Adaptive Multi-View Path Tracing

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Mercenaries Engineering

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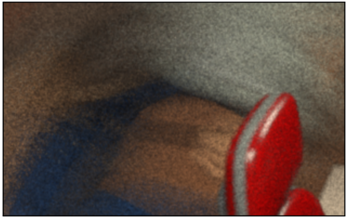
Path tracing

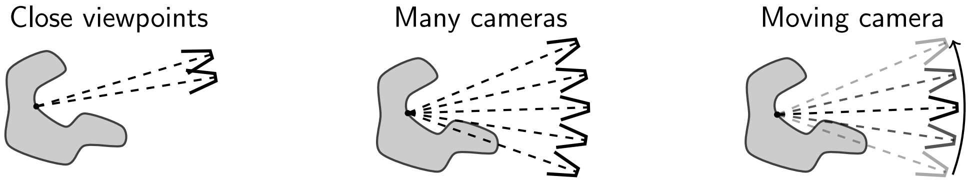
- Heavy computations to render noise-free images
- Even more computations to remove flickering in sequences



1 minute

2 hours

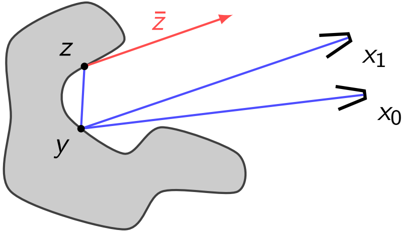
Multi-view rendering



- Heavy computations despite high similarity of nearby frames
- Redundant light paths may be reused

Approach

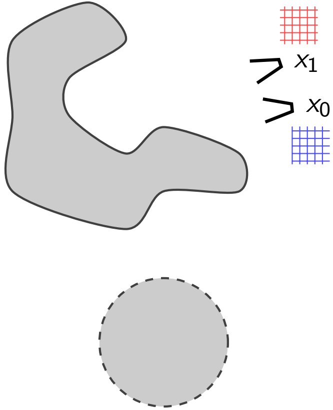
Observation can be decoupled from light transport



- At fixed time t
- For any visible point y (non truly specular)
- Common suffix paths $\bar{z}$ exist

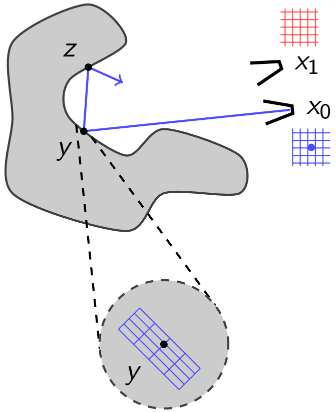
How to sample y ? How to sample z ? How to weight contributions ?

Multiple view path reuse



- Havran et al, 2003, Feliu et al. 2006, Henrich et al. 2011
  - reuse paths to increase the number of contributions
  - do not consider the change in density in MIS weigths
  - may add variance to the result with glossy materials
- Lethinen et al. 2013
  - use path transformations
  - account for the change in density

Multiple view path reuse



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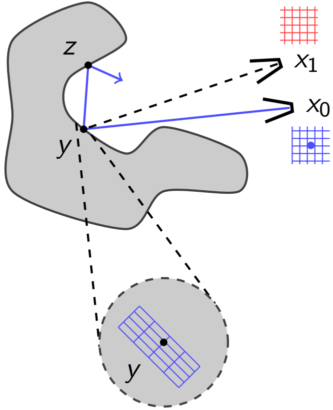

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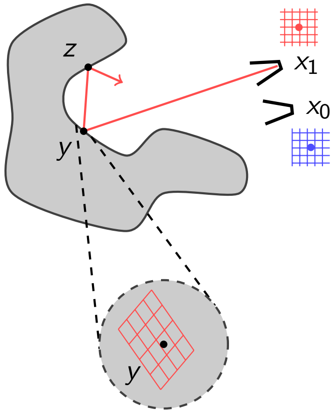

