Direct3D Drawing

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Drawing

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Vertex Buffer / Index Buffer 생성

- Vertex buffer, Index buffer
  - Vertex data와 index data를 보관하는 연속적인 memory 덩어리
  - Buffer를 video memory에 저장할 수 있어서 빠른 rendering이 가능
  - IDirect3DVertexBuffer9, IDirect3DIndexBuffer9
- Vertex buffer 생성

```
HRESULT IDirect3DDevice9::CreateVertexBuffer(
    UINT Length,            // buffer size in bytes – n*sizeof(Vertex)
    DWORD Usage,            // usage – 0 indicates no usage value D3DUSAGE_XXX
    DWORD FVF,              // combination of D3DFVF
    D3DPOOL Pool,           // member of D3DPOOL enum type
    IDirect3DVertexBuffer9 **ppVertexBuffer, // created vertex buffer
    HANDEL *pSharedHandle                    // set this to NULL
);
```

Vertex Buffer / Index Buffer 생성

- Index buffer 생성

```
HRESULT IDirect3DDevice9::CreateIndexBuffer(
    UINT Length,            // buffer size in bytes
    DWORD Usage,            // usage value D3DUSAGE_XXX
    DWORD Format,           // D3DFORMAT enum type – D3DFMT_INDEX16/32
    D3DPOOL Pool,           // member of D3DPOOL enum type
    IDirect3DIndexBuffer9 **ppIndexBuffer,   // created index buffer
    HANDEL *pSharedHandle                    // set this to NULL
);
```

Vertex Buffer / Index Buffer 생성

- D3DUSAGE constants
  - D3DUSAGE_DYNAMIC: dynamic buffer를 생성함. Default는 지정하지 않을 시 static임.
    - Static buffer는 video memory(접근 속도가 느림)에 보관됨. 자주 바뀌지 않는 데이터의 경우에 유리함
    - Dynamic buffer는 AGP memory(빠른 속도로 갱신이 가능함)에 보관됨. Video memory로 전송해야 하므로 갱신이 없는 경우에는 static buffer 보다 느리나, 자주 갱신하는 경우 (즉, 매 프레임마다 기하정보를 갱신해야 하는 경우)에는 dynamic buffer가 빠름.
  - D3DUSAGE_WITEONLY
    - Buffer에 write만 수행할 것임을 지정함. 이 flag가 설정된 buffer에 read를 시도하면 오류가 발생함.
  - Other flags

Vertex Buffer / Index Buffer 생성

- 예: Vertex형의 vertex 8개를 보관할 만큼의 static vertex buffer를 생성

```
IDirect3DVertexBuffer9* _vb;
_device->CreateVertexBuffer( 8*sizeof(Vertex),
                             0,     // usage
                             D3DFVF_XYZ,
                             D3DPOOL_MANAGED,
                             &_vb, 0);
```

- 예: 36개의 16-bit index를 보관할 만큼의 dynamic index buffer를 생성

```
IDirect3DIndexBuffer9* _ib;
_device->CreateIndexBuffer( 36*sizeof(WORD),
                            D3DUSAGE_DYNAMIC|D3DUSAGE_WRITEONLY,
                            D3DFMT_INDEX16,
                            D3DPOOL_MANAGED,
                            &_ib, 0);
```

Vertex Buffer / Index Buffer 접근

- Buffer 접근
  1. Lock method를 사용하여 buffer pointer를 얻음
  2. 읽기 및 쓰기 (D3DUSAGE_WRITEONLY경우 읽기 불가)
  3. 사용이 끝난 후에는 반드시 Unlock method를 이용해 buffer의 잠금을 해제

```
HRESULT IDirect3DVertexBuffer9::Lock(
    UINT OffsetToLock,  // offset into the vertex data to lock (in bytes)
    UINT SizeToLock,    // size of the vertex data to lock (in bytes)
    VOID **ppbData,     // pointer to memory buffer of vertex data
    DWORD Flags         // flags for the type of lock to perform, 0 또는 D3DLOCK_XXX
);
HRESULT IDirect3DIndexBuffer9::Lock(
    UINT OffsetToLock,  // offset into the index data to lock (in bytes)
    UINT SizeToLock,    // size of the index data to lock (in bytes)
    VOID **ppbData,     // pointer to memory buffer of index data
    DWORD Flags         // flags for the type of lock to perform
);
```

