# unity Developer Day

MEXICO 2016

## Mobile Optimizations

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Product Manager of Doom

## Goal

Arm you with more possibilities for optimizations
that you will be able to utilize

## Agenda

- Recognizing Your Performance Bottleneck
- Profiling in and out of Unity
- Optimizing Tips

## What do we mean, Performance?

Frametime

- CPU usage (Gamecode, Physics, Skinning, Particles, …)
- GPU usage (Drawcalls, Shader usage, Image effects, …)

Stalls

- Spikes in framerate caused by heavy tasks (e.g. GC.Collect)
- Physics world rebuild due to moved static colliders*

Memory

- Optimizing memory is very important on device
- Avoid GC Hickups by reducing memory activity
- Leak detection

## Know Your Bottlenecks

Question: Why are we slow?

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- CPU or GPU Bound?
- Physics or Rendering?
- Update() or FixedUpdate() loop?

## Know Your Bottlenecks

Answer: Always start in the same place...

- Profile
- Profile
- Profile

## CPU-Heavy Tasks

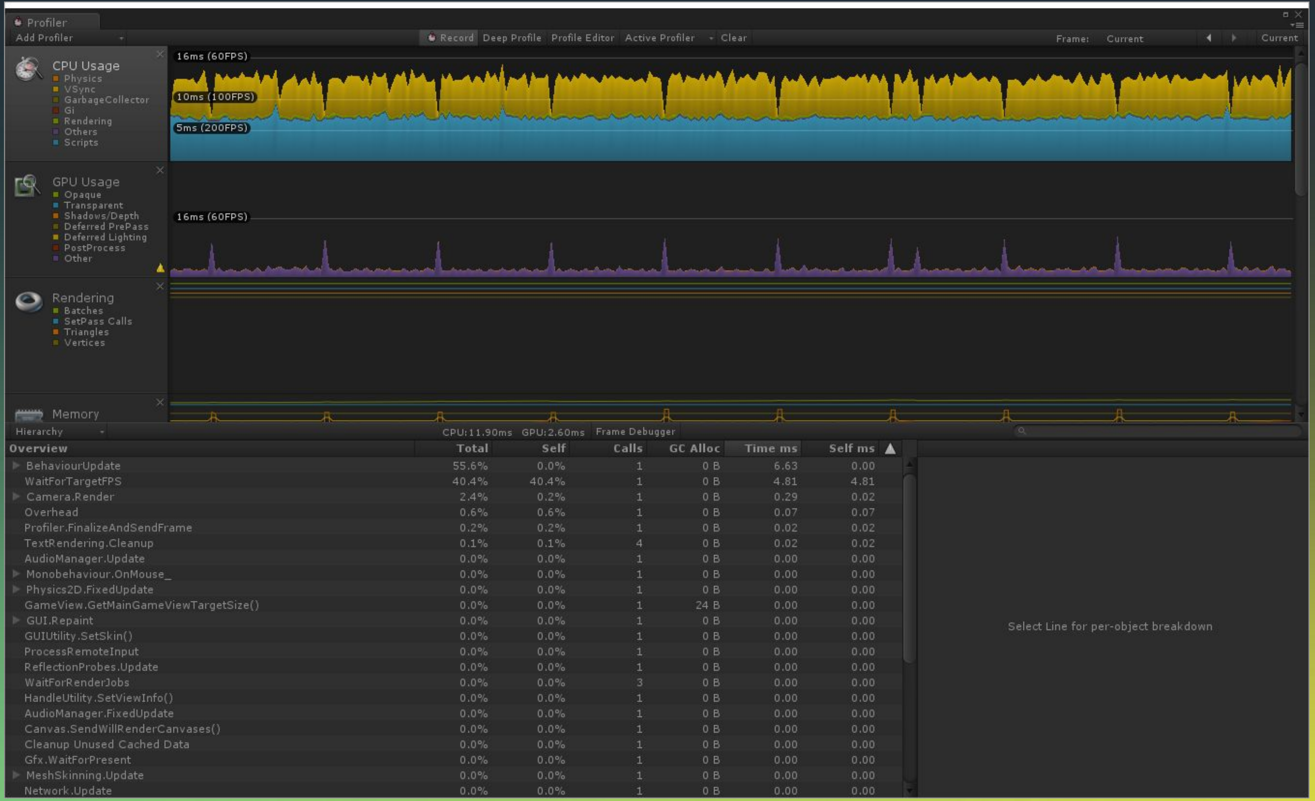
- Physics
- Animation
- Gameplay code
- Runtime GI
- Reflection probes
- Particles
- Creating Batches

## GPU-Heavy Tasks

- Switching Batches
- Geometry/Pixel shaders
- Compute shaders
- Skinning

## Profiling in Unity

- Unity Profiler
    - In-Editor
    - Live Builds on devices
    - Rapid Iteration
    - Memory usage of individual assets



