Universidad Católica San Pablo

CUDA **Getting started**

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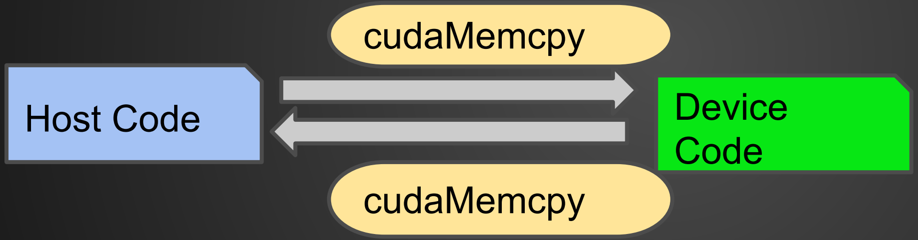
CUDA - Arquitectura de un programa

- **Host Code == programación clásica C en CPU**
- **Device Code == Programación en GPU**



- **Ejemplo Host**

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

Kernel

- **Función GPU**
- **`__global__` == Device (para el compilador)**

- **Ejemplo**

```
__global__ void kernel (void)
{}


int main( void ) {
     kernel<<<1,1>>>();
     printf( "Hello, World!\n" );
     return 0;
}
```

Kernel - Parámetros

- Clásico C
- cudaMalloc : Asignación memoria en el device
- cudaMemCpy : Copia datos memoria Host <-> Device
- cudaFree : Liberar memoria alocada con cudaMalloc
- Ejemplo

```
__global__ void add( int a, int b, int *c ) {
	*c = a + b;
}
int main( void ) {
	int c;
	int *dev_c;
	cudaMalloc((void**)&dev_c, sizeof(int));
	add<<<1,1>>>( 4, 8, dev_c );
	cudaMemcpy( &c,dev_c,sizeof(int),cudaMemcpyDeviceToHost);
	printf( "2 + 7 = %d\n", c );
	cudaFree( dev_c );
	return 0;
}
```

Kernel - cudaMalloc

- Qué puedes hacer con un puntero asignado con cudaMalloc ?
- Puedes pasarlo como parametro a una función que se ejecutará en el Device
- Puedes usarlo para leer o escribir en una función del Device
- Puedes pasarlo como parametro a una función que se ejecutará en el Host
- No puedes usarlo para leer o escribir en una función del Host

Kernel - cudaMemCpy

- **Standard C memcpy**
  - cudaMemcpyHostToDevice
  - cudaMemcpyDeviceToHost
  - cudaMemcpyDeviceToDevice
  - memcpy HostToHost

Propiedades del Device

- **Cuantos devices y Como recuperar sus propiedades ?**

```
cudaDeviceProp prop ;
int count;
cudaGetDeviceCount ( &count );
for (int i=0; i< count; i++) {
     cudaGetDeviceProperties ( &prop, i);
```

Propiedades del Device

```
struct cudaDeviceProp {
        char name[256];
        size_t totalGlobalMem;
        size_t sharedMemPerBlock;
        int regsPerBlock;
        int warpSize;
        size_t memPitch;
        int maxThreadsPerBlock;
        int maxThreadsDim[3];
        int maxGridSize[3];
        int clockRate;
        size_t totalConstMem;
        int major;
        int minor;
        size_t textureAlignment;
        size_t texturePitchAlignment;
        int deviceOverlap;
        int multiProcessorCount;
        int kernelExecTimeoutEnabled;
        int integrated;
        int canMapHostMemory;
        int computeMode;
        int maxTexture1D;
        int maxTexture1DLinear;
        int maxTexture2D[2];
        int maxTexture2DLinear[3];
        int maxTexture2DGather[2];
        int maxTexture3D[3];
        int maxTextureCubemap;
        int maxTexture1DLayered[2];
        int maxTexture2DLayered[3];
        int maxTextureCubemapLayered[2];
        int maxSurface1D;
        int maxSurface2D[2];
        int maxSurface3D[3];
        int maxSurface1DLayered[2];
        int maxSurface2DLayered[3];
        int maxSurfaceCubemap;
        int maxSurfaceCubemapLayered[2];
        size_t surfaceAlignment;
        int concurrentKernels;
        int ECCEnabled;
         int pciBusID;
        int pciDeviceID;
        int pciDomainID;
        int tccDriver;
        int asyncEngineCount;
        int unifiedAddressing;
        int memoryClockRate;
```

