Introduction to Shader Programming

Game Design Experience

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UC SANTA CRUZ

Announcements

- Days until Final Project Due: 7
  - Due Monday, March 16
  - Few students have been attending help sessions
  - We will not be able to help you as well at the last minute
- 3D modeling homework
  - Due Today, by 5PM
  - Submit code via Homework submission website

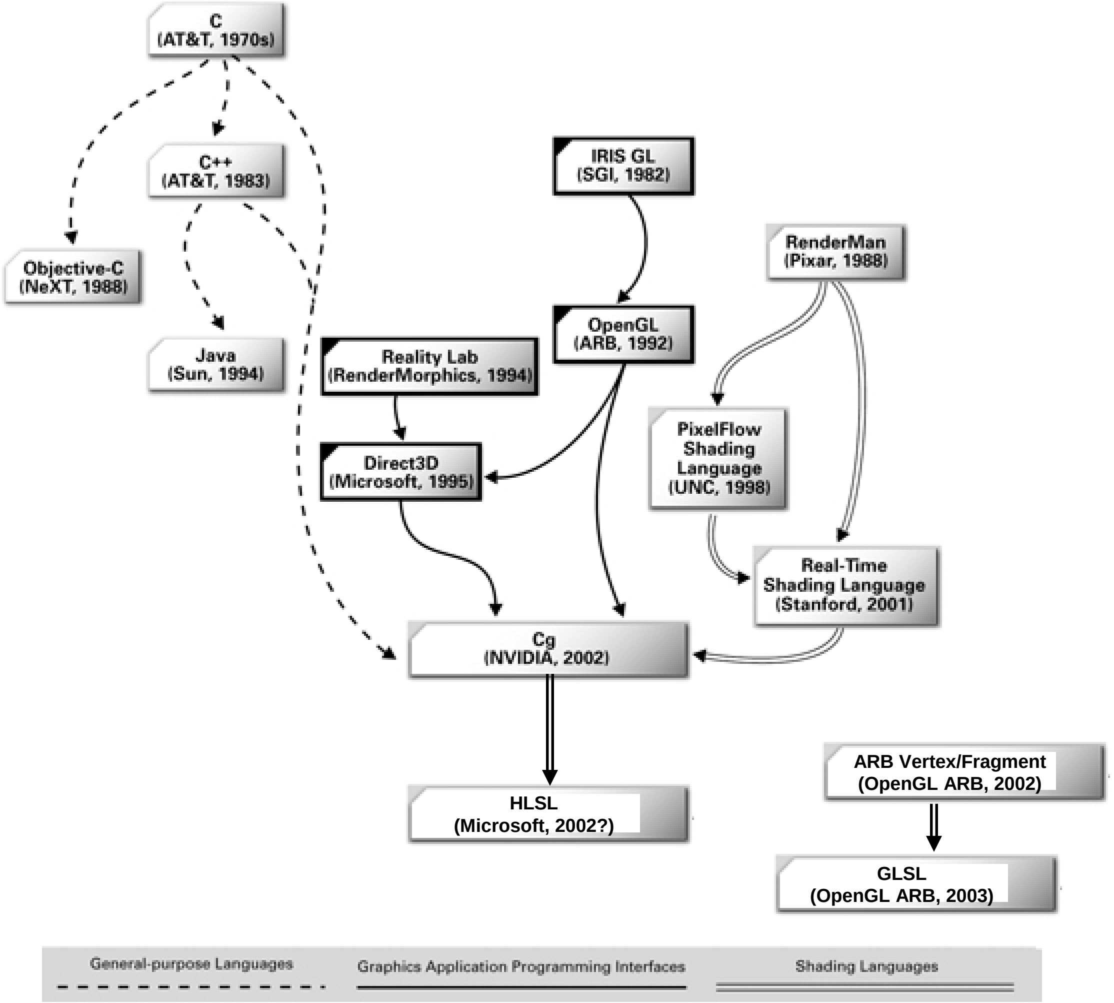
What is a Shader?

