VU Rendering SS 2013
186.101

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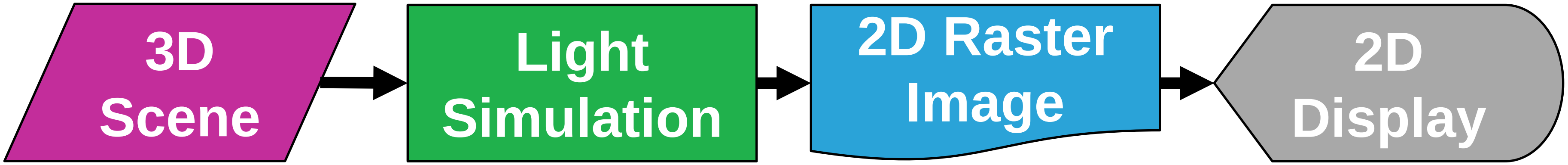
VU Rendering SS 2013

Unit 06 – Filtering

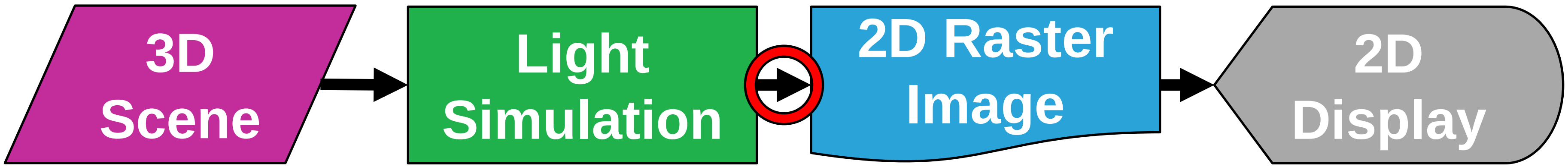
Scope

Rendering pipeline



Scope

Rendering pipeline



General Problem

Given a (piece-wise) continuous signal

(e.g. light simulation result).

We arrive at 2 main questions:

- How to reconstruct it efficiently from a set of samples?
- How to convert it to a discrete output format?

Simplest Solution

- Obtain a **single** radiance sample for each pixel area.
- Assume radiance is **constant** on each pixel area.
- Draw one sample from each pixel area to generate the final output image.

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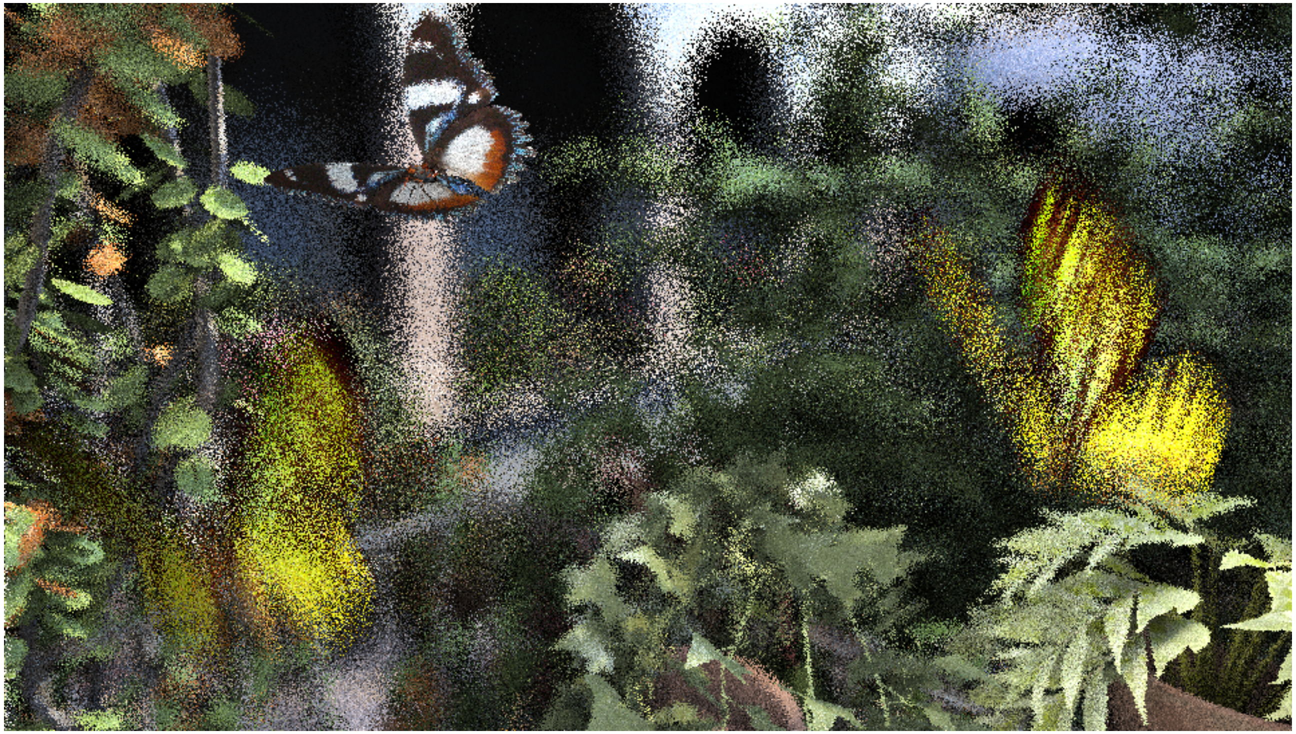

- Noisy

(from **Lehtinen et al. 2011**)

Simple Solution

- Obtain **many** radiance samples for each pixel area.
- Assume radiance is their **average** on each pixel area.
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- Slow

(from **Lehtinen et al. 2011**)

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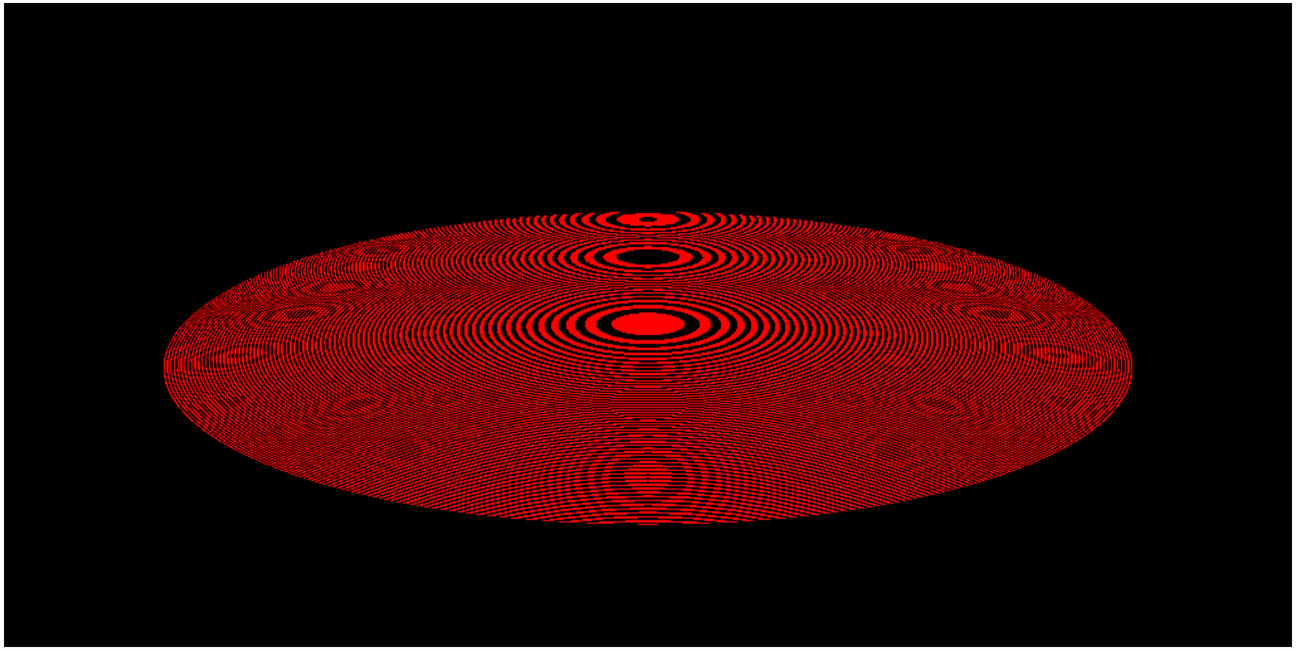
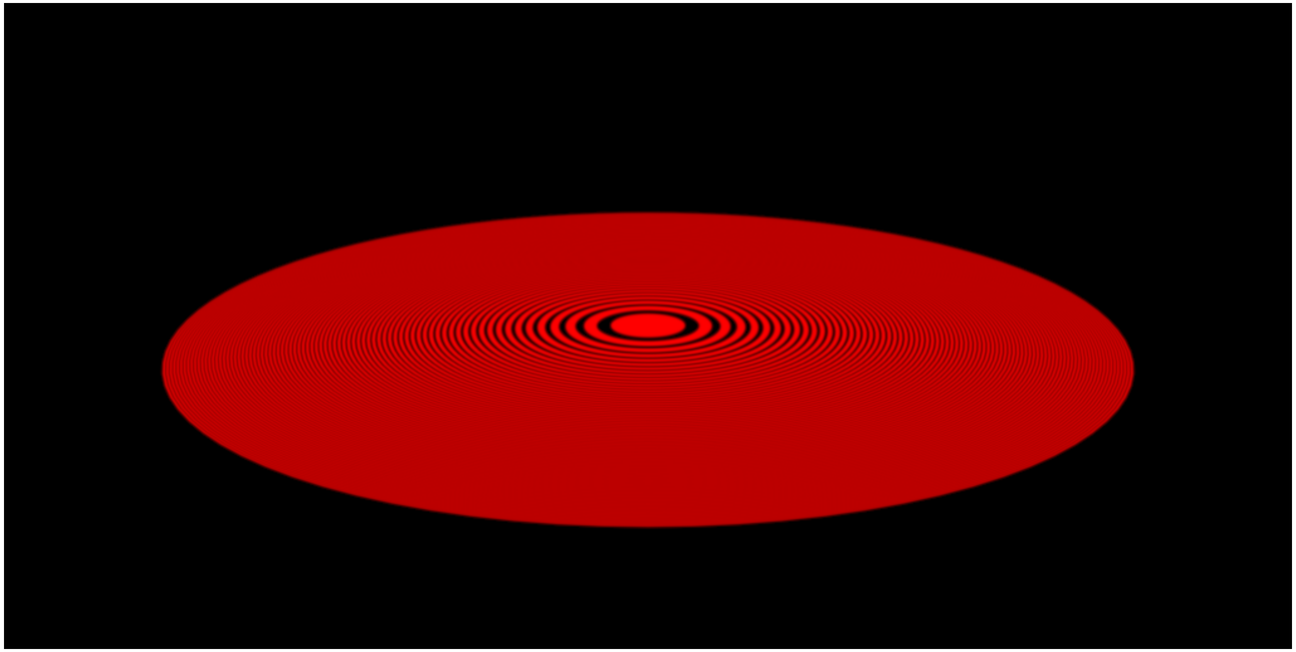


