CS193P - Lecture 19

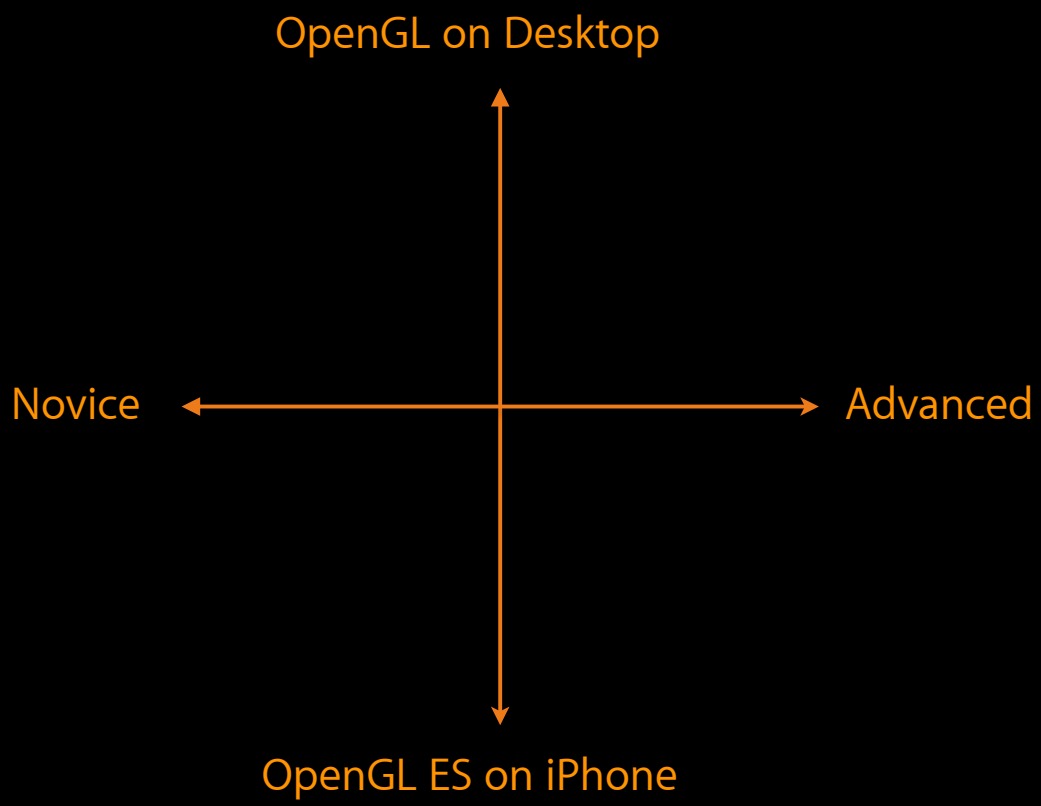
iPhone Application Development

OpenGL ES

Announcements

- **Final projects** due in 7 days
  - Tuesday, March 16th 11:59 pm
  - Submit:
    - Code
    - Power-point/Keynote slides
    - ReadMe file
- Final project **demos**
  - March 18, from 12:15 - 3:15 pm in Hewlett 201
  - 2 minute presentation, followed by demo-fair
    - Rapid-fire!!
    - Time limit strictly enforced
  - Let us know if you do not want to be recorded

Today's Topics



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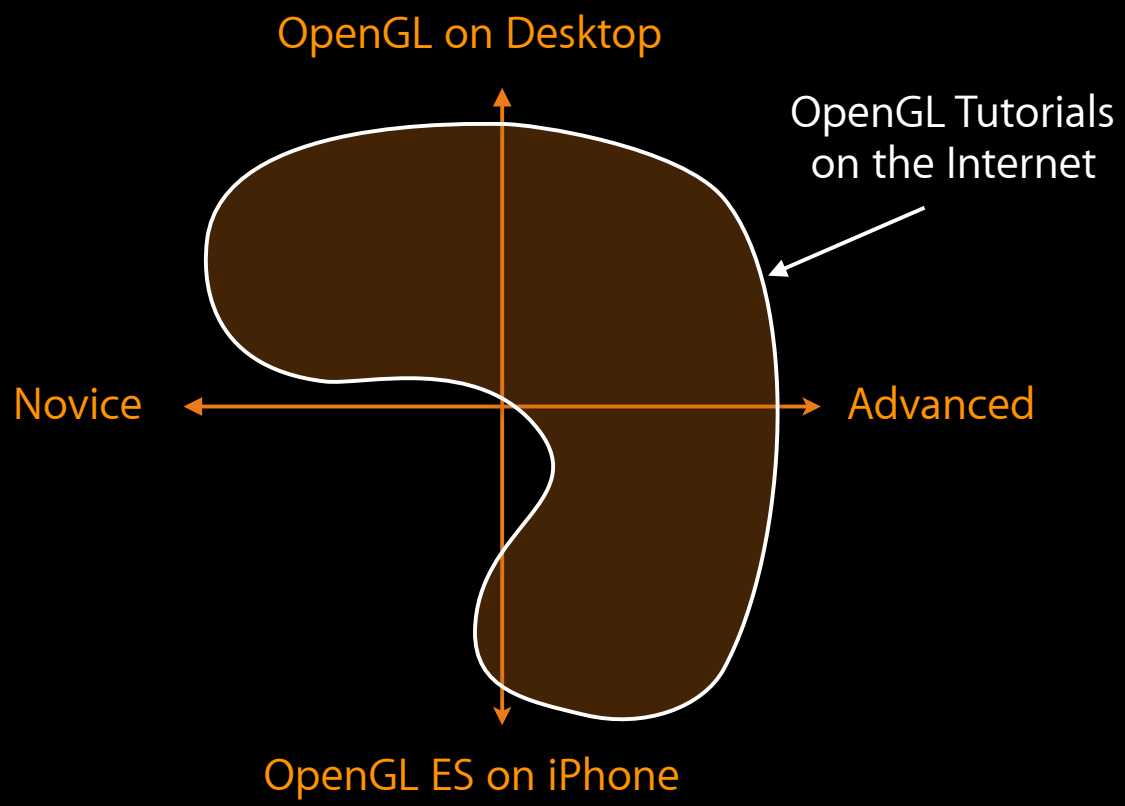

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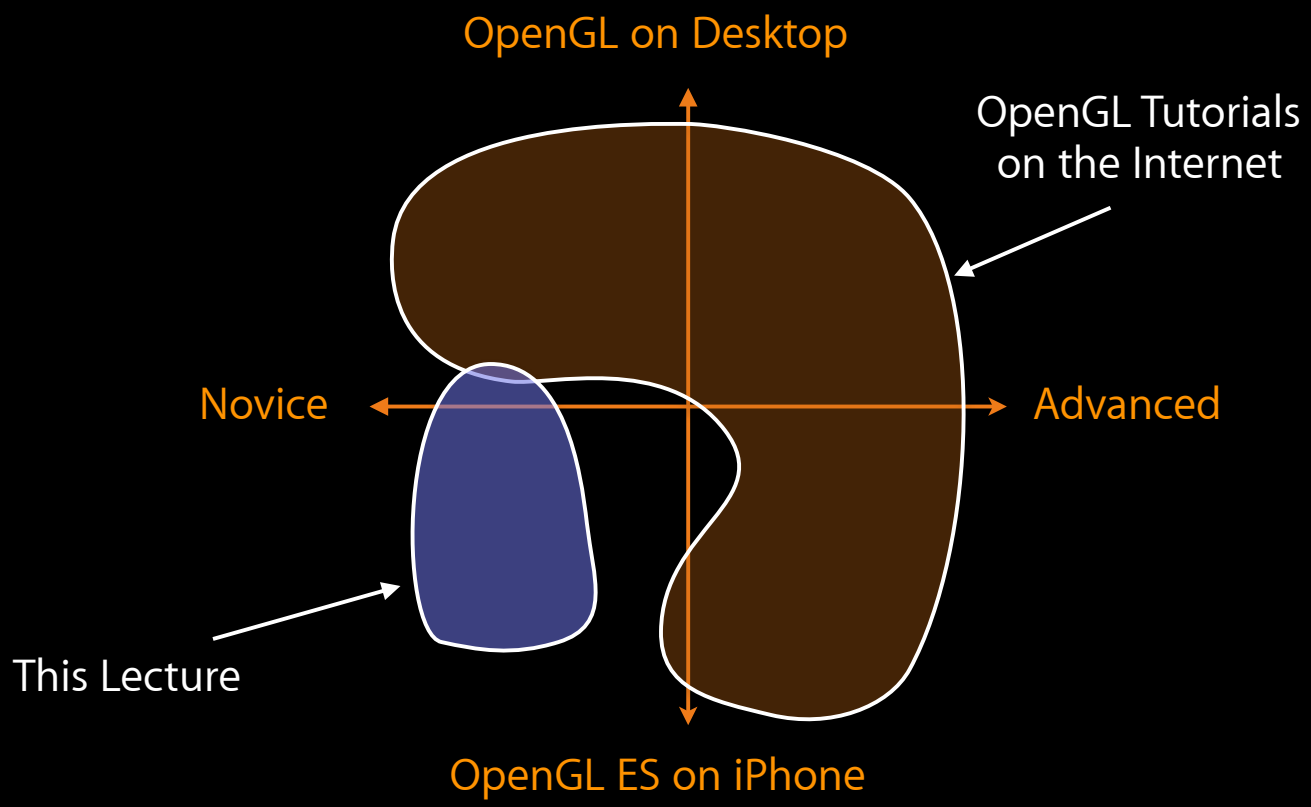

Today's Topics

- OpenGL Overview
- Coordinate Systems and Transformations
- Drawing Geometry
- Using Textures
- Other Details

OpenGL Overview

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- Software interface for graphics hardware

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- Quickly render 2D or 3D graphics

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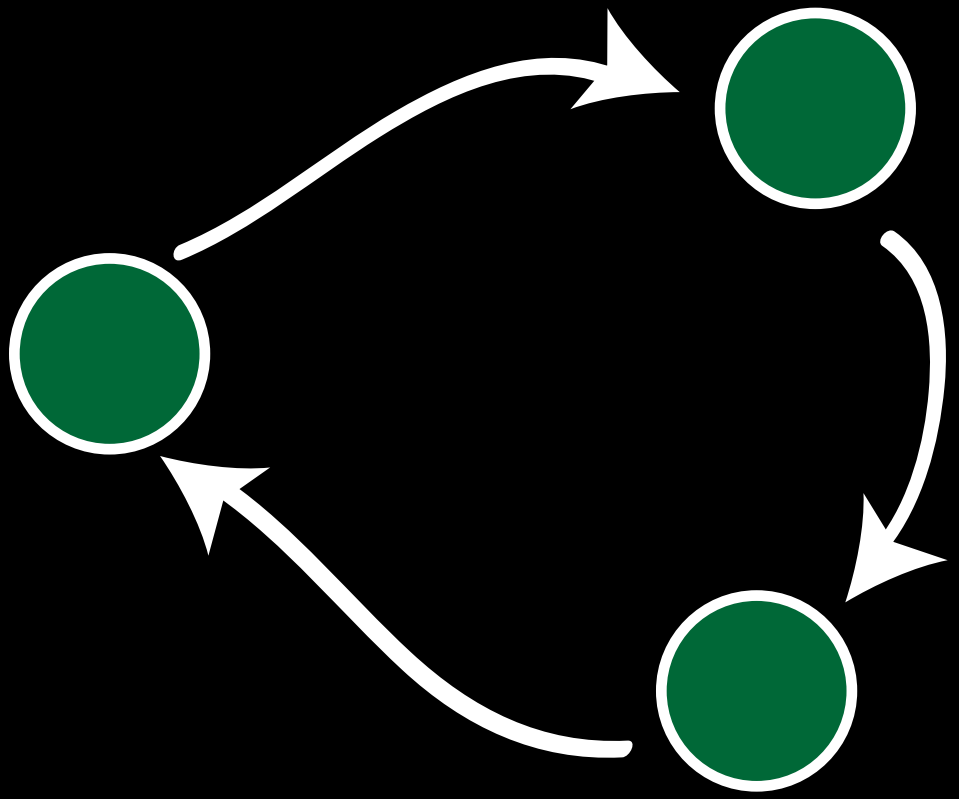
- OpenGL ES is a subset of OpenGL
  - GLUT and GLU are not available on the iPhone

