Lecture slides (AI3501/CT4201/EC4215 – Computer Graphics)

Sampling and Denoising for Monte Carlo Rendering

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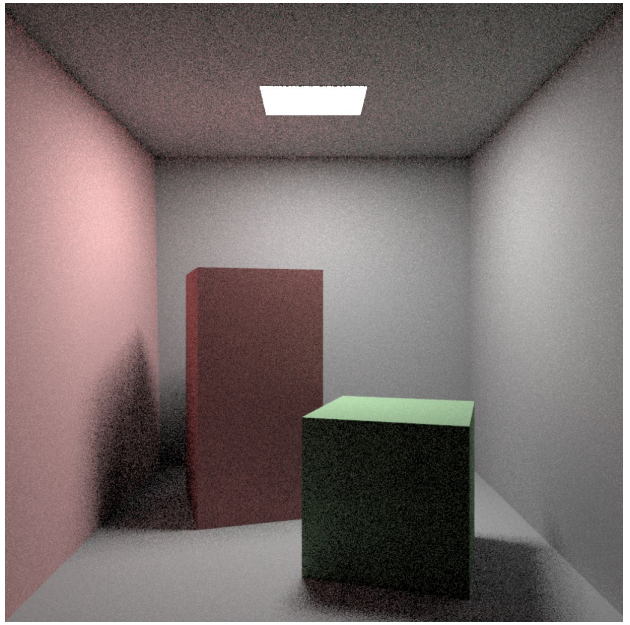
Observation

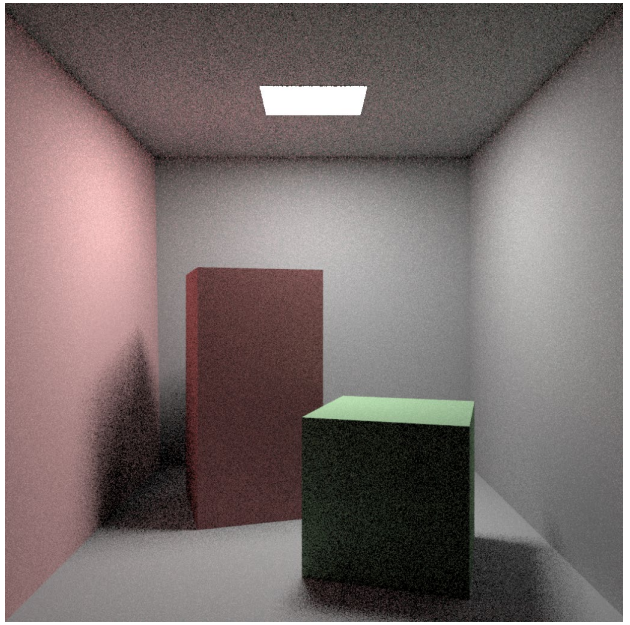
- The amount of noise varies across image pixels.



4 samples / pixel (1.25 secs)

Adaptive sampling

- Adaptive sampling:
  - Allocate more samples to the pixels with higher errors
- A procedure for adaptive sampling:
  - Use a small number of samples per pixel
  - Compute per-pixel sample variance
  - Allocate more samples only to the pixels with higher variances

