Shading of Spellsouls: Achieving AAA Quality on Mobile

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About Nordeus

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Spellsouls

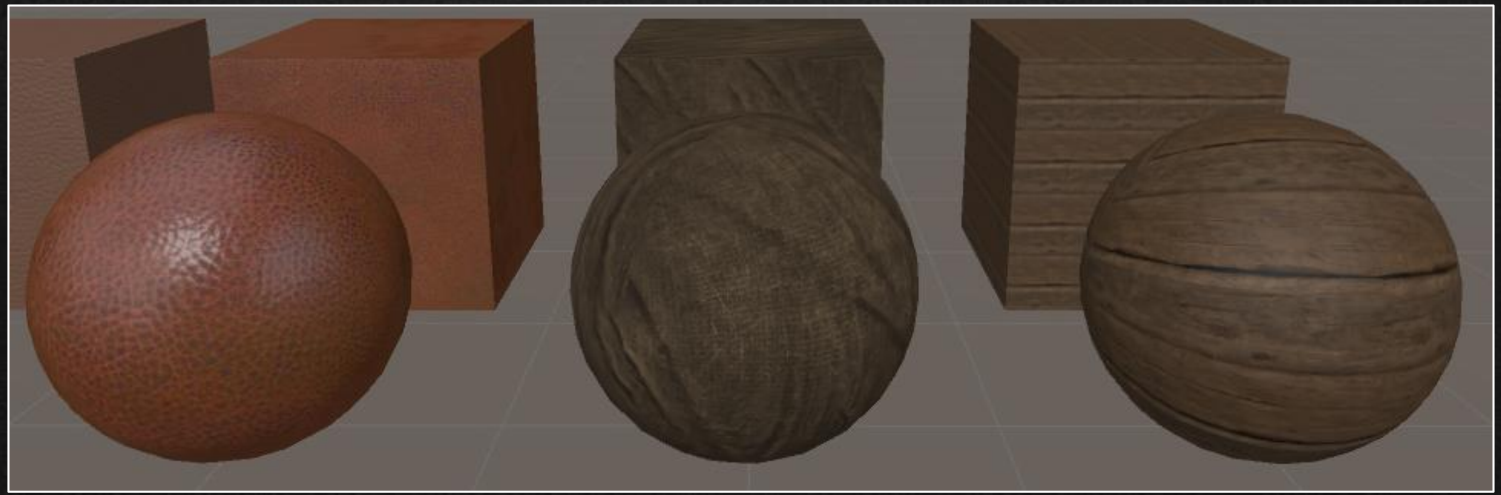
- AAA experience on mobile
- Wide range of devices

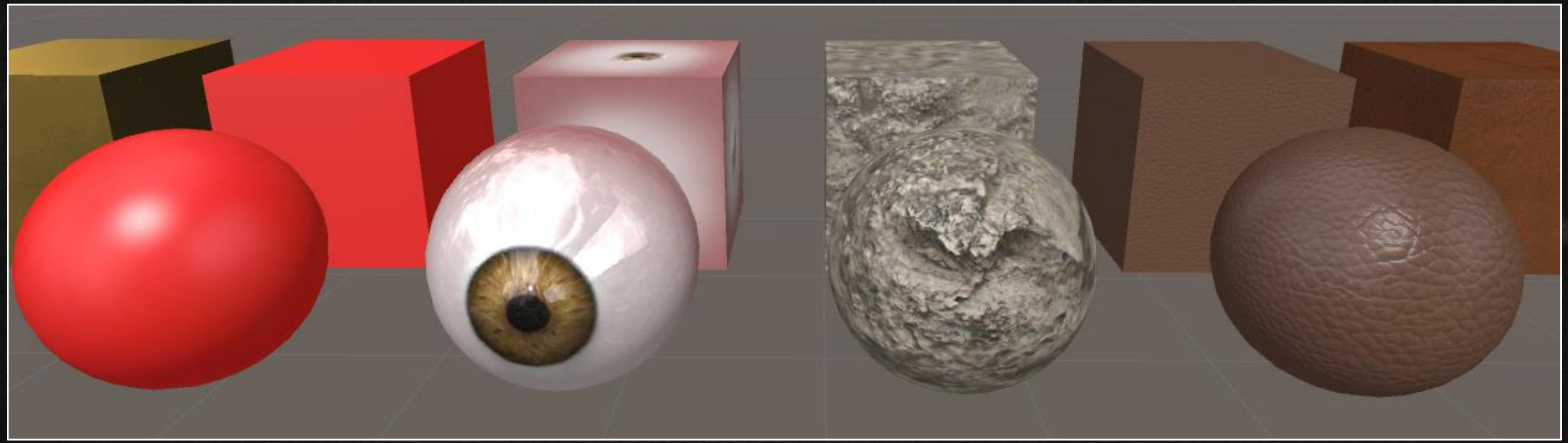
Challenges

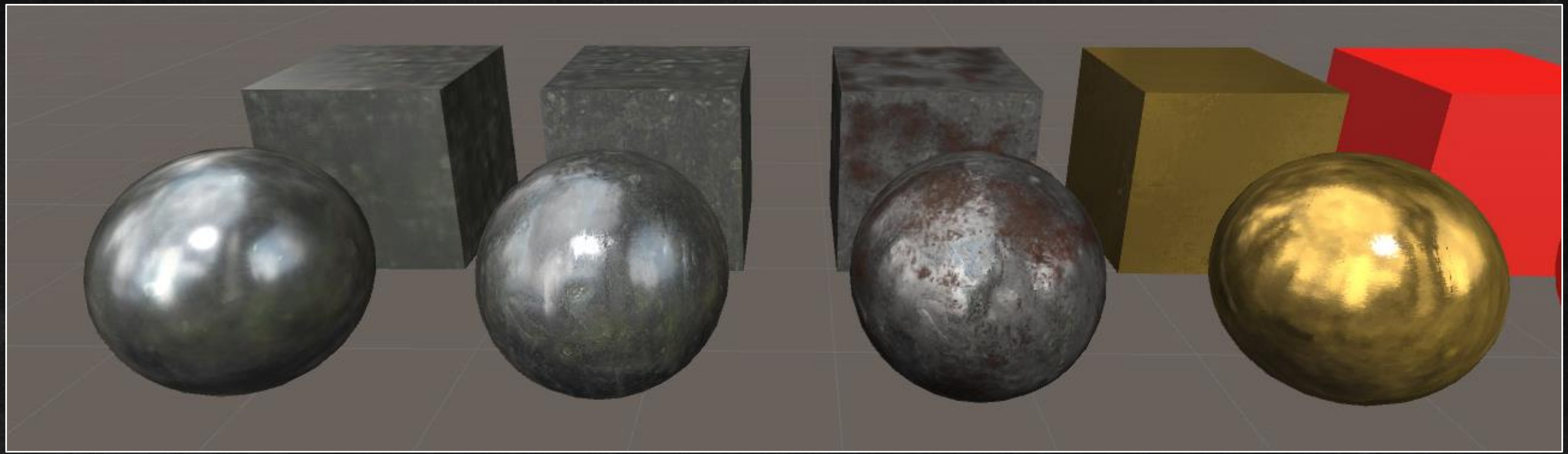
- PBR Shading
- VFX Shading
- Skinning
- Optimizing to 60 FPS

PBR

- Realistic look, different lighting conditions
- Standard GGX approach is expensive
- Normalized Blinn-Phong

