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Robust Adaptive Sampling for Monte-Carlo-based rendering

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Monte-Carlo rendering
- Value of each pixel defined as the expected value of a random variable \( X \)
  \[ I = E[X] \]
- Estimated using samples of \( X \)
  \[ < I > = \frac{1}{N} \sum_{i=1}^{N} x_i \]

Our goals
- Focus processing power where convergence is harder to reach during Monte-Carlo based rendering
- Make the error over the pixels uniform at any moment for progressive or time-constrained rendering

Relative error and robustness to outliers

For each pixel, relative error:
\[ e_r(I) = \frac{V(x_1, \ldots, x_n)}{V(x_1, \ldots, x_n)} \]

Standard estimation:
\[ e_s(I) = \frac{e_r(I)}{< I >} \]

Not robust to outliers: underestimation

Goal: focus on bright spots

Previous work and their limitations
- Adaptive sampling based on the statistical nature of the estimation [Purgathofer 1987]
  Not a relative error: does not take into account dynamic reduction during tonemapping
- Adaptive sampling based on information-theoretic approaches and entropy measures [Xu et al 2007]
  Does not make the error uniform during rendering, thus less adapted for progressive or time-constrained rendering

Both approaches can lead to poor sampling due to low-samples error estimations which underestimate the actual error

Alternative: avoid poor low-samples error estimation

Adaptive sampling based on error measure, poor error estimate → poor sampling

Our proposal: alternate adaptive and uniform sampling

Complete adaptive sampling algorithm

Uniform sampling → Update error and pixel probabilities → Adaptive sampling → Uniform sampling

Comparison with Tsallis entropy [Xu, Sbert, Xinh and Zhan 2007]

Test scene → Noise measure for uniform sampling → Noise measure for Tsallis entropy → Noise measure for our method