Mergesort with CUDA

25.02.2020

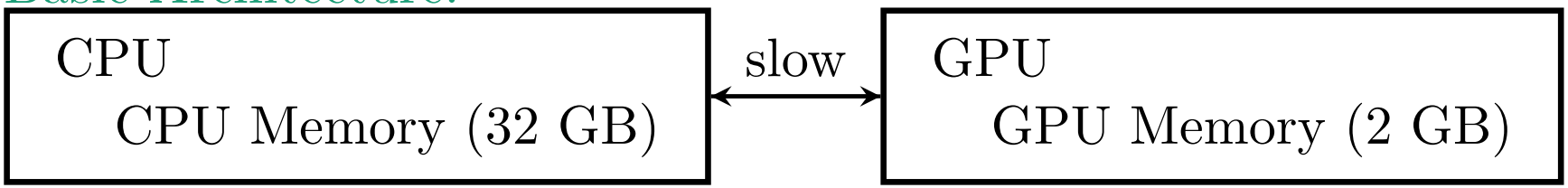
Basic Architecture

Big Ideas

SMID, No fancy stuff, Latency Hiding. Can I show that?

GPU and CPU uses different memories

Basic Architecture:



Memory Creation:

```
1 T* gpu_pointer;
2 unsigned int nBytes = 10*sizeof(int);
3 cudaMalloc((void**)&_gpu_pointer, nBytes);
```

Memory Transfer:

```
1 cudaMemcpy(_gpu_pointer, _cpu_pointer, nBytes, cudal
```

Ideas for Memory Management

```
1  template <typename T>
2  class Storage {
3      public:
4       explicit Storage(const std::vector<T>&);
5
6      private:
7       std::vector<T> _data;
8       T* _cpu_pointer;
9       T* _gpu_pointer;
10      void initialize_gpu_memory();
11 };
```

Memory pool, takes ownership

Initializes the gpu memory as copy

Pointers for cpu/gpu locations

Lazy Memory Sync

```
1  class Storage {
2      public:
3       T* cpu_pointer();
4       T* gpu_pointer();
5       const T* cpu_pointer_const();
6       const T* gpu_pointer_const();
7
8      private:
9       std::string head;
10      void sync_to_cpu();
11      void sync_to_gpu();
12 };
```

accesses const or non-const pointers

head $\in \{\text{CPU}, \text{GPU}, \text{SYNC}\}$

if non-const function: change head to location

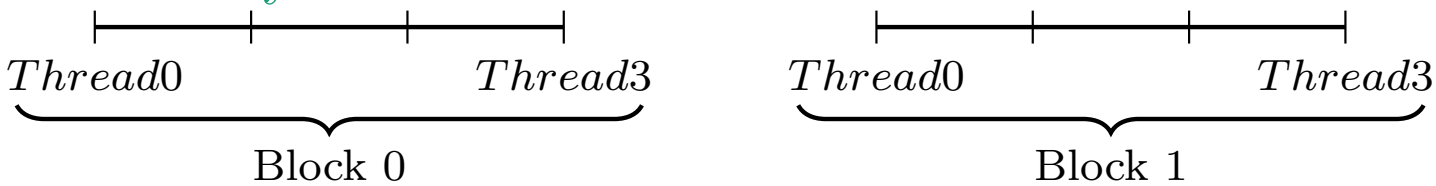
Lazily sync if required pointer $!=$ head

Launching CUDA threads

Cuda Program

```
1  dim3 Grid(2)
2  dim3 Block(4)
3  add_kernel<<<Grid, Block>>>(...)
```

Thread Layout:

