Revista Argentina de Clínica Psicológica
2021, Vol. XXX, N°2,325-334
DOI: 10.24205/03276716.2020.4031

The Application of Computer Vision in the Detection of Ancient Ceramic Art

Yueming He

Abstract
According to the definition of UNESCO, ceramic culture belongs to the category of cultural heritage protection, which includes "accessible heritage" and "inaccessible heritage" and their related information. Based on computer vision, this paper analyzes the information of ancient ceramics from the perspective of cultural ecology, and discusses the presentation mode of computer vision inspection of ancient ceramics, as well as several reasonable and practical digital modeling techniques and drawing methods. Finally, the representative ceramics are selected as the research object, and the summarized methods and techniques are used to model and reconstruct them and texture map them, which achieves ideal results. It is believed that with the gradual application of computer vision technology in the field of ancient ceramics, people can apply it to more fields and provide scientific professional help for collectors who like ancient ceramics.
Keywords: Ancient ceramics verification, Computer Vision, Application, Cultural ecology

1. Introduction

China is the only ancient civilization with a continuous history in the world, and ceramics is one of the important heritages left by the ancients. After the 1970s, many scientific research institutions at home and abroad began to participate in the research of ancient ceramics science and technology, and the research of using scientific and technological methods to analyze producing areas was gradually enriched. It can be said that using chemical composition analysis technology to study the origin of ancient ceramics is the most effective technology at present. In recent years, the study of chemical element composition characteristics of ceramics has become increasingly important in the study of ancient ceramics [1-3], and remarkable achievements have been made. X-ray fluorescence spectroscopy is an early analytical method applied to ancient ceramics research. Because of its advantages of fast analysis speed, low detection limit, simple sample preparation and low cost, it has become one of the main methods for analyzing ancient ceramics composition.

In the diversified ceramic product information, the product type has distinct characteristics of times and regions, so the ancient ceramic type plays an incomparable role in the appraisal [4]. By extracting and analyzing features, digital ancient ceramics can sum up the structural features of artifacts in different historical periods and different kiln mouths, and discover the evolution law of ancient ceramics, which can provide reference for the dating of ancient ceramics and the identification of authenticity. In recent years, it has become a new research direction of ancient ceramics to accurately restore two-dimensional image information into three-dimensional model by using machine vision technology. Literature [5] has done some work on curve fitting of skimming bowl, and literature [6] has done some research on edge characteristics of skimming bowl.

As traditional culture is increasingly valued, the influence of cultural and ecological concepts on traditional art is subtle. At present, people have higher and higher requirements for the quality of ancient ceramics. Before the collection, people always expected to obtain scientific testing methods of ancient ceramics and obtain comprehensive and scientific information about their favorite ancient ceramics. As a result, computer vision has also been widely used in the field of ceramics. Therefore, from the perspective of cultural ecology, this paper discu-

Fuzhou University (Xiamen Academy of Arts and Design, Xiamen, 361021), China
***Correspondence author: Yueming He. Email: 53591448@qq.com**

sses how to use computer vision technology to detect ancient ceramics.

2. Detection and Computer Vision of Ancient Ceramics

2.1. Detection of Ancient Ceramics

Ancient ceramics is a precious historical relic that occupies an important position in traditional culture. Therefore, how to put it into the cultural and ecological background, the real ancient ceramics and fake ceramics that recognize modern technology processing have realistic social significance. At present, there are two kinds of ancient ceramics detection methods: the traditional one and the modern one. The traditional detection method mainly refers to an ancient method of identifying ancient ceramics with the naked eye, relying on many years of industrial experience. This method is greatly influenced by subjective factors, so different inspectors may draw completely different conclusions because of their different personal experience when inspecting the same ancient ceramics works of art. Secondly, with the development of science and technology, there are many kinds of ancient ceramics detection methods in modern science. It mainly includes concentrated types: 1. Element identification method: any part of ceramics is composed of a certain amount of chemical elements, which is the basic starting point of element identification method. When people use this method to detect ancient ceramics, they can detect the content of each element in the ceramics and get the proportion. Because the content ratio of elements in ancient ceramics of different periods, different origins and different varieties is obviously different, people can infer the origin and production age according to the data of detected elements. 2. Aging identification method: The aging identification of ancient ceramics includes the identification of various kinds of aging traces of ancient ceramics, such as linear traces, pit traces, patch traces, exfoliation traces and other traces, which can be used to determine whether the ancient ceramics belong to a newly processed fake or from a certain age of ancient ceramics. But we can not make an accurate judgment on the production age of ancient ceramics. At the same time, the aging identification method also includes the de-vitrification structure analysis method, thermoluminescence dating method and other high accuracy testing and identification methods, which can predict the more accurate production age. These methods mentioned above are basically the detection methods of the inner materials of ancient ceramics, and seldom involve the appearance detection of ancient ceramics. Therefore, new ways still need to be explored on the way of scientific detection.

