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Research on Removing Shadow in Workpiece Image Based on Homomorphic Filtering

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Abstract

The shadow in the image has a great influnece for the accuracy of the image segmentation and measurement, while the workpiece is detected in the machine vision system. In the paper a homomorphic filter algorithm is designed for removing shadow, through the analysis of the relationship between the shadow and the brightness of the image. Firstly the image from RGB form is converted to HSV form, based on the relationship between the variation of the V-component and the shadow, the components of the related shadow can be identified. Then a filter is designed, which uses the principle of homomorphic filtering to filter the component of the related shadow in the image. Finally, a new complete image is formed by using the method of image synthesis to incorporate the treated V-component into the original image. The experiment results show that this method can remove the cast shadows in the image effectively, which has improved the image quality for the subsequence image processing.

Keywords: Image segmentation; Homomorphic filtering; Shadow detection and removal; High-pass filter

1. Introduction

The workpiece measurement technology has been the foundation of the development of manufacturing industry. Machine vision technology is becoming increasingly widely on the application of the dimensional measurement of workpiece because of its simple operation, high efficiency, and suitable for the requirements of non-contact measurement online in the production line. However, due to the effects of

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the external environment, light source and other factors, the shadow interference on the image target become the main reason of affecting the image accuracy of measurement.

The process of the image shadow is mainly divided into the two directions: shadow detection and shadow elimination. The image researchers at home and abroad have put forward a lot of methods about processing shadows, such as the image shadow extraction algorithm of the SAR targets based on SVM [1], the method of shadow elimination by multi-threshold image segmentation, the method of removal shadow based on comparison the original image with the intrinsic image [2] and so on. However these methods must be used in a certain applicable scope, none of each method can remove the effects of the various shadows. Thus there is still further prospect to research on removing the shadows of the image. In the paper, the method of removing shadows is used for the collected images of parts in the industrial production.

2. Formation and Influence of the Shadow

The shadow is a common physical phenomenon in the nature. It is arisen from imaging light blocked by the obstacles which come from the direction of the light source [3], and is the result of the interaction of light with objects. Shadows are various, and mainly can be divided into two categories: own shadows and cast shadows [4].During the process of the computer vision system for measuring two-dimensional graphics, the shadows are due to the thickness of the workpiece, illumination conditions, and so on. The paper is aimed for the cast shadow, shown in Figure 1.

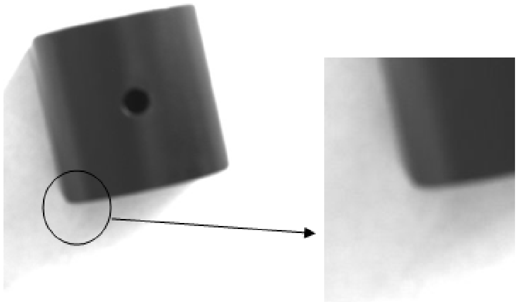

Fig. 1. Shadow of the collected image

Currently, the method for measuring part dimension is through the image gray-scale, preprocessing, the image segmentation, edge detection, and counting the number of pixels for size measurement. The aboved processes cannot identify and remove the shadow on the image, while the shadow of the collected image will have a great interference on the image information, make the quality of the image down, and have a serious influence on the subsequent image segmentation, target recognition and measurement, which lead to unstable measurement results, and even be impossible to measure.

3. Shadow Elimination Based on Homonorphic Filter

3.1. Shift from RGB model to HSV model

The color spaces often need to be transformed in image processing. The image acquisition format of machine vision is usually RGB32 or RGB24, which is the commonly used color space to display and save color images, composing of three components of R (red) G (green) B (blue) [5]. RGB color space is widely used in the computer image equipment, because computer monitors need to use the three kinds of colors to form a variety of colors [6], but in the terms of removing the shadow, the modeling format based on RGB space color is not suitable for the image analysis for removing shadows.

HSV color space is based on Hue (H), Saturation (S) and brightness Value (V), in which Hue can be distinguished from Saturation and brightness Value. In image processing, one property can be changed alone to adjust the image, while at the same time the other properties will not be affected. To benefit from the characteristic of HSV color space, the brightness Value can be separated from the color information, thus the obvious difference between shadow areas and non-shadow areas can be found. This method has a good ability of recognizing the target shadow, which can only make out brightness Value closely related with shadow in the image. So the transformation of the mode form RGB to HSV is the first step of removing the shadow.

