Graphics Programming

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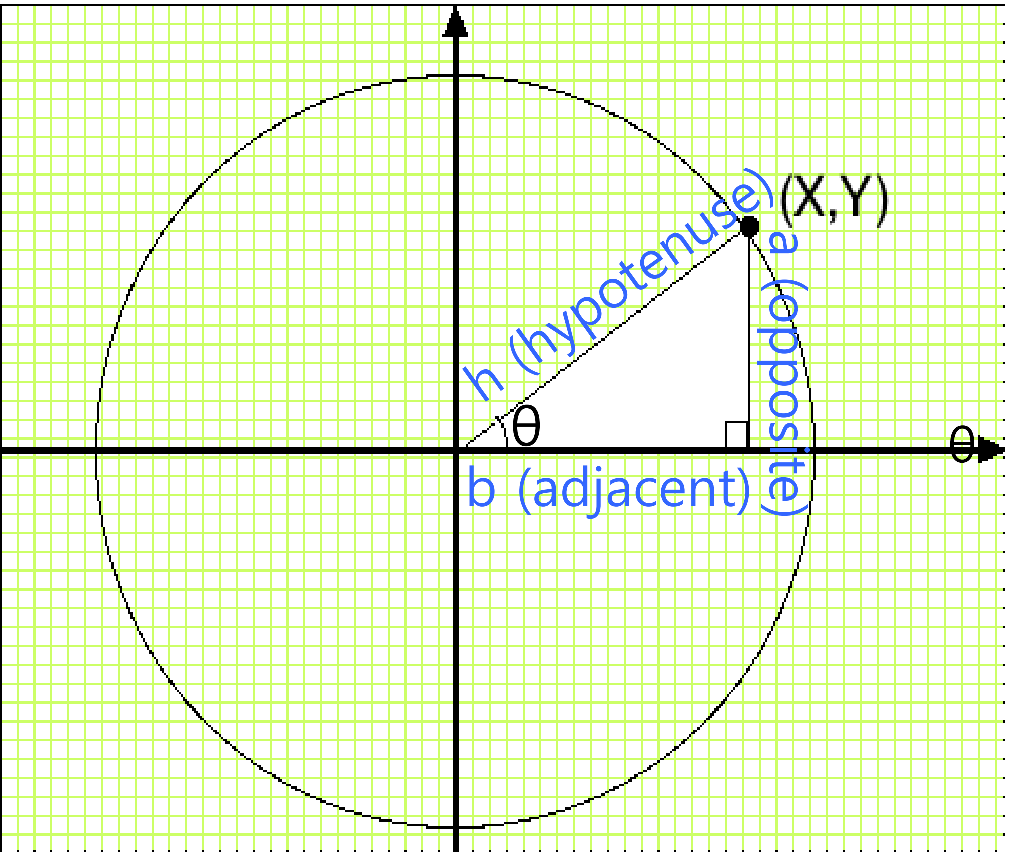
Angles, Degrees, and Radians

- General math library functions uses radians.
- 360 degrees(°) = 1 full circle = 2 πradians
- 1 radian = 180.0/π degree ≈ 57.29578 degree

  or 1 degree = π/180.0 radian ≈ 0.01745329 radian

```
#ifndef M_PI
#define M_PI 3.141592654f
#endif
#define DegreesToRadians(degree) ((degree) * (M_PI / 180.0f))
#define RadiansToDegrees(radian) ((radian) * (180.0f / M_PI))
```

Trignometry



- $\sin\theta = a/h$
  $\cos\theta = b/h$
  $\tan\theta = a/b$
- $b = h*\cos\theta$
  $a = h*\sin\theta$
- $x^2 + y^2 = 1$
  $x = \cos\theta$
  $y = \sin\theta$
  $y/x = \sin\theta/\cos\theta = \tan\theta$
- $x = \text{distance} * \cos\theta$
  $y = \text{distance} * \sin\theta$

Trignometry

- Multiplicative inverse:
  cscθ = 1/sinθ
  secθ = 1/cosθ
  cotθ = 1/tanθ = cosθ/sinθ = x/y
- Inverse:
  arcsin(x)= $\sin^{-1}(x)$
  where y=arcsin(x) x:[-1, 1]-> y:[-π/2, π/2]
  arccos(x) = $\cos^{-1}(x)$
  where y=arccos(x) x:[-1, 1]-> y:[0, π]
  arctan(x) = $\tan^{-1}(x)$
  where y=arctan(x) x:[-∞, ∞]-> y:[-π/2, π/2]

