ECE4893A/CS4803MPG: Multicore and GPU Programming for Video Games

XNA 3-D API Basics

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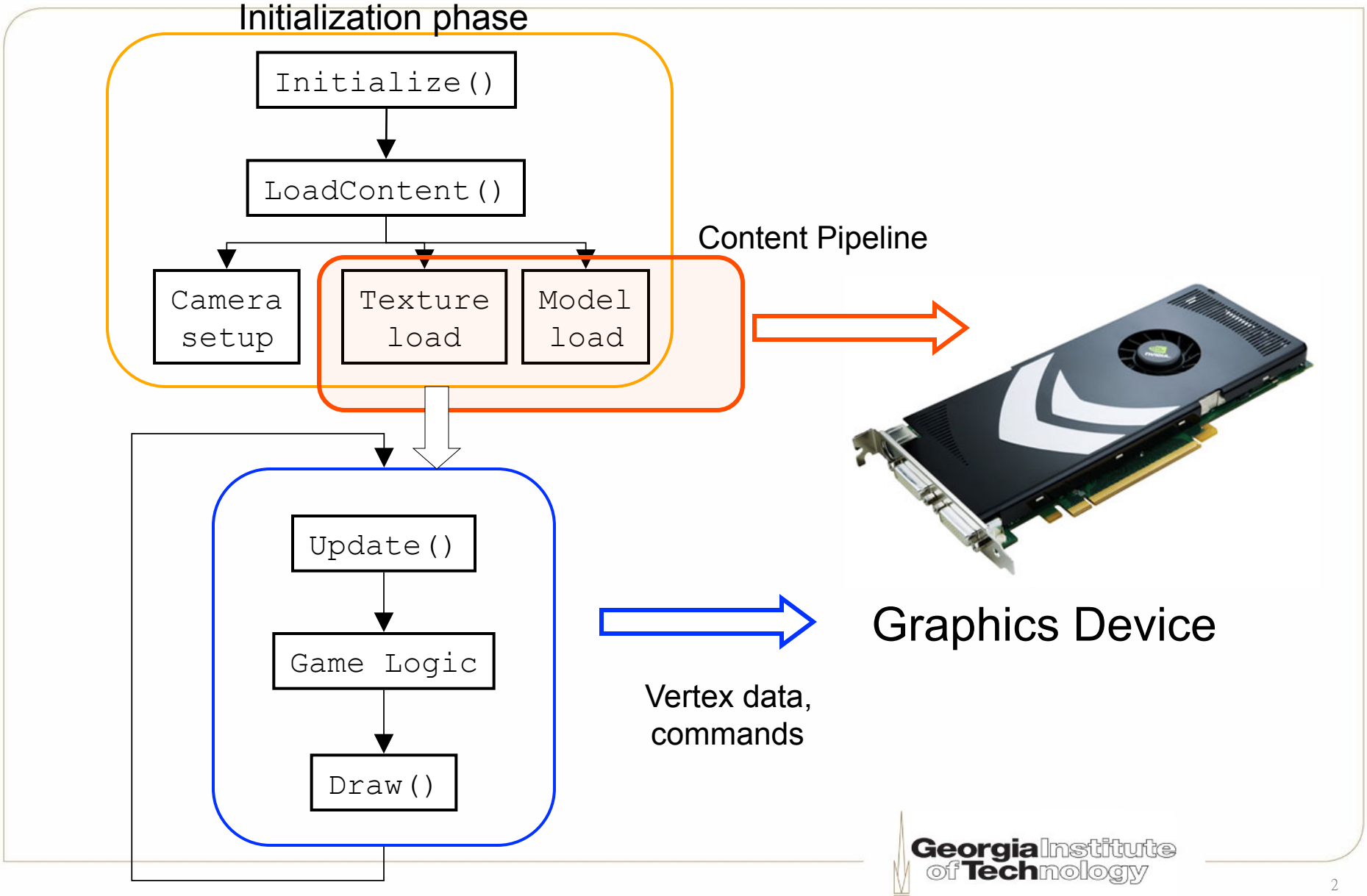
XNA: The Big Picture



Careful when googling

- XNA Math is different from old D3DX... It's your decision whether you start to use it or not, because it's completely separate library that can be used with DirectX 11, 10, 9 or without anyone of them. On the other hand, you can still link with old D3DX while coding in new DirectX 11, so it's all your choice.