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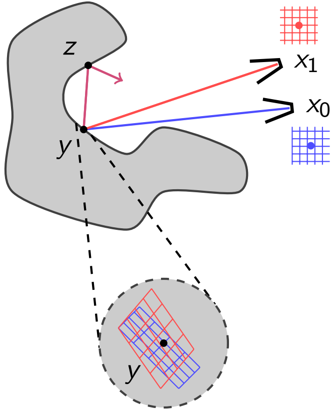

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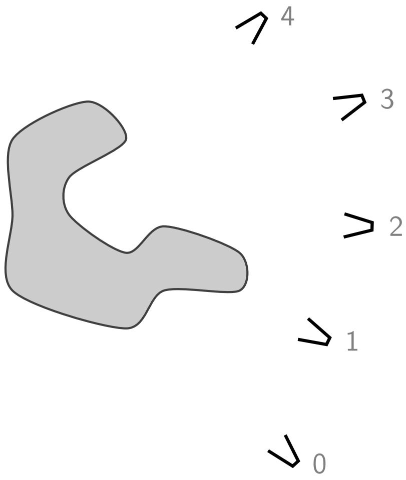
Contribution

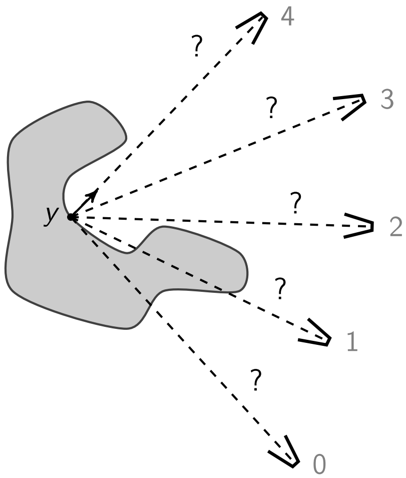
Overview



Progressive path construction

1. Hit point sampling
2. Camera selection
3. Suffix path sampling

Overview



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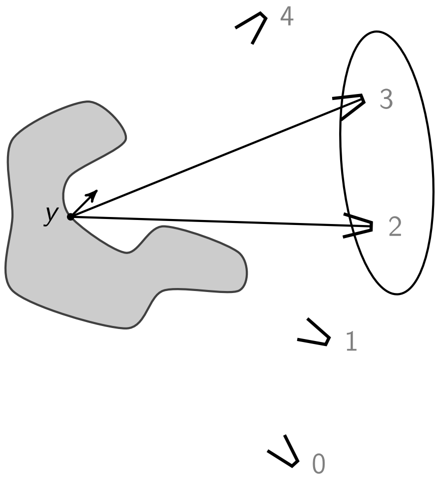

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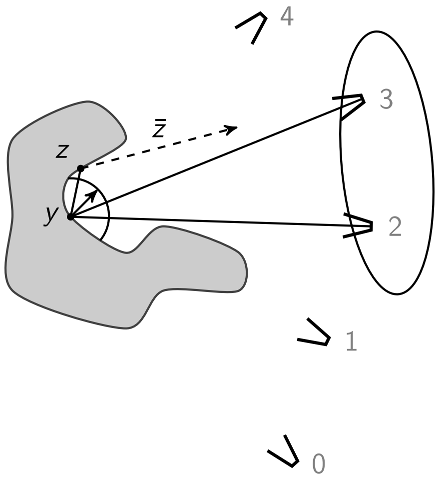