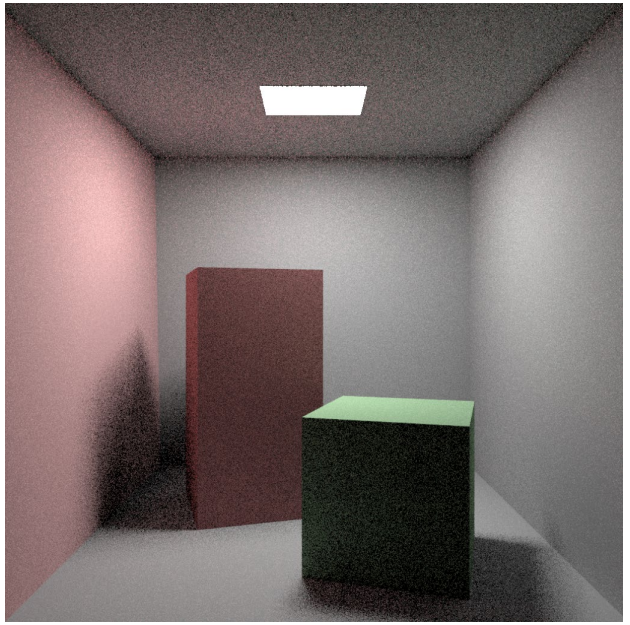


4 samples / pixel (1.25 secs)

Image denoising

- Image denoising:
  - Blend pixel colors with their neighboring pixels

- A procedure for image denoising:
  - Generate a noisy image using sampling (or optionally adaptive sampling)
  - Apply an image filter to each pixel so that noise in a pixel color can be reduced



4 samples / pixel (1.25 secs)

Classical Image Space Adaptive Rendering

- Controlling sample density using sample variances is not optimal
- Suppose a typical combination:
  - Path tracing + image denoising
  - The variance of the final image (reconstruction variance) can be very different from the sample variance
  - Adaptive sampling should allocate more samples to the regions with high reconstruction errors

Classical Image Space Adaptive Rendering

- Adaptive Sampling and Reconstruction using Greedy Error Minimization
  - [Rousselle et al. 11]
- Control two parameters
  - Sampling rate per pixel
  - Reconstruction parameter per pixel
- Target combination
  - Path tracing + Gaussian filter

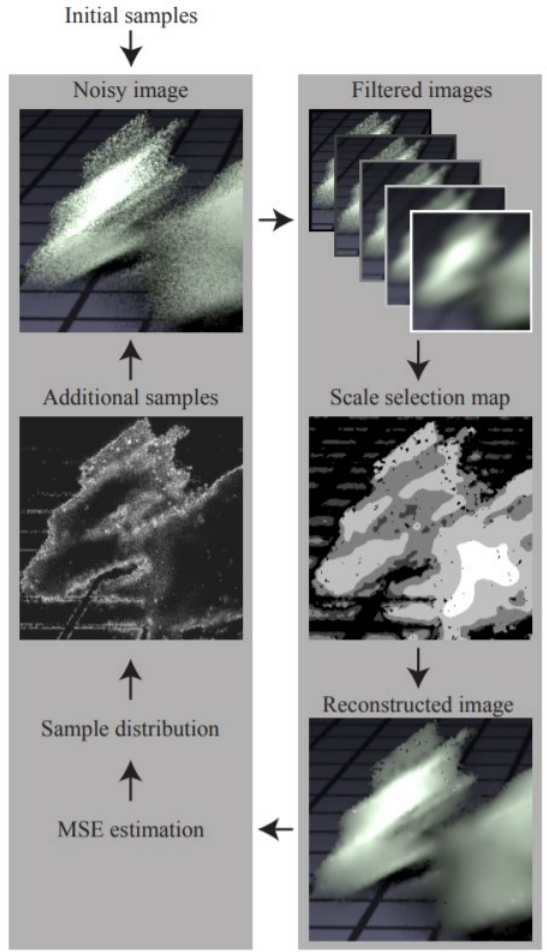
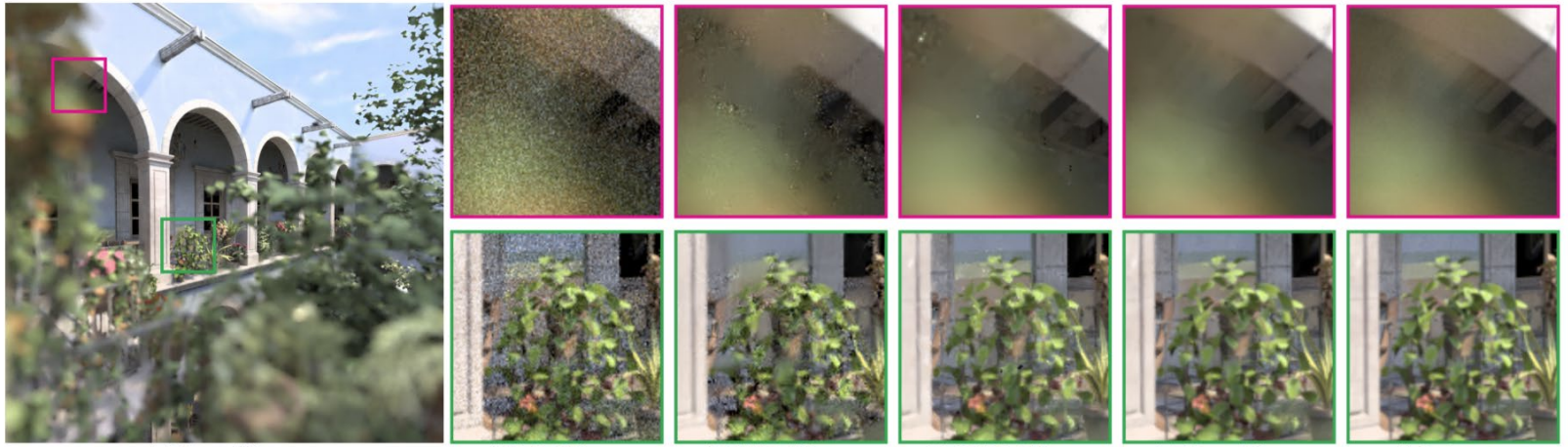