- Slow
- Aliasing

(from **Auzinger et al., CGF, 2013**)

Simple Anti-aliased Solution

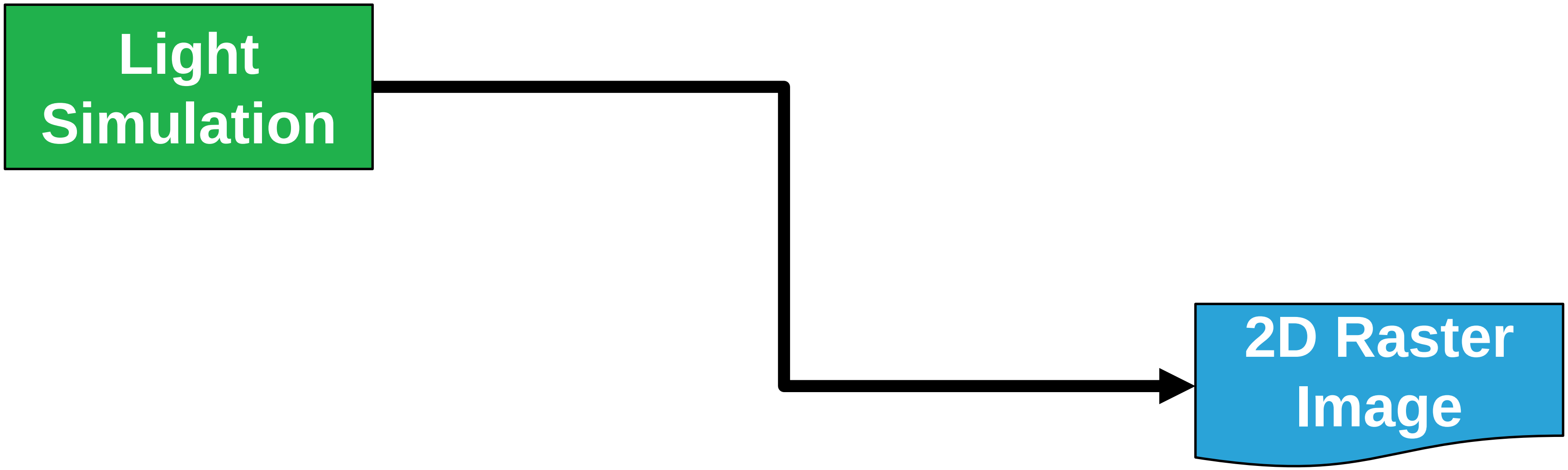
- Obtain **many** radiance samples for each pixel area.
- Assume radiance is their **average** on each pixel area.
- After **prefiltering** draw one sample from each pixel area to generate the final output image.



- Slow

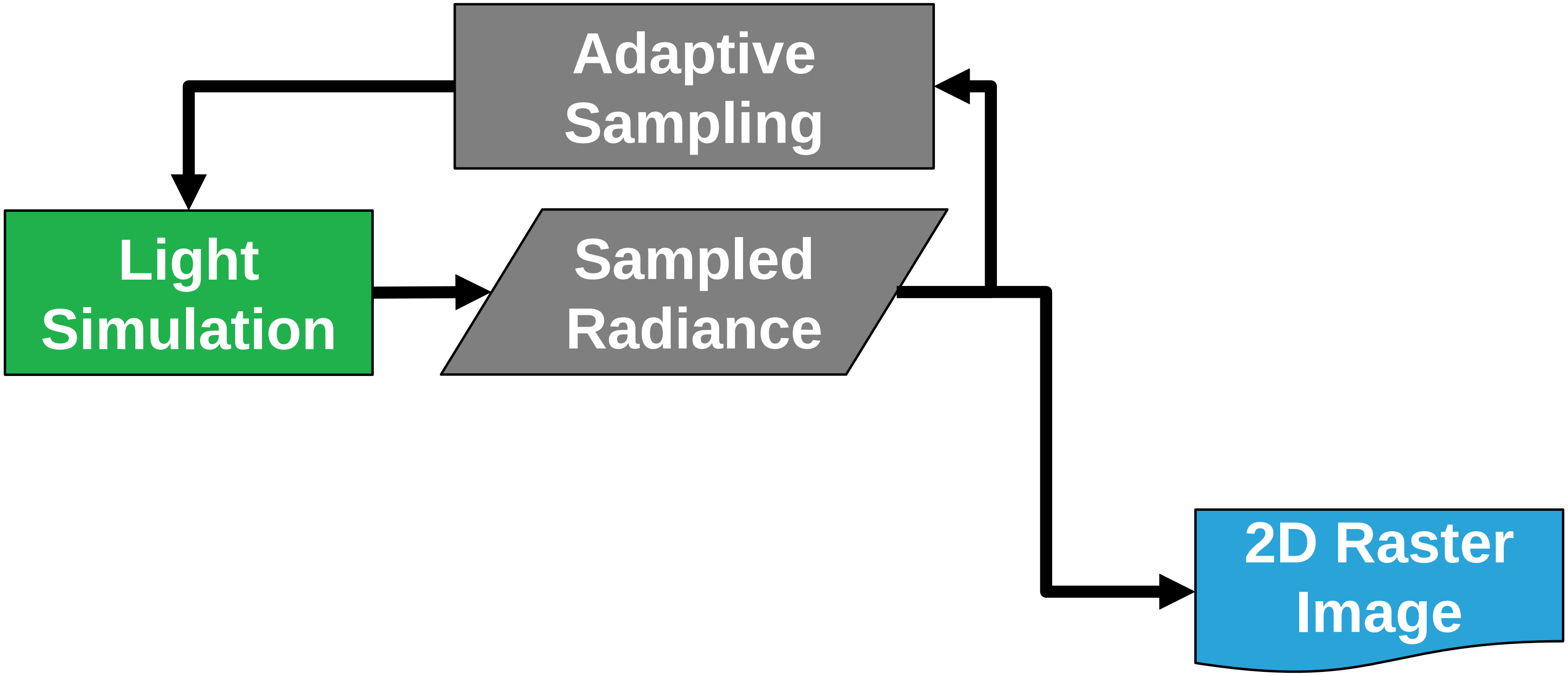
(from **Auzinger et al., CGF, 2013**)

