

Render the Possibilities

SIGGRAPH 2016

THE 43RD INTERNATIONAL
CONFERENCE AND EXHIBITION ON



Computer Graphics
Interactive Techniques

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Computer Graphics
Interactive Techniques

ARM

Moving Mobile Graphics
Advanced Real-time Shadowing

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ARM

Agenda

- Shadow algorithms
- Shadow filters
- Results

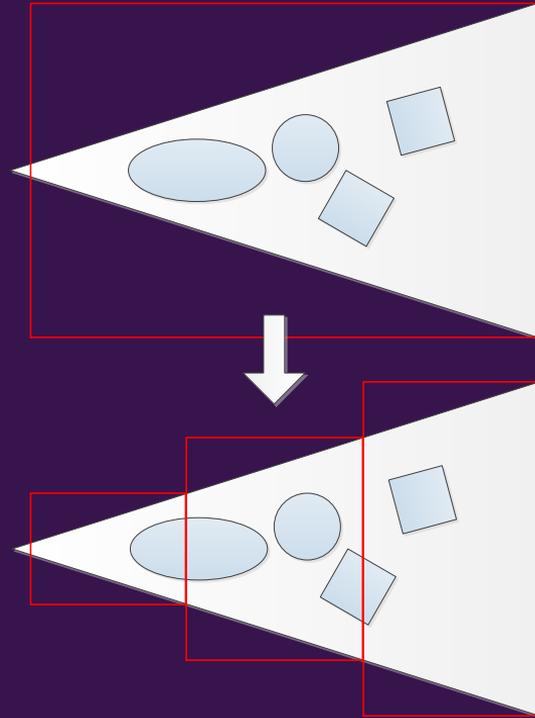
SHADOW ALGORITHMS

Shadow Algorithms

- Shadow mapping
- Depends on light type
 - Directional, spot light, point light, area light, etc...

Cascaded shadow maps

- Builds on regular shadow mapping
- Split visible depth range into N partitions
- Slice distribution
 - Logarithmic?
 - Uniform?



Cascaded shadow maps

- Requires rendering geometry N times
 - Same geometry might be rendered multiple times into different shadow slices
- Interleaved updates?
- Geometry shader could help, but is not efficient (on mobile)
 - Multiview extension!

Multiview extension

- `GL_OVR_multiview`
 - Originally conceived in order to make VR rendering more efficient
 - Bind multiple slices of a 2D texture array as framebuffer output
- Submit draw calls for all cascades once

Multiview extension

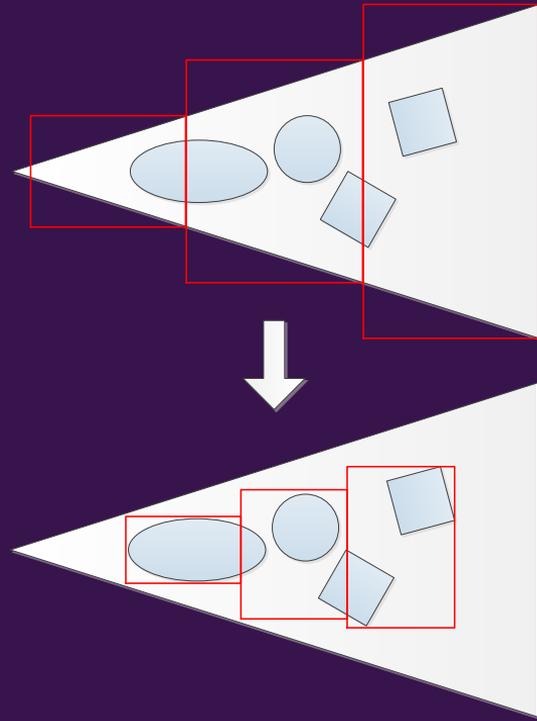
```
#extension GL_OVR_multiview: require
```

```
layout (num_views = 4) in;  
uniform mat4 uViewProj[4];  
in vec3 aPos;
```

```
void main()  
{  
    gl_Position = vec4(aPos, 1.0) * uViewProj[gl_ViewID_OVR];  
}
```

