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Ceramic Art Based on Digital Technology Image Processing

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Abstract: Ceramics first emerged in ancient China, and the development of ceramic art has a long history. In today's digital age, how to use the power of science and technology to conduct research on ceramic art is a problem worthy of attention. Digital Image Processing (DIP for short) is a method of using computer to perform graphics calculation, which has the characteristics of high efficiency and intelligence. It aims to use DIP technology to study ceramic art. In this regard, it has proposed to use convolutional neural network (CNN for short) to extract image features, identify and detect ceramic artworks, and has used mean filtering and median filtering to optimize the noise reduction of the identified images, so that the obtained image Higher quality. In the simulation test, it has selected 50 ceramic products for image recognition and detection, and has divided them into two groups for analysis. The results have showed that the inverse histograms of the two sets of images could reflect the defective parts of the ceramic products. Based on this, the lowest accuracy rate of CNN recognition was over 85%, and the highest accuracy rate was 94%. In the first group of images, the SNRs obtained by mean filtering and median filtering are the lowest of 7.7, 6.5, the highest are 8.7, 8.3, and the average SNR is about 8.0, 7.2; the SNR obtained by the two filtering methods of the second group of images is around 6.5 to 8.0, and the SNR of the mean filtering is slightly higher. Therefore, some practical results have been achieved in the research of ceramic art using DIP technology.

1. Introduction

Nowadays, ceramics has become an indispensable building material for interior decoration, and its application range has become more and more extensive. China's ceramic industry has a long history of development, but there is a certain gap with developed countries in the modern ceramic industry. Therefore, in recent years, China has been working hard to develop in the ceramic industry, and is gradually narrowing the gap with industrialized countries. In the past few decades, China's ceramic output has also been greatly improved, and it has become a leader in the world's ceramic production industry and has become a veritable production country. In recent years, with the continuous development of China's building ceramics industry, not only the production technology has been improved, but also the artistic design of ceramic products has been greatly improved. Among them, DIP can quickly and efficiently identify and detect ceramic artworks. There is good practice in this area, and DIP technology is being widely used in various fields of science and engineering. DIP technology is used to study ceramic art, which has important commercial value and historical significance.

The development of ceramics has a long history, and now many scholars have carried out related research on ceramic art. Among them: Kim H A has studied how to increase the understanding of ceramic art in the museum and has translated the terminology of ceramic art [1]. Cho S N has studied its extension to traditional modeling pottery through the fusion of design media [2]. Onuzulike O has analyzed the forms in African pottery modernism research according to different paradigms as a dividing line [3]. Scher S has studied foreign women dressed up with a Moche ceramic art [4]. However, most of these studies were based on theory, with less practical application, and less involved in image processing of ceramic artworks, so further research is needed.

In the study of ceramic art, some scholars have used DIP technology. Among them: Chrysafi A P has used active infrared thermography as a non-destructive testing technique to detect damage in carbon fiber reinforced plastics (CFRP) [5]. Prasad D S has employed a color threshold-based image segmentation method through digital images of corona to identify possible applications of DIP, so as to obtain image parameters that could be used as indicators for estimating corona power [6]. Szabo K Z utilized DIP for the identification and characterization of spatial patterns of measured environmental gamma dose equivalence rates in the field. Abnormalities of measured gamma dose rates in the study area could be identified and numerically characterized [7]. Loke K F has used DIP to study the modes and behavior of aqueous and non-aqueous liquid migration in a fractured dual-porosity soil. This study showed that digital image analysis can provide detailed information to help researchers better understand and model the patterns and characteristics of liquid transport that affect groundwater resources [8]. These studies have promoted the development of digital image processing technology to a certain extent. However, these methods still have problems of low efficiency and high cost, so it is necessary to further optimize them.