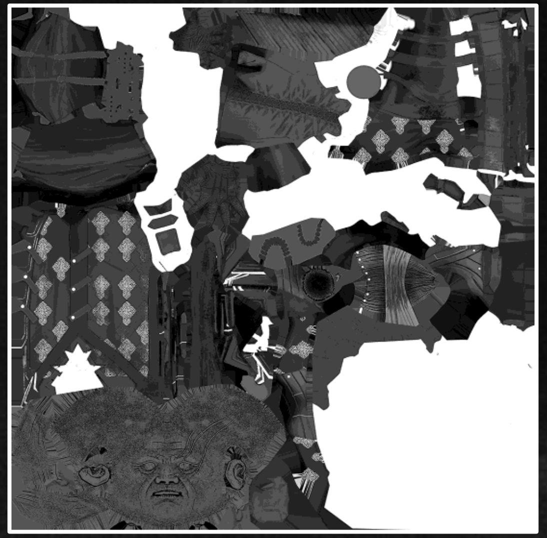






Material parameters texture

- Roughness - standard
- Metalness - reflection color
- Reflectivity - environment reflection



Normalized Blinn-Phong

$$specularPower = (512, 1 - roughness)$$

$$\frac{(1.04\ - roughness) * (specularPower + 8)}{8} * (N \cdot H)^{specularPower}$$

Diffuse

Environment light

Specular &
rim lighting

Linear color space

- Necessary for PBR
- Only 50% of devices support it

Linear color space

Gamma = 2.2

Gamma = 1

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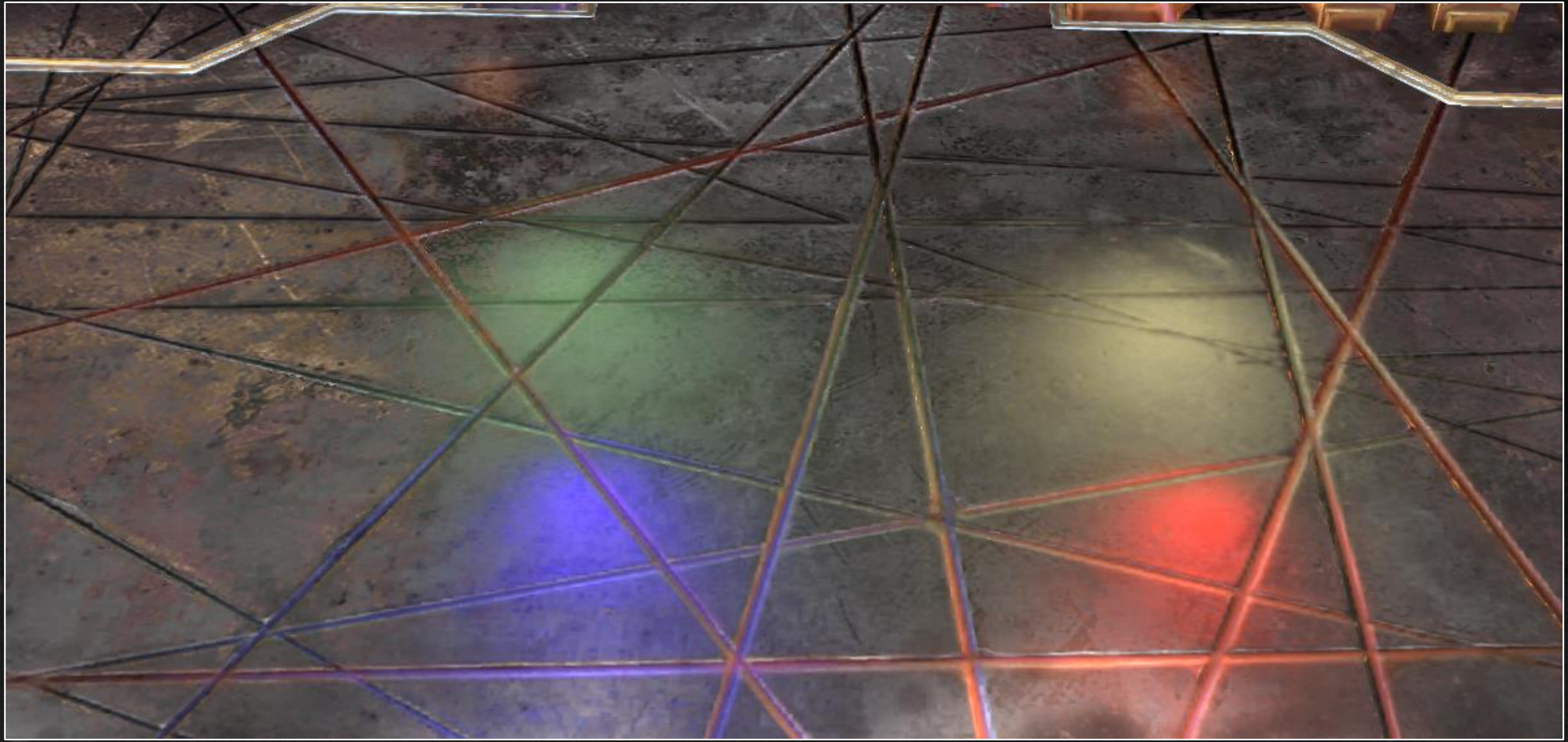
Linear color space

- Went with Gamma = 2.0
- On fetch – correctedColor = color * color
- Shader correction – correctedColor = pow(color, 1/2.2)

Additional lights

- 4 point lights
- Per object lights?
- Forward+?