Sample distribution shadow maps

- Analyze the current view to determine best fit for shadow projection



Sample distribution shadow maps

- Compute hierarchical min-max depth buffer from scene depth buffer
- To avoid GPU stalls, use depth buffer from previous frame
 - Re-project depth values and add some rubber band region

Sample distribution shadow maps

- Compute shader used to generate cascade split distances
- Min-max depth buffer used to further trim size of splits
 - Read-back to CPU to allow further per split culling
 - ...or store to buffer and draw “everything”

Sample distribution shadow maps

- Balanced primitive count per cascade
- Better ratio between shadow map resolution and output resolution
- Can lower resolution to get similar result as higher resolution non-SDSM approach

SHADOW FILTERING

Percentage Closer Filtering

- Depth textures cannot be filtered the same way as color textures
- Compare depth around current pixel
 - Returned value is average of the comparison results
 - Modern GPUs have HW support for this

Shadow aliasing

- Shadow resolution doesn't map 1:1 with rendered image
- 2x2 PCF is not enough
 - ... and going higher is expensive at run-time

Variance Shadow Maps

- Approximates a distribution of depth values
 - Variance moments
- Filterable to some extent
- <http://www.punkuser.net/vsm/>

Variance Shadow Maps

- Multi-sampled render to texture
 - Output variance moments in fragment shader
 - Result is resolved to single sample
- Apply separable blur (optional)
- Apply shadow map using Chebychev's inequality

Variance Shadow Maps

- Requires two components rather than a single depth value
- Sensitive to floating point precision
 - Use `RG32_FLOAT`
- Light bleeding issues
- Careful when filtering with too large kernels