Propiedades del Device

name[256]	is an ASCII string identifying the device;
totalGlobalMem	is the total amount of global memory available on the device in bytes
sharedMemPerBlock	is the maximum amount of shared memory available to a thread block in bytes; this amount is shared by all thread blocks simultaneously resident on a multiprocessor
regsPerBlock	is the maximum number of 32-bit registers available to a thread block
warpSize	is the warp size in threads;
maxThreadsPerBlock	is the maximum number of threads per block;
maxThreadsDim[3]	contains the maximum size of each dimension of a block
maxGridSize[3]	contains the maximum size of each dimension of a grid;
maxTexture2D[2]	contains the maximum 2D texture dimensions.

http://developer.download.nvidia.com/compute/cuda/4_1/rel/toolkit/docs/online/group__CUDART__DEVICE_g5aa4f47938af8276f08074d09b7d520c.html

Propiedades del Device

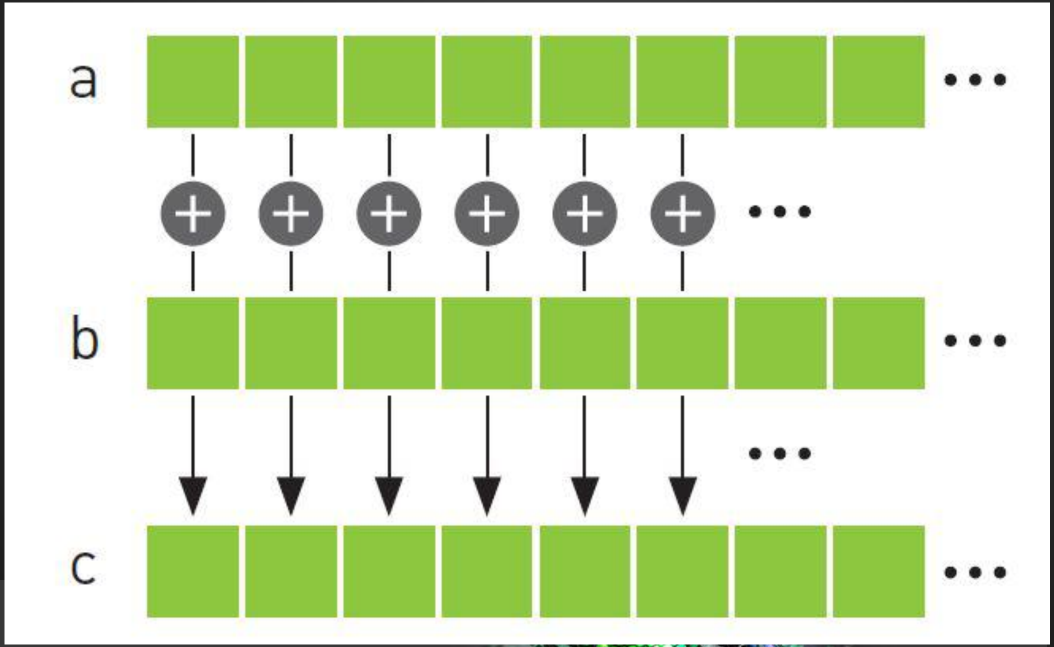
- **Exemplo de uso :**

```
int main( void ) {
     cudaDeviceProp prop;
     int dev;
     cudaGetDevice( &dev );

     printf( "ID of current CUDA device: %d\n", dev );
     memset( &prop, 0, sizeof( cudaDeviceProp ) );
     prop.major = 3;
     prop.minor = 0;
     cudaChooseDevice( &dev, &prop );
     printf( "ID of CUDA device closest to revision 3.0: %d\n", dev );
     cudaSetDevice( dev );
}
```

Primer programa

- **Sumar dos vectores**



Primer programa

- **Sumar dos vectores**
- **CPU**

```
void add( int *a, int *b, int *c ) {
      int tid = 0; // this is CPU zero, so we start at zero
      while (tid < N) {
          c[tid] = a[tid] + b[tid];
          // we have one CPU, so we increment by one
          tid += 1;      }
}
```

```
void add( int *a, int *b, int *c ) {
    for (i=0; i < N; i++) {
          c[i] = a[i] + b[i];
    }

}
```

Primer programa

- **Sumar dos vectores**
- **2 CPU**

```c
void add( int *a, int *b, int *c ) {
        int tid = 0; // this is CPU zero, so we start at zero
        while (tid < N) {
            c[tid] = a[tid] + b[tid];
            tid += 2;
        }
}
```