With the development of science and technology, the traditional DIP method can no longer meet the current environment. The innovation of it is that a CNN image recognition technology is proposed, which can perform efficient feature extraction and detection on ceramic products. Combined with filtering technology, the extracted image is denoised, so that the quality of the detected image is higher, and the functions of ceramic defect simulation repair and ceramic product identification and inspection can be efficiently completed.

2. Application of DIP Technology in Ceramic Art

2.1 Ceramic Art

Ceramic art works are carriers of dual attributes of material and spiritual culture. In the continuous development and evolution of human civilization, the practicability and artistry of modern ceramic art works have always been complementary to each other. It reflects people's way of life and ideas, and also reflects people's pursuit of life art [9- 10]. Modern ceramic art works reflect people's aesthetic taste and artistic tendency through its shape, decoration and glaze color, giving people emotional sustenance and spiritual enjoyment [11-12]. The reason why ceramics sell well is that they are widely used and have many advantages. Several ceramics with larger uses are shown in Figure 1.

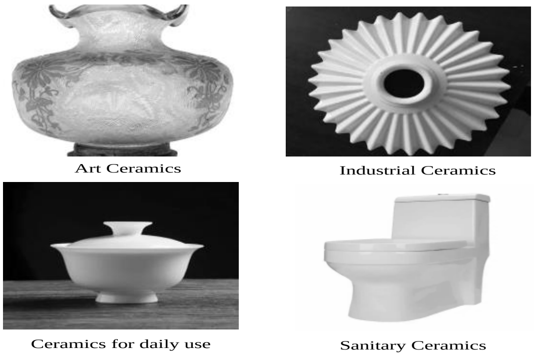


Figure 1: Ceramics for different uses

The artistic ceramics in the Figure 1 is ornamental and can usually be matched with flowers and green plants. It can be placed indoors to be eye-catching and to reduce radiation. Industrial ceramics are generally used to make industrial parts and have superior corrosion resistance and high temperature resistance. Ceramics for daily use can be used to make water cups, tableware and other supplies, which are easy to clean and durable. Sanitary ceramics can be used as toilets, sinks, etc, which are not easy to leave stolen goods and odors and are also very convenient to flush [13-14].

Modern ceramic art works are the incarnation of water, soil, fire and art, which is also the fundamental difference from other practical art works [15-16]. The practicality of ceramic art works is ahead of art. It not only meets the practical requirements, but also brings people the enjoyment of beauty and adds interest to people's spiritual life. No matter what era human beings live in, they all have a natural pursuit and desire for beauty. With the progress of society and the growth of human beauty, modern ceramic art works are more and more satisfying people's pursuit of life quality, and its practicality and aesthetics have become the most important features. Modern ceramic art works are the materialization of people's lifestyles. The diversification of human lifestyles has created the diversification of ceramic culture. To a certain extent, ceramic culture is a reflection of human life culture, and the lifestyles of different periods are carried and materialized by ceramic utensils in different periods [17-18]. From the earliest beginnings of the Neolithic pottery in the Yellow River Basin, the practical function is always the first demand of people, and the shape and decoration of pottery are almost the true portrayal of people's life style. The Tang Dynasty paid attention to drinking tea, and the ceramic tea set has a wide variety and various shapes, which can reflect the creator's ingenuity in different aspects. During the prosperous Tang Dynasty, the mouth of the tea bowl had various flower-shaped mouth styles such as lotus, sunflower, and begonia. The belly of the tea bowl had various ups and downs, which conformed to the habitual laws of people's use and made the tea bowl have both aesthetic functions on the basis of practicality, adding to the fun of drinking tea [19].

2.2 DIP Technology

The key equipment required for the ceramic image online detection system includes an image acquisition camera, optical lens, light source, image transmission network cable, computer, dark box, motor, visual sensor, guide rail, conveyor belt, etc. The ceramics are placed on a black uniform rubber conveyor belt, which moves at a constant speed with the conveyor belt. The vision sensor is placed at the end of the vertical rail; after the previous work is adjusted, the conveyor belt will be started. At this time, the ceramics are running under the drive of the conveyor belt. When the vision sensor senses the arrival of the front edge of the ceramics, it transmits the signal to the camera, and the camera starts to automatically collect the ceramics after an appropriate delay.

