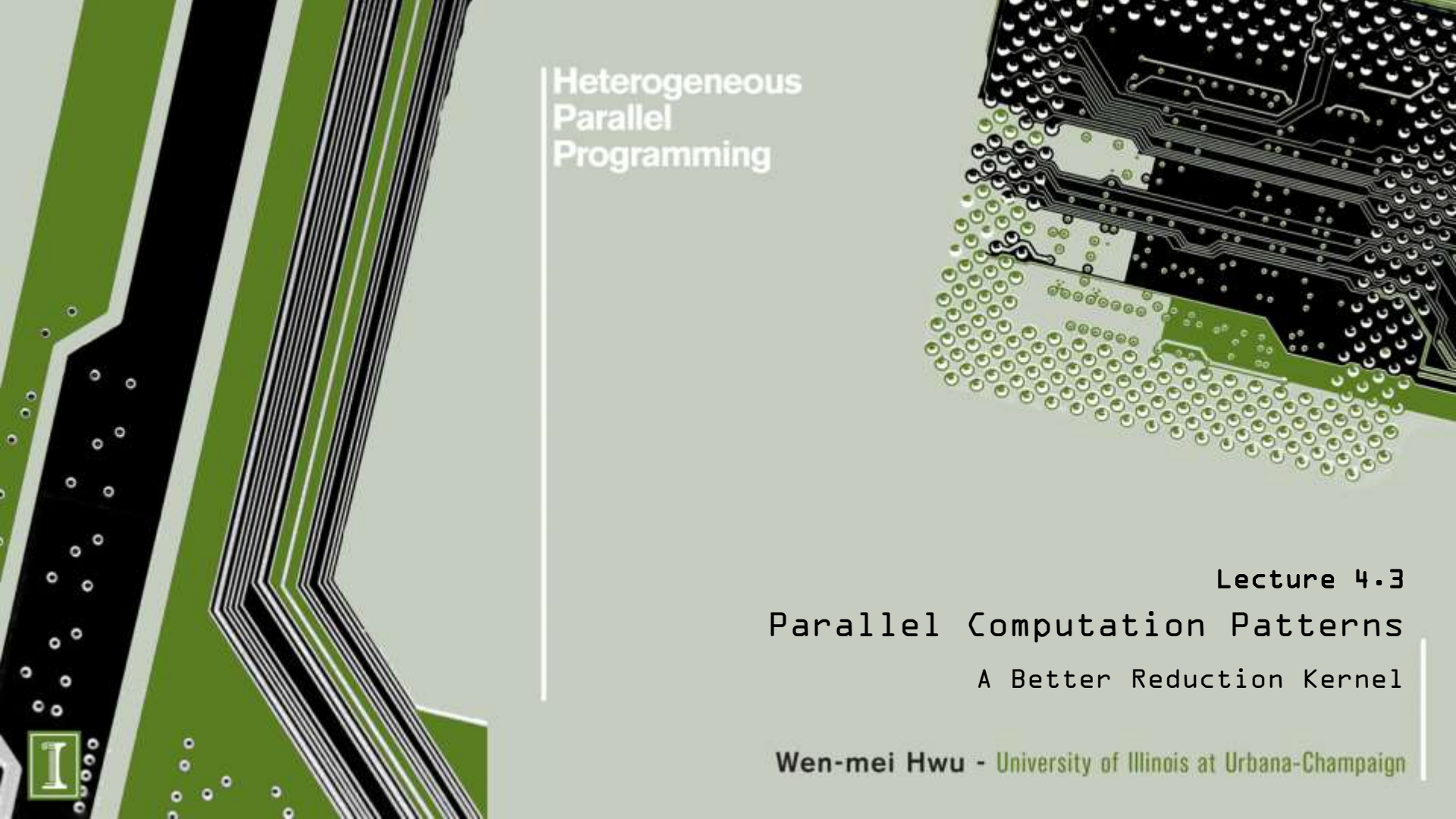

Heterogeneous Parallel Programming

Lecture 4.3

Parallel Computation Patterns

A Better Reduction Kernel

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Objective

- To learn to write a better reduction kernel
  - Resource efficiency analysis
  - Thread to data index mapping
  - Turning off threads
  - Control divergence

