
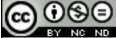


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CUDA Array Multiplication



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

```

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

// CUDA runtime
#include <cuda_runtime.h>

// Helper functions and utilities to work with CUDA
#include "helper_functions.h"
#include "helper_cuda.h"


#ifndef THREADS_PER_BLOCK
#define THREADS_PER_BLOCK      128      // number of threads in each block
#endif

#ifndef DATASET_SIZE
#define DATASET_SIZE           ( 8*1024*1024 ) // size of the array
// WARNING: DON'T CALL THIS "ARRAYSIZE" !
#endif


float hA[ DATASET_SIZE ];
float hB[ DATASET_SIZE ];
float hC[ DATASET_SIZE ];

```

The defined constant **ARRAYSIZE** is already used in one of the CUDA .h files



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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));
    }
}

```



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Anatomy of a CUDA Program: The Kernel Function


```

// array multiplication on the device: C = A * B
__global__ void ArrayMul( float *dA, float *dB, float *dC )
{
    int gid = blockIdx.x*blockDim.x + threadIdx.x;


    if( gid < DATASET_SIZE )
        dC[gid] = dA[gid] * dB[gid];
}

```

Note: " __ " is 2 underscore characters



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

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```

// fill host memory:
for( int i = 0; i < SIZE; i++ )
{
    hA[ i ] = hB[ i ] = (float) sqrtf( (float)i );
}

// allocate device memory:
float *dA, *dB, *dC;

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

CudaCheckError( );
    
```

} Assign values into
host (CPU) memory

} Allocate storage in
device (GPU) memory

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

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```

// copy host memory to the device:
cudaMemcpy( dA, hA, DATASET_SIZE*sizeof(float), cudaMemcpyHostToDevice );
cudaMemcpy( dB, hB, DATASET_SIZE*sizeof(float), cudaMemcpyHostToDevice );

CudaCheckError( );
    
```

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!

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Anatomy of a CUDA Program: Getting Ready to Execute

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```

// setup the execution parameters:
dim3 grid( DATASET_SIZE / THREADS_PER_BLOCK, 1, 1 );
dim3 threads( THREADS_PER_BLOCK, 1, 1 );

// create and start the timer:
cudaDeviceSynchronize( );

// allocate the events that we'll use for timing:
cudaEvent_t start, stop;
cudaEventCreate( &start );
cudaEventCreate( &stop );
CudaCheckError( );

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

} **Grid Size and
Block Size**

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Anatomy of a CUDA Program: Executing the Kernel

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```

// execute the kernel:
ArrayMul<<< grid, threads >>>( dA, dB, dC );
    
```

of blocks

of threads per block

Function call arguments

The call to `ArrayMul()` 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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Anatomy of a CUDA Program: Getting the Stop Time and Printing Performance

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

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

float msecTotal;
cudaEventElapsedTime( &msecTotal, start, stop );
CudaCheckError( );

// compute and print the performance
double secondsTotal = 0.001 * (double)msecTotal;
double multsPerSecond = (double)DATASET_SIZE / secondsTotal;
double megaMultsPerSecond = multsPerSecond / 1000000.;
fprintf( stderr, "%12d\t%4d\t%10.2f\n", DATASET_SIZE, THREADS_PER_BLOCK, megaMultsPerSecond );
```



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

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```
// copy result from the device to the host:
cudaMemcpy( hC, dC, sizeof(hC), cudaMemcpyDeviceToHost );
CudaCheckError( );

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

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!



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Anatomy of a CUDA Program: Running the Program

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```
rabbit 139% cat Makefile
CUDA_PATH    = /usr/local/apps/cuda/cuda-10.1
CUDA_BIN_PATH = $(CUDA_PATH)/bin
CUDA_NVCC    = $(CUDA_BIN_PATH)/nvcc

arrayMul:    arrayMul.cu
             $(CUDA_NVCC) -o arrayMul arrayMul.cu

rabbit 140% make arrayMul
/usr/local/apps/cuda/cuda-10.1/bin/nvcc -o arrayMul arrayMul.cu

rabbit 141% ./arrayMul
8388608 128 16169.75
```



We also have the CUDA-11 and CUDA-12 tools loaded for your use. You can use them if you want. But, given the wide breadth of different Nvidia cards around campus, **CUDA-10** seems to be the one that will run **everywhere!** I recommend you use it.

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Anatomy of a CUDA Program: Running the Program within a Loop

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```
rabbit 142% cat loop.csh
#!/bin/csh
foreach t ( 32 64 128 256 )
    /usr/local/apps/cuda/cuda-10.1/bin/nvcc -DTHREADS_PER_BLOCK=$t -o arrayMul arrayMul.cu
end

rabbit 143% loop.csh
8388608 32 9204.82
8388608 64 13363.10
8388608 128 16576.70
8388608 256 15496.81
```

We also have the CUDA-11 and CUDA-12 tools loaded for your use. You can use them if you want. But, given the wide breadth of different Nvidia cards around campus, **CUDA-10** seems to be the one that will run **everywhere!** I recommend you use it.



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