3D Game Programming Geometric Transformations

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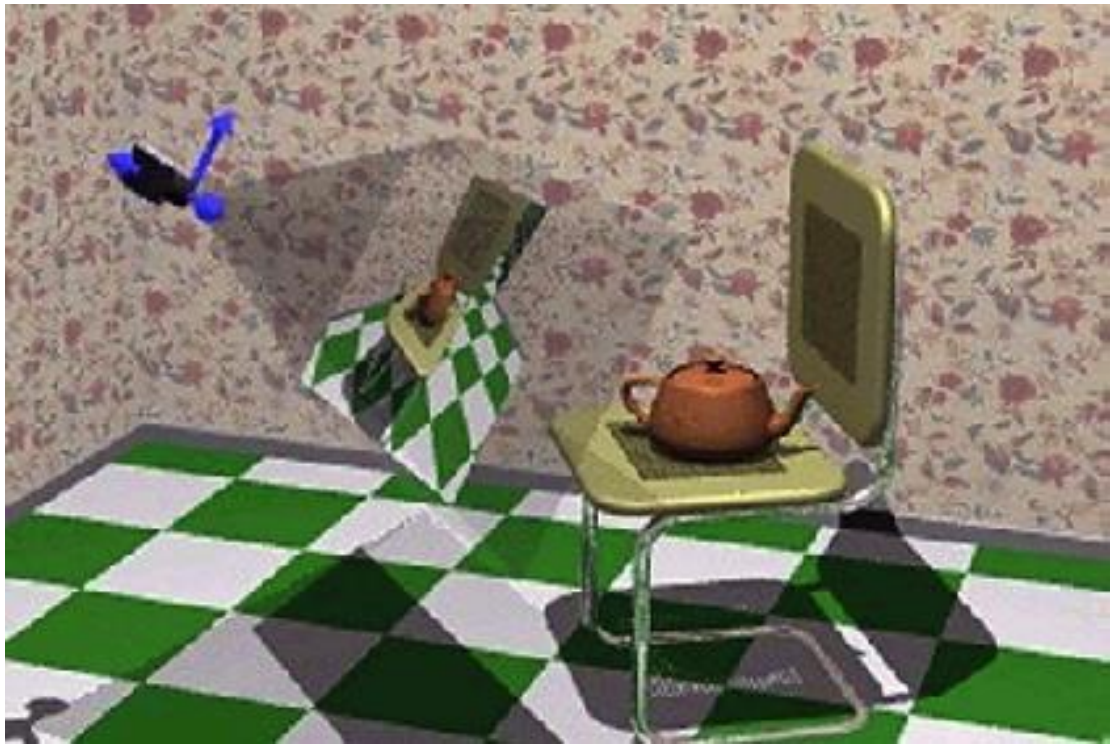
Outline

- Geometric Transformations
- Basic transformation
  - The coordinates
  - Hierarchy transformation
- Modeling
  - Mesh format / import
  - Unity ProBuilder

Transformation Terminology

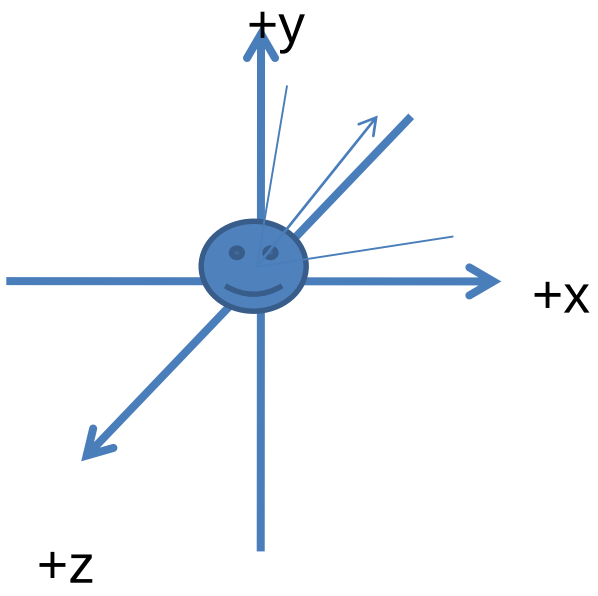
- Viewing
- Modeling
- Modelview
- Projection
- Viewport



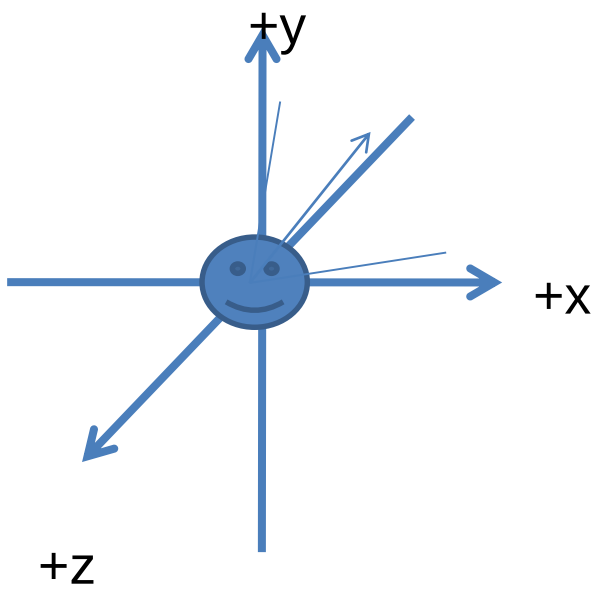
Transformations

- Translation
- Rotation
- Scaling

The Modelview Duality

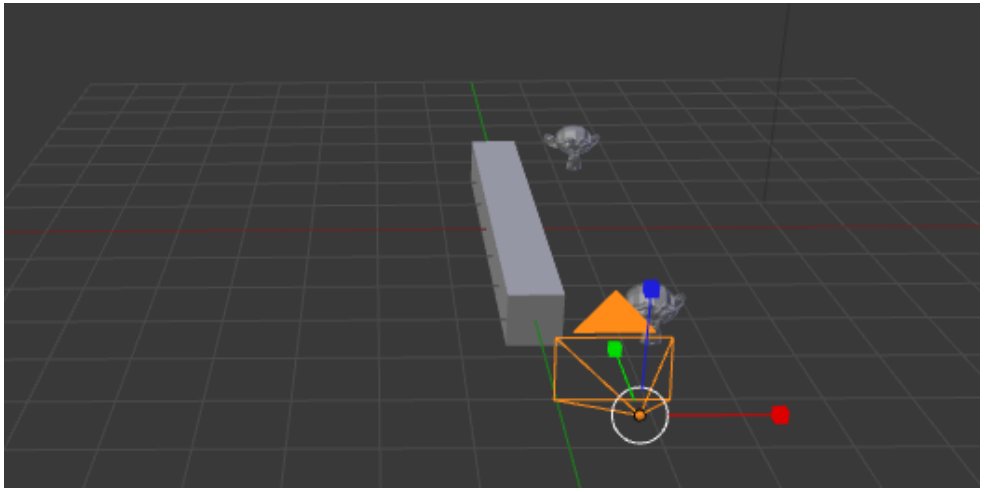


View moving

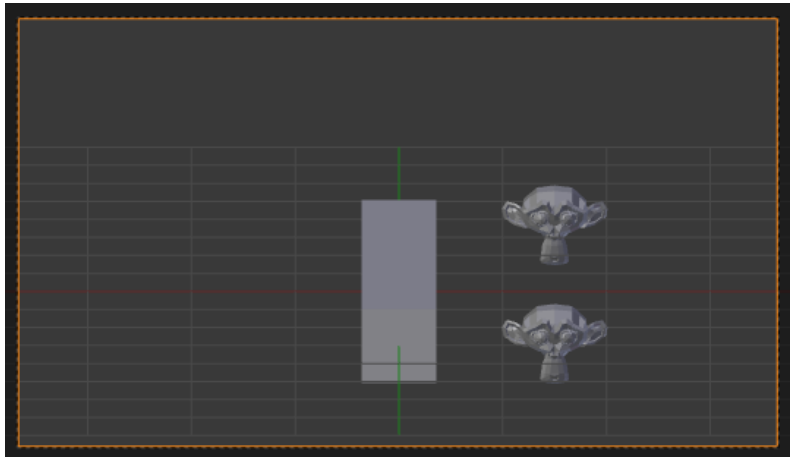


Model moving

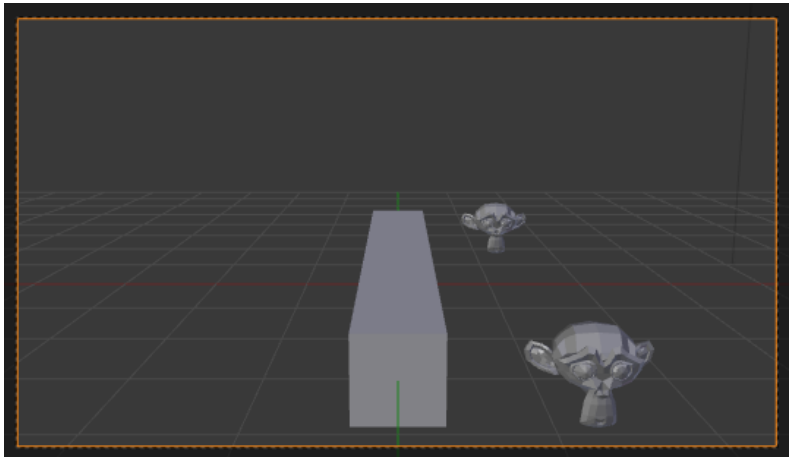
Projection



World space



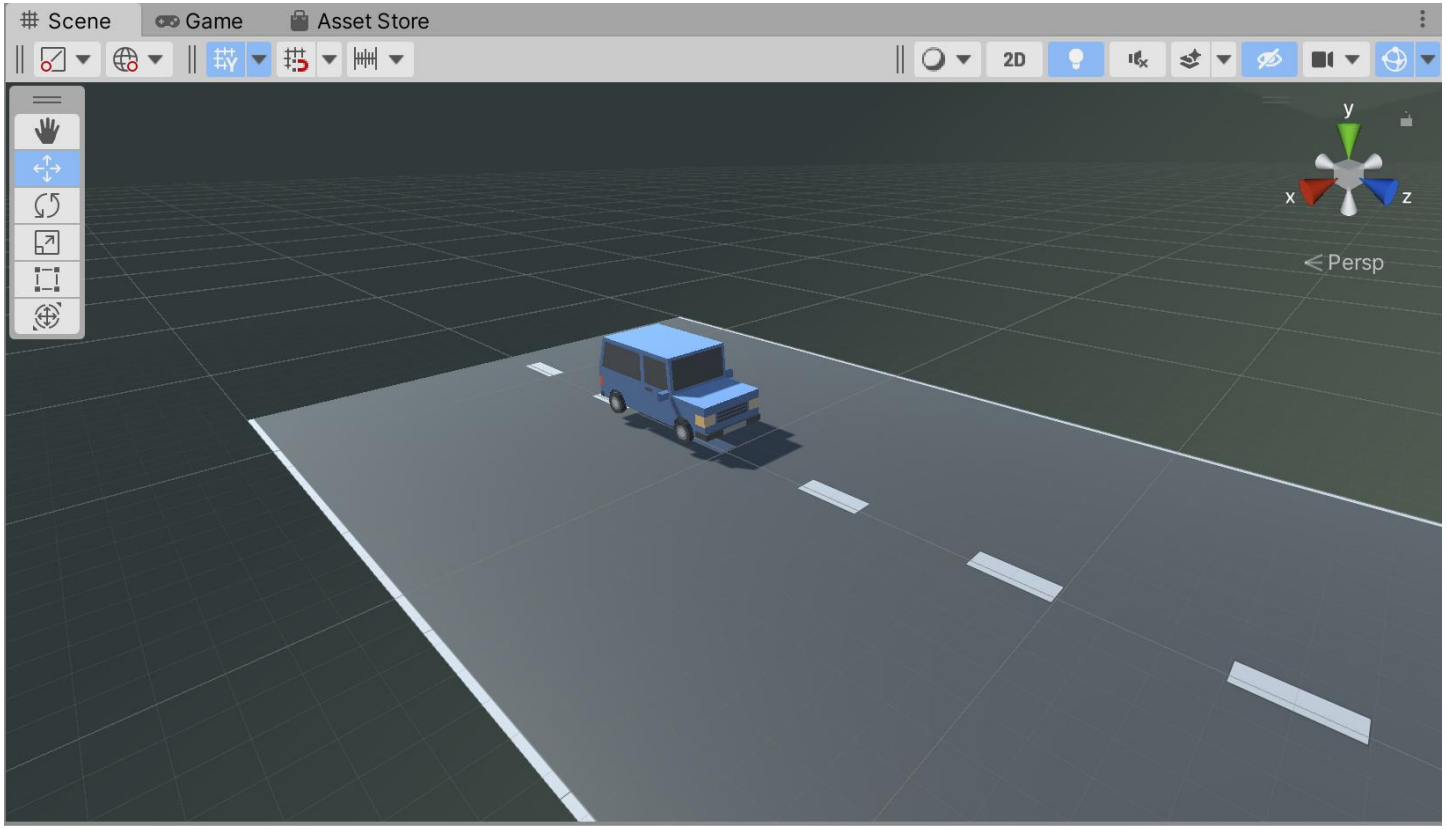
Orthographic



Perspective

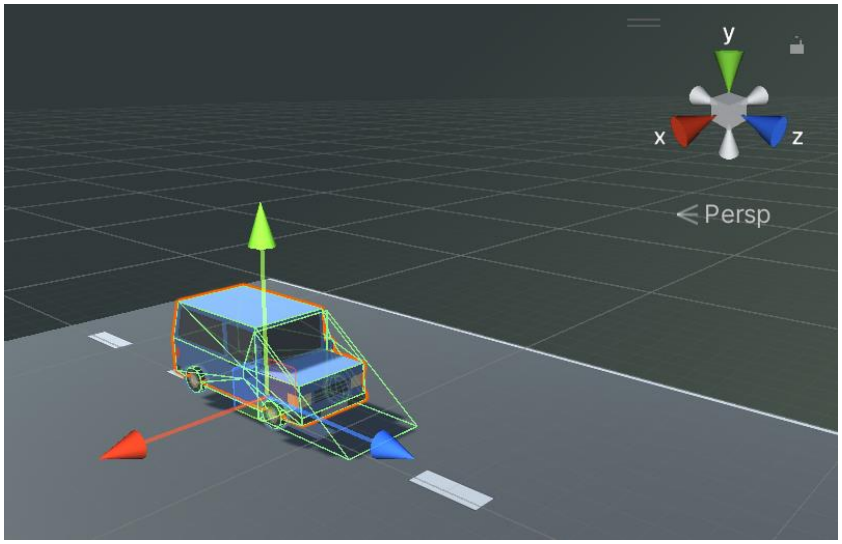
Transform

- Transform used to store and manipulate the position, rotation and scale of the object.



