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Research on the intelligent analysis of double-stamp engraved symbols and the application of AI in product design

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Abstract The pottery carved symbols excavated from Shuangdun site carry the cultural information of 7300 years ago, and their digital inheritance and innovative application are of great significance. This paper adopted deep learning and computer vision technology, constructs an image brightness feature extraction model based on the principle of perceptron, and intelligently recognized and extracted features of Shuangdun Carved Symbols through convolution operation, Harris corner detection, SIFT and SURF algorithms. The study established a complete algorithmic process including luminance value conversion, feature enhancement, thresholding and inversion operations, realizing the automated analysis and processing of symbol images. The results show that the overall user satisfaction of cultural and creative products reaches 4.0581 points, with the highest satisfaction of 4.1993 points in the innovativeness dimension. The market research found that 71.6485% of consumers pay more attention to the beautiful symbolism of the products, 76.6485% of purchasers use the cultural and creative products for souvenir collection, and 52.3485% of respondents prefer the national trend style design. Through the deep integration of intelligent algorithms and traditional cultural symbols, a complete technical system was established, covering symbol analysis to product design, which provides a feasible technical solution for the digital inheritance and innovative development of Neolithic cultural heritage.

Index Terms Shuangdun Carved Symbols, image feature extraction, deep learning, cultural products, user satisfaction, digital heritage

I. Introduction

Shuangdun Carved Symbols date back approximately 7,300 to 7,100 years, making them among the earliest known carved symbols in China [1]. These symbols are a testament to the intellectual achievements of the Shuangdun ancestors and contain rich ancient cultural information [2]. Unlike other ancient decorative patterns, Shuangdun Carved Symbols are predominantly found on the external bases of these artifacts, rather than on the exposed parts such as the rims or necks of the vessels. The location of Shuangdun Carved Symbols on artifacts is relatively concealed, suggesting that their significance likely extends beyond mere decoration [3]. In the new era, with the application of artificial intelligence in design gradually mature, the use of intelligent methods to analyze the Shuangdun Carved Symbols and their application in product design is an important form of protection and inheritance of traditional culture [4], [5].

In traditional design, designers need to collect a large amount of information from the market and user needs, and through experience and reflection, come up with innovative design solutions [6]. However, artificial intelligence (AI) can better help designers realize these tasks [7]. First, AI can effectively manage market and user information and analyze user needs and preferences from big data [8]. Based on user behavior and interest models, AI can provide more accurate user experience design [9]. Second, AI can interact with users using natural language processing and generative dialog technologies to quickly understand user needs [10]. This enables designers to understand directly from users during the design process, which is closer to actual user needs [11]. In addition, AI can assist designers to realize some repetitive work or search for information [12]. All of this can greatly improve the design efficiency and liberate the designer's time [13]. In the Shuangdun Carved Symbols analysis and product design, the computational method based on artificial intelligence realizes the integration of the application of Shuangdun Carved Symbols analysis and product design through the creation of symbol digitization, intelligent analysis, and design transformation.

This paper takes the pottery incised symbols excavated from the Shuangdun site as the research object, and adopts a multilevel and interdisciplinary research strategy. Specifically, firstly, the cultural connotation and artistic characteristics of Shuangdun Carved Symbols are deeply analyzed through archaeological methods, and the symbol classification system and cultural interpretation framework are established. Secondly, computer vision technology is used to construct an intelligent feature extraction model, including image pre-processing, feature point detection, descriptor generation and other key links, to realize the automated analysis and processing of symbol images. Then, based on the extracted symbolic features, we design and develop series of cultural and creative products to explore the application mode of traditional cultural symbols in modern design. Finally, the design effect is verified through market research and user feedback, and the feasibility and practicability of the technical program is evaluated, forming a complete closed loop from theoretical research to practical application.