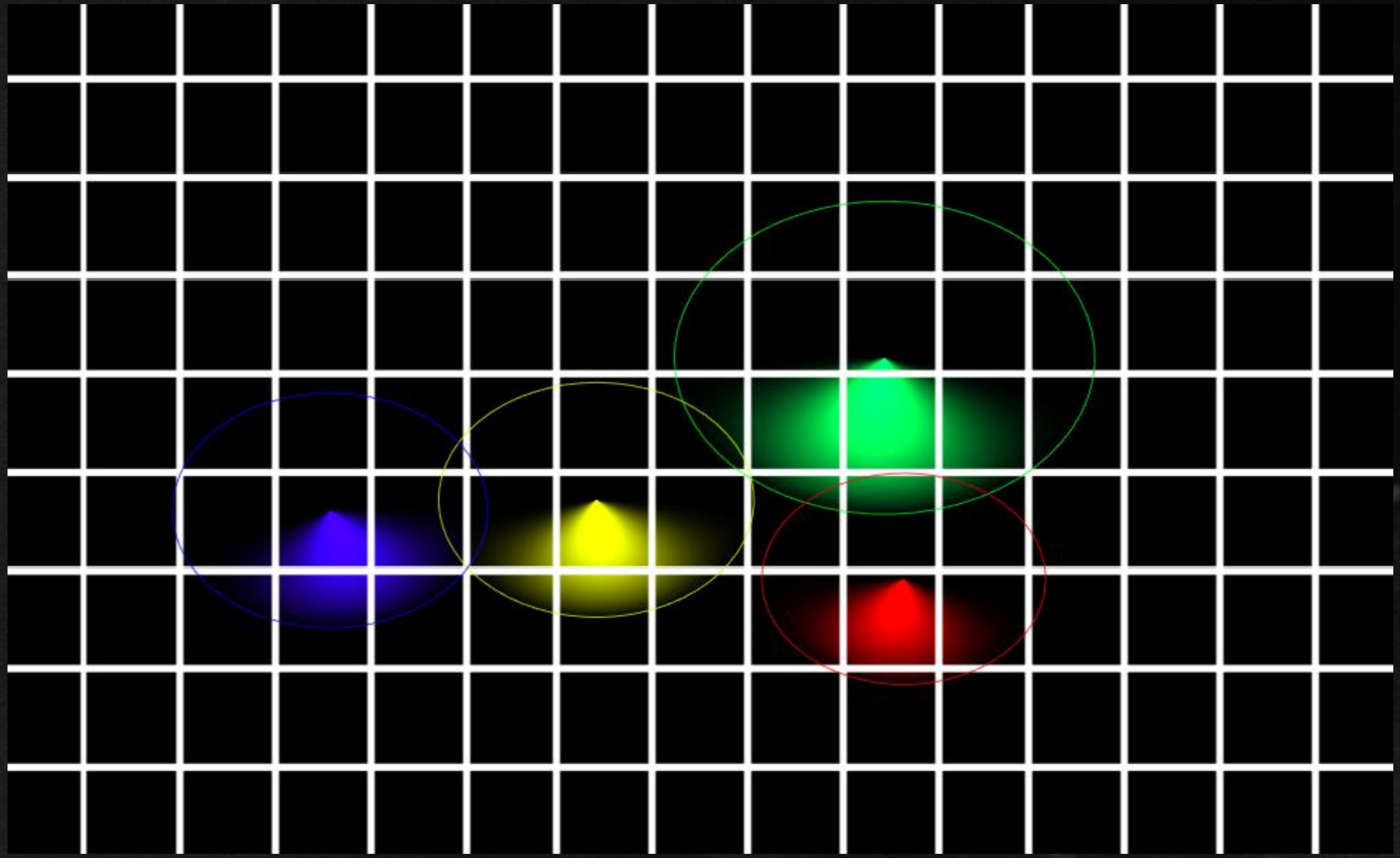


Forward+?

- Spotty compute shader support
- Already GPU bound

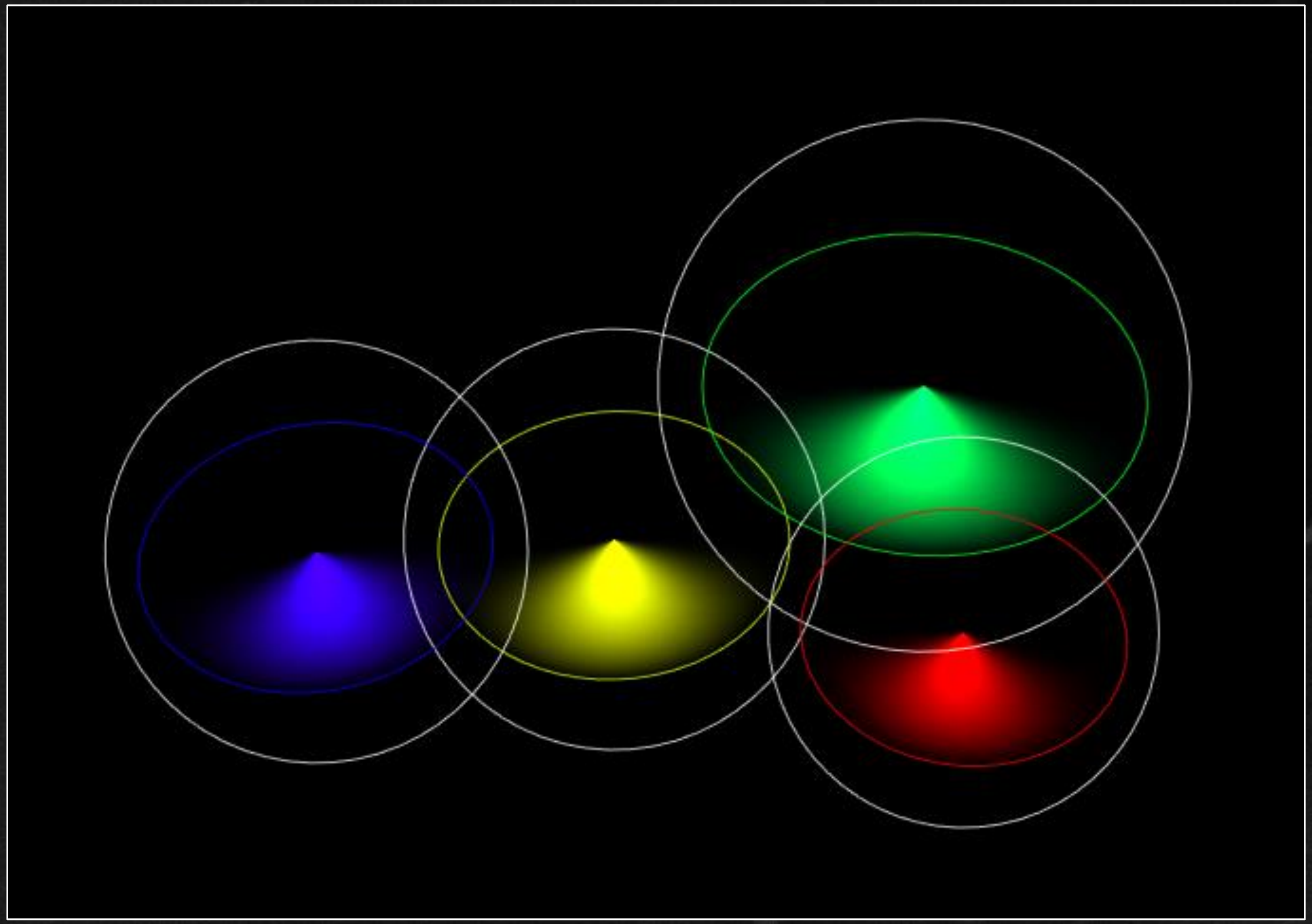
Forward+?

- Try to simplify?
- No depth pre-pass
- CPU light culling
  - 64x64 pixel tiles
  - Approximate light area with spheres



Bounding circle

- Can use when perspective is not strong
- Project assuming camera is ortographic and increase radius for safety
- Strong perspective? – project into an AABB