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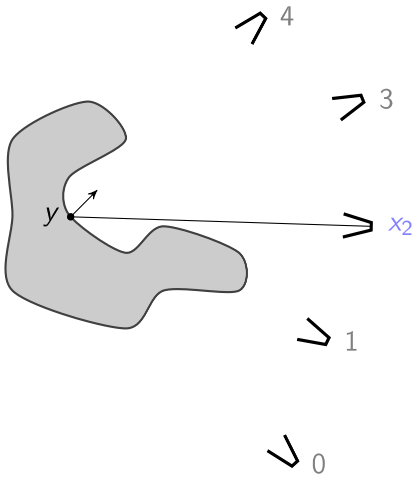
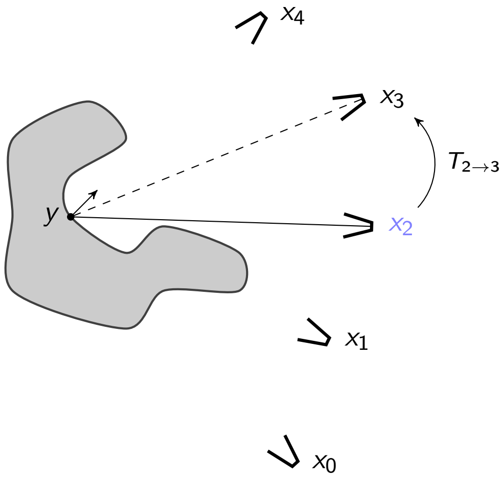
Camera sampling



Given a camera and a pixel :

- sample a time t in the shutter interval
- sample a point in the pixel
- sample a point on the lens (x_2)
- cast a ray and find a hit point y

Prefix transformation

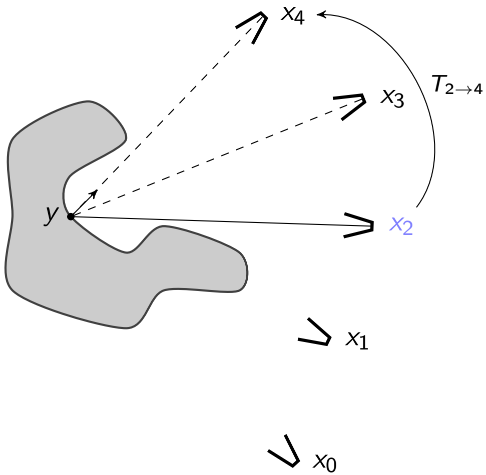


Shift the initial lens position onto other cameras:

$$T_{\ell\to k}(\{x_\ell, y\}) = \{x_k, y\} \qquad x_k = \frac{r_k}{r_\ell} x_\ell$$

r_k and r_ℓ are the respective lens radii.

Prefix transformation



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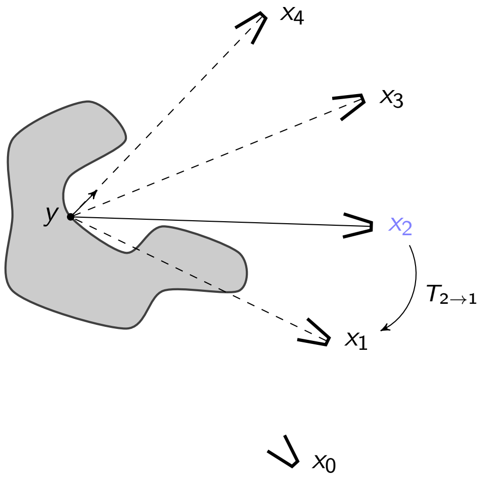

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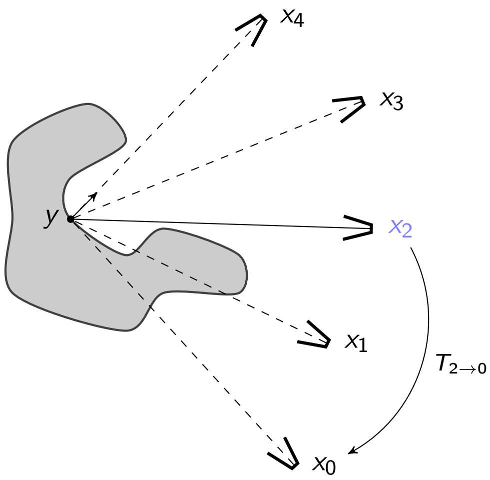

