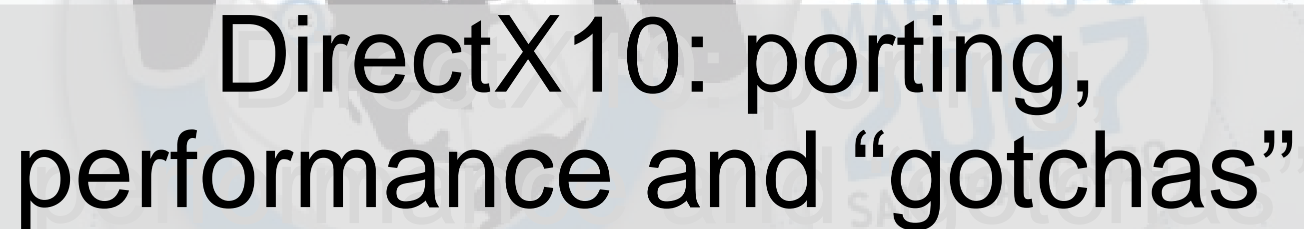
DirectX10: porting, performance and “gotchas”



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DirectX 10 and Me…

- The best DirectX ever – I love it!
- Powerful feature set
  - With power comes responsibility
  - More ways to do something wrong and kill performance
- New or changed behaviors – many porting “gotchas”

Deprecated Features

- Alpha test
- Triangle fans
- Point sprites
- Wrap texture modes
- TnL clip planes

Fullscreen Initialization

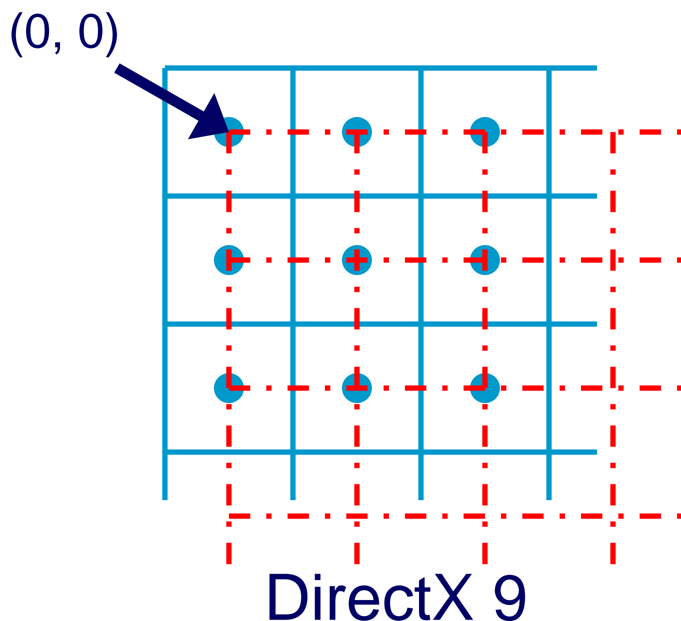
- Special flag in swap chain description to allow mode switch

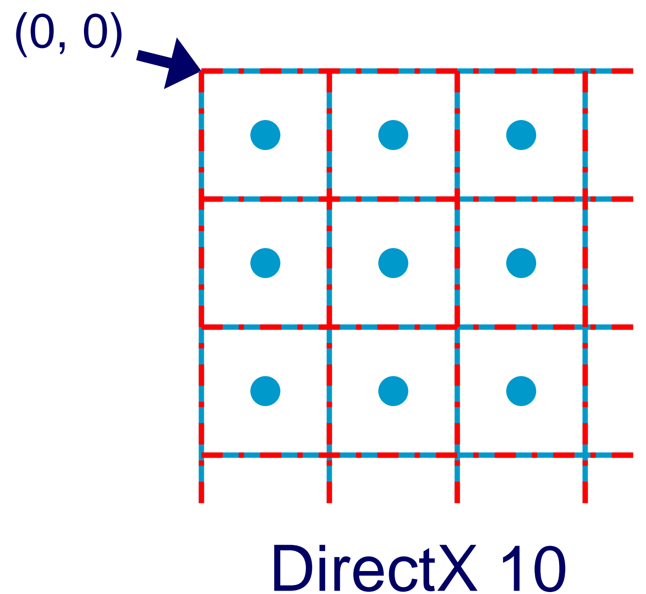
```
DXGI_SWAP_CHAIN_DESC scd;
scd.Flags = DXGI_SWAP_CHAIN_FLAG_ALLOW_MODE_SWITCH;

D3D10CreateDeviceAndSwapChain(…, scd, …);
```