Trignometric Identity

- $\sin^2\theta + \cos^2\theta = 1$
  $1 + \tan^2\theta = \sec^2\theta$
  $1 + \cot^2\theta = \csc^2\theta$
- $\sin(\pi/2 - \theta) = \cos\theta$
  $\cos(\pi/2 - \theta) = \sin\theta$
  $\tan(\pi/2 - \theta) = \cot\theta$
- $\sin(x+y) = \sin x \cos y + \cos x \sin y$
  $\sin(x-y) = \sin x \cos y - \cos x \sin y$
  $\cos(x+y) = \cos x \cos y - \sin x \sin y$
  $\cos(x-y) = \cos x \cos y + \sin x \sin y$
- $\sin 2\theta = 2\sin\theta\cos\theta$
  $\cos 2\theta = \cos^2\theta - \sin^2\theta = 2\cos^2\theta - 1 = 1 - 2\sin^2\theta$

Geometric Primitives

- The most basic elements in expressing object
- In real-time graphics, linear primitives are used
  - Point
  - Line, Line Segment, Ray
  - Sphere, Cylinder, Cone
  - Cube (Box)
  - Triangle
  - Polygon, …
- Requirements for polygons
  - The polygon specified must **not intersect** itself.
  - Must be **convex.**
  - Its vertices are co-planar.

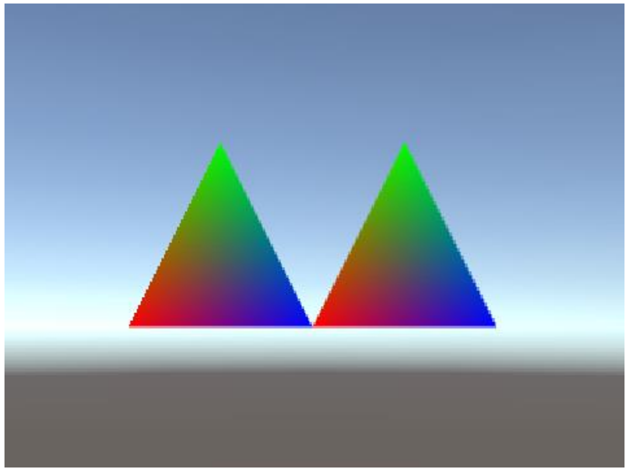
Primitive Types

- Unity GL primitive types
  - **GL.LINES**
  - **GL.LINE_STRIP**
  - **GL.TRIANGLES**
  - **GL.TRIANGLE_STRIP**
  - **GL.QUADS**

2 Triangles

- Draw 2 triangles(Unity LHS x+ right y+ up z+ inside) CW
  - GL_TRIANGLES

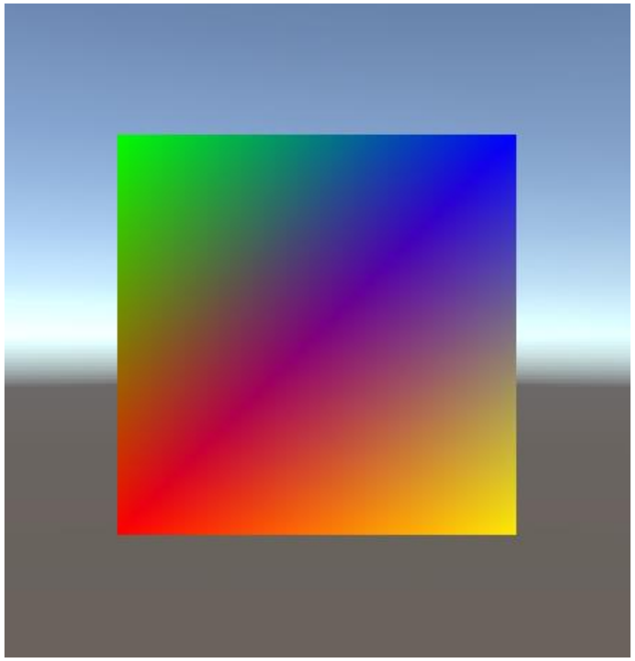
```
void FilledTriangle(Color c1, Color c2, Color c3, Vector3 p1, Vector3 p2, Vector3 p3) {
        GL.PushMatrix();
        GL.Begin(GL.TRIANGLES);
        GL.Color(c1);
        GL.Vertex(p1);
        GL.Color(c2);
        GL.Vertex(p2);
        GL.Color(c3);
        GL.Vertex(p3);
        GL.End();
        GL.PopMatrix();
 }
GLGeometry.FilledTriangle(Color.red, Color.green, Color.blue, new Vector3(-2, 0, 0),
new Vector3(-1, 2, 0), new Vector3(0, 0, 0));
GLGeometry.FilledTriangle(Color.red, Color.green, Color.blue, new Vector3(0, 0, 0),
new Vector3(1, 2, 0), new Vector3(2, 0, 0));
```



