Diplomarbeitspräsentation

FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

Quantifying the Convergence of Light-Transport Algorithms

Masterstudium:
Visual Computing

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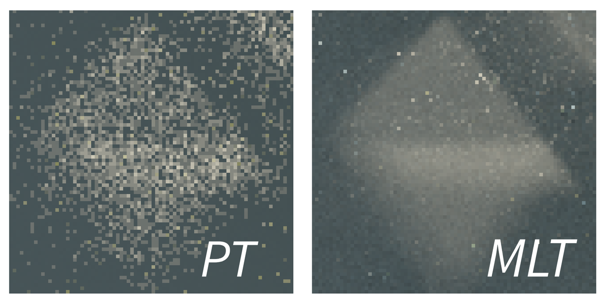
Problem Statement / Motivation

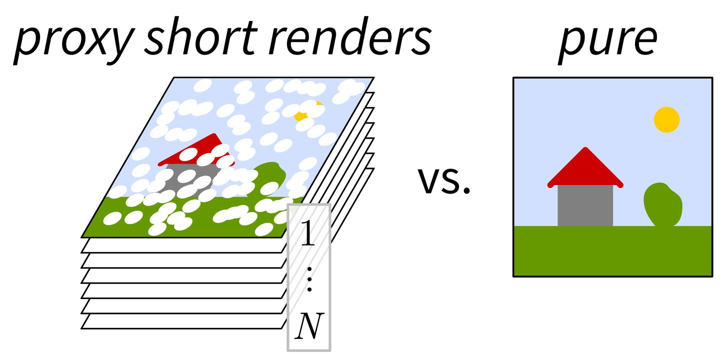
This work aims at improving methods for measuring the error of unbiased, physically based light-transport algorithms. State-of-the-art papers use error measures like Mean Square Error (MSE) or visual comparisons of equal-time renderings (example on the right). Those methods can be unreliable if outliers are present, and they do not measure the amount of outliers. Simple error measures like MSE use only one value, which allows objective comparisons but is little descriptive. Visual comparisons, on the other hand, are subjective. We propose a method that improves reliability, measures outliers and shows the frequency content of the error.

Example of equal-time comparison (caustic detail)

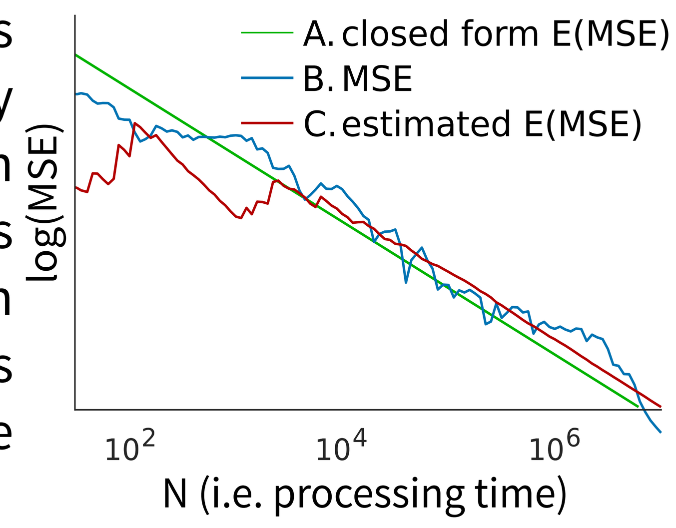


Proxy algorithm

We introduce a simple *proxy* algorithm: Given a computation budget of N, *pure* algorithms would consume the samples and produce one image I_N. The proxy, on the other hand, averages N independent images with sample budget 1. As a result, the Central Limit Theorem (CLT) applies, hence the convergence rate is $\Theta(1/N)$. Standard deviation per pixel images can be routinely computed. Monte Carlo (MC) algorithms are equivalent to their proxies. We did not see measurable difference between pure Markov Chain Monte Carlo (MCMC) and its proxy.