II. Shuangdun Site Excavation and Pottery Carved Symbols Connotation Analysis

II. A.Excavations at Shuangdun Site

The Shuangdun site was discovered in November 1985 by staff from the Bengbu Museum during a national cultural relics survey. Based on collected specimens such as stone axes and pottery, it is identified as a Neolithic site in the middle reaches of the Huaihe River. Located on the northern side of Shuangdun Village in Bengbu City, Anhui Province, it lies 3.5 kilometers south of the Huaihe River and dates back approximately 7,300 years.The site is narrow in the north and wide in the south, with a core area of about 12,000 square meters. The Anhui Provincial Institute of Cultural Relics and Archaeology conducted three excavations at the Shuangdun site in 1985, 1991, and 1992. In 1986, villagers leveling land southeast of the site uncovered numerous pottery fragments and animal bones, prompting the Bengbu Museum to carry out salvage excavations. Three test pits (each 5 m × 5 m) were dug, revealing thick cultural layers rich in artifacts, some resembling those from Houjiazhai.

Subsequent excavations occurred in 1991 and 1992. The 1991 excavation involved laying out four pits (each 5 m × 5 m) near the 1986 test area, totaling 100 square meters. The 1992 excavation expanded east and south, adding eight pits. From 1986 to 1992, three excavation phases focused on a concave groove in the southeastern terrace, uncovering 15 pits (375 m² total) and yielding pottery fragments, stone tools, bone artifacts, and shells.

In 2014, to further explore the Shuangdun culture's broader significance, the Anhui team from the Institute of Archaeology (Chinese Academy of Social Sciences) conducted a fourth excavation. They uncovered an area exceeding 1,000 square meters, discovering artificial earthen platforms and multiple ash pits in the eastern sector

II. B.Analysis of the Connotation of Pottery Carved Symbols at Shuangdun Site

II. B. 1) Shuangdun Carved Symbols incision method

Shuangdun Carved Symbols are rich in meaning and wide in variety, containing both realistic pictorial carvings and simple geometric configurations, as well as combinations of the two. They exhibit strong narrative characteristics, with fish, pig, and four-petal-flower motifs being the most representative. The carvings are exquisitely crafted.Examined from their carriers, these symbols are primarily carved on pottery, mostly on the exterior base of bowls, with a few on the outer foot of dou vessels. Some bowl exteriors feature 2–4 radial grooves that cut through the red ceramic coating, indicating these grooves were carved after the coating was applied or during use to convey meaning [14].

From the carving methods, the lines and forms are standardized and smooth, demonstrating skilled techniques. Most symbols were carved into the unfired clay as intaglio designs (Yinwen), with deep, clear marks. A few shallow grooves cut through the artifact's glaze, suggesting they were added post-firing. Additionally, a small number appear to use "reduced-ground relief carving" or fine-clay appliqué trimmed with tools to create raised designs (Yangwen) on unfired vessels.

II. B. 2) Classification of Shuangdun Carved symbols

The visual representation of Shuangdun Carved Symbols is highly complex, they can be classified in various ways. The first scholar to classify the Shuangdun Carved Symbols was Mr. Xu Dali. In 1987, Mr. Xu sorted out the pottery carved symbols unearthed in the 1980s at the Bengbu site and divided them into four categories: animal, plant, single symbol and combined symbol (Niu,2013). This classification method generally grasps the shape characteristics of the Shuangdun Carved Symbols, but due to different classification standards, the symbols of each group overlap.

Based on the traditional Chinese “Liu Shu” theory, Mr. Ge Yinghui divided the Shuangdun Carved Symbols into three categories: symbols of objects, symbols of events, and other symbols (those with unknown meanings are also included in this category). Symbols of objects are divided into animals, artificial objects, buildings, natural objects, counting tools, etc; symbols of events are divided into tool-shaped symbols, tool-shaped compound symbols, etc.

In 2013, Dr. Niu Qingbo categorized Shuangdun Carved Symbols based on previous research, specifically following the work of Mr. Xu Dali and Mr. Ge Huiying. Using cases with rubbings or tracings, conducted the most comprehensive and systematic classification of Shuangdun Carved Symbols to date. A total of 559 symbols were categorized into pictorial, geometric, and other categories. The "other" category includes symbols that are composite symbols formed by combining pictorial and geometric elements, as well as symbols that are fragmented and cannot be reconstructed based on their form.

II. C. Shuangdun carved symbols of cultural and creative product design

II. C. 1) Shuangdun carved symbols design principles

(1) Artistic aesthetic principles

With the improvement of people's living standards, there is an increasing pursuit of expressive and aesthetically pleasing imagery. Whether it pertains to social beauty, natural beauty, or artistic beauty, beauty must manifest as a concrete sensory existence - an objective reality that can be directly perceived, where content and form combine to create a specific beautiful image. This realization requires specific material elements like lines and colors, and structural methods that compose perceptual forms, thereby creating a distinct visual representation.As unique visual symbols representing traditional culture, the Shuangdun Carved Symbols need to maximize their aesthetic characteristics through artistic design techniques when presented to the public, demonstrating their inherent aesthetic value.

