Multipass Rendering

Multipass Rendering: Why?

- Many effects possible with multiple passes
  - Dynamic environment maps
  - Dynamic shadow maps
  - Reflections/mirrors
  - Dynamic impostors
  - (Light maps)

Note

- Conventional OpenGL allows for many effects using multipass
  - Still in use for mobile devices and last gen consoles
  - Modern form: render to texture
    - Much more flexible but same principle
- Programmable shading makes things easier
  - Specialized calls in shading languages

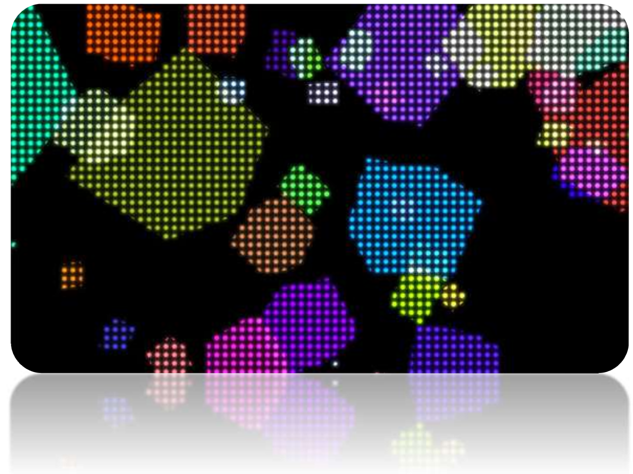
Multipass Rendering: How?

- Render to auxiliary buffers, use result as texture
  - E.g.: environment maps, shadow maps
  - Requires pbuffer/fbo-support
- Redraw scene using fragment operations
  - E.g.: reflections, mirrors
  - Uses depth, stencil, alpha, … tests

Multipass Rendering: How?

- First pass
  - Establishes z-buffer (and maybe stencil)
    `glDepthFunc(GL_LEQUAL);`
  - Usually diffuse lighting
- Second pass
  - Z-*Testing* only
    `glDepthFunc(GL_LEQUAL);`
  - Render special effect using (examples):
    - Blending
      `glStencilFunc(GL_EQUAL, 1, 1);`





Screenspace Effects



Introduction

- General idea:
  - Render all data necessary into textures
  - Process textures to calculate final image
- Achievable Effects:
  - Glow/Bloom
  - Depth of field
  - Distortions
  - High dynamic range compression (HDR)
  - Edge detection
  - Cartoon rendering
  - Lots more…

Hardware considerations

- Older hardware:
  - Multipass and Blending operators
  - Is costly and not very flexible
- Newer hardware:
  - Shaders render into up to 8 textures
  - Second pass maps textures to a quad in screenspace
    - Fragment shaders process textures

Standard Image Filters

- Image is filtered with 3x3 kernel:
  - Weighted texture lookups in adjacent texels
  - Edge detection through laplacian:

0	1	0
1	-4	1
0	1	0

  - Emboss filter

2	0	0
0	-1	0
0	0	-1

Gaussian Filter

- Many effects based on gaussian filter
- 5x5 gaussian filter requires 25 texture lookups:

