

Scenario and Goal

Goal: Simplified high dynamic range (HDR) image generation

- ▶ Scenario: Dynamic range of scene is larger than dynamic range of sensor
- ▶ Common HDR: exposure bracketing \Rightarrow several shots
 - \Rightarrow Long total acquisition time
 - \Rightarrow Ghosting likely to occur
 - \Rightarrow Challenging free-hand shots
- ▶ HDR image generation from several low dynamic range (LDR) images may be challenging and computationally complex



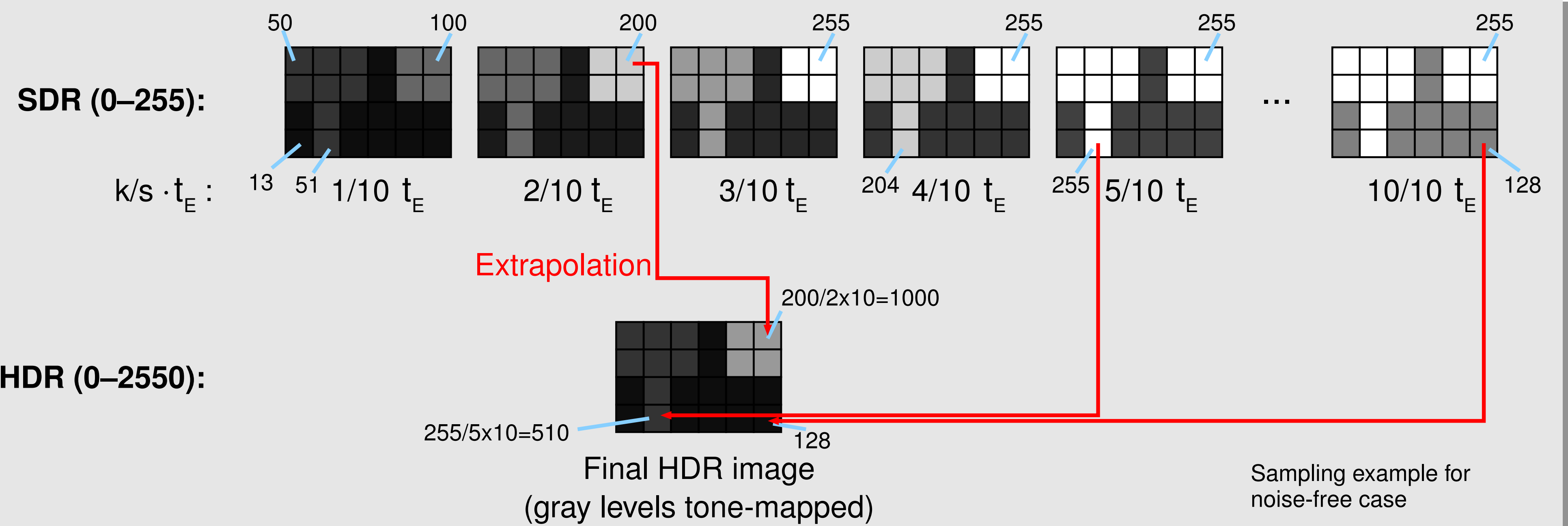
Underexposed \Rightarrow highlights OK

Overexposed \Rightarrow shadows OK

Idea: Sampling during exposure

Sampling during Exposure

- ▶ Consider only pels below saturation for each sampling step
- ▶ Pel-wise temporal extrapolation
- ▶ Pel-wise averaging of temporally extrapolated pels



