

ECE/CS 433 Introduction to Computer Graphics

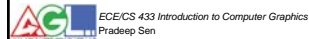
Class 18
October 23, 2007

Pradeep Sen
Advanced Graphics Lab



Announcements

- Homework 3 is due Sunday



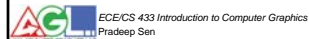
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Halo3 Party

- November 9 (tentatively 9pm – midnight)
- ARTS Lab
- Prizes, fun!



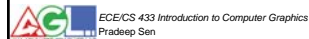
Brought to you by



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Last time

- Started talking about texture mapping



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Today

- Texture mapping revisited
- OpenGL vs DirectX



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Texture filtering

- Screen space samples are closer together than texture samples (magnification)
 - OpenGL provides two reconstruction filters: GL_NEAREST, GL_LINEAR
- Screen space samples are farther apart than texture samples (minification)
 - Summed area tables
 - Mipmapping



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Summed area tables

Mipmapping

- MIP- *multum in parvo* (many things in a small place)
- Technique in which to perform pre-computed filtering for minification

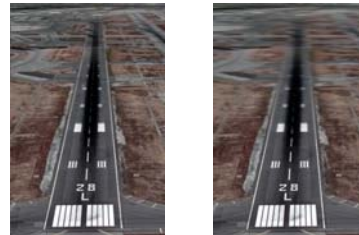


Mipmapping

- Accessing the mipmap

Problems with mipmapping

- Decimated textures all have a square footprint (isotropic)



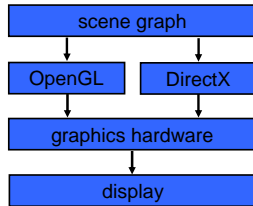
Anisotropic filtering

- Approximate the pixel “footprint” with an ellipse
- Compute contribution in ellipse through multi-sampling

Real-time APIs

- Rendering engine communicates to the hardware via a real-time API
- There are currently two popular real-time APIs:
 - OpenGL
 - DirectX

Real-time APIs



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OpenGL

- Design led by Kurt Akeley, one of the founders of Silicon Graphics
- Expose the graphics hardware as a state machine
- Specification controlled by the “ARB”: Architecture Review Board

<http://www.opengl.org>



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OpenGL state machine



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Issuing geometry

- There are two ways to pass geometry down to the hardware in OpenGL:
 - Immediate mode
 - Display lists



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Immediate mode

- Vertices are passed down as soon as they are specified

```
for each vertex i in geometry{
  // specify the vertex normal
  glNormal3f (n[i][0],n[i][1],n[i][2]);
  // specify the vertex color
  glColor4f (c[i][0],c[i][1],c[i][2],c[i][3]);
  // specify the texture coordinates
  glTexCoord2f (tex[i][0], tex[i][1]);
  // specify the vertex position
  glVertex3f (v[i][0], v[i][1], v[i][2]);
}
```



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Immediate mode

- Note that there are various commands to allow different format types:

```
void glVertex{234}{sifd}[v](TYPE coords);
```

- Examples:

```
glVertex2d(3,4);
glVertex2f(3.1,4.2);

float v[3] = {1.0, 2.9, 3.5};
glVertex3f(v);
```



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Immediate mode

- The `glBegin()` statement indicates what kind of primitive is being drawn

```
glBegin(GL_TRIANGLES);
glVertex2d(0,0);
glVertex2d(2,3);
glVertex2d(-1,5);
glEnd();
```

- Some others include `GL_POINTS`, `GL_LINES`, `GL_QUADS`, `GL_TRIANGLE_STRIP`, etc.



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Vertex arrays

- Instead of performing individual calls per vertex, pack them into an array and call it once
- First we must enable the “vertex arrays”

```
void glEnableClientState(GLenum array);
```
- Where array can be:
 - `GL_VERTEX_ARRAY`
 - `GL_COLOR_ARRAY`
 - `GL_TEXTURE_COORD_ARRAY`
 - etc



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Vertex arrays

- Provide a pointer to the array that contains the appropriate information

```
void glVertexPointer(int size, GLenum type,
                    GLsizei stride,
                    const GLvoid *ptr);
```

- Similar calls exist for color, texture coordinates, etc.



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Vertex arrays

- To draw, use

```
void glArrayElement(int i);
```
- To send down the i^{th} element, or

```
void glDrawArrays(GLenum mode, int first,
                  GLsizei count);
```
- To draw a group of elements

```
int i;
glBegin(mode);
for (i=0; i < count; i++)
    glArrayElement(first+i);
glEnd();
```



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Display lists

- Provides a cache of OpenGL commands

```
glNewList(1, GL_COMPILE);
drawScene();
glEndList();
```

```
glLoadMatrix(M);
glCallList(1);
```

- Cannot be modified!



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OpenGL Extensions

- OpenGL was meant to be dynamic and to evolve as hardware capabilities changed
- Designers developed an extension-based architecture, where the driver reports to OpenGL what extensions it exposes
- Complete list of extensions can be seen in the extension registry:

<http://www.opengl.org/registry/>



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DirectX

- Really a collection of APIs for different tasks, in the form of COM-compliant objects:
 - DirectInput (to handle IO from input devices such as joysticks, keyboard, etc)
 - DirectPlay (to handle networking between PCs)
 - DirectSound (for playing/recording of sound fx)
 - DirectMusic (for playing audio soundtracks)
 - DirectXMedia (for animation and multimedia streaming apps)
 - DirectDraw (for 2-D drawing to the screen)
 - Direct3D (for 3-D rendering)



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History of DirectX

- In 1992, a company was founded called RenderMorphics
- They created a 3D API called RealityLab
- In 1995, Microsoft bought RenderMorphics and soon produced the 3D API called DirectX 2.0 for Windows95.
- DirectX 2.0 released June 1996
- DirectX 3.0 released September 1996
- People began to use it...



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History of DirectX

- DirectX 4 was never released (back to the drawing board)
- DirectX 5 was released July 1997
- Latest version is DirectX 10, released Nov 2006 only on Windows Vista



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Differences between DirectX and OpenGL

- At a high-level, OpenGL is much easier to get something to draw to the screen.
- DirectX is intended for high-performance applications, so drawing a single triangle is complicated.



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Differences between DirectX and OpenGL

- DirectX is natively left-handed (OpenGL is right-handed)
- Projection matrix maps z-depths to 0 to 1 range (-1 to 1 in OpenGL)
- Row major matrix representation (column major in OpenGL)
- etc.



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Reading

- Angel thru Ch 8



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