전체 buffer를 lock하려면 OffsetToLock = SizeToLock = 0으로 하면 index buffer를 lock함

Vertex Buffer / Index Buffer 접근

- D3DLOCK constants
  - D3DLOCK_DISCARD
    - dynamic buffer에만 사용가능. HW에게 이전 buffer를 버리라고 지시함. 새로 할당된 buffer에 접근하면서 동시에 버려진 buffer에서 rendering을 수행함. HW 지연을 막음.
  - D3DLOCK_NOOVERWRITE
    - Dynamic buffer에만 사용가능. Buffer에 data를 추가하는 작업만 가능함. 현재 rendering 중인 memory에 overwirte할 수 없음. 새 data를 추가하면서 동시에 rendering할 수 있음.
  - D3DLOCK_READONLY
    - Buffer를 read-only로 지정. 약간의 내부 최적화를 가능하게 함.

```
Vertex *vertices;
_vb->Lock(0, 0, (void**)&vertices, 0);          // lock entire buffer
vertices[0] = Vertex(-1.0, 0.0, 2.0);
vertices[0] = Vertex(0.0, 1.0, 2.0);
vertices[0] = Vertex(1.0, 0.0, 2.0);
_vb->Unlock();                                  // unlock
```

Vertex Buffer / Index Buffer 정보 얻기

- Vertex buffer/Index buffer 정보 얻기

```
D3DVERTEXBUFFER_DESC vbDescription;
_vertexBuffer->GetDesc(&vbDescription); //retrieve description

D3DINDEXBUFFER_DESC ibDescription;
_indexBuffer->GetDesc(&ibDescription); //retrieve description
```

- D3DVERTEXBUFFER_DESC 구조체

```
typedef struct _D3DVERTEXBUFFER_DESC {
    D3DFORMAT Format;           // describe the surface format of buffer
    D3DRESOURCETYPE Type;       // identify this resource is a vertex buffer
    DWORD Usage;                // combination of D3DUSAGE flags
    D3DPOOL Pool;               // the class of memory allocated for the buffer
    UNIT Size;                  // size of vertex buffer (in bytes)
    DWORD FVF;                  // describe vertex format of the vertices
} D3DVERTEXBUFFER_DESC;
```

Vertex Buffer / Index Buffer 정보 얻기

- D3DINDEXBUFFER_DESC 구조체

```
typedef struct _D3DINDEXBUFFER_DESC {
    D3DFORMAT Format;           // describe the surface format of buffer
    D3DRESOURCETYPE Type;       // identify this resource is a index buffer
    DWORD Usage;                // usage
    D3DPOOL Pool;               // the class of memory
    UNIT Size;                  // size of index buffer (in bytes)
} D3DINDEXBUFFER_DESC;
```

Render State

- Render state
  - Default 모드 값으로 동작함
  - Default가 아닌 다른 값으로 바꿀 경우 SetRenderState을 호출

```
HRESULT IDirect3DDevice9::SetRenderState(
    D3DRENDERSTATETYPE State, // device state variable to be modified
    DWORD Value         // New value for the device render state to be set
);
```

- D3DRENDERSTATETYPE
  - Enum of many state variables about 100
  - 예: State가 D3DRS_SHADEMODE이면 Value는 D3DSHADEMODE enum형의 멤버를 주어야 함.

```
// 물체를 wireframe으로 rendering하고자 할 때
_device->SetRenderState(D3DRS_FILLMODE, D3DFILL_WIREFRAME);
```

Drawing 준비

- Vertex buffer/ Index buffer를 만든 후 내용물을 rendering할 마지막 준비
  1. SetStreamSource를 사용하여 Stream source 지정
     - Stream source를 vertex buffer와 연결하여 buffer의 기하정보를 rendering pipeline으로 보낼 수 있도록 함.

```
HRESULT IDirect3DDevice9::SetStreamSource(
    UINT StreamNumber, // vertex buffer를 연결할 stream 소스 번호 지정
    IDirect3DVertexBuffer9 *pStreamData, // 명시한 data stream과
                                         // bind할 vertex buffer
    UINT OffsetInBytes,  // vertex buffer에서의 시작 위치 (in bytes)
    UNIT Stride          // vertex buffer애의 각 요소의 byte 수
);

_device->SetStreamSource(0, vb, 0, sizeof(Vertex));
```

