Image Defect Inspection Based on Human Visual Characteristics

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Abstract—**This paper presents a new image defects inspection algorithm based on image morphology analysis and human visual characteristics. In this algorithm, the difference image is obtained by subtracting of the standard gray image and the image to be detected, referred to as noised image. The noises' characteristics are analyzed by considering three parameters, namely, the area of noises region and perimeter, the degree of roundness, and the ratio of the noises in the region. Finally, determine those analyzed noises whether or not can be accepted by human eyes according to the human eyes' sensitivity on background brightness and textures' changes. Experimental results clearly prove that the algorithm can effectively distinguish image defects. This algorithm retains a great potential in image defects inspection such as printing related areas.**

Keywords- Image defects inspection, image morphology, human visual characteristics

I. INTRODUCTION

As advanced development in signal processing and computer vision, image defects inspection plays a more and more important role. For example, in a printing process, due to the not perfect printing technology as well as some random factors, there might be defects in print copies. To make sure the printing quality, it is highly needed to accurately inspect defects in the printing process. Current image defects inspection is mainly based on artificial visual, which always has the drawbacks of low speed and high error rate. Therefore, it's highly required to develop an automatic inspection method to accurately detect image defects.

In recent years, some research works have focus on the automatic image defects inspection. For object identification, blob analysis has been introduced to analyze connected regions with the same pixel values in an image [1]. By applying blob analysis, characteristic information such as the center, circumference, area, and position can be obtained to analyze different defects. For detecting the defects of gravure image, a statistical threshold method has been proposed by using the statistical process principle to determine the fluctuation of each pixel [2]. For both blob analysis and the statistical threshold methods, they have the drawback of lose of useful information such as texture details, and color changes, resulting in inaccurate inspection. Another method to inspect image defects by utilizing pixel-by-pixel image matching in sub-regions has also been presented in [3,4]. It decomposes the standard image and the image to be detected by pyramid structure, respectively, followed by matching these decomposed layer by layer. Nevertheless, such method still has the drawback of the difficulty to determine appropriate tolerance. In addition, Fourier [5] and Gabor transforms [6] have been applied to inspect image defects by comparing their spectra. However, if images have little errors, they can not always get enough accuracy for defects inspection. Some researchers also have used the Hessian matrix and object scale to investigate a new inspection response measure [7]. The measure uses blobness, which is based on eigenvalues of Hessian matrix and local object scale, to detect blob-like structures. Pixels with higher blobness are clustered as detected blobs. But this method is limited in blob-like defects inspection. The all methods mentioned above just inspect the defects, but do not analyze the characteristics of different defects and dot not take into account the characteristics of human visual system to measure that different defects can have different impacts on human eyes. For example, human eyes can easily recognize defect of big size while may not be aware of the small size, or may not identify the difference, whose brightness or texture are close to its background in original image. In order to measure the degree of image distortion, image quality assessment methods considering human visual characteristic have been considered in [8,9]. They mainly discuss the impacts of image's brightness, texture details and the behavior of noises on human visual system. Those assessment algorithms just provide theories for measuring the degree of image distortion. So far, they are not introduced in the image defects inspection.

In this paper, we propose a new method for image defects inspection by focusing on human visual system characteristics to define whether or not defects are destructive after image morphology analysis. Experiments show that our method can not only inspect image defects but can also analyze the characteristics of different defects and at the same time can highly meet the characteristics of human eyes.

II. THE PROPOSED IMAGE INSPECTION ALGORITHM

The quality of image may be changed in the transmission, encoding or conversion process because of human or random factors. The changes in an image can be called defects, and the changed image can be called the image to be detected or noised image while the original image of no changes can be stated as the standard image.

We will explain our inspection algorithm in the following aspects. Classify the defects by regions, then analysis the classified defects using the morphological analysis. Finally, combine the characteristics of human visual system to determine which noises can be accepted or rejected by human eyes. We can define those defects being accepted by human eyes as non-destructive defects, in other words, defects bringing to great impact on human eyes can be defined as destructive defects.

A. Zone defects

According to pattern recognition, classification is to divide feature space into type space. Defects are essentially caused by the noises' spatial gathering. The relative Euclidean distance [9] between noises is the best feature to distinguish defects of different types. In the difference image, which subtracted by the standard image and the image to be detected, the noises pixels' values may be many options from 0 to 255 since we mainly consider the gray or color images. In this paper, we define defects in different regions by using the Euclidean distance between each noise and other noises. If the Euclidean distance of two noises is less than R, then classify them to the same region.

B. Morphological analysis

After zoning the defects' regions, it should analyze the defects' characteristics, such as the number of noises in a region, the size, location and type. We use blob analysis to analysis those features. Blob analysis is to analyze the connected regions of the same defect. In computer vision applications, the being analyzed defects often be called spots. In this paper, the following parameters of defects are calculated in order to type those different noises.

(1) The area of noises A.

The area of noises is the number of pixels in a noises region and also is the most intuitive performance of noises' features. The larger of the area is, the more obvious the noises can be seen. If the area is too small, the special case is isolated noise only with one pixel, it may not be discovered by human noise. Thus, we set a threshold A_t for this area value to class whether noises are larger or small noises.