- Recall that all 3D drawing in XNA uses a Shader
  - Have been using BasicEffect shader so far
- But, more generally, what is a shader?
  - Today, gaming computers have both a CPU, and a GPU
    - CPU is on motherboard, GPU is on graphics card
      - CPU is an unspecialized computer
    - GPU is a computer specialized for 3D graphics
      - Advantage: faster 3D graphics, more effects, larger scenes
  - A Shader is a small program that runs on the GPU
    - Written in a Shader language (HLSL, Cg, GLSL)
    - XNA supports only the HLSL shader language

Shader Languages

- Currently 3 major shader languages
  - ▸ Cg (Nvidia)
  - ▸ HLSL (Microsoft)
    - Derived from Cg
  - ▸ GLSL (OpenGL)
- Main influences are
  - ▸ C language
  - ▸ pre-existing Shader languages developed in university and industry

Source: http://http.developer.nvidia.com/CgTutorial/cg_tutorial_chapter01.html
(Modified with information on HLSL and GLSL)


C (AT&T, 1970s)
C++ (AT&T, 1983)
Objective-C (NeXT, 1988)
Java (Sun, 1994)
IRIS GL (SGI, 1982)
OpenGL (ARB, 1992)
Reality Lab (RenderMorphics, 1994)
Direct3D (Microsoft, 1995)
RenderMan (Pixar, 1988)
PixelFlow Shading Language (UNC, 1998)
Real-Time Shading Language (Stanford, 2001)
Cg (NVIDIA, 2002)
HLSL (Microsoft, 2002?)
ARB Vertex/Fragment (OpenGL ARB, 2002)
GLSL (OpenGL ARB, 2003)
General-purpose Languages
Graphics Application Programming Interfaces
Shading Languages

Brief history

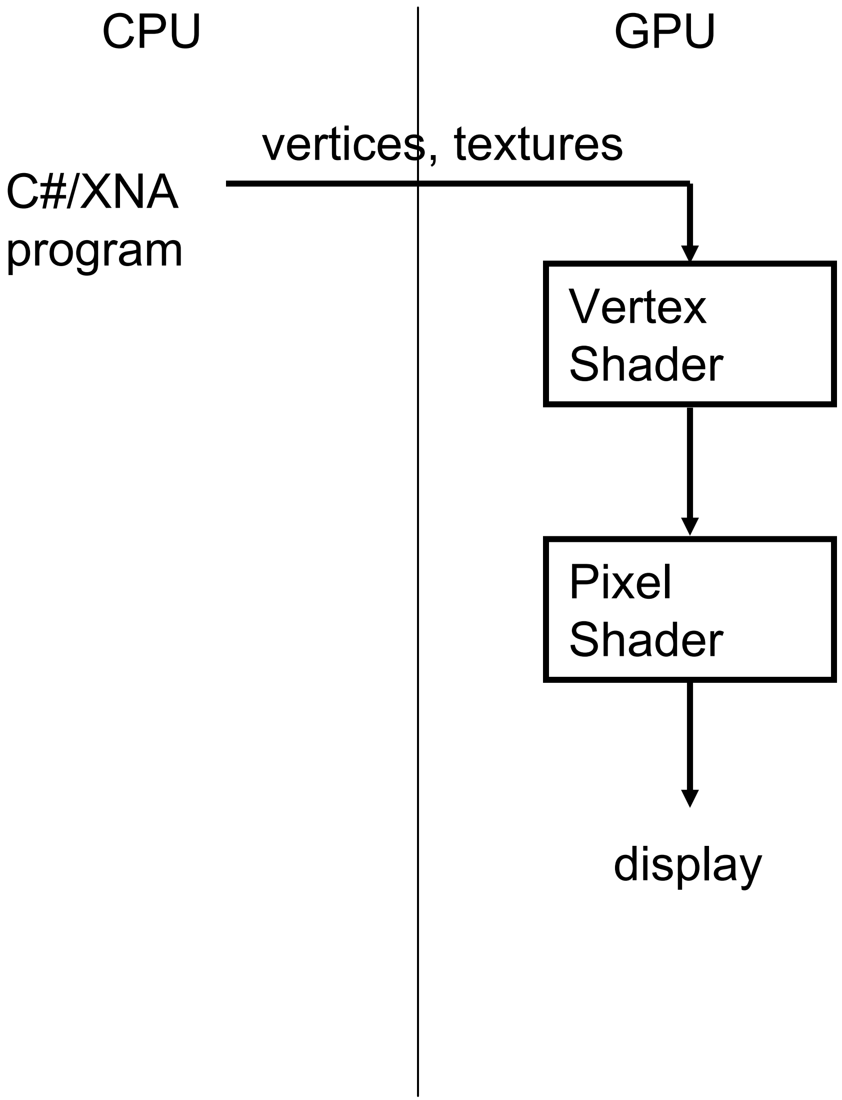
- Initially, computers did not have specialized graphics hardware
  - In mid-90’s 3D acceleration hardware appeared
    - OpenGL typically provided better support
  - DirectX 7 (1999) introduced support for hardware T&L
    - Transform and lighting
    - Moved vertex transformations and lighting computations from CPU to GPU
    - Improved game graphics, but at a cost: lighting and display calculations hard-wired into cards
    - Led to games having similar look
  - In 2002, first consumer-level programmable GPUs became available
    - Led to development of Cg, HLSL, and GLSL shader languages
    - Benefit: can have game-specific custom graphics programs running on GPU
    - Games can have very distinctive visuals