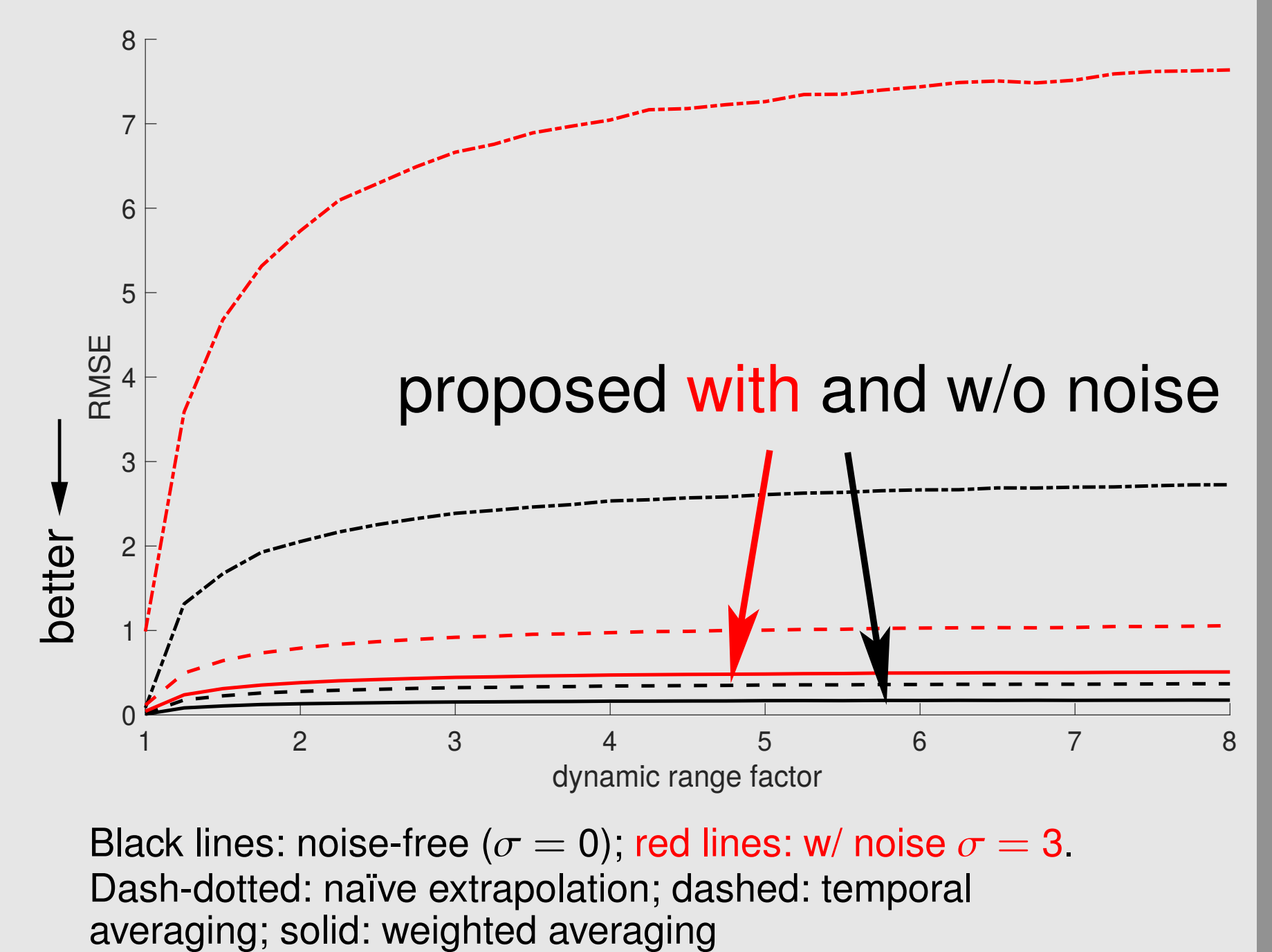
Total acquisition time $t_E \ll t_{total,common} \Rightarrow$ ghosting artifacts less likely to occur

Error Analysis

- ▶ Rounding error for each intermediate sampling step: $|e| \leq \frac{1}{2}$
- ▶ Rounding error after extrapolation from k -th out of s sampling steps: $|e_k| \leq \frac{s}{2k}$
- ▶ Error for noise-free case: $e_k = |\bar{v}(x, y, t_E) - g_k|$,
with $\bar{v}(x, y, t_E)$: non-measurable, true value for pixel (x, y) after total exposure time t_E ,
 $g_k = \frac{s}{k} \cdot \left[\frac{k}{s} \cdot \bar{v}(x, y, t_E) \right]$: extrapolated value, $[\cdot]$: rounding function
- ▶ Error with zero-mean white Gaussian noise: $e_k \leq |\bar{v}(x, y, t_E) - (g_k + \frac{s}{k} [\eta_k])| + \nu_k$
with η, g, ν : random variables with realizations $\eta_k, g_k, \nu_k = \frac{s}{k} \cdot 1$

