New Method for Eliminating Background Noise in Characteristic Spectral Imaging

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Abstract. We proposed a method to eliminate the background noise, which is based on subtraction of two different central wavelength filters according to the characteristic spectral imaging. In the experiment, the sodium yellow light with 589 nm wavelength is selected as the characteristic wavelength of spectral imaging experiment, and the visible light industrial camera was used to collect diffuse reflective wall images. Firstly, two narrow-band filters with a center wavelength of 589 nm and 579 nm are placed in front of the camera separately, and two images of the signal light containing the narrow-band characteristic wavelength are acquired. Then, the surf algorithm is used to find the feature points of the two images, and the two images are matched, geometrically transformed and cropped to obtain images of the same size and the same angle. After the histogram matching, the background gray values in the two images are close, and the two images are subtracted, which can obtain an image with removed background noise. The experimental results show that this method can provide a simple, high-speed method to effectively eliminate the background noise of the characteristic spectrum.

1. Introduction
In recent years, research on spectroscopy has attracted more and more extensive and widespread attention. A characteristic spectrum is a light emitted by a certain element or light source passing through an element to display a specific bright band or a dark band on the spectrum [1]. According to the range of the spectrum, it is divided into ultraviolet light, visible light and infrared light [2]. The spectrum of the material is unique, and its properties can be identified [3]. The background light contains direct sunlight, scattering and reflection of atmospheric clouds, and transmission and reflection of various particles in the air [4,5,6]. The full spectrum of the target under ambient light contains a variety of noises that the naked eye cannot distinguish from the background. Moreover, the full spectrum image information data is huge and the algorithm is complex with poor real-time performance. When the background radiation intensity is similar or stronger than the target spot, it is indistinguishable to the naked eye.

The method of feature spectrum elimination background can be applied in various applications, such as criminal investigation. The visible light spectrum imager is used to collect multi-spectral images of sweat fingerprints in two cases with severe background interference. The spectrometer is in the range of 400 to 720 nm. By comparing the fingerprint and background spectra, the two images are divided and then processed. The image is stretched linearly to obtain enhanced fingerprints and weakened interference background [7]. In the non-invasive biochemical detection of near-infrared spectroscopy, some people used the blood flow volume spectral subtraction method to eliminate the interference of tissue background and the effectiveness of the method.[8] The hyperspectral imager performs spectral
data acquisition on blood fingerprints in different complex backgrounds and selects regions of interest. People use the spectral properties of blood to spectrally decompose the image to achieve segmentation and extraction of the target blood fingerprint image. The method can effectively eliminate complex background interference and has widely applications. [9] The characteristic spectrum is also very important for the national defense. With different empirical models, such as atmospheric transmission law, unique spectral line type, and target grayscale defocusing principle, the characteristic spectral images containing specific targets have been investigated [10,11]. However, the difference between the background and the target spot is obvious and easy to distinguish on the spectrum. According to the characteristics of target and background, simple and high-speed spectral imaging method needs to be explored to eliminate background noise, which can not only improve the signal-to-noise ratio, but also ensure the real-time performance.

Here, it is proposed a method to eliminate the background noise based on subtraction of two different central wavelength filters according to the characteristic spectral imaging. With the sodium yellow light with 589 nm wavelength and the visible light industrial camera, the method has been validated experimentally. The experimental results show that this method can provide a simple, high-speed method to effectively eliminate the background noise of the characteristic spectrum.