Quad

- Draw a quad(Unity LHS x+ right y+ up z+ inside) CW
  - GL_QUADS

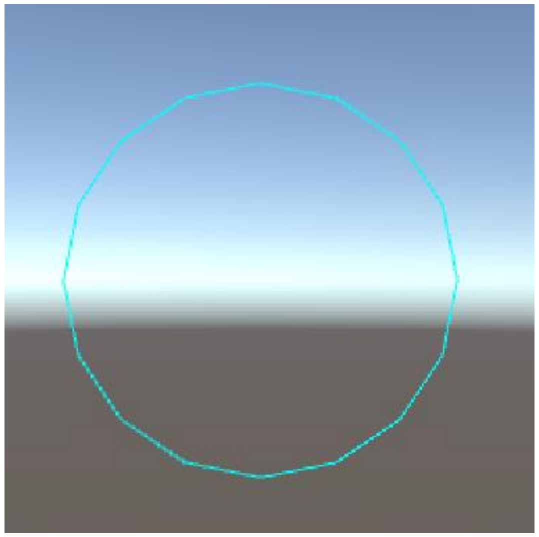
```
void Quad(Color c1, Color c2, Color c3, Color c4, Vector3 p1, Vector3 p2, Vector3
p3, Vector3 p4) {
	GL.PushMatrix();
	GL.Begin(GL.QUADS);
	GL.Color(c1);
	GL.Vertex(p1);
	GL.Color(c2);
	GL.Vertex(p2);
	GL.Color(c3);
	GL.Vertex(p3);
	GL.Color(c4);
	GL.Vertex(p4);
	GL.End();
	GL.PopMatrix();
}
GLGeometry.Quad(Color.red, Color.green, Color.blue, Color.yellow, new Vector3(-2,
-2, 0), new Vector3(-2, 2, 0), new Vector3(2, 2, 0), new Vector3(2, -2, 0));
```



Circle

- Draw a wireframe circle
  - GL_LINE_STRIP

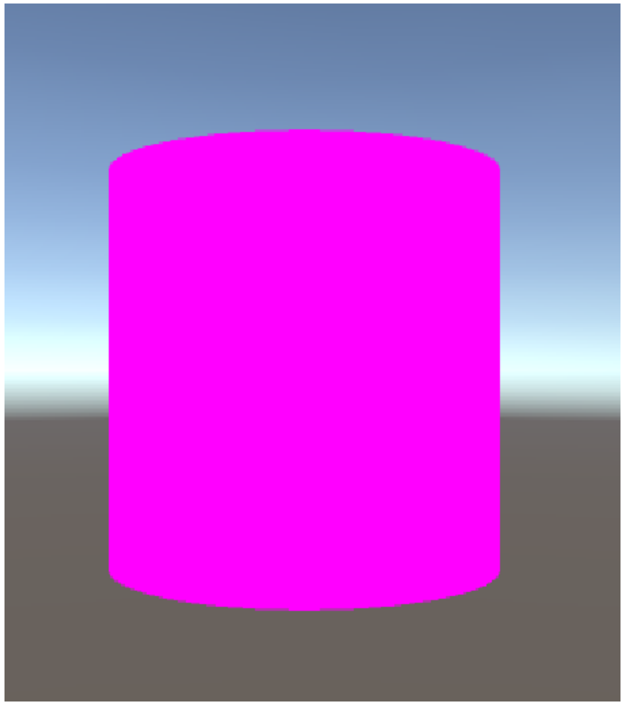
```
void Circle(Color color, float radius, int segments) {
    GL.PushMatrix();
    GL.Begin(GL.LINE_STRIP);
    GL.Color(color);
    float deltaTheta = -2.0f * Mathf.PI / segments;
    for (int i = 0; i <= segments; i++) {
        float theta = i * deltaTheta;
        float x = radius * Mathf.Cos(theta);
        float y = radius * Mathf.Sin(theta);
        GL.Vertex(new Vector3(x, y, 0));
    }
    GL.End();
    GL.PopMatrix();
}
GLGeometry.Circle(Color.cyan, 2, 16);
```