Improvements



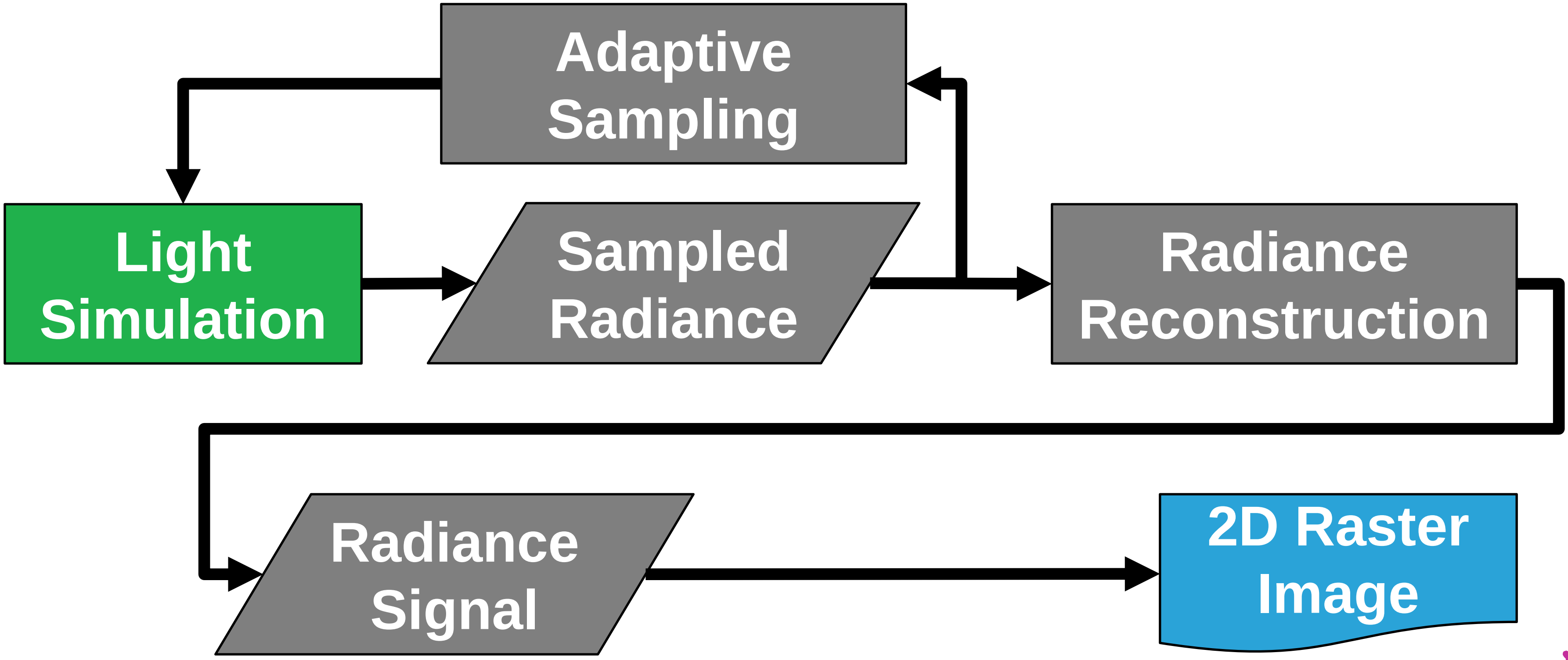
Improvements

- Place more samples in *difficult* regions.



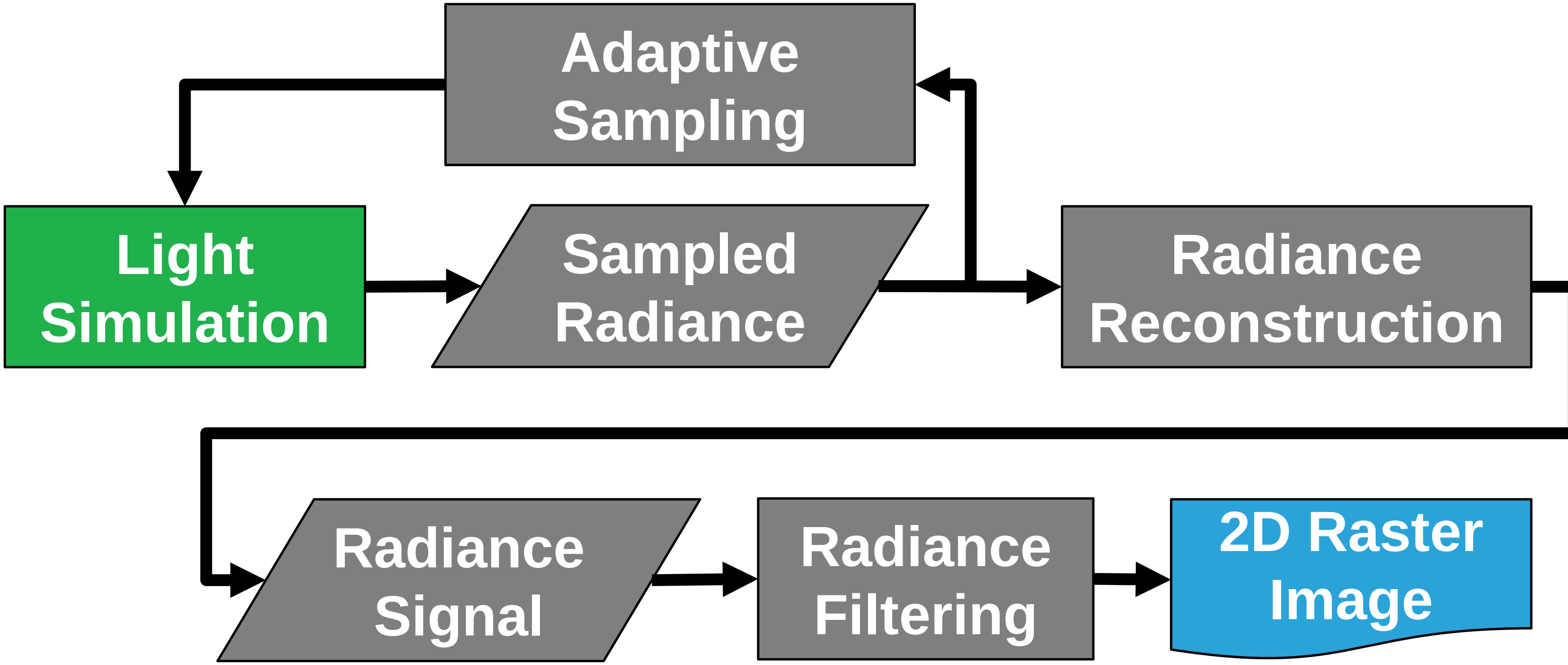
Improvements

- Place more samples in *difficult* regions.
- Use better reconstruction methods that *share samples* between different locations.

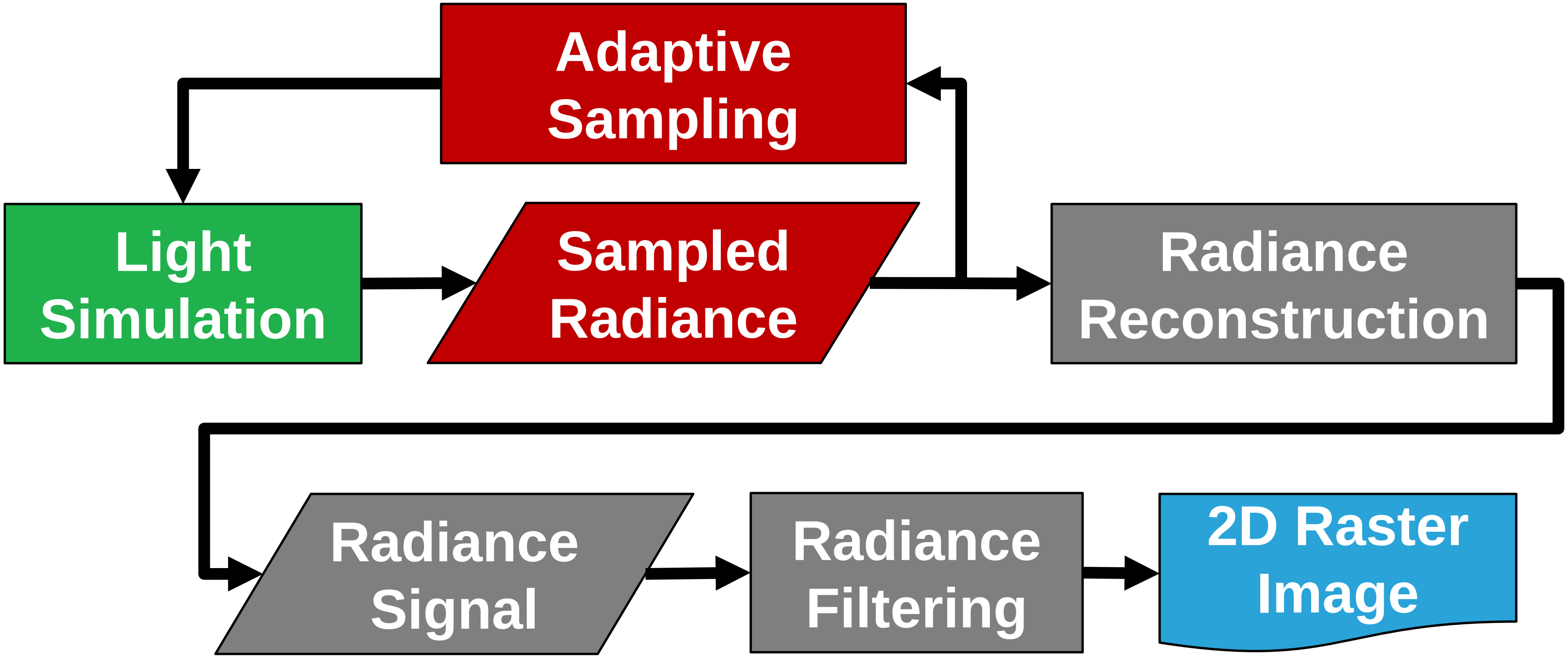


Improvements

- Place more samples in *difficult* regions.
- Use better reconstruction methods that *share samples* between different locations.
- Use filtered sampling to avoid aliasing artifacts.



