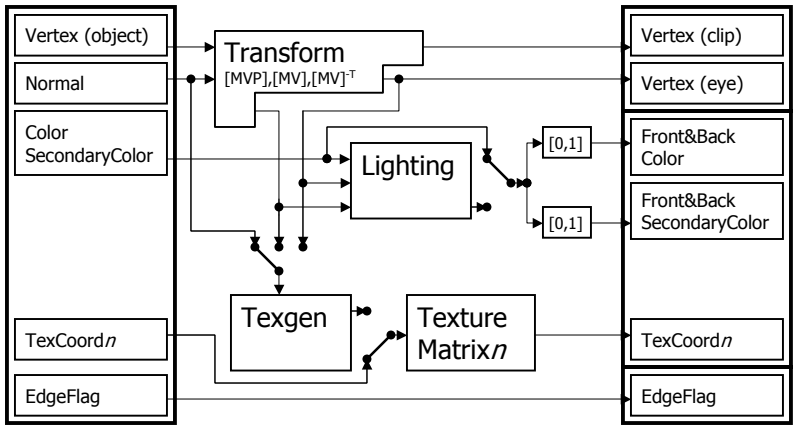
Programmable Shading

May 15, 2006

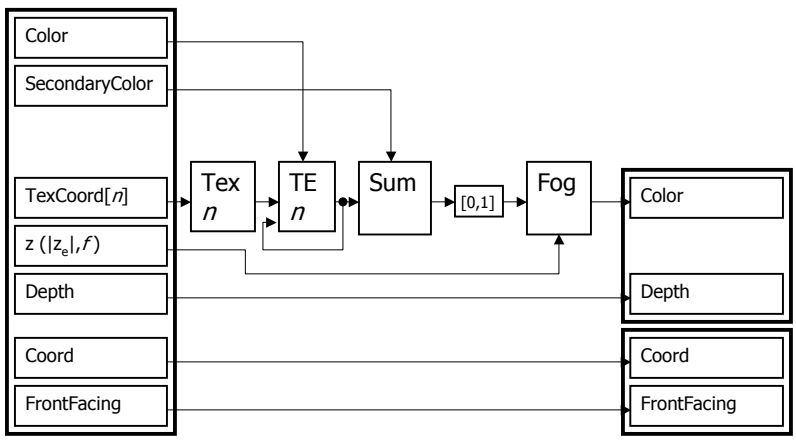
Motivation

- Recall what are done in the graphics pipeline:
  - Front End: Transformations (Modeling, Viewing, and Projection) and Lighting.
  - Back End: Rasterization and Interpolations (of Colors, Depth, and Texture Coordinates)
  - What are their input/output parameters?

