CUDA Matrix Multiplication

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1

Anatomy of the CUDA *matrixMult* Program: #defines, #includes, and Globals


```
#include <stdio.h>
#include <assert.h>
#include <malloc.h>
#include <math.h>
#include <stdlib.h>

#include <cuda_runtime.h>
#include "helper_functions.h"
#include "helper_cuda.h"

#ifndef  MATRIX_SIZE
#define MATRIX_SIZE     1024
#endif

#define AROWS               MATRIX_SIZE
#define ACOLS               MATRIX_SIZE

#define BROWS               MATRIX_SIZE
#define BCOLS               MATRIX_SIZE
#define ACOLSBROWS      ACOLS          // better be the same!
#define CROWS               AROWS
#define CCOLS               BCOLS

#ifndef  NUMT
#define NUMT          32
#endif

float   hA[AROWS][ACOLS];
float   hB[BROWS][BCOLS];
float   hC[CROWS][CCOLS];
```

2

Anatomy of a CUDA Program: Error-Checking


```
void
CudaCheckError( )
{
        cudaError_t e = cudaGetLastError( );
        if( e != cudaSuccess )
        {
                fprintf( stderr, "CUDA failure %s:%d: '%s'\n", __FILE__, __LINE__, cudaGetErrorString(e));
        }
}
```

3

Anatomy of a CUDA Program: The Kernel Function


```
__global__ void MatrixMul( float *A, float *B, float *C )
{
        // [A] is AROWS x ACOLS
        // [B] is BROWS x BCOLS
        // [C] is CROWS x CCOLS  =  AROWS x BCOLS

        int blockNum      = blockIdx.y*gridDim.x + blockIdx.x;
        int blockThreads = blockNum*blockDim.x*blockDim.y;
        int gid                 = blockThreads + threadIdx.y*blockDim.x + threadIdx.x;

        int crow = gid  /  CCOLS;
        int ccol  = gid % CCOLS;

        int aindex = crow * ACOLS;                  // a[i][0]
        int bindex = ccol;                          // b[0][j]
        int cindex = crow * CCOLS + ccol;       // c[i][j]

        float cij = 0.;
        for( int k = 0; k < ACOLSBROWS; k++ )
        {
                cij += A[aindex] * B[bindex];
                aindex++;
                bindex += BCOLS;
        }
        C[cindex] = cij;
       // __syncthreads( );
}
```

4

Anatomy of a CUDA Program: Setting Up the Memory for the Matrices


```
// allocate device memory:

float *dA, *dB, *dC;
cudaMalloc( (void **)(&dA), sizeof(hA) );
cudaMalloc( (void **)(&dB), sizeof(hB) );
cudaMalloc( (void **)(&dC), sizeof(hC) );
CudaCheckError( );

// copy host memory to device memory:

cudaMemcpy( dA, hA, sizeof(hA), cudaMemcpyHostToDevice );
cudaMemcpy( dB, hB, sizeof(hB), cudaMemcpyHostToDevice );
```

This is a defined constant in one of the CUDA .h files

In **cudaMemcpy( ),** it's always the second argument getting copied to the first!

5

Anatomy of a CUDA Program: Getting Ready to Execute


```
 // setup execution parameters:
dim3 threads( NUMT, NUMT, 1 );
if( threads.x > CROWS )
        threads.x = CROWS;
if( threads.y > CCOLS )
        threads.y = CCOLS;
dim3 grid( CROWS / threads.x,  CCOLS / threads.y );

// create cuda events for timing:
cudaEvent_t start, stop;
cudaEventCreate( &start );
cudaEventCreate( &stop  );
CudaCheckError( );

// record the start event:
cudaEventRecord( start, NULL );
```

6

Anatomy of a CUDA Program: Executing the Kernel

7

```
// execute the kernel:

MatrixMul<<<grid,threads>>>( dA, dB, dC );
```

Function call arguments

# of blocks

# of threads per block

- The call to **MatrixMul( )** returns *immediately*!
- If you upload the resulting array (dC) right away, it will have garbage in it.
- To block until the kernel is finished, call:
  cudaDeviceSynchronize( );

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7

Anatomy of a CUDA Program: Getting the Stop Time and Printing Performance

8

```
cudaDeviceSynchronize( );

// record the stop event:
cudaEventRecord( stop, NULL );

// wait for the stop event to complete:
cudaEventSynchronize( stop );

float msecTotal;
cudaEventElapsedTime( &millisecsTotal, start, stop );          // note: this in milliseconds

// performance in multiplies per second:

double secondsTotal = millisecsTotal / 1000.0;          // change it to seconds
double multipliesTotal = (double)CROWS * (double)CCOLS * (double)ACOLSBROWS;
double gigaMultipliesPerSecond = ( multipliesTotal / 1000000000. ) / secondsTotal;
fprintf( stderr, "%6d\t%6d\t%10.3lf\n", CROWS, CCOLS, gigaMultipliesPerSecond );
```

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8

Anatomy of a CUDA Program: Copying the Matrix from the Device back to the Host

9

```
cudaMemcpy( hC, dC ,sizeof(hC), cudaMemcpyDeviceToHost );
CudaCheckError( );

// clean up:
cudaFree( dA );
cudaFree( dB );
cudaFree( dC );
CudaCheckError( );
```

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9