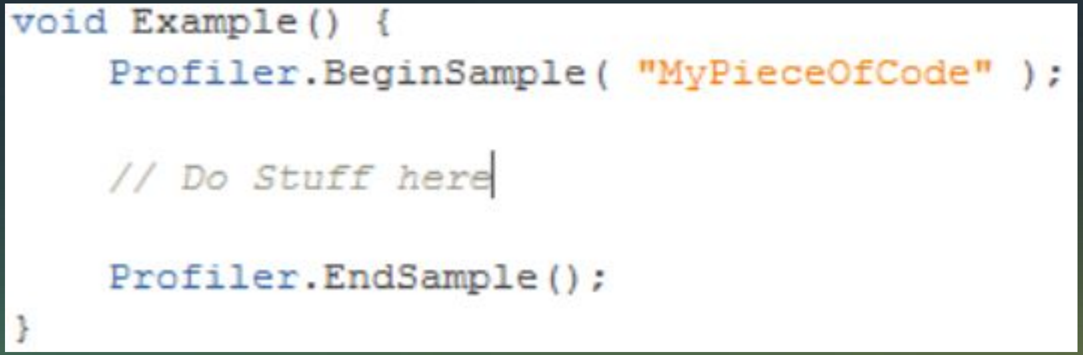
CPU:11.90ms GPU:2.60ms

| Overview | Total | Self | Calls | GC Alloc | Time ms | Self ms |
|---|---|---|---|---|---|---|
| ▶ BehaviourUpdate | 55.6% | 0.0% | 1 | 0 B | 6.63 | 0.00 |
| WaitForTargetFPS | 40.4% | 40.4% | 1 | 0 B | 4.81 | 4.81 |
| ▶ Camera.Render | 2.4% | 0.2% | 1 | 0 B | 0.29 | 0.02 |
| Overhead | 0.6% | 0.6% | 1 | 0 B | 0.07 | 0.07 |
| Profiler.FinalizeAndSendFrame | 0.2% | 0.2% | 1 | 0 B | 0.02 | 0.02 |
| TextRendering.Cleanup | 0.1% | 0.1% | 4 | 0 B | 0.02 | 0.02 |
| AudioManager.Update | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| ▶ Monobehaviour.OnMouse_ | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| ▶ Physics2D.FixedUpdate | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| GameView.GetMainGameViewTargetSize() | 0.0% | 0.0% | 1 | 24 B | 0.00 | 0.00 |
| ▶ GUI.Repaint | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| GUIUtility.SetSkin() | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| ProcessRemoteInput | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| ReflectionProbes.Update | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| WaitForRenderJobs | 0.0% | 0.0% | 3 | 0 B | 0.00 | 0.00 |
| HandleUtility.SetViewInfo() | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| AudioManager.FixedUpdate | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| Canvas.SendWillRenderCanvases() | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| Cleanup Unused Cached Data | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| Gfx.WaitForPresent | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| ▶ MeshSkinning.Update | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |
| Network.Update | 0.0% | 0.0% | 1 | 0 B | 0.00 | 0.00 |

**TIPS:**
**Use Deep Profile to see calls to all methods (including game code)**
**Use BeginSample() EndSample() to minimize overhead**

# Custom Profiler Tags

Do this:

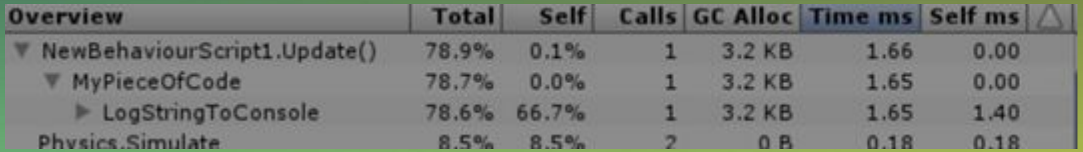


```
void Example() {
    Profiler.BeginSample( "MyPieceOfCode" );

    // Do Stuff here

    Profiler.EndSample();
}
```

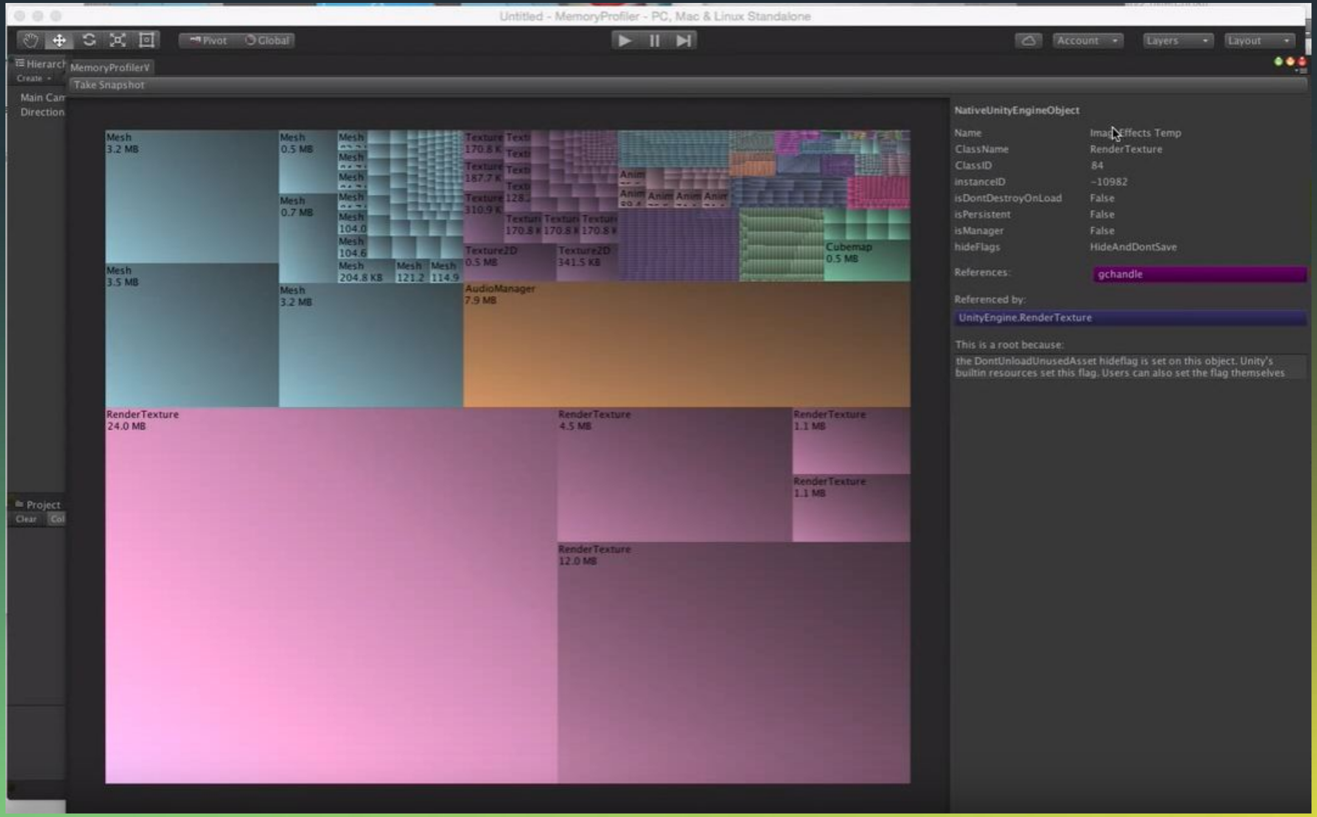
Get This:



```
Overview                           Total    Self   Calls  GC Alloc  Time ms  Self ms
▼ NewBehaviourScript1.Update()     78.9%    0.1%       1    3.2 KB     1.66     0.00
  ▼ MyPieceOfCode                  78.7%    0.0%       1    3.2 KB     1.65     0.00
    ▶ LogStringToConsole           78.6%   66.7%       1    3.2 KB     1.65     1.40
 Physics.Simulate                   8.5%    8.5%       2       0 B     0.18     0.18
```