- Otherwise back buffer is stretch blit'ed to desktop resolution

Pixel Coordinate System

- Finally pixels and texels match
- Don't need to offset position or texture coords by 0.5 texel





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Pixel Coordinate System

- This will affect all the screen space DirectX 9 code/shaders
- If offset is done in PS, move it to app code
  - Make shaders DX9/10 cross-compatible

Small Batch Problem

- DirectX 10 API helps
  - Currently up to 2x measured improvement over DX9 from API changes
- New features provide additional boost
  - Instancing
  - Uber-shaders
  - GS (e.g.. render to cubemap)
- Trade GPU performance to solve problem

Instancing

- Draw as many objects per draw call as possible
- Create object variations with…
  - Large constant storage
  - Displacement maps
  - Uber-shaders

Uber-shaders

- Combine multiple materials within single shader
- Pros:
  - Keep common code portion in on-chip shader cache
- Cons:
  - Flow control
  - Higher GPR pressure

Optional DX10 Features

- Yes, there's such a thing
  - Some format support is optional
  - E.g. MSAA
  - E.g. FP32 filtering
- Always check with ID3D10Device::CheckFormatSupport()

MSAA Capabilities

- Multiple support flags for MSAA:
  - D3D10_FORMAT_SUPPORT_MULTISAMPLE_RENDERTARGET
  - D3D10_FORMAT_SUPPORT_MULTISAMPLE_RESOLVE
  - D3D10_FORMAT_SUPPORT_MULTISAMPLE_LOAD
- Some formats might be renderable, but not resolvable!

Constants

- Literal HLSL constants are the fastest, don't put common constants in buffers
  - E.g. -1, 0.5, 2…
- Non-indexed constants or indexed with a literal could be faster than indexed with a computed value
  - Is there anything you can do to help this, beyond simple unrolling?

Constant Management

- Need to specify const location in HLSL when not using Effects
- Even with Effects might want to do “smarter” custom const management
- Special syntax for “manual” constant placement

Manual Const Binding

- HLSL syntax

```
// Will bind constant buffer to slot #4
cbuffer MyConstantBuffer : register(b4)
{
        // Specify exact offset
        float  fMyConstant1 :   packoffset(c2.z);
        float4 vecMyConstant2 : packoffset(c4);
        // etc.
};
```

Primitive Topology and Draw Calls

- Primitive topology is separate from draw function

```
dev->IASetPrimitiveTopology(blah);
dev->Draw(3, 0);
```

- Keep these 2 functions together
  - Easy to forget to set proper topology
  - Will be chasing false corruption, driver bug and etc.

Input Layout

- Matching vertex data to VS inputs
- Unlike in DirectX 9 it now requires knowledge about VS (input signature)
- Don't need to create a unique one for each VS
  - Enough if shader signature matches

Input Layout

- Knowledge of VS at decl/input layout creation time might be a problem for DX9 engine architectures
- Quick DX9 port hack
  - Keep copies of "dummy" VS just for the signatures
  - Create input layouts from them

Stream Out

- Primitive topology is converted to lists
- For subsequent passes loses the benefit of the vertex reuse
- Solution:
  - Use points for stream out
  - Use indexed primitives with proper topology on the second pass

Stream Out

- With SO enabled each call appends to the end of the bound buffers
- Need to bind the same buffers again to output to the beginning of the buffers
  - Might interfere with renderer state caching
- Good idea to un-bind buffers as soon as done with SO
  - Easy to forget and cause some corruption

