

RND102 - Intro to Path Tracing & RIS in RenderMan



- ▶ Why this course?
- ▶ With a new version of RenderMan (19) comes an additional completely different rendering architecture: path tracing (uni & bi-directional) in RIS mode, new BRDF's and Integrators wrapped in a new shading pipeline.

Slides from Siggraph 2014 Pixar Booth Talk by Christos Obretenov

RND102 - Intro to Path Tracing & RIS in RenderMan

Christos Obretenov



Senior Technical Director in animated feature film and visual effects features. Some films worked on are Disney's The Wild, Superman Returns, SpiderMan-3, Beowulf, Christmas Carol, Mars Needs Moms. Specialize in Shader Development in RenderMan, Look Development, Lighting, and Rendering.

Educated at Simon Fraser University in Vancouver, Canada with Bachelor of Science in Computing Science.

Owner and Shader Architect at lollipopshaders.com, providing unique shading software and support for international clients.

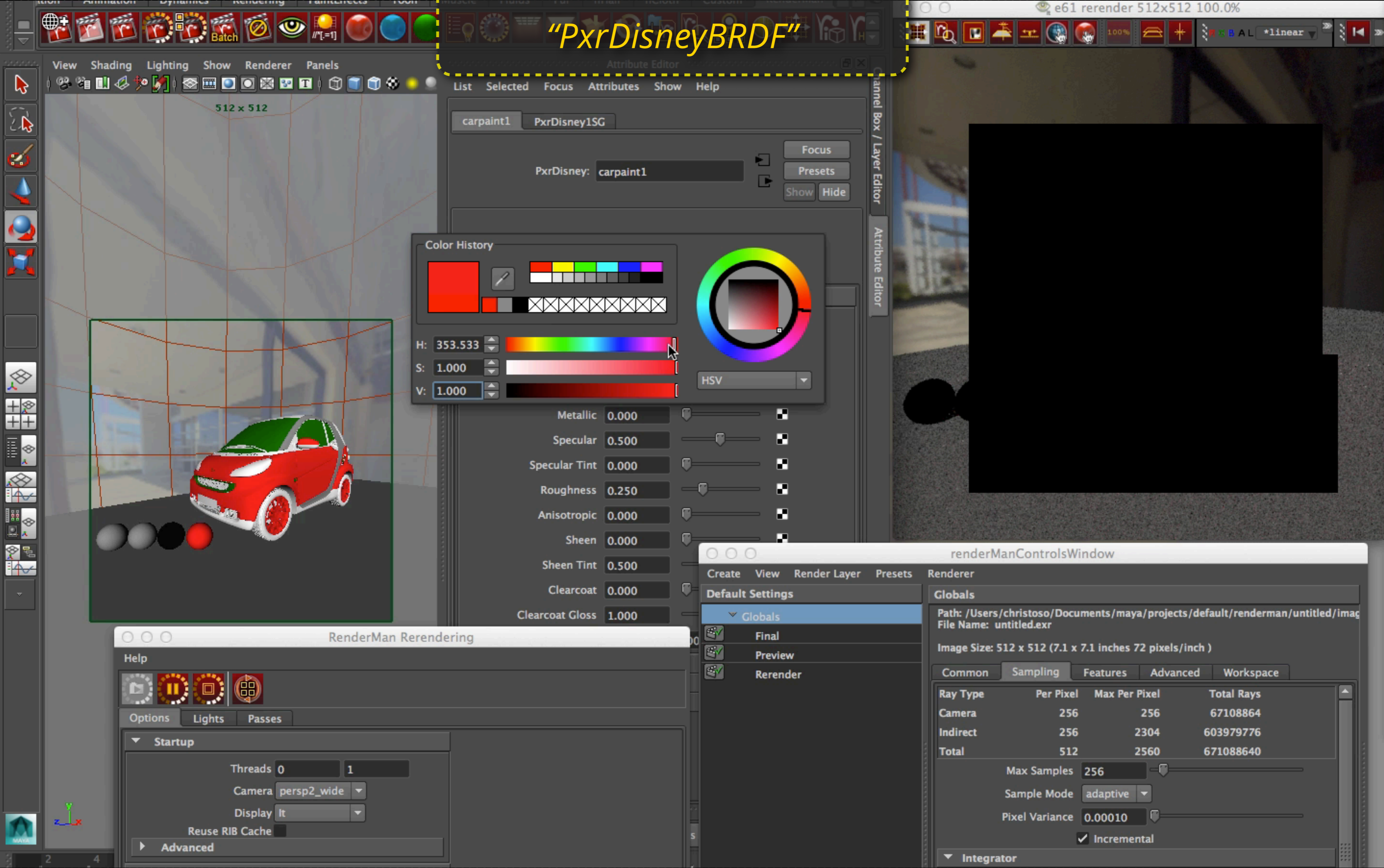
Path Tracer



VCM



"PxrDisneyBRDF"



List Selected Focus Attributes Show Help

carpaint1 PxrDisney1SG
PxrDisney: carpaint1
Focus Presets Show Hide

Color History

H: 353.533
S: 1.000
V: 1.000

HSV

- Metallic 0.000
- Specular 0.500
- Specular Tint 0.000
- Roughness 0.250
- Anisotropic 0.000
- Sheen 0.000
- Sheen Tint 0.500
- Clearcoat 0.000
- Clearcoat Gloss 1.000

RenderMan Rerendering

Options Lights Passes

Startup

Threads 0 1
Camera persp2_wide
Display It
Reuse RIB Cache
Advanced

renderManControlsWindow

Default Settings

Globals

Ray Type	Per Pixel	Max Per Pixel	Total Rays
Camera	256	256	67108864
Indirect	256	2304	603979776
Total	512	2560	671088640

Max Samples 256
Sample Mode adaptive
Pixel Variance 0.00010
Incremental



RIS
Integrator: Path Tracer
Max Samples=1
9s



RIS
Integrator: Path Tracer
Max Samples=256
5m17s

Render Using **RenderMan/RIS**

Common | **Sampling** | Features | Passes | Advanced

Ray Type	Per Pixel	Max Per Pixel	Total Rays
Camera	256	256	67108864
Indirect	256	512	134217728
Total	512	768	201326592

Max Samples: 1
Sample Mode: adaptive
Pixel Variance: 0.00010
 Incremental

Integrator

Integrator: **Path Tracer**

Max Path Length: 10
Sample Mode: bxdf
Light Samples: 8
Bxdf Samples: 8
Indirect Samples: 1
 Allow Caustics



RIS
Integrator: VCM
Max Samples=1
11s



RIS
Integrator: VCM
Max Samples=256
7m33s

Render Using **RenderMan/RIS**

Common | **Sampling** | Features | Passes | Advanced

Ray Type	Per Pixel	Max Per Pixel	Total Rays
Camera	256	256	67108864
Indirect	256	2304	603979776
Total	512	2560	671088640

Max Samples: 256
Sample Mode: fixed
 Incremental

Integrator

Integrator: **VCM**

Max Path Length: 10
Light Samples: 8
Bxdf Samples: 8
 Merge Paths
 Connect Paths



RIS
Integrator: VCM
Max Samples=256
7m33s



RIS
Integrator: Path Tracer
Max Samples=256
Max Path Length=1
Direct Lighting Only
5m25s



RIS
Integrator: Path Tracer
Max Samples=256
5m17s

RND102 - Intro to Path Tracing & RIS in RenderMan

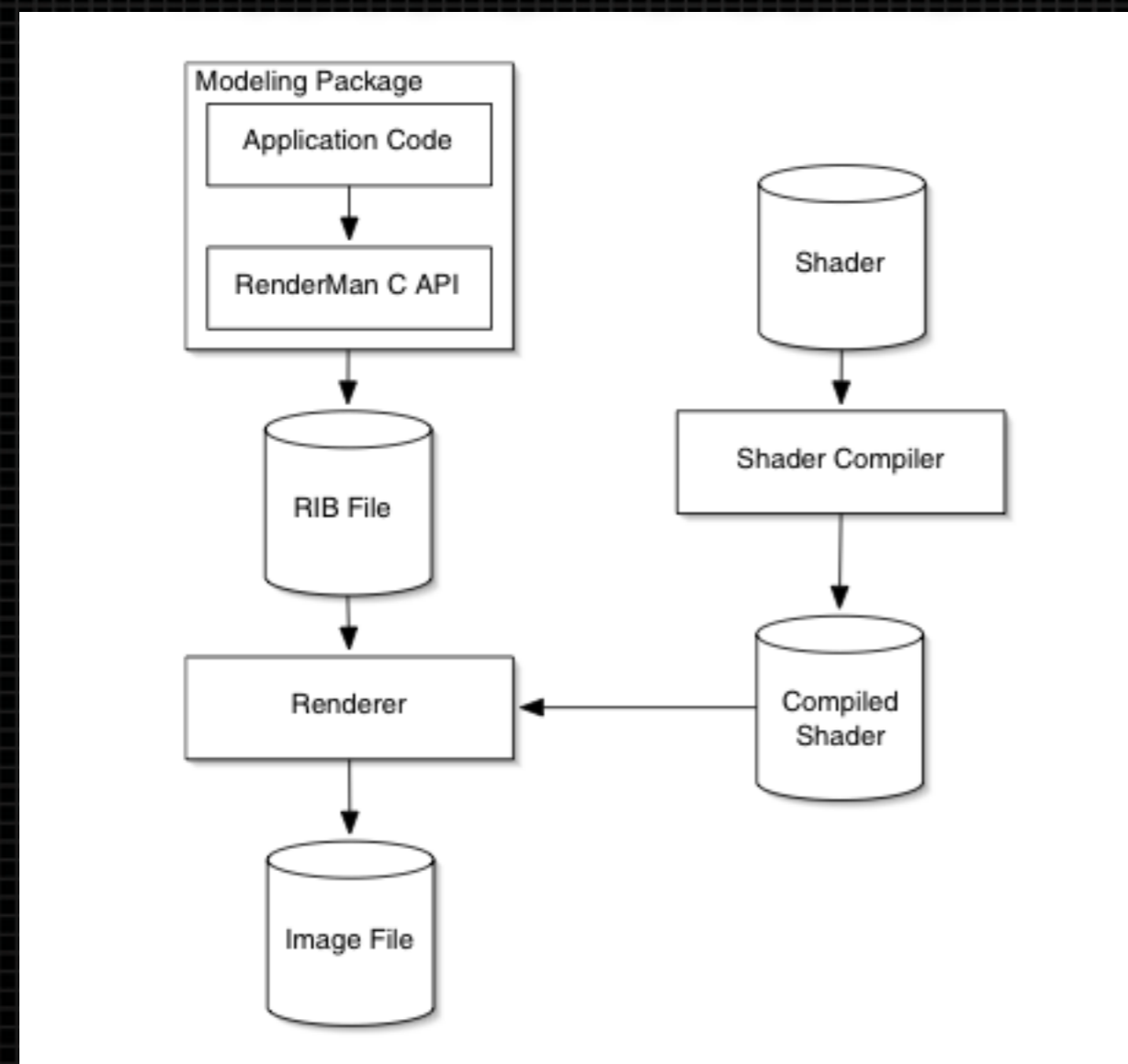


Rix Integration Subsystem

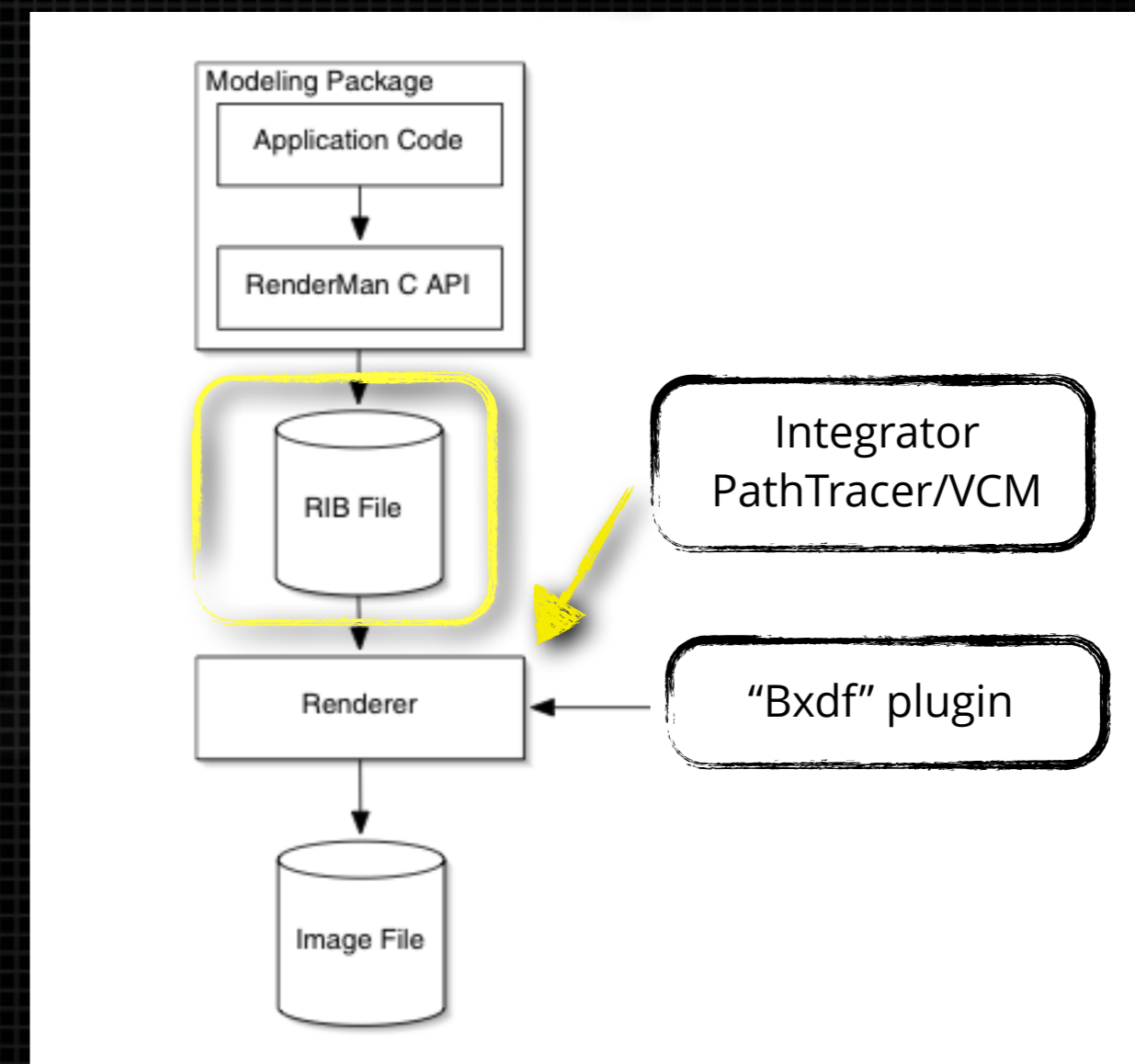
- ▶ “System” of Integrators, BxDF’s, in a path-tracing (uni & bi-directional) architecture
- ▶ Global illumination works out of the box and interactive re-rendering provides rapid iteration for artists.
- ▶ Supports many of the same features as traditional RenderMan, but introduces a completely new shading pipeline.
- ▶ Radical departure from the traditional RenderMan approach: avoids the use of RenderMan Shading Language (RSL) for characterizing material shading and light path integration

RND102 - Intro to Path Tracing & RIS in RenderMan

Traditional RenderMan

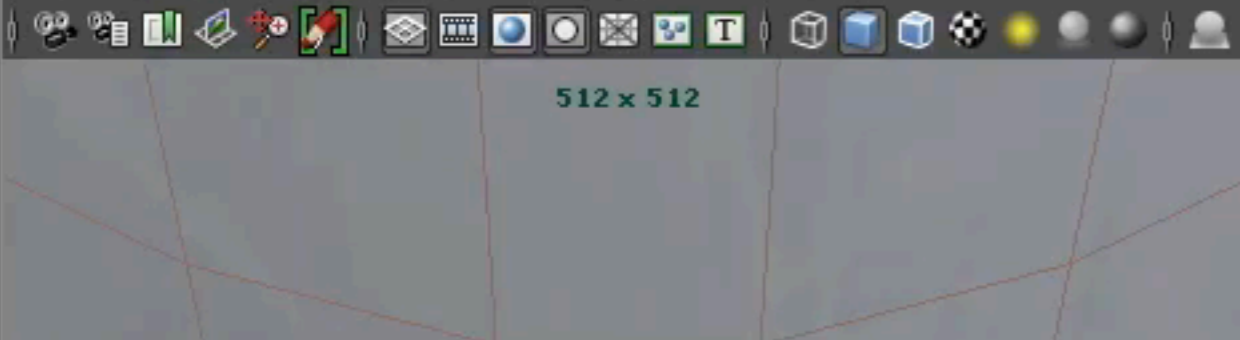


RIS





View Shading Lighting Show Renderer Panels



512 x 512

Render Settings

Edit Presets Help

Render Layer: masterLayer

Render Using: RenderMan/RIS

Common | **Sampling** | Features | Passes | Advanced | Workspace

Ray Type	Per Pixel	Max Per Pixel	Total Rays
Camera	256	256	67108864
Indirect	0	0	0
Total	256	256	67108864

Max Samples: 256

Sample Mode: fixed

Incremental

Integrator

Integrator: VCM

Max Path Length: 1

Light Samples: 8

Bxdf Samples: 8

Merge Paths

Connect Paths

▶ Radius

▶ Russian Roulette

▶ Filter

Close

List Selected Focus Attribute

carpaint1 hyperLayout2

PxrDisney: carpaint1

Sample

Pxr Disney Attributes

Base Color: ■

Emit Color: ■

Subsurface: 0.00

Subsurface Color: ■

Metallic: 1.00

Specular: 5.00

Specular Tint: 0.00

Roughness: 0.100

Anisotropic: 0.803

Sheen: 1.000

Sheen Tint: 0.500

Clearcoat: 1.000

Clearcoat Gloss: 0.100

Bump Normal: 0.000 0.000 0.000

▶ Node Behavior

▶ Hardware Texturing

▶ Extra Attributes

Select Load Attributes Copy

- Catalog1
- vespa.0027 91m
- vespa.0027 84m
- vespa.0027 81m
- vespa.0027 75m
- vespa.0027 55m
- vespa.0027 45m
- vespa 1s**



Create Bins

Materials Textures

Pxr... bro... car... chr...

sha... tir...