# Unity Memory Profiler

- Open Source [https://bitbucket.org/Unity-Technologies/memoryprofiler](https://bitbucket.org/Unity-Technologies/memoryprofiler)
  - Profile memory of games running on device



NativeUnityEngineObject

| | |
|---|---|
| Name | ImageEffects Temp |
| ClassName | RenderTexture |
| ClassID | 84 |
| instanceID | -10982 |
| isDontDestroyOnLoad | False |
| isPersistent | False |
| isManager | False |
| hideFlags | HideAndDontSave |

References: gchandle

Referenced by:

UnityEngine.RenderTexture

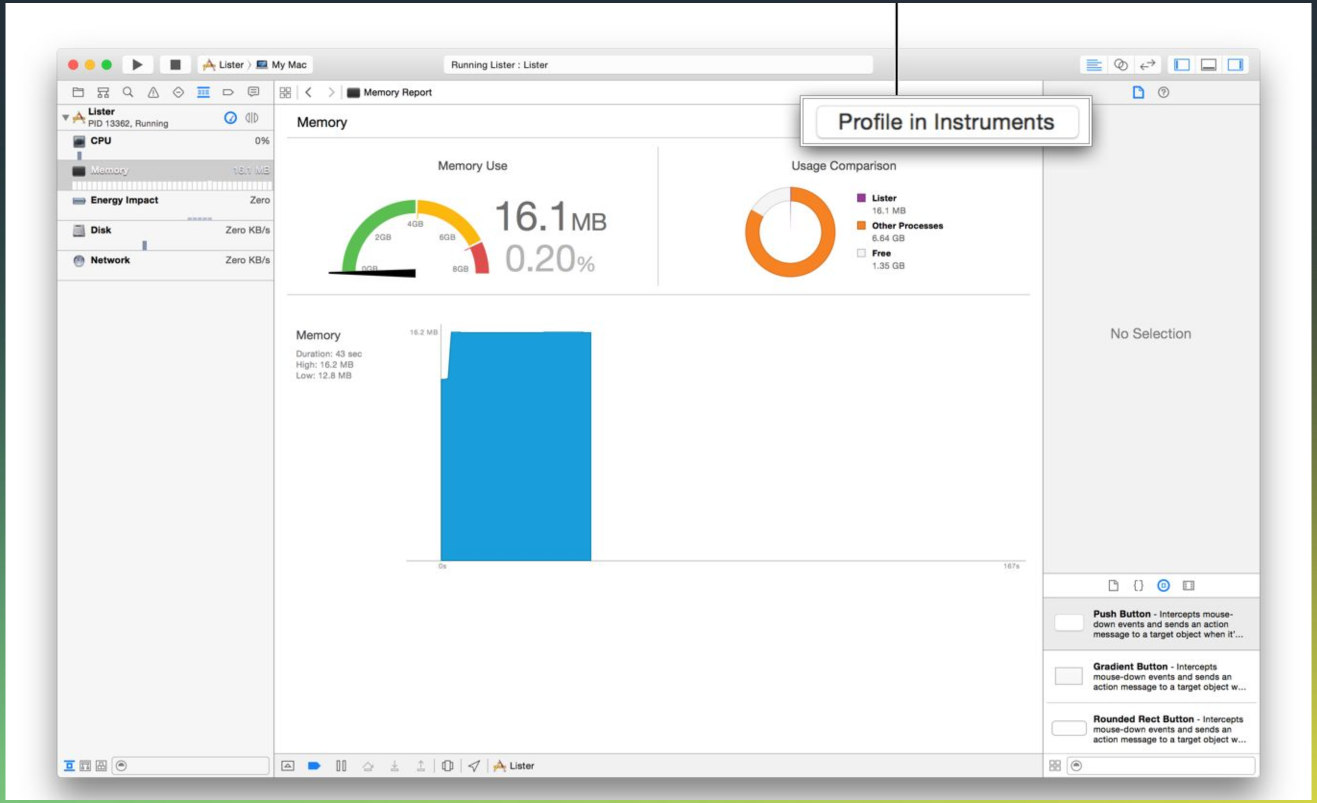
This is a root because:

the DontUnloadUnusedAsset hideflag is set on this object. Unity's builtin resources set this flag. Users can also set the flag themselves

**TIPS:**
**IL2CPP memory info is better than Mono**
**Under active development**

# Profiling outside of Unity (iOS)

- Instruments
  - Profile game running on iOS device
  - Mono & IL2CPP Builds



Push Button - Intercepts mouse-down events and sends an action message to a target object when it'...

Gradient Button - Intercepts mouse-down events and sends an action message to a target object w...

