

BIDIRECTIONAL PATH SAMPLING TECHNIQUES

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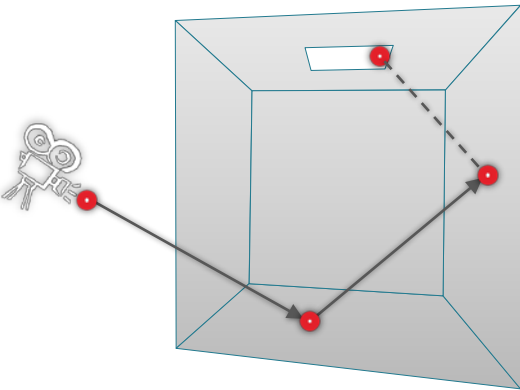
<http://cgg.mff.cuni.cz/~jaroslav/>



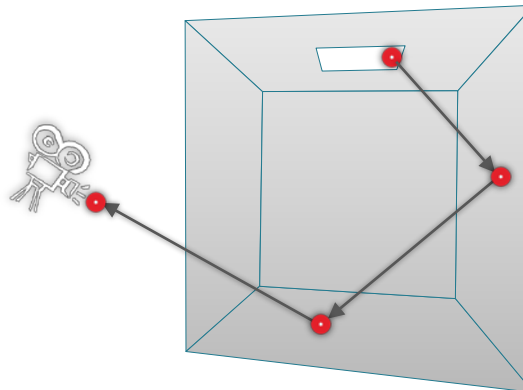
Bidirectional path sampling

- Algorithms = different path sampling techniques

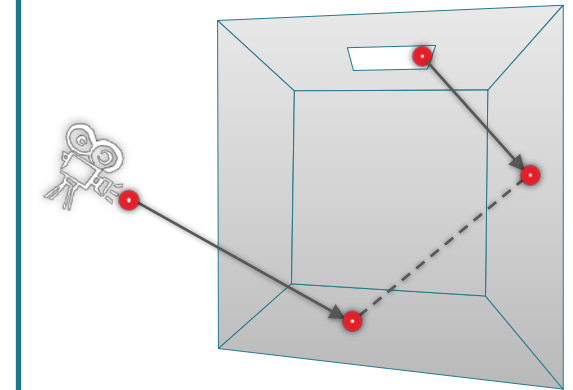
Path tracing



Light tracing



Bidirectional path tracing



VPL RENDERING

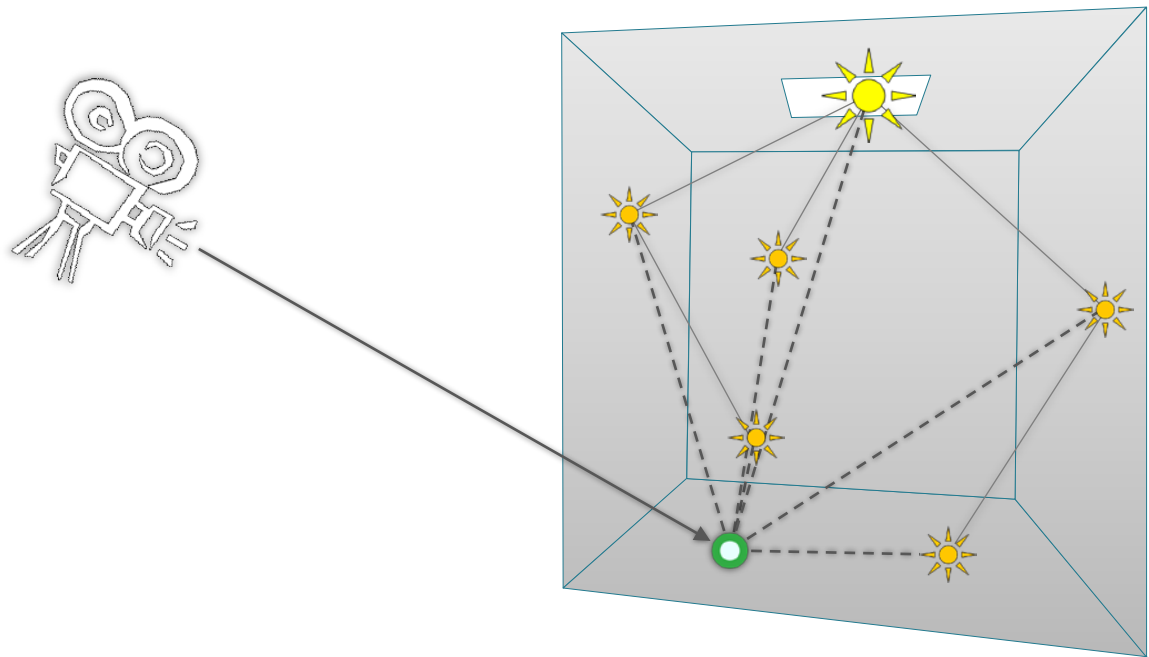
**AS A PATH SAMPLING
TECHNIQUE**



Instant radiosity – VPL rendering

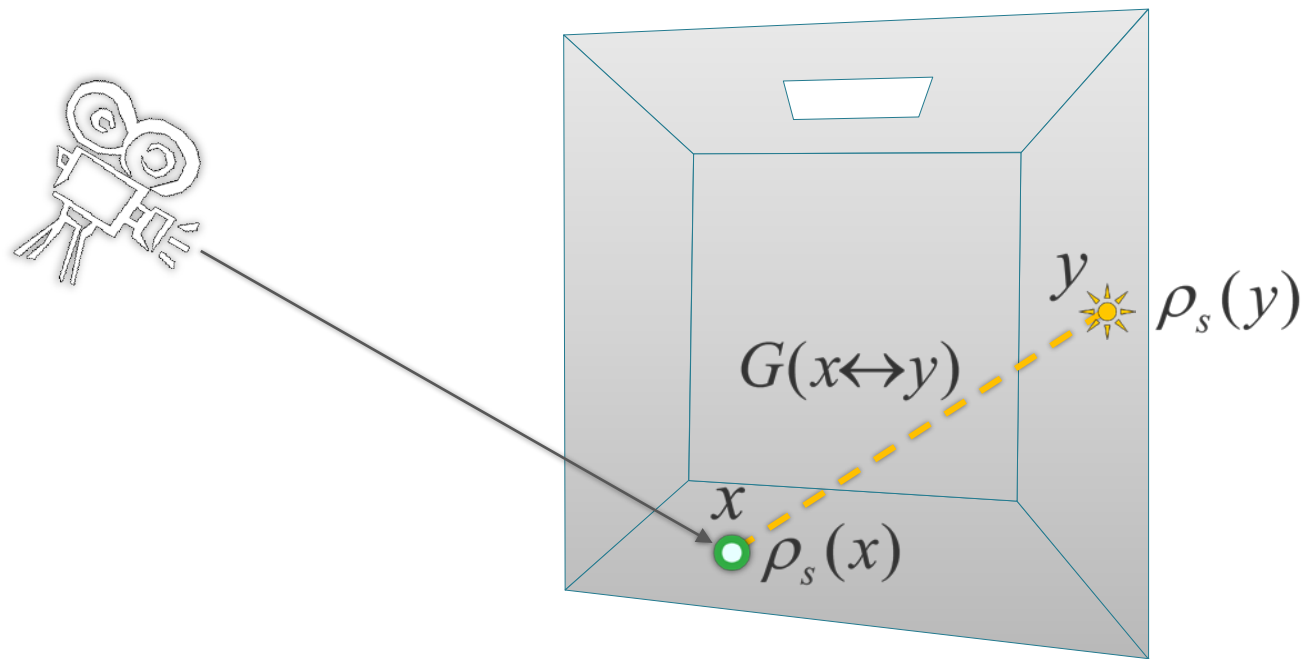
[Keller 1997]

