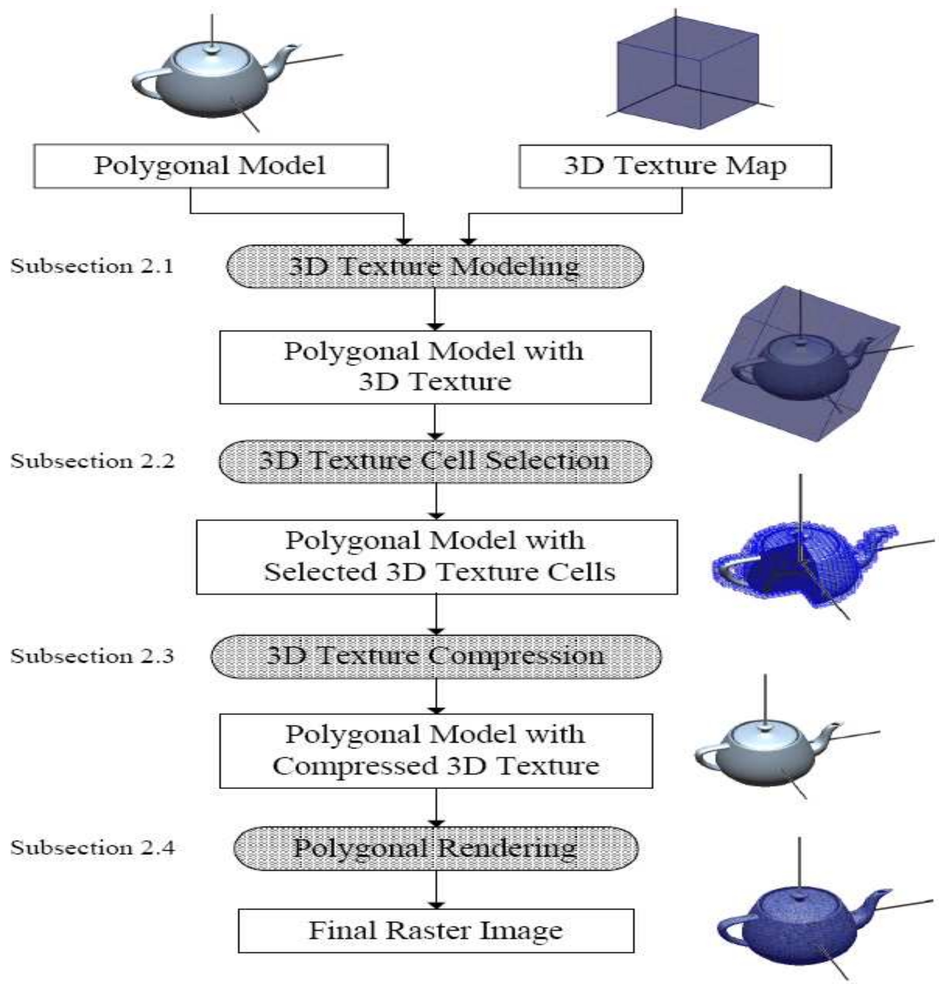
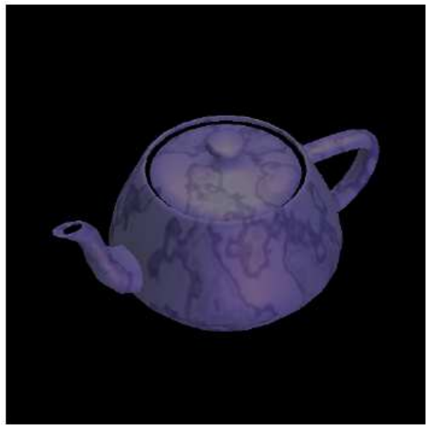
CG Programming: 3D Texturing

- 3D texturing is used as image based rendering
- Applications
  - 3D texture mapping for complicate geometric objects
    - It generates highly natural visual effects in which objects appear carved from lumps of materials rather than laminated with thin sheets as in 2D texture mapping.
  - Volume rendering
    - Ray casting
    - 3D texture mapping-based rendering