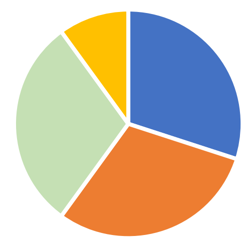

Figure 1. Proportion of methods used

2.2. Computer vision technology under the concept of ecological culture

Computer vision is a science that studies how machines "see". The combination of computer vision technology and cultural ecology is conducive to people to appreciate the research object with cultural sentiments. The computational theory of human vision is the theoretical source of the development of computer vision technology. Theories and techniques related to computer vision research attempt to create an artificial intelligence system that can extract information from images or multidimensional data. The combination of computer vision science and image processing, pattern recognition and image understanding plays a unique role in the detection of ancient ceramics, lamp types and product packaging shapes.

Computer visualization is such a process, which transforms data information and knowledge into a visual form, enabling users to directly interact with visual data information and explain the meaning of abstract information through people's visual discrimination ability [7-8]. Visualization connects human brain and modern computer, the two most powerful information processing systems. The effective visual interface enables us to observe, manipulate, study, browse, explore, filter, discover and understand large-scale data, and interact with it conveniently, so as to find the features and laws hidden in information effectively.

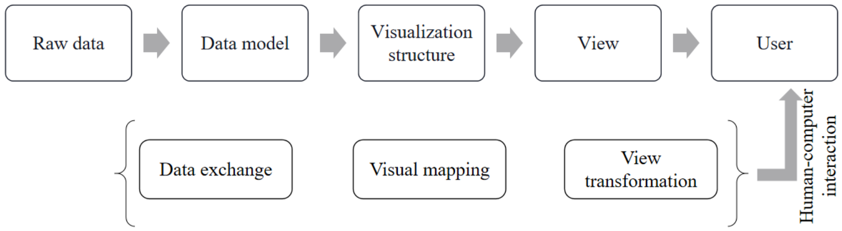

Figure 2 Information visualization reference model

We can think of visualization as an adjustable mapping from data to visualization form and then to human perception system. Figure 2 is a diagram of these mappings, which is a simple reference model for information visualization.

Figure 3. Ancient ceramics

3. The Basic Principle of Computer Vision in the Detection of Ancient Ceramics

In the application of computer vision, it is necessary to use image processing technology to pre-process, feature extraction, analysis, shaping and other functions. It can be divided into image acquisition, image preprocessing, feature extraction, morphological measurement, data output and storage module.

3.1. Image acquisition

The first step in computer vision inspection of ancient ceramics is to collect the image of the object of inspection, that is, ancient ceramics. Based on the high requirement of ancient ceramics for the detection of pattern details, it is suggested to adopt a higher resolution camera system for image acquisition in the acquisition stage, which is very helpful for the later details processing. After image acquisition according to the basic standard operation of photo acquisition, image data is transmitted to the computer, and image processing is further carried out with the analysis software system of computer vision. This step is the basic work of all Post-visual analysis work, so when collecting materials, we must follow the standard process.