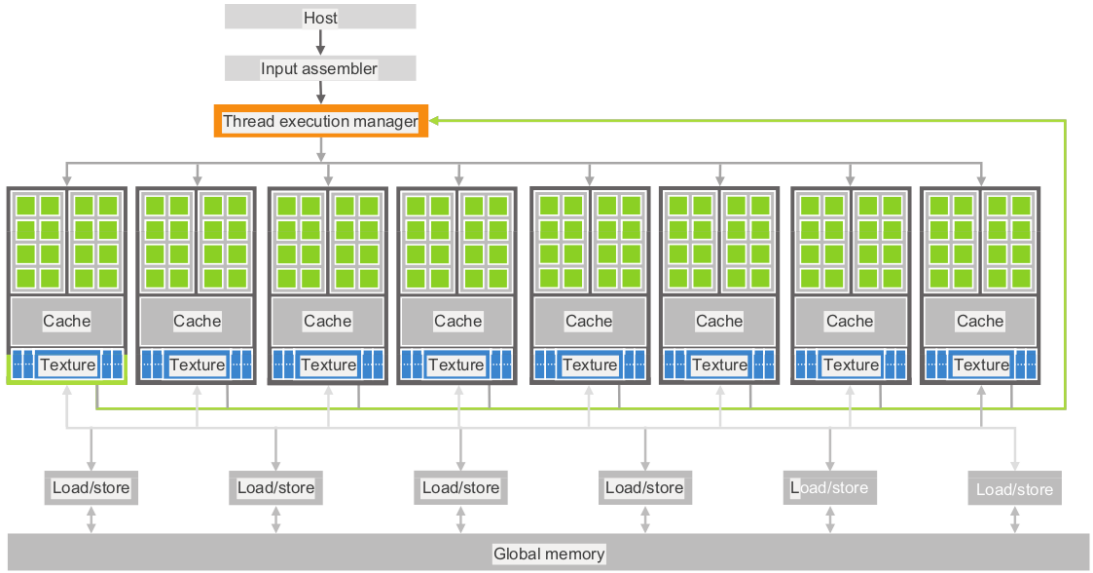


Addition:

```
1  __global__
2  add_kernel(float* A, float* B, float* C, int n) {
3      int i = blockDim.x * blockIdx.x + threadIdx.x;
4      if (i < n) {
5          C[i] = A[i] + B[i];
6      }
7  }
```

Software/Hardware connection

Programmer: Specifies number of blocks and threads

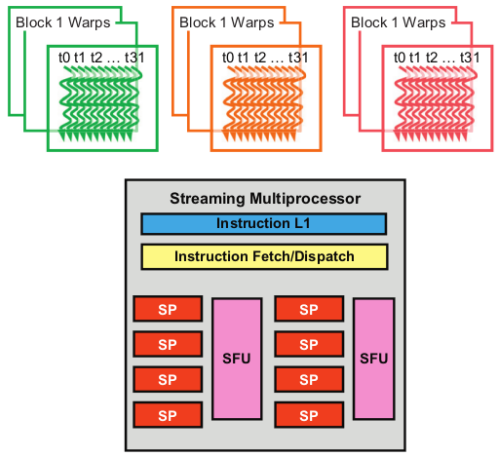


Dispatch:

1. Blocks to SM: Block 1 $\rightarrow$ SM1, Block 2 $\rightarrow$ SM2 ...

Software/Hardware connection

Programmer: Specifies number of blocks and threads



Dispatch:

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2. Grouping: Wrappend threads are allocated

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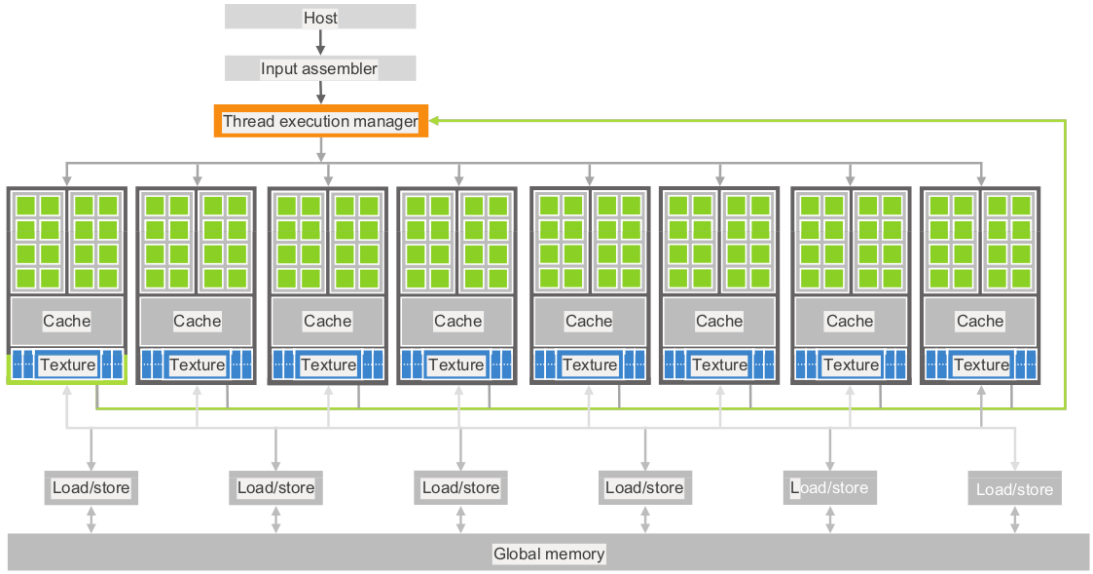

