Introduction to Parallel Programming

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Outline

The basics
- Data types
- Pointers

Parallel programming
- Hardware
- Parallel primitives

The CUDA programming model
- Thread Hierarchy
- Memory Hierarchy
- Simple code example

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Hello World!

This code simply prints “Hello World!”.

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

int main() {
    printf("Hello␣World!\n");
    return 0;
}
```

C++ has explicit data types.

```
bool isEmpty = true;

int particles = 1024;

float Tf = 273.15;

double phi = 1.61803398875;
```

Structs are complex data types.

We can define the 3D vector data type.

```
struct float3{
    float x, y, z;
};

float3 pos;
pos.x = 3.2;
pos.y = -4.7;
pos.z = 1.34;
```

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- The program does not explicitly decide the exact memory location.
- A pointer is used to access data cells that are at a certain postion relative to it.

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```
float val;  \\ val is declared as a variable
float *ptr; \\ ptr is declared as a pointer

val=0.577;
*ptr=0.577;

printf("Address␣of␣val␣%d\n", &val);
printf("Address␣of␣*ptr␣%d\n", ptr);
```

An array may be declared with a pointer.

```
int N = 1024;
double *foo = new double[N];

for(int i=0; i<N; i++){
    foo[i]=cos(pi/N*i));
}
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The pointer `foo` refers to the memory address of the first element `foo[0]`.

The pointer `foo+k`, where `k` is an integer, refers to the memory address of the k-th element `foo[k]`.

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A matrix of size $m \times n$ may be indexed in column-major storage

```
int m=128, n=256;
double *A = new double[m*n];
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int m=128, n=256;
double *A = new double[m*n];