OpenGL is a state machine



OpenGL is a state machine

- Change Machine State

```
glEnable(); glDisable(); glMatrixMode(); glBindFramebufferOES();
glViewport(); glVertexPointer(); glColorPointer(); glTranslatef() ...
```

- Issue Drawing Commands

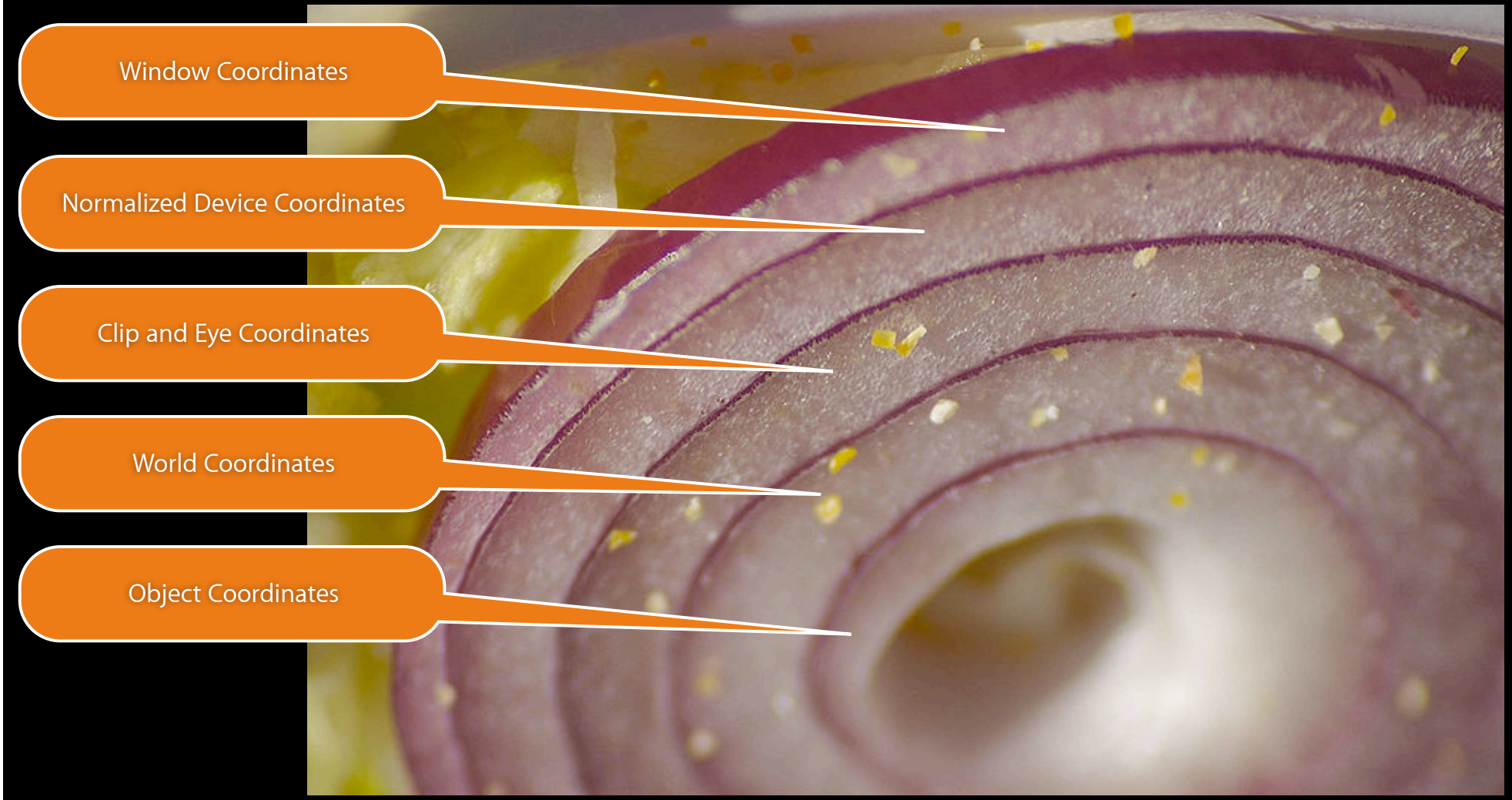
```
glDrawArrays(); glDrawElements(); ...
```

- Read Back State, Drawing Results

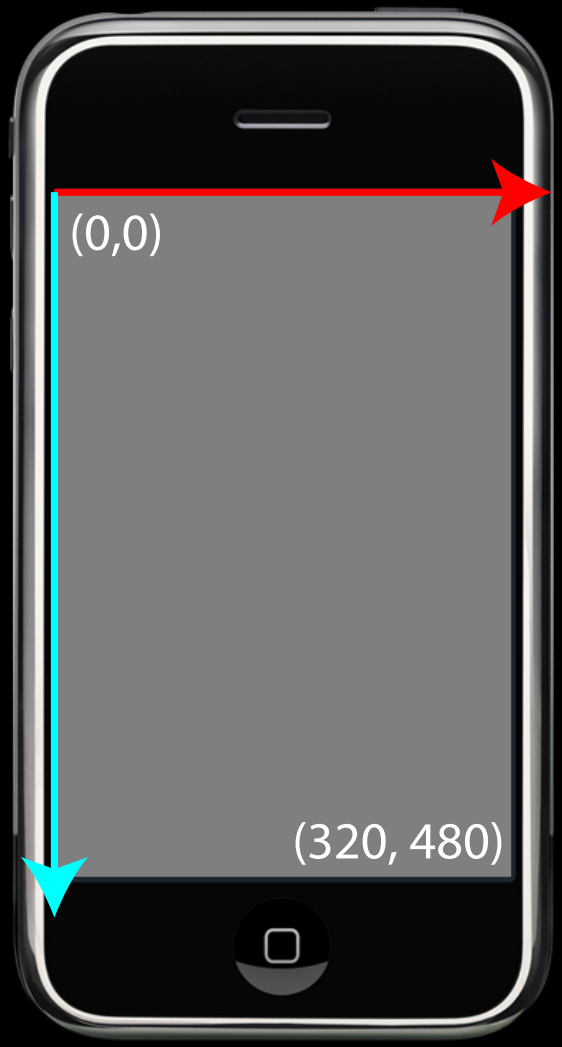
```
glGetBooleanv(); glGetFloatv(); glReadPixels(); ...
```