The image acquisition camera is an image sensor that carries a lot of information, and has high image stability and high anti-interference ability. In the process of ceramic chromatic aberration online detection, the camera selection plays a decisive role in the speed of ceramic image acquisition and the quality of shooting. The following factors need to be considered when choosing a camera.The types of acquired images can be divided into: color cameras (which can acquire both black and white images and color images) and black and white cameras (which can only acquire black and white images). When the number of photosensitive elements of a color camera and a black-and-white camera is the same, the resolution of the latter is larger than that of the former. In addition, the internal data processing process of color cameras is more complicated than that of black and white cameras, and the shooting speed is also lower than that of black and white cameras. Although under the same conditions, the resolution of the color camera is lower than that of the black and white camera, but considering that the ceramic image to be collected is color, the color camera is finally selected [20].

In the industrial production process, the most commonly used camera chip types are CCD (charge-coupled element) and CMOS metal oxide semiconductor device. The principle of the image sensor used in the photoelectric conversion process of the two types of cameras is the same. The difference lies in the process of signal readout. Although the signal output performance and sensitivity of CMOS sensors were not as good as those of CCD sensors in the early days, with the continuous development of integrated circuit technology, the gap between them has become smaller and smaller, and the price is cheaper than that of CCD cameras. Under the same conditions, the image acquisition speed of CMOS camera is also faster than that of CCD. Combined with this article, the color difference of ceramics is to be detected online, so CMOS sensor is finally selected.

The camera scanning mode mainly has two scanning modes: progressive scanning mode (is to scan and display a frame of image sequentially from the first line to the last line. Because it is necessary to combine two frames of images obtained by odd line scanning and even line scanning when processing one frame of image, but the ceramic color difference online detection system needs to shoot moving ceramics, so in the end, progressive scanning way will be chosen. Considering the complexity of the transmission system required by the line scan camera to complete one shot, it finally chooses the area scan camera as the acquisition device of the measured target image. In the selection of resolution and frame rate, the smaller the minimum acquisition accuracy of the image acquisition device, the more pixels in the acquired picture, and the slower the processing. If the minimum acquisition accuracy of the image acquisition equipment is larger, the effect of the captured ceramic pictures will be worse, so it is necessary to select a moderate resolution and frame rate.

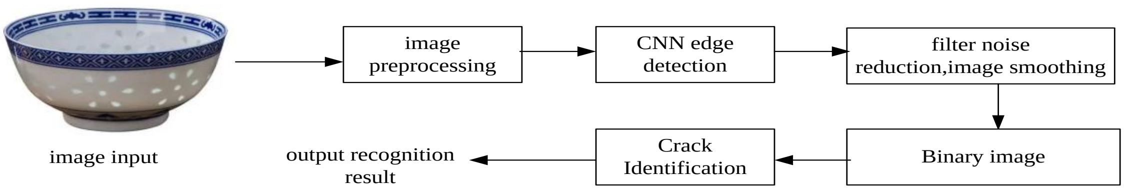


Figure 2: Ceramic image recognition and inspection process

After a suitable ceramic image processing equipment is available, image recognition and detection are carried out, as shown in Figure 2. The first step is to pre-process the input image, then perform edge detection and CNN feature extraction, and then filter and denoise the image.

The method for DIP of ceramic products is shown in Figure 3. The light source of the system in the figure is generally indoors because the ceramic production line is indoors, and the image acquisition camera is very sensitive to the interference of various environmental factors, so it is necessary to design a reasonable lighting system for the ceramic color difference online detection system to ensure that the camera is fully, stable, and uniform illumination. The selection of the light source is a key step in the entire lighting system, and the entire detection system needs to rely on the light source. Good lighting conditions are the basis for achieving good image acquisition effects. Under such conditions, ideal experimental results and accurate and reliable data and data can be obtained, so as to lay a solid foundation for the subsequent detection experiments. There are many types of light sources for image acquisition systems, such as fluorescent lamps, halogen lamps, and LED lamps.