3D Texture Mapping



3D Texture Mapping Results



(a) Teapot with Bmarble

(b) Dragon with Wood

(c) Bunny with Eroded

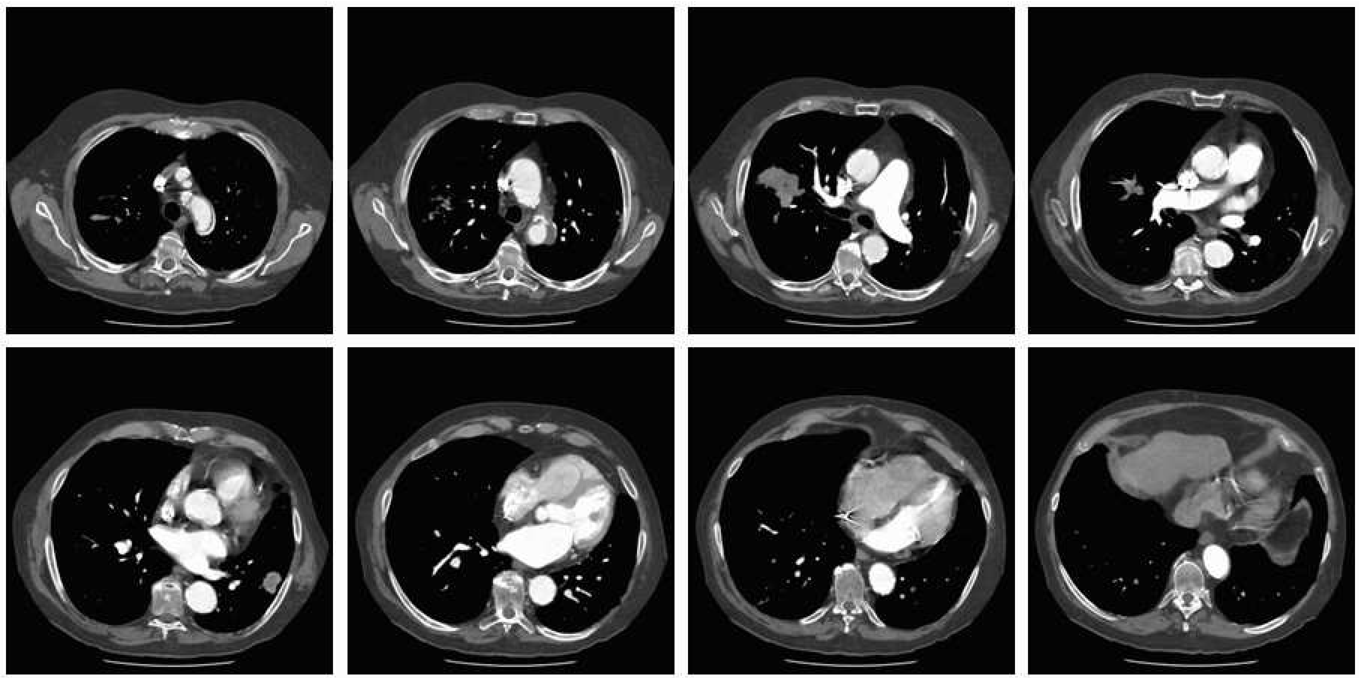
(d) Sdragon with Wood

Volume Rendering and CG Programs

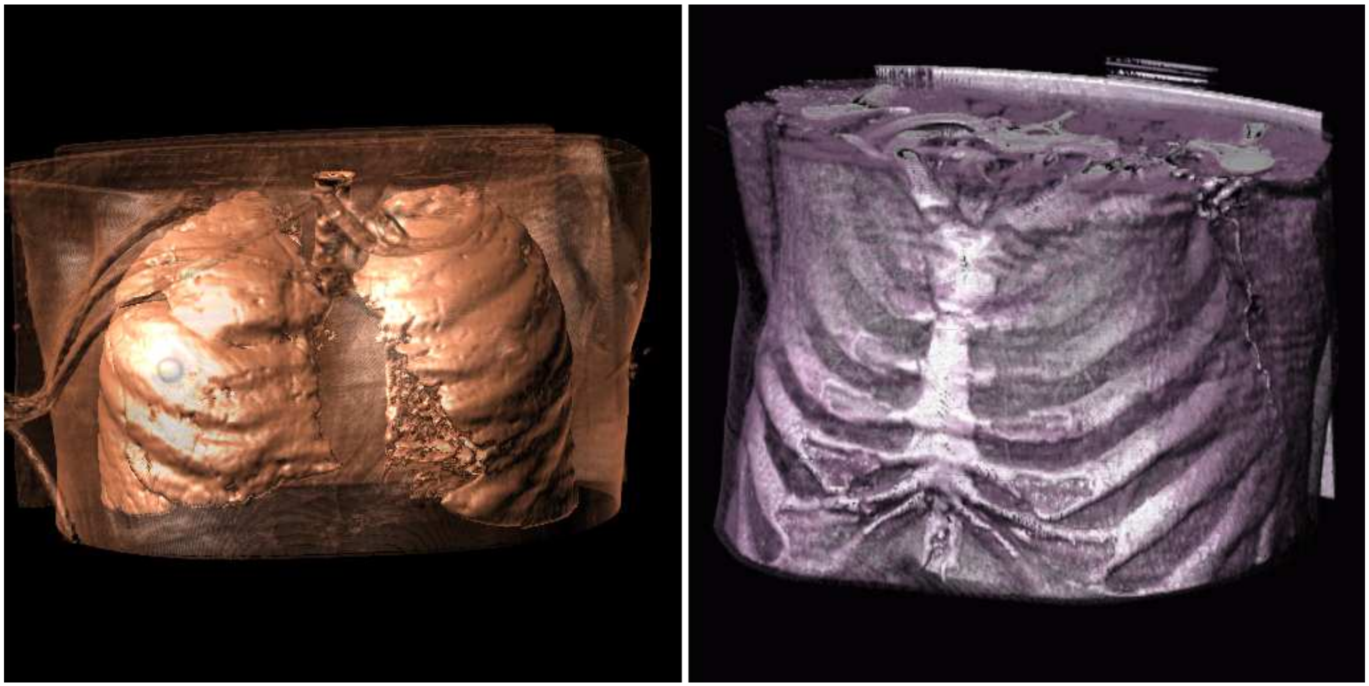
Volume rendering describes techniques that allow the visualization of three-dimensional image data.

- *Ray casting*
- *3D Texture mapping-based rendering*
- *Iso-surface generation (marching cubes)*

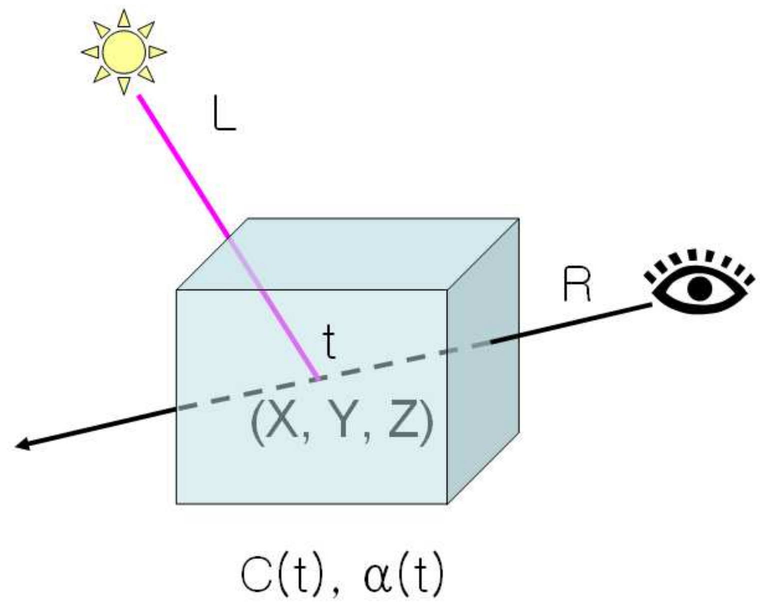
3D Volumetric Images (CT scan)



Volume Rendering Results



Ray Casting



At each volume sampling point (x, y, z) along the ray, function values are estimated using tri-linear interpolation. Furthermore illumination I(x, y, z) reaches each sampling point from the light source (L).