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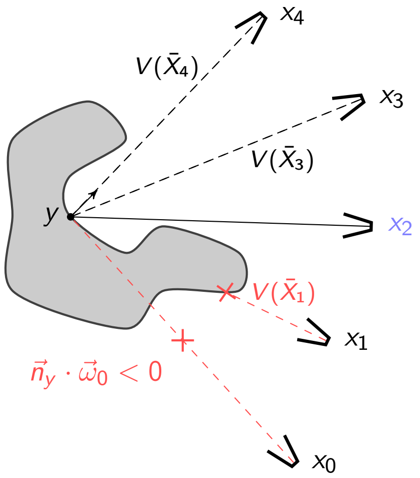
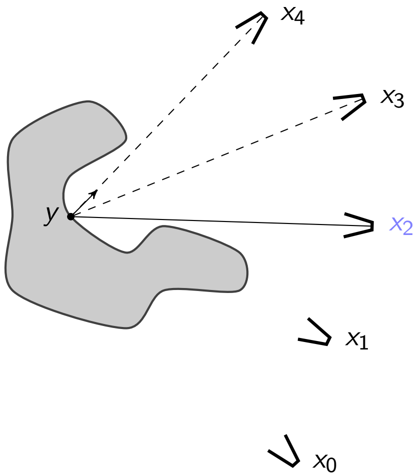
Check prefix validity



- Check shutter interval
- Check camera orientation
- Check image projection of y
- Check visibility

Camera selection

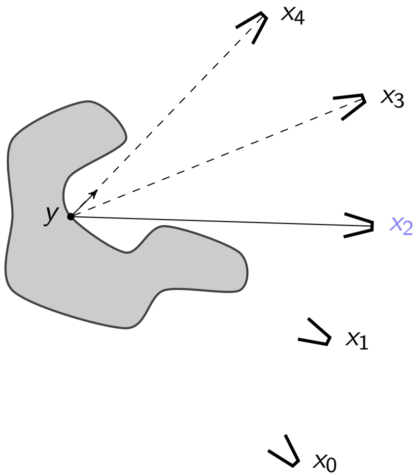
Prefix probability density



$$p_{\ell \to k}(\{x_\ell, y\}) = \frac{p_\ell(\{x_\ell, y\}) \ |T'_{\ell \to k}|}{K_{\ell \to k}}$$

- Initial prefix pdf
- Jacobian of the transformation
- Normalization term

Multiple importance sampling

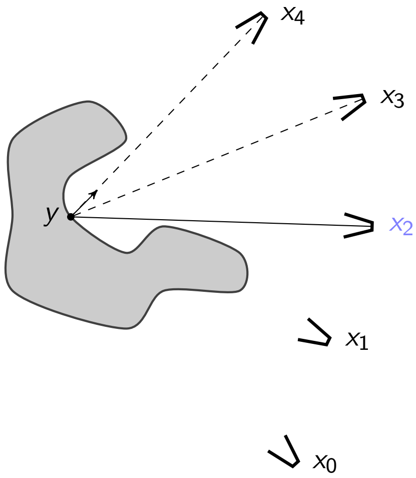


Several available strategies to sample $y \rightarrow$ MIS

$$w_{\ell \to k}(\{x_\ell, y\}) = \frac{p_\ell(\{x_\ell, y\}) \; |T'_{\ell \to k}| \; K^{-1}_{\ell \to k}}{\sum_j \; p_j(\{x_j, y\}) \; |T'_{j \to k}| \; K^{-1}_{j \to k}}$$

- Normalization terms are costly to evaluate (integration)
- Suppose terms K constant to cancel them out