Principle of pattern transformation

In designing the Shuangdun Carved Symbols, we must consider not only aesthetic principles in extracting visual elements but also innovative approaches to artistic creation. As society progresses, people increasingly desire novel and interesting modern products to enrich their lives. Therefore, innovative thinking should permeate the entire cultural creative product design process.

This study applies pattern transformation principles to various types of Shuangdun Carved Symbols, creating new symbolic imagery with contemporary art design styles to better preserve and develop their cultural significance.

II. C. 2) Design of the base pattern of the Shuangdun carved symbols

(1) Basic Pattern Design

The most representative cultural relics unearthed from the Shuangdun culture site is the pottery sculpture of human head. The pottery sculpture of human head has a history of more than 7300 years, and it is the earliest sculpture of human face unearthed in China so far, which has very important research value. The pottery sculpture is pure, refined and natural, and it expresses the spiritual temperament of the characters in a realistic and realistic way. Compared with the known Neolithic pottery figures in China, it represents the highest level of that era and has a milestone status in the history of Chinese sculpture.

(2) Shuangdun Cultural Site Logo Design

In the logo design of Shuangdun culture, the three visual elements of font design, pattern design and color design are comprehensively designed.

First, in the font design, the most direct word “Shuangdun” is chosen as the main part of the logo design. In the design process, the historical factors of Shuangdun culture are fully considered, as an important part of the early civilization of the Huaihe River Basin, the two characters of “Shuangdun” are used as the basis of the seal script in the design, and then in the AI software, it is used as the bottom text, and the skeleton of the font is built using the pen tool, and the fonts are reassembled, and the framework is built using rounded lines. After the framework is built, it is processed by using rounded lines and rounded corners design [15]. The final design has the visual effect of “Shuangdun” two words, showing the most intuitive visual perception of Shuangdun culture. The two words “Shuangdun” are arranged in the order of up and down, with equal proportions, indicating that in the long history and culture, the Shuangdun culture continues the development of the early civilization of the Huaihe River Basin.

Secondly, in the design of the pattern, the most representative “water pattern” symbol is used in the symbols of Shuangdun. By choosing a “water pattern”, extracting the lines in AI and expressing them concisely, it implies that water in the Huaihe River basin plays a vital role in the life of the primitive ancestors, and that without water, there would not be any culture. At the same time, it also expresses that in the process of historical development, the Shuangdun culture still stands in the long river of history and culture, and never breaks the flow. The design of the external round frame signifies the bottom outer contour of the unearthed pottery, without which there would be no complete presentation of the engraved symbols without these pottery as the material carrier of the Shuangdun engraved symbols.

Thirdly, in the color design, red is chosen as the bottom color, red symbolizes passion, indicating that Shuangdun culture is still as hot and vibrant as a flame in the new era. At the same time, it also expresses the vigorous development of cultural and creative industries in Bengbu, which is bound to have a better tomorrow.

III. Intelligent feature image design based on pottery incised symbols

III. A. Image characteristics of pottery incised symbols

This period of pottery incised symbols are mostly incised, pressed and scratched on the surface of the pottery to form groove lines, and most of the scratches are thicker, simple lines, combined as a single or combined symbols. Such as the intersection of straight lines combined as a cross, reverse arcs cross the formation of fish, single, back or phase to arcs repeated to form a water pattern shape, arcs and straight lines intersected by a combination of half-frame shape and so on. There are also some prototypes of Chinese characters in the engraved symbols, such as the number of characters, the "field" character, the "human" character, and so on. In addition, these symbols also have a certain degree of internal regularity. Among them, the more common ones are geometrical and hieroglyphic symbols.

III. B. Pottery incised symbols intelligent feature graphic design practice process

Extracting the image features of pottery incised symbols and applying them to the graphical interface design of smart products is an innovative research that applies traditional graphic arts to the field of artificial intelligence. Based on the existing convolutional operation and image feature extraction methods, the image brightness features of pottery engraved symbols are extracted and applied to the graphical interface design and display of intelligent products.