Coordinate Systems

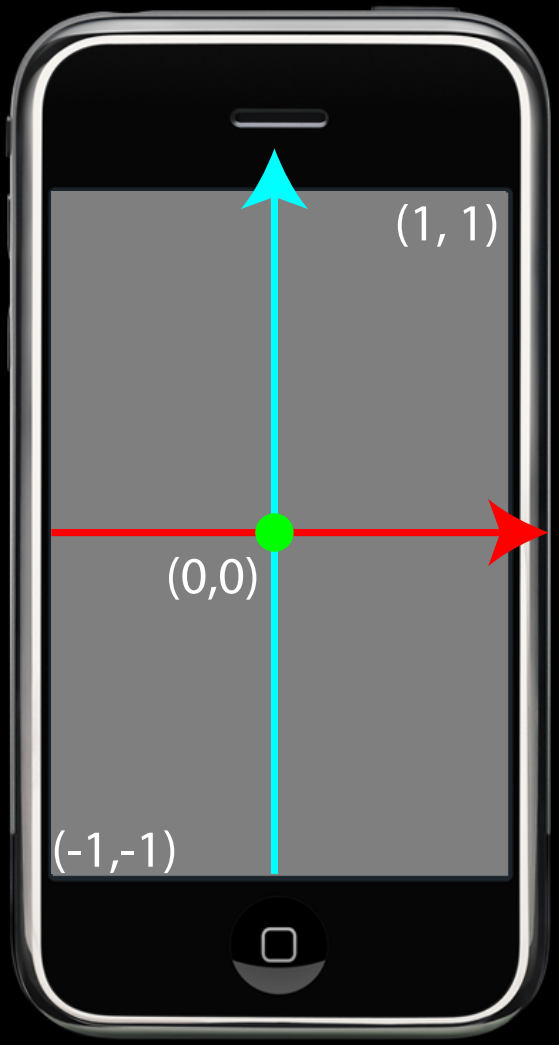
The Coordinate System Onion



Window Coordinates



Normalized Device Coordinates



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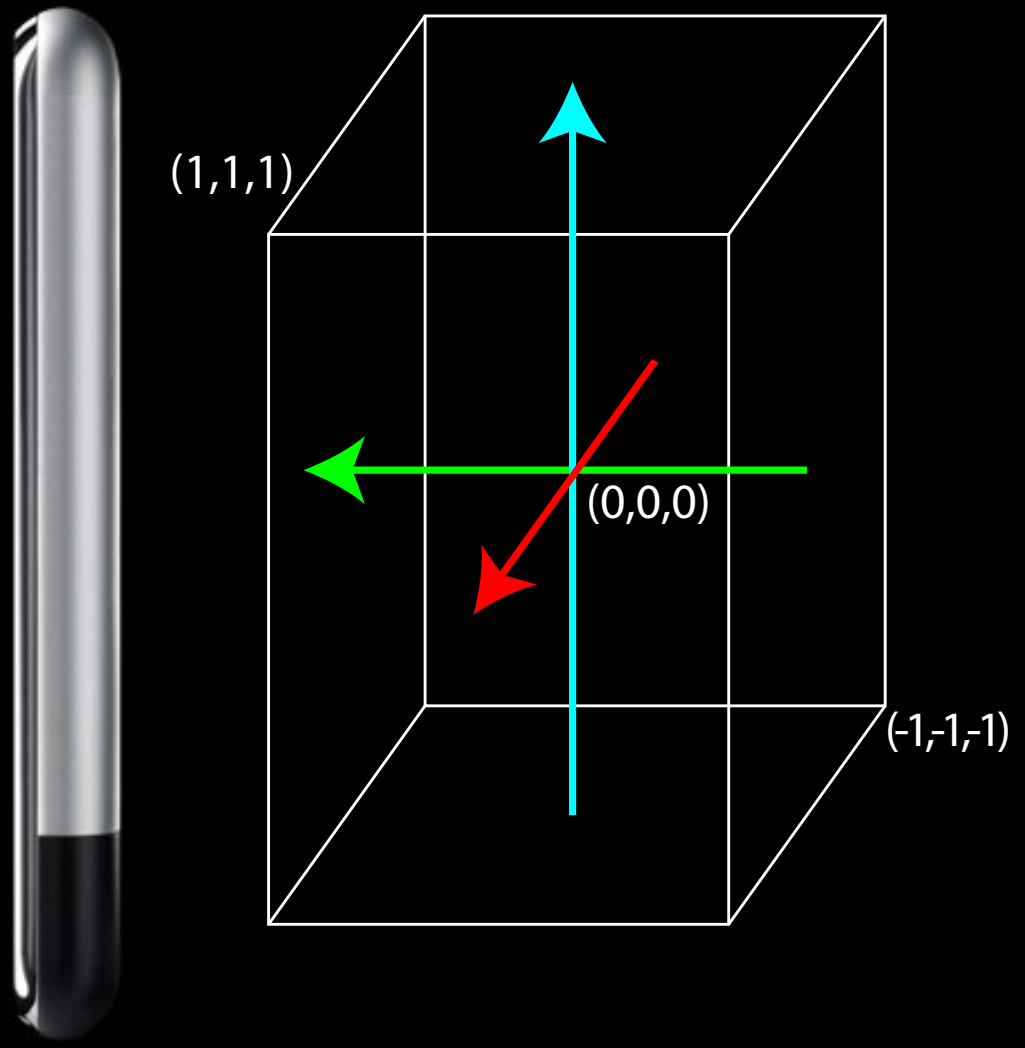
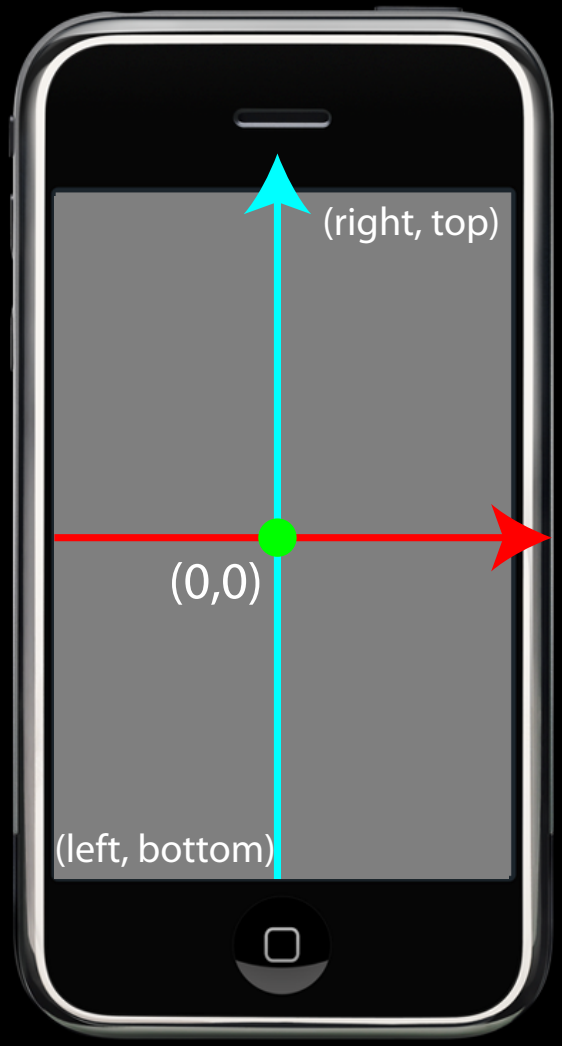


Clip Coordinates

ILLUSTRATION
NOT FOUND

Eye Coordinates



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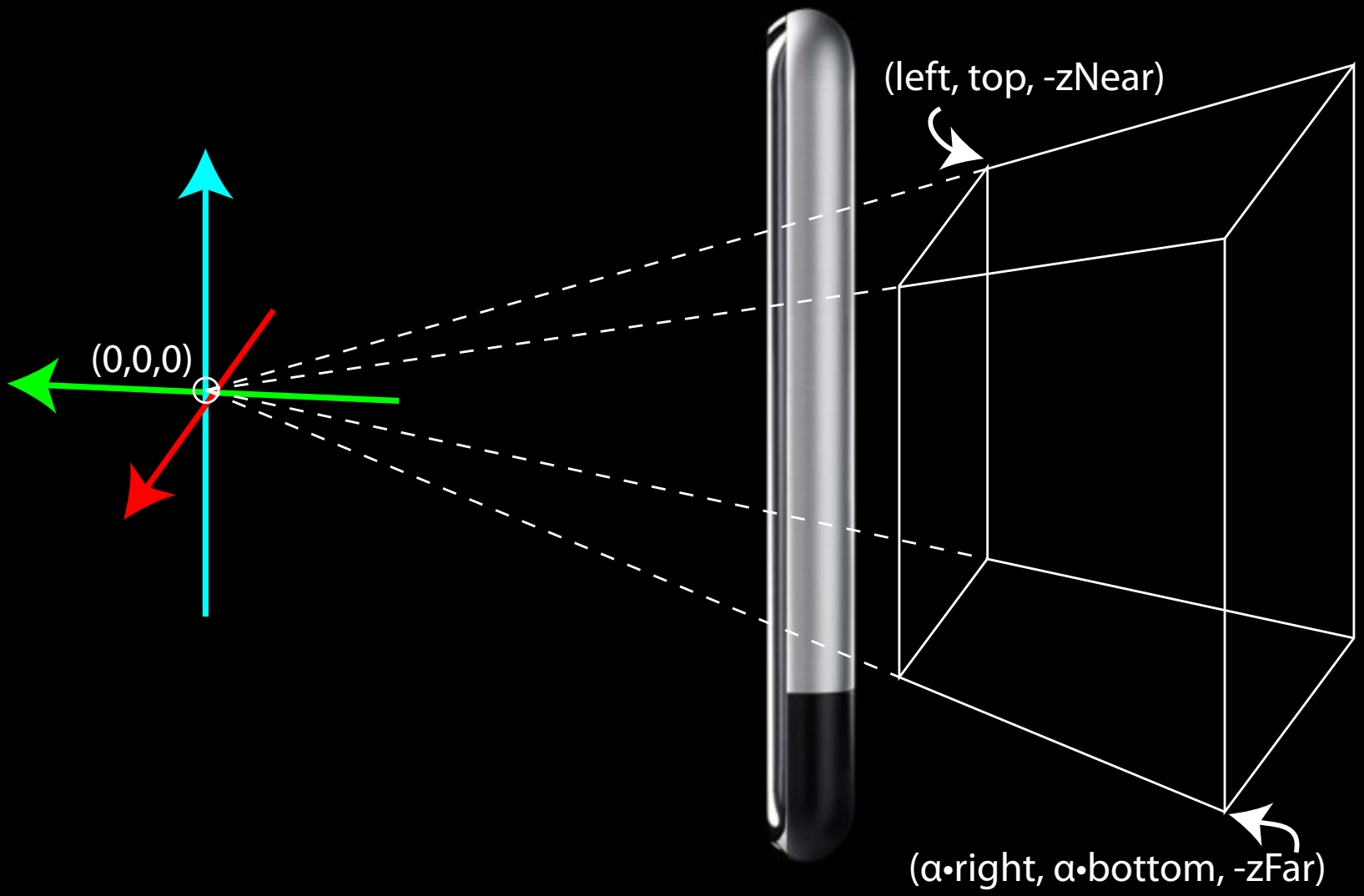
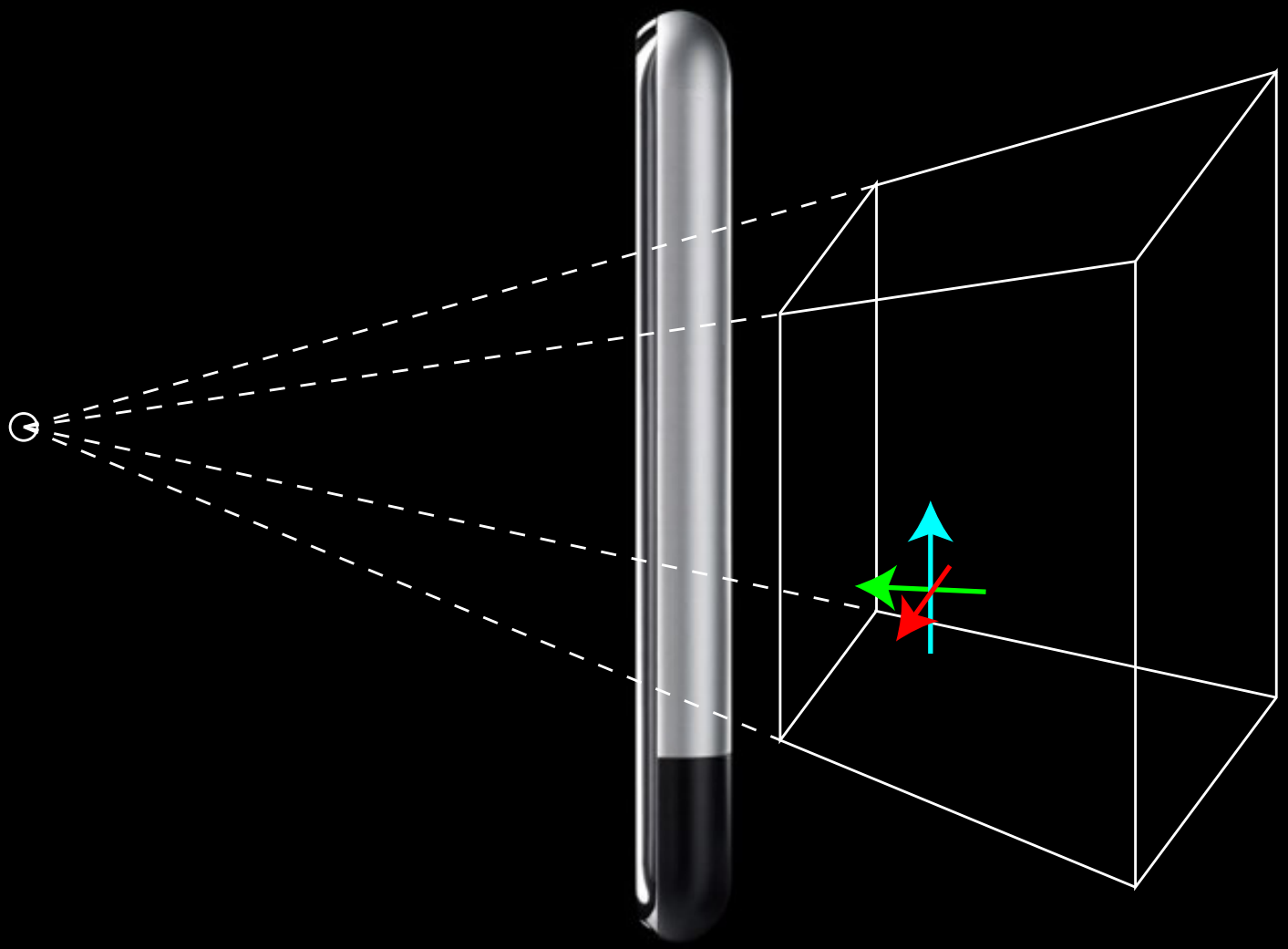