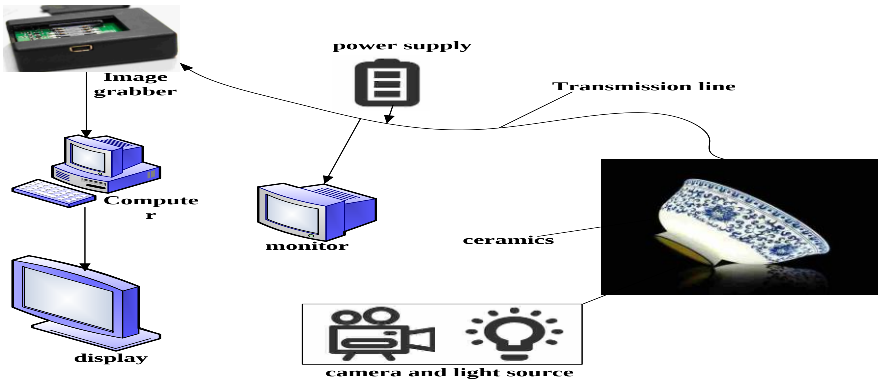


Figure 3: DIP ceramic inspection method

The shorter the image acquisition time, the more time is left for the algorithm operation. It is assumed here that the image acquisition time is set to 0.02s. Then in order to meet the speed requirements for the online detection of ceramic chromatic aberration, the frame rate of the camera should be greater than 50 frames per second. In this way, the standard of the camera can be determined: color camera; CMOS sensor target surface; progressive scan; rectangular array; resolution higher than 2000×2000; the frame rate is over 50 fps. As long as it meets the conditions, it can be used as the camera for this article. The lens can generally be divided into three types of optical lenses: wide-angle, standard, and telephoto; according to the different focusing methods, the lenses can be divided into manual focusing and automatic focusing; according to the different interface types, it is divided into C-type, CS-type, C/Y-type, F-type, EF-type, PK-type and other lens interfaces. According to different usage conditions, choosing the appropriate lens is an important part of the design of the ceramic chromatic aberration online detection system. When selecting the optical lens, the imaging size of the lens should be consistent with the size of the photosensitive element array of the camera; the interface of the lens and the interface of the camera should be as consistent as possible; the resolution of the lens and the resolution of the photosensitive element array of the camera should be matched as much as possible, so that the performance of the two can be fully utilized [21].

2.3 Image Processing Algorithms

The image processing process includes key image feature extraction and recognition, as well as image noise reduction process. CNN is used for image extraction and recognition, and the filtering principle is used to optimize image noise reduction.

(1) CNN image feature extraction

The principle of image feature extraction of CNN is shown in Figure 4. It mainly includes multiple convolution and pooling processes, and finally the fully connected image is extracted.

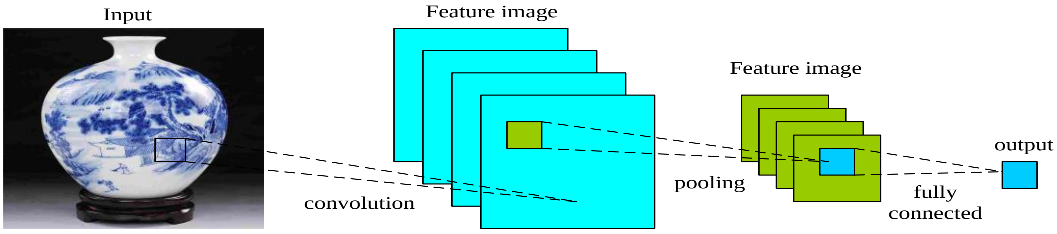


Figure 4: CNN ceramic identification

Assuming that the original image captured by the camera was I_0, and the pixel matrix contained in the image was W, then the convolution process was:

$$a_{i,j} = f\left(\sum_{a=0}^{2}\sum_{b=0}^{2} w_{m,n} x_{i+a,j+b} + w_b\right) \tag{1}$$

