Parallel Programming

Parallel Histogram

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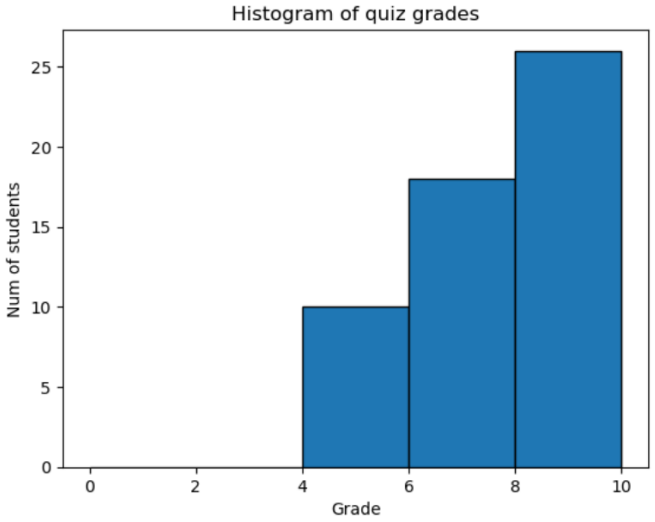
Overview

- The “histogram” task
- Sequential implementation
- Parallel implementation
  - A naïve kernel
  - A kernel using atomic operation
  - A fast kernel using atomic operation

Histogram

- A method for extracting notable features and patterns from large data sets rút trích đặc trưng
  - *Feature extraction* for object recognition in images
  - *Fraud detection* in credit card transactions phát hiện giao dịch lỗi
  - *Correlating* heavenly object movements in astrophysics
- Basic histograms: for each element in the data set, use the value to identify a “bin counter” to increment



The “histogram” task

Input

0	5	4	0
7	1	1	2
2	3	0	6

Histogram 4 bin

Bin	Index	0	1	2	3
	Range	[0, 1]	[2, 3]	[4, 5]	[6, 7]
	Count	5	3	2	2

The “histogram” task

Input

0	5	4	0
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Histogram 8 bin

Bin	Index	0	1	2	3	4	5	6	7
	Range	0	1	2	3	4	5	6	7
	Count								

Histogram 4 bin

Bin	Index	0	1	2	3
	Range	[0, 1]	[2, 3]	[4, 5]	[6, 7]
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The “histogram” task

Input

0	5	4	0
7	1	1	2
2	3	0	6

Histogram 8 bin

Bin	Index	0	1	2	3	4	5	6	7
	Range	0	1	2	3	4	5	6	7
	Count	3	2	2	1	1	1	1	1

Histogram 4 bin

Bin	Index	0	1	2	3
	Range	[0, 1]	[2, 3]	[4, 5]	[6, 7]
	Count	5	3	2	2

Sequential implementation

```
void computeHistOnHost(int *in, int *hist, int n, int nBins)
{
   for (int i = 0; i < nBins; i++)
      hist[i] = 0;
   for (int i = 0; i < n; i++)
      hist[computeBin(in[i])] += 1;
}
```

Set mảng hist về 0

Tăng giá trị của bin tương ứng

Compute **bin** which **in[i]** falls into

In the rest of this lecture, we'll assume: **in[i]** $\geq$ **0** and **computeBin(in[i]) = in[i]**

Parallel implementation: a naïve kernel

- Let each thread take care of one element in the input array
- Thread will identify the bin of its element and increase the bin counter by 1

```
__global__ void computeHistOnDevice1(int *in, int *hist, int n, int nBins)
{
   int i = blockIdx.x * blockDim.x + threadIdx.x;

   if (i < nBins)
      hist[i] = 0;

   if (i < n)
      hist[in[i]] += 1;
}
```

Need synchronize globally, but we can only synchronize within each block ☹
One simple solution: from host, call **cudaMemset** function ☺

