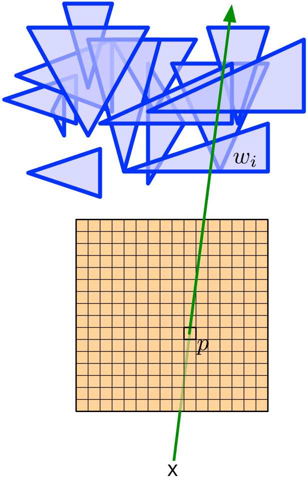
Introduction to and History of GPU Algorithms

Jeff M. Phillips

November 9, 2011

Early Computer Graphics



Draw each pixel on screen.
For each pixel p:

- Determine if pixel could “see” triangle
- Determine which object “in front”
- If we can “see through” object, what is behind?
- Does light reach that object?

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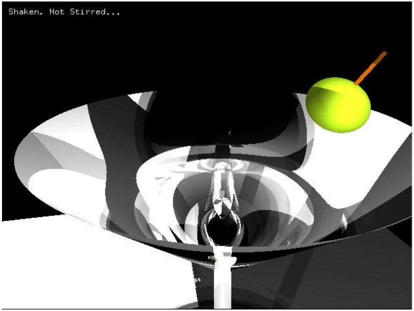

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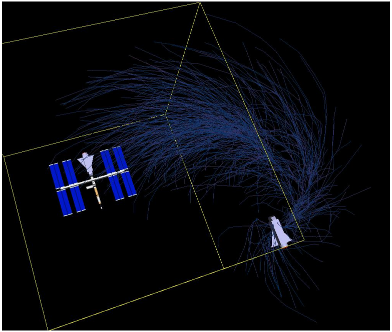

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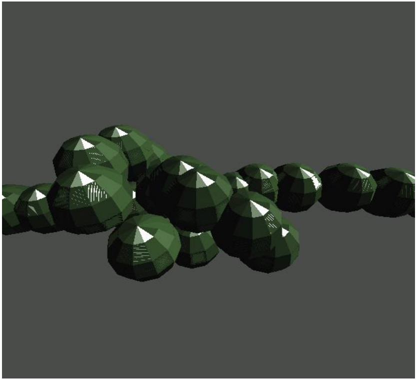

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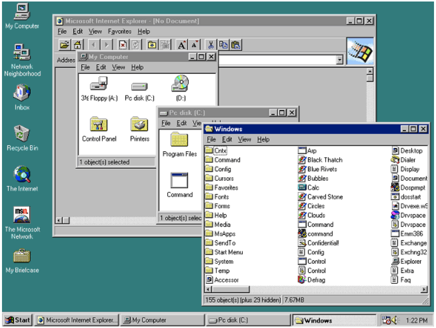
Blitters in Hardware

1980s.

- Commodore Amiga, IBM
- Block copying of memory; in parallel on CPU
- Copied image bitmaps quickly (for moving GUIs)



3D Graphics

1990s.

3D Gaming!

- OpenGL and DirectX APIs
- GPU directly implemented these APIs
  fixed functional pipeline
- nVidia vs. ATI vs. 3dfx

Early GPUs

"Fixed Functional Pipeline"

- All games / 3D Graphics looked all about the same
- Triangle Rasterization = very efficient
- RayTracing looked, better, but too slow, took much memory!

OpenGL

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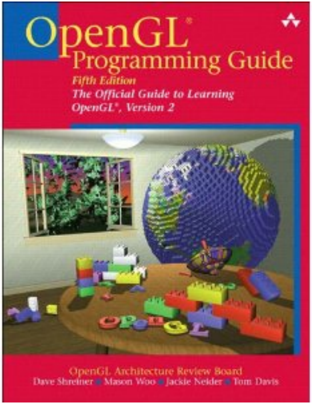
- Just a specification!
- Hardware vendor implemented specification (sometimes slight variation).
- before 2.0, entirely fixed-function
- after 2.0, some different effects added



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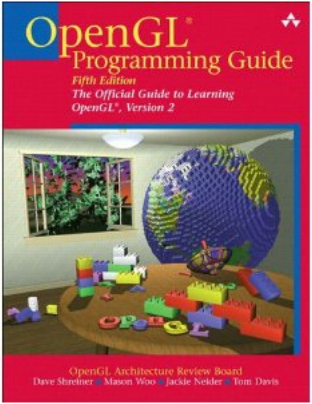
DirectX: a Windows library.

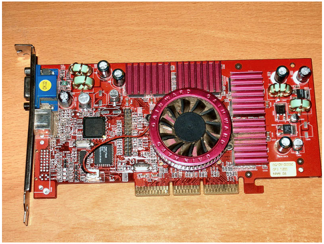
- Direct3D is the graphics component



Early GPU programming

Direct3D 8.0 (2000) and OpenGL 2.0 (2004) added support for assembly language programming for shaders.