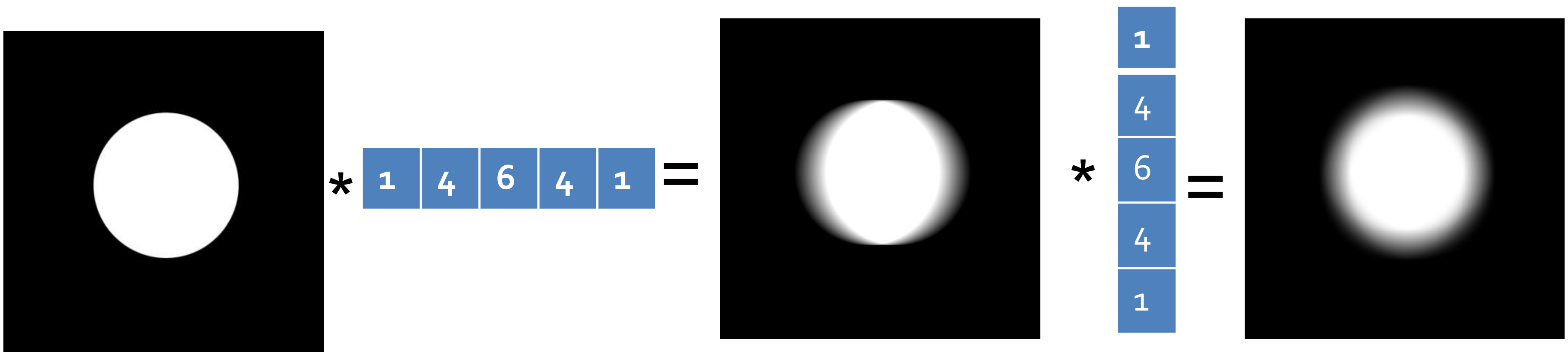
1	4	6	4	1
4	16	26	16	4
6	26	41	26	6
4	16	26	16	4
1	4	6	4	1

* 1/256

  - Too slow and too expensive

Gaussian Filter

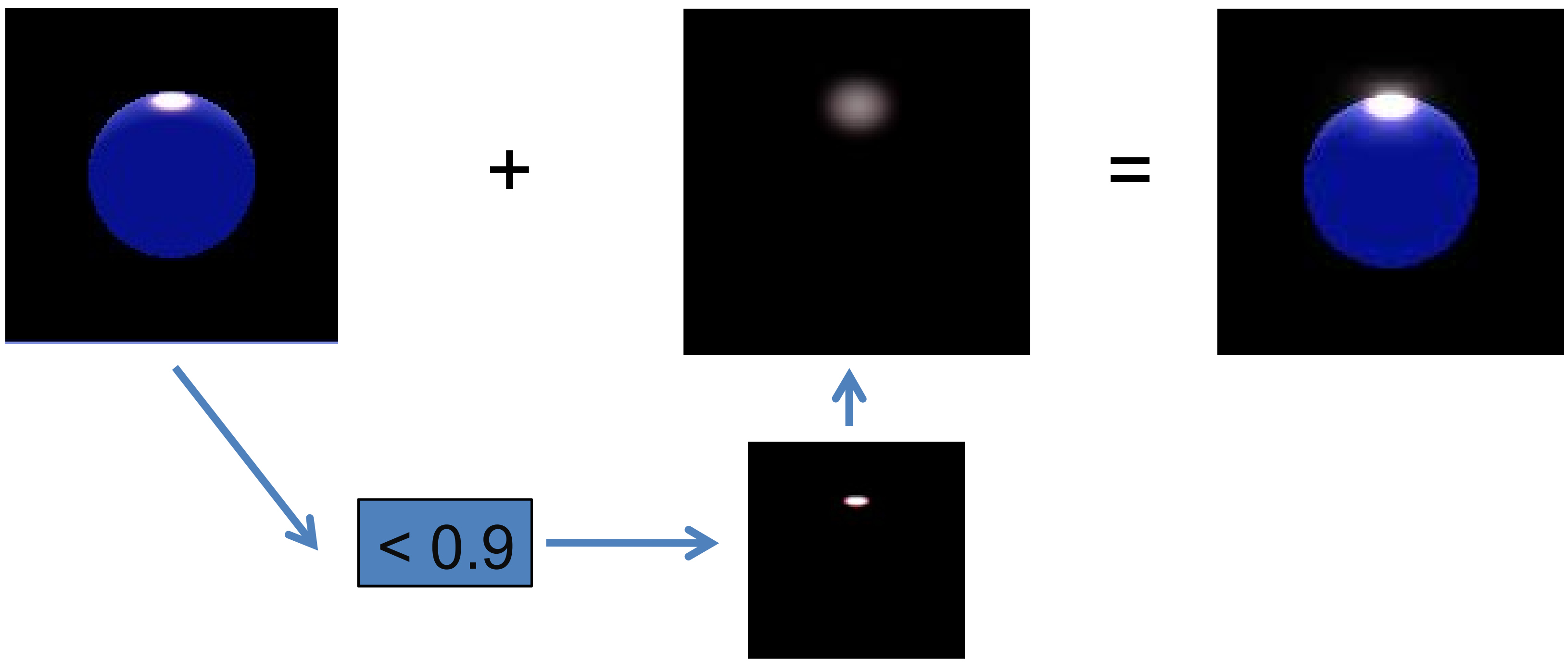
- Separate 5x5 filter into 2 passes
- Perform 5x1 filter in u
- Followed by 1x5 filter in v



