Lecture 13 of 41

Surface Detail 4 of 5: Pixel & Vertex Shaders
Lab 2b: Shading in Direct3D

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KSOL course pages: http://bit.ly/hGvXlH / http://bit.ly/eVizrE
Public mirror web site: http://www.kddresearch.org/Courses/CIS636
Instructor home page: http://www.cis.ksu.edu/~bhsu

Readings:

Today: Section 3.1, Eberly 2e – see http://bit.ly/ieUq45
Next class: Section 3.2 – 3.4, Eberly 2e; Direct3D handout *
* *Toymaker* tutorials, K. Ditchburn: http://bit.ly/hMqxMI
NeHe article #21 (*NB*: not an old lesson): http://bit.ly/gi9g47

Lecture Outline

- Reading for Last Class: §20.5 – 20.13, Eberly 2e (Many Mappings)
- Reading for Today: §3.1, Eberly 2e
- Reading for Next Class: §3.2 – 3.4, Eberly 2e; Direct3D handout
- Last Time: Mappings, OpenGL Texturing
  - Shadow, reflection/environment, transparency, bump, displacement
  - Other mappings: gloss, volumetric fog, skins, rainbows, water
  - OpenGL texture mapping how-to
- Previously: Classical Fixed-Function Pipeline, Drawing in Direct3D
- Today: Shaders in Modern Pipeline
  - Vertex shaders: vertex attributes to illumination at vertices
  - Pixel shaders: lit vertices to pixel colors, transparency
- Hardware Rendering: Application Programmer Interfaces (APIs)
- Next: Shader Languages – (O)GLSL, HLSL / Direct3D, Renderman

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Where We Are

Lecture	Topic	Primary Source(s)
0	Course Overview	Chapter 1, Eberly 2e
1	**CG Basics: Transformation Matrices; Lab 0**	**Sections (§) 2.1, 2.2**
2	Viewing 1: Overview, Projections	§ 2.2.3 – 2.2.4, 2.8
3	Viewing 2: Viewing Transformation	§ 2.3 esp. 2.3.4; FVFH slides
4	**Lab 1a: Flash & OpenGL Basics**	**Ch. 2, 16[1]**, Angel *Primer*
5	Viewing 3: Graphics Pipeline	§ 2.3 esp. 2.3.7; 2.6, 2.7
6	Scan Conversion 1: Lines, Midpoint Algorithm	§ 2.5.1, 3.1; FVFH slides
7	**Viewing 4: Clipping & Culling; Lab 1b**	**§ 2.3.5, 2.4, 3.1.3**
8	Scan Conversion 2: Polygons, Clipping Intro	§ 2.4, 2.5 esp. 2.5.4, 3.1.6
9	Surface Detail 1: Illumination & Shading	§ 2.5, 2.6.1 – 2.6.2, 4.3.2, 20.2
10	**Lab 2a: Direct3D / DirectX Intro**	**§ 2.7, Direct3D handout**
11	Surface Detail 2: Textures; OpenGL Shading	§ 2.6.3, 20.3 – 20.4, *Primer*
12	Surface Detail 3: Mappings; OpenGL Textures	§ 20.5 – 20.13
13	**Surface Detail 4: Pixel/Vertex Shad.; Lab 2b**	**§ 3.1**
14	Surface Detail 5: Direct3D Shading; OGLSL	§ 3.2 – 3.4, Direct3D handout
15	Demos 1: CGA, Fun; Scene Graphs: State	§ 4.1 – 4.3, **CGA handout**
16	**Lab 3a: Shading & Transparency**	**§ 2.6, 20.1, *Primer***
17	**Animation 1: Basics, Keyframes; HW/Exam**	**§ 5.1 – 5.2**
	Exam 1 review; Hour Exam 1 (evening)	**Chapters 1 – 4, 20**
18	**Scene Graphs: Rendering; Lab 3b: Shader**	**§ 4.4 – 4.7**
19	**Demos 2: SFX; Skinning, Morphing**	**§ 5.3 – 5.5, CGA handout**
20	Demos 3: Surfaces; B-reps/Volume Graphics	§ 10.4, 12.7, **Mesh handout**

Lightly-shaded entries denote the due date of a written problem set; heavily-shaded entries, that of a machine problem (programming assignment); blue-shaded entries, that of a paper review; and the green-shaded entry, that of the term project.