- By the way, I don't know why is this library called "XNA Math." It looks like it has nothing to do with the XNA technology. XNA is a .NET library with its own vector and matrix classes while XNA Math is pure native C++ library distributed with DirectX SDK. It looks like a misnomer.

Vectors in XNA

- Various types
  - Vector2 vec2 = new Vector2(100, 100);
  - Vector3 vec3 = new Vector3(10, 10, 10);
  - Vector4 vec4 = new Vector4(1, 1, 10, 2);
  - Vector4 vec4 = new Vector4(
    new Vector2(1,1),10,2);

Standard vector types

- Vector4 vec4 = Vector4.One;

  vec4 = (1,1,1,1)

- Vector4 vec4 = Vector4.UnitX;

  vec4 = (1,0,0,0)

- Vector4 vec4 = Vector4.Zero

  vec4 = (0,0,0,0)

Vector member functions

- Vector4 vec4 = new Vector4(1, 1, 10, 2);
- vec4.X = vec4.Y + vec4.Z;
- Result: vec4 = (11,1,10,2)

Adding and subtracting vectors

- Vector3.Add(a,b,c); // a=b+c
- a = Vector3.Add(b,c); // a=b+c
- a = b + c; (look up “op_Addition” method)

- Vector3.Subtract(a,b,c); // a=b-c
- a = Vector3.Subtract(b,c); // a=b-c
- a = b – c; (look up “op_Subtraction” method)

- In general, there may be performance reasons to choose one over another or to “DIY”

Multiplying & dividing vectors

- c = a*b; c=a/b;
- Works elementwise for vectors
- Work as you'd expect for a scalar and a vector
- Various corresponding explicit method calls

Common vector functions

- float len = v3.Length()
- float len = Vector3.Length(v)
- float dp = Vector3.Dot(va,vb)

- Vector3 cp = Vector3.Cross(va,vb)
- Vector3.Cross(cp,va,vb)
- Vector3 lerpv = Vector3.Lerp(va,vb,afloat)
- Vector3 dist = Vector3.Distance(va,vb)

2nd vector's weight

- Check out http://msdn.microsoft.com for more

Normalizing vectors

- Vector3 nv = Vector3.Normalize(va)
- Vector3.Normalize(nv,va)
- va.Normalize(); // “destructive” call

- Can normalize other vector types too, but note you’ll most likely want to normalize 3-D vectors (usually for lighting calculations) and not 4-D vectors

VECTOR Example

Vectors

(See Demo in Visual Studio)

Matrices (4x4) in XNA

- Matrix Rmat44 =

  new Matrix(M11,M12,M13,M14,
  M21,M22,M23,M24,
  M31,M32,M33,M34,
  M41,M42,M43,M44);

- Most often use one of the special matrix initialization routines
  - See if what you need is already there first
- Rmat44.M13 = Rmat44.M43 + 3;

Common matrix functions

- Vector4 Rmat14= Vector4.Transform(vec4, mat);
  // [1x4]*[4x4]

- Matrix Rmat44 = Matrix.Multiply(mat1, mat2);
  // [4x4]*[4x4]
- Overloaded with operator *, thus Rmat44=M1*M2;

- Matrix inv = Matrix.Invert(mat); // find its inverse
- Matrix tr = Matrix.Transpose(mat); // transpose
- Matrix im = Matrix.Identity; // return an identity matrix

MATRIX Example

SimpleMatrix

(See Demo in Visual Studio)

Planes

- Plane plane1 = new Plane(vec3, d)

  vec3 describes a normal vector

  d = plane's distance from the origin

- A useful plane function
  - Plane.Intersects(boundingbox)
  - Many others, check msdn

Shaders in XNA

- You always need an “effect file” (.fx)
- An effect file is a shader code consisting of
  - Vertex Shader
  - Pixel Shader
- Need to communicate variables between your C# code and the shader code, e.g., matrices
- Even rendering a simple triangle requires an effect file
  - Use XNA’s BasicEffect to “fake” a classic DirectX9 style fixed-function pipeline

