Deblurring and Enhancing Astrophotographs Using PSF Based Digital Image Processing Group - 19

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***Abstract*—The following Image Processing Pipeline is implemented to process raw astronomical data and create clean, colored astrophotographs using only classical image processing techniques.**

***Index Terms*—Wiener-Deblurring, Richardson-Lucy Deconvolution,**

I. Introduction

Astrophotography, the practice of photographing celestial objects, is highly crucial as it provides data and builds the foundation for observational astronomy. It enables the study of distant cosmic objects, such as neighborhood galaxies, star clusters, etc. However, astrophotography is highly constrained by atmospheric seeing and optical diffraction even in advanced optic imaging systems. Atmospheric seeing, which is the degradation of images due to turbulence in the Earth's atmosphere in ground-based telescopes, imperfect optics, optical aberrations, and diffraction, are the primary factors that cause this blurring. This blurring causes dispersion of light intensity, which in turn causes the light source to appear spread out rather than as a single point. This distribution of light intensity in a pattern is known as the Point Spread Function. The Point Spread function is defined as the response of an imaging system to a perfect point source. The Point Spread Function causes this blurring by creating a circular blur around the light source. Since this blurring significantly reduces visibility and makes it very difficult to distinguish celestial objects, image de-blurring and restoration are extremely necessary. Computational image processing techniques, such as deconvolution and color mapping, combined with other image enhancement techniques, will enhance image quality, aiding in its restoration. The goal of this project is to restore the image for better visibility and interpretation by using deconvolution-based processing to mitigate the effects of the PSF.

II. Methodology

The input image data have been acquired in the form of a raw (.fits) file from the Hubble Space Telescope (HST). The noise, in the form of a PSF, gets convolved with the image. Therefore, a deconvolution operation is required to remove the PSF. At first, the image is passed through the Wiener Filter. It transfers the image, using the Fourier Transform, into the frequency domain and removes the high-frequency noise from the image, and transfers back to the spatial domain, using the Inverse Fourier Transform. Afterward, the Richardson-Lucy deconvolution is applied over the intermediate image. Initially, a guess of the original image is taken, and the passed PSF is applied to the guessed image. Here, the Gaussian PSF is used, as the diffraction intensity is highest at the center of the light source and decreases gradually as one moves further away from the center. The blurred guessed image is then matched with the input image. In the guessed image, if a part is darker than in the input image, the intensity of that part is increased, and vice versa. By iterating this process multiple times, we obtain a more accurate estimation of the original image. The PSF can never be fully removed from the image; we can only get the closest approximation of the original image. Due to the characteristics of the deconvolution operation, the high-frequency noise is also amplified; therefore, the Wiener Filter noise removal is applied prior to the deconvolution operation.

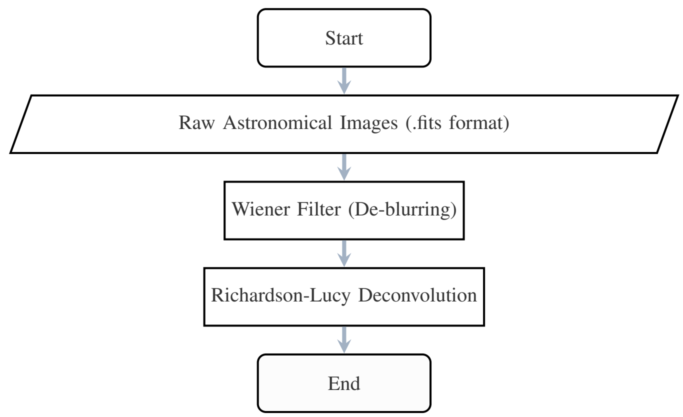

Fig. 1. Flowchart of Image Enhancement Process

III. Results

We see the following changes in the image after applying the Wiener Filter and the Richard-Lucy Deconvolution to the images:

1) The noise from the image is greatly reduced because of the Wiener filter.
2) Due to the Richard-Lucy Deconvolution, we see that the PSF has been reduced to some extent.

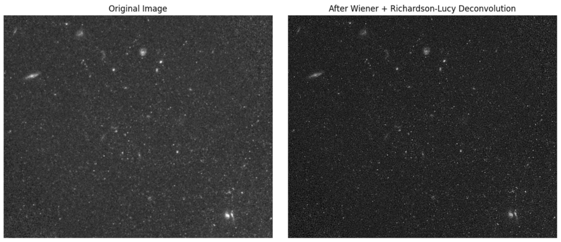

Fig. 2. Image 1

Fig. 3. Image 2

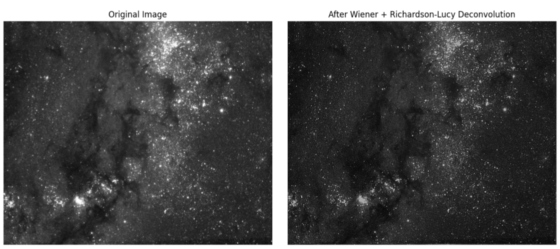

Fig. 4. Image 3

3) The image has better quality overall and looks richer in terms of fidelity.

In terms of limitations,

1) The entire PSF is not eliminated.
2) The noise grain is comparable to the size of the points (celestial objects) in the image. Therefore, proper noise removal leads to damping of the intensity of these points.
3) For very large objects, the PSF is not removal is negligible.

IV. Discussion

The findings show the usefulness of using a mixture of a Wiener filtering and Richardson-Lucy deconvolution to restore astronomical images. The Hubble original raw images are extensively blurred and noisy imagery, artifacts of the point spread function (PSF) of the imaging system as well as sensor noise used to take images.

With the Wiener filter, then the Richardson-Lucy deconvolution, the images become clearer and more distinct and the stars and the background around them are clearer. Wiener filter is useful in eliminating high-frequency noise and retaining the overall structure of heavenly bodies. Because the Richardson-Lucy algorithm is an iterative deconvolution algorithm, it further improves the image by correcting the PSF and therefore returns more finer details in space which have been smeared out in the image.

The resultant sequential combination is much more effective at removing noise (with the Wiener filter) and restoring image detail (with Richardson-Lucy deconvolution). It is especially facilitated in the second example, which has brighter sources that have smaller halo effects, and faint galaxies are made more visible. Nevertheless, some little noise amplification in darker areas is not absent, which shows that over-iteration or over-deconvolution may result in instability or artifacts.

On balance, the findings validate that the hybrid methodology will greatly improve the visibility and definition of astronomical features, and therefore can be used in preprocessing work like object detection and photometric measurements in the analysis of astronomy.

V. Conclusion

As a result of our work, utilizing PSF-based deblurring methods gave a significant increase in the recovery of the details of the astronomical images. The Wiener filter, in particular, for the high-frequency case lowered much of the high frequency noise and the Richardson Lucy deconvolution technique that utilized a Gaussian PSF aided in showing faint objects beyond noise. While there is still a slight increase in noise amplification and artifacts remained in the images, this research has shown that deconvolution iterations have the potential in improving astrophotographs. Plans for future work include improving accuracy of the images rendered, in addition to rendering the images in a representation of the visible spectrum colors mapped and incorporated.

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