1. **Distribute VPLs**
2. **Accumulate VPL contributions**

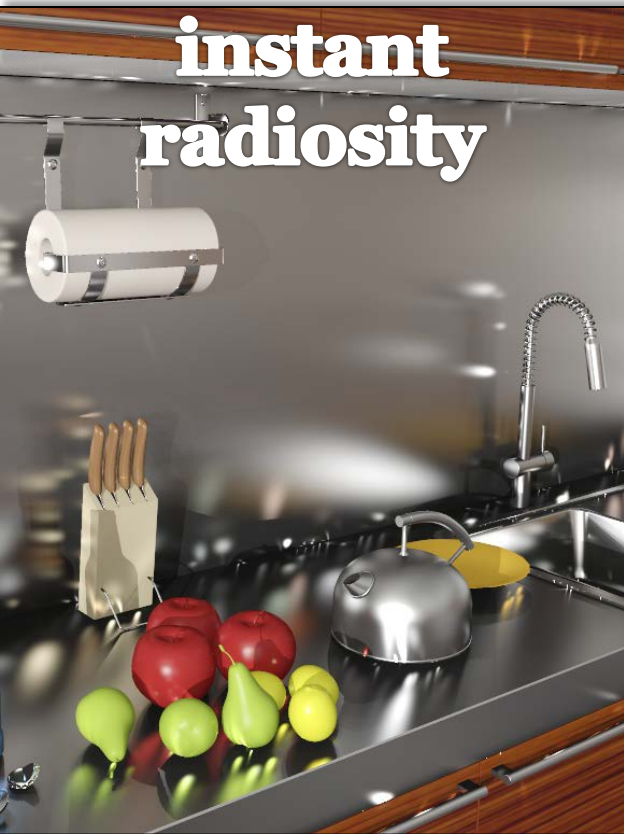


VPL contribution

- High values for spiky BRDFs
- Diverges as $\|x - y\| \rightarrow 0$



Clamping



**splotches
(variance)**

**no local light
inter-reflections**

VPL rendering as a bidirectional path sampling technique

1. Distribute VPLs

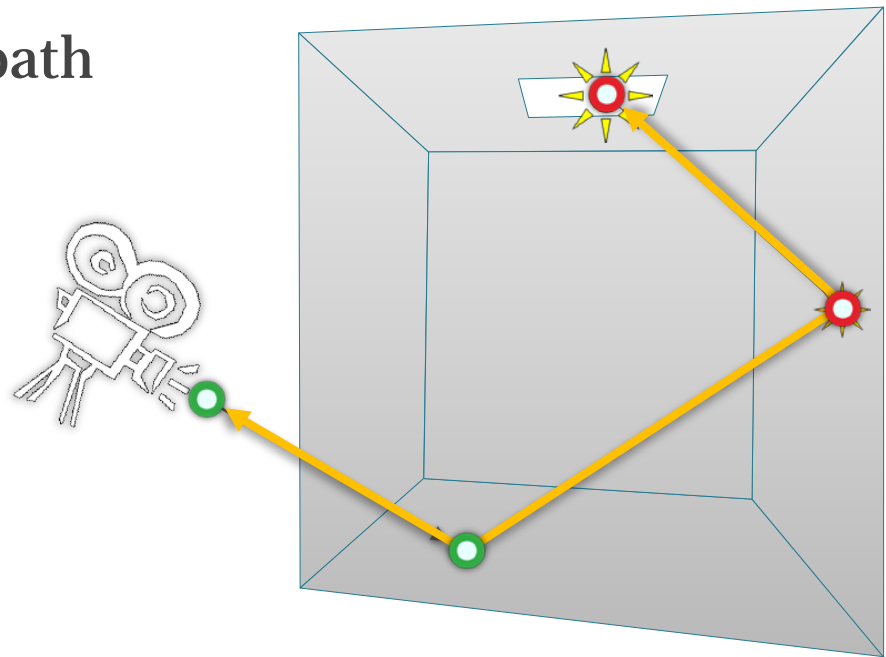
- = sample light sub-paths

2. Camera ray

- = sample camera sub-path

3. VPL contribution

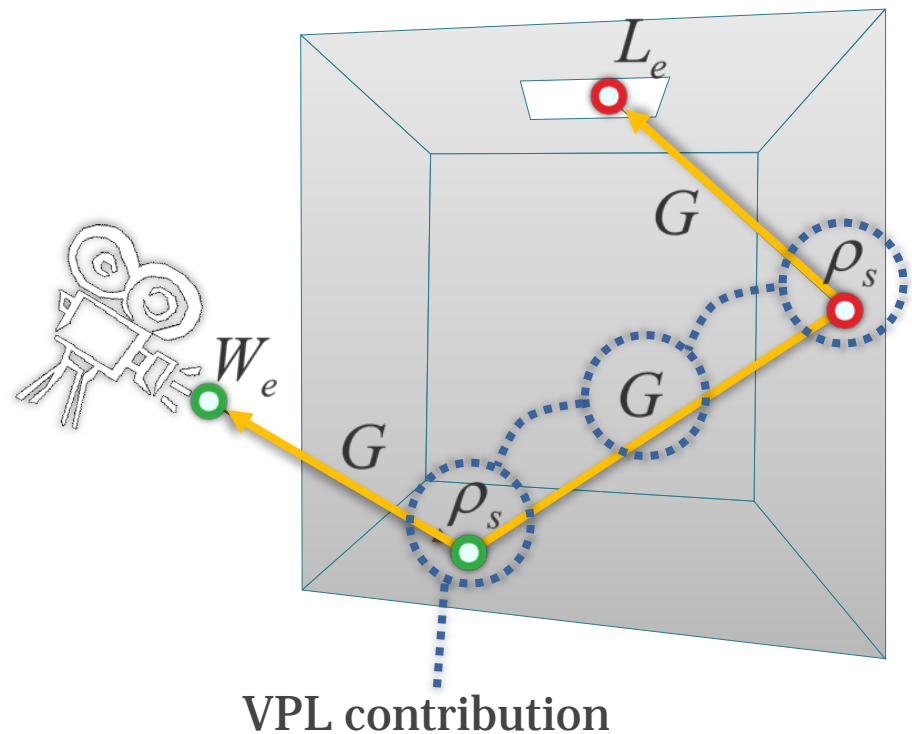
- = sub-path connection



VPL rendering as a bidirectional path sampling technique

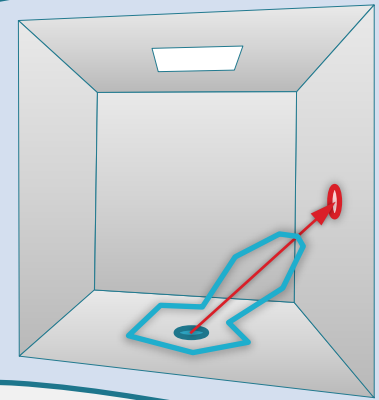
- The usual path integral **estimator**

$$\langle I_j \rangle = \frac{f_j(\bar{x})}{p(\bar{x})}$$



Digression

- Sample direction from an existing vertex

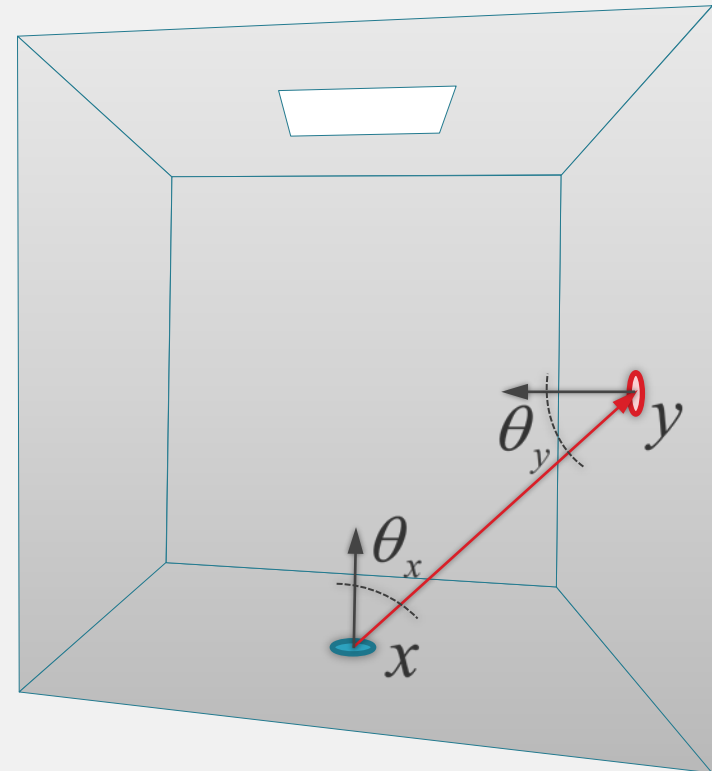


$$\underline{p(y)} = \underline{p^\perp(x \rightarrow y)} G(x \leftrightarrow y)$$

