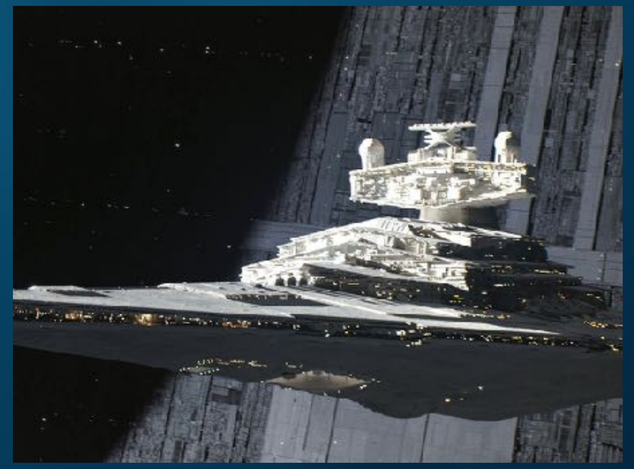
Advanced Path Tracing in RenderMan



Per Christensen
Pixar Animation Studios

SIGGRAPH 2017, Los Angeles

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RenderMan: used for CG and VFX

- Used for animated movies: Toy Story, Incredibles, Cars, Up, …, Finding Dory, Cars 3 (18 so far)
- Used for visual effects: The Abyss, Terminator 2, …, Harry Potter, Lord of the Rings, Star Wars, Jungle Book … (100s more)

See the RenderMan Showreel 2017 at:
https://www.youtube.com/watch?v=f0YXOHJ0cng

Outline

- RenderMan history and architecture
- Surface materials (and volumes)
- Light simulation algorithms
- Interactive rendering

RenderMan: background

- Originally based on REYES scanline algorithm [Cook87]
- Later augmented with ray tracing, point-based global illumination, distribution ray tracing with radiosity cache …
- Rewritten as a path tracer:
  - better multithreading, progressive rendering, complexity through instancing, single pass, simpler lighting setup

RenderMan: architecture

- Realistic rendering based on Monte Carlo simulation of physics (with cheats)
- Surface materials: bxdfs and texture patterns
- Light simulation algorithms: path tracing, bi-dir, VCM, …
- Interface inspired by PBRT book [Pharr04,17]

RenderMan: architecture

- Trace ray groups: 100s of rays
  - utilizes coherency (when possible)
- Shade point groups: 100s of points
  - enables optimizations, better coherency, reduces call overhead

Surface materials (bxdfs)

- Evaluate and Generate functions (100s of shade points)
- The same materials as used in Pixar movies (Finding Dory, ...) : “Uber”-shader developed by Pixar studio tools illumination group
- Hair and fur [Marschner03,Pekelis15], subsurface scattering [Burley/Christensen15]
- Plus: write your own materials

Surface materials (bxdfs): examples

image credit: Philippe Leprince

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Hair, fur, feathers

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Subsurface scattering

- Diffusion models:
  - dipole [Jensen01,d'Eon12]: waxy look
  - normalized diffusion [Burley/ Christensen15]: simple, good for realistic skin