Shadows

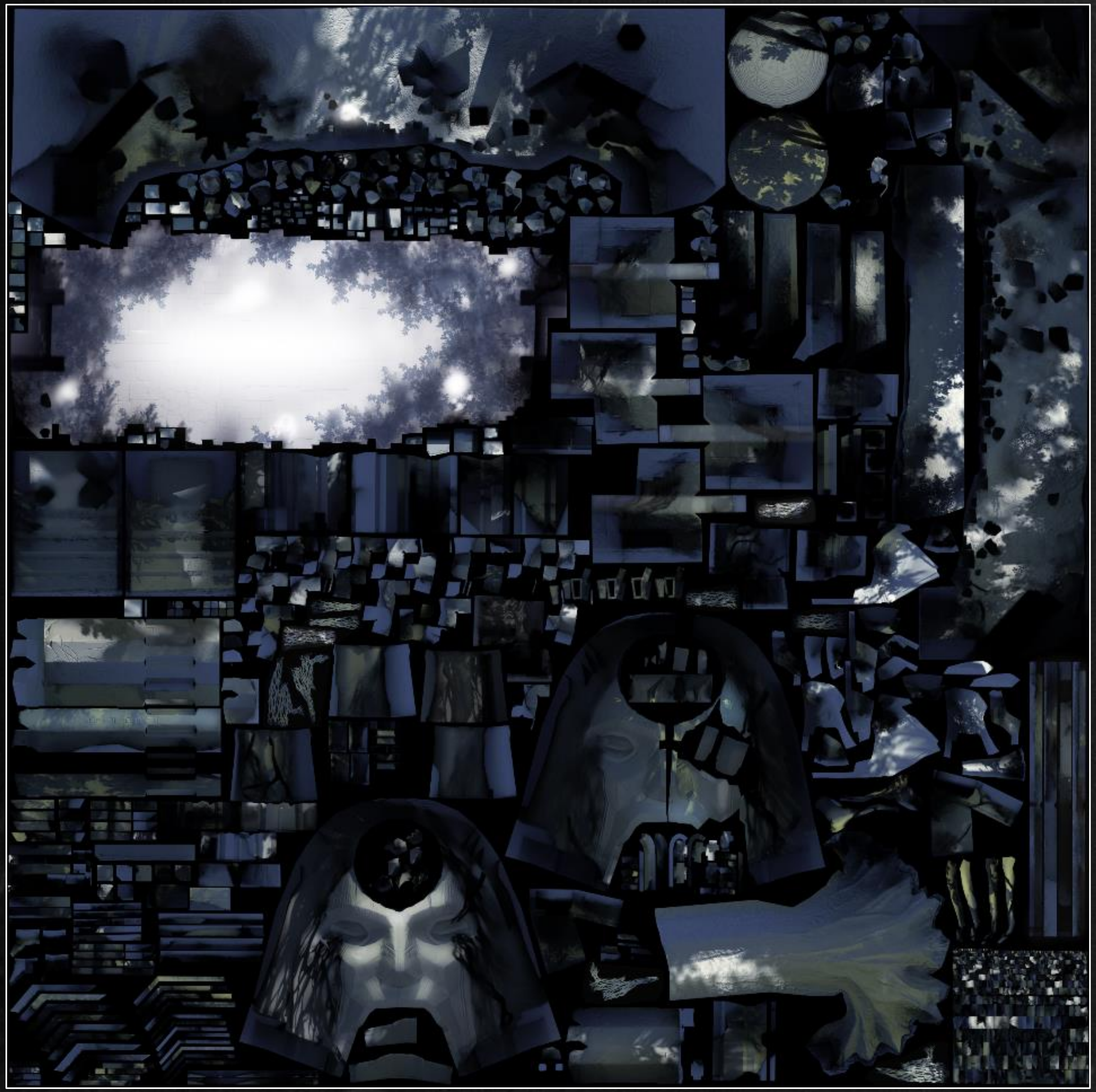
Dynamic shadows for moving objects

Static shadows for the environment

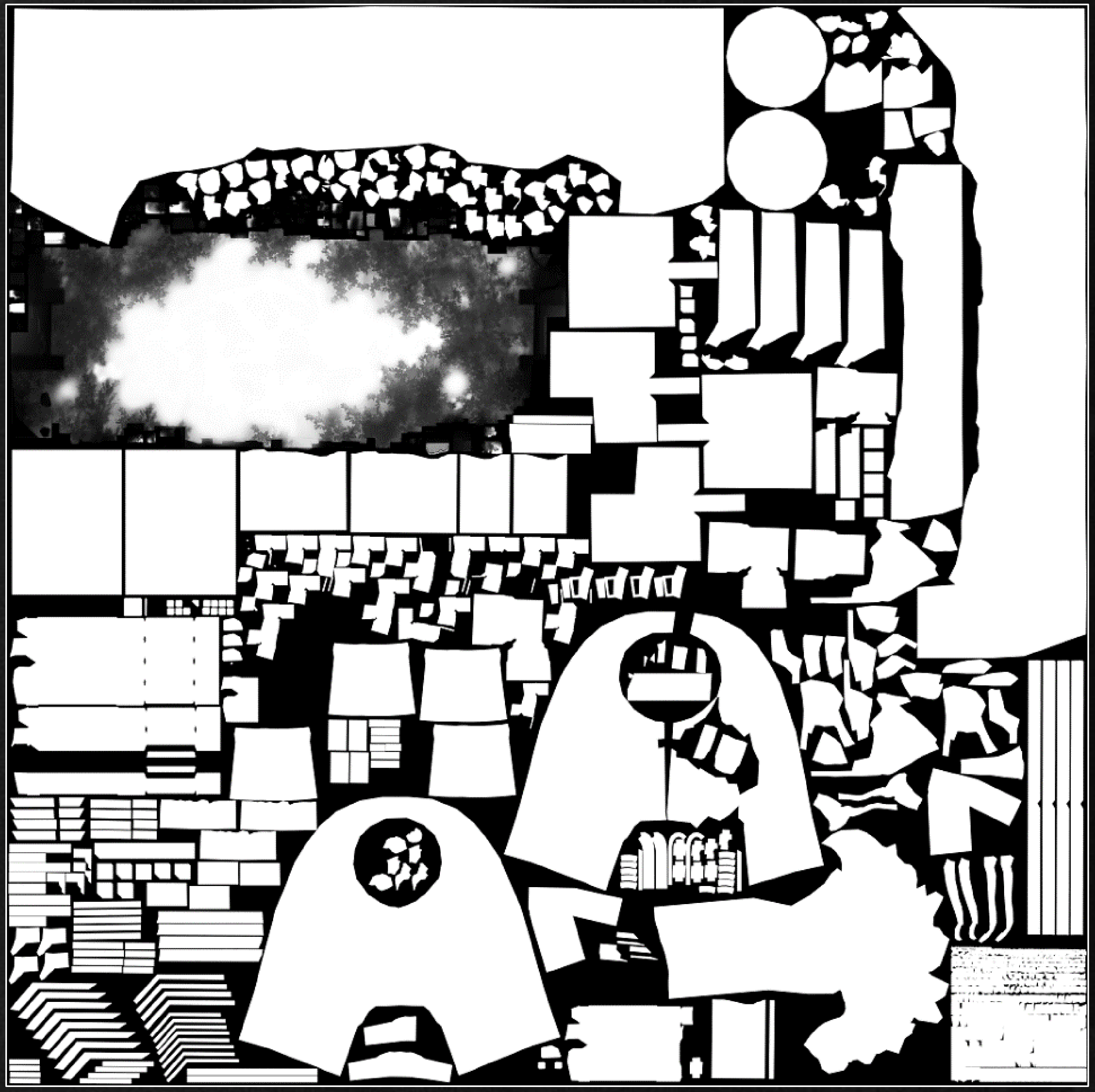
Dynamic shadows

- Dynamic shadowmap
- Hardware 4-tap PCF

Static shadows



Lightmap



Shadowmap

Combining shadows

- Combining is done when rendering the floor
- Both lightmap color and dynamic shadow color are evaluated for every pixel

Combining shadows

$$color = albedo.rgb \ * lightmap.rgb$$

$$color = color \ * lerp(lightColor, shadowColor, lightmap.a \ * \min(N \cdot L, dynamicShadow))$$