- Lookups can use linear filtering
  - 5x1 filter with 3 lookups

Bloom

- Use only bright parts for blur



Bloom

- Bloom usually applied to downsampled render textures
  - 2x or 4x downsampled
    - Effectively increases kernel size
  - But: Sharp highlights are lost
  - Combination of differently downsampled and filtered render textures possible
    - Allows high controllability of bloom

- Filter in *u* and *v* and separate addition leads to star effect

Bloom

Picture: Oblivion

Bloom remarks

- Disguises aliasing artifacts
- Works best for shiny materials and sun/sky
  - Only render sun and sky to blur pass
  - Only render specular term to blur pass
- A little bit overused these days
  - Use sparsely for most effect
- Can smudge out a scene too much
  - Contrast and sharp features are lost (fairytale look)

Bloom remarks

- Extreme example

Motion blur

- Keep previous frames as textures
  - Blend weighted frames to final result
- Render camera space speed of each pixel in texture
- Blur along motion vector
  - Harder to implement, but looks very good
  - Faster than blending

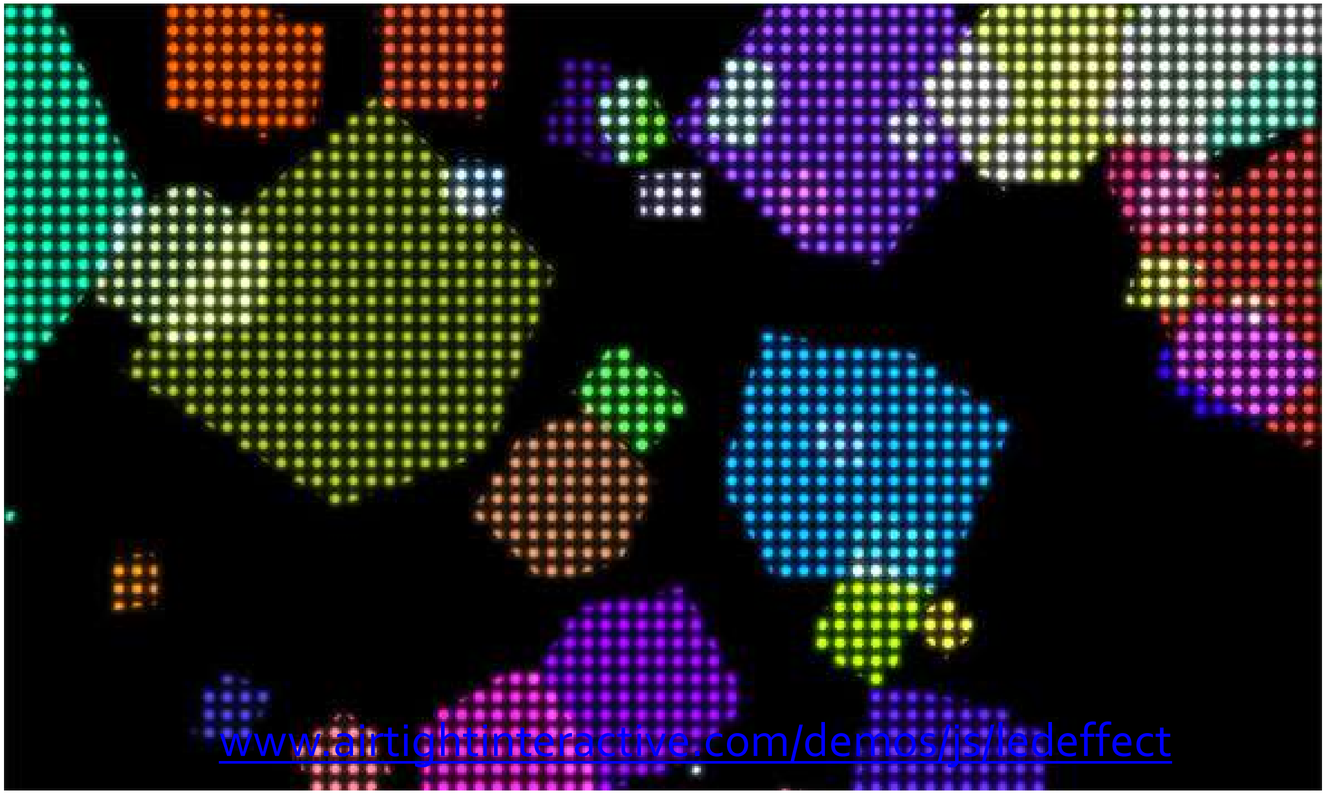
Bad TV

- Vertical distortions
- Chroma displacement

www.airtightinteractive.com/demos/js/badtvshader

Dot Matrix Shader

- Render texture as a grid of dots
- Glow pass



www.airtightinteractive.com/demos/js/ledeffect

Other filters

- Use precomputed noise maps
  - Modulate Color with noise:
    - TV snow emulation
  - Modulate texture coordinates:
    - glass refractions
    - TV distortions
    - Warping
  - Remap intensity:
    - Heat vision
    - Eye adaptation

HDR Rendering

- Up to now, colors are in [0..1]
- Real world
  - Dynamic Range is about 1:100 000
  - 1: dark at night
  - 100 000: direct sunlight
  - Eye adapts to light intensities
- Current hardware allows to calculate everything in floating point precision and range
  - Use lights/environment maps with intensities of high dynamic range

