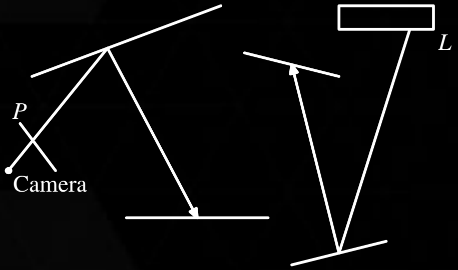
Path Space Filtering

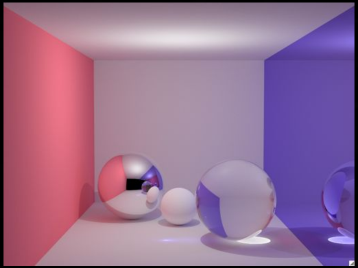
Alexander Keller, Ken Dahm, and Nikolaus Binder

Consistent Image Synthesis

Light transport simulation

- trace light transport path segments from the light and camera





Consistent Image Synthesis

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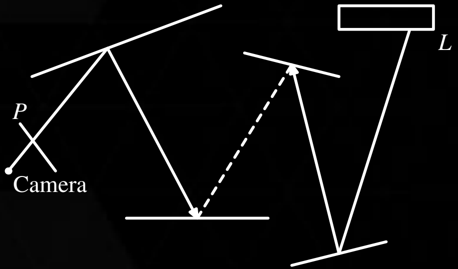
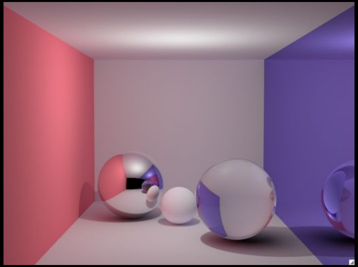
- trace light transport path segments from the light and camera,
  - connect them by shadow rays





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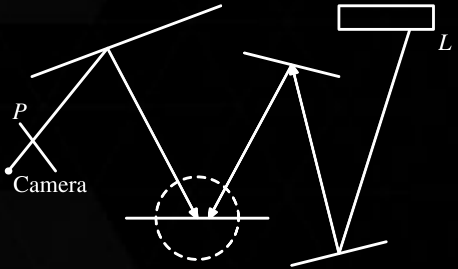

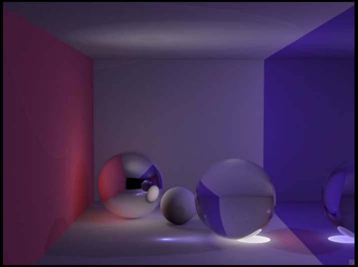

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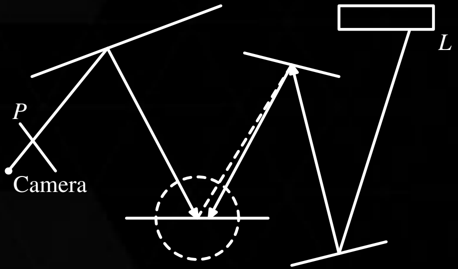

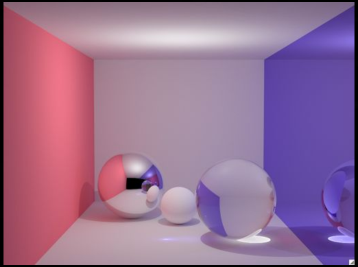

and sum up the weighted contributions of all light transport paths

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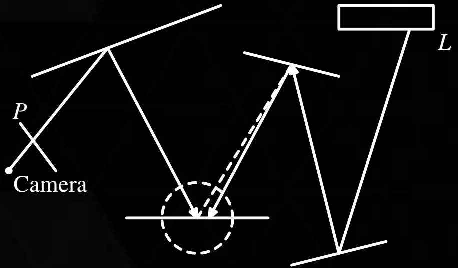