The output feature image size width was:

$$W_2 = (W_1 - E + 2Q)/S + 1 \tag{2}$$

Likewise, the output feature image size height:

$$H_2 = (H_1 - E + 2Q)/S + 1 \tag{3}$$

Output image information:

$$I_0 = \sum_{i=1}^{n} w_i x_i \tag{4}$$

(2) Image filtering and noise reduction

In the process of collecting ceramic images, various noises will inevitably be introduced, and there are many factors that cause these noises, which can be roughly divided into two categories. The first category is caused by the internal factors of the image acquisition system itself, such as unstable voltage during operation, mutual conversion of transmission equipment, image input and output, and uneven lighting of the acquisition camera lens; the second category is the interference of external factors, such as external light, photoelectric interference in the collection process, etc. These factors will affect the processing of subsequent images more or less, so it is necessary to filter and denoise the image of the collected tile image. And the premise of denoising is to choose a more suitable color space.

According to the principle of image color, it could be known that:

$$H = \begin{cases} \theta, B < G \\ 2\pi - \theta, B > G \end{cases} \tag{5}$$

where the S component:

$$S = 1 - 3/(R + G + B) \tag{6}$$

According to the CNN features the ceramic image extracted was represented as:

$$I_0 = (RGB, 'image0'', 1/2) \tag{7}$$

Its color space could be expressed as:

$$V_{hsv} = 255 * RGB * 2hsv(N) \tag{8}$$

Assuming that any pixel was (x, y), the mean filtering method was used to first perform grayscale processing, that was:

$$g(x,y) = \frac{1}{m}\sum f(x,y) \tag{9}$$

Operation method was filter:

$$I_1 = filter(g(x,y),V)/255 \tag{10}$$

Or median filtering was used for smoothing, which was:

$$g(x,y) = med\{f(x-m, y-n)\} \tag{11}$$

The color components was processed and given:

$$J = medfilt(V,[3,3]) \tag{12}$$

The minimum variance method could also be used for filtering, but the calculation of the local pixel matrix must be performed first. The Formula 13 was:

$$u = \frac{1}{MN}\sum a(n_1 n_2) \tag{13}$$

The pixel variance was:

$$\sigma^2 = \frac{1}{MN}\sum a^2(n_1 n_2) - u^2 \tag{14}$$

Then the gray value of each pixel was calculated :

$$b(n_1 n_2) = u + \frac{\sigma^2 - v^2}{\sigma^2}(a(n_1, n_2) - u) \tag{15}$$

Then the filtered and denoised image could be obtained:

$$I_K = af(V,[9,9]) \tag{16}$$

Then the information difference of the denoised image could be obtained:

$$\Delta I = I_K - I_0 \tag{17}$$

Finally, the signal-to-noise ratio of the image was obtained according to the variance of the two images:

$$SNR = \frac{\sigma_{\Delta I}^2}{\sigma_{I_0}^2} \tag{18}$$

3. Dip Simulation Test of Ceramic Artwork

3.1 Design of the Experiment

The three main equipment selected for the simulation test are shown in Table 1. Although these devices are not high-end, they can basically meet the requirements of the experiments.

Table 1: Selection of equipment

device code	device name	Device model
1	Camera	HIKVISION B12HV2-IA
2	Computer	ASUS i5-12500H
3	Image grabber	MAGEWELL 4K Plus

For the connection method of these devices is showed in Figure 5. The first camera is connected to the image collector for image capture and collection, and then the camera is wirelessly connected to the router, and the pictures are transmitted to the computer through the Internet for image processing.