Specifying an effect (1)

- Either use a BasicEffect or specify a provided .fx file

```
public class Game1 : Microsoft.Xna.Framework.Game
{
    GraphicsDeviceManager graphics;
    SpriteBatch spriteBatch;

    private BasicEffect effect;
```

Specifying an effect (2)

- Either use a BasicEffect or specify a provided .fx file

An effect file called effects.fx has been dropped into the Content folder

```
#if LEE_EFFECT
            effect = Content.Load<Effect>("effects");
#else
            effect = new BasicEffect(graphics.GraphicsDevice);
#endif
```

Specifying an effect (3)

- Either use a BasicEffect or specify a provided .fx file

```
#if LEE_EFFECT
  effect.CurrentTechnique = effect.Techniques["NoTechniques"];
#endif

  foreach (EffectPass pass in effect.CurrentTechnique.Passes)
  {
    pass.Apply();

    graphics.GraphicsDevice.DrawPrimitives
       (PrimitiveType.TriangleList, 0, 1);

  }
```

BasicEffect before XNA 4.0

- 12 Vertex Shaders
  - Lighting: none, per vertex, per pixel
  - Vertex color: off, on
  - Texture: off, on
- 4 Pixel Shaders
  - Per pixel lighting: off, on
  - Texture: off, on

From blogs.msdn.com/b/shawnhar/archive/2010/04/25/basiceffect-optimizations-in-xna-game-studio-4-0.aspx

BasicEffect in XNA 4.0

- 20 Vertex Shaders
  - Lighting: none, 1 vertex light, 3 vertex lights, 3 pixel lights
  - Vertex color: off, on
  - Texture: off, on
  - Fog: off, on (*fog=off only for the versions that do not include lighting*)
- 10 Pixel Shaders
  - Lighting: none, per vertex, per pixel
  - Texture: off, on
  - Fog: off, on (*fog=off only for the versions that do not include per pixel lighting*)

From blogs.msdn.com/b/shawnhar/archive/2010/04/25/basiceffect-optimizations-in-xna-game-studio-4-0.aspx

BasicEffect handles 3 directional lights

- Parameters
  - AmbientLightColor
  - DirLight0Direction
  - DirLight0DiffuseColor
  - DirLight0SpecularColor
  - DirLight1Direction
  - DirLight1DiffuseColor
  - DirLight1SpecularColor
  - DirLight2Direction
  - DirLight2DiffuseColor
  - DirLight2SpecularColor

http://creators.xna.com/en-us/utilities/basiceffectshader

BasicEffect material properties

- Colors range 0 to 1:
  - DiffuseColor
  - EmissiveColor
  - SpecularColor
  - SpecularPower
  - Alpha

http://creators.xna.com/en-us/utilities/basiceffectshader

BasicEffect fog properties

- FogEnabled
  - 0 to disable, 1 to enable
- FogStart
- FogEnd
- FogColor

http://creators.xna.com/en-us/utilities/basiceffectshader

Set up BasicEffect

```
effect = new BasicEffect(graphics.GraphicsDevice);

effect.Alpha = 1.0f;
effect.DiffuseColor = new Vector3(1.0f, 1.0f, 1.0f);
effect.SpecularColor =
                    new Vector3(0.25f, 0.25f, 0.25f);
effect.SpecularPower = 5.0f;
effect.AmbientLightColor =
                    new Vector3(1.0f, 1.0f, 1.0f);

effect.DirectionalLight0.Enabled = true;
effect.DirectionalLight0.DiffuseColor = Vector3.One;
effect.DirectionalLight0.Direction =
  Vector3.Normalize(new Vector3(1.0f, -1.0f, -1.0f));
effect.DirectionalLight0.SpecularColor = Vector3.One;
```

VertexBuffer

- Contains a list of vertices
  - 4-D colors
  - 3-D positions
  - 2-D texture coordinates
  - 3-D normals

VertexBuffer structures

- VertexPositionColor
- VertexPositionColorTexture
- VertexPositionNormalTexture
- VertexPositionTexture
- Can make your own if you really need to