Temporal averaging and weighting for noise-reduction

- ▶ Extrapolated rounding errors and noise decrease for later sampling steps, but **all** sampling steps are affected by independent noise \Rightarrow temporal averaging
- ▶ Signal-to-noise ratio (SNR) increases for longer exposure times
 \Rightarrow higher weighting of later sampling values, e. g. with weighting function $w_k = \frac{k}{\sum_{j=1}^s j}$



Experimental Results

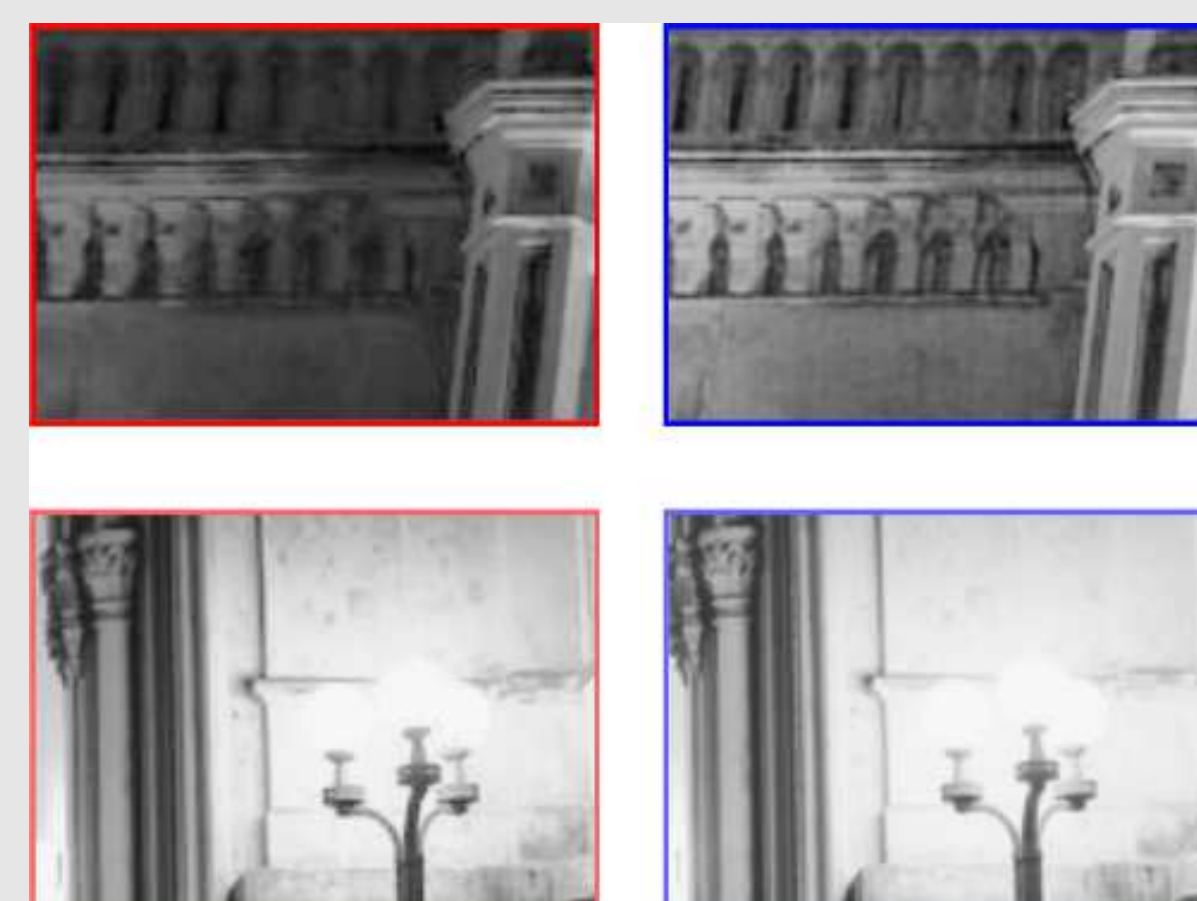
- ▶ 10 intermediate samplings simulated by taking 10 photos with increasing exposure times
 \Rightarrow worst-case due to independent noise and rounding in each photo
- ▶ Matlab's default tone mapping



