Information-Driven Design of Imaging Systems

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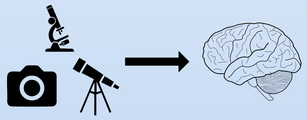
Project website

Why?

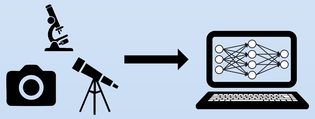
Modern imaging systems computationally process raw measurements

So capturing lots of information is more important than capturing a pretty, human-interpretable picture

Traditional: human interpretation

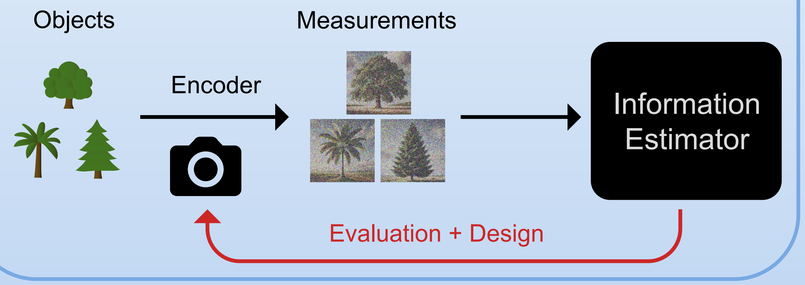


Modern: Computational processing



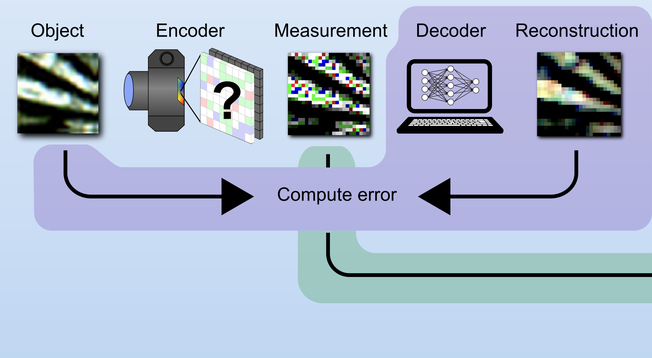
What?

We developed an **Information estimator**, which enables the evaluation and design of imaging based on information capture, not visual appearance



For example?

What is the best color filter mask for photography?

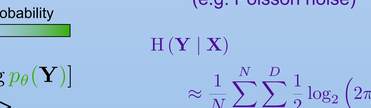


How?

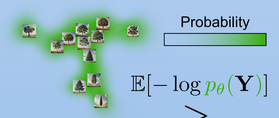
Decompose estimation into tractable subproblems

Information in measurements | Diversity of measurements | Diversity of noise alone

