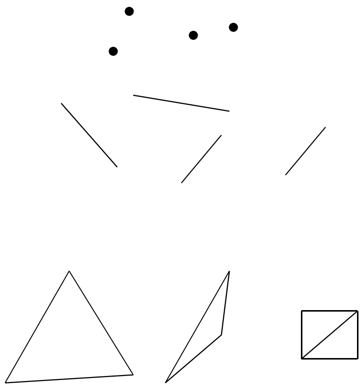
Drawing Primitives

Rendering Objects

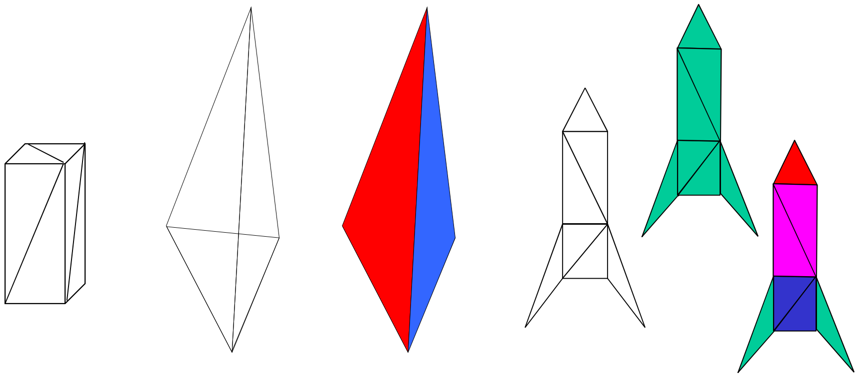
- Direct3D is geared towards 3D visualization.
  - Affects the type of primitives that can be rendered
  - Primitives should be easily rendered in 3D
- Issues
  - Accuracy of the computer
  - Consistency of the rendered data
    - Plane should stay a plane
    - Connected lines should stay connected

Primitive Objects

- Direct3D supports the following primitives
  - Points – 0D objects
  - Lines – 1D objects
  - Triangles – 2D objects



2D and 3D Objects

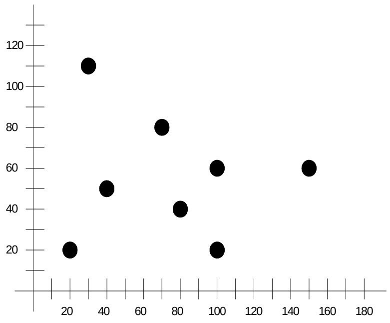


Direct3D Primitives

- Point lists
- Line lists
- Line Strip
- Triangle lists
- Triangles Strips
- Triangle fans

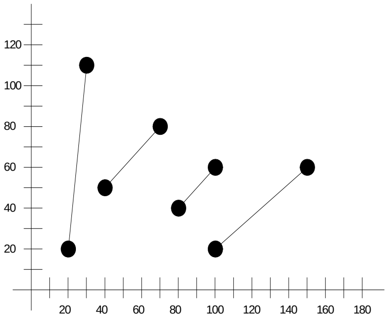
Point List

- Vertices
  - (20, 20)
  - (30, 110)
  - (40, 50)
  - (70, 80)
  - (80, 40)
  - (100, 60)
  - (100, 20)
  - (150, 60)



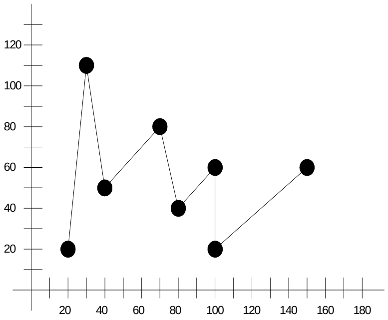
Line List

- Vertices
  - (20, 20)
  - (30, 110)
  - (40, 50)
  - (70, 80)
  - (80, 40)
  - (100, 60)
  - (100, 20)
  - (150, 60)



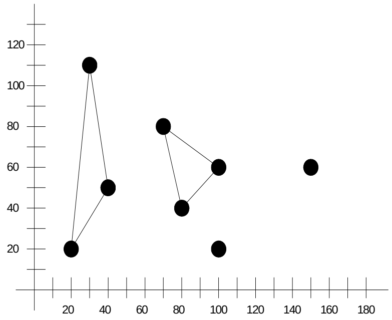
Line Strip

- Vertices
  - (20, 20)
  - (30, 110)
  - (40, 50)
  - (70, 80)
  - (80, 40)
  - (100, 60)
  - (100, 20)
  - (150, 60)



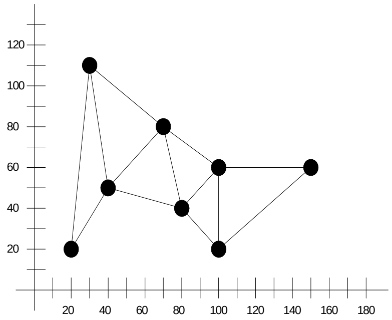
Triangle List

- Vertices
  - (20, 20)
  - (30, 110)
  - (40, 50)
  - (70, 80)
  - (80, 40)
  - (100, 60)
  - (100, 20)
  - (150, 60)



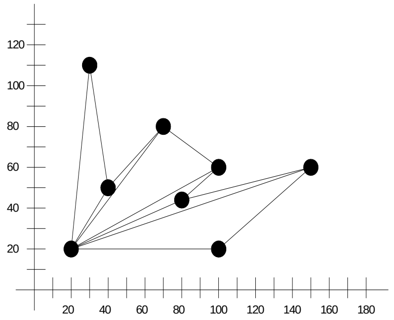
Triangle Strip

- Point list
  - (20, 120)
  - (25, 165)
  - (30, 135)
  - (45, 150)
  - (50, 130)
  - (60, 140)
  - (60, 120)
  - (85,140)



