

Fundamental Tradeoffs in Space-Time Multiplexed Computational Imaging

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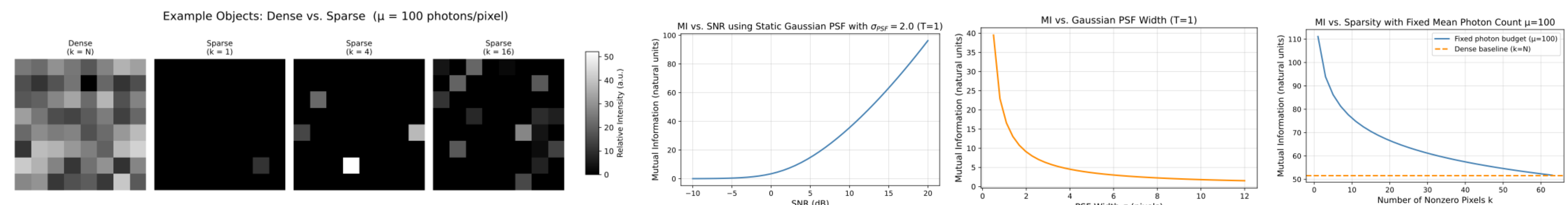
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Motivation

- Temporal coded imaging techniques have proven useful in tasks such as motion deblurring, high dynamic range capture, and light field acquisition.
- Most prior work optimizes static spatial encoders and the role of temporal multiplexing (i.e. varying the PSF across frames) remains underexplored from an information-theoretic perspective
- This work:** Using mutual information-based framework, when does temporal multiplexing increase information content and for which object types? How do scene dynamics limit its benefit?

Mutual Information-based Approach

- Model imaging system as $y_t = H_t x + n_t$, where H_t encodes a time-varying PSF at frame t
- Use **mutual information** as performance metric: decoder-independent upper bound on recoverable information, unlike SNR or SSIM which depend on reconstruction algorithm choice
- Closed-form MI expression under Gaussian priors: $I(x, y) = \frac{1}{2} \log \det \left(I + \frac{\sigma_x^2}{\sigma_n^2} \sum_{t=1}^T H_t^T H_t \right)$
- Extend to **dynamic scenes** via motion model $x_t = x_0 + \delta_t, \delta_t \sim \mathcal{N}(0, \sigma_d^2 I)$



Related Work

- Existing performance analyses are **decoder-dependent** (eg: SNR, SSIM) and require ground-truth reconstructions [1, 2]
- Ref. [1] establishes theoretical bounds showing that computational imaging outperforms impulse imaging only in low-light regimes
- Recent works apply mutual information as a metric to design encoders for maximal information capture \rightarrow show higher decoder performance [3]

References

- [1] O. Cossairt, M. Gupta, and S. K. Nayar, "When does computational imaging improve performance?" IEEE Transactions on Image Processing, vol. 22, no. 2, pp. 447–458, 2013.
- [2] G. Wetzstein, I. Ihrke, and W. Heidrich, "On plenoptic multiplexing and reconstruction," International Journal of Computer Vision, vol. 101, no. 2, pp. 384–400, 2013.
- [3] L. A. Kabuli, H. Pinkard, E. Markley, C. S. Hung, and L. Waller, "Designing lensless imaging systems to maximize information capture," Optica, vol. 13, no. 2, pp. 227–235, Feb 2026.

Experimental Results

