What is a Good Model for Depth from Defocus?

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DFD Models

Motivation DFD relies on depth dependent PSFs which can exhibit large variations due to aperture shape, diffraction, etc. (Fig. 3)

Main Conclusions

- Gaussian relative blur is less accurate than others in most cases.
- BET has consistent performance except when PSFs are Gaussian (Fig. 5(e)).
- Deconvolution's performance worsens for pillbox and Gaussian PSFs (Figs. 5 (d) and (e)).
- Estimated relative blur works well in most cases except for complex PSF pairs (Fig. 5 (c))

Relative Blur Model

$$\underset{d}{\operatorname{argmin}} \|i_{blurrier} - i_{sharper} * h_R(d)\|^2 \qquad (1)$$

We evaluate two cases with the relative blur h_R being 1) estimated directly (please see our blur calibration poster) and 2) approximated with a Gaussian.

Blur Equalization Technique (BET)

$$\underset{d}{\operatorname{argmin}} \|i_1 * h_2(d) - i_2 * h_1(d)\|^2. \qquad (2)$$

Deconvolution Model

$$\underset{i_0, d}{\operatorname{argmin}} \sum_j ||i_0 * h_j(d) - i_j||^2 + ||C * i_0||^2 \qquad (3)$$

Modelling Accuracy

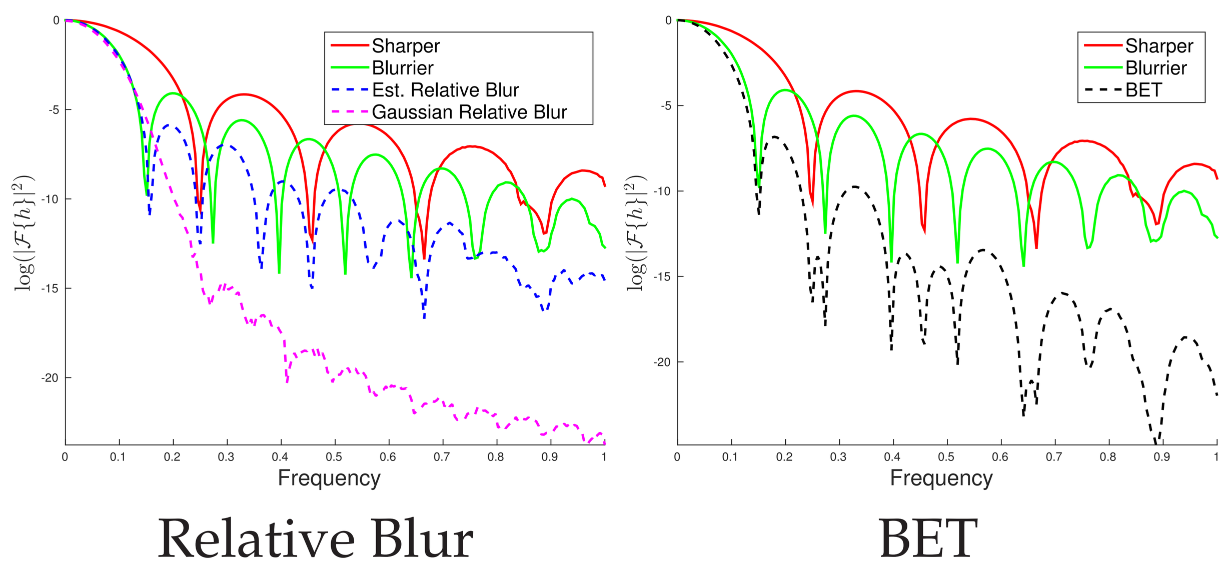


Figure 1: Log power spectrum for a) relative blur based reconstruction (dashed) of blurrier PSF (green) and b) performing BET for pillbox PSFs.

