CS454 Topics in Advanced Computer Science
Introduction to NVIDIA CUDA

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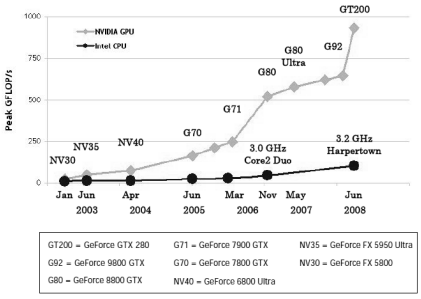
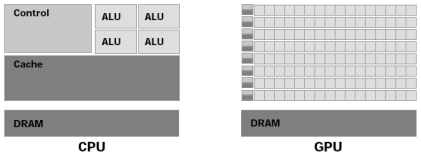
Super Computer on a Chip

GPU	Number of Processors
GeForce GTX 275,280,285	240
GeForce GTX 260	192
GeForce GTX 250	128
GeForce 9800 GTX	128
GeForce 9800 GT	112
GeForce 9600 GSO	96
GeForce 9600 GT	64
GeForce 8800 GTX	128
GeForce 8800 GT	112

GPU vs. CPU



Why GPU Is Faster



Use GPU for General-Purposed Computing

- Old approach: map the computation task to some graphics operation
  - DirectX
  - OpenGL
- New approach: use a general-purposed API for GPU
  - NVIDIA CUDA
  - ATI Steam SDK

Vector Add

- Input : A[], B[], N
- Output: C[]

```
for( int i=0 ; i < N ; ++i )
{
   C[i] = A[i] + B[i];
}
```

Vector Add in CUDA

```
// kernel definition
__global__ void VecAdd(float* A, float* B, float* C)
{
    int i = threadIdx.x;
    C[i] = A[i] + B[i];
}

int main()
{
    // kernel invocation
    VecAdd<<<1, N>>>(A, B, C);
}
```

About the Example

- CUDA is a C API with some extended syntax
- Kernel: a C function that can be executed N times by N different threads *in parallel*
- Each thread has a unique id threadIdx

ThreadIdx and Thread Blocks

- Threads can be created in 1D, 2D, or 3D block
- Example:

KernelFunction<<<**1,N**>>>(*arguments*);

Create a 1D block of threads, and each thread can be identified by threadIdx.x

Matrix Add

```
__global__ void MatAdd(float A[N][N],
      float B[N][N], float C[N][N]) {
    int i = threadIdx.x;
    int j = threadIdx.y;
    C[i][j] = A[i][j] + B[i][j];
}

int main() {
    dim3 dimBlock(N, N);
    MatAdd<<<1, dimBlock>>>(A, B, C);
}
```

Identify a thread in a 2D block

Create a 2D block of threads

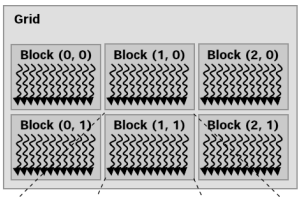
Thread Grid

- Multiple thread blocks form a thread grid
- Each block in the grid can be identified by blockIdx
- Example:

```
dim3 dimGrid(3,2);
dim3 dimBlock(4,3);
KernelFunction<<<dimGrid, dimBlock>>>( arguments );
```

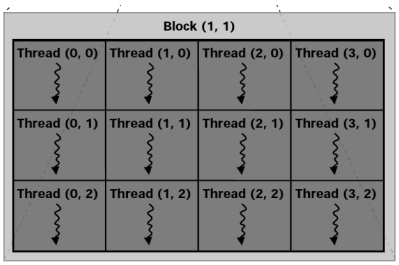
Thread Grid Example …

- A grid has 2x3 blocks



… Thread Grid Example

- A block has 3x4 threads



Matrix Add Using Thread Grid

```
__global__ void MatAdd(float A[N][N], float B[N][N], float C[N][N])
{
   int i = blockIdx.x * blockDim.x + threadIdx.x;
   int j = blockIdx.y * blockDim.y + threadIdx.y;
   if (i < N && j < N)
      C[i][j] = A[i][j] + B[i][j];
}

int main()
{
   dim3 dimBlock(16, 16);
   dim3 dimGrid((N + dimBlock.x – 1) / dimBlock.x,
                (N + dimBlock.y – 1) / dimBlock.y);
   MatAdd<<<dimGrid, dimBlock>>>(A, B, C);
}
```

About CUDA Threads

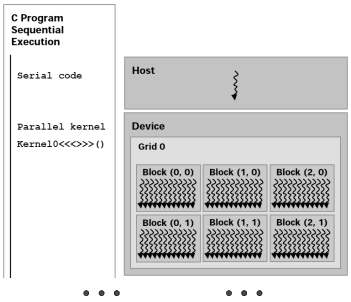
- Overhead of creating a thread is extremely low
- There can be more threads than the actual number of processors

About Thread Blocks

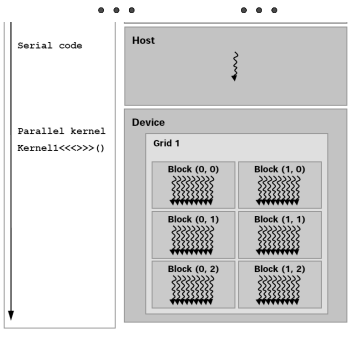
- All threads in a block are expected to reside on the same processor
  - Up to 512 threads per block
- Threads within the same block share memory and can be synchronized
- Thread blocks are required to be executed independently in any order

CUDA Program Execution …

- Host + Device



… CUDA Program Execution



Example: VecAdd.c

- Copy vectors from host memory to device memory
- Copy results from device memory to host memory

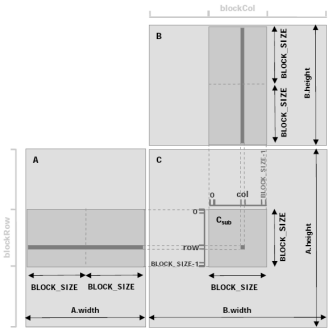
Memory

- Host memory
- Device memory
  - Global
    - Not cached, slow
  - Per-block shared
    - On chip, very fast
  - Per-thread local
    - Not cached, as slow as global memory

Example: MatMul1.c

- Use device global memory
- Kernel invocation
- Kernel

Matrix Multiplication Using Shared Memory …



… Matrix Multiplication Using Shared Memory

- Only A_{sub} and B_{sub} are needed to calculate C_{sub}
- Each element in A_{sub} and B_{sub} is used multiple times during the calculation of C_{sub}
- *How do we get Asub and Bsub into shared memory??*

Example: MatMul2.c

- `__shared__`
- `__syncthread()`

Summary

- Kernel
- Thread grid
- Program execution
- Memories
- Barrier synchronization

References

- NVIDIA CUDA Programming Guide Version 2.3