A Fair Comparison of Single Pixel Compressive Sensing (CS) and conventional Pixel Array Cameras

The problem with the analysis of Duarte et al (Duarte et al. 2008; Takhar et al. 2006; Wakin et al. 2006) in their series of conference and journal papers is that they compare their CS system of M<N (typically M=1300, N=65532, or 50 times below Nyquist sampling) with a conventional image array of 256x256=65536 pixels.

Single-Pixel Imaging via Compressive Sampling

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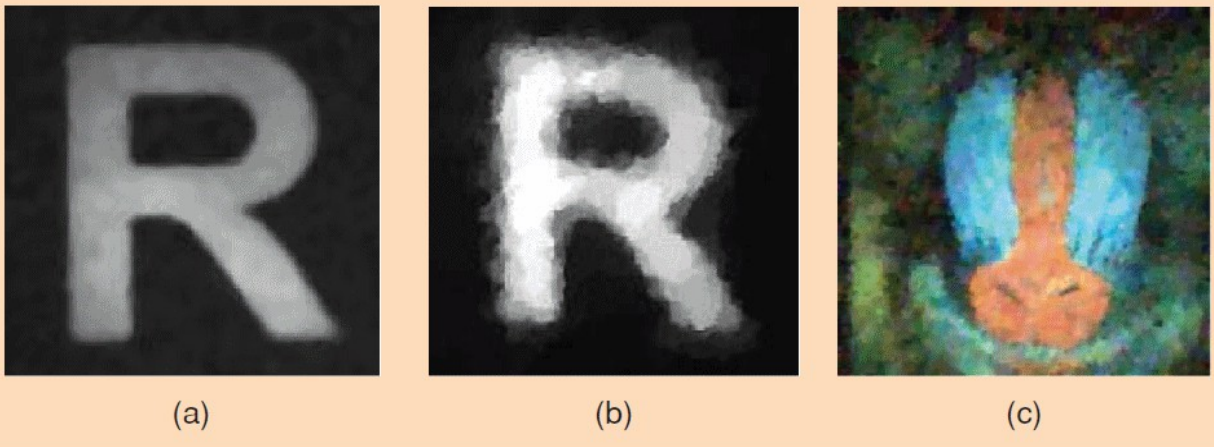
[TABLE 1] COMPARISON OF THE FOUR CAMERA SCANNING METHODOLOGIES.

	PIXEL ARRAY	RASTER SCAN	BASIS SCAN	COMPRESSIVE SAMPLING
NUMBER OF MEASUREMENTS	N	N	N	$M \leq N$
DYNAMIC RANGE	D	D	$\frac{ND}{2}$	$\frac{ND}{2}$
QUANTIZATION (TOTAL BITS)	NB	NB	$N(B+\log_2 N)$	$M(B+\log_2 N+\log_2 C_N+1)$
PHOTON COUNTING MSE	$\frac{P}{T}$	$N\frac{P}{T}$	$(3N-2)\frac{P}{T}$	$< 3C_N^2 M\frac{P}{T}$

But an image sensor array with just 36x36=1296 pixels would actually give better results than the results they presented in their Signal Processing Magazine article:

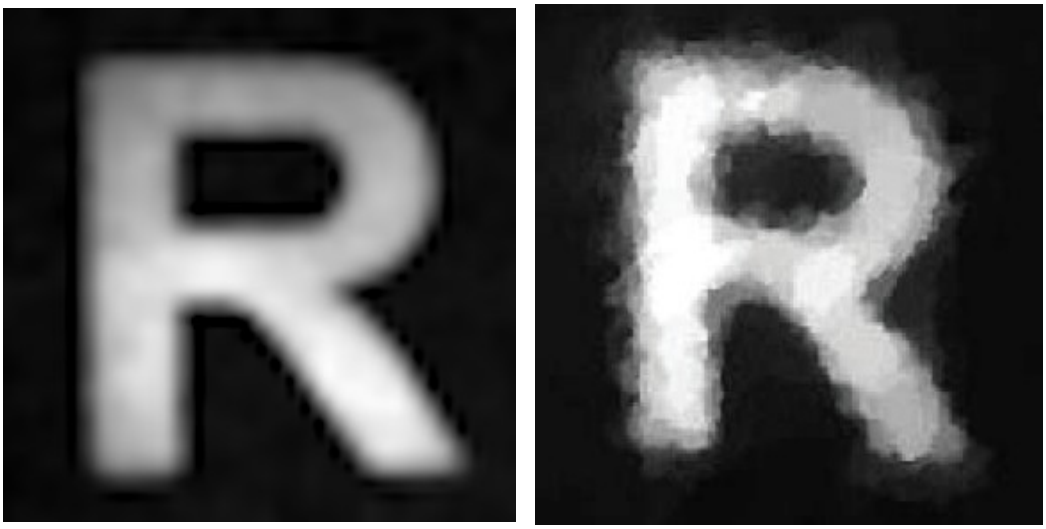


[FIG2] Single-pixel photo album. (a) 256 × 256 conventional image of a black-and-white R. (b) Single-pixel camera reconstructed image from $M = 1,300$ random measurements (50× sub-Nyquist).

Consider the image “R” on a 36x36 pixel image sensor (instead of 256x256 shown in Duarte FIG2):

Example 1, 36x36=1296 pixel image (actual size)

If we now display this image at the same size as, and alongside Duarte et al's example we have:



(a) (b)

Example 2, (a) 36x36 =1296 pixels image bicubic up-sampled to 256x256
(b) compressesd sensing image with 1300 randommeasurements

The compressive sensed (single pixel) image on the RHS is not obviously superior (as Duarte et al imply) to the image array version on the LHS. Quite the contrary in fact.

Questions

So we have the important question: why are the Single Pixel Camera papers of Duarte et al considered to be proof that Compressive Sensing gives superior results to old fashioned image sensor arrays?

My answer is that the CS conclusions are based on the false premiss that a 1300 sample CS random measurement should be compared to a 65536 image array measurement. This makes the CS measurement look more efficient (50 times more efficient) and also has a 50 times noise advantage due to the much smaller sensor elements in the unfair comparison.

One last question: why have no researchers published similar comments about the fatal flaws in the methodology of the Single Pixel Camera papers?

I honestly do not know the answer. I have met one eminent CS researcher who suggested that everyone knew that the single pixel camera research was a failure. But I am not aware of any published confirmation of this view.

References

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