Adaptive Sampling

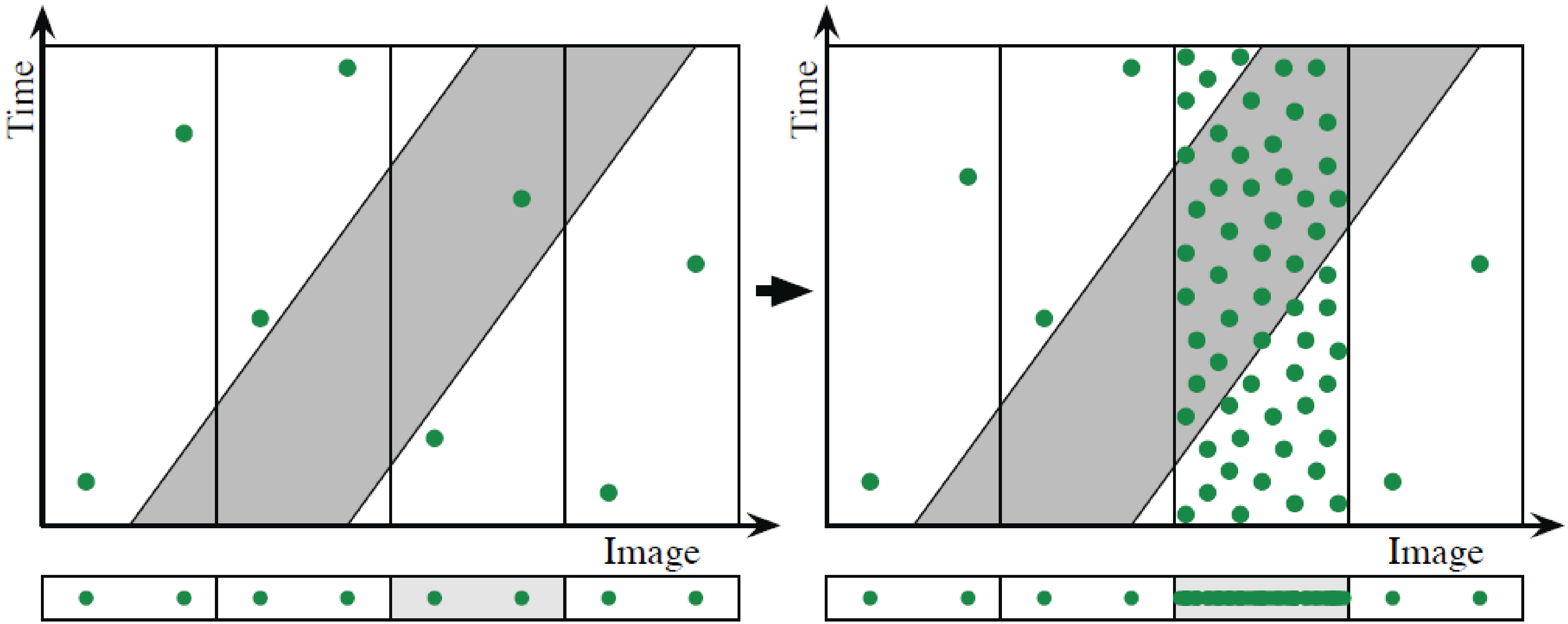


Adaptive Sampling

1. Compute initial samples.
2. Compute error metric.
3. If error above threshold, compute additional samples and go to 2.
4. If not, finished.

Error Metrics

- Contrast $C = \frac{L_{\max} - L_{\min}}{L_{\max} + L_{\min}}$ per pixel in image space [Mitchell 1987]

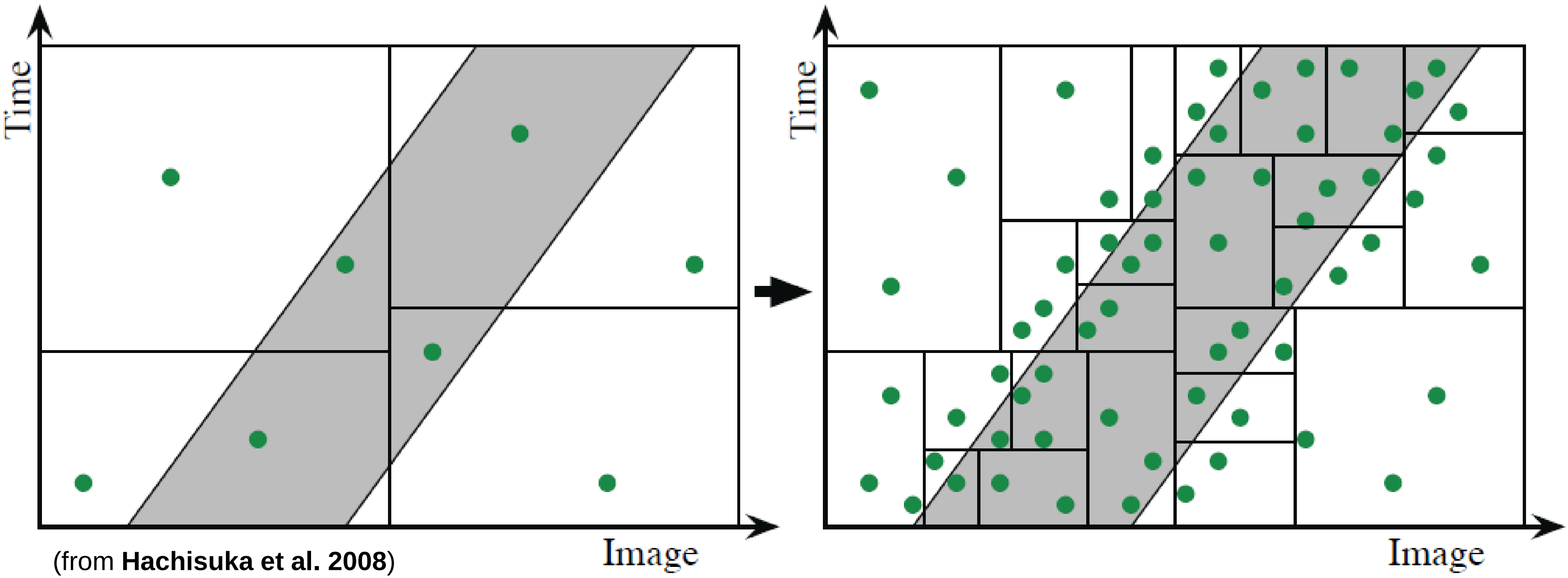


(from **Hachisuka et al. 2008**)

Error Metrics

- Contrast in high-dimensional space

[Hachisuka et al. 2008]

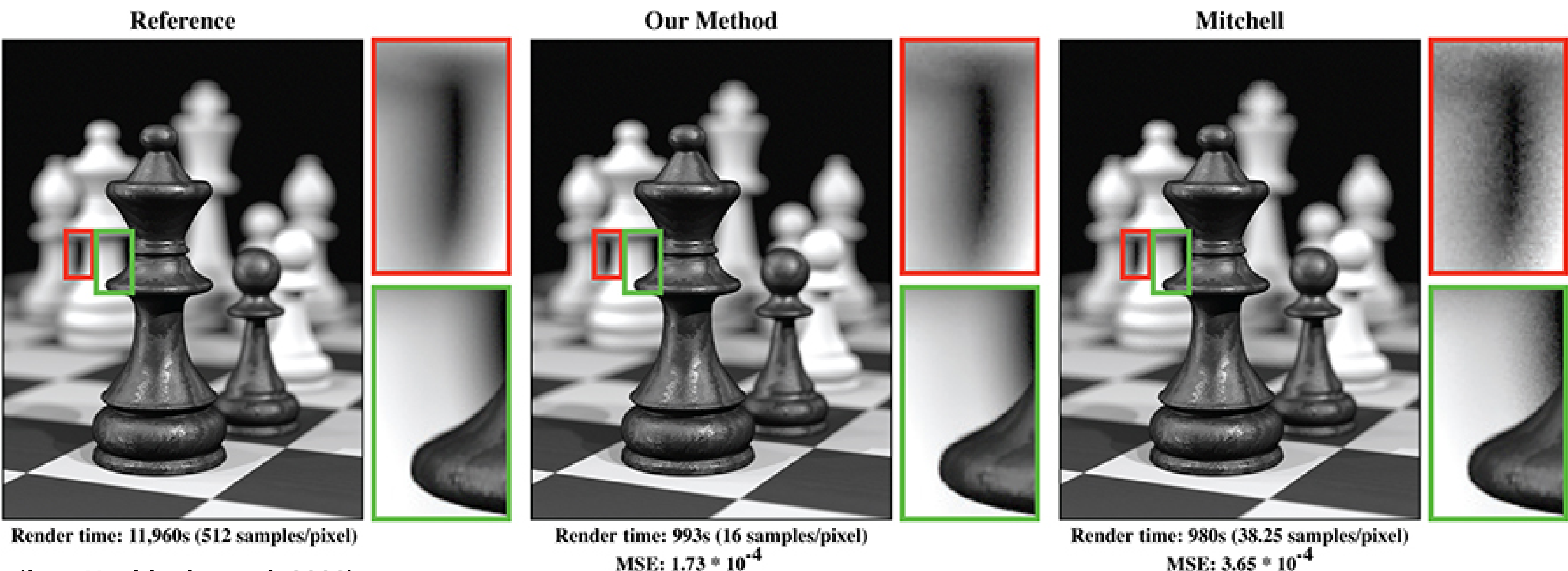


(from **Hachisuka et al. 2008**)

Error Metrics

- Contrast in high-dimensional space

  [Hachisuka et al. 2008]