World Coordinates



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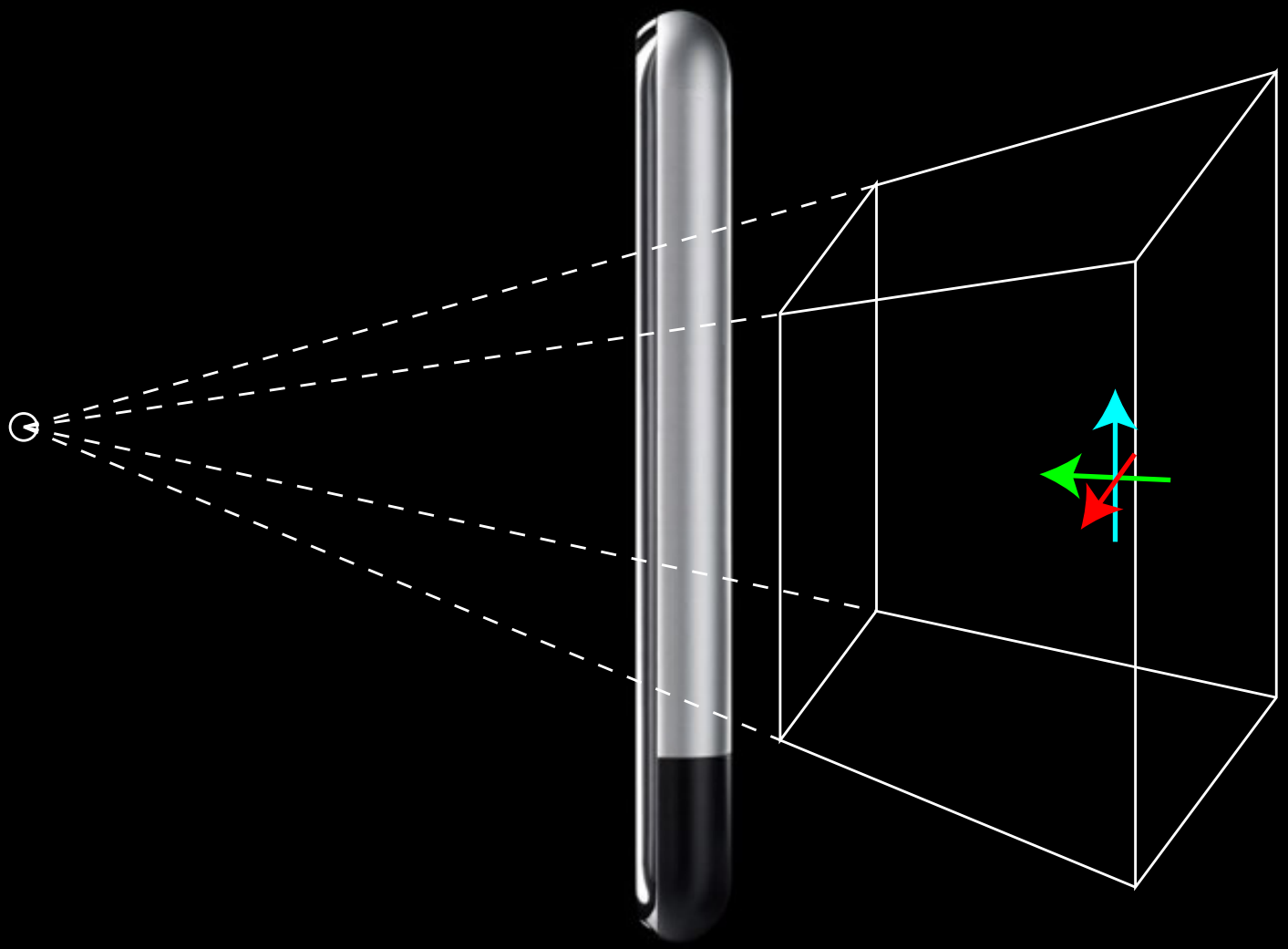
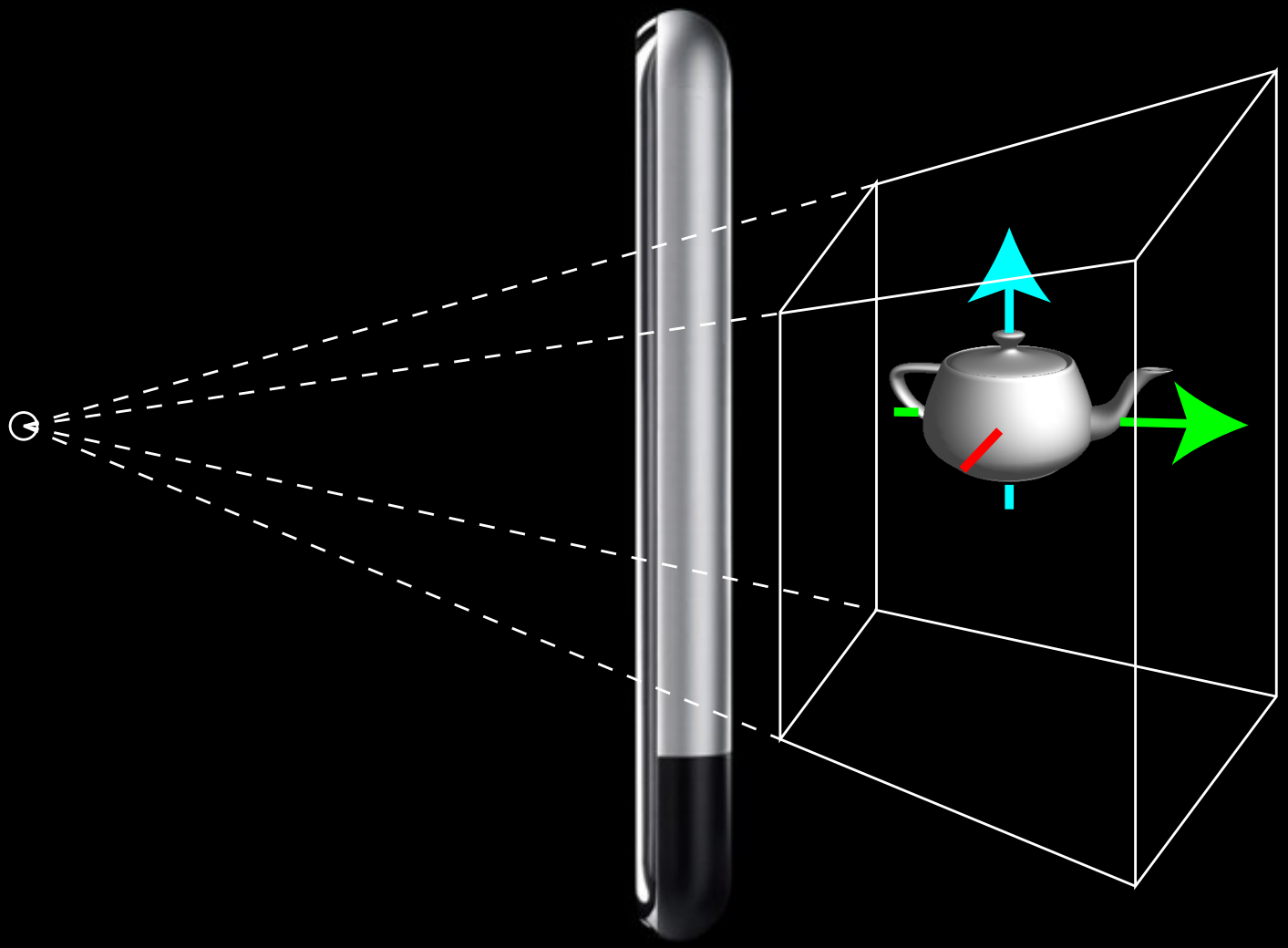


Object Coordinates



Demo

Transformations

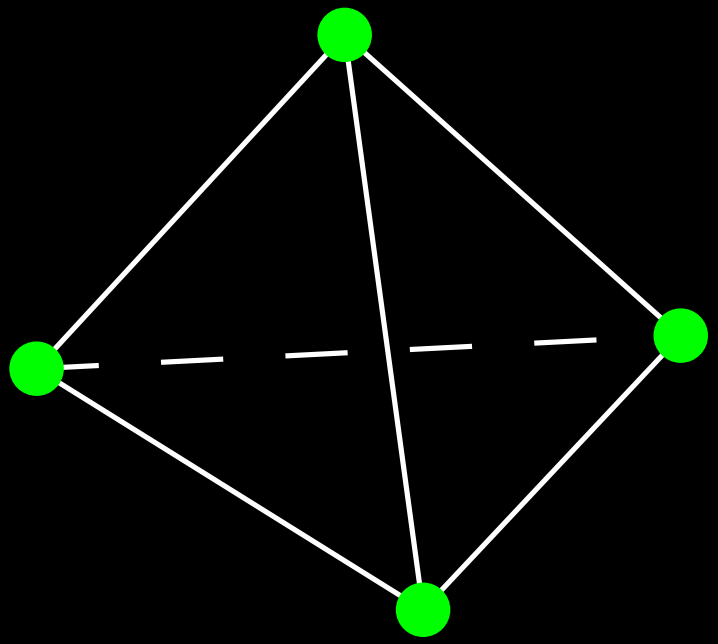
Transformations Cheat Sheet

```
glMatrixMode(GL_PROJECTION);
glMatrixMode(GL_MODELVIEW);

glLoadIdentity();

glOrthof(left, right, bottom, top, zNear, zFar);
glFrustumf(left, right, bottom, top, zNear, zFar);

glRotatef(degrees, x, y, z);
glTranslatef(x, y, z);
glScalef(x, y, z);
glMultMatrixf(matrix);

glPushMatrix();
glPopMatrix();
```

Drawing Geometry

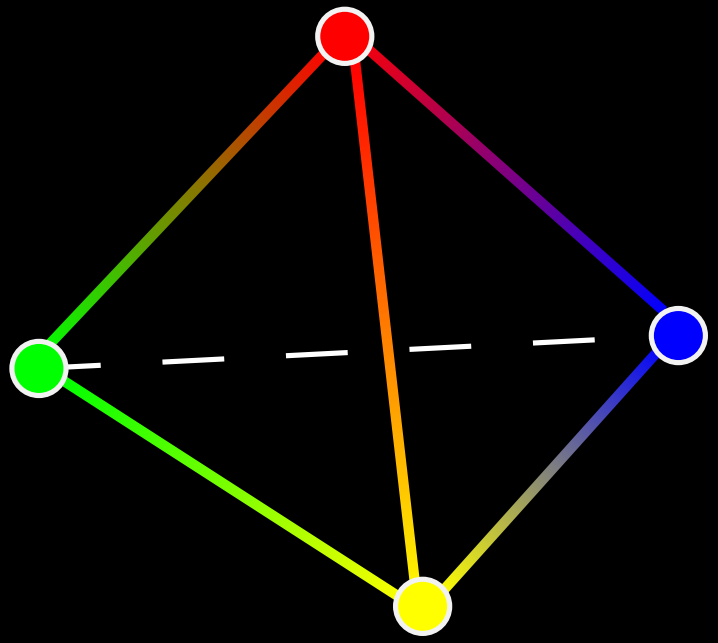
Vertices

- OpenGL ES draws triangles, lines, and points
- Object space vertices mapped into window space
- Rasterize the shapes to get pixels



Colors

- Each vertex can have a color associated
- RGBA
  - Alpha usually means opacity
- Lines and triangles interpolate colors



Drawing Modes

- Vertices are passed to OpenGL ES in arrays
- Drawing modes determine how vertices are interpreted to produce shapes
- Vertex order matters

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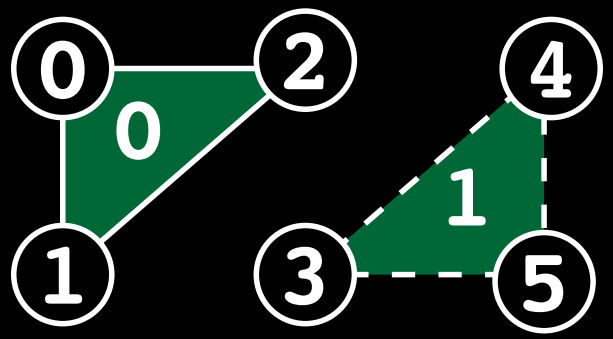
`GL_TRIANGLES`