3.2. Preprocessing module

After the image acquisition is completed, it enters the image preprocessing stage. The main purpose of this stage is to improve the quality of the images captured in the previous work, and to obtain the scale of the images, so as to prepare for the follow-up work. In the process of preprocessing, people need to deal with special techniques according to the actual situation of the collected images, such as geometric distortion correction, image enhancement and smoothing filtering, in order to make the images more suitable for later related work. We know that ancient ceramics and other objects have exquisite appearance and images, pay attention to detail changes, and have various colors. They are made of various colors through combination and tinting. With the passage of time, the patterns of ancient ceramics may become unclear, details are defective, and so on. In addition, the shape of ancient ceramics is also exquisite. Different kinds of three-dimensional curves are combined to form different ancient ceramics, which presents a unique aesthetic feeling of Chinese style. Therefore, it is very difficult to process the image information of the shape of ancient ceramics. If there is no special processing such as image enhancement and distortion correction in this case, the final result may not be satisfactory.

3.3. Automatic measurement module

In this step, the image information can be segmented by the automatic detection module, and the ancient ceramics can be separated from the background. The background can be set to white, and the ancient ceramics themselves can keep the color unchanged or set to a specific color, such as black. Next, detailed operation is carried out to obtain the information of the central axis and the edge line segment of the ancient ceramic image, and then the relevant information of the ancient ceramic is measured. The operation of the automatic measurement module is mostly accomplished by the computer automatically, and the measurement results may have errors, so in some cases it still needs to be processed manually.

3.4. Manual measurement module

Manual measurement refers to the measurement of images by manual tracing. For example, drawing key points along the shape size of ancient ceramics, drawing the appearance curve, and then after drawing the curve, using mathematical methods to obtain other characteristic parameters. This method is complementary to the automatic measurement module. In the general preliminary steps, the automatic measurement module is used to process the data initially. Then, in special cases, it needs to refine or adjust the error value, so it needs to be detected manually and then corrected. This can be combined with each other, complementary advantages, so that speed and quality can be taken into account at the same time.

3.5. Database Management Module

Because some characteristics of ancient ceramics need to be processed by three-dimensional graphics, it is necessary to store the measured data in the database, and then use the processing software to process the data and generate the three-dimensional images. After such a series of processing, we can present the appearance information of ancient ceramics in front of people by visual way on the computer system. The overall process module is shown in Figure 4.

Overall, in the computer vision system, it involves image acquisition module, pre-processing module and post-processing module. Through this series of processes, we can finally get the visual effect image. Of course, the knowledge system involved in computer vision system is far more than this, but the ultimate goal people pursue is very clear, that is, to replace the visual organs with various imaging systems, and to assist human beings to complete the observation and understanding of the external world by computer.