OpenGL
Fixed Function Vertex

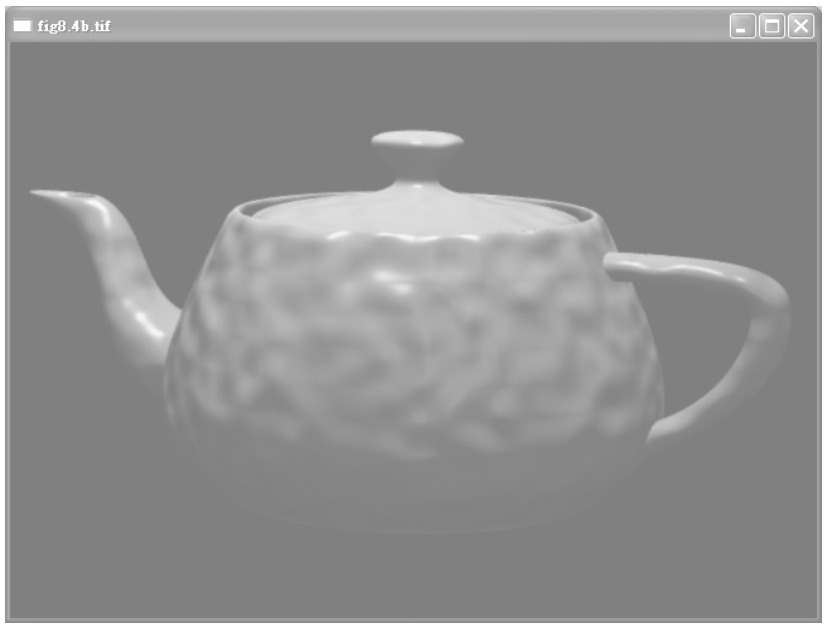


OpenGL
Fixed Function Fragment



Programmable Shading

- Why not doing something different with those input?
- Case in focus: bump mapping
- Bump mapping simulates detail with a surface normal that varies across a surface.



RenderMan & Its Shading Language

Key Idea of a Shading Language

- Image synthesis can be divided into two basic concerns
  - Shape: Geometric Objects, Coordinates, Transformations, Hidden-Surface Methods…
  - Shading: Light, Surface, Material, Texture, …
- Control shading not only by adjusting parameters and options, but by *telling the shader what you want it to do directly* in the form of a procedure

Pixar's RenderMan

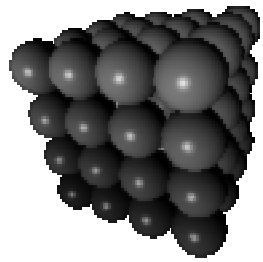
- Separation of Modeling and Rendering
  - RenderMan serves as the interface.
- Scene = Shape + Shading
- The power of RenderMan is in the shading part.

Example #1

```
#include <ri.h>
RtPoint Square[4]={{.5,.5,.5},{.5,-.5,.5},
          {-.5,-.5,.5},{-.5,.5,.5}};
Main(){
   RiBegin(RI_NULL);
   RiWorldBegin();
      RiSurface("constant", RI_NULL);
      RiPolygon(4, RI_P, (RtPointer)Square, RI_NULL);
   RiWorldEnd();
   RiEnd();
}
```

Example #2

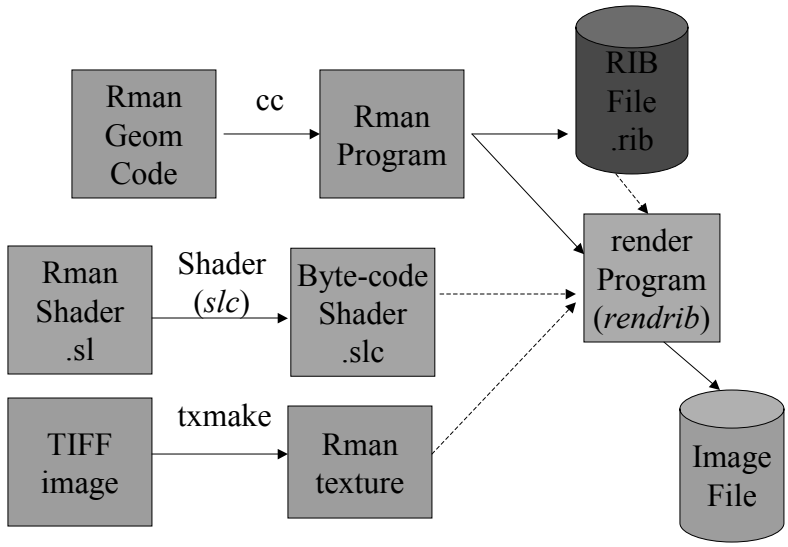
- Colorspheres.c in the BMRT/examples folder.



Building and Running

- Must have the following:
  - Header file: ri.h
  - Link library
  - A renderer
- The program generates a “RenderMan Interface” file, but doesn’t render it
  - So that you may pick a renderer that matches the graphics power of your machine.