Configurations

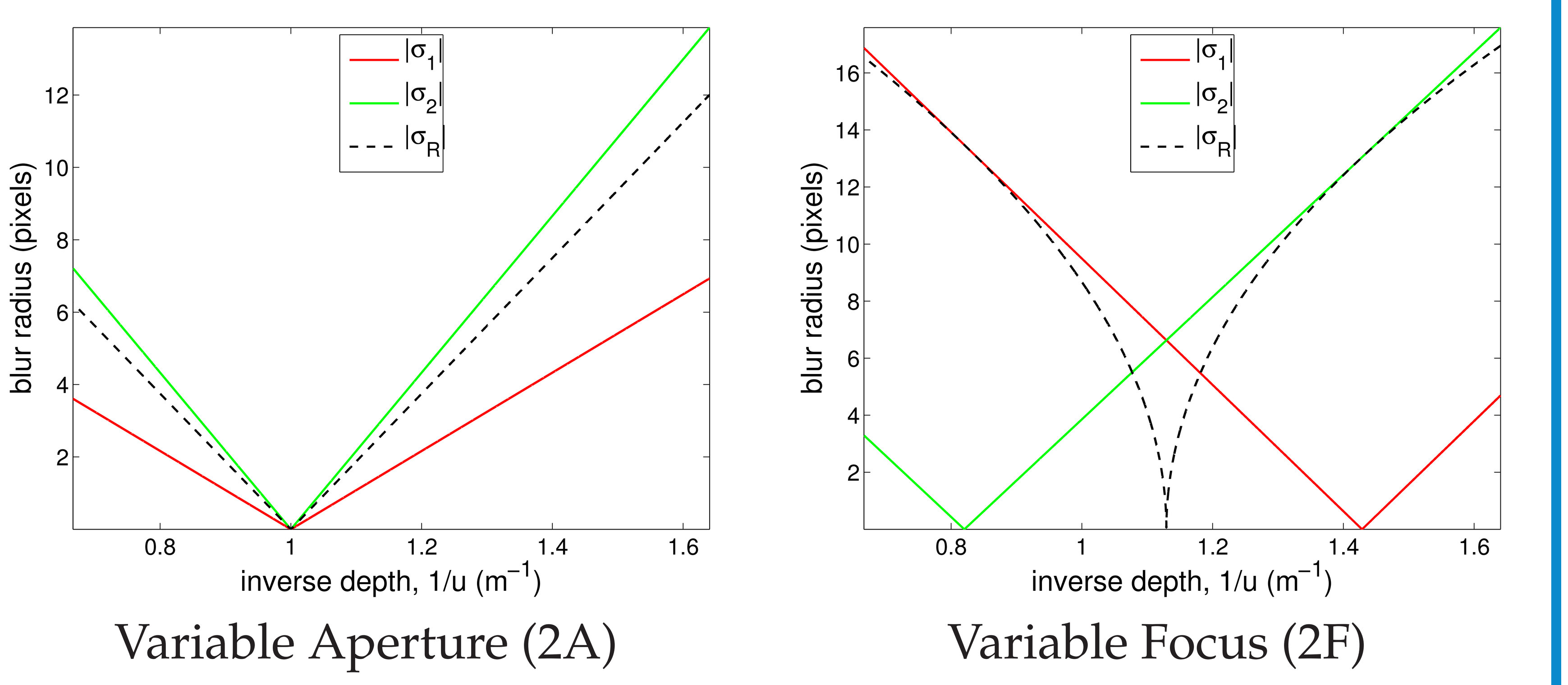


Figure 2: DFD models typically use a pair of defocused images. A defocus pair is usually taken by varying the aperture (2A) or focus distance (2F). The relative blur at each depth is $\sigma_R = \sqrt{|\sigma_2^2 - \sigma_1^2|}$.