PrimitiveType enumeration

Member name	Description
TriangleList	The data is ordered as a sequence of triangles; each triangle is described by three new vertices. Back-face culling is affected by the current winding-order render state.
TriangleStrip	The data is ordered as a sequence of triangles; each triangle is described by two new vertices and one vertex from the previous triangle. The back-face culling flag is flipped automatically on even-numbered triangles.
LineList	The data is ordered as a sequence of line segments; each line segment is described by two new vertices. The count may be any positive integer.
LineStrip	The data is ordered as a sequence of line segments; each line segment is described by one new vertex and the last vertex from the previous line seqment. The count may be any positive integer.

http://msdn.microsoft.com/en-us/library/microsoft.xna.framework.graphics.priamitivetype.aspx

Set Up Vertex Buffer

```
private VertexBuffer VBuffer;
```

Create a container Vertex Buffer for allocating vertices

```
private void TriangleOne() {
  vertex = new VertexPositionColor[3];
  vertexcount = 3;

  vertex[0] = new VertexPositionColor(new Vector3(-0.9f, -0.5f, 0.5f),
                                      Color.Red);
  vertex[1] = new VertexPositionColor(new Vector3(0.0f, 0.5f, 0.5f),
                                      Color.Green);
  vertex[2] = new VertexPositionColor(new Vector3(0.5f, -0.5f, 0.5f),
                                      Color.Blue);

  VBuffer = new VertexBuffer(graphics.GraphicsDevice,
    typeof(VertexPositionColor), vertexcount, BufferUsage.WriteOnly);

  VBuffer.SetData(vertex);
}
```