Subsurface scattering: skin examples

image credit: MPC

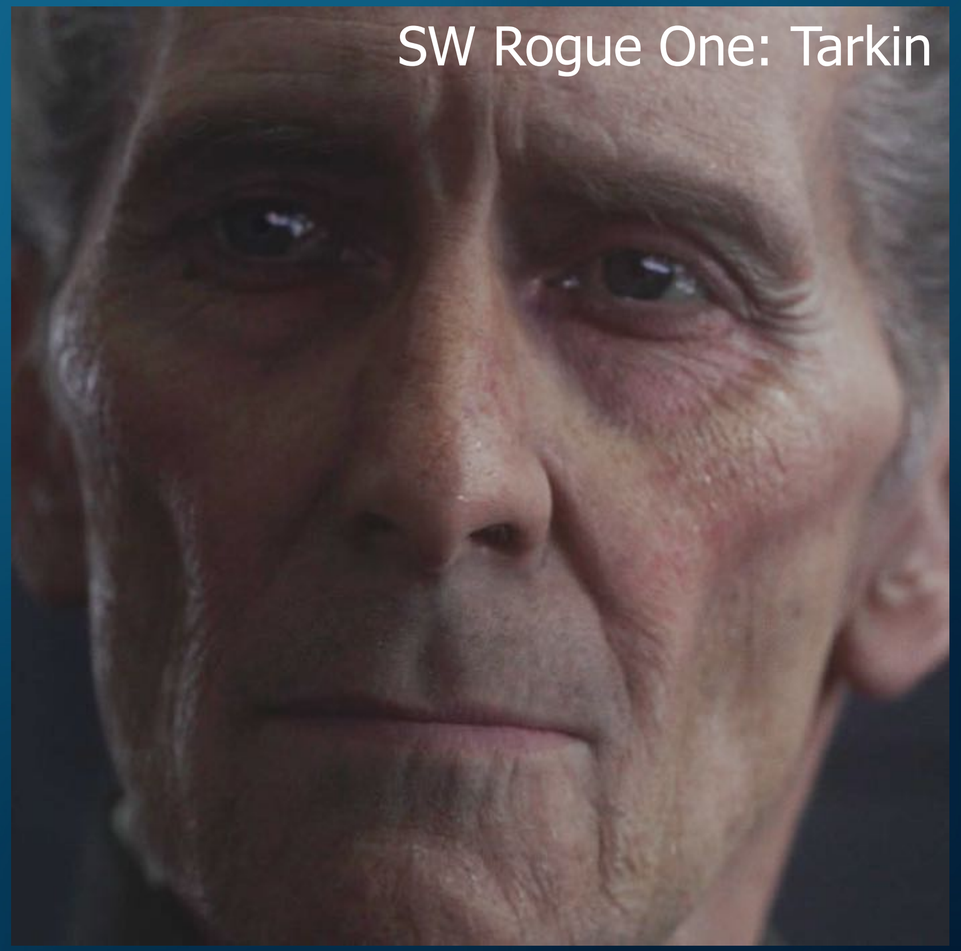
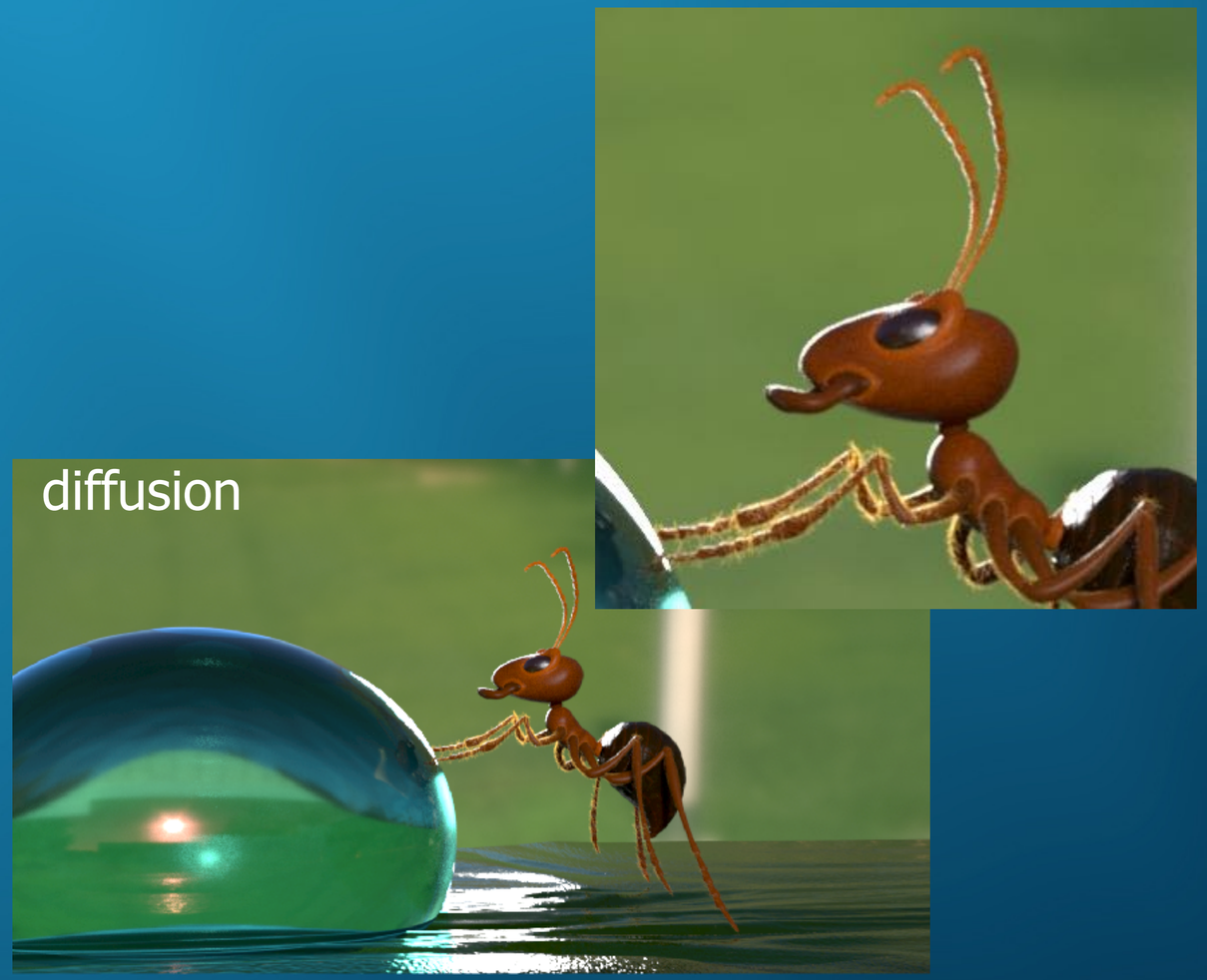


