Research Article

Piezoelectric Sensing Element-Assisted Ceramic Art Process Optimization and Visual Quantitative Characterization

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In this paper, piezoelectric sensing elements are used to assist in the study and analysis of ceramic art process optimization and visual quantization characteristics. A series piezoelectric element impedance sensor is designed based on the resonant frequency characteristics of the series piezoelectric element. Combining the resonant frequency characteristics of the series piezoelectric element and the basic principle of the impedance method, a multisensing impedance method based on the series piezoelectric element impedance sensor is proposed. The feasibility of the multisensing impedance method for monitoring the grout compactness was verified experimentally, and the basic principle of the method was further investigated by finite element simulation. The vase-type porcelain vessels were classified according to symmetry elements to find the characteristic points, the abdominal morphology was used as the basis for classification, and the screened samples were extracted from the contours to exclude the influence of other factors on the vessel shape. By the symmetrical elements of each type of ware, the classification principle of the ware type was designed and divided into six types, and each type was further subdivided into various types to establish a typological map of Qing dynasty bottle porcelain. The information entropy redundancy that describes the uniformity of the code appearance probability and the visual redundancy that describes the human eye's sensitivity to image content or details are all entry points that can be considered for image coding. The experimental results show that the LBP-HOG fusion features can digitally express the information of ancient ceramic ornamentation and dig and verify the evolution of ceramic ornamentation with the times from the digital quantity. The GRNN model has an excellent performance in processing small samples of ancient ceramic data.

1. Introduction

With the rapid development of computer and multimedia technology, the era of information and big data has come. At present, WeChat, microblogging, and other multimedia applications have become indispensable information transfer tools in people's lives, and a huge amount of data information is sent and received every moment, among which image data occupies a considerable proportion [1]. The core idea of image coding is to eliminate all kinds of redundant information in images. Including spatial redundancy describing the correlation of pixels at different locations of the image, structural redundancy describing the presence of strong texture in a particular region of the image, information entropy redundancy describing the probability of code occurrence uniformity, and visual redundancy describ-

ing the human eye's sensitivity to image content or details are all entry points that can be considered for image coding [2]. The elimination of all kinds of redundant information as much as possible, while ensuring that the reconstructed image meets certain imaging quality requirements, is what needs to be accomplished and the goal of image coding. For the visual redundant information carried by the image, HEVC adopts a method based on structural similarity to objectively evaluate the image distortion, which considers the visual characteristics of the human eye and achieves the estimation of image perceptual distortion to a certain extent, but the method is mainly used to evaluate the distortion of the reconstructed image, while in the actual image coding process based on rate-distortion optimization theory, HEVC uses the absolute difference between the original and reconstructed pixels to represent the pixel distortion of the

image, and the reconstructed image obtained by coding without considering the visual characteristics of the human eye is bound to carry a large amount of visual redundant information. Consider the application of the reconstructed image, which can be only oriented to feature extraction for data processing or image display for end devices.

The main objectives of a structural health monitoring system are to monitor the response of a structure under various loading conditions, to assess the operation and structural performance of the structure, to detect damage or deterioration, and to guide inspection and maintenance [3]. This method considers the visual characteristics of the human eye and to a certain extent realizes the estimation of image distortion, but this method is mainly used to evaluate the distortion of the reconstructed image. Depending on the target structural inspection area, structural health monitoring can be classified as global structural health monitoring, local structural health monitoring, and hybrid structural health monitoring. Global structural health monitoring typically uses low-frequency dynamic properties or structural deformation to characterize the integrity of the entire structure. However, this method utilizes a low-frequency vibration response and is not very sensitive to localized small dimensional damage. Local structural health monitoring utilizes high-frequency characteristics to assess the integrity of localized areas in the vicinity of the sensor. Using high-frequency response, local structural health monitoring techniques can be effective in assessing the structural condition of local critical members. Piezoelectric materials have been studied in local structural health monitoring. However, since most conventional piezoelectric sensor designs are based on the KLM model, which only considers the thickness vibration mode of the piezoelectric element, less research has been conducted on piezoelectric sensor design using the resonant frequency characteristics of the radial vibration of the piezoelectric element. The study of the use of morphological bionics in the design of modern ceramic teaware can not only find the existing shortcomings in the design of modern ceramic teaware but also explore the development trend of modern ceramic teaware design, with the help of the design principles of morphological bionic modern ceramic tea set design to explore the direction of modern ceramic tea set design; creativity and individual needs make up for the shortcomings of modern ceramic tea set design. The individuality and creativity of morphometric modern ceramic tea set design further fit with people's demand for modern ceramic tea set design [4]. This paper starts from the origin and evolution of the use of morphological bionics in ceramic design and highlights the importance of the use of morphological bionics in modern ceramic tea set design by examining the shortcomings and development trends of modern ceramic tea set design. Through the study and analysis of the principles and embodied values of modern ceramic tea set design, it is concluded that the design of modern ceramic tea set should meet the practical functional needs and create products that meet the personalized and creative needs of the society with the help of morphological bionics. Through the study of the use of morphological bionics in modern ceramic tea set design and the practical exploration of the use of morphological bionics in modern ceramic tea set design, it not only is a review and summary of the knowledge learned during the postgraduate period but also is paving for my future research in this field.

