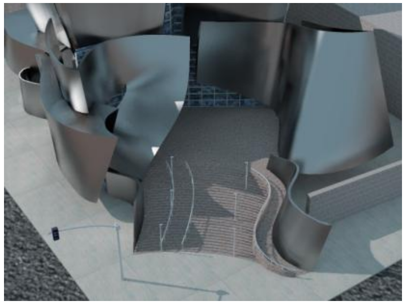
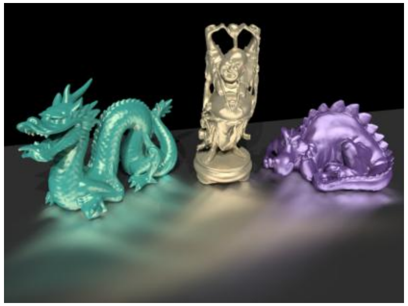
Virtual Spherical Lights for Many-Light Rendering of Glossy Scenes

Milos Hasan
Jaroslav Krivanek
Bruce Walter
Kavita Bala

Guillaume de Choulot

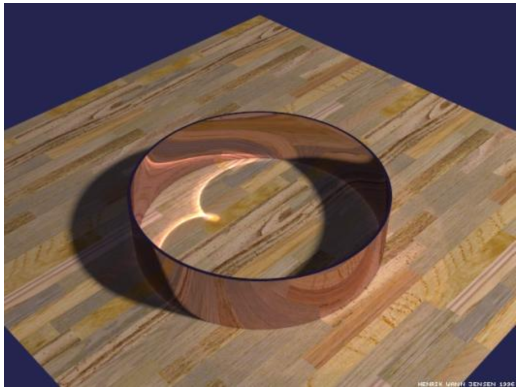
KAIST (Korea Advanced Institute of Science and Technology)

Global Illumination Effects

Soft shadows

Color bleeding



Caustics

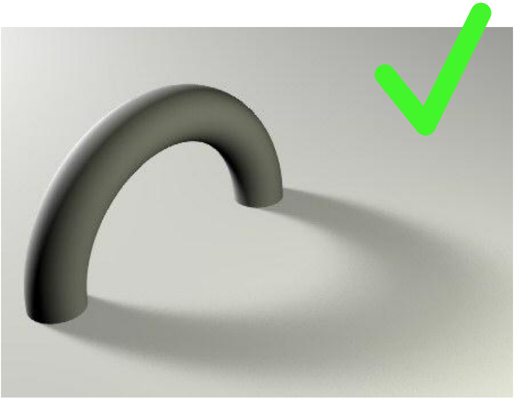
Mirror reflection

Refraction

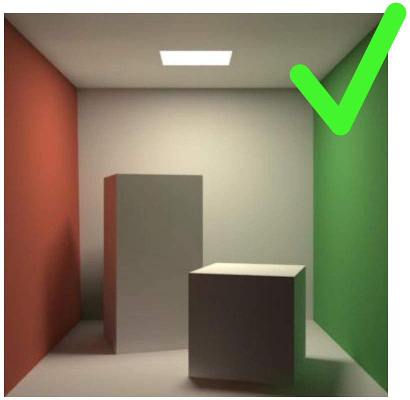
Glossy inter-reflection

Monte Carlo can handle them all… but is very slow

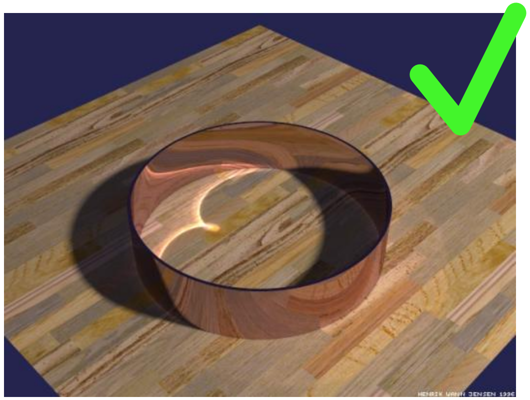
Faster algorithms exist…



Soft shadows

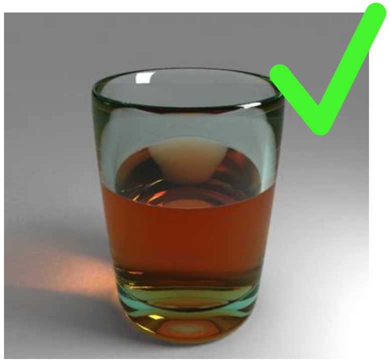


Color bleeding

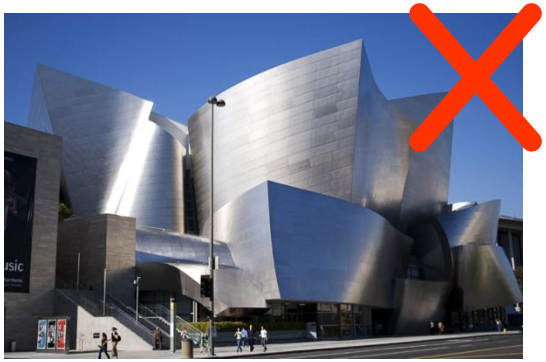


Caustics

Mirror reflection



Refraction



Glossy inter-reflection

But no satisfying solution for glossy inter-reflection

Glossy Inter-reflections

Previous Work

- Unbiased methods
  - (Bidirectional) Path tracing
    [Kajiya 1985, Lafortune et al. 1993]
  - Metropolis Light Transport
    [Veach and Guibas 1997]

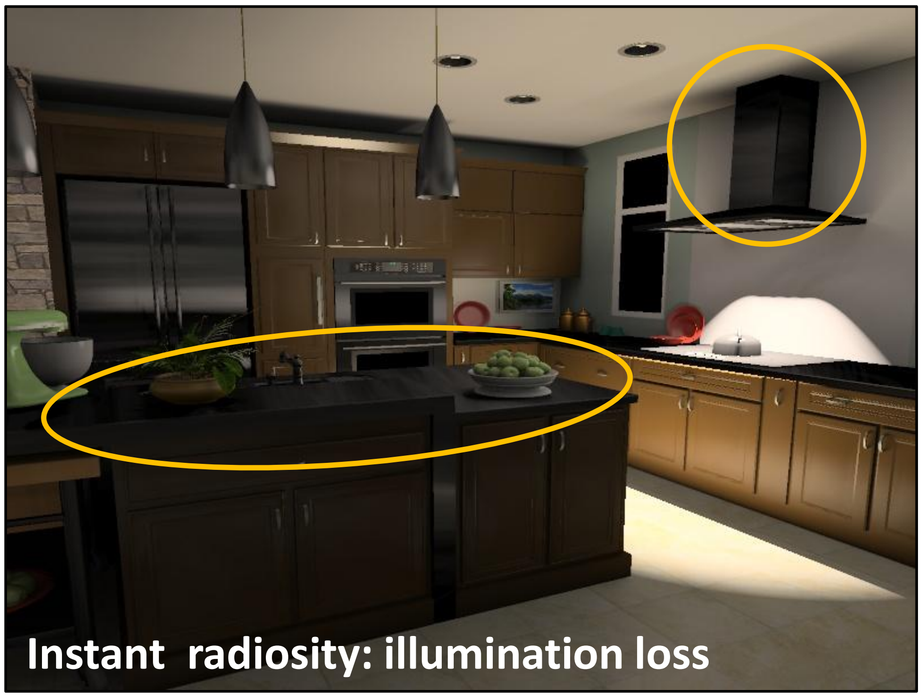
- Biased methods
  - Photon Mapping
    [Jensen 2001]
  - Radiance caching
    [Křivánek 2005]

Previous Work – Instant Radiosity

- Virtual Point Lights (VPLs)
- Very efficient in mostly diffuse scenes
  - Real-time global illumination
    [Wald et al. 2002, Segovia et al. 2006, 2007, Laine et al. 2007, Ritschel et al. 2008, Dong et al. 2009]

Limitations of Instant Radiosity

- So far: ~~Instant radiosity & Glossy inter-reflections~~



Previous Work on Compensation

- Compute the missing components by path tracing [Kollig and Keller 2004]


Path traced compensation: 3.5 hours


Reference

- Glossy scenes
  - As slow as path-tracing everything

New Method

- New type of light: Virtual Spherical Light

Outline

- Problems with Virtual Point Lights (VPLs)
- Our solution: Virtual Spherical Lights (VSLs)
- Implementation
- Results

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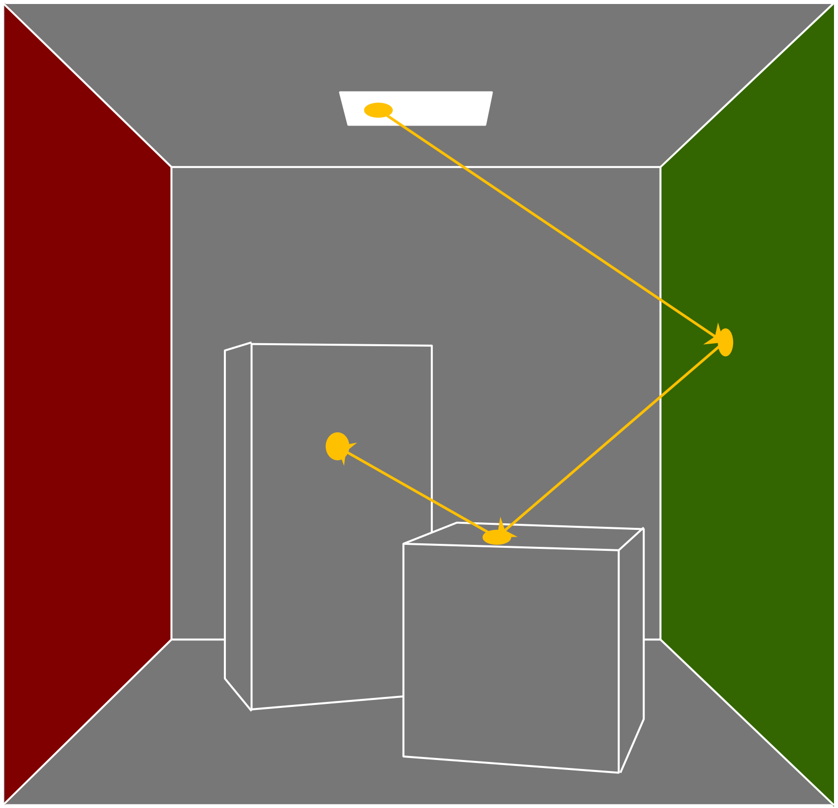
Instant Radiosity



