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Removal of Moiré Patterns in Frequency Domain

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ABSTRACT

Images in life hold many interpretations for different people across the globe. Sometimes these images come in a blotchy form that we can't interpret any of them. Such noisy new pattern appears when two similar, repetitive, grid-like patterns of lines, circles or arrays of dots overlap with imperfect alignment and is known as moiré pattern. Actually, it is not a physical pattern etched in the original structures but rather an optical illusion created in the vision of the viewer. So this paper aims to remove or reduce moiré patterns by filtering. This filtering is done in the frequency domain and some selective filters are chosen to filter the image. We'll also discuss the halftone methods and use filters along with MATLAB.

General Terms

Digital Images, Artifact, Halftone, Noisy Images, Sampling, Moiré Pattern, Frequency Domain, Filtering

Keywords

Moiré Pattern, Filtering in Frequency Domain, Notch Filters, Band stop or Band reject Filters, Sampling by Periodic Components

1. INTRODUCTION

In this era of digitalization of every existence material, multimedia publishing has increased in importance. So scanned graphics has become wide spread. In digital image processing, when scanning media print such as newspapers and magazines or in images with periodic components whose spacing is comparable to the spacing to the spacing between samples, a blotchy image appears which is having a new pattern. This pattern is moiré pattern which is sometimes resulting from sampling scenes with periodic or nearly periodic components.

2. Moiré Pattern

Actually, moiré patterns are a common everyday occurrence. Moiré patterns appear by superimposing of two transparent layers containing correlated opaque patterns. In this way superimposing of one pattern on the other creates a beat pattern that has frequencies not present in either of the original patterns. It is important to note that moiré patterns are more general than sampling artifacts.

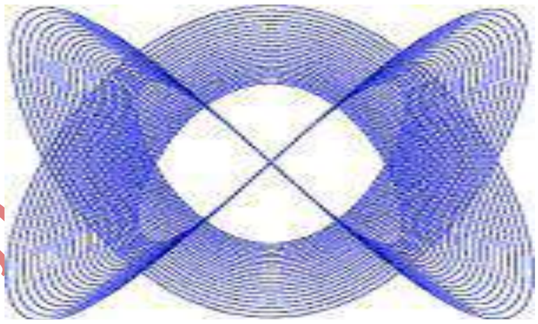


Fig.1. Moiré pattern

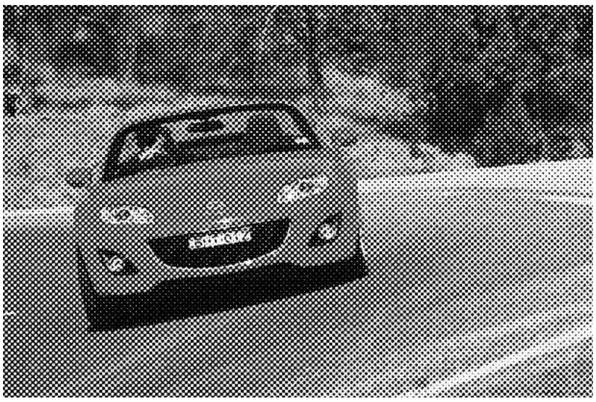


Fig.2. Moiré pattern in printed material

All pictures from printed material, journals, and newspapers make use of halftone dots, which are black dots or ellipse whose sizes and various joining schemes are used to simulate gray tones. As a rule, newspaper printing use 75 halftone dots per inch, magazines use 133 dpi; high quality broachers use 175 dpi. And in this way they have the moiré pattern effect. The dot size is inversely proportional to image intensity. In light areas, dots are small or totally absent (see, for example, the white part of the road in Fig.2.) In light gray areas, dots are larger (see, for example, the gray part of the road in Fig.2.). In darker

areas, when dot size exceeds a specified value, dots are allowed to join along two specified directions to form an interconnected mesh (see, for example, the black part of the driver joining with the black line of car Fig.2)

3. Filtering in Frequency Domain

There are applications in which it is of interest to process on specific bands of frequencies or small regions of the frequency rectangle. This is filtering and there are two categories of filters: band pass and band reject filters. The relation between them is:

$$H_{BP}(u,v) = 1 - H_{BR}(u,v) \quad \ldots (1)$$

Where, $H_{BP}(u,v)$: *Band pass filter* and $H_{BR}(u,v)$: Band reject filter.

We'll use selective filters in band reject filters to remove moiré effect from images. They are called *notch filters*. If we have a blotchy image from moiré pattern then notch filter can exclude "bad" frequencies from an image in order to remove isolated noise or distortion.