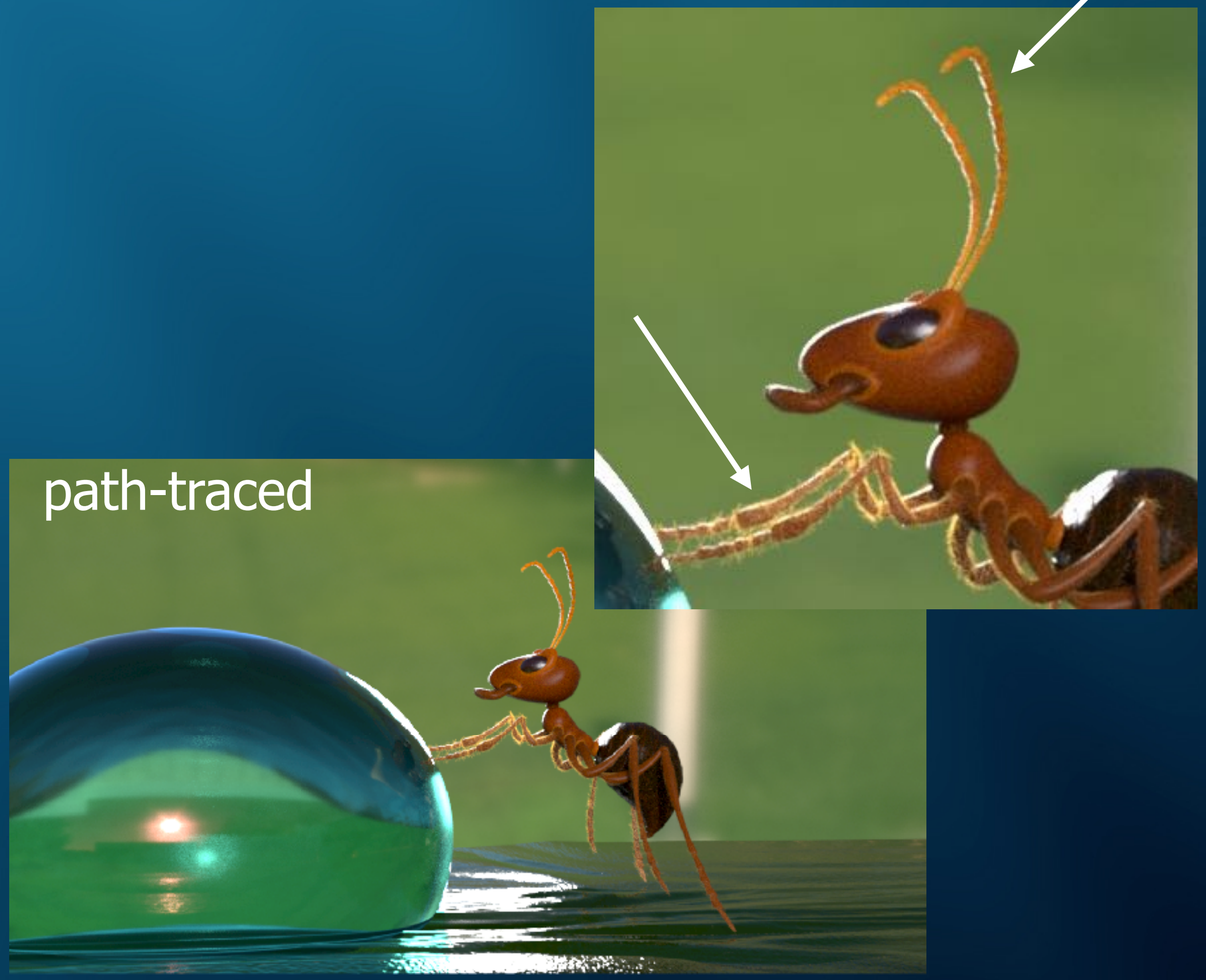
image credit: ILM

Subsurface scattering

- New: path-traced brute-force Monte Carlo simulation of scattering in a (dense) volume
- More realistic for thin/curved objects
- Parameter conversion: intuitive surface params to physical volume params [Jensen01,Hery12,Chiang16]
- Pioneered by Weta and Disney; Pixar studio tools illumination group — more this afternoon