Coordinate System

- Unity is a Left-Handed Coordinate System



right	The red axis of the transform in world space.	X
up	The green axis of the transform in world space	Y
forward	the blue axis of the transform in world space.	Z

Vector3: **Static Properties**

Translate in Unity

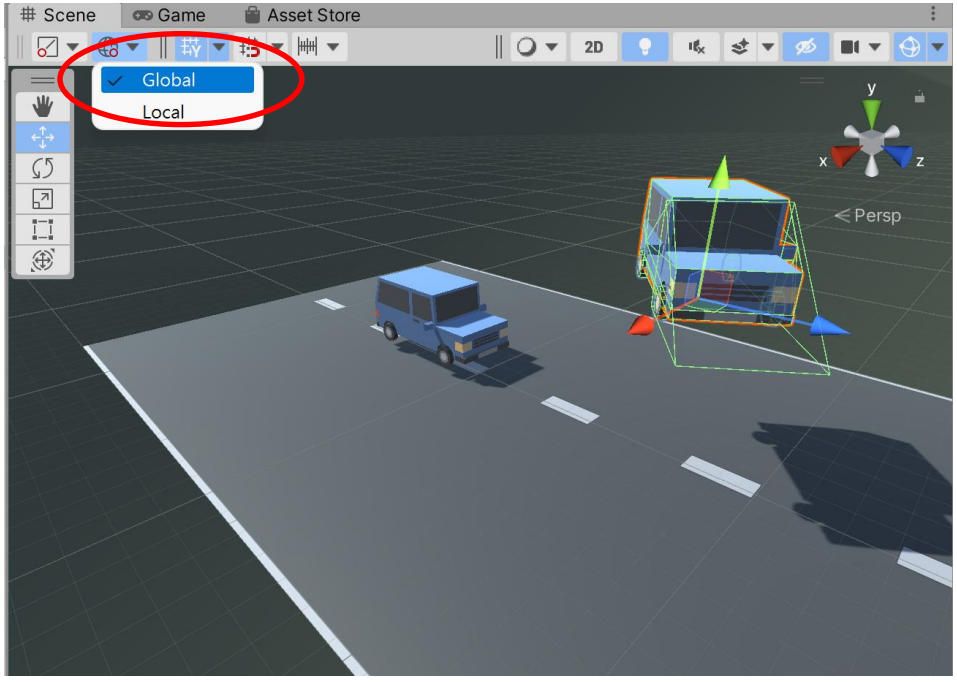
$$\begin{bmatrix} 1 & 0 & 0 & tx \\ 0 & 1 & 0 & ty \\ 0 & 0 & 1 & tz \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

- public void **Translate**(Vector3 **translation**, Space **relativeTo** = Space.Self);

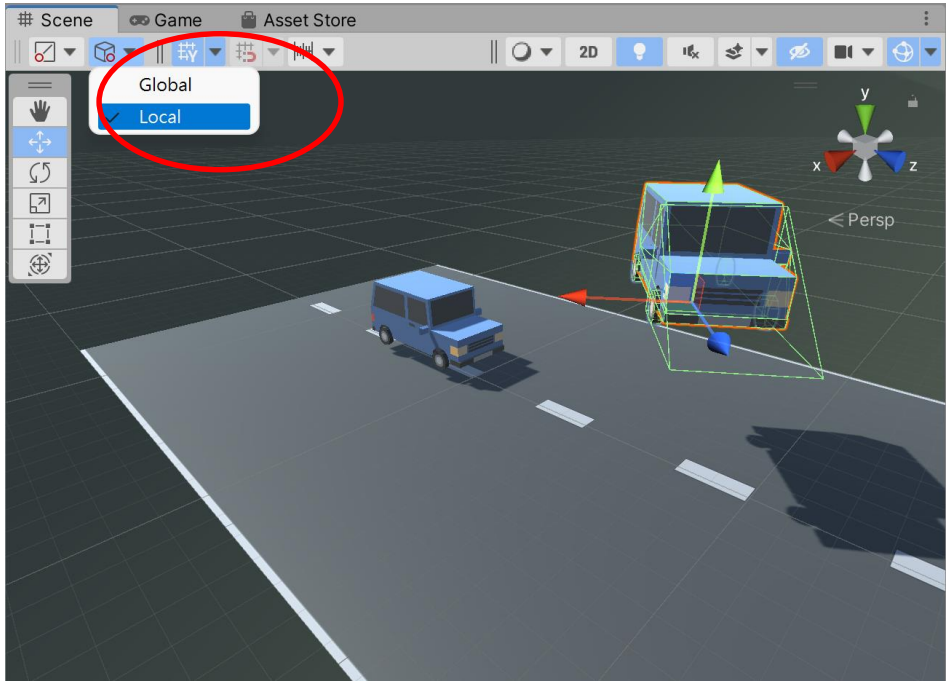
```
// Move the object forward along its z axis 1 unit/second.
transform.Translate(Vector3.forward * Time.deltaTime);

// Move the object upward in world space 1 unit/second.
transform.Translate(Vector3.up * Time.deltaTime, Space.World);
```

- public void **Translate**(float **x**, float **y**, float **z**);

Space



Space.World



Space.Self

Matrix/vector

$$\begin{bmatrix} 1 & 5 & 9 & 13 \\ 2 & 6 & 10 & 14 \\ 3 & 7 & 11 & 15 \\ 4 & 8 & 12 & 16 \end{bmatrix} \qquad \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \end{bmatrix}$$

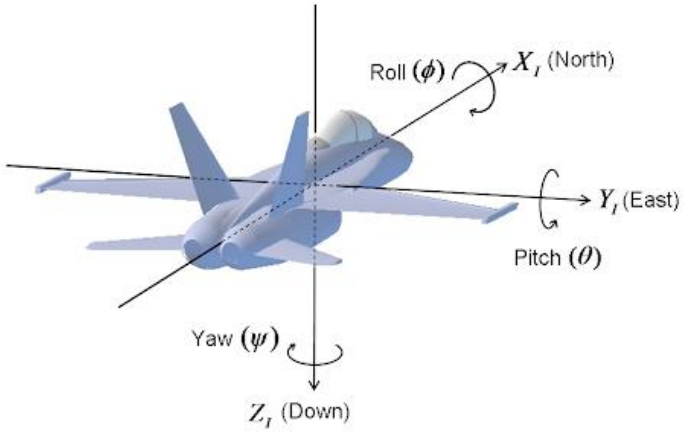
Scale

- public Vector3 localScale;
  - The scale of the transform relative to the GameObjects parent.

```
public float x = 0.1f;
public float y = 0.1f;
public float z = 0.1f;
void Update() {
    // Widen the object by x, y, and z values
    transform.localScale += new Vector3(x, y, z);
}
```

Rotate - Euler Angles

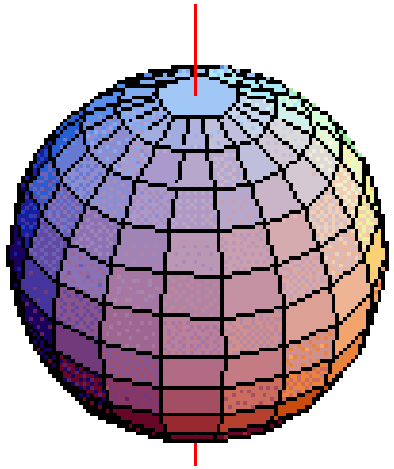
public
void **Rotate**(Vector3 **eulerAngles**, Space **relativeTo** = Space.Self);



Rotate – Axis

public void **Rotate**(Vector3 **axis**,
float **angle**, Space **relativeTo** = Space.Self);

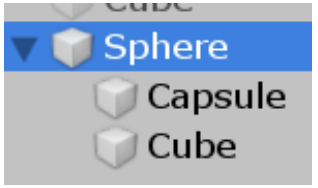
public
void **RotateAround**(Vector3 **point**, Vector3 **axis**,
float **angle**);

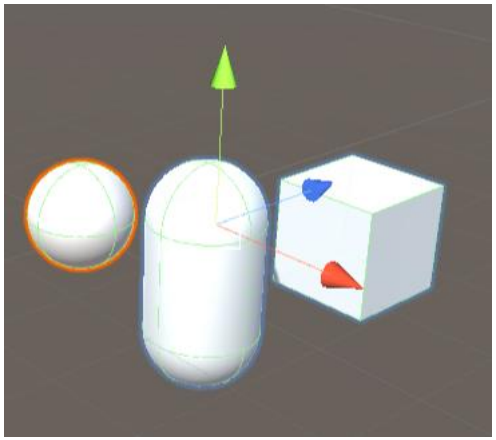


【傅老師】用一顆石頭架場景！！】

Parent/Child

```
// Moves all transform children 10 units upwards!
void Start()
{
    foreach (Transform child in transform)
    {
        child.position += Vector3.up * 10.0f;
    }
}
```





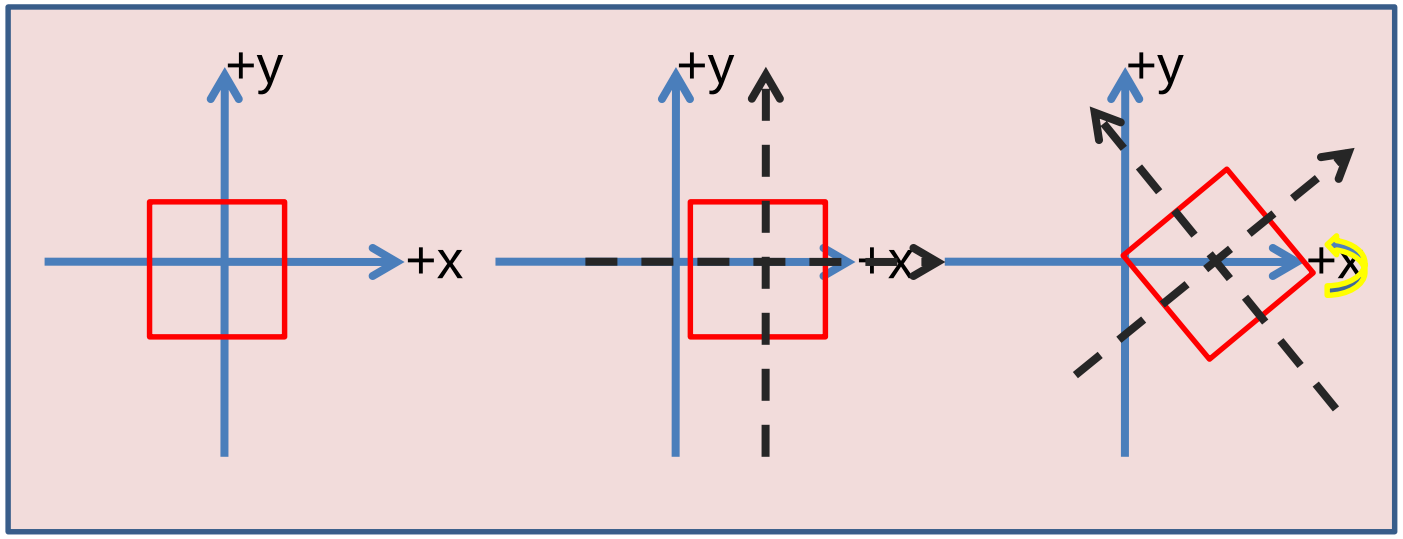
Reset to parent transform

```
transform.rotation = transform.parent.transform.rotation;
transform.localPosition = Vector3.zero;
transform.localScale = Vector3.one;
```

SetParent

```
public void Example(Transform newParent)
{
//Sets "newParent" as the new parent of the player GameObject.
player.transform.SetParent(newParent);

//Same as above, except this makes the player keep its local orientat
//rather than its global orientation.
player.transform.SetParent(newParent, false);
}
```

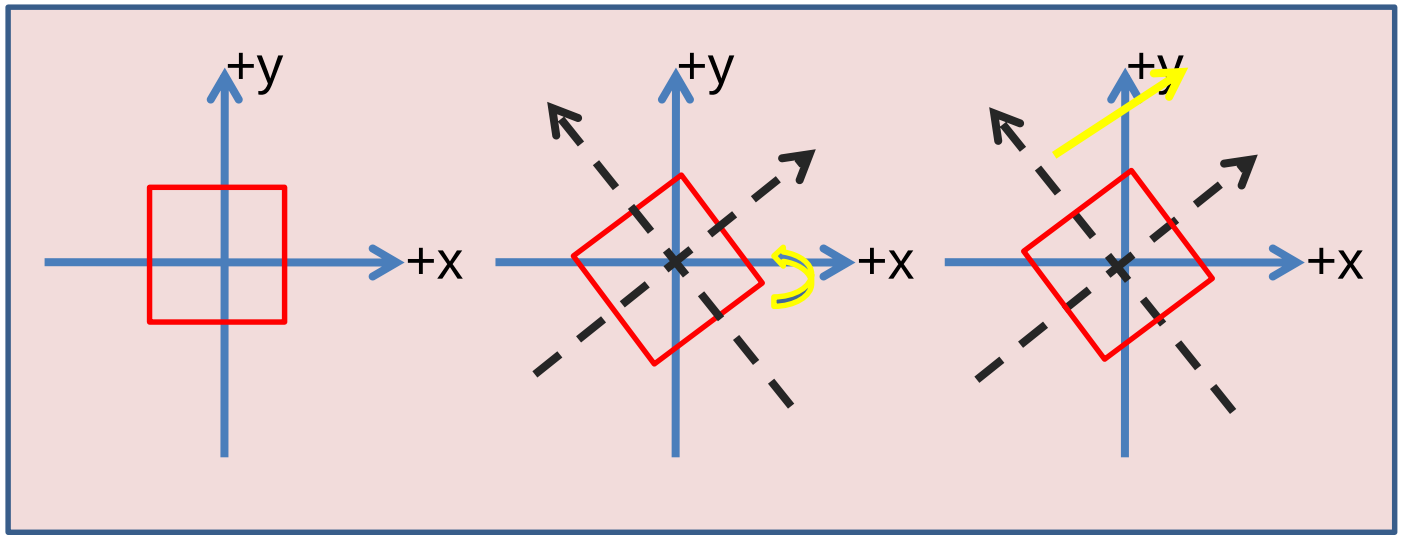
Rotation/Translation
from world to object