3.2. Theory of Homomorphic filter algorithm

Homomorphic filter is a method that can compress the range of image brightness and enhance the image contrast in the frequency domain. It can not only eliminate the influence of uneven illumination, but also can enhance the detail of the image. Its process is through doing the mathematical function D to the nonlinear mixed signal in the image, which can make the non-additive factors of the image to be the additive factors of the image. Then the method of the linear filter is used, D^{-1} operation is done .After that the processed image is restored [7]. The process of Homomorphic filter is shown in Figure 2.

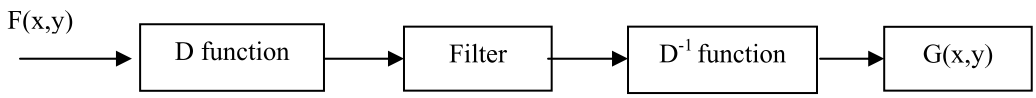

Fig. 2 Flow chart of the process of homomorphic filter

3.3. Removing shadows based on Homomorphic filter

T.G Stockham in 1972 proposed a model for the image of light reflection [8], in which the image brightness (that is grayscale) can be regarded as a combination of two parts: one is the light illumination component of the object; the other is the light reflection component by the object. Here Im is expressed as an image collected in a real scene of capture vision; *V (x, y)* is defined as the brightness value in the Im spatial coordinates (x, y). Here the equation of brightness value is:

$$V(x,y) = i(x,y)\, r(x, y) \qquad (1)$$

Where i(x, y) is the illumination component, r(x, y) is the reflectance component.

The illumination component is the amount of light in visible scene, while reflectance component is the quantity of the object for light reflectivity, which reflects the image content and changes rapidly with the different of the image detail. Therefore, the spectrum of illumination component falls on the low frequency space region, while the spectrum of reflectance component falling on the high frequency region. In order to acquire the image of workpieces without shadows, it is necessary to filter off illumination component and keep reflectance component.

According to the principle of Homomorphic filter, Eq. (2) is obtained by using a Logarithm operation for Eq.(1).

$$lnV(x,y) = ln\ i(x,y) + ln\ r(x, y) \quad (2)$$

From the above results, it can be seen that the Logarithm operation separate the illumination and reflectance component. Eq.(3) is obtained by using a Fourier operation for Eq.(2).

$$F_v(x,y) = F_i(x,y) + F_r(x,y) \quad (3)$$

According to illumination–reflectance model, we can see that the reflectance component represents the spatial variation amongst the object, thus falling on high frequency, depending on the amount of minute detail in the object. The illumination component falls on lower frequency, corresponding shadows and other weak interference. With applying the filter function $H(x, y)$, the illumination component is removed, and a good image without shadows can be seen later. After applying the filter in the frequency-domain, it is necessary to use Inverse Fourier transformation for the resulting modified spectrum, and undo the Logarithmic transform. It is noted that the final image need to synthetize the modified illumination component with the H-component and S-component of the original image. Thus the final image is obtained.

During the process of removing shadow by Homomorphic filter, it is very important to choose an N dimensional filter function suitable for homomorphic filtering. The high-pass Butterworth filter has a good adaptability, the transform function of the Butterworth high-pass filter is given as follows:

$$H(u,v) = \frac{1}{1 + [D_0 / \sqrt{u^2 + v^2}]^{2n}} \quad (4)$$

Where D_0 represents the cutoff frequency and n is positive integer which determines the attenuation.

The original Butterworth filter has been changed based on the characteristics of the shadow in image. Let $n = 3$, $D_0 = 0.05\pi$, the filtering function is changed as follows:

$$H = 0.53 + \frac{0.85}{[1 + \frac{D_0}{\sqrt{u^2 + v^2}}]^{2n}} \quad (5)$$

3.4. Experiments

Figure 3(a) is the image with shadow, which collected from an actual machine vision system. Through this method, it can be clearly seen that the image quality improved significantly after treated (shown in Figure 3(b)). The outer shadow is removed completely and the shadow in the middle region of the image is obviously reduced.

Fig. 3 . (a)original image; (b) processed image

4. Conclusion

In visual measurement acquisition systems, the shadows in image always affect the precise measurement of workpieces. Through the analysis based on HSV color space and the relationship between brightness values and shadows, a suitable Butterworth high-pass filter function was derived for removing shadow with the Homomorphic filter approach. The experiments are shown that the method is suitable to eliminate the effect of shadow in the image, and retain the original information to the greatest extent.

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