- **STEP 1**
  - Trace paths from the light

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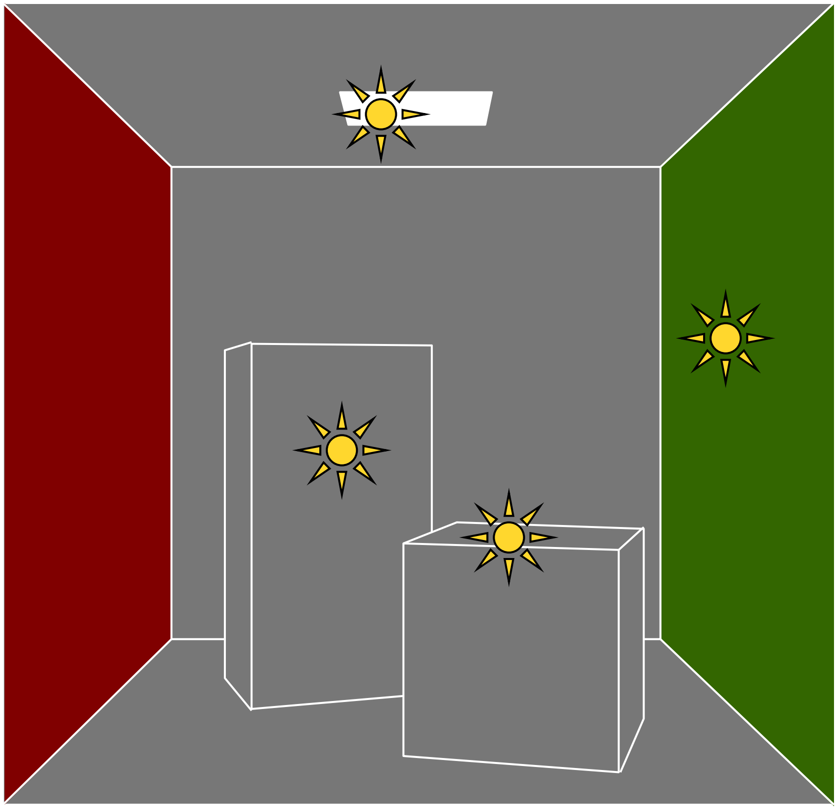
Instant Radiosity



- **STEP 1**
  - Trace paths from the light
  - Treat path vertices as Virtual Point Lights (VPLs)

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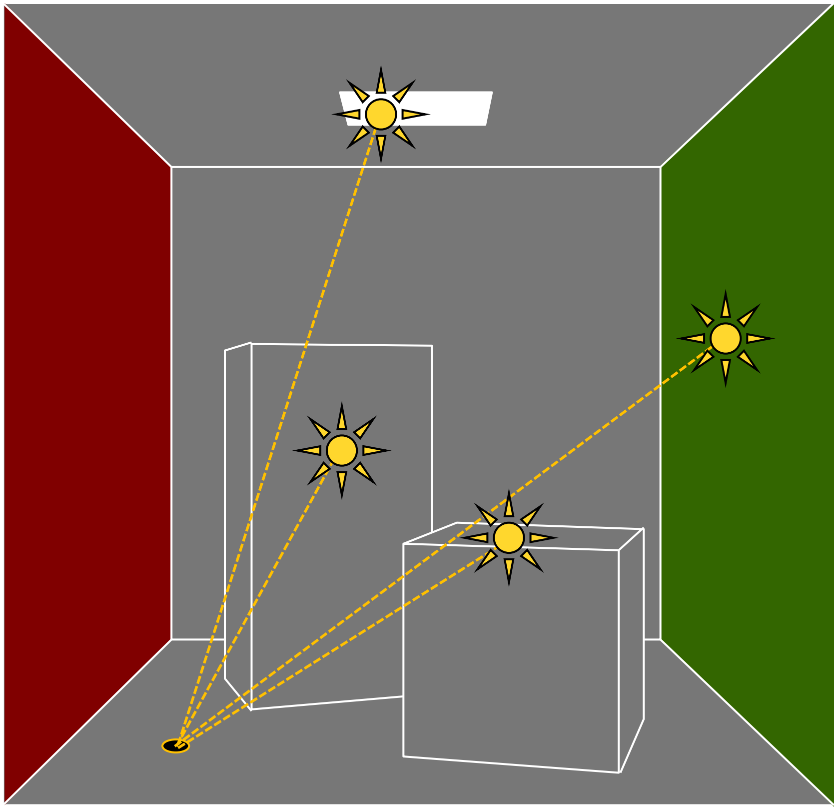
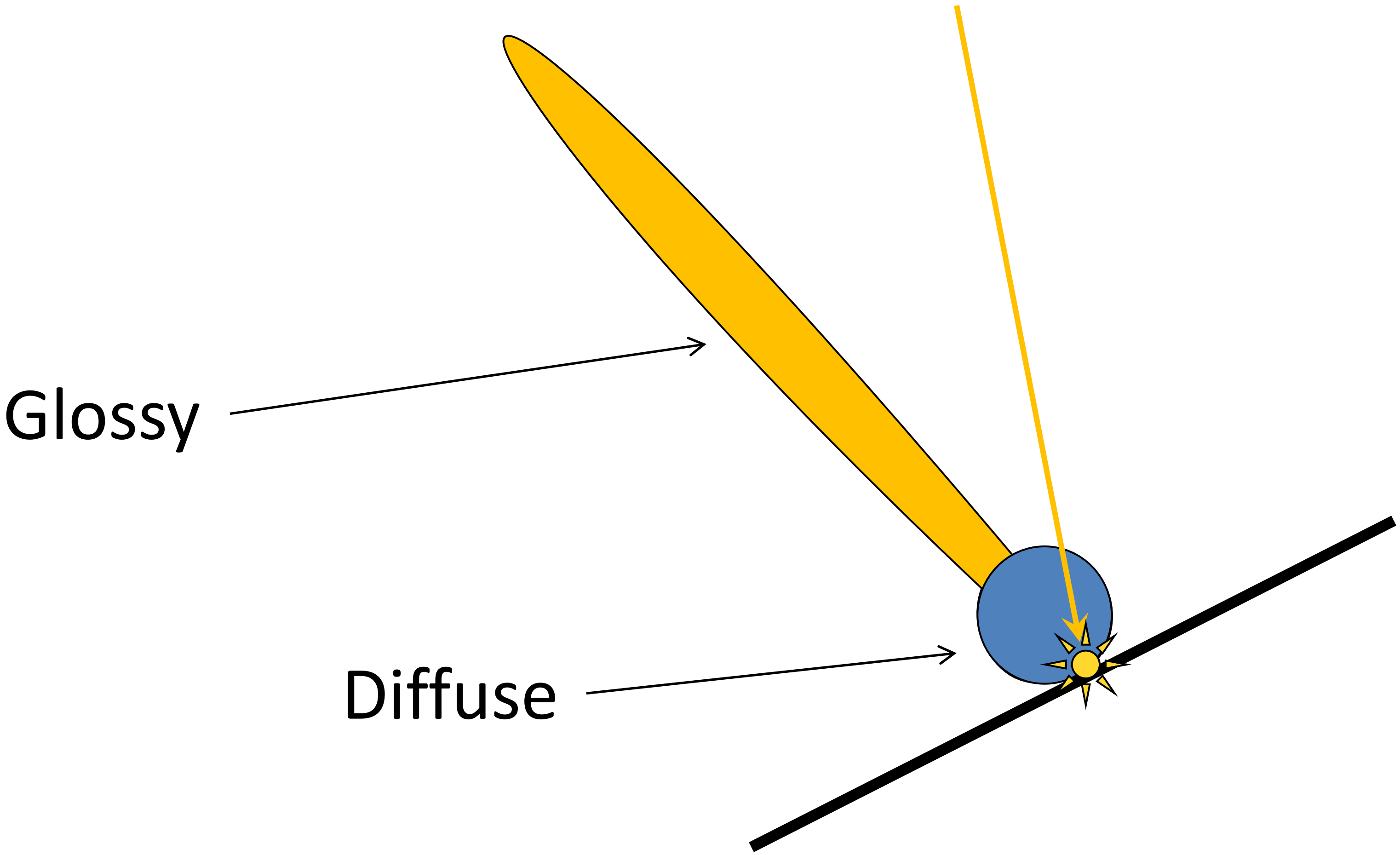
Instant Radiosity



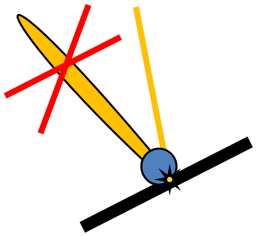
- **STEP 1**
  - Trace paths from the light
  - Treat path vertices as Virtual Point Lights (VPLs)
- STEP 2
  - Render scene with VPLs

Emission Distribution of a VPL

- Cosine-weighted BRDF lobe at the VPL location



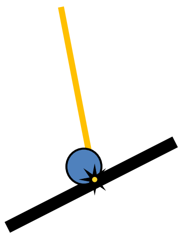
Glossy VPL Emission: Illumination Spikes