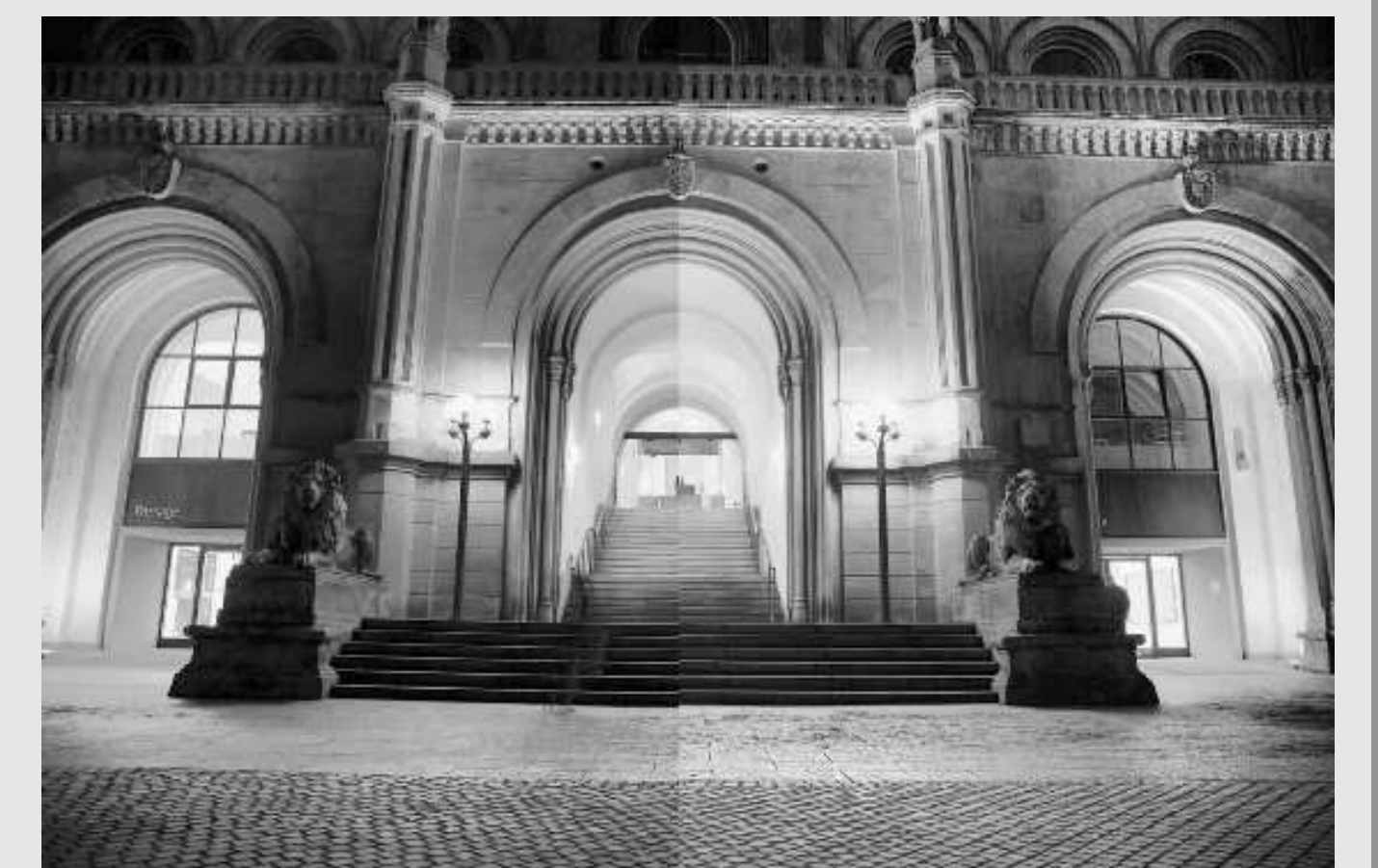
Common Matlab-HDR



Proposed w/ weighted averaging



Magnifications (colors match colors left)



Side-by-side: left: common, right: proposed

Summary

- ▶ Simple HDR image generation
- ▶ Intermediate read-outs (samplings) *without* reset
- ▶ Pel-wise extrapolation
- ▶ Reduced image noise for low-light scenarios
- ▶ Improved detail preservation
- ▶ Reduced total image-acquisition time \Rightarrow reduced ghosting

No or small hardware changes \Rightarrow applicable for low-cost sensors (e. g. in smartphones)