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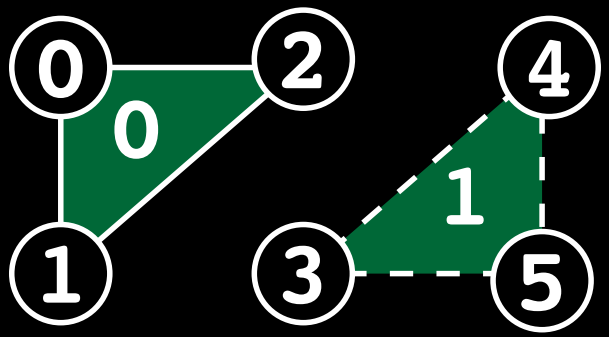
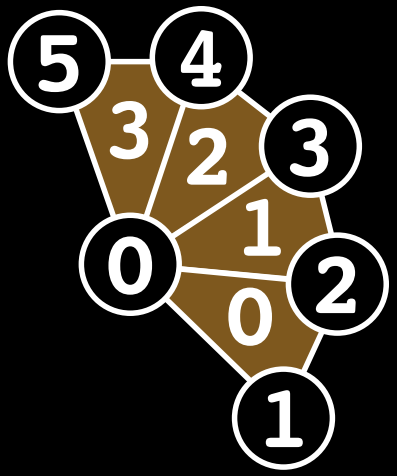


GL_TRIANGLE_FAN



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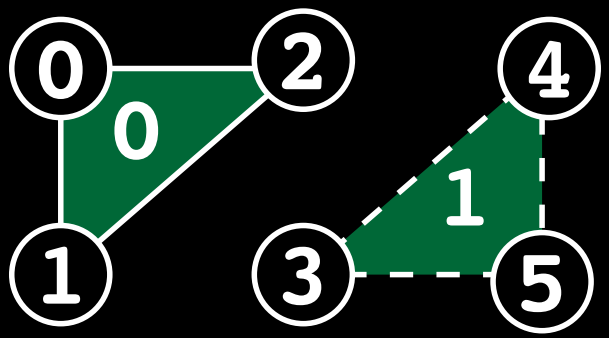

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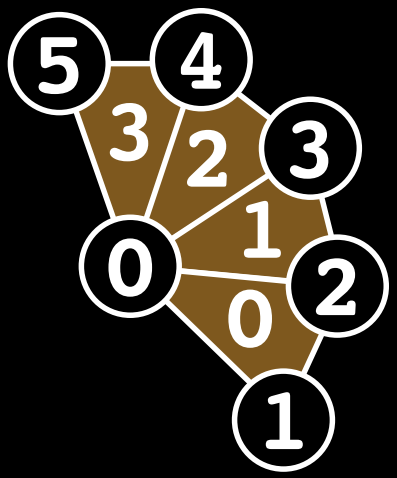
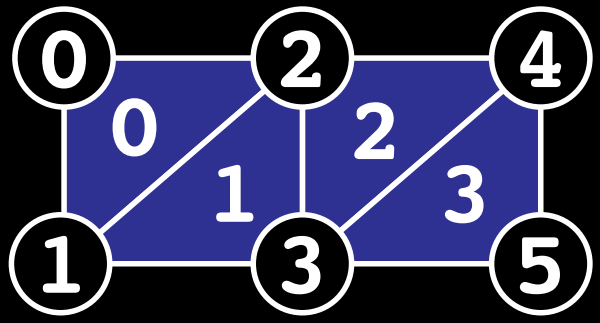
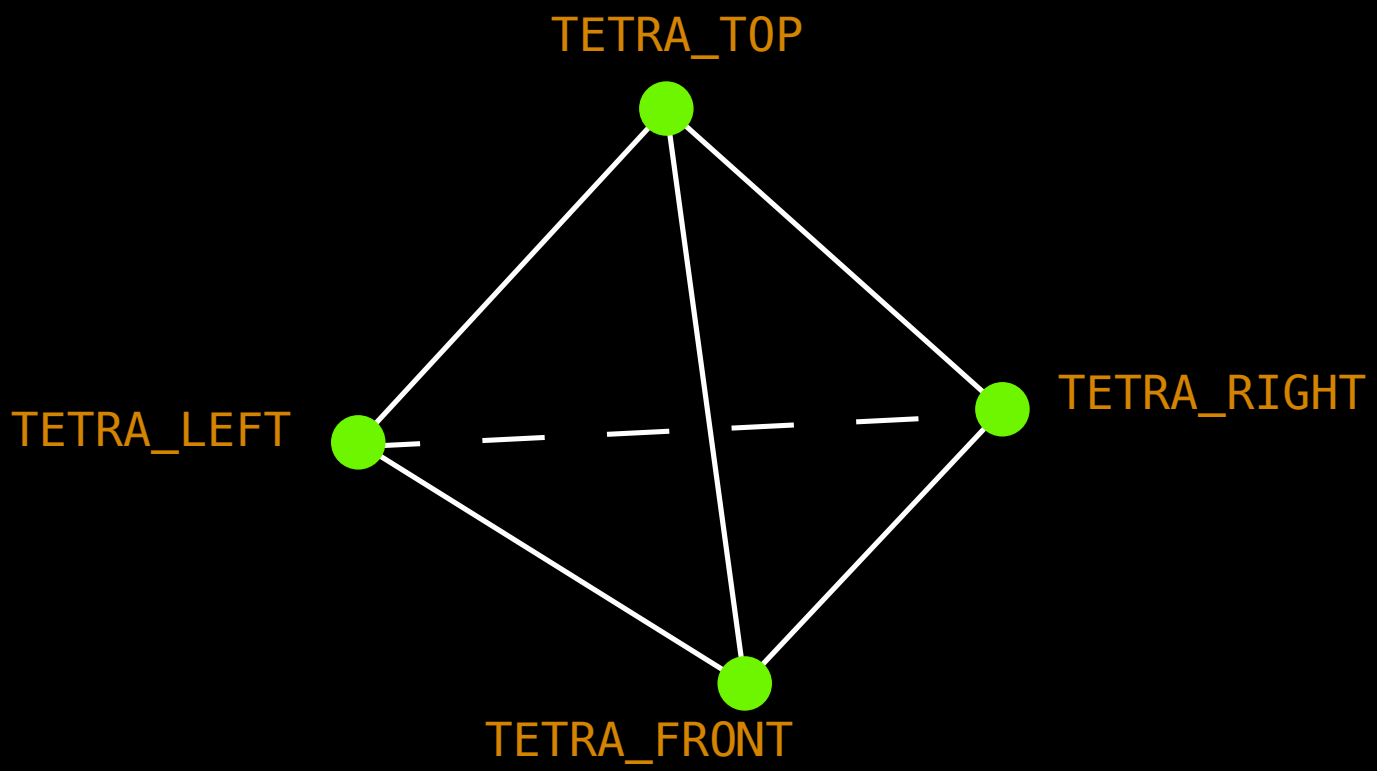


GL_TRIANGLE_STRIP



Drawing a Tetrahedron

- Use a triangle strip



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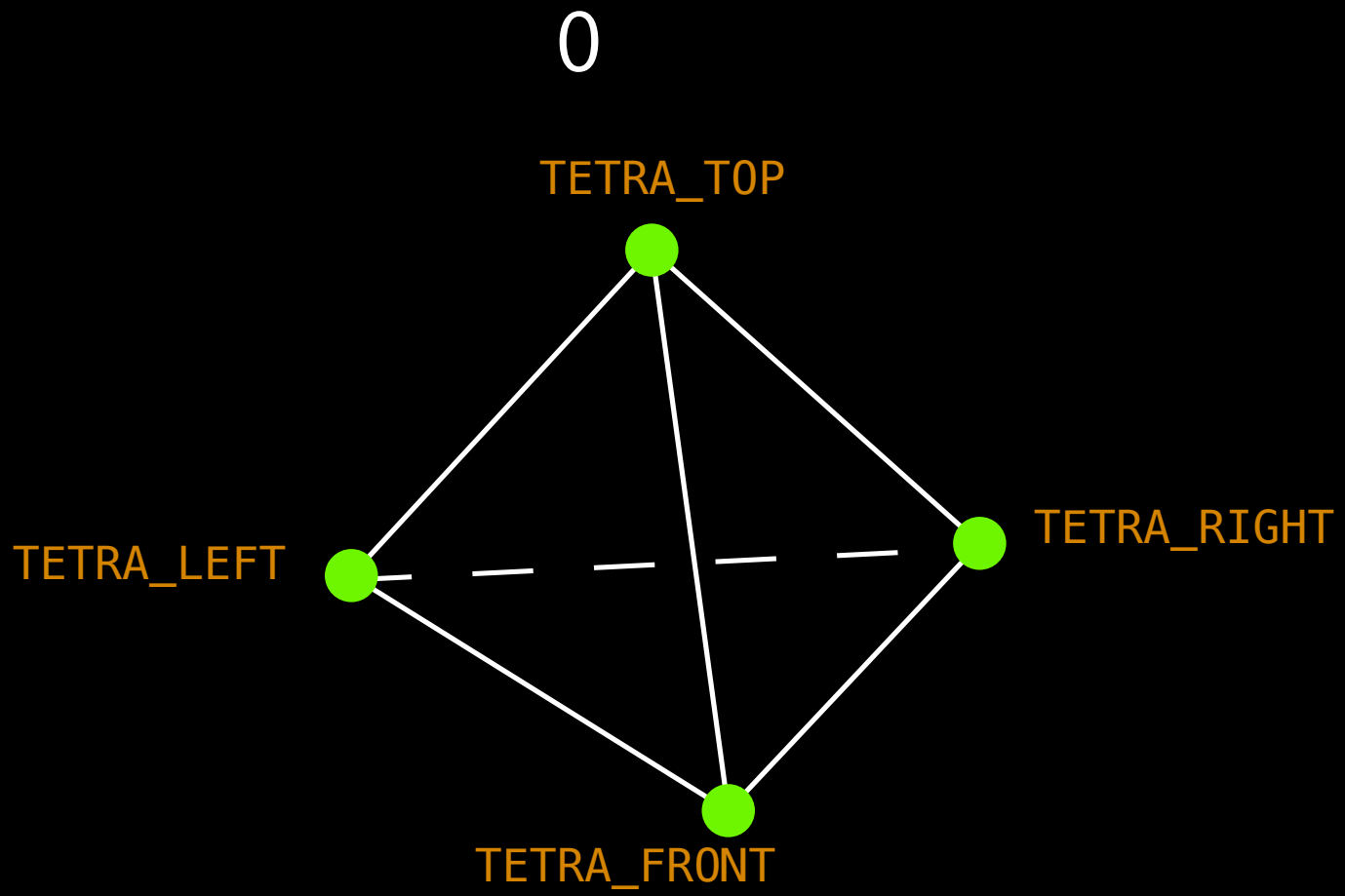