2. Signal collection
A clean whitewashed wall, the white wall resembling Lambert, and a room with good shading performance constitute the basic laboratory environment. The camera is an industrial camera produced by Daheng Image Company (model MER-131-210U3M) with a resolution of 1280*1024, a spectral range of 350-950 nm, and a lens with focal length of 25 nm. The spectrometer is produced by Ocean Optics, model USB4000, with a wavelength range of 400-1100 nm and a resolution of 2 nm. The power-adjustable tungsten lamp simulates natural light. The sodium lamp is an ND20 with low voltage power and its wavelength is 589 nm. A set of Convex lens and beam splitter system are coupled to the spectrometer for aligning the target spot. The center wavelengths of the narrow band filters are 579 nm and 589 nm. The sodium lamp power is not adjustable, so the light is illuminated onto the concave mirror and then reflected onto the wall. The size and brightness of the sodium spot are adjusted by controlling the distance between the concave mirror and the wall. The focal length of the spectroscope system is 100mm. The spectroscope system transmission end is connected to the input fiber of the spectrometer. The reflection end is connected to an industrial camera. The system is fixed on a tripod 5 meters from the wall measuring the relative radiation intensity of the tungsten and sodium lamp launching walls. Another tripod with industrial camera can be placed 5 m away from the wall.
The wall is smooth and the light will cause specular reflection. The actual background environment is similar to the Lambertian body, and the incident light is uniformly reflected in all directions, also known as diffuse reflection. A slightly rough A4 paper is attached to the wall to prevent specular reflection, which is similar to the actual environment and the results are more reliable. Connecting the spectrometer, computer and convex lens and beam splitter system, we turn on the tungsten lamp and the sodium lamp. The position of the tungsten lamp and the concave mirror is adjusted to control the spot illuminance on the white wall. It is mentioned that the two spots are approximately the same at 589 nm, as shown in Fig. 1(a). The measured solar background spectrum is shown in Fig. 1(b). The spectrum of the tungsten lamp of the simulated background is still different from the background spectrum in the details, but the envelope is roughly the same, as shown in Fig. 1(c). Figure 1(d) is a spectrum of a sodium lamp, which is a narrow band spectrum. According to the optical signal-to-noise ratio formula

$$\text{OSNR} = 10 \log \left( \frac{P}{N} \right) + 10 \log \left( \frac{B}{B_r} \right)$$

where $P$ is the signal power, $N$ is the noise power in the range of equivalent noise bandwidth $B$, $B_r$ represents optical bandwidth, and $B$ is the noise equivalent bandwidth. The ambient light should be minimized into the narrow-band filter, and a sodium lamp with a narrow wavelength range should be selected to simulate the target, which is beneficial to improve the signal-to-noise ratio.
Fig. 2. Grayscale image acquired by industrial cameras. (a) Sodium lamp; (b) Tungsten lamp; (c) Sodium and tungsten lamps with 579 nm filter; (d) Sodium and tungsten lamps with 589 nm filter.

The feature points are the points where the gray value changes drastically or the curvature on the edge of the image changes greatly. This experiment is carried out in front of a single-color wall without edges and corners. It is impossible to collect enough feature points. Therefore, when the image is collected, a camera with a sharp angle is placed in front of the lens to facilitate the extraction of feature points for later image processing. The spectrometer is turned off and the computer is connected to an industrial camera. Then the industrial camera to capture the picture, the steps are as follows:

1. When the entire laboratory only the sodium lamp is turned on, the industrial camera without the filter is used to take a picture of the spot on the white wall, which is shown in Fig. 2(a);
2. After turning off the sodium lamp and turning on the tungsten lamp, the camera without the filter is used to take a picture of the spot on the white wall, as shown in Fig. 2(b);
3. By simultaneously turning on the sodium and tungsten lamps, we install the filter with center wavelength of the 579 nm, and take a picture of the spot on the white wall, as shown in Fig. 2(c);
4. The camera is installed with a center wavelength of 589 nm filter, and repeat step (3) to obtain Fig. 2(d).

3. Background noise elimination method

The purpose of eliminating background noise is to improve the signal-to-noise ratio of the characteristic spectral imaging. In the characteristic spectral imaging experiment, the difference between the signal light and the background noise intensity in the characteristic spectrum segment is not large, resulting in poor imaging contrast, which greatly affects the characteristic spectral imaging results. In order to eliminate the influence of background noise, a method based on two different central filters for subtraction to eliminate background noise is proposed. In the smaller wavelength range, it is considered that the background intensity is independent of wavelength.