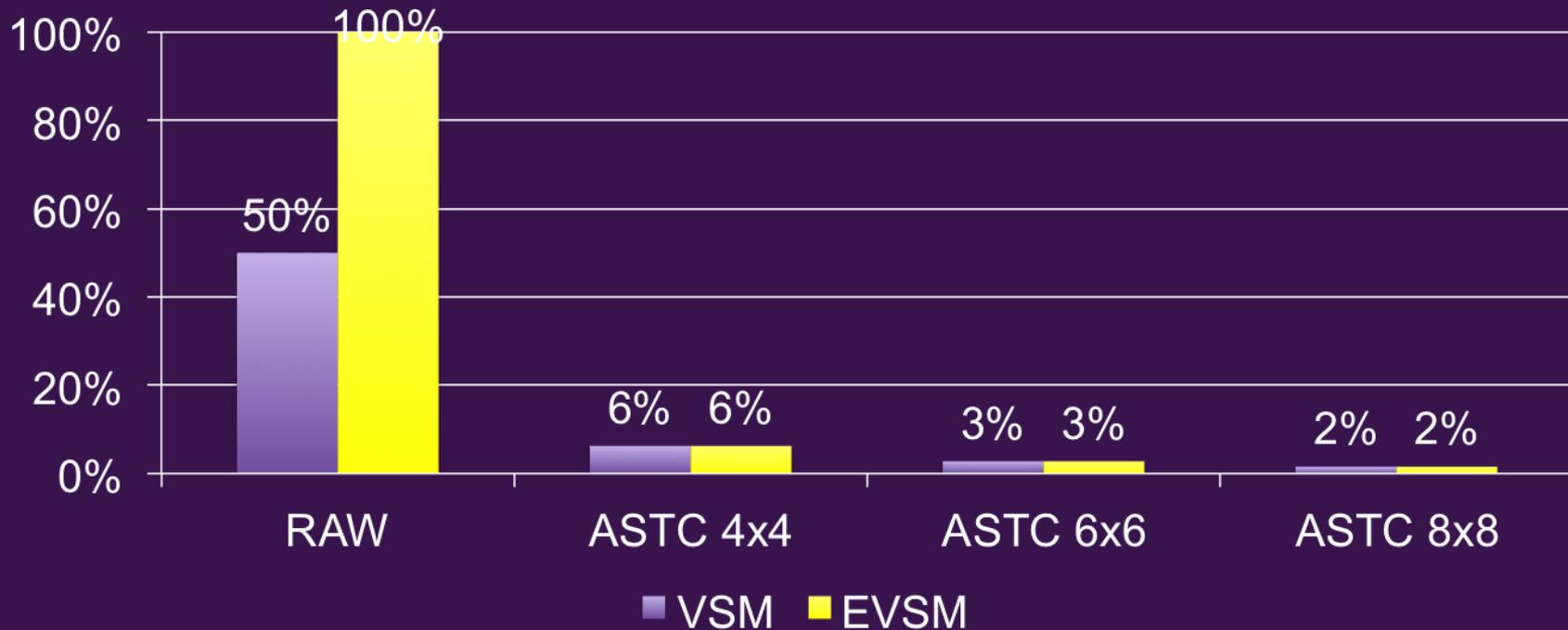
Exponential Variance Shadow Maps

- Builds on variance shadow maps and exponential shadow maps*
- Fixes most of the light bleeding issues
- Apply exponential warp to shadow map depth
 - Positive and negative bounds
- Best result with `RGBA32_FLOAT` textures

ASTC compressed shadow maps

- Idea: Compress VSM/EVSM to HDR ASTC textures
- Useful for static scenes with static lighting
 - Can still have dynamic geometry
- Massive storage savings
- Requires tweaking with ASTC encoder to get good results

