Image Enhancement & Implementation by using CLAHE algorithm

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***Abstract*—In the era of digital cameras, one can capture the whole range of images in one's daily life. Most images are good, while some images are not so satisfactory. Images are also degraded by noise, which may be because of less light or other intensity problems. This proposal is proposed for exploring various image enhancement techniques in an attempt to overcome these types of degradation issues and improve the quality of the image. [1] HE is one of the common enhancement techniques employed in images, although it may not be effective for certain cases. CLAHE is its improved variant that enhances image properties on a localized basis. In the first stages of this proposal, bilinear interpolation and the CLAHE algorithm will be applied for image enhancement with the key objective being noise reduction. Furthermore, contrast improvement techniques can be used on the image to further enhance it. The methodology proposed minimizes noise levels and increases visually perceivable contrast, binarization, etc. thereby forming noisefree highly quality images. Improved images are directly saved to the example output/directory.**

Keywords—Image enhancement, CLAHE algorithm, Bilinear interpolation, contrast stretching, noisefree image, noisefull image.

I. INTRODUCTION

In image processing, an essential step in image reduction is noise reduction since it aims to remove disturbing figures that lower the quality of images. Noise appears as sudden changes in brightness or color contrast and is mostly external. Noisy images containing various sources have stronger noticeable activity in brighter regions of the image. Pre-processing is one of the critical enhancements of images as it removes noise and blurs. This study focuses on leveraging Contrast Limited Adaptive Histogram Equalization (CLAHE) to improve human-perceived image quality. [2]

Real-time image sequences captured in poor lighting conditions can look pretty terrible at first. This work aims to improve real-time image quality by using a solution that reduces latency without affecting accuracy. CLAHE effectively solves the tasks of binarization, noise removal, and contrast enhancement. Bilinear interpolation calculates the average value of the four nearest pixels to replace the damaged pixels with new values. By using linear interpolation,

It is accomplished by first in one direction and then the other. Contrast stretching is an image enhancement technique that seeks to extend the range of intensity values of an image so that it covers its dynamic range. The transfer function used in contrast stretching is always linear and monotonically increasing. [3]

II. PROBLEM STATEMENT

Noising in real-time image sequences affects their display quality making details hard to discern clearly. Sources of such noise might be inadequate lighting conditions or sensor noise, as well as electronic disturbances. As such, the solution comes in the form of a necessity for improving real-time image quality. The most promising and the most commonly used methods are Contrast Limited Adaptive Histogram Equalization, bilinear interpolation, and contrast stretching. The techniques have been known to reduce noise, improve the contrast, and enhance visual appeal.

III. IMAGE ENHANCEMENT TECHNIQUES

Enhancing an image typically involves improving its clarity, visibility, and overall appeal for human perception while also providing better input for automated image processing systems. The fundamental goal of image processing is to modify an image's characteristics to make it more suitable for a specific task or audience. This implies a change in the image in one or more aspects, and the attributes to change depend on the task in question. The choice of an image enhancement technique is not only objective but also includes a subjective element due to observerspecific factors such as the human visual system and individual experiences. Many techniques exist that can enhance a digital image without compromising its integrity. These techniques can be broadly categorized into two main groups:

a) Spatial Domain Methods

b) Frequency Domain Methods

Spatial domain technique directly manipulates pixel values to enhance images. It adjusts factors like brightness, contrast, or grayscale distribution to improve. In the case of frequency domain techniques, the image is first converted into the frequency domain. This means that the computation of the Fourier transform of the image comes first. All image enhancement techniques apply to the Fourier transform of the image, and the final image is created by the inverse Fourier transform. These operations are used to enhance the quality of the image by altering pixel values, thus changing intensities and improving features such as brightness, contrast, and grayscale distribution. The output image's pixel values, or intensities, are modified by the transform function after applying it to the input values. [4]

Image enhancement is that technique by which the image quality can be improved. It has a variety of usage, like in satellite analysis and medical image analysis. Actually, image enhancement is a quick easy way to improve the quality of an image. This involves using transform function, T, where the pixel values of an image are changed. The equation for the relationship of the pixel values in the original image, f, with those in the enhanced image, g, is given by s = T(r), where r is a pixel value in f and s is the corresponding pixel value in g. The transform function, T, can be any function mapping pixel values to other pixel values. In the case of image enhancement, the transform function is usually selected such that the visual quality of the image is enhanced. [5]

For example, an 8-bit image has pixel values between [0, 255]. These techniques are often intuitive and based on heuristics, which makes them very easy to implement but less effective. Moreover, there does not exist a measure of image quality that is universally accepted, so the desired outcome is also ambiguous. Consequently, a good technique for one application may prove useless in another. It is within this context that the paper examines the mathematical foundations behind some of the most essential image enhancement techniques, providing some theoretical underpinning to understand what these techniques are and how they may be used. It also states some important concepts and describes some common image enhancement techniques along with point processing methods, histogram processing in the framework of spatial domain image enhancements. The aim of image enhancement is to obtain an optimized image, but the specific optimality criteria depend on the application.