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VFX

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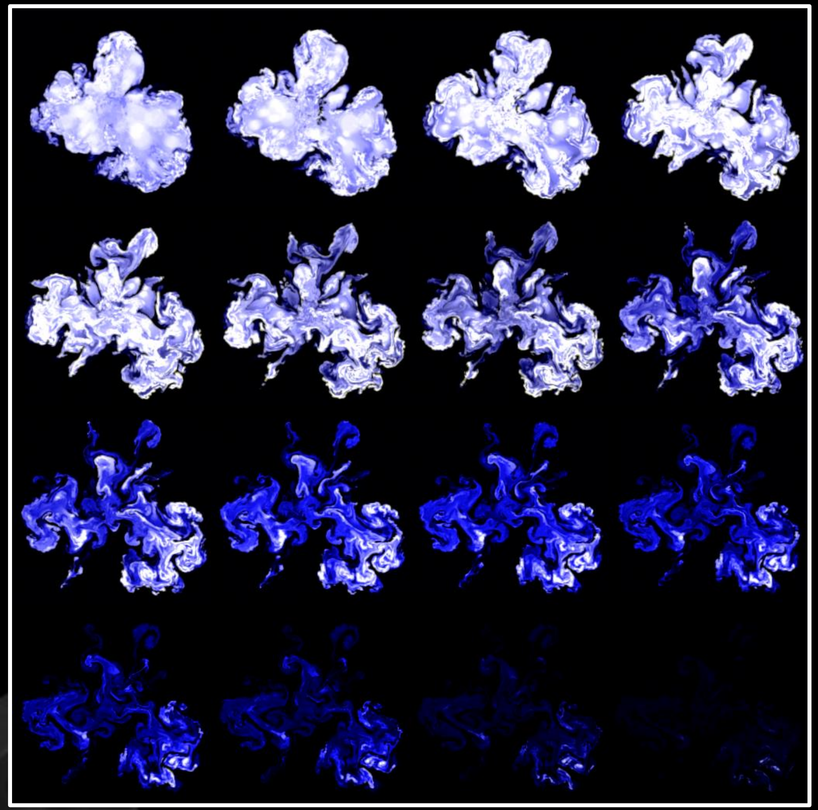
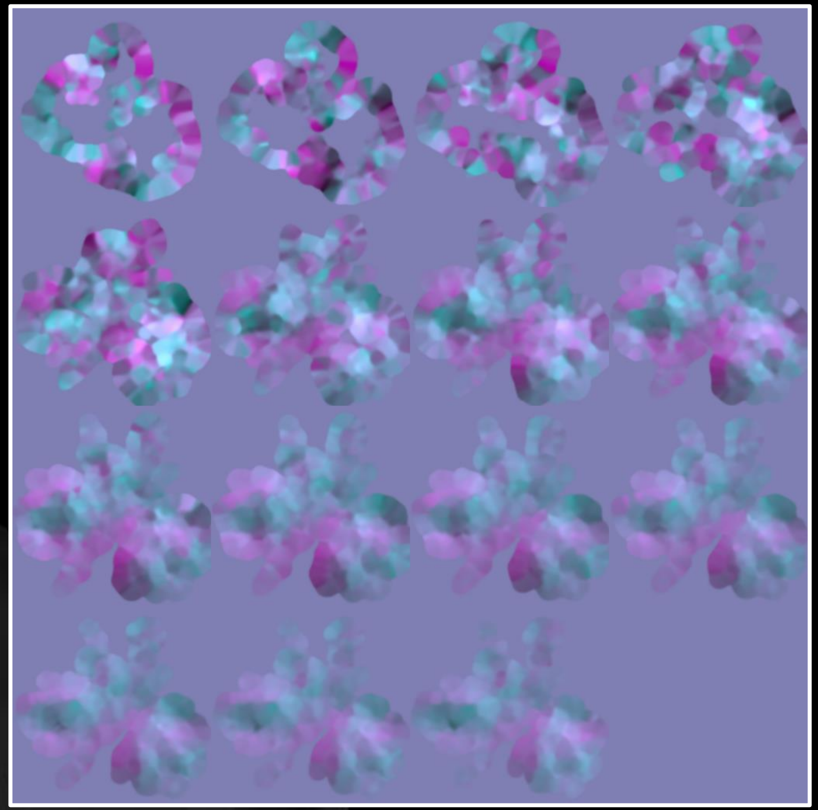
VFX

- No postprocessing
- Particle systems are expensive
- Spritesheets!

Motion Vectors

Spritesheet - Low FPS





Motion Vectors

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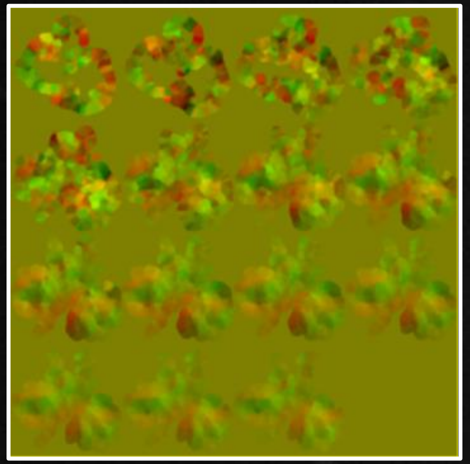
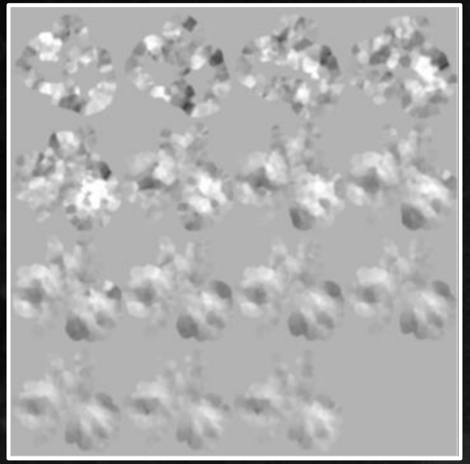
Motion Vectors



Red & Green channels
UV coordinates for next pixel to read



Blue channel
Scale factor for Red and Green channels

norde.us/vfxmv

1. Read current frame pixel and motion vectors value from same UV coordinates
2. Determine UV coordinates to read from next frame using motion vectors
3. Interpolate between current pixel and the next frame's one

Skinning

- CPU skinning was taking 2 full cores
- Uploading meshes to GPU every frame was killing performance

Endgame scenario with 40 units

GPU Skinning

Requirements:

- No GPU mesh uploads
- Supports instancing
- Fast

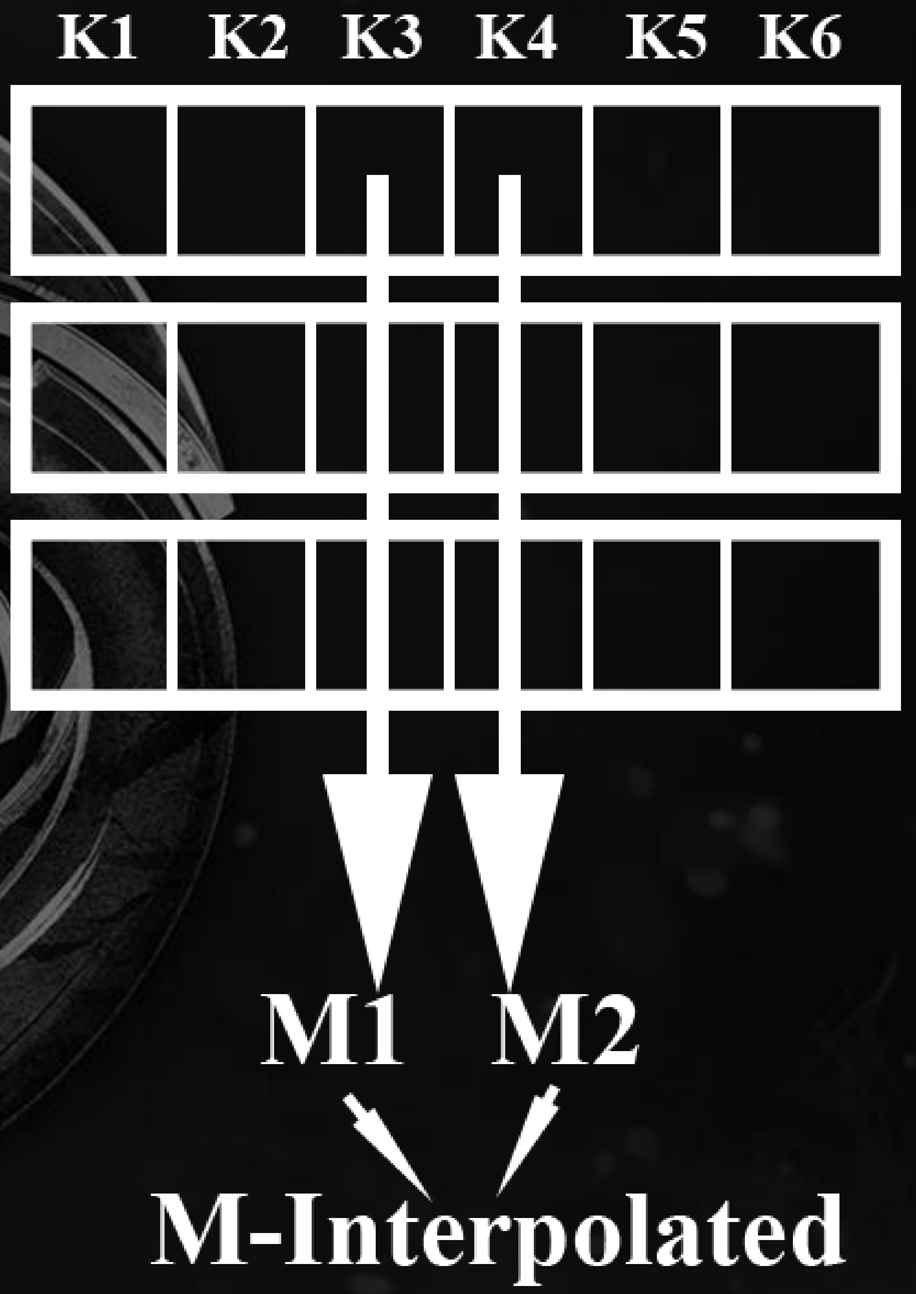
Texture Based Matrix-palette GPU Skinning

- Sample bone TRS at regular intervals
- Bake bone TRS into textures
- 3x4 floats – 3 textures needed
- Per Instance data – 1 float, U coordinate
- How to interpolate?

Texture Based Matrix-palette GPU Skinning

1. Read two keyframes
2. Reconstruct matrices
3. Interpolate

- 6 texture reads per bone influence!



Texture Based Matrix-palette GPU Skinning

- Problems to solve:
  - 6 texture reads
  - 3 textures
  - Interpolation math

Texture Based Dual Quaternion GPU Skinning

- Dual quaternions! - norde.us/dualq
- 2 textures – 3rd scaling texture optional
- Bilinear filtering
- Looks good with low sampling rate – 15FPS for us
- Blending animations? – Double texture reads

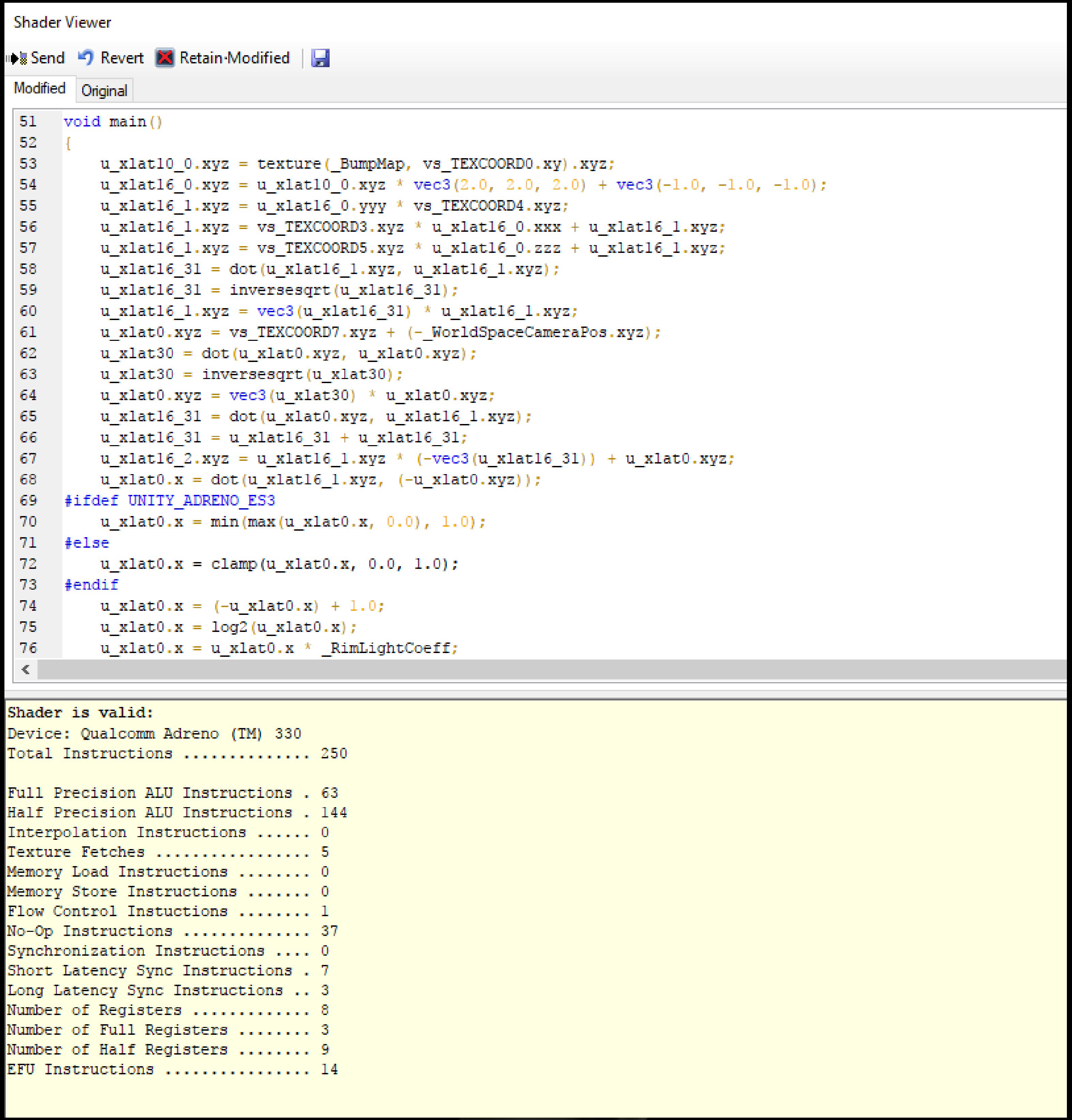
Performance & optimization

We optimize for:

- Framerate
- Heating
- Battery drain

Graphics Profilers

Good for fast shader iteration



Shader instructions

- Never use fixed precision
- Convert between precisions sparingly
- Watch out for No-ops

```
Total Instructions .............. 250

Full Precision ALU Instructions . 63
Half Precision ALU Instructions . 144
Interpolation Instructions ...... 0
Texture Fetches ................. 5
Memory Load Instructions ........ 0
Memory Store Instructions ....... 0
Flow Control Instuctions ........ 1
No-Op Instructions .............. 37
```