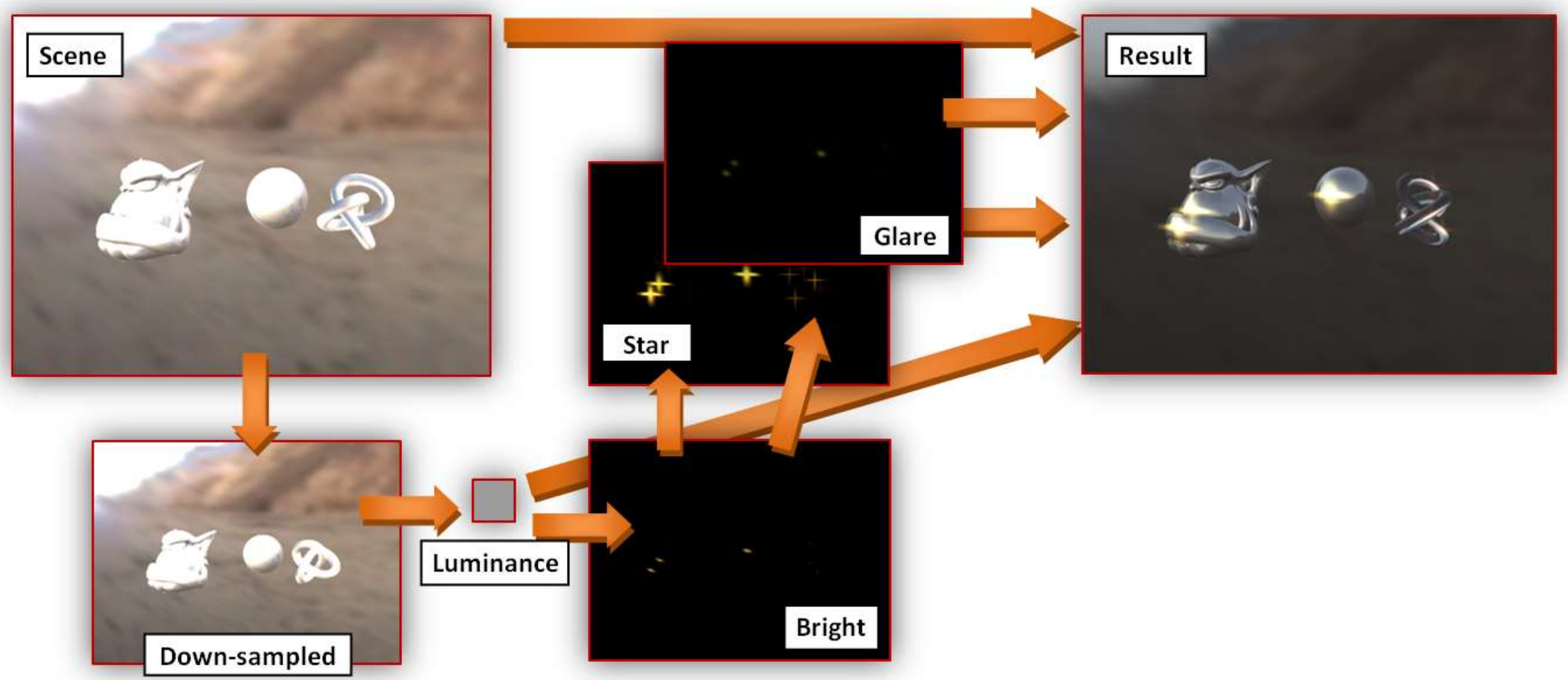
HDR rendering

- **But**: we cannot display a HDR image!
- Solution: Remap HDR intensities to low dynamic range
- **Tone mapping**
  - Imitates human perception
  - Can mimic time delayed eye adaptation
  - Can mimic color desaturation
  - Can imitate photographic effects
  - Over exposure
  - Glares

HDR Rendering

- Tone mapping requires information about the intensities of the HDR image
  - Extract average/maximum luminance through downsampling
    - Hardware MIP-map generation
    - Or through a series of fragment shaders
- Feed high intensities to bloom pass
  - Mimics over exposure, glare, streaks…

HDR Processing Overview



Tone mapping Operators (1)