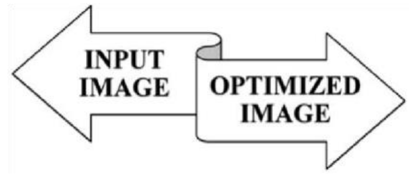


Fig.1. Image Enhancement Techniques [6]

This means that data processing techniques applied in the spatial domain can similarly be applied to enhance images in the frequency domain. Using both methods of data processing is possible, including that in the frequency domain and in the spatial domain, which improve pictures. The term "spatial domain" just refers to the image plane, and this class includes methods that directly change the values of image pixels. The groups of linear logarithmic and power transforms used to create the histograms. The histogram of the histogram-aligned digital image is more horizontal than the histogram of the original image. Increases in brightness range, contrast, sharpness, and sharpness are essential for greater image quality[7]

Modifying the histogram of an image can enhance individual or combined properties of an image. Histogram equalization techniques are often used to enhance grayscale digital images. These algorithms are efficient with low processing times, user-friendly, and have effective results. Generally, these techniques adjust the levels of a halftone picture according to the probability distribution function specific to an image, which aims to expand the dynamic range of luminance distribution. Outcomes Improved visual effects, such as higher sharpness, resolution, and contrast.

IV. PROPOSED METHODOLGY

Here we use various techniques to enhance the image and filter the noise. Like: -

A. Gamma Correction for Contrast Adjustment

Gamma correction is a nonlinear operation widely used in image processing to adjust the brightness or contrast of an image. The equation for gamma correction is given by: O = Iγ

- O: Output pixel intensity
- I: Input pixel intensity
- γ: Gamma value

In our experiment, we used various gamma values to determine the best contrast adjustment for our project.

B. Unsharp Masking

Unsharp masking is an image sharpening technique. To sharpen the image, one can create a blurred version of the same image and subtract it from the original. The steps one follows in this process are:

i) Low-pass filtering:

One uses a smoothing filter like a Gaussian filter and makes a blurred version of the image.

ii)Subtraction:

Subtract the blurred image from the original to enhance edges.

In our code, we attempted to use unsharp masking with a Gaussian filter, but the results were not good.

C. Laplacian Filter

The Laplacian filter is commonly used for edge detection. It highlights regions of rapid intensity change in an image. The filter is defined as:

0	−1	0
−1	4	−1
0	−1	0

Fig.2. Laplacian Filter [8]

Applying this filter to an image emphasizes edges by accentuating changes in intensity. In our project, we tried Laplacian filter to enhance edges, but it did not yield desired results

D. Band-pass Filtering for Image Sharpening

Band-pass filtering is actually an application of low pass and high pass filters to strengthen some frequency components in a digital image. The steps comprise the following:

•Low-pass filter: Smooth the image to reduce the noise.

•High-pass filter: Subtract the low-pass filtered image from the original.

We tested two Gaussian filters, both of different sizes in order to achieve band pass filtering and sharpen the image with minimizing amplification of noise during that process.

E. Y'CbCr Color Space and HSV Color Space Enhancement

• Y'CbCr Color Space:

Y'CbCr is a color space that splits an image into luminance (Y') and chrominance (Cb, Cr) components. Contrast adjustment in the Y' channel can enhance the image quality.

• HSV Color Space:

HSV separates an image based on its color information: Hue (color), Saturation (intensity of the color), and Value (brightness). In our project, we enhanced the value (brightness) channel to improve the image.

F. Median Filtering

Median filtering is a nonlinear filtering technique used for noise reduction, particularly effective against impulse noise (salt-andpepper noise). It replaces each pixel value with the median value in its local neighbourhood.

G.Adaptive Histogram Equalization (AHE)

Adaptive Histogram Equalization is a local contrast enhancement technique rather than global. It divides the image into small regions and equalizes the histogram of each region independently. AHE helps to improve contrast in both bright and dark regions.

H.Gaussian Filtering

Gaussian filtering is a type of smoothing technique where it computes the weighted average for each pixel. Sometimes, it is applied as a blur filter for eliminating the noise. In our project, we used it in order to make edges smooth.

I.Binarization

Binarization: It is the process of converting a grayscale image into a binary image. In a binary image, the pixels are classified as either foreground or background. This is often done by choosing a threshold value. Here, we experimented with different combinations of Gaussian filtering and thresholding to achieve optimal binarization.

