Low-Overhead Rendering with Direct3D

Evan Hart
Principal Engineer - NVIDIA

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Ground Rules

- No DX9
- Need to move fast
  - Big topic in 30 minutes
  - Assuming experienced audience
- Everything is a tradeoff
  - These are suggestions **if** an app is SW limited

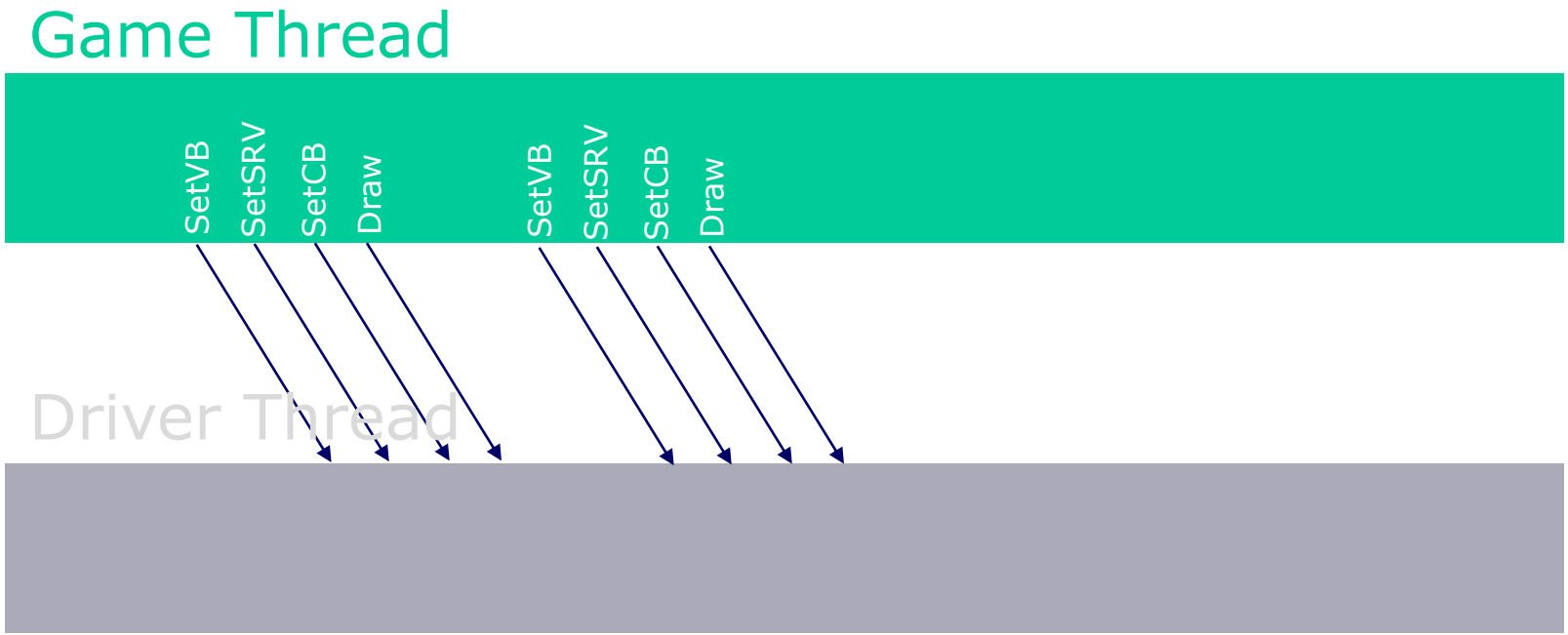
Why care about overhead?

- Overhead translates to draws per second
- Everyone wants more draws
  - More detailed/interesting world
  - Further draw distance
  - More shadows

Do I have a problem?

- Optimizing the wrong thing is harmful
- All games are CPU limited somewhere
  - Also likely GPU-bound somewhere
- Need to find the tradeoff for your game
- Genre/style can influence balance
  - Online / strategy can be worse

Game / Driver Interaction



Game/Driver Interaction

- Driver thread does most real API work
  - Not easily visible in app threads
- App threads just queue commands
  - Typically very fast
- Deferred context is slightly different
  - Driver work is done on app thread
  - Work is kept minimal though

State of the World

- 5 Million draws / second is feasible
  - >50k draws / scene
- 290K draws / second w/ state changes
  - Change most relevant state
- Drawing is cheap
- Object references are expensive

“Full” Draw Call

```
Ctx->IASetInputLayout( … );
Ctx->IASetVertexBuffers( … );
Ctx->IASetIndexBuffer( … );
Ctx->VSSetShader( … );
Ctx->Map( … );
Ctx->VSSetConstantBuffers( … );
Ctx->PSSetShader( … );
Ctx->Map( … );
Ctx->PSSetConstantBuffers( … );
Ctx->PSSetShaderResources( … );
Ctx->PSSetSamplers( … );
Ctx->DrawIndexed( … );
```

