ECE4893A/CS4803MPG: Multicore and GPU Programming for Video Games

Environment & Bump Mapping

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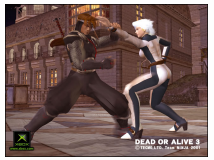
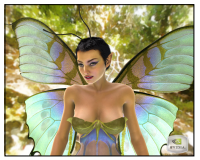
Real-time graphics has come a long way

Virtua Fighter
(SEGA Corporation)
NV1
50K triangles/sec
1M pixel ops/sec
1995



Dead or Alive 3
(Tecmo Corporation)
Xbox (NV2A)
100M triangles/sec
1G pixel ops/sec
2001



Dawn
(NVIDIA Corporation)
GeForce FX (NV30)
200M triangles/sec
2G pixel ops/sec
2003

Slide from from "Teaching Cg" Powerpoint presentation:
developer.nvidia.com/object/cg_tutorial_teaching.html

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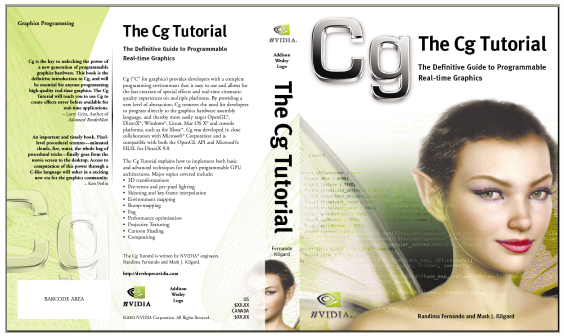
The Cg Tutorial



- Can get Cg Toolkit, example code, text of the entire book, etc. here: http://developer.nvidia.com/object/cg_tutorial_home.html

Image from "Teaching Cg" Powerpoint presentation:
developer.nvidia.com/object/cg_tutorial_teaching.html

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Nice framework for experimentation

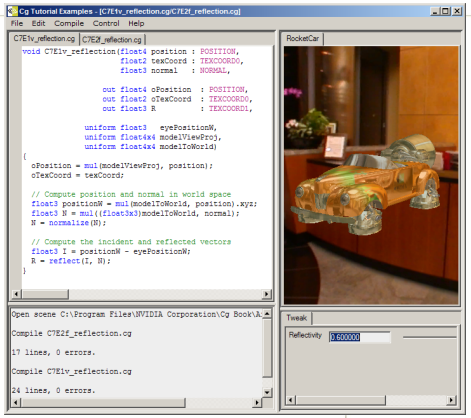

Image from "Teaching Cg" Powerpoint presentation:
developer.nvidia.com/object/cg_tutorial_teaching.html

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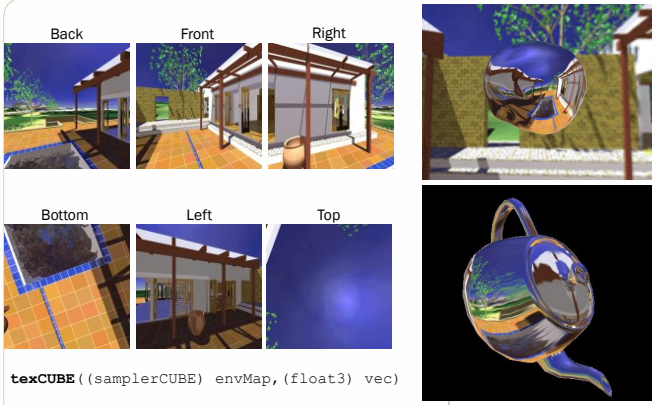
Cube maps




```
texCUBE((samplerCUBE) envMap,(float3) vec)
```

Images from "OpenGL Cube Map Texturing."
developer.nvidia.com/object/cube_map_ogl_tutorial.html

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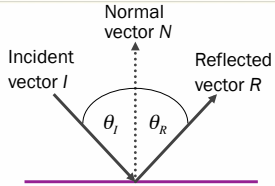
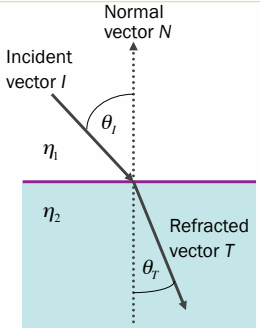
Reflection and refraction



$\theta_I = \theta_R$

```
R=reflect(I,N)
```



$\eta_1 \sin(\theta_I) = \eta_2 \sin(\theta_T)$

```
T=refract(I,N,etaRatio)
```

etaRatio= η_1 / η_2

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Vertex shader for reflective mapping

```
void C7E1v_reflection(float4 position : POSITION,
    float2 texCoord : TEXCOORD0, float3 normal   : NORMAL,
                  out float4 oPosition  : POSITION,
                  out float2 oTexCoord  : TEXCOORD0,
                  out float3 R          : TEXCOORD1,
uniform float3   eyePositionW,
uniform float4x4 modelViewProj, uniform float4x4 modelToWorld)
{
  oPosition = mul(modelViewProj, position);
  oTexCoord = texCoord;
  // Compute position and normal in world space
  float3 positionW = mul(modelToWorld, position).xyz;
  float3 N = mul((float3x3)modelToWorld, normal);
  N = normalize(N);
  // Compute the incident and reflected vectors
  float3 I = positionW - eyePositionW; R = reflect(I, N);
}
```