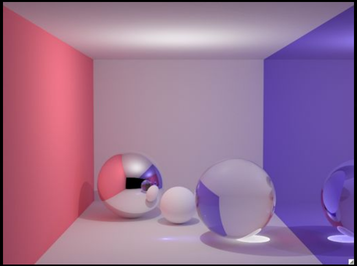

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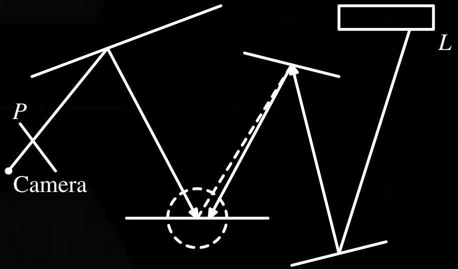

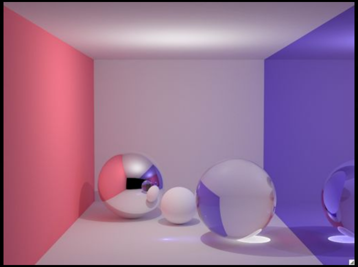

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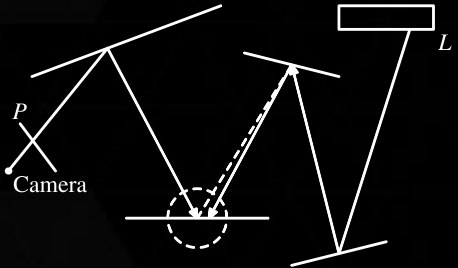

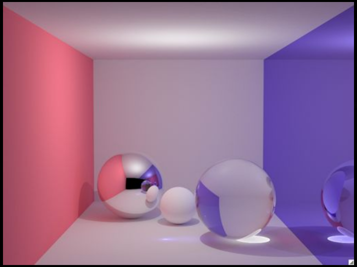

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  - check out the state of the art report "Quasi-Monte Carlo Image Synthesis in a Nutshell"

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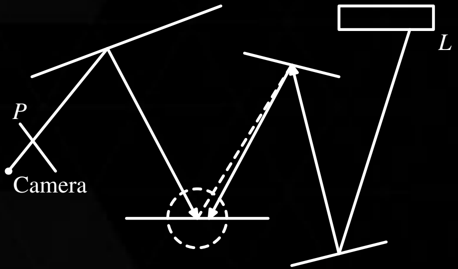

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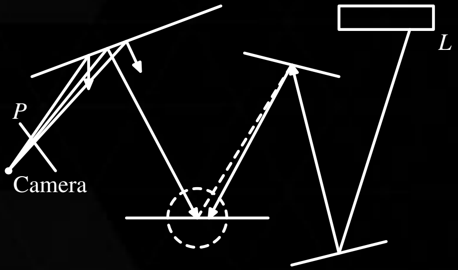

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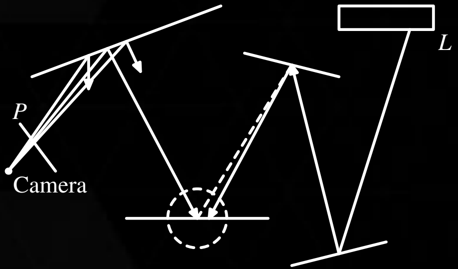
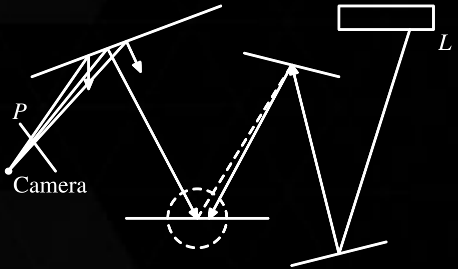


Consistent Image Synthesis

Light transport simulation

- sum up the weighted contributions of all light transport paths
  - noise vanishing only slowly with increasing number of samples