Work Area

▶ Favorites

+ Maya

▶ Maya

Surface

Volumetric

Displacement

2D Textures

3D Textures

Env Textures

Other Textures

Lights

Utilities

Image Planes

Glow

Rendering

▶ RenderMan\Reye

Surfaces

Lights

Textures

Shaders

Utilities

▶ RenderMan\RIS

Bxdf

Patterns

PxrBxdfBlend

PxrConstant

PxrDiffuse

PxrDisney

PxrGlass

PxrHair

PxrSkin

PxrVolume

persp2_wide

RIS: What's going on under the hood in the RIB?

REYES

```
Hider "hidden" "int jitter" [1] "int sigma" [0] "float sigmaBlur" [1] "int minsamples" [2] "int maxsamples" [0]
...
Surface "mySurfaceShader" "carpaint" "color baseColor" [0 0 0]
...
Procedural2 "DelayedReadArchive2" "SimpleBound" "string filename" ["renderman/vespa/rib/job/pSphereShape3.job.rib"] ...
```

REYES With Raytrace/Distributed Hider (pre RenderMan 19)

```
Hider "raytrace" "string samplemode" ["adaptive"] "string integrationmode" ["distribution"] "int incremental" [0] ...
```

REYES With Raytrace/Path Hider (pre RenderMan 19)

```
Hider "raytrace" "string samplemode" ["adaptive"] "string integrationmode" ["path"] "int incremental" [0] ...
```

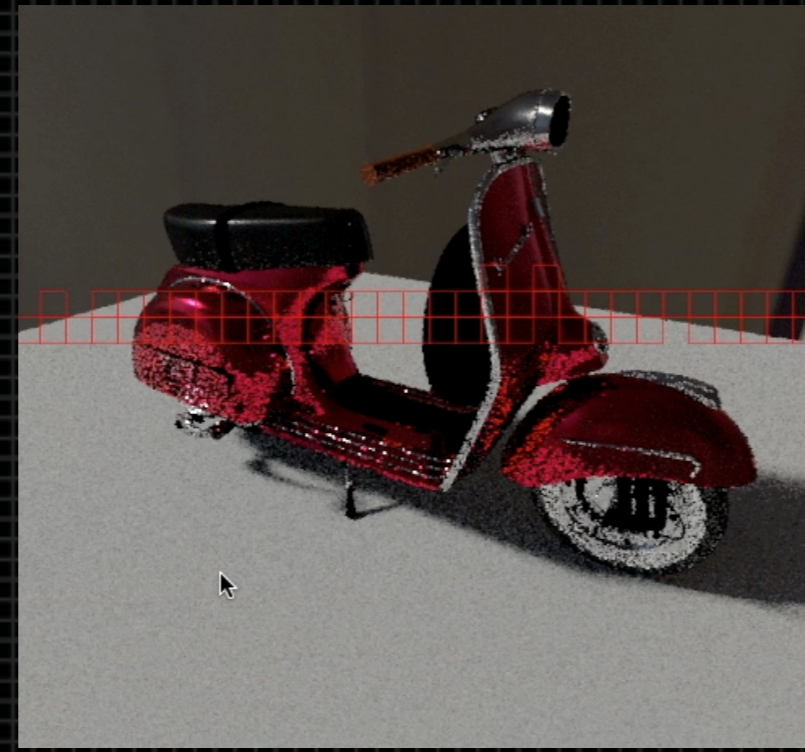
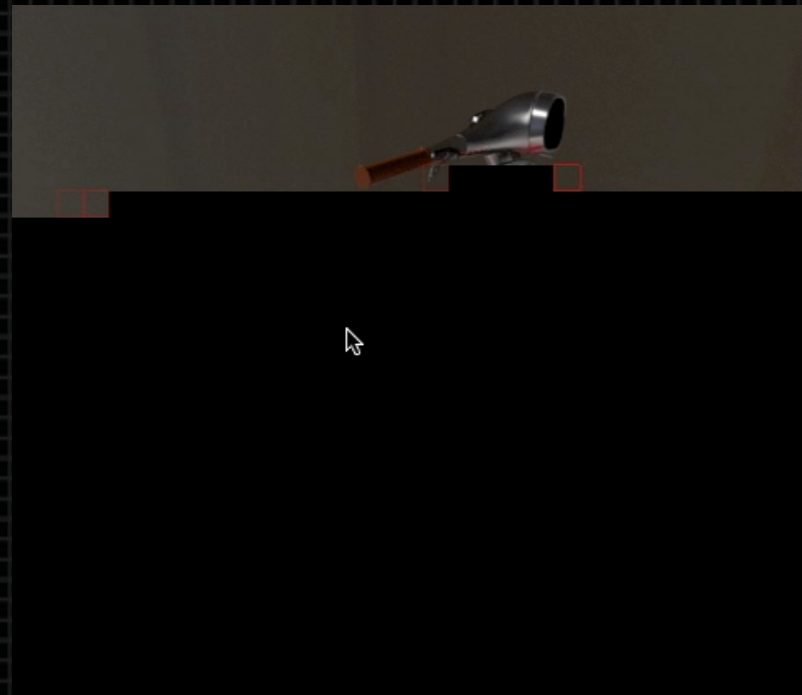
RIS

```
Hider "raytrace" "string samplemode" ["adaptive"] "string integrationmode" ["path"] "int incremental" [1] ...
Integrator "PxrPathTracer" "PxrPathTracer" "int maxPathLength" [10] "string sampleMode" ["bxdf"] "int numLightSamples"
...
Bxdf "PxrDisney" "PxrDisney2" "color baseColor" [0 0 0]
...
Procedural2 "DelayedReadArchive2" "SimpleBound" "string filename" ["renderman/vespa/rib/job/pSphereShape3.job.rib"] ...
```

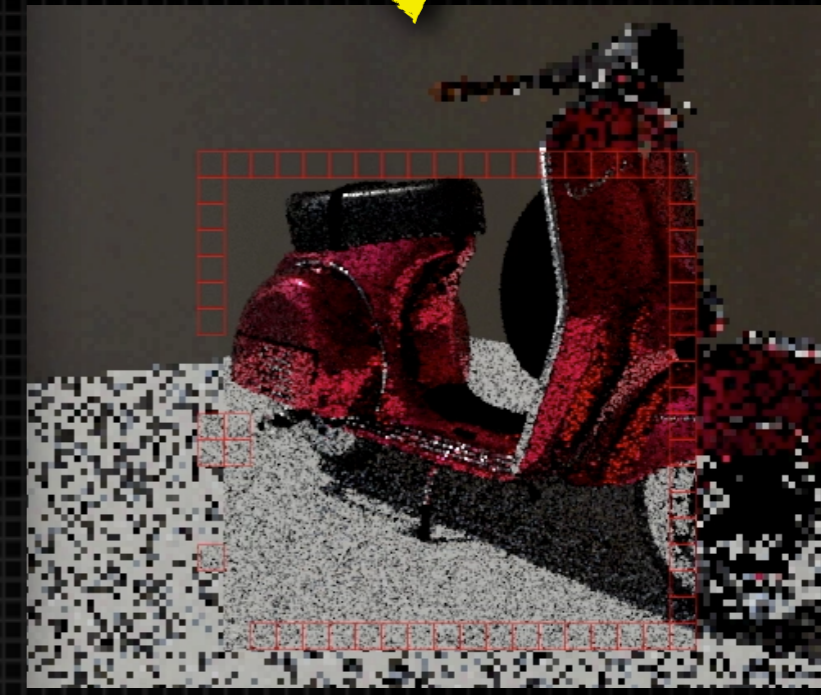
"Offline" Rendering

Standard

Incremental



Re-render "realtime" Rendering



Render Settings

Edit Presets Help

Render Layer masterLayer

Render Using RenderMan/RIS

Common Sampling Features Passes Advanced Workspace

Ray Type	Per Pixel	Max Per Pixel	Total Rays
Camera	256	256	132710400
Indirect	256	512	265420800
Total	512	768	398131200

Max Samples 256

Sample Mode adaptive

Pixel Variance 0.00010

Incremental

Integrator Path Tracer

Max Path Length 10

RenderMan Rerendering

Help

Options Lights Passes

Startup

Threads 0 1

Camera persp

Display It

Reuse RIB Cache

Advanced

Rerendering

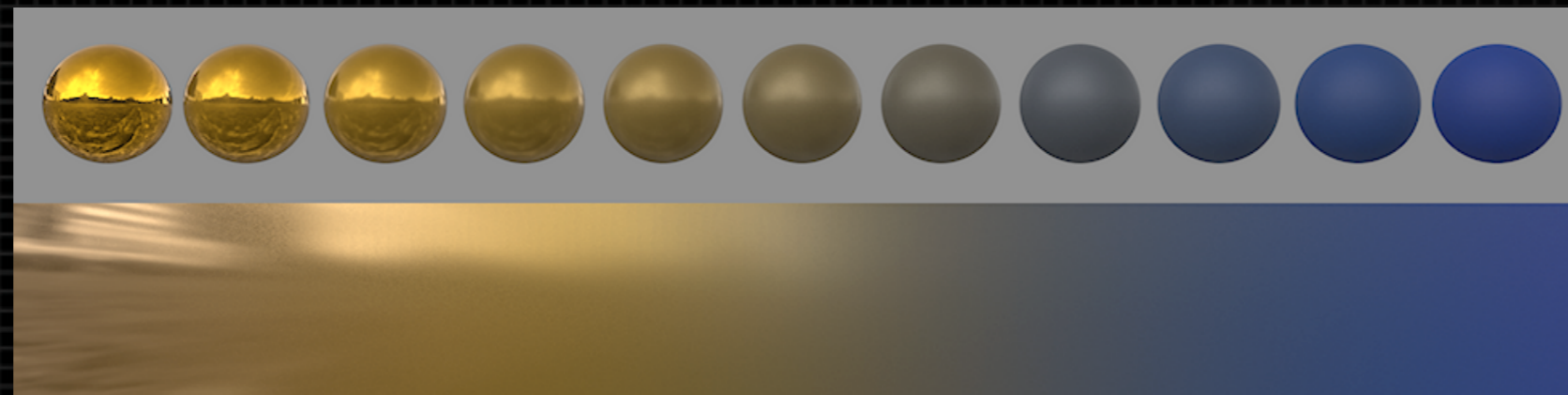
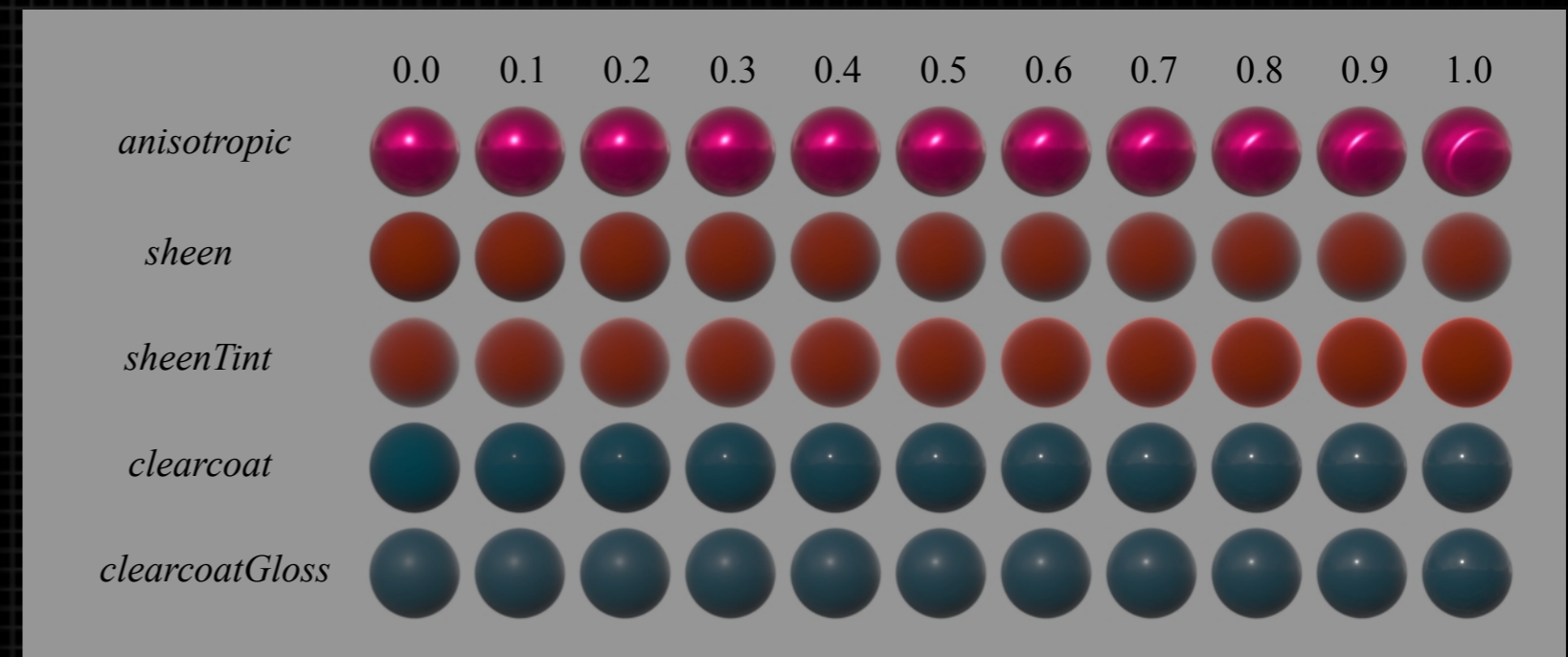
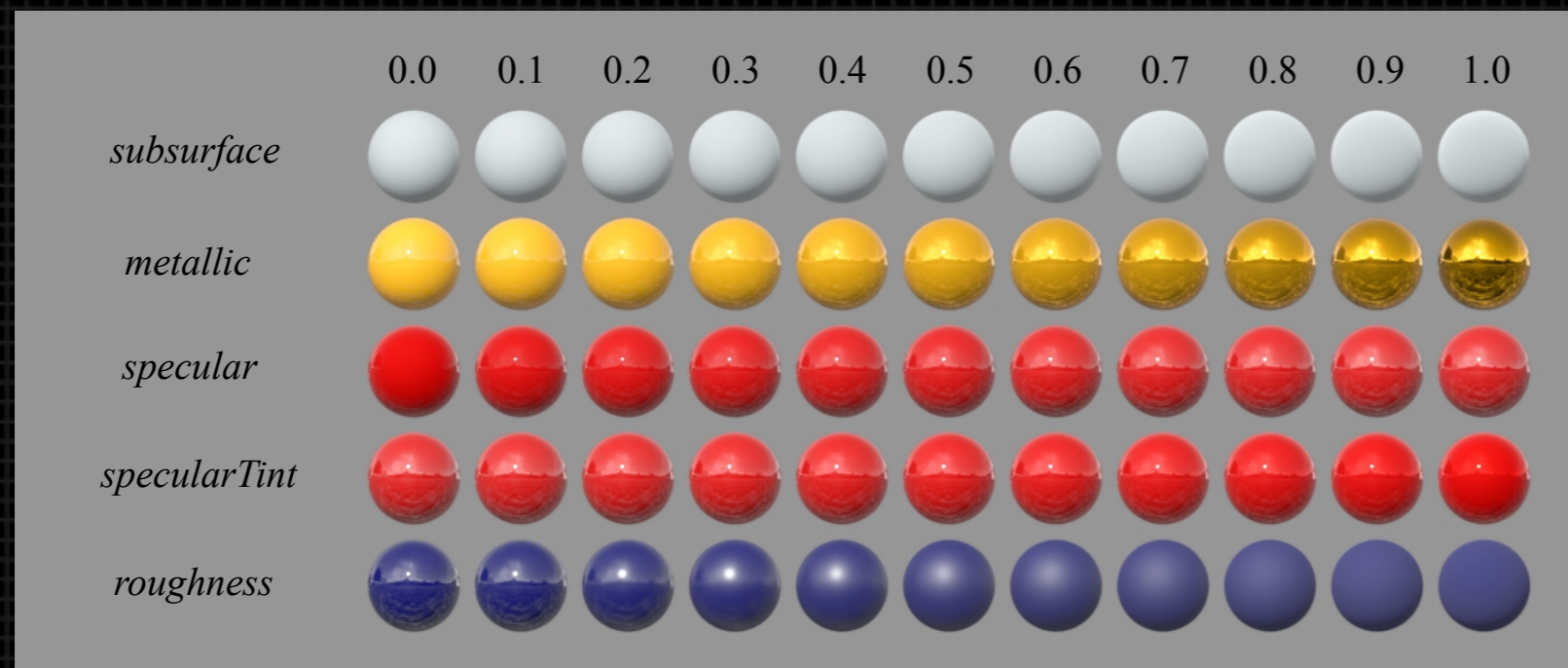
Update Mode On Idle

Update Frequency 1.000

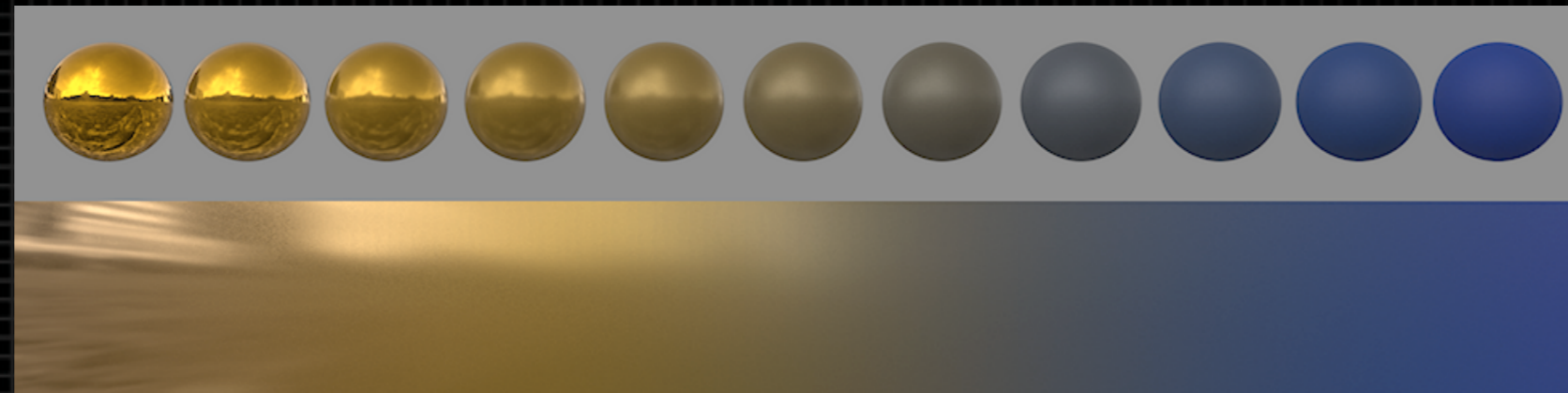
Finest Level of Detail 0

Coarsest Level of Detail 3

"Principled" BRDF Paper by Brent Burley



"Principled" BRDF Paper by Brent Burley



- ▶ Why?
- ▶ Lots of existing models for Diffuse & Specular
- ▶ Diffuse: Lambert "accepted norm"
- ▶ Specular: different options:

Ashikhmin-Shirley

(default in *RMSGPSurface*)

"*SpecularAS.h*"

...RenderManProServer/lib/rsl/include/stdrsl/[SpecularAS.h](#)

Beckmann Anisotropic

Sharper Hilights

More realistic reflections

Different "roughness" model

"*SpecularDBRDF.h*"

...RenderManProServer/lib/rsl/include/stdrsl/[SpecularDBRDF.h](#)

“Principled” BRDF Paper by Brent Burley

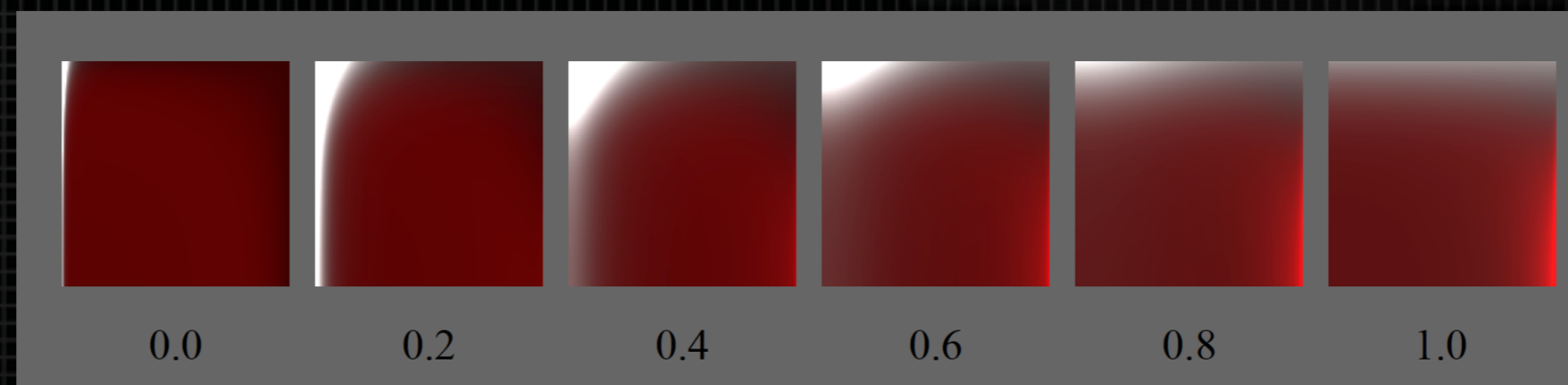
“With all the different models, could have implemented several and let artist choose, but would have led to parameter explosion.”

- ▶ Artists: needs to be art-directable, not necessarily physically correct
- ▶ Hence the name “principled”, rather than “physical”
- ▶ Principals:
 1. Intuitive rather than physical
 2. As few parameters as possible
 3. Parameters: 0..1
 4. Parameters should be allowed to be pushed beyond their range where it makes sense
 5. All combinations of parameters should be as “robust” & “plausible” as possible → mixing/masking layers should remain plausible

“Principled” BRDF Paper by Brent Burley

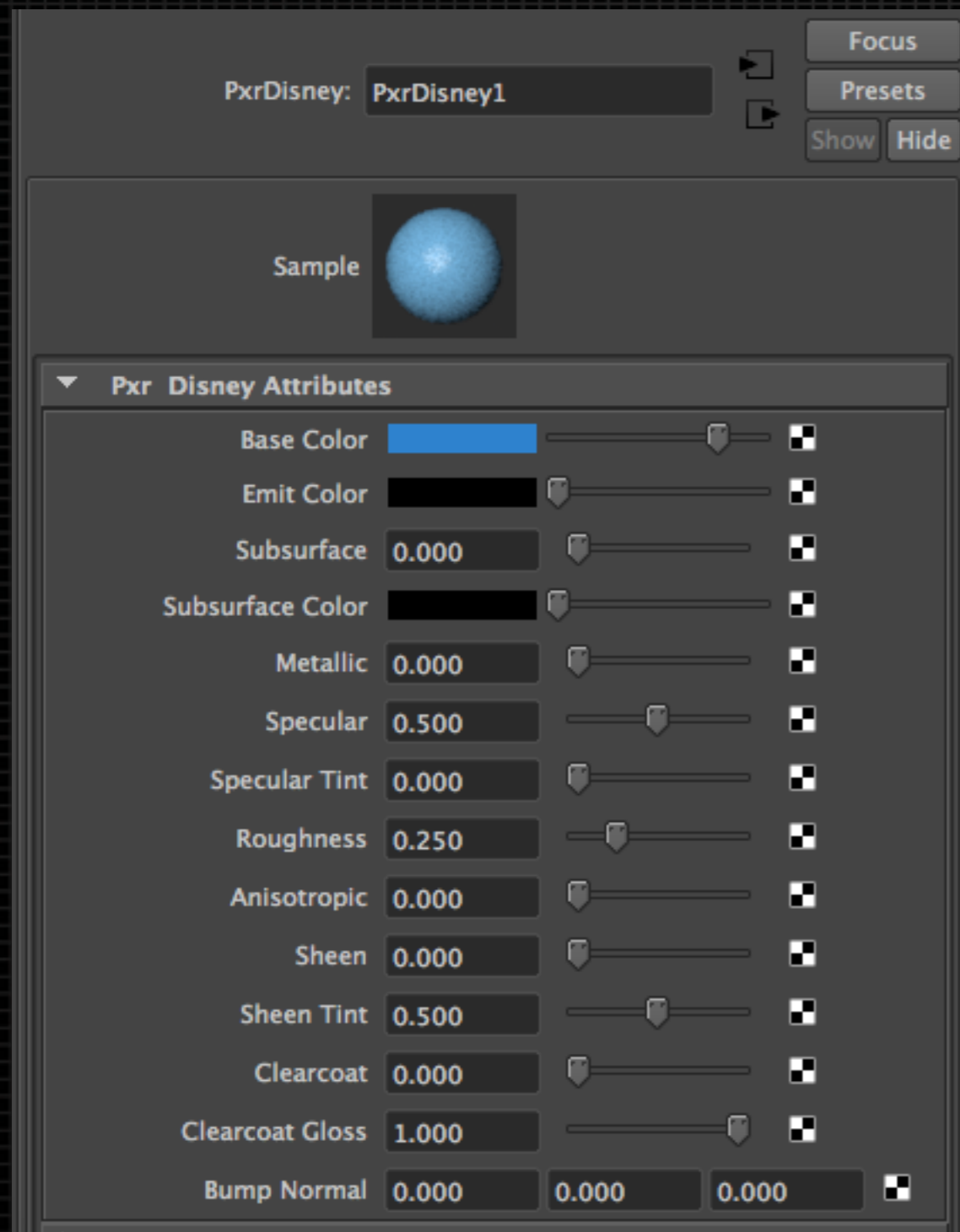
Diffuse Model Details

- ▶ Lambert diffuse model “often too dark on edges”
- ▶ Disney developed novel empirical model for diffuse retroreflection: transitions between a diffuse Fresnel shadow (smooth surfaces) added highlight for rough surfaces
- ▶ Their model:
 - Ignore index-of-refraction for diffuse Fresnel factor
 - Assume no incident diffuse loss
 - Use Schlick-Fresnel approximation
 - Provides a reasonable match to MERL data, and artistically pleasing

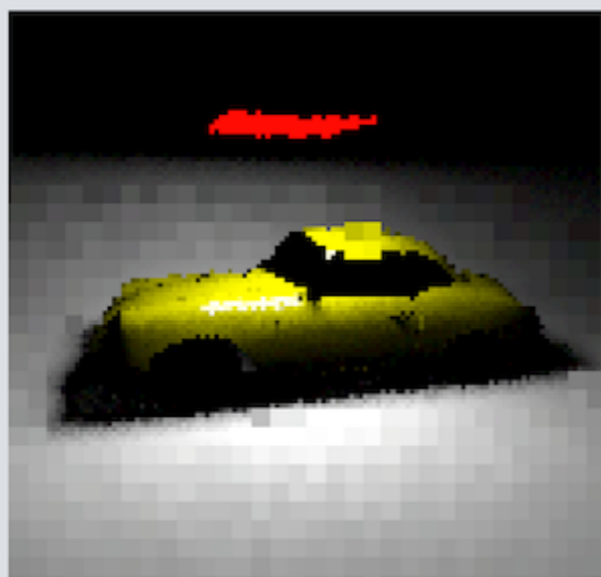


Various roughness values

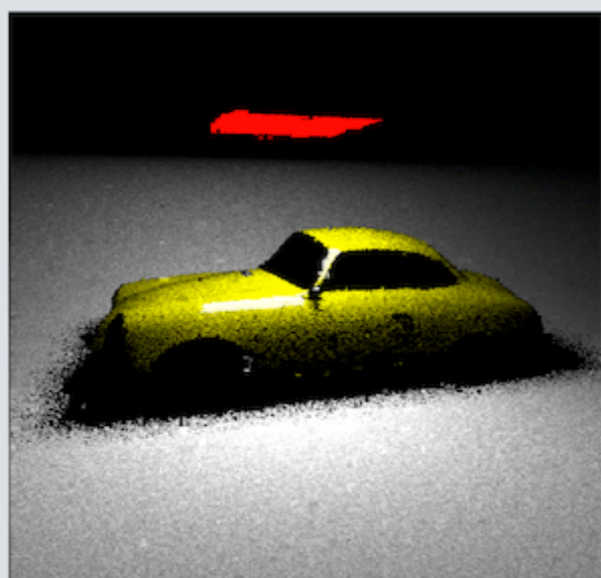
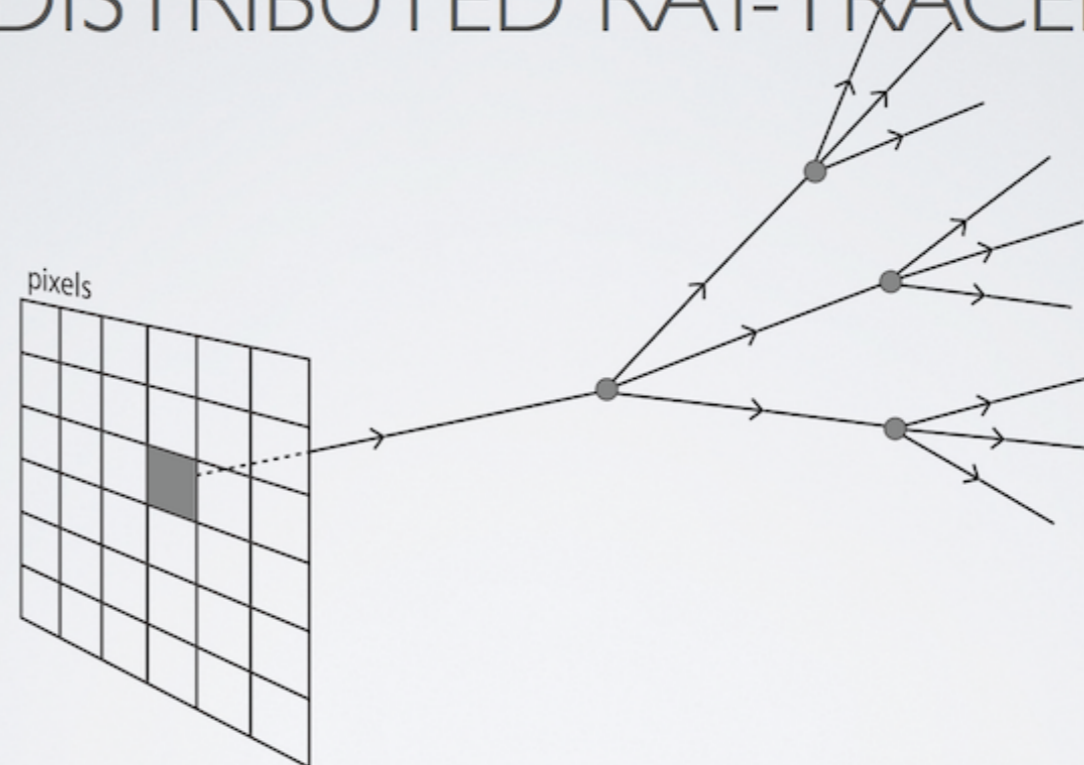
"Principled" BRDF Paper by Brent Burley



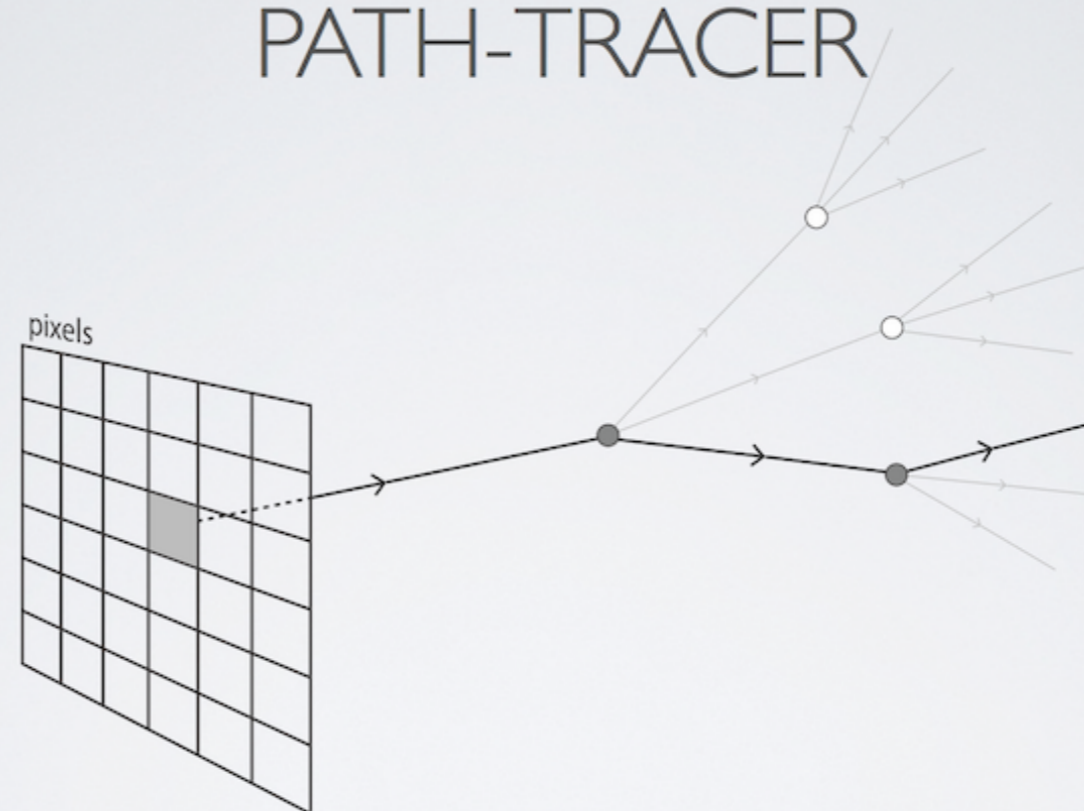
- ▶ baseColor - the surface color, usually supplied by texture maps.
- ▶ Emit Color - *not in paper* - "Emission Energy" non-black colors represent glow.
- ▶ subsurface - controls diffuse shape using a subsurface approximation.
- ▶ metallic - the metallic-ness (0 = dielectric, 1 = metallic). This is a linear blend between two different models. The metallic model has no diffuse component and also has a tinted incident specular, equal to the base color.
- ▶ specular - incident specular amount. This is in lieu of an explicit index-of-refraction.
- ▶ specularTint - a concession for artistic control that tints incident specular towards the base color. Grazing specular is still achromatic.
- ▶ roughness - surface roughness, controls both diffuse and specular response.
- ▶ anisotropic - degree of anisotropy. This controls the aspect ratio of the specular highlight. (0 = isotropic, 1 = maximally anisotropic).
- ▶ sheen - an additional grazing component, primarily intended for cloth.
- ▶ sheenTint - amount to tint sheen towards base color.
- ▶ clearcoat - a second, special-purpose specular lobe.
- ▶ clearcoatGloss - controls clearcoat glossiness (0 = a "satin" appearance, 1 = a "gloss" appearance)



DISTRIBUTED RAY-TRACER



PATH-TRACER



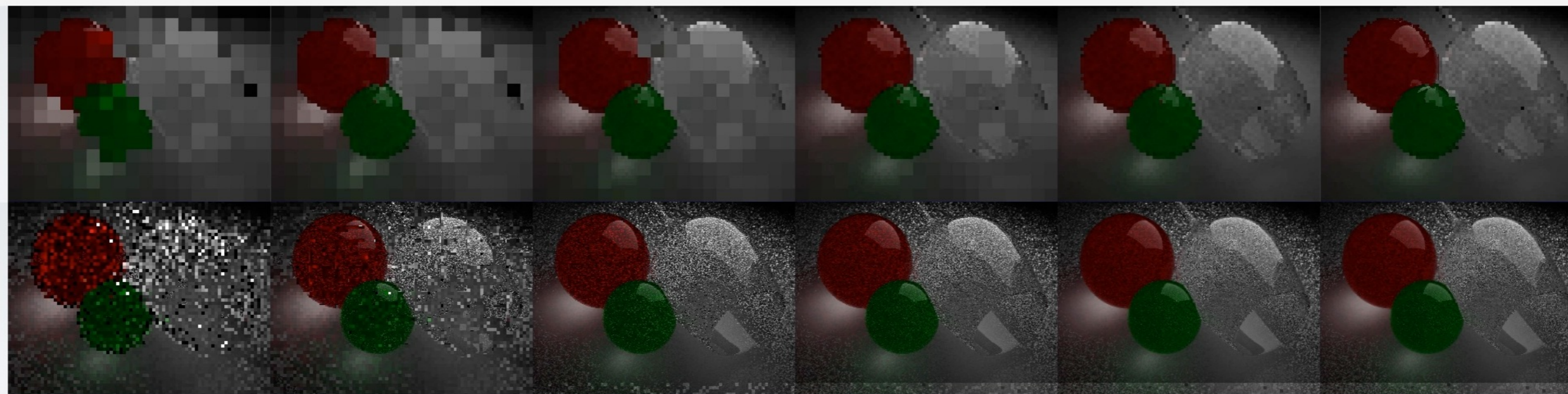
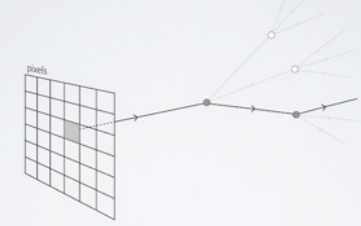
Re-render in RenderMan Distributed Ray-Tracer vs Path-Tracer