Types of Shaders

- Shaders (GPU programs) are specialized into 3 different types:
  - ▸ Vertex shaders
    - Executed once per vertex in a scene.
    - Transforms 3D position in space to 2D coordinate on screen
    - Can manipulate position, color, texture coordinates
    - Cannot add new vertices
  - ▸ Geometry shaders
    - Can add/remove vertices from a mesh
    - Can procedurally generate geometry, or add detail to shapes
  - ▸ Pixel shaders (fragment shaders)
    - Calculates the color of individual pixels
    - Used for lighting, texturing, bump mapping, etc.
    - Executed once per pixel per geometric primitive

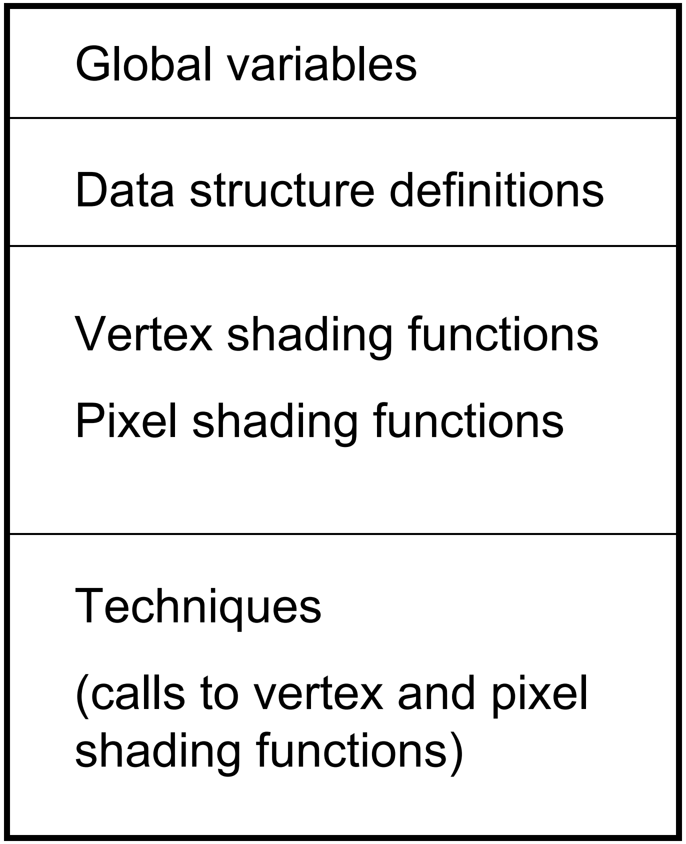
Shader control flow

- C#/XNA program sends vertices and textures to the GPU
  - These are the input for the vertex and pixel shader
- Shader executes vertex shader
  - Once per vertex
- Shader executes pixel shader
  - Once per pixel in each primitive object



Anatomy of a Shader in HLSL

- Shader is a program written in textual form in HLSL
- Programs tend to have these parts
  - Global variables
    - Variables used by multiple functions
    - Way to pass arbitrary data from C#/XNA to Shader
  - Data structure definitions
    - Data structures used within the shader functions
  - Vertex and Pixel shaders
    - Functions written in HLSL
  - Techniques
    - Describe grouping of vertex and pixel shaders
    - Describe ordering of same