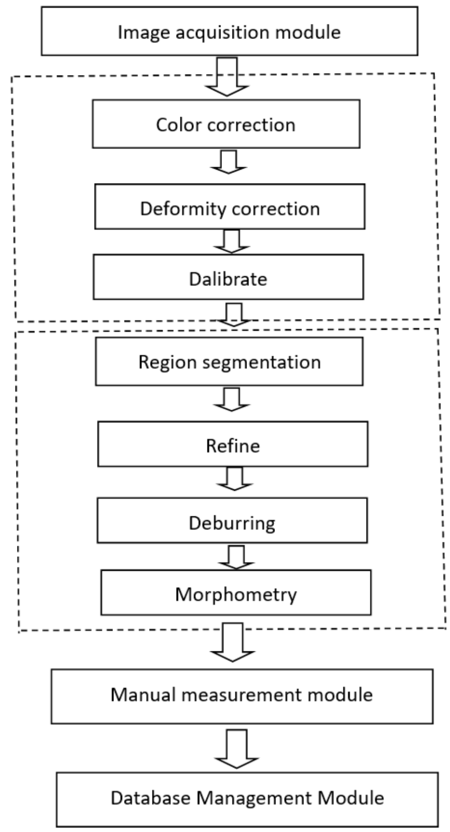

Figure 4. Structure of measurement system

4. Application of Computer Vision in the Detection of Ancient Ceramics

4.1. Extraction of Shape Characteristics of Ancient Ceramics.

In many cases, people are concerned about the appearance damage of ancient ceramics. Moreover, in archaeology, if the appearance curve of ancient ceramics with serious appearance damage can be accurately identified by computer vision, it will be of great benefit to the later maintenance and restoration work. Aiming at the shape problem of ancient ceramics, feature extraction and detection can be carried out by morphological methods in computer vision. Computer vision system is just like human vision system. In fact, the primary stage of human understanding of scenery is to recognize the external shape and color of objects. After edge extraction and image segmentation, the shape of the scene is finally perceived. For example, in recent black hole images, people recognize that black holes also describe other known information on the edge of black holes. Based on the shape characteristics of ancient ceramics, they can be expressed by their geometric attributes. Therefore, people can recognize the overall shape of ancient ceramics as a whole by extracting and processing the relevant information on their edges.

(1) Image segmentation

Image threshold segmentation is a widely used image segmentation technology, which takes advantage of the difference in gray characteristics between the target to be extracted and its background, regards the image as a combination of two types of regions (target and background) with different gray levels, and selects a threshold to determine whether each pixel in the image should belong to the target or background region, thus producing a corresponding binary image. Threshold segmentation can not only compress a lot of data and reduce storage capacity, but also greatly simplify the subsequent analysis and processing steps.

The basic principle of image threshold segmentation can be expressed as follows [9]:

$$g(x,y)=\begin{cases} Z_E & f(x,y)\in Z \\ Z_B & other \end{cases} \quad (1)$$

In this formula, Z is the threshold, Z_E and Z_B are the gray levels of any selected target and background. It can be seen that the selection of threshold is the key of threshold segmentation technology in order to distinguish objects from complex scenes and extract their shapes completely. If the threshold is selected too high, too many target points will be mistaken for the background, and if the threshold is selected too low, the opposite will happen. Here we introduce several commonly used threshold selection methods.

(2) Edge detection

The edge of an image has two characteristics: direction and amplitude. Generally, pixels along the edge trend change gently, while pixels perpendicular to the edge trend change sharply. This kind of transformation may take the form of attached step, roof and flange [10]. These changes correspond to different physical states in the scene. For example, the step change often corresponds to the depth or reflection boundary of the target, and the latter two often reflect the discontinuity of the surface normal direction.

The edge detection operator checks the domain of each pixel and quantifies the gray change rate, including the determination of the direction. Most methods use mask convolution based on directional derivative. Laplace operator is the second derivative operator that operates on two-dimensional functions. The laplace operator formula of function $f(x,y)$ is:

$$\Delta^2 f=\frac{\partial^2 f}{\partial x^2}+\frac{\partial^2 f}{\partial y^2}$$

$$\frac{\partial^2 f}{\partial x^2}=(f[i,j+1]-2f[i,j]+f[i,j-1]) \quad (2)$$

$$\frac{\partial^2 f}{\partial y^2}=(f[i+1,j]-2f[i,j]+f[i-1,j])$$

Because Laplace operator is very sensitive to noise, it is desirable to filter out noise before edge enhancement. And the Gaussian Laplace operator is undoubtedly a good choice. It combines Gaussian smoothing filter and Laplace sharpening filter, smoothes out noise first, and then carries out edge detection, so the effect is better. Consider functions:

$$h(r)=-e^{-\frac{r^2}{2\sigma 2}} \quad (3)$$

Here $r^2=x^2+y^2$, σ is the standard deviation here. Convolution of an image with this function blurs the image, and the degree of blurring is determined by σ value. The laplace operator of h (the second derivative of h with respect to r) is [11]:

$$\Delta^2 h(r)=-\left(\frac{r^2-\sigma^2}{\sigma^4}\right)e^{-\frac{r^2}{2\sigma^2}} \quad (4)$$

This formula is the Gaussian Laplace operator. Commonly used 5×5 Laplacian Gaussian templates are as follows:

$$\begin{bmatrix} 0 & 0 & -1 & 0 & 0 \\ 0 & -1 & -2 & -1 & 0 \\ -1 & -2 & 16 & -2 & -1 \\ 0 & -1 & -2 & -1 & 0 \\ 0 & 0 & -1 & 0 & 0 \end{bmatrix} \quad (5)$$

When edge detection operator is used to extract contour edges, the accuracy of edge contour extraction is determined by the algorithm of the selected operator, so in practical application, the appropriate operator is usually selected according to the actual situation [12-13].