Tests by Christos Obretenov / LollipopShaders.com

DISTRIBUTED RAY-TRACER



PATH-TRACER



5 sec

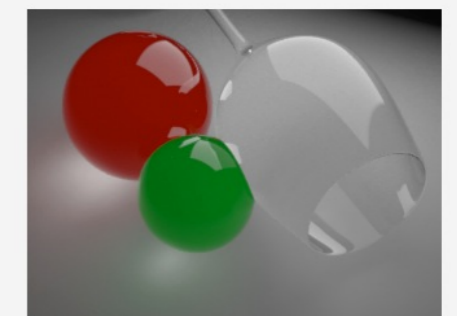
10 sec

15 sec

20 sec

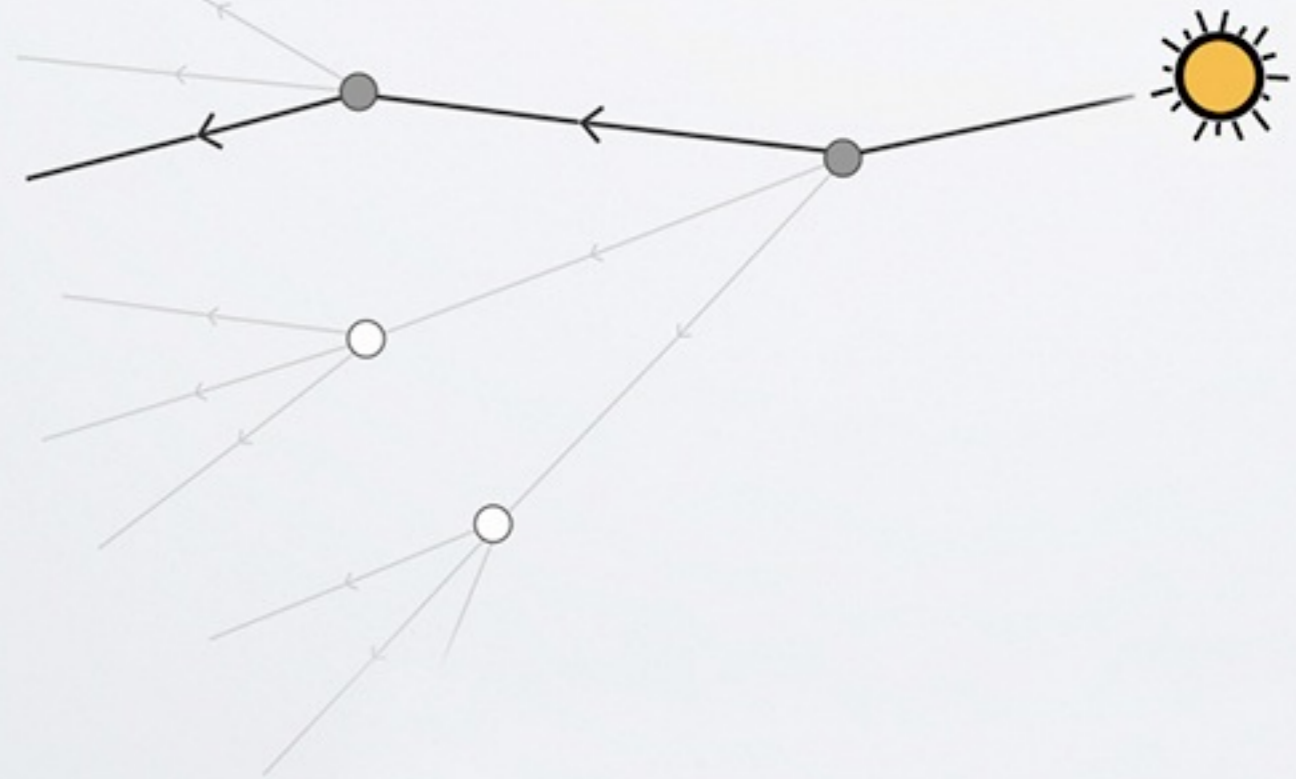
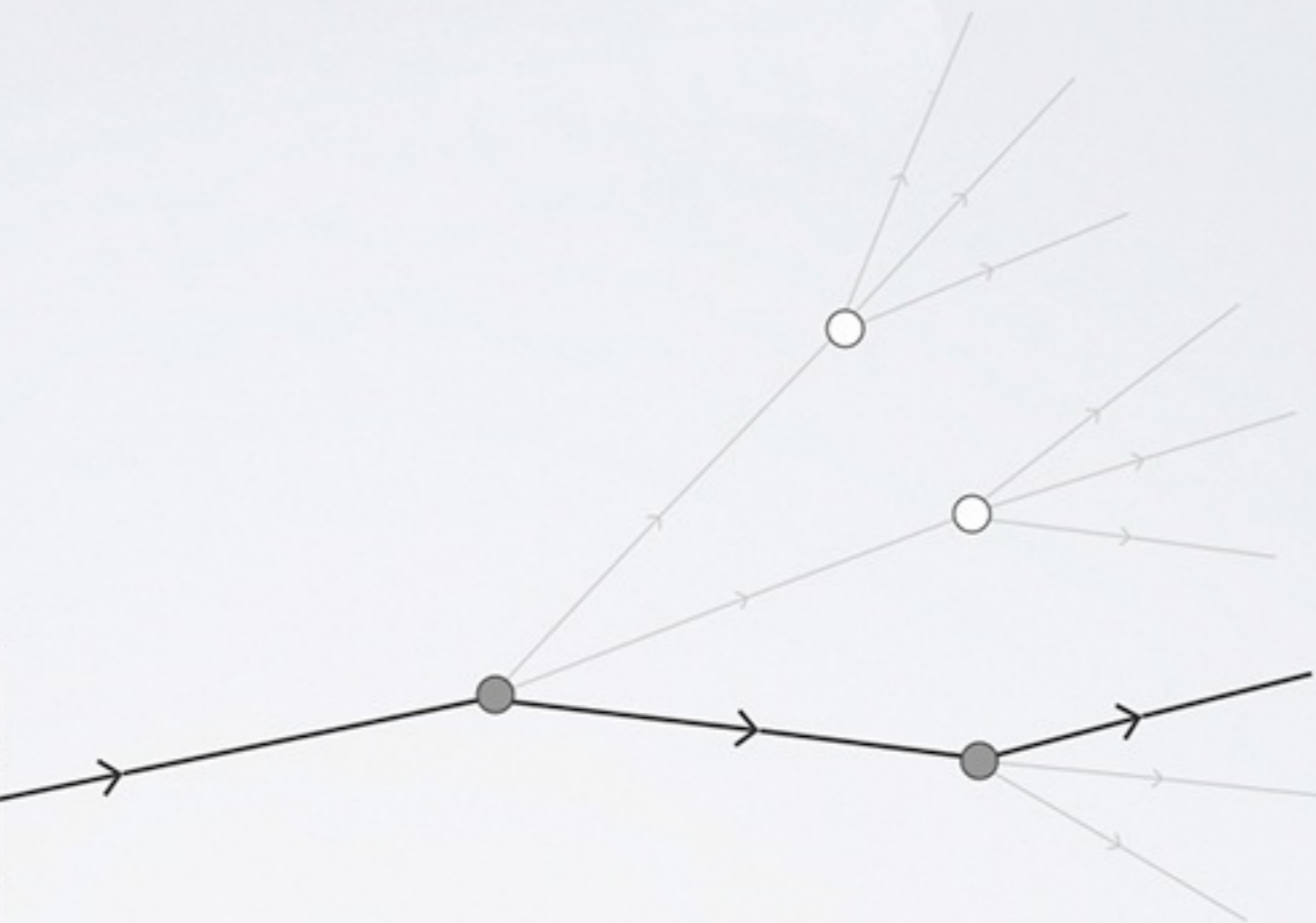
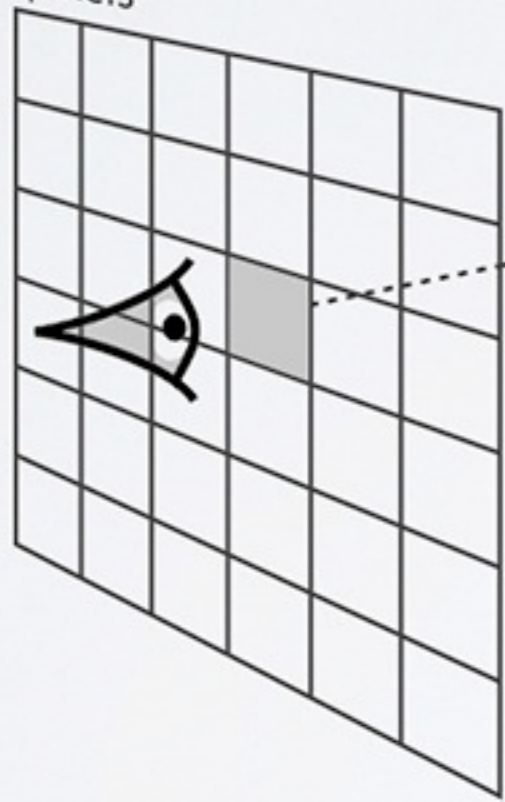
30 sec

1 min

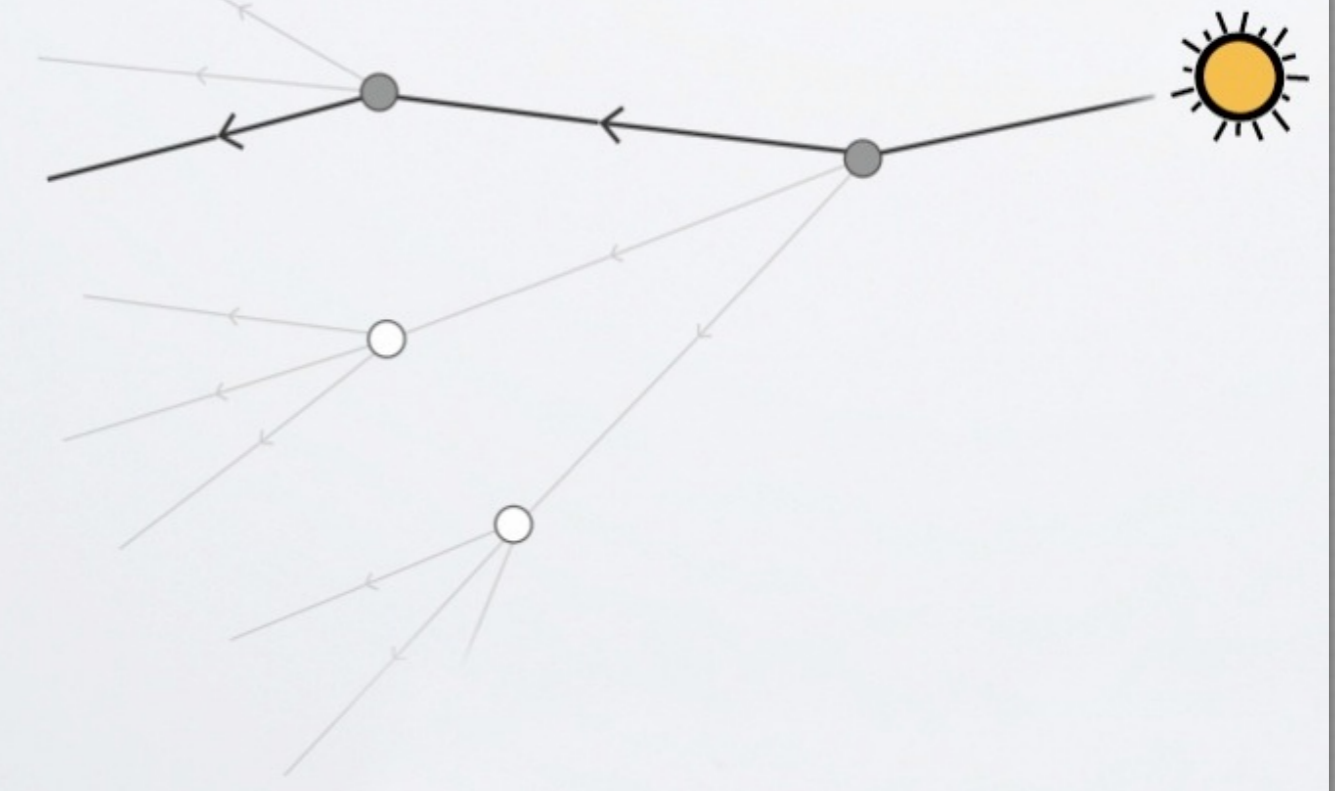
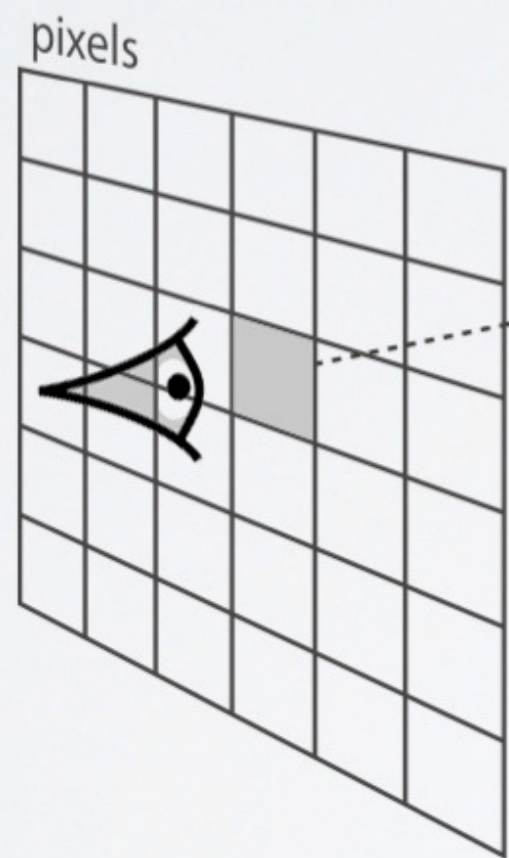


Final converged
(with sRGB)