Experiment with Real Images

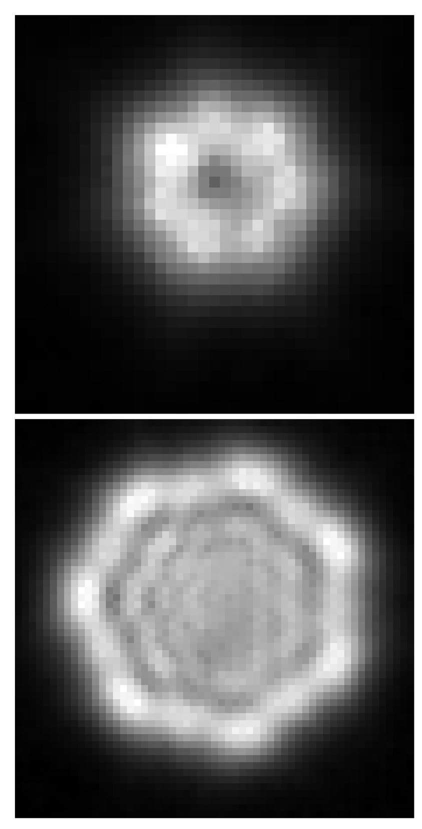


Figure 3: Examples of real PSFs. Top: $f/22$ and Bottom: $f/11$.