We proposed the method to eliminate the background as follows. The images taken by the filter industrial cameras are stored in the image set format, and the two gray images are used to find the feature points of the two images by the surf algorithm. The surf algorithm extracts feature points by comparing the grayscale differences of surrounding pixels. Each pixel in the image can find a Hessian matrix whose matrix is,
The matrix describes the local curvature of the function.

The scale space of the surf algorithm consists of several groups. Each group contains several layers in the scale space. Each group selects adjacent three-layer Hessian determinant images. For each Hessian determinant value of the middle layer, it can be used as the point to be compared. In the space, 26 points around the point are selected for comparison. If the point is larger than the other 26 points, the point is a feature point. The two images are matched according to the obtained feature points. The image is geometrically transformed by the matching result. The image is cropped to a given size of the overlap. In order to reduce the grayscale difference, the two images are used histogram matching, and thus the signal-to-noise ratio is improved. Figure 3(a) is the image of experimental results without histogram matching, and its background is a little gray, indicating that there are grayscale differences between the two images. There is a large area of white area around the sodium lamp, and the illumination range of the sodium lamp is smaller than the actual one, and the noise has a large influence. Finally, the two images are subtracted and the contrast is not noticeable. This formula (3) is used to enhance the contrast, and the result is shown in Fig.3(b), where \( y \) is the value obtained after the difference between the two figures, and \( z \) is the value after the result is enhanced.

\[
H(f(x, y)) = \begin{bmatrix}
\frac{\partial^2 f}{\partial x^2} & \frac{\partial^2 f}{\partial x \partial y} \\
\frac{\partial^2 f}{\partial x \partial y} & \frac{\partial^2 f}{\partial y^2}
\end{bmatrix}
\]  

(2)

\[
z = \frac{255}{[\max(y)-\min(y)]+[y-\min(y)]}
\]  

(3)

Fig.3. Experimental results. (a) Image without noise reduction; (b) Histogram matching processed image.

4. Analysis of results

The sum of gray value of Fig. 3(a) is 895556, and there are 854 gray values of pixels exceeding 110. The sum of gray value of Fig. 3(b) is 557736, and there are 861 gray values of pixels exceeding 110. The gray value range of the sodium lamp is approximately between 90 and 150. This means that the background gray value of Fig. 3(b) is closer to 0, that is, eliminating background noise is more superb. The histograms of Fig. 3(a) and Fig. 3(b) are shown in Fig. 4(a) and (b). There are a large range of gray scales and prominent details in Fig. 4(a). The grayscale range of image Fig. 3(b) is mainly concentrated above 150, and the contrast is strong, and irrelevant details and noise are removed. It is shown that the histogram matching effectively adjusts the difference in background gray values. There are many experimental steps and the filter is changed frequently, which cause some noise. The algorithm also introduces some noise, but the final imaging results are reasonable and the signal-to-noise ratio is significantly improved. Comparing Fig. 2(a) with Fig. 3(b), the result is close to the ideal case, but the background has a small range of distortion.
5. Conclusion
A method is proposed to eliminate the background noise, which is based on the subtraction of two different central wavelength filters according to the characteristic spectral imaging. Feature spectrum imaging eliminates background noise making full use of the characteristics of light. The difference of light radiation cannot be distinguished between background and target. But it is distinguished by its spectral. Two filters are used to extract the background and the target respectively. The match and noise reduction processing are performed to suppress the noise. The background image is subtracted from the target image, which can enhance the background and target contrast greatly. On the whole, the influence of background noise of the image is eliminated. Therefore, the signal-to-noise ratio of the image is improved. The experimental results show that the method can provide a simple and high-speed method for feature spectral imaging to eliminate background noise.

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