Common solution:

Only **diffuse** BRDF at light location

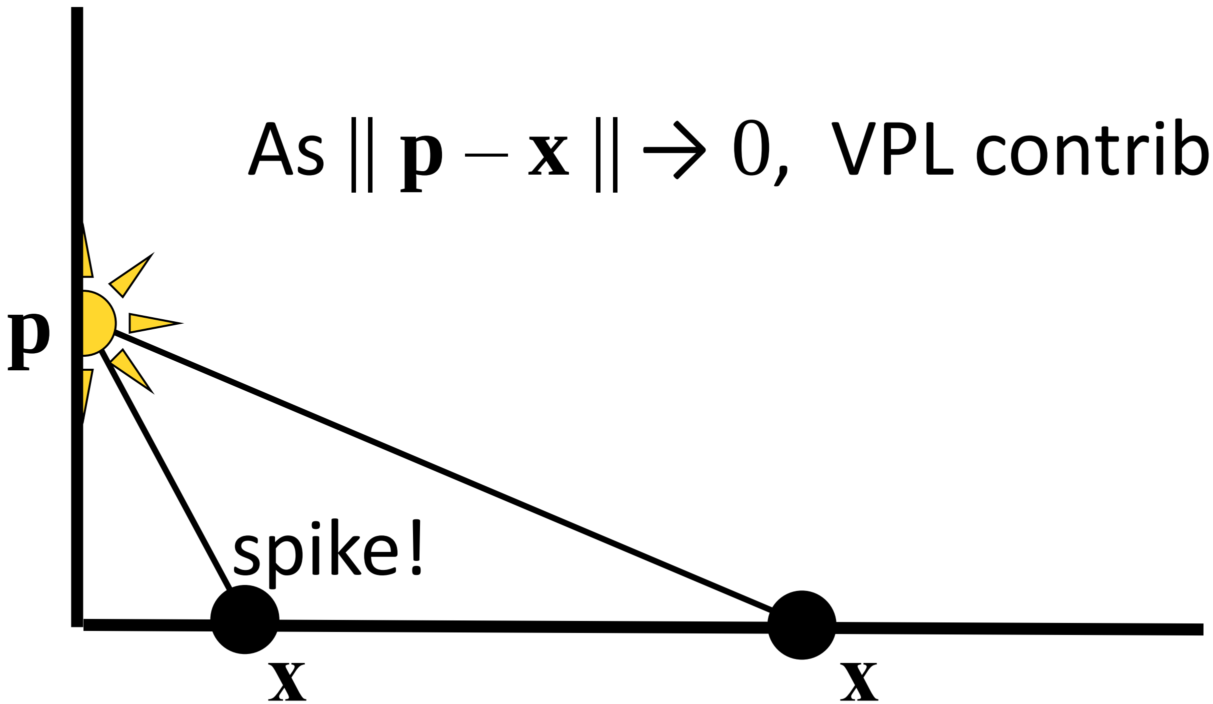
Remaining Spikes



Remaining Spikes

- VPL contribution =

As $\|\mathbf{p} - \mathbf{x}\| \rightarrow 0$, VPL contribution $\rightarrow \infty$



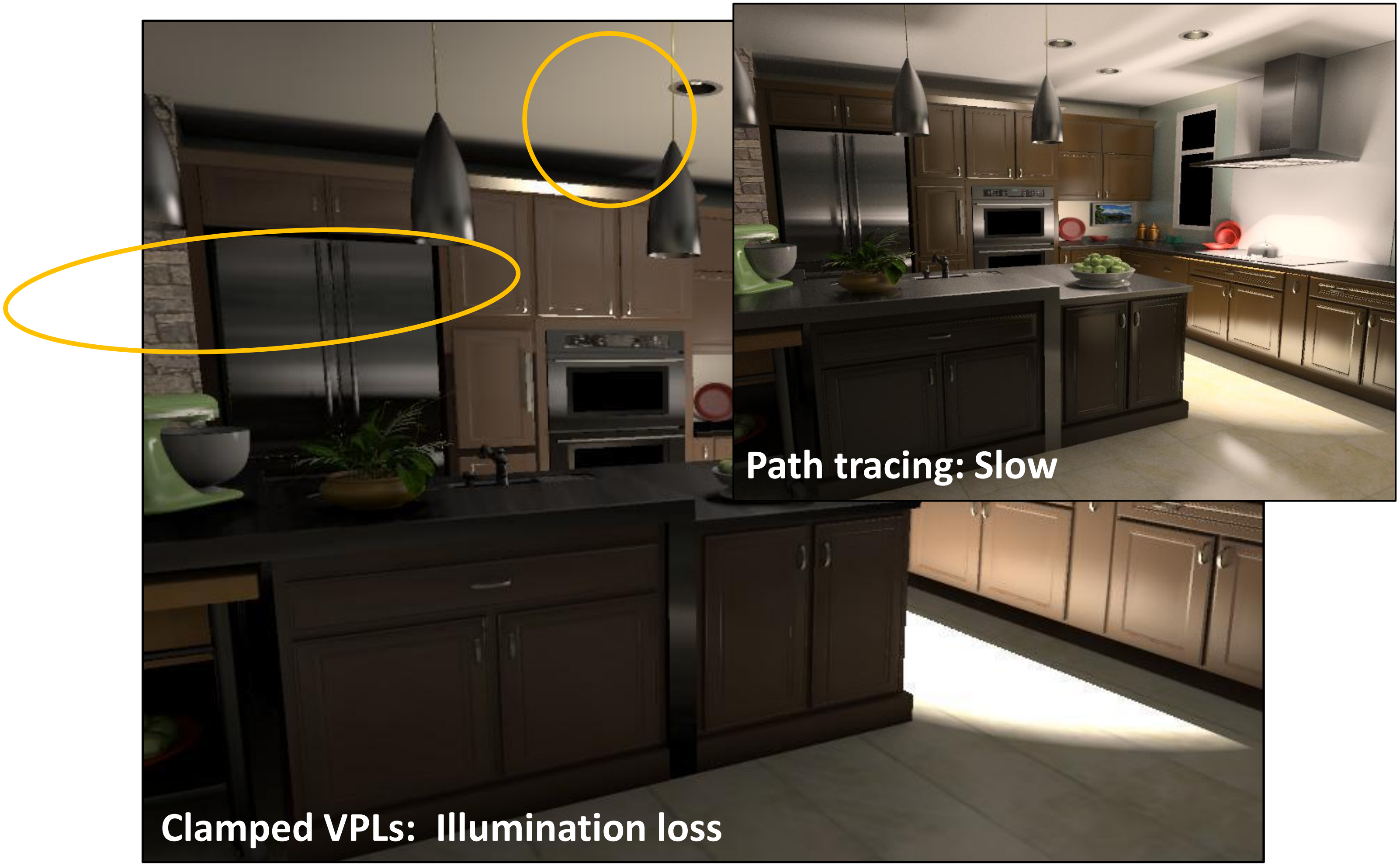
- Common solution: **Clamp** VPL contributions

Instant Radiosity: The Practical Version

Clamping and diffuse-only VPLs:

Illumination is lost!

Comparison: no equivalence



Effects of Global Illumination Approximations on Material Appearance

 ACM SIGGRAPH '10, by Jaroslav Krivanek, James A. Ferwerda, Kavita Bala

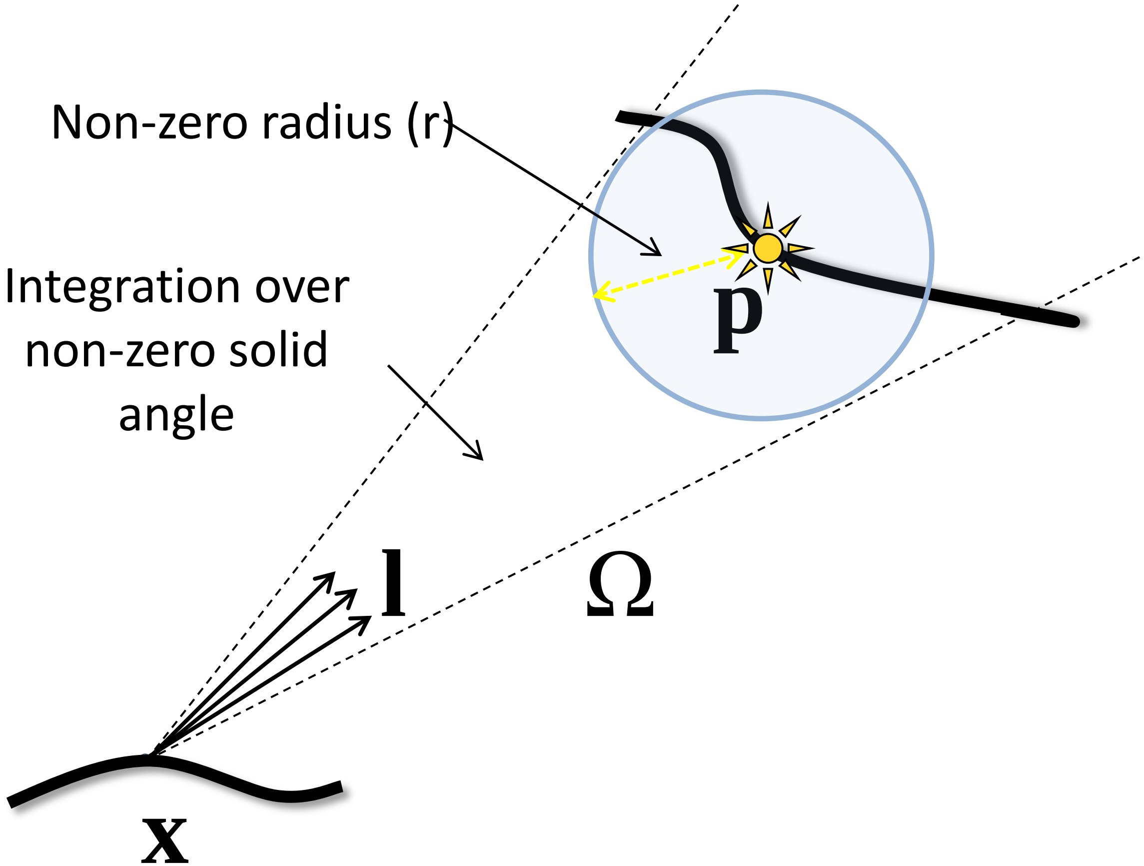
Outline

- Problems with Virtual Point Lights (VPLs)
- New Method: Virtual Spherical Lights (VSLs)
- Implementation
- Results