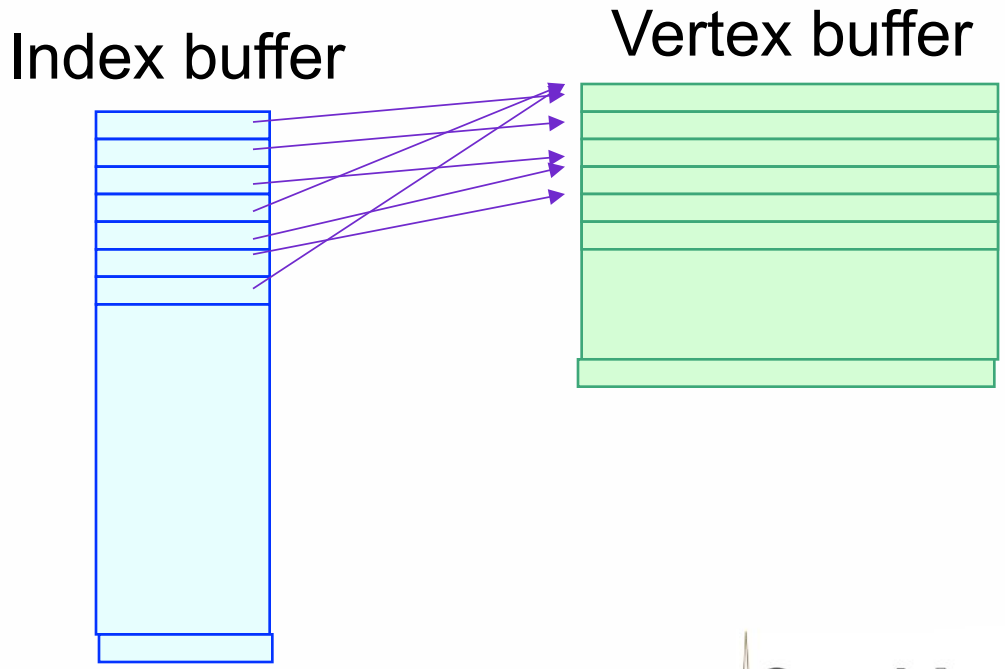
DrawPrimitives Example

FirstTriangle

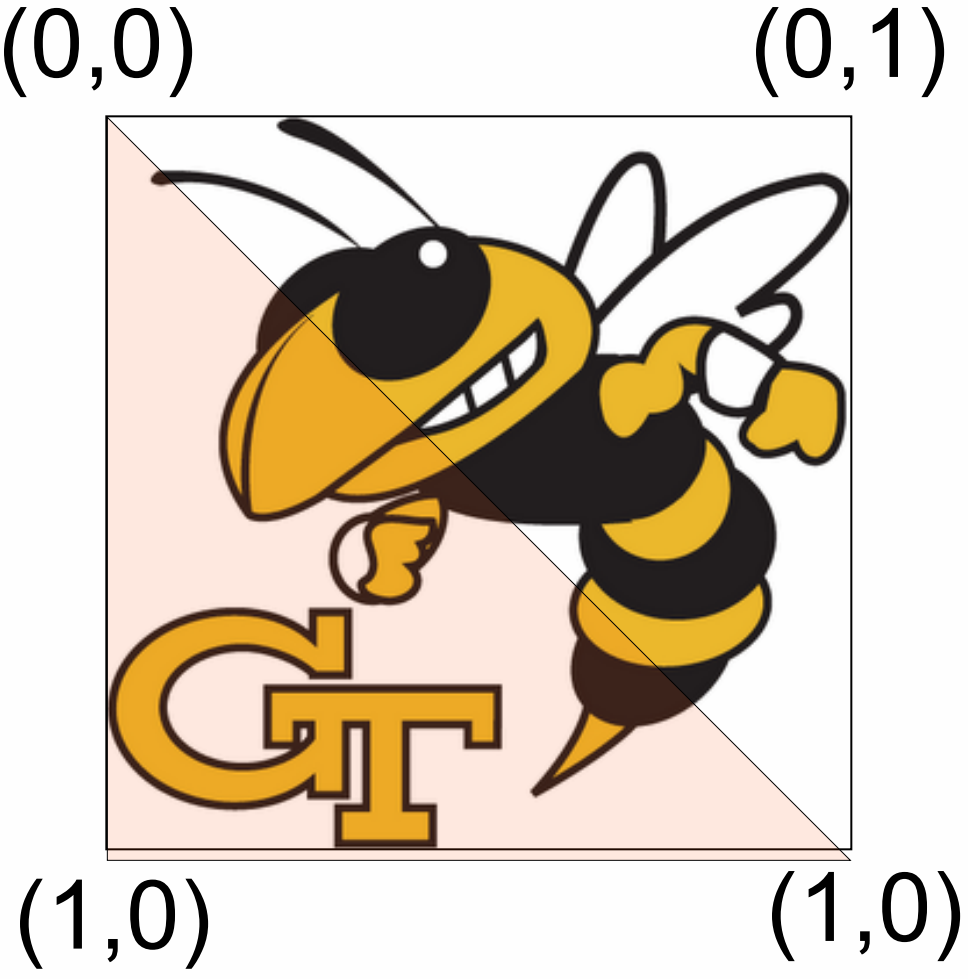
(See Demo in Visual Studio)

Indexed vertex buffers

- To eliminate the repetitive definition of vertices
- Use a **vertex buffer** to store unique vertices
- Use an **index buffer** to store Index



Let's make a Buzz cube (1)



Let's make a Buzz cube (2)

