GPU Teaching Kit

Accelerated Computing

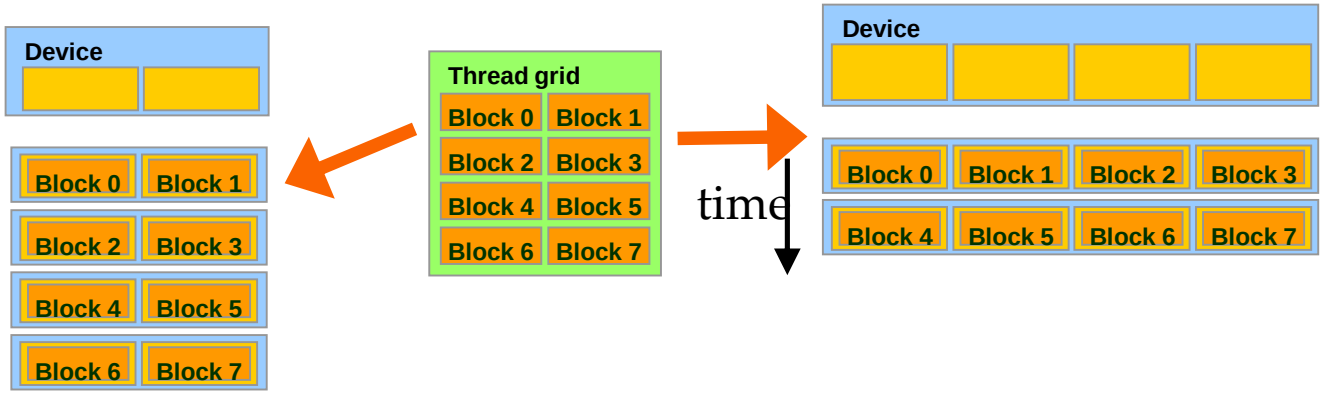
Lecture 3.5 – CUDA Parallelism Model

Thread Scheduling

Objective

- To learn how a CUDA kernel utilizes hardware execution resources
  - Assigning thread blocks to execution resources
  - Capacity constrains of execution resources
  - Zero-overhead thread scheduling

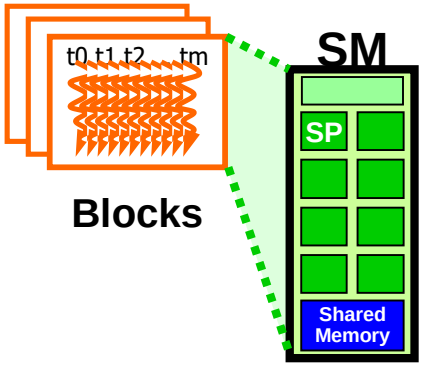
Transparent Scalability



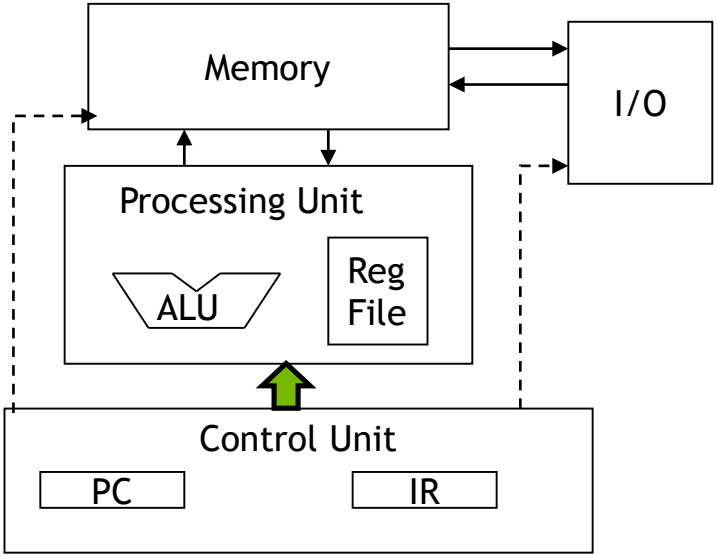
- Each block can execute in any order relative to others.
- Hardware is free to assign blocks to any processor at any time
  - A kernel scales to any number of parallel processors