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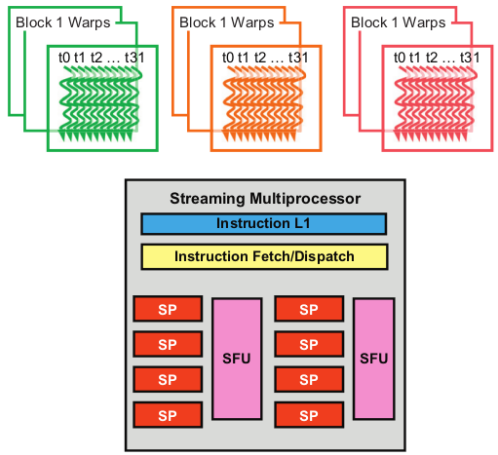

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Latency Hiding: If wrap 1 stalls, scheduler starts wrap 2

Merge

Basic Merge Operation

$$A = 578912141516$$

$$B = 12346101113$$

$$C = ????????????????$$

```
1  void merge(T* a, T* b, T* c, int sz_a, int sz_b) {
2       int i = 0, j = 0, k = 0;
3       while (k < sz_a + sz_b) {
4            if (i == sz_a)
5                 c[k++] = b[j++];
6            else if (j == sz_b)
7                 c[k++] = a[i++];
8            else if (a[i] <= b[j])
9                 c[k++] = a[i++];
10           else
11                c[k++] = b[j++];
12      }
13 }
```

How to spwan to many threads?

Naive: 2 Threads, half A and B

Example:

$$A = 0000$$

$$B = 1111$$

$$C = ????????$$

$$A = \underbrace{00}_{\text{Thread 1}} \mid \underbrace{00}_{\text{Thread 2}}$$

$$B = \underbrace{11}_{\text{Thread 1}} \mid \underbrace{11}_{\text{Thread 2}}$$

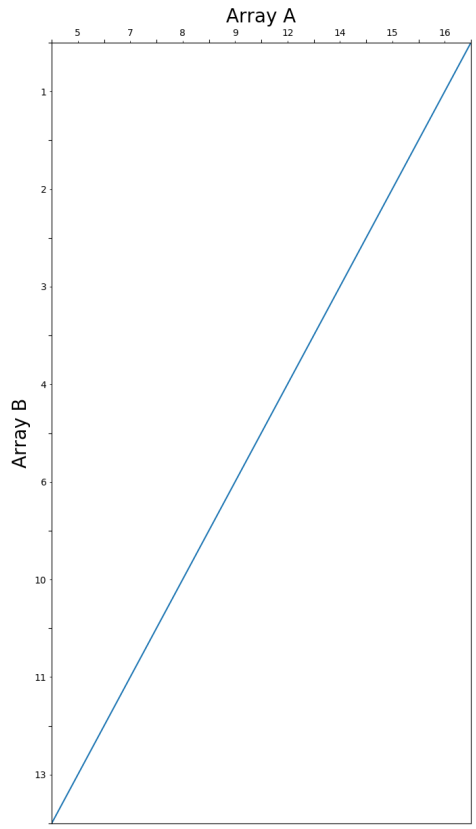
$$C = \underbrace{????}_{\text{Thread 1}} \mid \underbrace{????}_{\text{Thread 2}}$$

Result:

$$C = \underbrace{0011}_{\text{Thread 1}} \mid \underbrace{0011}_{\text{Thread 2}}$$

Merge

How to allocated work?