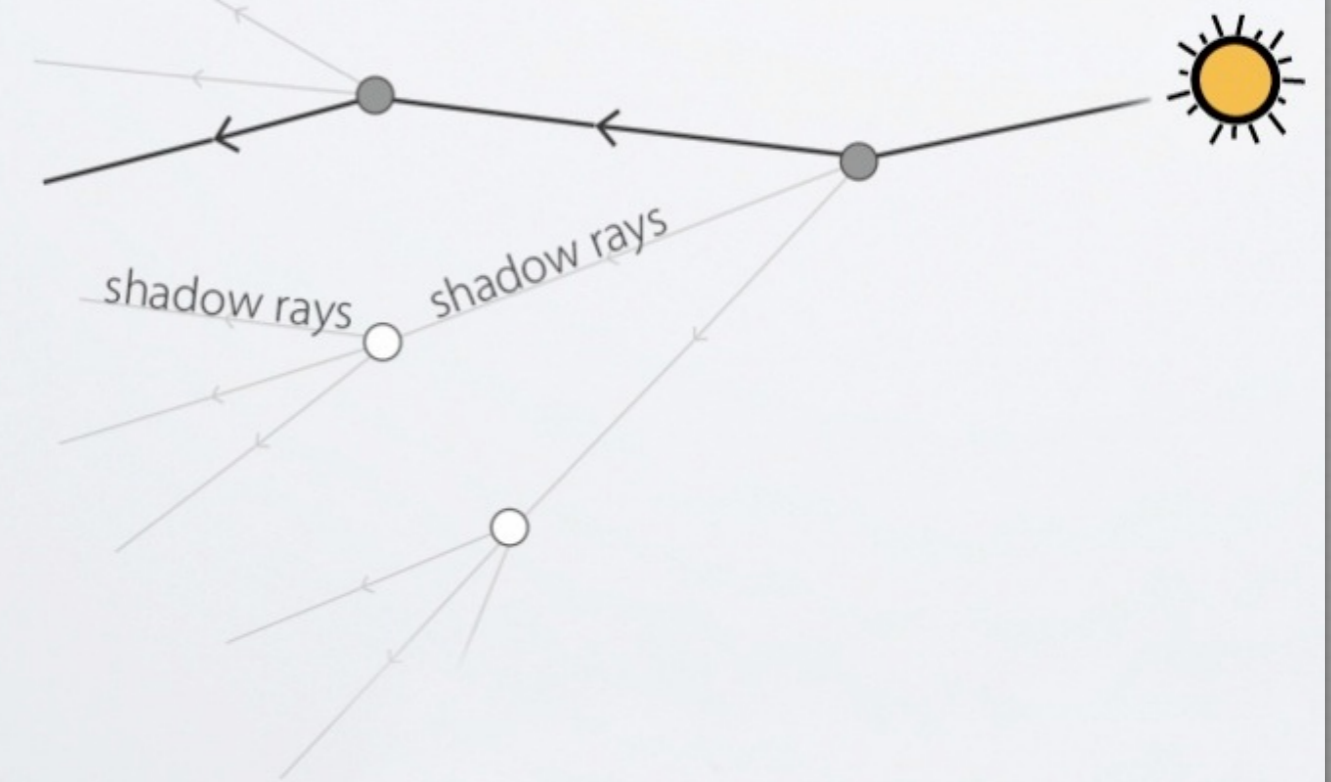
pixels



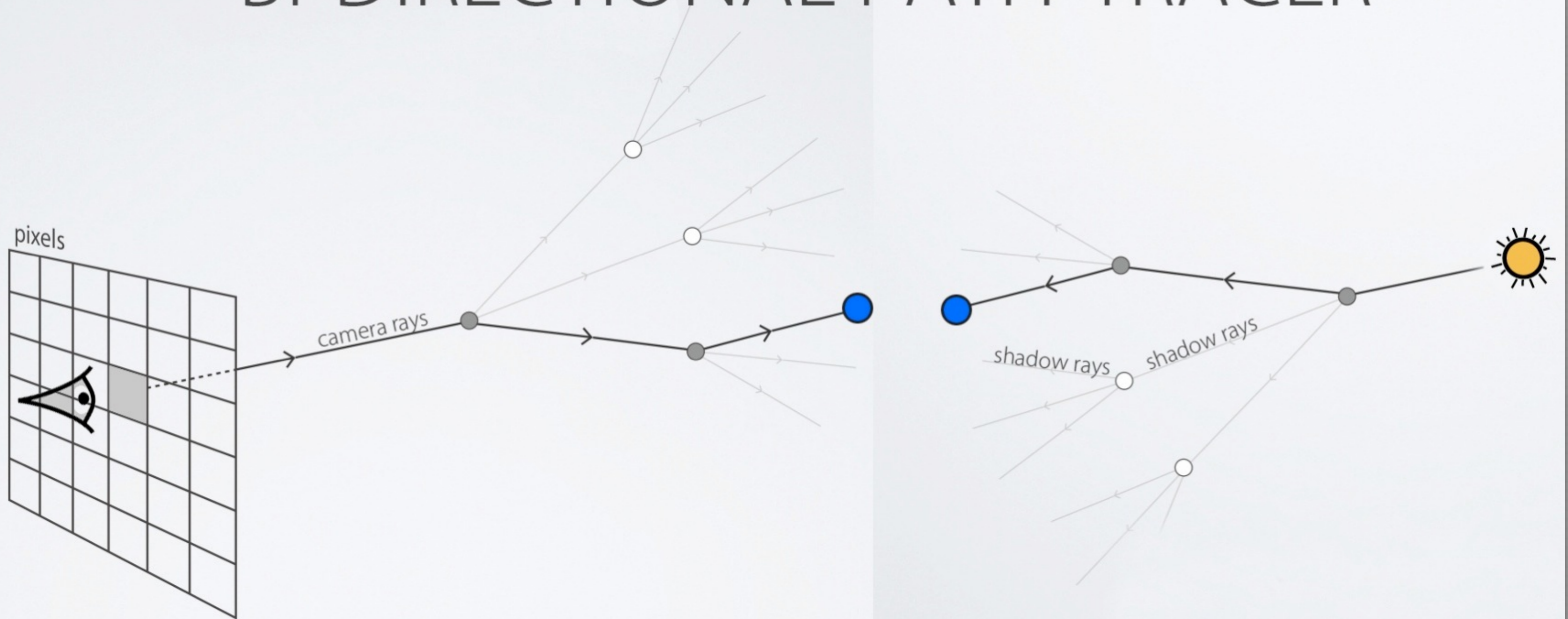
BI-DIRECTIONAL PATH-TRACER



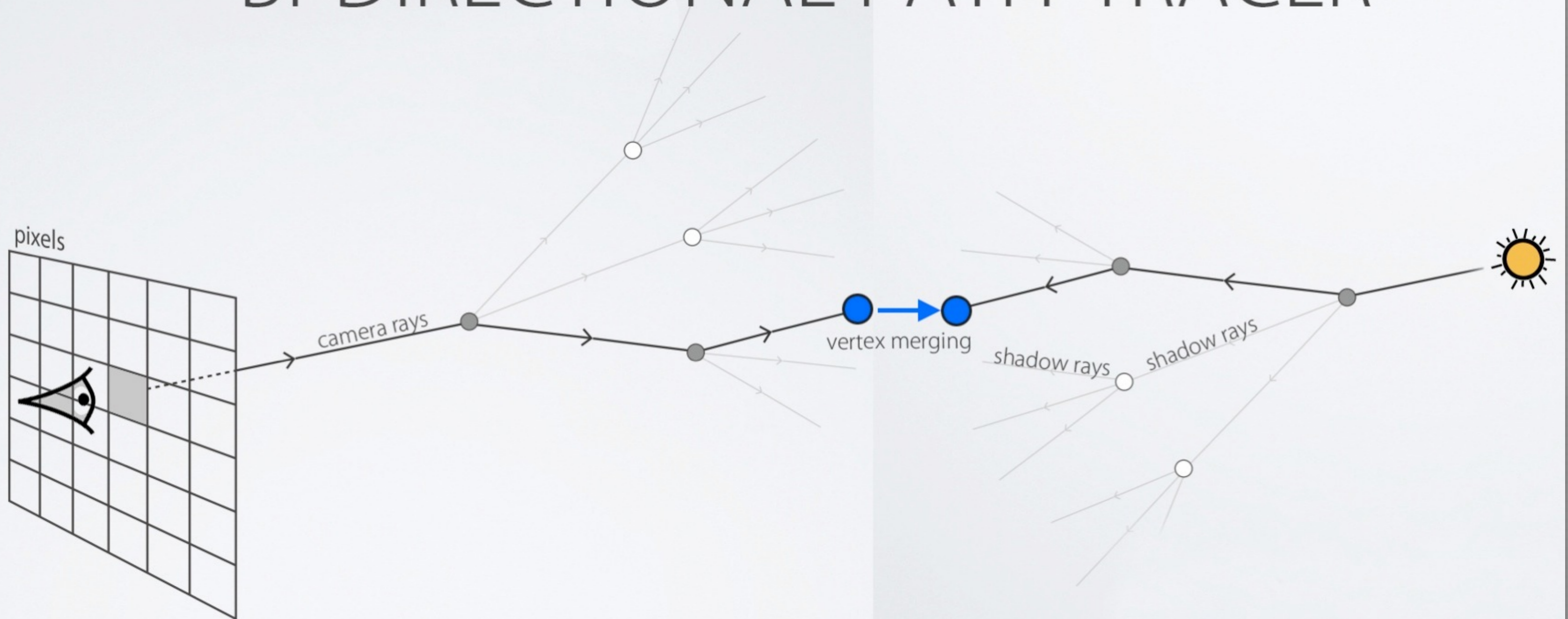
BI-DIRECTIONAL PATH-TRACER



BI-DIRECTIONAL PATH-TRACER



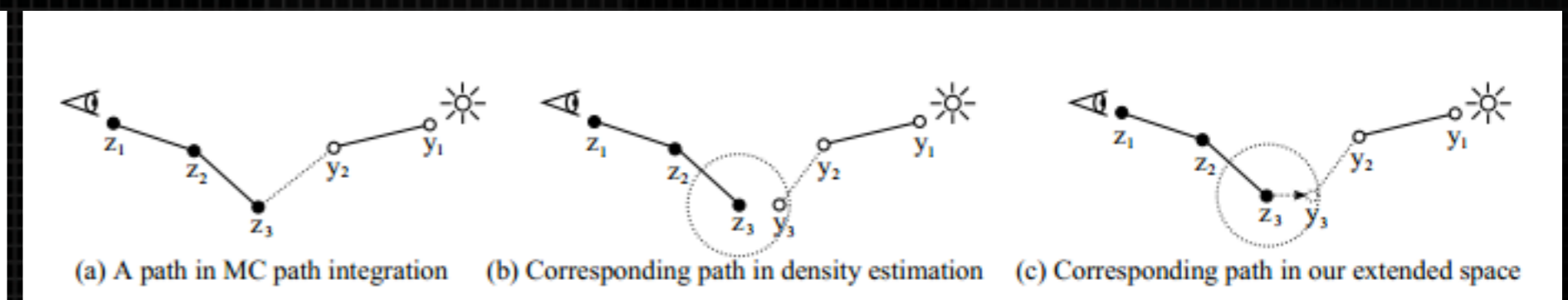
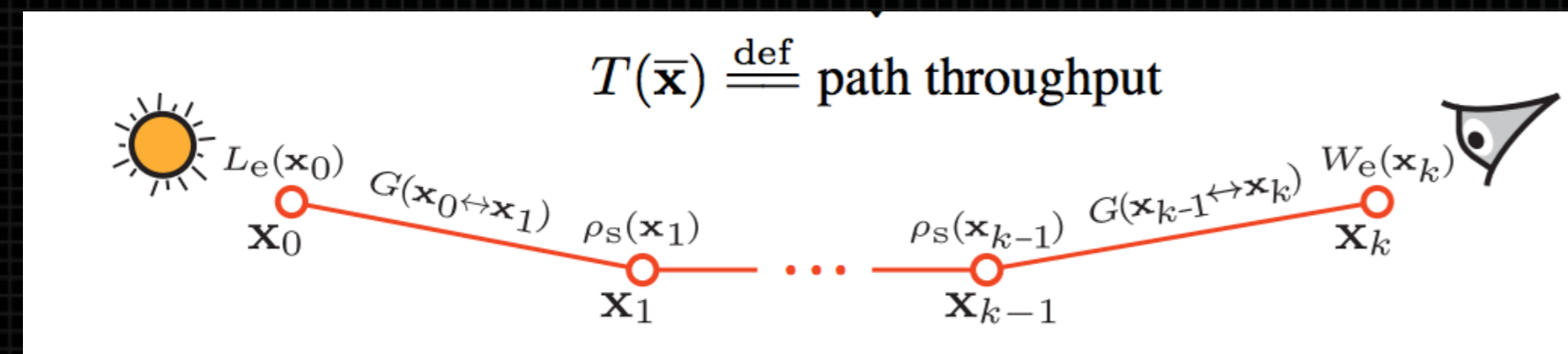
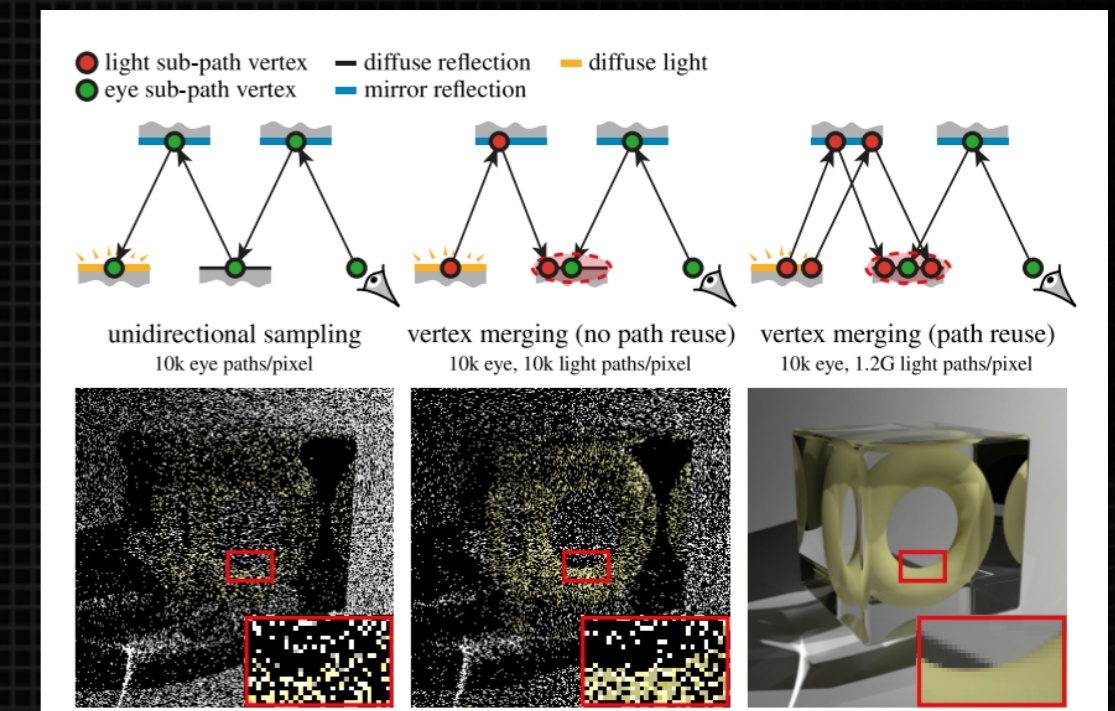
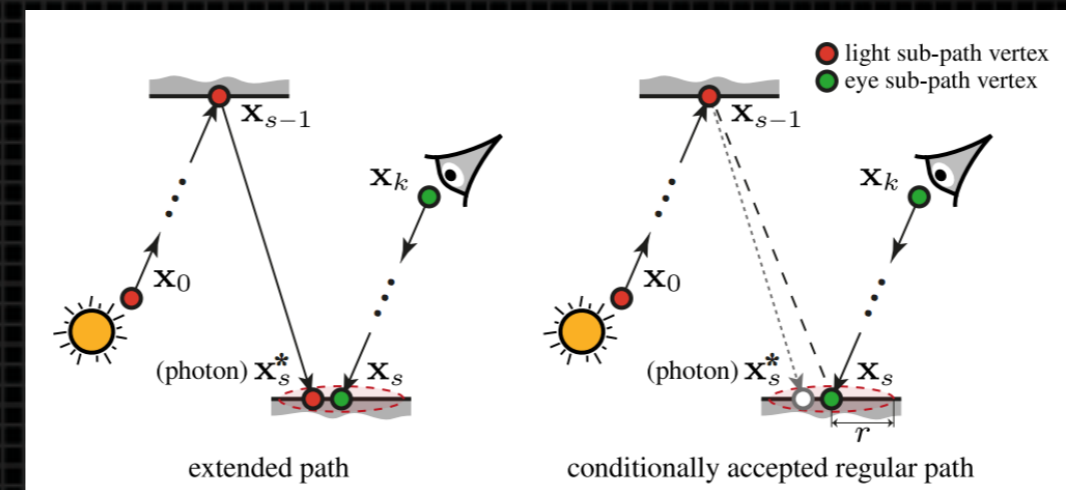
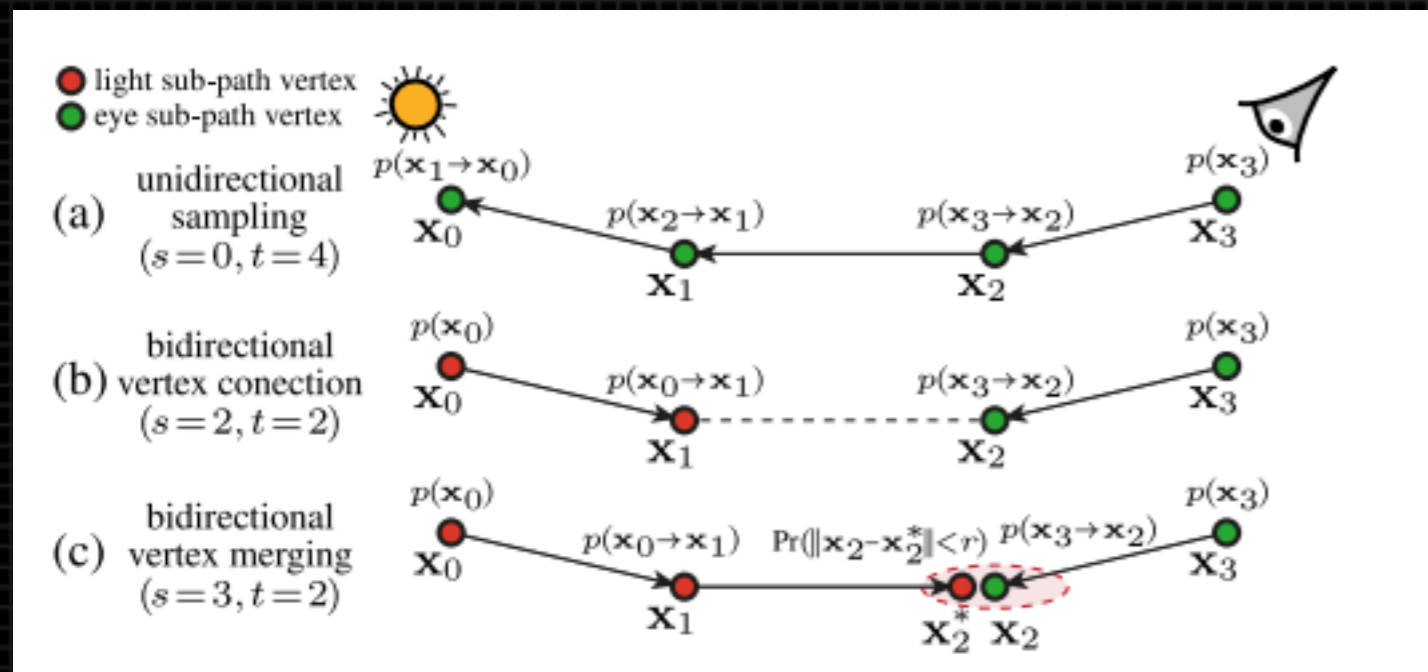
BI-DIRECTIONAL PATH-TRACER



Papers on Bi-Directional Path Tracing

Light Transport Simulation with Vertex Connection and Merging
<https://graphics.cg.uni-saarland.de/2012/vertex-connection-and-merging/>

A Path Space Extension for Robust Light Transport Simulation
<http://cs.au.dk/~toshiya/ups.pdf>