ASTC compressed shadow maps



RESULTS



Fixed distribution

512x512 w/4 splits



Sample distribution

512x512 w/4 splits



Fixed distribution

1024x1024 w/4 splits



Sample distribution

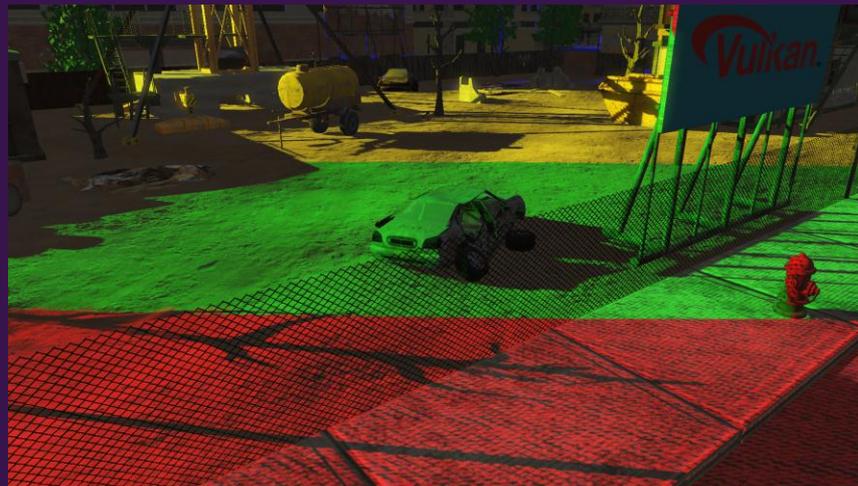
1024x1024 w/4 splits

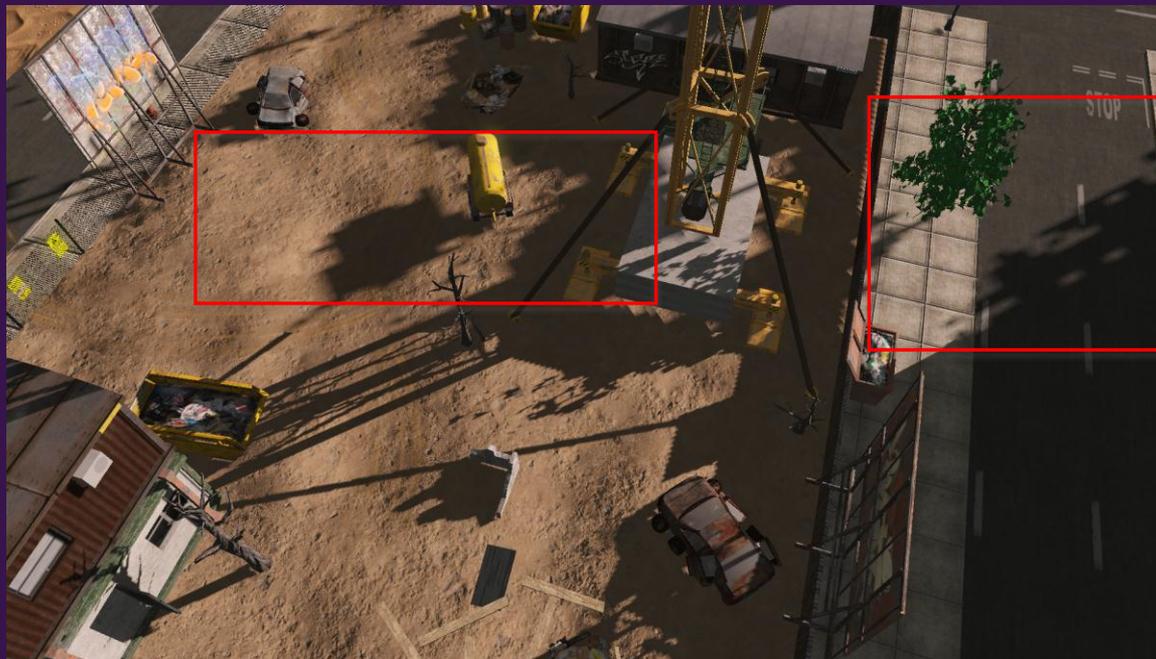
Split comparison

