Shader Programming vs CUDA

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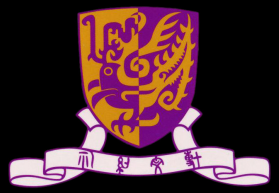

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GPGPU

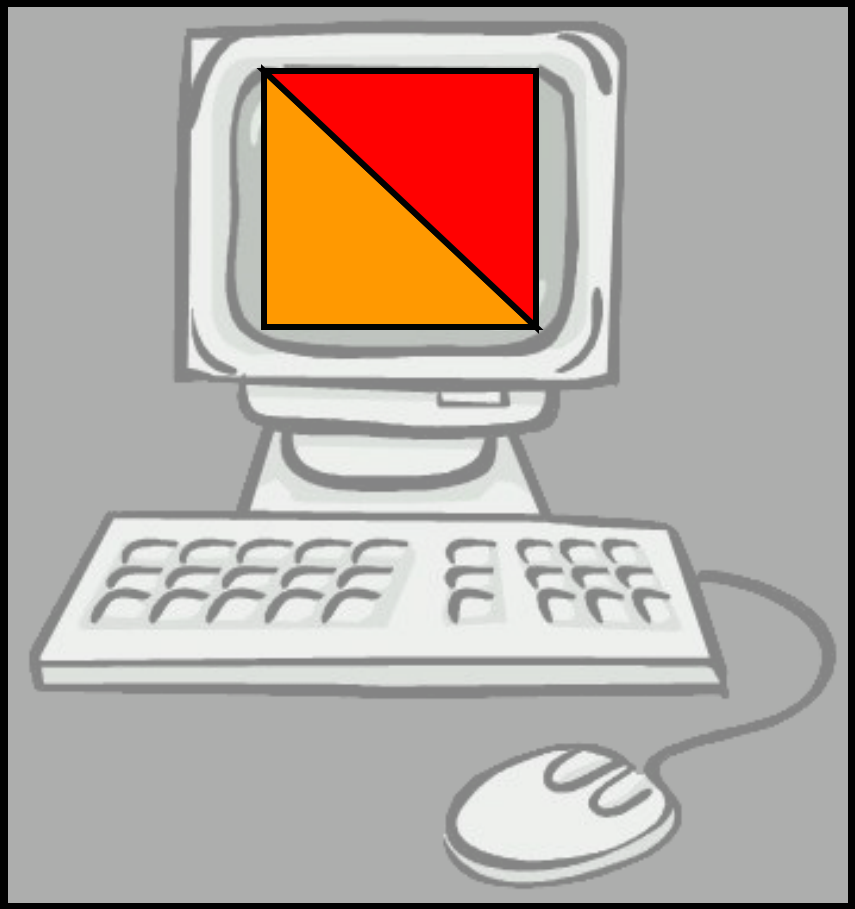
- Apply consumer parallel graphics hardware for general purpose (GP) computing
- GPU almost comes with every PC
- Let's focus on two approaches:
  - Shader programming
  - CUDA

Shader Programming

- GPU is not originally designed for GPGPU, but for graphics
- Shader (program)
- Shading language (specialized language, C-like)
- A graphics "shell" is needed to perform your GP program

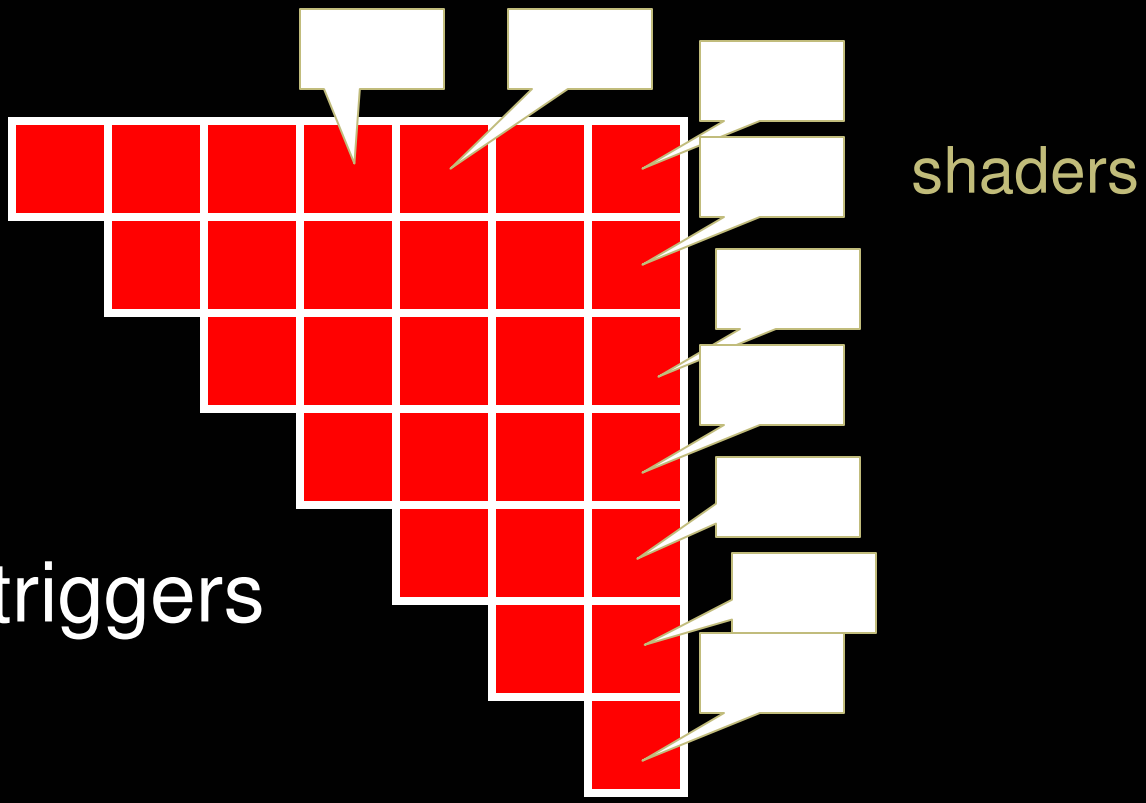
Programming as “Drawing”