$$I(\mathbf{X};\mathbf{Y}) = H(\mathbf{Y}) - H(\mathbf{Y} \mid \mathbf{X})$$



Upper bound by fitting probabilistic model

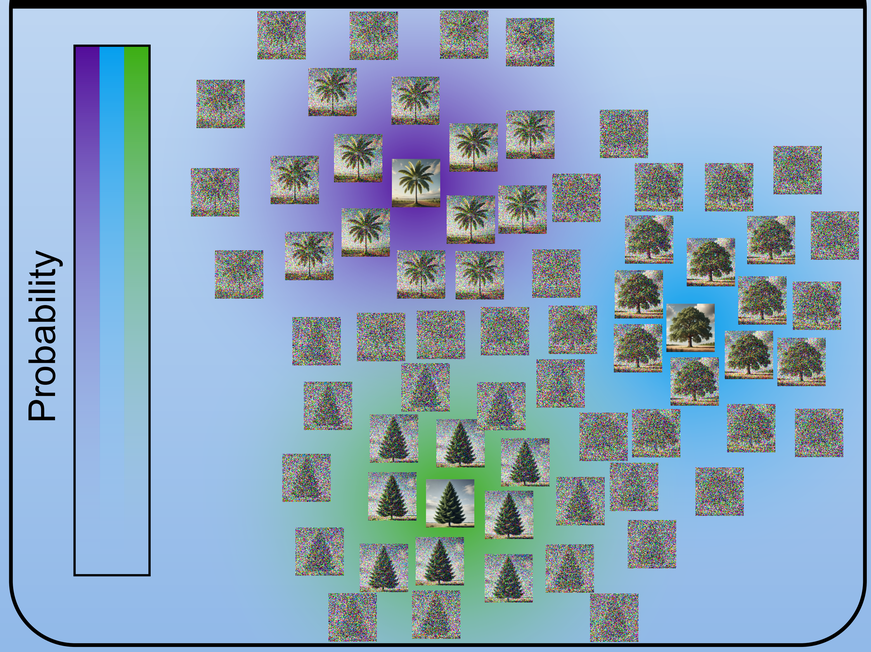


$$\mathbb{E}[-\log p_\theta(\mathbf{Y})] \geq H(\mathbf{Y}) = \mathbb{E}[-\log p(\mathbf{Y})]$$

Analytically calculate using physics-based noise model (e.g. Poisson noise)

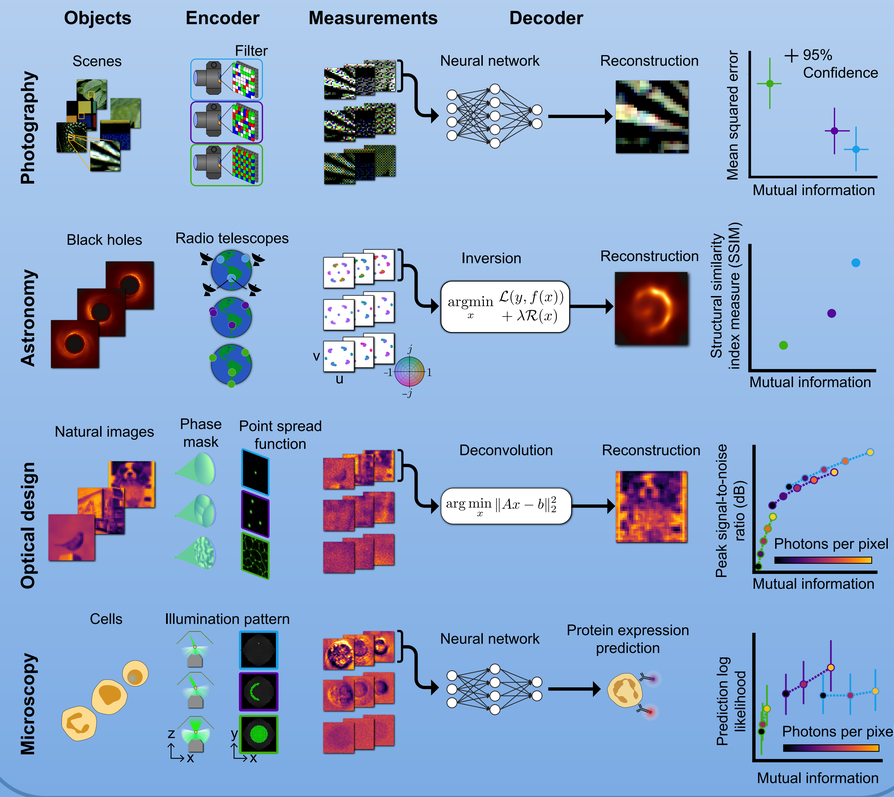
$$\mathrm{H}(\mathbf{Y} \mid \mathbf{X}) \approx \frac{1}{N}\sum_{i=1}^{N}\sum_{k=1}^{D}\frac{1}{2}\log_2\left(2\pi e x_k^{(i)}\right)$$

Information quantifies discernibility



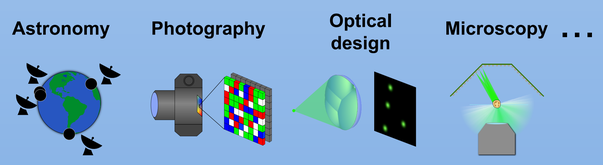
Does it work?

Yes! Information estimates consistently predicted task performance across applications



Advantages?

1) Broadly applicable



2) Ground truth-free ⟶ Field-deployable

3) Optimizable + computationally efficient