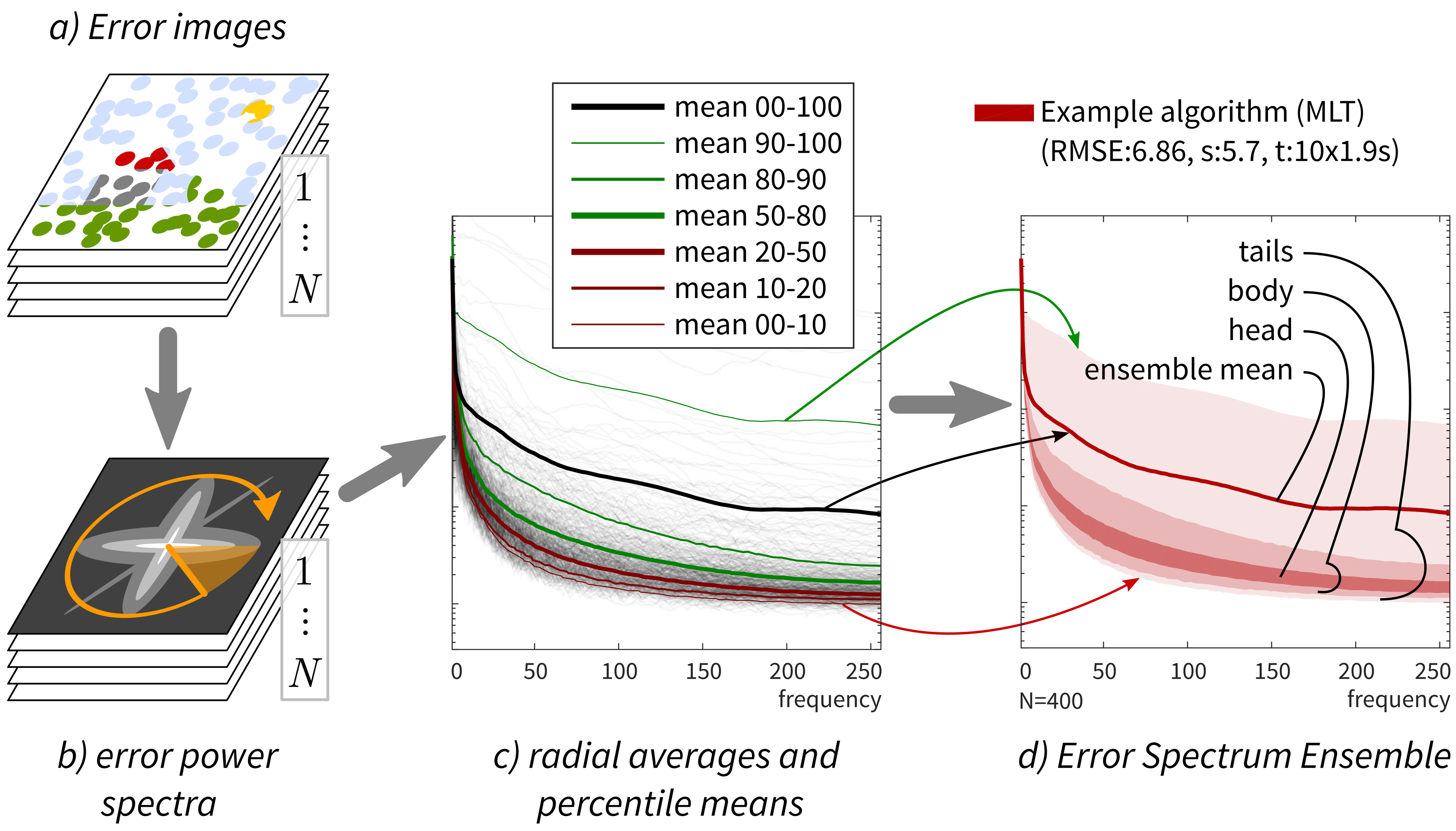


Contribution: Error expectation



The plot shows the MSE of a toy MC integration example. *B* is traditional: run for N samples and compute the MSE. *C* takes the mean of the N MSE values in the proxy algorithm. Effectively, this is an estimation of the MSE expectation. It can be seen, that *C* con-verges to *A butB* does not. The same problem of instable MSE values exists for scenes that cause outliers, no matter the rendering budget. Again, the proxy can be used to compute expected MSE as a remedy.

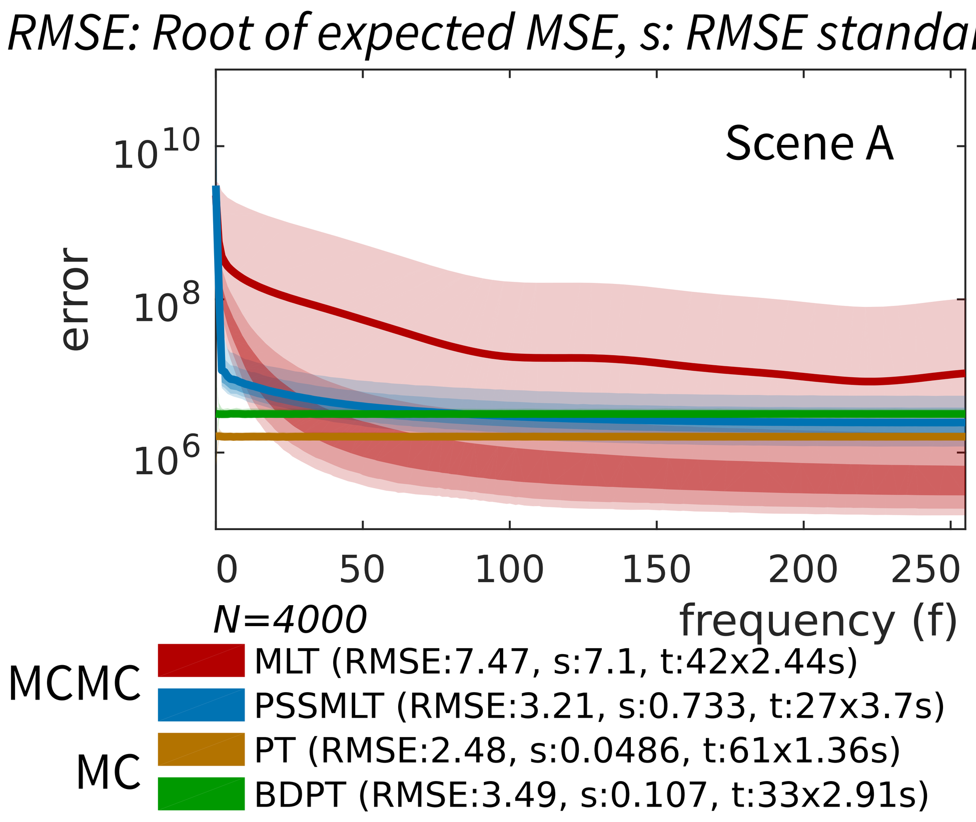
Contribution: Error Spectrum Ensemble (ESE)