"Emissive" on PxrDisneyBRDF

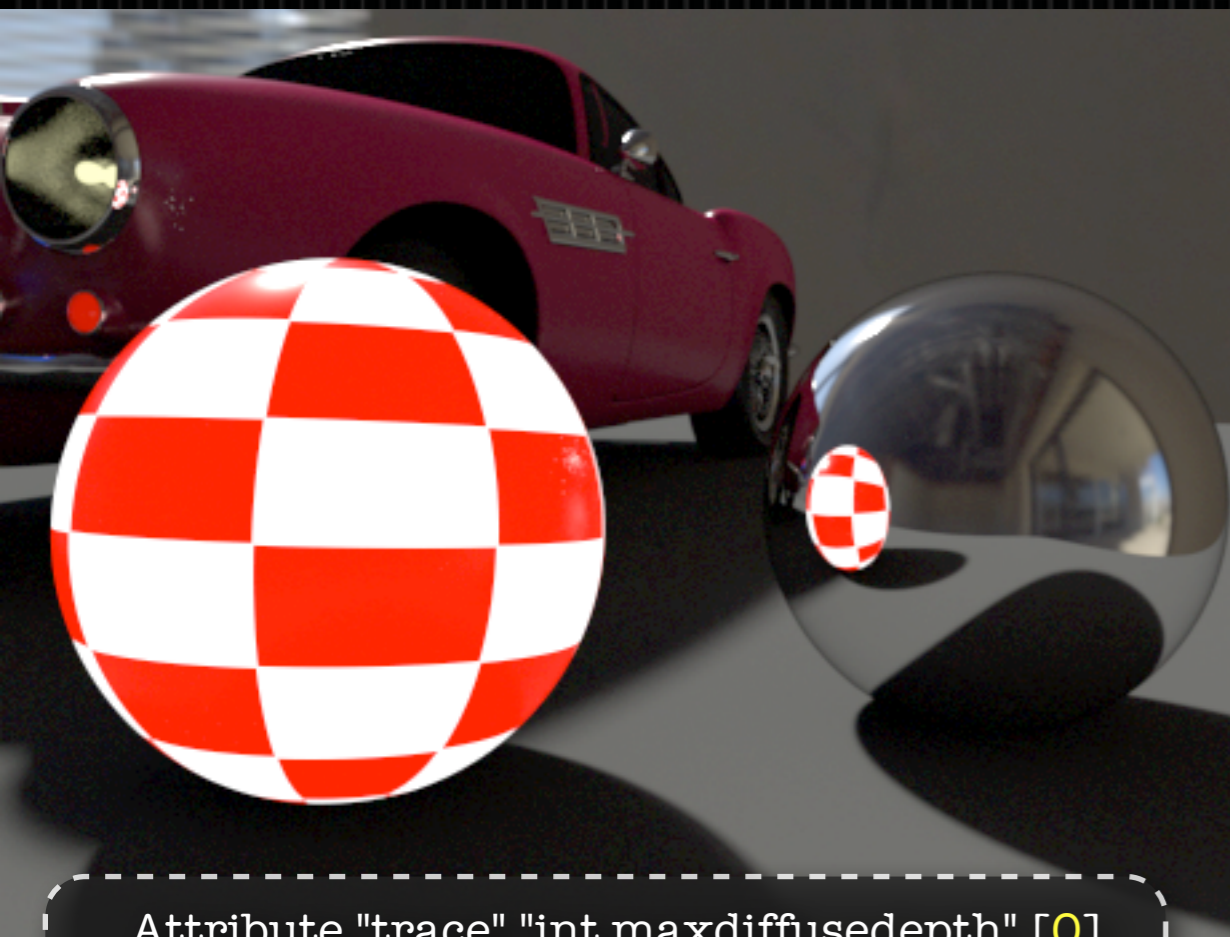




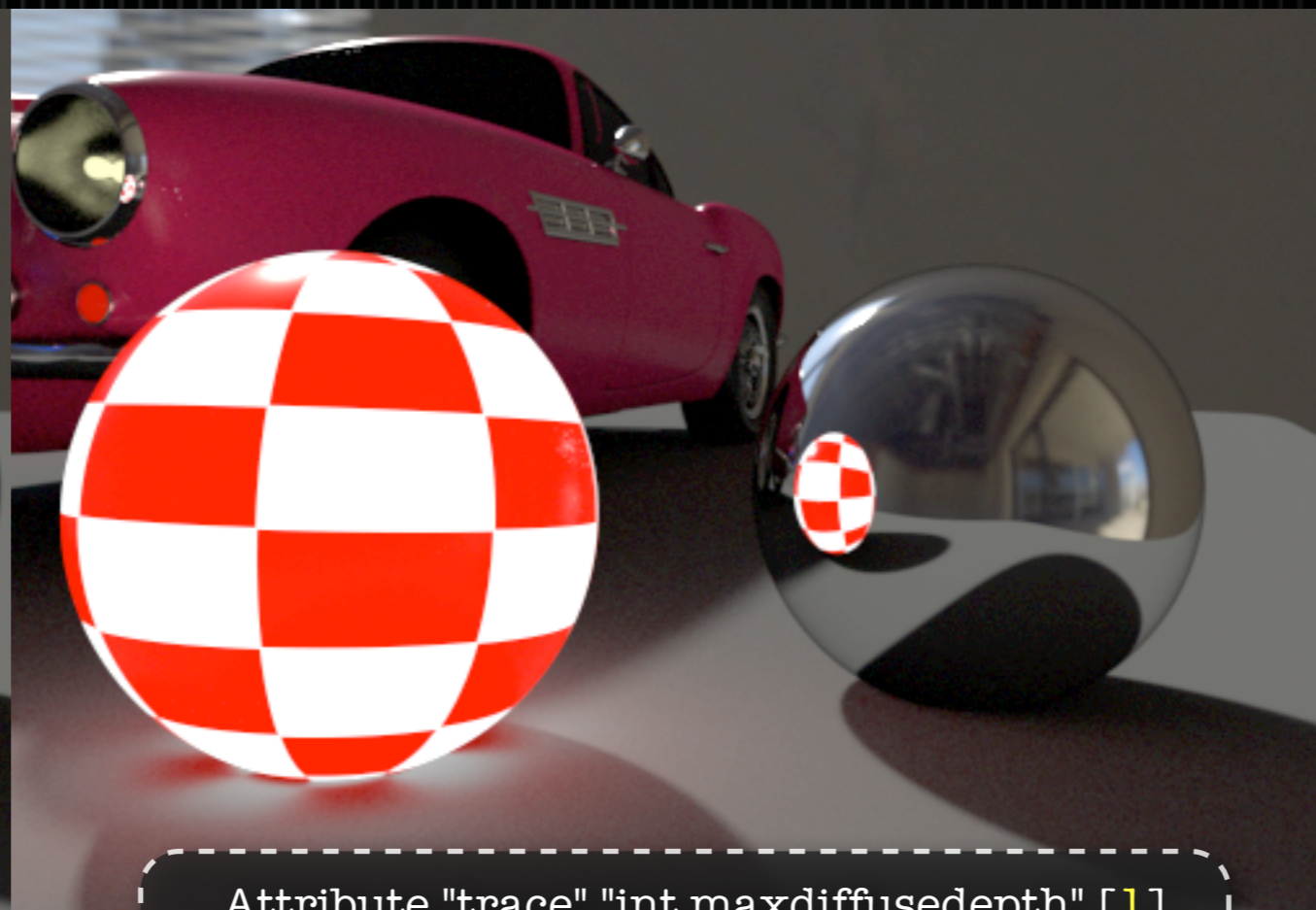




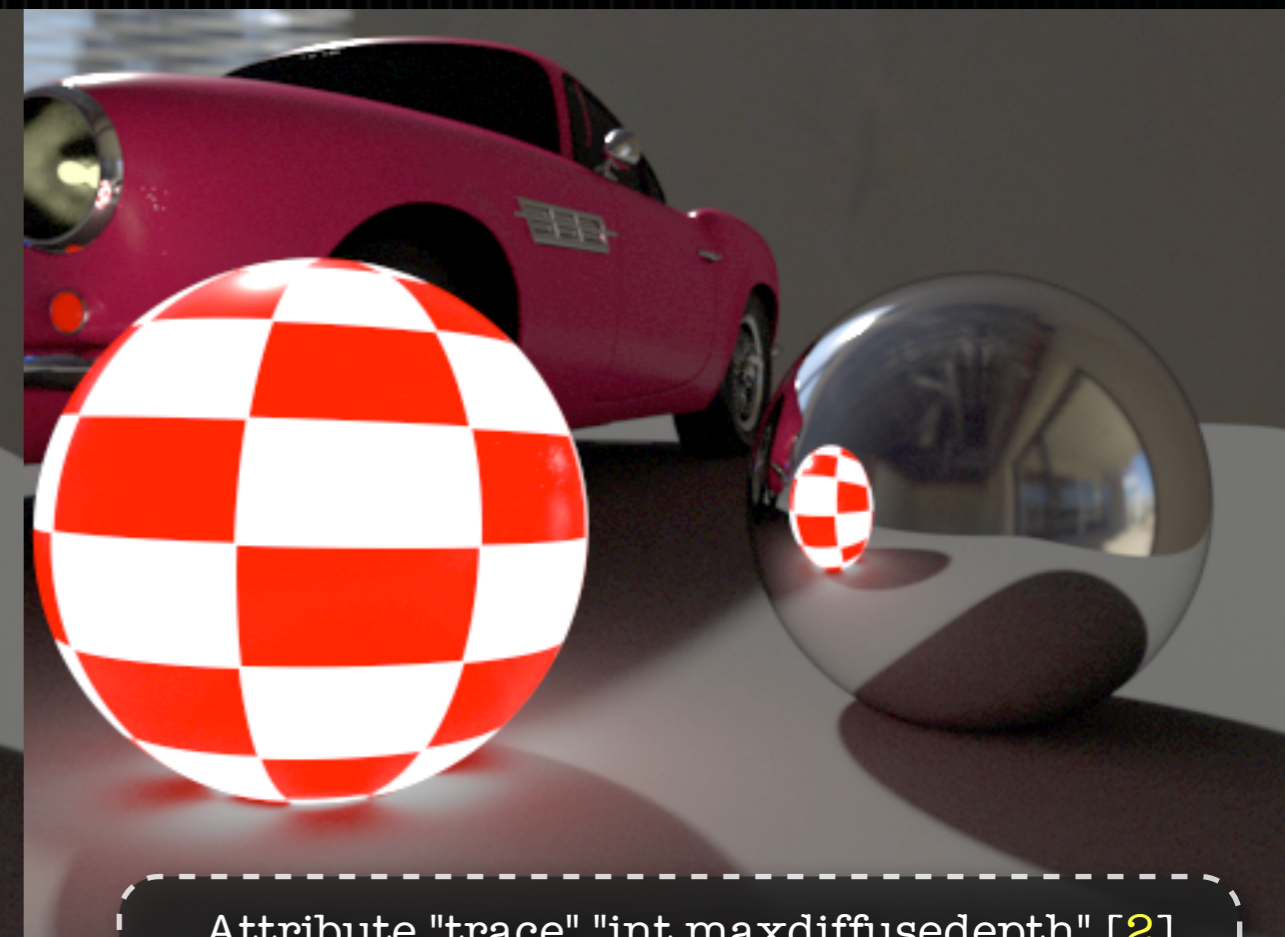
RIS: What's going on under the hood in the RIB?



Attribute "trace" "int maxdiffusedepth" [0]
2m46s



Attribute "trace" "int maxdiffusedepth" [1]
3m20s



Attribute "trace" "int maxdiffusedepth" [2]
6m42s





RIS: What's going on under the hood in the RIB?

RIS - Global MaxDiffuseDepth Attribute

WorldBegin

...

Attribute "visibility" "int transmission" [1] "int indirect" [1]

Surface "defaultsurface"

Attribute "user" "int shader_bindingstrength" [0]

Attribute "trace" "int maxdiffusedepth" [2] "int maxspeculardepth" [2] "int samplemotion" [1] "float bias" [0.001] "int displacements" [1]

...

RIS - Per-Object MaxDiffuseDepth Attribute

AttributeBegin

...

Attribute "identifier" "string name" ["floorShape"]

...

Sides 2

Attribute "user" "int receivesShadows" [1]

Attribute "visibility" "int camera" [1] "int indirect" [1] "int transmission" [1]

Attribute "shade" "string transmissionhitmode" ["shader"]

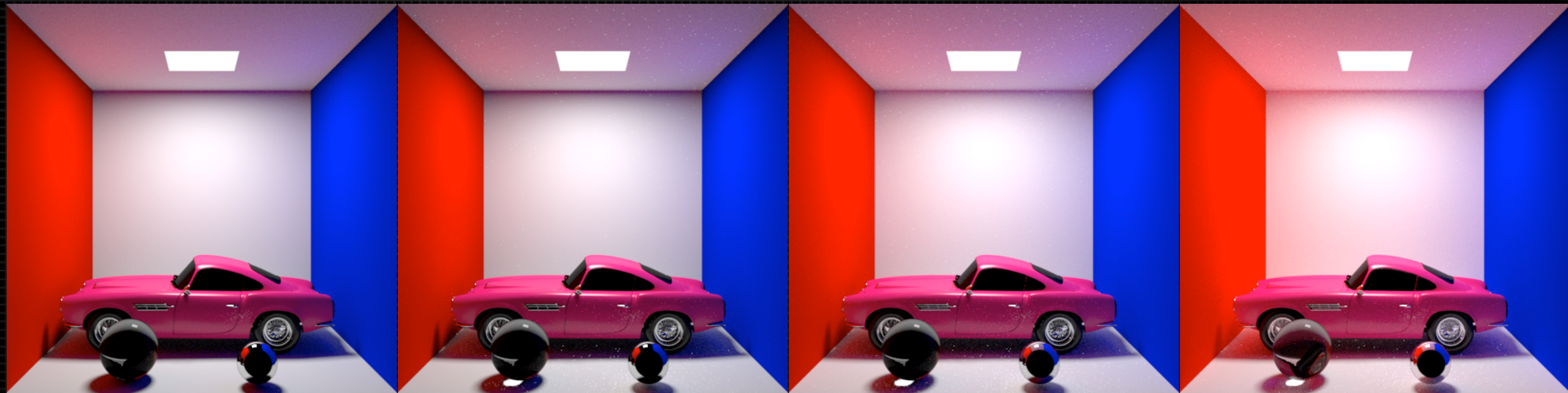
ShadingRate 1

Attribute "trace" "int maxdiffusedepth" [2]

Bxdf "PxrDiffuse" "PxrDiffuse1" "color diffuseColor" [0.222466 0.222466 0.222466] ...

...

PathTracer (Uni) vs VCM (Bi-directional)