From "The Cg Tutorial," p. 177

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Pixel shader for reflective mapping

```
void C7E2f_reflection(float2 texCoord : TEXCOORD0,
                      float3 R        : TEXCOORD1,
                  out float4 color    : COLOR,
              uniform float reflectivity,
              uniform sampler2D decalMap,
              uniform samplerCUBE environmentMap)
{
  // Fetch reflected environment color
  float4 reflectedColor = texCUBE(environmentMap, R);

  // Fetch the decal base color
  float4 decalColor = tex2D(decalMap, texCoord);

  color = lerp(decalColor, reflectedColor, reflectivity);
}
```

From "The Cg Tutorial," p. 180

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Vertex shader for refractive mapping

```
void C7E3v_refraction(float4 position : POSITION,
    float2 texCoord : TEXCOORD0, float3 normal   : NORMAL,
                  out float4 oPosition  : POSITION,
                  out float2 oTexCoord  : TEXCOORD0,
                  out float3 T          : TEXCOORD1,
 uniform float etaRatio, uniform float3 eyePositionW,
 uniform float4x4 modelViewProj, uniform float4x4 modelToWorld)
{
  oPosition = mul(modelViewProj, position);
  oTexCoord = texCoord;
  // Compute position and normal in world space
  float3 positionW = mul(modelToWorld, position).xyz;
  float3 N = mul((float3x3)modelToWorld, normal);
  N = normalize(N);
  // Compute the incident and refracted vectors
  float3 I = positionW - eyePositionW;
  T = refract(I, N, etaRatio);
}
```

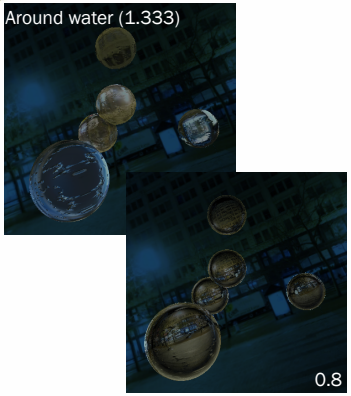
From "The Cg Tutorial," p. 187

Pixel shader for refractive mapping

```
void C7E4f_refraction(float2 texCoord : TEXCOORD0,
                      float3 T        : TEXCOORD1,
                  out float4 color    : COLOR,
              uniform float       transmittance,
              uniform sampler2D   decalMap,
              uniform samplerCUBE environmentMap)
{
  // Fetch the decal base color
  float4 decalColor = tex2D(decalMap, texCoord);
  // Fetch refracted environment color
  float4 refractedColor = texCUBE(environmentMap, T);
  // Compute the final color
  color = lerp(decalColor, refractedColor, transmittance);
}
```

From "The Cg Tutorial," p. 188

Different indices of refraction

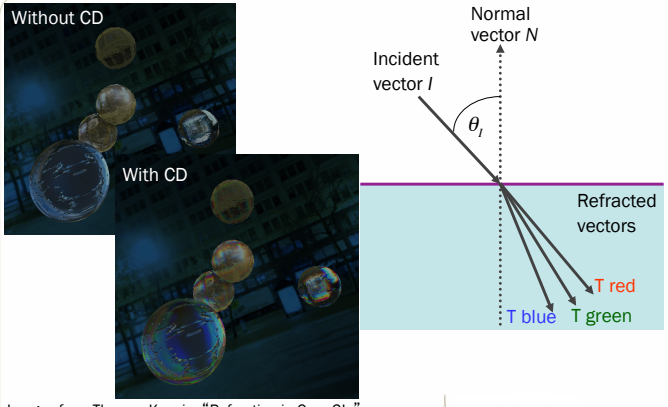


Vacuum: 1.0
Air: 1.0003
Water: 1.333
Glass: 1.5 (ordinary window glass)
Plastic: 1.5
Diamond: 2.417

Data from "The Cg Tutorial," p. 184

Images from Thomas Kerwin, "Refraction in OpenGL," www.cse.ohio-state.edu/~kerwin/refraction.html

Chromatic dispersion



Images from Thomas Kerwin, "Refraction in OpenGL," www.cse.ohio-state.edu/~kerwin/refraction.html