Green, **blue** and **red** letters denote **exam review**, **exam**, and **exam solution review** dates.

Review: Vertex Shaders *vs.* Pixel Shaders

- Classical Fixed-Function Pipeline (FFP): Per-Vertex Lighting, MVT + VT
  - Largely superseded on desktop by programmable pipeline
  - Still used in mobile computing
- Modern Programmable Pipeline: Per-Pixel Lighting
- Vertex Shaders (FFP and Programmable)
  - Input: per-vertex attributes (*e.g.*, object space position, normal
  - Output: lighting model terms (*e.g.*, diffuse, specular, *etc.*)
- Pixel Shaders (Programmable Only)
  - Input: output of vertex shaders (lighting *aka* illumination)
  - Output: pixel color, transparency (R, G, B, A)
- Brief Digression
  - Note: vertices are *lit*, pixels are *shaded*
    - "Pixel shader": well-defined (iff "pixel" is)
    - "Vertex shader": misnomer (somewhat)
  - Most people refer to both as "shaders"

Acknowledgements: Many Mappings

Stefan Jeschke
Research Assistant
http://bit.ly/hUUM94

Eduard Gröller
Associate Professor
Director, Visualization Working Group
http://bit.ly/hUUM94

Institute of Computer Graphics and Algorithms
Technical University of Vienna

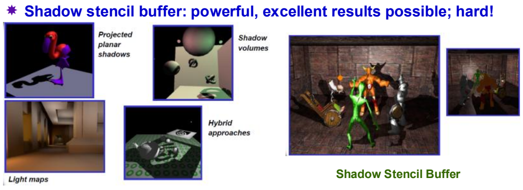
TECHNISCHE UNIVERSITÄT WIEN
Institut für Computergraphik und Algorithmen
Arbeitsbereich Computergraphik

Texturing material from slides © 2002 E. Gröller & S. Jeschke, Vienna University of Technology
http://bit.ly/dJFYq9

Mapping material from slides © 1995 – 2009 P. Hanrahan, Stanford University
http://bit.ly/hZfsjZ (CS 348B, Computer Graphics: Image Synthesis Techniques)

Review [1]: Shadow Mapping

- Ways to Handle Shadows
  - Projected planar shadows: works well on flat surfaces only
  - Shadow stencil buffer: powerful, excellent results possible; hard!



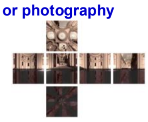
Shadow Stencil Buffer

- OpenGL Shadow Mapping Tutorials
  - Beginner/Intermediate (Baker, 2003): http://bit.ly/e1LA2N
  - Advanced (Octavian *et al.*, 2000): http://bit.ly/f1iRYB (old NeHe #27)

Adapted from "Shadow Mapping" © 2001 C. Everitt, nVidia
http://developer.nvidia.com/object/shadow_mapping.html

Review [2]: Reflection/Environment Mapping

- How To Create Direction Maps
  - Latitude-Longitude (Map Projections) - paint
  - Gazing Ball - photograph reflective sphere
  - Fisheye Lens - standard (wide-angle) camera lens
  - Cubical Environment Map - rendering program or photography
    - Easy to produce
    - "Uniform" resolution
    - Simple texture coordinates calculation

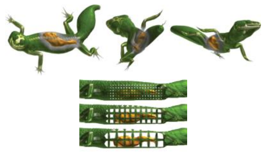


- Old NeHe OpenGL Mapping Tutorials (2000)
  - #6 (texture map onto cube) – Beginner (Molofee): http://bit.ly/gKj2Nb
  - #23 (sphere) – Intermediate (Schmick & Molofee): http://bit.ly/e3Zb8h
- nVidia Tutorial: OpenGL Sphere Map (1999): http://bit.ly/eJEdAM
- Issues: Non-Linear Mapping, Area Distortion, Converting Between Maps

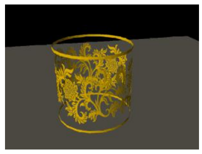
Adapted from slides © 1995 – 2009 P. Hanrahan, Stanford University
http://bit.ly/hZfsjZ (CS 348B)