Motivation

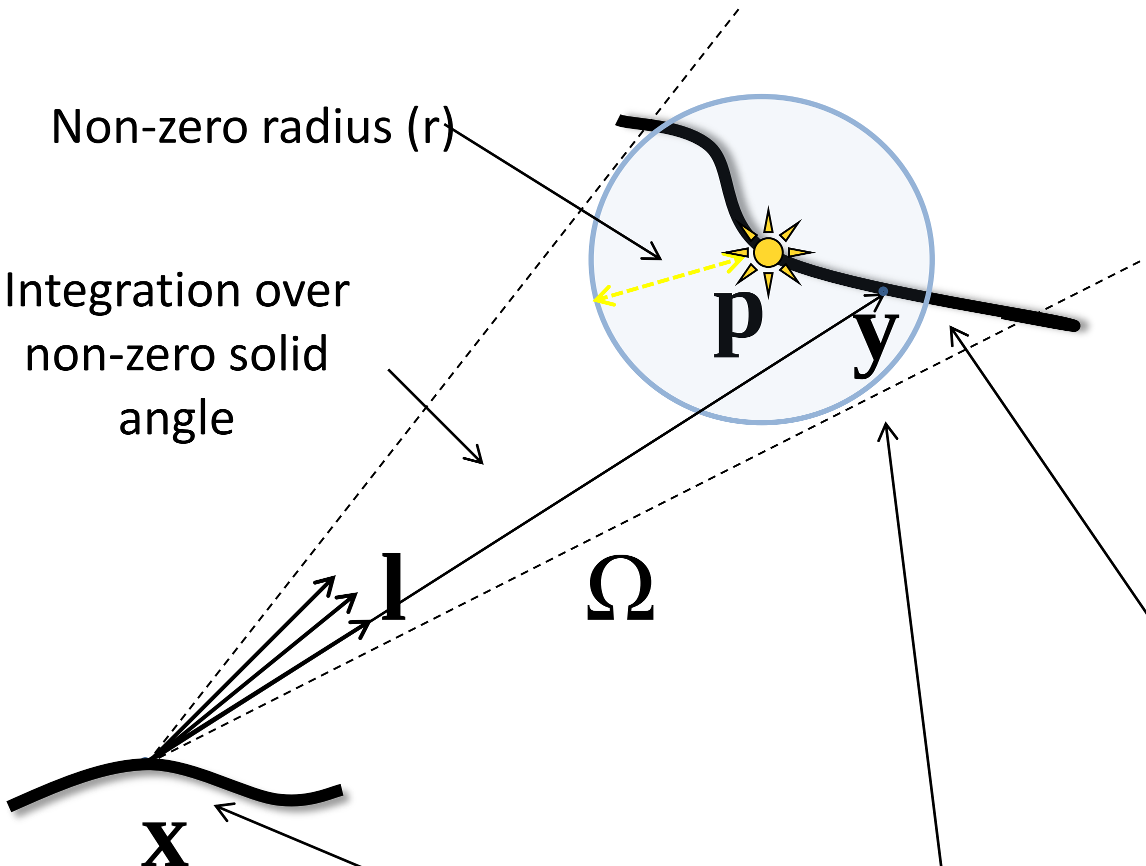
- VPLs: image splotches due to
  - Spikes in the VPL emission distribution
  - $1 / \| \mathbf{p} - \mathbf{x} \|$ term
- Idea
  - Spread VPL energy over a finite surface
  - Compute contribution as solid angle integral (over non-zero solid angle)

VPL to VSL



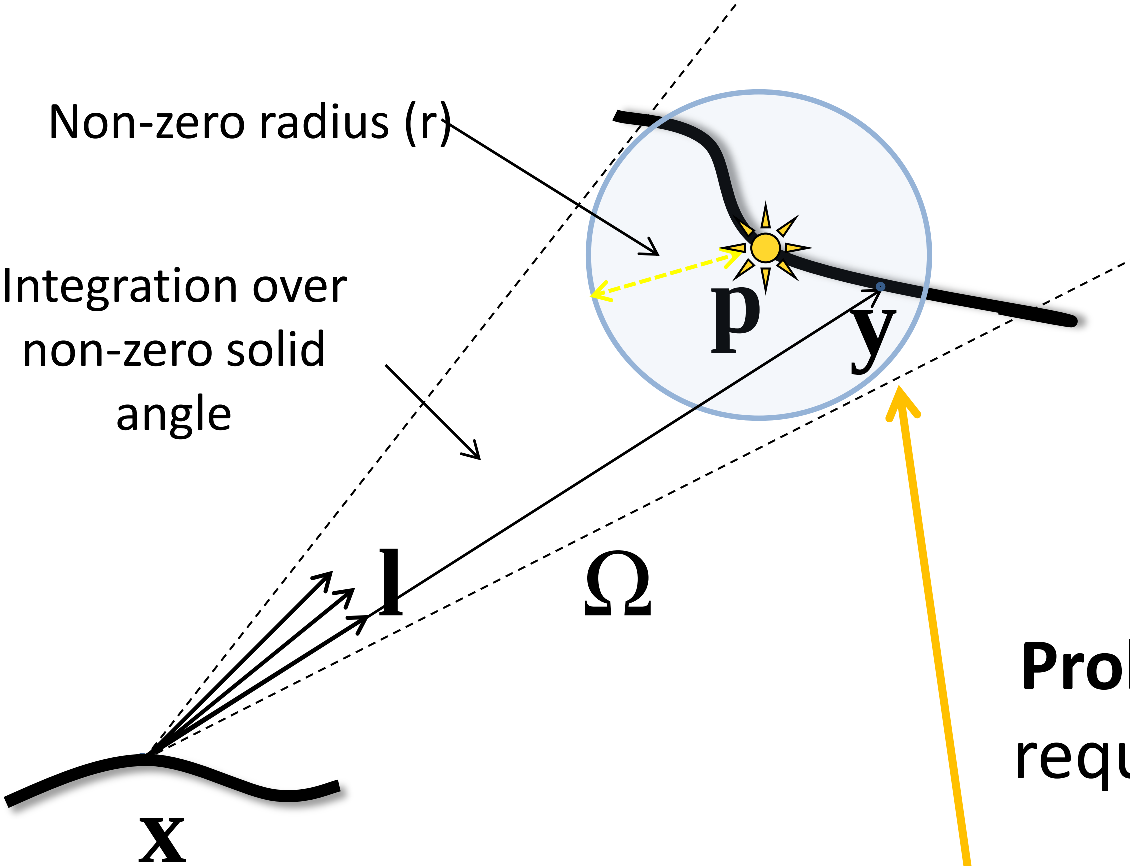
Non-zero radius (r)
Integration over
non-zero solid
angle
p
l
Ω
x

Light Contribution



$$\frac{\Phi}{\pi r^2}\int_{\Omega} \quad \text{[Cosine weighted BRDF]} \quad \text{[BRDF at y]} \quad \text{[Indicator term (zero if y outside)]} \quad d\mathbf{l}$$

