Many-Light Rendering

Digital Image Synthesis

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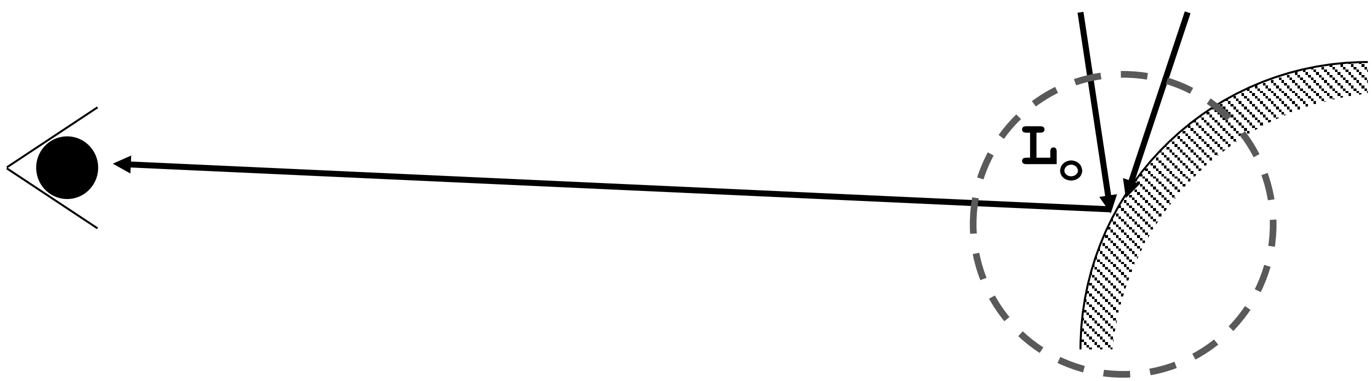
Surface integrators

- Remember the radiance can be estimated by solving the rendering equation:

$$L_o(\mathrm{p},\omega_\mathrm{o}) = L_e(\mathrm{p},\omega_\mathrm{o}) + \boxed{\int_{S^2} f(\mathrm{p},\omega_\mathrm{o},\omega_\mathrm{i}) L_i(\mathrm{p},\omega_\mathrm{i}) \left|\cos\theta_\mathrm{i}\right| \, d\omega_\mathrm{i}}$$