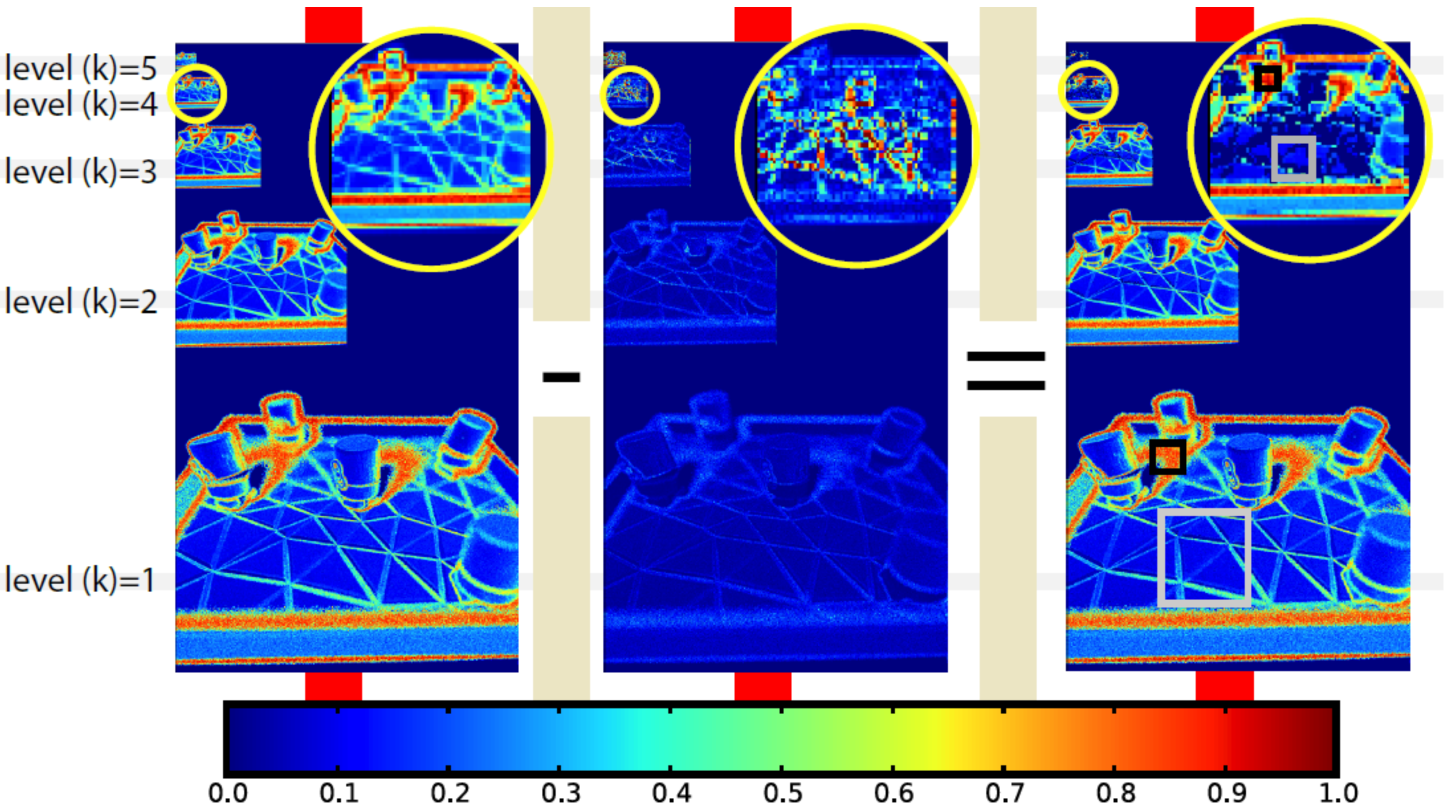


(from **Hachisuka et al. 2008**)

Error Metrics

- Magnitude of wavelet coefficients

[Overbeck et al. 2009]



(from **Overbeck et al. 2009**)

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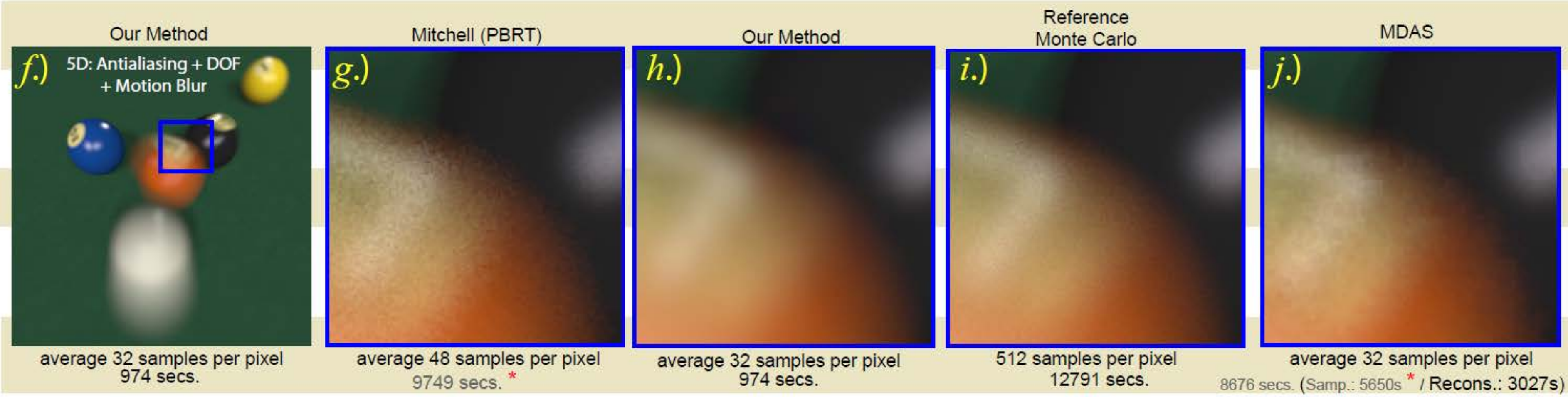

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- Magnitude of wavelet coefficients

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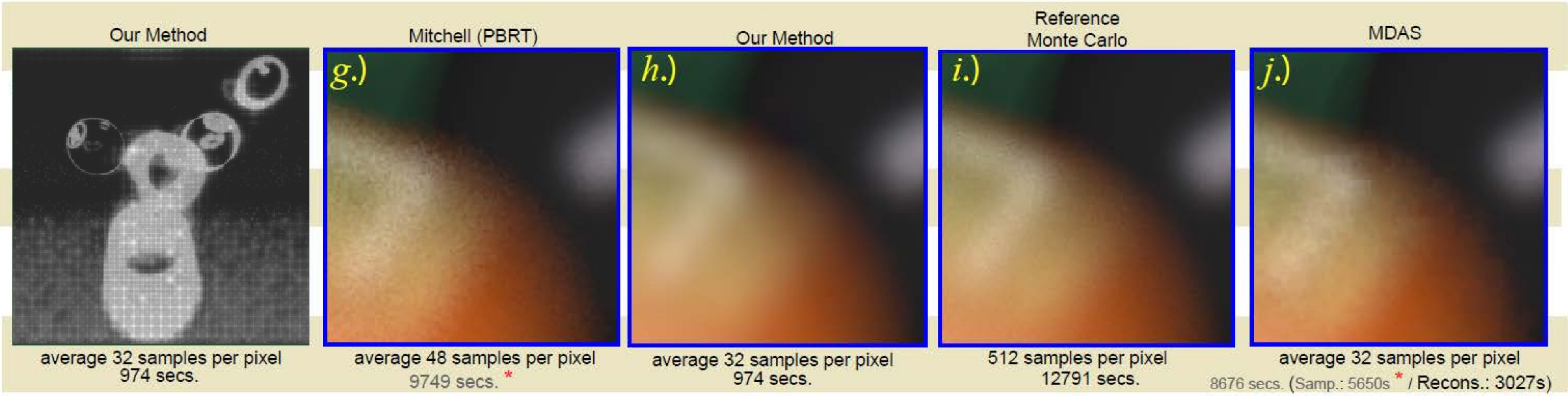
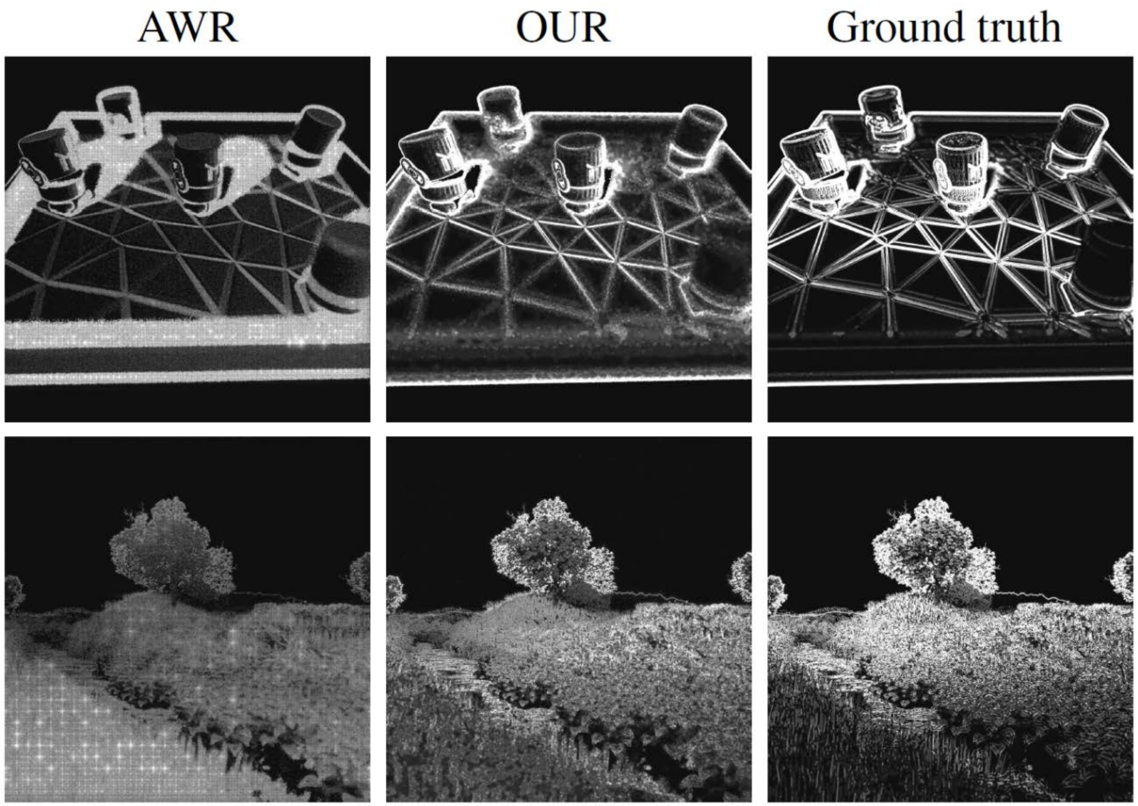