CPU #1

```c
void add( int *a, int *b, int *c ) {
        int tid = 1; // this is CPU one, so we start at one
        while (tid < N) {
            c[tid] = a[tid] + b[tid];
            tid += 2;

        }
}
```

CPU #2

Primer programa

- Sumar dos vectores
- GPU
  - __global__

```
__global__ void add( int *a, int *b, int *c )
{
     int tid = blockIdx.x;
     if(tid < N)
        c[tid] = a[tid] + b[tid];
}
```

Primer programa

- Sumar dos vectores
- `<<N,1>>` N copias del kernel (N < 65,535)
- `blockIdx.x` el índice del block actual

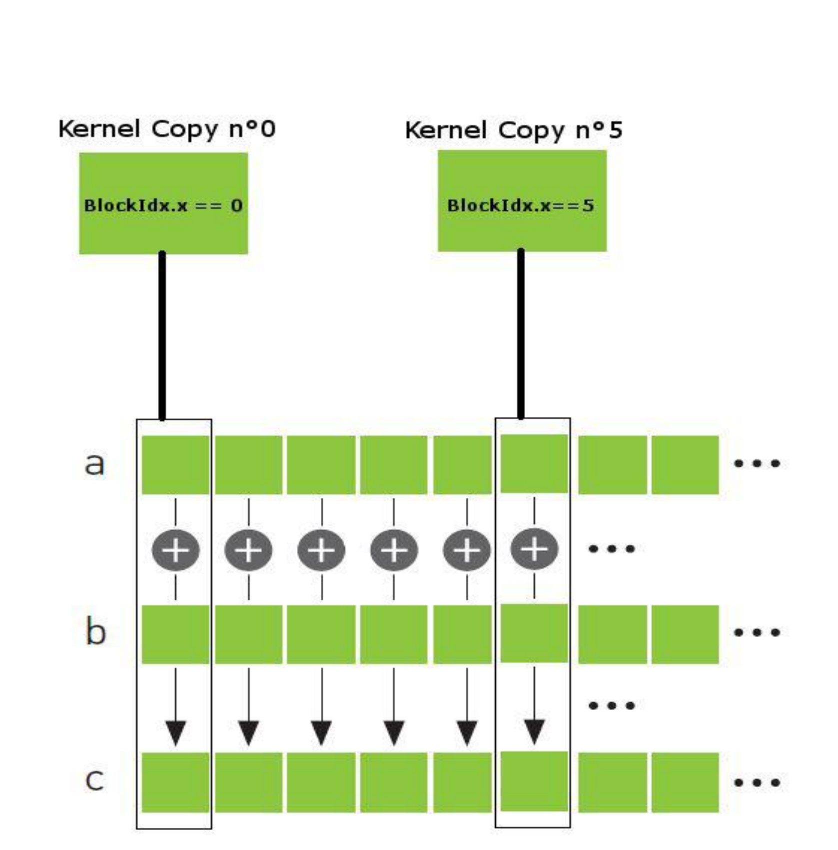
```
__global__ void add( int *a, int *b, int *c )
{
    int tid = blockIdx.x;
    if(tid < N)
        c[tid] = a[tid] + b[tid];
}
```

GPU

```
add<<<N,1>>>(vec_a,vec_b,vec_c);
```

main

Primer programa



Primer programa

```
int main( void ) {
     // Host variables
    int a[N], b[N], c[N];
     // device variables
    int *dev_a, *dev_b, *dev_c;
```

Primer programa

```
int main( void ) {
       // Host variables
         int a[N], b[N], c[N];
       // device variables
         int *dev_a, *dev_b, *dev_c;

         // allocate the memory on the GPU
         cudaMalloc( (void**)&dev_a, N * sizeof(int) );
         cudaMalloc( (void**)&dev_b, N * sizeof(int) );
         cudaMalloc( (void**)&dev_c, N * sizeof(int) );

         // fill the arrays 'a' and 'b' on the CPU
         for (int i=0; i<N; i++) {
            a[i] = -i;
            b[i] = i * i;
         }
```

Primer programa

```
int main( void ) {
       // Host variables
         int a[N], b[N], c[N];
       // device variables
         int *dev_a, *dev_b, *dev_c;

         // allocate the memory on the GPU
         cudaMalloc( (void**)&dev_a, N * sizeof(int) );
         cudaMalloc( (void**)&dev_b, N * sizeof(int) );
         cudaMalloc( (void**)&dev_c, N * sizeof(int) );

         // fill the arrays 'a' and 'b' on the CPU
         for (int i=0; i<N; i++) {
            a[i] = -i;
            b[i] = i * i;
         }
```

```
// copy the arrays 'a' and 'b' to the GPU
cudaMemcpy( dev_a, a, N * sizeof(int),
                            cudaMemcpyHostToDevice );
cudaMemcpy( dev_b, b, N * sizeof(int),
                            cudaMemcpyHostToDevice );
```