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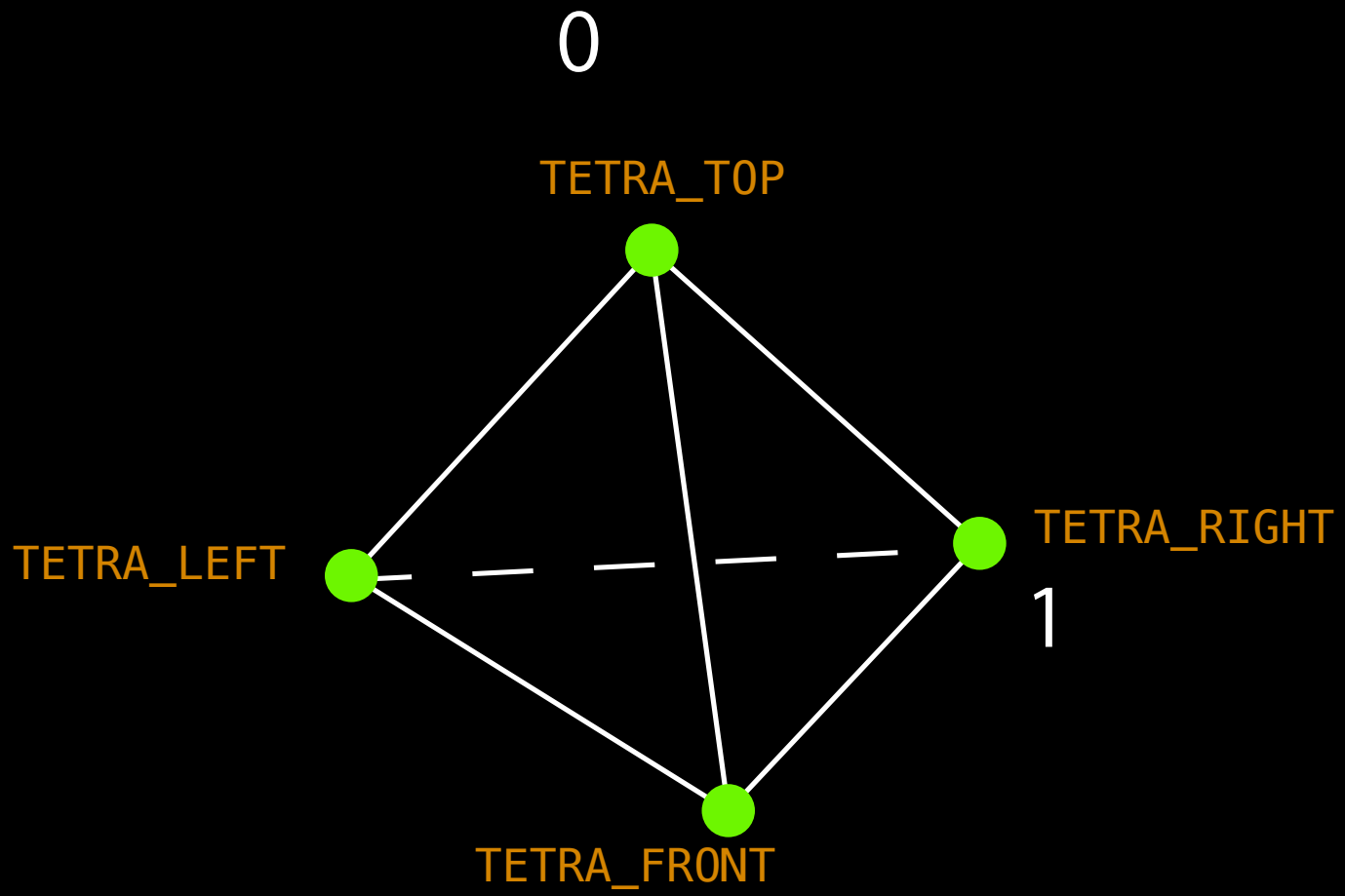

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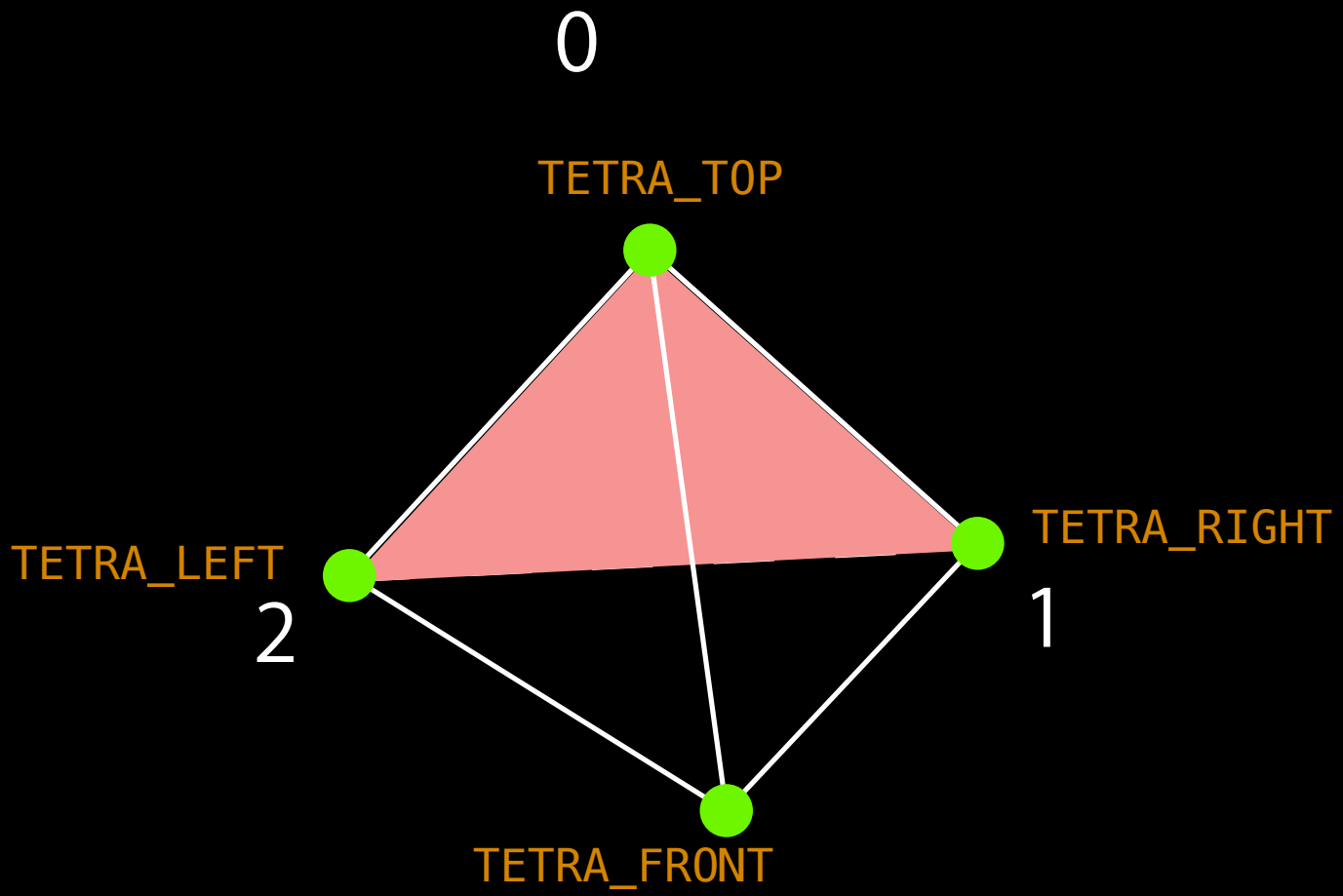

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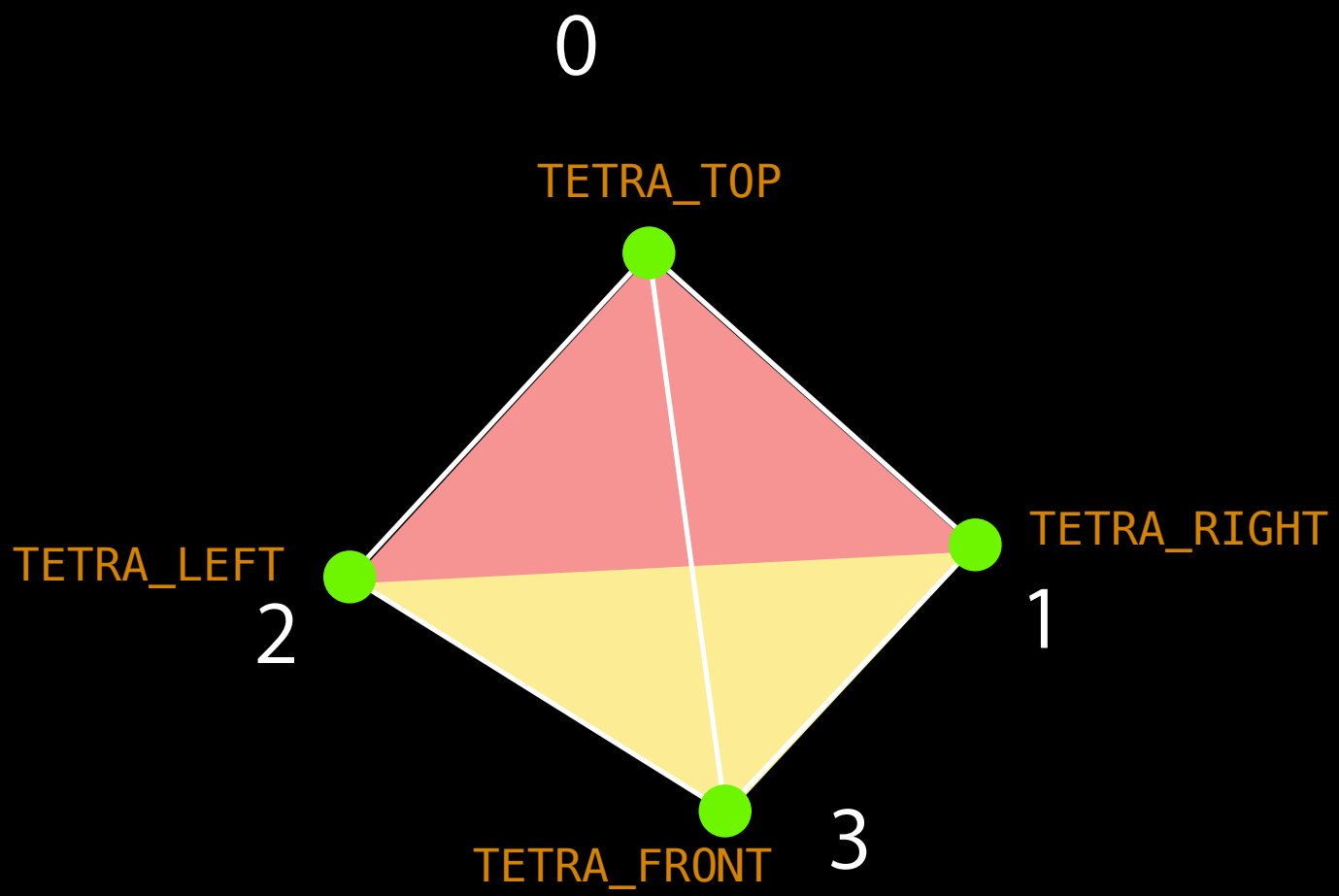