Pixar's RenderMan



RenderMan's RIB File Structure

Options global to the entire animation

- Frame Block
  - Image options
  - Camera options
  - World Block
    - Attributes, lights, primitives
  - Changed Options
  - Another world block
- Next frame block

Comparison to OpenGL

- It doesn't do the actual rendering.
  - Separation of modeling and rendering.
  - It's the task of the renderer.
- RiSurface() changes the graphics state
  - Similar to glColor()
- RiPolygon() to describe the models
  - Similar to glBegin(GL_POLYGON)

Why C?

- Binding to other programming language is also possible.
- (My guess) Maybe just to avoid writing a compiler for its own scripting language…

RenderMan Interface Spec

•Where do you find the meaning of the arguments to those Ri…() functions?

- Check the spec! (available directly from Pixar).
- Appendix G contains a quick reference.

http://www.pixar.com/renderman/developers_corner/rispec/rispec_pdf/RISpec3_2.pdf

BMRT

- A public-domain implementation of Pixar Photorealistic RenderMan (PRMan).
- Three main components:
  - Rendrib: the renderer
  - Rgl: quick rendering for preview
  - Slc: shading language compiler

Shading Language

- Many types of shaders are possible:
  - Light source shaders
  - Surface shaders
  - Atmosphere shaders
  - Volume shaders…etc.
- We will discuss only the surface shaders.

Shader Writing

- Global variables: (from Table 14.2 of *The RenderMan Companion* book)
  - Camera position, surface color/opacity, surface position/normal, texture coordinates…etc.
  - Must output: color of light from surface, opacity of surface.
- Many built-in operators (Table 14.4) and functions (Ch.15, Tables 15.1-15.2).

Example: Plastic Surface

```
surface
plastic (float Ka = 1, Kd = 0.5, Ks = 0.5,
                roughness = 0.1;
         color specularcolor = 1)
{
    normal Nf = faceforward (normalize(N),I);
    Ci = Cs * (Ka*ambient() + Kd*diffuse(Nf)) +
         specularcolor *
         Ks*specular(Nf,-normalize(I),roughness);
    Oi = Os;  Ci *= Oi;
}
```

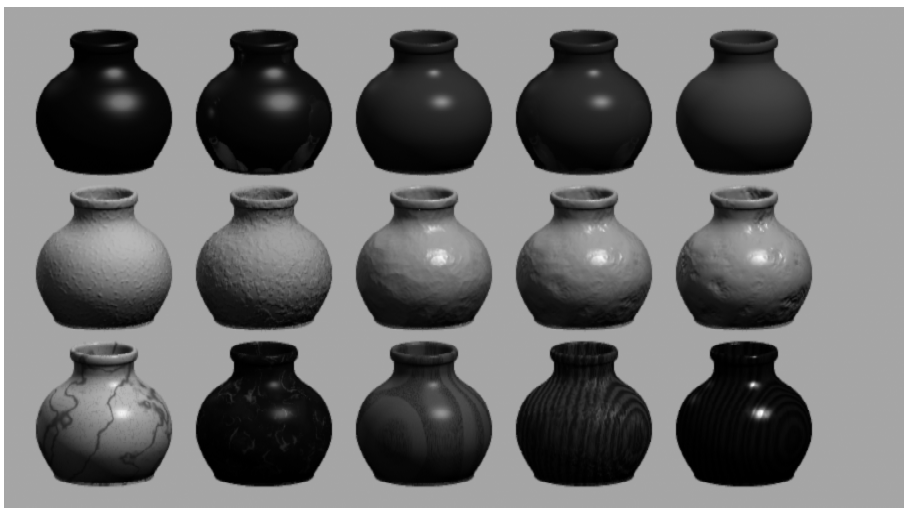
RenderMan's Shader

- Phong shader

```
surface phong( float Ka = 1, Kd =1, Ks = 0.5;
        float roughness = 0.1;
       color specularcolor = 1; )
{
   normal Nf = faceforward( normalize(N), I );
   vector V = -normalize(I);
   color C = 0;
   illuminance( P ) {
      vector R = 2*normalize(N)*
                (normalize(N) . normalize( L )) -
                 normalize( L );
      C += Ka*Cs +
           Kd*Cs*( normalize(N) . normalize(L) ) +
           Ks*specularcolor* pow(( R . V ), 10);
   }
   Ci = C*Cs;
}
```

Gallery of Shaders

- Procedural textures: e.g., wood
- Bump mapping and displacement mapping.
- For more, see Ch. 16 of *The RenderMan Companion*
- See also the `shaders` and `examples` folders of BMRT.