Rounded Rect Button - Intercepts mouse-down events and sends an action message to a target object w...

**TIPS:**
**Best for profiling on-device memory usage**
**Best for determining method CPU usage**

## Profiling outside of Unity (Android)

- Unity Profiler
  - adb
  - logcat
- GPU
  - Adreno (Qualcomm)
  - PVRTune, PVRUniSCo (PowerVR)
  - Intel GPA

## Garbage Collection

- Managed Memory
  - Size doubles when limit is hit
  - NEVER SHRINKS
  - Can stall when collected

- Can explicitly call System.GC.Collect() during breaks in game

## Garbage Collection - Stack vs Heap

- Heap Objects
  - Memory block allocated on the Heap and must be Garbage Collected when no longer in use
  - As Heap expands and contains more objects it takes longer for the GC to scan & clean
  - Classes, Strings, Arrays, Lists
- Stack Objects
  - Only live within their scope and memory is freed when it goes out of scope
  - Structs, primitive types

# Data Layout Matters

```
    struct Stuff {
        int a;
        float b;
        bool c;
        string name;
        }
    Stuff[] arrayOfStuff;               //<< Everything is scanned. GC takes more time
VS
    int[] As;
    float[] Bs;
    bool[] Cs;
    string[] names;                     //<< Only this is scanned. GC takes less time.
```

## Object Pooling

- Create a pool of objects to reuse
  - Instantiate as many objects as you'll need before you need them
  - Enable as-needed
  - Disable, Reset when they're done
- No more Instantiate/Destroy cycle (expensive)
- Saves GC from having to run as often
  - No new memory allocated
- Allocate a sensible number of objects
  - Don't allocate TOO many objects as they do take up their own memory in the Heap that can't be reused

# Use System.Text.StringBuilder over string

```
string str = “1 allocation” + “ 2 allocations”;
```

- Each string concatenation allocates multiple objects
  - Plus a 3rd for the actual result
  - Problematic if called in loops, Update(), FixedUpdate(), etc
- Use System.Text.StringBuilder
  - .Append() is faster in loops
  - Starts with a capacity, increases when it is surpassed in an Append() call. Then it allocates more memory
- Mecanim: Use Animator.StringToHash() for release
  - Can be used for custom code

# More Memory Optimizations

## Reuse temporary buffers

- If buffers for data processing are needed every frame, allocate the buffer once and reuse

## Don’t use OnGUI

- Even empty OnGUI calls are very memory intensive

## Don’t .tag == .tag

- Use CompareTag()

## Other GC Optimizations

- for(;;) instead of foreach
  - foreach on anything but arrays allocates an Enumerator (due to old Mono implementation)
- Avoid LINQ functions
  - Allocates memory for Enumerators, essentially a foreach
- Avoid anonymous functions and lambda expressions
  - Allocates memory if needing to access variables outside its scope
- Avoid Boxing value types
  - Converts them to reference types allocated on the Heap

## Marshalling Cost

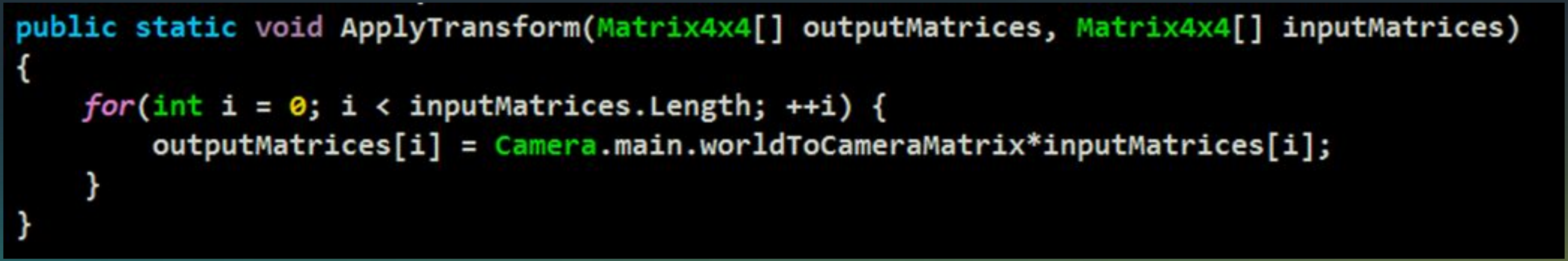
You can write native plugins

- Can be super fast!
- Can be expensive!
- Design plugins carefully to avoid marshalling cost

Can sneak up on you

- gameObject.GetComponent<...>()
- Cache your components

## Case Study - Caching

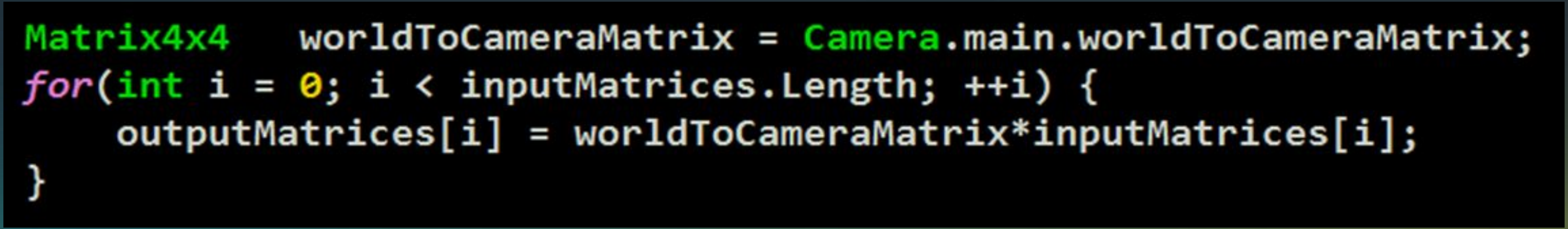


```
public static void ApplyTransform(Matrix4x4[] outputMatrices, Matrix4x4[] inputMatrices)
{
    for(int i = 0; i < inputMatrices.Length; ++i) {
        outputMatrices[i] = Camera.main.worldToCameraMatrix*inputMatrices[i];
    }
}
```