Cylinder

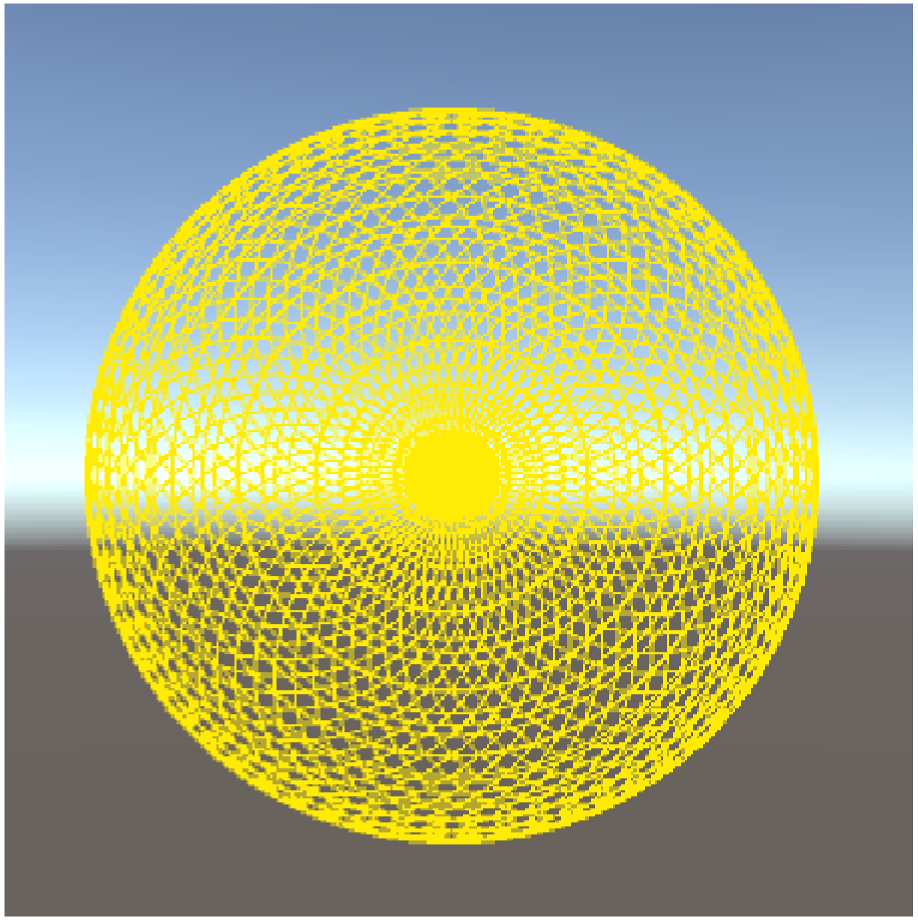
- Draw a wireframe cylinder
  - GL_LINE_STRIP

```
void Cylinder(Color color, float radius, float height, int segments) {
    GL.PushMatrix();
    GL.Begin(GL.TRIANGLE_STRIP);
    GL.Color(color);
    float deltaTheta = 2.0f * Mathf.PI / segments;
    for (int i = 0; i <= segments; i++) {
        float theta = i * deltaTheta;
        float x = radius * Mathf.Cos(theta);
        float y = -height/2;
        float z = radius * Mathf.Sin(theta);
        GL.Vertex(new Vector3(x, y, z));
        y = height/2;
        GL.Vertex(new Vector3(x, y, z));
    }
    GL.End();
    GL.PopMatrix();
}
```

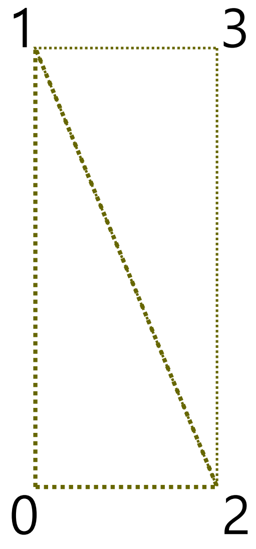


Sphere

- Draw a wireframe sphere
  - GL_LINE_STRIP
- Draw a solid sphere
  - GL_TRIANGLE_STRIP



```
void Sphere(Color color, float radius, int stacks, int slices)  {
    GL.PushMatrix();
    GL.Begin(GL.TRIANGLE_STRIP);
    GL.Color(color);
    float lonstep = Mathf.PI / stacks; float latstep = Mathf.PI / slices;
    for (float lon = 0.0f; lon <= 2*Mathf.PI; lon += lonstep)   {
        for (float lat = 0.0f; lat <= Mathf.PI + latstep; lat += latstep)  {
            float x = radius * Mathf.Cos(lon) * Mathf.Sin(lat);
            float y = radius * Mathf.Sin(lon) * Mathf.Sin(lat);
            float z = radius * Mathf.Cos(lat);
            GL.Vertex(new Vector3(x, y, z));
            x = radius * Mathf.Cos(lon + lonstep) * Mathf.Sin(lat);
            y = radius * Mathf.Sin(lon + lonstep) * Mathf.Sin(lat);
            z = radius * Mathf.Cos(lat);
            GL.Vertex(new Vector3(x, y, z));
        }
    }
    GL.End();
    GL.PopMatrix();
}
```