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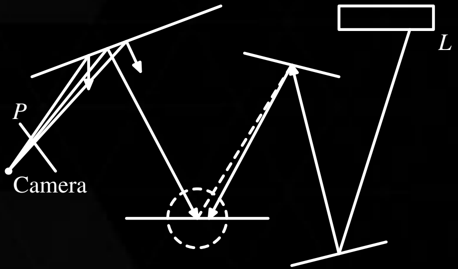
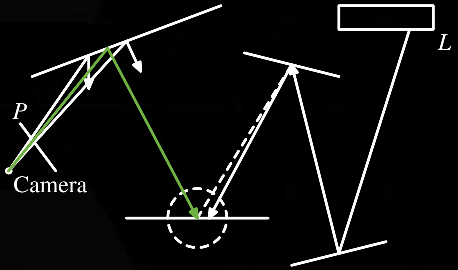
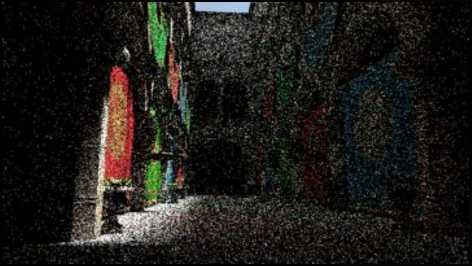


Path Space Filtering

Noise reduction by averaging contributions of close-by vertices

- range search





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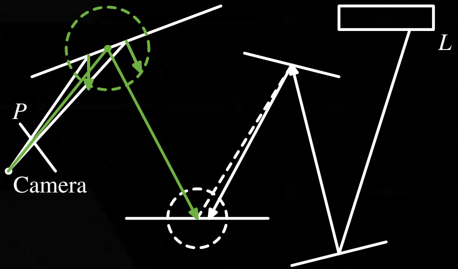
Path Space Filtering

Noise reduction by averaging contributions of close-by vertices

- range search
  - initial radius r_0 proportional to distance of ray origin and location of averaging



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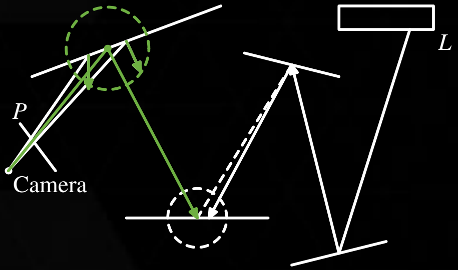
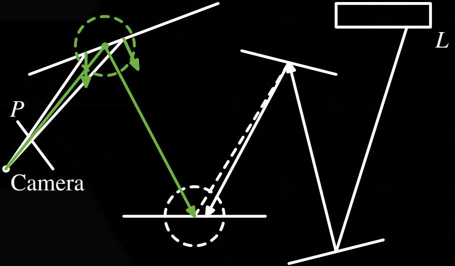


Path Space Filtering

Noise reduction by averaging contributions of close-by vertices

- range search with radius $r(n)$ decreasing with number n of samples
  - initial radius r_0 proportional to distance of ray origin and location of averaging



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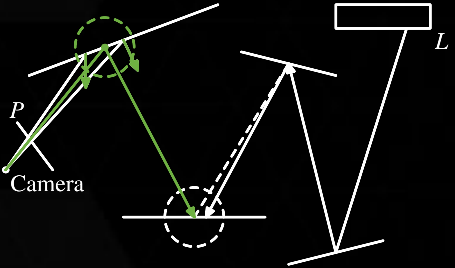

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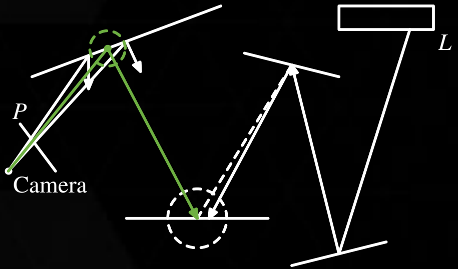

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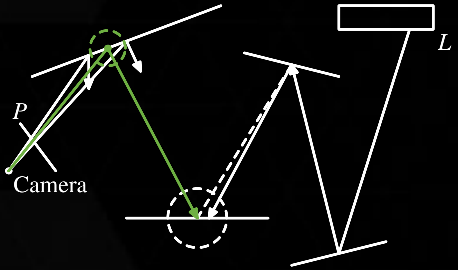