Applying mathematical thinking to the field of ceramic art, the relationship between the evolutionary pattern of bottle porcelain vessel types and actual function is quantitatively analyzed. From the perspective of function, we collect data samples of Qing dynasty porcelain vessel types and complete a preliminary summary of the external characteristics of the vessel type. The relationship between the porcelain parts and the whole was analyzed in the form of graphs and charts, and then, the link between form and function was analyzed. The identification of the bottle shape is an important feature in the identification of ancient ceramics, and the features are used to classify the Qing dynasty bottle porcelain types, and the logical order of the identification of the Qing dynasty bottle porcelain-type features is established by using the methods of feature extraction and classification. We propose a systematic analysis of the extant visible and imageable Qing dynasty bottle porcelain modeling varieties and overall shape and analyze the types and patterns of hundreds of Qing dynasty bottle porcelain with different modeling and decorative techniques and techniques excavated and handed down from archaeological excavation sites of the Qing dynasty with the help of typological methods; we propose a coding method for Qing dynasty bottle porcelain types to provide identity proof for the types, which helps to classify and obtain information quickly. It can be feature extraction only for data processing, or it can be image display for terminal devices. The method of coding the Qing dynasty vase types is proposed to provide identification for the types, which can help to classify and obtain information quickly, for the inheritance of the tradition of the predecessors is not a single-blind imitation and adoption, to selectively borrow, reference, and enhance the ability of independent innovation, stimulate innovative vitality, and drive the vigorous development of technology for the porcelain ware type.

2. Current Status of Research

Improving the coding efficiency of images has been the goal of scholars, and research work on image compression based on the visual properties of the human eye addresses the visual redundancy of images, combining the visual information of the human eye with image coding in some way to reduce the visual redundant information as much as possible while retaining the necessary image information [5]. Research work on the human eye visual system related to image coding includes two aspects: on the one hand, chaotic distortion, which describes the sensitivity information of the human eye: it indicates that the difference between two pixels representing the same content exceeds a specific threshold before it is perceived by the human eye, and on the other hand, region of interest, which describes the attention information of the human eye: when the human eye views an image frame, there are image regions that attract the most attention of the human eye [6]. The chronometrical

distortion and the region of interest describe the visual properties of the human eye from different aspects, respectively, without any correlation, so they can be used as two separate problems to find a solution. The results of the study demonstrate the accuracy of the electromechanical impedance method in detecting the initial stage damage [7]. It is not very sensitive to local small-scale damage. Local structural health monitoring uses high-frequency characteristics to assess the integrity of the local area near the sensor. Furthermore, the feasibility of applying the electromechanical impedance method for the health monitoring of large reinforced concrete structures is well demonstrated. Based on the linear relationship between the damage volume ratio and the damage relative stability index, the researchers proposed a damage calculation method for concrete structures based on the damage volume ratio index.

For a long time, the manual identification method has been recognized and has also caused certain controversies. This method is easily affected by subjective factors. For the same ancient ceramics, the appraisal conclusions are different due to the appraiser's appraisal experience, knowledge reserve, moral quality and other factors. In addition, human manipulation and profit-driven will also lead to misjudgment [8]. In addition, there is no scientific test support. In addition, without the support of scientific tests and quantitative unified objective standards, the identification results lack certain scientific credibility; these factors make the ophthalmology identification method to not have sufficient authority [9]. More importantly, the method cannot accurately express the characteristics and attributes of ancient ceramics through linguistic descriptions, and due to the lack of multiple information management and data support, the elements of identifying ancient ceramics are not easily grasped, it is difficult to form quantitative theories on the characteristics and development patterns of ancient ceramics, and the development patterns of ancient ceramics and their cultural, technical, and historical connotations cannot be comprehensively interpreted, which is not conducive to the objective measurement. Research on the application of morphological bionics in the design of modern ceramic tea sets can not only find the existing shortcomings in the design of modern ceramic tea sets but also explore the development trend of modern ceramic tea set design. This is not conducive to the objective measurement of the value of ancient ceramics and the protection, inheritance, and promotion of ancient ceramic relics [10].

The essence is to replace the human brain with an artificial intelligence system to complete the analysis and processing of data [11]. The use of machine learning, pattern recognition, and other technologies to extract features from images of ancient ceramics that can characterize the era and kiln and other information, mainly from the most significant images of ancient ceramics in several aspects such as shape, ornamental patterns, glaze color, and inscriptions and according to these features to identify ancient ceramics, has become a new discipline of ceramic craftsmanship, archaeology, and artificial intelligence science intersection direction. Since the appearance information of ancient ceramics can not only reflect the level of artisanship and

show its unique artistic charm but also be an important basis for the identification of ancient ceramics and the use of humans. The research on the appearance characteristics of ancient ceramics using artificial intelligence methods can effectively improve the accuracy and objectivity of ancient ceramics identification, which can strongly assist in the manual identification, and at the same time, it can fully quantify and systematize the identification experience and sensory information, discover the development pattern of subtle changes in the appearance of ancient ceramics, and provide a scientific basis for the cultural heritage of ancient ceramics.

3. Piezoelectric Sensing Element-Assisted Ceramic Art Process Optimization and Visual Quantization Characterization

3.1. Visual Quantization Feature Design Aided by Piezoelectric Sensing Elements. Piezoelectric sensors are the core devices for structural health monitoring based on piezoelectric materials, and the piezoelectric element is the core component that determines the performance of the piezoelectric sensor; an adequate study of the characteristics of the piezoelectric element is the basis for structural health monitoring [12]. Given the little research on the design of piezoelectric sensors using radial vibration resonant frequency characteristics of piezoelectric elements, the content of this paper investigates the radial vibration resonant frequency characteristics of single piezoelectric elements and multiple piezoelectric elements in series, which provides a theoretical basis for further optimization of traditional structural health monitoring methods based on piezoelectric materials. A piezoelectric material is a material that can convert mechanical energy into electrical energy and electrical energy into mechanical energy. The mechanical strain applied to a piezoelectric material produces an electrical charge on its surface, i.e., a positive piezoelectric effect. The piezoelectric principle can be characterized by the electromechanical principal equation, and the strain-charge relationship can be expressed in tensor form as follows. It highlights the importance of form bionics in the design of modern ceramic tea sets. Through the research and analysis of the design principles and embodied values of modern ceramic tea sets, it is concluded that the design of modern ceramic tea sets should meet the requirements of practical functions.