Stream Out FX Syntax

```
// Output position only
SetGeometryShader(ConstructGSWithSO(shader,
   "SV_Position"));

// Output 2 streams, use 2D tex coords
SetGeometryShader(ConstructGSWithSO(shader,
   “0:SV_Position,1:tex.xy"));

// Output only z component of position
SetGeometryShader(ConstructGSWithSO(shader,
   “SV_Position.z"));
```

Stream Out From VS

- Output is after GS, but GS can be pass-through NULL shader
  - Pass VS code instead of GS
  - Just requires the output signature from VS
- Don’t write the actual GS shader!

Stream Out From VS

- Effects code:

```
technique10 t0
{
  pass p0
  {
    SetVertexShader(CompileShader(vs_4_0,
      VsMain()));
    SetGeometryShader(ConstructGSWithSO(
      CompileShader(vs_4_0, VsMain()),
      "SV_Position"));
    SetPixelShader(CompileShader(ps_4_0, PsMain()));
  }
}
```

SO as VS optimization

- Unified architecture requires a new thinking
  - VS isn't free anymore when PS-bound
  - Think about total workload throughout VS/GS/PS
- Could stream out data that would be computed multiple times in VS/GS
  - E.g. animation
- SO might not be a win for small VS

Scatter Implementation

- SO isn't flexible enough to implement scatter
- Could implement scatter with point primitives
  - Tweak point position in VS/GS
- E.g. sort on GPU, data binning, etc.

Data Binning with Scatter

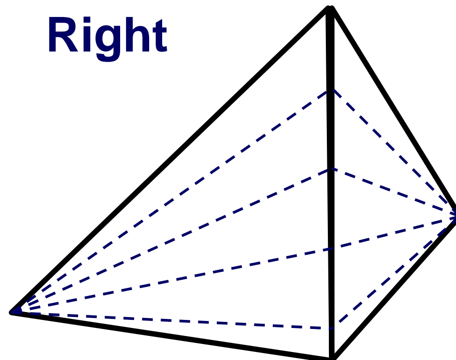
- E.g. building histogram for HDR
  - Draw points
    - Output is 1D render target with histogram
  - For each point in the image
    - Fetch from RTT in VS
    - Adjust position (bin index) based on the texture value, output 1 for counting
    - Additively blend to count points in the bins

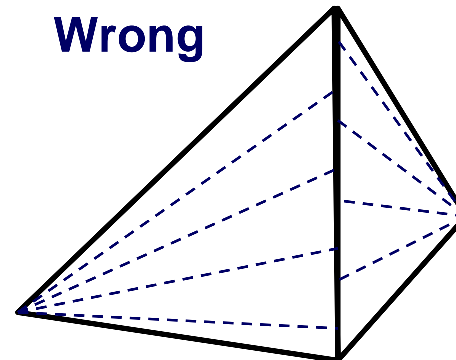
Shader Signature Matching

- In DirectX 9 semantics matched automatically
- In DirectX 10 shader input/output structure order should match
  - Put optional data at the end
  - Partial match might be hard to track
- Might be a big problem for DX9 ports

GS: Edge Orientation

- When computing per-edge data need to ensure it matches for adjacent triangles
  - Could tag vertices for selecting proper orientation
- E.g. edge tessellation, fur fins





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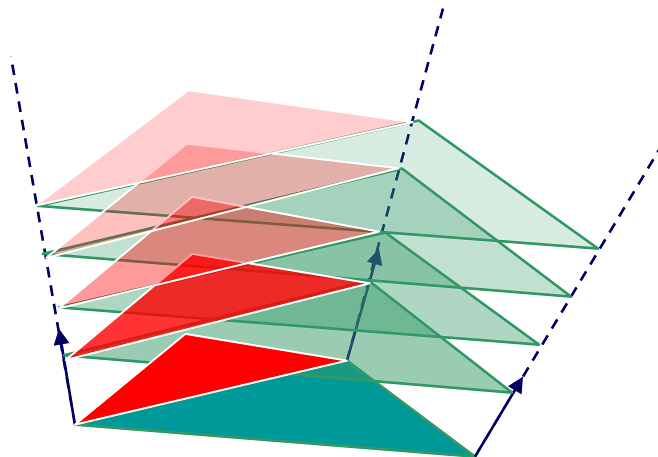
GS: Order of Output Triangles