w.r.t. area

w.r.t. proj.
solid angle

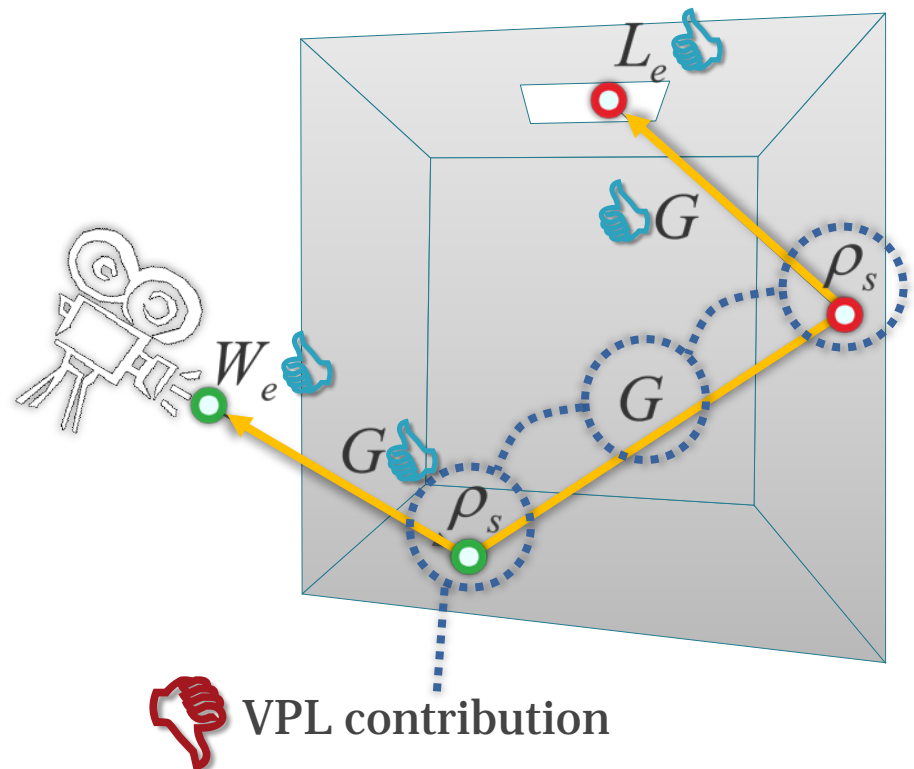
$$\langle I_j \rangle = \frac{\cdots \rho_s(x \rightarrow y) G(x \leftrightarrow y) \cdots}{\cdots p^\perp(x \rightarrow y) G(x \leftrightarrow y) \cdots}$$



VPL rendering as a bidirectional path sampling technique

- The usual estimator

$$\langle I_j \rangle = \frac{f_j(\bar{x})}{p(\bar{x})}$$



VPL rendering summary

- **VPL rendering** corresponds to a **bidirectional path sampling technique**
- Splotches = noise = variance
 - ❑ Due to **bad path sampling**
 - ❑ Correlation