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Path Space Filtering

Algorithm

- enumerate contiguous blocks of b^m light transport paths
  - for each light transport path store a selected vertex x_i with
    - its throughput α_i of the camera path segment and
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  - for each vertex x_i determine the weighted average contribution

$$\bar{c}_i := \frac{\sum_{j=0}^{b^m-1} \chi_{\mathscr{B}(n)}\left(x_{s_i+j} - x_i\right) \cdot w_{i,j} \cdot c_{s_i+j}}{\sum_{j=0}^{b^m-1} \chi_{\mathscr{B}(n)}\left(x_{s_i+j} - x_i\right) \cdot w_{i,j}}$$

of all vertices x_{s_i+j} in the block starting at index $s_i := \left\lfloor \frac{i}{b^m} \right\rfloor b^m$

inside the ball $\mathscr{B}$ of radius $r(n)$ around x_i

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  - accumulate $\alpha_i \bar{c}_i$ instead of $\alpha_i c_i$
- consistent due to $\lim_{n\to\infty} \bar{c}_i = c_i$, because $\lim_{n\to\infty} r(n) = 0$

Path Space Filtering

Mimicking trajectory splitting

- only include contributions from x_{s_i+j} that could have been generated in x_i
  - input of 16 path space samples per pixel

Path Space Filtering

Mimicking trajectory splitting

- only include contributions from x_{s_i+j} that could have been generated in x_i
  - input of 16 path space samples per pixel filtered without weighting

Path Space Filtering

Mimicking trajectory splitting

- only include contributions from x_{s_i+j} that could have been generated in x_i
  - input of 16 path space samples per pixel accounting for similar normals
    - weights $w_{i,j}$ in fact are similarity heuristics from irradiance interpolation

Path Space Filtering

Mimicking trajectory splitting

- only include contributions from x_{s_i+j} that could have been generated in x_i
  - input of 16 path space samples per pixel accounting for similar normals, reflectance
    - weights $w_{i,j}$ in fact are similarity heuristics from irradiance interpolation

Path Space Filtering

Mimicking trajectory splitting

- only include contributions from x_{s_i+j} that could have been generated in x_i
  - input of 16 path space samples per pixel accounting for similar normals, reflectance, and visibility
    - weights $w_{i,j}$ in fact are similarity heuristics from irradiance interpolation

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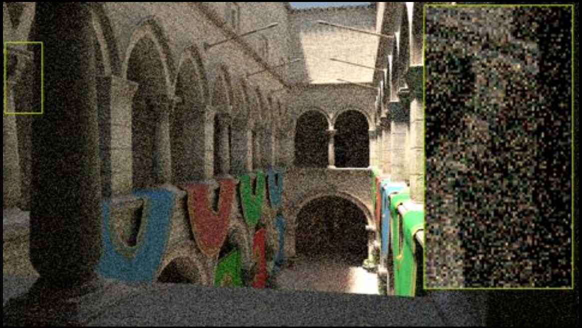

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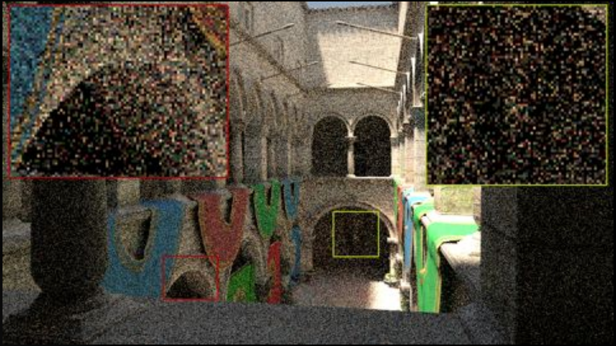
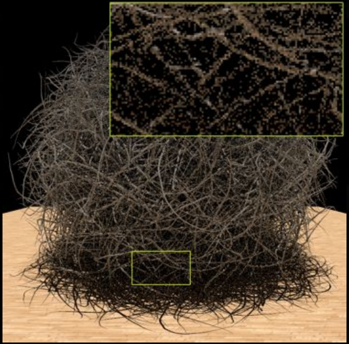
Path Space Filtering