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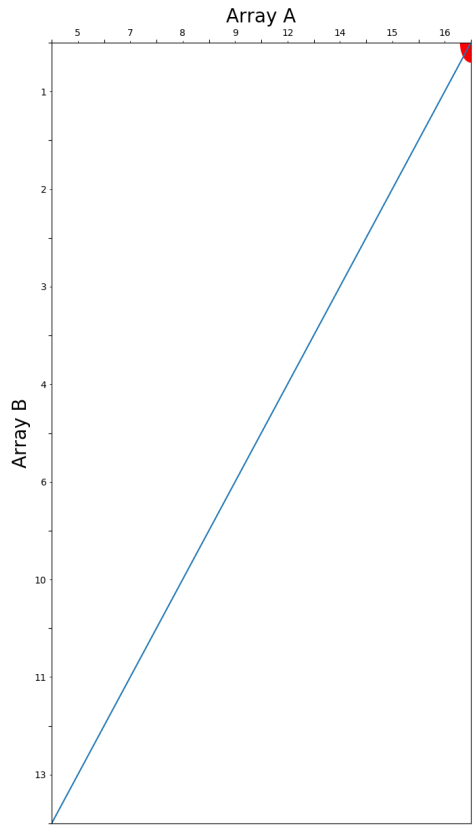

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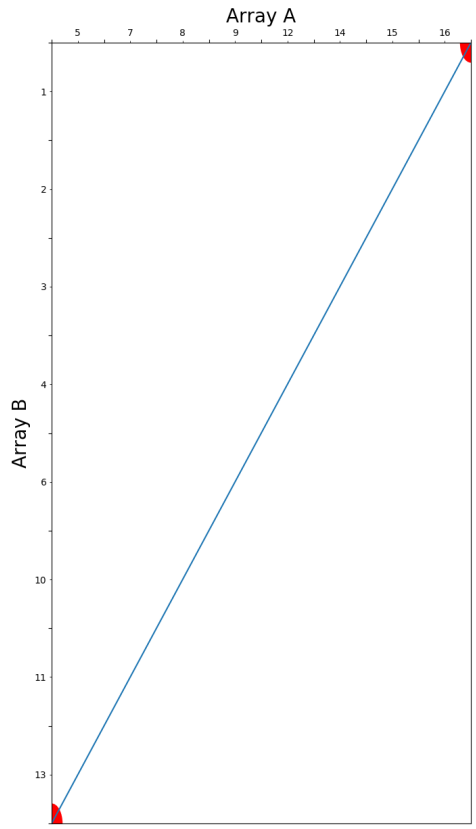

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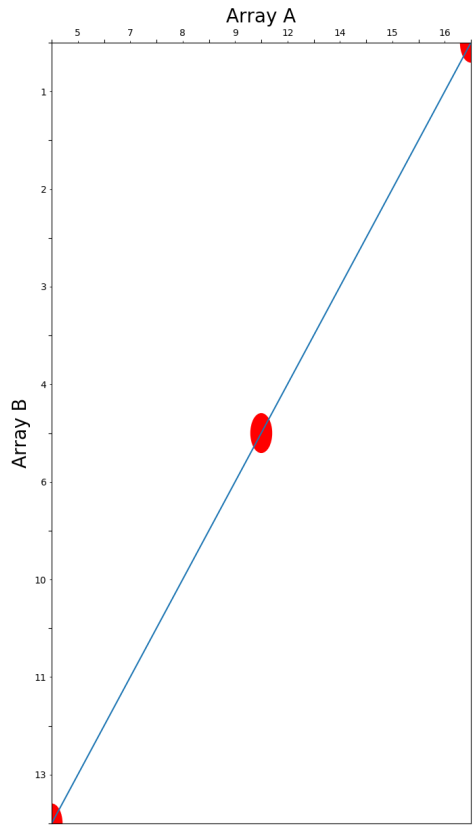