Define vertices of a Cube
VertexPositionNormalTexture

```
vertex = new VertexPositionNormalTexture[24];
vertexcount = 24;

// Front
vertex[0] = new VertexPositionNormalTexture(new Vector3(-0.5f,  0.5f, 0.0f), FrontNormal, new Vector2(0.0f, 0.0f));
vertex[1] = new VertexPositionNormalTexture(new Vector3( 0.5f,  0.5f, 0.0f), FrontNormal, new Vector2(0.5f, 0.0f));
vertex[2] = new VertexPositionNormalTexture(new Vector3( 0.5f, -0.5f, 0.0f), FrontNormal, new Vector2(0.5f, 0.5f));
vertex[3] = new VertexPositionNormalTexture(new Vector3(-0.5f, -0.5f, 0.0f), FrontNormal, new Vector2(0.0f, 0.5f));

// Right
vertex[4] = new VertexPositionNormalTexture(new Vector3(0.5f,  0.5f,  0.0f), RightNormal, new Vector2(0.0f, 0.0f));
vertex[5] = new VertexPositionNormalTexture(new Vector3(0.5f,  0.5f, -1.0f), RightNormal, new Vector2(1.0f, 0.0f));
vertex[6] = new VertexPositionNormalTexture(new Vector3(0.5f, -0.5f, -1.0f), RightNormal, new Vector2(1.0f, 1.0f));
vertex[7] = new VertexPositionNormalTexture(new Vector3(0.5f, -0.5f,  0.0f), RightNormal, new Vector2(0.0f, 1.0f));

// Top
vertex[8] =  new VertexPositionNormalTexture(new Vector3(-0.5f, 0.5f,  0.0f), TopNormal, new Vector2(0.0f, 1.0f));
vertex[9] =  new VertexPositionNormalTexture(new Vector3( 0.5f, 0.5f,  0.0f), TopNormal, new Vector2(1.0f, 1.0f));
vertex[10] = new VertexPositionNormalTexture(new Vector3( 0.5f, 0.5f, -1.0f), TopNormal, new Vector2(1.0f, 0.0f));
vertex[11] = new VertexPositionNormalTexture(new Vector3(-0.5f, 0.5f, -1.0f), TopNormal, new Vector2(0.0f, 0.0f));

//Left
vertex[12] = new VertexPositionNormalTexture(new Vector3(-0.5f,  0.5f,  0.0f), LeftNormal, new Vector2(2.0f, 0.0f));
vertex[13] = new VertexPositionNormalTexture(new Vector3(-0.5f, -0.5f,  0.0f), LeftNormal, new Vector2(2.0f, 2.0f));
vertex[14] = new VertexPositionNormalTexture(new Vector3(-0.5f, -0.5f, -1.0f), LeftNormal, new Vector2(0.0f, 2.0f));
vertex[15] = new VertexPositionNormalTexture(new Vector3(-0.5f,  0.5f, -1.0f), LeftNormal, new Vector2(0.0f, 0.0f));

//Back
vertex[16] = new VertexPositionNormalTexture(new Vector3( 0.5f,  0.5f, -1.0f), BackNormal, new Vector2(0.0f, 0.0f));
vertex[17] = new VertexPositionNormalTexture(new Vector3( 0.5f, -0.5f, -1.0f), BackNormal, new Vector2(0.0f, 4.0f));
vertex[18] = new VertexPositionNormalTexture(new Vector3(-0.5f, -0.5f, -1.0f), BackNormal, new Vector2(4.0f, 4.0f));
```

Texture Coordinates

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A more complex example (3)

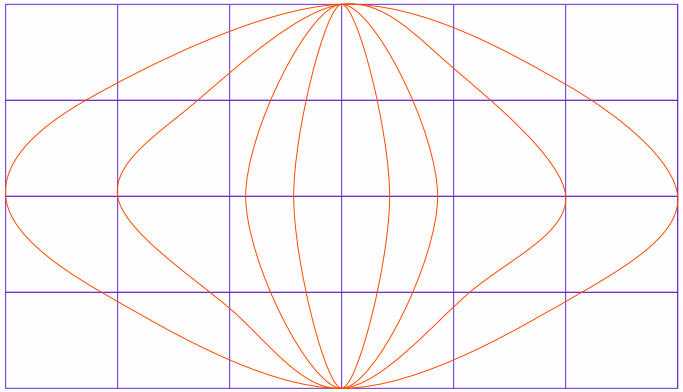
```
triangleListIndices = new short[36] {   0, 1, 2,
                                        2, 3, 0,
                                        4, 5, 6,
                                        4, 6, 7,
                                        8, 11, 10,
                                        8, 10, 9,
                                        12, 13, 14,
                                        15, 12, 14,
                                        16, 19, 17,
                                        19, 18, 17,
                                        20, 21, 22,
                                        23, 20, 22};
```

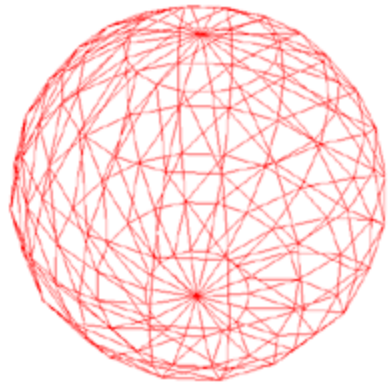
```
foreach (EffectPass pass in effect.CurrentTechnique.Passes)
{
  pass.Apply();
  graphics.GraphicsDevice.DrawUserIndexedPrimitives
       (PrimitiveType.TriangleList, vertex, 0, 24,
        triangleListIndices, 0, 12);
}
```