Edge is a basic feature of an image, which carries a lot of information in the image. The edge detection of ancient ceramics can not only get useful structural information about its appearance boundary, but also reduce the amount of data to be processed and the influence of background image. Because many image processing and recognition algorithms are based on edge detection. In the process of processing, image edges can be divided into gray edges and color edges according to color features. Gray-level image can be described by image brightness function. Gray-level edge can be defined as a set of discontinuous points with edge characteristics of image brightness function. It describes the local mutation of gray-level function. Color image can be described by image color function, and color edge can be defined as a set of discontinuous points with edge characteristics of image color function, which describes the local mutation of color number. In the process of extracting the contour boundary of ancient ceramics, we can get the information of ancient ceramics'appearance damage through a series of operations, such as searching the boundary and obtaining the coordinates of the pixels of each boundary point.

(3) Spot analysis

The appearance defect of ancient ceramics can also be analyzed by Blob Analysis. This method is an important application of computer vision. It can not only provide information about the number, location, shape and direction of speckles in ancient ceramic images, but also provide the topological structure of related speckles. Speckle analysis is a basic method for analyzing and processing the shape of closed targets. Fixed threshold segmentation (Hard Threshold) and dynamic threshold segmentation (Soft Threshold) can be used in segmentation. When the image is segmented into target and background pixels, connectivity analysis is carried out to find one or more similar gray-scale "spots" in the image. Connectivity analysis is carried out according to four or eight neighborhoods. The target pixels are aggregated into the connectors of the target pixels or spots, and a Blob unit is formed. By analyzing the graphic features of the Blob unit, the gray information of the pattern can be quickly transformed into the shape information of the pattern, including the center of mass, area and perimeter of the graph. Using Blob analysis and multi-level classifier filtering, the detection and analysis of ancient ceramics defects can be completed to a certain extent.

4.2. Edge contour image enhancement of low-quality images

In recent years, a large number of researchers began to study how to calibrate the digital camera. Researchers can reconstruct the motion of the scene related to the digital camera and related geometry through two or more uncalibrated images at the same time. In the traditional 3D reconstruction method, the calibration of the digital camera is essential. For scene reconstruction, this has many advantages: first, in the shooting process, the slight change of digital camera parameters or inaccurate calibration information will not affect the reconstruction results; Secondly, we can move the position of the camera freely and adjust the focal length of the camera according to the need. After the camera self-calibration is completed, the geometric model can be reconstructed by the above method; The work flow of image-based 3D modeling technology is shown in Figure 5.

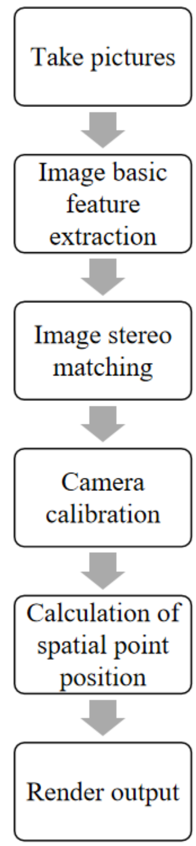

Figure 5 Work flow of 3D modeling technology based on image.

When the model of an object is divided into grids, the points of each grid show the texture of the object through the condensation of different colors [14]. In other words, texture is the color information displayed on the surface of mesh model. In order to obtain a three-dimensional model with high resolution and realize the characteristics with high requirements of surface accuracy, the most important thing in the process is to establish the corresponding relationship between the image and the grid model, that is, the mapping 1 of the collection relationship of each point color. Must be accurate, this relationship is the texture mapping relationship.

