Low Spatial Frequency Denoising with Applications to Light Field Moment Imaging

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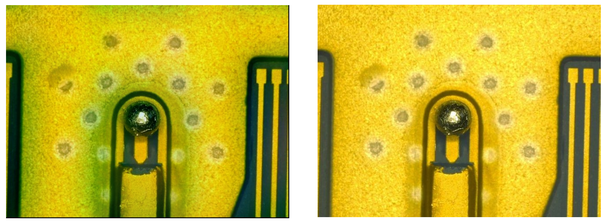
Motivation

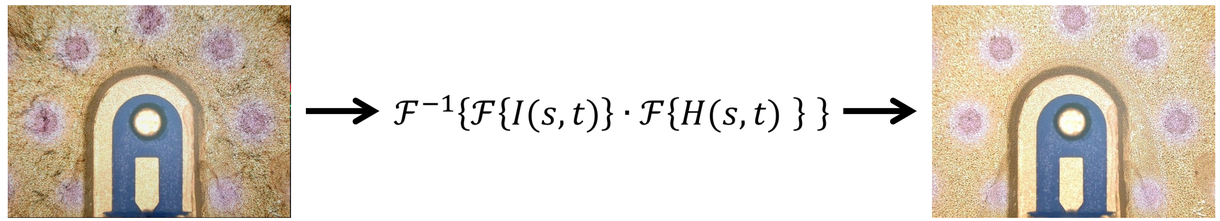
- The Light Field Moment Imaging (LMI) technique provides a unique perspective shift effect using a single lens mechanism found in most microscopy systems.
- However, LMI images are susceptible to low spatial frequency noise due to the mathematical approximations used in the algorithm.



Noisy image (left) compared to clean image (right). Note the color shift in the low spatial frequency areas. Noise was purposely imposed by adjusting the value of Δz in the algorithm.

New Technique

- In order to improve the visual accuracy of the computed images, I propose experimenting with multiple denoising algorithms and methods, including ideal, Gaussian and Butterworth BPFs intended to attenuate frequencies where noise is typically present, and frequency domain Wiener filtering (FDWF), a technique based on a 2012 paper by Sari et. al. [1] All of these are intended to work in the frequency domain rather than the spatial domain typical of most denoising algorithms.



[1] Sari Suhaila,Shimamura Tetsuya Frequency Domain Wiener Filter for Image Denoising: Derivation of a New Power Spectrum Estimation Method

Related Work

- Filtering in the frequency domain has been studied extensively primarily for use in digital signal processing. However, it has seen limited use in image filtering where the spatial domain is often utilized instead.

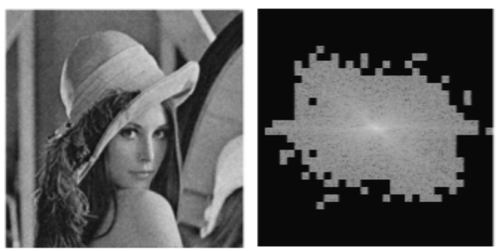
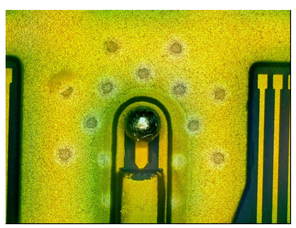


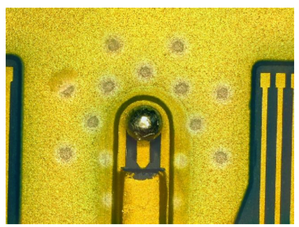
Image of Lena showing filtered logarithmic power spectrum. This technique is used in FDWF filtering implemented in this project.

Experimental Results

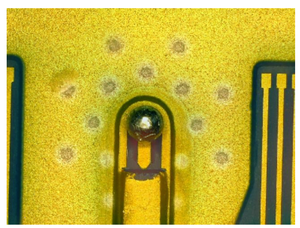
- An unfortunate consequence of the LMI algorithm is that noise is introduced via a gradient matrix that is necessary to perform the perspective shift. Over-filtering results in a clean image whose PSNR approaches infinity, but the perspective shift is lost in the process. This makes measurement of filter effectiveness more difficult than usual.
- An attempt to match PSNR in all three filters was made while examining the resultant photos for visual accuracy, maintenance of details, and focusing shift required for perspective.



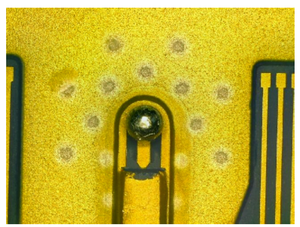
Noisy image, original,
PSNR: 17.49 dB
Computation time: N/A



Gaussian LPF
PSNR: 26.42 dB
Computation time: 0.13s



Butterworth LPF
PSNR: 26.40 dB
Computation time: 0.85 s



FDWF
PSNR: 26.75 dB
Computation time: 0.46s