Review [3]: Transparency Mapping

- OpenGL Transparency How-To at OpenGL.org: http://bit.ly/hRaQgk
- Screen Door Transparency
  - Use `glPolygonStipple()`, `glEnable(GL_POLYGON_STIPPLE)`
  - See http://bit.ly/g1hQpJ
- Glass-Like Transparency using Alpha Blending
  - Use `glEnable(GL_BLEND)`, `glBlendFunc(…)`
  - See http://bit.ly/hs82Za



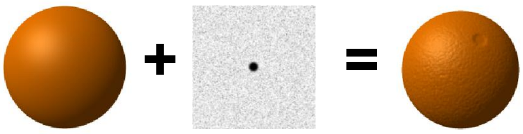
Viola *et al.* (2004), http://bit.ly/dVEa7I
Technical University of Vienna, IEEE Vis 2004



Alpha blending: Lim (2010), http://bit.ly/6TsJrb
Goon Creative, Maya Transparency Tutorial

Review [4]: Bump Mapping

- Goal: Create Illusion of Textured Surface

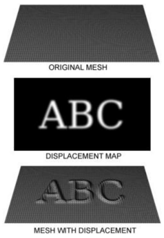


Bump Mapping © 2010 Wikipedia
http://en.wikipedia.org/wiki/Bump_mapping

- Idea
  - Start with regular smooth object
  - Make height map (by hand and/or using program, *i.e.*, procedurally)
  - Use map to perturb surface normals
  - Plug new normals into illumination equation
- Tutorial for OpenGL (Baker, 2003): http://bit.ly/fun4a5

Review [5]: Displacement Mapping

- Displacement Map: Similar to Bump Map – Contains Delta Values



Displacement Mapping © 2005 Wikipedia
http://en.wikipedia.org/wiki/Displacement_mapping

$\mathbf{P}(u,v)$

$\mathbf{S}(u,v) = \frac{\partial \mathbf{P}(u,v)}{\partial u} \quad \mathbf{T}(u,v) = \frac{\partial \mathbf{P}(u,v)}{\partial v}$

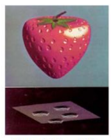
$\mathbf{N}(u,v) = \mathbf{S} \times \mathbf{T}$

- Displacement

$\mathbf{P}'(u,v) = \mathbf{P}(u,v) + h(u,v)\mathbf{N}(u,v)$

- Perturbed normal

$\mathbf{N}'(u,v) = \mathbf{P}'_u \times \mathbf{P}'_v = \mathbf{N} + h_u(\mathbf{T}\times\mathbf{N}) + h_v(\mathbf{S}\times\mathbf{N})$



From Blinn 1976

Adapted from slides © 1995 – 2009 P. Hanrahan, Stanford University
http://bit.ly/hZfsjZ (CS 348B)

- Displacement Mapping: Uses Open GL Shading Language (GLSL)
- Tutorial using GLSL (Guinot, 2006): http://bit.ly/dWXNya

Review [6]: OpenGL Shading (Overview)

Frank Pfenning
Professor of Computer Science
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http://www.cs.cmu.edu/~fp/

See also: *OpenGL: A Primer, 3e* (Angel)
http://bit.ly/hVcVWN

- Set Up Point Light Sources
  - Directional light given by "position" vector
```
GLfloat light_position[] = {-1.0, 1.0, -1.0, 0.0};
glLightfv(GL_LIGHT0, GL_POSITION, light_position);
```
  - Point source given by "position" point
```
GLfloat light_position[] = {-1.0, 1.0, -1.0, 1.0};
glLightfv(GL_LIGHT0, GL_POSITION, light_position);
```
- Set Up Materials, Turn Lights On
```
GLfloat mat_specular[]={0.0, 0.0, 0.0, 1.0};
GLfloat mat_diffuse[]={0.8, 0.6, 0.4, 1.0};
GLfloat mat_ambient[]={0.8, 0.6, 0.4, 1.0};
GLfloat mat_shininess={20.0};
glMaterialfv(GL_FRONT, GL_SPECULAR, mat_specular);
glMaterialfv(GL_FRONT, GL_AMBIENT, mat_ambient);
glMaterialfv(GL_FRONT, GL_DIFFUSE, mat_diffuse);
glMaterialf(GL_FRONT, GL_SHININESS, mat_shininess);

glShadeModel(GL_SMOOTH); /*enable smooth shading */
glEnable(GL_LIGHTING); /* enable lighting */
glEnable(GL_LIGHT0);  /* enable light 0 */
```
- Start Drawing (`glBegin … glEnd`)