Accurately extracting the outline of ancient ceramic objects from two-dimensional images is the first step of three-dimensional restoration of ceramic objects. However, due to the problems of low image pixels, blurred imaging and low contrast between ceramic objects and background, the three-dimensional model restored by such images is far from the real ancient ceramic objects, and its accuracy is extremely low, even it is impossible to obtain the three-dimensional model at all. Therefore, this algorithm firstly uses wavelet transform to enhance the image edge, improve the identifiability of ancient ceramics edge, and realize clear extraction and accurate positioning of ancient ceramics edge contour. The specific process is as follows [15]:

Wavelet decomposition of original image.

Two-dimensional discrete wavelet transform is applied to the image $f(x,y)$ with the original image size $M \times N$ by using formula (6) and formula (7), and the original image is decomposed into a low-frequency sub-image band containing image contour information and a high-frequency sub-image band dominated by background noise.

$$W_{\varphi}(j_0,M,N)=\frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\varphi_{j_0,M,N}(x,y) \quad (6)$$

$$W_{\Psi}{}^{i}(j,M,N)=\frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\Psi^{i}_{j_0,M,N}(x,y), i=\{H,V,D\} \quad (7)$$

In which: W_{φ} is the approximate coefficient representing the contour information of the image; $W_{\Psi}{}^{i}$ is the detail coefficient of the identification image; $\varphi_{j_0,M,N}$ is the scale basis function; $\Psi^{i}_{j_0,M,N}$ is a translation basis function; $\{H,V,D\}$ represents image details in different directions [16].

Filter out the background noise components in the image

Adjusting the weights of approximate coefficient W_{φ} and detail coefficient $W_{\Psi}{}^{i}$ of high and low frequency subbands in formula (6) and formula (7) after wavelet transform can improve the definition of picture outline and further reduce noise [17].

$$f(x,y)=\frac{1}{\sqrt{MN}}\sum_{M}\sum_{N}W_{\varphi}(j_0,M,N)\varphi_{j_0,M,N}(x,y)+ \frac{1}{\sqrt{MN}}\sum_{i=H,V,D}\sum_{j=j_0}\sum_{M}\sum_{N}\Psi^{i}_{j_0,M,N}(j,M,N)\Psi^{i}_{j,M,N}(x,y) \quad (8)$$

Finally, using the inverse wavelet transform formula of formula (8) to synthesize the image after edge enhancement [18], the image edge enhancement can be realized, and the purpose of highlighting the edge contour of ceramic ware image can be achieved [19].

4.3. Analysis of Color Uniformity on the Surface of Ancient Ceramics

Because the production process of ancient ceramics is very complex, and because of the long history and other reasons, the surface color of ancient ceramics may appear aging, partial dim, uneven and other phenomena. However, these surface characteristics have a great impact on the collection value of an ancient ceramics, and are also important appearance indicators for evaluating the value of an ancient ceramics bottle. Therefore, the scientific analysis of the surface color uniformity of ceramic sheets plays an important role in the reasonable evaluation of the value of ancient ceramics.

At this time, computer vision can be used to detect and classify the chroma of ancient ceramics. The color uniformity of ancient ceramics with uniform color distribution was tested, and the objective recognition method of color uniformity detection was given. Using this recognition method, online uniformity detection can be easily realized by computer vision system.

In the computer vision detection method, the light reflected from the surface of the ancient ceramics is transformed into analog electric signals by using the area array CCD device, and the digital signals are input into the computer through the A D acquisition card. After the analysis and processing of computer software, the digital image file is formed. Then the information in the image is finally analyzed by applying the knowledge of computer vision and combining with the homogeneity test method of ancient ceramics. This method can not only analyze and describe the color distribution in the whole measuring area, but also synthesize various uniformity parameters to determine a more scientific comprehensive uniformity index. The test results can be displayed on the computer screen and meet the requirements of real-time monitoring. And eventually it can be printed out.According to the photoelectric conversion principle of CCD device, the relationship between the output charge signal Q and the illumination E on the sensitive surface is as follows:

$$Q = k_1 t E \quad (9)$$

Among them, k_1 is a proportional constant and t is an integral time, which can be regarded as a constant for a certain CCD device.