Multiple importance sampling



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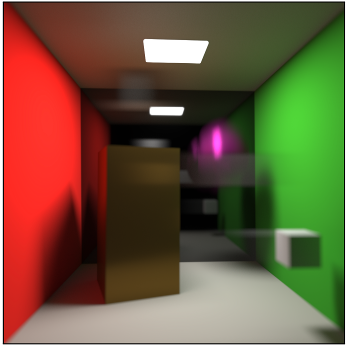
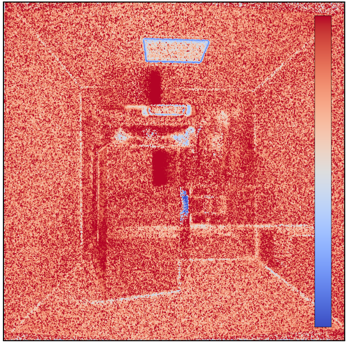
Variations of the normalization terms

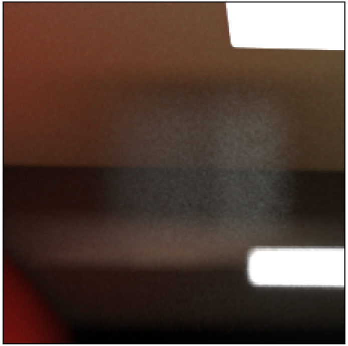




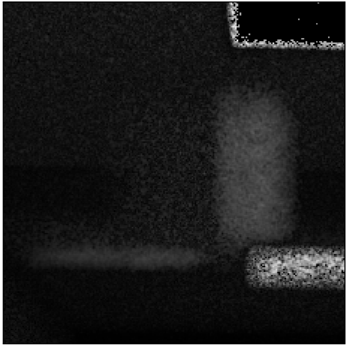
relative standard deviation

Variations of the normalization terms

reference

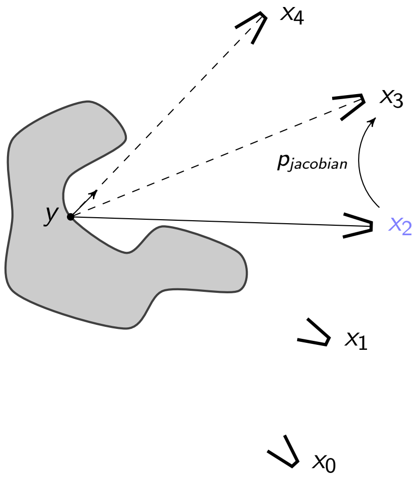


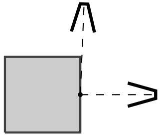
biased result



difference

Similarity selection: Jacobian





- Limiting the variations of the Jacobian
- Using a selection probability

$$p_{\text{jacobian}} = \begin{cases} \left|T'_{\ell\to k}\right|^{-1} & \text{if } \left|T'_{\ell\to k}\right| > 1 \\ \left|T'_{\ell\to k}\right| & \text{otherwise} \end{cases}$$

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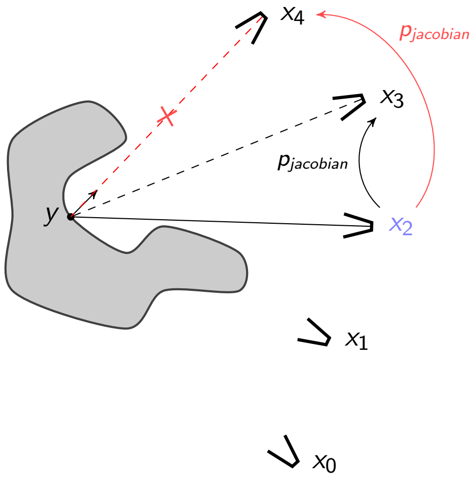