Subsurface scattering: ant example





ant model by Sunny Chopra, image by Chu Tang

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Volumes

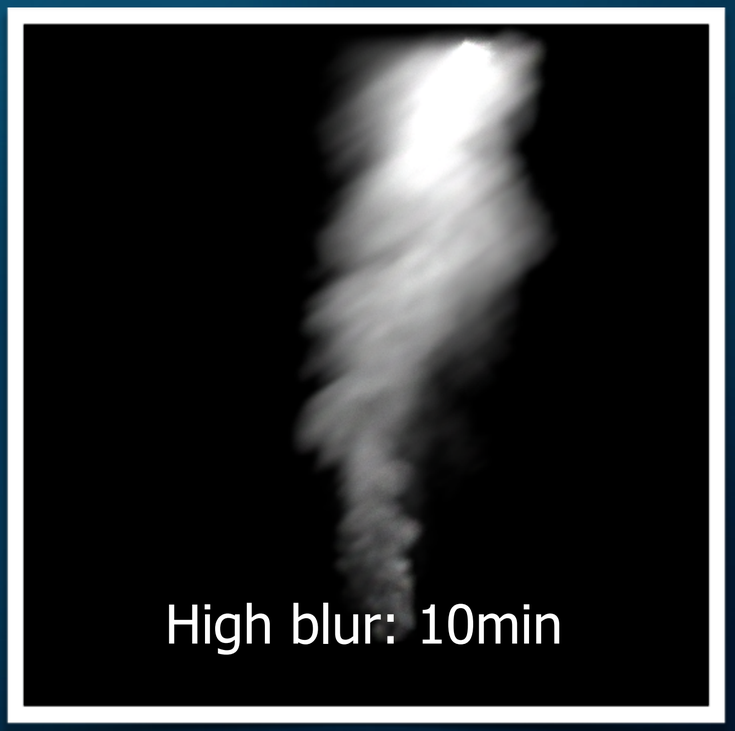
- Just attenuation (Beer's law)
- Single scattering
- Multiple scattering
- Emission (flames, neon tubes, …)

Nested/overlapping volumes

- Renderer keeps track of all volumes entered / exited
- Integrates over **all** volumes covering a region ("aggregate volumes")
- For efficiency: keeps kd-tree of volume density bounds

Volumes with motion blur

- Temporal volume buffers allow for fast, accurate, deforming motion blur [Wrenninge16]



Patterns

- Pattern networks drive Bxdf parameters
- Nodes can be C++ or OSL
- OSL is easier to write and share
- OSL is being vectorized (OSL version 2.0) — thanks Intel!
  - Speedups up to 9x on 16-wide units (AVX512)

image credit: Max Liani

Light simulation algorithms

- “Integrators”:
  - Path tracing (uni-directional)
  - Bi-directional path tracing
  - VCM
  - UPBP
  - Plus: write your own algorithm

(uni-directional) Path tracing

- By far the most commonly used integrator. For example:

copyright (c) Pixar/Disney

image credit: MPC

(uni-directional) Path tracing

- Some technical details:
- Camera + specular rays are coherent, diffuse rays are not
- Manage texture accesses:
  - multi-res texture format and tile cache
  - ray differentials (specular and diffuse) determine resolution
- Manage geometry accesses: similar to texture

Bi-directional path tracing

- Less noise than uni-directional if most light is indirect
- Reuses shading results: combines shading points in multiple paths (important speedup if complex texturing)
- Guides photons toward visible parts of the scene