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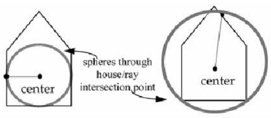
http://bit.ly/g1J2nj

Review [7]: Texturing – Object Center Method

- When we treat the object intersection point as a point on a sphere, our "sphere" won't always have the same radius



- What radius to use?
  - Compute the radius as the distance from the center of the complex object to the intersection point. Use that as the radius for the (u, v) mapping.

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Review [8]: OpenGL Texturing

In initialization:

```
glGenTextures(…);
glBindTexture( … );
glTexParameteri(…); glTexParameteri(…); …
glTexImage2D(…);
glEnable(GL_TEXTURE_2D);
```

In display:

```
glBindTexture( … ); // Activate the texture defined in initialization
glBegin(GL_TRIANGLES);
 glTexCoord2f(…); glVertex3f(…);
glTexCoord2f(…); glVertex3f(…);
glTexCoord2f(…); glVertex3f(…);
glEnd( );
```

Adapted from slides

Review [9]: Mappings, Eberly 2ᵉ

- Fine Surface Detail: Bump (§20.5 Eberly 2ᵉ)
- Material Effects: Gloss (§20.6)
- Enclosing Volumes
  - Sphere (§20.7)
  - Cube (§20.8)
- Light
  - Refraction for Transparency (§20.9)
  - Reflection *aka* Environment (§20.10)
- Shadow
  - Shadow Maps (§20.11, 20.13)
  - Projective Textures (§20.12)
- More Special Effects (SFX)
  - Fog (§20.14)
  - Skinning (§20.15)
  - Iridescence (§20.16), Water (§20.17)

Babylon 5

Acknowledgements

Nathan H. Bean
Instructor
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Kansas State University
http://bit.ly/gC3vwH

Direct3D material from slides © 2006 – 2010 N. Bean, Kansas State University
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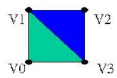
Cg material from figures © 2003 R. Fernando & M. Kilgard, Nvidia, from *The Cg Tutorial*
http://bit.ly/59ffSR

Review: Drawing in Direct3D

- Specify the material we wish to use for the following triangles
- Specify the texture we wish to use (if we want one or NULL if not)
- Set the stream source to our vertex buffer
- Set the FVF we will be using
- Set the index buffer we will be using
- Call the required `DrawPrimitive` function




```
void CGfxEntityCube::Render()
  {
   gD3dDevice->SetMaterial( &m_material );
      gD3dDevice->SetTexture(0,NULL);
      gD3dDevice->SetStreamSource( 0, m_vb,0, sizeof(CUBEVERTEX) );
      gD3dDevice->SetFVF( D3DFVF_CUBEVERTEX );
      gD3dDevice->SetIndices( m_ib);

      // draw a triangle list using 24 vertices and 12 triangles
      gD3dDevice->DrawIndexedPrimitive( D3DPT_TRIANGLELIST,0,0,24,0,12);
}
```

Toymaker © 2004 – 2010 K. Ditchburn, Teesside University
http://bit.ly/hMqxMl

History

- 1992 - id's *Wolfenstein 3D* video game rocks gaming world, all objects are billboards (flat planes) and rendered in software
- 1996 - id's *Quake* introduces a full 3D polygonal game, lighting vertices and shading pixels is still done in software
- 1996 - Voodoo 3Dfx graphics card released, does shading operations (such as texturing) in hardware. *QuakeWorld* brings hardware acceleration to *Quake*
- 1999 - Geforce 256 graphics card released, now transform and lighting (T&L) of vertices is done in hardware as well (uses the fixed function pipeline)
- 2001 – Geforce 3 graphics card lets programmers download assembly programs to control vertex lighting and pixel shading keeping the speed of the fixed function pipeline with none of the restrictions
- ~~Future~~ 2004 – Expanded features and high level API's for vertex and pixel shaders, increased use of lighting effects such as bump mapping and shadowing, higher resolution color values. *Doom III* and *Half-Life 2* usher in a new era of realism