Integrator: PATH
2m27s

Integrator: PATH
"Allow Caustics"
2m38s

Integrator: PATH
"Allow Caustics"
MaxDiffDepth=2
3m17s

Integrator: VCM
11m27s

128 Max Samples

Adaptive Sampling: Pixel Variance

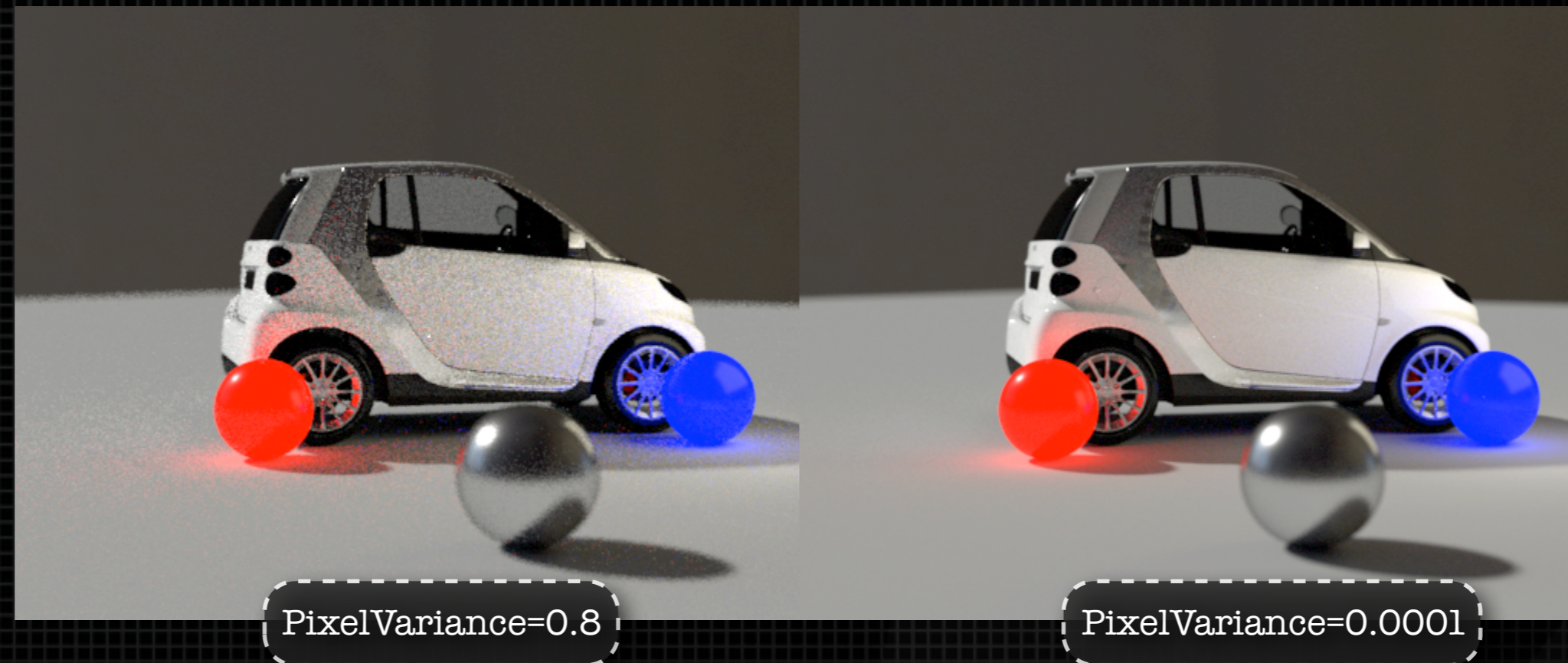
Sample Mode

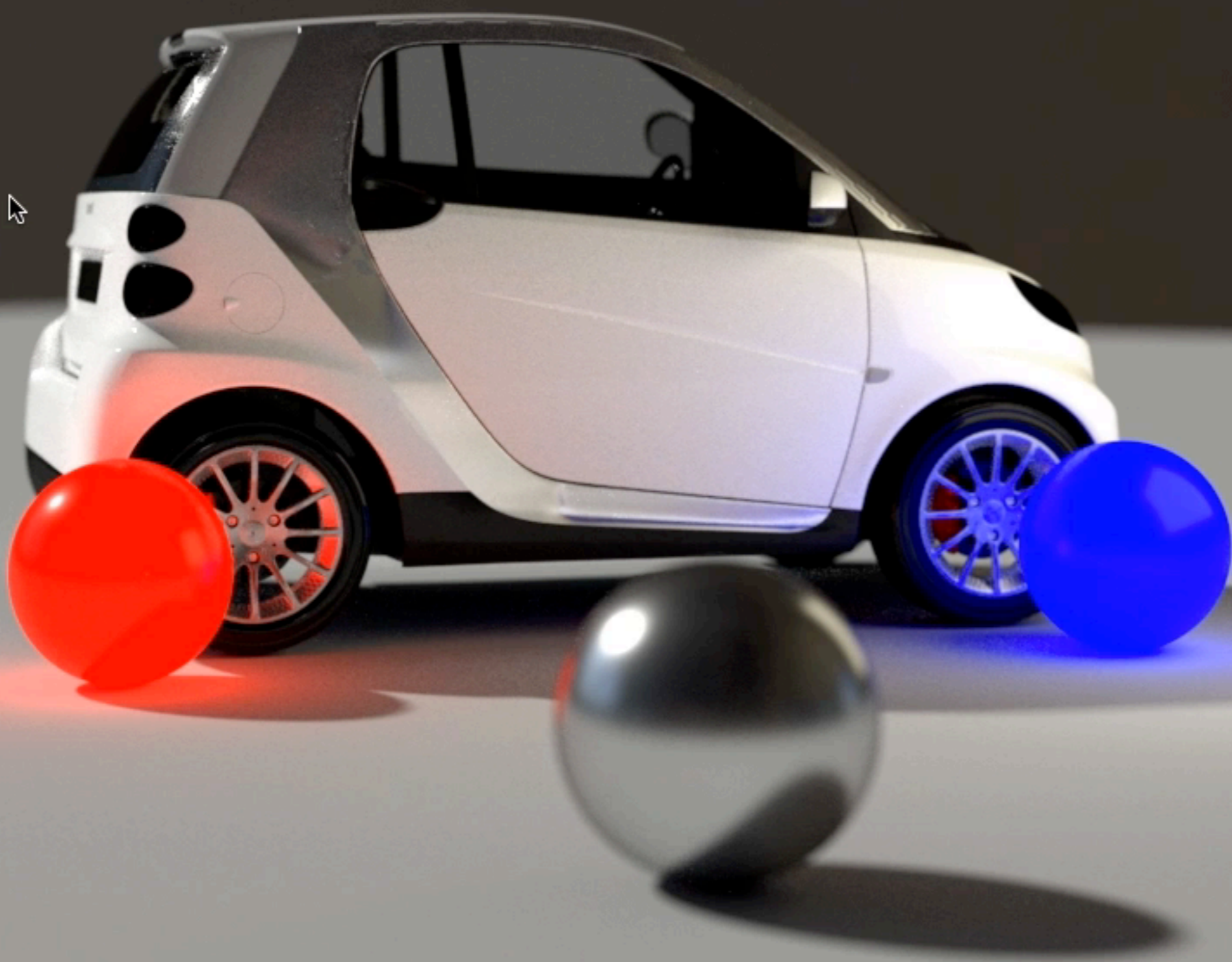
If the `samplemode` is **adaptive**, the raytracer hider will trace a variable number of rays per pixel. At a maximum, it will trace as many camera rays per pixel as it would have in fixed mode. In smoother regions of the image, it may trace as few as one per pixel. The `minsamples` parameter may be used to increase this minimum. It should be raised if the adaptive sampling produces artifacts.

If `samplemode` is **fixed**, the number of rays traced per pixel is determined by the `maxsamples` setting.

Pixel Variance

Used when doing adaptive sampling. Reducing this value increases the likelihood that more rays will be traced while increasing its value allows undersampling.