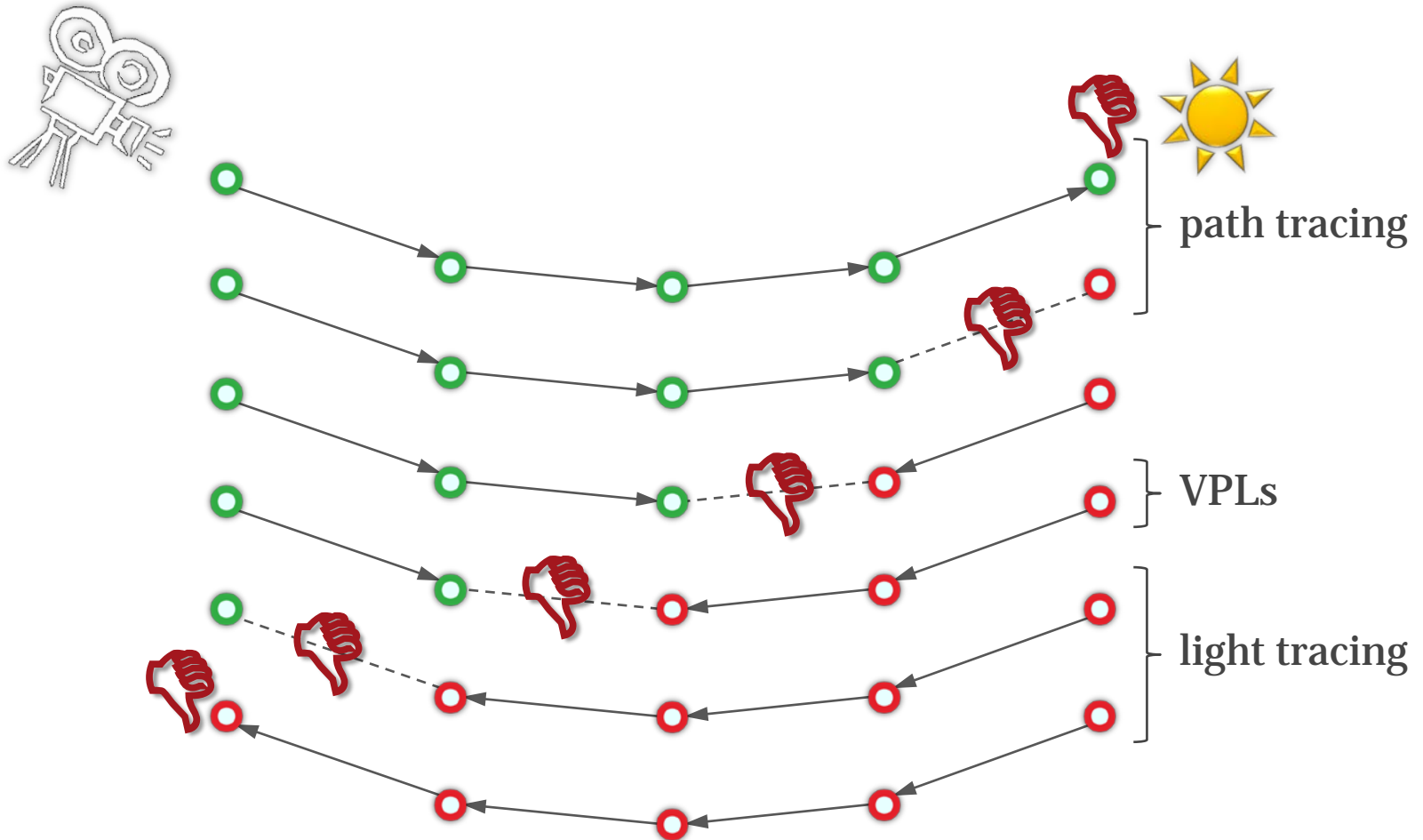
COMBINING PATH SAMPLING TECHNIQUES



All possible bidirectional techniques

○ vertex on a **light sub-path**

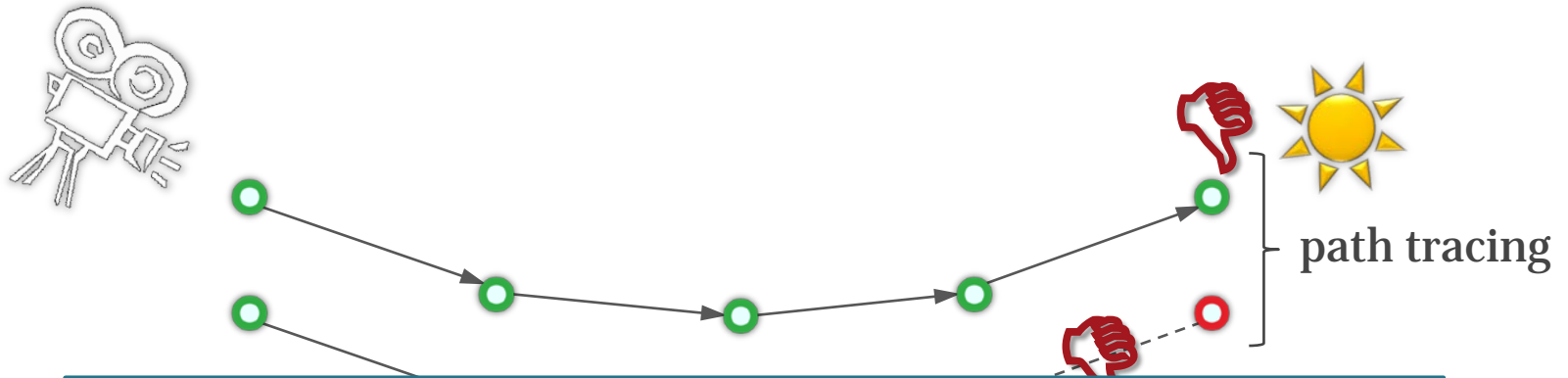
○ vertex on an **eye subpath**



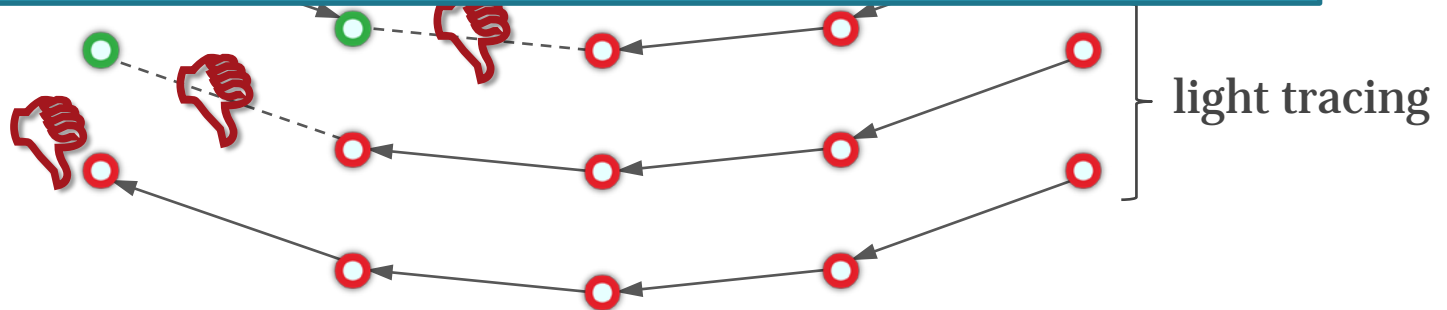