No-ops

```
float4x4 sum = (boneMatrices[index0] * weight0) + (boneMatrices[index1] * weight1);
```

250 No-ops

ALU here

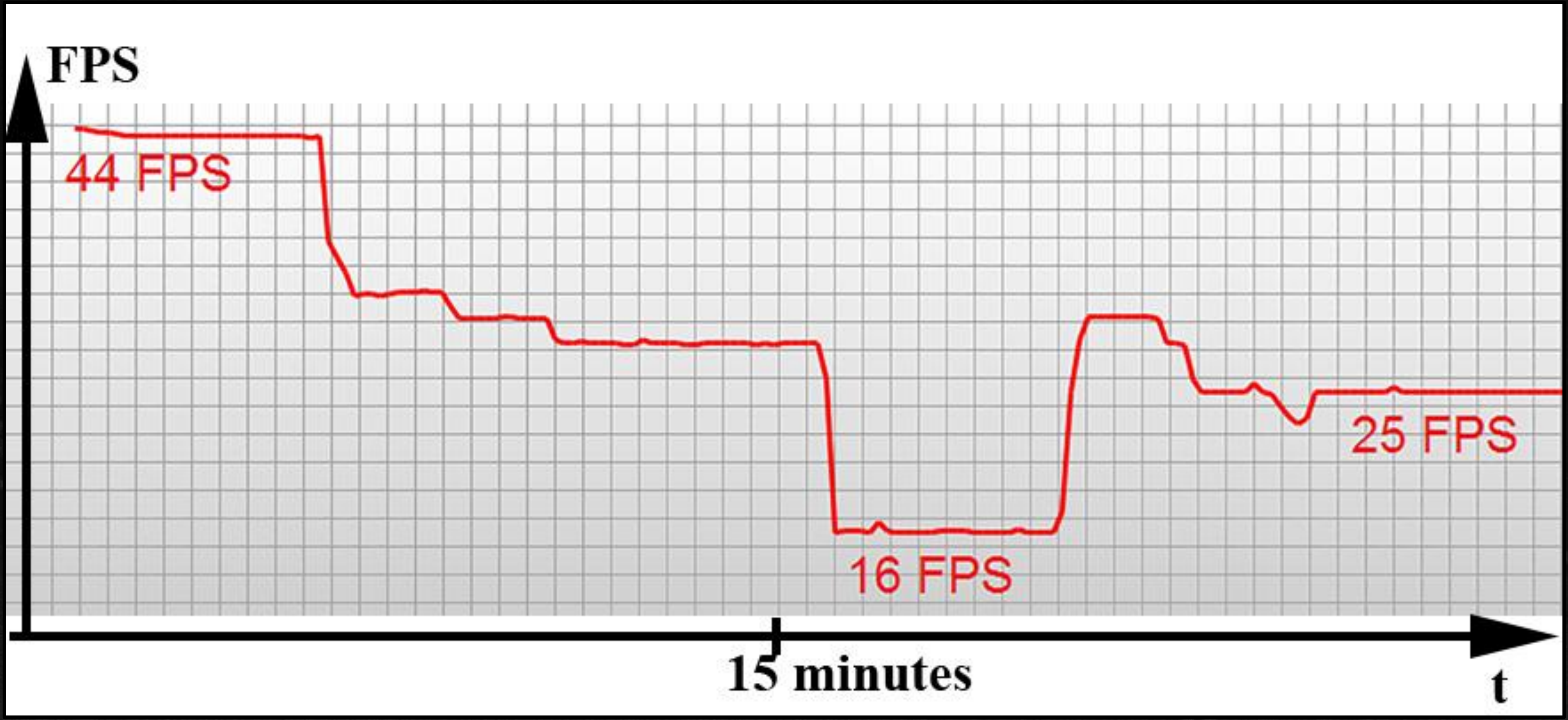
```
float4x4 matrix0 = boneMatrices[index0];
float4x4 matrix1 = boneMatrices[index1];

float4x4 sum = (matrix0  * weight0) + (matrix1  * weight1);
```