(from **Overbeck et al. 2009**)

Error Metrics

- Decrease in the mean squared error

[Rousselle et al. 2011]



(from **Rousselle et al. 2011**)

Error Metrics

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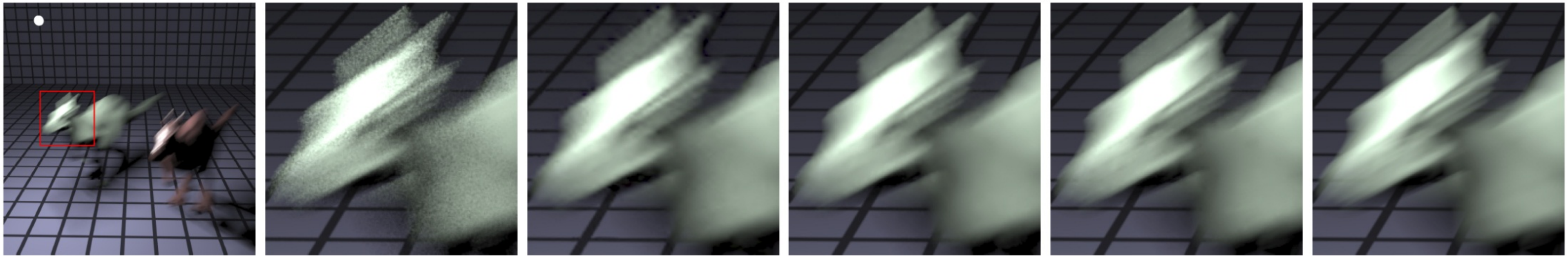
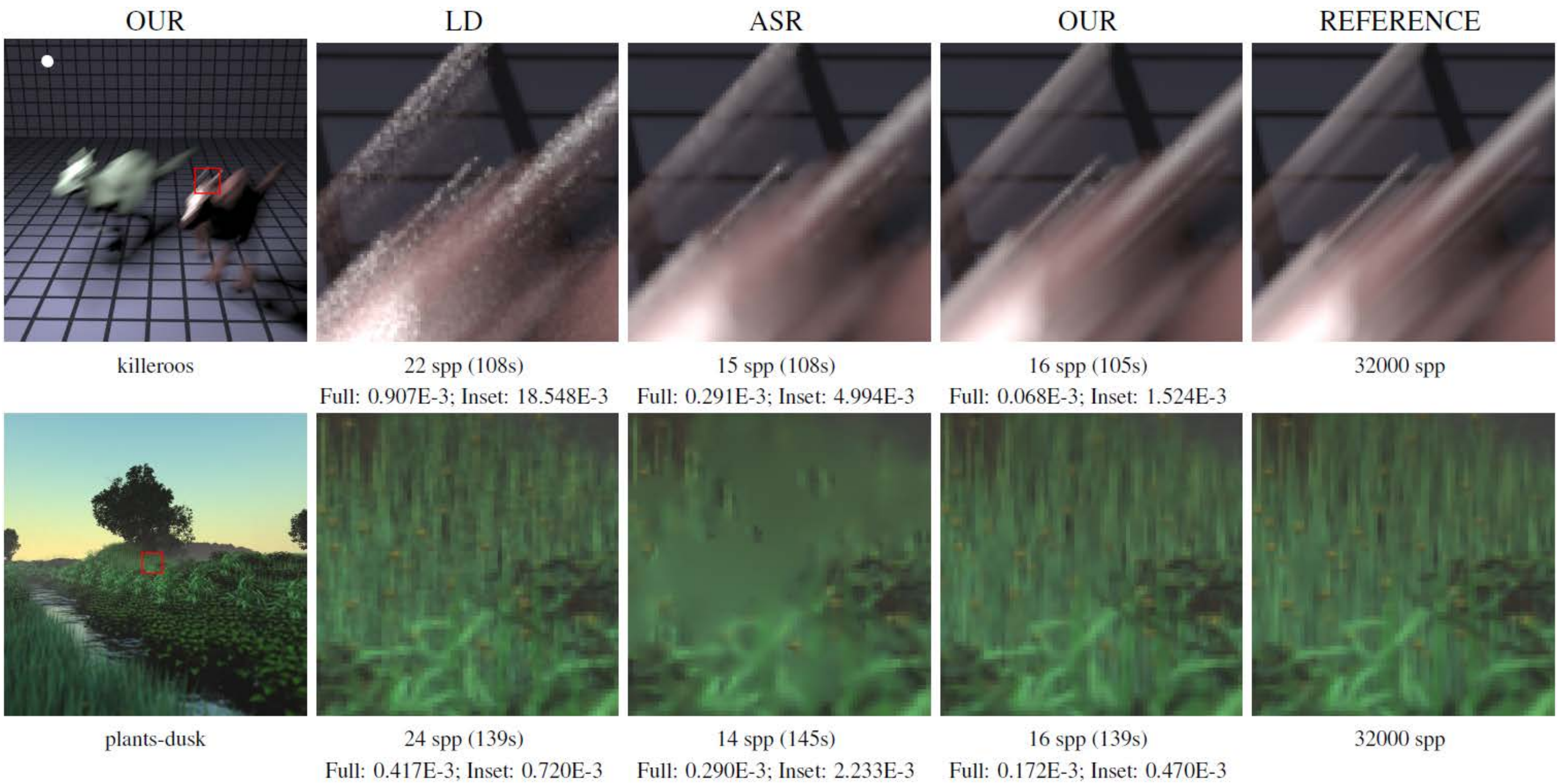


(from **Rousselle et al. 2011**)

Error Metrics

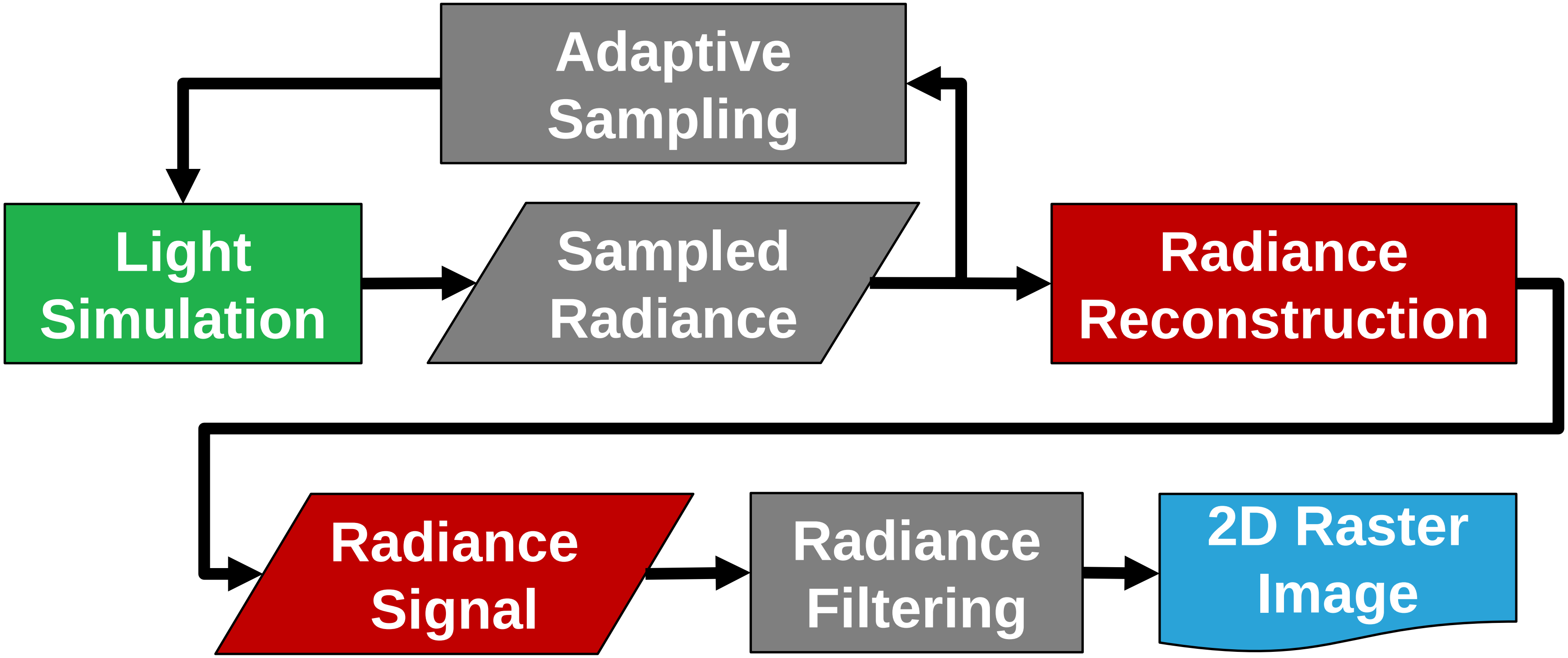
- Difference from denoised image

[Rousselle et al. 2012]