All possible bidirectional techniques

○ vertex on a **light sub-path**

○ vertex on an **eye subpath**



no single technique importance
samples all the terms

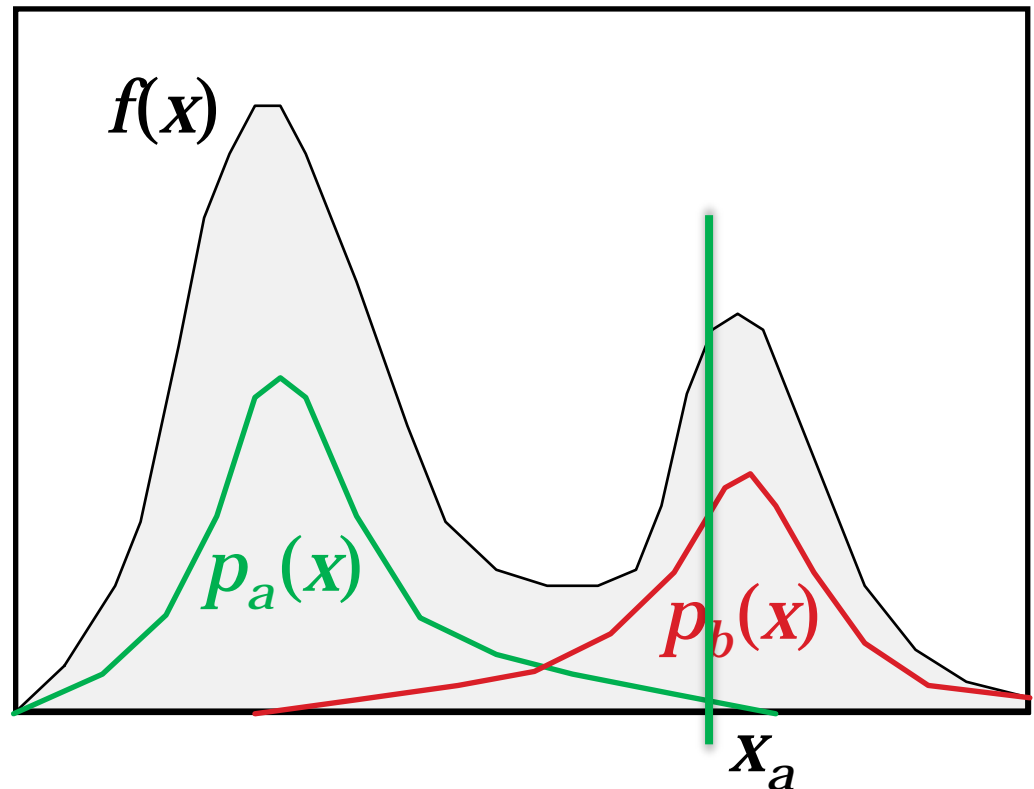


Multiple Importance Sampling (MIS)