Fixed distribution



Sample distribution





Fixed distribution

1024x1024 w/4 splits



Sample distribution

1024x1024 w/4 splits

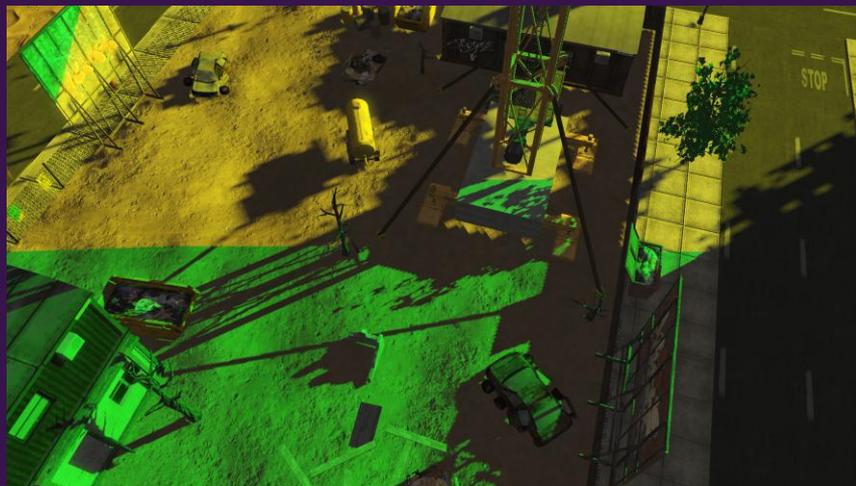


Sample distribution

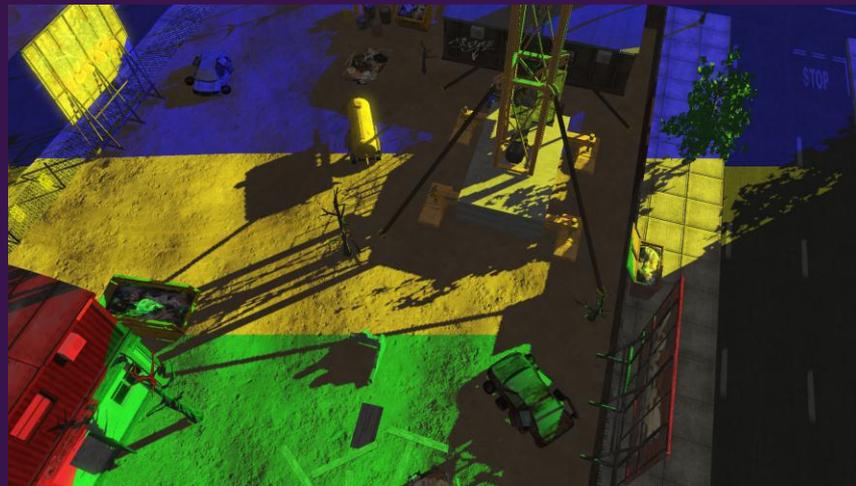
1024x1024 w/2 splits

Split comparison

Fixed distribution



Sample distribution