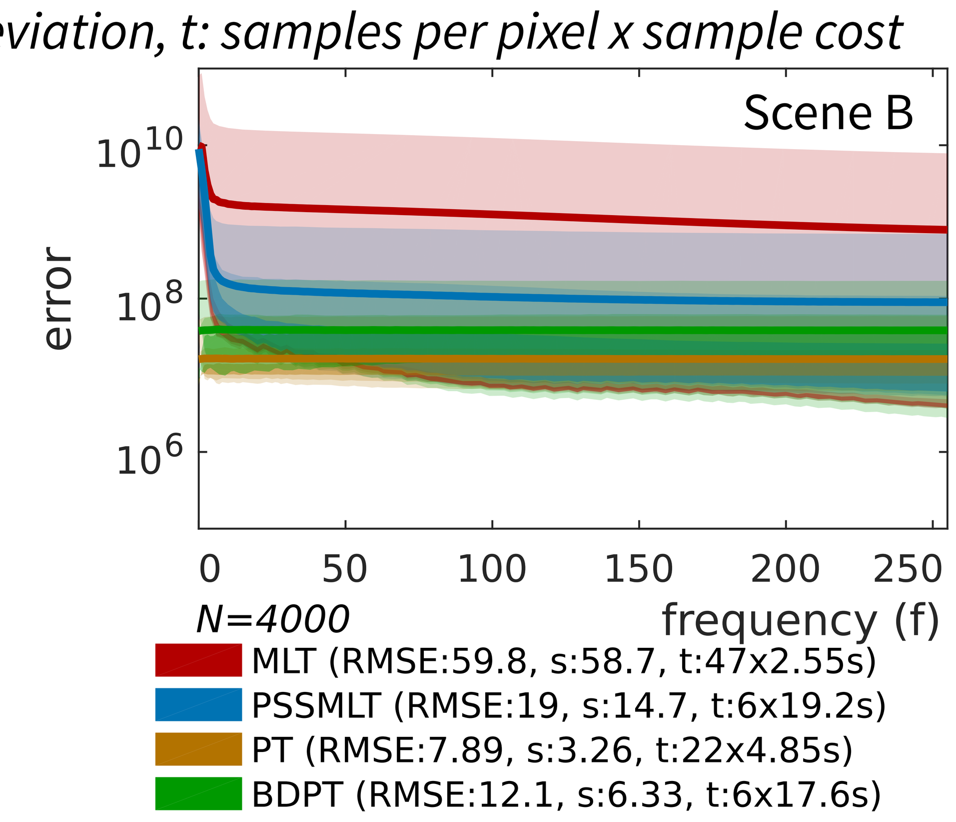
Based on the idea of estimating error expectation, we propose the Error Spectrum Ensemble (ESE) as a new tool for evaluating light-transport algorithms. It summarises error and outliers over frequency. ESE is generated from a large number (up to 4000 in our tests) of short renders (typically 10 CPU seconds each). Error images are computed using a reference (a), transformed into Fourier power spectra (b) and compressed using radial averages (c). The averages are sorted according to MSE. Means of the data between two percentiles form the descriptor (c and d).

Examples

RMSE: Root of expected MSE, s: RMSE standard deviation, t: samples per pixel x sample cost



Typically, MCMC methods have more error in low frequencies, i.e. correlated areas. MC methods have a flat spectrum.



Isolated pixel outliers make the ensemble mean of MLT almost horizontal. Outliers spoil the otherwise good MLT performance.

Conclusion

We introduce a simple proxy algorithm that allows:
- computing standard-deviation images for any algorithm routinely,
- estimating MSE expectation,
- and computing ESE, an error descriptor that shows amplitude intensity and spread accross frequencies.

These tools are more reliable and have more explanatory power compared to state-of-the-art methods. It is easy to apply them to any unbiased algorithm.

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