3.1 Notch Filters:

A notch filter passes frequencies in a predefined neighborhood about the center of the frequency rectangle. Hence, a notch with center at (u_0, v_0) must have a corresponding notch at location $(-u_0, -v_0)$. Notch reject filters are constructed as products of high pass filters whose centers have been translated to the centers of the notches. The general form is:

$$H_{NR}(u,v) = \prod_{k=1}^{Q} H_K(u,v)\, H_{-K}(u,v) \quad \ldots (2)$$

Where, $H_K(u,v)$ and $H_{-K}(u,v)$ are high pass filters whose centers are at (u_k, v_k) and (u_{-k}, v_{-k}) resp.

These centers are specified with respect to the center of the frequency rectangle (M/2, N/2). The distance computations for each filter are given as follows:

$$D_K(u,v) = \left[\left(u - \frac{M}{2} - u_K\right)^2 + \left(v - \frac{N}{2} - v_K\right)^2\right]^{1/2} \quad \ldots (3)$$

$$D_{-K}(u,v) = \left[\left(u - \frac{M}{2} + u_K\right)^2 + \left(v - \frac{N}{2} + v_K\right)^2\right]^{1/2} \quad \ldots (4)$$

There are Ideal, Butterworth and Gaussian notch filters. Let W be the width of the band, D be the distance D (u, v) from the center of the filter, D_0 be the cutoff frequency, and n be the order of the filter. We'll use D in place of D (u, v) for simplicity in the equations of each filters discussed bellow with their 3-D plots and images and effects on moiré effects.

3.1.1 Ideal Notch Filter

Ideal notch filter is the basic notch filter. It has the expression of the form:

$$H(u,v) = \begin{cases} 0 \text{ if } D_0 - \frac{W}{2} \le D \le D_0 - \frac{W}{2} \\ 1 \quad \text{otherwise} \end{cases} \quad \ldots (5)$$

Plot of Ideal notch Filter:

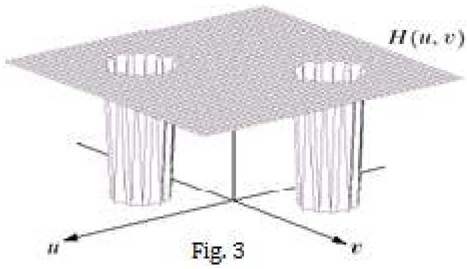
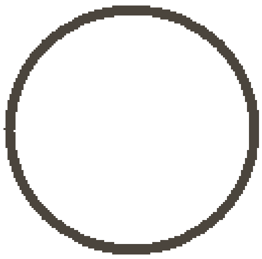


Fig. 3



Ideal notch filter example

3.1.2 Butterworth Notch Filter:

It has the expression of the form:

$$H(u,v) = \frac{1}{1 + \left[\frac{DW}{D^2 - D_0^2}\right]^{2n}} \quad \ldots (6)$$

The corresponding Butterworth notch filter of order n is given by:

$$H_{NR}(u,v) = \prod_{k=1}^{Q} \left[\frac{1}{1 + \left[\frac{D_{0k}}{D_k(u,v)}\right]^{2n}}\right]\left[\frac{1}{1 + \left[\frac{D_{0k}}{D_{-k}(u,v)}\right]^{2n}}\right] \quad \ldots (7)$$

Plot of Butterworth notch Filter:

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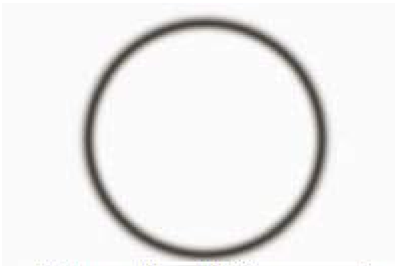
Fig. 4



Butterworth notch filter example

3.1.3 Gaussian Notch Filter:

It has the expression of the form:

$$H(u,v) = 1 - e^{-\left[\frac{D^2 - D_0^2}{DW}\right]} \quad \ldots (8)$$

The corresponding Gaussian notch filter of order n is given by:

$$H_{NR}(u,v) = \prod_{k=1}^{Q}\left[1 - e^{-\left[\frac{D_k(u,v)}{D_{0k}}\right]^2}\right]\left[1 - e^{-\left[\frac{D_{-k}(u,v)}{D_{0k}}\right]^2}\right] \quad \ldots (9)$$

Plot of Gaussian notch Filter:

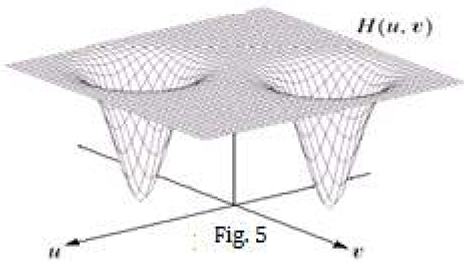
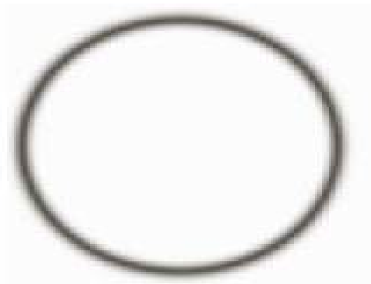