- nVidia GeForce 3
- ATI Radeon 8000



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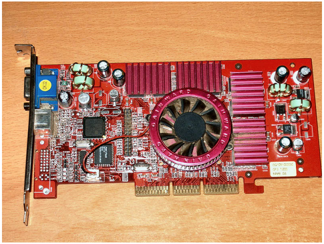

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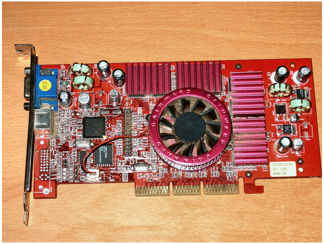

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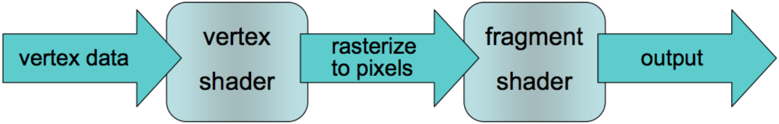
More minor increments...

Early GPU Pipeline

- Vertex data sent via graphics API (e.g. OpenGL, DirectX)
- vertex data processed by **vertex shader**
- vertex shader outputs pixels
- **fragment shader** processes pixels



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- slightly different rules
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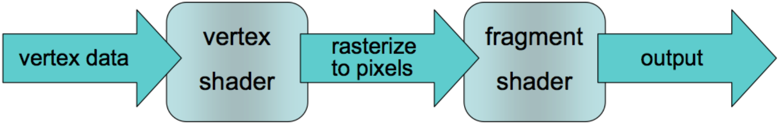
GPUs now use same core to run all shaders



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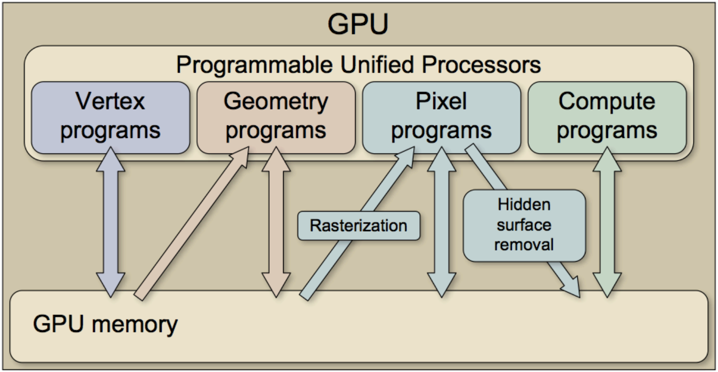
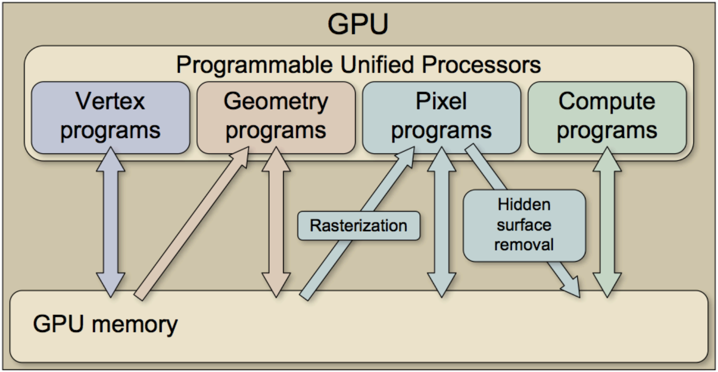


Shader Languages

No longer write in assembly!

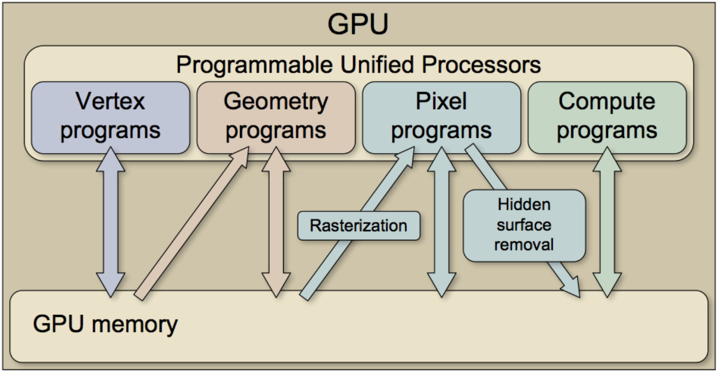
- GLSL, HLSL, cG, offer C-style shader programming
- write two main() functions which are run on each vertex/pixel
- Auxiliary functions and local variables
- output by setting position and color (write to special variables)



CUDA

Compute **U**nified **D**evice **A**rchitecture

- created by nVidia
- came with GeForce 8000 line
- runs general C code (not restricted graphics APIs)
- Linear Memory Access (no buffer objects)
- runs *thousands* of separate scalar cores



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- added *hull* and *domain* shaders to pipeline
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OpenGL 4 similar to Direct 11

- also added two stages to pipeline

GPU Programming

Top of line:

- 3 Teraflops
- 100+ GB/s memory access bandwidth
- high-speed atomic operations

Now easier to program:

- nVidia's Fermi architcture supports C++
- MATLAB integration

Many applications:

- Folding@Home
- Photoshop
- Mathematica 8
- large scale data mining
- physics fluid simulation
- computational ecology