Getting 20k matrices which transform object from local to camera space

Naive implementation: **125 ms**

# Case Study - Caching

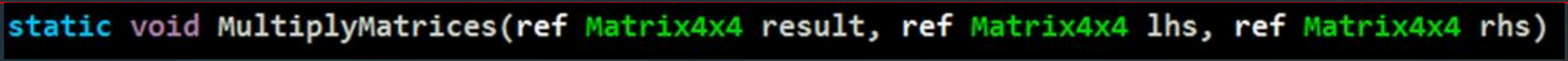


```
Matrix4x4   worldToCameraMatrix = Camera.main.worldToCameraMatrix;
for(int i = 0; i < inputMatrices.Length; ++i) {
    outputMatrices[i] = worldToCameraMatrix*inputMatrices[i];
}
```

- Cache complex expressions
- Properties can hide expensive operations

Optimized implementation: **33.5ms**

## Case study - Copying



```
static void MultiplyMatrices(ref Matrix4x4 result, ref Matrix4x4 lhs, ref Matrix4x4 rhs)
```

Create a method using references

- We had 3 redundant copies (2 inputs, 1 output)
- Matrix4x4 is a value-type

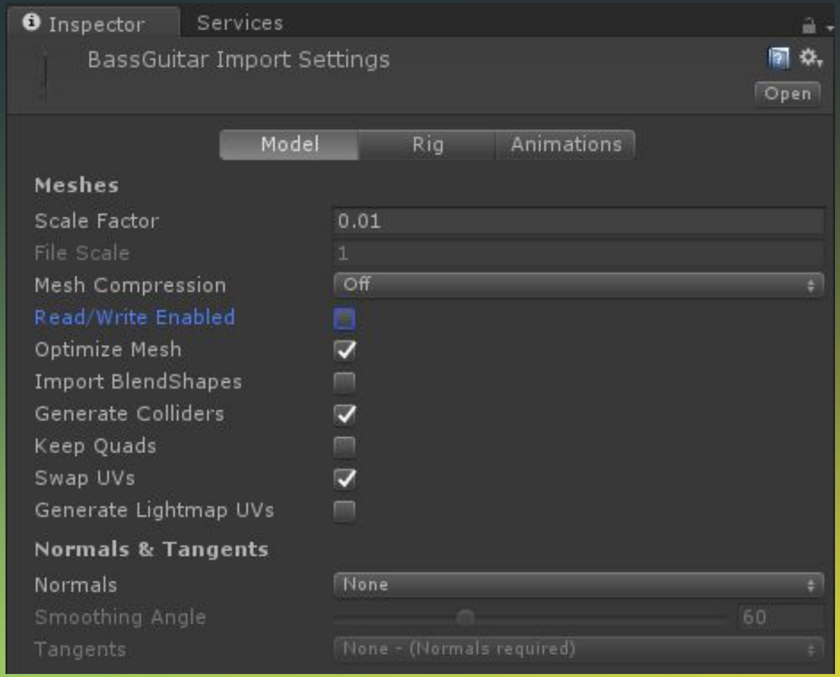
Optimized implementation: **21.5ms**

## Optimizing Graphics

- Bake what can be baked
  - Lighting
  - Shadows
- Batch what can be batched
  - Static Meshes
  - Materials
  - UI Canvas elements

## Optimizing Meshes

- Only use as many vertices as you need
- Set "Read/Write" to false if not accessing vertices in script
  - Enabled = extra copy in memory
  - Non-uniform scaling requires read/write
- Enable "Optimize Mesh"
  - Reorder vertex info for fast reading
- Always enable '**Optimize Mesh Data**' in '**Player Settings->Other Settings**'
  - Removes redundant vertex attributes (tangents, normal, color, etc)



BassGuitar Import Settings

**Meshes**

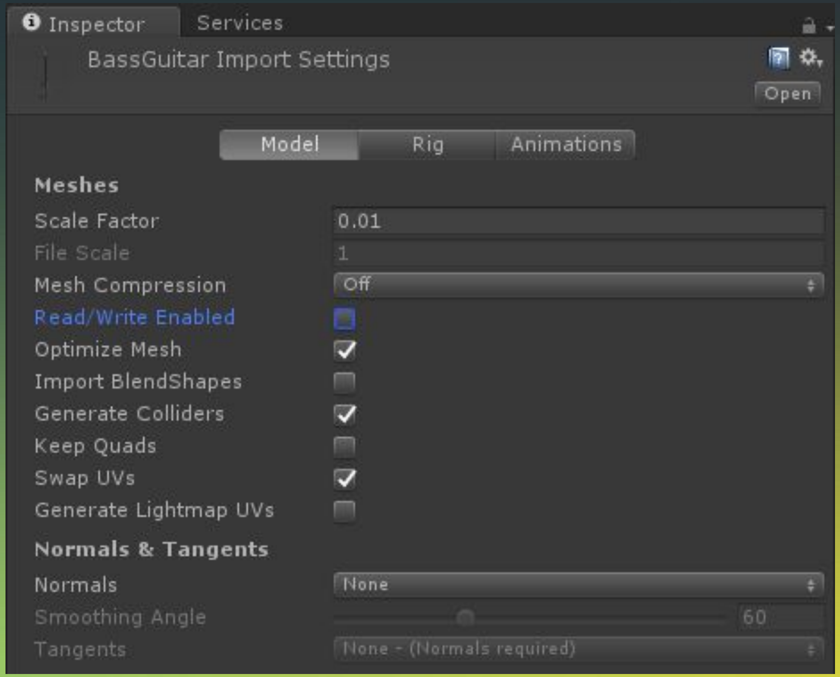
| | |
|---|---|
| Scale Factor | 0.01 |
| File Scale | 1 |
| Mesh Compression | Off |
| Read/Write Enabled | ☐ |
| Optimize Mesh | ✓ |
| Import BlendShapes | ☐ |
| Generate Colliders | ✓ |
| Keep Quads | ☐ |
| Swap UVs | ✓ |
| Generate Lightmap UVs | ☐ |