Fig. 5

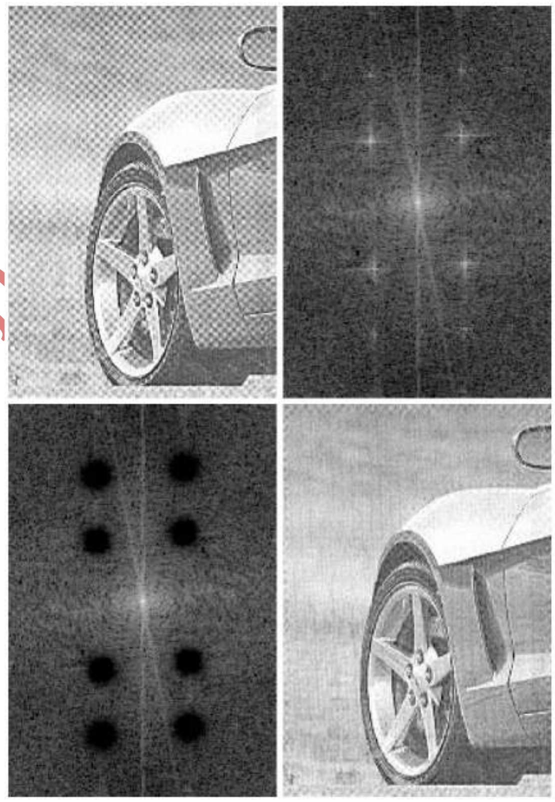


Gaussian notch filter example

The constant D_{0k} in equation (7) and (9) is the same for each picture but it may be different for different pairs.

Here we studied 3-D plots of Ideal , Butterworth and Gaussian Notch filters. Due to symmetry of the Fourier transform, notch filter must appear in symmetric pairs about the origin in order to obtain meaningful results. It is applicable if the notch filter is located at the origin, in which case it appears by itself. Although here we have shown only one pair for illustration purpose, the number of pairs of notch filters that can be implemented as arbitrary. The shape of notch areas also can be arbitrary. Say rectangle or so.

(a) (b)



(c) (d)

Fig. 6

Here in Fig. 6,

(a) Sampled newspaper image with moiré pattern

(b) Spectrum

(c) Butterworth notch filter multiplied by the Fourier Transform

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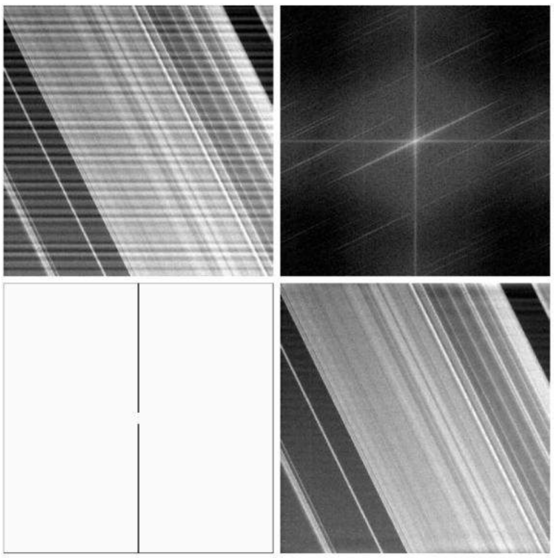
(d) Filtered image

Fig. 6 (a) is the scanned newspaper image showing a prominent moiré pattern. Fig. 6 (b0 is its spectrum. We know that the Fourier Transform of a pure sine, which is a periodic function, is a pair of conjugate symmetric impulses. The symmetric bursts in Fig.6 (b) are a result of the near periodicity of the moiré pattern. We can attenuate these bursts by using notch filtering. Fig. 6(c) shows the result of multiplying DFT of Fig. 6(a) by a Butterworth notch reject filter with D_0 = 3 and n=4 for all notch pairs. The value of the radius was selected to encompass the energy bursts completely, and the value of n was selected to give notches with mildly sharp transitions. The locations of the center of the notches were determined from spectrum. Fig. 6(d) shows the result obtained with this filter. The improvement is significant, considering the low resolution and degradation of the original image.

(a) (b)



(c) (d)

Here in Fig. 7

(a) Original image

(b) FT of original

(c) Notch Reject filter

(d) Filtered image

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