- Well defined output triangle order
  - It's as if each triangle processed serially
- Consider interaction with transparency
  - E.g. won't work for fur shells generation



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GS: Triangle Winding

- Backface culling happens in the rasterizer after GS
- Need to keep winding in mind when generating geometry in GS
  - Easy to neglect and blame drivers for missing geometry

GS: Render to Cubemap

- An interesting feature to combat small batch performance
  - GS replicates triangles to different cubemap faces
- Performance tradeoff
  - Lighter CPU load (fewer draw calls)
  - Heavier GPU load
- Could cull in GS to reduce amount of generated data

Render to Cubemap Example 1/2

```
[maxvertexcount(18)]
void main(triangle GsInShadow In[3],
  inout TriangleStream<PsInShadow> Stream)
{
  PsInShadow Out;
  // Loop though all faces
  [unroll]
  for (int k = 0; k < 6; k++) {
    // Select face target
    Out.target = k;
    // Transform verts
    float4 pos[3];
    pos[0] = mul(mvpArray[k], In[0].pos);
    pos[1] = mul(mvpArray[k], In[1].pos);
    pos[2] = mul(mvpArray[k], In[2].pos);
    // Frustum culling
    float4 t0 = saturate(pos[0].xyxy*float4(-1,-1,1,1)-pos[0].w);
    float4 t1 = saturate(pos[1].xyxy*float4(-1,-1,1,1)-pos[1].w);
    float4 t2 = saturate(pos[2].xyxy*float4(-1,-1,1,1)-pos[2].w);
    float4 t = t0 * t1 * t2;
    [branch]
    if (!any(t)) {
```

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Render to Cubemap Example 2/2

```
. . .
      // Back face culling
      float2 d0 = pos[1].xy/abs(pos[1].w)-pos[0].xy/abs(pos[0].w);
      float2 d1 = pos[2].xy/abs(pos[2].w)-pos[0].xy/abs(pos[0].w);
      [branch]
      if (d1.x * d0.y > d0.x * d1.y) {
        // Triangle is visible - emit
        [unroll]
        for (int i = 0; i < 3; i++) {
          Out.pos = pos[i];
          // Other data processed here
          // . . .

          Stream.Append(Out);
        }
        Stream.RestartStrip();
      }
    }
  }
}
```

Position in PS

- PS could have SV_Position as input
  - …VS or GS also have SV_Position output
- Same name, different values
  - VS/GS – position in clipping space
  - PS – screen space position (like vPos register) and z, rhw
- Returns 0.5, 1.5, 2.5, … coordinates
  - Due to new pixel coordinate system

Integer Data and Instructions

- Use integer types to compact data
  - Bit packing vertex data, consts, etc.
  - E.g. conditionals for uber-shaders encoded per vertex or per primitive
- Beware of some int instruction cost
  - Division is expensive
  - Explore optimization opportunities

Backwards Compatible Shader Compilation

- Special compiler flag
  - **D3D10_SHADER_ENABLE_BACKWARDS_COMPATIBILITY**
  - Enable old shaders to compile to SM 4.0
  - Not valid for geometry shaders
- Could cause compilation errors when mixing GS with old VS
  - Old POSITION semantic is translated to SV_Position
  - Solution: replicate structures for GS with new semantics

Texture/Sampler States

- Samplers and textures are decoupled in DirectX 10
- Important to keep in mind when porting from DirectX 9
  - Might require significant engine re-architecture effort

Disabling Mipmapping

- There's no NONE mip filtering mode in DirectX 10
  - No direct way to disable mipmapping
- Hacks to emulate functionality
  - Textures with only 1 mip level
  - Setting MaxLOD in sampler state to 0

```
D3D10_SAMPLER_DESC samp;
samp.MaxLOD = 0.0f;
```