$$
\begin{aligned}
D_i &= \varepsilon_{ij}^T E_j + d_{im} T_m, \\
S_k &= d_{im} T_m + s_{km}^E T_m.
\end{aligned}
\tag{1}
$$

One of the problems with the electromechanical impedance method in the field of structural health monitoring is the high cost of the monitoring system. Since the impedance sensors used in the conventional electromechanical impedance method are usually small-sized piezoelectric materials, full-coverage monitoring of large concrete structures with large spans and high levels requires a large amount of monitoring equipment. Therefore, to meet the growing demand

for structural health monitoring of large concrete structures, the technique must be cost-effective and requires rapid scanning of large areas with minimal disturbance to the operation of the structure [13]. In this model, the piezoelectric sheet considered as a thin rod was subjected to axial vibration under an applied alternating voltage. The AC voltage and output current of the piezoelectric sheet are noted as V and I, respectively. One end of the piezoelectric sheet is fixed, and the other end is coupled to a structure represented as a single degree of freedom (SDOF) spring-mass damping system. The electrical conductance of the piezoelectric sheet coupled to the structure is frequency-dependent.

$$y(w) = iwa\left(\varepsilon_{ij}^T(1 + i\delta) + \frac{Z_s(w)}{Z_s(w) - Z_a(w)} d_{3x}^2 Y_{22}^E\right). \quad (2)$$

The mechanical properties of the PZT patch remain constant during the monitoring process, so the frequency-dependent conductance is directly related to the mechanical properties of the structure. In this paper, the real part of the impedance is used because the real part is less sensitive to temperature changes compared to the imaginary part. The electromagnetic vibration energy harvester is based on Faraday's law of electromagnetic induction when the vibration source in which the device is located vibrates, at which time it is known that the magnetic flux in the coil will change due to the relative motion of the magnetic body and the conducting coil in the device thus generates an electrical signal. The most important structure in the device is the induction coil and permanent magnet when the vibration source is vibration coil and permanent magnet vibration at the same time or separately, so the electromagnetic vibration energy harvester according to the different vibration modes can be divided into three different types of its type: moving iron, moving coil, and iron coil with vibration, as shown in Figure 1.

The piezoelectric effect is a kind of mechanical energy and electrical energy interchange effect in dielectric materials. Generally, the piezoelectric materials we are talking about are polarized materials, not polarized raw materials, and generally do not have piezoelectric properties. Here, a DC electric field is applied to the polarization of the raw material. The polarization direction of the electric domains in the original material is chaotic before the arrangement, and the overall polarization intensity is zero [14]. However, after polarization, the polarization direction of the electric domains inside the material follows the direction of the applied electric field to a certain extent, and the piezoelectricity is obtained. No matter what kind of device is made with piezoelectric materials, the main energy supply material is the piezoelectric material, and vibration energy harvesters are no exception. Establish the logical sequence of classification and recognition of the characteristics of the vase porcelain in the Qing dynasty. A systematic review of the existing visible and measurable types and overall appearances of Qing dynasty bottle porcelain uses typological methods for reference to hundreds of examples of different decorative techniques and crafts unearthed and handed down from

the archaeological excavations of the Qing dynasty at the same time. The types and styles of the vase porcelains in the Qing dynasty were analyzed; the coding method of the vase porcelains in the Qing dynasty was proposed. There are different ways to classify piezoelectric raw materials into a variety of categories, according to the type of raw materials to classify, which can be divided into a single crystal, polycrystalline (piezoelectric ceramic), piezoelectric polymer, and piezoelectric composite materials; this classification is our main classification. Another classification is according to the form of raw materials, which can be divided into two main categories, which are body raw materials and piezoelectric films.

The vortex vibration energy collector and the vibration energy collector have completely different design characteristics because they work in two different environments and the mechanism of vibration is very different. The source of the vortex street energy collector comes from the vortex street generated when the fluid bypasses the blunt body, so the vibration frequency of the device is mainly influenced by the shedding frequency of the vortex street that occurs after the fluid bypasses the blunt body. Different shapes of obtuse body bypassing the vortex street are also different; to facilitate testing and application, a cylinder is selected as the bypassing obtuse body in this paper. The vibration source of the vibration energy collector mainly comes from the vibration frequency of the vibration machinery. Therefore, the structural parameters of the two energy harvesters must be reasonably designed, and the frequency of the vortex shedding and the frequency of the vibrating machinery must be comparable or close to the intrinsic frequency of the device to make the device have a more objective output.

$$\begin{aligned} \text{Re} &= pvD * \bar{\omega}^2, \\ F &= StV * d^2. \end{aligned} \quad (3)$$

The flow field condition of the vortex vibration energy harvester is a key factor to determine its output performance; therefore, in this paper, the flow field of the vortex vibration energy harvester is simulated in a fluid-solid coupling, and the simulation conditions are the experimental conditions we need: the inner diameter of the pipe is 25 cm, the diameter of the obtuse body is 6 mm, the water velocity is 0.8 m/s, and the Reynolds number is 20000 [15]. The piezoelectric sheet fixed behind the obtuse body does not vibrate, and as the water flows around the obtuse body, an unstable boundary layer separation occurs; on both sides of the downstream of the obtuse body, two asymmetrically arranged vortices are generated, with the vortex on one side rotating clockwise and the vortex on the other side rotating in the opposite direction, and the two vortices are staggered with each other. This alternating arrangement of vortices causes the up and down vibration of the piezoelectric sheet. This is the mechanism of vortex-excited vibration generation, as shown in Figure 2.