20% Faster

180 No-ops

Thermal throttling



Thermal throttling

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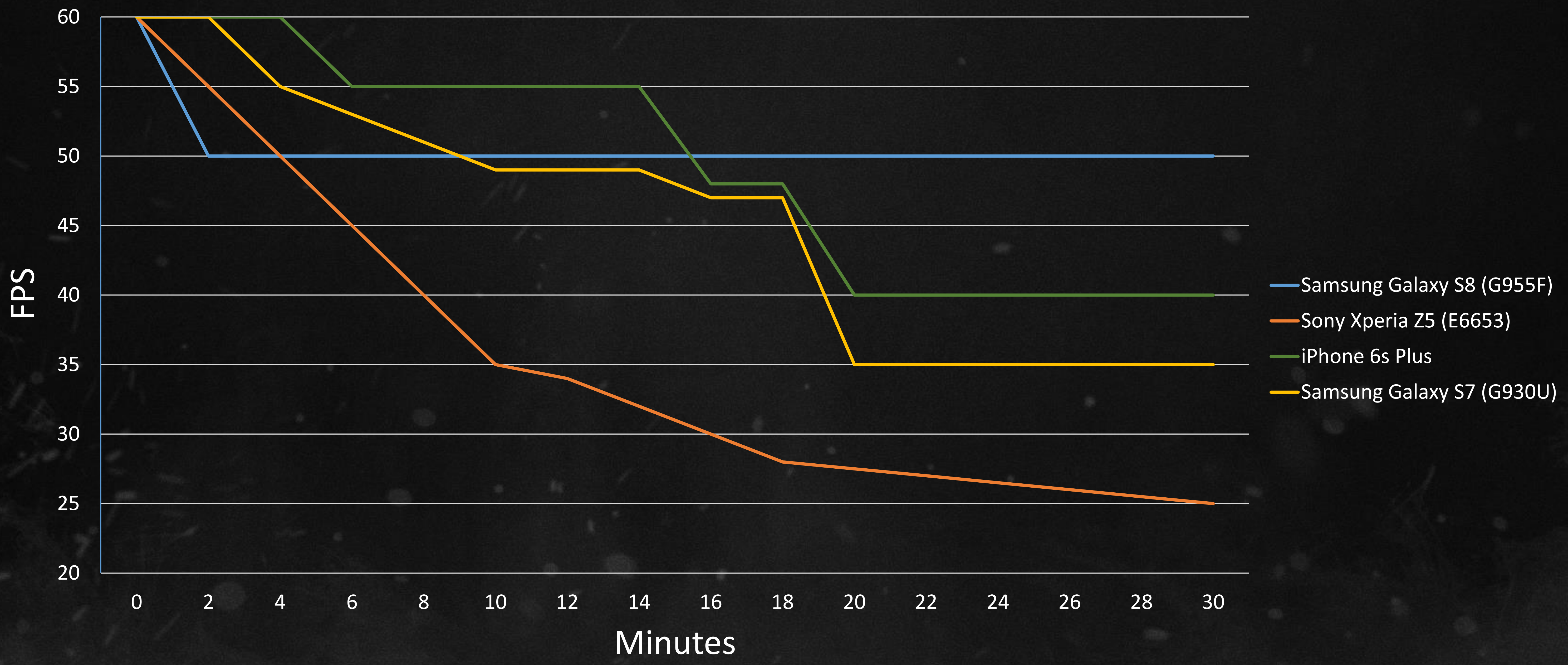
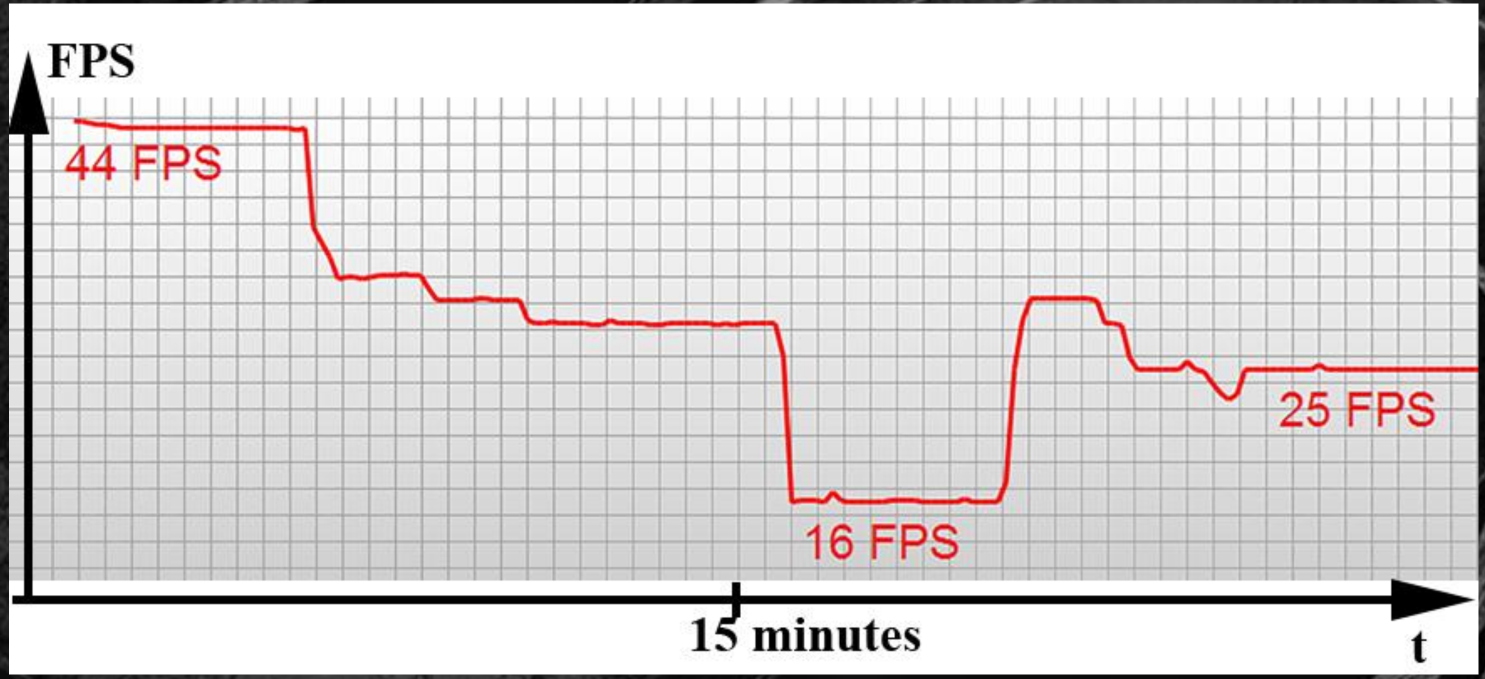


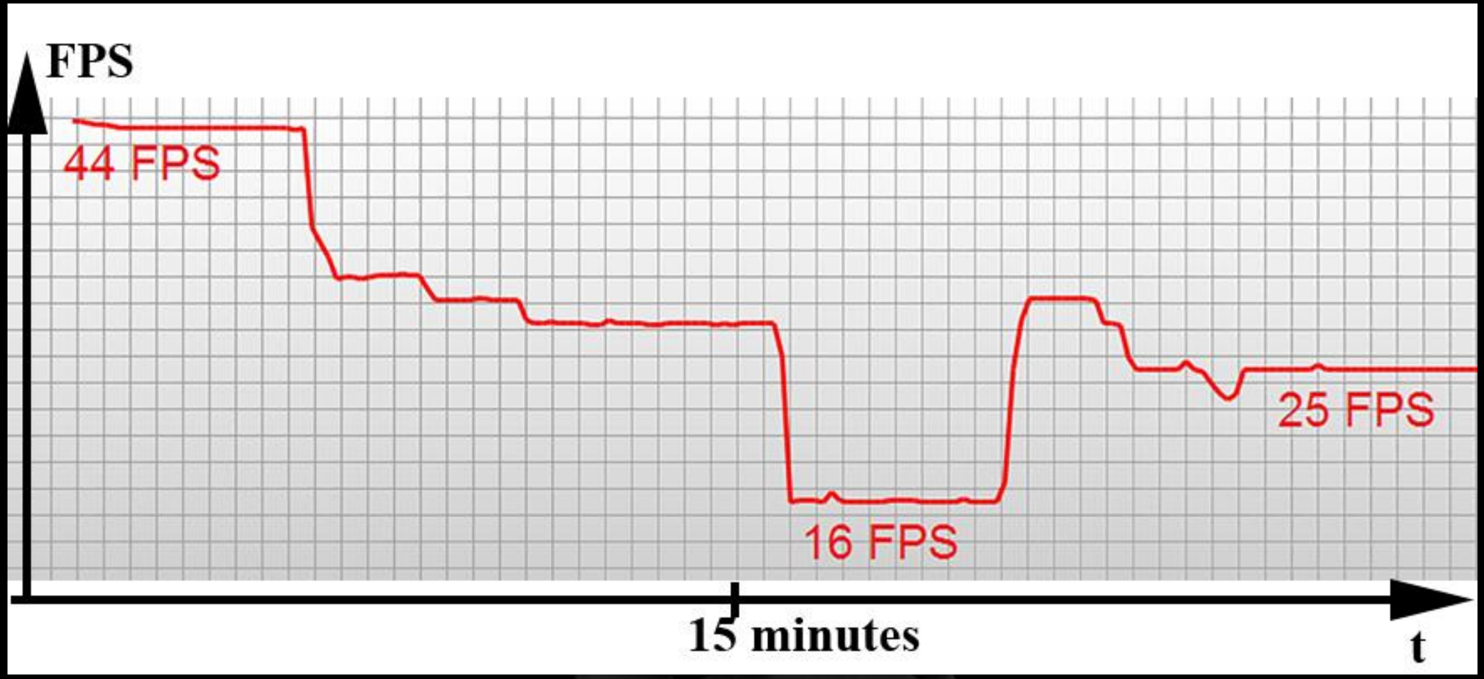
Thermal throttling

1. Wait until the device goes into stable state (25FPS)
2. Determine target framerate – in this case 30FPS
3. Set graphical quality so FPS is 30% above the target – 40FPS
4. Cap framerate to target – 30FPS



Thermal throttling

- Benefits:
  - We are not using all of the computational resources of the device
  - Amortizes frametime spikes
- Quality settings determined per GPU



Performance tracking

- Analytics tracking:
  - Average FPS
  - Battery drain
- Battery drain is correlated with heating
- New settings distributed on every game start from our server

Recap

- Specialize your techniques
- It’s worth it to go old-school
- Be mindful of heating

Questions?

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Thank You!