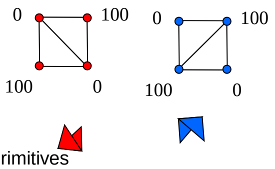
Triangle Fan

- Vertices
  - (20, 20)
  - (30, 110)
  - (40, 50)
  - (70, 80)
  - (80, 40)
  - (100, 60)
  - (100, 20)
  - (150, 60)



Vertices

- Vertices are the fundamental building blocks
- Vertices are 0D objects but they implicitly define (topology)
  - 1D (lines)
  - 2D (triangles)
  - 3D (tetrahedron)
- The objects are made by a “decision” on how to connect the vertices
- Vertices are usually shared among a number of objects (triangles)
  - Magic number is 6



Vertex data

- Vertices are associated with different type of data
  - Spatial – position in space
  - Attributes – colour
  - Geometry
    - Normal
    - Texture coordinates

```
struct myVertex {
        D3DVECTOR3 pos;
        D3DCOLOR color;
} ;

struct anotherVertex {
        D3DVECTOR3 pos;
        D3DVECTOR3 normal;
        D3DVECTOR2 TexCoords;
};
```

Vertex data

- Need to inform Direct3D what is in the vertex structure
  - Where is it stored?
  - What is it?
  - What is its type/size?

```
struct myVertex {
        D3DVECTOR3 pos;
         D3DVECTOR2 TexCoords;
        D3DVECTOR3 normal;
} ;

struct anotherVertex {
        D3DVECTOR3 pos;
        D3DVECTOR3 normal;
        D3DVECTOR2 TexCoords;
};
```

The two vertices contain the same data

Vertex Declaration

- A structure that describes the content of the vertex structure
- One structure for each field in the vertex structure

```
typedef struct D3DVERTEXELEMENT9 {
      WORD Stream;
      WORD Offset;
      BYTE Type;
      BYTE Method;
      BYTE Usage;
      BYTE UsageIndex;
 } D3DVERTEXELEMENT9,
*LPD3DVERTEXELEMENT9;
```

Output stream – Use 0

Offset – offset in bytes from the beginning of structure

Type – what is the field type
(see D3DDECLTYPE)
Common types:
D3DDECLTYPE_FLOAT1 a float
D3DDECLTYPE_FLOAT3 a 3D float vector
D3DDECLTYPE_D3DCOLOR – color as a 4D vector

Method – used in tessellation
Use D3DDECLMETHOD_DEFAULT

Usage – What does the field store
(see D3DDECLUSAGE
Common types
D3DDECLUSAGE_POSITION
D3DDECLUSAGE_NORMAL

Usage Index – differentiates between multiple similar fields

Examples

```
struct myVertex {
      D3DVECTOR3 pos;
      D3DVECTOR3 normal;
} ;

D3DVERTEXELEMENT9 decl[] {
{0,0, D3DDECLTYPE_FLOAT3,D3DDECLMETHOD_DEFAULT, D3DDECLUSAGE_POSITION, 0}
{0,12, D3DDECLTYPE_FLOAT3,D3DDECLMETHOD_DEFAULT, D3DDECLUSAGE_NORMAL, 0}
D3DDECL_END()
};
```

```
struct anotherVertex {
      D3DVECTOR3 pos;
      D3DVECTOR3 normal0;
      D3DVECTOR3 normal1;
} ;

D3DVERTEXELEMENT9 decl[] {
{0,0, D3DDECLTYPE_FLOAT3,D3DDECLMETHOD_DEFAULT, D3DDECLUSAGE_POSITION, 0}
{0,12, D3DDECLTYPE_FLOAT3,D3DDECLMETHOD_DEFAULT, D3DDECLUSAGE_NORMAL, 0}
{0,24, D3DDECLTYPE_FLOAT3,D3DDECLMETHOD_DEFAULT, D3DDECLUSAGE_NORMAL, 1}
D3DDECL_END()
};
```

Vertex Declaration

- Store the vertex declaration structure in an object that can be invoked by direct3D

```
struct myVertex {
      D3DVECTOR3 pos;
      D3DVECTOR3 normal;
} ;

D3DVERTEXELEMENT9 decl[] {
{0,0, D3DDECLTYPE_FLOAT3,D3DDECLMETHOD_DEFAULT, D3DDECLUSAGE_POSITION, 0}
{0,12, D3DDECLTYPE_FLOAT3,D3DDECLMETHOD_DEFAULT, D3DDECLUSAGE_NORMAL, 0}
D3DDECL_END()
};

IDirect3DVertexDeclaration9* myVertexDecl = NULL;

d3dDev->CreateVertexDeclaration(decl, &myVertexDecl);
```

Alternative
Flexible Vertex Format

- Each vertex has some properties
  - Location
  - Colour
    - Diffuse
    - Specular
  - Texture information

- Not all data is required all the time
  - Waste of space

Flexible Vertex Format

- Select only attributes that are needed
- #define D3DFVF_MYVERTEX (D3D_XYZ | D3DFVF_DIFFUSE)

- D3DFVF_XYZ
  - the location of the point
  - Type – three float values
- D3DFVF_DIFFUSE – a color for the vertex