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Fixed Function Pipeline

- Starting in 1999 some graphics cards began to do the standard lighting model and transformations in hardware (T&L). CPUs everywhere sighed in relief.
  - Hardware T&L existed in the 60s and 70s, it was just really slow and *really* expensive.
- Implementing the pipeline in hardware made processing polygons much faster, but the developer could not modify the pipeline (hence "fixed function pipeline"). The fixed function pipeline dates back to the first SGI workstations.
- New programmable hardware allows programmers to write vertex and pixel programs to change the pipeline
  - Vertex and pixel programs aren't necessarily slower than the fixed function alternative
- Note that the common term "vertex shader" to describe a vertex program is misleading: vertices are lit and pixels are shaded

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Programmable Hardware

Crysis 2
© 2011 Electronic Arts, Inc. – http://bit.ly/idNET9

Starcraft II: Wings of Liberty
© 2010 Blizzard Entertainment, Inc. – http://bit.ly/9B1qZp

Rage & id Tech 5
© 2011 id Software, Inc. – http://bit.ly/eR0m2B

Unreal Tournament 3 & Steamworks
© 2010 Epic Games & Valve – http://bit.ly/9QKAS7

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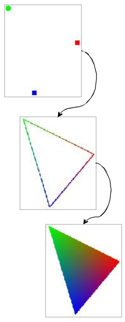
Quick Review: Interpolative Shading in OpenGL

By default, GL will do the following:

1. Take as input various per-vertex quantities (color, light source, eye point, texture coordinates, etc.)
2. Calculate a final color for each vertex using a basic lighting model (OpenGL uses Phong lighting)
3. For each pixel, linearly interpolate the three surrounding vertex colors to shade the pixel (OpenGL uses Gouraud shading)
4. Write the pixel color value to the frame buffer



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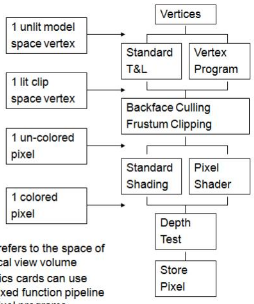
Programmable Hardware Pipeline



- clip space refers to the space of the canonical view volume
- New graphics cards can use either the fixed function pipeline or vertex/pixel programs

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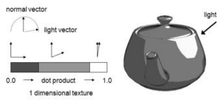
Example: Cartoon Shader & Utah Teapot

- Cartoon shading is a cheap and neat looking effect used in video games such as *Jet Set Radio Future*
- Instead of using traditional methods to light a vertex, use the dot product of the light vector and the normal of the vertex to index into a 1 dimensional "texture" (A texture is simply a lookup function for colors – nothing more and nothing less)
- Instead of a smooth transition from low intensity light (small dot product) to high intensity light (large dot product) make the 1 dimensional texture have sharp transitions
- Textures aren't just for "wrapping" 2D images on 3D geometry!
- Viola! Cartoon Teapot

JSRF © 2002 SEGA Games, Inc.
http://youtu.be/-J3bmKLw5hw



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What is Cg?

- Cg is a C-like language that the graphics card compiles in to a program
  - The program is run once per-vertex and/or per-pixel *on the graphics card*
- Cg does *not* have all the functionality of C
  - Different type systems
  - Can't include standard system headers
  - No malloc
  - http://www.cgshaders.org/articles/ has the technical documentation for Cg
- Cg is actually an abstraction of the more primitive assembly language that the programmable hardware originally supported

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Cg Tips

- Understand the different spaces your vertices may exist in
  - model space: the space in which your input vertex positions exist, in this space the center of the model is at the origin
  - world space: the space in which you will do most of your calculations
  - clip space: the space in which your output vertex positions must exist, this space represents the canonical view volume
- If you want a vector to have length 1 make sure to normalize the vector, this often happens when you want to use a vector to represent a direction
- When writing a Cg program try to go one step at a time, one sequence of steps might be
  - Make sure the model vertex positions are being calculated correctly
  - set the color or texture coordinates to an arbitrary value, verify that you are changing the surface color
  - Calculate the color or texture coordinates correctly
- Check out http://cgshaders.org/articles/ for some helpful documents