GPU Program Model

We will focus on computational properties and data analysis (not graphics)

- Suited for **highly** parallel, fine-grain parallel programs
- Suited for **regular** number-crunching

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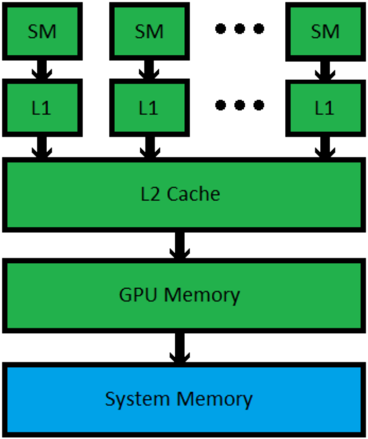
- Need to model hierarchy of processors and memory

GPU Hierarchy



Each processor (SM) has private L1 Cache

- 16-48 kB (small)
- not coherent (CRCW causes problems)
- (256-512 kB on CPU)

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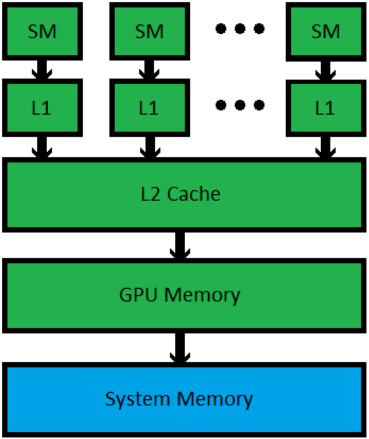

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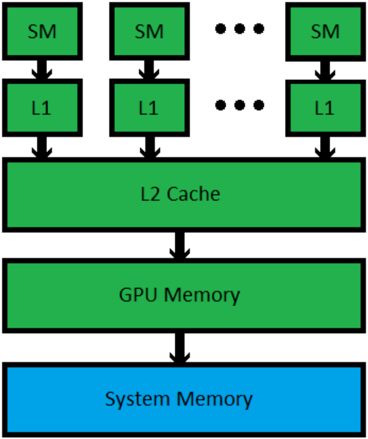

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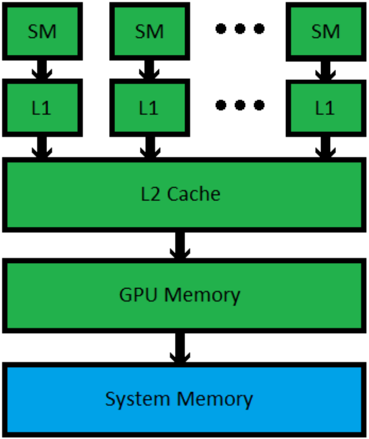

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Memory size is small!

- 768MB - 6GB
- and ... separate from CPU
- (6 - 64 GB on CPU)

NVidia GeForce 8800 GTX

G80 series

- 128 stream processors:
- 16 multiprocessors
- a multiprocessor has 8 processor units

Higher in hierarchy, more shared memory
Lower in hierarchy, less shared/private memory

GPU Hype

Much hype of 100-200x speed-up on GPU!

- not always fair comparison: 128 GPU cores vs 1CPU core
- optimized GPU code vs. un-optimized CPU code
- work in single precision (double precision slow on GPU)
- not counting memory transfer time

- As CUDA functionality increased, so did its overhead!

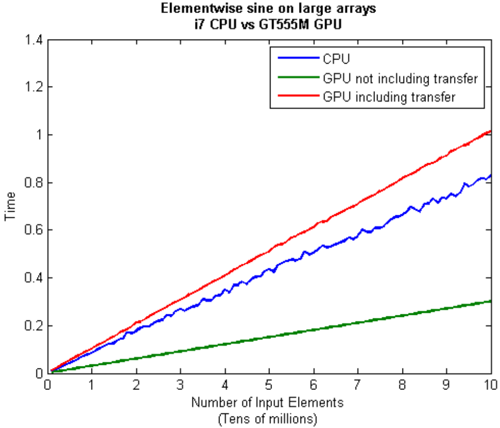
But sometimes GPU is very useful.

Cheap, highly parallel computer!

GPU in Matlab

pMatlab: Parallel Matlab Toolbox v2.0.1

```
cpu_x = rand(1,100000000)*10*pi;
gpu_x = gpuArray(cpu_x);
gpu_y = sin(gpu_x);
cpu_y = gather(gpu_y);
```



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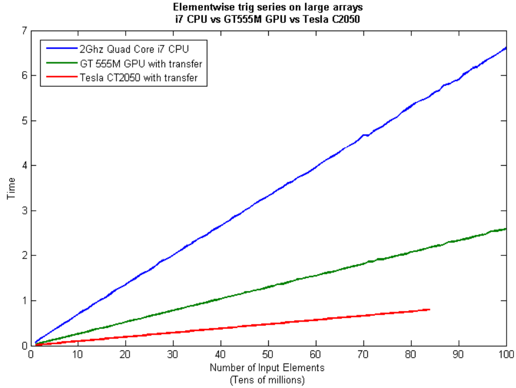

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