Drawing 준비

2. SetFVF를 사용하여 Vertex format 지정
   - 이후의 drawing에서 이용될 vertex format을 지정함.

```
_device->SetFVF(D3DFVF_XYZ | D3DFVF_DIFFUSE | D3DFVF_TEX1);
```

3. SetIndices를 사용하여 Index buffer 지정
   - 이후의 drawing에서 이용될 index buffer을 지정함.
   - 한 번에 하나의 index buffer만 이용할 수 있음. 다른 index buffer를 가진 물체를 그리기 위해서는 index buffer를 전환하여야 함.

```
_device->SetIndices(_ib);
```

Vertex Buffer를 이용한 Drawing

- DrawPrimitive를 사용하여 index정보를 이용하지 않고 primitive를 drawing.

```
HRESULT IDirect3DDevice9::DrawPrimitive(
    D3DPRIMITIVETYPE PrimitiveType,// rendering할 primitive type
    UINT StartVertex,              // vertex buffer 의 첫번째 index
    UINT PrimitiveCount            // rendering할 primivites 수
    // 한번 호출 시마다 가능한 최대 개수는 D3DCAPS9.MaxPrimitiveCount임
);

// 4개의 삼각형을 그림
_device->DrawPrimitives(D3DPT_TRIANGLELIST, 0, 4);
```

Vertex/Index Buffer를 이용한 Drawing

- DrawIndexedPrimitive를 사용하여 primitive를 drawing

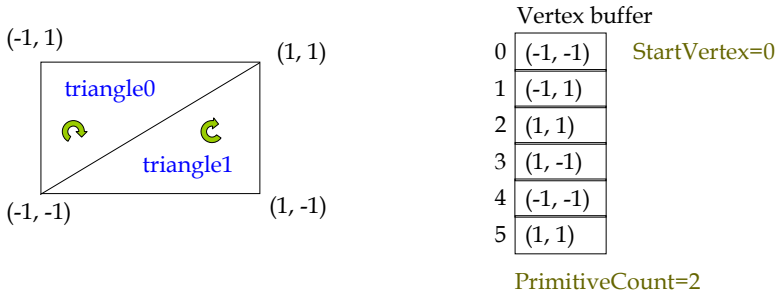
```
HRESULT IDirect3DDevice9::DrawIndexedPrimitive(
    D3DPRIMITIVETYPE PrimitiveType,      // rendering할 primitive type
    INT BaseVertexIndex, // vertex buffer에서 첫번째 vertex의 offset
    UINT MinIndex,       // 이번 호출에 이용될 vertex들의 최소 vertex index
    UINT NumVertices,    // 이번 호출에 이용될 vertex들의 수
    UINT StartIndex,     // vertex buffer를 접근하는 index buffer에서 첫번째 index
    UINT PrimitiveCount // rendering할 primivites 수
);

//MinIndex와 index stream에 대한 모든 index들은 BaseVertexIndex에 상대적임
//MinIndex와 NumVertices는 사용될 vertex index들의 범위를 명시함

_device->DrawIndexedPrimitive(D3DPT_TRIANGLELIST, 0, 0, 8, 0, 12);
```

Drawing Example

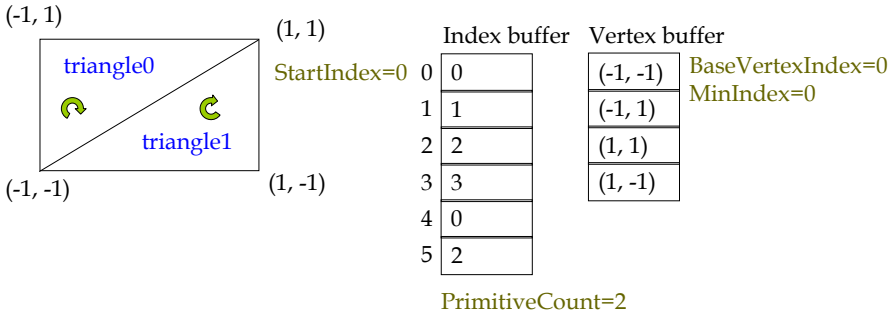
- Eg.1: 2개의 삼각형을 index를 사용하지 않고 drawing




```
DrawPrimitive(D3DPT_TRIANGLELIST, 0, 2);
```