Translate()

Rotate()

Rect()

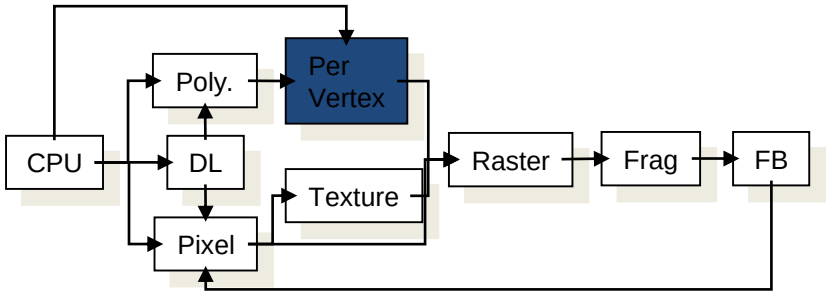


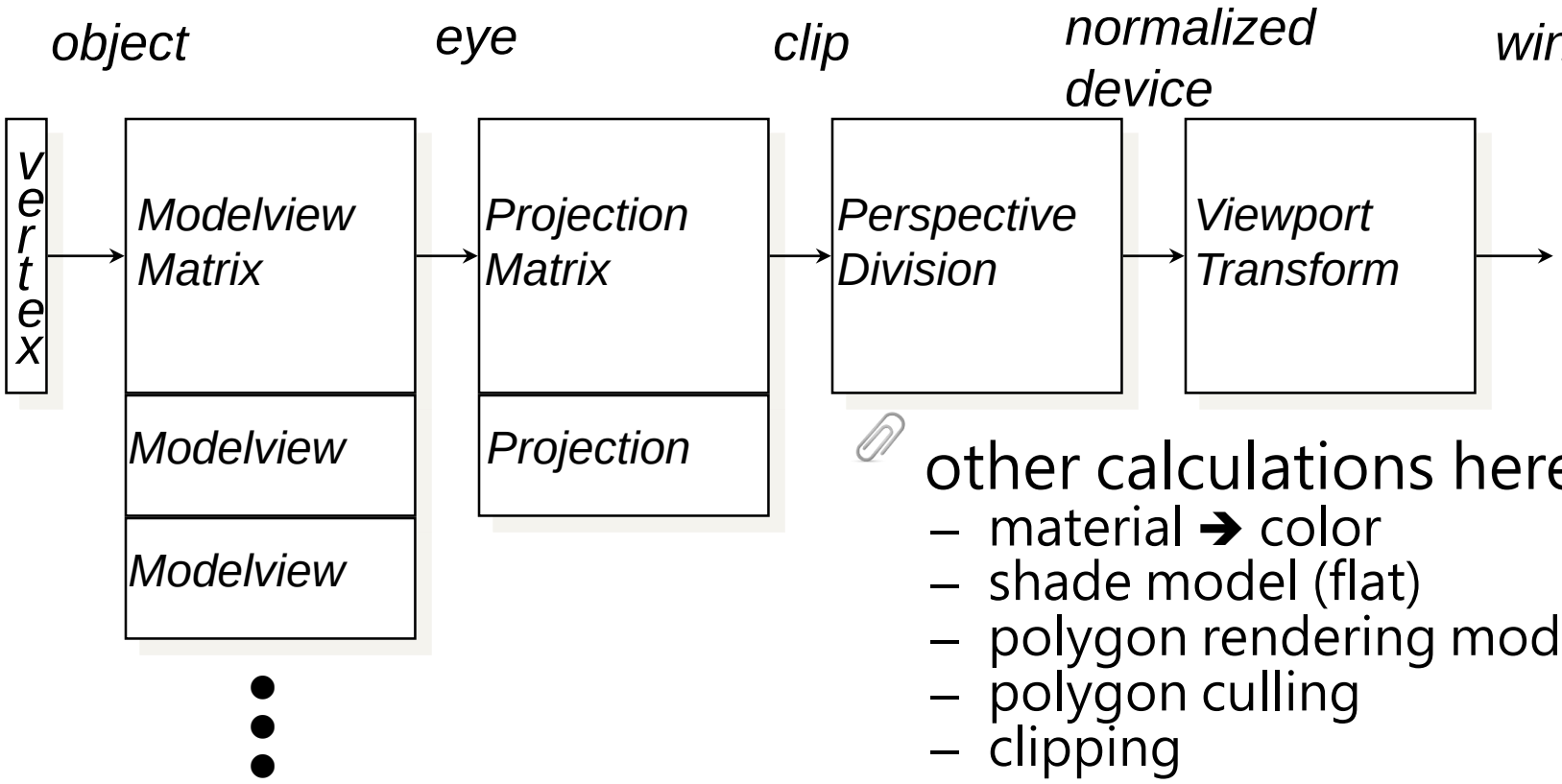
Rotate()

Translate()

Rect()

Transformation Pipeline





other calculations here
- material ➔ color
- shade model (flat)
- polygon rendering mode
- polygon culling
- clipping

The Life of a vertex

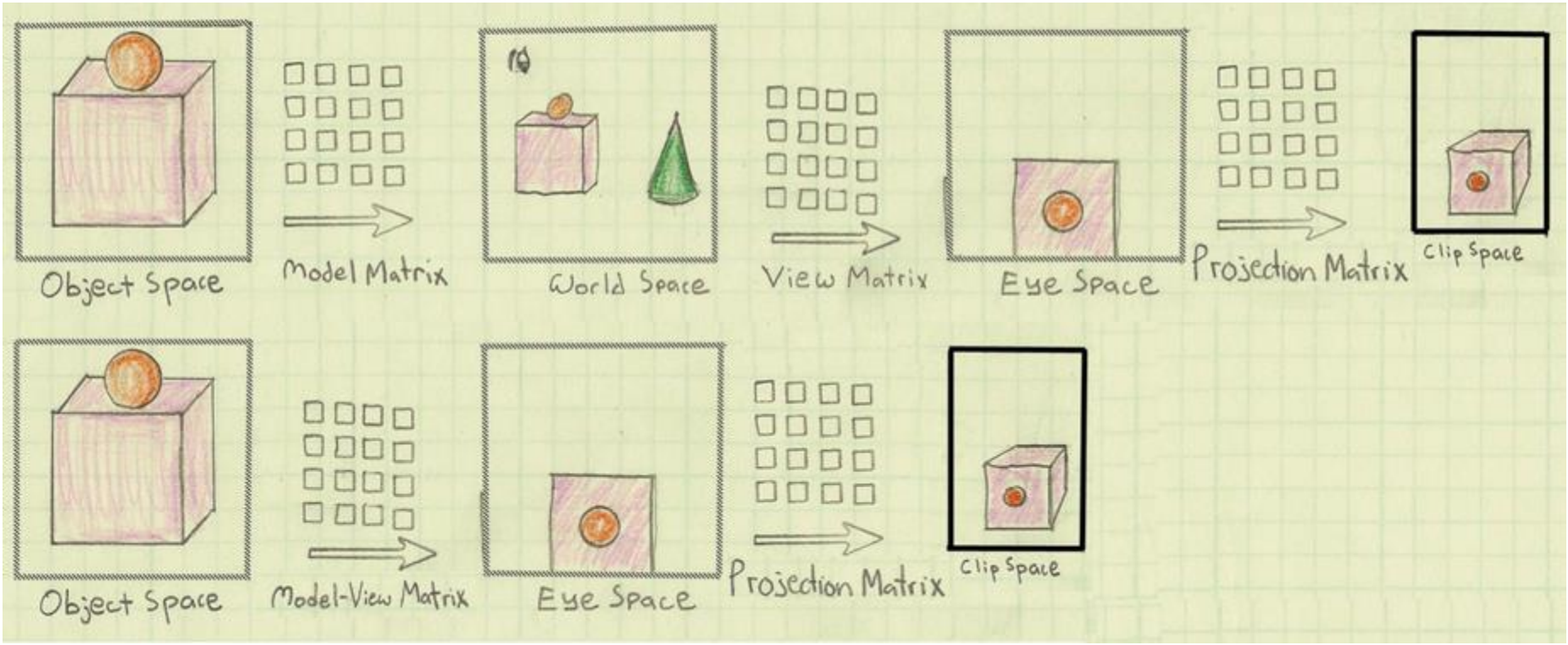
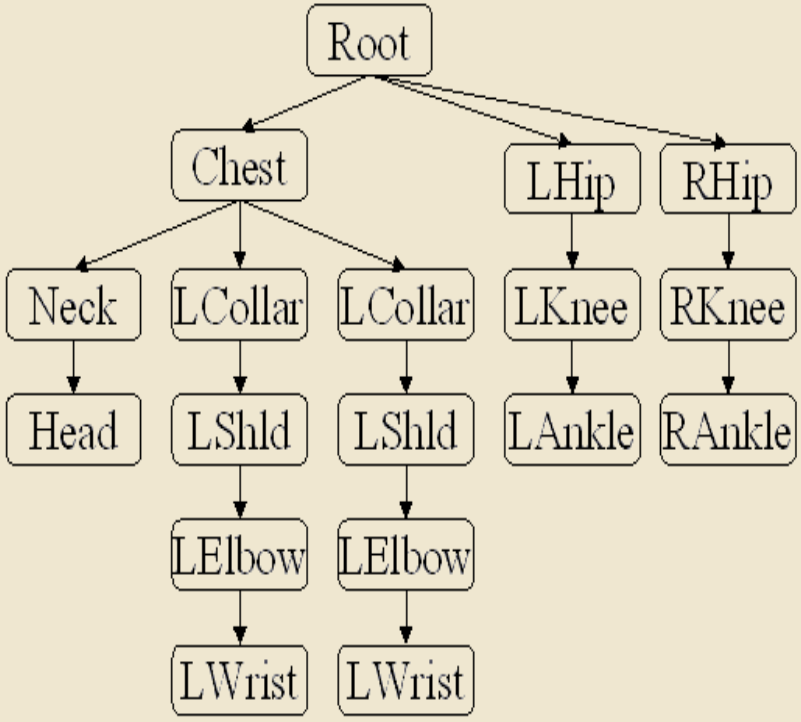
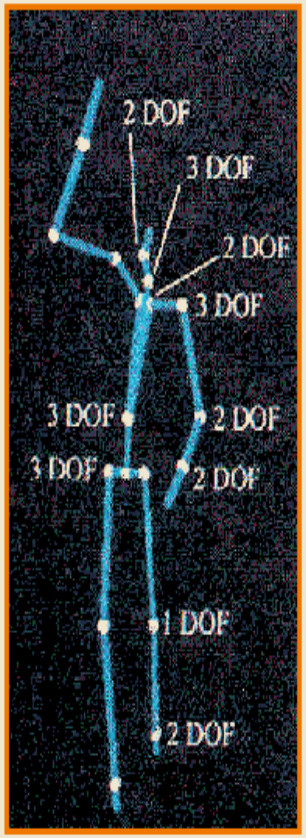


