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Applying Butterworth Low Pass Filtering to Reduce Image Color Loss

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Abstract:

The image's high-frequency components are undetectable to the human eye. Consequently, carrying the high-frequency components is superfluous since they hog all the storage space and bandwidth. One solution to this issue is to apply a filter to the picture, which will remove any high-frequency elements. Using Butterworth Low Pass Filtering (LPF), we provide a new approach to color picture filtering in this article. Three planes—red, green, and blue—make up the chosen color picture. Before being combined, the individual planes undergo Butterworth Low Pass Filtering. To enhance the output picture quality, the cut-off frequency is adjusted. The PSNR approach is used for quality control. The whole process is executed in MATLAB, and the outcome is up to par. Any kind of picture may benefit from this method.

Keywords: Image, Fourier Transform, Low Pass Filtering, Cut-off frequency, PSNR

1. Introduction:

When improving images, filtering is an important step. Image compression and quality enhancement are two goals of filtering. first to third Images may be affected by issues with lighting, noise, and low light levels [3-5]. Consequently, eliminating noise from photographs is a task [6-8]. As a result, creating a sample converter that can filter out noise in photos using a low-pass filter is essential [9, 10].

Blurring or smoothing images is a popular usage for Butterworth low-pass filters. Our goal with this project is to make the color picture smoother and more aesthetically pleasing by reducing the high-frequency noise in it. The Butterworth filter improves low-frequency details by reducing the image's high-frequency components. If you're trying to emphasize certain structural or textural details in a picture, this may work. Investigating the color image's frequency domain properties can be part of the study. If you want to learn more about or change any aspect of a picture, you may use a Butterworth filter to study its frequency content. You may change the filtering features of a Butterworth filter by adjusting factors like the order and cutoff frequency.

In this study, we improve images using the Fourier domain Butterworth low-pass filter. We achieved this by partitioning the picture into three planes and then taking its Fourier spectrum. In order to gather specifics about the picture, this is done. The frequency on each spectral plane is

The frequency is greatest in the four corners of the spectrum, while it is zero in the middle area (dc).

Our low cutoff frequency is based on the fact that low-frequency components are enough for picture reconstruction. We have tried several values of cutoff frequency to see what works best.

The Butterworth low-pass filter's mathematical formula has been used. To get the PSNR value, we look at the final pictures. They had previously employed a number of methods, but the chosen photographs were of poor quality visually. The solution we have developed makes use of a high-quality photograph. Following a discussion of the technique in Section 2, the findings are presented in Section 3, and finally, a conclusion is given in Section 4.

2. Methodology

Here, we have used the frequency domain compression technique of satellite images. Let us assume that f (x, y) is the original image that is used for compression. For a satellite image of size M × N, the two-dimensional DFT is given by: [11-14]

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)\mathrm{e}^{-i2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)}$$

where f(x, y) is the original image and F(u, v) is the Fourier transform of the image.

The transfer function of the low-pass filter is
H(u, v) = 1, for D (u, v) ≤ D_0
= 0, for D (u, v) > D_0

Here, the cutoff frequency is represented by D_0, and D (u, v) represents the gap of point (u, v) from the center point in the frequency band. Here,

$$D(u,v) = \left[\left(u-\frac{M}{2}\right)^2 + \left(v-\frac{N}{2}\right)^2\right]^{\frac{1}{2}}$$

and

$$H(u,v) = \frac{1}{\left[1+\frac{D(u,v)}{D_0}\right]^{2n}}$$

where n is the order of spatial domain frequency.

The methodology is explained with the help of the following diagram:

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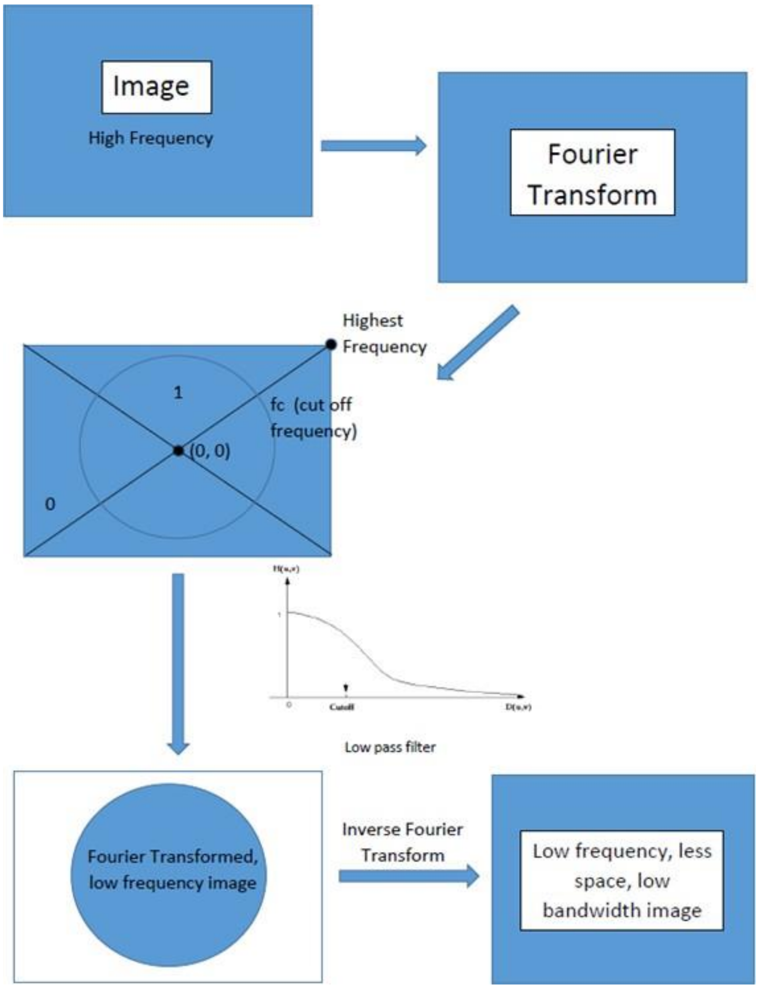