Example: Executing Thread Blocks

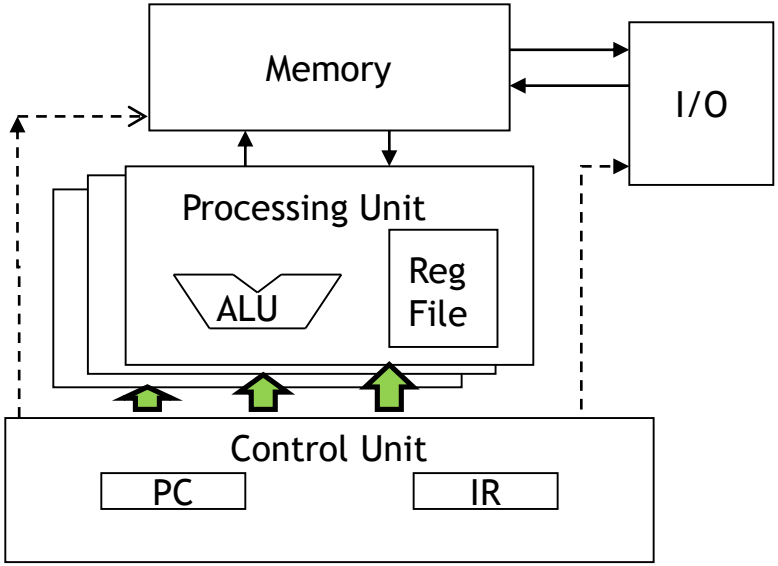
- Threads are assigned to Streaming Multiprocessors (SM) in block granularity
  - Up to 32 blocks to each SM as resource allows
  - Volta SM can take up to **2048** threads
    - Could be 256 (threads/block) * 8 blocks
    - Or 512 (threads/block) * 4 blocks, etc.
- SM maintains thread/block idx #'s
- SM manages/schedules thread execution



The Von-Neumann Model



The Von-Neumann Model with SIMD units



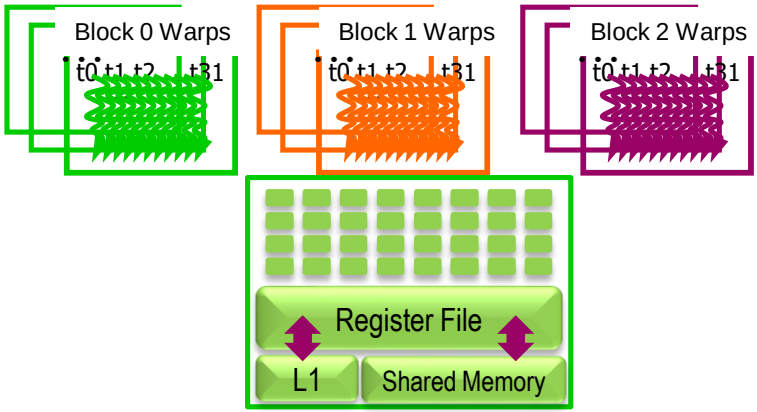
Single Instruction Multiple Data
(SIMD)

Warps as Scheduling Units

- Each Block is executed as 32-thread Warps
  - An implementation decision, not part of the CUDA programming model
  - Warps are scheduling units in SM
  - Threads in a warp execute in SIMD
  - Future GPUs may have different number of threads in each warp

Warp Example

- If 3 blocks are assigned to an SM and each block has 256 threads, how many Warps are there in an SM?
  - Each Block is divided into 256/32 = 8 Warps
  - There are 8 * 3 = 24 Warps



Example: Thread Scheduling (Cont.)

- SM implements zero-overhead warp scheduling
  - Warps whose next instruction has its operands ready for consumption are eligible for execution
  - Eligible Warps are selected for execution based on a prioritized scheduling policy
  - All threads in a warp execute the same instruction when selected

Block Granularity Considerations

- For Matrix Multiplication using multiple blocks, should each block have 4X4, 8X8 or 30X30 threads for Volta?
  - For 4X4, we have 16 threads per Block. Each SM can take up to 2048 threads, which translates to 128 Blocks. However, each SM can only take up to 32 Blocks, so only 512 threads will go into each SM!
  - For 8X8, we have 64 threads per Block. Since each SM can take up to 2048 threads, it can take up to 32 Blocks and achieve full capacity unless other resource considerations overrule.
  - For 30X30, we would have 900 threads per Block. Only two blocks could fit into an SM for Volta, so only 1800/2048 of the SM thread capacity would be utilized.

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