In the application of perceptual video coding, the JND model is constructed mainly from the null and time domains. In the null domain, distortion occurring in
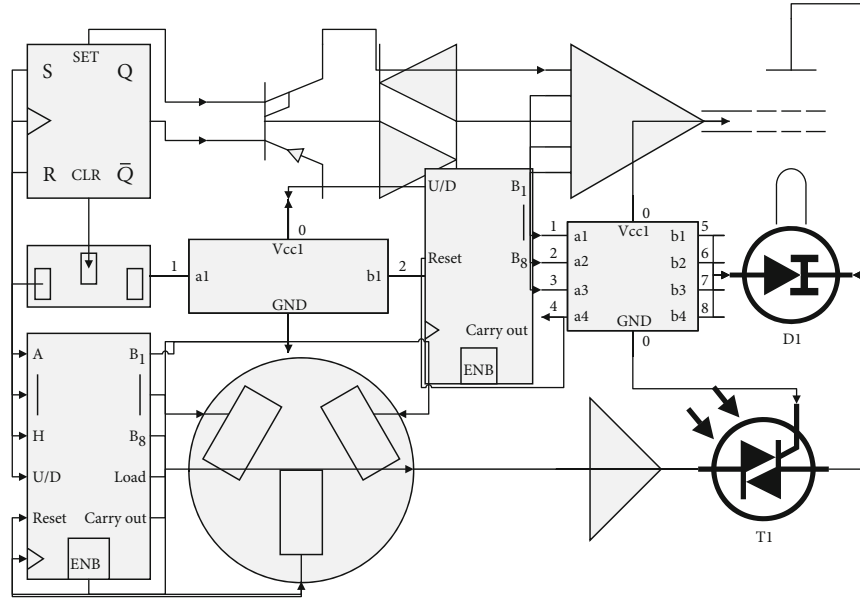
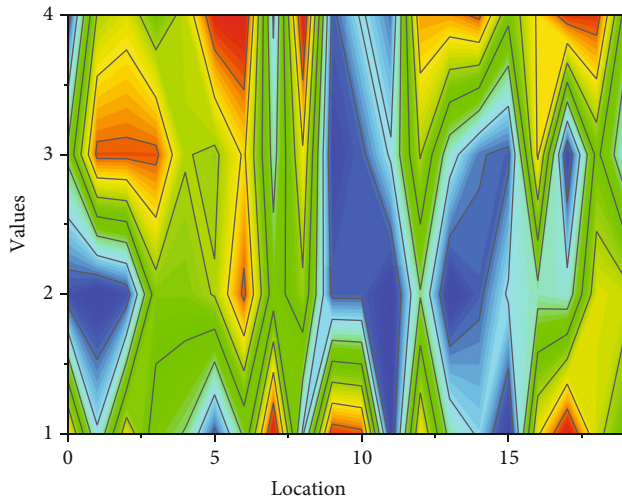FIGURE 1: Principle of the multisensor electromechanical impedance method.

FIGURE 2: Flow field simulation diagram.

tual characteristics into the rate-distortion optimization framework for video coding and to construct subjective and objective evaluation methods that conform to human eye perceptual characteristics.

$$S_{\text{ave}} = \sum_{i=-1}^{M} \sum_{j=1}^{N} \frac{s(i,j)}{\text{Num}_{\text{ctu}}}. \tag{4}$$

The above-mentioned shape features enable the recognition of shapes in images in a macro sense, but it is difficult to detect the local and detailed features of shapes. In particular for ancient ceramics, its shape has evolved and been inherited through the times, and the style of each era has been formed to meet the development needs of the times [16]. The number of features is not enough to reflect the most essential characteristics of the era, and it is difficult to accurately distinguish the different eras of ancient ceramics and cannot meet the needs of ancient ceramic identification of the broken generation identification. Since the profile curve of ancient ceramics covers all the characteristics of the shape, especially the rotated body-shaped objects produced by the billet process, only the half-edge profile can be rotated to restore the three-dimensional shape of ancient ceramics, so the construction of an accurate side edge profile model of ancient ceramics is the first prerequisite to fully refine the information of ancient ceramic shape, followed by the excavation of the geometric parameters with the attributes of the era hidden in the structure of the object shape, to provide sufficient digital basis for ancient ceramics. It provides a theoretical basis for further optimizing the traditional structural health monitoring methods based on piezoelectric materials. Piezoelectric materials are materials that can convert mechanical energy into electrical energy and electrical energy into mechanical energy. The second step is to explore the geometric parameters hidden in the structure of the

texturally flat regions will be more easily detected than complex regions, and in the time domain, drastic changes in content between adjacent frames in a video sequence or large differences in brightness between frames will lead to reduced perception by the eye, a phenomenon generally referred to as the masking effect of the vision, due to which one cannot perceive distortion at a certain threshold, and this threshold is referred to as cha perceptual distortion. The peak signal-to-noise ratio, mean square error, and mean absolute difference are popular distortion metrics that calculate interpixel errors from the perspective of signal processing. Although these methods are widely used and simple to calculate, pixel-based distortion metrics such as the peak signal-to-noise ratio and mean square error do not reflect human perceptual characteristics. Researchers have continuously attempted to incorporate suitable human eye visual percep-

artifacts with the attributes of the period, to provide sufficient digital basis for the identification of ancient ceramics.