**Normals & Tangents**

| | |
|---|---|
| Normals | None |
| Smoothing Angle | 60 |
| Tangents | None - (Normals required) |

# Optimizing Meshes

- Disable “Import Blend Shapes” if none are used
- Disable “Normals and Tangents” if they won’t be used by materials
- Pre-transform static geometry to world space
- Enable Static and Dynamic batching



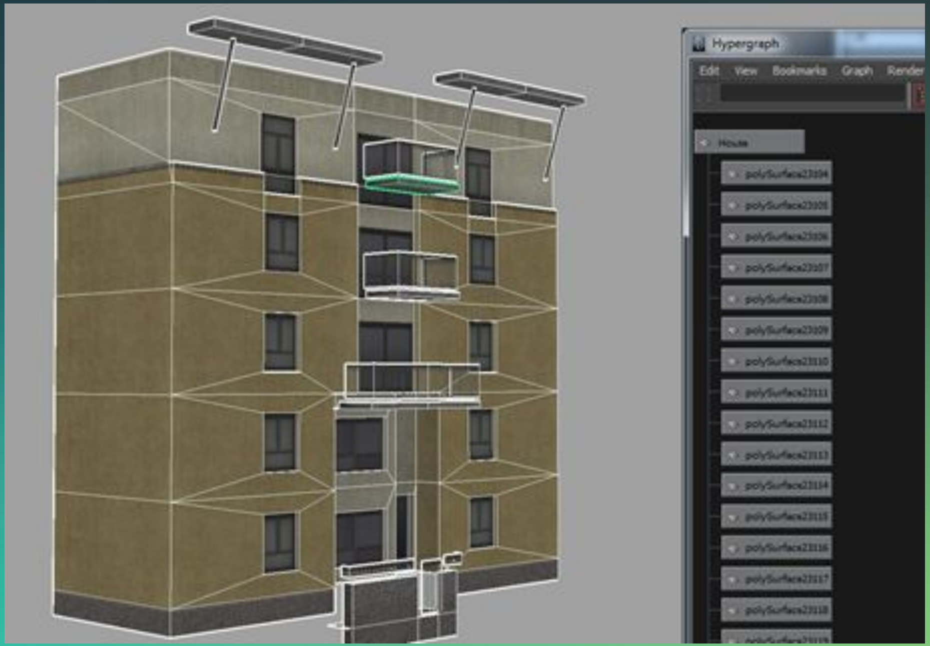
Meshes

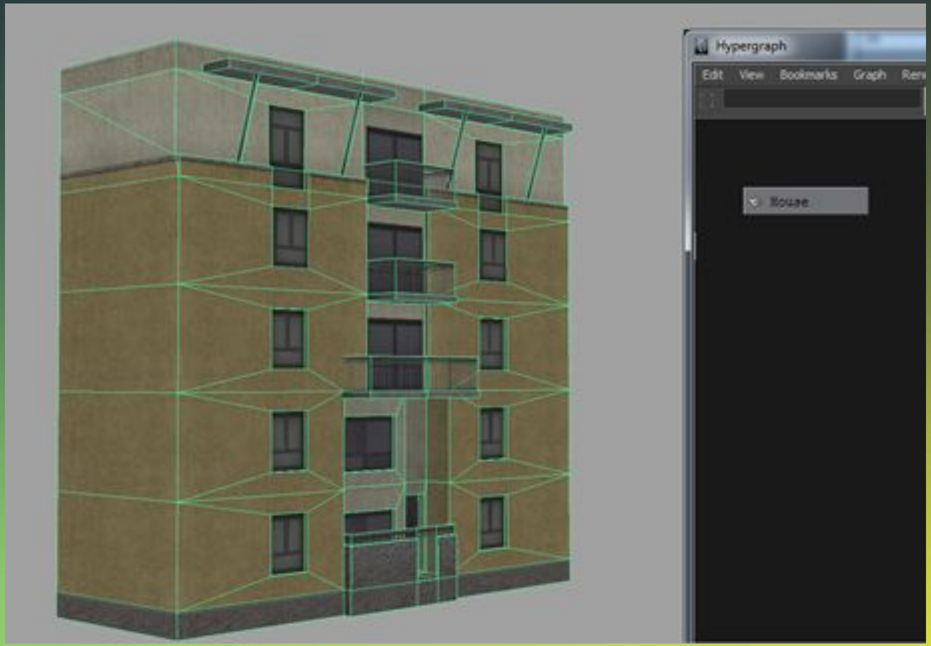
| | |
|---|---|
| Scale Factor | 0.01 |
| File Scale | 1 |
| Mesh Compression | Off |
| Read/Write Enabled | ☐ |
| Optimize Mesh | ✓ |
| Import BlendShapes | ☐ |
| Generate Colliders | ✓ |
| Keep Quads | ☐ |
| Swap UVs | ✓ |
| Generate Lightmap UVs | ☐ |

Normals & Tangents

| | |
|---|---|
| Normals | None |
| Smoothing Angle | 60 |
| Tangents | None - (Normals required) |