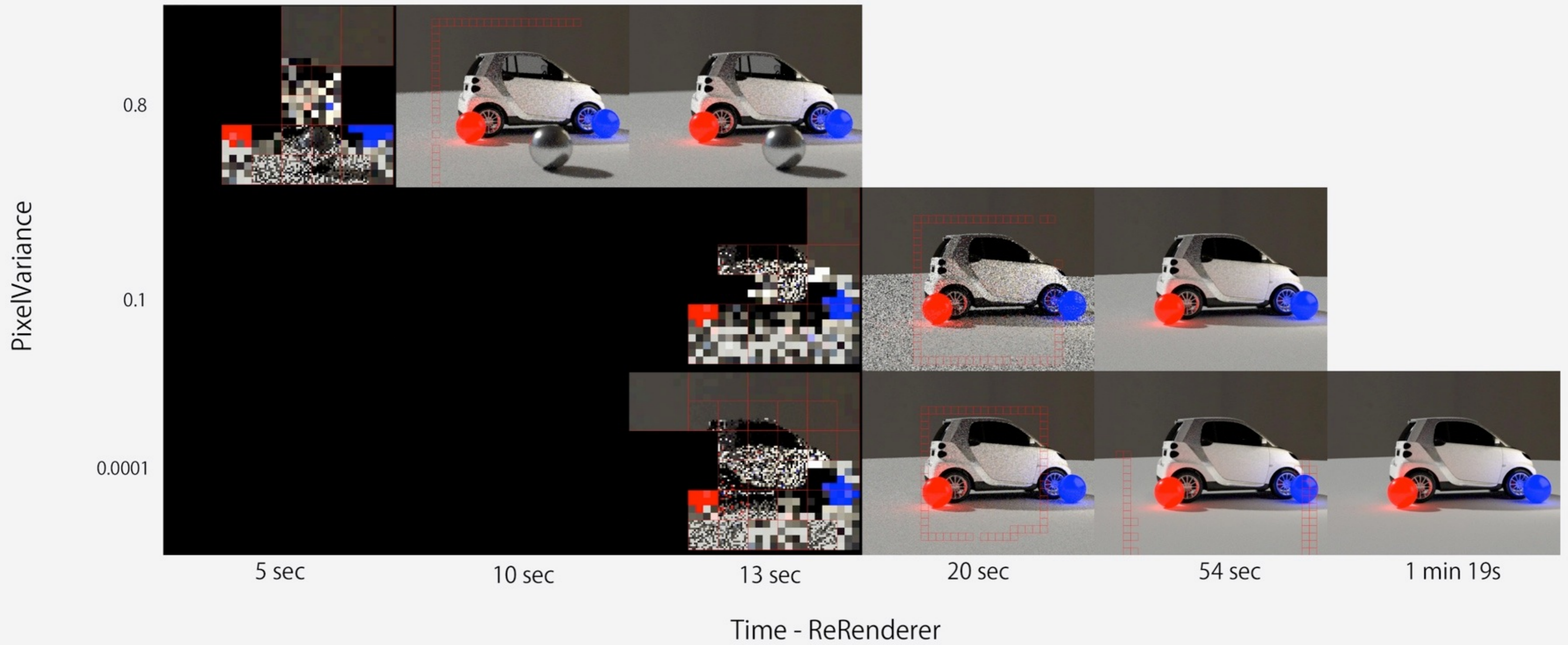




43

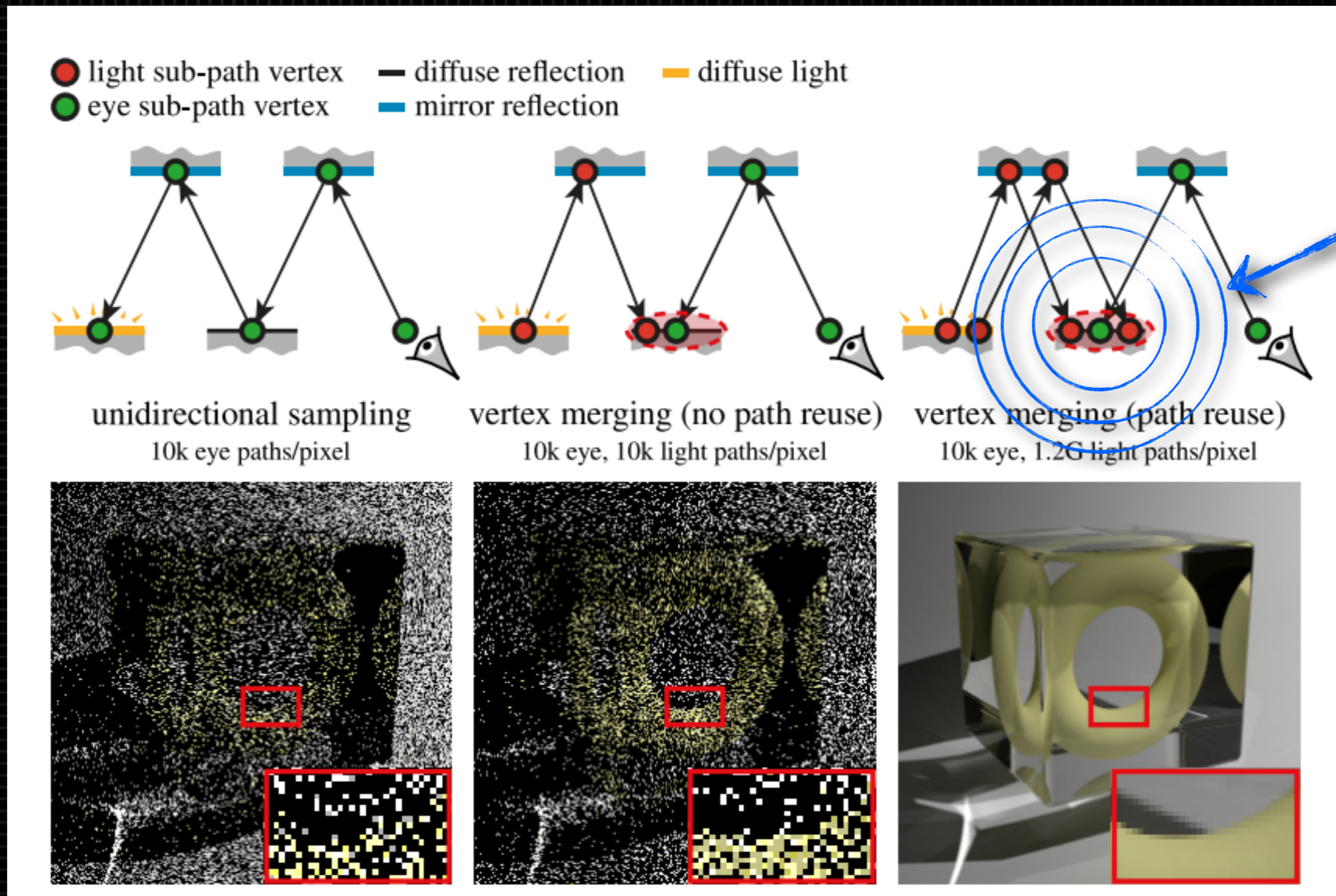


PixelVariance Tests - Path Tracer / RIS - Adaptive Sampling Mode - RenderMan19

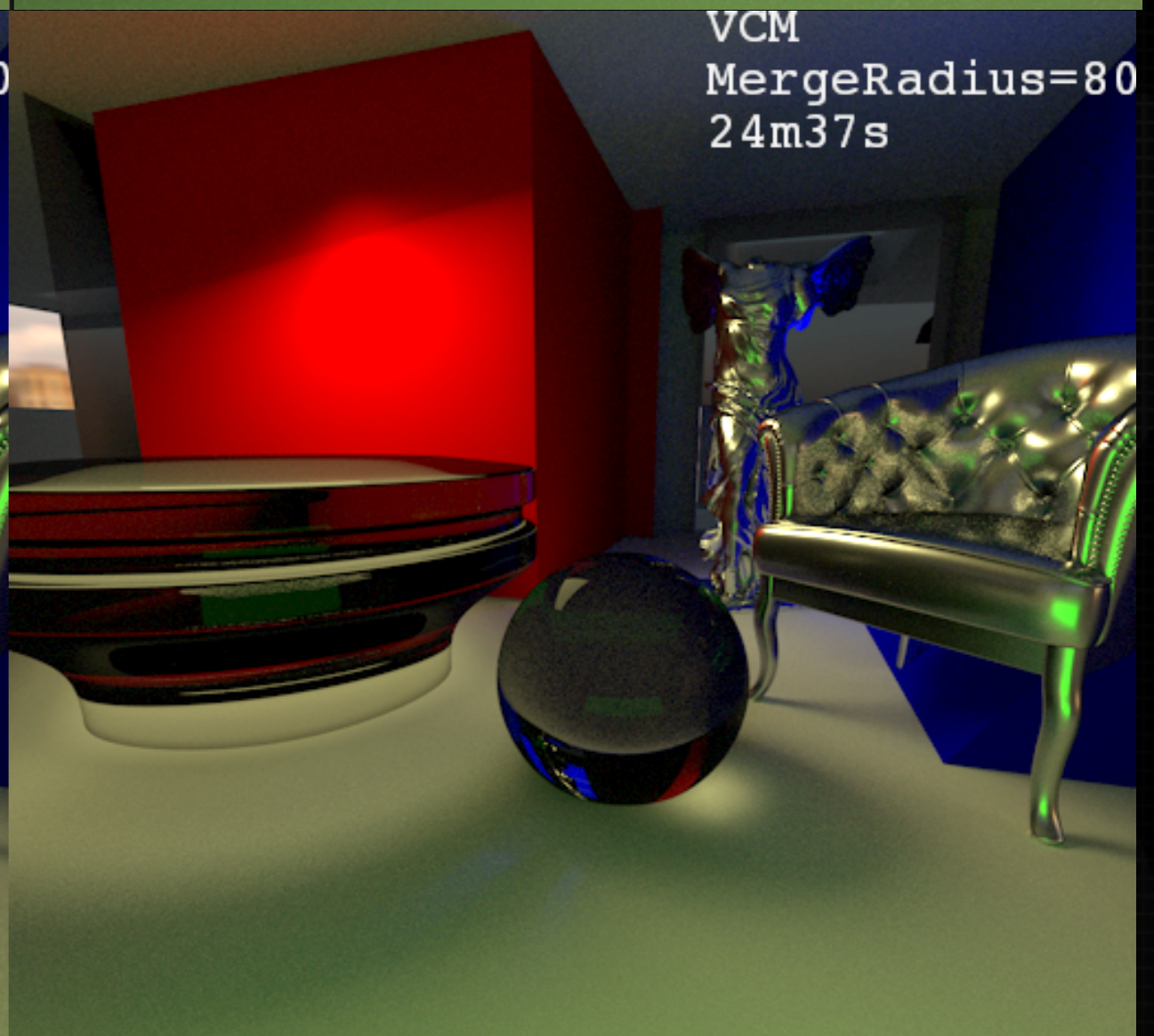
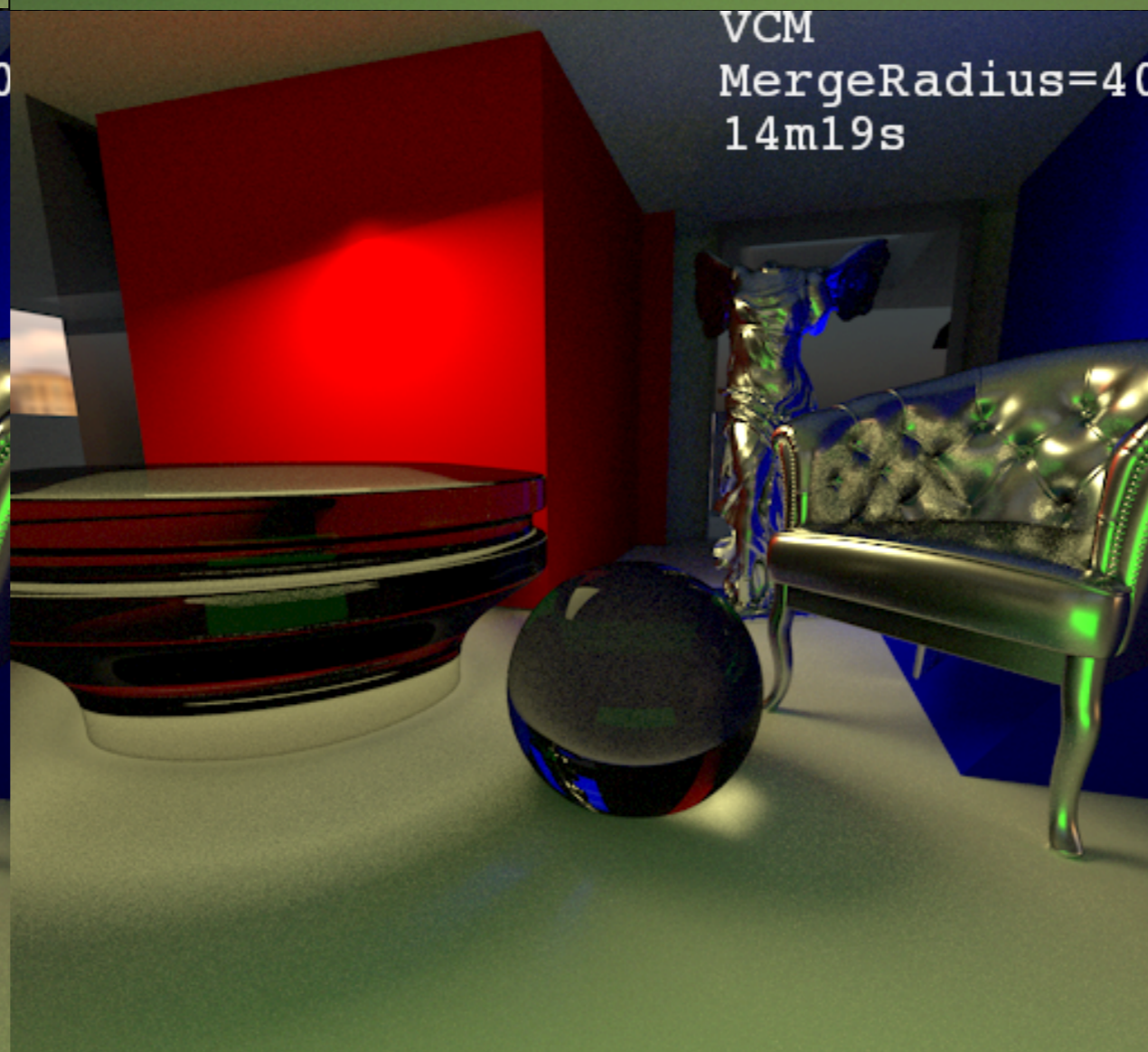
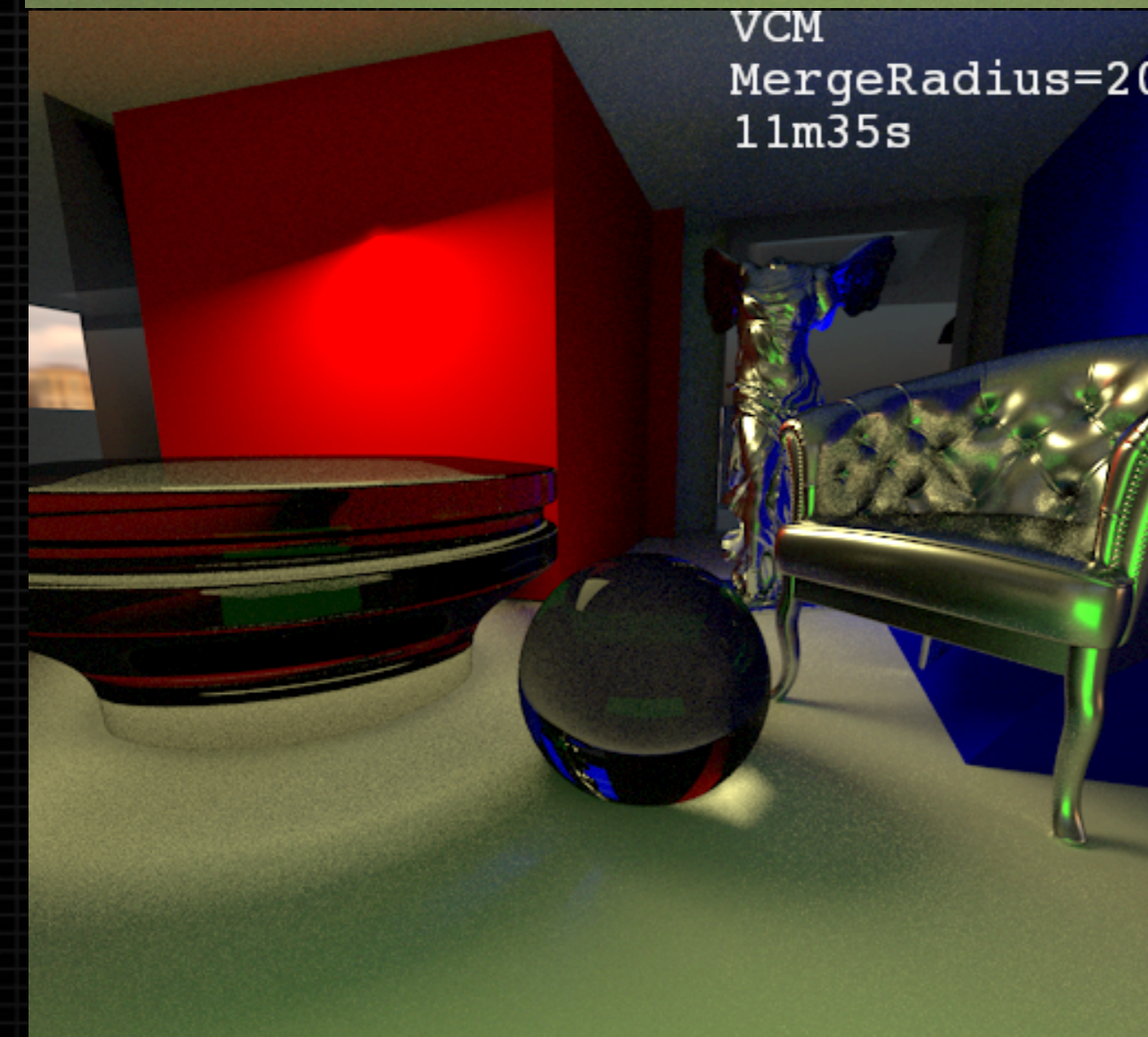
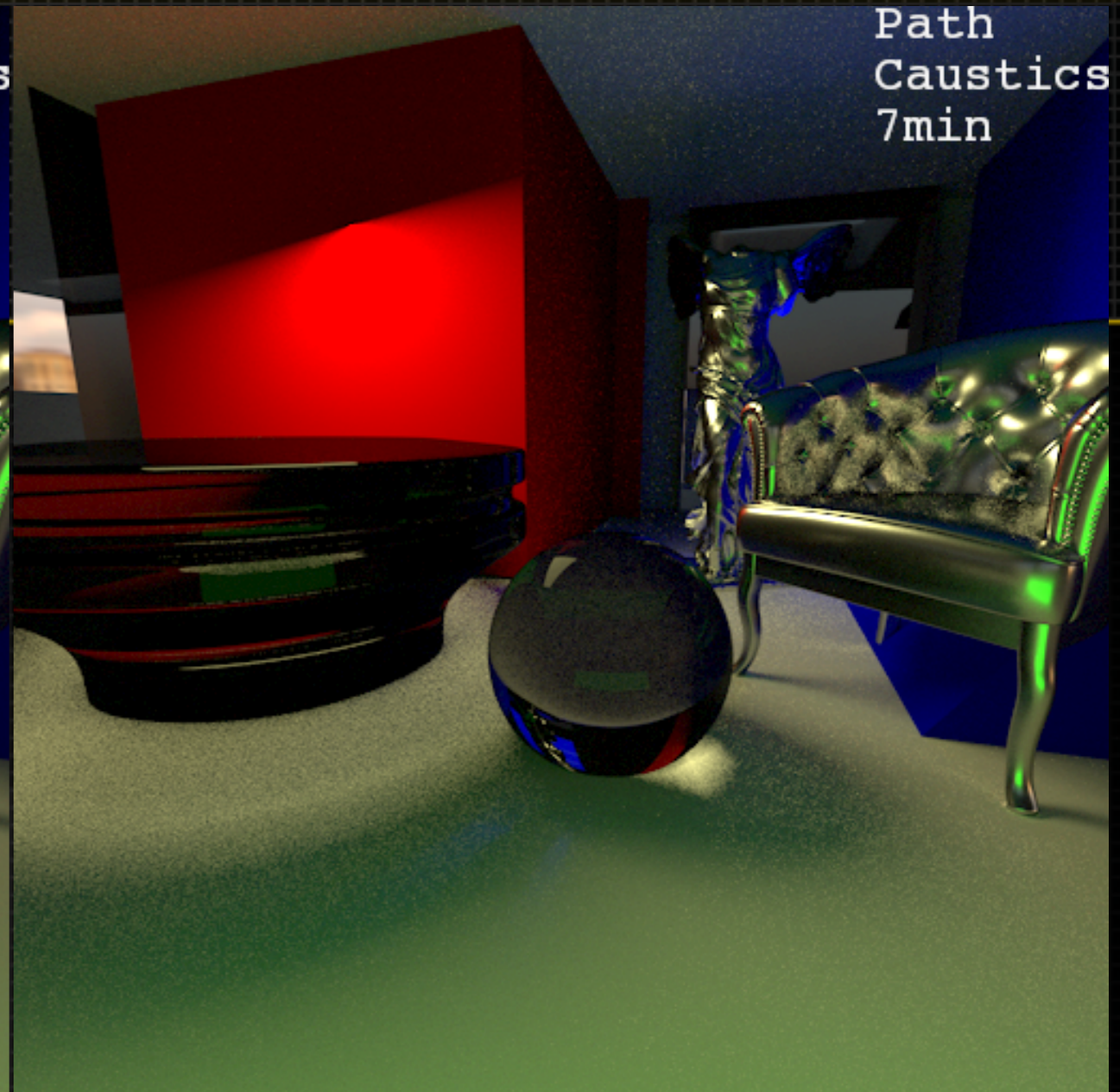
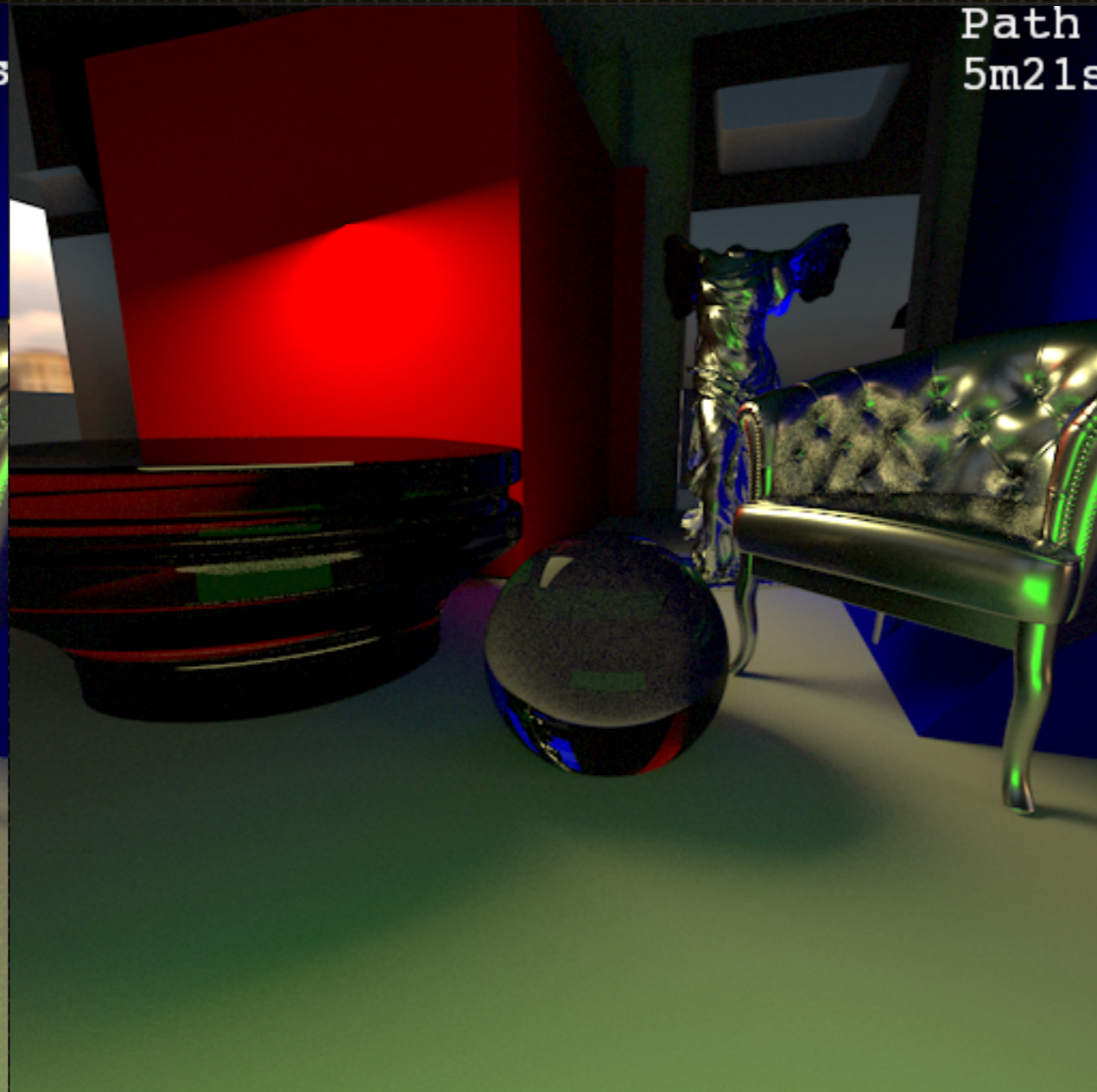
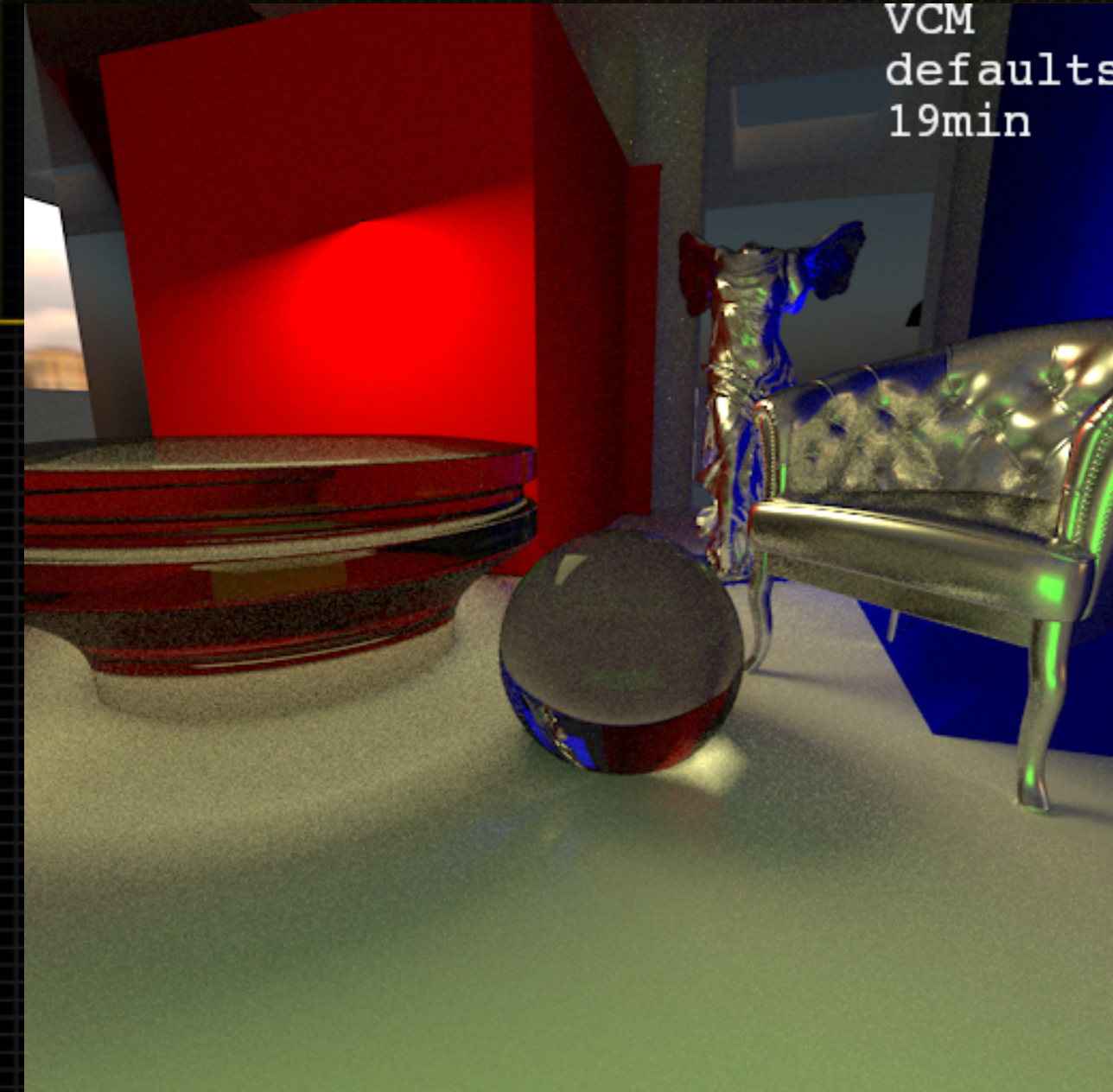


VCM "Merge Radius Scale"

Scaling factor for radius used in vertex merging. Increasing the radius will lead to increased blurring of a photon, which may be helpful in reducing noisy caustics. However, this will also slow down merging, and may also lead to more iterations in order to arrive at a bias-free result



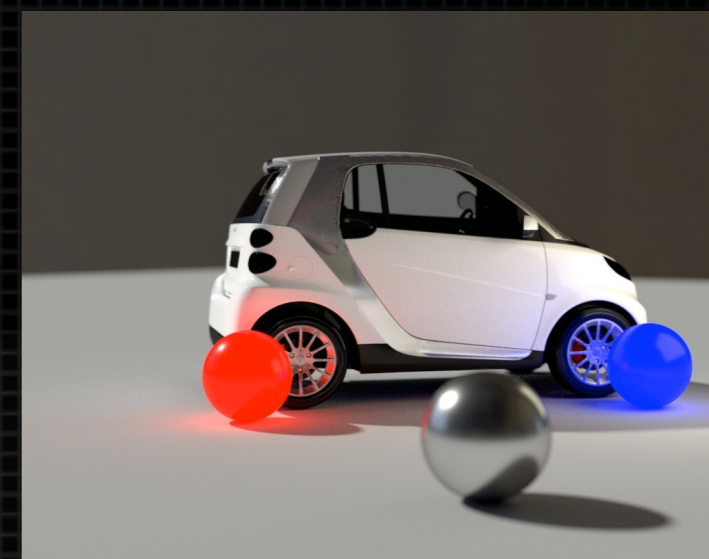
Merge Radius Scale



Path Tracer vs VCM: Summary

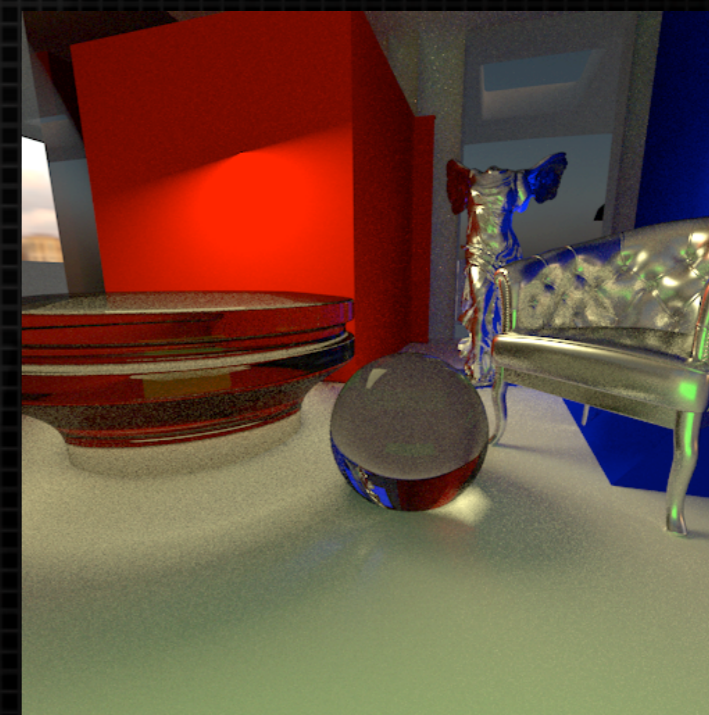
Uni-Directional Path Tracer

- ▶ Outdoor scenes
- ▶ Env Light, high-contrast
- ▶ PixelVariance in Adaptive Sampling



VCM Bi-Directional Path Tracer

- ▶ Indoor Scenes
- ▶ Lots of light sources
- ▶ Dimly lit
- ▶ Lots of bounce
- ▶ Sharp caustics in glass & metals
- ▶ Merge Radius Scale for quality of caustics & light sources



Thank you!



Thanks to Pixar's RenderMan team and FXPHD!

More info: fxphd.com & lollipopshaders.com