(from **Rousselle et al. 2012**)

Reconstruction

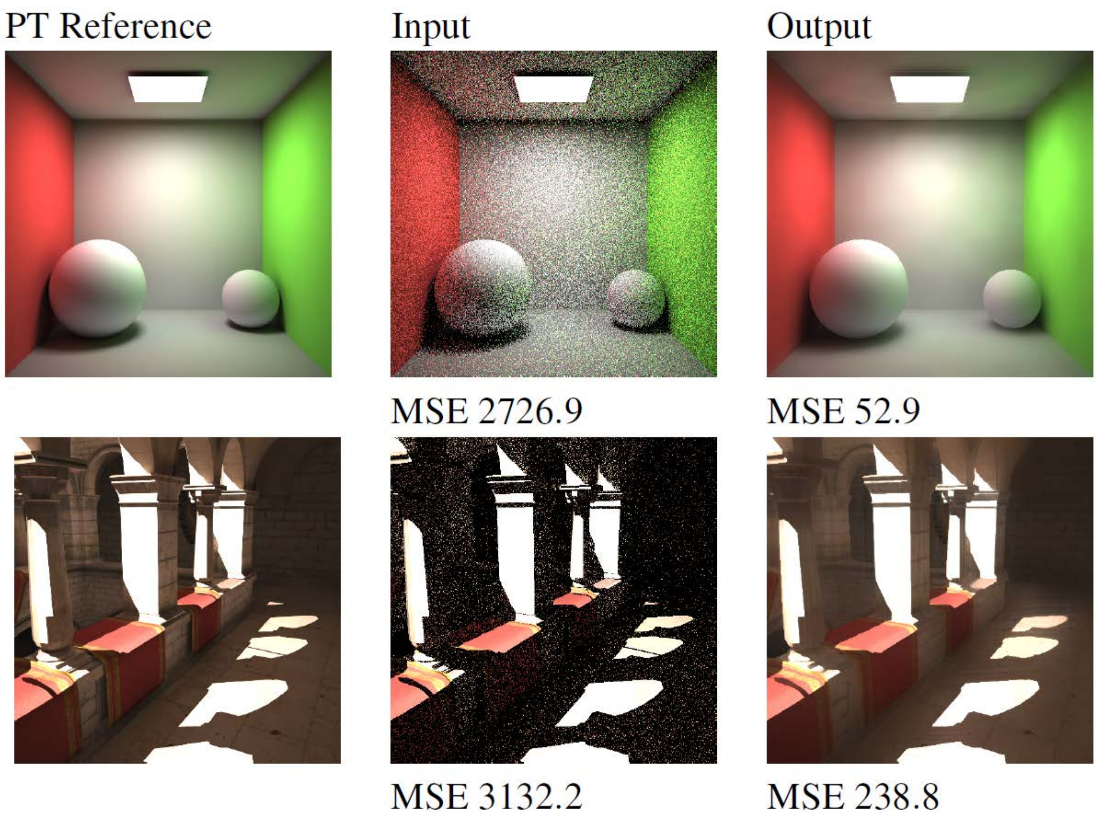


Reconstruction

1. Determine reconstruction filter for each location
   - Either using filters from the adaptive process
   - or using additional data (depth, velocity,...)
2. Convolve samples with these filters.

Error Metrics

- À-Trous Wavelets using normals and depth
  [Dammertz et al. 2010]



(from **Dammertz et al. 2010**)

Error Metrics

- Reprojection of light field samples for various effects (depth of field, motion blur, ...)

[Lehtinen et al. 2011]

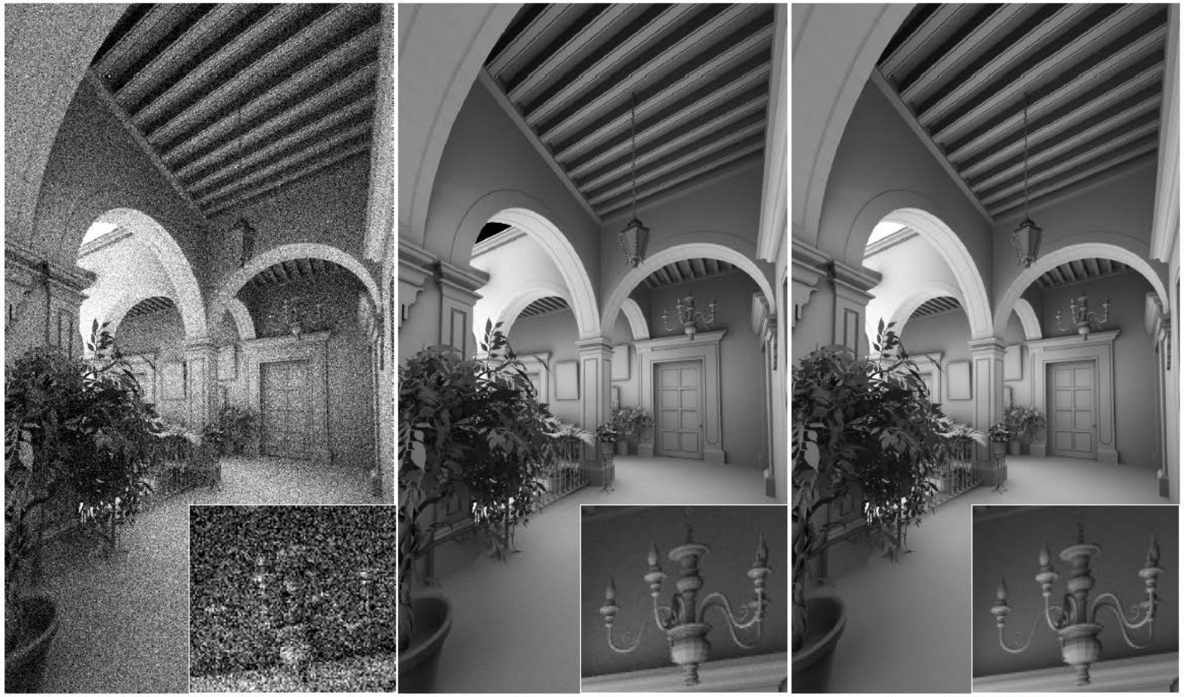
PBRT, 16 spp, 403 s   PBRT, 256 spp, 6426 s   Our result, 16 spp, 403 + 10 s (+2,5%)

(from **Lehtinen et al. 2011**)

Error Metrics

- Reprojection of light field samples for indirect illumination

[Lehtinen et al. 2012]

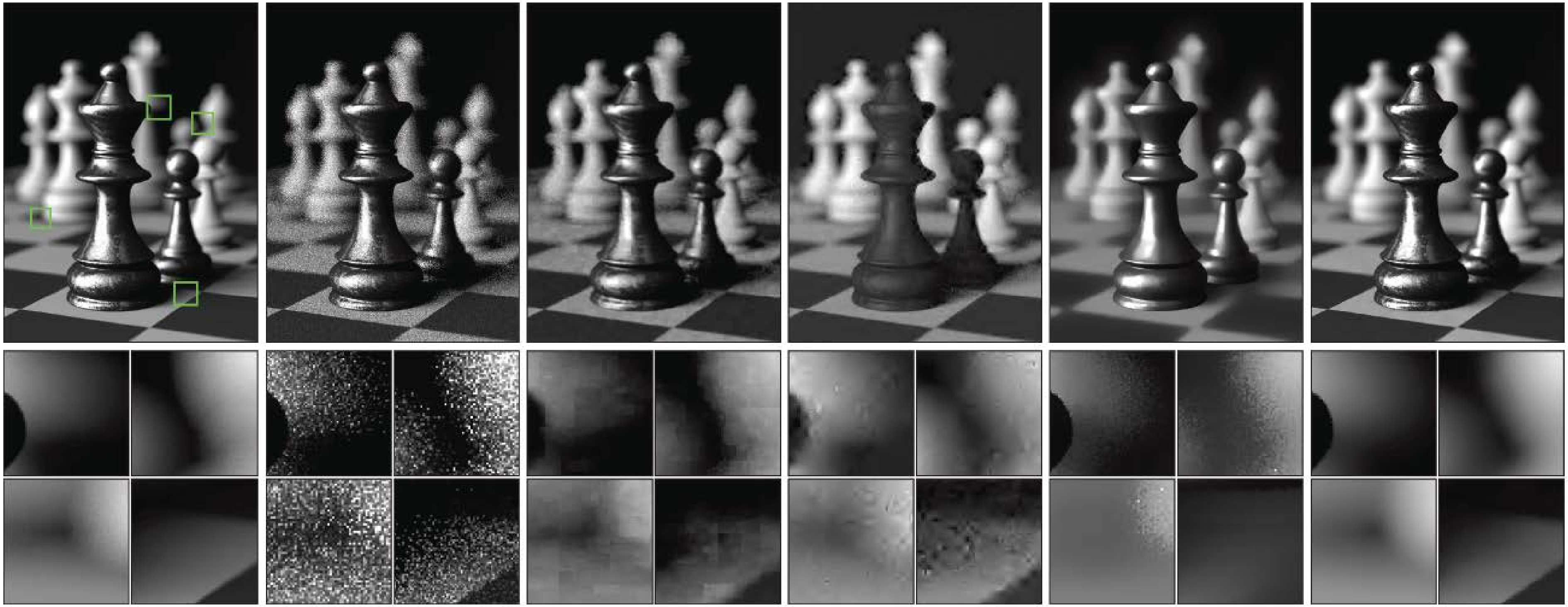


Input (4 spp) | Our reconstruction | Ground truth (2048 spp)