Image from [Rousselle et al. 11]

Classical Image Space Adaptive Rendering

- General procedure
  - Allocate sparse samples initially
  - Reconstruct the image using a non-linear filtering
    - Estimate optimal parameters for the reconstruction
    - Estimate MSE (bias^2 + variance) of the image
  - Allocate more samples to the image regions with high MSEs



(a) Ours 115 spp (660 s) rMSE 0.00448 | (b) LD 128 spp (665 s) rMSE 0.06288 | (c) NLM 115 spp (665 s) rMSE 0.01242 | (d) SURE 113 spp (665 s) rMSE 0.01521 | (e) Ours 115 spp (660 s) rMSE 0.00448 | (f) Reference 16K spp

Image from [Moon et al. 14]

Neural Image Space Adaptive Rendering

- So far:
  - Reconstruction filters are hand-crafted ones
  - Estimating MSE is often a tedious task (and also quite difficult to be robust)

- Deep learning based approaches
  - Kernel-Predicting Convolutional Networks for Denoising Monte Carlo Renderings [Bako et al. 17]
  - A general weighting can be represented as
    - $\hat{y}_c = \Sigma_i w_i y_i$
    - $w_i > 0$
  - Key advantage is that we don't need to assume a specific functional form for w_i

Neural Image Space Adaptive Rendering

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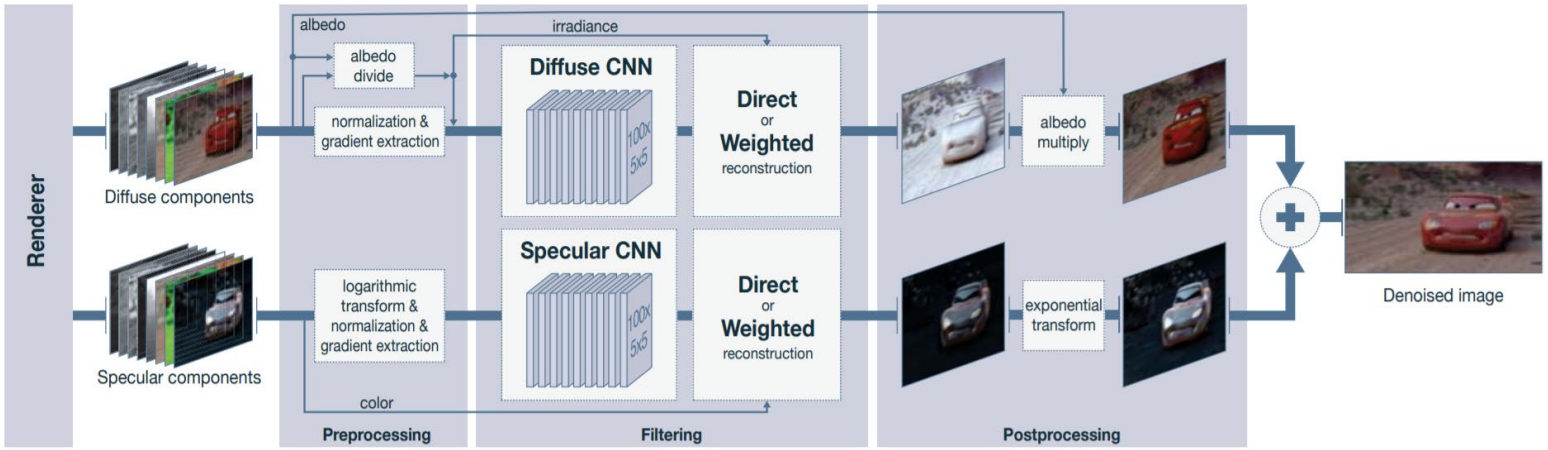

Image from [Bako et al. 17]