III. C. Image Feature Extraction in Intelligent Information Environment

III. C. 1) Principles of Image Feature Extraction

The perceptron recognizes, extracts and classifies graphic features by judging the input information, and Fig. 1 shows the principle of the perceptron. Its judgment method is as follows: the feature values extracted from the original image, such as brightness, pixel intensity, contour, etc., are used as the input layer information, and a weighted sum is obtained, which is used as the basis for feature recognition and judgment. The application of convolutional operation in image processing, which also uses perceptron as the basic principle, can realize intelligent operation and processing of graphic images. Using convolutional operation to extract image features, first set the appropriate size and features of the convolution kernel, that is, the filter matrix, the original image pixel matrix into the operation model, after the convolution kernel in the original image pixel matrix "move" (unit move spacing for the step) in the process of each weighted sum of the judgment, to achieve the extraction of image features. The extraction of image features is realized. In this study, the image storage mode is converted into a brightness value matrix, and after a series of enhancement and simplification processes, it is input into the convolutional operation model to realize the extraction of image brightness features, which greatly simplifies the process of image feature extraction.

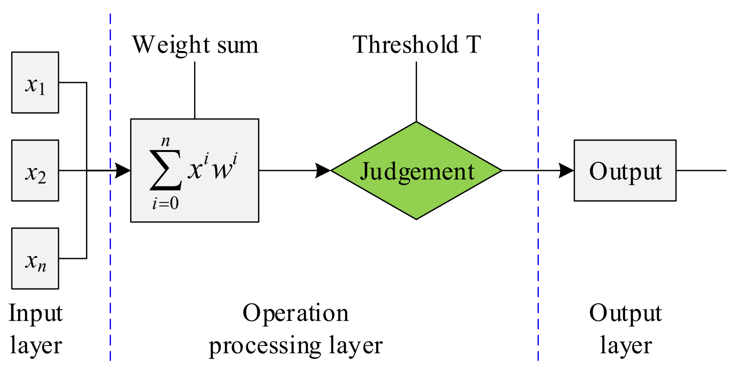

Figure 1: Perceptron principle

III. C. 2) Model of image feature extraction algorithm

Since pottery incised symbols are mostly shaped in the form of forming line grooves by pressing and incising, there exists a significant luminance difference between its incised line part and the surrounding image, and the luminance feature shows the line feature of the image to a large extent. In this paper, based on the perceptron principle and convolutional operation method, we construct image brightness feature extraction model and use it for batch extraction of sample image features. In order to maximize the image brightness features, the image feature extraction process is simplified and the accuracy is improved. Before applying the convolutional operation to image feature extraction of pottery engraved symbols, a series of luminance feature processing, such as luminance mode conversion, luminance enhancement, thresholding, inversion operation, etc., are required. The algorithm model of image feature extraction is divided into the following steps:

(1) Convert the image storage mode from color value matrix to luminance value matrix using equation (1):

$$I = \frac{r+g+b}{3} \tag{1}$$

where r, g, b are the input image pixel point color values and I is the luminance value.

(2) Enhancement of image luminance features:

$$I_0 = I * k \tag{2}$$

where k is the enhancement coefficient and I_0 is the enhanced brightness value.

(3) Image brightness thresholding, judgment conditions and processing methods are:

$$dst(x,y) = \begin{cases} \max val & if\ src(x,y) > T_0 \\ 0 & otherwise \end{cases} \tag{3}$$

When the luminance value at pixel (x, y) is greater than the threshold value, the maximum value is taken, otherwise the luminance value is 0. The thresholding process realizes the binary conversion of the image and highlights the image luminance characteristics. Take a horizontal line-shaped engraved symbol as an example, the result after luminance value conversion, luminance enhancement $(k = 4)$, luminance thresholding $(\max val = 255, T_0 = 128)$.

(4) Remove discrete points: Use the `remove_small_objects() method to remove discrete points in the image, and control the size of the removed discrete points by setting the connectivity domain area threshold T_a, and the processing result at $T_a = 25$.

(5) Inversion operation:

$$I_1 = 255 - I_0 \tag{4}$$

I_1 is the luminance value matrix after the inversion operation. The inverse luminance feature map is obtained so that the inscribed lines are at high luminance values for further image luminance feature extraction.