Cost of the “Full” Draw Call

- Binding 5+ GPU memory objects
  - Vertices, Indices, Constants, Textures
- Two memory management operations
  - Map + DISCARD
- Whole bunch of indirections and cache misses

User costs for “Full” draw call

- ~14 COM calls
- Copying of data tied to buffer update
- Gathering of any data needed to make the calls
- Map probably looks the most expensive
  - Requires driver to provide an immediate response

Driver costs for a “Full” draw

- Every object ref potentially requires
  - Pointer indirection
  - Object lifetime management
  - Object residency management
- Map + Discard requires
  - Rename active object
  - Manage memory pool

What can be done?

- Parallelize the load
- Reduce non-draw functions
- Reduce draw calls
  - Seems counter-intuitive to our goals

Deferred Contexts

- Can allow the load to be spread out
- Biggest help is Map related to constants
  - 30-50% faster isn’t unreasonable
    - On drivers that support them natively
- Not a panacea as the driver thread still does a lot of serial work

Reducing Draw Setup

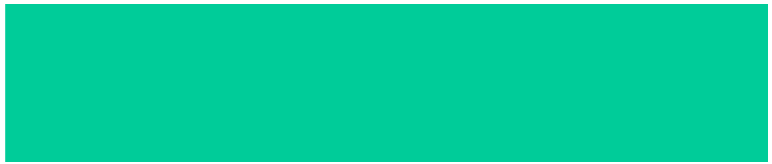
- Übershaders
- Optimize Constant Buffers
- Sub-allocate Vertex and Index Buffers
- Managing SRVs
- Managing Samplers

Ubershaders

- Changing shaders snowballs costs
  - Shader is connected to everything
- Conditionals are fairly cheap
  - `if (hasSpec)  / for( numLayers )`
- Can have a negative impact on GPU costs
  - Secondary factors like register pressure

Reducing Constant Buffer Costs

Per-Frame Constants



Per-View Constants

Per-Draw Constants

Shared Constant Buffers DX 11.1

```
PSSetConstantBuffers1(
        // Parameters from older methods
        UINT StartSlot,
        UINT NumBuffers,
        ID3DBuffer *const *Buffers,

        // Offset in number of constants (16 bytes each)
        const UINT* FirstConstant,

        // Size of the block in constants ( Num % 16 == 0)
        const UINT* NumConstants
)
```

Shared Constant Buffers DX 11

```
// Vertex Shader

// VS constants at the beginning
float4x4 WVP_matrix :       packoffset( c0 );
float4x4 W_matrix   :       packoffset( c4 );
…

// Pixel Shader

// PS constants later
float4 Ambient      :       packoffset( c16 );
 …
```

Vertex and Index Suballocation

- Simple concept
  - Multiple objects can share the same buffer
- Most games standardize vertex formats
  - Handful of configurations
- DrawIndexed offers BaseIndex/BaseVertex
  - Vastly cuts down on # of IASetXXX calls

SRV Management Basics

- Assign slots for “global” textures
  - Shadow maps, environment maps
- Don’t “Clean-up” slots
  - Binding NULL does have a cost
- Group SRVs that change together
  - Albedo and normal

SRV Management Advanced

- Suballocate from texture arrays
  - Sizes and format are typically quasi-standard
  - Terrain tiles are a fantastic example
  - Just need to add an extra index to CB
- Need to take some care
  - Allocating the max array for all combinations probably doesn’t make sense

Sampler Management

- Repeat SRV basic advice
- Samplers don’t change much
  - Fairly limited set of common choices

Revised Draw Call

```
// Setup:
//   ubershader constants
//   texture array indices
//   normal constants, like transform
Ctx->Map( … );

// Don’t need to rebind CBs

// Offsets in multiuse IB/VB
//  StartIndexLocation -> offset to IB
//  VertexOffset -> offset for vertices
Ctx->DrawIndexed( … );
```

DX 11.1 is better still

- Use one Map() for batch of draw calls
- Change offset into constant buffer per draw

Reducing draw calls

- You've heard it for years
  - Instancing
- Nearly every game could benefit
  - Same model drawn N times in a frame
- There are practical concerns
  - Depth sorting
  - Constant buffer size

Wrap-up

- Analyze **your** situation
- Consider API options
- Get the engine out of the way
  - See appendix slides online

Thanks

NVIDIA Devtech team

NVIDIA D3D Driver Performance Team

Bryan Dudash

Dan Baker