3.2. Experimental Design for Ceramic Art Process Optimization.

Although the color characteristics have good stability and do not change with the pan, flip, and other changes in the image, the color is sensitive to changes in light intensity, environment, etc., the same object is photographed in different light intensities for image acquisition, and the image color will have a large difference; in addition, due to shading, shadows or direct light source caused by the reflection phenomenon can seriously affect the color information presented by the object [17]. Due to the influence of equipment and environment, the color of the object image often distorted from the real color of the object also makes color recognition very difficult. In this study, we need to use the image information of the ancient ceramics to dig the number of color characteristics to assist in the identification of ancient ceramics, which requires a high level of color recognition ability, and the image set of this subject is collected from the public collection of various museums. The degree of color distortion of the images is not known, which causes certain errors in color identification. To ensure the rigor of the algorithm and the accuracy of the recognition results, this paper considers extracting the stable characteristics of ornament and vessel type and extracting the period information through their digital representation. The digital representation is used to mine the era information, to achieve the generation of ancient ceramics, as shown in Table 1.

Culture and society are constantly changing and developing, and according to the characteristics of the times, the form, shape, and texture of the products are constantly being improved with the changes in society. Since the modern ceramic tea is set to design the shape, the first thing is to have the ability to analyze modern society; all kinds of human needs can be attributed to cultural needs, which shows that design and culture have a close relationship. The design of modern ceramic tea sets also conveys cultural information and highlights the psychological significance of a particular image. In particular in the design of modern ceramic tea sets, to better satisfy consumers, we need to consider cultural characteristics and aesthetic interests when designing. With China's reform and development over the years, globalization is an inevitable development trend, globalization has both advantages and disadvantages, our various cultures are communicating with each other and influencing each other, the nation is also the world, we keep the nation in the design, we should not be isolated from the world but instead closer to the world, and the shape design of tea sets also needs to do so [18]. The design of ceramic tea sets has gone through a process from simple to complex and from low to high. However, with the development of modern industry, the tea set is a good carrier to reflect the poetry and harmony of nature. In addition to the delicate shape, elegant decoration, stable and generous design of ceramic tea set style, modern designers also pursue more dynamic, geometric, and other fashion elements, many tea sets on the market reflect the taste of modern streamline, and futur-

TABLE 1: Comparison of subjective coding performance.

Sequences	QP	HM16.7	Proposed	Improve
Race horses	1	4.9	3.4	3.3
	2	4.5	2.5	3.5
Basketball pass	3	3.4	3.2	2.3
	4	4.9	2	2.3
	5	4.2	4.2	5

istic and space-type designs are also applied to ceramic tea sets. In the production process, tea sets mostly use a combination of cold pressing and conjoined grouting to form an artistic style different from that of traditional ceramic tea sets. The future design trend of bionic ceramic tea sets should be based on design concepts related to the traditional tea set culture, combining modern design elements and concepts with traditional cultural elements, combining their functional and aesthetic needs, further improving traditional tea sets, satisfying the spiritual and material needs, so that it can meet the needs of modern social development and show a more perfect attitude in people's daily life, as shown in Figure 3. The most important structure in the device is the induction coil and the permanent magnet. When the vibration source vibrates, the coil and the permanent magnet vibrate simultaneously or separately. Therefore, the electromagnetic vibration energy harvester can be divided into three different types according to the different vibration modes. Moving iron, moving coil, and iron ring simultaneously vibrate.

By mining, the subtle differences are contained in the banana leaf motifs of each dynasty; extracting the period characteristics from the variations of the motifs and establishing quantifiable feature quantities are key aspects of intelligent identification of ancient ceramics. Given that the banana leaf motif occupies an extremely important position in porcelain decoration, this paper will take the ancient porcelain with banana leaf motif as the starting point of research to identify the era of ancient ceramics with banana leaf motifs by refining the period features of banana leaf motifs in the images. At present, there are many methods for image ROI segmentation, edge detection, and threshold-based segmentation methods mentioned in Section 3, and the specific process will not be discussed in this section, in addition to region-based segmentation methods which are also widely used in various technical fields of detection problems [19]. The principle of the edge detection-based image segmentation method is to segment the regions in the image by detecting the boundaries of different regions in the image; the algorithm is fast in detection and more accurate in edge localization, but this type of method can only detect a series of edge points, which cannot ensure the closure and continuity of the edges, so it is not a true sense of image segmentation; the threshold-based segmentation method is performed by setting a reasonable threshold value. The most commonly used is the single-threshold segmentation method, by setting a threshold to segment the image into only two major parts containing the target object and the

FIGURE 3: Optimal process optimization model selection process.
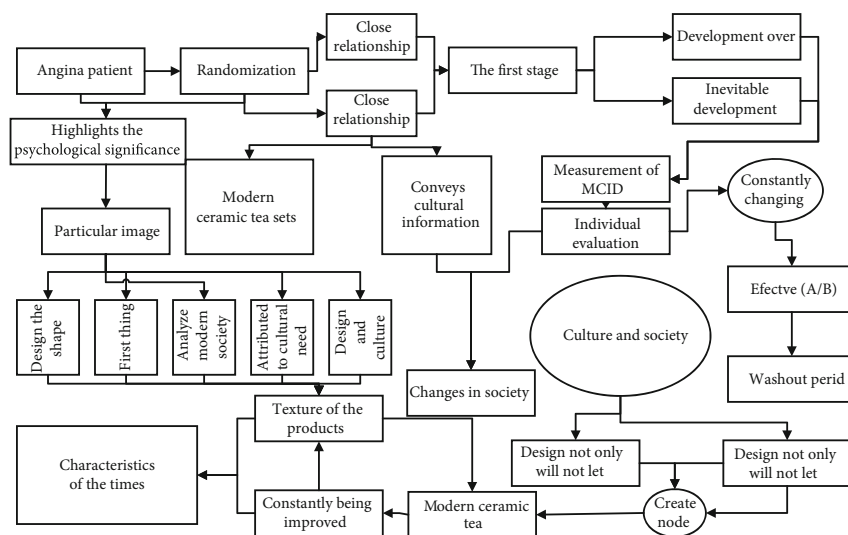
background, the principle of this algorithm is simple, the segmentation operation is easy, and the processing speed is faster, but the reasonable setting of the segmentation threshold has not been a universal solution, making the algorithm have some limitations, for the same piece of ancient object. For the ornaments on the same ancient ceramic object, the materials used, painting style, and other factors have a high degree of consistency, and the grayscale difference in the target region is not very large, so it is difficult to segment the ROI by the grayscale difference.