J.Contrast Limited Adaptive Histogram Equalization

(CLAHE)

CLAHE is an enhancement of AHE that limits the amplification of noise in flat regions of the image. It operates similarly by enhancing local contrast but avoids over-amplification of noise. Rather than processing the entire provided image, this method operates on small tiled portions to eliminate noise and enhance contrast. The procedure is specifically applied to the luminance channel of a color image and yields much better results than adjusting all channels of the BGR image. This technique is applicable to both grayscale and color photos.

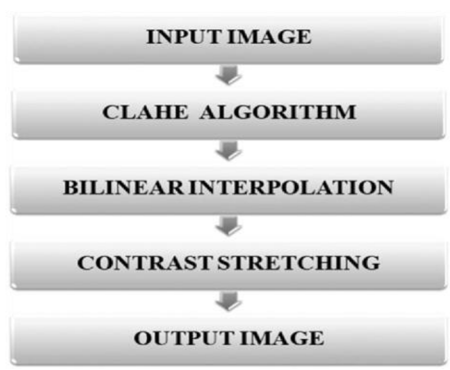


Fig.3. Proposed Methodology [9]

V. Results And Conclusion

1. For the first we took a giraffe image and tried to use above methods to enhance the image. So, firstly we got its histogram as in Fig 1.2.

We can see that the image contrast is very bad as the pixels are% accumulated in the range [0.37, 0.64].

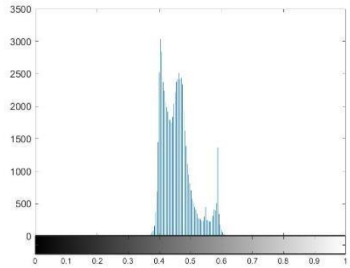


Fig 1.1 Input image

Fig 1.2 Histogram

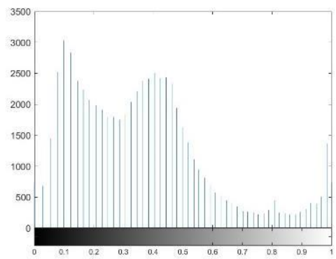
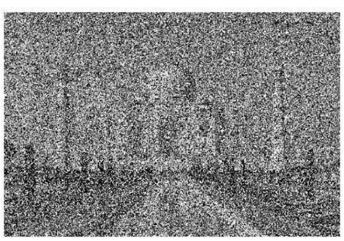


Fig 1.3. Image After Contrast Stretching

Fig 1.4. Output image histogram

So, we tried contrast stretching and find the optimal gamma value. Which came out to be 0.9. After that we tried Unsharp Mask and Laplacian on the image but we didn't find any good result.

In example 2, as we can see from the histogram that there is peak at higher value of intensities and also there is random dark and bright circles in the image. So, these proposed the presence of salt and pepper noise.



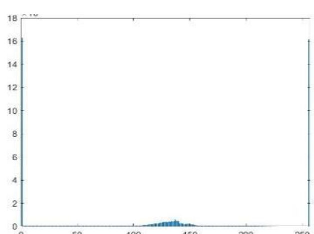


Fig 1.5. Image After Contrast Stretching

Fig 1.4. Output image Histogram

Thus, we used Median filter to remove noise whose optimal value came out to be 11(window sizeis 11x11).

On, increasing the value image was becoming blur. The processed image was not having a good contrast which can also be seen from the histogram.So we enhanced the contrast.A 9x9 averaging filter is applied to the contrast-adjusted image to obtain a low-pass component.The high-pass component is obtained by subtracting the low-pass component from the contrast-adjusted image The final sharpened image is obtained by adding the high-pass component to the contrast-adjusted image .

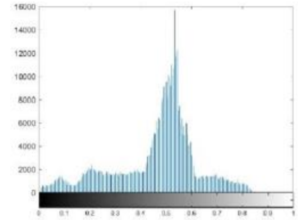


Fig 2.3. Image after Median Filter **Fig 2.4.** Its Histogram

Fig 2.1 After Contrast Stretching **Fig 2.2.** Final Image

3. In example 3, Image is converted to grayscale. We can see that the image contrast is very bad. So, contrast adjustment is done with gamma =0.7. Adaptive Histogram Equalisation is then applied with Clip Limit=0.03 and tile Size [30 15]. Edge is smoothened by applying Gaussian filter.