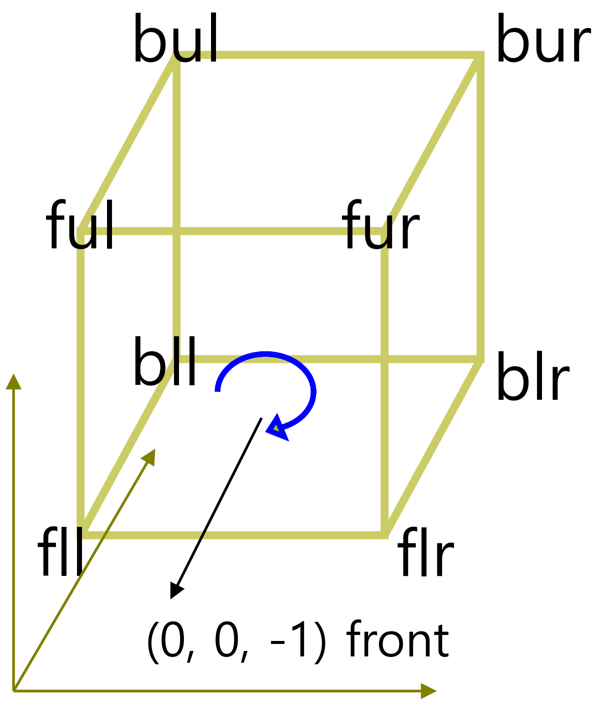


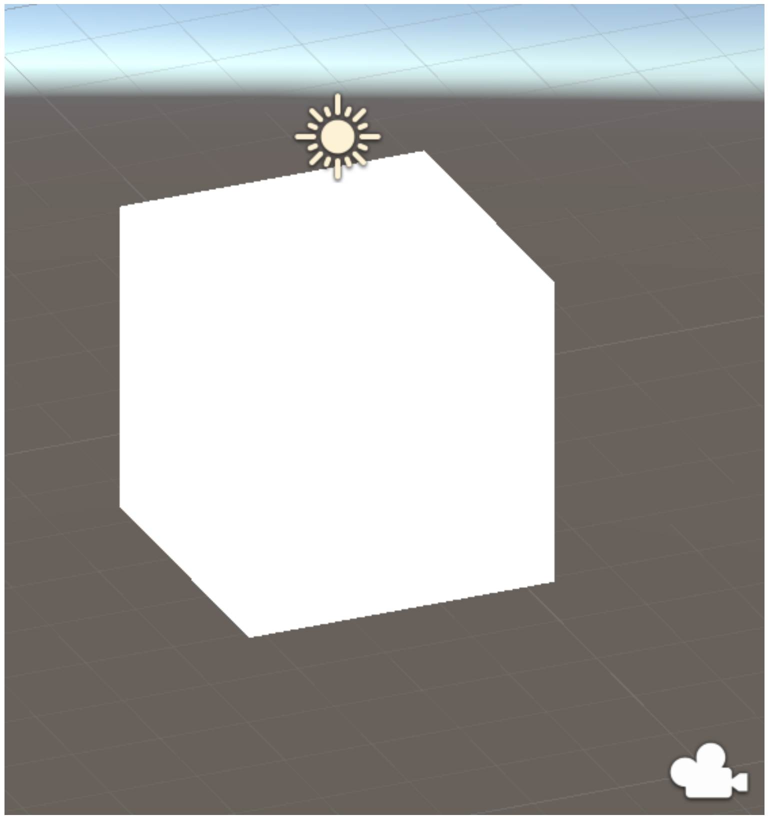
경도(lon) 위도(lat)

$x = \cos\varphi * \cos\theta$
$y = \sin\theta$
$z = \sin\varphi * \cos\theta$
where $0 \le \varphi \le 2\pi$, $-\pi/2 \le \theta \le \pi/2$

Cube

- Draw a solid cube(Unity LHS x+ right y+ up z+ inside) CW
  - GL_QUADS





```
void Cube(Color color, Vector3 center, float size) {
        Vector3 fll = center + new Vector3(-size, -size,  -size);
        Vector3 flr = center + new Vector3( size, -size,  -size);
        Vector3 ful = center + new Vector3(-size,  size,  -size);
        Vector3 fur = center + new Vector3(size, size, -size);
        Vector3 bll = center + new Vector3(-size, -size,  size);
        Vector3 blr = center + new Vector3( size, -size,  size);
        Vector3 bul = center + new Vector3(-size,  size,  size);
        Vector3 bur = center + new Vector3(size, size, size);

        GL.PushMatrix();
        GL.Begin(GL.QUADS);
        GL.Color(color);

        // front face
        GL.Vertex(fll);
        GL.Vertex(ful);
        GL.Vertex(fur);
        GL.Vertex(flr);
```