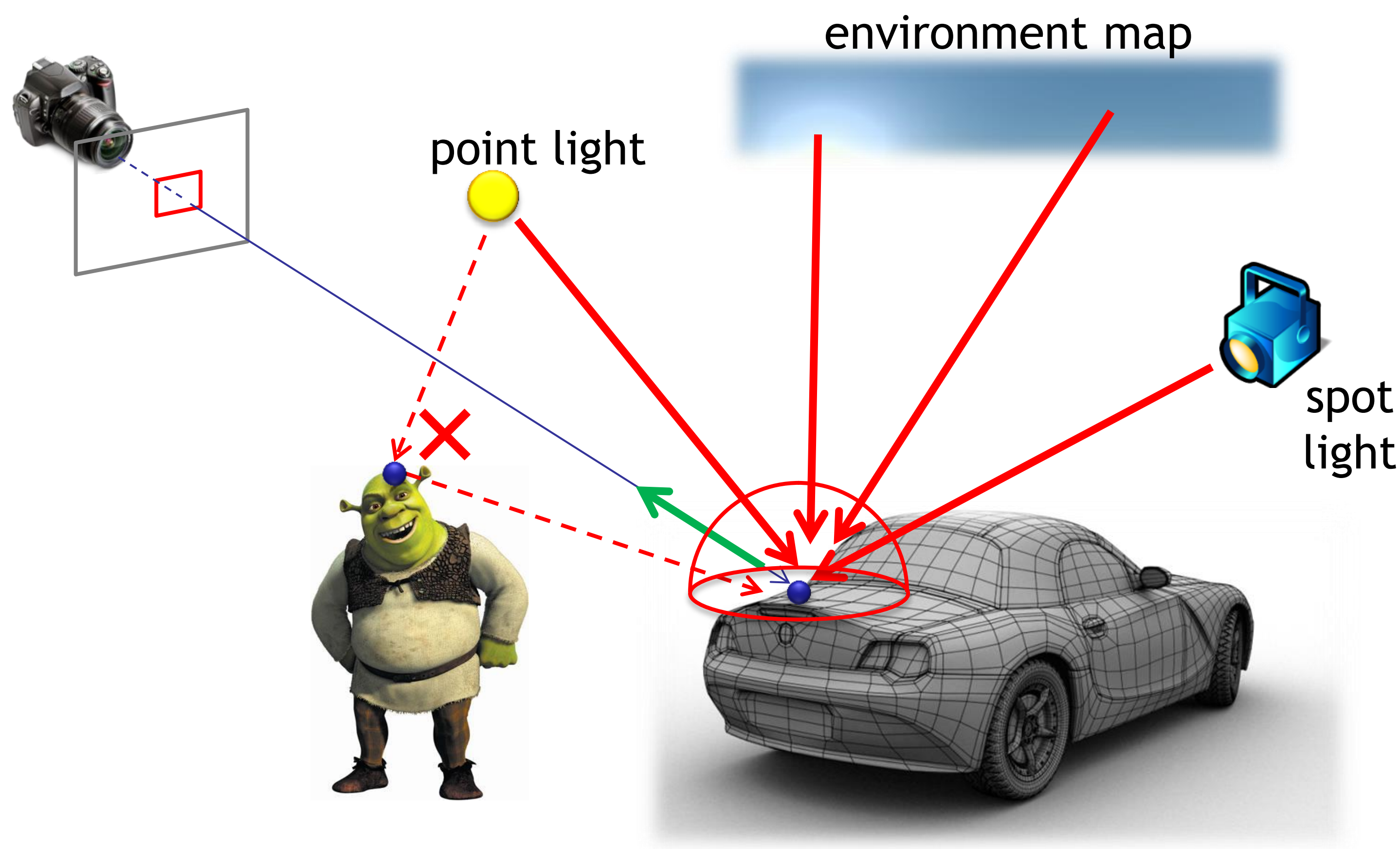


- Surface integrators are responsible for approximating the integral