In this section, the characteristics of the shape profile curves of bottles from different periods are studied. According to the fractal formula, the extracted contour curves of similar forms of bottles from each period are stacked and summarized together for comparative analysis, and the results are summarized by observing the individuality and commonality among them. The extracted contour curves were stacked in the same coordinate system, and the actual height of each bottle was used as a reference standard to overlap the symmetry axis of each contour line, thus facilitating the comparison of the differences and similarities between the curves. In Figure 4, the contour curves are constructed by using the base diameter of the bottle as the horizontal coordinate and the height of the bottle as the vertical coordinate, and the stylistic characteristics of the bottles are analyzed through their contour and curve variations. It can be concluded that the curve changes of the AI type of porcelain bottles of the Qing dynasty show a certain pattern: the mouth modeling lines are flat and straight and curly, the necklines are also curved and straight, and the curved and straight changes form a sharp contrast; the mouth to the neck and waistlines are some of them in one go smooth and continuous curves, and some of them are bent and curved, which increases the sense of hierarchy in modeling design, and the lines are beautiful and rhythmic. Therefore, the design of the two energy harvesters has completely different characteristics. The vibration source of the vortex energy collector comes from the vortex street generated

when the fluid flows around the bluff body, so the vibration frequency of the device is mainly affected by the shedding frequency of the vortex street that occurs after the fluid flows around the bluff body.

Selecting a suitable classification model is a prerequisite for the accurate determination of ancient ceramics [20]. With the continuous development of pattern recognition systems, the variety of classifier models has become increasingly abundant, but each algorithm has its advantages and disadvantages and its scope of application; therefore, in practical applications, the specific analysis should be done for specific problems, and the selection of the most suitable classification model is essential to achieve accurate identification. Due to the influence of the equipment and the environment, the color of the image of the object is often distorted from the true color of the object, which also results in a great difficulty in color recognition. The plane is defined as the separating surface that maximizes the distance between the data on both sides, and since the closer the data to the hyperplane, the more likely it is to be misclassified, the correct separation of these data is the criterion to test whether the constructed hyperplane is reasonable, and when constructing the hyperplane, under the premise of ensuring that the data points can be accurately separated, it should also ensure that a certain functional distance is maintained between the hyperplane and all samples.

4. Analysis of Results

4.1. Visual Quantitative Feature Extraction Results. Due to the functional and aesthetic needs of ceramic tea sets, ceramic tea set design has produced a variety of forms, with practicality being the basic requirement of every ceramic vessel. Ceramic tea set design in the actual process is to meet people's needs for tea for daily use. With the enrichment of people's material life and the increase in aesthetic needs, correspondingly, there are utensils to meet various needs, there are utensils that meet the corresponding needs. The types of
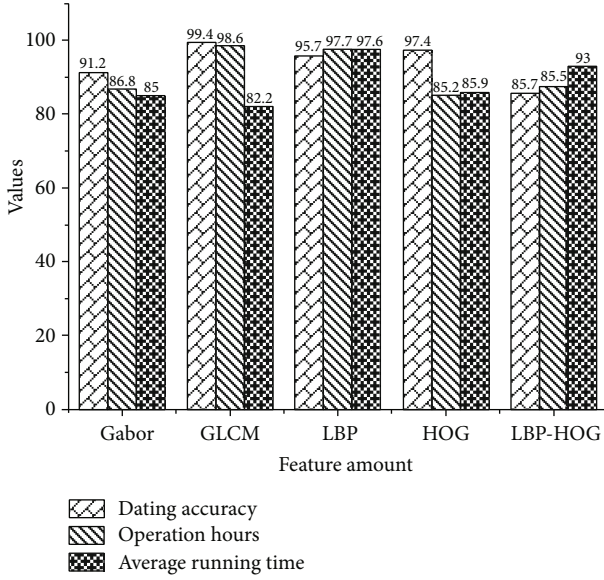
FIGURE 4: Feature extraction steps.

tea sets range from single to diversified, and the shapes range from simple to rich. A mature bionic ceramic tea set needs to be constructed with ingenious design and unique shape and function and has a certain sense of beauty. It should be noted that function is the basic attribute of the container, and its appearance is designed based on functional use criteria. When appreciating these exquisite ceramic tea sets, the function should be the main evaluation criterion, and abandoning this criterion and using the ceramic tea set only as an appreciation item will lose its functional attributes as an everyday utensil, as shown in Figure 5.