The sampling and quantization principles of AD acquisition card are as follows:

$$f(x,y) = \begin{cases} N-1 & Q(x,y) \geq a_u \\ \mathrm{mod}\left[\dfrac{Q(x,y)}{(a_u - a_l)/N}\right] & a_l < Q(x,y) < a_u \\ 0 & Q(x,y) \leq a_l \end{cases} \quad (10)$$

Among them, $f(x,y)$ is the gray value at the pixel point (x, y), $Q(x,y)$ is the charge signal of the corresponding pixel point (x, y), N is the gray level of the output image of the AD acquisition card, and a_u and a_1 are the maximum and minimum values of the allowable input signal amplitude of the AD acquisition card, respectively.

4.4. Color difference detection method based on histogram distribution

HIS model is widely used in color detection system, considering that I component reflects the brightness of color, S component reflects the purity of color, and does not represent the essential information of color; H component reflects the kind of color, so H component is selected to detect the color of ancient ceramics [2]. Images collected by cameras are stored in computer memory with three components: R, G and B. After transforming the digital image information of ancient ceramics from the model to HIS model, the eigenvalue is calculated as the classification standard of ancient ceramics [5].

Calculation method of eigenvalue:

1. Preprocessing and threshold segmentation are carried out on images collected by CCD to extract ancient ceramic images;

2. Transform the ancient ceramic image into HIS space;

3. Calculate the H value of each pixel after conversion, and calculate the average gray value of the image according to the following formula:

$$T = \frac{\sum_{i=1}^{n} h(i)}{n} \quad (11)$$

In which $h(i)$ is the H value of the i th pixel and n is the number of effective pixels.

We conducted experiments on six ancient ceramics. We take pictures orderly according to the marks (1-6) added to ancient ceramics. In the process of taking pictures, the influence of vibration produced by belt drive on the measurement results can not be ignored. In order to test the influence of belt vibration on data, we did the following experiments: Taking No.6 brick as the measurement object, the detection of fixed-point no increase, random no increase and fixed-point increase was carried out. The so-called fixed-point heightening detection means that the ancient ceramics are placed at the same position on the belt every time, and the whole ancient ceramics heightens 1mm. Random inspection is placed at any position of the belt. The measurement results are shown in Table 1:

Table 1 Measurement results of three States of No.6 brick

No increase at fixed point	There was no increase in random detection	The fixed-point detection is increased by 1mm
36.02	36.21	37.11
36.33	36.27	37.82
36.07	36.03	37.96
36.69	36.10	37.71
36.17	36.08	37.05
36.02	36.62	37.81

The form of the disconnection diagram is shown in Figure 6

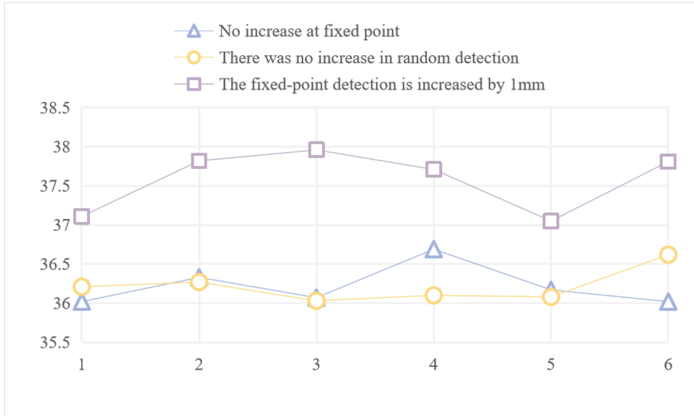

Figure 6 Unplugging diagram of measurement results of No.6 brick in three States

It can be clearly seen from Figure 6that under the condition of no increase at fixed point and no increase at random, the data does not shift and the fluctuation range is within the acceptable range; However, when 1mm is increased, the data is obviously shifted. Therefore, it can be inferred that the belt vibration has no obvious influence on the ancient ceramic data, and it is within the controllable range, so it can be said that it has no influence on the final classification results.