- Reinhard's operator

a ... Key
$\bar{L}_W$ ... Average luminance
L_W ... Pixel luminace

$$L_{scaled} = \frac{a \cdot L_W}{\bar{L}_W}$$

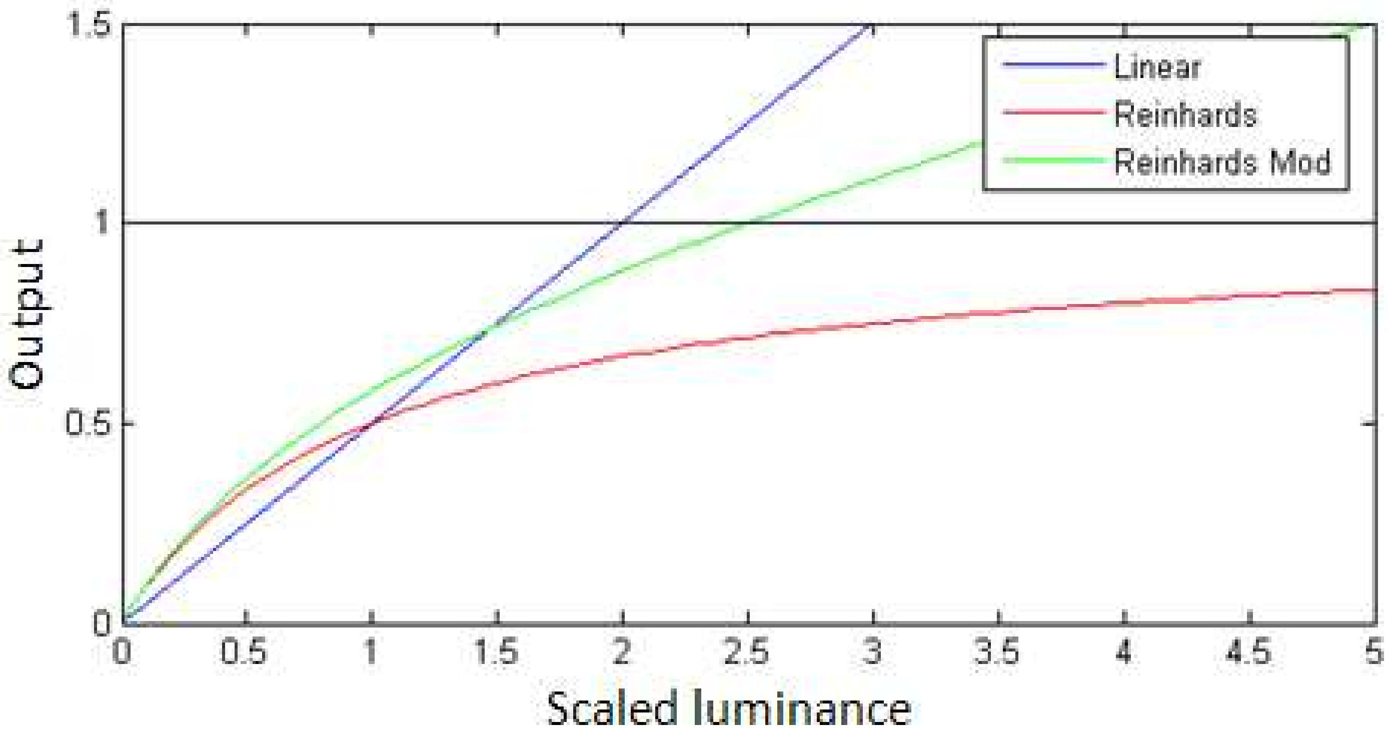
- Original $$Color = \frac{L_{scaled}}{1 + L_{scaled}}$$

- Modified $$Color = \frac{L_{scaled} \cdot \left(1 + \frac{L_{scaled}}{L^2_{white}}\right)}{1 + L_{scaled}}$$

  - Key ***a*** *is* set by user or some predefined curve $a(l_a)$ dependent on average luminance l_a
  - Calculations need to be done in linear color space! (floating point buffers)

Tone mapping Operators (2)

- Reinhard's operator



Tone mapping Operators (3)