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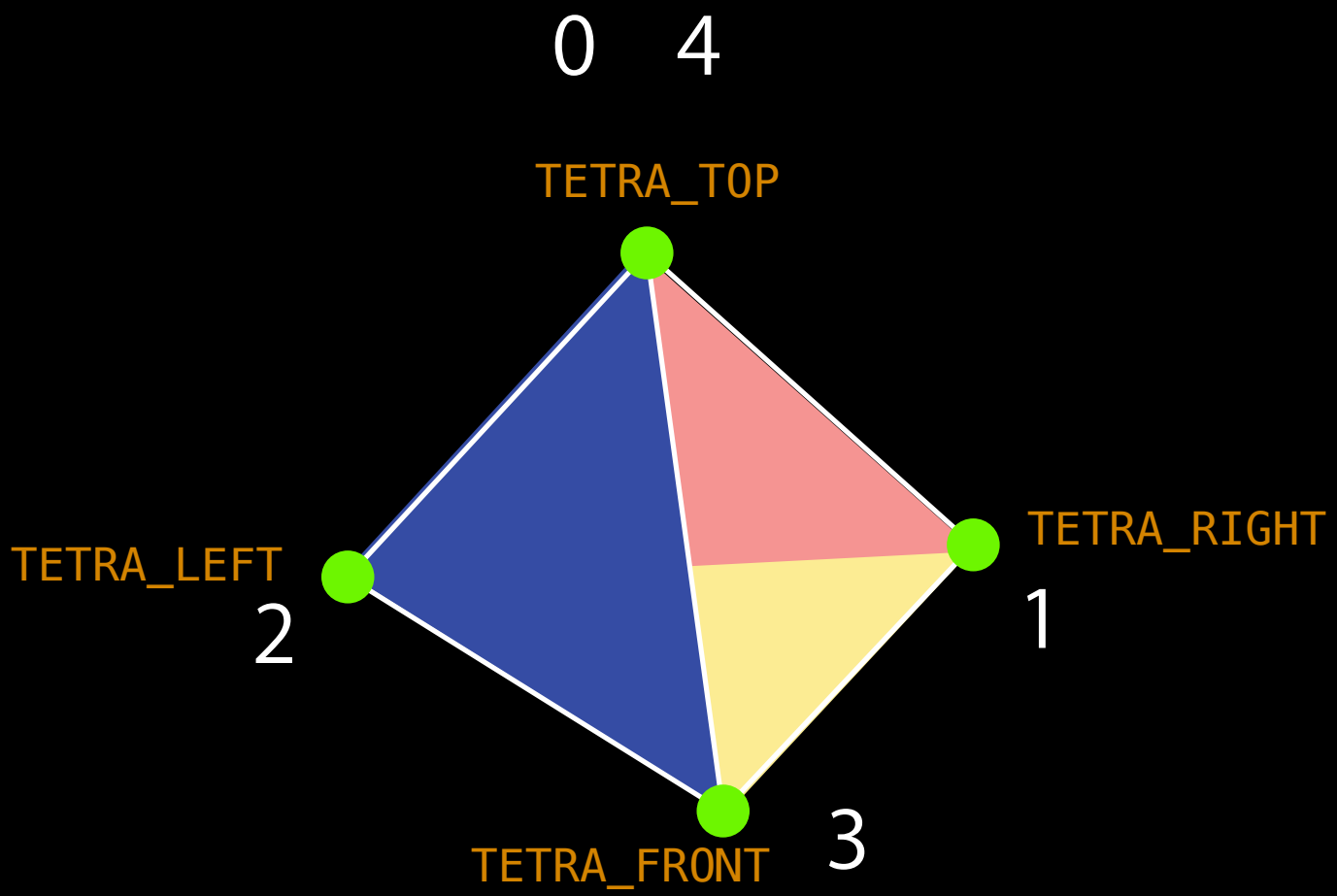

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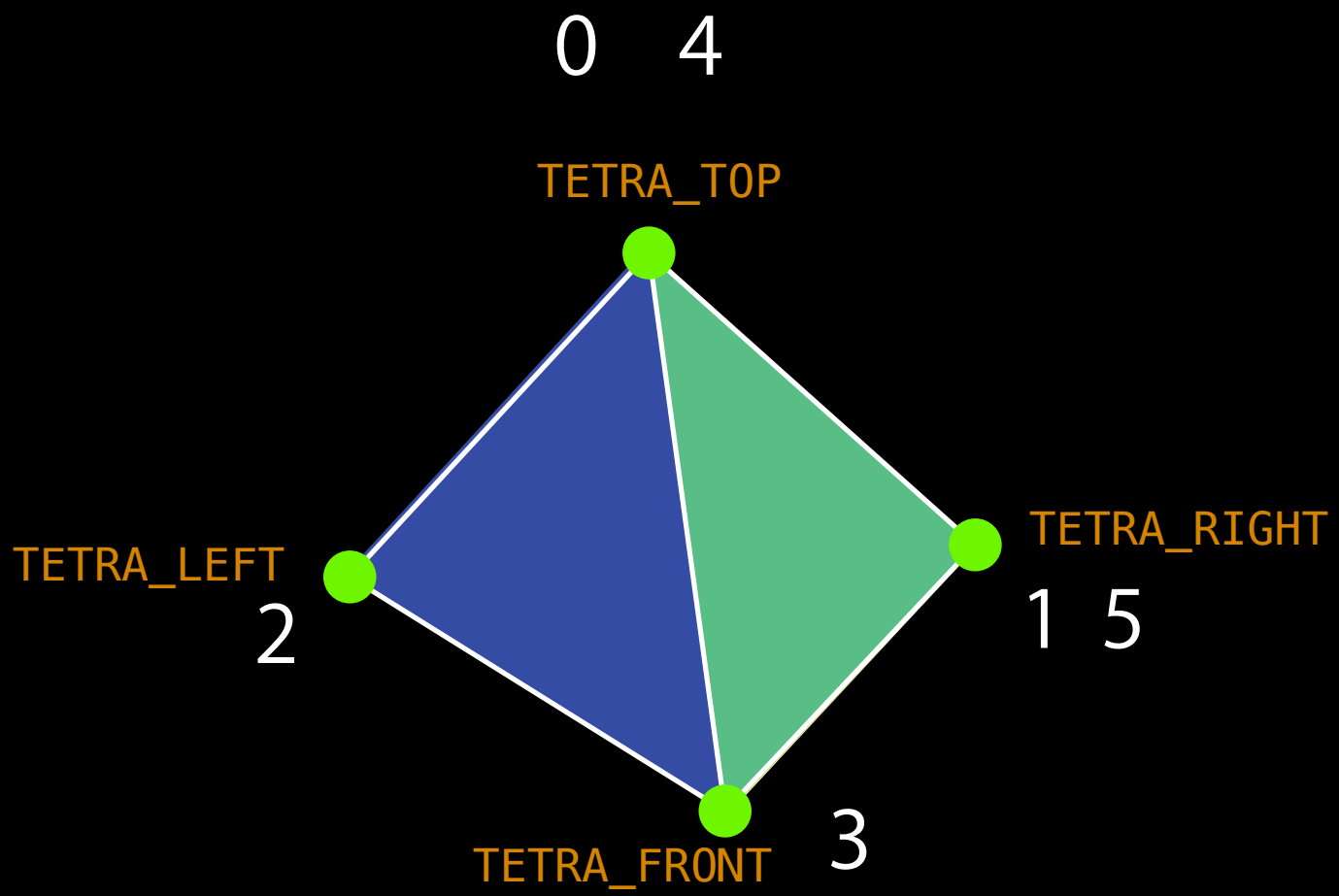


Demo

Geometry

Geometry Cheat Sheet

```
GLfloat vertexArray[] = {
    x1,y1,z1,
    x2,y2,z2,
    x3,y3,z3, ... };

GLubyte colorArray[] = {
    r1,g1,b1,a1,
    r2,g2,b2,a2,
    r3,g3,b3,a3, ... };

glVertexPointer(dimOfVertices, GL_FLOAT, arrayOffset, vertexArray);
glEnableClientState(GL_VERTEX_ARRAY);
glColorPointer(4, GL_UNSIGNED_BYTE, arrayOffset, colorArray);
glEnableClientState(GL_COLOR_ARRAY);

glDrawArrays(GL_TRIANGLE_STRIP, arrayOffset, numberOfVertices);
   // or GL_TRIANGLE_FAN, GL_TRIANGLES

glDisableClientState(GL_VERTEX_ARRAY);
glDisableClientState(GL_COLOR_ARRAY);
```

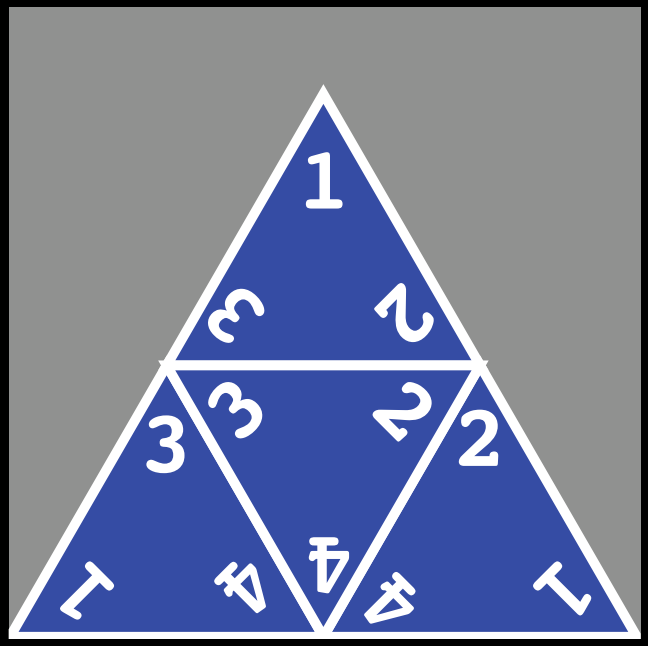
Using Textures

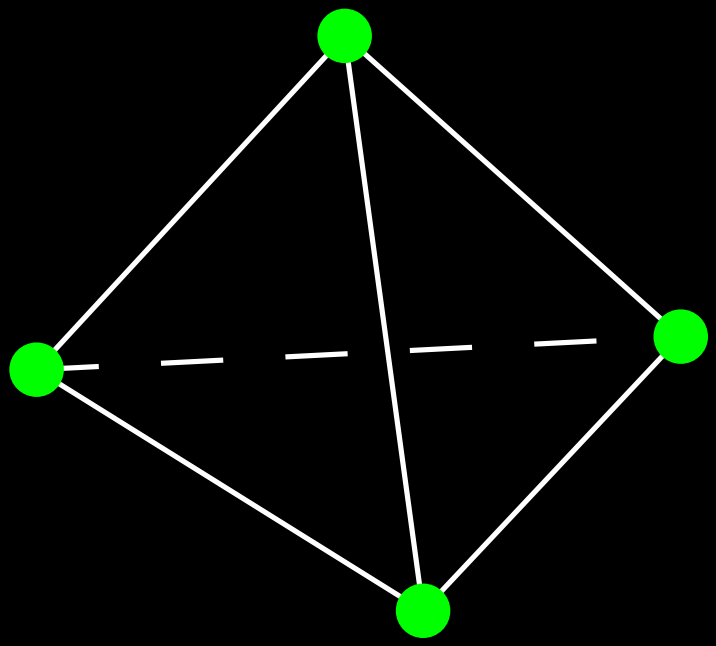
Texture Mapping

- Color pixels according to an image in memory
- Almost always 2D (3D textures are possible though)
- Vertices are given texture coordinates (u,v)