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Cg: Big Picture

- Write a .cg file. This will invariably take some sort of information as a parameter to its "`main()`" function
  - Note that this `main()` is not compiled by gcc (or any C/C++ compiler). That would generate a symbol conflict, among other things. It is only processed by NVidia's Cg compiler
- Write a class that extends `CGEffect`. This is cs123's object-oriented wrapper around the basic C interface provided by Nvidia
  - The `CGEffect` subclass allows you to bind data from your .C files to variables in your .cg vertex program
- Make that `CGEffect` the `IScene`'s current `CGEffect` by calling `IScene::setCGEffect()`. `IScene` will take ownership of the `CGEffect*` at this point, so you will not be deleting the memory you allocated yourself. Rendering will now be done using your vertex shader
- Call `IScene::removeCGEffect()` if you want to turn vertex shaders off again

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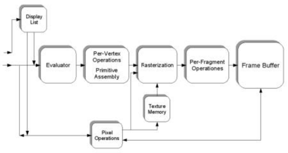
Shader Languages Overview



OpenGL State Machine (Simplified) from Wikipedia: *Shader*
http://bit.ly/fi8tBP

- **HLSL**: Shader language and API developed by **Microsoft**, only usable from within a DirectX application.
- **Cg**: Shader language and API developed by **Nvidia**, usable from within a DirectX and OpenGL application. Cg has a stark resemblance to HLSL.
- **GLSL**: Shader language and API developed by the **OpenGL** consortium and usable from withing an OpenGL application.

© 2009 Koen Samyn
http://knol.google.com/k/hlsl-shaders

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HLSL [1]

- High-Level Shader Language (HLSL) is Microsoft's language for programming GPUs
- Looks like C
- Example vertex and pixel shader for projective texturing (texture should appear to be projected onto the scene, as if from a slide projector)

```
struct VS_OUTPUTPROJTEX       // output structure
{
    float4 Pos : POSITION;
    float4 Tex : TEXCOORD0;
};

VS_OUTPUTPROJTEX VSProjTexture(float4 Pos : POSITION, float3 Normal : NORMAL)
{
    VS_OUTPUTPROJTEX Out = (VS_OUTPUTPROJTEX)0;
    Out.Pos = mul(Pos, matWorldViewProj);          // transform Position
    Out.Tex = mul(ProjTextureMatrix, Pos);         // project texture coordinates

   return Out;
}

float4 PSProjTexture(float4 Tex: TEXCOORD0) : COLOR
{
    return tex2Dproj(ProjTexMapSampler, Tex);
}
```

Adapted from slide 2003 Wolfgang Engel, http://www.wolfgang-engel.info
Visiondays 2003, http://bit.ly/hhkANP

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HLSL [2]: Code Example

```
// This is used by 3dsmax to load the correct parser
string ParamID = "0x0";
// DxMaterial specific
float4x4 wvp : WORLDVIEWPROJ;
struct VS_OUTPUT
{
    float4 Pos : POSITION;
    float4 Col : COLOR0;
};
VS_OUTPUT VS( float3 Pos : POSITION )
{
    VS_OUTPUT Out = (VS_OUTPUT)0;
    float4 hPos = float4( Pos, 1);
    Out.Pos = mul( hPos, wvp);
    Out.Col = float4( 1, 1, 1, 1);
    return Out;
}
technique Default
{
    pass P0
    {
        // shaders
        CullMode = None;
        VertexShader = compile vs_2_0 VS();
    }
}
```

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http://knol.google.com/k/hlsl-shaders

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Cg [1]

- Q: What Is Cg?
  - A1: Nvidia's high-level shading language
  - A2: An OpenGL, Direct3D, RenderMan descendant…

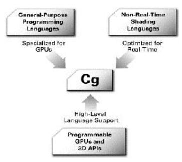

Figure 1-10, Fernando & Kilgard (2003)

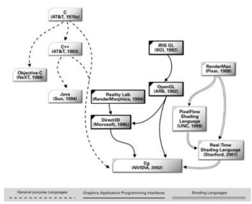

Figure 1-11, Fernando & Kilgard (2003)