Drawing Example

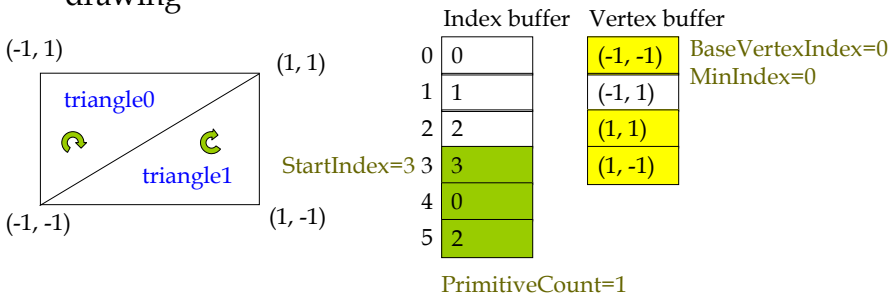
- Eg.2: 2개의 삼각형을 index를 사용해서 drawing




```
DrawIndexedPrimitive(D3DPT_TRIANGLELIST, 0, 0, 4, 0, 2);
```

Drawing Example

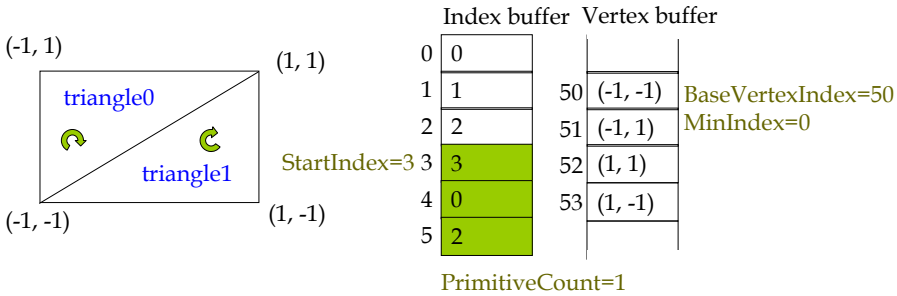
- Eg.3: 1개의 삼각형(즉, 두 번째 것)을 index를 사용해서 drawing




```
DrawIndexedPrimitive(D3DPT_TRIANGLELIST, 0, 0, 4, 3, 1);
```

Drawing Example

- Eg.4: Offset indexing을 사용해서 1개의 삼각형을 drawing
  - 일반적으로 BaseVertexIndex를 0으로 지정함.
  - 그러나 vertex data의 구조는 알지만 data가 놓여질 위치를 아직 모를 경우, 또는 동일 구조의 vertex data가 vertex buffer에 여러 번 놓여있는 경우 이를 하나의 index buffer로 그릴 경우 유용함.




```
DrawIndexedPrimitive(D3DPT_TRIANGLELIST, 50, 0, 4, 3, 1);
```

BeginScene / EndScene

- 모든 drawing method들은 IDirect3DDevice9::BeginScene과 IDirect3DDevice9::EndScene 내부에 포함되어야 함.

```
_device->BeginScene();
…
_device->DrawPrimitive( … );
…
_device->EndScene();
```

  - 새로운 BeginScene은 다른 BeginScene/EndScene 안에 불릴 수 없음.
  - IDirect3DDevice9::Present 또는 IDirect3DSwapChain9::Present가 불려질 때 적어도 하나의 BeginScene/EndScene이 존재해야 함.
  - EndScene이 Present전에 불려야 함.