Image by Philp Rideout

Transformation Example 1

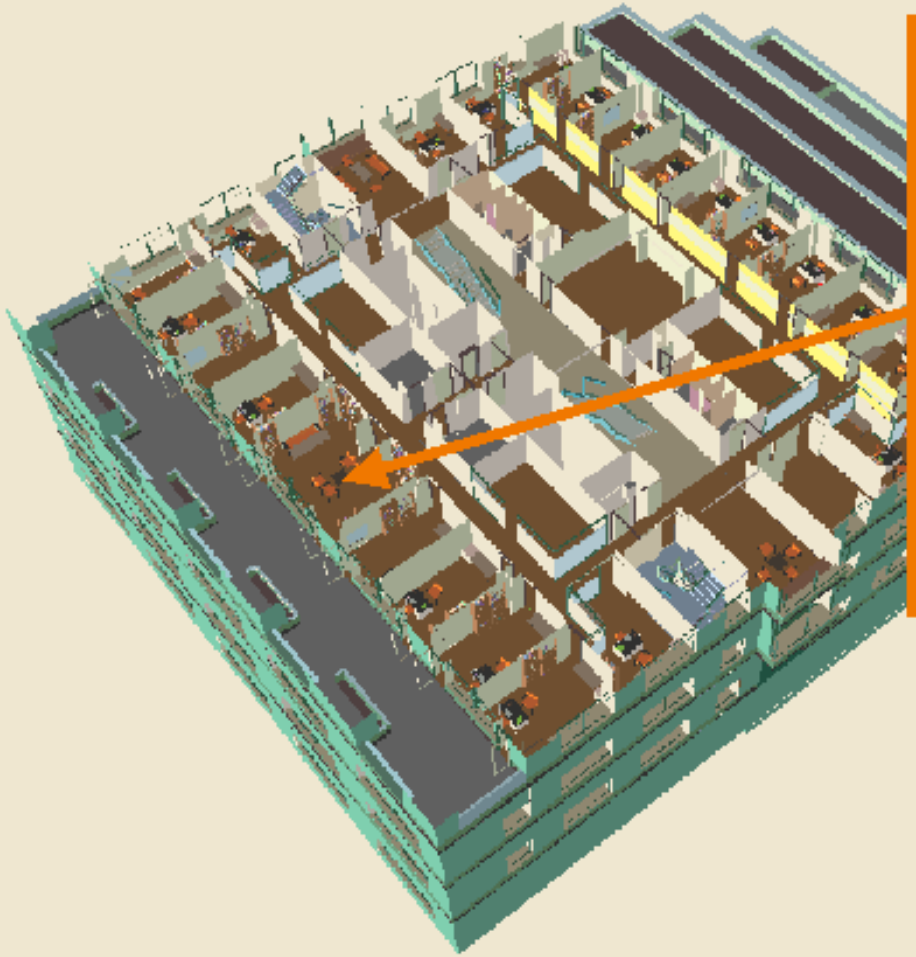
- Well-suited for humanoid characters

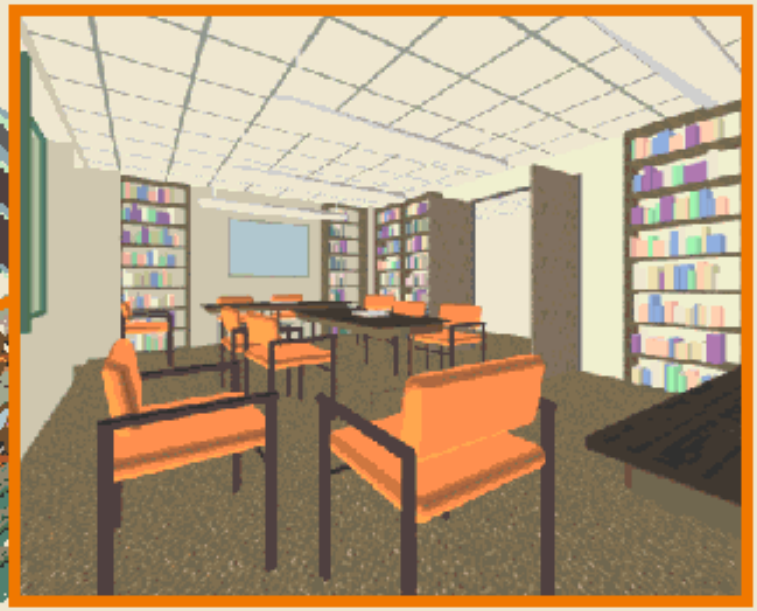




Transformation Example 2

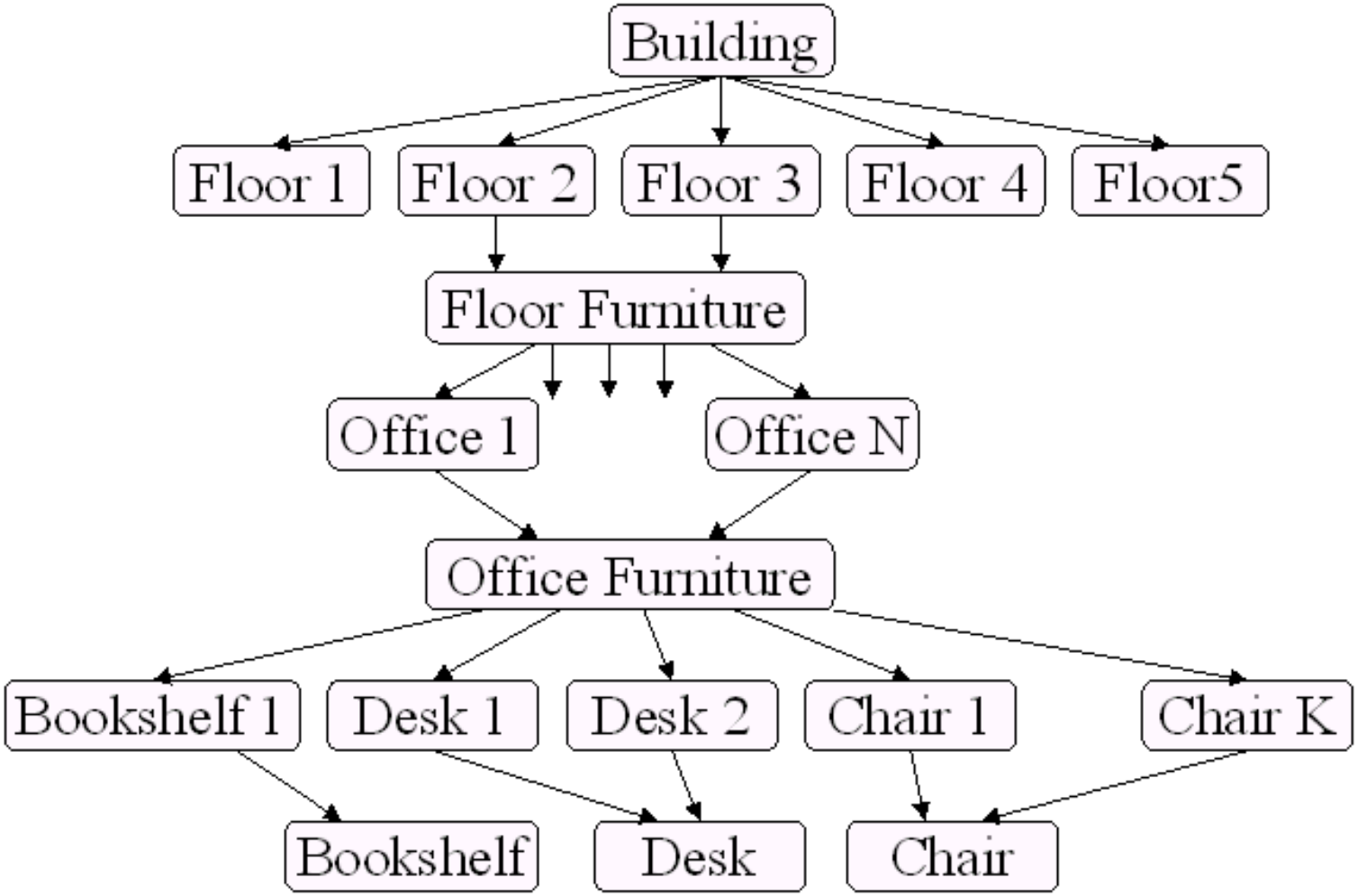
- An object may appear in a scene multiple times





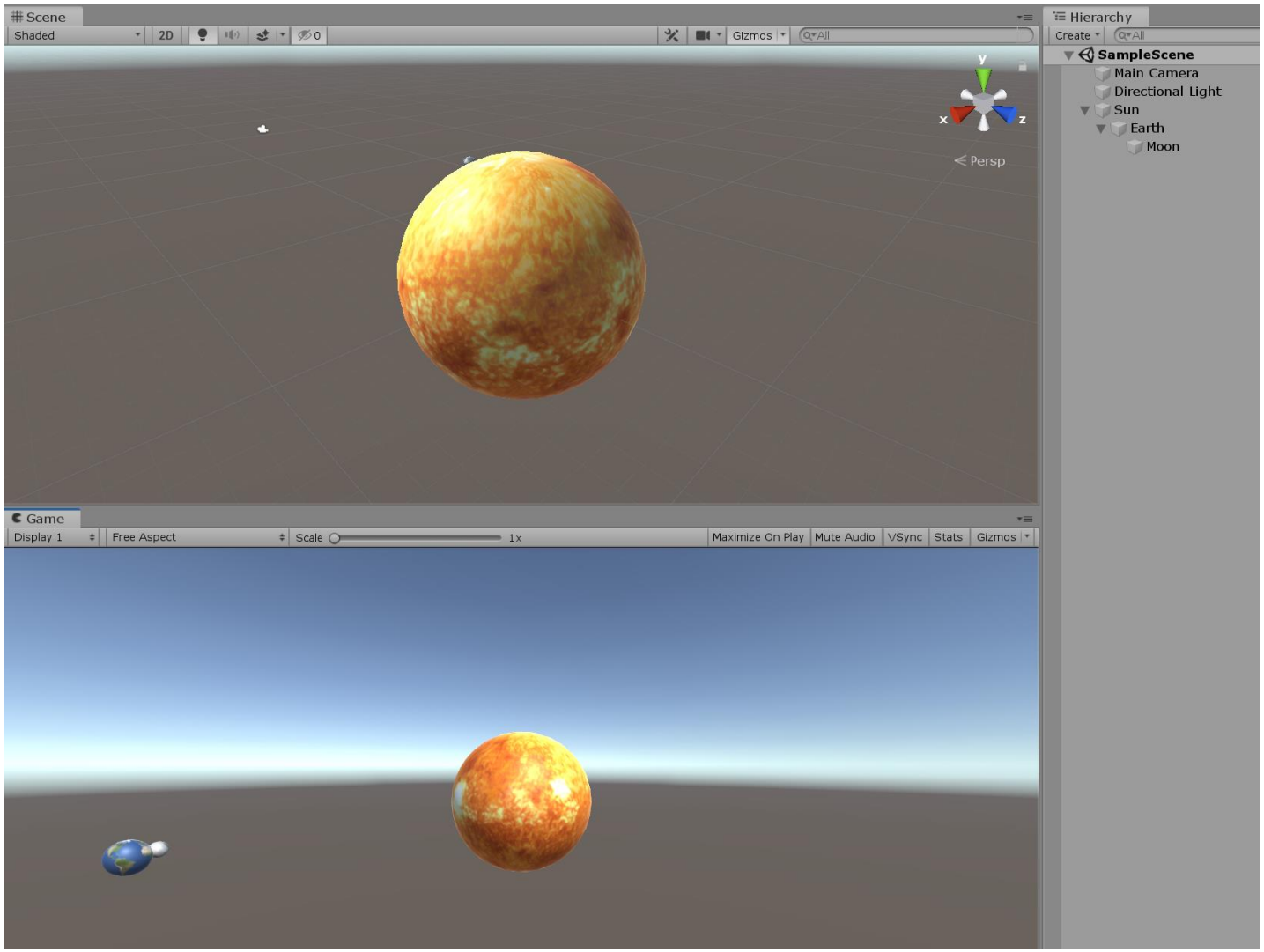
Draw same 3D data with different transformations

Transformation Example 2

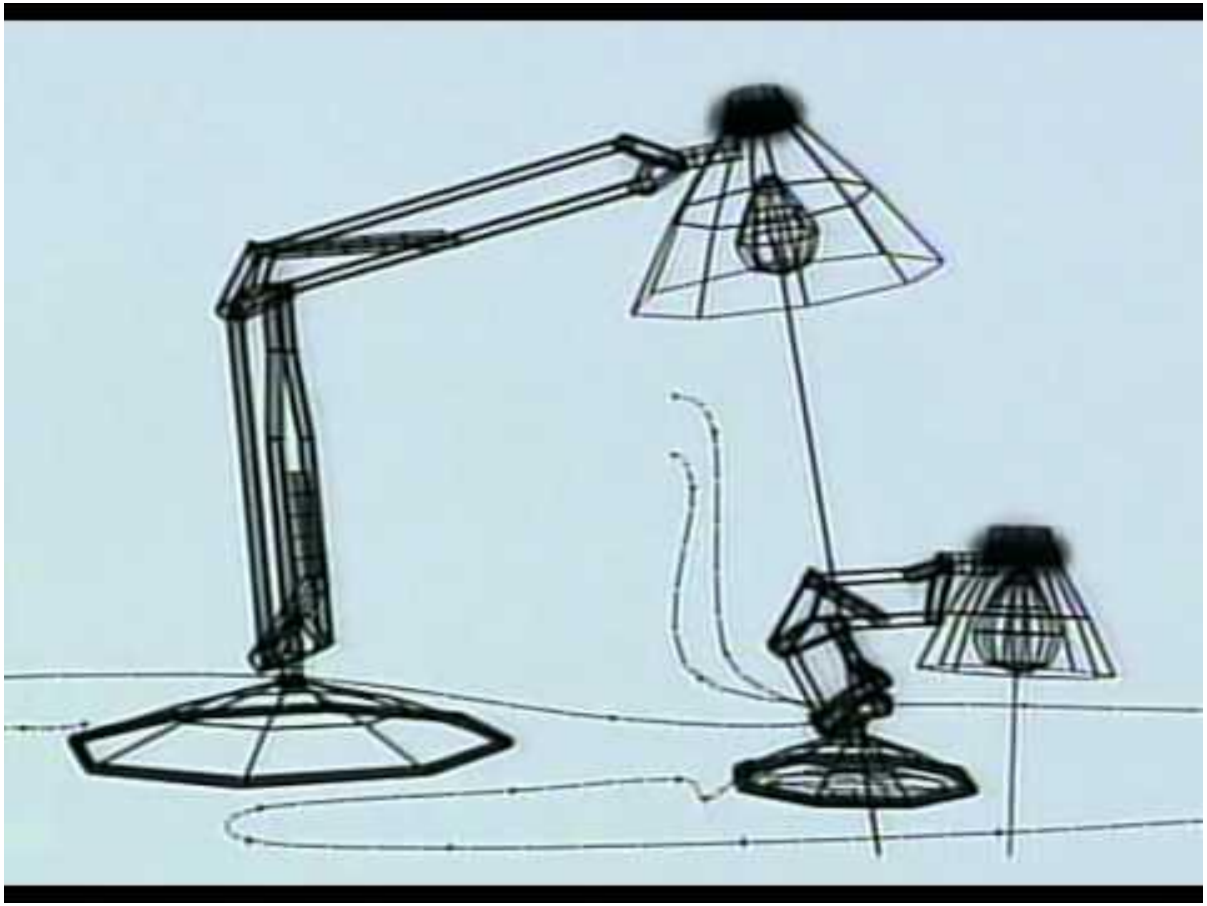


Sun Earth Moon

Assets download



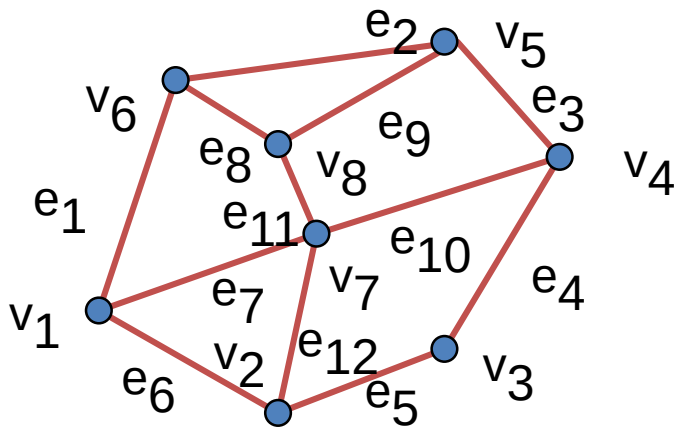
Luxo Jr [Pencil Test] [1986]