(from **Lehtinen et al. 2012**)

Error Metrics

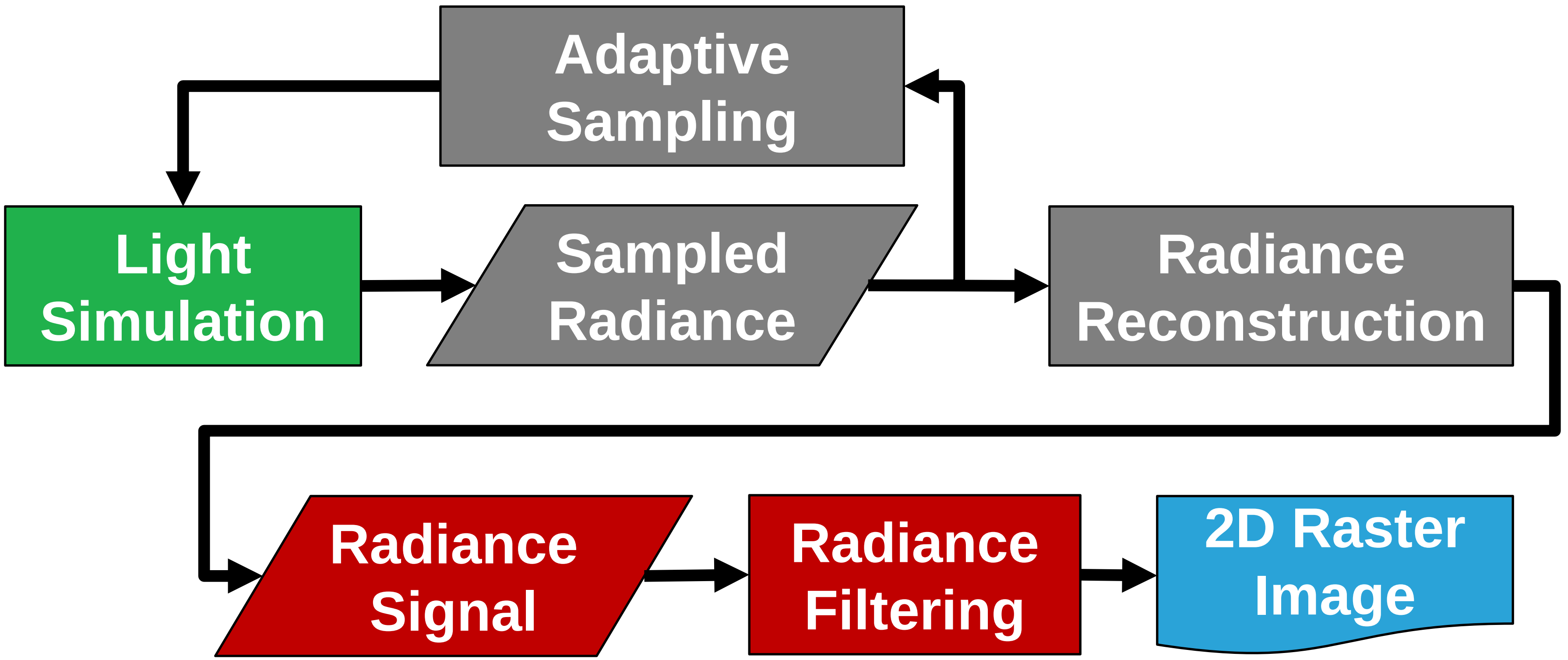
- Cross-bilateral filters using random parameters [Sen and Darabi 2012]



Reference (8,192 spp) Input Monte Carlo (8 spp) MDAS AWR À-Trous Our approach (RPF)

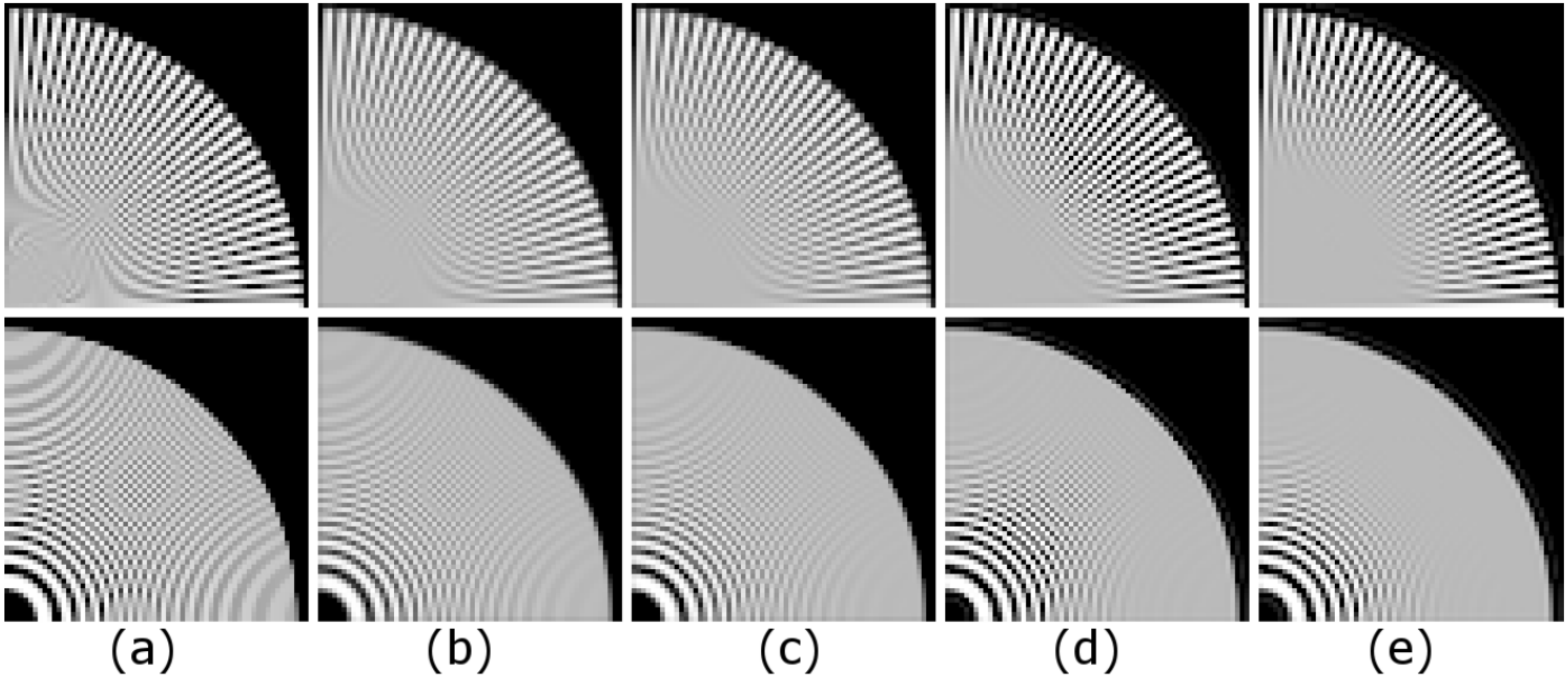
(from **Sen and Darabi 2010**)

Adaptive Sampling



Anti-Aliasing

- Convolve continuous signal with a filter to eliminate high frequencies.
- Usually already done in the reconstruction step.
- Many filters to choose from.



(from **Manson and Schaefer, CGF, 2013**)

Literature

Textbooks

- PBRT chapter 7
- R. Bracewell, *The Fourier Transform and its Applications*, 1999

Papers – Adaptive Sampling

- D.P. Mitchell, *Generating antialiased images at low sampling densities*, Siggraph 1987
- T. Hachisuka et al., *Multidimensional adaptive sampling and reconstruction for ray tracing*, Siggraph 2008
- R. Overbeck et al., *Adaptive wavelet rendering*, Siggraph Asia 2009
- F. Rouselle et al., *Adaptive sampling and reconstruction using greedy error minimization*, Siggraph Asia 2010
- F. Rouselle et al., *Adaptive rendering with non-local means filtering*, Siggraph Asia 2012

Literature

Papers – Reconstruction

- H.Dammertz et al., *Edge-avoiding À-Trous wavelet transform for fast global illumination filtering*, HPG 2010
- J. Lehtinen et al., *Temporal light field reconstruction for rendering distribution effects*, Siggraph 2011
- J. Lehtinen et al., *Reconstructing the indirect light field for global illumination*, Siggraph 2012
- P. Sen and S. Darabi, *On filtering the noise from random parameters in Monte Carlo rendering*, TOG 2012

Literature

Lecture notes – Anti-Aliasing

- P. Rautek at al., Sampling and Reconstruction, VO 186.830, VUT, http://cg.tuwien.ac.at/courses/CG/VO.html
- K. Bala, *Sampling and Anti-Aliasing*, CS5620, Cornell http://www.cs.cornell.edu/courses/CS4620/2012fa/lectures/26sampling.pdf
- M. Levoy and P. Hanrahan, *Computer Graphics*, CS348B, Stanford http://graphics.stanford.edu/courses/#cs348b

Questions?

(from **Lehtinen et al. 2011**)