Possible attributes of FVF

- D3DFVF_XYZ
  - 3 floats
- D3DFVF_XYZRHW
  - Location of vertex (in screen coordinates)
  - 4 floats
- D3DFVF_DIFFUSE
  - Colour of diffuse lighting
  - 32 bits colur
- D3DFVF_SPECULAR
  - Colour of specular lighting
  - 32 bits colur
- D3DFVF_TEX0 - D3DFVF_TEX8
  - Coordinates for texture mapping
  - 2 floats each

```
#define MYVERTEXFVF (D3D_XYZ | D3DFVF_COLOR)
```

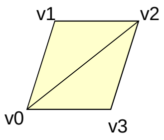
- The corresponding data structure
  - Onus is on the programmer to declare the structure

```
struct MyVertex{
    D3DVECTOR3 v;       // the vertex location
    DWORD colour;       // the colour of the vertex
}
```

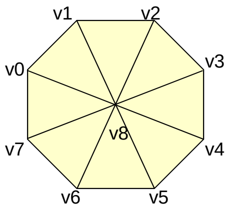
Constructing Triangles

- Quad
- Coarse Circle

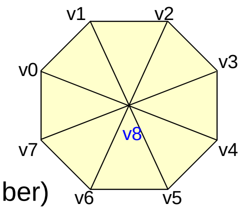
```
Vertex quad[6] {
        v0, v1, v2,  // Triangle 1
        v0, v2, v3  // Triangle 2
}
```



```
Vertex circle [24] {
        v8, v0, v1  //  Triangle 1
        v8, v1, v2,  // Triangle 2
        v8, v2, v3  //  Triangle 3
        v8, v3, v4  //  Triangle 4
        v8, v4, v5  //  Triangle 5
        v8, v5, v6  //  Triangle 6
        v8, v6, v7  //  Triangle 7
        v8, v7, v0  //  Triangle 8
}
```



Using Indices



- Using vertices is problematic
  - Each vertex appears 6 times (expected number)
  - Waste of space –
    - E.g., Position 16B/vertex (four floats)
  - Redundancy –
    - Update is time consuming
    - Expensive book keeping
  - Waste of computation resources
    - 6 times the amount of work

```
Vertex circle [24] {
        v8, v0, v1  //  Triangle 1
        v8, v1, v2,  // Triangle 2
        v8, v2, v3  //  Triangle 3
        v8, v3, v4  //  Triangle 4
        v8, v4, v5  //  Triangle 5
        v8, v5, v6  //  Triangle 6
        v8, v6, v7  //  Triangle 7
        v8, v7, v0  //  Triangle 8
}
```

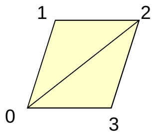
Using Indices

- Solution
  - Store the vertices in one location
  - Use indirect access to the vertex information - indices
- Advantages
  - Indirect access
    - Independent of the vertex data – can be associated with multiple sets of vertices
  - No redundancy
    - Vertex data appears only once
    - Changing of vertex data is easy – occurs only once
  - Simple book keeping
  - Saves space – “short” or “long” as indices (2B or 4B)
  - Speeds computation resources
    - Each vertex is process only once
- Disadvantage
  - Requires two data structures

Defining Triangles using Indices

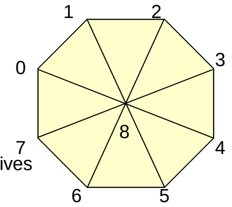
- Quad

```
Vertex v[4] = {v0,v1,v2,v3}

long indexQuad[6] {
        0, 1, 2,  // Triangle 1
        0, 2, 3  // Triangle 2
}
```



- Coarse Circle

```
Vertex v[9] = {v0,v1,v2,v3,v4,v5,v6,v7,v8}

long indexCircle[24] {
        8, 0, 1  //  Triangle 1
        8, 1, 2,  // Triangle 2
        8, 2, 3  //  Triangle 3
        8, 3, 4  //  Triangle 4
        8, 4, 5  //  Triangle 5
        8, 5, 6  //  Triangle 6
        8, 6, 7  //  Triangle 7
        8, 7, 0  //  Triangle 8
}
```



Vectors in DirectX

- Provides basic vector type
  - D3DVECTOR3 vec(x,y,z)
  - D3DVECTOR4 vec(x,y,z,w) // homogenous
- Provides basic manipulation of vectors
  - Basic operations - +, - , *, /
  - Dot product – prod = D3DXVec3Dot(&inV1, &inV2)
  - Cross product – pOutV1 = D3DXVec3Vec(&outV, &inV1, &inV2)
  - Normalize – pOutV1 = D3DXVec3Normalize(&outV, &inV1)
  - Magnitude/length – len = D3DXVec3Length(&inV1)

Matrices in DirectX

- Basic type
  - D3DMATRIX - a 4x4 matrix
- Provides basic manipulation of vectors
  - Basic matrix-matrix operations – +, -, *
  - Basic matrix scalar operations – *, /
  - Identity – D3DXMatrixIdentity(*outMat)
  - Transpose – D3DXMatrixTranspose(*outMat, *inMat)
  - Inverse – D3DXMatrixInvese(*outMat, *inDet,*inMat)
  - Transform – D3DXMatrixTranspose(*outV, *inV, *inMat)
  - Multiply – D3DXMatrixMultiply(*outMat, *inMat1,*inMat2)
  - Transpose – D3DXMatrixTranspose(*outMat, *inMat)

Object graphics initialization

Declare the vertex structure

```
struct MyVertex{
   float x, y, z;          // position
   DWORD colour;   // colour
}
```