MESH FORMAT

Representing a Mesh

- Consider a mesh



- There are 8 nodes and 12 edges
  - 5 interior polygons
  - 6 interior (shared) edges
- Each vertex has a location $v_i = (x_i\ y_i\ z_i)$

3D model format

SIMPLE

- Triangle
  vertex1_X vertex1_Y vertex1_Z normal1_X normal1_Y normal1_Z
  vertex2_X vertex2_Y vertex2_Z normal2_X normal2_Y normal2_Z
  vertex3_X vertex3_Y vertex3_Z normal3_X normal3_Y normal3_Z

COLOR

- Triangle
  frontcolor_R frontcolor_G frontcolor_B backcolor_R backcolor_G backcolor_B
  vertex1_X vertex1_Y vertex1_Z normal1_X normal1_Y normal1_Z
  vertex2_X vertex2_Y vertex2_Z normal2_X normal2_Y normal2_Z
  vertex3_X vertex3_Y vertex3_Z normal3_X normal3_Y normal3_Z

Simple Representation

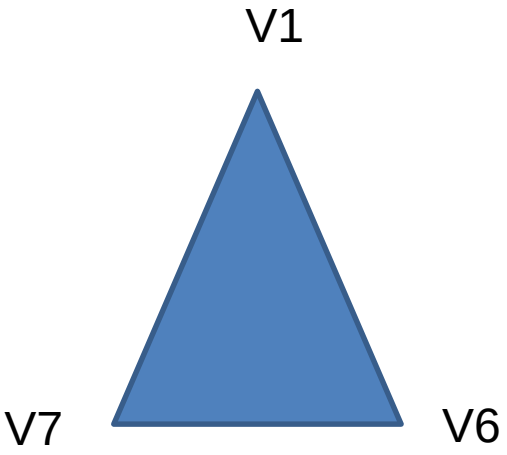
- Define each polygon by the geometric locations of its vertices
- Leads to OpenGL code such as

```
glBegin(GL_POLYGON);
    glVertex3f(x1, x1, x1);
    glVertex3f(x6, x6, x6);
    glVertex3f(x7, x7, x7);
glEnd();
```

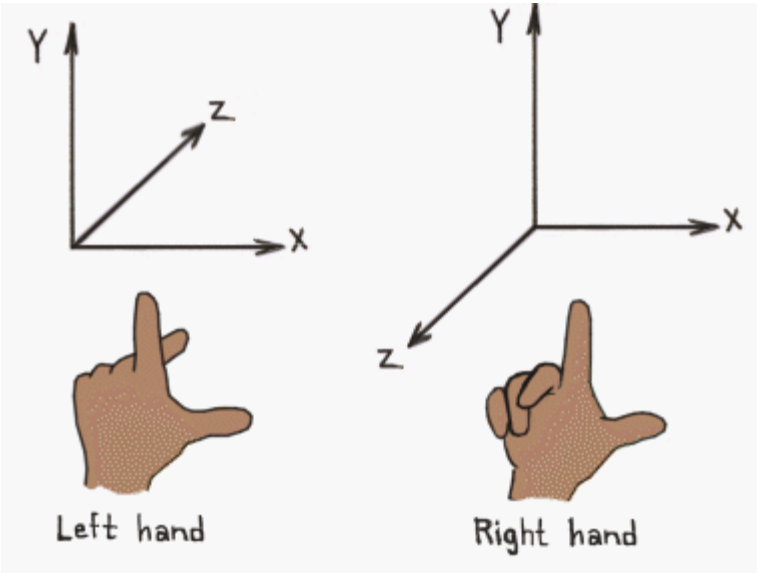
- Inefficient and unstructured
  - Consider moving a vertex to a new location
  - Must search for all occurrences

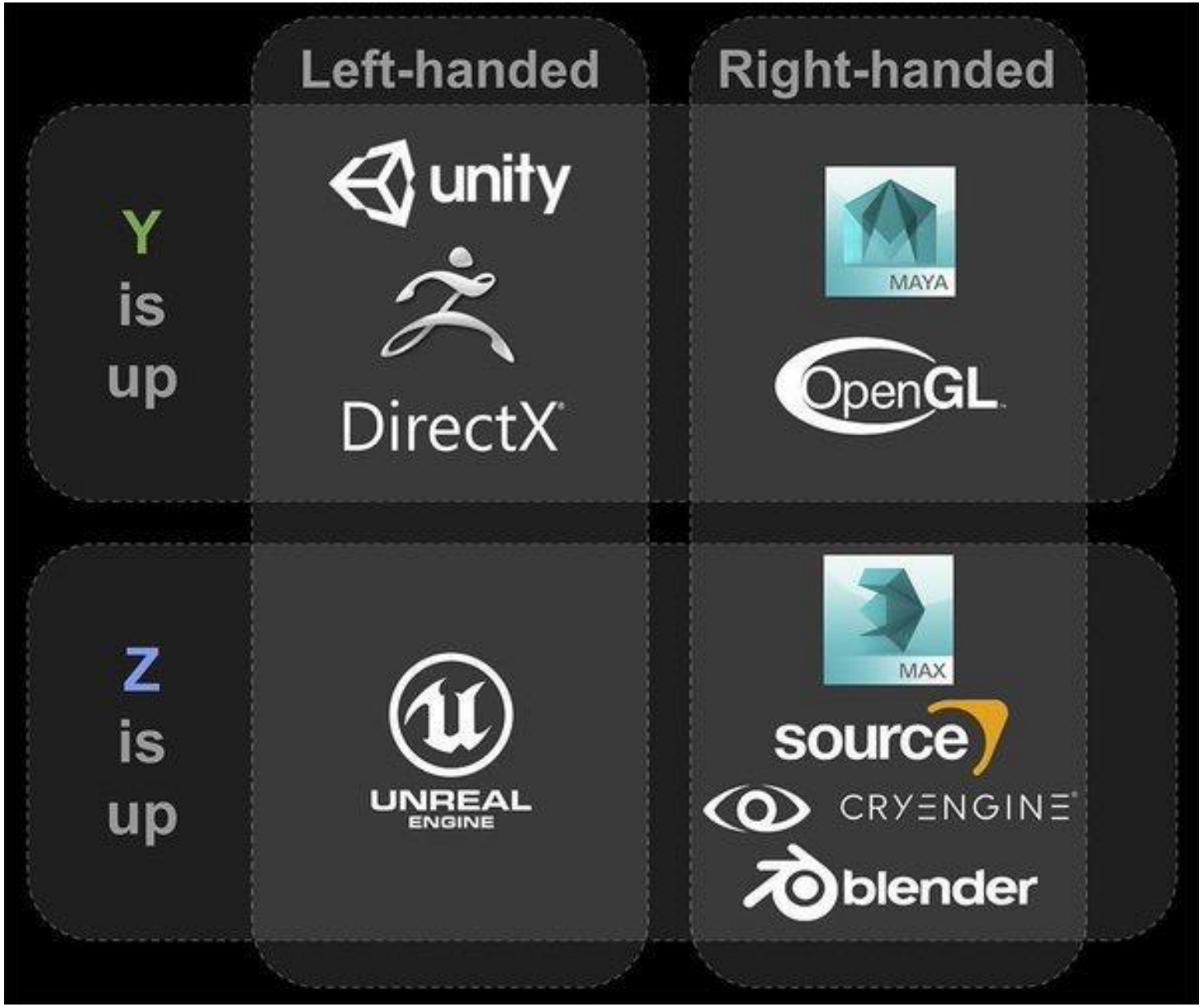
Inward and Outward Facing Polygons

- The order $\{v_1, v_6, v_7\}$ and $\{v_6, v_7, v_1\}$ are equivalent in that the same polygon will be rendered but the order $\{v_1, v_7, v_6\}$ is different.



- Use the *left-hand rule* = clockwise encirclement of outward-pointing normal




Left-handed
Right-handed
Y
is
up
unity
DirectX
MAYA
OpenGL
Z
is
up
UNREAL
ENGINE
MAX
source
CRYENGINE
blender

Wavefront obj format

#example obj file

v -1.63326156 -3.04798102 -8.81131839

....

vn 0.00379090 0.40057179 0.01256634

...

vt 0.22390614 0.97395277 (texture)

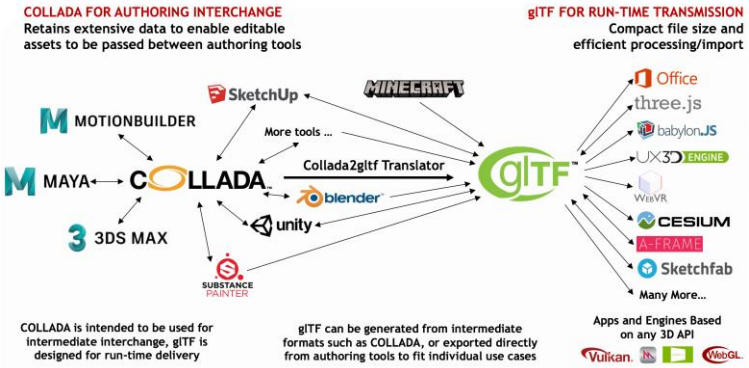
...

f 4/2/4 3/1/3 2/2/2 (index to v/t/n)

Reference

- obj format http://www.martinreddy.net/gfx/3d/OBJ.spec
- ply format
- STL format - http://en.wikipedia.org/wiki/STL_(file_format)