[Veach & Guibas, 95]

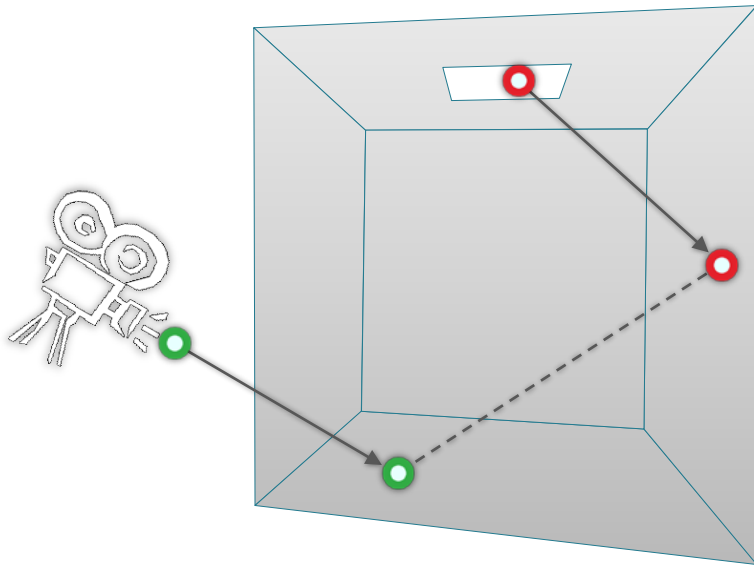
Combined estimator:

$$\langle I \rangle = \frac{f(x)}{[p_a(x) + p_b(x)]/2}$$



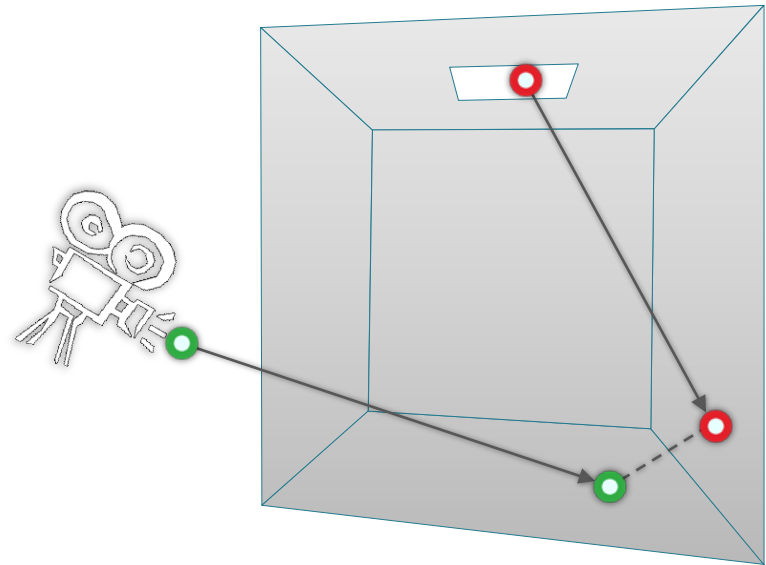
Multiple Importance Sampling (MIS)