Select block size b^m as large as possible

- accumulating 16 passes
  - 1 path space sample per pixel

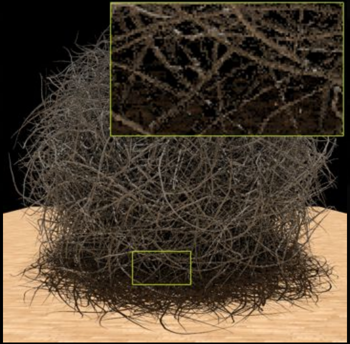




Path Space Filtering

Select block size b^m as large as possible

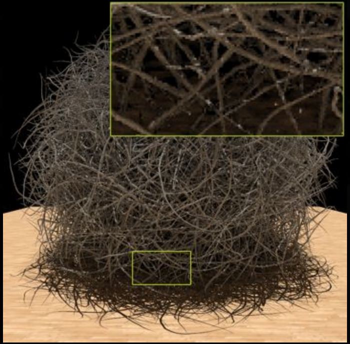
- accumulating 16 passes
  - filtered across 1 path space sample per pixel



Path Space Filtering

Select block size b^m as large as possible

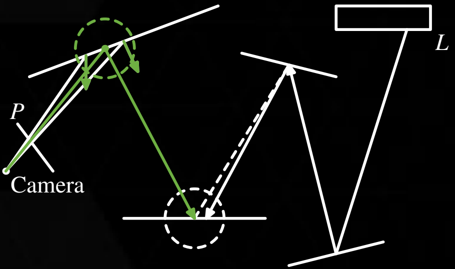
- accumulating 2 passes
  - filtered across 8 path space samples per pixel

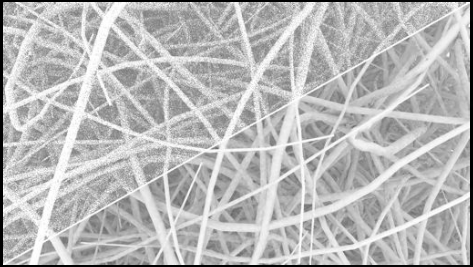


Path Space Filtering

Example applications

- results for
  - ambient occlusion





Path Space Filtering

Example applications

- results for
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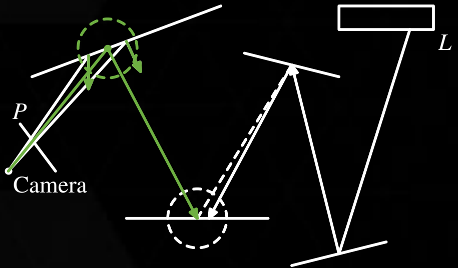

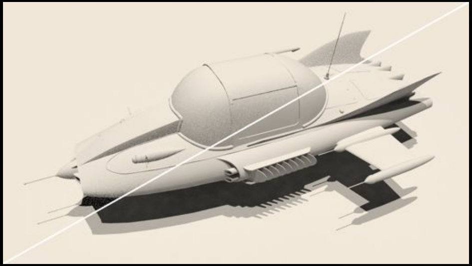

Path Space Filtering

Example applications

- results for
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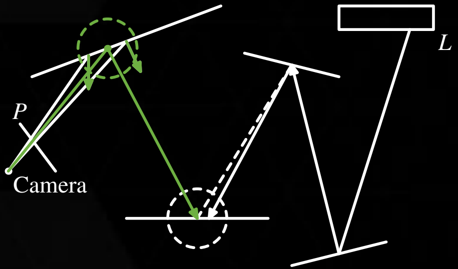