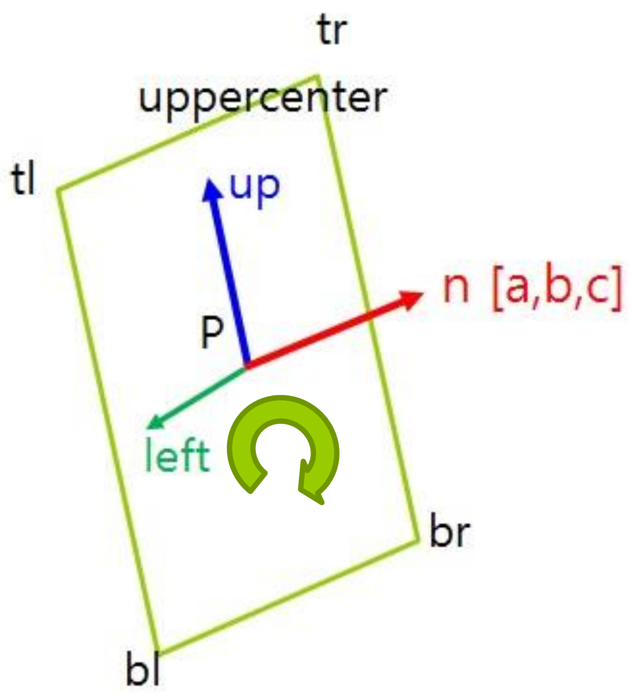
Cube

```
 // back face
GL.Vertex(blr);
GL.Vertex(bur);
GL.Vertex(bul);
GL.Vertex(bll);

// left face
GL.Vertex(bll);
GL.Vertex(bul);
GL.Vertex(ful);
GL.Vertex(fll);

// right face
GL.Vertex(flr);
GL.Vertex(fur);
GL.Vertex(bur);
GL.Vertex(blr);
```

Cube

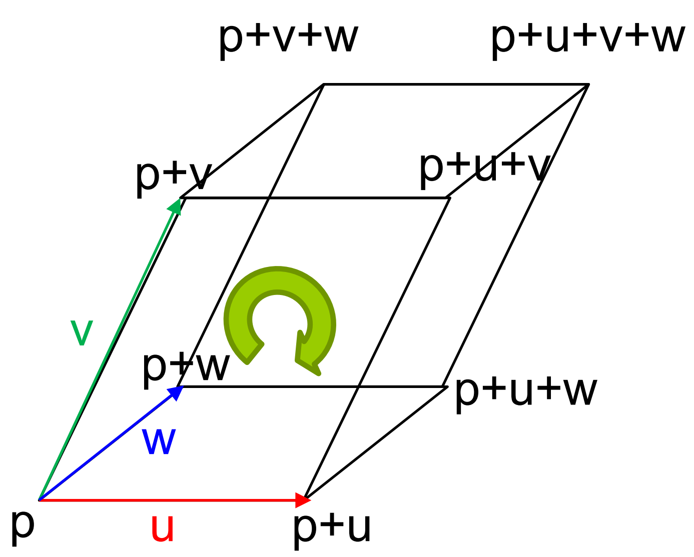
```
    // top face
    GL.Vertex(ful);
    GL.Vertex(bul);
    GL.Vertex(bur);
    GL.Vertex(fur);

    // bottom face
    GL.Vertex(blr);
    GL.Vertex(bll);
    GL.Vertex(fll);
    GL.Vertex(flr);

    GL.End();
    GL.PopMatrix();
}
```

Quad



```
up.Normalize();
n.Normalize();
Vector3 left = Vector3.Cross(up, n);
Vector3 uppercenter = (u * height/2.0f) + p;
Vector3 tl = uppercenter + (left * width/2.0f);
Vector3 tr = uppercenter - (left * width/2.0f);
Vector3 bl = tl - (u * height);
Vector3 br = tr - (u * height);
GL.PushMatrix();
GL.Begin(GL.QUADS);
GL.Color(c);
GL.Vertex(bl);
GL.Vertex(tl);
GL.Vertex(tr);
GL.Vertex(br);
GL.End();
GL.PopMatrix();
```