Shading Languages for Graphics Hardware

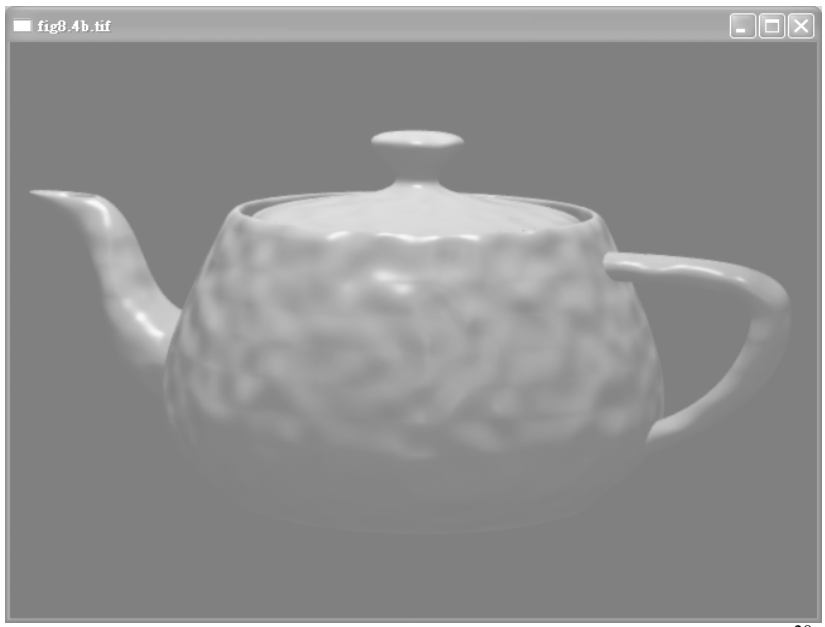
A Brief Introduction to Cg

- Cg is "C for Graphics," a high-level, cross-platform language for graphics programming
- Cg replaces tedious assembly coding with a C-like language and a compiler that generates assembly for you
- Cg is a cross-API and cross-platform language:
  - It works with both OpenGL and DirectX
  - It runs on Windows and Linux (more in the works)
  - It supports hardware from NVIDIA, ATI, Matrox, and any other programmable hardware that supports OpenGL or DirectX
- The Cg Runtime simplifies parameter passing from your application to the vertex and fragment programs

NVIDIA.

Bump Map Example

- Bump mapping simulates detail with a surface normal that varies across a surface

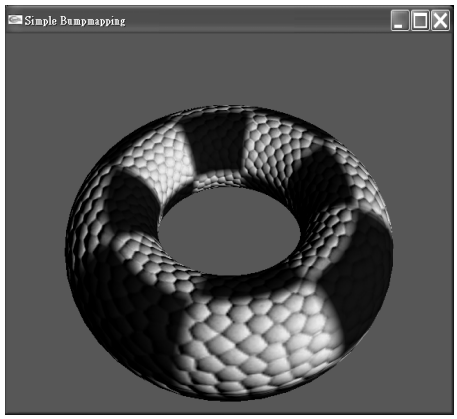


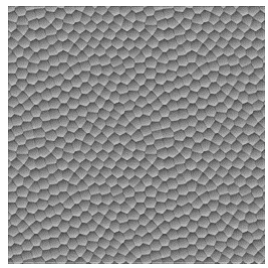
RenderMan Example

```
displacement
lumpy ( float Km = 1, frequency = 1, maxoctaves = 6;
        string shadingspace = "shader";
        float truedisp = 1;)
{
   point Pshad = transform (shadingspace, frequency*P);
   float dPshad = filterwidthp(Pshad);
   float magnitude = fBm (Pshad, dPshad, maxoctaves, 2, 0.5);
   N = Displace (normalize(N), shadingspace, Km*magnitude, truedisp);
}
```