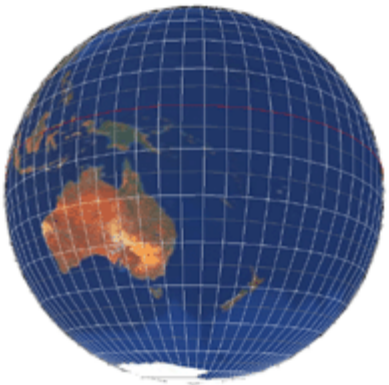
In Draw()

Texture mapping for sphere

- Warping the map could lead to distortion
- Geometric calculation involved







Globe image source: P. Bourke from uwa.edu.au

Classic transformation matrices

- Translation (by amount to translate)

```
Matrix.CreateTranslation(Vector3 position);
```

- Scaling (by amount to scale in x, y, and z)

```
Matrix.CreateScale(Vector3 scales);
```

- Rotation

```
Matrix.CreateRotationX(float radians);
Matrix.CreateRotationY(float radians);
Matrix.CreateRotationZ(float radians);
```

- Special function

```
Matrix.CreateShadow(Vector3 lightDir, Plane plane);
```

Movement control

```
if (keyboard.IsKeyDown(Keys.Up))
{
    zoom -= 0.1f;
}
else if (keyboard.IsKeyDown(Keys.Down))
{
    zoom += 0.1f;
}
else if (keyboard.IsKeyDown(Keys.Left))
{
    move -= 0.1f;
}
else if (keyboard.IsKeyDown(Keys.Right))
{
    move += 0.1f;
}
```

Composite (*) into “one matrix” for effect file

```
Movement();
rot += offset*speed;

worldMatrix = Matrix.CreateRotationY(rot.Y) * Matrix.CreateRotationX(rot.X) * Matrix.CreateRotationZ(rot.Z)*
              Matrix.CreateTranslation(move, updown, zoom);
effect.World = worldMatrix;
```

Be cautious on operation ordering

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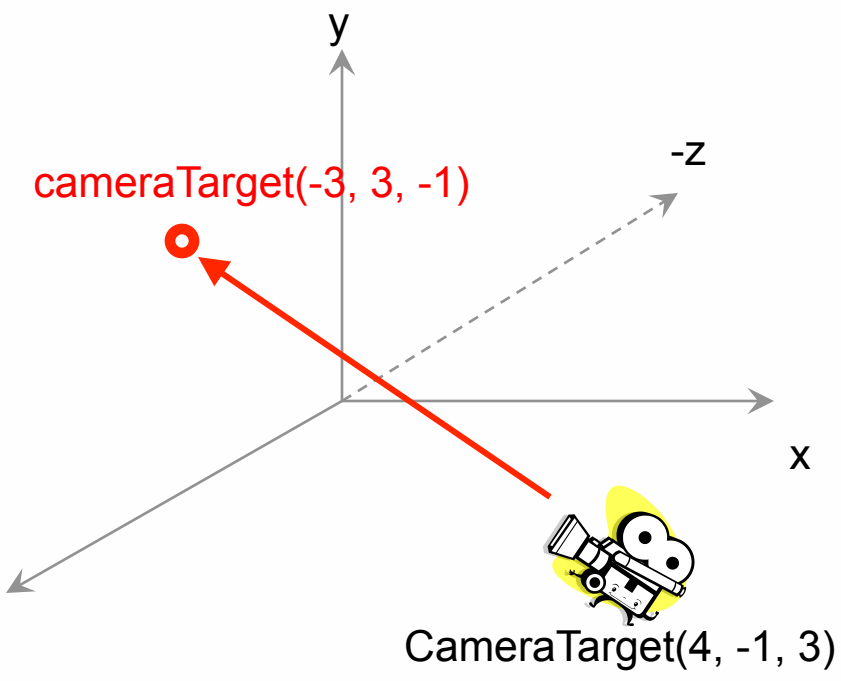
Create view transformation matrix

- View Transformation

```
Matrix.CreateLookAt(Vector3 cameraPosition,
                    Vector3 cameraTarget,
                    Vector3 cameraUpVector);
```