Fig 3.1. Input Image 3.2 Gray Scale Image

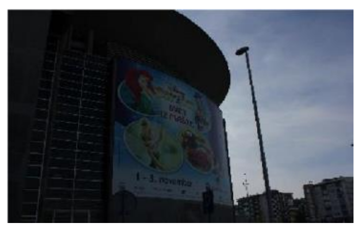


Fig 3.3. Contrast Stretching Fig 3.4. After AHE

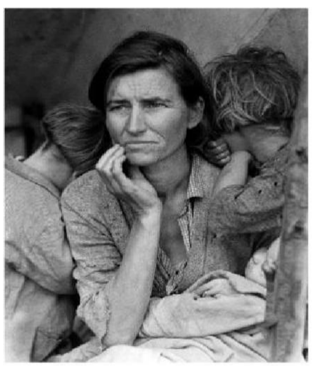
Fig 3.5. After Gaussian (Final Image)

4.We attempted to switch to Y'CbCr and do the contrast enhancement on the same Disney image. Best result at gamma=0.5 and Gaussian Filter is applied to further enhance it. Then we tried to enhance by switching HSV color space. Best gamma came out to be 0.5 and then Gaussian filter was also applied.

HSV provided better outcome.

Fig 4.1. HSV & Gaussian   Fig 4.2. Y'CbCr & Gaussian

5. In example 5, we sharpen the image using Band Pass Filter.



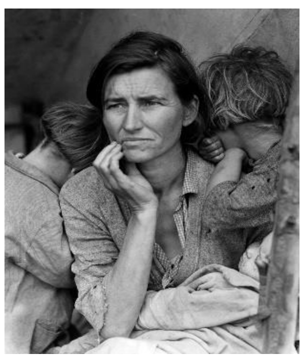


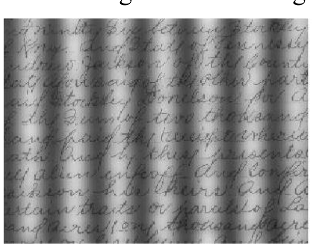
Fig 5.1. Input Image   Fig.5.2. Output Image

6. In example 6, we are doing filtering and binarization on the image to remove the strips lines.

For that we applied Gaussian filter with sigma(s)=60, filter size = [45 45].

From input image, gaussian filtered image was subtracted and from its histogram threshold was determined to be 0.57.

Finally, threshold was applied on subtracted image to get the final image.



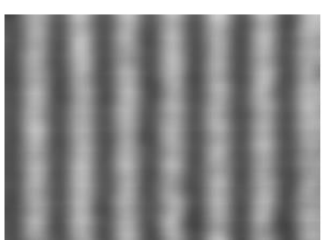
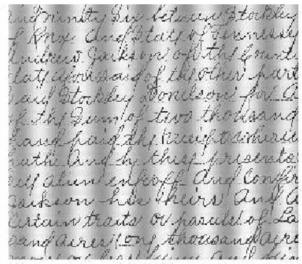


Fig 6.1. Input Image   Fig 6.2.Gaussian Filtered



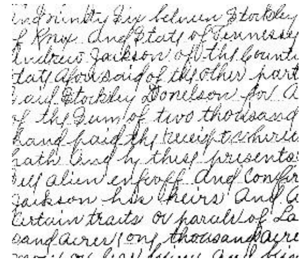


Fig 6.3. Input-Gaussian   Fig 6.4. Final Image

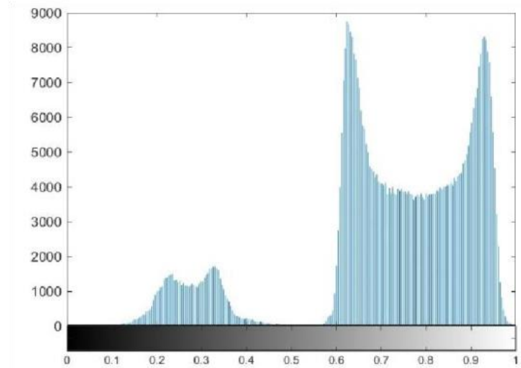


Fig 6.5. Histogram of Input-Gaussian

4. We implemented CLAHE Algorithm.

We changed the Tile numbers and limits to get different images. The best image which we got is:

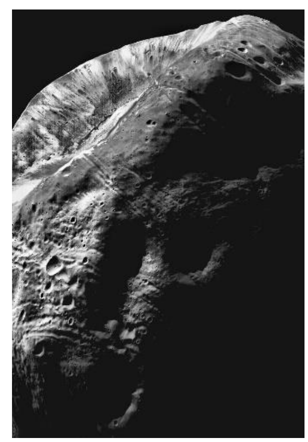


Fig 7.1. Input Image   **Fig 7.2.** Best Image

VI. REFERENCES

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Coding for CLAHE has been done by Meenakshi

Coding for file named “main” has been done by Gulshan and Aman

Coding for computing cdf matrix is done by Arun kumar Bharti