Direct lighting

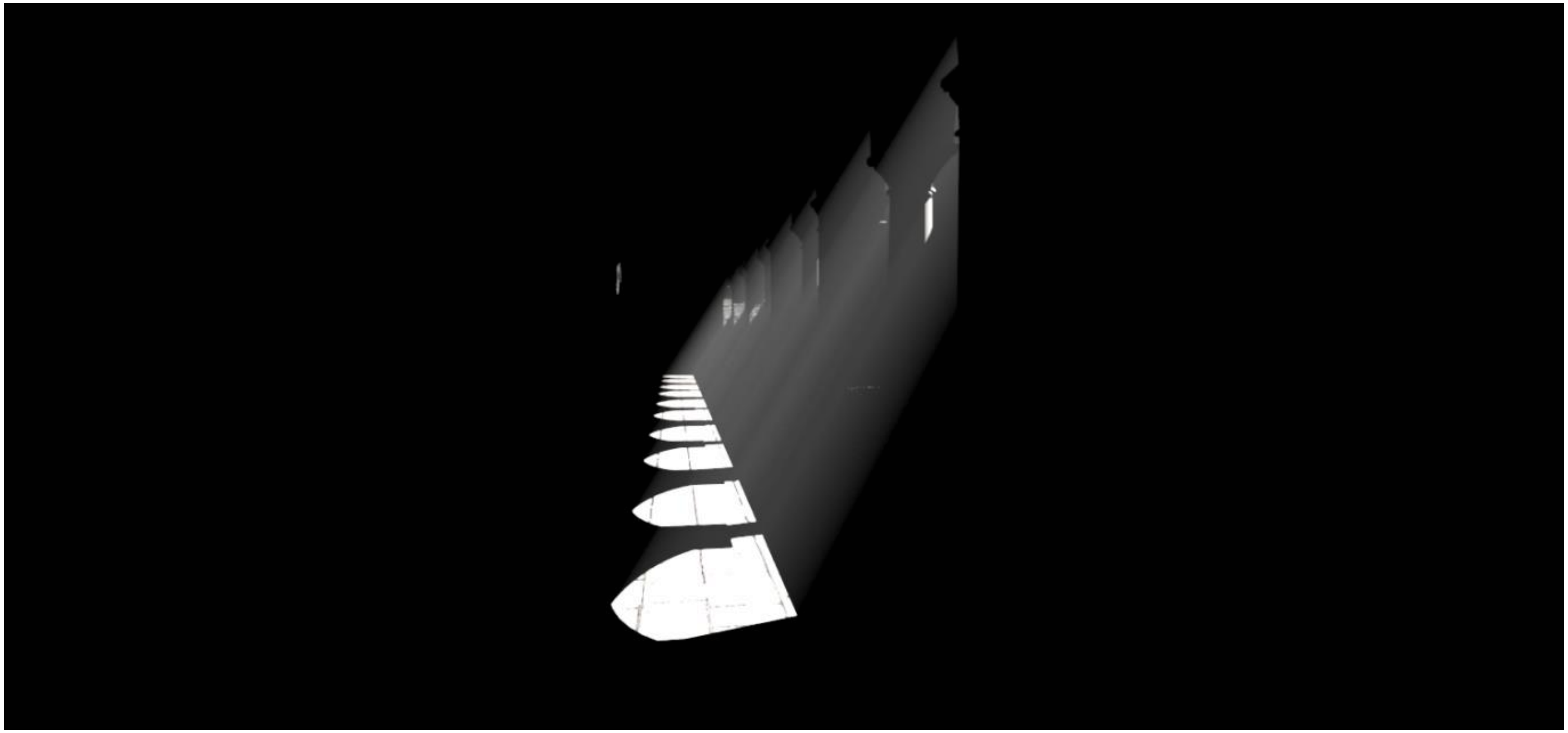
- The simplest surface integrator: direct lighting