Filter comparisons

256x256 PCF



1024x1024 PCF



Filter comparisons

256x256 VSM



1024x1024 VSM



Filter comparisons

256x256 EVSM



1024x1024 EVSM



Performance

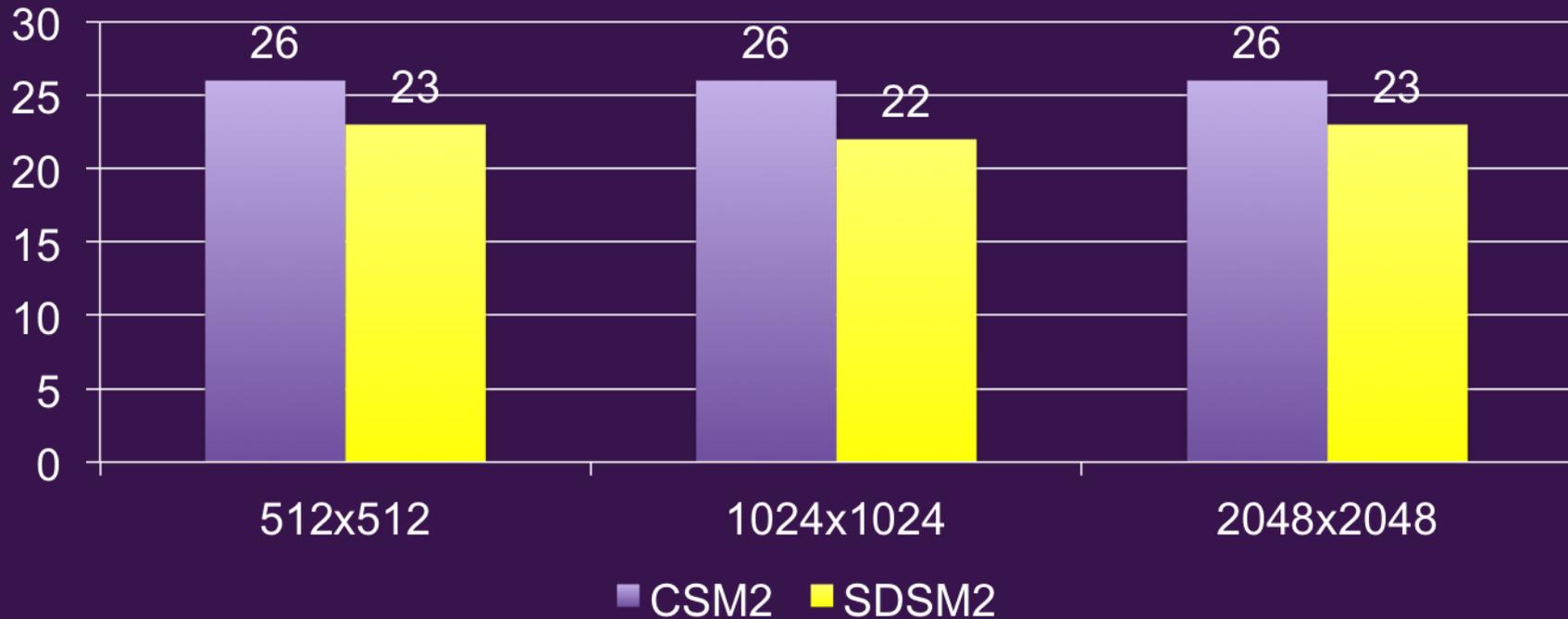
- Test scene contains ~2.5 million primitives
- Tested on a Mali-T880 MP12 running at 720p resolution