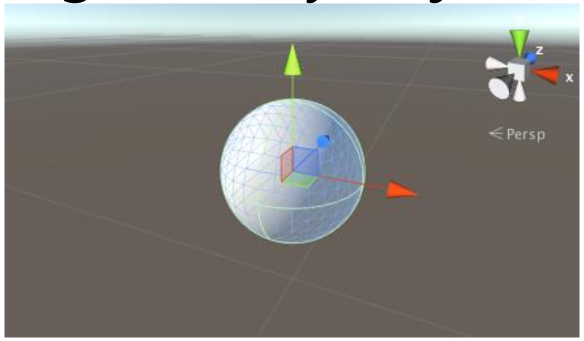
Parallelepiped

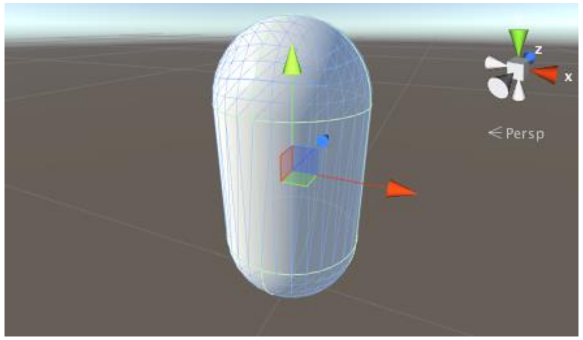


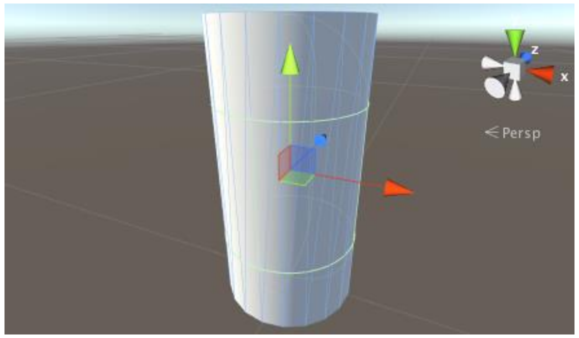
```
Vector3 fll = p;
Vector3 flr = p + u;
Vector3 fur = p + u + v;
Vector3 ful = p + v;
Vector3 bll = p + w;
Vector3 blr = p + u + w;
Vector3 bur = p + u + v + w;
Vector3 bul = p + v + w;

// front face
GL.Vertex(fll);
GL.Vertex(ful);
GL.Vertex(fur);
GL.Vertex(flr);
```

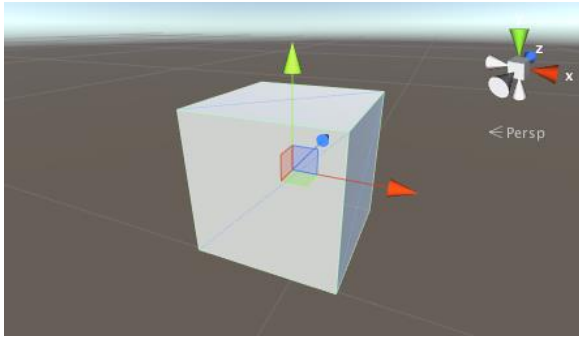
3D Geometry Object

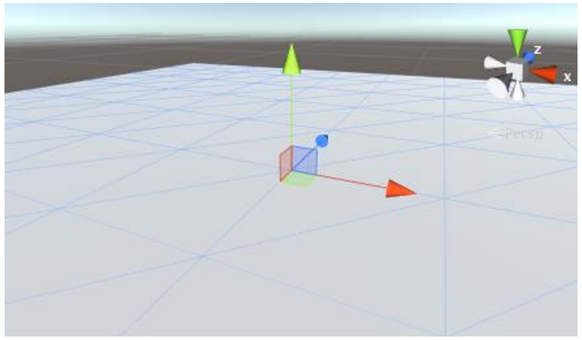
- Unity basic 3D geometry object
  - Sphere = 0
  - Capsule = 1
  - Cylinder = 2
  - Cube = 3
  - Plane = 4
  - Quad = 5

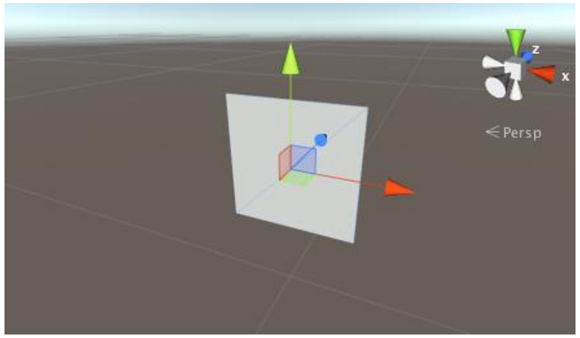












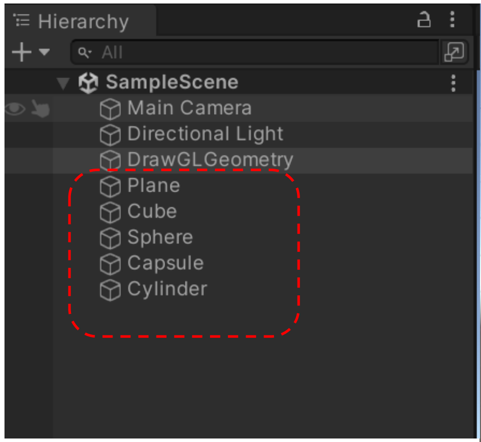
https://docs.unity3d.com/510/Documentation/Manual/PrimitiveObjects.html