Allocate memory for the vertices of the object

```
struct MyVertex vtx[6];
```

Initialize the vertices

```
vtx[0].x = vtx[0].y = vtx[0].z = 10.0;
Vtx[0].colour = D3DCOLOR_XRGB(255,0,0)
```

Allocated memory for the vertices in the video memory

```
CreateVertexBuffer( )
```

Load the vertices to the video memory

Create Vertex Buffer

- A device function
- Purpose: creates a placeholder/container for the vertices
- Receive a handle to the vertex buffer

```
struct myVertex {
                D3DVECTOR3 pos;
};

IDirect3DVertexBuffer9 *vBuf;

d3dDev->CreateVertexBuffer(
      3 * sizeof(struct myVertex),   // size
      0,                             // usage
      FVF_VertexFormat,              // flexible vertex format
     D3DPOOL_MANAGED,                // video memory or managed resource
     &vBuf,                          // address of handle
     NULL)                           // set to NULL
```

Memory pools

- Purpose: state where to store the resource

Options

- D3DPOOL_DEFAULT
  - Let Direct3D choose the best location for the resource (e.g., system mem, video mem)
- D3DPOOL_MANAGED
  - Direct3D manages the resource (moving to and from as needed automatically).
  - Backup copy is kept by Direct3D in system memory
- D3DPOOL_SYSTEMMEM
  - Asks the resource to be in system memory
- D3DPOOL_SCRATCH
  - Asks the resource to be in system memory
  - Device cannot access this resource
  - This resources can be copied to and from each other

Usage

- Purpose – specifies how the buffer is used

- D3DUSAGE_DYNAMIC
  - Buffer will be modified during the program execution
  - Usually placed in the Accelerated Graphics Port (AGP) memory
  - Can be updated fast
  - Memory must be copied to the video card
- D3DUSAGE_POINTS
  - Buffer will hold point primitives (particle systems)
- D3DUSAGE_SOFTWAREPROCESSING
  - Vertex processing is done by software
- D3DUSAGE_WRITEONLY
  - Application will only write to this location
  - Will be placed in a location that supports fast writing_

Notes

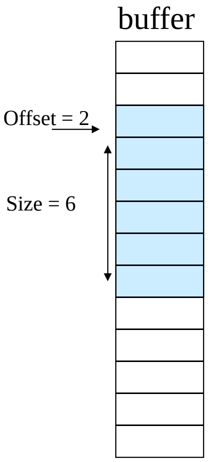
- Writing to and reading from video memory and or AGP is very slow
  - Keep a copy of the geometry locally
- Memory that is not declared dynamic is static
  - Used to store data that does not change (e.g., streets, houses, terrain, etc.)
  - Stored in the video memory

Accessing the Buffer's Memory

- Buffer contains a number of fields (e.g., size, memory type, usage…)
- One of the structure fields is the geometry
- Two functions are used to obtain access to the buffer geometry section
  - IDirect3dVertexBuffer::Lock()
  - IDirect3dVertexBuffer::Unlock()

The Lock function

- Purpose
  - Locks a portion of the geometry buffer
- Offset - number of bytes from the start of buffer
- Size – the number of bytes to lock (0 == lock the array)
- ppBufAddress – address of the locked section
- Flags –
  - D3DLOCK_DISCARD
    - Use only with dyanmic memory mode
    - Buffer is used only once
  - D3DLOCK_NOOVERWRITE
    - Append mode
    - Allows device to keep rendering
    - Used only with dynamic memory mode
  - D3DLOCK_READONLY
    - Locking for reading
    - No writing



Load Vertex Buffer

Declare a void pointer	void* pVtx;
Ask the system for an exclusive write privilege to a video memory location	g_pVB->Lock(0,sizeof(MyVertex)*6, &pVtx,0)))
Copy the vertices to the video memory	memcpy(pVertices, vtxBuf, sizeof(MyVertex)*6);
Release the write privilege	g_pVB->Unlock();

Setting the Vertex Buffer

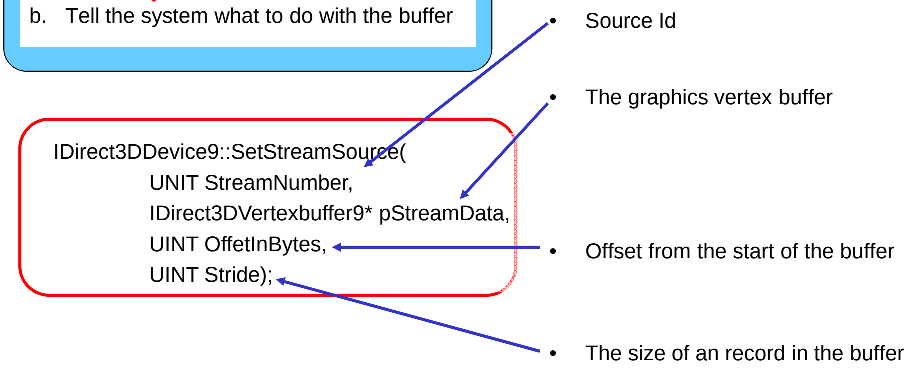
```
IDirect3DVertexBuffer9::Lock(
  UINT OffsetToLock,
  UINT SizeToLock,
  BYTE** ppbData, // return a ptr to the locked mem
  DWORD Flags);
```

```
struct myVertex {
                D3DVECTOR3 pos;
} vtxBuf[3];
IDirect3DVertexBuffer9 *gBuf;        // the graphics memory

void *vBuf;
Vertex* vertices;

gBuf->Lock(0, 3*sizeof(Vertex), (void**)&vBuf, 0);
    memcpy(&vBuf[0*sizeof(Vertex)],&vverteicesf[0], sizeof(struct MyVertex));
    memcpy(&vBuf[1*sizeof(Vertex)],&verteices[1], sizeof(struct MyVertex));
    memcpy(&vBuf[2*sizeof(Vertex)],&verteices[2], sizeof(struct MyVertex));
gBuf->Unlock();
```