$$L_o(p,\omega_o) = L_e(p,\omega_o) + \int_{\Omega} f(p,\omega_o,\omega_i)\boxed{L_d}(p,\omega_i)\,|\cos\theta_i|\,d\omega_i$$



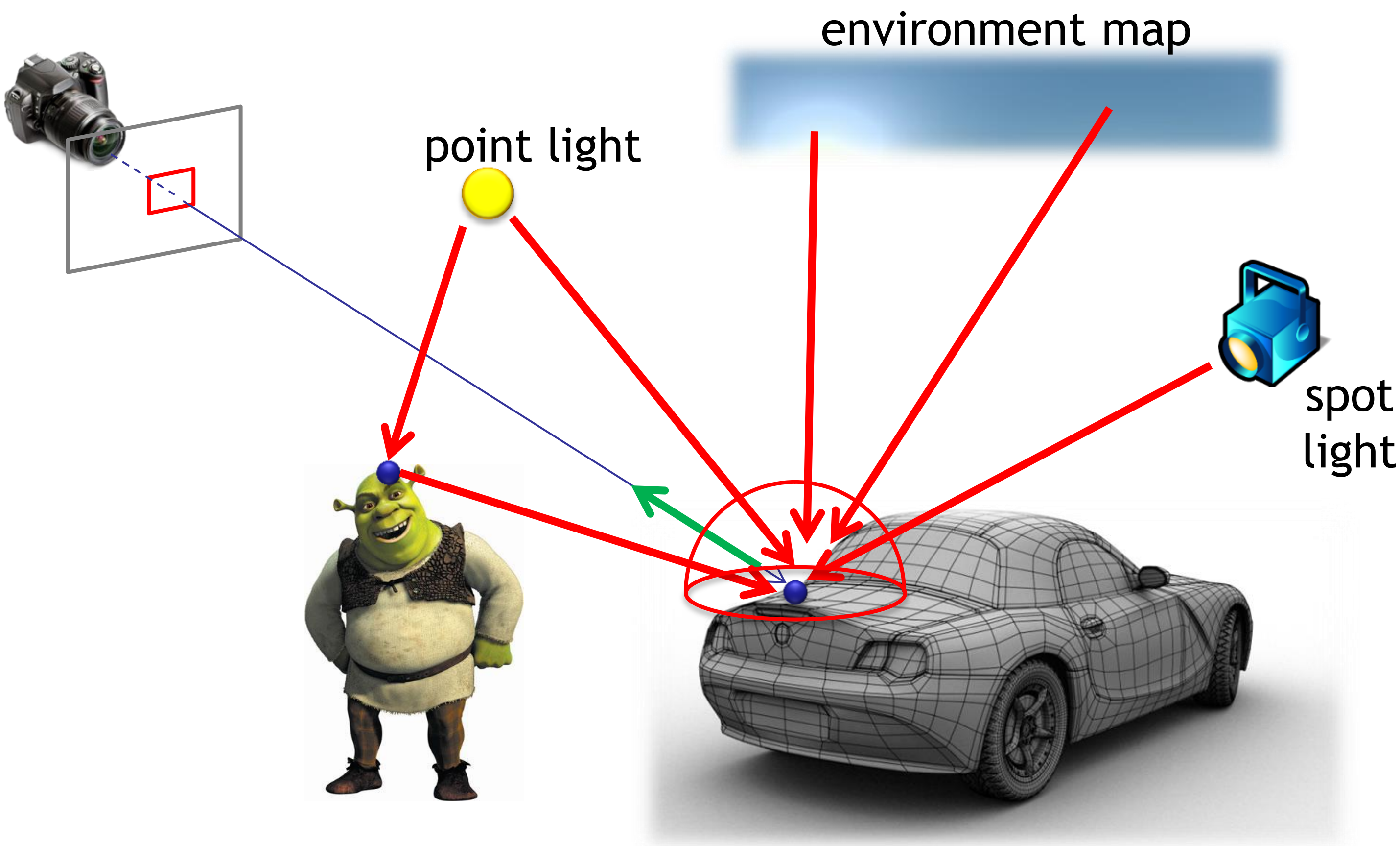
Direct lighting

- For high-quality rendering, simulating direct lighting only is not enough



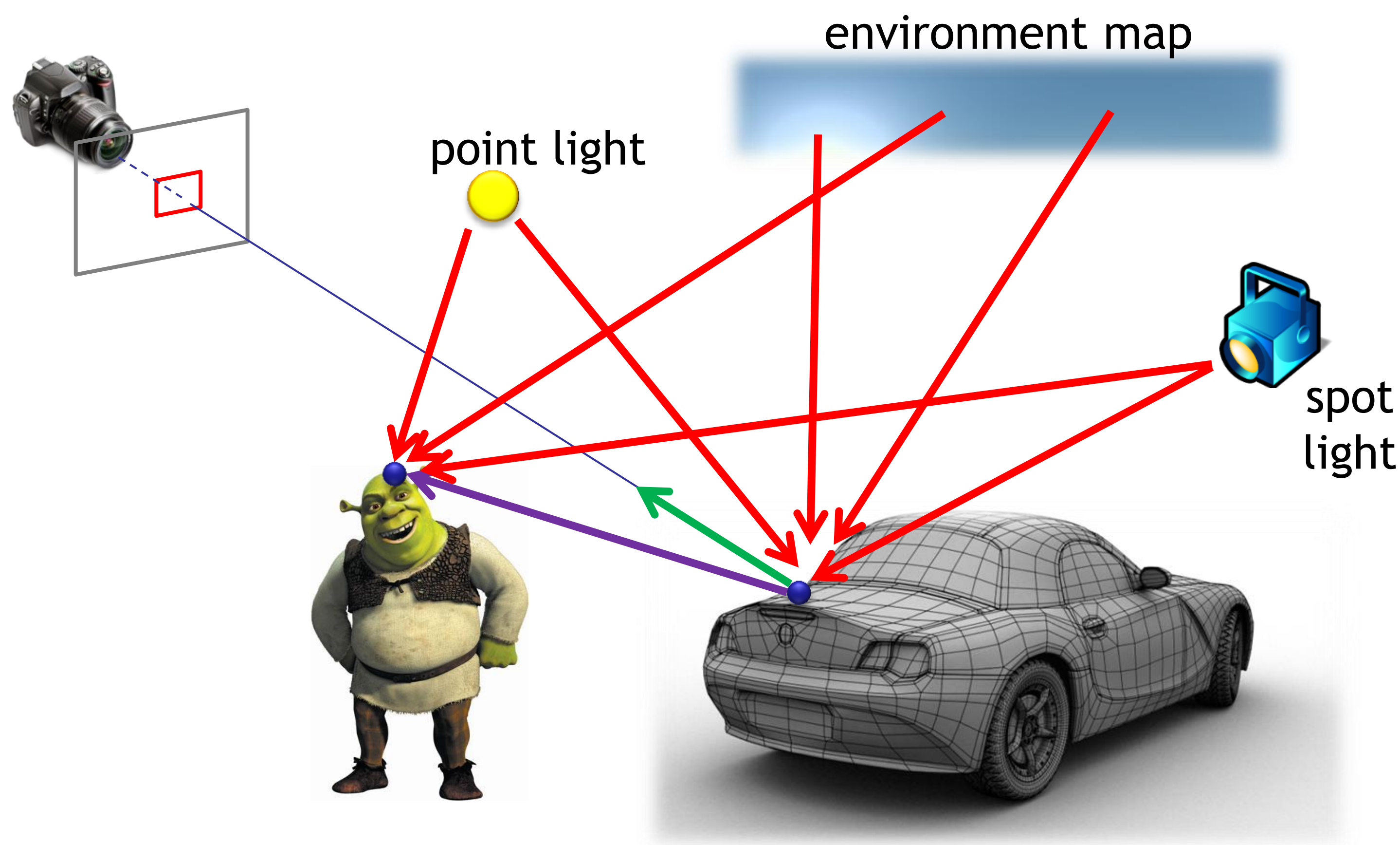
Global illumination

- Simulate light paths with multi-bounce
- The number of rays increase exponentially



Path tracing

- The most common surface integrator for global illumination