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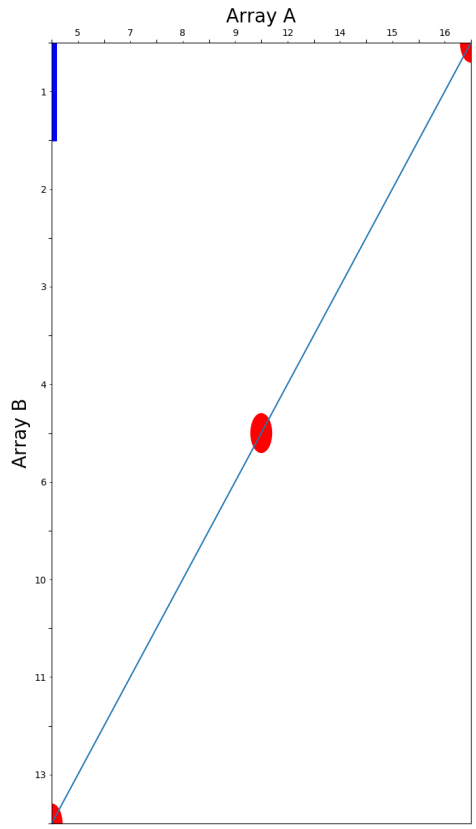

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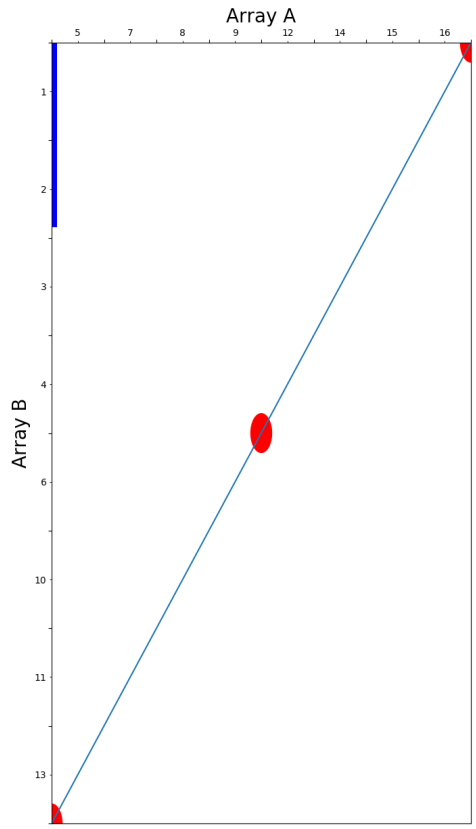

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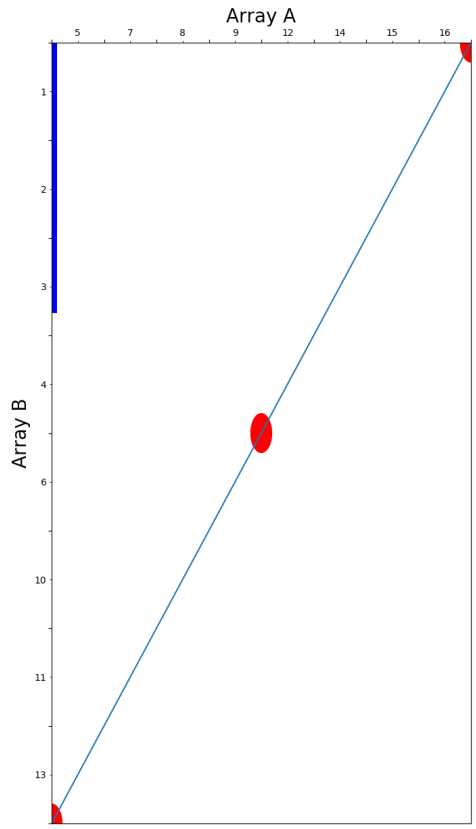

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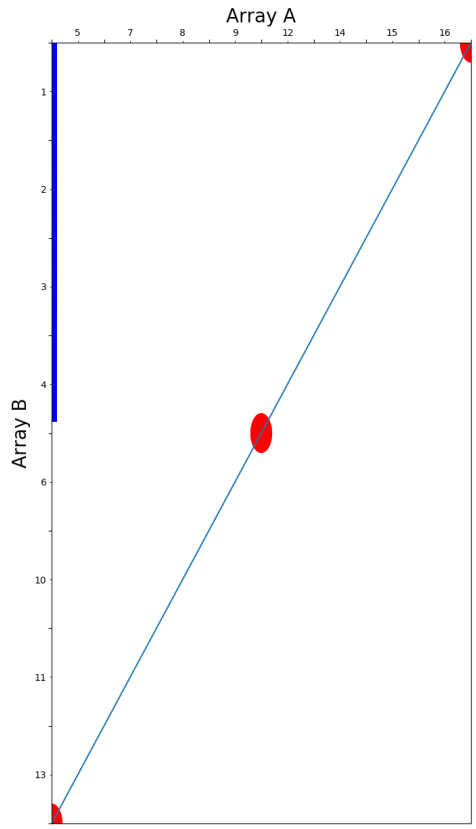

