# Measurement-Adapted Eigentask Representations for Photon-Limited Optical Readout

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Optical readout in low-light imaging is fundamentally limited by measurement noise, including photon shot noise, detector noise, and quantization error. In this regime, downstream inference depends not only on the optical front end, but also on how noisy high-dimensional sensor measurements are represented before classification or decision-making. Here we show that eigentasks provide a measurement-adapted representation for optical sensor outputs by ordering readout features according to their resolvability under noise. Using experimental data from a lens-based optical imaging system and a reanalysis of published data from a single-photon-detection neural network, we find that eigentask representations frequently outperform standard baselines including principal component analysis and filtering-based compression. The advantage is most pronounced in photon-limited, few-shot, and higher-difficulty classification regimes. In few-shot MPEG-7 classification, for example, the advantage over other methods reaches about 10 percentage points as the number of classes increases. In these settings, eigentasks yield more informative low-dimensional features and improve sample-efficient downstream learning. These results identify measurement-adapted representation as a promising strategy for optical inference when photon budget, acquisition time, and task complexity are constrained. (with T Chen, M M Sohoni, S A Khan, J Laydevant, S Ma, T Wang and P L McMahon)