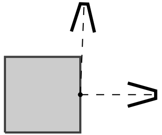

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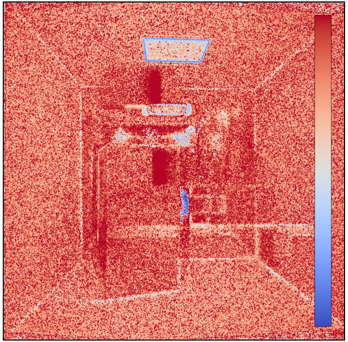
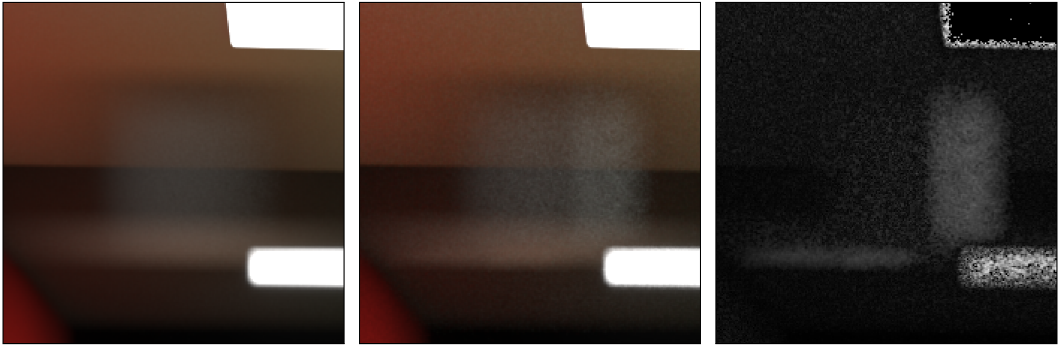


w/o selection

w/ selection

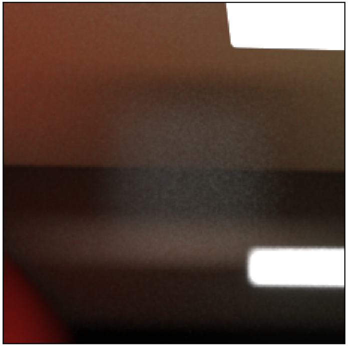
Similarity selection: Jacobian

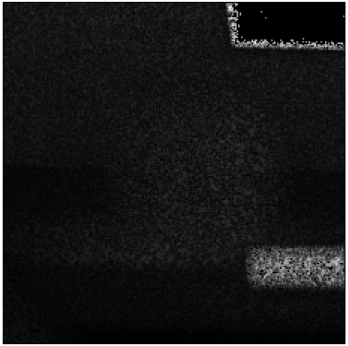


reference w/o selection difference

Similarity selection: Jacobian

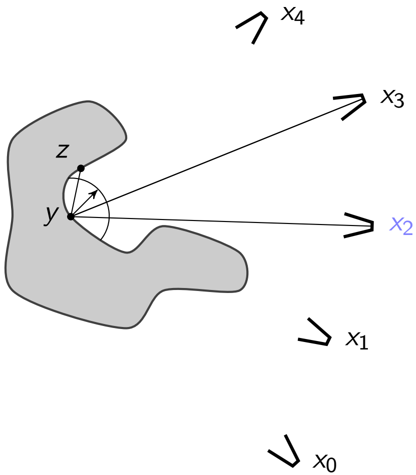

reference


w/ selection


difference

Suffix path sampling

Sampling second hit point

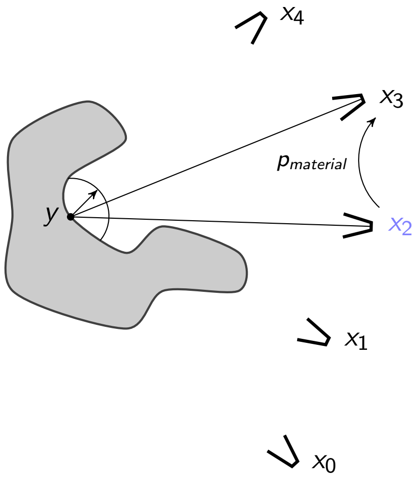


- Each camera has an associated importance function to sample z
- We build a mixture importance function

Problem:

- Poor importance sampling may increase variance
- The observers must have similar importance