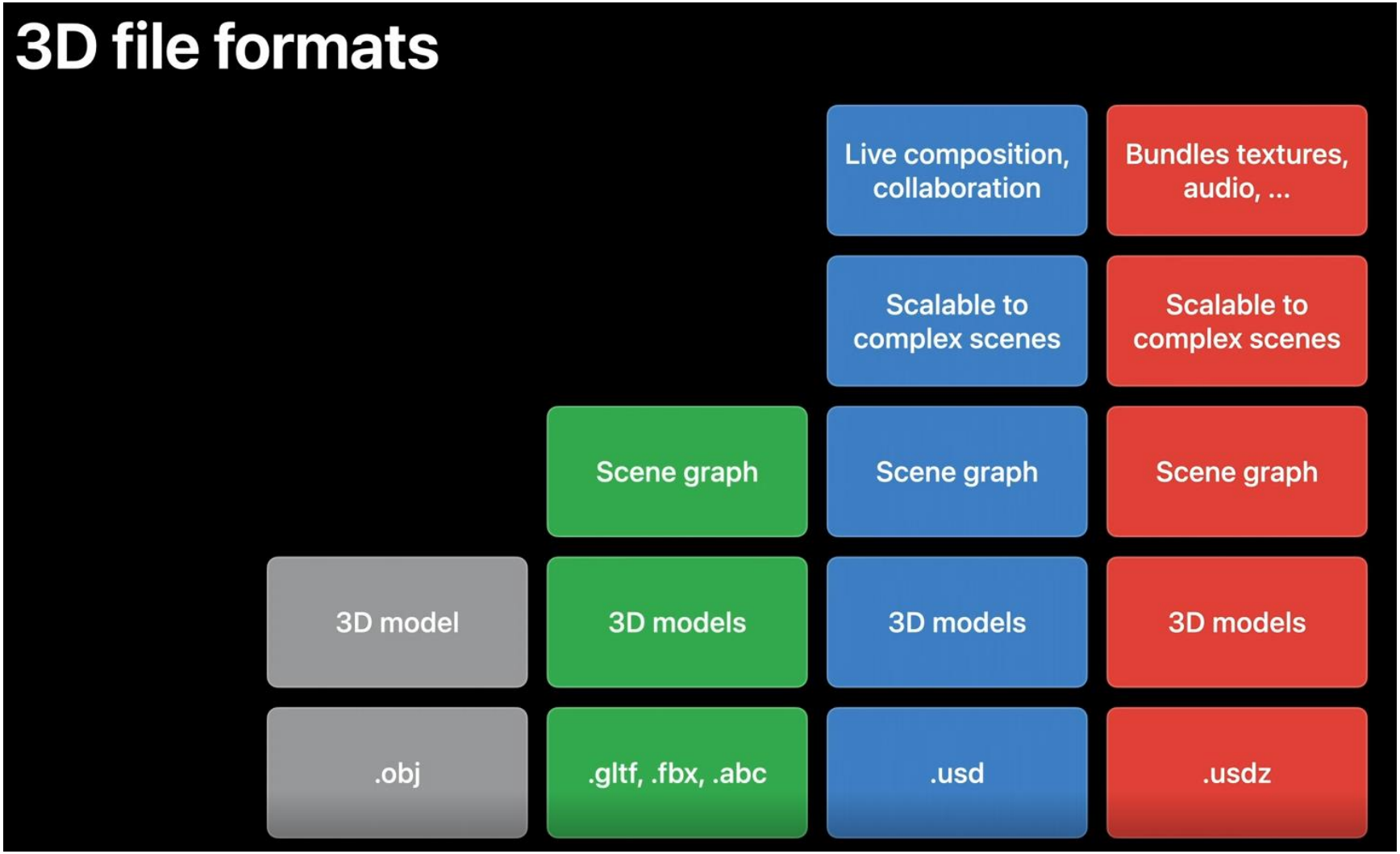
Scene Graph



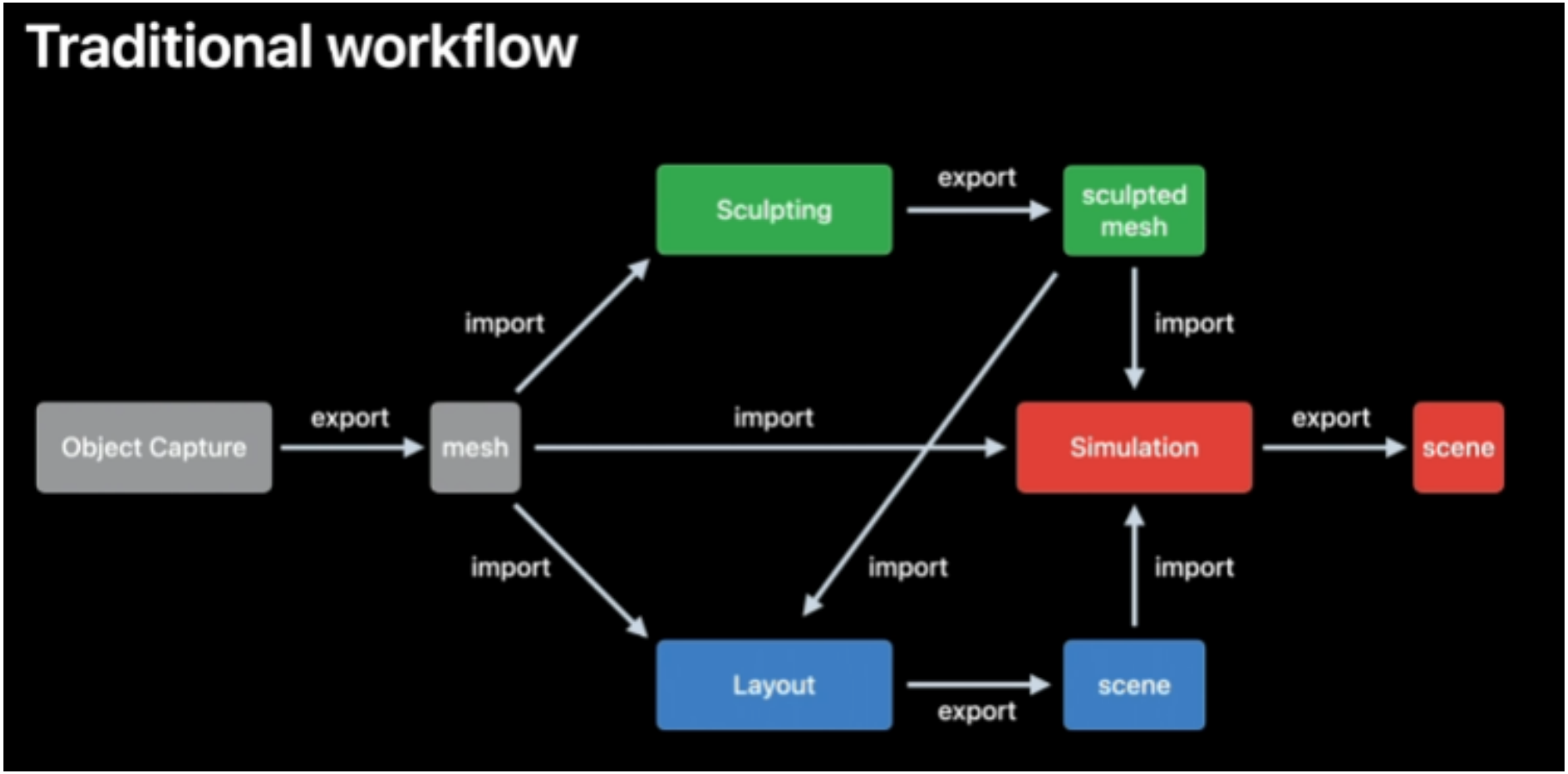
- FBX (**Film**box) by Autodesk
- COLLADA (***COLLA**borative **D**esign **A**ctivity*)
- Alembic by sony

- USD (Universal Scene Description) by pixar
  - Five Things to Know About USD

Universal Scene Description, USD (WWDC 2021)



Create 3D workflows with USD (WWDC 2021)



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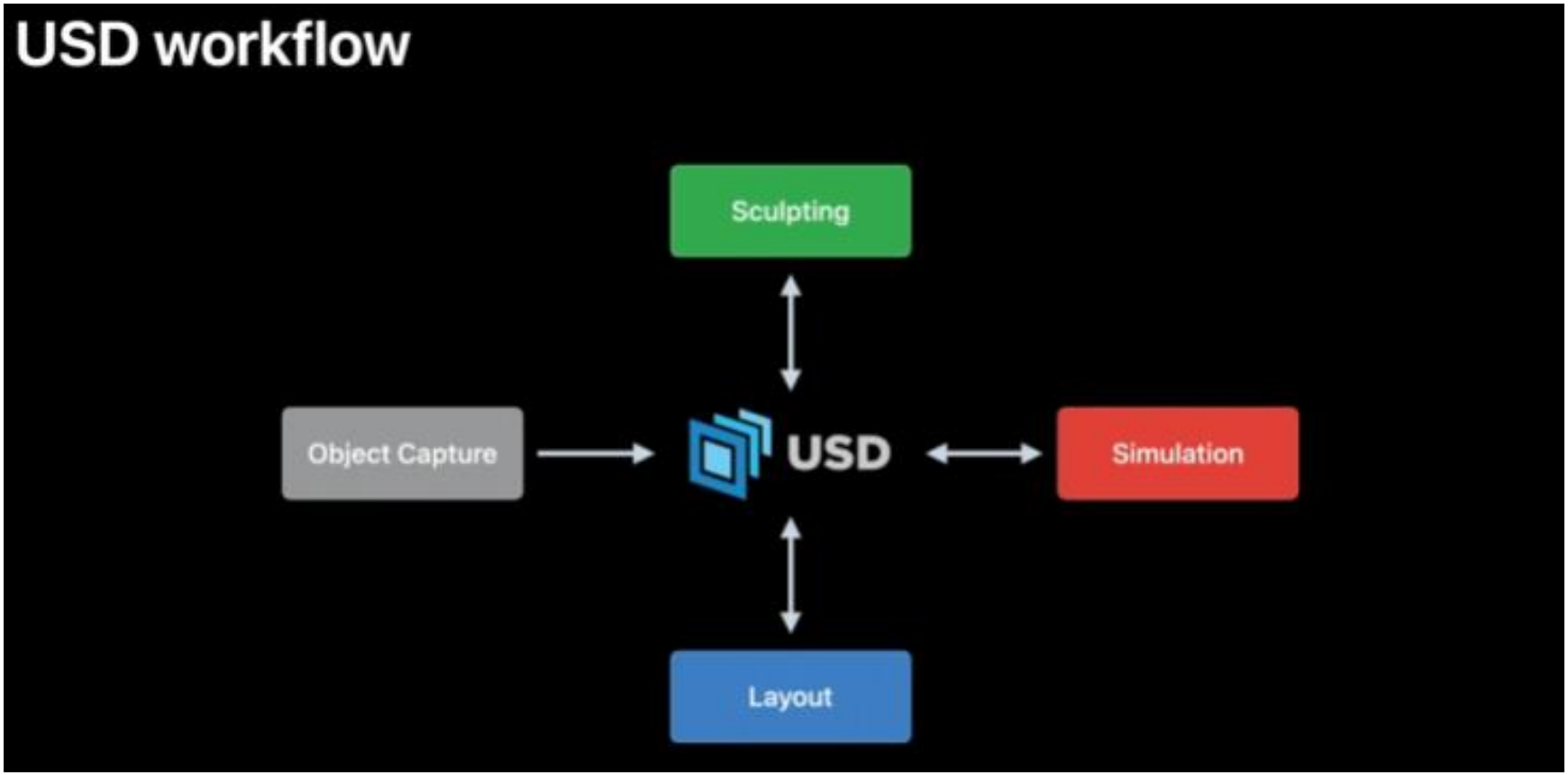


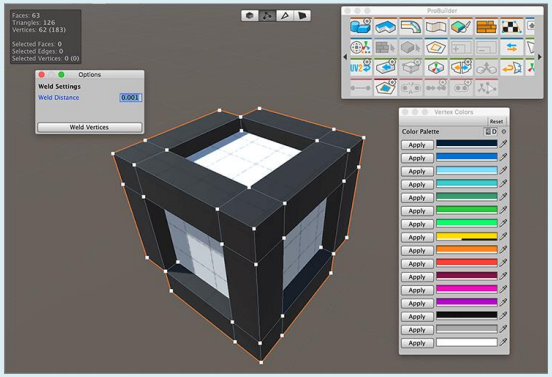
Create 3D workflows with USD (WWDC 2021)

PROBUILDER

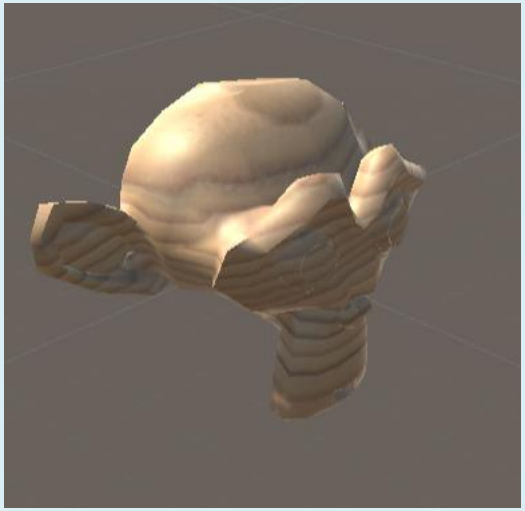
Building and editing complex Meshes inside Unity

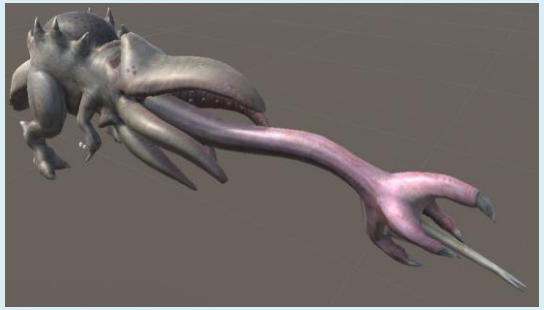
Modeling

Assemble
with Primitive



ProBuilder
inside Unity

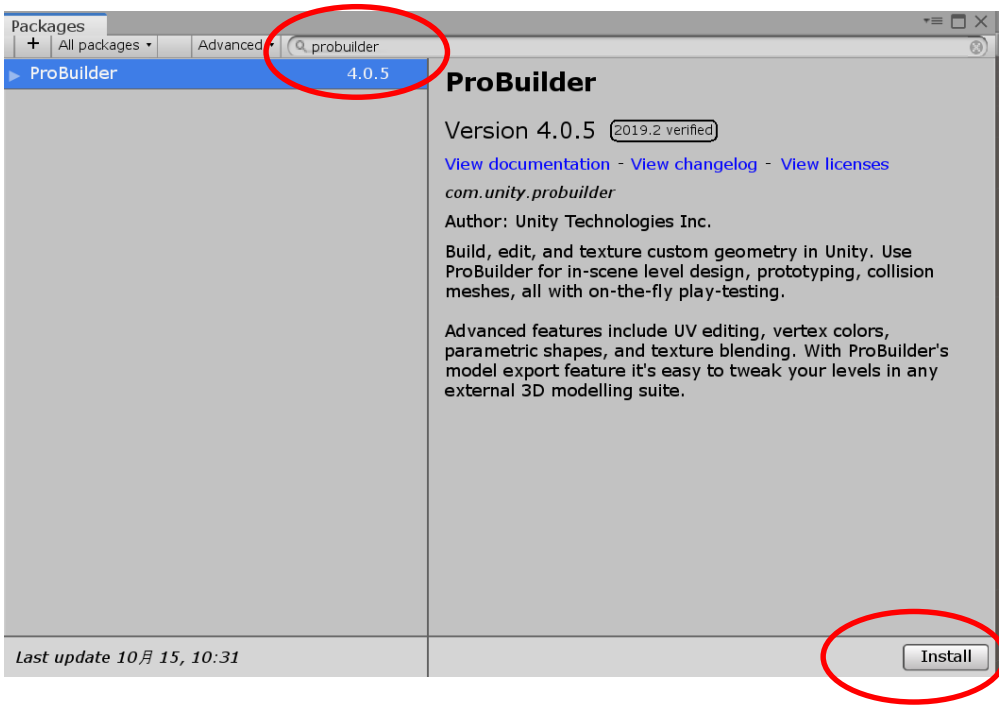




Import
from modeling
tools

Installing ProBuilder

- Open the Package Manager (in Unity's top menu: **Window** > **Package Manager**).
- Enter **ProBuilder** in the search box.
- Click **ProBuilder** in the package list (left side), then click the **Install** button in the package details (right side).