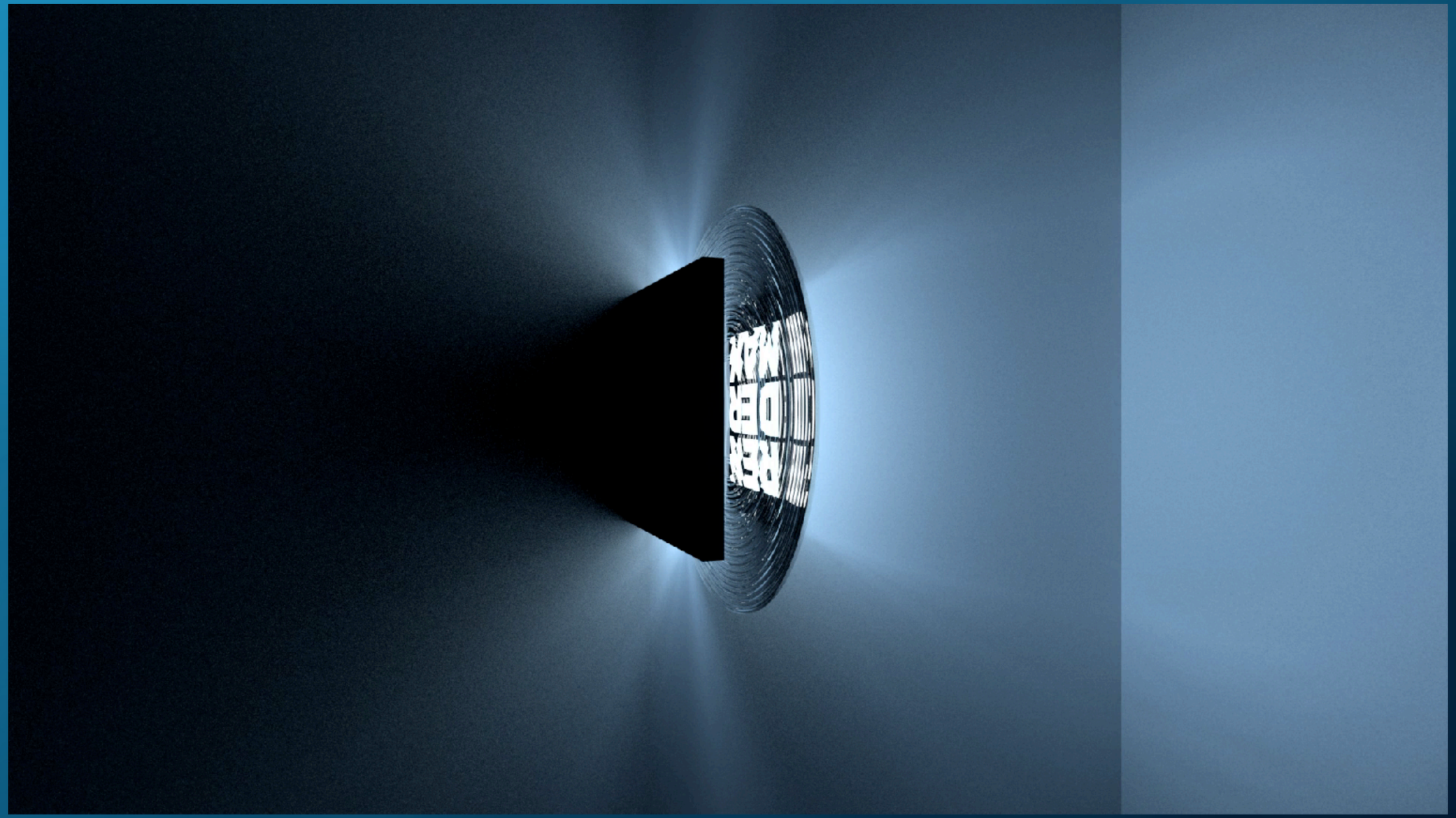
Bi-directional path tracing

- Wall sconce comparison: equal time

Vertex connection and merging: VCM

- Bidirectional path tracing + progressive photon mapping [Georgiev12,Hachisuka12] (also called UPT)
- Difficult light paths: caustics, reflected caustics

VCM example: Fresnel lens



video credit: Andrew Kensler

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Vertex connection and merging: VCM

- Practical use: eye caustic
- Cornea focuses light onto iris
- (There is also subsurface scattering in sclera)
- No movie images yet …

Unified points, beams, paths: UPBP

- [Krivanek14]: “VCM for volumes” — much less noise in volumes
- Store photons in volumes as points and beams
- Excellent at difficult paths in volumes
- Experimental for now: only homogeneous volumes, but otherwise fully featured