Global variables

Data structure definitions

Vertex shading functions

Pixel shading functions

Techniques

(calls to vertex and pixel shading functions)

Common data types in HLSL

- HLSL has well known data types
  - int, float, bool, string, void
- Vectors
  - float3, float4 – 3/4 item floating point vector
    - float4 color = float4(1, 0, 0, 1);
    - Red, in RGBA (red, green, blue, alpha) color space
    - Used to represent vertices, colors
- Matrices
  - floatRxC – creates matrix with R rows, C cols
    - Float4x4 – a 4x4 matrix
    - Used to represent transformation matrices
- Structures

```
struct structname {
   variable declarations of members
}
```

Example:

```
struct myStruct {
   float4 position;
}
```

Passing Information to/from a Shader

- There are two ways information is passed into a Shader
  - ► Directly set global variables
    - In C#/XNA:
    - effect.Parameters[“*global variable name*”].SetValue(*value*)
    - Example:
    - HLSL: float4x4 World; ← The global variable
    - C#/XNA: effect.Parameters[“World”].SetValue(Matrix.Identity);
  - ► Semantics
    - “Magic” variables
    - Names and meaning are hard-wired by HLSL language specification
    - Examples:
      - – POSITION0: a float4 representing the current vertex
        - » When the HLSL program is executing, before each Vertex shader is called, POSITION0 is updated with the next vertex
      - – COLOR0: a float4 representing the current pixel color

Example Shader

- Example is Shader from Chapter 13 of *Learning XNA 3.0*, Aaron Reed, O’Reilly, 2009.

```
float4x4 World;
float4x4 View;
float4x4 Projection;
```

Global variables

```
struct VertexShaderInput
{
    float4 Position : POSITION0;
};

struct VertexShaderOutput
{
    float4 Position : POSITION0;
};
```

semantic

Data structures

Vertex Shader

Computes final output position (x,y,z,w) from input position

```
VertexShaderOutput VertexShaderFunction(VertexShaderInput
input) {
    VertexShaderOutput output;

    float4 worldPosition = mul(input.Position, World);
    float4 viewPosition = mul(worldPosition, View);
    output.Position = mul(viewPosition, Projection);
    return output;
}
```

Example Shader (cont’d)

An *output* semantic

```
float4 PixelShaderFunction() : COLOR0
{
   return float4(1, 0, 0, 1);
}
```

Pixel Shader function

Makes every pixel red.

```
Technique Technique1
{
    pass Pass1
    {
         VertexShader = compile vs_1_1 VertexShaderFunction();
         PixelShader = compile ps_1_1 PixelShaderFunction();
    }
}
```

Define a technique combining the vertex and pixel shaders

Contains a single pass

Compile Vertex and Pixel shaders using Shader version 1.1

Connecting Shader to C#/XNA

Four main steps in using a Shader from XNA

1. Load the Shader via the Content manager
   - ▸ Creates Effect variable using the loaded shader
   - ▸ Add shader under Content directory
     - Move .fx file in file system to Content directory
     - On Content, right-click, then Add … Existing Item to add to project
   - ▸ Content.Load<Effect>(@”*name of effect*”)
2. Identify current technique to use
   - effect.CurrentTechnique = effect.Techniques[“*technique name from HLSL source code*”]
3. Set global variables
   - ▸ effect.Parameters[“*global variable name*”].SetValue(*value*)
4. Iterate through passes (techniques) in the shader

Connecting sample shader to C#/XNA

```
Effect effect;

effect = Content.Load<Effect>(@”red”);
```

Create effect, load it via Content manager

```
effect.CurrentTechnique = effect.Techniques[“Technique1”];
```

Set current technique

```
effect.Parameters[“World”].SetValue(Matrix.Identity);
effect.Parameters[“View”].SetValue(camera.view);
effect.Parameters[“Projection”].SetValue(camera.projection);
```

Set global variables in HLSL code

```
effect.Begin();
foreach (EffectPass pass in effect.CurrentTechnique.Passes)
{
   pass.Begin();
   GraphicsDevice.DrawUserPrimitives<VertexPositionTexture>
      (PrimitiveType.TriangleStrip, verts, 0, 2);
  pass.End();
}
effect.End();
```

Iterate through passes inside current technique