High MIS weight



Low MIS weight

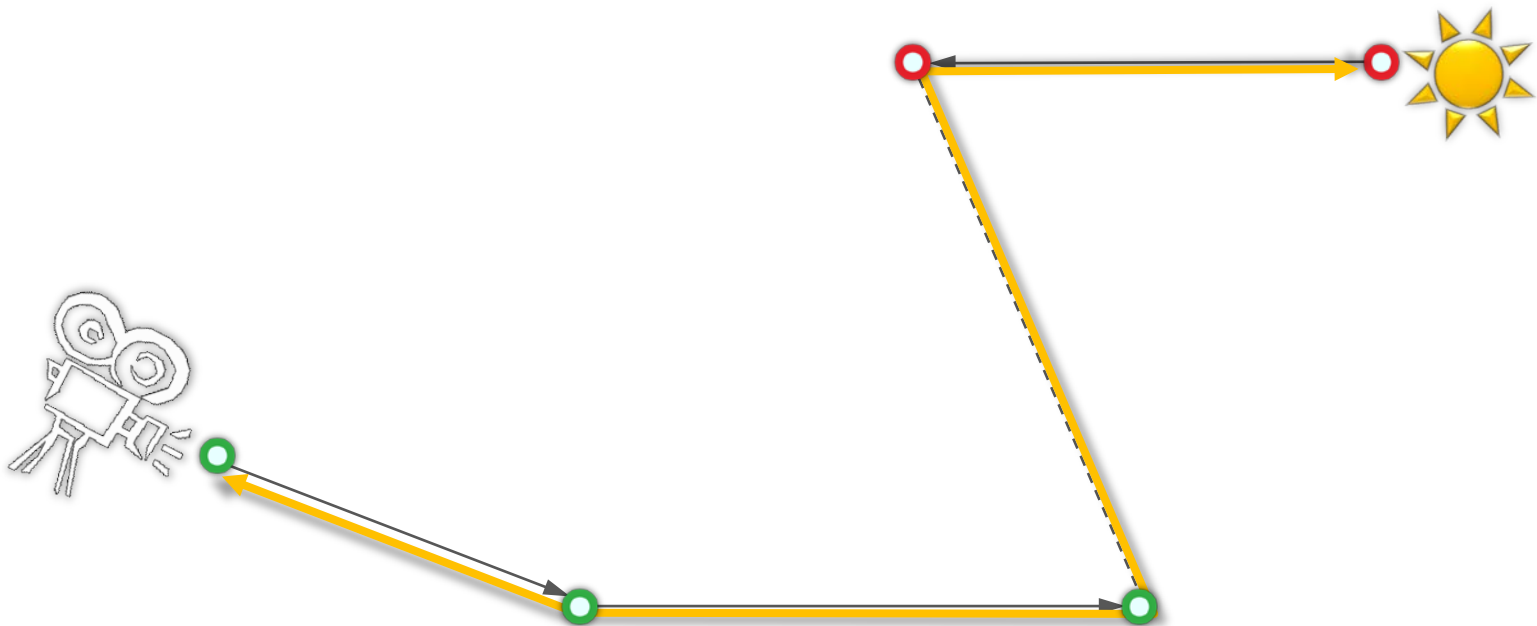
Singularity cancelled



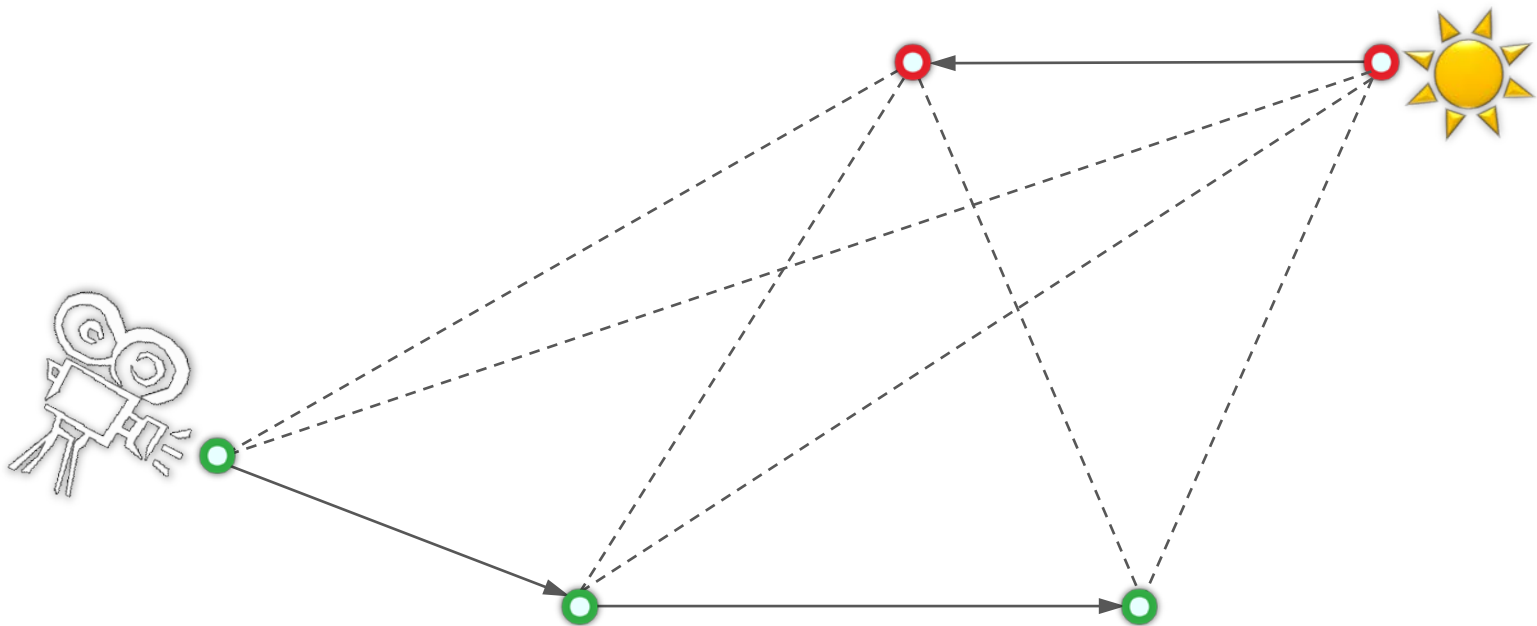
Bidirectional path tracing

- Use **all** of the above sampling techniques
- Combine using **Multiple Importance Sampling**