In addition to elegant decoration and stable and generous design, modern designers also pursue dynamics, geometry, and other fashionable elements. There are many teas on the market that have a modern streamlined taste, and futuristic and space-based designs have also been applied to ceramic tea sets. If a ceramic tea set is just a novel idea and the coordination of shape and function is not considered in use, it will only be counterproductive; the shape of the external shape should display the function of the set; for a variety of different functions of ceramic tea set, we should be able to see from the appearance of how to use; the appearance of the shape should be coordinated with the function, and only then can the role of ceramic tea set better play. Many accessories, such as hand-held handles, cover knobs, and spouts, should be considered in terms of both shape and function; therefore, the size and thickness of the accessories should be combined with the overall shape size and comfort, and the size gap will lead to an overall incongruity; if it is too thick, it will lack beauty; if it is too slim, the human hand cannot hold it and it is not convenient to use; therefore, in the design of ceramic tamper style, it cannot be mechanically copied. The function imposed on the shape

of the tea set is to consider the ease of use. If the shape of the ceramic tea set design and its functional utility cannot be coordinated, it will inevitably affect the use of the function and will also cause aesthetic defects. With the advancement of production technology, the various aspects of production are more scientifically controllable, the materials are more abundant, the temperature is more standardized and programmed, and the ceramic tea set can be mechanized and produced with more standardized and programmed features.

The changes in the form of each part of the porcelain are concentrated in the context of an era of change, reflecting the popular style and artistic taste of the times. The foot of the porcelain vase is mainly a circle foot, which can improve the actual height of the object but also visually increase the sense of atmosphere or slenderness. In the Qing dynasty, the flared ring foot was the main feature, and the foot evolved from a short ring foot to a flared foot, which not only reduced the risk of spilling liquids in the pouring process but also effectively improved the stability of the object. The process of change in the development of the foot reflects the changes in the craft techniques of the porcelain industry, with various structural forms of the foot rim contrasting with the porcelain mouth, and such changes and differences improve the rhythm and rhyme of the vessel type. In addition, from the physical point of view, the formation of the foot ring makes the porcelain and the contact surface produce a blocking space and can effectively play a thermal insulation and heat preservation, slowing down the rate of temperature reduction in the bottle, as shown in Table 2.

For different quantization parameters, as the JND threshold value gradually increases, the weight coefficient μ

Figure 5: Feature result statistics.

Table 2: Relationship between threshold values and weighting factors.

n	Porcelain vase	Ring foot
1	3	2.1
2	4.4	2.9
3	4	4
4	4.3	4.2
5	3.4	2.3
6	3.7	3.9

improve the perceptual coding performance of the image compared to a calculation method that takes 1 as a step.

4.2. Experimental Results of Visual Quantization Features. Through the mapping of the shape of ceramic bottles in the Qing dynasty, the following points are summarized: firstly, bottles were fired in all periods of the Qing dynasty; with the advancement of history, its shape is constantly changing, with continuous innovation and breakthroughs. Secondly, the overall shape of porcelain vases can be judged to be stable through the fractal atlas, and although the shape presents certain differences in the context of different eras, they all retain the original characteristics of the bottle. With the development of the history of the bottle porcelain ware type, new changes are constantly produced, through the different periods of this subtle changes which can be seen in the evolution of the bottle shape from a single gradually developed trend of diversity. The reason for the maturity of the shape development, on the one hand, thanks to the dynastic change in the inheritance of superb skills and innovative development, expressed in the shape of the profile is the curve from the early active fluctuations which gradually tend to stabilize and focus; on the one hand, with the help of the experience accumulated by the craftsmen and the accumulation of years of appreciation ability, it can be found that the overlap rate of the contour curves of some shapes and specifications close to the size in the middle and late stages is high. The aesthetics of each dynasty differed to some extent, and the typical wares produced were distinctive and had the marks of the times. In the long process of change, the contour curves converge, and the overall shape of the ware evolves from disorderly to traceable, from simple and rough to fresh patterns and small but refined ware, all of which reflect the rapid development of the porcelain industry from the side, as shown in Figure 6.

By comparing the default, lookup table, and preprocessing methods, the accuracy of the perceptual Lagrange multipliers determines the performance of the image encoding and illustrates the contradictory dichotomy between encoding performance and time loss. Invoking perceptual distortion adds no additional time loss; the added time loss all originates from the acquisition of the perceptual multipliers. The preprocessing method is the most time consuming, adding more than one-third of the coding time, but the perceptual coding performance is the best and is suitable for applications where the image quality is more important and the time loss is relatively unconcerned; the lookup table method adds 6% of the time loss and the performance of the image perceptual coding is improved more compared to that of the default method, while the time loss is sufficiently reduced compared to that of the preprocessing method to balance between time loss and coding performance.

From the analysis of the choice of perceptual models, the simultaneous citation of both models has better image perceptual coding performance than using only either model, and the improvement is very significant, which fully illustrates the good results achieved by the proposed method using both models to evaluate image perceptual distortion in the pixel domain in eliminating image visual redundancy