Usually (0, 1, 0) → the world is upward

Use Vector3.Up

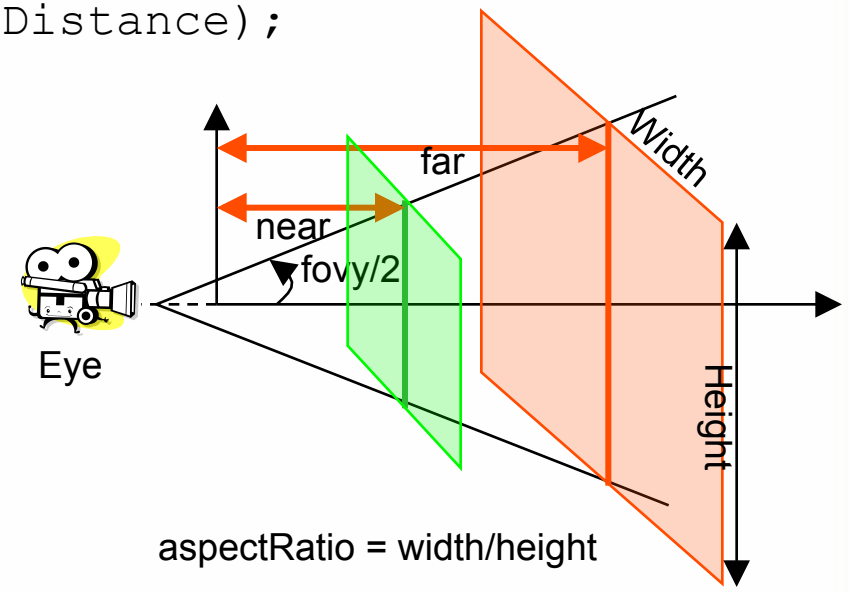


Create perspective transformation matrix

- Build a “look-at matrix”

```
Matrix.CreatePerspectiveFieldOfView(
                    float fieldOfView, // In radians
                    float aspectRatio,
                    float nearPlaneDistance,
                    float farPlaneDistance);
```

- Can use MathHelper.ToRadians(degree) for fieldOfView



DrawUserIndexedPrimitives Example

DrawIndexedCube
(See Demo in Visual Studio)

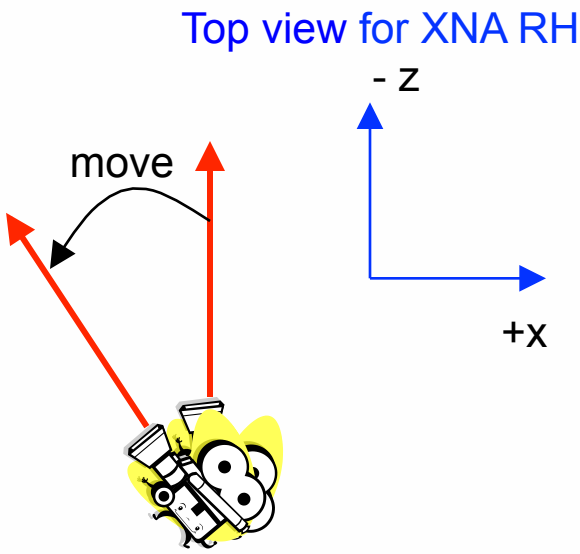
Note that, in this example, all controls move the "Object," *not* the viewer.

Rotate camera (looking around)

```
protected void CamMove()
{
    KeyboardState keyboard = Keyboard.GetState();

    if (keyboard.IsKeyDown(Keys.Left))
    {
        move -= 0.01f;
    }
    else if (keyboard.IsKeyDown(Keys.Right))
    {
        move += 0.01f;
    }

    camLookat.X = radius * (float) Math.Sin(move);
    camLookat.Z = 0.0f - radius * (float) Math.Cos(move);
    camLookat.Y = 0.0f;
}
```




```
// Camera movement
CamMove();

viewMatrix = Matrix.CreateLookAt(camPos, camLookat, Vector3.Up);
effect.View = viewMatrix;
```

Moving Camera Example

MovingCam

(See Demo in Visual Studio)