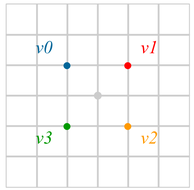
vertex buffer / index buffer

3D cheat sheet

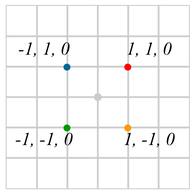
the vertex buffer is used to store the vertices coordinates. each vertex is stored as a triplet of XYZ values in a linear array.



given 4 vertices (points in 3D space)

v0	v1	v2	v3
x y z	x y z	x y z	x y z

the vertex buffer will store them like this



so given the following coordinates

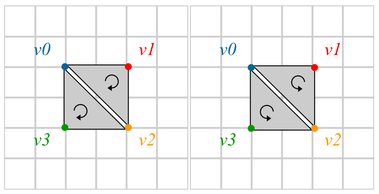
0	1	2	3
-1 1 0	1 1 0	1 -1 0	-1 -1 0

here's what our vertex buffer looks like

now given this vertex buffer, the index buffer describes how the triangles of a mesh are built and stores triplets of vertices' indices.

t0	t1	t2	t3
v0 v1 v2	v0 v2 v3	v1 v0 v2	v2 v0 v3

if we want to build a double sided quadrilateral, we'll need these triangles



we'll associate the vertices' position in the vertex buffer. V0 is our first vertex in the vertex buffer ; it's index is 0. V1 is index 1, V2 is index 2 and V3 is index 3.

0 1 2	0 2 3	1 0 2	2 0 3
CW	CW	CCW	CCW

some benefits of using separate buffers:
- it saves memory because we re-use vertices
- therefore it saves data transmission time
- the topology (point connectivity) is independant from the shape (point locations)
- it makes model deformation easy

the visibility of a triangle depends on its *winding*. the winding is the order in which the vertices of a triangle are associated ; CW or CCW.

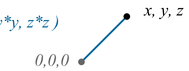
CW ClockWise

CCW Counter ClockWise

vector

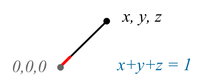
length

*sqrt(x*x, y*y, z*z)*



normalization

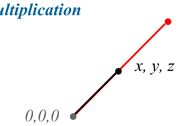
x / length
y / length
z / length



x+y+z = 1

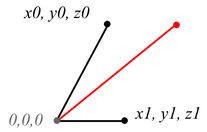
scalar multiplication

*x * scale*
*y * scale*
*z * scale*



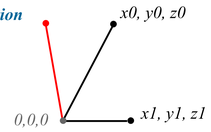
addition

x0 + x1
y0 + y1
z0 + z1



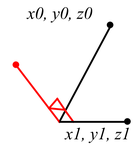
subtraction

x0 - x1
y0 - y1
z0 - z1



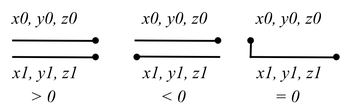
cross product

*y0 * z1 - z0 * y1*
*z0 * x1 - x0 * z1*
*x0 * y1 - y0 * x1*



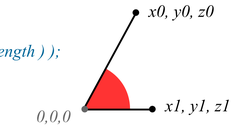
dot product

*x0 * x1 + y0 * y1 + z0 * z1*



angle

dp = v0.dotProduct(v1)
*acos(dp / (v0.length * v1.length));*



matrix

matrix

$$\begin{bmatrix} m0 & m1 & m2 & m3 \\ m4 & m5 & m6 & m7 \\ m8 & m9 & m10 & m11 \\ m12 & m13 & m14 & m15 \end{bmatrix}$$

identity (no transform)

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

transpose

$$\begin{bmatrix} m0 & m4 & m8 & m12 \\ m1 & m5 & m9 & m13 \\ m2 & m6 & m10 & m14 \\ m3 & m7 & m11 & m15 \end{bmatrix}$$

multiplication

$$\begin{bmatrix} a & b & c & d \\ e & f & g & h \end{bmatrix} * \begin{bmatrix} 0 & 1 \\ 2 & 3 \\ 4 & 5 \\ 6 & 7 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

A = a * 0 + b * 2 + c * 4 + d * 6
B = a * 1 + b * 3 + c * 5 + d * 7
C = e * 0 + f * 2 + g * 4 + h * 6
D = e * 1 + f * 3 + g * 5 + h * 7

transform point 3d (multiplication again)

$$\begin{bmatrix} x & y & z & w \end{bmatrix} * \begin{bmatrix} m0 & m1 & m2 & m3 \\ m4 & m5 & m6 & m7 \\ m8 & m9 & m10 & m11 \\ m12 & m13 & m14 & m15 \end{bmatrix}$$