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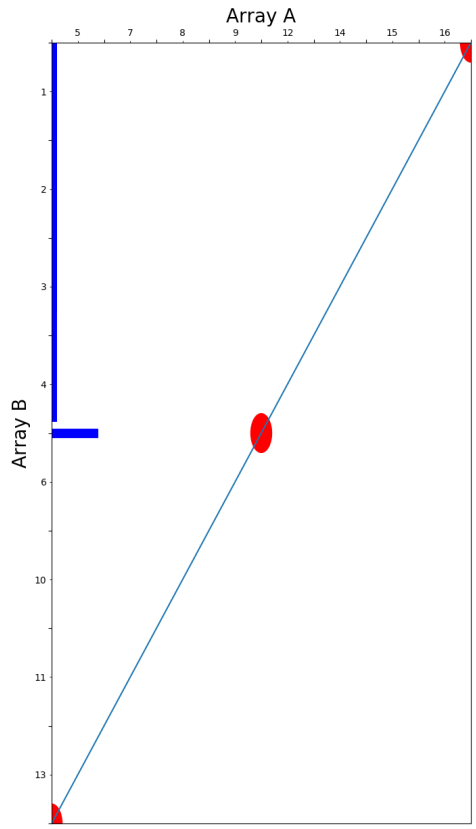

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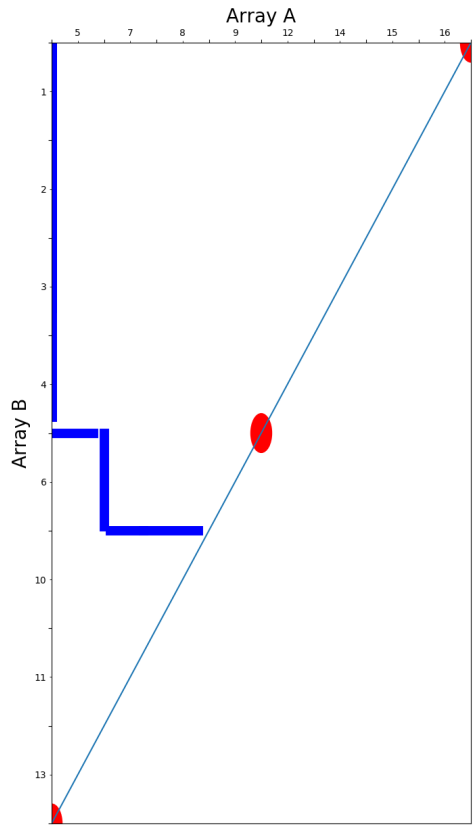

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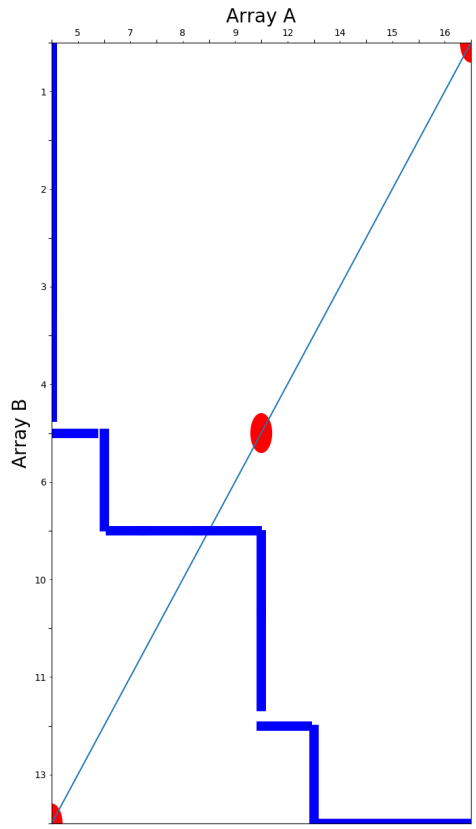