$C(t)$: a shaded color computed by an illumination model
$\alpha(t)$: an opacity value set by Transfer function maps (more about this below)

Illumination

$$I = K_a I_a + K_d(\vec{N} \cdot \vec{L}) + K_s(\vec{N} \cdot \vec{H})^n$$

$\vec{L}$: Light vector

$\vec{V}$: View vector

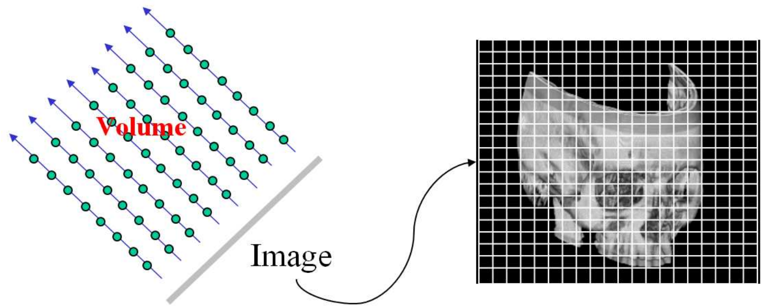
$$\vec{H} = \text{Normalize}(\vec{L} + \vec{V})$$

Gradient at x_i: $\nabla f(x_i) =$

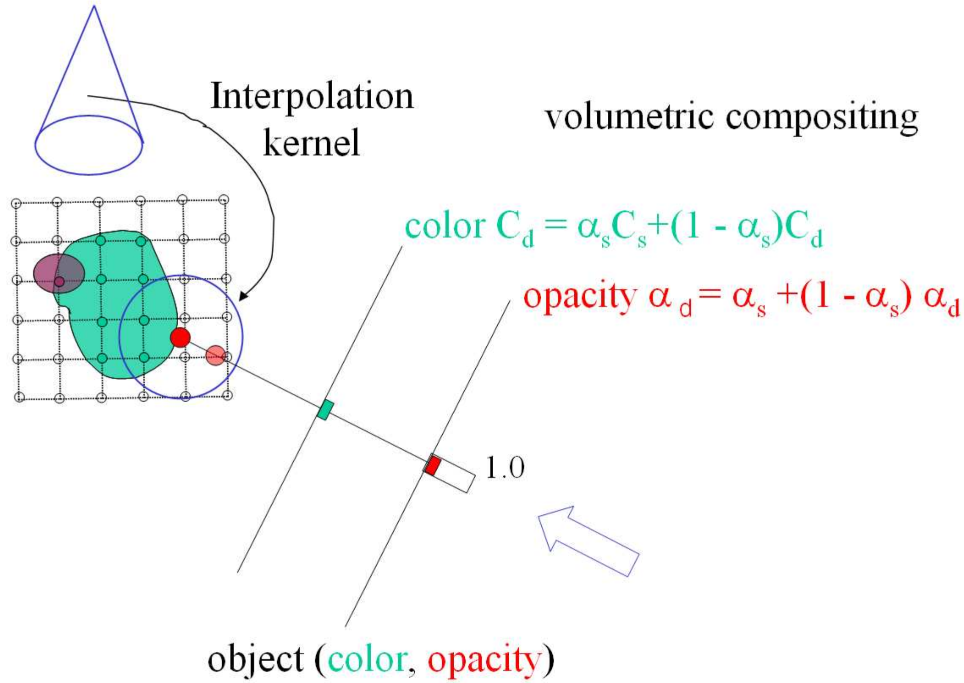
$$\big((f(x_{i+1}, y_i, z_i) - f(x_{i-1}, y_i, z_i))/D_x,$$
$$(f(x_i, y_{i+1}, z_i) - f(x_i, y_{i-1}, z_i)/D_y,$$
$$(f(x_i, y_i, z_{i+1}) - f(x_i, y_i, z_{i-1})/D_z)\big)$$

$$\vec{N}_i = \|\nabla f(x_i)\|$$

Ray Casting -revisited



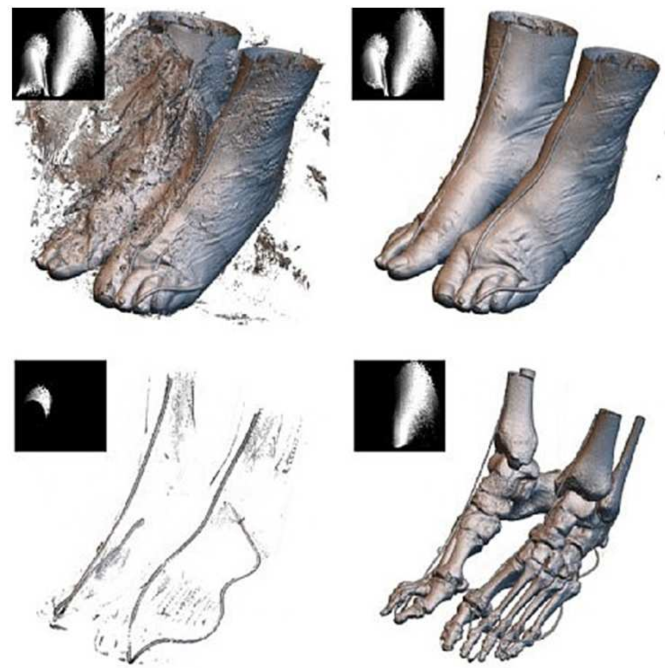
- Advantages
  - Not necessary to explicitly extract surfaces from volume when rendering
  - Can change the transfer functions to make various surfaces stand out within the volume
- Disadvantages
  - Do not have explicit representations for surfaces, therefore not straightforward to compute integral/differential properties
  - Much more computationally intensive to render volume since not dealing directly with the efficient polygon pipeline