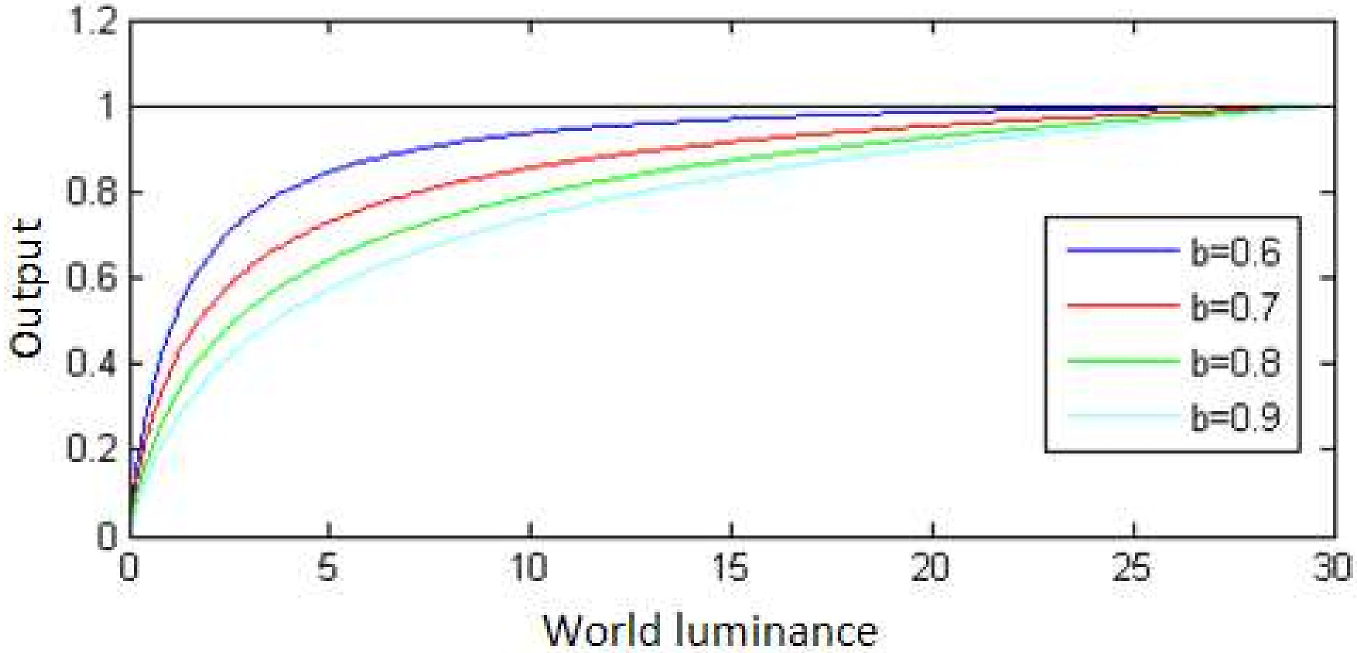
- Logarithmic mapping

$$L_d = \frac{\log_x(L_w + 1)}{\log_x(L_{max} + 1)}$$

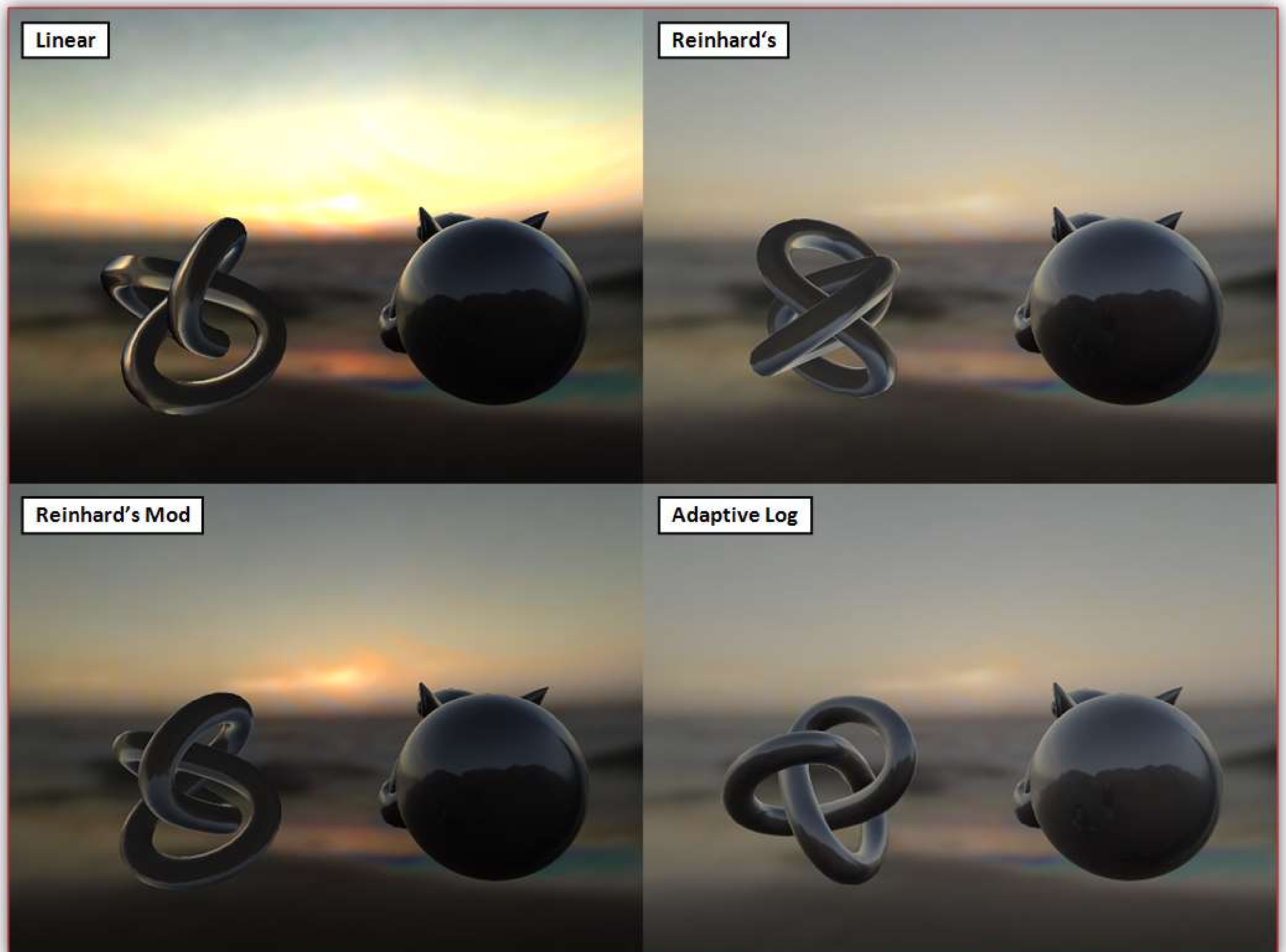
  - Improvement: Adaptive logarithmic mapping
  - L_{max} causes heavy changes of the output color when moving through the scene