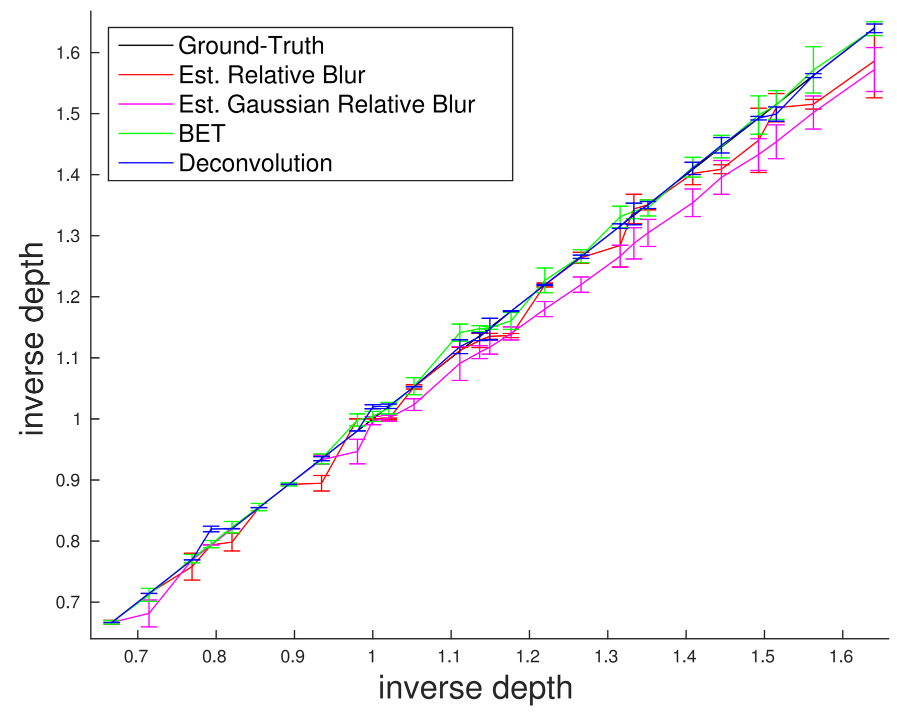
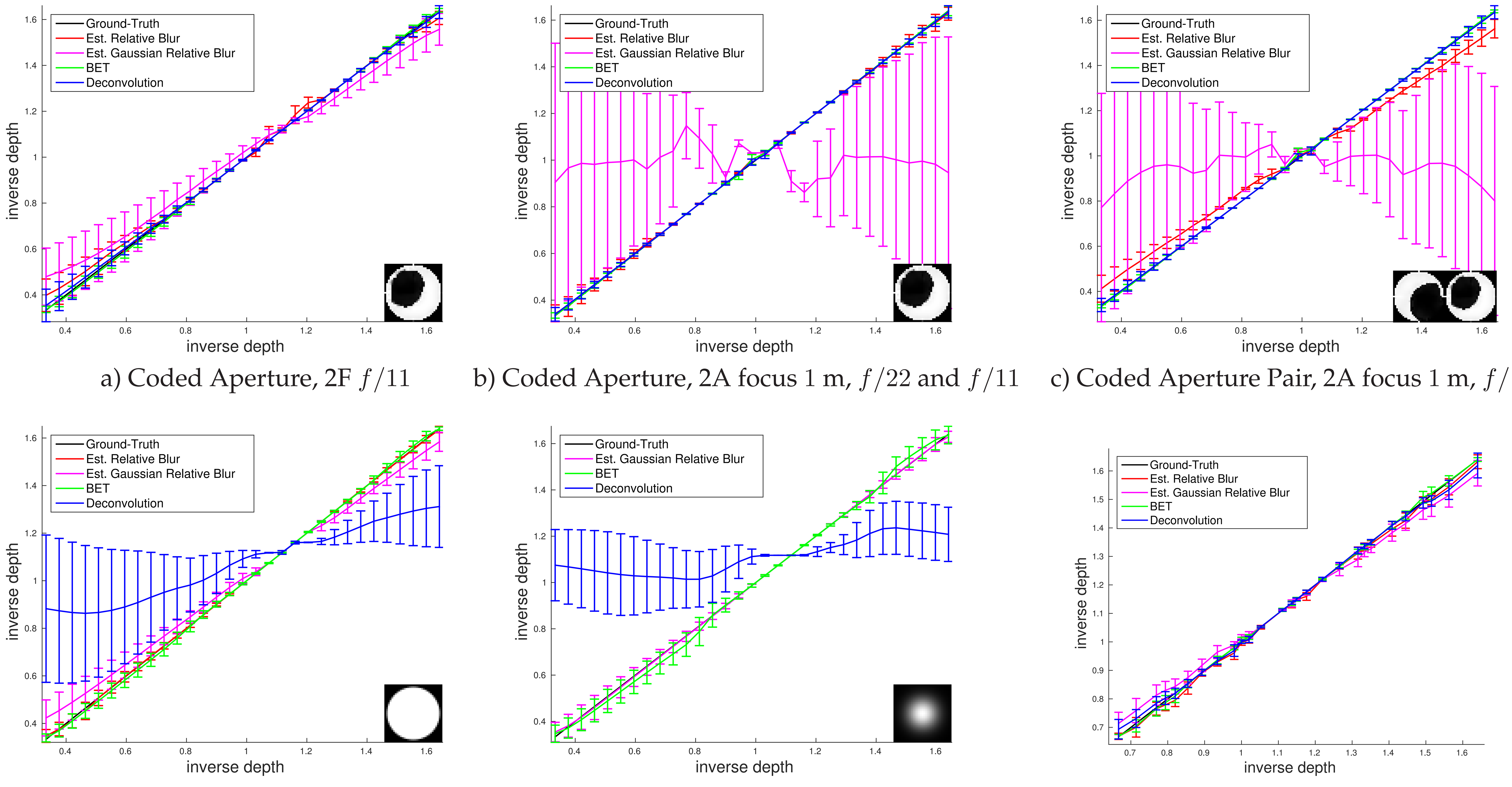


Figure 4: Results from real defocused images of a $1/f$ noise texture with focus at 1.5 m, and aperture pair $f/11$ and $f/22$.

Experiments with Synthetic Images using various PSFs (inset)



a) Coded Aperture, 2F $f/11$

b) Coded Aperture, 2A focus 1 m, $f/22$ and $f/11$

c) Coded Aperture Pair, 2A focus 1 m, $f/11$

d) Pillbox, 2F $f/11$

e) Gaussian, 2F $f/11$

f) Estimated PSF, 2F $f/11$

Figure 5: Synthetically defocused image with different PSFs, camera settings, and noise $\sigma_n = 2\%$.