- Every program must be a “drawing” even you draw nothing
- Two dummy triangles to cover the screen



Programming as “Drawing” (2)

- Then, rasterization (discretization to pixels)



- Each pixel triggers a shader

Pixel as Chromosome

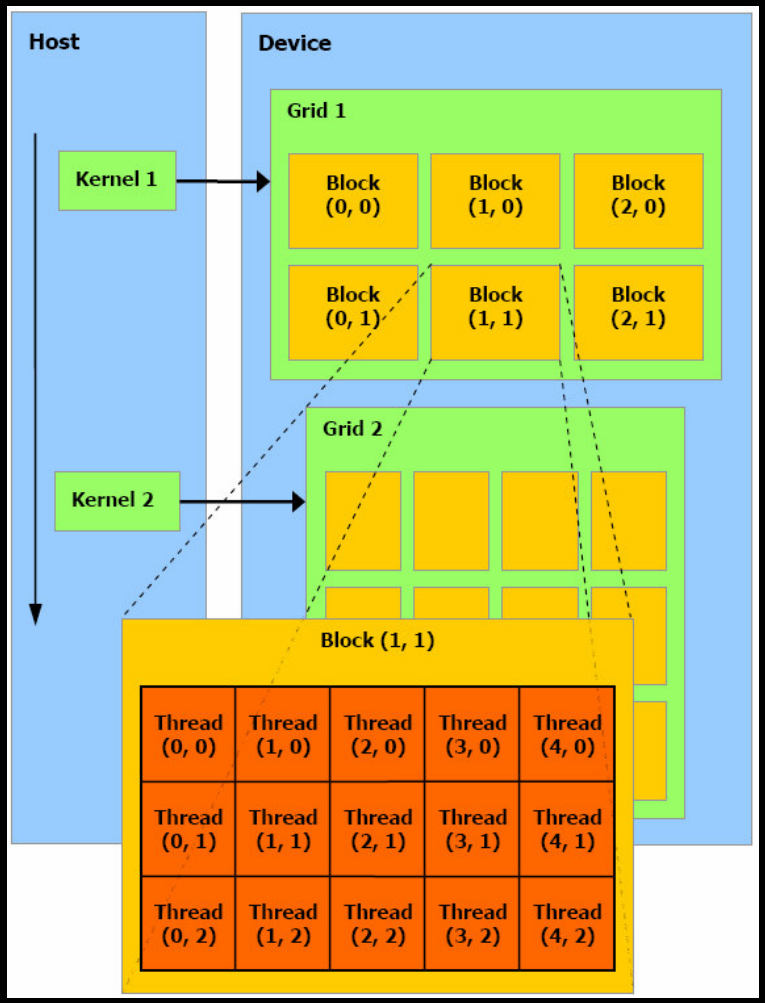
- For EC, it is natural to have each pixel being a chromosome
- Each shader evaluates the objective function

CUDA

- A tailormade platform for GPGPU on GPU
- No dummy graphics “shell”

CUDA Architecture

- shader => kernel
- Shared memory
- Thread synchronization
- Communication!