$x' = x * m0 + y * m4 + z * m8 + w * m12$
$y' = x * m1 + y * m5 + z * m9 + w * m13$
$z' = x * m2 + y * m6 + z * m10 + w * m14$
$w' = x * m3 + y * m7 + z * m11 + w * m15$

scale

$$\begin{bmatrix} *sx & 0 & 0 & 0 \\ 0 & *sy & 0 & 0 \\ 0 & 0 & *sz & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

*m0 *= sx*
*m5 *= sy*
*m10 *= sz*

rotation X

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & cx & -sx & 0 \\ 0 & sx & cx & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

rotation Y

$$\begin{bmatrix} cy & 0 & sy & 0 \\ 0 & 1 & 0 & 0 \\ -sy & 0 & cy & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

rotation Z

$$\begin{bmatrix} cz & -sz & 0 & 0 \\ sz & cz & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

translate

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

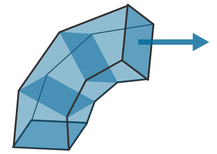
m12 += tx
m13 += ty
m14 += tz

projection

$$\begin{bmatrix} e & 0 & 0 & 0 \\ 0 & e/a & 0 & 0 \\ 0 & 0 & -(f+n)/(f-n) & -(2fn/(f-n) \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

n, f = distances to near, far planes
e = focal length = 1 / tan(FOV / 2)
a = viewport height / width

linear extrusion

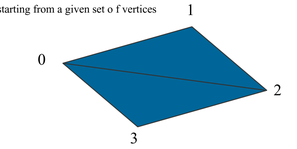


if we need o keep the caps:
for the top 4-5-6 & 4-6-7 are the same as the original 0-1-2 & 0-2-3 triangles
simply add 4 (the count of new vertices) to the original indices
0+4 = 4 1+4 = 5 2+4 = 6 => 4 - 5 - 6
0+4 = 4 2+4 = 6 3+4 = 7 => 4 - 6 - 7
if the vertices describe a simple polygon, it will work for all the original faces.

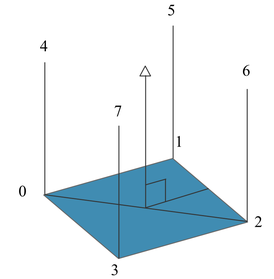
for the bottom cap, flip the original indices to make them point outwards.
0 - 1 - 2 => 1 - 0 - 2
0 - 2 - 3 => 2 - 0 - 3

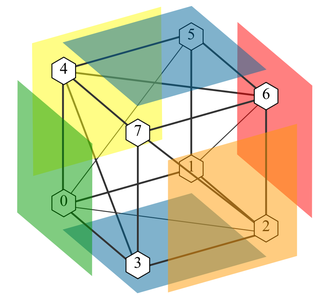
then create the necessary indices:
0-4-5, 0-5-1, 1-5-6, 1-6-2, 2-6-7, 2-7-3, 3-7-4, 3-4-0

starting from a given set o f vertices



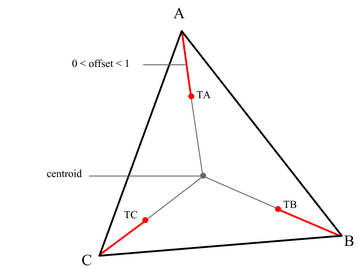
create new vertices and push them into the vertex buffer

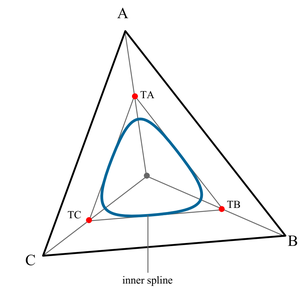


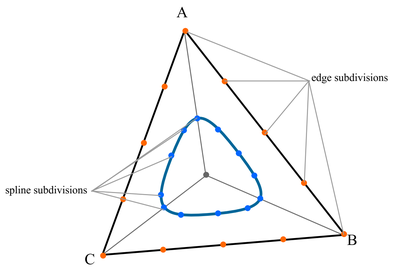


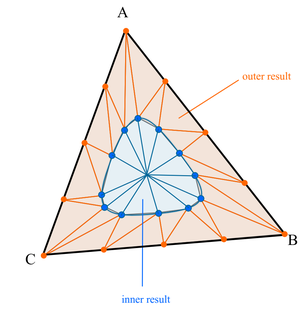
very complex and organic looking shapes can be achieved by performing multiple linear extrusions. it's usually called a LOFT and it's one of the most useful tools in the 3D toolbox.

face subdivision









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