Primitives per slice

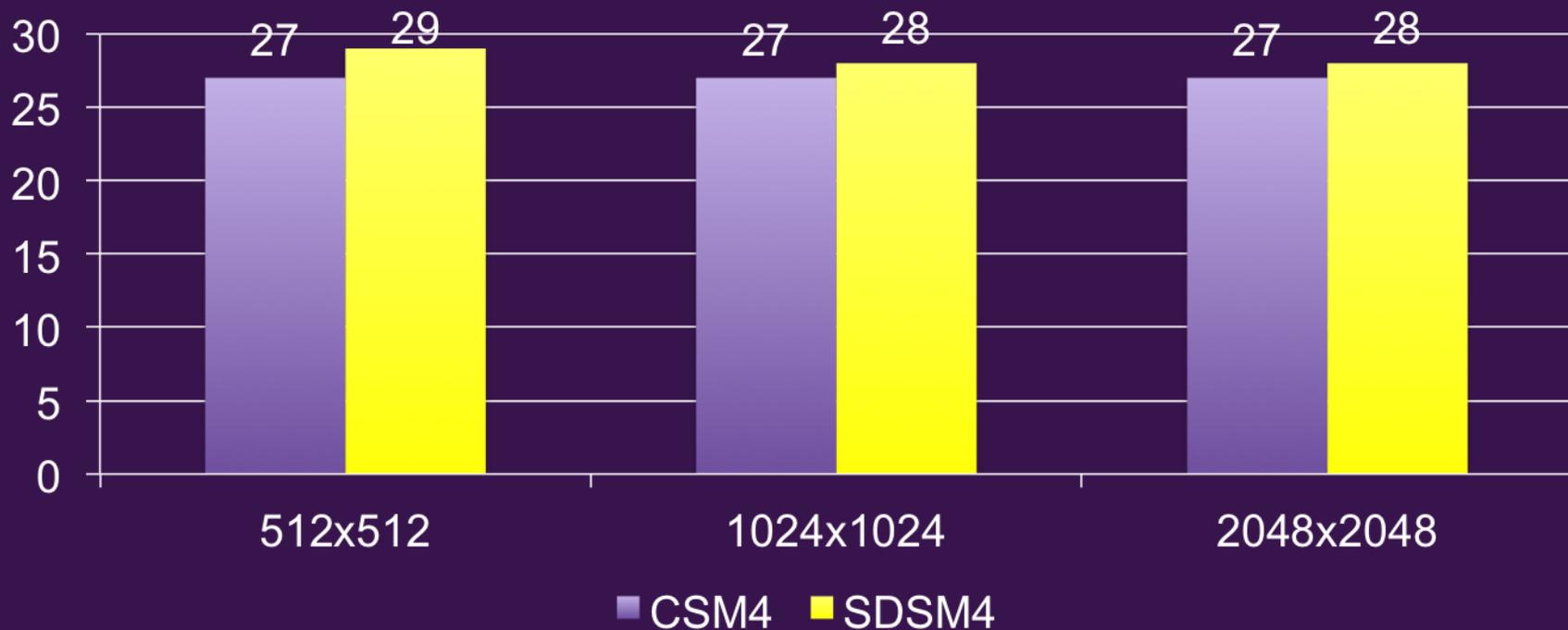


Performance w/2 splits



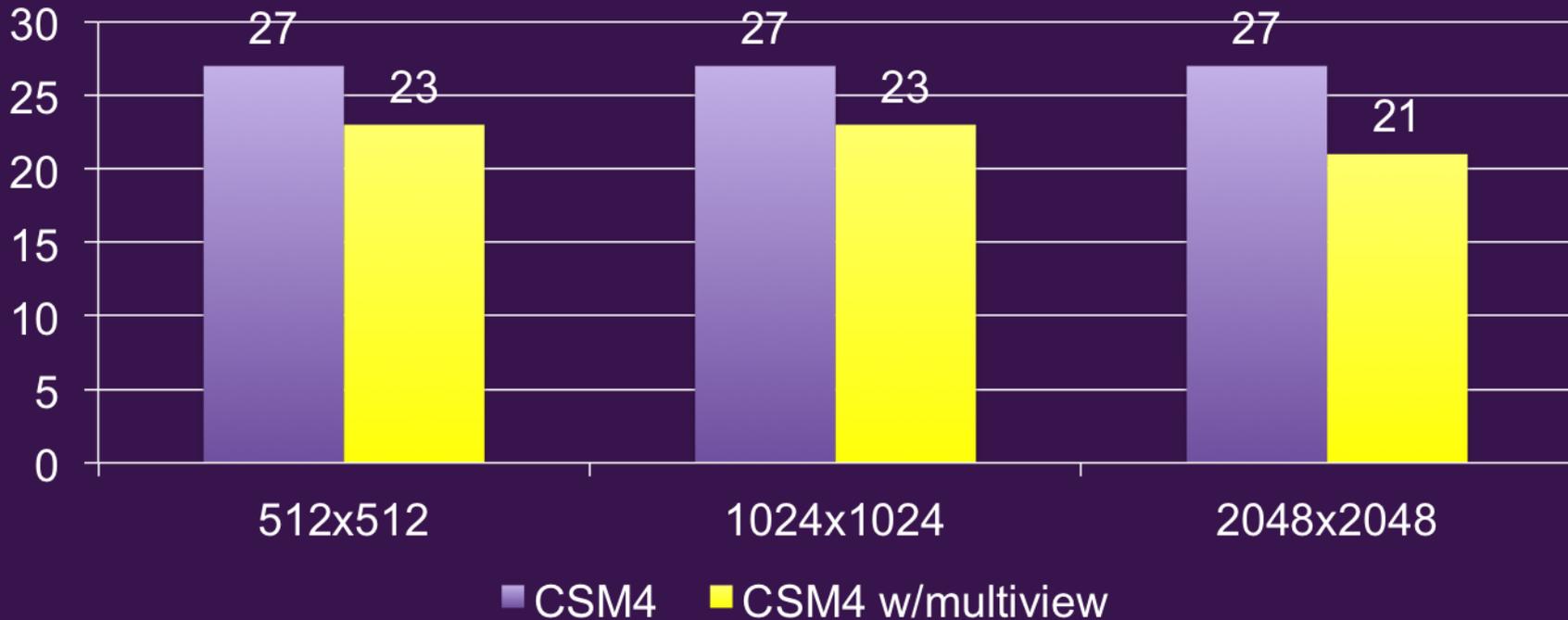
Frametime in ms (lower is better)