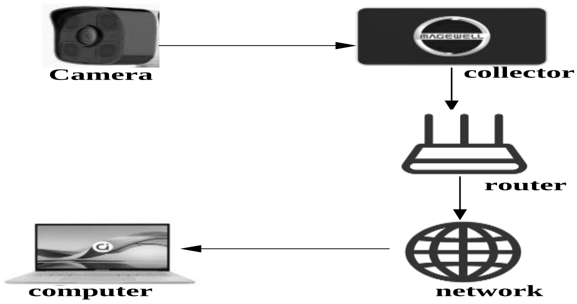


Figure 5: How the device is connected

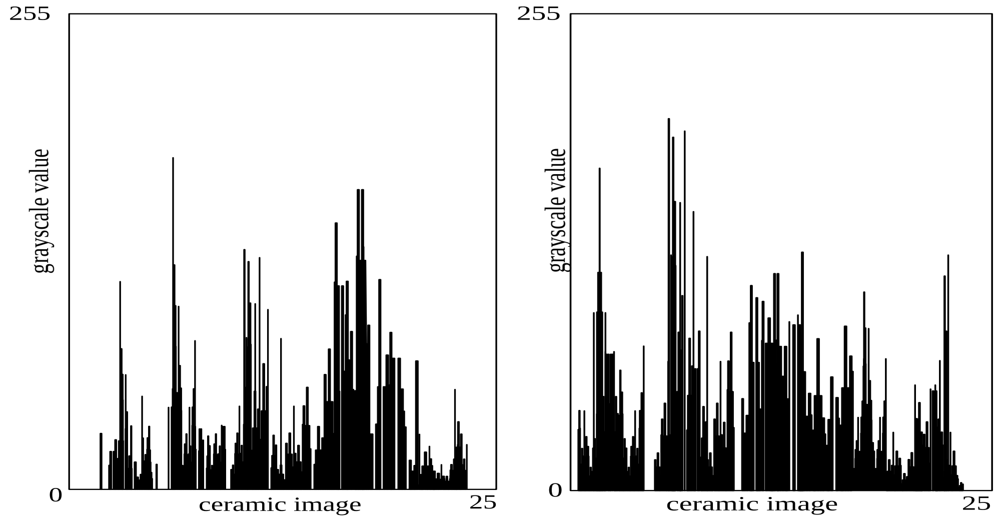
Among them, the camera selected is a HIKVISION camera with infrared night vision that can be remotely shot, and has a 2T hard disk. Some basic parameters of the camera are shown in Table 2.

Table 2: Camera detailed parameters

device code	part	parameter
1	Infrared night vision distance	2million
2	Number of supplementary lights	4mm
3	focal distance	4
4	pixel	50m