Tone mapping Operators (4)

- Adaptive logarithmic mapping [Drago 03]



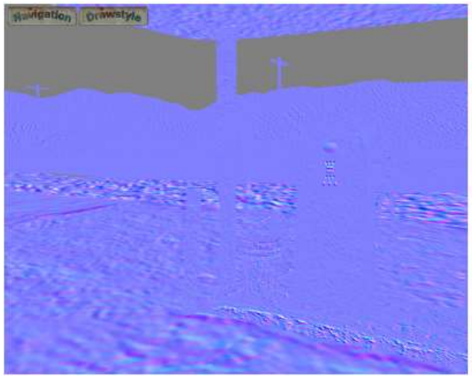
Comparison

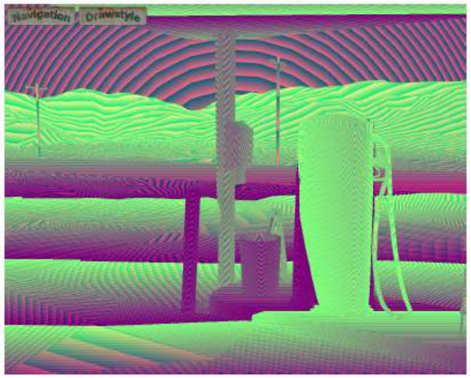


HDR Rendering (OGRE Beach Demo)

Deferred Shading

- General Idea: Treat lighting as a 2D postprocess
  - Deferred Shading rendered textures:
    - Normals
    - Position
    - Diffuse color
    - Material parameters
- Execute lighting calculations using the textures as input





Deferred Shading

- Pros:
  - Visibility resolved before expensive shading
  - Perfect batching
  - Many small lights are just as cheap as a few big ones (32 lights and up are no problem)
  - Combines well with screen-space effects
- Cons:
  - High bandwidth required
    - Not applicable on older hardware
  - Alpha blending hard to achieve
  - Hardware multisampling not available

Deferred Shading

Screen Space Ambient Occlusion (SSAO)

- Popularized by Crysis (Crytec)
- Render textures needed:
  - Depth (as linear z-buffer) or world space
  - Normals
- Approach:
  - Fragment analyses its surrounding
    - Fragment samples z-buffer around screen position
    - Simplest approach: depth difference of fragment and sample

Screen Space Ambient Occlusion (SSAO)

- Pros:
  - Independent from scene complexity
  - No preprocessing
  - Dynamic scenes

- Cons:
  - Not correct
  - Only evaluates what is seen
  - Only close range shadowing
  - Sampling artifacts (needs additional smoothing/blur)

OGRE SSAO Demo