(6) Use the inverted luminance feature salient map output from the previous operation as the input image for image feature extraction using the convolution operation, which can be expressed as:

$$S = f(I \Delta K + b) \tag{5}$$

where f represents the activation function, I is the image luminance matrix, K is the convolution kernel, Δ represents the convolution operation and b is the bias value. Sobel convolution kernel is used here, and the size of the convolution kernel is 3×3, Gx and Gy indicate the size of the horizontal and vertical directions, respectively. Since the image features after the luminance feature processing are more significant, a convolution operation can be used to find more accurate feature vectors.

The Gx and Gy convolution kernels are used to do the convolution operation on the image, and each element of the resulting matrix is added with the bias value and then input into the activation function to get a new matrix, and the Sigmoid function is used here:

$$f(x) = \frac{1}{1+e^{-x}} \tag{6}$$

The luminance value matrix of the input image, the matrix obtained by convolution operation is the feature vector, which can be directly displayed as the feature map in python environment. According to the output results of the feature map, the size and position of the feature map are more accurate when the bias value is $b = 0.2$. Since the input image is displayed in black and white binarization after brightness processing, the feature vectors obtained by convolution operation are also more obvious.

To summarize the above image brightness feature processing methods and extraction algorithms, Figure 2 shows the image brightness feature extraction model. The sample image is input into the model, a series of luminance feature processing, and then through the convolution operation to obtain the image luminance feature vector, the output is the luminance feature map. The model is also fine-tuned according to the test results to obtain a computational model that is most suitable for this study.

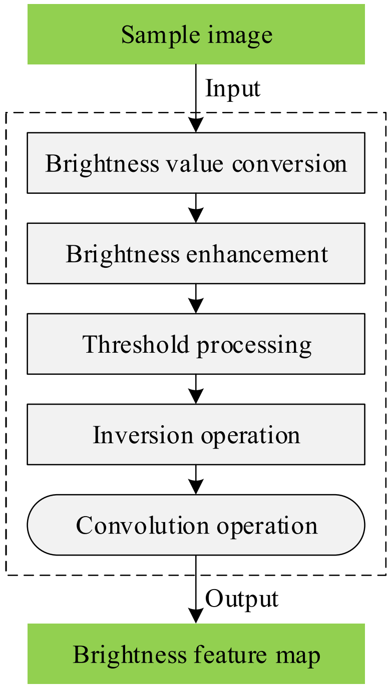

Figure 2: Image brightness feature extraction model

III. D. Shuangdun Carved product features graphic design

III. D. 1) Image feature point extraction

Feature extraction and matching is an important direction in the development of visual navigation, which combines knowledge from several disciplines. Image features can generally be divided into three categories from a structural point of view: point features, line features, and surface features (also called area features).

III. D. 2) Harris corner point detection methods

In the process of production, Harris corner detection is the most used a feature point detection method, because this method has a certain degree of rotation, light invariance, that is to say, for the two pictures of the scene does not change much, the picture of the same place in the algorithm to extract the number and location of feature points close to the number and location of the algorithm. At present, many domestic and foreign process applications use Harris corner detection method to extract feature points, which shows the importance of the method.

The idea of Harris corner detection is to use the nature of the local autocorrelation function of the image. The image local autocorrelation function can be started from the definition, then its autocorrelation function is shown in equation (7):

$$E = \sum_{w_{u,v}} \left(I_{u+\Delta x, v+\Delta y} - I_{u,v} \right)^2 \tag{7}$$

where $(\Delta x, \Delta y)$ is the image point offset and (u, v) denotes the point coordinates.

It is then expressed in the form of a first order derivative by Taylor series expansion:

$$I_{u+\Delta x, v+\Delta y} \approx I_{u,v} + \left(\frac{\partial I_{u,v}}{\partial x} \Delta x + \frac{\partial I_{u,v}}{\partial y} \Delta y \right) \tag{8}$$

Substituting (8) into (7) yields the following equation:

$$\begin{aligned} E &= [\Delta x \ \Delta y] \begin{bmatrix} \sum_w \frac{\partial I_{u,v}^2}{\partial x} & \sum_w \frac{\partial I_{u,v}}{\partial x}\frac{\partial I_{u,v}}{\partial y} \\ \sum_w \frac{\partial I_{u,v}}{\partial y}\frac{\partial I_{u,v}}{\partial x} & \sum_w \frac{\partial I_{u,v}^2}{\partial y} \end{bmatrix} \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix} \\ &= [\Delta x \ \Delta y] M \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix} \end{aligned} \tag{9}$$

III. D. 3) SIFT feature point extraction algorithm

Sift algorithm for image feature point extraction can be summarized in two major processes, the first process is the detection and extraction of feature points and the second process is the description of the detected and extracted points.