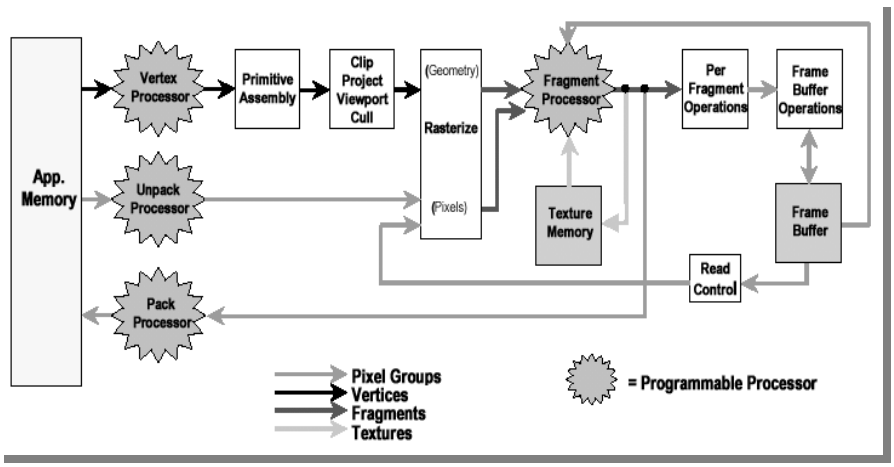

Cg Example

```
f2fb DiffuseBumpPS(v2f IN, uniform sampler2D DiffuseMap,
                   uniform sampler2D NormalMap, uniform float4 bumpHeight)
{
    f2fb OUT;
    float4 color = tex2D(DiffuseMap); //fetch base color
    //fetch bump normal
    float4 bumpNormal = expand(tex2D(NormalMap)) * bumpHeight;
    //expand iterated light vector to [-1,1]
    float4 lightVector = expand(passthrough(IN.LightVector));
    //compute final color (diffuse + ambient)
    float4 bump = uclamp(dot3_rgba(bumpNormal.xyz, lightVector.xyz));
    OUT.col = color * bump;
    return OUT;
}
```