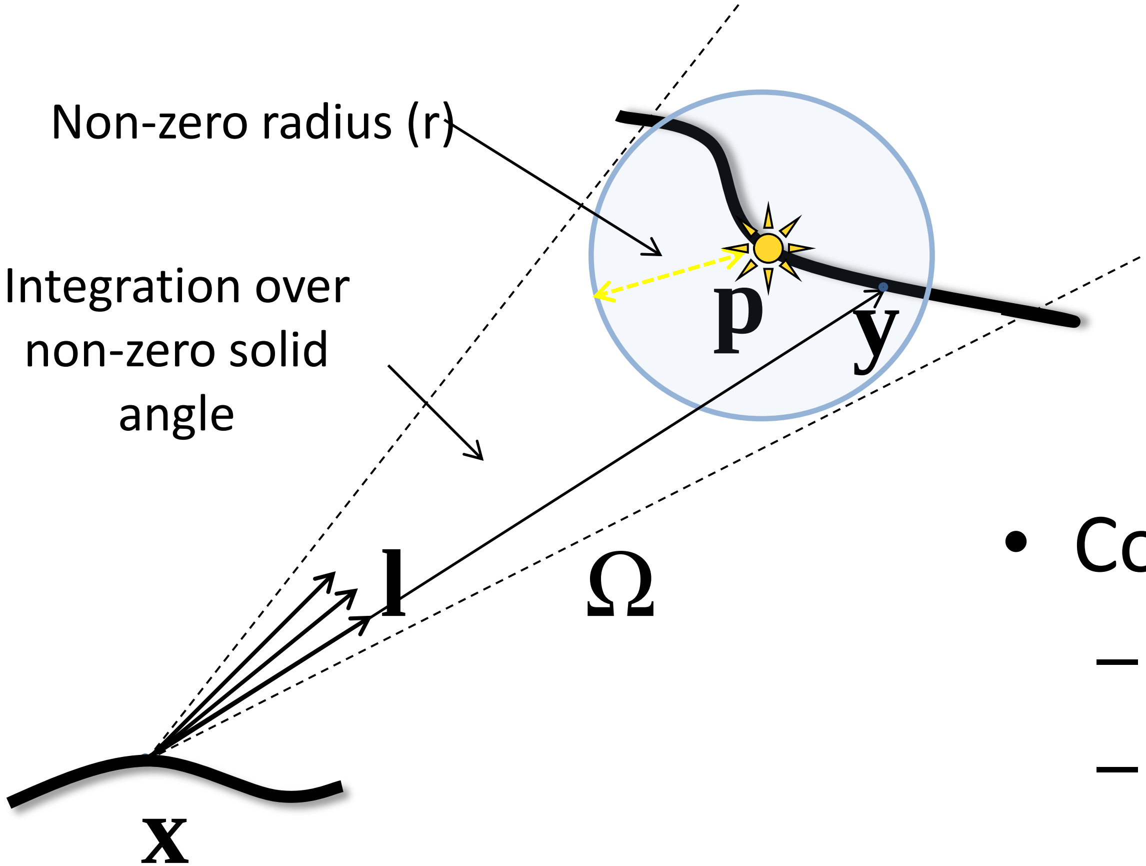
Light Contribution



Problem: Finding $\mathbf{y}$ requires ray-tracing

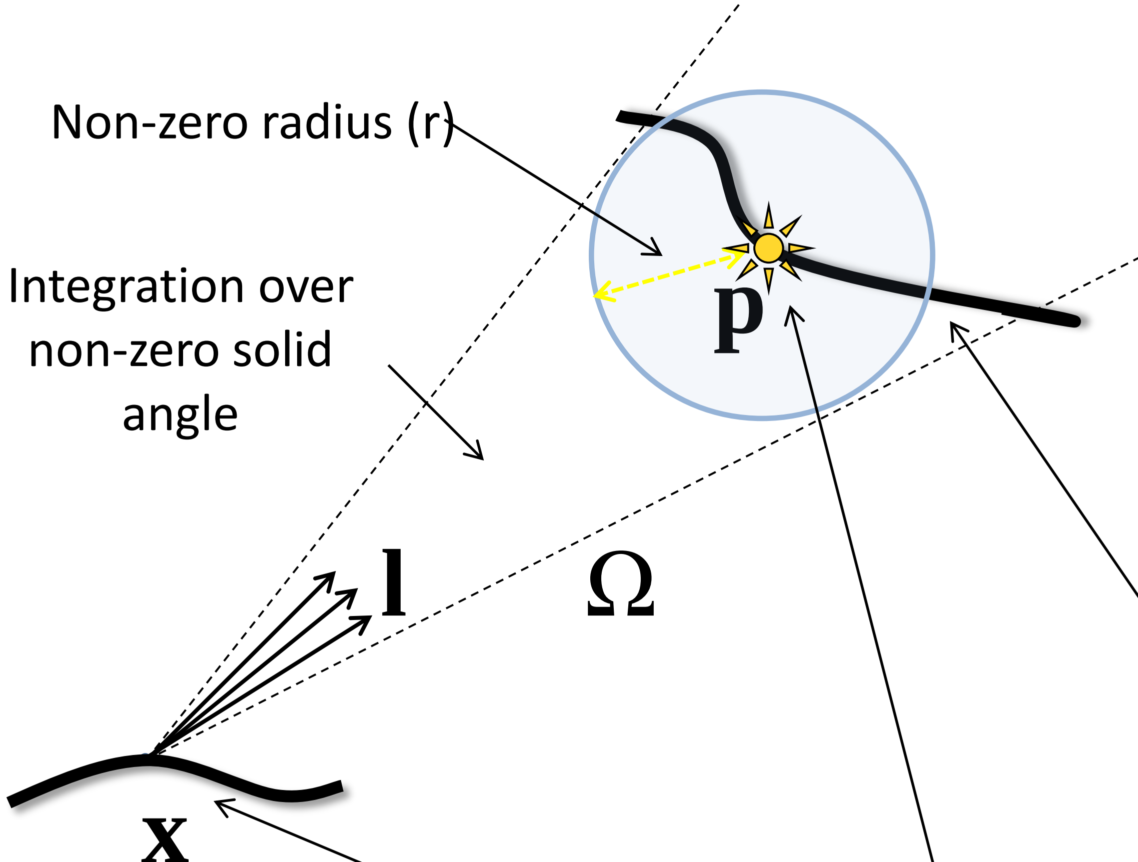
$$\frac{\Phi}{\pi r^2}\int_{\Omega} f_r(\mathbf{x})\cos\theta_{\mathbf{x}}\; f_r(\mathbf{y})\;(\|\mathbf{p}-\mathbf{y}\|<r)\,\mathrm{d}\mathbf{l}$$

Simplifying Assumptions



- Constant in Ω:
  - Visibility
  - Surface normal
  - Light BRDF
- Taken from **p**, the light location

Light Contribution Updated



$$V\,\frac{\Phi}{\pi r^2}\int_{\Omega} f_r(\mathbf{x})\cos\theta_{\mathbf{x}}\; f_r(\mathbf{p})\; \cos\theta_{\mathbf{p}}\,\mathrm{dl}$$

Virtual Spherical Light

- Allow local computation (x and p)
- Can be implemented in a GPU shader
- Can use shadow maps

Outline

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- New Method: Virtual Spherical Lights (VSLs)
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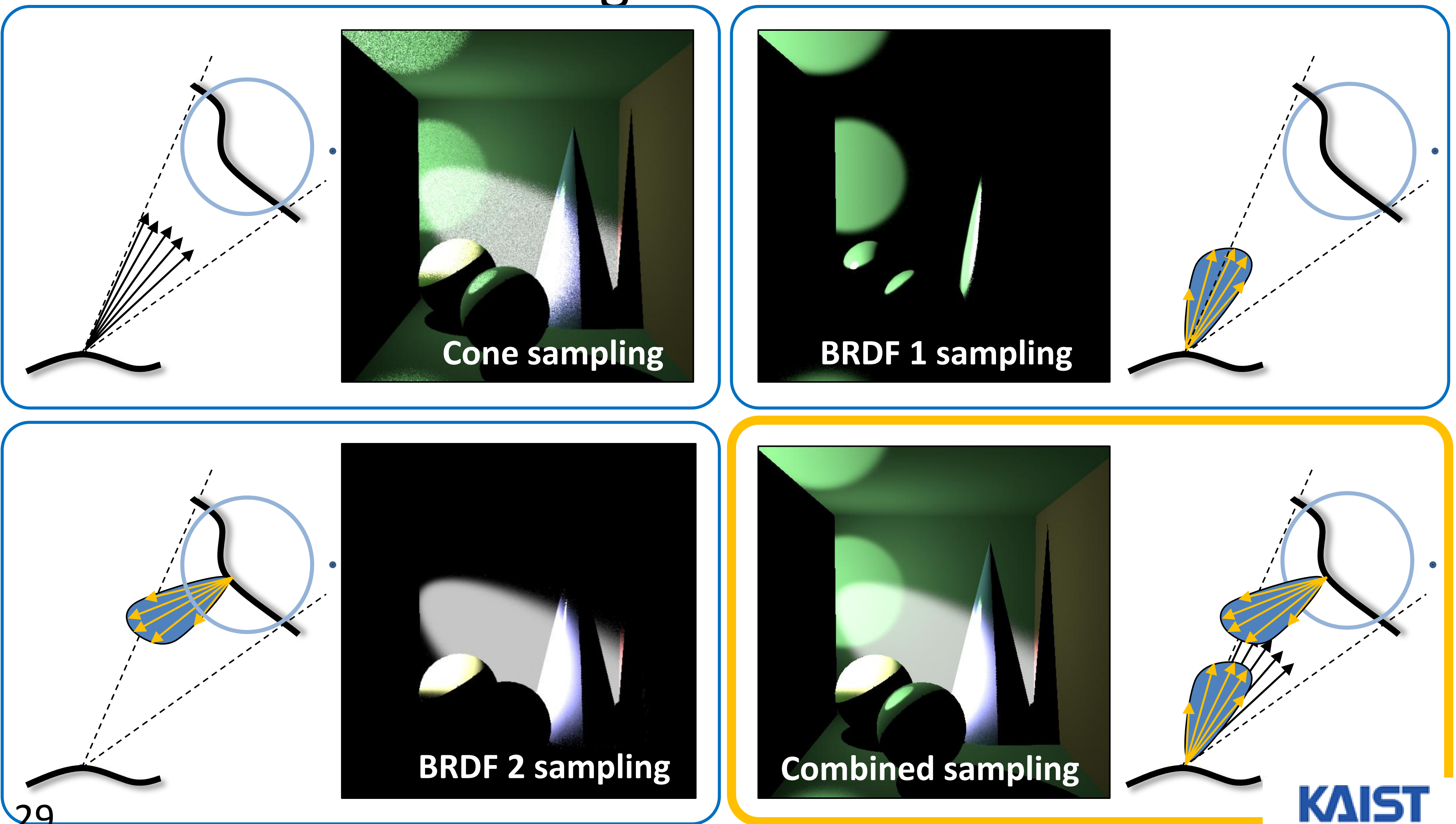
Computing the VSL integral

- Monte Carlo integration



Implementation

- Matrix row-column sampling [Miloš Hašan, Fabio Pellacini, Kavita Bala. 2007]
  - Shadow mapping for visibility
  - VSL integral evaluated in a GPU shader
- Need more lights than in diffuse scenes
- VSL radius proportional to local VSL density
  - determined by k-NN queries