Presenting the primitives

A two step action

a. Tell the system which vertex buffer to use
b. Tell the system what to do with the buffer

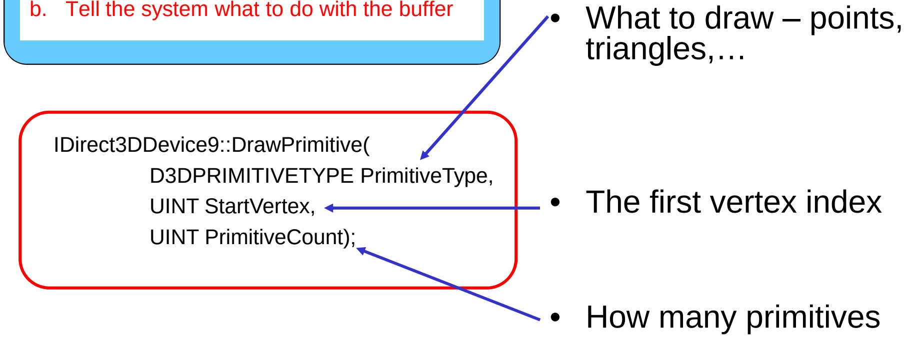


```
IDirect3DDevice9::SetStreamSource(
            UNIT StreamNumber,
            IDirect3DVertexbuffer9* pStreamData,
            UINT OffetInBytes,
            UINT Stride);
```

- Source Id
- The graphics vertex buffer
- Offset from the start of the buffer
- The size of an record in the buffer

Drawing the primitives

A two step action
a. Tell the system which vertex buffer to use
b. Tell the system what to do with the buffer



```
IDirect3DDevice9::DrawPrimitive(
            D3DPRIMITIVETYPE PrimitiveType,
            UINT StartVertex,
            UINT PrimitiveCount);
```

- What to draw – points, triangles,…
- The first vertex index
- How many primitives

Example

```
Clear(0, NULL, D3DCLEAR_TARGET, D3DCOLOR_XRGB(r, g, b), 1.0f, 0);

BeginScene();    // begin the 3D scene

SetStreamSource( 0, g_pVB, 0, sizeof(MyVertex));  // which vtx buffer to use


SetVertexDeclaration(myVertexDecl );

DrawPrimitive( D3DPT_LINESTRIP, 0,3);
DrawPrimitive(D3DPT_TRIANGLEFAN, 2, 2 );

EndScene();    // ends the 3D scene

Present(NULL, NULL, NULL, NULL); // displays the created frame on the screen
```

The index buffer

- Purpose: to reuse the vertices
- Idea: store the vertices once and access them many times

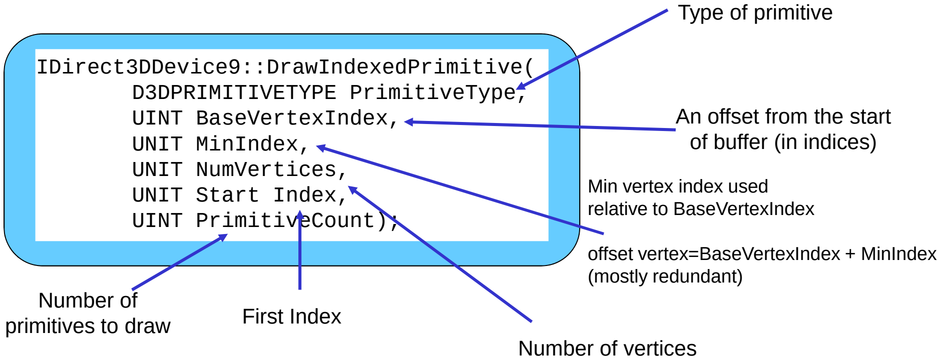
- Reuse the vertices
  - Single copy of data –
    - no redundancy
    - Error in data can be easily fixed
  - Saves space
  - Easy to manipulate

```
IDirect3DIndexBuffer9* Indexbuf;
gd3dDevice->CreateIndexBuffer(
          buffer size,
          Usage,              // how the buffer is used
          format,             //indices format (e.g.,  16-bit)
          pool,               // how the memory is managed
          &IndexBuf,          // return address of buffer
          0);                 // reserved, not used
```

The index buffer

```
IDirect3DIndexBuffer9* IndexBuf;
d3dDev->CreateIndexBuffer(
          30*sizesof(short),          // buffer size
          D3DUSAGE_WRITEONLY,         // usage
          D3DFMT_INDEX16,             // 16-bit indices
          D3DPOOL_MANAGED,            // indicate buffer in video mem
          &IndexBuf,                  // the buffer
          0);                         // reserved, not used
```