Process (1) includes constructing a Gaussian difference space image and locating the feature extreme points.

Process (2) includes determining the main direction of the feature point and generating the descriptor of the feature point, thus completing the feature point extraction algorithm. Each of these four steps is described below.

Step 1: Construct Gaussian Difference Space Image

The feature points on the object should be able to be repeatedly labeled in multiple viewpoints, which involves the scale space of the image, and the algorithm requires the ability to traverse the entire image scale space to find stable feature points. Let the input image is $I(x,y)$, Gaussian function is $G(x,y,\sigma)$, then the scale space of the image can be obtained by the convolution of the Gaussian function and the input image:

$$L(x,y,\sigma) = G(x,y,\sigma) * I(x,y) \tag{10}$$

Then the corresponding differential Gaussian image (DOG) is:

$$\begin{aligned} D(x,y,\sigma) &= [G(x,y,k\sigma) - G(x,y,\sigma)] * I(x,y) \\ &= L(x,y,k\sigma) - L(x,y,\sigma) \end{aligned} \tag{11}$$

where σ is the scale of the image and k is a constant factor. The reason for choosing Gaussian function is because Gaussian function has linear kernel for scale variation.

Step 2: Locate the extreme value point of the feature

Here, the search for the extreme value points is divided into two steps, the first step is to find the very large and very small value points, and the second step is to locate the extreme value points precisely.

To find the extremely small value points, each pixel point is compared with the other 8 pixel points in the neighborhood of the image it is located in and the 9 pixel points in the corresponding positions of the upper and lower two images in the scale space where it is located, a total of 26 pixel points, and the largest or the smallest point is temporarily recorded as the feature point.

After the initial search can only find the feature points to be selected, but the low contrast points and edge response points are easily affected by changes in light intensity, so to filter out these unstable factors, the Sift algorithm uses a Taylor series to find the sub-pixel level feature points.

Taylor expansion of the scale space equation $D(x,y,\sigma)$ to a quadratic term:

$$D(x) = D + \frac{\partial D^T}{\partial x} x + \frac{1}{2} x^T \frac{\partial^2 D}{\partial x^2} x \tag{12}$$

Let the above equation take zero partial derivation and find the position x_0 when taking the extreme value:

$$x_0 = -\frac{\partial^2 D^{-1}}{\partial x^2} \frac{\partial D}{\partial x} \tag{13}$$

Parameter $D(x_0)$ is effective in removing unstable extreme points:

$$D(x_0) = D + \frac{1}{2} \frac{\partial D^T}{\partial x} x_0 \tag{14}$$

When $|D(x_0)|$ is less than a set threshold it is considered that the contrast is low, then the point is removed.

Step 3: Select the main direction of feature points

The location of the feature points is determined, but it is necessary to make the feature points different from each other. The main direction of the feature points is the mark of mutual distinction between the feature points, which also makes the feature points have rotation without deformation.

A region is selected near the feature point and a histogram of directions with 36 bins is counted for the region, the direction with the largest bin in the histogram is taken as the primary direction of the point, and the direction with a bin greater than 80% of the primary direction is taken as the secondary direction of the feature point. In this way, each feature point has one primary direction and multiple secondary directions.

Step 4: Construct feature point descriptor

First of all, take the main direction of the feature point as the positive direction of the horizontal axis to establish the coordinate axis, in order to ensure the rotational invariance of the feature point. Take the feature point as the center and select the 8*8 neighborhood as the sampling window to get the 8-direction histogram, and finally get the 4*4*8 128-dimensional feature descriptor.

