Performance evaluation of compressed sensing set-ups for optical and transmission electron microscopy

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Compressed sensing [1] (CS) considers K-sparse signals x that have N components, K of which are non-zero when written in a suitable basis. The signal's sparseness is exploited during the recording process so as to retrieve it afterwards from $M << N$ linear measurements $y = Ax$ if M is of the order $K\log(N/K)$.

In this abstract it is acknowledged that for the single-pixel camera [1] and annular dark field scanning transmission electron microscopy (ADF-STEM), see Fig. 1, the conventional zero-mean sensing matrices are non-physical and that unbounded non-additive Poisson noise must be considered. Furthermore, in the light of potential beam damage, the conventional performance criterion of number of measurements is abandoned in favor of the Cramér Rao lower bound (CRB) [2], which yields the lowest possible variance on the estimate of x's non-zero components for a given electron budget; or alternatively, the highest amount of Fisher information. Insight into the CRB is provided by the detective quantum efficiency (DQE), defined [3] as the signal-to-noise ratio squared of the recorded signal (SNR_{out}) to that of the incoming signal (SNRin): DQE = $(M/N)(SNR_{out}/SNR_{in})$. Furthermore, a total variation (TV) reconstruction is introduced that solves

$$\min \mathrm{TV}(x) \text{ s.t. } \ln L(y|x) = \mathrm{E}(\ln L(y|x))$$

by minimizing the associated augmented Lagrangian through an alternating direction scheme [4]. Here, $\ln L$ is the measurements' log likelihood function and E denotes the expectation value. The noise is taken as pure Poisson, Poisson plus additive normal read-out noise and only read-out noise.

Simulations are carried out on a 100x100 Shepp-Logan phantom with $M = 1862$. From Fig. 2 it is clear that for ADF-STEM the CRB and DQE^{-1} coincide well, and that the optimal amount of on-pixels per row of A is 1, independent of the noise model. It can furthermore be shown that in the absence of read-out noise the DQE of CS is equal to that of a conventional denoised Shannon scan and provides no relative advantage. In Fig. 3 the mean squared error of reconstructions from simulated single-pixel camera measurements are shown for a range of on-pixels. The noise model is Poissonian plus read-out. An excellent agreement with DQE^{-1} is observed.

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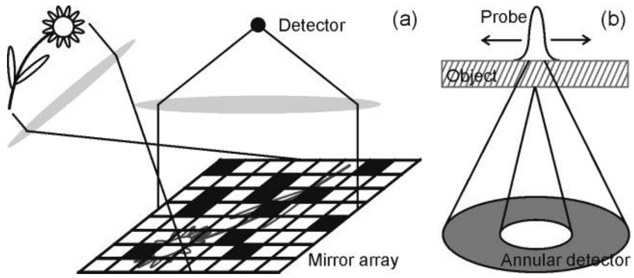

Fig. 1. (a): Single-pixel camera. (b): ADF-STEM.

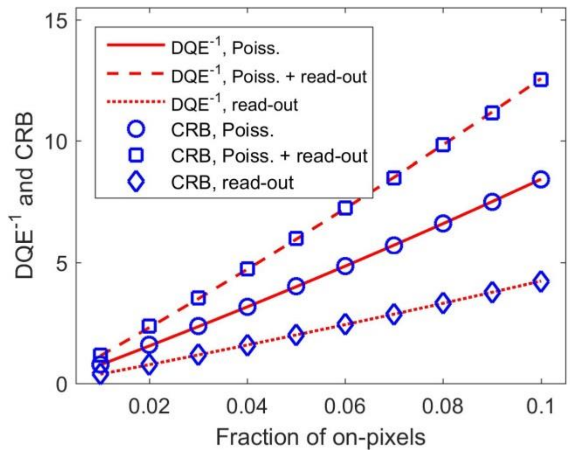

Fig. 2. DQE^{-1} and CRB vs. fraction of on-pixels for ADF-STEM. The beam intensity was 258 and the read-out noise variance 27.1.

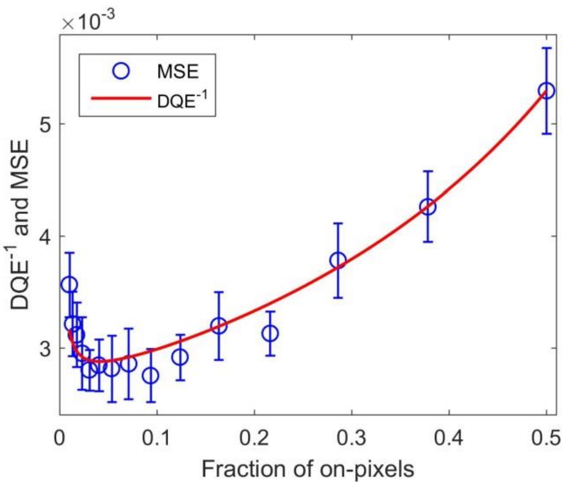

Fig. 3. DQE^{-1} and MSE vs. the fraction of on-pixels for the single-pixel camera for Poisson noise and read-out noise. The beam intensity was 4.81×10^5 and the read-out noise variance 1010.

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