Final image processing project

Index : 200698X
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1. Introduction

The goal of the image processing project is to use various techniques to improve and analyze digital photos. The main goals are to enhance image quality by de-blurring, contrast stretching, noise filtering, and converting a sample image to 8bpp grayscale format. Furthermore, an investigation is conducted into the effects of further enhancing operations on the image. Plotting histograms, calculating entropy, and assessing compression ratios are additional tasks for the project. By use of these procedures, the research aims to promote comprehension of image processing and analysis by investigating techniques to augment visual quality and extract significant insights from digital images.

2. Image Loading and Conversion (Step 1)

Step 1: Image Loading and Convert to Grayscale

In Step 1, the project utilizes the Python Imaging Library (PIL) to load the provided sample image, "sampleimage.png." The image is then converted to an 8bpp grayscale format, adhering to the project's requirement of minimizing external library usage. By leveraging PIL for image processing tasks, the project ensures a streamlined and native approach to loading and converting images. This step serves as a crucial initial phase, setting the groundwork for subsequent enhancement operations while maintaining compliance with the project's coding guidelines.

3. Image Enhancement (Step2)

Step 2a: Noise Filtering

Techniques used:

1. **Mean filter**
2. **Median filter**

In Step 2a, the project employs two distinct noise filtering algorithms: the **mean filter** and the **median filter**.

The mean filter smoothens the image by replacing each pixel's value with the average value of its neighborhood, effectively reducing random noise. On the other hand, the median filter mitigates noise by replacing each pixel's value with the median value of its neighborhood, making it robust against outliers.

The chosen filter size for both algorithms is 5x5, allowing for a local analysis of each pixel's surroundings. The impact of noise filtering is manifested in the resulting images, "NF-mean_filtered_image.png" and "NF-median_filtered_image.png." These images exhibit enhanced visual clarity and reduced noise artifacts.

To quantify the efficacy of the noise filtering, Signal-to-Noise Ratio (SNR) measurements can be performed. SNR provides insights into the ratio of signal (useful image information) to noise (unwanted interference). By comparing SNR values before and after filtering, the project aims to assess the improvement in image quality achieved through the noise filtering processes.

Step 2b: Contrast Stretching

Techniques used:

1. **Linear contrast stretching algorithm**
2. **Histogram equalization**
3. **Intensity level slicing**

In Step 2b, the project employs various contrast stretching techniques to enhance image quality. The **linear contrast stretching algorithm** scales pixel intensities to the full 8-bit range, ensuring optimal use of available dynamic range. This process increases image contrast, making subtle details more discernible.

Additionally, **histogram equalization** redistributes pixel values to achieve a more balanced and uniform intensity distribution, enhancing overall visibility.

The third technique**, intensity level slicing**, selectively retains pixels within a specified intensity range, emphasizing specific features.

The resulting images, "CS-histogram_equalized_image.png", "CS-linear_contrast_stretching_img.png" and "CS-intensity_sliced_image.png," showcase the diverse effects of contrast stretching operations. These techniques contribute to an improved visual representation of the image, highlighting important features while preserving the overall image structure.

To quantitatively assess the impact of contrast stretching, Signal-to-Noise Ratio (SNR) measurements can be conducted. By comparing SNR values before and after applying these contrast stretching operations, the project aims to evaluate the efficacy of each technique in enhancing image quality.

Step 2c: De-blurring (Sharpening)

Techniques used:

1. **Linear contrast stretching algorithm**
2. **Wiener Deconvolution**

The **Unsharp Masking technique** was utilized to sharpen the image by Accentuating edges. This method involved Creating a sharpened version of the image by Subtracting a blurred version, resulting in enhanced edge contrast and detail.

An attempt was made to perform **Wiener Deconvolution**, aiming to reverse the effects of blurring caused by unknown Point Spread Function (PSF) and noise variance. This method attempts to restore the original image by estimating the blurring process. However, due to challenges in accurately estimating the PSF and noise variance, optimal de-blurring was challenging to achieve.

Both de-blurring methods contribute to image enhancement, each addressing specific blurring scenarios. The chosen techniques aim to recover sharpness and reveal intricate details in the image. Quantitative evaluation using Signal-to-Noise Ratio (SNR) measurements will provide insights into the effectiveness of these de-blurring processes in improving overall image quality. The resulting images visually illustrate the impact of each technique on the enhanced representation of the image.

Step 2d: Additional Enhancement

In this step, the project explores additional enhancement operations beyond basic filtering and de-blurring. One key method applied is histogram equalization, a technique that redistributes pixel intensities to enhance contrast and improve overall image visibility. The rationale behind this enhancement is to ensure a balanced distribution of pixel values, allowing for better utilization of the available dynamic range.