III. D. 4) SURF feature point extraction algorithm

Surf feature is an image local feature based on scale space, which has good invariance to translation, rotation, scaling, and so on, and also maintains a certain degree of stability to lighting changes and affine transformations. Sift algorithm was mentioned earlier, and the performance of Sift algorithm is also relatively stable, but its computational complexity is high and time-consuming. Later, many scholars have optimized and improved it, and one of the more famous ones is the Surf algorithm.

Because Surf algorithm is improved on the basis of Sift algorithm, Surf algorithm feature extraction is also divided into two processes, i.e., feature point detection and feature point description, in which feature point detection is divided into two steps: constructing the Gaussian pyramid scale space, and determining the extreme value points. The feature point description is divided into two steps: determining the main direction of the feature point and generating the feature point descriptor.

These four steps are described below.

Step 1: Construct Gaussian pyramid scale space

The Surf algorithm uses a Hessian matrix determinant approximation of the image. Where the Hessian matrix of a pixel point in the image is as follows:

$$H(f(x,y)) = \begin{bmatrix} \frac{\partial^2 f}{\partial x^2} & \frac{\partial^2 f}{\partial x \partial y} \\ \frac{\partial^2 f}{\partial x \partial y} & \frac{\partial^2 f}{\partial y^2} \end{bmatrix} \tag{15}$$

The Hessian matrix after Gaussian filtering is as follows:

$$H(x,\sigma) = \begin{bmatrix} L_{xx}(x,\sigma) & L_{xy}(x,\sigma) \\ L_{xy}(x,\sigma) & L_{yy}(x,\sigma) \end{bmatrix} \tag{16}$$

The Hessian matrix determinant is approximated by the following determinant approximation formula:

$$\det(H_{approx}) = D_{xx}D_{yy} - (0.9D_{xy})^2 \tag{17}$$

Step 2: Feature point localization

The process of feature point localization Surf and Sift keep the same, each pixel point is compared with the other 8 pixel points in the neighborhood of that image where it is located and the other 9 pixel points in the corresponding positions of the upper and lower two images of the scale space where it is located, a total of 26 pixel points, and the largest or smallest point is temporarily remembered as a feature point, Fig. 3 is the localization of the feature point.

Step 3: Determination of the main direction of the feature point

The main direction of the Surf feature point is to calculate the Hal response in the circular neighborhood of each feature point, and then count the sum of the Hal response in the horizontal and vertical directions in the 60° sector, and then traverse the entire circular region with 0.2 rad radius each time. The direction of the sector with the largest Haar response in the traversal process is taken as the main direction of the feature point. Fig. 4 shows the schematic of determining the main direction of the feature point.

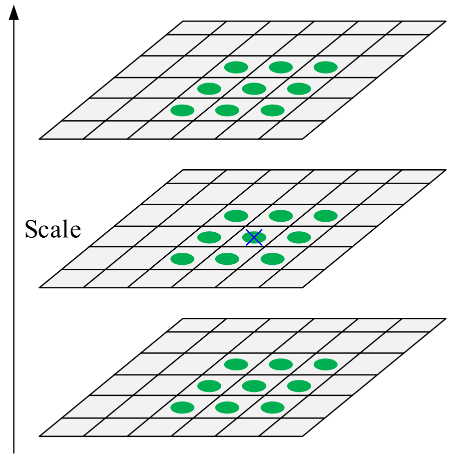

Figure 3: Feature point location

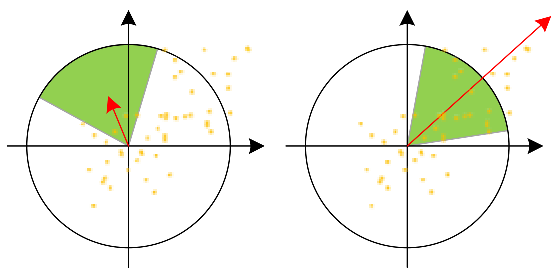

Figure 4: Indication of the determination of the main direction of the feature point

Step 4: Descriptor Generation

The descriptor generation for Surf feature points is done by creating a small region of $4*4$ around each feature point with each feature point as the center, and calculating the haar response of 25 pixel points in each small region, with the directions including horizontal and vertical directions. This response is the sum of the horizontal direction, the sum of the vertical direction, the sum of the absolute value of the horizontal direction, and the sum of the absolute value of the vertical direction, totaling 4 directions. So the Surf feature is $4*4*4=64$ dimensional.