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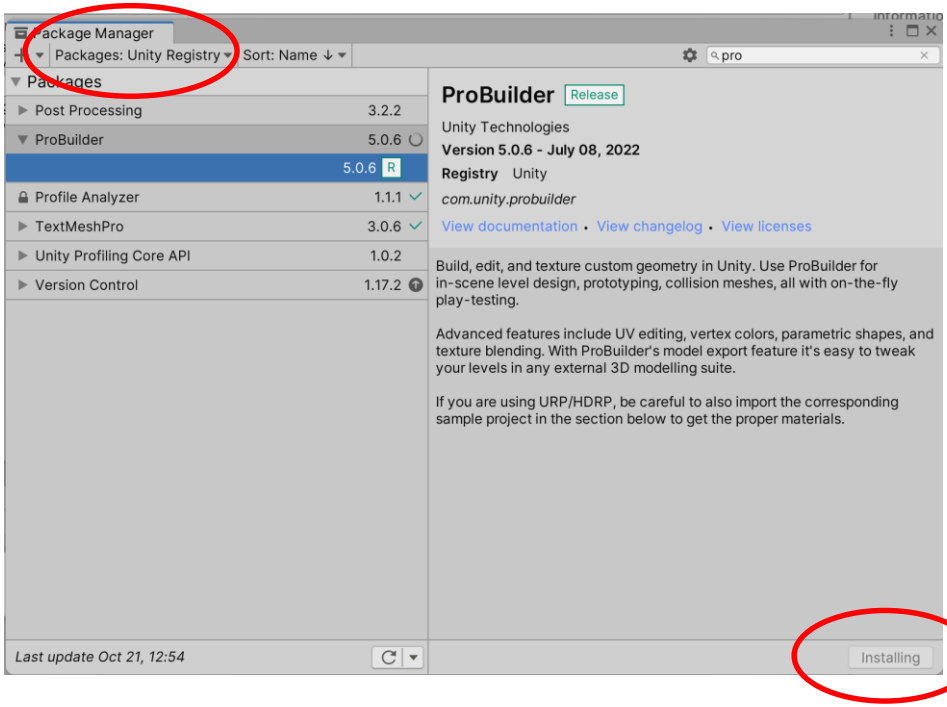
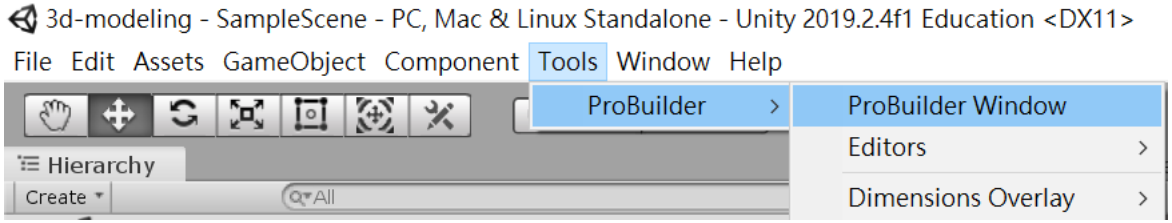
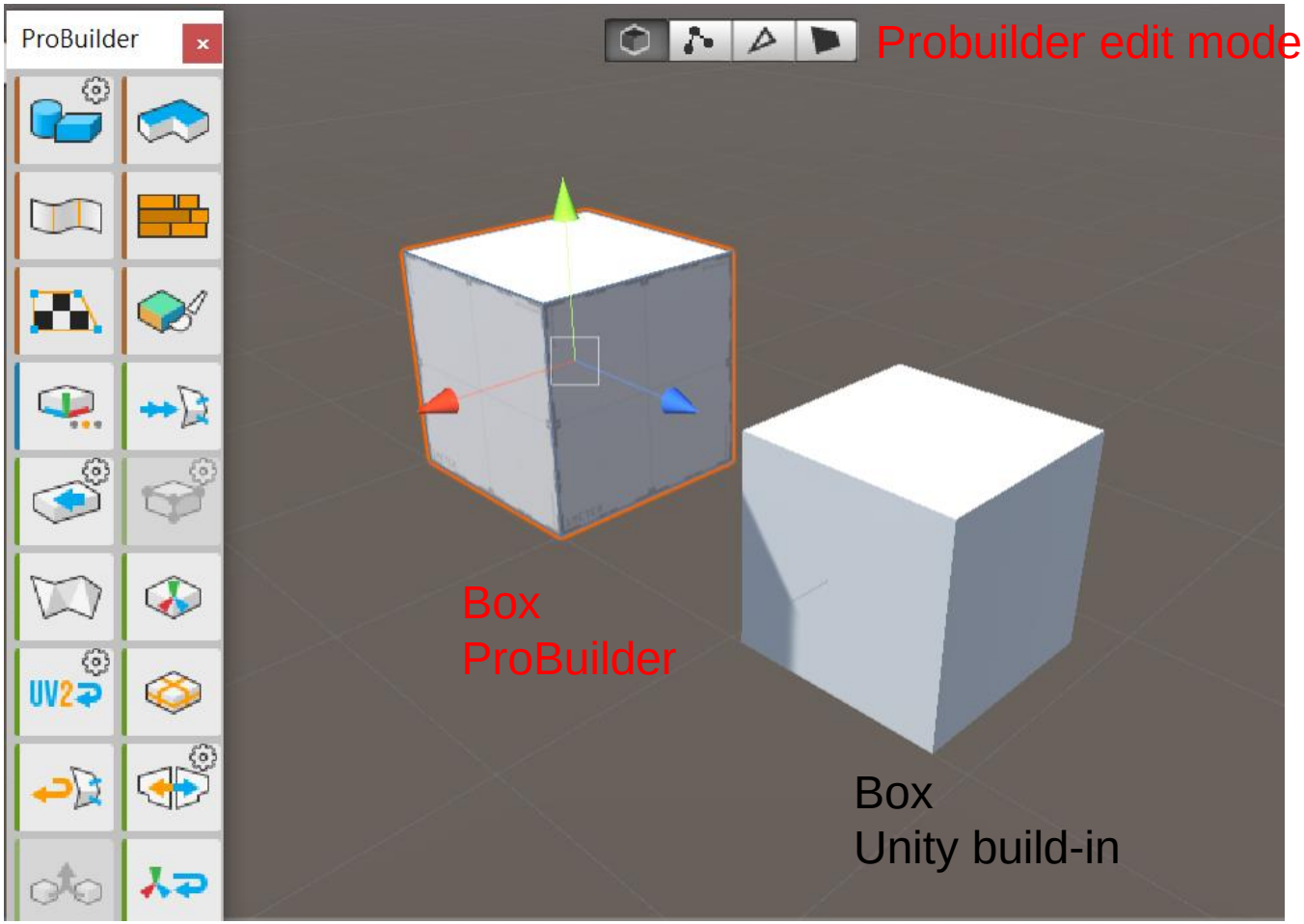


To verify that ProBuilder is correctly installed, open the ProBuilder toolbar (from Unity's top menu: **Tools** > **ProBuilder** > **ProBuilder Window**).

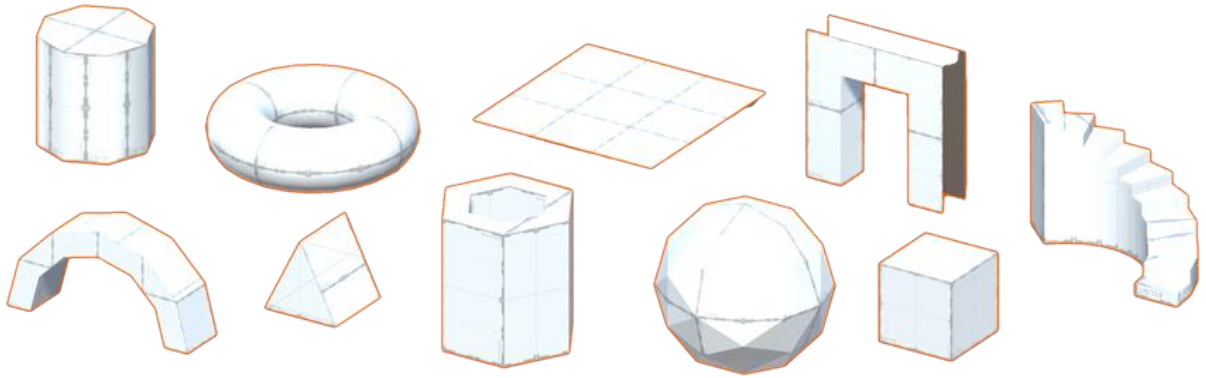
If you don't see the ProBuilder Window menu item, then ProBuilder did not install correctly.

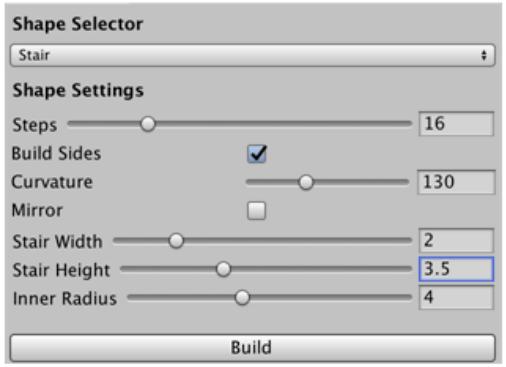


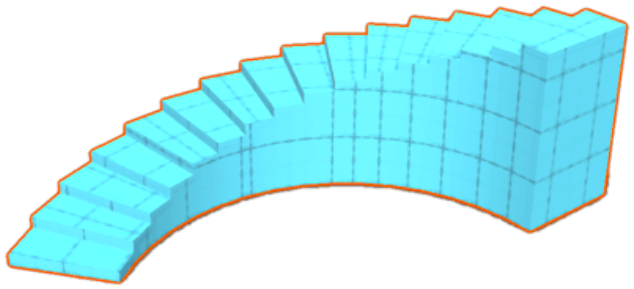


Probuilder toolbar

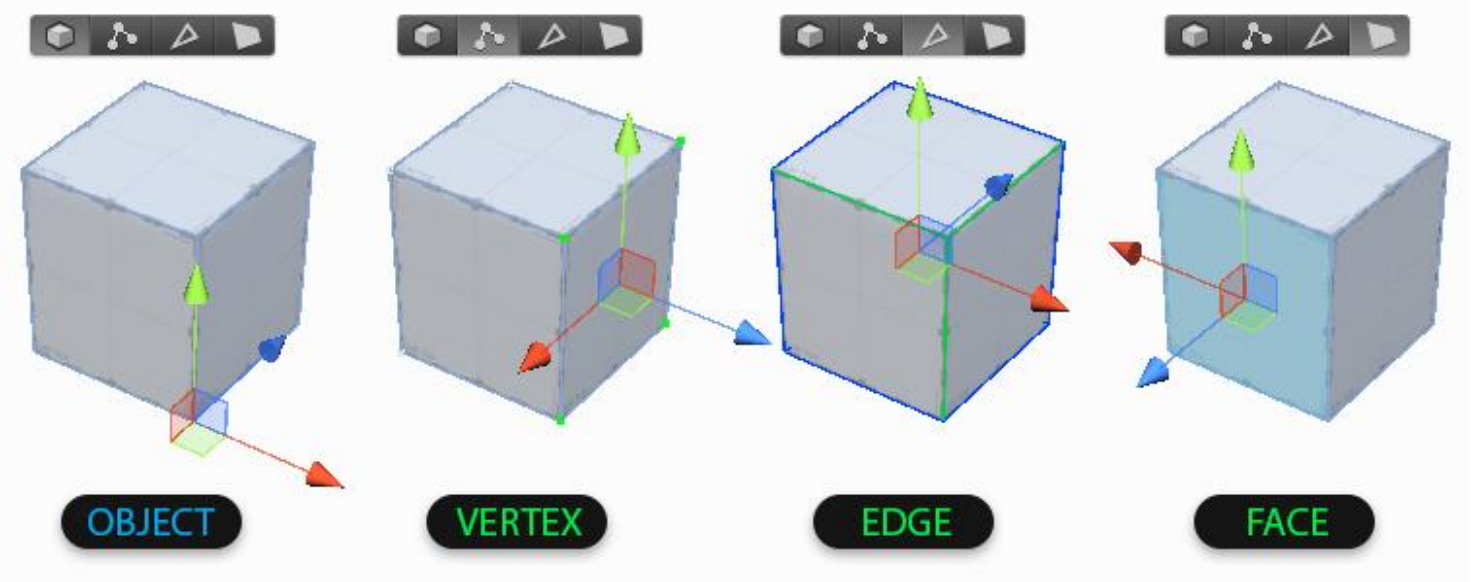
Creating Meshes



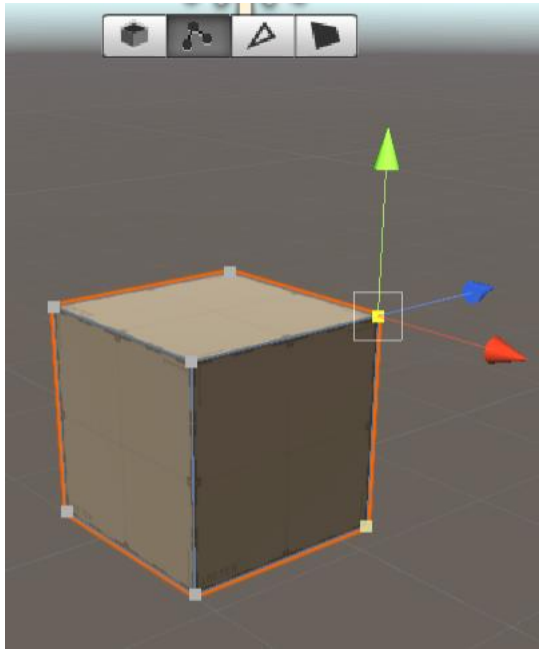


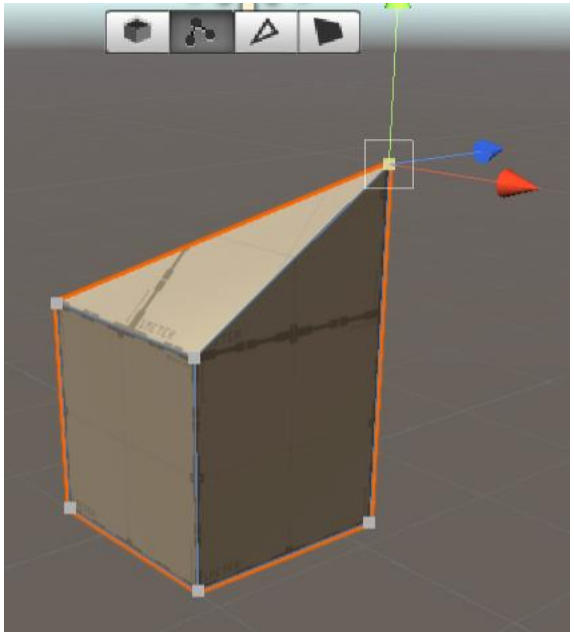


Edit modes (Object vs Element)