Naive BPT implementation



BPT Implementation in practice



Results



BPT, 25 samples per pixel

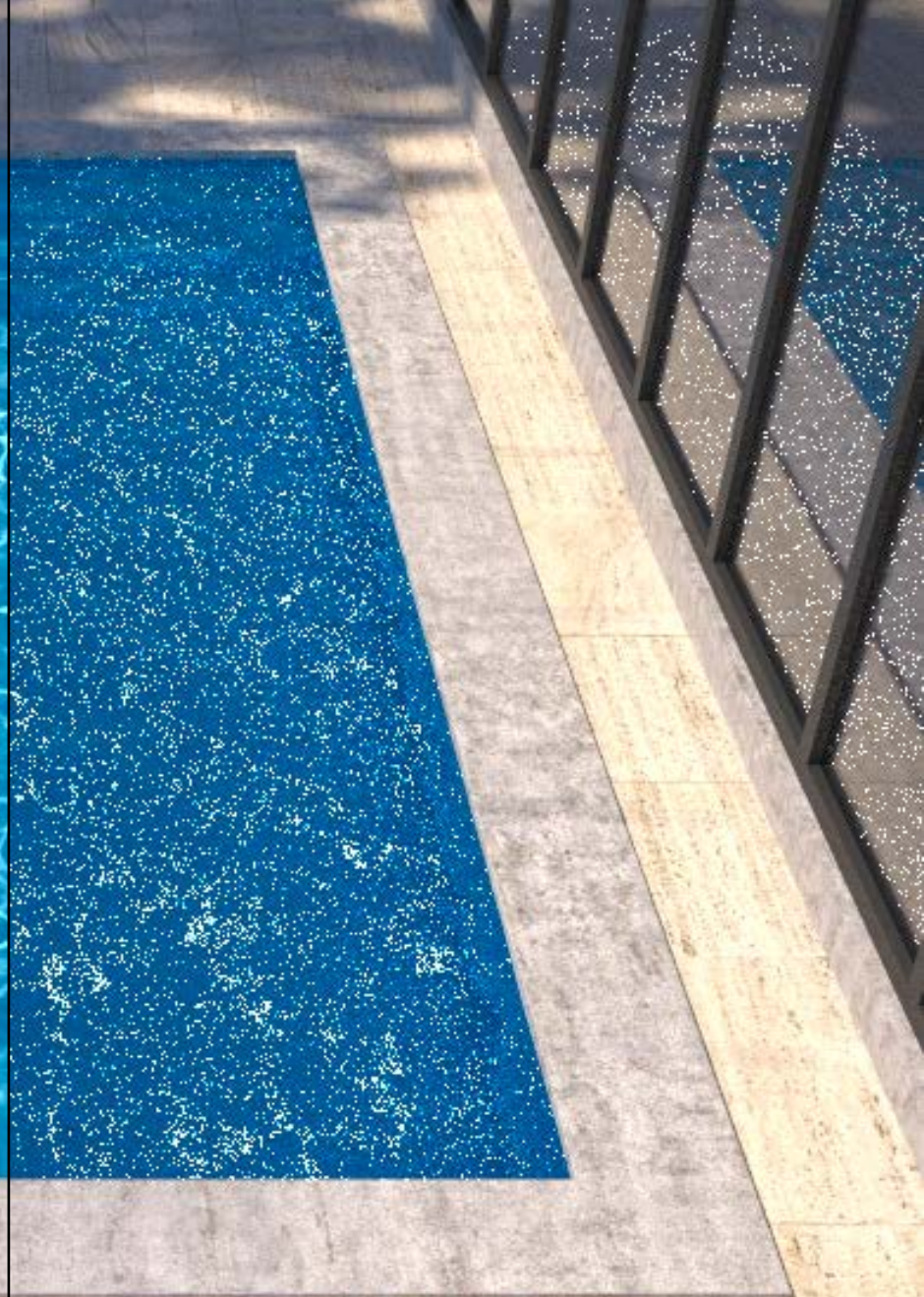


PT, 56 samples per pixel

Images: Eric Veach

LIMITATIONS OF LOCAL PATH SAMPLING



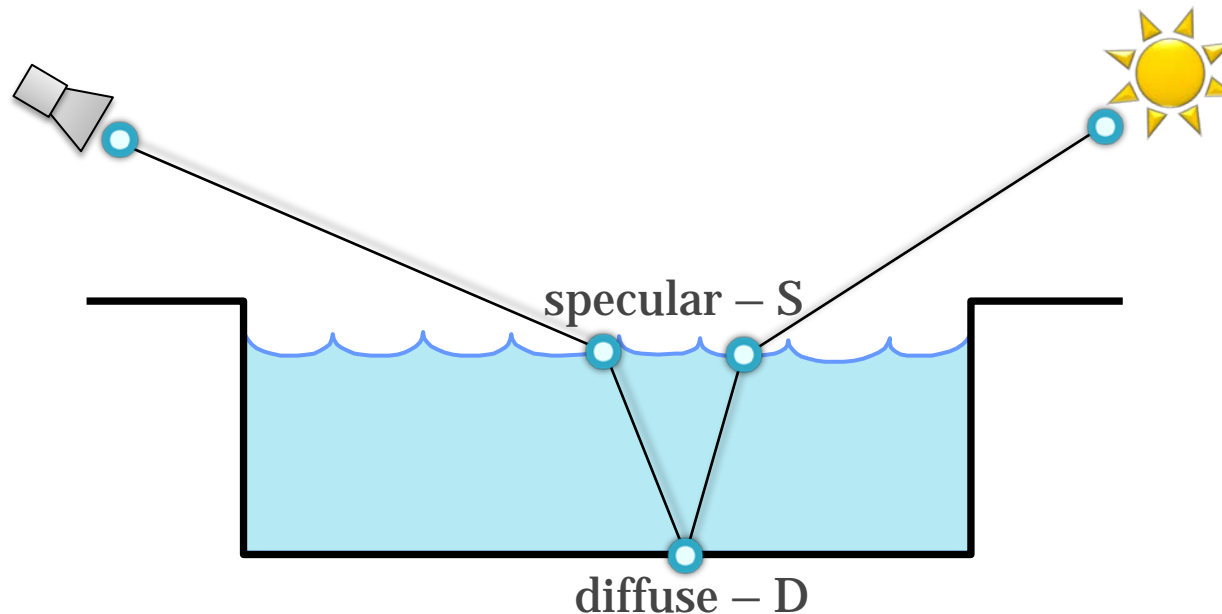


Reference solution

Bidirectional path tracing

Insufficient path sampling techniques

- Some paths sampled with zero (or very small) probability



Alternatives to local path sampling

- **Global path sampling – Metropolis light transport**
 - Initial proposal still relies on local sampling
- Leave path integral framework
 - Density estimation – **photon mapping**
- **Unify path integral framework and density estimation**
 - **Vertex Connection & Merging**

NEARLY THERE...



“Path integral” – A historical remark

- This course [Veach and Guibas 1995], [Veach 1997]
 - Easily derived from the rendering equation [Veach 1997]
- Feynman path integral formulation of quantum mechanics [Feynman and Hibbs 65]
- Homogeneous materials [Tessendorf 89, 91, 92]
- Rendering [Premože et al. 03, 04]

Summary

■ **VPL rendering**

- ❑ One bidirectional path sampling technique
- ❑ Not robust

■ **Bidirectional path tracing**

- ❑ Combines many bidirectional techniques
- ❑ More robust
- ❑ Bad at reflected caustics

Acknowledgements

- **Czech Science Foundation**
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 - **Eric Tabellion**
 - **Marcos Fajardo**

THANK YOU!

Time for questions...

Tutorial: Path Integral Methods for Light Transport Simulation

Jaroslav Křivánek – Bidirectional Path Sampling Techniques