- Intro Slides for Cg Tutorial (Online Book): http://bit.ly/59ffSR

© 2003 R. Fernando & M. Kilgard. *The Cg Tutorial.*
http://bit.ly/59ffSR

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Cg [2]

- Polygons-to-Pixels Pipeline (Fixed-Function & Programmable) in Action

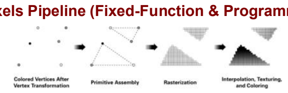

Figure 1-6, Fernando & Kilgard (2003)

- Programmable Graphics Pipeline

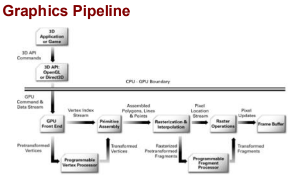

Figure 1-7, Fernando & Kilgard (2003)

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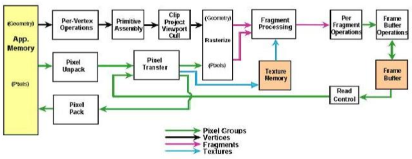
GLSL [1]: Building on Top of OpenGL

- How It Used to Be (in OpenGL)



OpenGL 1.5 Fixed Function Pipeline (see *OpenGL Reference Manual*)
"GLSL: An Introduction" © 2004 F. Rudolf, NeHe Productions – http://bit.ly/gi9g47

- New Function: Fragment (Pixel-Level) Shaders
  - Programmable pipeline – like HLSL, Cg
  - Compiles to shader objects
  - Runs on hardware: ATI Radeon 9x00+, nVidia GeForce 5x00+

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GLSL [2]: Hybrid Shader Example – Color Cube

Vertex Shader

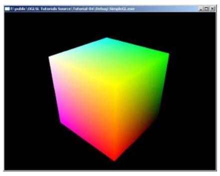
```
varying float xpos;
varying float ypos;
varying float zpos;
void main(void)
{
    xpos = clamp(gl_Vertex.x,0.0,1.0);
    ypos = clamp(gl_Vertex.y,0.0,1.0);
    zpos = clamp(gl_Vertex.z,0.0,1.0);

    gl_Position = gl_ModelViewProjectionMatrix *    gl_Vertex;
}
```

Fragment Shader

```
varying float xpos;
varying float ypos;
varying float zpos;

void main (void)
{
 gl_FragColor = vec4 (xpos, ypos, zpos, 1.0);
}
```



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http://bit.ly/et5qOp

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Vertex Shaders [1]

- "Fixed-Function"
  - Standard pipeline
  - Typical examples include simple "my first shader" definitions
    - Constant (flat) shading
    - Smooth (Gouraud) shading
- Brief Digression: Sample-Based *vs.* Geometry-Based Graphics
  - Sample-based: image manipulation
    - Not rendered from (3-D) model
    - Examples: Photoshop, GIMP
  - Geometry-based: transform and render representations of objects
- Programmable
  - Fixed material properties selected by user
  - Procedural material properties
  - Gradients
  - Lots of other things you see in sample-based graphics

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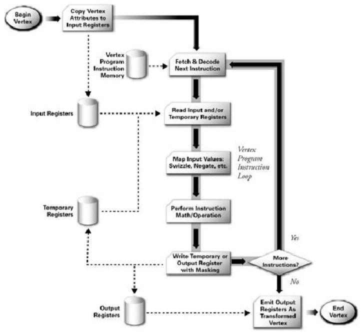
Vertex Shaders [2]: Cg/HLSL-Style Pipeline



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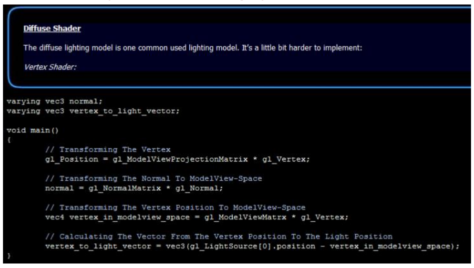
Vertex Shaders [3]: GLSL Example

- Diffuse Shader (NeHe GLSL Example)



Diffuse Shader

The diffuse lighting model is one common used lighting model. It's a little bit harder to implement:

Vertex Shader:

```
varying vec3 normal;
varying vec3 vertex_to_light_vector;

void main()
{
        // Transforming The Vertex
        gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;

        // Transforming The Normal To ModelView-Space
        normal = gl_NormalMatrix * gl_Normal;

        // Transforming The Vertex Position To ModelView-Space
        vec4 vertex_in_modelview_space = gl_ModelViewMatrx * gl_Vertex;

        // Calculating The Vector From The Vertex Position To The Light Position
        vertex_to_light_vector = vec3(gl_LightSource[0].position - vertex_in_modelview_space);
}
```

- Machine Problems, Projects: Will Use Combination of Shaders

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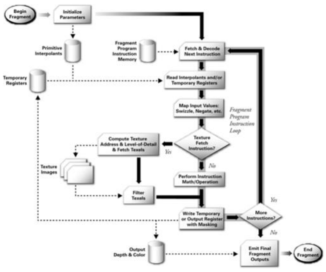
Pixel & Fragment Shaders [1]

- Fragments: Pixels Plus Properties
  - Everything needed to shade pixel
  - Coordinates
  - Normals
  - Object colors: diffuse, specular
  - Other properties
  - May involve local computation of lighting (local to pixel)
  - Typical example: Phong-like shading (normal interpolation)
- Programmable
  - Use fragment data
  - Combine it with lights, textures, *etc.*
- Hybridization: Combine Vertex and Pixel Shading
  - Varying attributes for vertex (basis for fragment shading)
  - Interpolating value from vertex shader across fragments

Pixel & Fragment Shaders [2]: Cg/HLSL-Style Pipeline



http://bit.ly/59fFSR

Pixel & Fragment Shaders [3]: GLSL Example

- Consider BRDF (Especially N ∢ L) From Last Lecture

```
varying vec3 normal;
varying vec3 vertex_to_light_vector;

void main()
{
        // Defining The Material Colors
        const vec4 AmbientColor = vec4(0.1, 0.0, 0.0, 1.0);
        const vec4 DiffuseColor = vec4(1.0, 0.0, 0.0, 1.0);

        // Scaling The Input Vector To Length 1
        vec3 normalized_normal = normalize(normal);
        vec3 normalized_vertex_to_light_vector = normalize(vertex_to_light_vector);

        // Calculating The Diffuse Term And Clamping It To [0;1]
        float DiffuseTerm = clamp(dot(normal, vertex_to_light_vector), 0.0, 1.0);

        // Calculating The Final Color
        gl_FragColor = AmbientColor + DiffuseColor * DiffuseTerm;
}
```

- Result: Diffuse Term for Phong Shading (One Light, No Specular)

http://bit.ly/gi9g47

Summary

- Last Time: Mappings, OpenGL Texturing
  - Shadow, reflection/environment, transparency, bump, displacement
  - Other mappings: gloss, volumetric fog, skins, rainbows, water
  - OpenGL texture mapping how-to
- Previously: Basic Drawing in Direct3D, Shading & Texturing in OpenGL
- Today: Shaders in Modern Pipeline
  - Vertex shaders
    - Input: per-vertex attributes (*e.g.*, object space position, normal)
    - Output: lighting model terms (*e.g.*, diffuse, specular, *etc.*)
  - Pixel shaders
    - Input: output of vertex shaders (lighting *aka* illumination)
    - Output: pixel color, transparency (R, G, B, A)
- Shader Languages – (O)GLSL, HLSL / Direct3D, Renderman
- Next: Using Shader Languages

Terminology

- Mappings
  - Shadow, reflection/environment, transparency, bump, displacement
  - Other mappings: gloss, volumetric fog, skins, rainbows, water
- Classical Fixed-Function Pipeline (FFP): Per-Vertex Lighting, MVT + VT
- Modern Programmable Pipeline: Per-Pixel Lighting
- Shader Languages (SLs)
  - Domain-specific programming languages
  - Geared towards hardware rendering
- Specific SLs Covered
  - HLSL / Direct3D – Microsoft's programmable pipeline; overview
  - Cg – Nvidia's OpenGL / Direct3D descendant
  - (O)GLSL – OpenGL shading language, covered in more detail
- Other Shader Languages Beyond Scope of This Course
  - Gelato – Nvidia's production render farm SL
  - Renderman – Pixar's specification, renderer, or SL