Path Space Filtering

Example applications

- results for
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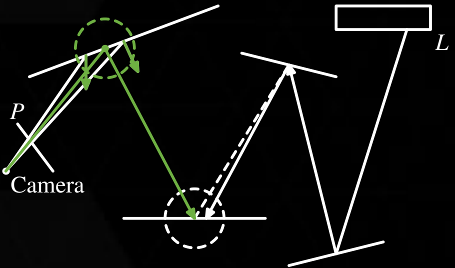

Path Space Filtering

Example applications

- results for
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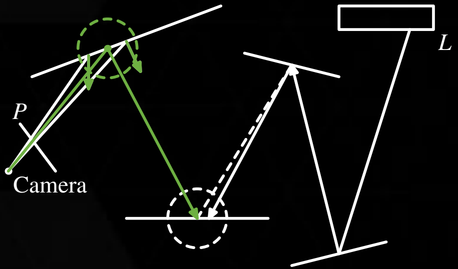

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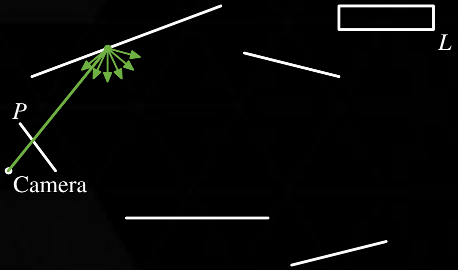
Extensions of Path Space Filtering

Variable rate shading

- trajectory splitting is costly



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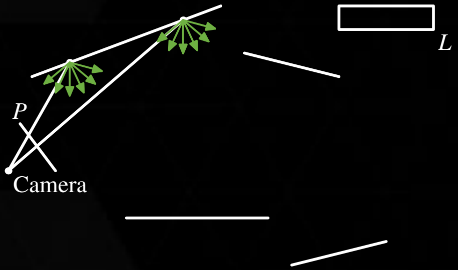

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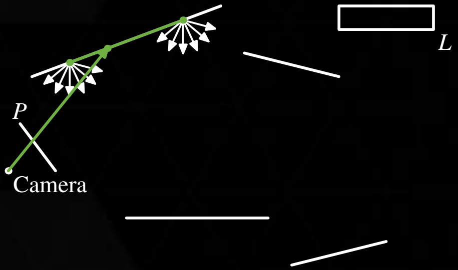
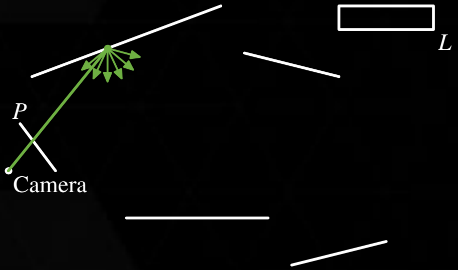


Extensions of Path Space Filtering

Variable rate shading

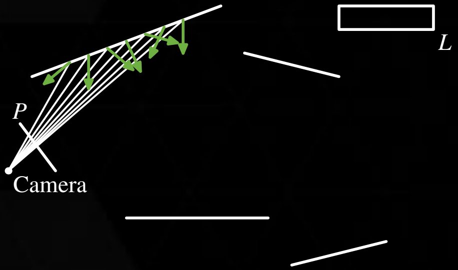
- mimicking trajectory splitting



Extensions of Path Space Filtering

Variable rate shading

- mimicking trajectory splitting by path space filtering is consistent



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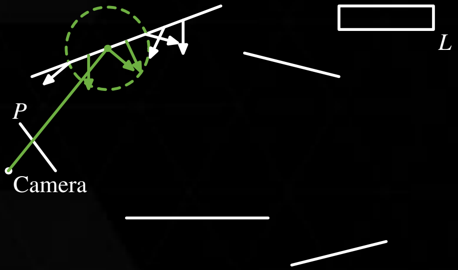