  - Recursively trace radiance rays



Comparison

- Path tracing

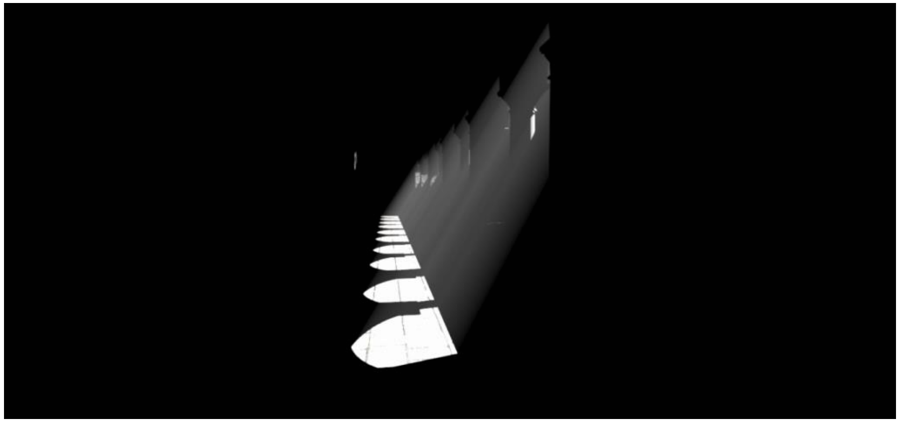
8 samples per pixel

Comparison

- Path tracing

1024 samples per pixel

Comparison



Direct lighting
(several seconds)

Path tracing (1024 spp)
(several hours)

- Path tracing produces beautiful images, but it converges slowly
- In the following, we will introduce the many-light rendering, a more efficient method for visually-pleasing global illumination