Index Buffer - Drawing Primitives

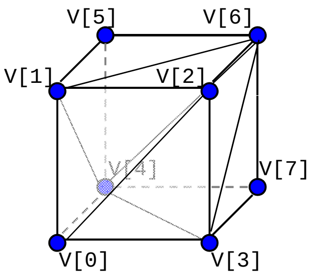


```
IDirect3DDevice9::DrawIndexedPrimitive(
       D3DPRIMITIVETYPE PrimitiveType,
       UINT BaseVertexIndex,
       UNIT MinIndex,
       UNIT NumVertices,
       UNIT Start Index,
       UINT PrimitiveCount);
```

Example

```
d3dDev->SetStreamSource(0, vBuf, 0, sizeof(myVertex));
d3dDev->SetIndices(ibuf);
d3dDev->DrawIndexedPrimitive(D3DPT_TRIANGLELIST, 0, 0, 8, 0, 12);
```

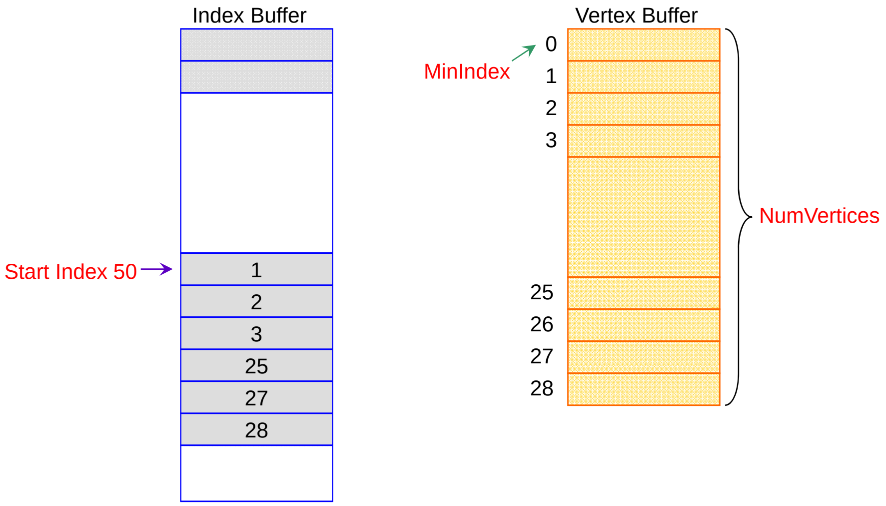
Indexed Vertex Structure



```
v_buffer->Lock(0,0,(void*)&v, 0);
v[0] = VertexPos(-1.0f, -1.0f, -1.0f);
v[1] = VertexPos(-1.0f,  1.0f, -1.0f);
v[2] = VertexPos( 1.0f,  1.0f, -1.0f);
v[3] = VertexPos( 1.0f, -1.0f, -1.0f);
v[4] = VertexPos(-1.0f, -1.0f,  1.0f);
v[5] = VertexPos(-1.0f,  1.0f,  1.0f);
v[6] = VertexPos( 1.0f,  1.0f,  1.0f);
v[7] = VertexPos( 1.0f, -1.0f,  1.0f);
v_buffer->Unlock();
```

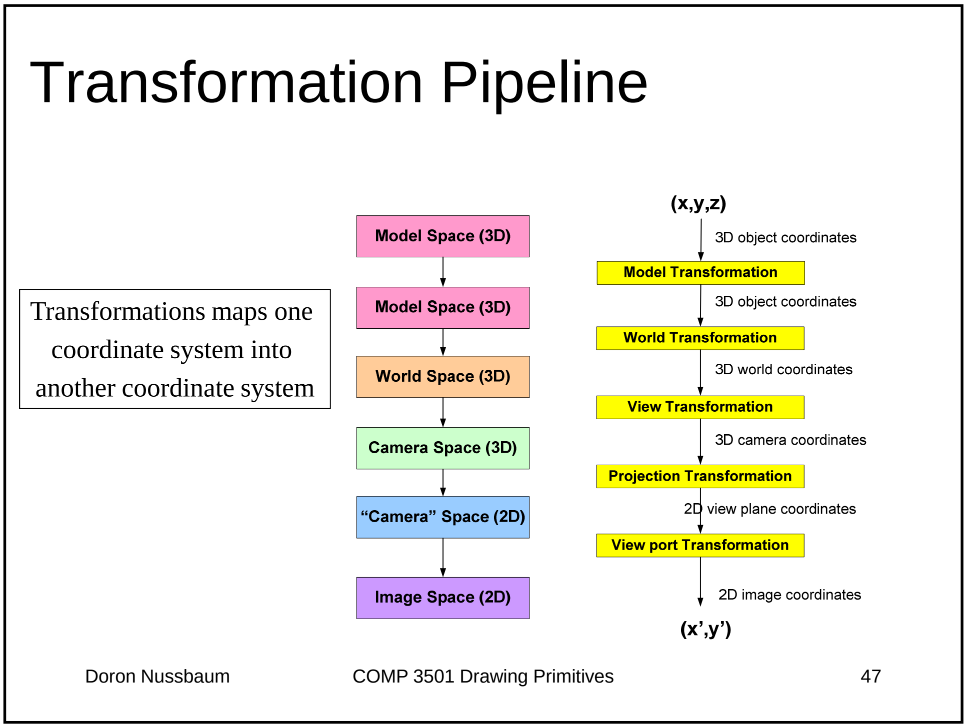
```
Index_buffer->Lock(0, 0, (void**)&k, 0);
k[0]  = 0; k[1]  = 1; k[2]  = 2; // Front face
k[3]  = 0; k[4]  = 2; k[5]  = 3;
k[6]  = 4; k[7]  = 6; k[8]  = 5; // Back face
k[9]  = 4; k[10] = 7; k[11] = 6;
k[12] = 4; k[13] = 5; k[14] = 1; // Left face
k[15] = 4; k[16] = 1; k[17] = 0;
k[18] = 3; k[19] = 2; k[20] = 6; // Right face
k[21] = 3; k[22] = 6; k[23] = 7;
k[24] = 1; k[25] = 5; k[26] = 6; // Top face
k[27] = 1; k[28] = 6; k[29] = 2;
k[30] = 4; k[31] = 0; k[32] = 3; // Bottom face
k[33] = 4; k[34] = 3; k[35] = 7;
Index_buffer->Unlock();
```