3D Geometry Object

```
public class Example : MonoBehaviour {
    // Create a plane, sphere and cube in the Scene.
    void Start()    {
        GameObject plane  = GameObject.CreatePrimitive(PrimitiveType.Plane);

        GameObject cube = GameObject.CreatePrimitive(PrimitiveType.Cube);
        cube.transform.position = new Vector3(0, 0.5f, 0);

        GameObject sphere = GameObject.CreatePrimitive(PrimitiveType.Sphere);
        sphere.transform.position = new Vector3(0, 1.5f, 0);

        GameObject capsule = GameObject.CreatePrimitive(PrimitiveType.Capsule);
        capsule.transform.position = new Vector3(2, 1, 0);

        GameObject cylinder = GameObject.CreatePrimitive(PrimitiveType.Cylinder);
        cylinder.transform.position = new Vector3(-2, 1, 0);
    }
}
```

https://docs.unity3d.com/ScriptReference/GameObject.CreatePrimitive.html

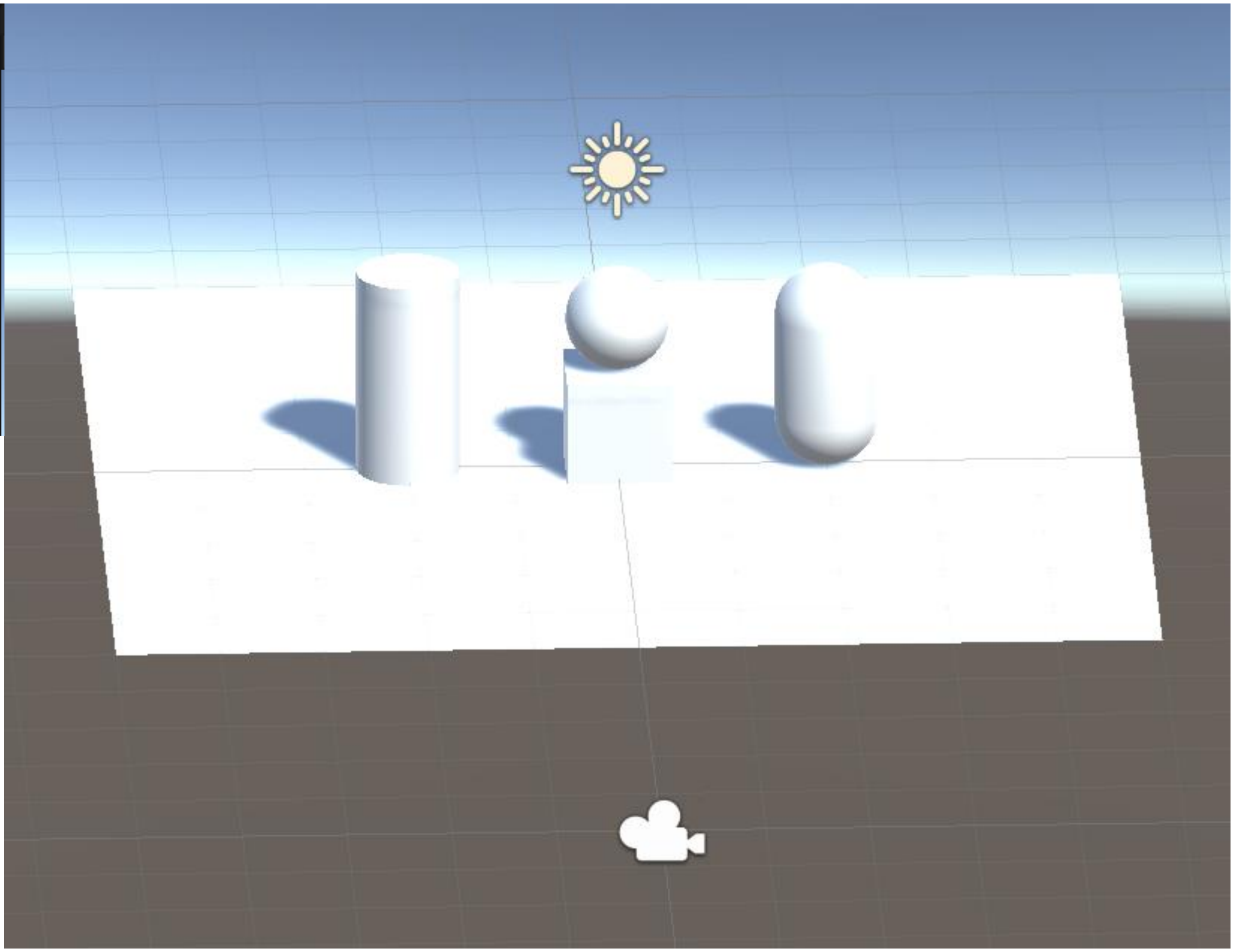
3D Geometry Object



Hierarchy

All

SampleScene
- Main Camera
- Directional Light
- DrawGLGeometry
- Plane
- Cube
- Sphere
- Capsule
- Cylinder



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