Similarity selection: Material

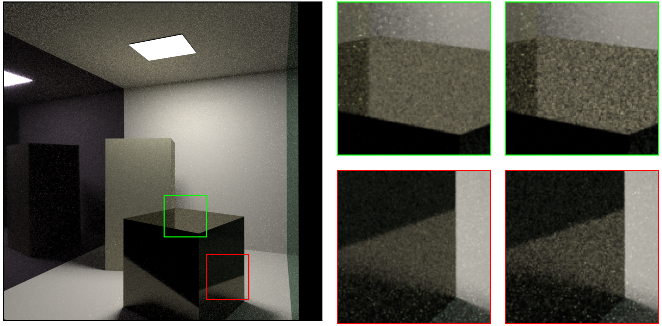


- Limiting poor importance sampling of the brdf
- Using a second selection probability

$$p_{\text{material}} = \left(1 - \widetilde{\delta}(\rho_\ell, \rho_k)\right)^{\frac{1}{\alpha}}$$

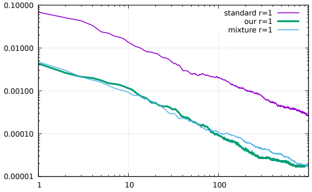
- $\widetilde{\delta}$ is the total variation distance
- α is the roughness of the material
- ρ_i is the distribution associated with camera i

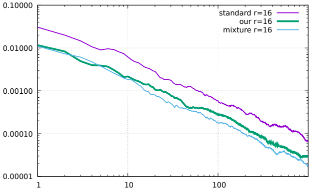
Similarity selection: Material

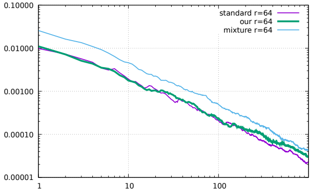


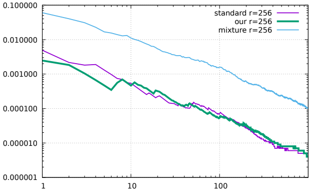
w/ selection w/o selection

Similarity selection: Material

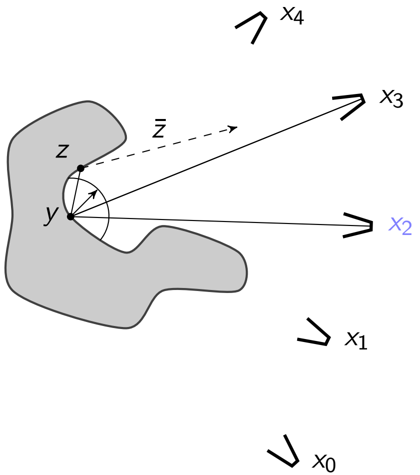








Suffix path sampling



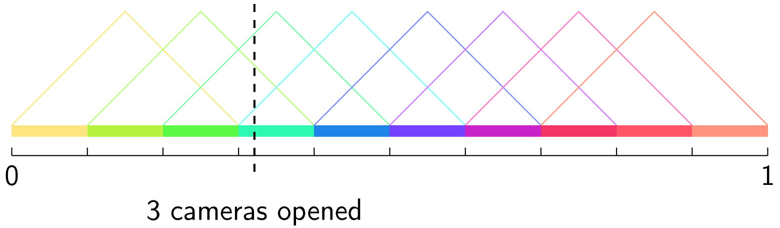
- continue path using regular path tracing
- weight contributions with MIS

$$w_{\ell \to k}(\bar{X}_\ell) = \frac{n_\ell p_{\ell \to k}(\bar{X}_\ell) p_{\text{jacobian}} p_{\text{material}}}{\sum_j n_j p_{j \to k}(\bar{X}_j) p_{\text{jacobian}} p_{\text{material}}}$$