Primer programa

```
int main( void ) {
      // Host variables
        int a[N], b[N], c[N];
      // device variables
        int *dev_a, *dev_b, *dev_c;

        // allocate the memory on the GPU
        cudaMalloc( (void**)&dev_a, N * sizeof(int) );
        cudaMalloc( (void**)&dev_b, N * sizeof(int) );
        cudaMalloc( (void**)&dev_c, N * sizeof(int) );

        // fill the arrays 'a' and 'b' on the CPU
        for (int i=0; i<N; i++) {
           a[i] = -i;
           b[i] = i * i;
        }
```

```
        // copy the arrays 'a' and 'b' to the GPU
        cudaMemcpy( dev_a, a, N * sizeof(int),
                                                );

        cudaMemcpy( dev_b, b, N * sizeof(int),
                                cudaMemcpyHostToDevice );

        add<<<N,1>>>( dev_a, dev_b, dev_c );
```

Primer programa

```
int main( void ) {
      // Host variables
        int a[N], b[N], c[N];
      // device variables
        int *dev_a, *dev_b, *dev_c;

        // allocate the memory on the GPU
        cudaMalloc( (void**)&dev_a, N * sizeof(int) );
        cudaMalloc( (void**)&dev_b, N * sizeof(int) );
        cudaMalloc( (void**)&dev_c, N * sizeof(int) );

        // fill the arrays 'a' and 'b' on the CPU
        for (int i=0; i<N; i++) {
           a[i] = -i;
           b[i] = i * i;
        }
```

```
        // copy the arrays 'a' and 'b' to the GPU
        cudaMemcpy( dev_a, a, N * sizeof(int),
                                                         );
        cudaMemcpy( dev_b, b, N * sizeof(int),
                                  cudaMemcpyHostToDevice );


        add<<<N,1>>>( dev_a, dev_b, dev_c );

        // copy the array 'c' back from the GPU to the CPU
        cudaMemcpy( c, dev_c, N * sizeof(int),
                                  cudaMemcpyDeviceToHost );

}
```

Primer programa

```
int main( void ) {
        // Host variables
          int a[N], b[N], c[N];
        // device variables
          int *dev_a, *dev_b, *dev_c;

          // allocate the memory on the GPU
          cudaMalloc( (void**)&dev_a, N * sizeof(int) );
          cudaMalloc( (void**)&dev_b, N * sizeof(int) );
          cudaMalloc( (void**)&dev_c, N * sizeof(int) );

          // fill the arrays 'a' and 'b' on the CPU
          for (int i=0; i<N; i++) {
             a[i] = -i;
             b[i] = i * i;
          }

          // copy the arrays 'a' and 'b' to the GPU
          cudaMemcpy( dev_a, a, N * sizeof(int),
                                                      );
          cudaMemcpy( dev_b, b, N * sizeof(int),
                                cudaMemcpyHostToDevice );


          add<<<N,1>>>( dev_a, dev_b, dev_c );

          // copy the array 'c' back from the GPU to the CPU
          cudaMemcpy( c, dev_c, N * sizeof(int),
                                cudaMemcpyDeviceToHost );

          // display the results
          for (int i=0; i<N; i++) {
          printf( "%d + %d = %d\n", a[i], b[i], c[i] );
          }

          // free the memory allocated on the GPU
          cudaFree( dev_a );
          cudaFree( dev_b );
          cudaFree( dev_c );

          return 0;
}
```

Primer programa

1. **Asignación de memoria en GPU**
2. **Copiar memoria del CPU hacia el GPU**
3. **Invocar al kernel de CUDA**
4. **Copiar datos del GPU hacia el CPU**
5. **Liberar la memoria del GPU**

Dificultad de programar en CUDA

- **Pensar en paralelo**
- **Entender la arquitectura de un GPU**
- **Entender la idea de proximidad “Locality” para reducir el tiempo de acceso a los datos**
- **Estructura jerárquica de memoria**
- **Estructura jerárquica de threads**

- **Cuda Ambiente de Desarrollo**
    - NVIDIA Nsight™ integrated development environment
    - CUDA-GDB command line debugger
    - CUDA-MEMCHECK memory analyzer
    - GPU device management tools