Performance w/4 splits



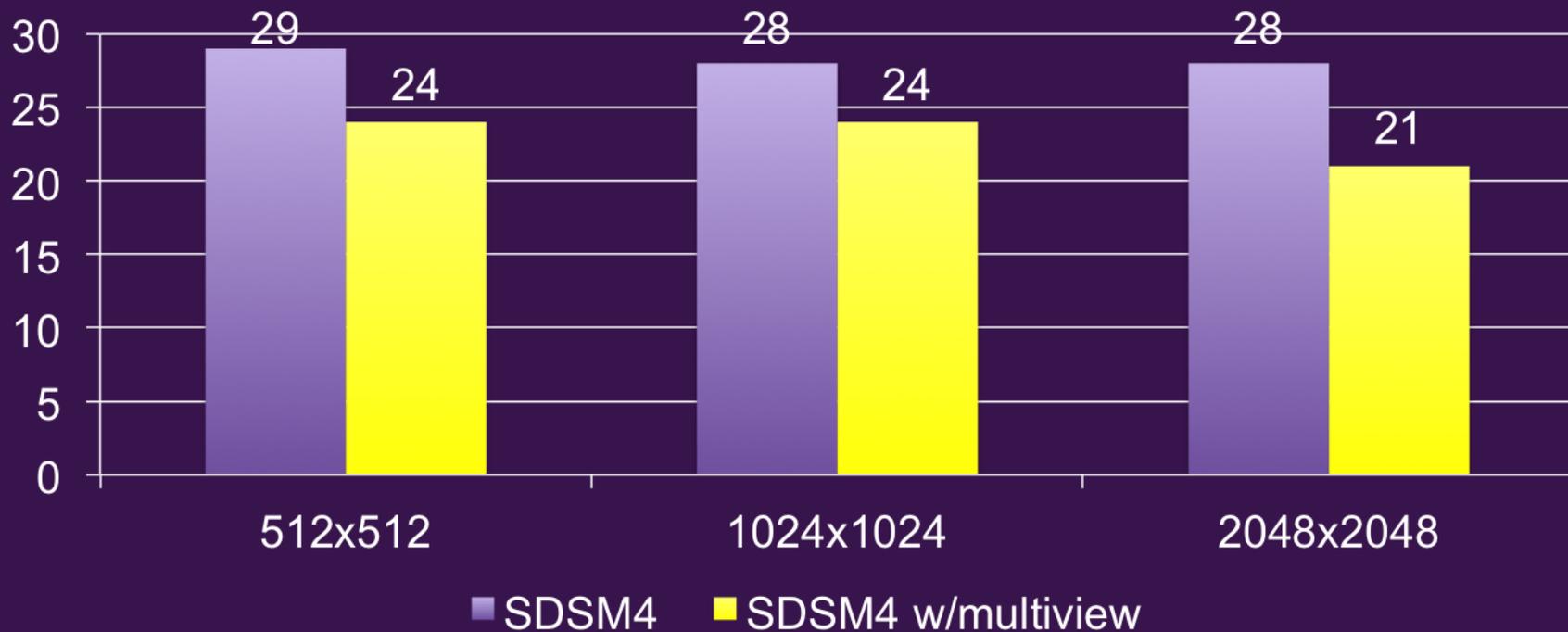
Frametime in ms (lower is better)

Performance multiview



Frametime in ms (lower is better)

Performance multiview



Frametime in ms (lower is better)

Conclusion

- Sample distribution shadow maps is practical on mobile
- Multiview is great for shadow rendering
- Future work
 - ASTC encoding and quality trade-off
 - Vulkan
 - Broader performance analysis

Thank you!

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References

1. Sample Distribution Shadow Maps
 - Lauritzen, Salvi, Lefohn
2. Variance Shadow Maps
 - Donnelly, Lauritzen
3. Exponential Shadow Maps
 - Annen, Mertens, Seidel, Flerackers, Kautz
4. GL_OVR_multiview
 - <https://www.opengl.org/registry/specs/OVR/multiview.txt>
5. Lighting Research at Bungie
 - Chen, Tatarchuk