UPBP example: Luxo lamp

image credit: Brian Savery, Martin Sik, Per Christensen

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UPBP example: Luxo lamp

volume caustic

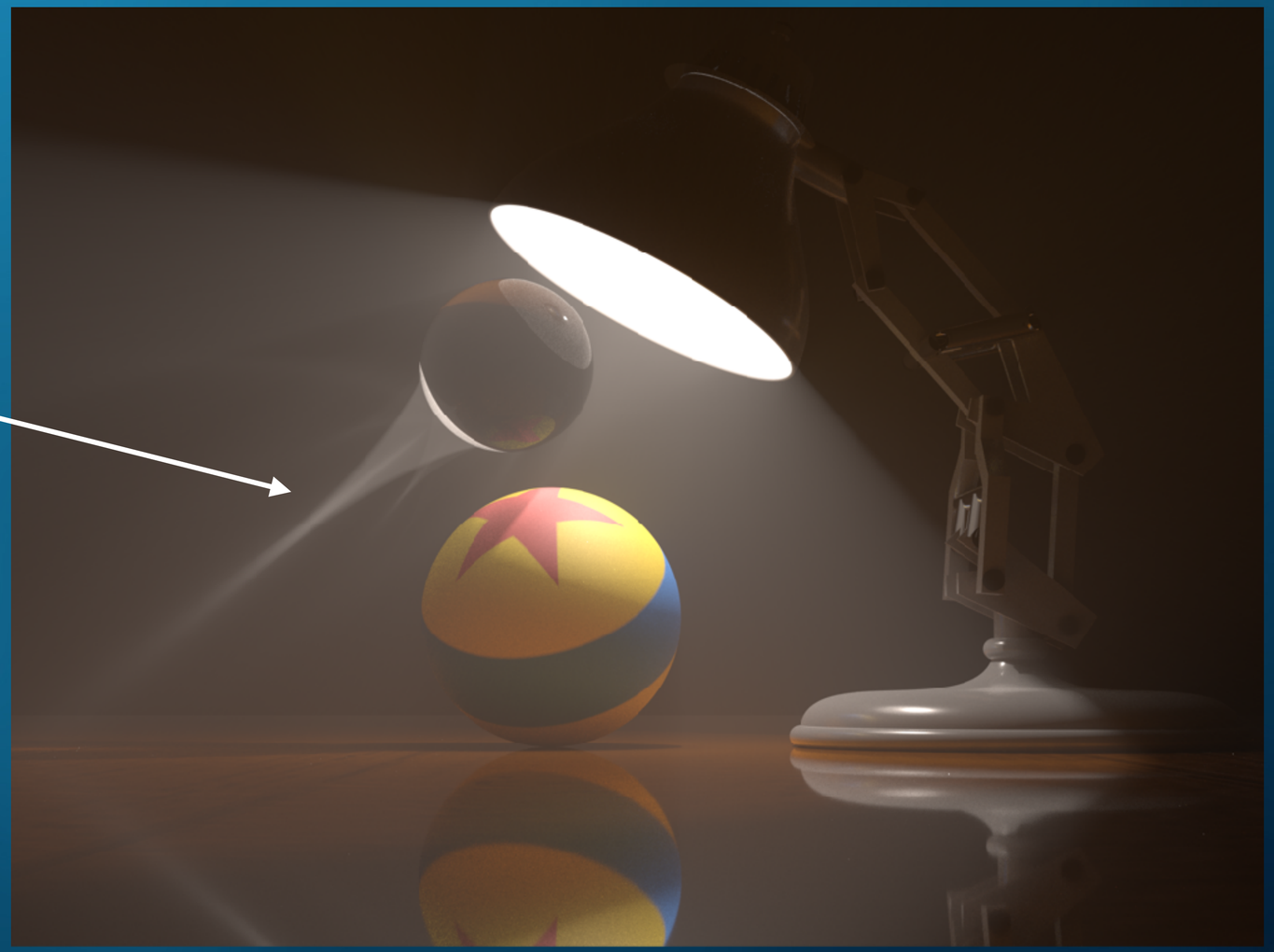