Shader vs CUDA

- Learning curve:
  - Shader: Dummy graphics “shell” needed, and specialized shading language
    => Longer learning curve for non-graphics people
  - CUDA: Just like multi-thread programming, basically C language
    => easier to catch up for most people

Shader vs CUDA

- Communication among processes:
  - Shader: No communication
    => multiple passes, read & write textures for data sharing
  - CUDA: Yes, via shared memory & synchronization
    => less passes, more efficient and flexible

Shader vs CUDA (2)

- Logical number of instances
  - Shader: Strongly coupled with screen resolution
    No. of pixels = No. of shader instances
    = No. of chromosomes
    => Straightforward problem formulation
  - CUDA: Depends on hardware limit
    No. of threads < No. of chromosomes
    => Each thread handles multiple chromosomes

Shader vs CUDA (3)

- Efficiency
- In theory, CUDA should be as efficient as shader programming

Shader vs CUDA (4)

- Standardization
  - Shader: There are standards
    GLSL (OpenGL shading language)
    HLSL (MS DirectX high level shading language)
    => cross-platform (can be ATI or nVidia)
  - CUDA: Standard is still forming
    CUDA is basically supported by vender nVidia,
    not sure whether it will be supported by ATI

Shader vs CUDA (5)

- Access to graphics specific functionalities
- Mipmapping, Cubemap look-up
  - Shader: Accessible
    => fast evaluation (lookup) of spherical functions
    => fast downsampling and upsampling
  - CUDA: No access

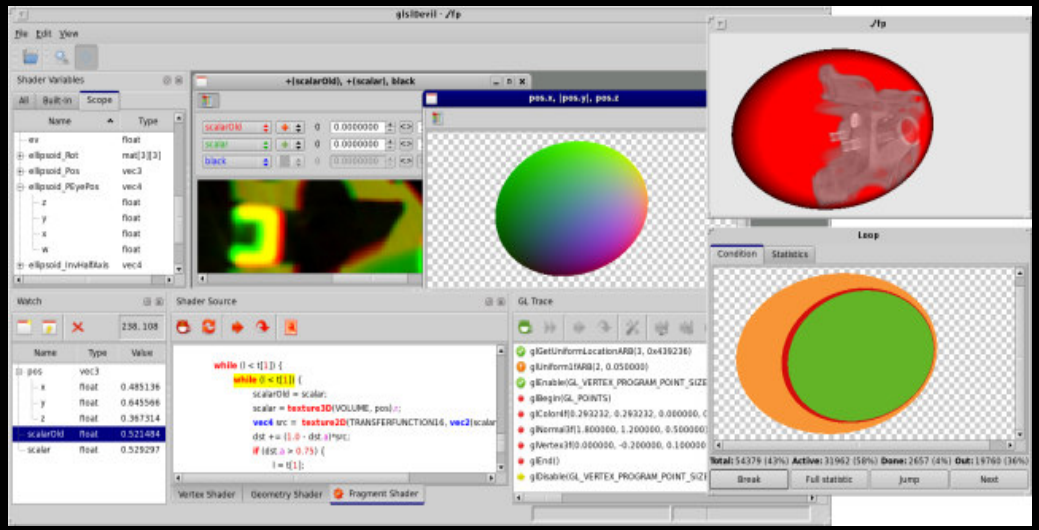
Debugging Shader

- So far, quite limited
- printf-style visual debugging (graphics)
- Microsoft Shader Debugger – MS DirectX shaders can be debugged
  - Shader emulation on CPU, not debugging on actual GPU
  - seldom use as we stick to OpenGL for backward compatibility

Debugging Shader (2)

- NVIDIA Shader Debugger for FX Composer
  - recently released in April 2008, as a plugin for FX composer!? http://developer.nvidia.com/object/shader_debugger_beta.html
- glsldevil, OpenGL GLSL Debugger