D3DX Geometry

- 기하 자료를 간편하게 구성하도록 하기 위해
  - 6가지 간단한 물체의 mesh data를 생성하는 method를 제공
  - D3DXCreateBox, D3DXCreateSphere, D3DXCreateCylinder, D3DXCreateTeapot, D3DXCreatePolygon, D3DXCreateTorus

```
HRESULT WINAPI D3DXCreateTeapot(
    LPDIRECT3DDEVICE9 pDevice,
    LPD3DXMESH **ppMesh, // output here
    LPD3DXBUFFER **ppAdjacency
            // array of three DWORDs per face
            // that specify the three neighbors for each face
            // NULL can be specified
);
ID3DXMesh* mesh = 0;
D3DXCreateTeapot(_device, &mesh, 0);
```

D3DX Geometry

- Mesh data의drawing은 ID3DXMesh::DrawSubset을 호출
  - Mesh의 subset을 지정해야 함
  - D3DXCreate* 함수로 생성된 mesh는 1개의 subset만을 가짐.

```
_device->BeginScene();
mesh->DrawSubset(0);
_device->EndScene();
```

- Mesh 이용이 끝난 뒤에는 이를 해제해 주어야 함.

```
mesh->Release();
mesh = 0;
```

Examples

- Triangle – wireframe 삼각형을 그림
  - Vertex buffer, render state, drawing commands
- Cube – 돌고 있는 wireframe 입방체를 그림
  - Vertex buffer, index buffer, world transformation, view transformation, render states, drawing commands
- Teapot – wireframe 주전자를 그림
  - D3DXCreateTeapot 함수 사용, ID3DXMesh::DrawSubset 방법
- D3DXCreate – wireframe D3DX shape들을 그림. 카메라가 장면 위를 자유롭게 움직임.
  - D3DXCreate* 함수 사용, 복잡한 transformation, camera movement

Triangle

```
#include "d3dUtility.h"

//
// Globals
//

IDirect3DDevice9* Device = 0;

const int Width  = 640;
const int Height = 480;

IDirect3DVertexBuffer9* Triangle = 0; // vertex buffer to store
                                      // our triangle data.

//
// Classes and Structures
//

struct Vertex
{
    Vertex(){}

    Vertex(float x, float y, float z)
    {
        _x = x;  _y = y;  _z = z;
    }

    float _x, _y, _z;

    static const DWORD FVF;
};
const DWORD Vertex::FVF = D3DFVF_XYZ;
```

Triangle

```
bool Setup()
{
    //
    // Create the vertex buffer.
    //

    Device->CreateVertexBuffer(
        3 * sizeof(Vertex), // size in bytes
        D3DUSAGE_WRITEONLY, // flags
        Vertex::FVF,        // vertex format
        D3DPOOL_MANAGED,    // managed memory pool
        &Triangle,          // return create vertex buffer
        0);                 // not used - set to 0

    //
    // Fill the buffers with the triangle data.
    //

    Vertex* vertices;
    Triangle->Lock(0, 0, (void**)&vertices, 0);

    vertices[0] = Vertex(-1.0f, 0.0f, 2.0f);
    vertices[1] = Vertex( 0.0f, 1.0f, 2.0f);
    vertices[2] = Vertex( 1.0f, 0.0f, 2.0f);

    Triangle->Unlock();

    //
    // Set the projection matrix.
    //

    D3DXMATRIX proj;
    D3DXMatrixPerspectiveFovLH(
            &proj,                      // result
            D3DX_PI * 0.5f,             // 90 - degrees
            (float)Width / (float)Height, // aspect ratio
            1.0f,                       // near plane
            1000.0f);                   // far plane
    Device->SetTransform(D3DTS_PROJECTION, &proj);

    //
    // Set wireframe mode render state.
    //

    Device->SetRenderState(D3DRS_FILLMODE, D3DFILL_WIREFRAME);

    return true;
}
```

Triangle

```
void Cleanup()
{
    d3d::Release<IDirect3DVertexBuffer9*>(Triangle);
}

bool Display(float timeDelta)
{
    if( Device )
    {
        Device->Clear(0, 0, D3DCLEAR_TARGET | D3DCLEAR_ZBUFFER, 0xffffffff, 1.0f, 0);
        Device->BeginScene();

        Device->SetStreamSource(0, Triangle, 0, sizeof(Vertex));
        Device->SetFVF(Vertex::FVF);

        // Draw one triangle.
        Device->DrawPrimitive(D3DPT_TRIANGLELIST, 0, 1);

        Device->EndScene();
        Device->Present(0, 0, 0, 0);
    }
    return true;
}


//
// WndProc
//
LRESULT CALLBACK d3d::WndProc(HWND hwnd, UINT msg, WPARAM wParam, LPARAM lParam)
{
    switch( msg )
    {
    case WM_DESTROY:
        ::PostQuitMessage(0);
        break;

    case WM_KEYDOWN:
        if( wParam == VK_ESCAPE )
            ::DestroyWindow(hwnd);
        break;
    }
    return ::DefWindowProc(hwnd, msg, wParam, lParam);
}
```