image credit: Brian Savery, Martin Sik, Per Christensen

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UPBP example: Luxo lamp

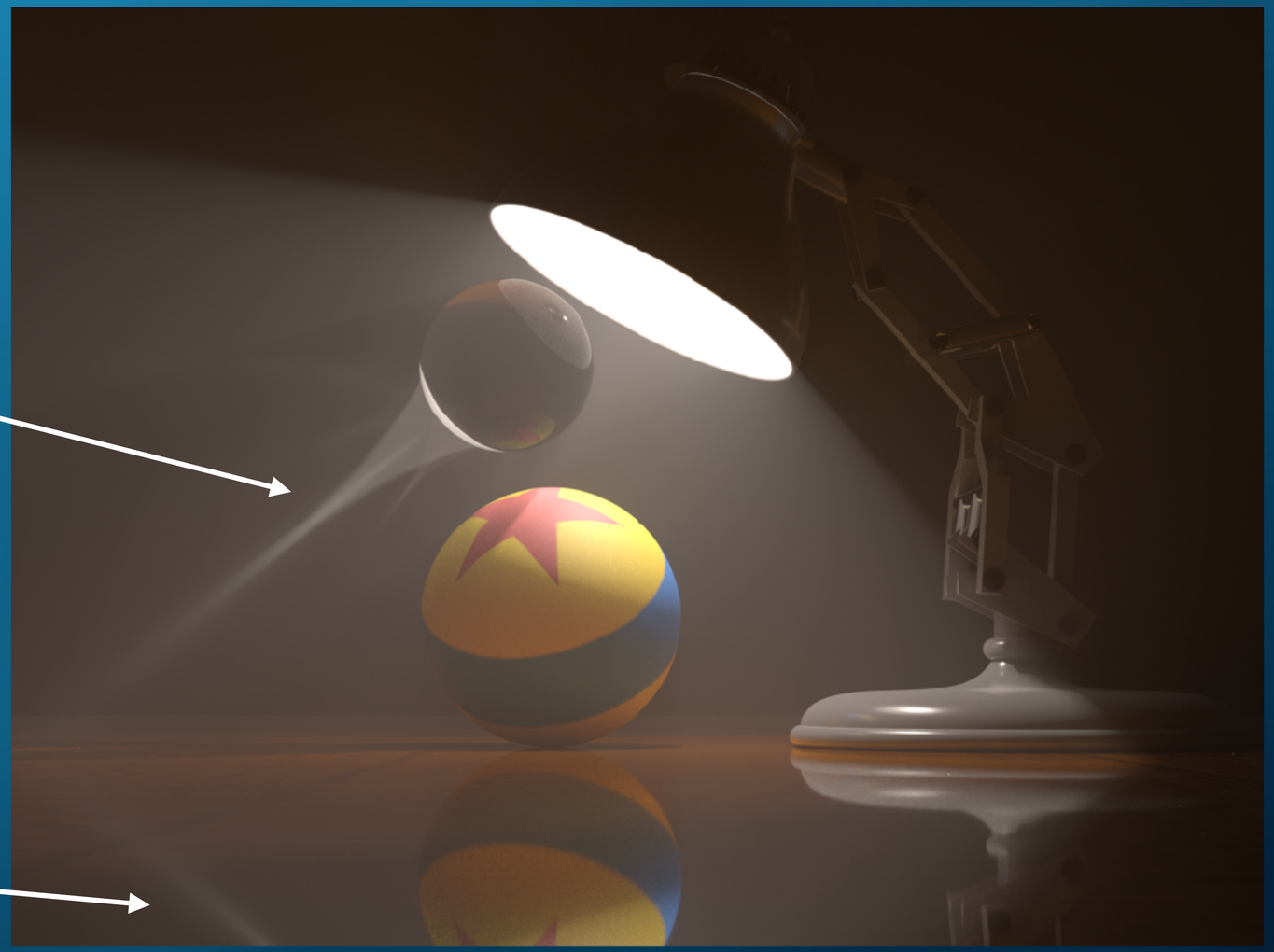
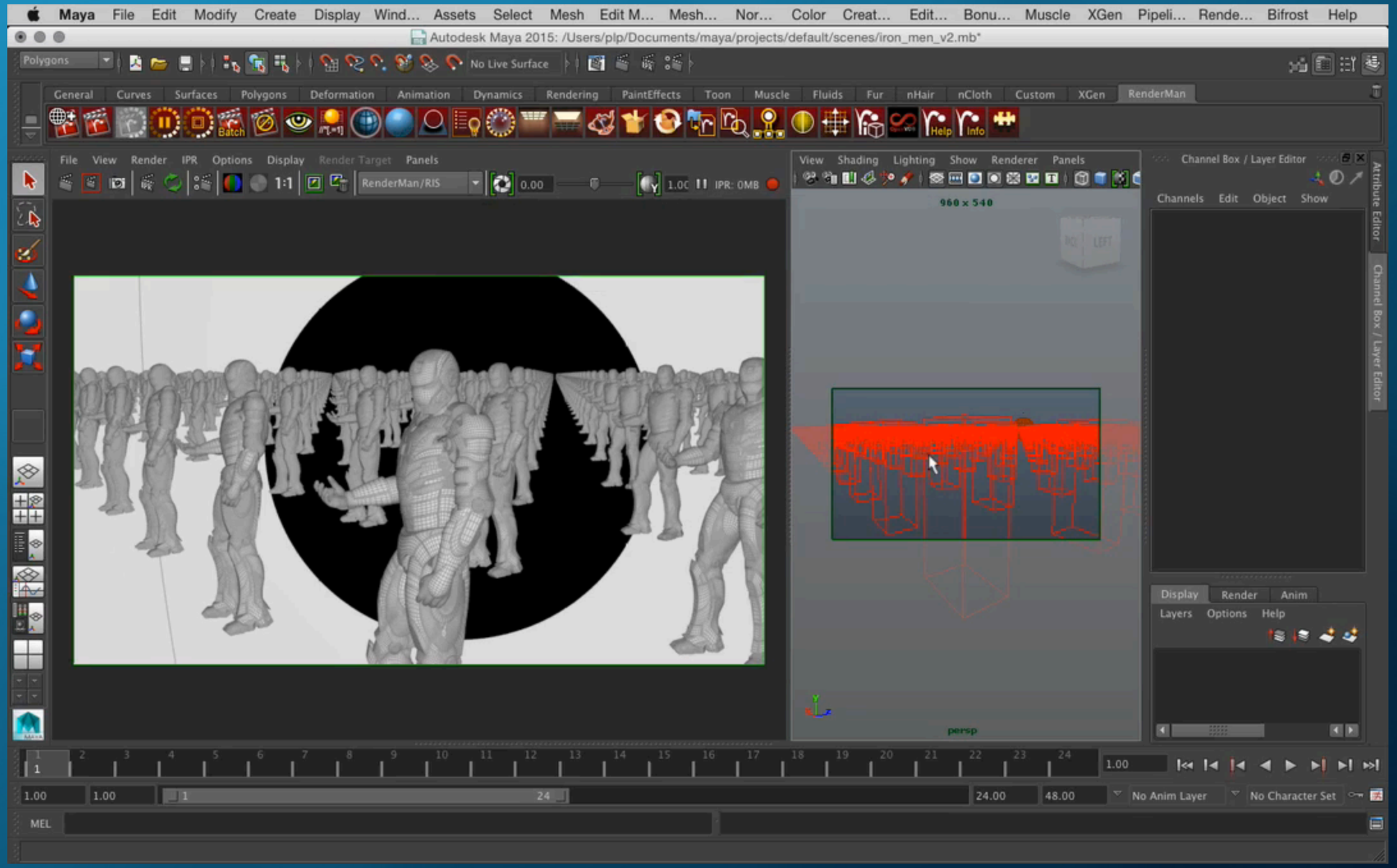


