Intelligent detection and removing of straight periodic streaks on digital images

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Abstract. Straight periodic streaks are common negative errors on images, an intelligent method is proposed to test and remove the periodic streaks on digital images. Because of many artificial errors or negative experiment factors, digital images are always contaminated by straight periodic streaks, which will correspondently incur error information on them. By Fast Two Dimensional Fourier Transform, the space spectra from these periodic streaks are discrete and can be test intelligently. After eliminate these frequency ingredient, the periodic streaks disappear after inverse Fourier Transform. The numerical simulation experiment shows that this method is robust in detesting and removing the periodic streaks on digital figures.

1. Introduction

During the recording process of optical pictures in fine optical lab, many environmental and man made mistakes always cause unwanted steaks on the result figures, especially for the laser source optical configuration with many optical devices. These fringes and steaks [1-3] are mostly the results of coherent interference between laser waves, which were reflected from different surfaces of various optical devices. These contaminated intensities can degrade the image quality and the measure precision in practice. Usually these additional figure intensities are removed by space filtering in 4f optical system for optical pictures or in computer for digital configures, where the space filtering method is more prosperous for digital figures because of the fast development of computing technology. Mostly, the space filtering is operated through two-dimensional Fourier Transform. Researcher ZHANG et al. [3] adjusted the noise effects on OCT images in Fourier domain. JIANPING LI AND YI XIAO [5] improved the fast Fourier Transform processing efficiency. MANDEEP SINGH AND KEDAR KHARE [6] used the Fourier Transform method to estimate the carrier parameters in digital holography.

However, it is a difficult task to test the steaks intelligently and accurately so that they can deleted completely. Here we provided an automatic a method to detect the target fringes on digital figures and remove it with high precision. The principle is discussed with the reasonable formula deduction first, then the numerical simulations is to show the working effect of our method, and at last the conclusion on the method is drawn.

2. Principles

In information optics research area, space frequency filtering methods are used to some negative information on images. To complete such work, Two Dimensional Fourier Transform (TDFT) is necessary for frequency component separation. For digital images, the TDFT process can be finished in computer automatically. Here the image with errors of straight steaks is expressed as IE, which is
the summation of the original image intensity distribution \( I_0 \) and the streaks intensity distribution is. Then we have

\[
I_E = I_0 + I_S
\]

After the TDFT operation of Eq. (1), the space frequency spectrum of \( I_E \) can be expressed as

\[
\text{FT}[I_E] = \text{FT}[I_0] + \text{FT}[I_S]
\]

Where symbol ‘\( \text{FT} [ ] \)’ represents the operation of Fourier Transform. To express the frequency spectrum function, Eq. (2) is rewritten in the form of

\[
F_E(f_x, f_y) = F_0(f_x, f_y) + F_S(f_x, f_y)
\]

Here \( f_x \) and \( f_y \) are space frequency coordinates along the horizontal and perpendicular direction on space frequency plane respectively. The two items of the right side of Eq. (2) are space spectrum distributions of the original image and streaks respectively. For most conditions, they are located on the different areas on the frequency plane. On one hand, the distribution of the first term of the right side of Eq. (2) is almost random with small spectrum value expect the absolute value of the zero spectrum. On the other hand, the latter one are commonly characterized as one delta function distribution or the combination of a series of delta functions, which are one or many small bright points on one straight line on the TDFT plane. Obviously, it is easy to find these points by our observation. In fact, these points are located by human eyes traditionally and then these spectrums from straight streaks are removed from TDFT spectrum.

\[
F_0(f_x, f_y) = F_E(f_x, f_y) + F_S(f_x, f_y)
\]

After Inverse Two Dimensional Fourier Transform (ITDFT) of Eq. (5), the original image without streaks is achieved.

\[
I_0 = I\text{FT}[F_0(f_x, f_y)]
\]

Where ‘\( \text{IFT} [ ] \)’ means ITDFT.

However, the current frequency filtering method needs human work to find the location of the corresponding spectrum of streaks on TDFT plane, which is inconvenient. Here we proposed an automatic detection method to found the streaks frequency for digital pictures in computer. Because the frequency spectrums of periodic streaks are delta functions, their absolute values are corresponding maximums in the space frequency data matrix. To search for these points, the method of maximum finding algorithm can be used automatically in computer. Unfortunately the absolute value of the zero frequency is commonly the biggest one on frequency plane. So before searching we should cross out the value of this point. The whole process of our method is illuminated step by step as the following.

Step 1: Read the target picture and carrying out the operation of TDFT on the picture with straight streaks by Eq. (2) and record the complex matrix of \( F_E(f_x, f_y) \) in Eq. (3).

Step 2: Calculate the absolute value of the data matrix of \( \text{abs}[F_E(f_x, f_y)] \) and keep it in computer memory.

Step 3: Replace the absolute value of zero frequency \( F_E(0, 0) \) with the value of zero. Then search the new data matrix for maximum value and keep down its coordinates \( (f_{x1}, f_{y1}) \), which is pixel number in data matrix. Replace this maximum value with zero again, find the next maximum value, and recorded the corresponding pixel number as \( (f_{x2}, f_{y2}) \). Repeat this operation until all the maximum frequency points are found and their coordinates are recorded.

Step 4: Rewrite all the values of the recorded coordinates in complex data matrix \( F_E(f_x, f_y) \) with zeros. The function \( F_0(f_x, f_y) \) in Eq. (4) is achieved.

Step 5: ITDFT operation in Eq. (5) is carried out to recover the picture without the straight streaks. The five steps mentioned above can be realized by computer programs and this algorithm is convenient for us to complete the digital frequency filtering automatically, which is useful and welcome by engineers in real application practice.
3. **Numerical Simulation**

To verify the availability of the algorithm suggested here, many computer simulations are introduced. A typical example using this method is carried out and the corresponding results are discussed latterly.

\[ I_S = 0.1 \{ \sin[0.4(x + y)] + 1 \} \]  

Fig. 1(a) is a commonly used picture added with periodic straight streaks for testing. Pixel numbers of Fig. 1(a) on both horizontal and perpendicular directions are 512 pixels respectively. The intensity distribution of streaks in it is described as

Fig. 2 (a) is a commonly used picture added with periodic straight streaks for testing. Pixel numbers of Fig. 1(a) on both horizontal and perpendicular directions are 512 pixels respectively. The intensity distribution of streaks in it is described as

The distribution of the absolute value of streaks spectrum is shown in Fig. 2 (a), where it is easy to see the three bright points on spectrum plane. One point locates at (0, 0), the center of the spectrum plane and the other two points distribute symmetrically about the point (0, 0). By using the method suggested here, the coordinates of two streaks spectrum are found intelligently and they are (224, 224) and (290, 290) on spectrum plane respectively. The three absolute values are \( 2.6175 \times 10^5 \), \( 7.4902 \times 10^3 \), and \( 7.4902 \times 10^3 \) respectively. Obviously, the point representing the zero frequency is much bigger than the absolute value of the streak frequency. In Fig. 2 (b), the two periodic streaks frequency are removed by zero replacement of step 4 in this method. By the operation of ITDFT in step 5, the picture without streaks is achieved in Fig 1. (b). obviously, there are very little difference between the original figure and Fig 1. (b). the results show that the method here is effective in detecting and removing the
figure streaks process.

4. Conclusion
On conclusion, an intelligent periodic streaks removing method based on the digital Fourier Transform filtering theory is proposed in this paper. This method can search and remove the streaks frequency spectrum on frequency plane automatically. The whole process of removing is completed by computer program. We hope that this technique has prosperous future in the application practice of image processing.

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