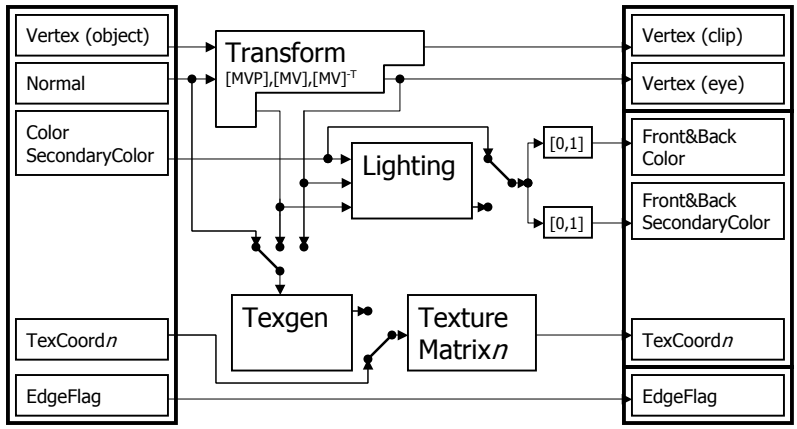




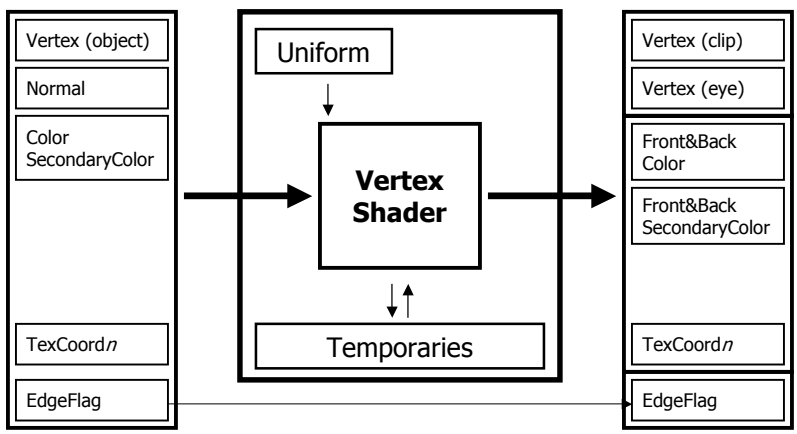
GL2 Logical Diagram



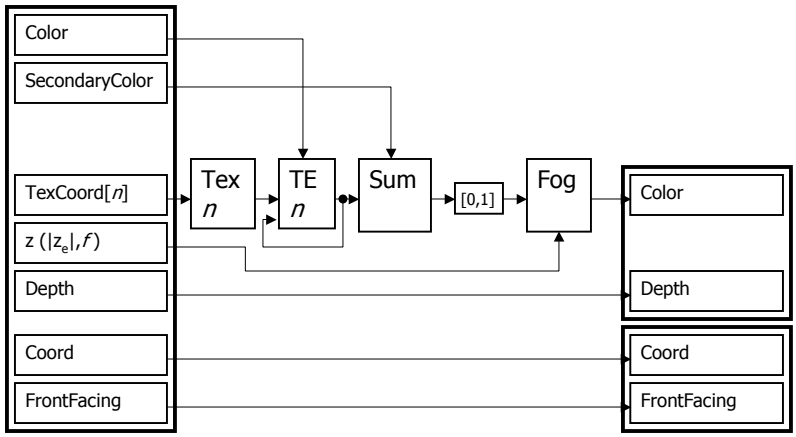
OpenGL
Fixed Function Vertex



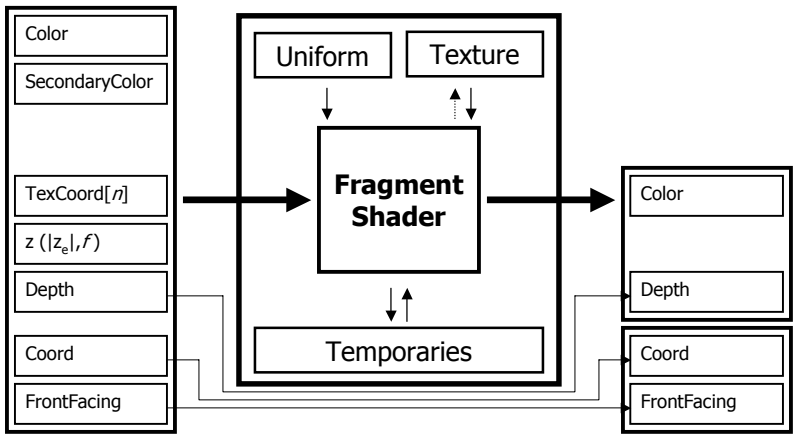
GL2 Vertex Processor



OpenGL
Fixed Function Fragment



GL2 Fragment Processor



Comparison

	RenderMan	OpenGL 2.0	D3D VS (2.0/3.0)	D3D PS (2.0/3.0)
Program Size	No limit	No limit	256/256	256/256
Vertex Attributes	No limit	>=16	16/16	
Constants	No limit	VS:>=512 floats PS: >= 64 floats	128/256	32/128
Varying Parameters	No limit	>= 40 interpolators	10/10	10/10
Texture Samplers	No limit	No limit		16/16
Temp Registers	No limit	No limit	12/16	12/16
Constant-Based Flow Control	Yes	Yes	Yes/Yes	No/Yes
Variable-Based Flow Control	Yes	Yes	No/No	No/No