for(int i=0; i<m; i++){
    for(int j=0; j<n; j++){
        A[j*m+i]=cos(pi/m*i*j);
    }
}
```

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Why parallelism?

If you were plowing a field, which would you rather use: Two strong oxen or 1024 chickens?

Seymour Cray, the father of supercomputing.

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Throughput is measured in **FL**oating-**P**oint **O**perations **P**er **S**econd or **flops**.

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- Many programs run entirely on the CPU.

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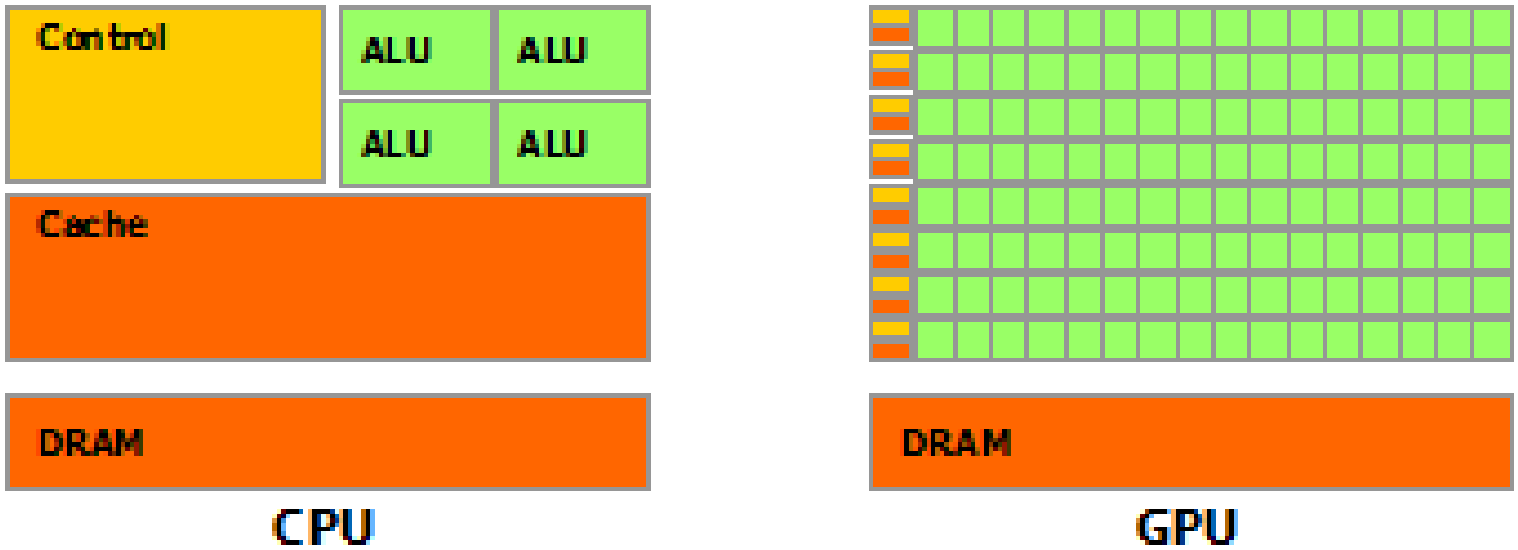
- General Purpose GPU Programming takes advantage of this enormous computing power.

The GPU devotes more transistors to data processing.

GPUs have many more Arithmetic Processing Units (ALUs).



Parallel primitives are common, highly parallelizable operations

- Mapping
- Stencil
- Reduction
- Scan or prefix sum

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- Transform each vertex of a 3D model.

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- Image filtering.
- Convolutional Neural Networks.

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- Find the maximum element of an array.
- Find the minimum element of an array.

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- Find the accumulated sum of an array.
- Compute the histogram of a series of data.
- Image processing, High Dynamic Range (HDR).

Parallel primitives are already implemented on libraries

Thrust is a CUDA library that allows you to implement high performance parallel applications with minimal programming effort.

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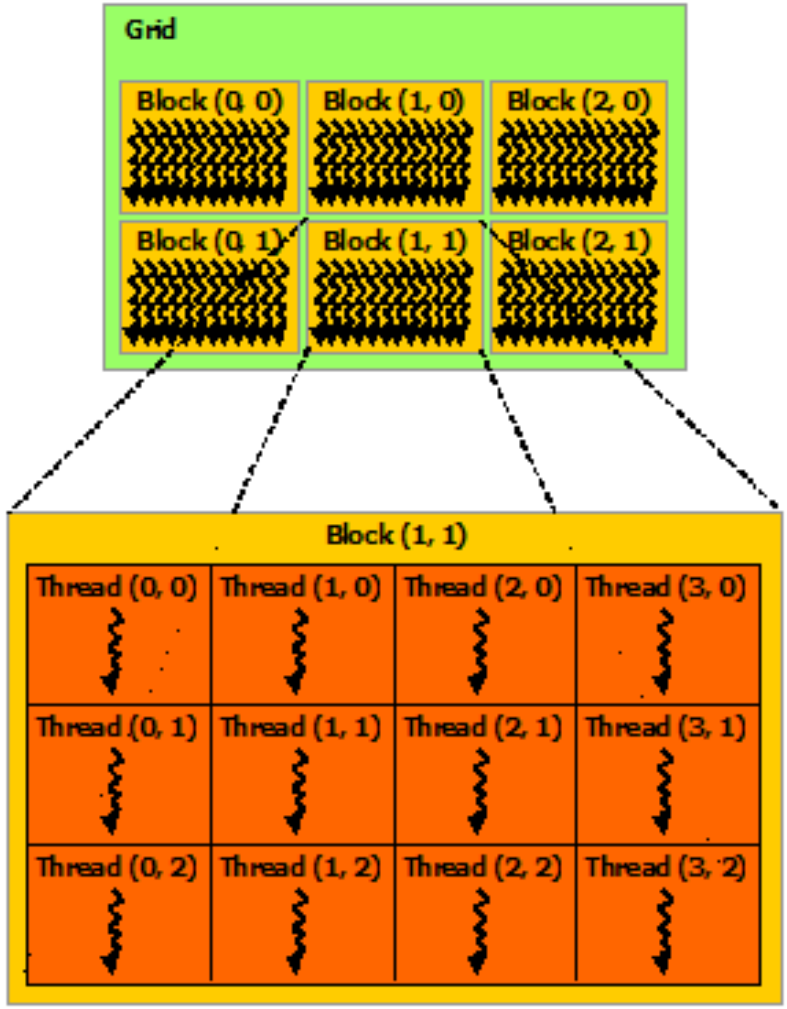
Parallel code execution is organized into a grid of thread blocks.



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- These pieces of serial code are known as **kernels**.
- Their execution is grouped into **thread blocks**.
- Thread blocks are grouped into a **block grid**.
- Threads and blocks may have up to three-dimensional indices.

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All threads within a thread block are ensured to be synchronous.

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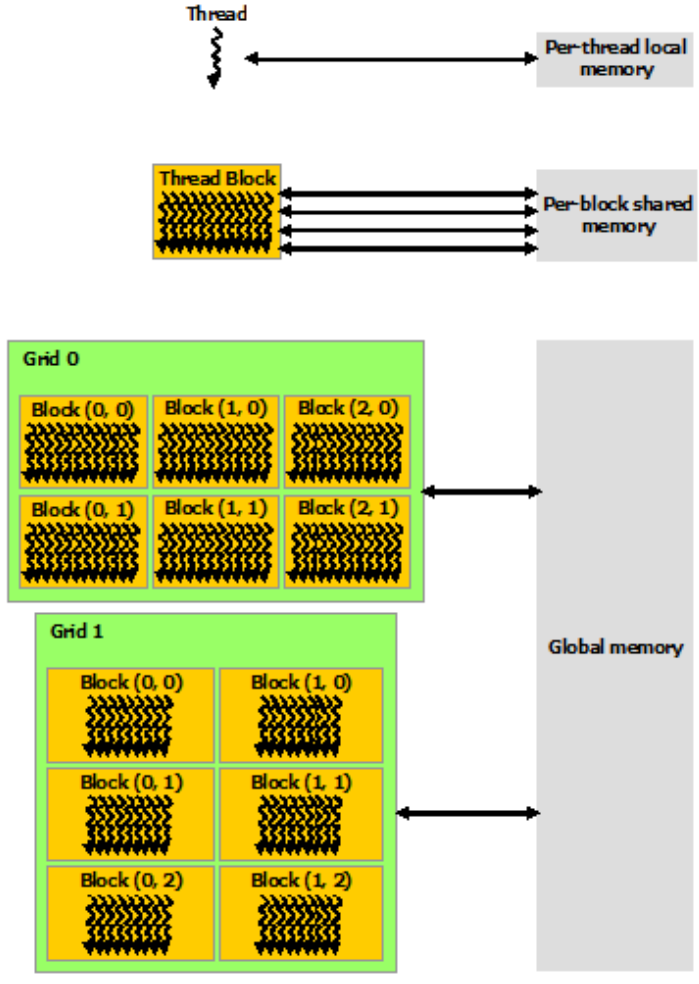

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- **Shared memory** is shared between threads of the same block.
- **Global memory** is the slowest, but may be accessed from any thread.

Memory allocation. Oh, no! pointers!

The CUDA unified memory model allows sharing between the host and the device. This is how to allocate global memory on the device.