Neural Image Space Adaptive Rendering

- Deep learning based approaches
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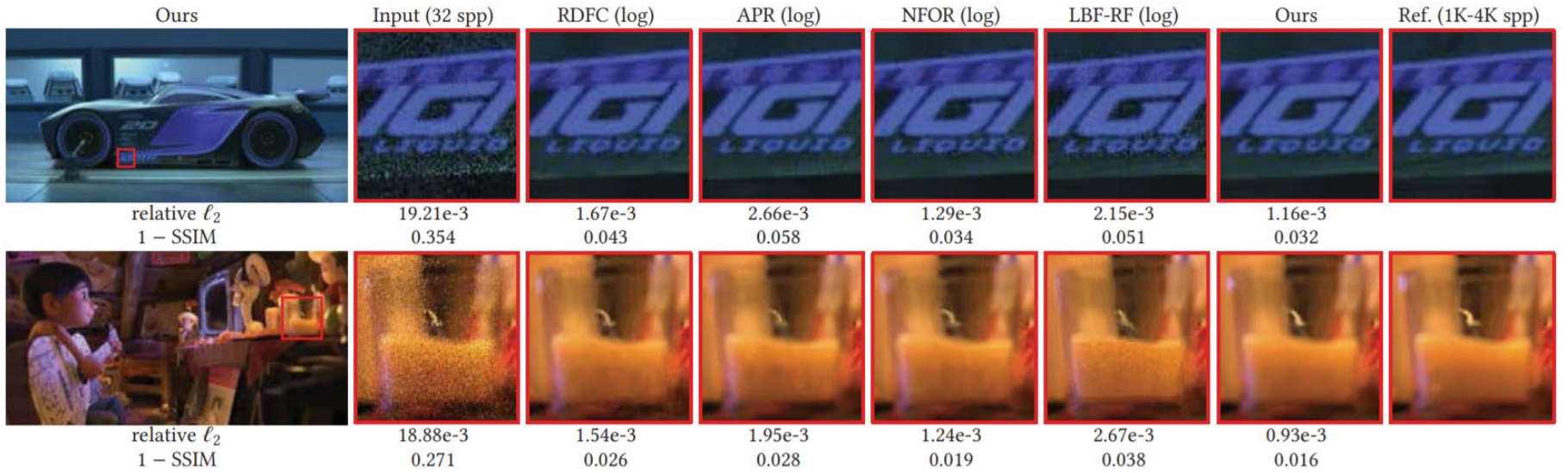
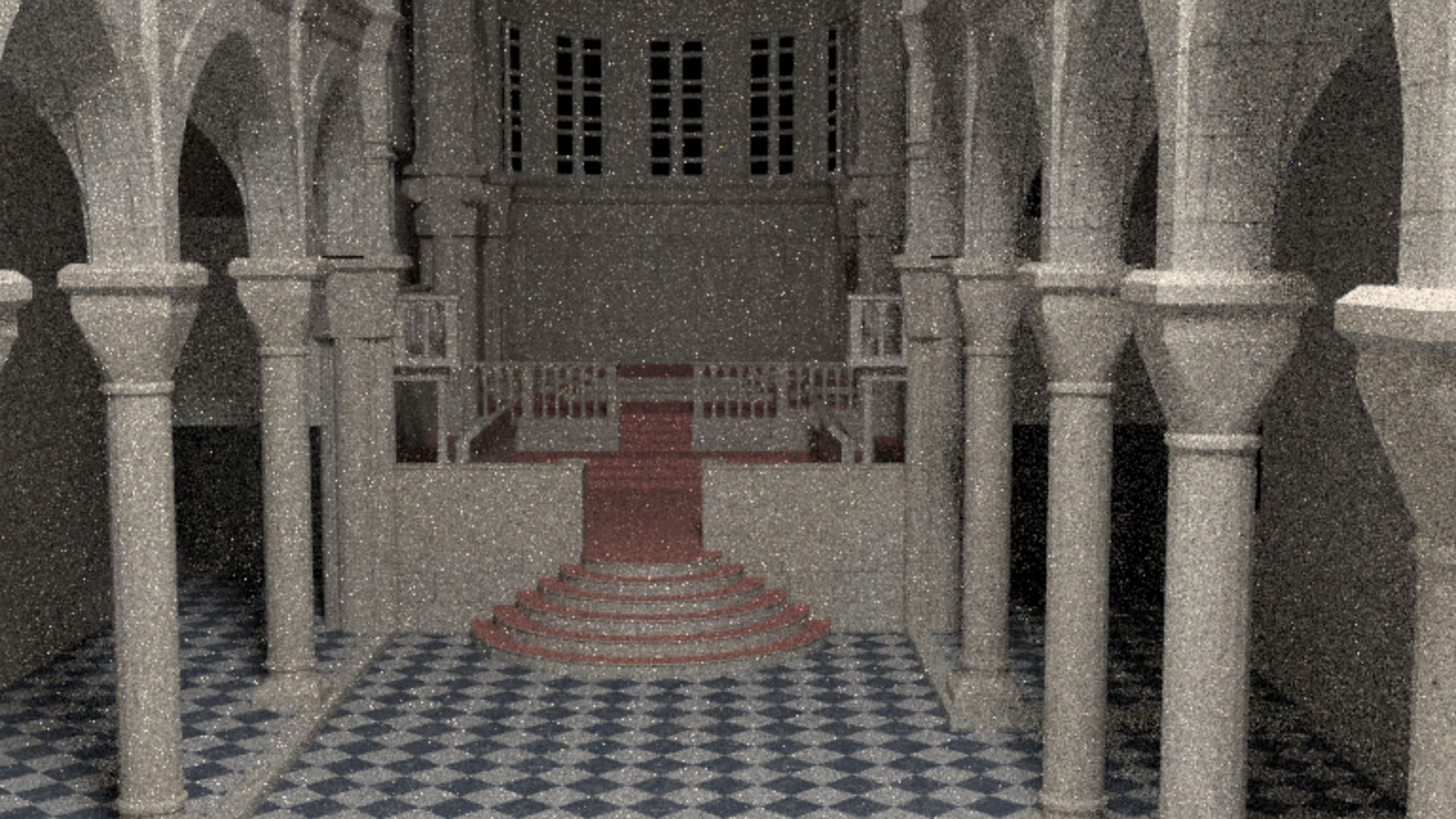
Image from [Bako et al. 17]