Read-Modify-Write (RMW); what if more than one threads RMW the same location? ☹

Parallel implementation: a naïve kernel

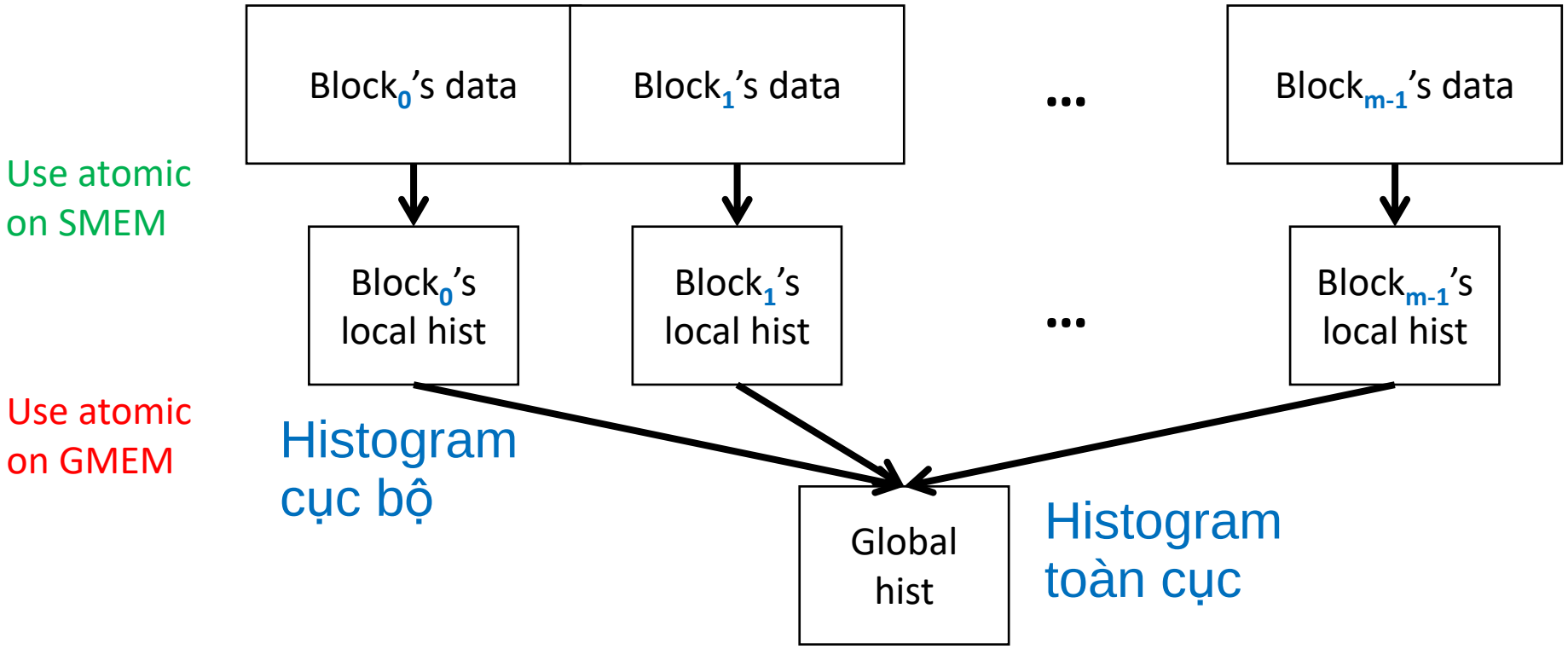
- A kernel using atomic operation: solve the conflict problem when many threads RMW the same location

```
__global__ void computeHistOnDevice2(int *in, int *hist, int n, int nBins)
{
   int i = blockIdx.x * blockDim.x + threadIdx.x;
   if (i < n)
      hist[int[i]] += 1;
      atomicAdd(&hist[in[i]], 1);
}
```

If many threads RMW the same location, they will be **serialized**: threads will RMW in turn
→ Guarantee correctness, but can hurt speed

Coding exercise: file “10-Histogram.cu”