Triangle

```
int WINAPI WinMain(HINSTANCE hinstance,
                   HINSTANCE prevInstance,
                   PSTR cmdLine,
                   int showCmd)
{
    if(!d3d::InitD3D(hinstance,
        Width, Height, true, D3DDEVTYPE_HAL, &Device))
    {
        ::MessageBox(0, "InitD3D() - FAILED", 0, 0);
        return 0;
    }

    if(!Setup())
    {
        ::MessageBox(0, "Setup() - FAILED", 0, 0);
        return 0;
    }

    d3d::EnterMsgLoop( Display );

    Cleanup();

    Device->Release();

    return 0;
}
```

Cube

In Setup() – create vertex/index buffer

```
bool Setup()
{
    //
    // Create vertex and index buffers.
    //

    Device->CreateVertexBuffer(
        8 * sizeof(Vertex),
        D3DUSAGE_WRITEONLY,
        Vertex::FVF,
        D3DPOOL_MANAGED,
        &VB,
        0);

    Device->CreateIndexBuffer(
        36 * sizeof(WORD),
        D3DUSAGE_WRITEONLY,
        D3DFMT_INDEX16,
        D3DPOOL_MANAGED,
        &IB,
        0);
```

Cube

In Setup() – define vertex

```
//
// Fill the buffers with the cube data.
//

// define unique vertices:
Vertex* vertices;
VB->Lock(0, 0, (void**)&vertices, 0);

// vertices of a unit cube
vertices[0] = Vertex(-1.0f, -1.0f, -1.0f);
vertices[1] = Vertex(-1.0f,  1.0f, -1.0f);
vertices[2] = Vertex( 1.0f,  1.0f, -1.0f);
vertices[3] = Vertex( 1.0f, -1.0f, -1.0f);
vertices[4] = Vertex(-1.0f, -1.0f,  1.0f);
vertices[5] = Vertex(-1.0f,  1.0f,  1.0f);
vertices[6] = Vertex( 1.0f,  1.0f,  1.0f);
vertices[7] = Vertex( 1.0f, -1.0f,  1.0f);

VB->Unlock();
```

Cube

In Setup() – define indices

```
// define the triangles of the cube:
WORD* indices = 0;
IB->Lock(0, 0, (void**)&indices, 0);

// front side
indices[0]  = 0; indices[1]  = 1; indices[2]  = 2;
indices[3]  = 0; indices[4]  = 2; indices[5]  = 3;

// back side
indices[6]  = 4; indices[7]  = 6; indices[8]  = 5;
indices[9]  = 4; indices[10] = 7; indices[11] = 6;

// left side
indices[12] = 4; indices[13] = 5; indices[14] = 1;
indices[15] = 4; indices[16] = 1; indices[17] = 0;

// right side
indices[18] = 3; indices[19] = 2; indices[20] = 6;
indices[21] = 3; indices[22] = 6; indices[23] = 7;

// top
indices[24] = 1; indices[25] = 5; indices[26] = 6;
indices[27] = 1; indices[28] = 6; indices[29] = 2;

// bottom
indices[30] = 4; indices[31] = 0; indices[32] = 3;
indices[33] = 4; indices[34] = 3; indices[35] = 7;

IB->Unlock();
```

