ECE4893A/CS4803MPG: Multicore and GPU Programming for Video Games

"Classic" GPGPU

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“Classic” vs. “Modern” GPGPU

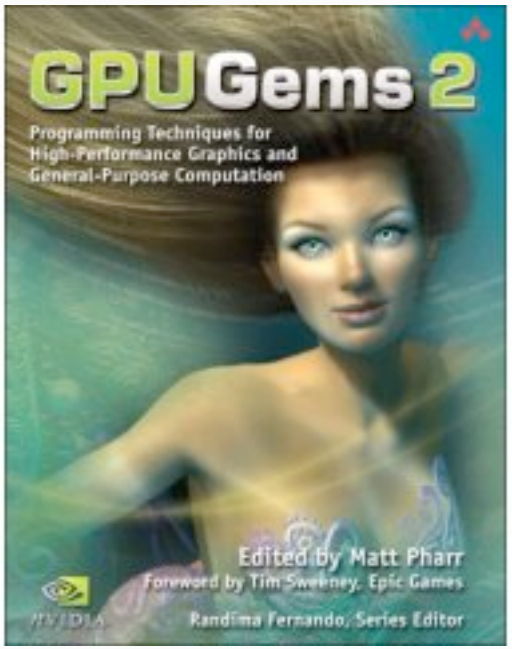
- “Classic GPGPU”
  - User must map their algorithm to a graphics framework not designed with general computation in mind
  - GPGPU implementations on the Playstation 3s RSX and the Xbox 360’s Xenos will need to be programmed in this mindset
  - Many PC users will have older graphics cards
- “Modern GPGPU”
  - Runs on hardware (e.g., NVIDIA G80) specifically designed to be friendly to GPGPU computations
  - NVIDIA’s Compute Unified Device Architecture (CUDA) framework hides low-level details
    - See Hyesoon Kim’s Spring 2008 class, CS8803SC: Software and Hardware Cooperative Computing
  - ATI’s CTM (Close-to-Metal) provides powerful low-level access to GPGPU-friendly hardware, but requires users to “roll their own”

Typical classic GPGPU setup

- Load inputs into textures
  - GPU textures <-> CPU arrays
  - Texture coordinates <-> computational domain
- Draw a quadrangle
- Do computation in pixel shaders
  - Older GPUs typically have more pixel shader units than vertex shader units
  - Older GPUs can't do texture fetch in vertex shaders
  - GPU pixel shaders <-> CPU inner loops
  - Texture sample (tex2D) <-> CPU memory read
- Render output as pixels in the quadrangle
  - Render-to-texture <-> CPU memory write
  - Vertex coordinates <-> computational range

Reference

- A lot of this discussion is inspired by various chapters in GPU Gems 2
  - Excellent reference for “classic GPGPU”
  - GPU Gems 3 focuses more on “modern GPGPU” solutions



Scattering vs. gathering on a typical GPU

- Gather:
  - Indirect read

  a = x[i]

- Texture fetch

  tex2D(x,...)

- Scatter:
  - Indirect write

  a[i] = x

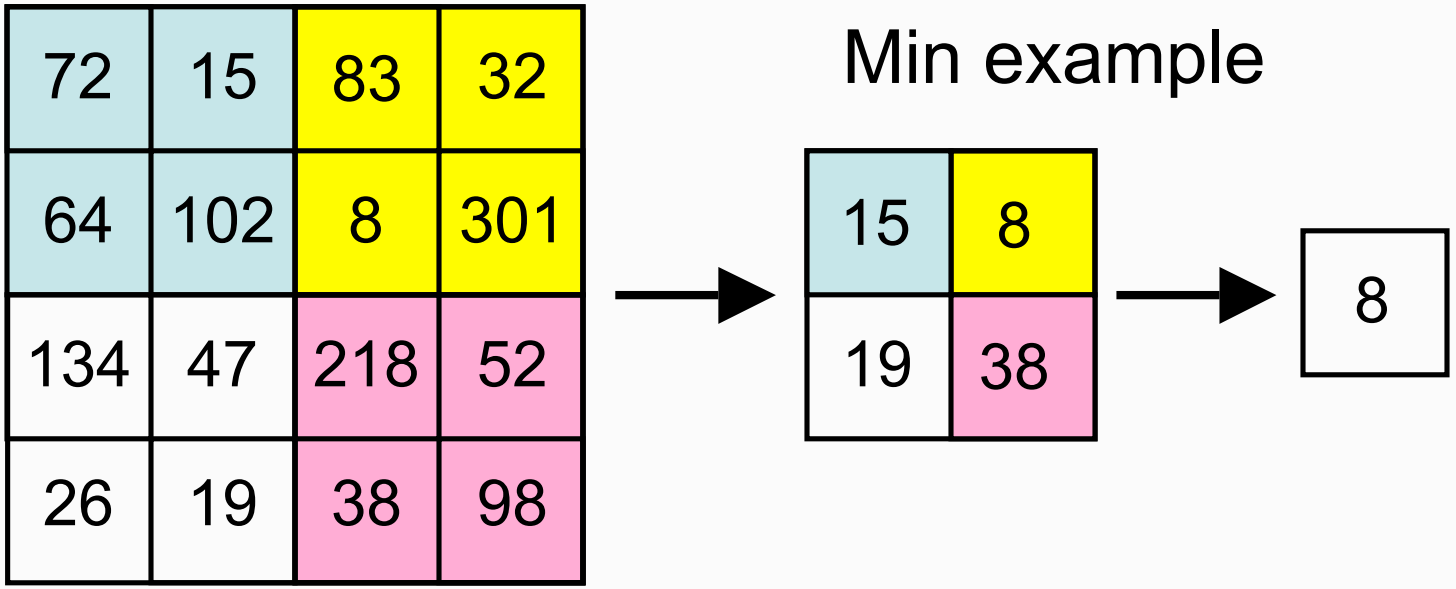
- No arbitrary texture writes on the GPU!
  - Can do “ordered writes” with “render to texture”