Example- draw two triangles



```
gd3dDevice->DrawIndexedPrimitive(D3DPT_TRIANGLELIST, 0, 0, 6, 50, 2);
```

Direct3D Transformation



Transformation Pipeline

Transformations maps one coordinate system into another coordinate system

Model Space (3D)
Model Space (3D)
World Space (3D)
Camera Space (3D)
"Camera" Space (2D)
Image Space (2D)

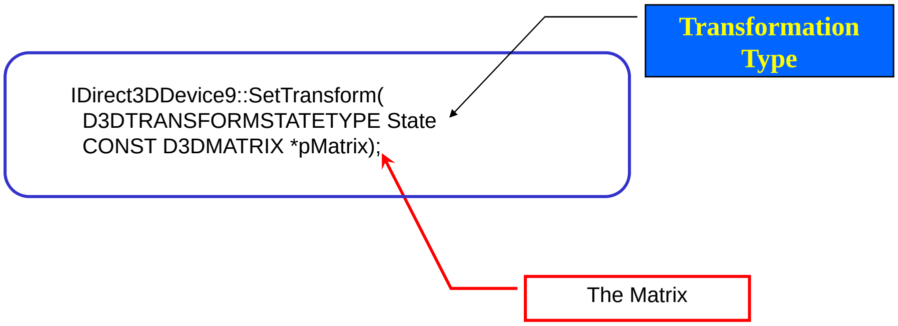
(x,y,z)
3D object coordinates
Model Transformation
3D object coordinates
World Transformation
3D world coordinates
View Transformation
3D camera coordinates
Projection Transformation
2D view plane coordinates
View port Transformation
2D image coordinates
(x',y')

Transformation Matrices

- Translation
  D3DXMatrixTranslation(D3DXMATRIX *Out, dx, dy, zz);
- Scaling
  D3DXMatrixScaling(D3DXMATRIX *Out, sx, sy, sz);
- Rotation
  D3DXMatrixRotationX(D3DXMATRIX *Out, float angle);
  D3DXMatrixRotationY(D3DXMATRIX *Out, float angle);
  D3DXMatrixRotationZ(D3DXMATRIX *Out, float angle);
  D3DXMatrixRotationAxis(D3DXMATRIX *Out, D3DXVECTOR3 *v, float angle);

Setting up the transformations

- Telling Direct3D which matrix to use for each step in the transformation pipeline

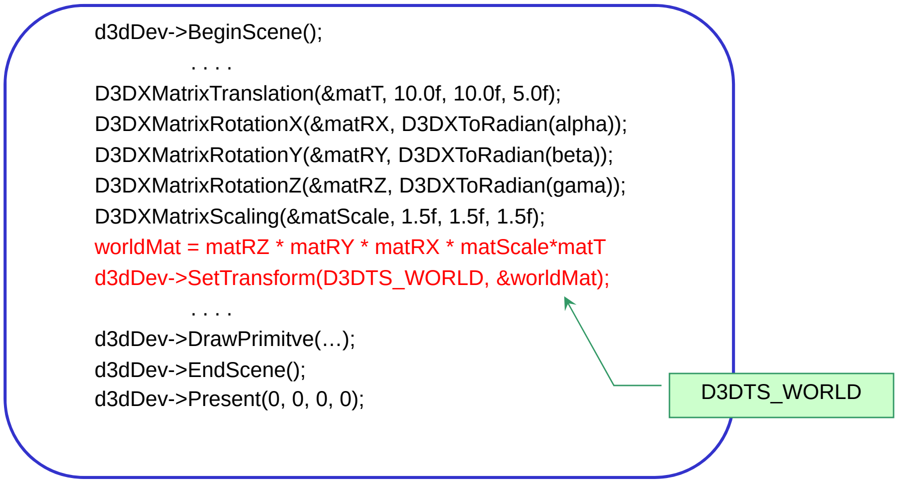


```
IDirect3DDevice9::SetTransform(
  D3DTRANSFORMSTATETYPE State
  CONST D3DMATRIX *pMatrix);
```

Transformation Type

The Matrix

D3D World Transformation



```
d3dDev->BeginScene();
        . . . .
D3DXMatrixTranslation(&matT, 10.0f, 10.0f, 5.0f);
D3DXMatrixRotationX(&matRX, D3DXToRadian(alpha));
D3DXMatrixRotationY(&matRY, D3DXToRadian(beta));
D3DXMatrixRotationZ(&matRZ, D3DXToRadian(gama));
D3DXMatrixScaling(&matScale, 1.5f, 1.5f, 1.5f);
worldMat = matRZ * matRY * matRX * matScale*matT
d3dDev->SetTransform(D3DTS_WORLD, &worldMat);
        . . . .
d3dDev->DrawPrimitve(…);
d3dDev->EndScene();
d3dDev->Present(0, 0, 0, 0);
```