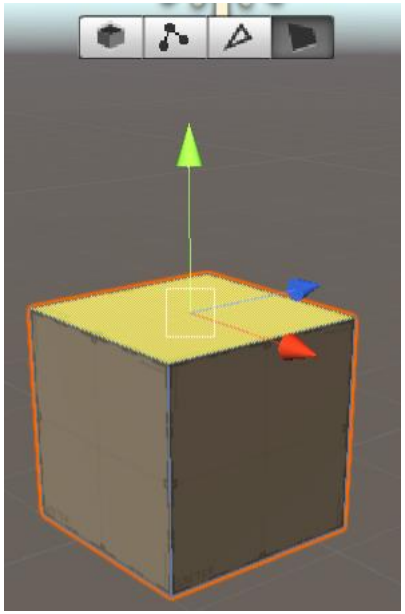


Select -> Transforming



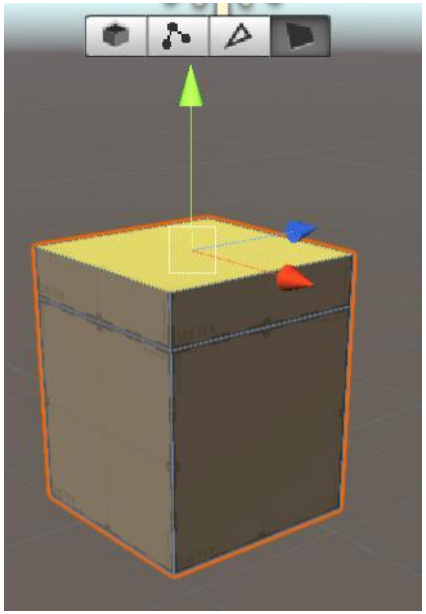


Select face -> Extruding



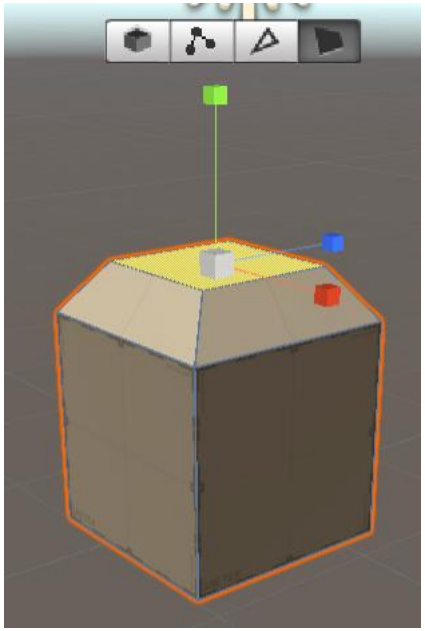
Select a face

Extruding



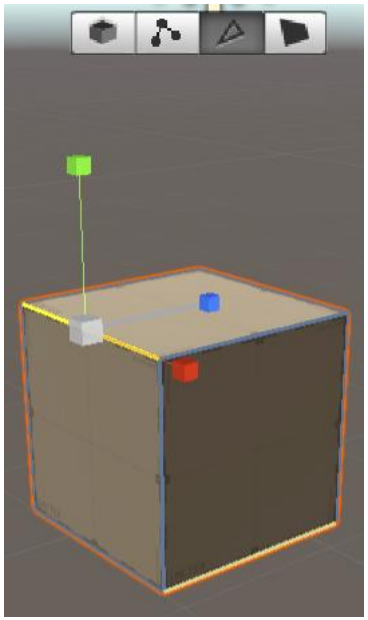
Shift key +
Translate

Insetting

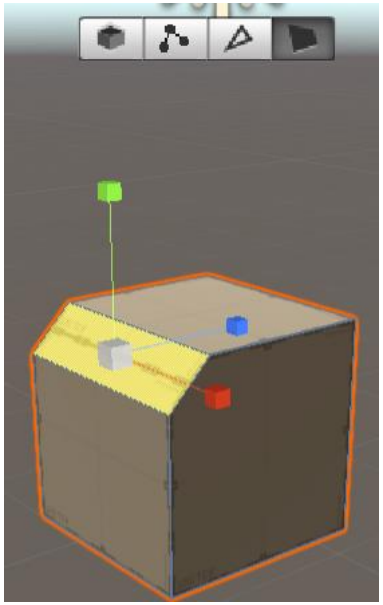


Shift key +
Scale

Select edge -> Bevel

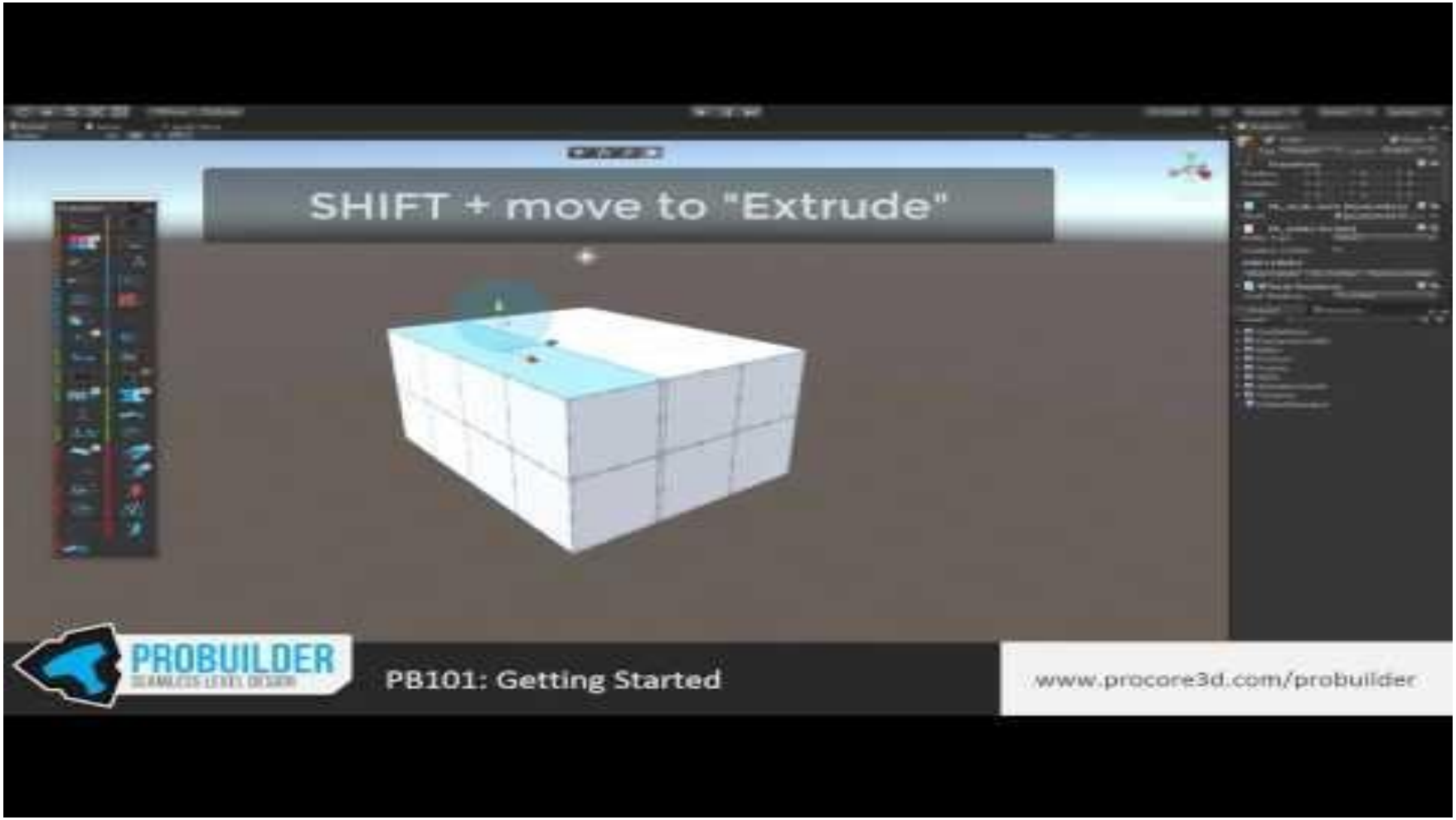


Select a edge

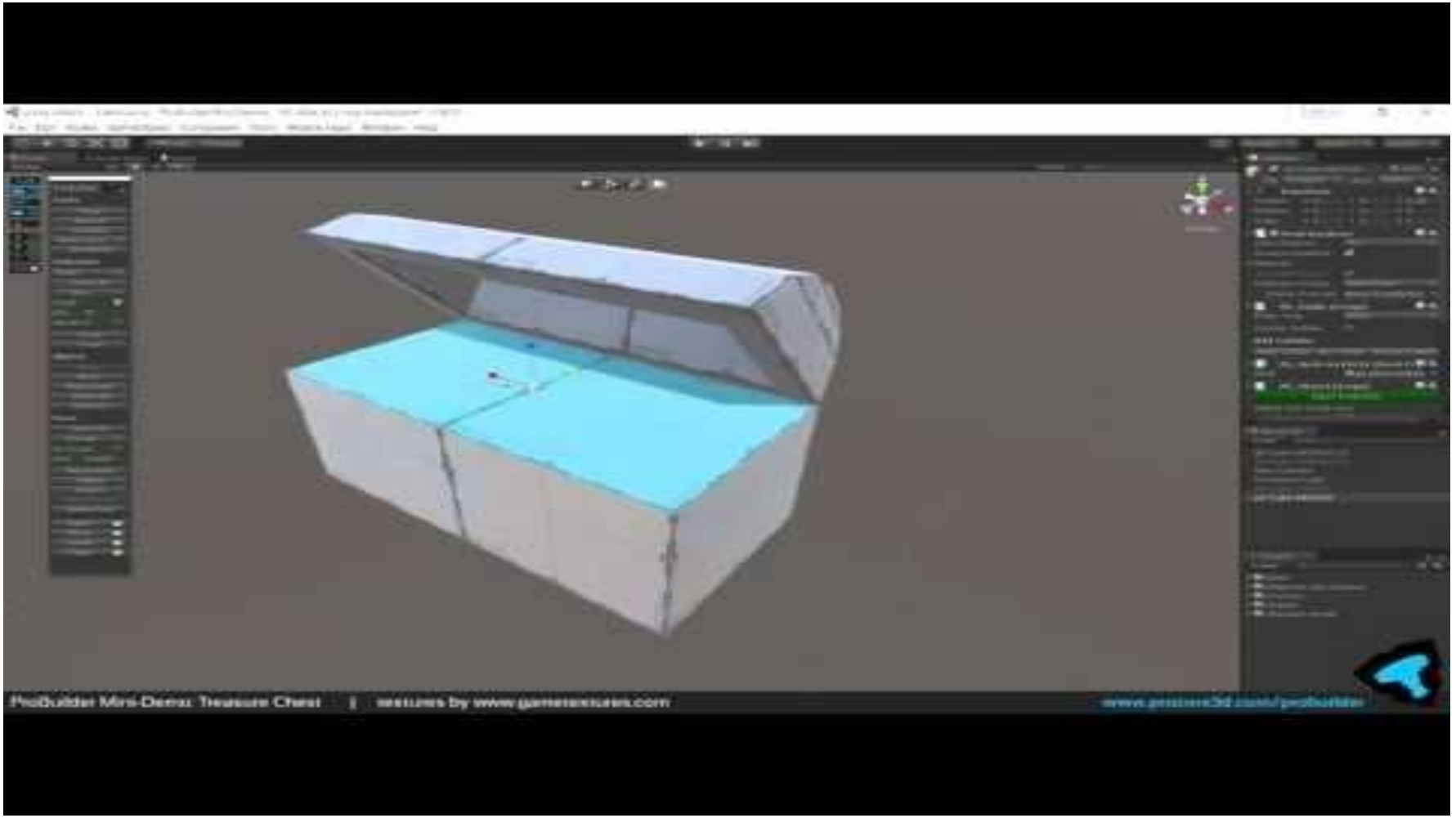


Bevel edge

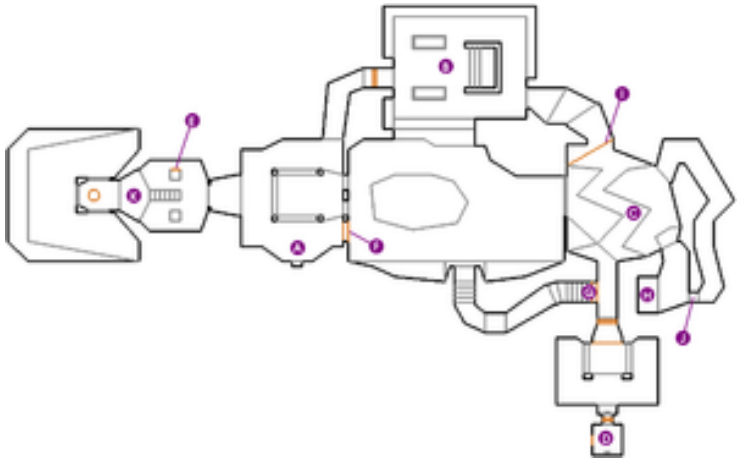
Getting Started with ProBuilder for Unity



Treasure Chest



Level Editor



PROBUILDER "*HOW TO MAKE...*" TUTORIAL SERIES:

RE-CREATING THE "E1M1" LEVEL FROM DOOM, IN UNITY 3D

PART 1: FLOORS

PART 2: WALLS

PART 3: CEILINGS

PART 4: COLORIZING

PART 5: TEXTURING

PART 6: DOORS

PART 7: CUSTOM COLLISION

PART 8: OCCLUSION

PART 9: TRIGGERS

PART 10: LIGHTING