- Front-to-back composition
  - $C_d = \alpha_s C_s + (1 - \alpha_s) C_d$
  - $\alpha_d = \alpha_s + (1 - \alpha_s)\alpha_d$
- Back-to-front composition
  - $C_d = C_d + (1 - \alpha_d)\alpha_s C_s$
  - $\alpha_d = \alpha_d + (1 - \alpha_d)\alpha_s$
- Color and Opacity Symbols
  - C_d : Destination color
  - C_s : Source color
  - α_d : Destination opacity
  - α_s : Source opacity

Transfer Functions

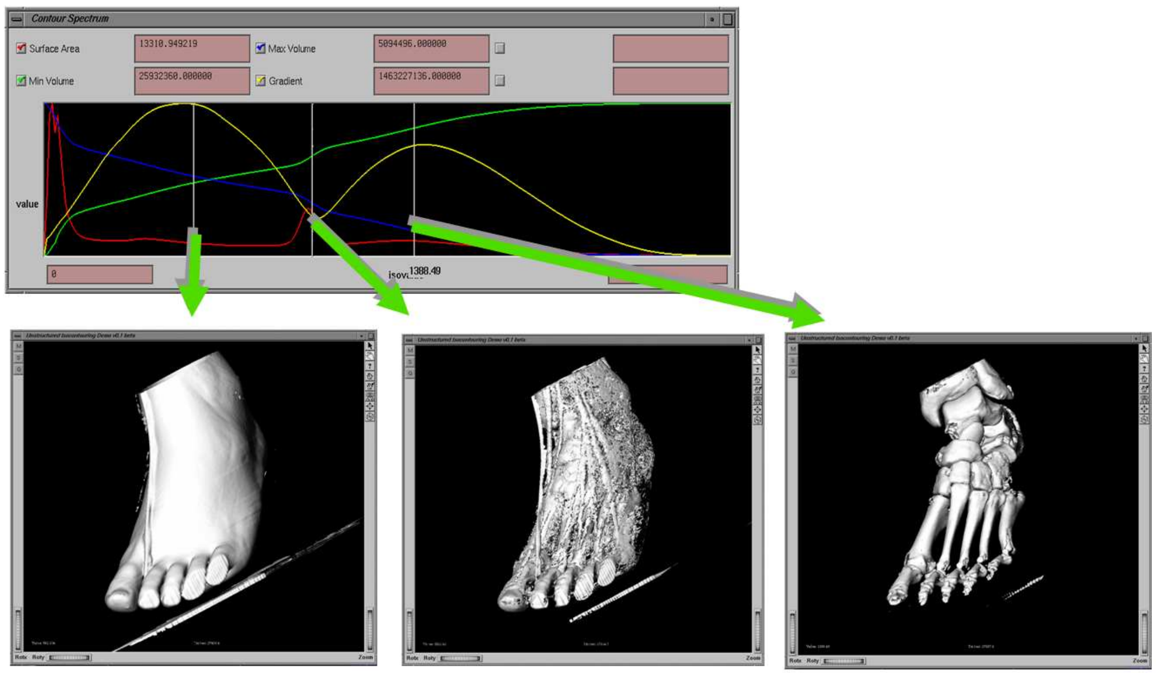
- Transfer functions make a volume dataset visible by assigning renderable properties such as opacities (and color)
- 1D transfer functions:
  - Intensity $\rightarrow$ RGBα
- 2D transfer functions:
  - Intensity, Gradient Magnitude $\rightarrow$ RGBα



For details, see: S. Park, C. Bajaj, "Feature Selection of 3D Volume Data through Multi-Dimensional Transfer Functions" Pattern Recognition Letters, 28, 3, pp. 367-374, 2007