D3DTS_WORLD

D3D View Transformation

- Build a Left-Handed, Look-at Matrix

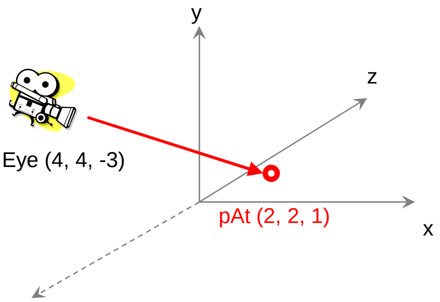
```
D3DXMatrixLookAtLH(
            D3DXMATRIX *Out,
            D3DXVECTOR3 *Eye,
            D3DXVECTOR3 *pAt,
            D3DXVECTOR3 *pUp);
```

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

- Setup

```
IDirect3DDevice9::SetTransform(
   D3DTRANSFORMSTATETYPE State
   CONST D3DMATRIX *pMatrix);
```

D3DTS_VIEW



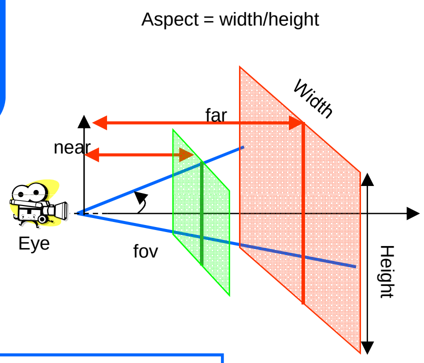
D3D View Transformation

```
d3dDev->BeginScene();
            . . . .

D3DXMatrixLookAtLH(
            &matView,
            &D3DXVECTOR3(4.0f, 4.0f, -3.0f), // camera loc
            &D3DXVECTOR3(2.0f, 2.0f, 1.0f),  // look-at target
            &D3DXVECTOR3(0.0f, 1.0f, 0.0f));

d3dDev->SetTransform(D3DTS_VIEW, &matView);
            . . . .
d3dDev->DrawPrimitve(…);
d3dDev->EndScene();
d3dDev->Present(0, 0, 0, 0);
```

D3D Perspective Projection Transformation

- Build a Left-Handed, Look-at Matrix

```
D3DXMatrixPerspectiveFovLH(
            D3DXMATRIX *Out,
            float fov,
            float Aspect,
            float near,
            float far);
```



- Setup

```
IDirect3DDevice9::SetTransform(
  D3DTRANSFORMSTATETYPE State
  CONST D3DMATRIX *pMatrix);
```

D3DTS_PROJECTION

D3D Projection Transformation

```
d3dDev->BeginScene();
        . . . .
D3DXPerspectiveProjectionFovLH(&matProjection,  // out matrix
        D3DXToRadian(45),                  // field of view
        Width/Height,                              // aspect ratio
        1.0f, 1000.0f);                            // near and far planes

 gd3dDev->SetTransform(D3DTS_PROJECTION, &matProjection);
        . . . .
 d3dDev->DrawPrimitve(…);
 d3dDev->EndScene();
 d3dDev->Present(0, 0, 0, 0);
}
```

Note that aspect ratio changes when the window is resized

D3D Orthographic Projection Transformation

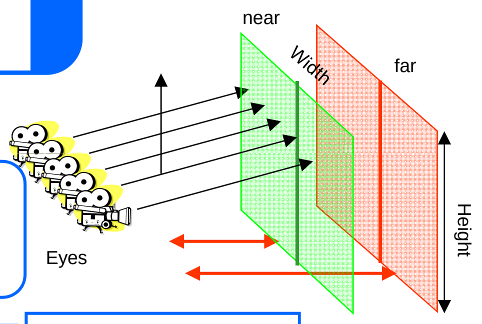
- Build a Left-Handed, Look-at Matrix

```
D3DXMATRIX * D3DXMatrixOrthoLH(
              D3DXMATRIX *pOut,
              float width,
              float height,
              float near,
              float far );
```

- Setup

```
IDirect3DDevice9::SetTransform(
  D3DTRANSFORMSTATETYPE State
  CONST D3DMATRIX *pMatrix);
```

D3DTS_PROJECTION



D3D Projection Transformation

```
d3dDev->BeginScene();
            . . . .
D3DXMatrixOrthoLH(&matProjection,  // out matrix
            800,                    // width
            600,                    // height
            1.0f, 1000.0f);         // near and far planes

 gd3dDev->SetTransform(D3DTS_PROJECTION, &matProjection);
            . . . .
 d3dDev->DrawPrimitve(…);
 d3dDev->EndScene();
 d3dDev->Present(0, 0, 0, 0);
}
```

View Port

- Sets the screen coordinates to be used
  - Convert from projection coordinates to screen coordinates
- By default the view port size is the back buffer
- Can be used to divide the screen into a number of sections
  - Each section of the screen is being drawn independently
  - Divide the screen into quadrants each with a different display

D3D View Port Transformation

```
typedef struct D3DVIEWPORT9 {
        DWORD X;        // upper left corner of the view port on the rendered surface
        DWORD Y;         // upper left corner of the view port on the rendered surface
        DWORD Width;    // width of the view port
        DWORD Height;   // height of the view port
        float MinZ;     // minimum z value (of z buffer)  normally 0
        float MaxZ; }   // maximum z value (of z buffer) normally 1

D3DVIEWPORT9, *LPD3DVIEWPORT9;

D3DVIEWPORT9 vp={50,50,300,300,0,1};
        md3dDev->SetViewport(&vp); d3dDev->BeginScene();
```