Rendering with virtual point lights

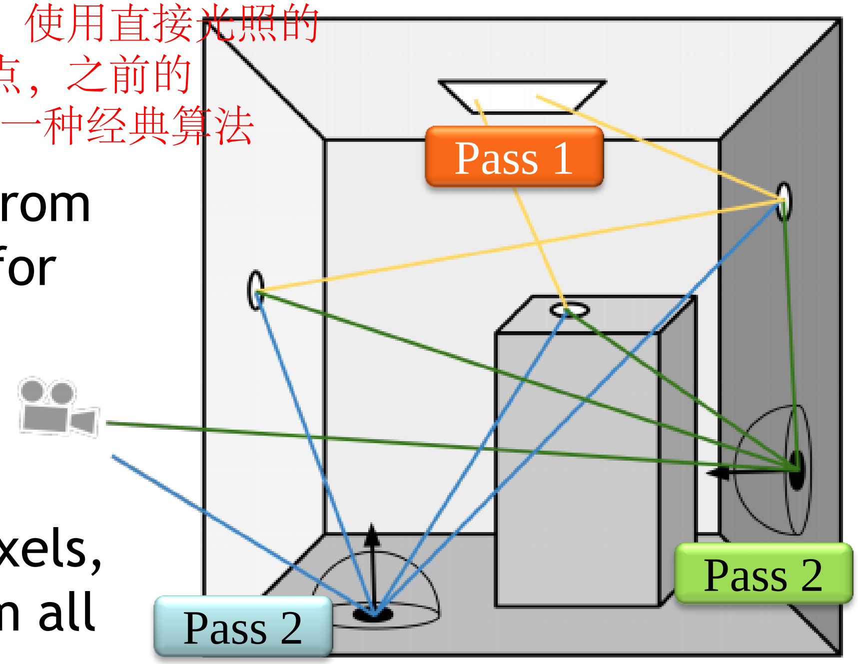
- First introduced in “Instant Radiosity” [Keller ‘1997]
- Two-pass approach

虚拟啊点光源的核心思想：使用直接光照的区域作为间接光照的光源点，之前的Reflective Shadow Maps就是一种经典算法

Pass I:
Trace virtual point lights (VPLs) from light sources (attached in scene for indirect illumination)

Pass II:
For each surface seen through pixels, gather lighting contributions from all virtual point lights

$$L(x,\omega_o) = \sum_{x_i \in S} contrib.\mathrm{VPL}(i)$$



virtual point light (VPL)

shading point w.r.t. pixel sample

Many-Light Rendering

- Later, VPL is also used to represent complex illumination, such as large area lights or environment lighting
  - Sample lights uniformly on env.map and area lights

Environment lighting
[Hasan et al. 2007]

Texture lights and indirect illumination
[Walter et al. 2005]

Rendering with virtual point lights

- Convert the illumination in scene into a large set of virtual point lights (Pass I)

第一步：将场景中得到照明转换成大量点光源

Environment lights, area lights, and indirect illumination

100000 VPLs

Rendering with virtual point lights

- For each pixel, gather all VPL's contributions (Pass II) 第二步：对于每个像素点，累计全部虚拟点光源的贡献

=

$\sum($  $)$

100000 VPLs

Virtual point lights

- Advantages of VPL-based (many-light) methods:
  - All types of illumination can be gathered with an unified approach
    - Indirect illumination
    - Large (textured) area lights
    - Environment lights
  - Low-noise property
  - Easier control of quality and performance

Real-time applications | *performance-quality tradeoff* | Off-line applications

Fewer VPLs | More VPLs

Rough (or none) visibility | Ray-traced visibility

Survey paper for Many-Light rendering

- Scalable Realistic Rendering with Many-Light Methods
  - C. Dashsbacher, J. Krivanek, M. Hasan, A. Arbree, B. Walter, J. Novak
  - Eurographics State of the Art Reports 2013

- Many-Light papers are classified into several categories according to their goals, performance, and capabilities

Challenges in Many-Light Rendering

- Complex scenes usually require a large number of VPLs for detailed illumination
  - For example, 100K – 500K
- It will be impractical to directly summing contributions from all lights

Museum scene from “LightSlice”
1024 x 1024 x 9 shading points
1.5 M triangles
153 K VPLs

brute-force gathering = hundreds of hours !

What’s for today

- Brief introduction to three SIGGRAPH papers for scalable many-light rendering

Lightcuts: a Scalable Approach to Complex Illumination
B. Walter, S. Fernandez, A. Arbree, K. Bala, M. Donikan, D. P. Greenberg
SIGGRAPH 2005

Matrix Row-Column Sampling for the Many-Light Problem
M. Hasan, F. Pellacini, K. Bala
SIGGRAPH 2007

LightSlice: Matrix Slice Sampling for the Many-Light Problem
J. Ou and F. Pellacini
SIGGRAPH Asia 2011