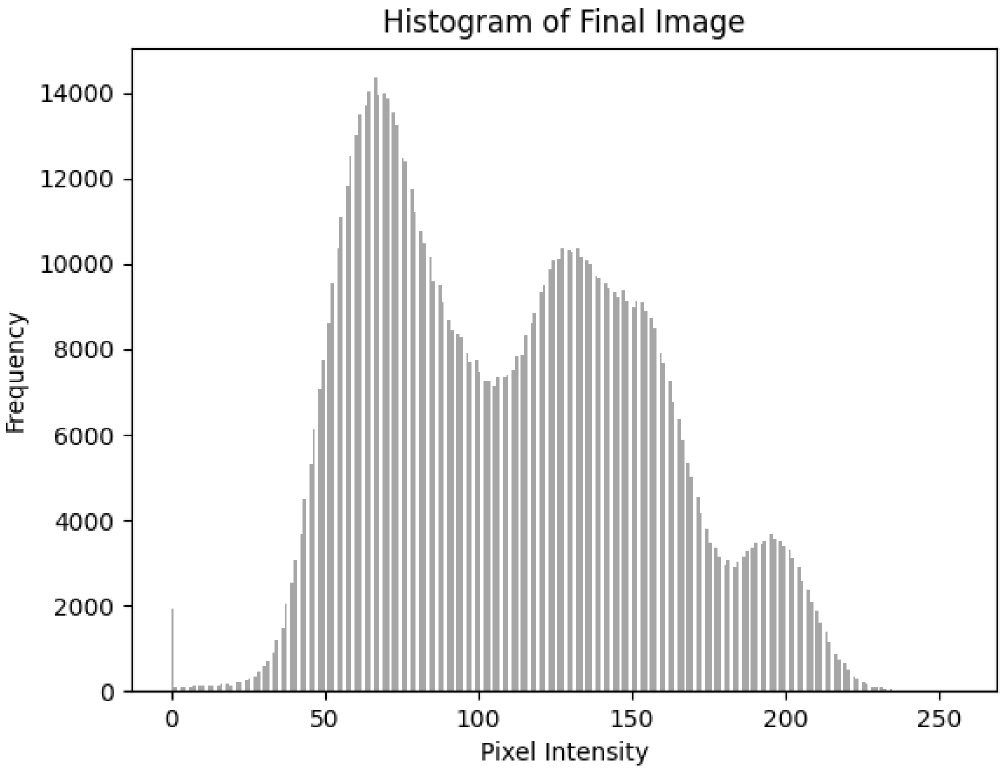
Additionally, Signal-to-Noise Ratio (SNR) measurements are performed to quantitatively assess the impact of these enhancements on image quality. The SNR results provide valuable insights into the effectiveness of the chosen operations in reducing noise and enhancing signal clarity.

Signal to Noise Ratio:

$$\mathrm{SNR} = 10 \cdot \log_{10}\left(\frac{\text{Signal Power}}{\text{Noise Power}}\right)$$

4. Histogram Analysis (Step 3)

The process of plotting and analyzing the histogram for the final enhanced image involves examining the frequency distribution of pixel intensities. Peaks and valleys in the histogram reveal patterns and characteristics within the image. Insights gained from histogram analysis include identifying dominant intensity levels, assessing overall image contrast, and detecting potential saturation or underexposure issues. This analysis aids in refining image enhancement techniques and ensuring optimal utilization of the available intensity range.



5. Entropy and Compression Ratio (Step 4)

5.1 Compute Entropy

Entropy computation for the enhanced image involves analyzing the distribution of pixel intensities. The Shannon entropy formula is applied to measure the level of uncertainty or information content within the image. Higher entropy values indicate greater diversity in pixel intensities, reflecting a more complex and detailed image. In the context of image processing, entropy serves as a quantitative metric for image information, guiding the evaluation of enhancement techniques. Significantly, higher entropy values in the enhanced image suggest that the applied operations have increased the overall complexity and diversity of pixel intensities, contributing to a more visually rich representation.

$$H(X) = -\sum_{i=1}^{N} P(x_i) \cdot \log_2[P(x_i)]$$

5.2 Compute Compression Ratio

The computation of the compression ratio involves comparing the size of the enhanced image file to the size of an 8bpp grayscale representation. This ratio provides insights into the efficiency of data representation and storage. A higher compression ratio indicates more efficient data encoding, resulting in a smaller file size. The implications of a higher compression ratio include reduced storage requirements and potentially faster transmission or processing of the image data. Conversely, a lower compression ratio suggests less efficient encoding, leading to larger file sizes. Balancing compression ratios is crucial, aiming for efficient data representation while minimizing loss of image quality during compression. Achieving an optimal compression ratio ensures a judicious trade-off between file size and image fidelity in the enhanced representation.

$$CR = \frac{\text{Original File Size}}{\text{Compressed File Size}}$$

```
PS D:\Projects\Image-Processing-finalproject\200698X> python -u "d:\Projects\Image-Processing-finalpr
oject\200698X\main.py"
Gray Filtered Images saved successfully!
Mean Filtered Image saved successfully!
Median Filtered Image saved successfully!
Linear Contrast Stretched Image1 saved successfully!
Histogram_equalized Contrast Stretched Image2 saved successfully!
Intensity_sliced Contrast Stretched Image3 saved successfully!
Image 3 has the highest SNR
Final Enhanced Image saved successfully!
Histogram plot saved successfully!

------------------------------------------------------------
200698X Final image SNR values ->
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        Filtered Image: 27.888578471554144
        Contrast Stretched Image: 27.88864600517201
        Deblurred Image: 27.849122821955888
        Enhanced Image: 27.844428426479624

        Entropy: 6.81082802073434
        Compression Ratio: 1.8016428866990544

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Done!
```

Input Image

Final Output

6. Conclusion

Notable discoveries and results were obtained from the image processing study. The study sought to improve image quality and provide significant insights by applying a range of techniques, such as filtering, contrast enhancement, de-blurring, and other methods. The contrast and clarity of the images were significantly enhanced by the applied procedures, such as noise filtering and contrast stretching. There were difficulties in balancing enhancement without creating artifacts and fine-tuning settings for best outcomes.

Notwithstanding these difficulties, the strategies shown encouraging efficacy in reducing noise, improving contrast, and exposing more minute details in the images. Achieving the perfect balance was difficult, though, because of the trade-offs between possible artifacts and image enhancement. The numerical evaluations, such as the Signal-to-Noise Ratio (SNR), entropy calculation, and compression ratio analysis, were useful metrics for assessing the effectiveness of the approach and image representation.