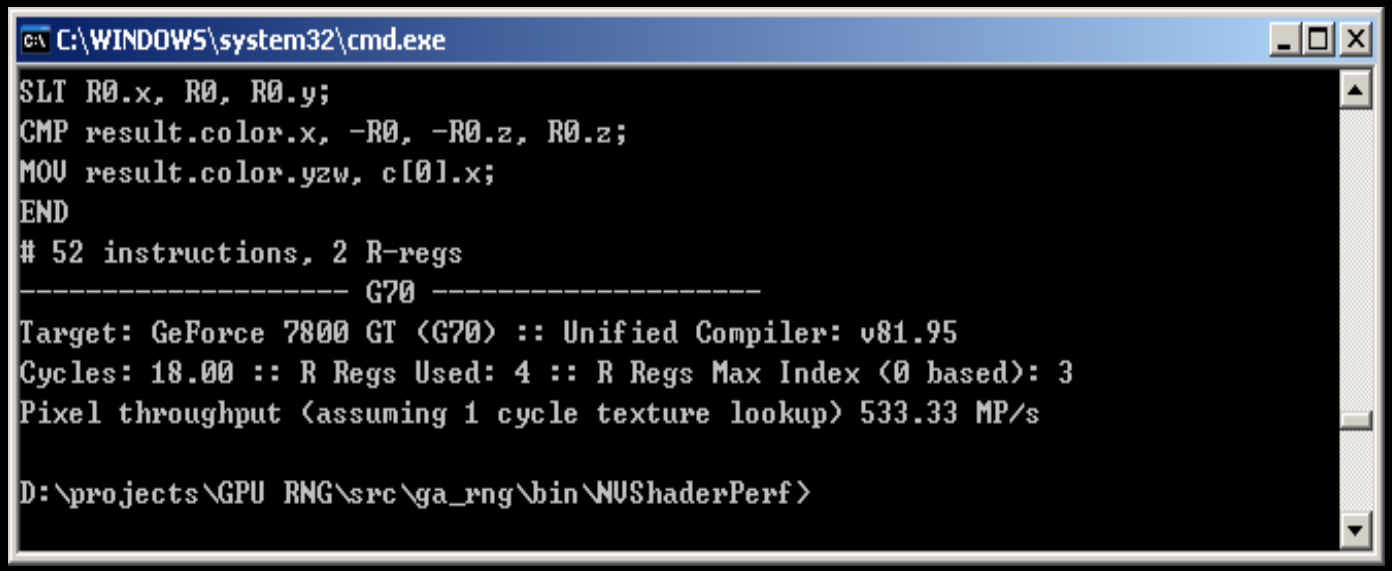
  http://www.vis.uni-stuttgart.de/glsldevil/



Debugging Shader (3)

- Execution cycle needed for a shader can be determined offline

```
nvshaderperf -a G70 -f main shader.cg
```



http://developer.nvidia.com/object/nvshaderperf_home.html

Debugging CUDA

- CUDA can be executed in device emulation mode => threads are executed sequentially
- Set break point is feasible
- Currently, debugging tools are still quite scarce

Debugging CUDA (2)

- VC++ debug modes
  - EmuDebug, Debug
- Kernel codes are traceable in EmuDebug (emulation) mode, not on actual hardware
- gdb debugger (not yet released)

Debugging CUDA (3)

- Profiling in CUDA

  By enabling
  CUDA_PROFILE: to enable (1) or disable (0)

```
./shaderprogram –N1024
method=[ memcopy ] gputime=[ 1427.200 ]
method=[ memcopy ] gputime=[ 10.112 ]
method=[ memcopy ] gputime=[ 9.632 ]
method=[ real2complex ] gputime=[ 1654.080 ] cputime=[ 1702.000 ] occupancy=[ 0.667 ]
method=[ c2c_radix4 ] gputime=[ 8651.936 ] cputime=[ 8683.000 ] occupancy=[ 0.333 ]
method=[ transpose ] gputime=[ 2728.640 ] cputime=[ 2773.000 ] occupancy=[ 0.333 ]
method=[ c2c_radix4 ] gputime=[ 8619.968 ] cputime=[ 8651.000 ] occupancy=[ 0.333 ]
method=[ c2c_transpose ] gputime=[ 2731.456 ] cputime=[ 2762.000 ] occupancy=[ 0.333 ]
method=[ solve_poisson] gputime=[ 6389.984 ] cputime=[ 6422.000 ] occupancy=[ 0.667 ]
method=[ c2c_radix4 ] gputime=[ 8518.208 ] cputime=[ 8556.000 ] occupancy=[ 0.333 ]
method=[ c2c_transpose] gputime=[ 2724.000 ] cputime=[ 2757.000 ] occupancy=[ 0.333 ]
method=[ c2c_radix4 ] gputime=[ 8618.752 ] cputime=[ 8652.000 ] occupancy=[ 0.333 ]
method=[ c2c_transpose] gputime=[ 2767.840 ] cputime=[ 5248.000 ] occupancy=[ 0.333 ]
method=[ complex2real_scaled ] gputime=[ 2844.096 ] cputime=[ 3613.000 ] occupancy=[ 0.667 ]
method=[ memcopy ] gputime=[ 2461.312 ]
```

Debugging CUDA (4)

- Occupancy -- amount of shared memory and registers used by each thread block
- CUDA occupancy calculator computes the multiprocessor occupancy of the GPU by a given CUDA kernel

  http://developer.download.nvidia.com/compute/cuda/CUDA_Occupancy_calculator.xls

Panel Discussions

- Components needed for GPGPU from the perspective of EC community
- Debugging experience
- Standardization of GPGPU platforms and languages
- Any other topics