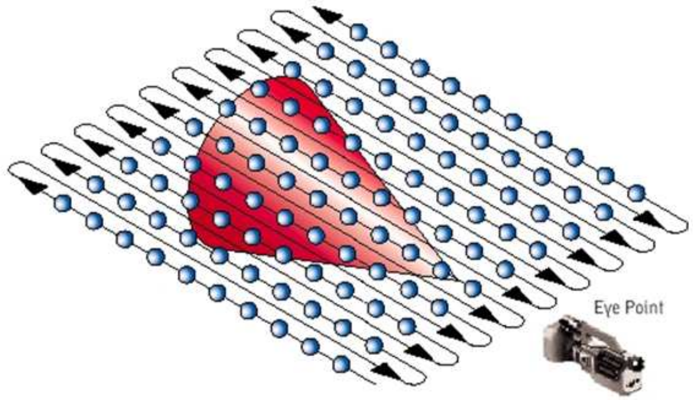
The Contour Spectrum

- The contour spectrum allows the selection of transfer functions

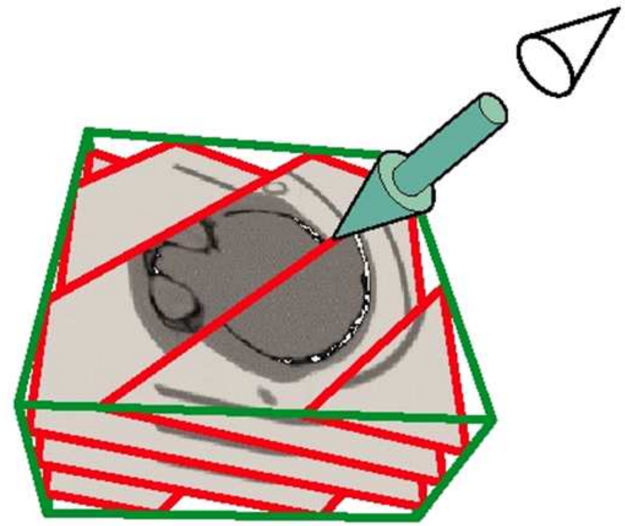


For details, see: C. Bajaj, V. Pascucci, D.Schikore "The Contour Spectrum" Proceedings of the 1997 IEEE Visualization Conference,167-173, October 1997 Phoeniz, Arizona