Outline

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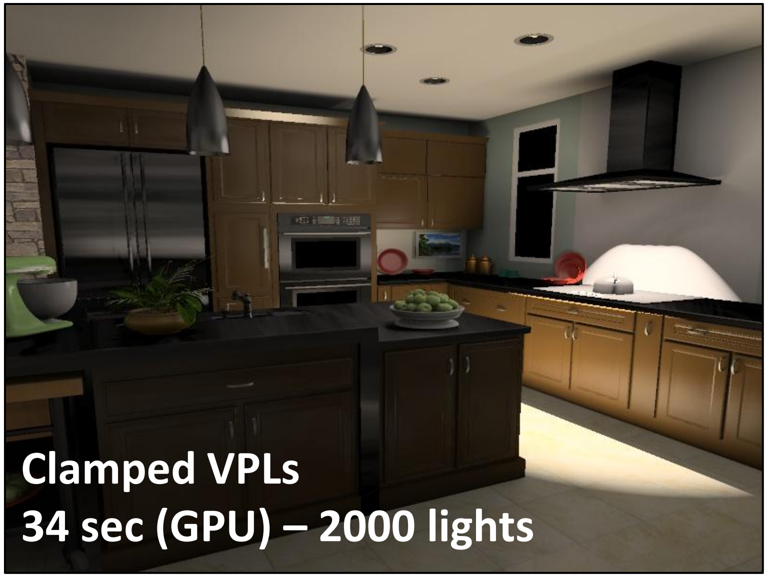
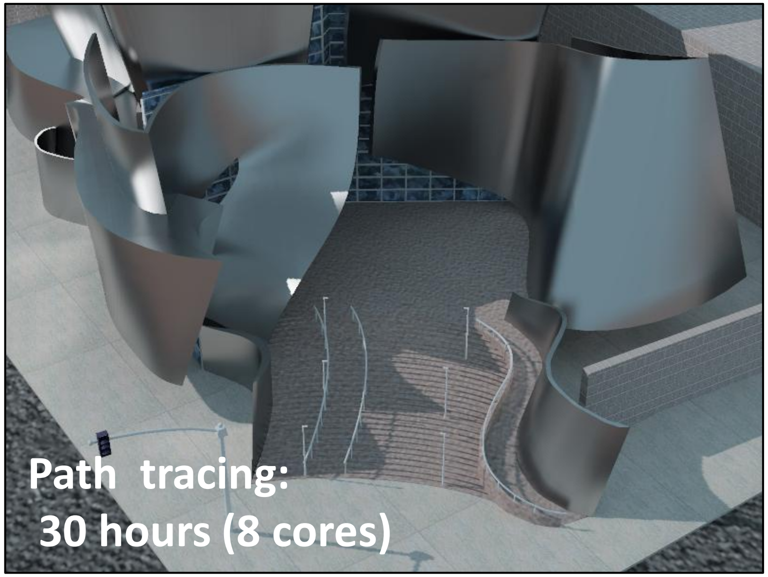
Results: Kitchen

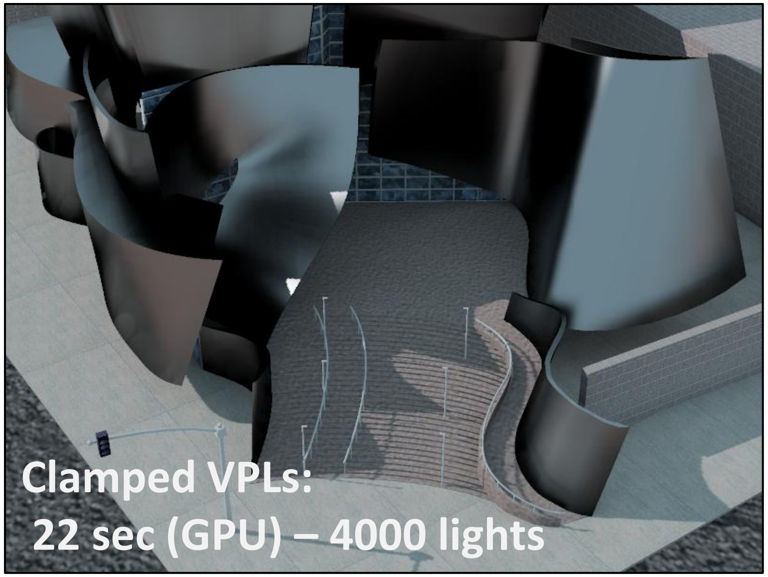
- Most of the scene lit indirectly
- Many materials glossy and anisotropic

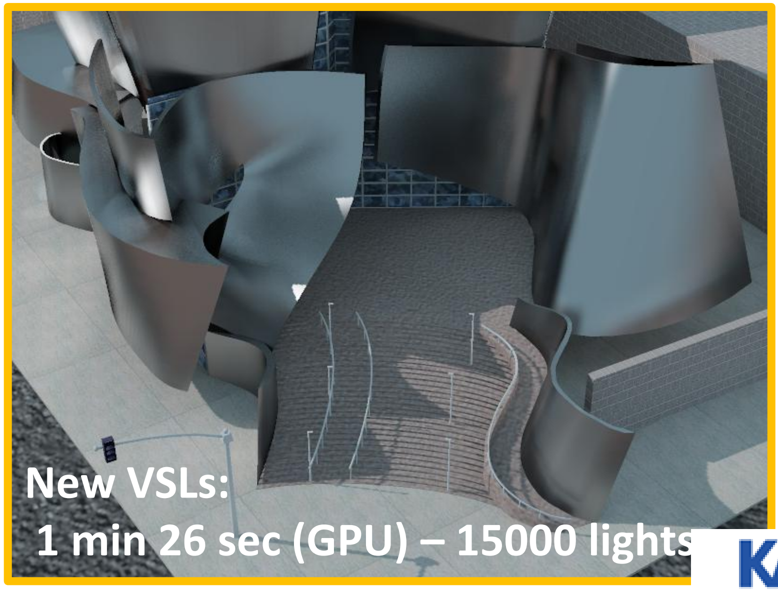


Results: Disney Concert Hall

- Curved walls with no diffuse component
- Standard VPLs cannot capture any reflection from walls







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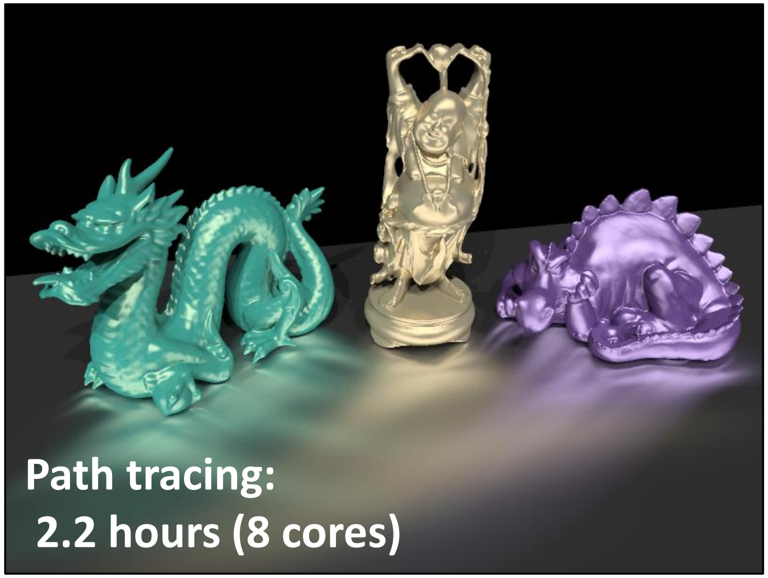
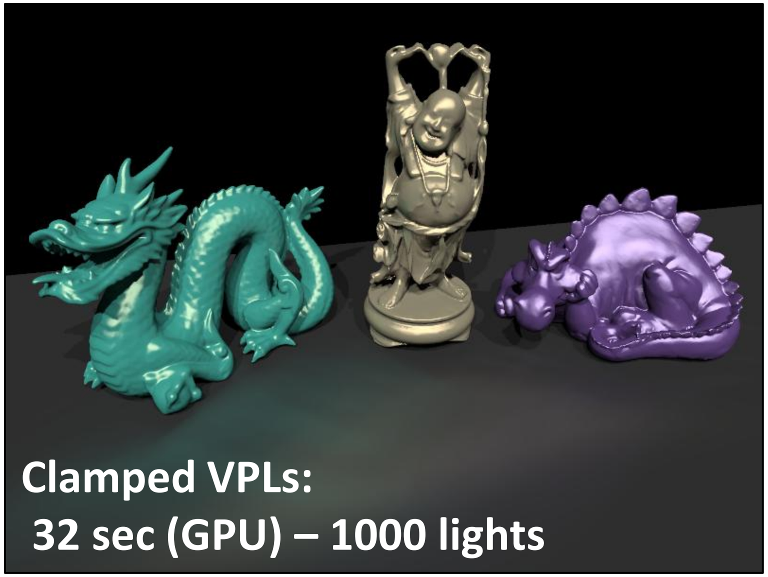
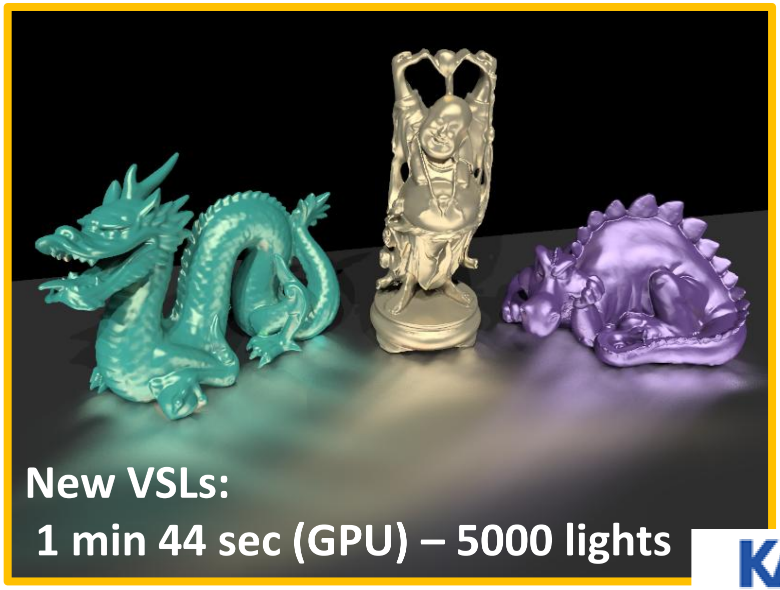
Results: Anisotropic Tableau