Mapping

- Apply some function to each element in parallel
- Store input values as textels in a texture
- Draw quadrangle with as many pixels as textels in input
- Pixel shader just computes the function
- Output values in pixels of rendered quadrangle
  - Use “render-to-texture” to use mapped values in another stage

Reduction

- Associative operations
  - Ex: sums, products, min, max
- Do multiple passes, rendering to smaller textures with each pass



- Could do more than four per pixel
  - Depending on how many “texture fetches” are allowed
  - Less passes, but increased time per pass

Flow control is tricky

- Most older GPUs don't "really" support branching
- Loops typically "unrolled" by the compiler
- Predicated branching:
  - Compute both parts of the branch
  - Use results from only one branch
- On some GPUs, vertex shaders support branching but pixel shaders don't
- Even newer GPUs that directly support branching may give you a significant performance hit
  - Parallel execution units may be restricted to executing only one branch at a time (locality is important)

Static branch resolution

- Instead of branching in the pixel shader, execute different pixel shaders on different output quadrangles
- Ex: boundary conditions in PDE

Info & examples from
p. 549-550 of GPU Gems 2

Skipping unnecesary work with Z-cull

- Setup
  - Write 0 to z-buffer of pixels where you want to skip computation
  - Write 1 to z-buffer of pixels where you do
- Feed pixel shader doing the computation z-buffer value of 0.5
- Ex: landlocked cells in fluid simulation
- Warning: GPU may do z-culling at coarser resolution than the pixels
  - Will skip shading only if all pixels in a region fail the depth test
- Can do similar tricks with alpha stenciling

Info & examples from
p. 550-552 of GPU Gems 2

Applications tailor-made for GPGPU

- Applications with high compute-to-communication ratios
- Partial differential equations
- Cellular automata
  - Sim City!
- Linear algebra
  - Chapter 44 of GPU Gems 2
  - There are clever ways to handle banded matrices, sparce matrices, etc.

GPGPU applications in games

- Collision detection
- Physics
  - Rigid bodies
  - Fluids, clouds, smoke, cloth
- Particle systems
- Line of sight calculations for AI?
- Aside:
  - AGEIA is marketing a Physics Processing Unit (PPU) to accelerate their “PhysX” SDK
  - Havok FX can exploit NVIDIA and ATI GPUs

General advice

- Quite often better to store long 1D arrays as “wrapped” 2D arrays
  - 1D arrays limited in length
  - GPUs seem to be faster at handling 2D textures than 1D
- Pre-compute constants on the CPU
- Pre-compute low-dimensional functions and store them as textures
  - GPU will naturally do an interpolated lookup

Limitations of GPGPU

- 32-bit floats (used to be worse!)
  - There's talk about 64-bit floats, but can the mass market support that?
- May not have integers
  - Can be a problem with precise texture accesses
- May not have bitwise operations
- Not-so-great with dynamic data structures (queues, stacks, trees, etc.)
  - But lots of clever people have come up with tricks
- Need to outside the box: strange algorithms that might be silly on a CPU might map well to a GPU

Some successful GPGPU applications

- Computed Tomography (CT)
- MRI (application of FFTs)
- Phase unwrapping for Synthetic Aperture Radar (SAR)
  - 35x speedup obtained by Peter Karasev, Dan Campbell, and Mark Richards
- Data mining
- Raytracing
  - Remember the line-triangle intersection lecture?

Quake 3: Raytraced

http://www.youtube.com/watch?v=bpNZt3yDXno

Images from graphics.cs.uni-sb.de/~sidapohl/egoshooter

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