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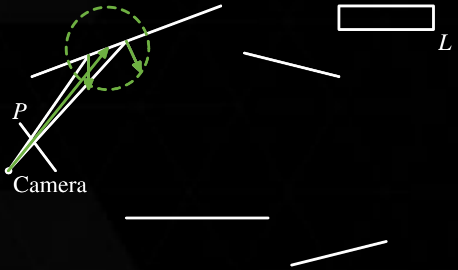
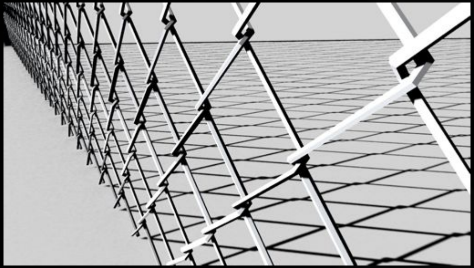
Extensions of Path Space Filtering

Variable rate shading

- mimicking trajectory splitting by path space filtering is consistent
  - and allows for subsampling





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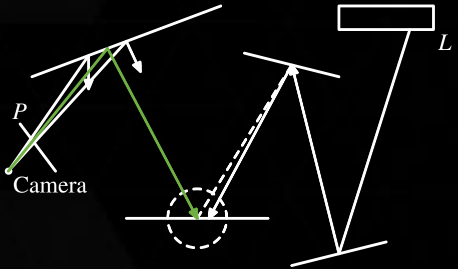

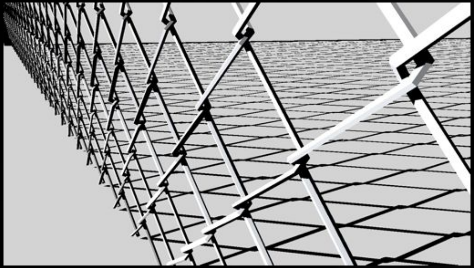

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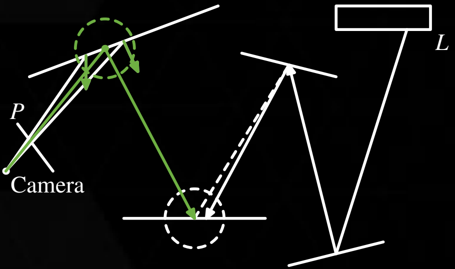
Iteration

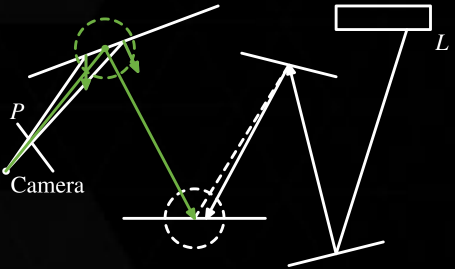
- input at one sample per pixel



Extensions of Path Space Filtering

Iteration

- input at one sample per pixel filtered once

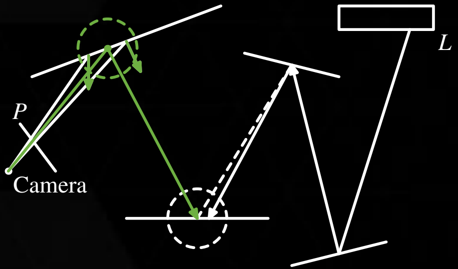


NVIDIA

Extensions of Path Space Filtering

Iteration

- input at one sample per pixel
  - after iterating the weighted average four times



Path Space Filtering

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- practical
  - orthogonal to any path space sampling based algorithm
  - two parameters
- dual to photon mapping
  - weighted average vs. division by disk area
  - similar particle inclusion heuristics and transient artifacts

Courtesies

Models

- Cornell Box by Kevin Beason in smallpt
- Sponza by Marko Dabrovic, modified by Crytek
- Hairball by Samuli Laine
- Trees by `http://www.laubwerk.com`
- Lucy Statue from the Stanford 3D Scanning Repository
- San Miguel by Guillermo M. Leal Llaguano
- Fence by Chris Wyman

Note that image quality may have suffered from PDF compression.