Merge

Comutation Procedure

```
1  ___global___
2  void paralleMerge(int* a, int sz_a, int* b, int sz_
3       int diag = threadIdx.x * length;
4       int a_start = mergepath(a, sz_a, b, sz_b, diag)
5       int b_start = diag - a_start;
6       merge(a, a_start, sz_a, b, b_start, sz_b, c, dia
7  }
```

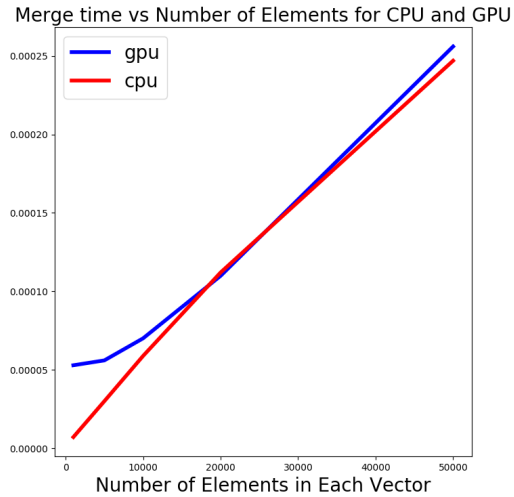
Each tread works on one part

Thread calculates the value A_lower for itself

Calcultes the also the B_lower (Why does that work again?)

merges the two arrays

Problem: Slow as a Snail



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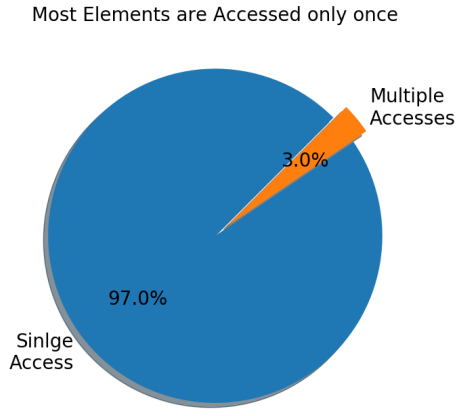
Reason: So much global meory access



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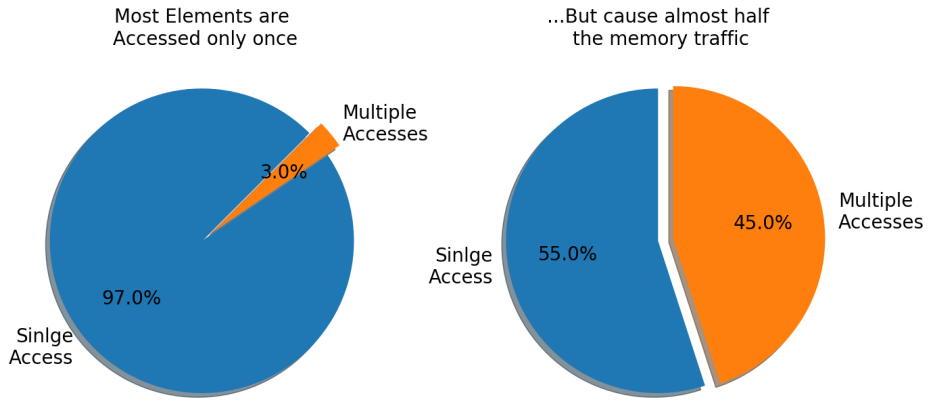
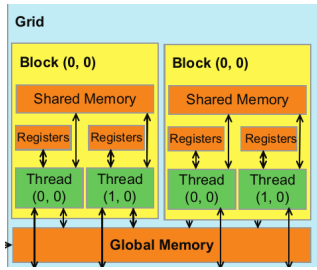


Merge

Memory Hirachy of CUDA

The different memories and their sizes



Visibility:
Global Memory: Can be accessed by all threads
Shared Memory: Private for each Block
Registers: Private for each Thread
Size:
Global Memory: 2 GB Shared Memory: Total: 192 KB, per block: 48 KB Latency:
Global Memory: 8 GB/s Shared Memory: 80 GB/s

Merging with local memory

Describe the shared memory

show the plot of the different memories and their relative size on my card

Show the results