3.2 Experimental Process and Result

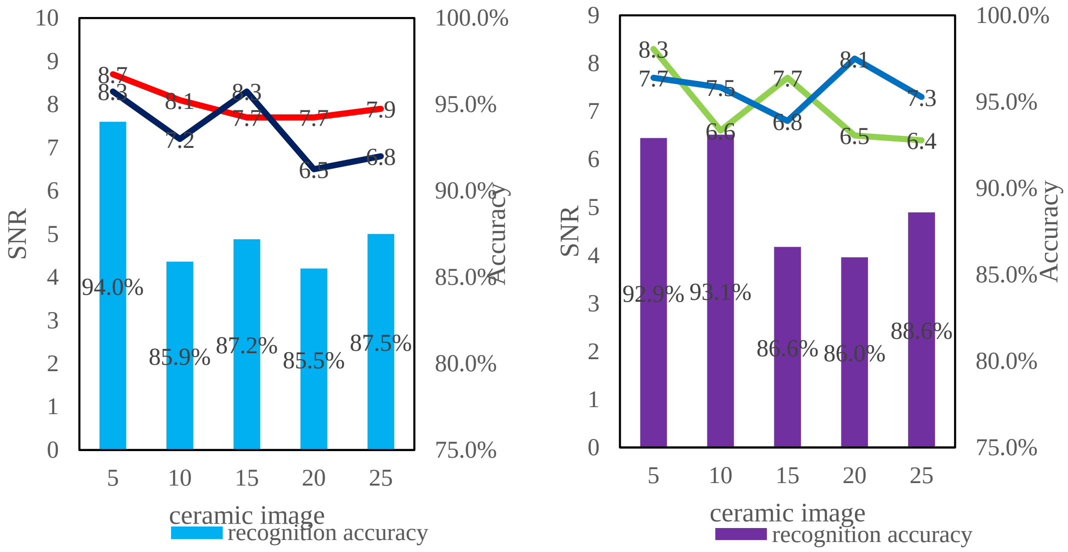
50 pieces of daily-use ceramic products and artistic ceramic products were selected, and image recognition processing was performed on them, so as to classify these ceramics and detect their defects. The images captured by 25 ceramic products were combined into one image, and the inverse histograms of the two sets of images obtained were shown in Figure 6. The histogram was a relatively simple and useful tool in DIP. The grayscale histogram summarized the grayscale content of an image. The histogram of any image contained considerable information. Certain types of images could also be fully described the histogram.



(a) The first set of images (b) The second set of images

Figure 6: Inverse histogram for image recognition

As can be seen from the figure 6, except for the blanks at both ends, there are some inverse histograms with no gray value, which are the defective parts in the ceramic products. Based on this, the ceramic images are counted in this paper. The identified SNR and detection accuracy are shown in Figure 7.



(a) Group 1 (b) Group 2

Figure 7: SNR and accuracy of image processing

As can be seen from Figure 7 the SNR obtained by mean filtering in the first group of images is the lowest of 7.7, the highest of 8.7, and the average SNR is about 8.0; the SNR obtained by median filtering is the lowest of 6.5 and the highest of 8.3, and the overall SNR is about 7.2 on average; the recognition accuracy rates are all over 85%, and the highest is 94%. The overall accuracy of the second group has been slightly improved, which may be related to the self-learning ability of CNN recognition. CNN has acquired more learning experience through the recognition of the first group, so the recognition accuracy will be improved somewhat. The average accuracy rate is more than 86%, and the highest is more than 93%. The SNR obtained by the two kinds of filtering is around

6.5 to 8.0, and the minimum is not lower than 6.4. And the mean filtering will be slightly higher, but the image quality obtained by both is very high. This shows that the use of CNN for image recognition and detection in this paper can more accurately identify the defects of ceramic artworks. The image quality obtained by using mean filtering or median filtering noise reduction is very high, and the mean filtering is slightly better.

4. Conclusions

At present, most of the images and detection of ceramics are still manual, because the human vision will always be fatigued, which will cause missed detection and false detection, and the efficiency of manual detection is low. Therefore, designing a set of efficient ceramic online detection scheme will have important practical significance to improve the automation level of the domestic ceramic industry. Based on the existing ceramic image processing methods, a set of reasonable DIP scheme was designed by referring to relevant materials. The hardware selection of the ceramic DIP system firstly was analyzed and designed in detail. And the hardware related to this system was selected. During the experiment, the methods of CNN image recognition and filtering and noise reduction were used, and 50 ceramics were selected and divided into two groups for analysis. The results showed that the inverse histogram of CNN image recognition could clearly detect the defects of ceramic products, and the accuracy rate of CNN image recognition was above 85%. The average SNR of the image obtained by filtering and noise reduction was above 6.4, slightly better than median filtering. It has achieved good practical results in the research of ceramic art using DIP technology. However, the ability and knowledge was limited. There were still many things to be improved in this article. For example, the research on DIP technology was not deep enough. In the noise reduction processing, more filtering techniques could be considered for comparison. Therefore, studying harder and striving will be done to do better in the future work.

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