```
int N=1024;
float *data;
cudaMallocManaged(&data, N*sizeof(float));
```

Kernel declaration. Oh, no! weird syntax!

```
// Generate equally spaced vector from a to b

__global__ void linspace(int N, float *data,
                         float a, float b){
    int i=blockIdx.x*blockDim.x+threadIdx.x;
    data[i]=a+(b-a)*i/(N-1);
}
```

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// Compute the square of each array element

__global__ void mapsquare(int N, float *data){
    int i=blockIdx.x*blockDim.x+threadIdx.x;
    data[i]=data[i]*data[i];
}
```

Kernel invocation. Oh, no! even weirder syntax!

```
// Define grid and block dimensions
dim3 block(512);
dim3 grid((N+512-1)/512);

// Kernel invocation
linspace<<<grid, block>>>(N, data, -10, 10);

mapsquare<<<grid, block>>>(N, data);
```

We forgot our data on the device,
we must take it back to the host.

```
// Must do this before passing data
// from device to host
cudaDeviceSynchronize();

// Print the result
for(int i=0; i<N; i++){
    printf("%f\n", data[i]);
}
```

Conclusion

Efficient parallel programming may seem very complicated at first, but its benefits are truly worth the effort.

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If you really liked it, enroll to the Introduction to Parallel Programming Course on Udacity.

References


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