Cube

In Setup() – define camera & projection matrix

```
    //
    // Position and aim the camera.
    //

    D3DXVECTOR3 position(0.0f, 0.0f, -5.0f);
    D3DXVECTOR3 target(0.0f, 0.0f, 0.0f);
    D3DXVECTOR3 up(0.0f, 1.0f, 0.0f);
    D3DXMATRIX V;
    D3DXMatrixLookAtLH(&V, &position, &target, &up);

    Device->SetTransform(D3DTS_VIEW, &V);

    //
    // Set the projection matrix.
    //

    D3DXMATRIX proj;
    D3DXMatrixPerspectiveFovLH(
            &proj,
            D3DX_PI * 0.5f, // 90 - degree
            (float)Width / (float)Height,
            1.0f,
            1000.0f);
    Device->SetTransform(D3DTS_PROJECTION, &proj);

    //
    // Switch to wireframe mode.
    //

    Device->SetRenderState(D3DRS_FILLMODE, D3DFILL_WIREFRAME);

    return true;
}
```

Cube

In Display() – rotation matrix for cube spinning & draw cube

```
bool Display(float timeDelta)
{
    if( Device )
    {
        //
        // spin the cube:
        //
        D3DXMATRIX Rx, Ry;

        // rotate 45 degrees on x-axis
        D3DXMatrixRotationX(&Rx, 3.14f / 4.0f);

        // incremement y-rotation angle each frame
        static float y = 0.0f;
        D3DXMatrixRotationY(&Ry, y);
        y += timeDelta;

        // reset angle to zero when angle reaches 2*PI
        if( y >= 6.28f )
            y = 0.0f;

        // combine x- and y-axis rotation transformations.
        D3DXMATRIX p = Rx * Ry;

        Device->SetTransform(D3DTS_WORLD, &p);

        //
        // draw the scene:
        //
        Device->Clear(0, 0, D3DCLEAR_TARGET | D3DCLEAR_ZBUFFER, 0xffffffff, 1.0f, 0);
        Device->BeginScene();

        Device->SetStreamSource(0, VB, 0, sizeof(Vertex));
        Device->SetIndices(IB);
        Device->SetFVF(Vertex::FVF);

        // Draw cube.
        Device->DrawIndexedPrimitive(D3DPT_TRIANGLELIST, 0, 0, 8, 0, 12);

        Device->EndScene();
        Device->Present(0, 0, 0, 0);
    }
    return true;
}
```

Teapot

```
bool Setup()
{
    //
    // Create the teapot geometry.
    //

    D3DXCreateTeapot(Device, &Teapot, 0);

    //
    // Position and aim the camera.
    //

    D3DXVECTOR3 position(0.0f, 0.0f, -3.0f);
    D3DXVECTOR3 target(0.0f, 0.0f, 0.0f);
    D3DXVECTOR3 up(0.0f, 1.0f, 0.0f);
    D3DXMATRIX V;
    D3DXMatrixLookAtLH(&V, &position, &target, &up);
    Device->SetTransform(D3DTS_VIEW, &V);

    //
    // Set projection matrix.
    //

    D3DXMATRIX proj;
    D3DXMatrixPerspectiveFovLH(
            &proj,
            D3DX_PI * 0.5f, // 90 - degree
            (float)Width / (float)Height,
            1.0f,
            1000.0f);
    Device->SetTransform(D3DTS_PROJECTION, &proj);

    //
    // Switch to wireframe mode.
    //

    Device->SetRenderState(D3DRS_FILLMODE, D3DFILL_WIREFRAME);

    return true;
}
```

Teapot

```
void Cleanup()
{
    d3d::Release<ID3DXMesh*>(Teapot);
}

bool Display(float timeDelta)
{
    if( Device )
    {
        //
        // Spin the teapot:
        //

        D3DXMATRIX Ry;
        static float y = 0.0f;
        D3DXMatrixRotationY(&Ry, y);

        y += timeDelta;
        if(y >= 6.28f)
            y = 0.0f;

        Device->SetTransform(D3DTS_WORLD, &Ry);

        //
        // Draw the Scene:
        //
        Device->Clear(0, 0, D3DCLEAR_TARGET | D3DCLEAR_ZBUFFER, 0xffffffff, 1.0f, 0);
        Device->BeginScene();

        // Draw teapot using DrawSubset method with 0 as the argument.
        Teapot->DrawSubset(0);

        Device->EndScene();
        Device->Present(0, 0, 0, 0);
    }
    return true;
}
```