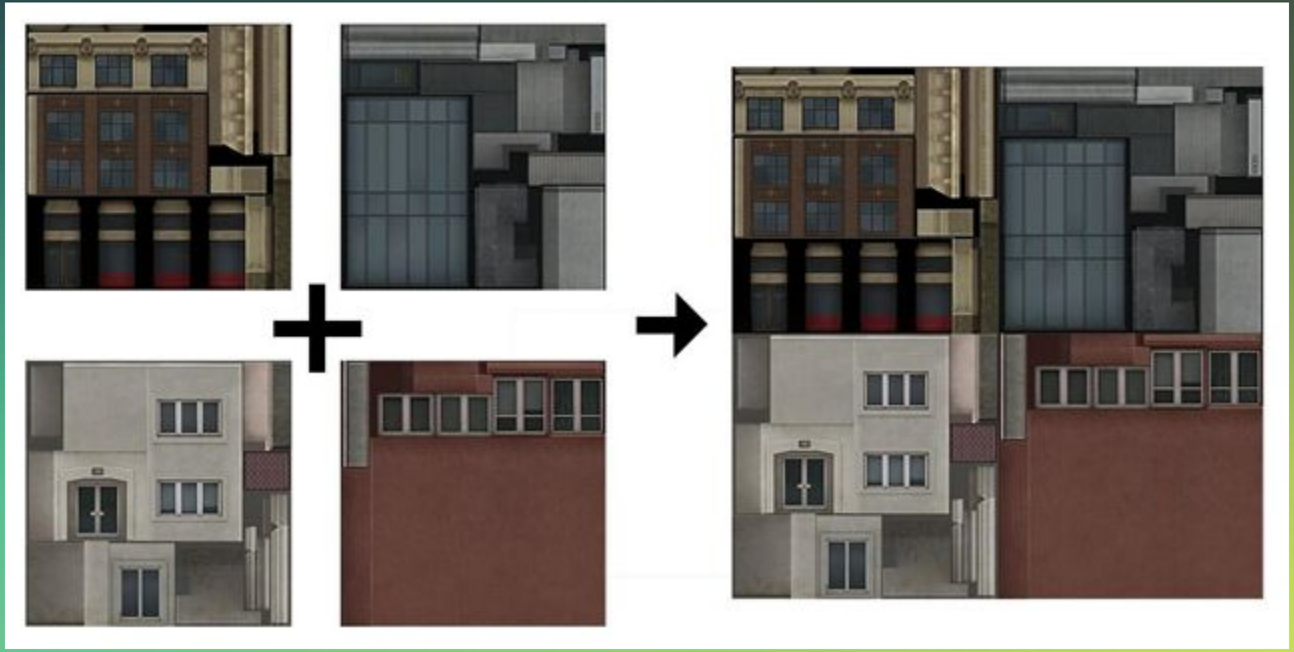
## Combine Meshes





## Combine Textures

Texture Atlases can be made by artists too…



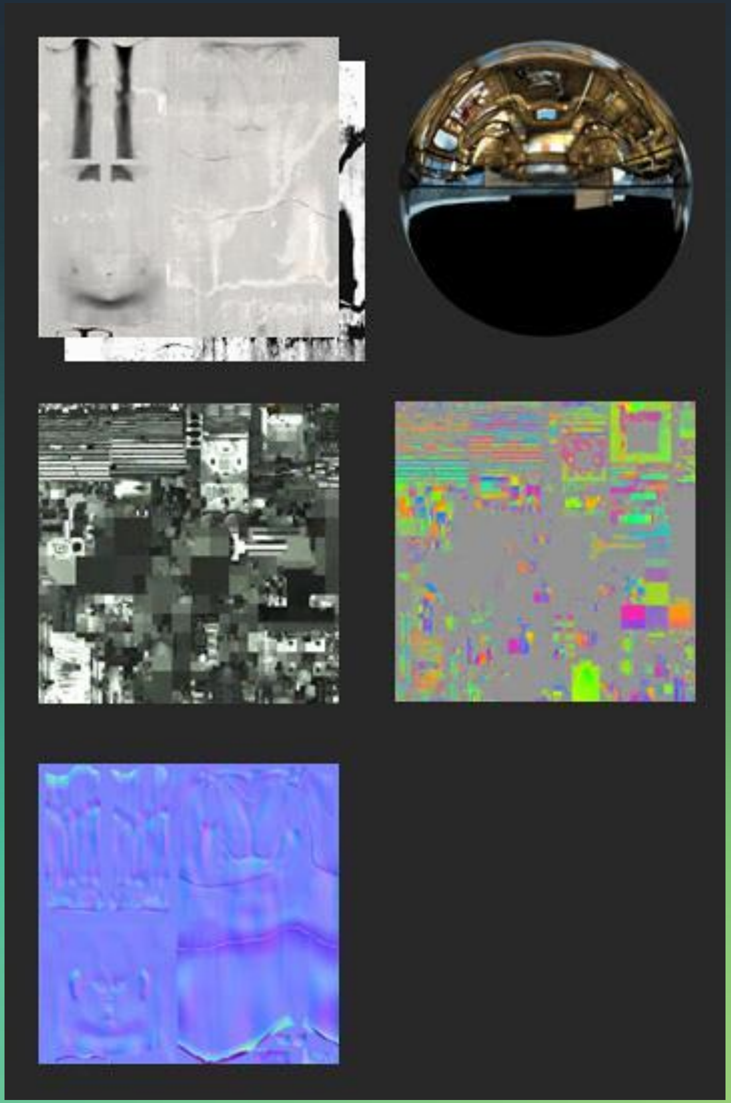
# Optimizing Textures

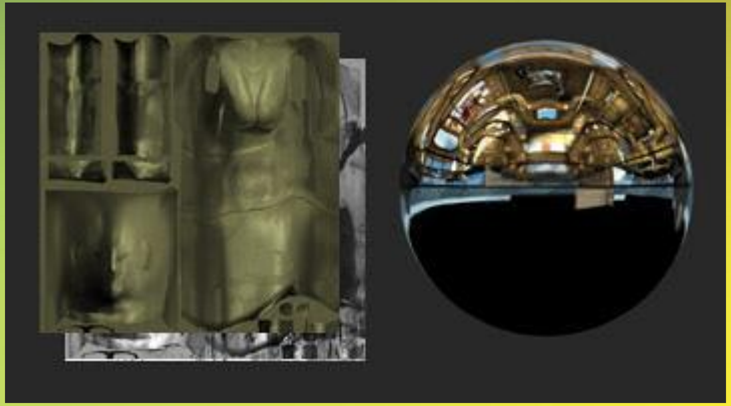
- iOS - Use PVRTC
- Android
    - OpenGLES 2.0 devices: ETC1
    - OpenGLES 3.0 devices: ETC2
    - Specific GPUs might handle other formats more efficiently
- UI - for textures that can’t be compressed without fidelity loss use 16-bit texture instead of 32
- 16-bit Texture Formats
    - Gradient alpha - RGBA4444
    - Only cutout alpha - RGBA5551
    - No alpha - RGB565