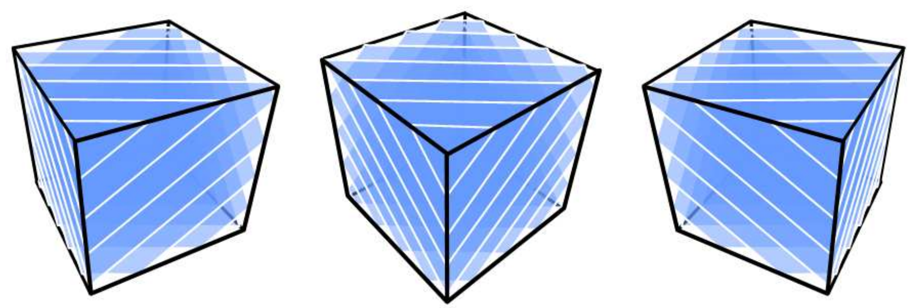
3D Texture based Volume Rendering



Ray Casting

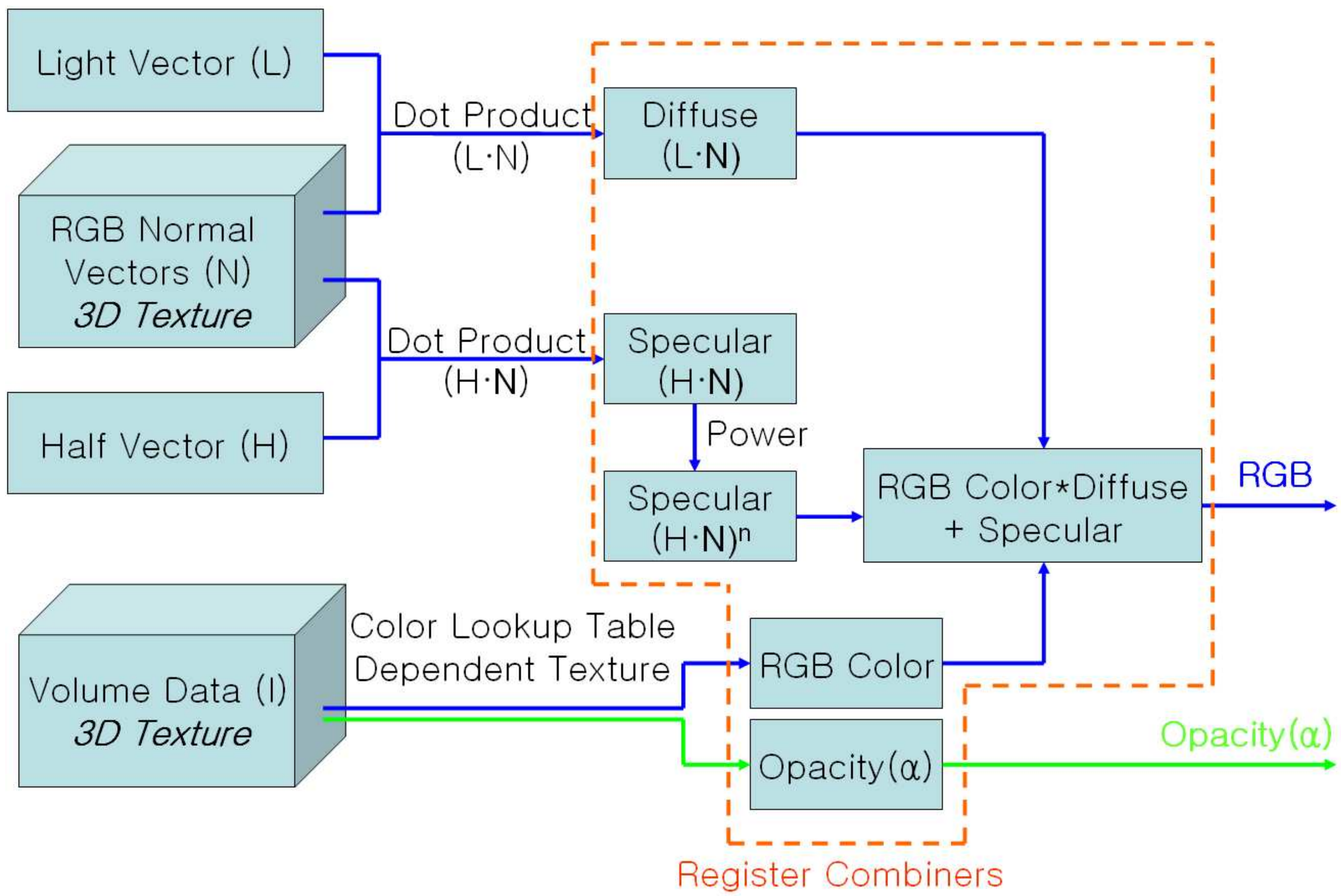


3D Texture Mapping

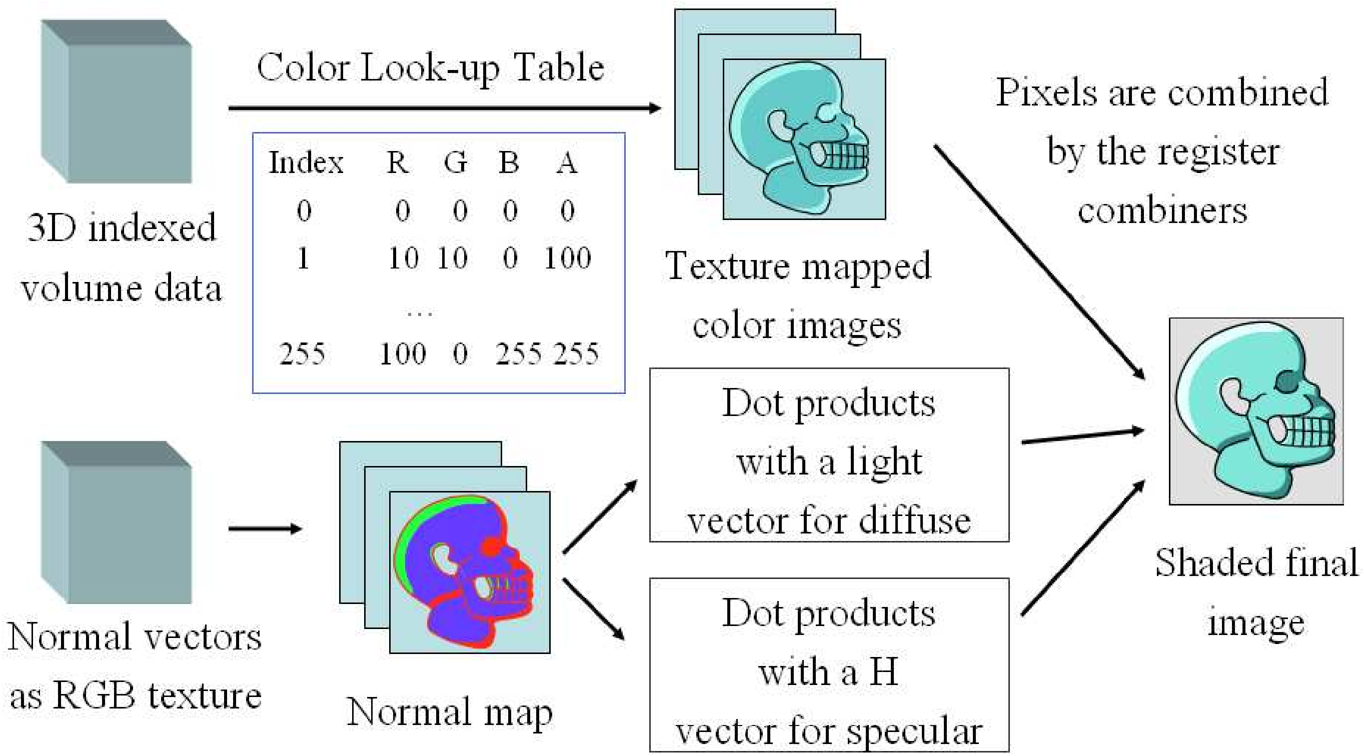


View point aligned slicing

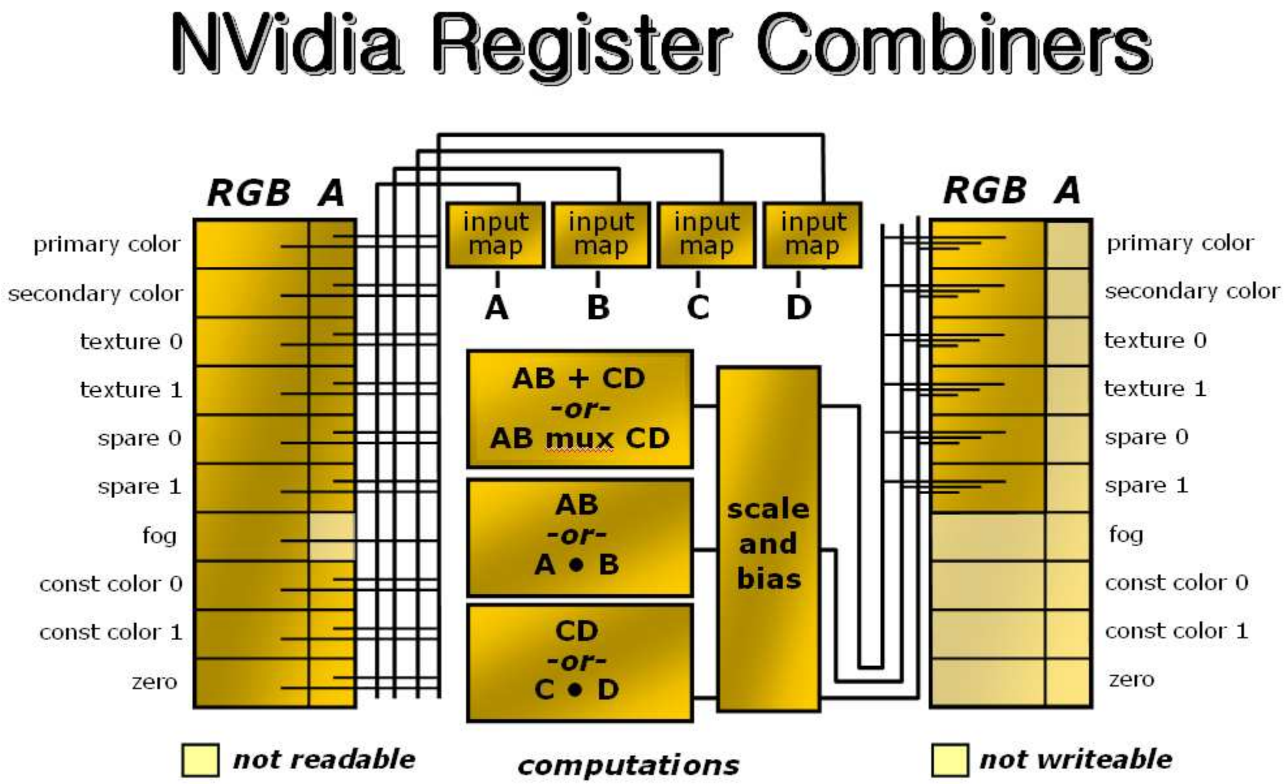
Shading in Graphics Hardware



Shading in Graphics Hardware (contd)



Register Combiners



Per-fragment operations (Programmable)

Cg Language

- C for graphics (or C for GPUs)
- High-level shading language for programming GPUs
- Developed by NVIDIA
- Works for both NVIDIA and ATI GPUs

Cg Vertex Program for Volume Rendering

```
void main( float4 Position : POSITION,
            float3 TexCoor : TEXCOORD0,
            uniform float4x4 ModelViewProj,
            out float4 oPosition :POSITION,
            out float3 oTexCoor :TEXCOORD0)
{
    oPosition = mul(ModelViewProj, Position);
    oTexCoor = TexCoor;
}
```

Cg Fragment Program for Volume Rendering

```
float3 Expand(float3 Vector) { return (Vector - 0.5)*2.0; }
void main ( float3 TexCoor   : TEXCOORD0,    // Texture Coordinates
     out float4 oColor : COLOR,        // Output RGBA
     uniform sampler3D RGB_NormalMap,  // Voxel Normal
     uniform sampler3D Data_I,         // Data Index
     uniform sampler1D TF,             // User Defined TF
     uniform float3 Lightv,            // Light Vector
     uniform float3 Halfv) {           // Half Vector
 float3 Normal = Expand(tex3D(RGB_NormalMap, TexCoor).rgb);
 float  Diffuse  = abs (dot (Normal, Lightv));   // Diffuse Color
 float  Specular = abs (dot (Normal, Halfv));    // Specular Color
 float  Power8 = pow(Specular, 8);               // 8th Power of Specular
 float3 Specularf3 = float3(Power8 , Power8 , Power8 );
 float  Intensity = tex3D(Data_I, TexCoor);      // (I) of Each Voxel
 float4 RGBA = tex1D(TF, Intensity);
 oColor.w = RGBA.w;
 oColor.xyz = (Diffuse*RGBA.xyz + Specularf3)*oColor.w;}
```

Cg Programs with OpenGL

Step 1: Cg profile selection

```
CGcontext contextCg_g;
CGprogram vertexProgramCg_g, fragmentProgramCg_g;
CGprofile vertexProfileCg_g, fragmentProfileCg_g;