Fresnel effect

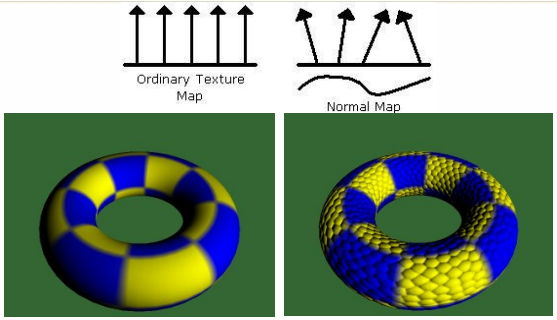
- Some light reflects and some refracts
- Think about looking into water
  - At shallow angles, a lot of reflection and little refraction
  - Looking straight in, a lot of refraction and a little reflection
- Empirical approximation:

$$reflectCoeff = \max(0,\min(1,bias + scale(1 + I \bullet N)^{power}))$$

$$C_{final} = reflectCoeff \times C_{reflected} + (1 - reflectCoeff)C_{refracted}$$

From "The Cg Tutorial," p. 189

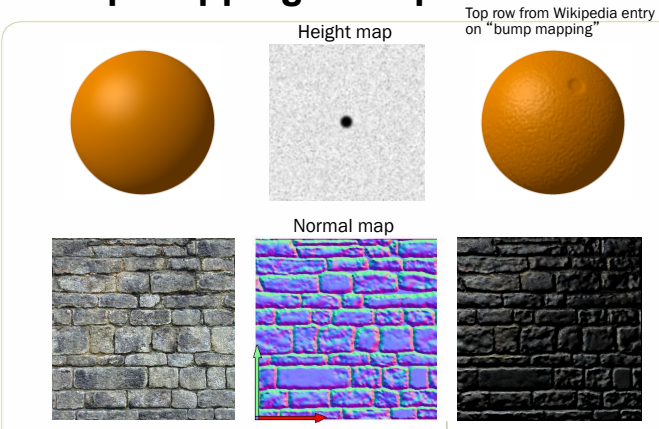
Bump mapping



Drawing from Søren Dreijer, "Bump Mapping Using Cg (3rd Edition)," www.blacksmith-studios.dk/projects/downloads/bumpmapping_using_cg.php

Images from Paul Baker, "Simple Bumpmapping," www.paulsprojects.net/tutorials/simplebump/simplebump.html

Bump mapping examples



Bottom row from Søren Dreijer, "Bump Mapping Using Cg (3rd Edition)," www.blacksmith-studios.dk/projects/downloads/bumpmapping_using_cg.php

Shader effect movies

- Bump mapping demo with the Cimg library
  http://video.google.com/videoplay?docid=1570416667092534064
- Bump mapping and reflective textures
  - (HLEH - Half Life mod???)

  http://www.youtube.com/watch?v=FmpyHc6hXc4
- Bump mapping on the Nintendo DS
  http://www.youtube.com/watch?v=6ypt5JE-ofg

Storing normals in textures

- Textures don't have to store color; we can store other things as well, like normals
  - Use r, g, b components to store, x, y, z of normal
- Problem: Textures take [0,1] values; normals need [-1,1] values
- Easy solution: "Range Compression"

```
colorComponent = 0.5 * normalComponent + 0.5;
normalComponent = 2 * (colorComponent - 0.5);
```

From "The Cg Tutorial," p. 202

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Creating normal map from height field

- Height field H(u,v)

$$normal = \frac{\left(H_g - H_r, H_g - H_a, 1\right)}{\left|\left(H_g - H_r, H_g - H_a, 1\right)\right|}$$

- In flat regions, normal is (0,0,1), i.e. pointing "up"

From "The Cg Tutorial," p. 203

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Vertex shader for bump mapping

```
void C8E1v_bumpWall(float4 position : POSITION,
                    float2 texCoord : TEXCOORD0,

                out float4 oPosition      : POSITION,
                out float2 oTexCoord      : TEXCOORD0,
                out float3 lightDirection : TEXCOORD1,

            uniform float3   lightPosition,  // Objectspace
            uniform float4x4 modelViewProj)
{
  oPosition = mul(modelViewProj, position);
  oTexCoord = texCoord;
  // Difference vectors for object-space light direction
  lightDirection = lightPosition - position.xyz;
}
```

From "The Cg Tutorial," p. 205

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Pixel shader for bump mapping

```
float3 expand(float3 v) { return (v-0.5)*2; }

void C8E2f_bumpSurf(float2 normalMapTexCoord : TEXCOORD0,
                    float3 lightDir          : TEXCOORD1,
                out float4 color : COLOR,
            uniform sampler2D   normalMap,
            uniform samplerCUBE normalizeCube)
{
  // Normalizes light vector with normalization cube map
  float3 lightTex = texCUBE(normalizeCube, lightDir).xyz;
  float3 light = expand(lightTex);
  // Sample and expand the normal map texture
  float3 normalTex = tex2D(normalMap,normalMapTexCoord).xyz;
  float3 normal = expand(normalTex);
  // Diffuse lighting
  color = dot(normal,light);
}
```

From "The Cg Tutorial," p. 206

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