image credit: Brian Savery, Martin Sik, Per Christensen

Interactive rendering

- Quick feedback during modeling, texturing and lighting
- Optimize time to first pixel (noisy image is okay)
- Use RenderMan instead of e.g. Maya viewport



video credit: Philippe Leprince

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More information

- Download non-commercial RenderMan for free: renderman.pixar.com
- Pharr et al., “Physically Based Rendering” book
- Christensen & Jarosz, “The path to path-traced movies”
- Special issue of TOG on production renderers (later this year)

Conclusion

- RenderMan is a production-proven renderer used by Pixar and for 100s of movies
- Now based on path tracing; includes advanced path tracing techniques
- For both off-line movie rendering and quick previews

Acknowledgements

- Colleagues in Pixar's RenderMan team
- Pixar studio tools illumination group
- Luca Fascione, Johannes Hanika
- You

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One more video …

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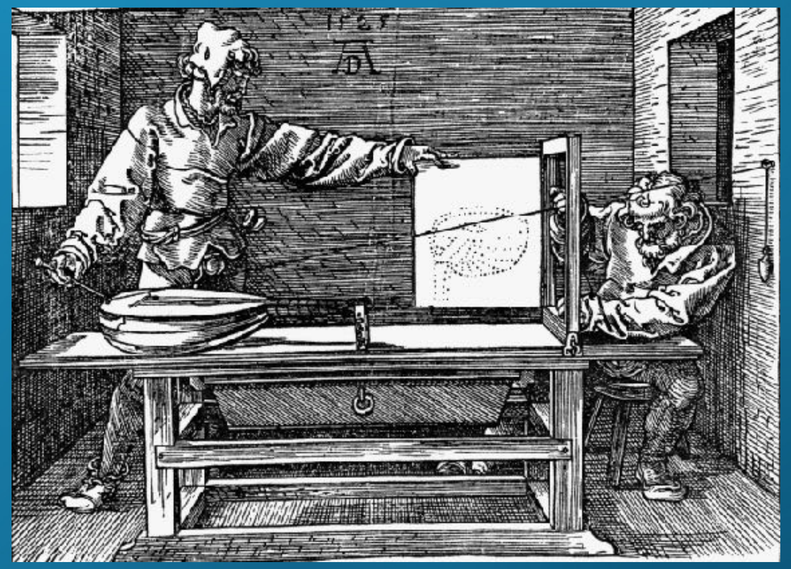
Thanks! Questions?



Durer (1525)

Cars (2006)

Coco (2017)

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