Some Observations on the naïve reduction kernel

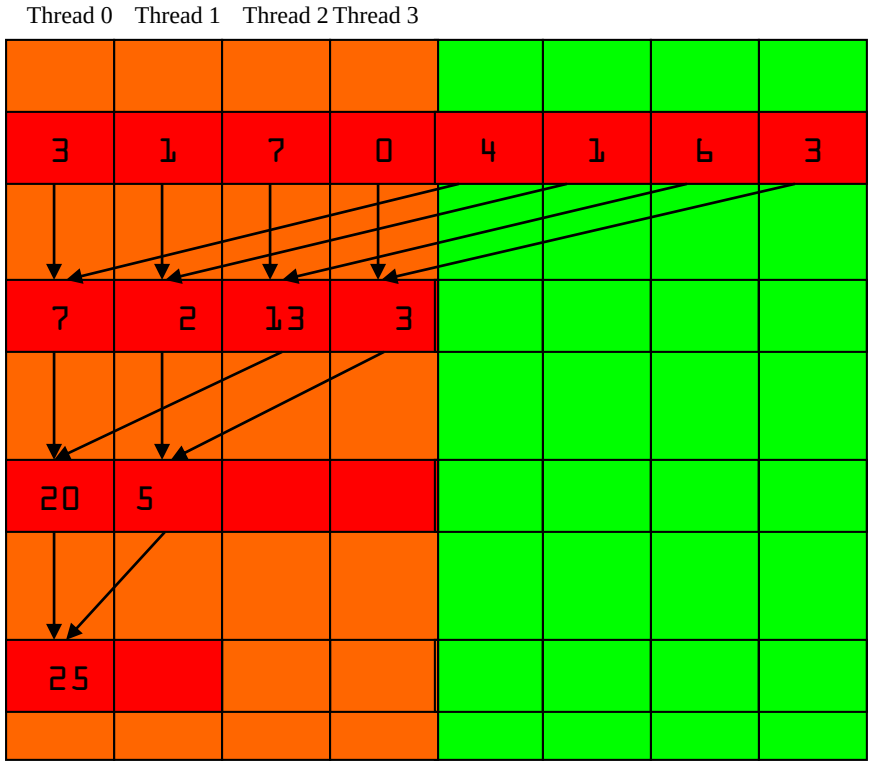
- In each iteration, two control flow paths will be sequentially traversed for each warp
  - Threads that perform addition and threads that do not
  - Threads that do not perform addition still consume execution resources

- Half or fewer of threads will be executing after the first step
  - All odd-index threads are disabled after first step
  - After the 5^{th} step, entire warps in each block will fail the if test, poor resource utilization but no divergence.
    - This can go on for a while, up to 6 more steps (stride = 32, 64, 128, 256, 512, 1024), where each active warp only has one productive thread until all warps in a block retire

Thread Index Usage Matters

- In some algorithms, one can shift the index usage to improve the divergence behavior
  - Commutative and associative operators
- Always compact the partial sums into the front locations in the partialSum[] array
- Keep the active threads consecutive

An Example of 4 threads



A Better Reduction Kernel

```
for (unsigned int stride = blockDim.x;
     stride > 0;  stride /= 2)
{
  __syncthreads();
  if (t < stride)
     partialSum[t] += partialSum[t+stride];
}
```

A Quick Analysis

- For a 1024 thread block
  - No divergence in the first 5 steps
    - 1024, 512, 256, 128, 64, 32 consecutive threads are active in each step
    - All threads in each warp either all active or all inactive
  - The final 5 steps will still have divergence

A Story about an Old Engineer

To learn more, read Section 6.1