Texture Atlasing

- Swapping textures often is inefficient
- Instead make one giant shared texture





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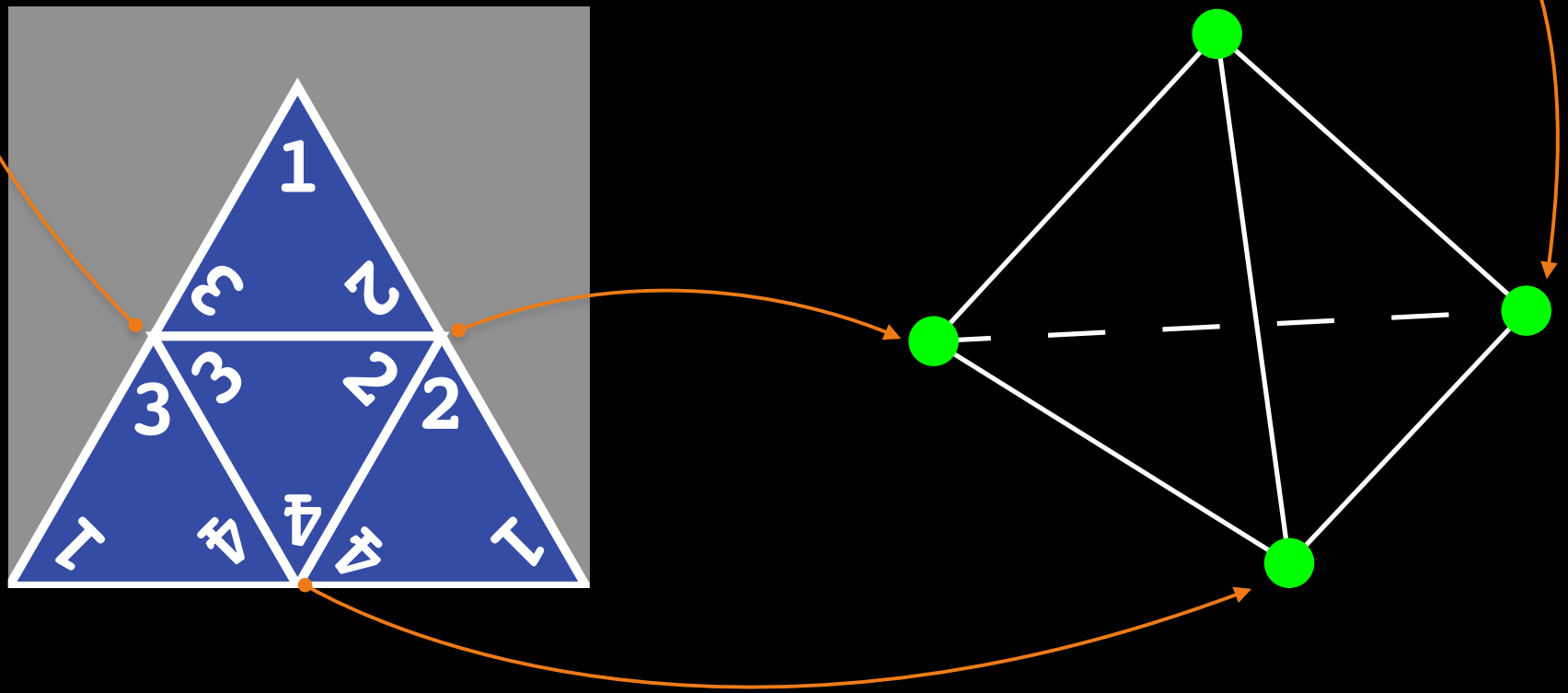

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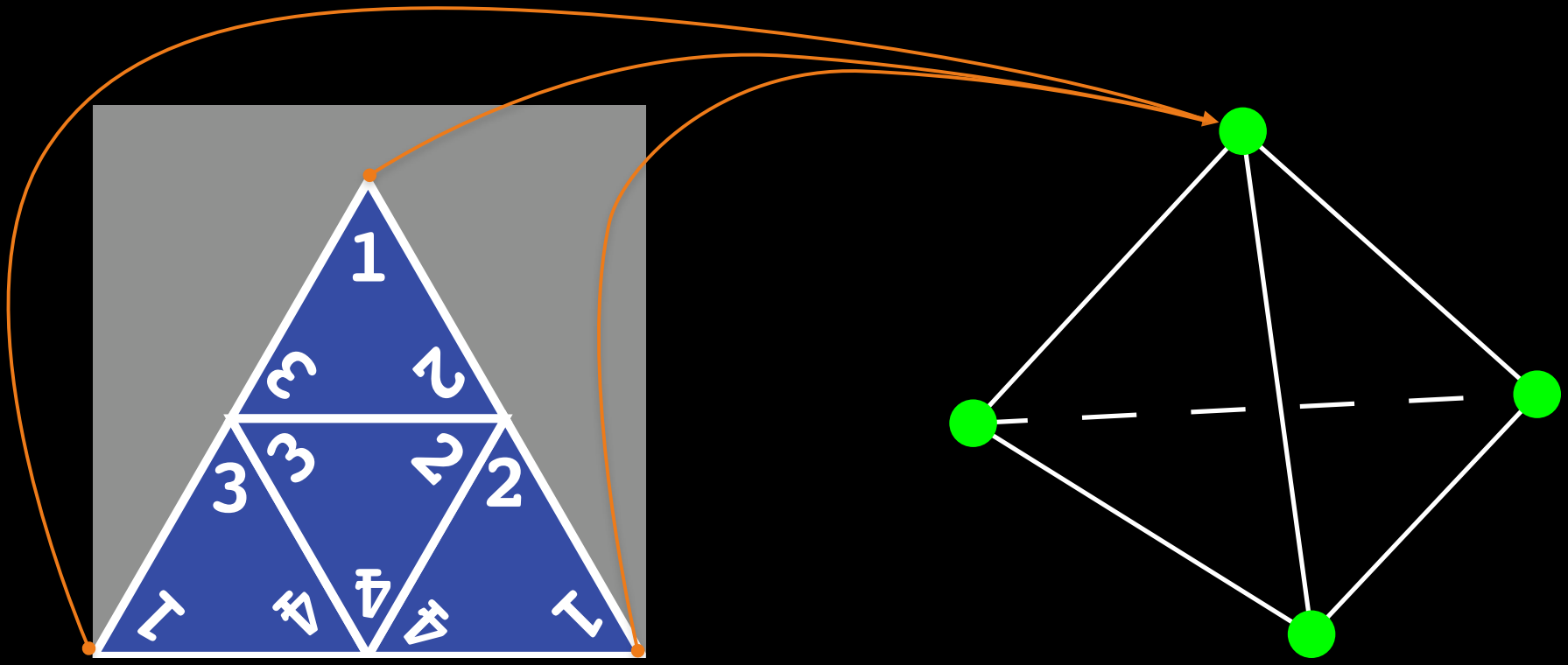

- Vertices may not have consistent (u,v) coordinates

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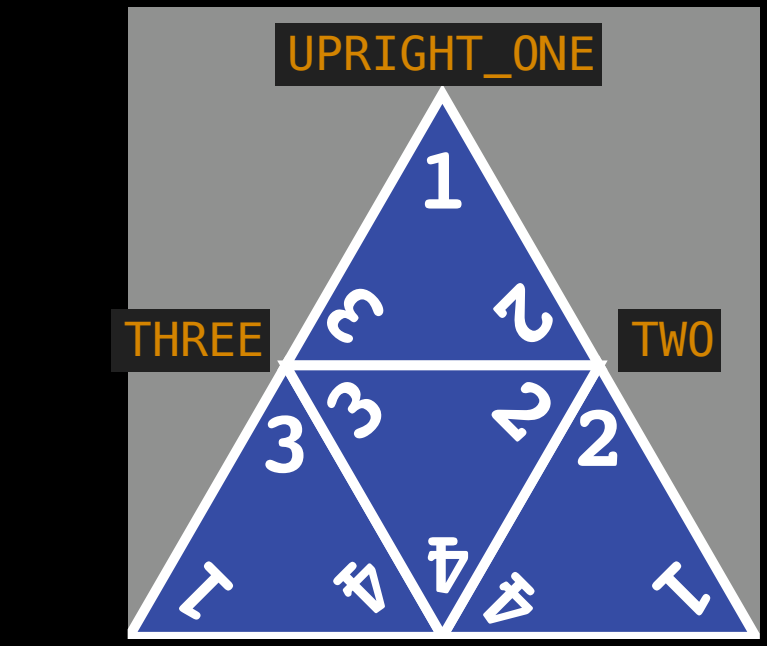

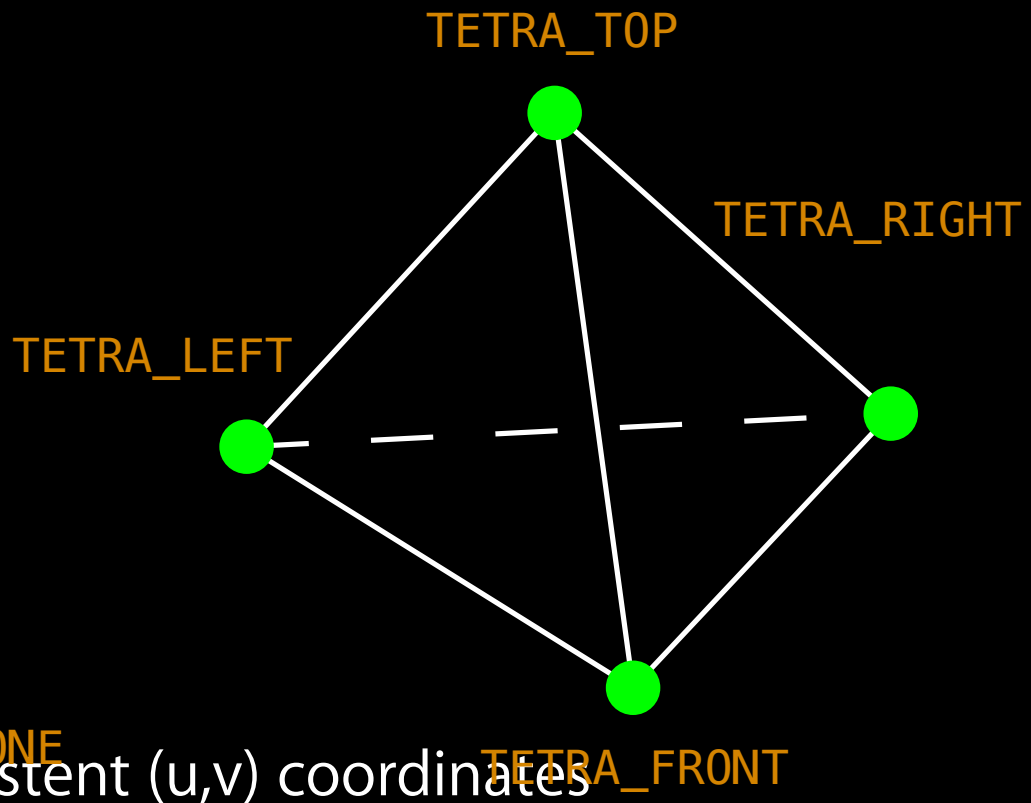

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Demo

Textures

Texture Cheat Sheet

```
bash$ export PATH=${PATH}:/Developer/Platforms/iPhoneOS.platform/Developer/usr/bin/
bash$ texturetool -f PVR -e PVRTC image.png -o image.pvrtc
bash$ # image.png must be square with power of side length -- e.g. 64, 256, 1024

#import "PVRTexture.h"
// From Apple's PVRTextureLoader Example Project

NSString * path = [[NSBundle mainBundle] pathForResource: @"image" ofType:@"pvrtc"];
PVRTexture * texture = [[PVRTexture alloc] initWithContentsOfFile: path];

glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
glTexParameterf(GL_TEXTURE_2D, GL_TEXTURE_MAX_ANISOTROPY_EXT, 1.0f);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, GL_CLAMP_TO_EDGE);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_T, GL_CLAMP_TO_EDGE);

glEnable(GL_TEXTURE_2D);
glBindTexture(GL_TEXTURE_2D, texture.name);

GLFloat textureCoordArray[] = {
    u1,v1,
    u2,v2,
    u3,v3, ... };

glTexCoordPointer(2, GL_FLOAT, arrayOffset, textureCoordArray);
glEnableClientState(GL_TEXTURE_COORD_ARRAY);
glDrawArrays(GL_TRIANGLE_STRIP, arrayOffset, numberOfVertices);
glDisableClientState(GL_TEXTURE_COORD_ARRAY);
```

Other Details

OpenGL ES 1.1 vs. ES 2.0

- This lecture described OpenGL ES1.1
- ES 2.0 is drastically different
  - Uses shader based approach
  - More flexible, harder to wrap your head around
- ES 2.0 not available in iPhones before 3GS

Want to know more?

- Apple OpenGL Programming Guide
- OpenGL Redbook
- The Internets
- Stanford CS 148, 248

- Topics of interest
  - Framebuffers
  - Depth Testing
  - Backface Culling
  - Animation (not inherently part of OpenGL)
  - Transparency and Blending
  - Lighting and Shading

Questions?