D3DXCreate

```
bool Setup()
{
    //
    // Create the objects.
    //

    D3DXCreateTeapot(
        Device,
        &Objects[0],
        0);

    D3DXCreateBox(
        Device,
        2.0f, // width
        2.0f, // height
        2.0f, // depth
        &Objects[1],
        0);

    // cylinder is built aligned on z-axis
    D3DXCreateCylinder(
        Device,
        1.0f, // radius at negative z end
        1.0f, // radius at positive z end
        3.0f, // length of cylinder
        10,   // slices
        10,   // stacks
        &Objects[2],
        0);

    D3DXCreateTorus(
        Device,
        1.0f, // inner radius
        3.0f, // outer radius
        10,   // sides
        10,   // rings
        &Objects[3],
        0);

    D3DXCreateSphere(
        Device,
        1.0f, // radius
        10,   // slices
        10,   // stacks
        &Objects[4],
        0);
```

D3DXCreate

```
    //
    // Build world matrices - position the objects in world space.
    // For example, ObjWorldMatrices[1] will position Objects[1] at
    // (-5, 0, 5).  Likewise, ObjWorldMatrices[2] will position
    // Objects[2] at (5, 0, 5).
    //

    D3DXMatrixTranslation(&ObjWorldMatrices[0],  0.0f, 0.0f,  0.0f);
    D3DXMatrixTranslation(&ObjWorldMatrices[1], -5.0f, 0.0f,  5.0f);
    D3DXMatrixTranslation(&ObjWorldMatrices[2],  5.0f, 0.0f,  5.0f);
    D3DXMatrixTranslation(&ObjWorldMatrices[3], -5.0f, 0.0f, -5.0f);
    D3DXMatrixTranslation(&ObjWorldMatrices[4],  5.0f, 0.0f, -5.0f);

    //
    // Set the projection matrix.
    //

    D3DXMATRIX proj;
    D3DXMatrixPerspectiveFovLH(
            &proj,
            D3DX_PI * 0.5f, // 90 - degree
            (float)Width / (float)Height,
            1.0f,
            1000.0f);
    Device->SetTransform(D3DTS_PROJECTION, &proj);

    //
    // Switch to wireframe mode.
    //

    Device->SetRenderState(D3DRS_FILLMODE, D3DFILL_WIREFRAME);

    return true;
}
void Cleanup()
{
    for(int i = 0; i < 5; i++)
        d3d::Release<ID3DXMesh*>(Objects[i]);
}
```

```
bool Display(float timeDelta)
{
    if( Device )
    {
        // Animate the camera:
        // The camera will circle around the center of the scene. We use the
        // sin and cos functions to generate points on the circle, then scale them
        // by 10 to further the radius.In addition the camera will move up and down as it circles about the scene.
        static float angle = (3.0f * D3DX_PI) / 2.0f;
        static float cameraHeight = 0.0f;
        static float cameraHeightDirection = 5.0f;

        D3DXVECTOR3 position( cosf(angle) * 10.0f, cameraHeight, sinf(angle) * 10.0f );

        // the camera is targetted at the origin of the world
        D3DXVECTOR3 target(0.0f, 0.0f, 0.0f);

        // the worlds up vector
        D3DXVECTOR3 up(0.0f, 1.0f, 0.0f);

        D3DXMATRIX V;
        D3DXMatrixLookAtLH(&V, &position, &target, &up);
        Device->SetTransform(D3DTS_VIEW, &V);

        // compute the position for the next frame
        angle += timeDelta;
        if( angle >= 6.28f )
            angle = 0.0f;

        // compute the height of the camera for the next frame
        cameraHeight += cameraHeightDirection * timeDelta;
        if( cameraHeight >= 10.0f )
            cameraHeightDirection = -5.0f;

        if( cameraHeight <= -10.0f )
            cameraHeightDirection = 5.0f;

        // Draw the Scene:
        Device->Clear(0, 0, D3DCLEAR_TARGET | D3DCLEAR_ZBUFFER, 0xffffffff, 1.0f, 0);
        Device->BeginScene( );

        for(int i = 0; i < 5; i++)
        {
            // Set the world matrix that positions the object.
            Device->SetTransform(D3DTS_WORLD, &ObjWorldMatrices[i]);

            // Draw the object using the previously set world matrix.
            Objects[i]->DrawSubset(0);
        }

        Device->EndScene( );
        Device->Present(0, 0, 0, 0);
    }
    return true;
}
```