Figure 1 – Diagram of the Process

3. Result:

For this research work, we have used only two good quality color images whose resolutions are 1200 x 800 respectively. The images are displayed in Figure 2. The whole research work is done using MATLAB software.

Figure 2 – Selected Images

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Vol-09 Issue-02 Aug 2024

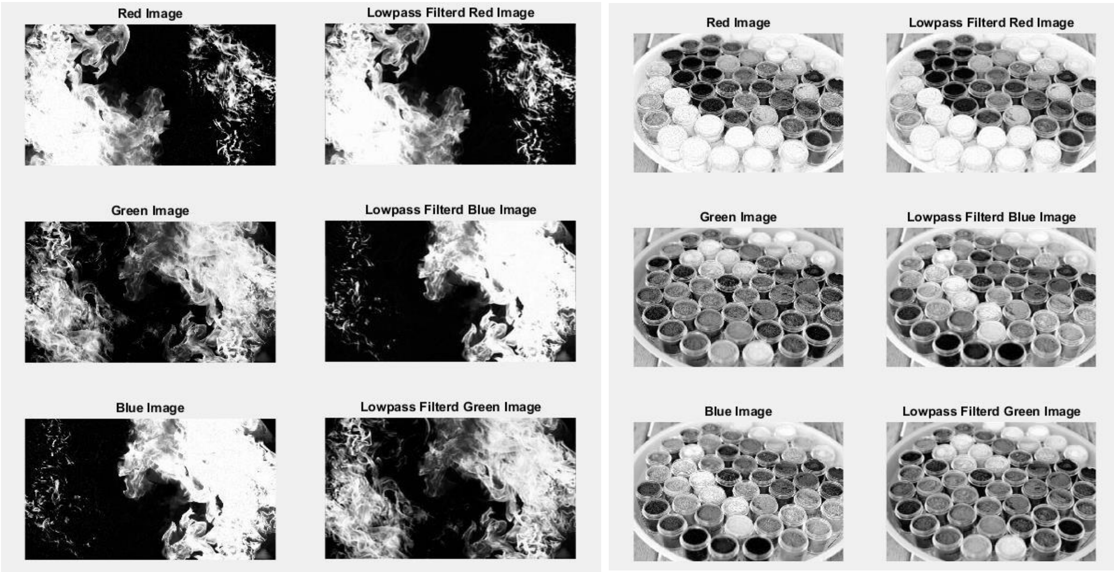

Figure 3 – Filtered Image of Each Plane

Figure 3 represents the division of each plane followed by the filtered part of the planes. For filtering, we have used a cut-off frequency of 150. We have observed that at this frequency, the quality of the output image is satisfactory. For filtering, the order of the Butterworth low-pass filter is 4^{th}.

Figure 4– Constructed Images

Figure 4 represents the constructed image using the lowpass filtered planes which is shown in Figure 3.

Size calculation:

The storage space of the image 1 = 230 kB

The storage space of the constructed image 1 = 195 kB

Compression Ratio = 1.18

The storage space of the image 2 = 217 kB

The storage space of the constructed image 2 = 189 kB

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Vol-09 Issue-02 Aug 2024

Compression Ratio = 1.15

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Vol-09 Issue-02 Aug 2024

PSNR:

Image 1 = 39.2

Image 2 = 38.9

Conclusion:

Here we provide a straightforward method for frequency domain picture compression that makes use of a Butterworth low-pass filter. Overall, the use of MATLAB's Digital Image Processing tools to apply a Butterworth Low Pass Filter to a color image effectively reduced noise while maintaining important picture elements. An aesthetically beautiful filtered picture was achieved by using a Butterworth filter, more especially a 4th-order transfer function, which facilitated a regulated and seamless transition between the passband and stopband. The architecture of this filter worked well with color pictures since it separated and then combined the three RGB components. To sum up, this study proved that utilizing MATLAB to apply a Butterworth Low Pass Filter on color pictures was effective. Researchers and practitioners in the area of digital image processing will find this approach interesting, as the findings demonstrate its potential for numerous image processing applications.

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