Goal: Capture photo of a subject in given total exposure time, with the highest per-pixel SNR over its dynamic range.

- number of shots?
- exposure time & ISO for each shot?

The High ISO Advantage

Conventional wisdom about ISO:
• shoot the lowest ISO possible” that avoids motion blur [Bloch 07][McCollough 08]

ISO for a fixed exposure time:
• high ISO trades lower dynamic range for higher SNR (esp. in shadows)

Exploit SNR benefit of high ISO with multi-photo capture

multiple exposures for high dynamic range

Globally Optimal Capture Sequence

optimal HDR merge: [Kirk & Andersen 06]
• per-pixel MMSE blending weights

\[
SNR(\Phi)^2 = \sum_{j=1}^{K} \Phi_t j^2 \left( \frac{I_j + \sigma_{\text{read}} \cdot g + \sigma_{\text{ADC}}}{I_{\text{max}}} \right)
\]

worst-case SNR:
• evaluate at finite #keypoints, K

mixed integer linear program (ILP):

\[
\text{maximize } SNR_{\text{optimal}} \\ \text{subject to } \sum_j m_j (t_j + t_{\text{read}}) \leq t_{\text{max}} + t_{\text{read}} \\
SNR(\Phi)^2 \geq SNR_{\text{optimal}} \ \ \text{for all } \Phi \in K
\]

#photos per camera setting

Experimental Results

- Canon 1D Mark III
- scene dynamic range = 6500 (12.7 stops)
- total exp. time ≤ 87 msec, max 3 photos

- Canon 1D Mark III
- scene dynamic range = 33900 (15.1 stops)
- total exp. time ≤ 0.25 sec, max 3 photos

- tractable: ~0.5 sec runtime for ILP

SNR (dB)

input

tone mapped
merged HDR

bright region
dark region
darkest

2 stops clipped

SNR-optimal (ours)

ideal HDR sensor

log scene brightness

exposure bracket (ref.)

ISO 100
(1/100, 1/25, 1/6) sec

ISO 3200
(1/3200, 1/125, 1/5) sec

0

12 dB

−20

−16

−14

−12

−10

−8

−6

−4

−2

0

2

log scene brightness

Exploit SNR benefit of high ISO with multi-photo capture

sensor noise (non-saturated pixel):

\[
I = \min(\Phi t \cdot g + n, I_{\text{max}})
\]

\[
\text{Var}(n) = \Phi t \cdot g^2 + \sigma_{\text{read}}^2 \cdot g^2 + \sigma_{\text{ADC}}^2
\]