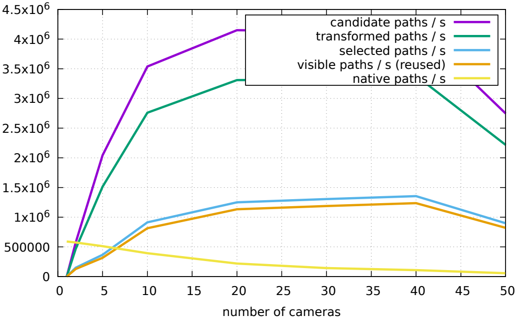
- n is the number of samples generated in the pixel
- may vary when adaptive sampling is used

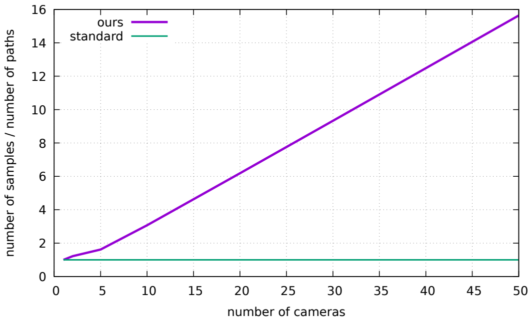
Results

- Animations are computed with the same time budget
- Cameras with overlapping exposure intervals



Performance





Conclusion

Contributions

- reuse aware path construction
- observer selection strategies
  - jacobian similarity
  - material similarity
- adaptive sampling support

Perspectives

- extend the method to depth of field (in progress)
- formal study of brdf similarity
- unify path reuse techniques (Bekaert et al. 2002)

Questions

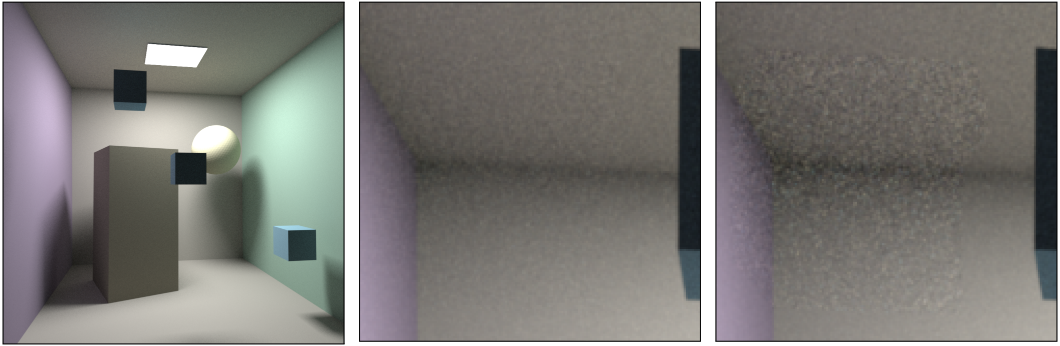
path tracing

ours - equal time

Aknowledgements:
Yasutoshi Mori for the Mori Knob model
Blender Institute for making freely available assets from the open movie Agent 327

Adaptive

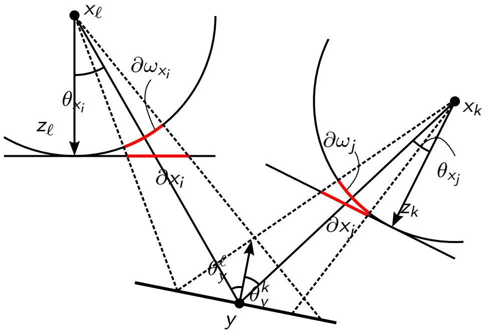
- Selective reuse + occlusions $\rightarrow$ inhomogeneous sample distribution



w/ adaptive

w/o adaptive

Jacobian



$$|T'_{\ell\to k}| = \frac{r_\ell^2}{r_k^2}\frac{\cos\theta_y^k}{\|y - x_k\|^2}\frac{d_k^2}{\cos^3\theta_{x_i}}\frac{\|y - x_\ell\|^2}{\cos\theta_y^\ell}\frac{\cos^3\theta_{x_j}}{d_\ell^2}$$