- Difficult case
- Standard VPLs capture almost no indirect illumination







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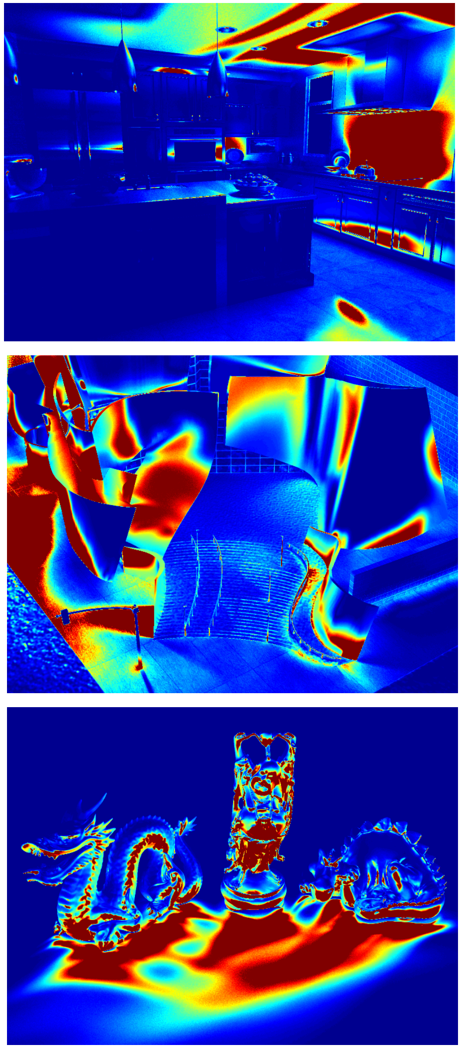
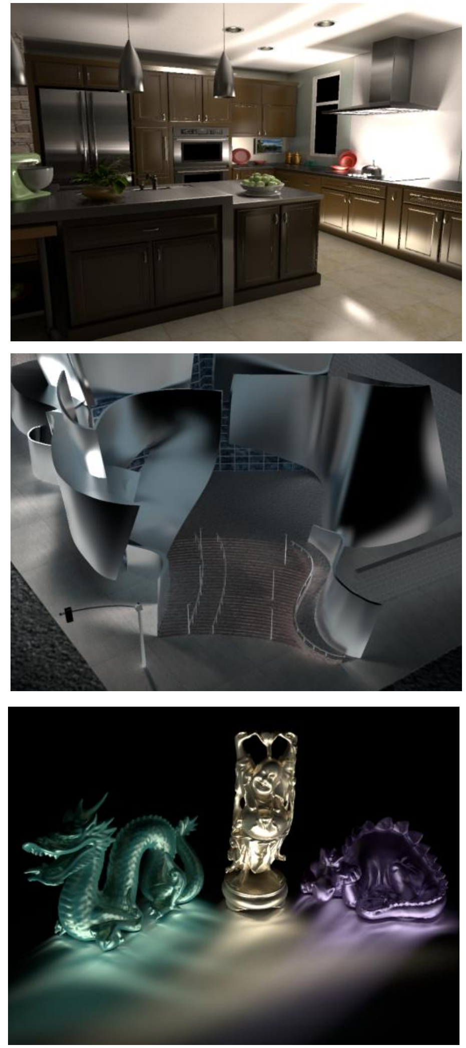
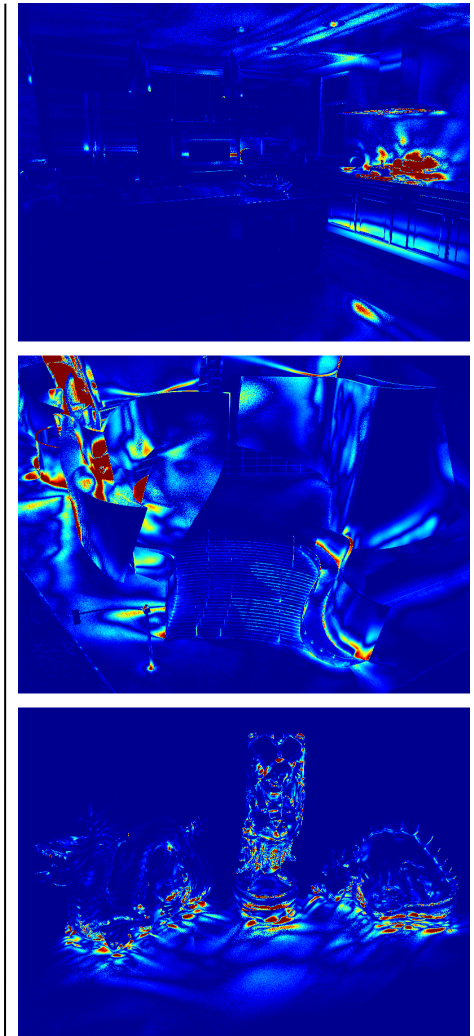
Error Images (Indirect Only)



VPL error
(previous work)



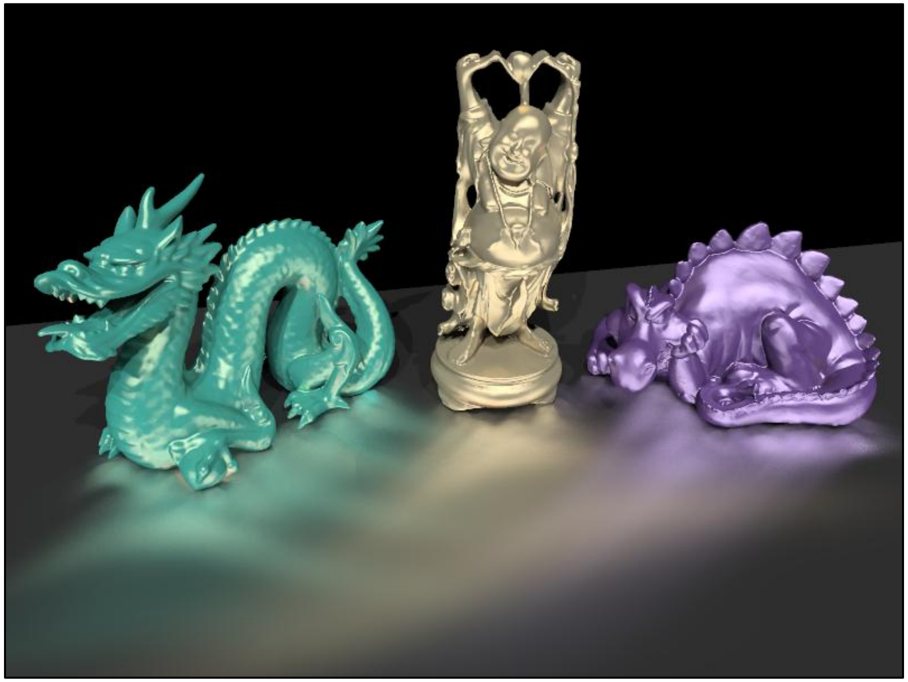
Ground truth



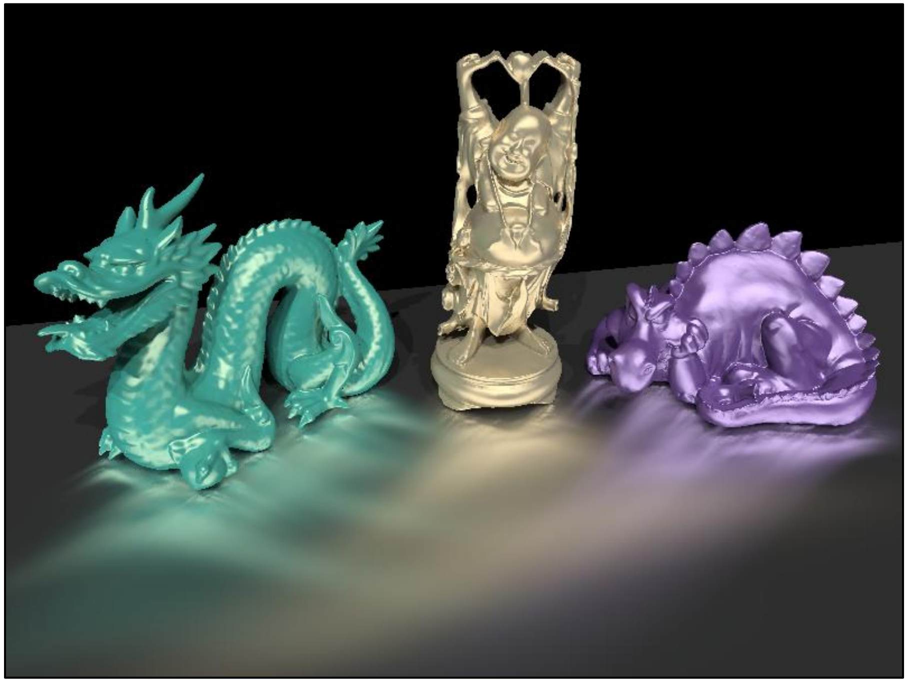
VSL error
(our method)