(2) The roundness of noise C.

Roundness is a more important parameter to depict the complexity of the boundary of a noises' region. The most common roundness is the ratio of the area and the square of perimeter of a noises' region. The perimeter P is the total length of noises' edge pixels.

In noises image, block or linear noises are common to be seen. Therefore, it will help to determine the types of noises with the introduction of roundness. For example, the roundness value of linear noises is smaller while round noises are relatively bigger. In addition, a roundness threshold C_t should be set.

(3) The ratio of noises in a noises region I.

The non-zeros values means the noises points while the zeros points present the non-noise point. However, binary image as special case can uses this method we propose in the paper. The ratio of noises in a noises' region can distinguish that noises whether is discrete type or block type. The ratio value of discrete type is lower while the block type is higher. In order to effectively distinguish the two types, it is also necessary to set a threshold of the ratio I_t. Set the S_n and S_t represent the noise points and total pixels in a noises region, respectively. The ratio I is obtained though S_n divided by S_t.

C. Defects inspection based on human visual system

Blob analysis simply describes defect's morphological characteristics, but in the actual image defects inspection process, the identification of defects should consider the human visual characteristics. Human eyes can mainly observe the significant change regions while ignore the smooth areas when they look at images. For example, if the brightness of a certain noises is very similar to the brightness of the background, human eyes may be difficult to distinguish such noises. Also a certain noises may be submerged if the texture of the around of the noises is very complex. In the following, we introduce our defects identification method from the two aspects of the brightness and texture of image based on visual characteristics.

(1) Brightness impact on human visual system.

Human visual system reflection on defects does not depend on the absolute brightness of those defects, but is relation to the relative brightness of the defects and their background. Then we have that :

$$\overline{I}=\frac{1}{N}\sum_{i=1}^{N}I(i) \tag{1}$$

$$\overline{I'}=\frac{1}{M}\sum_{j=1}^{M}I'(j) \tag{2}$$

$$L=\left|\log_{10}\frac{\overline{I}}{\overline{I'}}\right| \tag{3}$$

where I and I' present noise pixels and non-noise pixels of a defect region, respectively. I' and $\overline{I'}$ are the means of the noise pixels and non-noise pixels. N and M are the total number of noise points and the total number of non-noise points in the defect region. And i and j are the certain noise point and the non-noise point in the defect region. We use brightness ratio L to illustrate the brightness impacting on the human eyes. If the value of L is smaller, it means the brightness of the defect is close to its background. In other words, the defect can not be discovered by human eyes. On the contrary, the defect can be easily found with the lager L.

(2) Texture changes impact on human visual system.

For the noises with the same type, it will bring to different visual effect when they are at the rich texture detail regions and the flat regions. This paper use pixels' variance to describe the roughness of the image's texture. The larger variance indicates that there are more texture details and the defect can attract human eyes' attention, whereas the smaller variance means less texture details. Then we have

$$D=\frac{1}{N}\sqrt{\sum_{i=1}^{N}\left(I(i)-\bar{I}\right)^{2}} \tag{4}$$

$$D'=\frac{1}{M}\sqrt{\sum_{j=1}^{M}\left(I(j)-\bar{I}'\right)^{2}} \tag{5}$$

$$V=\left|\log_{10}\frac{D}{D'}\right| \tag{6}$$

where D and D' means the pixels of variances of the noise points and non-noise points in the zoned defect region mentioned above. We use texture ratio V to illustrate the texture details impact on human visual system. The larger V means the defect can be easily found while smaller V represents the defect can not be discovered by human. In the inspection process, Set L_t and V_t as the thresholds of the brightness ratio and the texture impact ratio, respectively. We prescribe the being inspected noises can be accepted by human visual system if a L less than L_t and the corresponding V also less than V_t. In other cases, being tested noises can not be accepted by human eyes. In order to better illustrate the different defects having different impacting on human visual system, the different defects are set in grades determined by the above parameters. Each grade is corresponding with human visual experience. In this paper, grades are set to four , which are very serious impacting, much serious impacting, generally impacting, and not-impacting, respectively.

Based on the above analysis, the inspection process can be illustrated by the following flow chart:

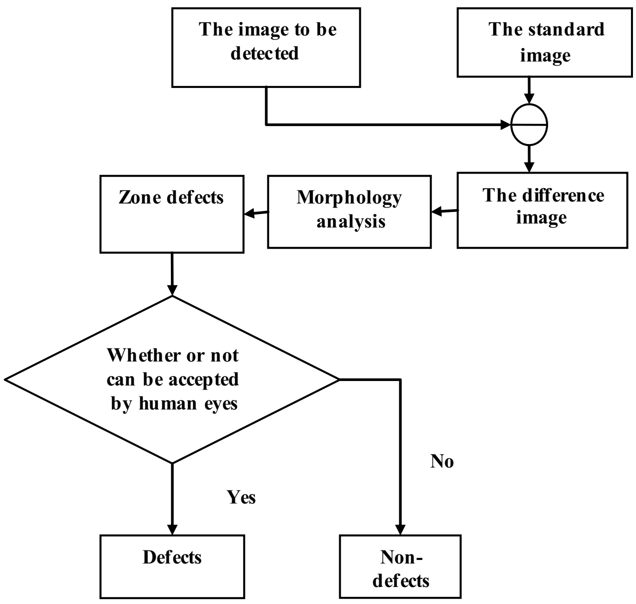


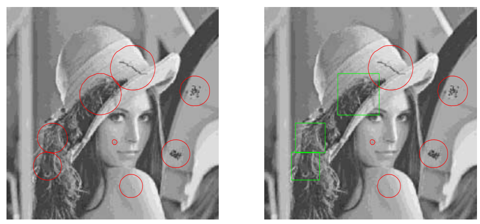
Figure 1. The flow chart of image defects inspection

III. EXPERIMENTAL RESULTS

In this section, we will show our experimental results to demonstrate the superiority of our proposed inspection algorithm compared with the traditional method [1]. We use a large number of images to participate the experiments. In this paper, we just show two cases to illustrate our experimental results. We assume that the standard images are the same size of the image to be detected. According to a large number of experiments, we set the thresholds R= 10, A_t=5, C_t=0.0796, I_t=0.71, L_t=0.11, V_t=0.1. In table I, the abbreviations of very serious impacting, much serious impacting, generally impacting, and not-impacting, are 4, 3, 2, and 1, respectively

From the experimental results, we can clearly see that the defects in Fig. 2(e) and Fig. 3(d) are inspected by our method with the consideration of the characteristics of human visual system. The defects having little impact on human visual system drawn with green boxes are defined as non-destructive noise points, while the defects having greater impact on human visual system are defined as destructive noises drawn with red circles in Fig. 2(e) and Fig. 3(d). For the traditional defects inspection methods, it just find the defects without the consideration of characteristics of human visual system, just as shown in Fig. 2(d) and Fig. 3(c). The table 1 shows the parameters of inspection results of Fig. 2(e) and the last column illustrates the impacting degrees of defects on human visual system. Take the eighth defect for example, which is corresponding with the block noises in Fig. 2(e), it can cause obvious impacting on human visual system.. And in our experiments, we use the parameters of brightness and texture to objectively measure the defect impacting on human visual system, which has high agreement with the characteristics of human visual system.

(a) Standard image (b) To image be tested (c) Difference image



(d) The traditional inspection method (e) Our inspection method

Figure 2. Image defects inspection result

TABLE I. THE PARAMETERS OF DEFECTS INSPECTION RESULTS

noise	Area (A)	Roundness (C)	Ratio (I)	Brightness (L)	Texture (V)	defect grade	types
1	1	1.0000	1.0000	0.7112	Inf	1	isolated
2	3	0.3333	1.0000	0.4351	1.36839	1	small
3	5	0.2144	0.8000	0.0443	Inf	4	small
4	17	0.1620	1.5294	0.0376	Inf	4	block
5	5	0.6250	2.2000	0.1398	Inf	4	block
6	46	0.0296	1.0000	0.3030	Inf	2	linear
7	91	0.1488	0.7912	0.3751	Inf	1	block

8	63	0.0951	0.8571	0.3663	Inf	1	block

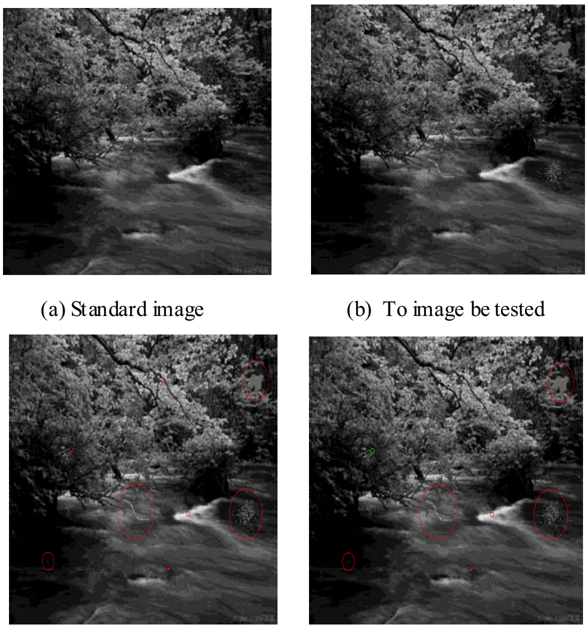


Figure 3. Image defects inspection result

IV. SUMMARY

This paper proposed a novel method for image defects inspection. First difference image is obtained by subtracting of the standard gray image and the image to be detected, referred to as noised image. Then noises' characteristics are analyzed by using three parameters, namely, the area of noises region and perimeter, the degree of roundness, and the ratio of the noises in the region. Finally, determine those analyzed noises whether or not can be accepted by human eyes according to the human eyes' sensitivity on background brightness and textures' changes.

In brief, this method mainly uses blob analysis to analyze the different defects characteristics and determines destructive defects based on the human visual characteristics. Experiment results proved that our proposed method can better analyze and detect various defects. Our approach provides a great potential for practical applications, such as printing industry.

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