contextCg_g = cgCreateContext();

// Vertex profile
if (cgGLIsProfileSupported(CG_PROFILE_VP30))
    vertexProfileCg_g = CG_PROFILE_VP30;
else {
    if (cgGLIsProfileSupported(CG_PROFILE_ARBVP1))
        vertexProfileCg_g = CG_PROFILE_ARBVP1;
    else exit(1);
}
```

```
// Fragment profile
if (cgGLIsProfileSupported(CG_PROFILE_FP30))
    fragmentProfileCg_g = CG_PROFILE_FP30;
else {
    if (cgGLIsProfileSupported(CG_PROFILE_ARBFP1))
        fragmentProfileCg_g = CG_PROFILE_ARBFP1;
    else exit(1);
}
```

Cg Programs with OpenGL

Step 2: Cg program loading and compile

```
vertexProgramCg_g = cgCreateProgramFromFile(
                            contextCg_g, CG_SOURCE, "vertex.cg",
                            vertexProfileCg_g, NULL, NULL);
if (!cgIsProgramCompiled(vertexProgramCg_g))
    cgCompileProgram(vertexProgramCg_g);
cgGLEnableProfile(vertexProfileCg_g);
cgGLLoadProgram(vertexProgramCg_g);

fragmentProgramCg_g = cgCreateProgramFromFile(
                            contextCg_g, CG_SOURCE, "fragment_FTB.cg",
                            fragmentProfileCg_g, NULL, NULL);
if (!cgIsProgramCompiled(fragmentProgramCg_g))
    cgCompileProgram(fragmentProgramCg_g);
cgGLEnableProfile(fragmentProfileCg_g);
cgGLLoadProgram(fragmentProgramCg_g);
```

Cg Programs with OpenGL

Step 3: Texture Loading

```
glTexImage3D(GL_TEXTURE_3D, 0, GL_COLOR_INDEX8_EXT, W, H, D, 0,
                GL_COLOR_INDEX, GL_UNSIGNED_BYTE, read_datauc);
cgGLSetTextureParameter(
                cgGetNamedParameter(fragmentProgramCg_g, "Data_I"),
                color_index_3DT.getTextureID());

glTexImage3D(GL_TEXTURE_3D, 0, GL_RGBA, W, H, D, 0,
                GL_RGBA, GL_UNSIGNED_BYTE, RGBNormals);
cgGLSetTextureParameter(
                cgGetNamedParameter(fragmentProgramCg_g, "RGB_NormalMap"),
                RGB_normals_3DT.getTextureID());
```

```
glTexImage1D(GL_TEXTURE_2D, 0, GL_RGBA, 256,
                0, GL_RGBA, GL_UNSIGNED_BYTE, TF_guc);
cgGLSetTextureParameter(
                cgGetNamedParameter(fragmentProgramCg_g, "TF"),
                TF_1DT.getTextureID());
```