Limitations: Blurring

- VSLs can blur illumination
- Converges as number of lights increases



5,000 lights - blurred

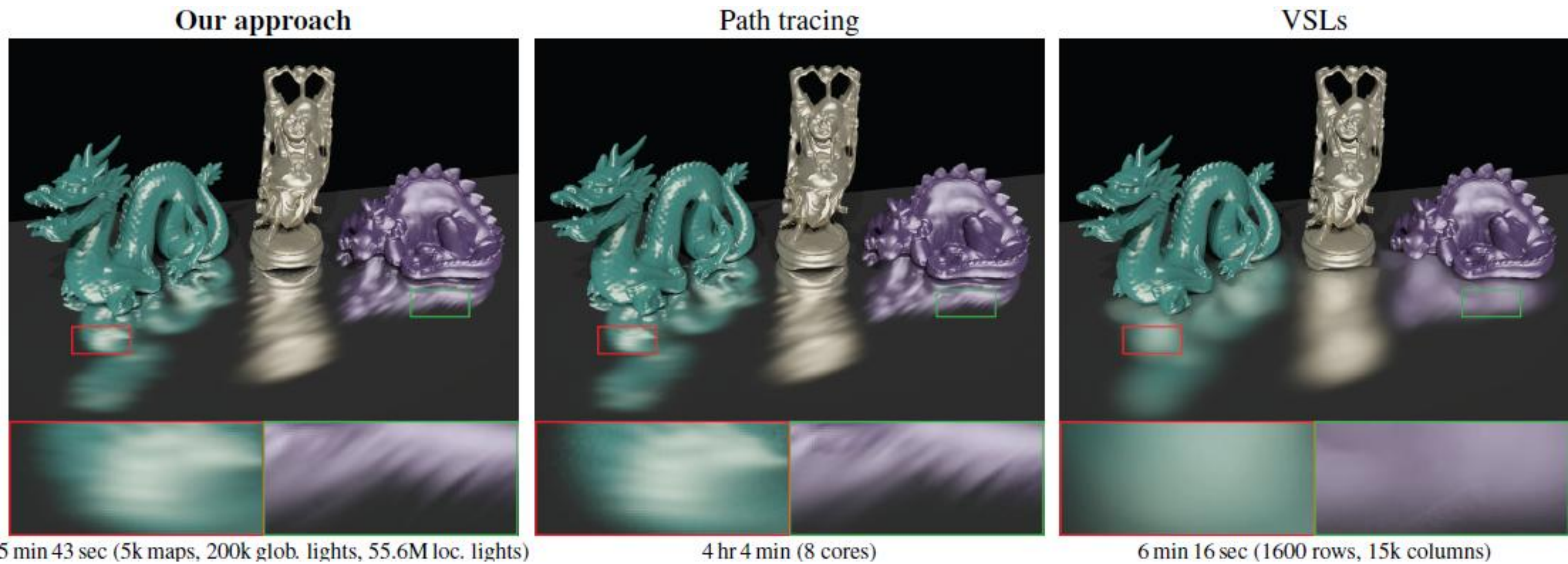


1,000,000 lights - converged

Other Limitations

- Some remaining corner darkening
- Computation overhead

Better solution?

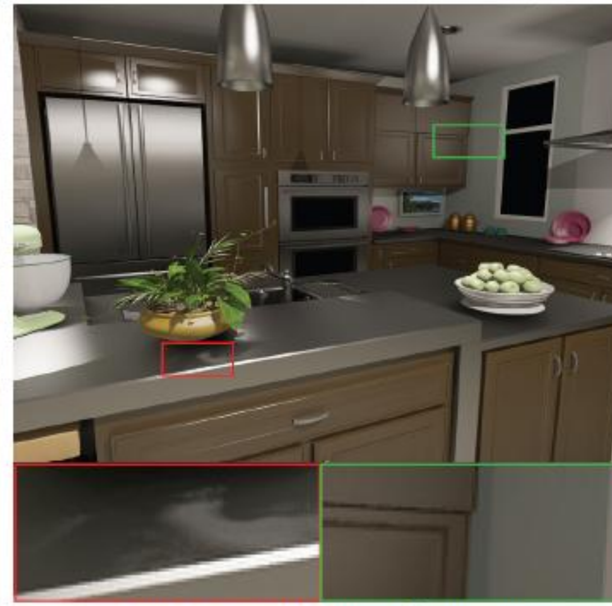


[Combining Global and Local Virtual Lights for Detailed Glossy Illumination]
ACM SIGGRAPH Asia '10
by Tomas Davidovic, **Jaroslav Krivanek, Milos Hasan**, Philipp Slusallek, **Kavita Bala**.

Better solution?

4 min 16 sec (10k maps, 100k glob. lights, 25.1M loc. lights)

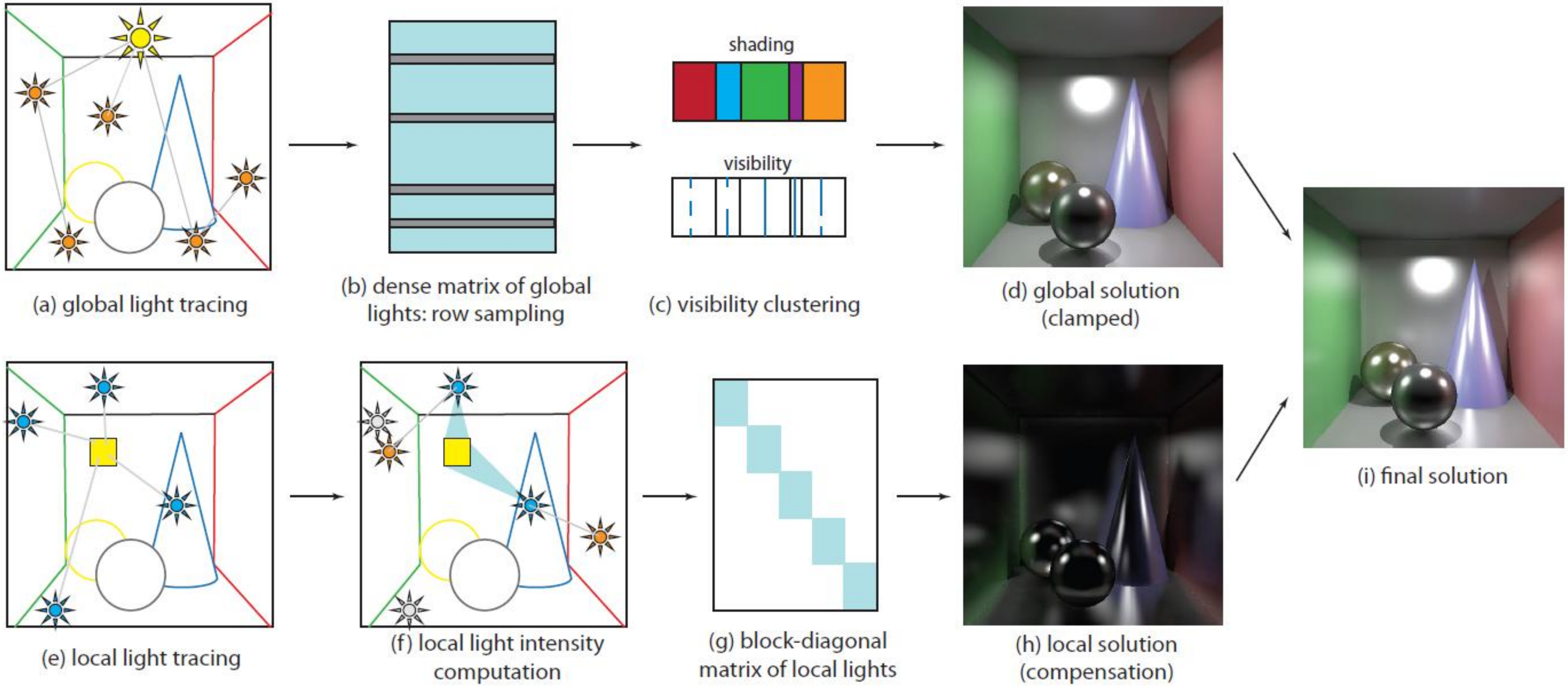
55 hr 43 min (8 cores)



4 min 24 sec (1024 rows, 10k columns)

Better solution?

Better solution?

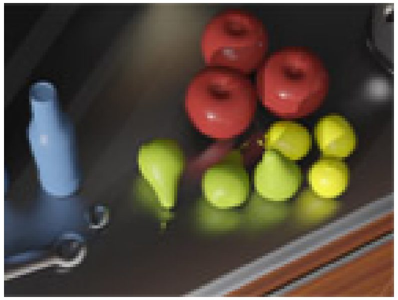


Conclusion

- Virtual Spherical Lights
  – No spikes, no clamping necessary
  – Solve illumination loss of VPL

- Many-light methods + VSLs:
  – A step to solve the glossy inter-reflection problem

Journal, Conference, and Workshop papers



Tomas Davidovic, Jaroslav Krivanek, Milos Hasan, Philipp Slusallek, **Kavita Bala**.
Combining Global and Local Virtual Lights for Detailed Glossy Illumination
SIGGRAPH Asia '10
December 2010, Seoul
Project, Supplementary Material, Bibtex

Jaroslav Krivanek, James Ferwerda, **Kavita Bala**.
Effects of Global Illumination Approximations on Material Appearance
SIGGRAPH '10
July 2010, LA
Project, Supplementary Material, Bibtex

Virtual Spherical Lights for Many-Light Rendering of Glossy Scenes

We want to compute Illumination for glossy Scene

Prob: Unbiased technics are too slow

↓

We want to use fast/ biased methods Such as VPL

Prob: artefacts appear in VPL location

↓

We clamp the contributions of VPL(s) And restrict to diffuse only

Prob: loose of glossy illumination which change material appearance

↓

We try compensation of missing components by path tracing (*Kollig and Keller)*

Prob: it's too noisy, as slow as PT from scratch to converge

→

We create a new Type of light : Virtual Spherical Light

We use the photon contribution equation slightly modified to render over a non-zero solid angle.

First solution to render glossy scenes