Deblurring and Enhancing Astrophotographs Using PSF Based Digital Image Processing

Group Number: 19

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Problem Statement: To develop an image processing model for the deblurring and enhancement of astrophotographs using Point Spread Function (PSF) based digital image processing methods.

1 Introduction

For the first week, we focused on understanding the problem statement in depth. Astrophotography for all imaging systems is often limited. This limitation might be due to atmospheric seeing in ground telescopes. Atmospheric seeing is referred to as degradation of the image of celestial objects due to turbulence in the atmosphere of the earth. The light captured by the imaging systems of the point source objects(stars, planets, etc.) does not appear to be point shaped but instead its intensity appears to be distributed producing a blurred effect of the image. This significantly reduces the visibility and clarity of the image. This blurring effect might be caused by various factors such as the type of lenses used (imperfect optics), seeing, but is primarily caused by the phenomenon of diffraction (bending of light).

2 Point Spread Function (PSF) and De-convolution:

The Point Spread describes the response of a telescope and its instruments to a point source of light, like a distant star. Instead of appearing as a single point in the image, the light source appears to spread out. The PSF generates blurring effects by creating a circular blur around the light source. It occurs primarily due to diffraction from light waves passing through the telescope's aperture, optical aberrations resulting from imperfections in the lenses and mirrors, and atmospheric turbulence. As the light wave bends with the surface of the telescope's aperture, it initiates a new waveform that in turn distorts the original light source. Another factor is optical aberrations, as different wavelengths of light focus at different focal lengths in refractive telescopes. This creates multiple focus points for different wavelengths, creating a cluster of light sources that should have been a single point. The atmospheric air is also not stationary, it keeps on moving due to temperature differences in local regions. This distorts the incoming light source, resulting in a blurry image.

3 Work Done (Week 1):

During the first week, our group focused on the following tasks:

- Learning the theory of image degradation and PSF modeling.
- Knowing how various PSFs (Gaussian, Moffat, Airy disk) look like.
- Understanding the influence of deconvolution on sharpness of an image.
- Mimicking simple blurring with the help of a Gaussian kernel in Python to see how PSF impacts the sharpness of an image.
- Finding data sets of actual astrophotographs to be utilized in subsequent phases of deblurring.
- Python code snippet was implementation to detect bright stars in an astronomical image. The code reads the image, normalizes and enhances its contrast, detects the brightest spots using a maximum filter, labels them as potential stars, and visualizes the results by highlighting detected stars with red circles.

```
import numpy as np
import matplotlib.pyplot as plt
from astropy.io import fits
from skimage import exposure
from scipy.ndimage import maximum_filter, label
import cv2

img = cv2.imread('/content/Hst1.jpg', cv2.IMREAD_GRAYSCALE)

if img is None:
    print("Error: Could not load image.
    Please ensure 'eso0106a.tif' is in the correct directory.")
else:
    img = img.astype(float)

    img = img - np.min(img)
    img = img / np.max(img)
    img_eq = exposure.equalize_adapthist(img, clip_limit=0.03)
```

```
footprint = np.ones((5,5))
max_filt = maximum_filter(img_eq, footprint=footprint)
stars_mask = (img_eq == max_filt) & (img_eq > np.percentile(img_eq, 99.5))
labels, num = label(stars_mask)

print(f"Detected {num} bright spots (potential stars).")

img_color = cv2.cvtColor((img_eq * 255).astype(np.uint8), cv2.COLOR_GRAY2BGR)

ys, xs = np.where(stars_mask)
for (x, y) in zip(xs, ys):
    cv2.circle(img_color, (x, y), 5, (0, 0, 255), 1)  # red circles

fig, axes = plt.subplots(1, 2, figsize=(12, 6))
axes[0].imshow(img_eq, cmap='gray')
axes[0].set_title("Original Enhanced Image")
axes[0].axis('off')

axes[1].imshow(img_color)
axes[1].set_title("Stars Detected and Highlighted")
axes[1].axis('off')

plt.tight_layout()
plt.show()

cv2.imwrite("segmented_stars.png", cv2.cvtColor(img_color, cv2.COLOR_RGB2BGR))
print(img.shape)
```

Result of Star Detection

The figure below shows the result of applying the star detection algorithm on the astronomical image. The left panel shows the original enhanced image, while the right panel highlights the detected stars with blue circles.

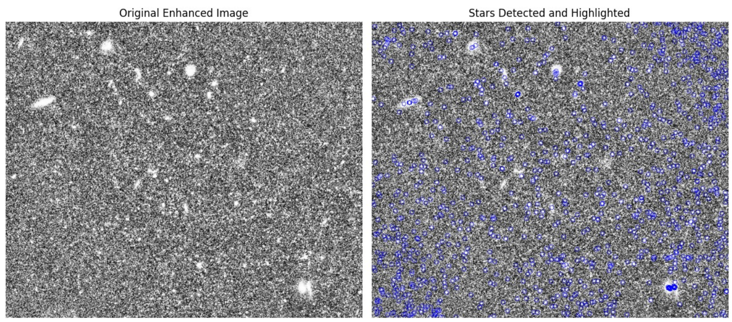

Figure 1: Original enhanced image (left) and stars detected and highlighted (right).

4 Problems Faced:

- Problem in visualizing the PSF and its parameters (size, shape, spread).
- None of the real astronomical PSFs; we simulated original synthetic Gaussian PSFs.
- Locating appropriate datasets in terms of blurred and reference image testing.

5 Next Set of Work:

In the upcoming week, we plan to:

- Compare the synthetic PSF and the measured PSF and contrast their impact on the quality of outputs.
- Implement Wiener and Richardson-Lucy deconvolution for PSF-based deblurring.

6 Conclusion

During the course of this first week, we have been able to create a theoretical background of the effect of blurring in astrophotographs and the role of PSF in modelling the act of blurring. Such background will assist us in applying and experimenting PSF based deblurring algorithms in the subsequent phase of the project.

7 References

1. J. M. Lee, J. H. Lee, K. T. Park, and Y. S. Moon, "Image deblurring based on the estimation of PSF parameters and the post-processing," *Optik*, vol. 124, no. 15, pp. 2224–2228, 2013, doi: 10.1016/j.ijleo.2012.06.067.

2. E. Thiébaut, L. Denis, F. Soulez, and R. Mourya, "Spatially variant PSF modeling and image deblurring," Biomedical Imaging Group, École Polytechnique Fédérale de Lausanne (EPFL), 2016. [Online]. Available: https://bigwww.epfl.ch/publications/thiebaut1601.pdf.