A fast kernel using atomic operation



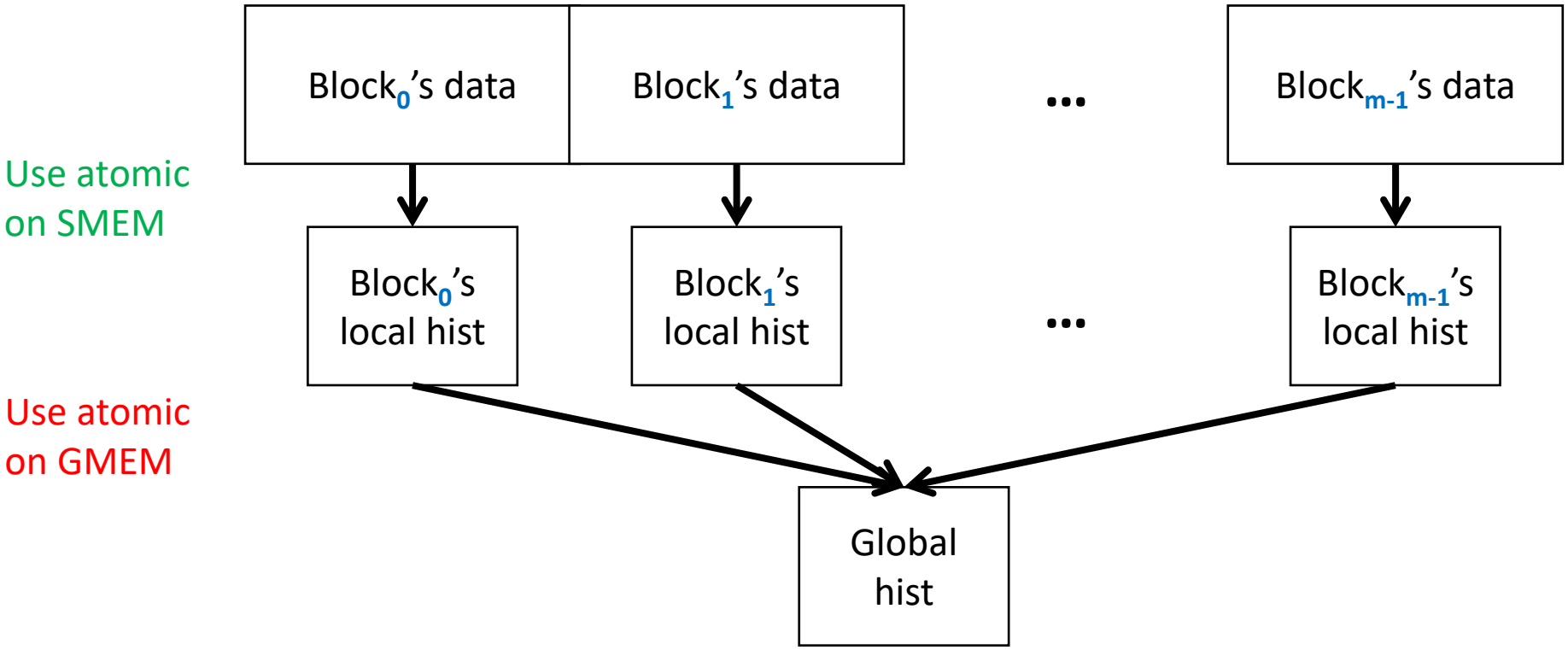
Will it run faster?

Consider a bin; assume in each block's data chunk there are 2 values falling into this bin

The old way costs: ? atomicAdd's on GMEM

This way costs: ?

A fast kernel using atomic operation



Will it run faster?

Consider a bin; assume in each block's data chunk there are 2 values falling into this bin

The old way costs: **2m** atomicAdd's on GMEM

This way costs: **2m** atomicAdd's on SMEM, 2 atomicAdd's/block and m blocks run in parallel

+ **m** atomicAdd's on GMEM

Coding exercise: file “10-Histogram.cu”

Reference

- [1] Wen-Mei, W. Hwu, David B. Kirk, and Izzat El Hajj. *Programming Massively Parallel Processors: A Hands-on Approach*. Morgan Kaufmann, 2022
- [2] Cheng John, Max Grossman, and Ty McKercher. *Professional Cuda C Programming*. John Wiley & Sons, 2014
- [3] Illinois GPU course

https://wiki.illinois.edu/wiki/display/ECE408/ECE408+Home

THE END