gradually decreases and the decreasing trend becomes smaller and smaller and finally tends to be parallel, and the transition from the curve to the parallel line is completed by an inflection point. The trend of the weighting coefficient μ is also easy to understand; an increase in the JND threshold value means that the tolerated pixel perceptual distortion becomes larger and the evaluated perceptual distortion value becomes smaller. For a defined quantization parameter, since the pixel distortion will exist in a certain range, there exists a point where all the distortions are tolerated as the JND threshold increases, and this point is the inflection point defined above, the exact value of which is estimated from the experimental data. Before the inflection point, some definite functional relationship should exist for the curve, although the paper does not verify the exact functional relationship. For various ceramic tea sets with different functions, we should be able to see how to use them from the appearance, and the appearance and shape should be coordinated with the functions. Only in this way can the ceramic tea sets play a better role and bring convenience to people's lives. If the functional relationship that exists can be estimated relatively accurately for the Chacocha threshold and the weight coefficients, the Lagrange multipliers needed for perceptual coding can be obtained more accurately and
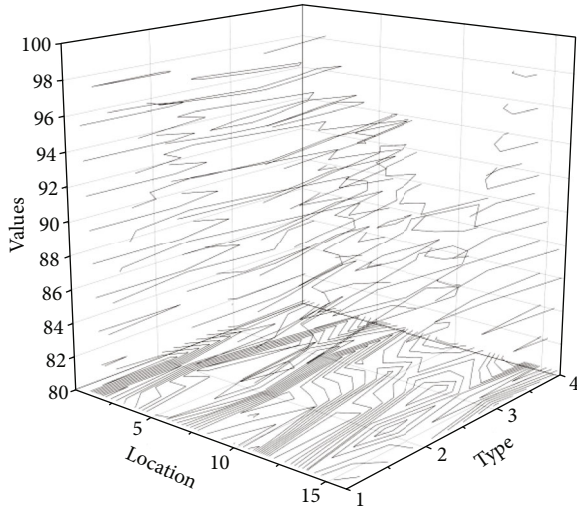
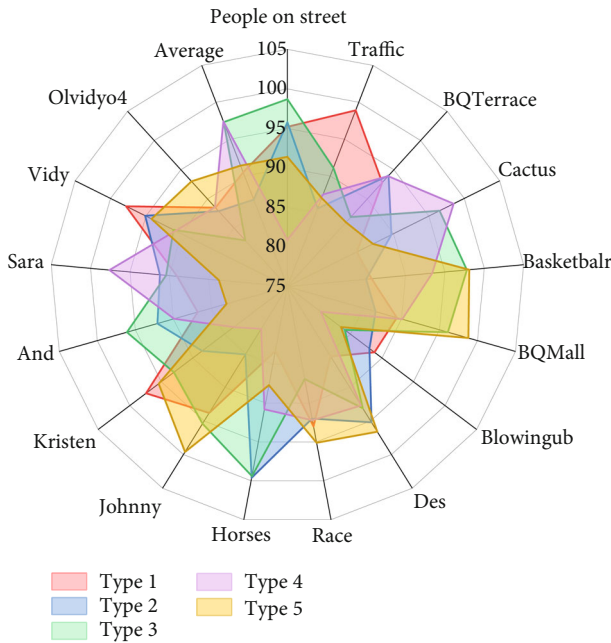Figure 6: BD-PCPSNR performance of the JND model.

Figure 7: Experimental results.

and is an effective way of perceptual coding; from the analysis of the method to obtain Lagrange multipliers, the default method also achieves some perceptual encoding performance in the model. The coding performance of the three Lagrange multipliers was compared with that of the model, and the perceptual multipliers are obtained using the recommended method; although the perceptual coding performance achieved in the model is still superior to that of the default method, the improvement is reduced compared to that in the model only, mainly because the model makes some of the perceptual distortion values zero, resulting in fewer operable pixel points in the model and a reduced weighting effect, as shown in Figure 7. It fully illustrates that the proposed method of using two models to evaluate image perception distortion in the pixel domain has achieved good

results in eliminating image visual redundancy and is an effective perceptual coding method; by analysis from the method of obtaining Lagrange multipliers, the default method also achieved certain perceptual coding performance in the model.

In summary, the experimental results can prove that the multifeature hierarchical fusion algorithm method in this paper can achieve the classification of the Yuan, Ming, and Qing dynasties of the jade pot spring vase with higher accuracy compared with various single feature quantity assertion methods commonly used at present, and the pattern of the evolution of the appearance features of the jade pot spring vase with the era can be obtained through the digital analysis of the ancient ceramic ornamentation and vessel-type feature quantity. In conclusion, the method in this paper has a strong reference value for the identification of ancient ceramics and can effectively assist in the manual identification of ancient ceramics.

5. Conclusion

In this paper, we study the data related to the bottle type of porcelain of the Qing dynasty and complete the preliminary summary of the measurement data of the external characteristics of the type. The correlation between the local value range and the corresponding function, the relationship between the local value and the overall value of the vessel type quantitatively analyzed, and the positive correlation between the ratio of the diameter and the height of the bottle and the development and evolution characteristics of the typical ware in each period are obtained, which help to make a reasonable definition of the quantity and size of the bottle type in the Qing dynasty. According to the morphological characteristics of Qing dynasty bottles, we can find the characteristic points according to the symmetry-demolition principle and quickly classify them and obtain the porcelain information. The bottles are coded in order, classified, and graded to determine the type category, the bottles are summarized in a table of characteristics to obtain the Qing dynasty bottle-type porcelain typology, and the porcelain form is scattered from disorderly to centralized and orderly, from various forms to gradually becoming regular, with standardized size and fixed standard range. The LBP-HOG fusion pattern and geometric parameters of ancient ceramics are extracted; finally, a GRNN model based on the particle swarm optimization algorithm is built as the classifier of ancient ceramics. To solve the problem of incomplete representation of image information by a single feature quantity, we designed an algorithm based on the hierarchical fusion of multiple visual features for the identification of ancient ceramics and used a feature fusion algorithm based on classification accuracy to complete the fusion decision of ornamentation and vessel shape features to achieve accurate identification of ancient ceramics. Finally, the algorithm simulation experiments are carried out for different amounts of ornamentation features, different feature categories, and different classification models on ancient ceramics, the accuracy and feasibility of this paper's algorithm are verified from the experimental results, and the development and

evolution of ceramics are further quantitatively interpreted through the analysis of digitized ornamentation and vessel-type features.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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