5. Conclusion

With the maturity of computer vision technology, it has been applied to many fields. From the perspective of cultural ecology, the application of computer perspective system in ceramic inspection is of great significance to the perfection of traditional cultural system. Nowadays, people call it the information age and digital age. It is one of the effective measures to inherit the traditional national cultural heritage to make the ancient ceramic cultural heritage catch up with the times express train and protect it by modern digital means. This paper analyzes ancient ceramics based on computer vision technology, and summarizes the applicable scope of computer vision technology in ancient ceramics protection, as well as several reasonable and practical digital modeling techniques and drawing methods. Finally, the specific application object is selected, and the image modeling method is used to model, reconstruct and texture map it, which achieves ideal results. With the increasingly popular concept of cultural ecology, computer vision technology can be widely used in the field of ceramic detection, providing scientific professional help for collectors who like ancient ceramics.

References

[1] Lin K L , Fang J L . Applications of computer vision on tile alignment inspection[J]. Automation in Construction, 2013, 35(Complete):562-567.

[2] Zhemin D , Zengpu X . THE APPLICATION OF COMPUTER VISION ANALYZING FOR COLOR EVEN DEGREE ON THE TILE SURFACE[J]. China Ceramic Industry, 2002.

[3] Zhang L , Li X H , Tang X J , et al. Chromatic Aberration Classification Technology of Ceramic Tile Base on Computer Vision[J]. Applied Mechanics and Materials, 2011, 48-49:308-313.

[4] Wang J, Ying L, Dong Z, et al. A new computer vision based multi-indentation inspection system for ceramics[J]. Multimedia Tools & Applications, 2016, 76(2):1-19.

[5] Hocenski, Željko; Matić, Tomislav; Vidović, et al. Technology transfer of computer vision defect detection to ceramic tiles industry[C]// PROCEEDINGS OF 2016 International Conference on Smart Systems and Technologies. 0.

[6] Liu Y , Li S Q , Wang J F , et al. A computer vision-based assistant system for the assembly of narrow cabin products[J]. The International Journal of Advanced Manufacturing Technology, 2015, 76(1-4):281-293.

[7] Zhou J , Li G , Wan X , et al. A real-time computer vision-based platform for fabric inspection part 2: platform design and real-time implementation[J]. Journal of the Textile Institute Proceedings & Abstracts, 2016, 107(2):264-272.

[8] Tang Y, Ding J, Guo W. A Study of Ancient Ceramics Verification Based on Vision Methods.[J]. Communications in Computer & Information Science, 2014, 484:63-71.

[9] Liao G, Lin M, Xi J. A Machine Vision Approach for Small Ceramic Tubes Detection[M]. 2009.
[10] Bay, H., Tuytelaars, T., Van Gool, L.: SURF: Speeded up robust features. In: Leonardis, A., Bischof, H., Pinz, A. (eds.) ECCV 2006, Part I. LNCS, vol. 3951, pp. 404–417. Springer, Heidelberg (2006)
[11] Lowe, D.G.: Distince image features from scale-invariant keypoints. International Journal of Computer Vision 60(2), 91–110 (2004)
[12] Cao Ligang, Tang Lei, Feng Hao. Design of wall and floor tile shape detection system based on computer vision [J]. Acta Ceramics Sinica, 2018, 039(003):332-335.
[13] Liu qi, tu zhengyu, Chen Chao, et al. application of computer vision technology in food quality inspection [J]. food research and development, 2020(16).
[14] Li suduo. application of computer vision technology in tea grade detection [J]. agricultural mechanization research, 2019, 041(005):219-222.
[15] Zhou Xiaolin. application of computer vision in tea grade inspection [J]. Fujian tea, 2020, v.42; No.221(05):31-32.
[16] Shi Chaojie. Application of computer vision and infrared thermal imaging in fruit sorting and damage detection [J]. IT Manager World, 2019, 022(005):88-90.
[17] Duan Lirong. Detection method and application based on computer vision [J]. Science and Technology Information, 2019, 17(07):7-8.
[18] Luo Jinyang. Application of analytical chemistry in the detection of ceramic materials [J]. Development Orientation of Building Materials, 2020(2):87-87.
[19] Dang Peiguang, Li Junheng. Gesture detection and recognition technology based on computer vision [J]. Computer Enthusiasm, 2017, 000(011):39.