Integer Textures

- Default texture declaration type is float
- Integer type texture declaration

```
// Using unsigned int
Texture2D <uint4> myTex0;
// Using int
Texture2D <int4> myTex1;
```

- E.g. important when reading stencil format (X24_TYPELESS_G8_UINT)

Reading Depth/Stencil

- Cannot simultaneously read depth and stencil from the same buffer
  - Create 2 separate shader resource views
    - Depth
    - Stencil
  - Treat as 2 separate textures in shader
- MSAA depth/stencil buffers can't be read

Gradients and Flow Control

- Same as before, can't sample textures with varying texture coordinates (different across pixel quad)
- Compiler is smart figuring out what is varying and what isn't
  - Don't blindly use t.SampleGrad() everywhere

MRT Rendering

- MRTs are more flexible in DirectX 10
  - Up to 8 render targets
  - Any of 8 slots can be set
- For performance reasons use the lowest MRT slots possible
  - Don’t leave holes in MRT slot assignment
- Can’t mix MSAA and non-MSAA

MRT Rendering

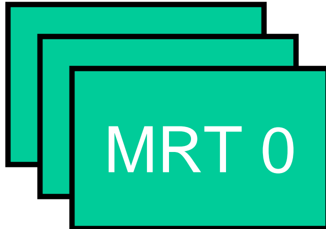
- Even if MRT #0 isn’t bound, target #0 alpha is used for Alpha-to-Coverage
- Don’t forget to enable render target masks to enable MRT output
  - Separate controls for each MRT

```
// enable MRT
D3D10_BLEND_DESC bd;
bd.RenderTargetWriteMask[0] = 0x0f;
bd.RenderTargetWriteMask[1] = 0x0f;
bd.RenderTargetWriteMask[4] = 0x0f;
```

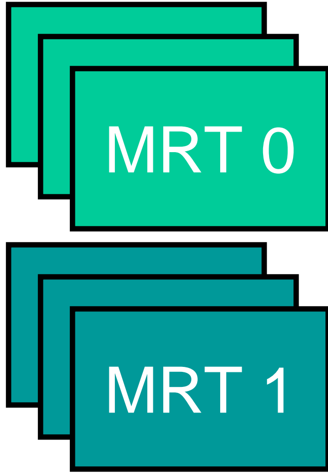
MRT vs. Indexable Render Target Array

- MRT and render target arrays are orthogonal

MRT example



Render array example



MRT + render array example

NULL Outputs

- Can have NULL SO, RTs and depth
- Can disable RTs/depth while doing stream out only

Depth Clamping/Clipping

- Back-end always clamps depth
  - Both interpolated and from PS
- Viewport can enable/disable depth clipping before it gets to clamping

```
// enable depth clipping
D3D10_RASTERIZER_DESC rd;
rd.DepthClipEnable = true;
```

- Also, W < 0 will clip

sRGB implementation differences

- DirectX 10 sRGB implementation is different from DirectX 9
  - Differently spec'ed gamma curve
  - All blend and filter in linear space
    - sRGB fetch – degamma before filter
    - sRGB blend – degamma DEST before blend
- DirectX 10: correct implementation that could make DX9 content look wrong

Separate Alpha Blend

- No more separate alpha blend enable
- It's always on, so don't forget to set
  - SrcBlendAlpha
  - DestBlendAlpha
  - BlendOpAlpha

Dual Source Color Blending

- Uses 2 PS outputs for blending equation
- New alpha blend arguments
  - D3D10_BLEND_SRC1COLOR
  - D3D10_BLEND_INVSRC1COLOR
  - D3D10_BLEND_SRC1ALPHA
  - D3D10_BLEND_INVSRC1ALPHA
- Doesn’t work with MRT!

