_FAILURE;
    }
}
//join threads
pthread_attr_destroy(&attr);
for (t = 0; t < numThreads; t++)
{
    rc = pthread_join(threads[t], &status);
    if (rc)
    {
        fprintf(stderr, "Thread %d could not join\n", t);
        return EXIT_FAILURE;
    }
}
return 0;
}
```