Compression of Color Image Using Butterworth Low Pass Filtering

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Abstract:

The human eye can't detect the high-frequency components of the image. Therefore, it is unnecessary to carry the high-frequency components as it consumes too much storage space as well as bandwidth. To overcome this problem, filtering of the image is performed which eliminates the high-frequency components from the image. In this article, we propose a novel method of color image filtering using Butterworth Low Pass Filtering (LPF). The selected color image is divided into three planes- Red, Green, and Blue. Butterworth Low Pass Filtering is applied to each plane separately and then they are joined together. The cut-off frequency is varied to improve the quality of the output image. Quality is checked by the PSNR method. The total operation is performed using MATLAB software and it provides a satisfactory result. This system is useful for all types of images.

Keywords:

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

1. Introduction:

Filtering is an essential part of the image enhancement process. Filtering is done to improve the image quality as well as compression of the images. [1-3] Problems present in images are illumination, noise, and under-light images [3-5]. Hence, one of the challenges is to remove noise from images [6-8]. Therefore, there is a need to develop a sample converter that works as a low-pass filter to remove the noise from images [9-10].

Butterworth low-pass filters are commonly used for image smoothing or blurring. The project aims to reduce high-frequency noise in the color image, resulting in a smoother and visually more appealing image. By attenuating high-frequency components in the image, the Butterworth filter can enhance low-frequency features. This may be useful in certain image processing applications where highlighting important structural or textural information is desired. The project may involve exploring the frequency domain characteristics of the color image. Applying a Butterworth filter allows the analysis of the image's frequency content, which can be useful for understanding and manipulating specific components of the image. Butterworth filters have parameters such as the order and cutoff frequency that can be adjusted to control the filtering characteristics.

In our present paper, we have applied the Butterworth low-pass filter in the Fourier domain for image enhancement. To do this, we have taken the Fourier spectrum of the image after dividing it into three planes. This is done to get detailed information on the image. In each of the spectrum planes, the frequency in the center region is zero (i.e., dc), whereas at each corner of the spectrum, the frequency is the highest. As low-frequency components are sufficient for image reconstruction, we have set a low cutoff frequency value. Values of cutoff frequency have been varied to obtain better results.

we have used the mathematical formula of the Butterworth low-pass filter. PSNR value of the output images is measured. Though various techniques were used earlier, the visual quality of their selected images was not good. Whereas in our method, we have used a good-quality image. The methodology has been discussed in Sect. 2 followed by results in Sect. 3, and a conclusion has been drawn in Sect. 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]

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

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 $D(u, v) \le D_0$
$= 0$, 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:

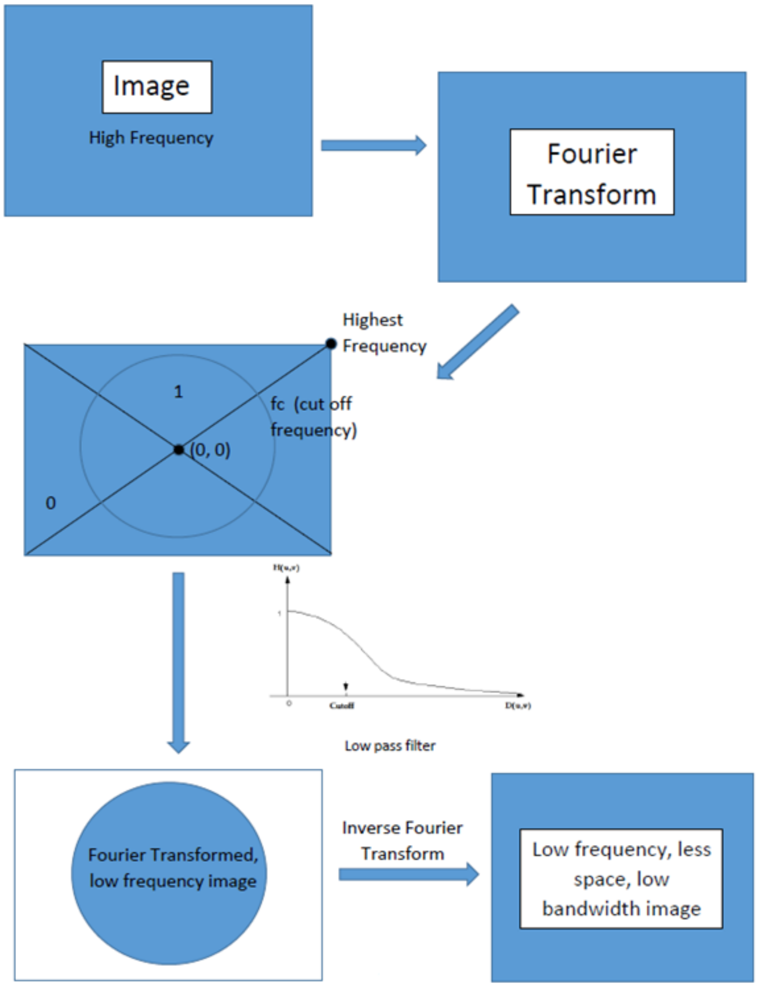

Figure 1 – Diagram of the Process

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

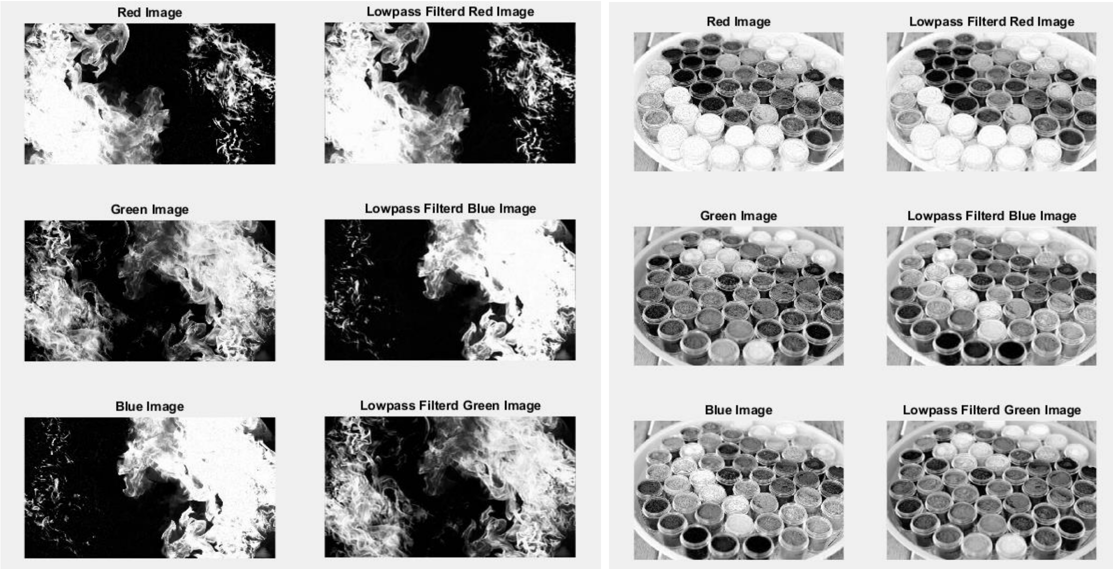

Figure 3 – Filtered Image of Each Plane

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

Compression Ratio = 1.15

PSNR:

Image 1 = 39.2 Image 2 = 38.9

Conclusion:

A simple technique of image compression in the frequency domain using a Butterworth low-pass filter is proposed here. In conclusion, the application of a Butterworth Low Pass Filter on a color image using Digital Image Processing techniques in MATLAB has proven to be an effective method for reducing noise and preserving essential image details. The choice of a Butterworth filter, specifically a 4th-order transfer function, allowed for a controlled and smooth transition between the passband and stopband, resulting in a visually pleasing filtered image. This filter design was particularly suitable for handling color images, as it effectively managed the three RGB components separately before merging them back together. In summary, this research work successfully demonstrated the efficacy of applying a Butterworth Low Pass Filter to color images using MATLAB. The results obtained highlight the potential of this technique for various image processing applications, providing a valuable tool for researchers and practitioners in the field of digital image processing.

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