Alpha-to-Coverage

- Works even without MSAA
  - Can produces screen-door effect
- Implementation is IHV dependent
  - Grey area of the spec
  - For better quantization HW can use some area dithering
  - Be careful not to make assumptions about implementation

Custom AA Resolves

- Application can implement custom resolves in PS
  - Access to individual RT samples
  - Special syntax for accessing samples

```
// Declare MSAA texture with 4 samples
Texture2DMS<float4,4> t;
// Load sample #0
a = t.Load(tc, 0); // tc – unnormalized tex. coords
// Load sample #1
b = t.Load(tc, 1);
```

Custom AA Resolves and HDR

- Need to perform tone mapping before resolve to get correct MSAA results

Custom AA Resolves and HDR

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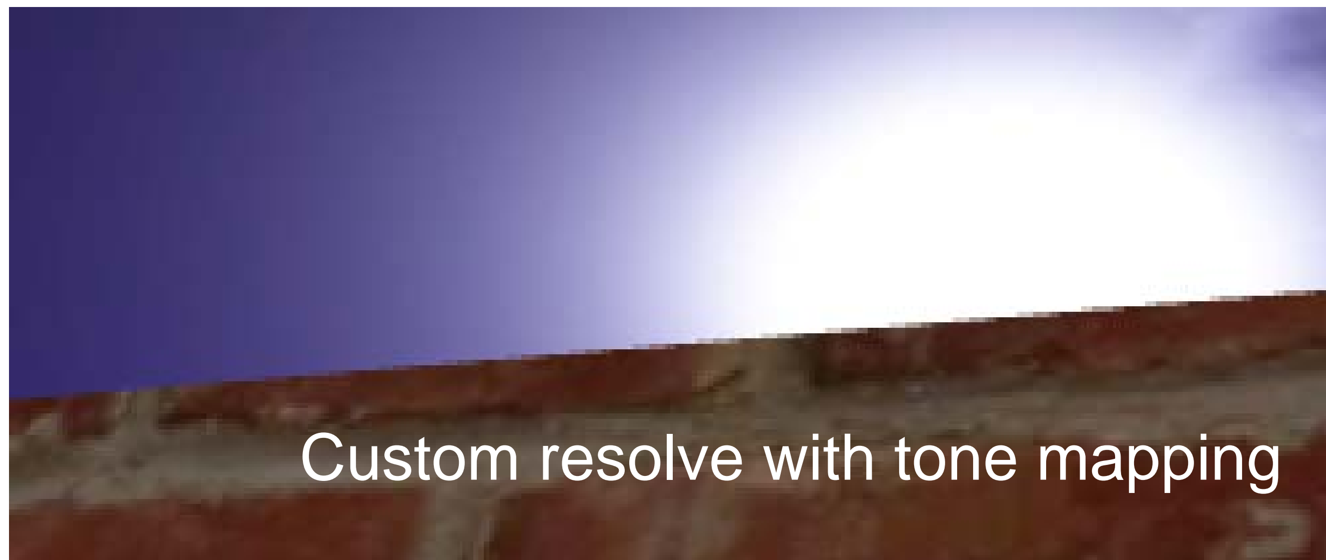

Custom AA Resolves and HDR

```
Texture2DMS<float4, SAMPLES> tHDR;

float4 main(float4 pos: SV_Position) : SV_Target
{
    int3 coord;
    coord.xy = (int2)In.pos.xy;
    coord.z = 0;
    // Correct exposure for individual samples and sum it up
    float4 sum = 0;
    [unroll]
    for (int i = 0; i < SAMPLES; i++)
    {
        float4 c = tHDR.Load(coord, i);
        sum.rgb += 1.0 - exp(-exposure * c.rgb);
    }
    sum *= (1.0 / SAMPLES);
    // Gamma correction
    sum.rgb = pow(sum.rgb, 1.0 / 2.2);
    return sum;
}
```

Acknowledgement & References

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  - Nicolas, Emil, Natasha, Thorsten and the rest of ISV and 3DARG teams

- Real-time HDR histogram generation
  - Check out upcoming I3D ’07 paper by Thorsten Scheuermann

Questions