## Optimizing Textures - Example

- Shadowgun
- Used “Render to Texel” tool to bake normal-mapped lighting into textures
    - https://www.assetstore.unity3d.com/en/#!/content/4153
    - Saved massive run time calculations

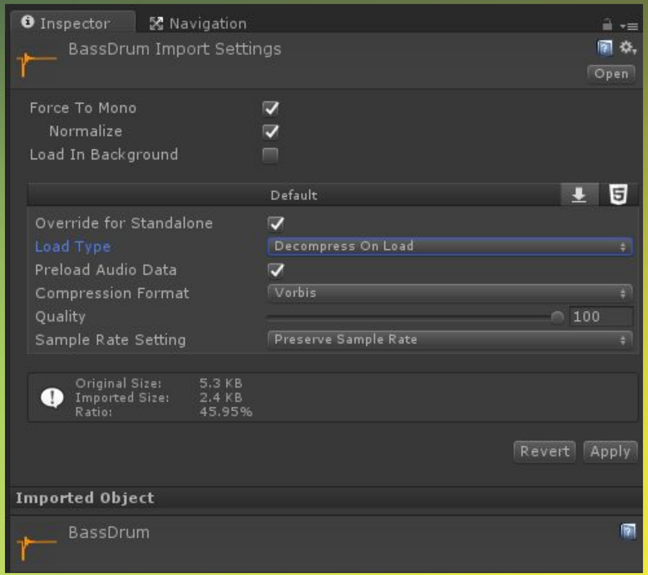
# Optimizing Textures - Example





# Optimizing Audio

- "Force to Mono" if sounds don't require 3D/Stereo
- Load Type "Decompress on Load" if clip smaller than 200kb
  - Unity uses 200kb playback buffer when decompressing audio so leave it decompressed. Saves memory when playing the sound.
- "Stream to Disk" for long audio clips
  - Only 1 clip at a time
  - Buffers compressed data
  - Decodes on the fly
  - Uses minimal memory
- "Compressed in Memory" for other clips



BassDrum Import Settings

| | |
|---|---|
| Force To Mono | ✓ |
| Normalize | ✓ |
| Load In Background | |

Default

| | |
|---|---|
| Override for Standalone | ✓ |
| Load Type | Decompress On Load |
| Preload Audio Data | ✓ |
| Compression Format | Vorbis |
| Quality | 100 |
| Sample Rate Setting | Preserve Sample Rate |

| | |
|---|---|
| Original Size: | 5.3 KB |
| Imported Size: | 2.4 KB |
| Ratio: | 45.95% |

Imported Object

BassDrum

# Optimizing UI

- Keep UI elements at the same z-depth
  - Different z-depths breaks batching
- Use Sprite Packer
  - Fewer draw calls for Sprites
- Separate UI into several Canvases (but not too many)
  - Batch time grows more than linearly by # of elements to sort, analyze
- Combine UI that doesn't change
  - Canvas won't need to be rebatched
- Reduce switching between overlapping Text and Sprites
- Reduce text in UI if possible
  - Text is batched separately from Sprites

## Other Optimizations

- Limiting Rigidbodies to 2 dimensions in a 2D game
  - Use Box2D or roll your own
  - Doesn’t pull in whole physics system(s)
- Rigidbodies on projectiles
  - Calculate collision on your own
- Lots of individual 3D objects for collectables or characters
  - Use animated sprites on particles to represent simple objects
- Perform expensive calculations every few frames and cache the results
  - Coroutines (maybe)

## Script Optimizations

- Avoid Find…() methods
  - Cache a reference instead
  - FindWithTag() is more optimized but still not as fast
- Use Non-allocating functions
  - i.e. pass array as parameter to fill instead of allocating and returning a new one
  - Unity's Physics system has examples of non-allocating functions

i.e. Physics2D.RaycastNonAlloc()

```
public static int RaycastNonAlloc(Vector2 origin, Vector2 direction, RaycastHit2D[] results)
```

# Vector Math Optimizations

- Normalize a vector once if used over and over
  - Normalization function takes longer than just storing and accessing it
- v.normalized slower than v * 1.0/v.length
- Use Vector's .sqrMagnitude to compare distances instead of getting the actual distance
  - Saves some calculations

## Shader Optimization

- In general, less instructions is better*
- Move calculations to Vertex Shader
    - High DPI devices make every pixel count
- Simplify math
    - Trig functions are super expensive
    - Bake into lookup textures
- Reduce temporary registers used
    - Number of shader threads that can work simultaneously depends on this

## 10000 Objects Update() vs Update() 10000 Objects

- Blog Post - http://blogs.unity3d.com/2015/12/23/1k-update-calls/ With Sample Project - https://github.com/valyard/Unity-Updates/commits/master By Unity’s Valentin Simonov
- Much faster to run a function on 10000 objects from a single manager GameObject’s Update() method
  - Due to remaining on the Managed side. Native → Managed call to Update and various safety checks Unity does internally makes Update() on 10000 objects slow

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GRACIAS