Cg Programs with OpenGL

Step 4: Parameter set-up

```
CGparameter param;

cgGLSetStateMatrixParameter(
    cgGetNamedParameter(vertexProgramCg_g, "ModelViewProj"),
        CG_GL_MODELVIEW_PROJECTION_MATRIX, CG_GL_MATRIX_IDENTITY);

// Vertex Program
// Set Parameter Pointers for the Vertex Program
param = cgGetNamedParameter(vertexProgramCg_g, "Position");
cgGLSetParameterPointer(param, 3, GL_FLOAT, 0, Vetices_f);
param = cgGetNamedParameter(vertexProgramCg_g, "TexCoor");
cgGLSetParameterPointer(param, 3, GL_FLOAT, 0, TexCoor_f);
// Enable the variables
cgGLEnableClientState(cgGetNamedParameter(vertexProgramCg_g, "Position"));
cgGLEnableClientState(cgGetNamedParameter(vertexProgramCg_g, "TexCoor"));
```

```
// Fragment Program
// Set Parameter Pointers for the Fragment Program
param = cgGetNamedParameter(fragmentProgramCg_g, "Lightv");
cgGLSetParameter3fv(param, &lightV3f[0]);
param = cgGetNamedParameter(fragmentProgramCg_g, "Halfv");
cgGLSetParameter3fv(param, &h_viewV3f[0]);

// Enable the variables
cgGLEnableTextureParameter(
    cgGetNamedParameter(fragmentProgramCg_g, "RGB_NormalMap"));
cgGLEnableTextureParameter(
    cgGetNamedParameter(fragmentProgramCg_g, "ColorIndexMap"));
cgGLEnableTextureParameter(
    cgGetNamedParameter(fragmentProgramCg_g, "TF"));
```

Cg Programs with OpenGL

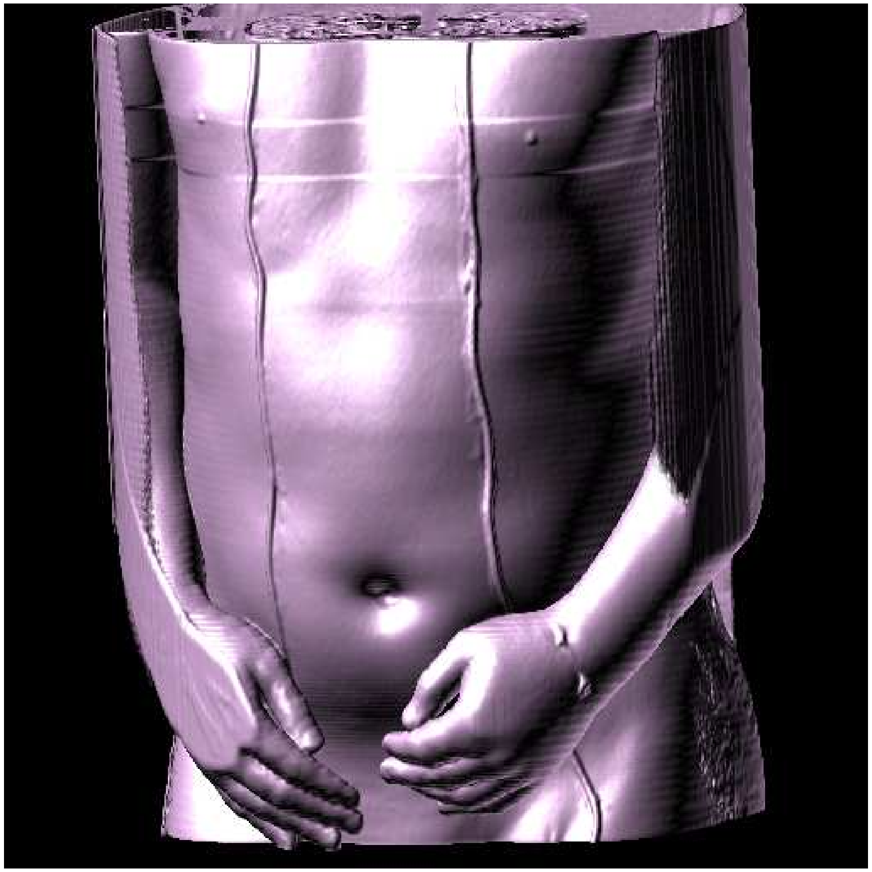
Step 5: Drawing Geometric Elements

```
// Drawing Triangles
glDrawElements(GL_TRIANGLES, 3*NumTriangles, GL_UNSIGNED_INT, Indices_i);

// Disable the variables
cgGLDisableClientState(cgGetNamedParameter(vertexProgramCg_g, "Position"));
cgGLDisableClientState(cgGetNamedParameter(vertexProgramCg_g, "TexCoor"));

// Disable the texture
cgGLDisableTextureParameter(
    cgGetNamedParameter(fragmentProgramCg_g, "RGB_NormalMap"));
cgGLDisableTextureParameter(
    cgGetNamedParameter(fragmentProgramCg_g, "ColorIndexMap"));
cgGLDisableTextureParameter(
    cgGetNamedParameter(fragmentProgramCg_g, "TF"));
```

More 3D Texture-Based Volume Rendering Results



Reading Assignment and News

Please review the appropriate sections related to this lecture in chapter 7, and associated exercises, of the recommended text.

(Recommended Text: Interactive Computer Graphics, by Edward Angel, Dave Shreiner, 6th edition, Addison-Wesley)

Please track Blackboard for the most recent Announcements and Project postings related to this course.

(http://www.cs.utexas.edu/users/bajaj/graphics2012/cs354/)