IV. Shuangdun Carved Symbols of cultural and creative products case study

IV. A. Carved Symbols cultural and creative products case design positioning

IV. A. 1) Cultural Creative Products Market Research

Figure 5 shows the revenue growth rate of cultural and creative industries in 2020. Under the trend of deep integration of the development of cultural industries with the national economy, the 13th Five-Year Plan for the Development of National Strategic Emerging Industries puts the development of digital creative industries and new-generation information technology, high-end manufacturing, biology, green and low-carbon industries as the core of the plan. Connotation. It is expected that by 2023, the scale of cultural industry related to digital creative industry will reach 13 trillion yuan(. Driven by the concept of “culture plus”, the development of cultural industry is highly integrated with related industries, and different industries of local economy have shown good effects of spillover and permeability, making cultural industry become a new economic growth point that promotes the development of China's national economy and the upgrading and transformation of industrial structure.

Among them, the industrial revenue growth rate of cultural information transmission service is the highest, reaching 32.7985%, and the industrial revenue growth rates of cultural leisure and entertainment services, cultural and artistic services, cultural and creative products production, arts and crafts industry and auxiliary production of cultural and creative products production are 16.8196%, 14.7045%, 13.2485%, 10.5265% and 10.0485% respectively. .

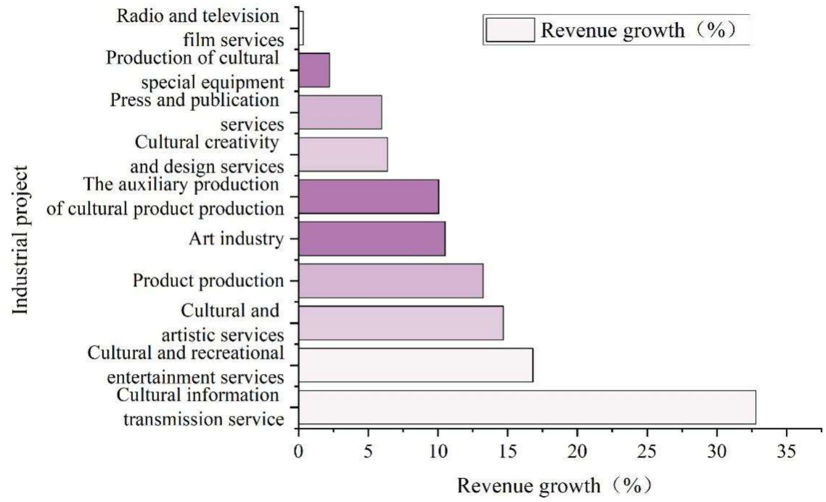

Figure 5: The growth rate of the related industries in 2020

As shown in Table 1, the five provinces of Beijing, Shanghai, Guangdong, Jiangsu and Zhejiang, which are the frontiers of China's cultural industry development, have all shown favorable trends in their cultural industry development during the period from 2019 to 2023.

The development of China's cultural and creative industries has the following advantages. The first is the market advantage. With the rapid development of China's economy, the disposable income of the residents is rapidly increasing and the demand for cultural and creative products is also increasing. China's market space with a huge population base gives China's cultural and creative products market an absolute advantage. The second is the advantage of profound cultural tradition. China's 5,000 years of civilization has precipitated a cultural heritage that includes a large number of cultural relics and monuments, historical sites, intangible cultural heritage, ethnic traditions, folk customs, etc., which provide a large amount of creative materials for cultural and creative products. The third is the carrier advantage. With the further deepening of the reform of China's market economic system, the traditional industries in the old cities around the world have completed the industrial transfer, and a large number of industrial zones with strong historical characteristics have been left behind, which have become important bases for the development of the city's cultural and creative industries.

Meanwhile, the value added of cultural and creative industries in each province has been increasing with each passing year, with Beijing, Guangdong, Jiangsu, and Zhejiang increasing by 62.3857%, 57.2648%, 56.106%, and 104.9665%, respectively, from 2019 to 2023.

Table 1: The development of Cultural and creative industry in five provinces and cities

/	Year	2019	2020	2021	2022	2023
Beijing	Cultural and creative industry added value (100 million yuan)	2185.2587	2408.9845	2795.4685	3084.3485	3548.5485
	Proportion in GDP(%)	12.3854	/	13.1488	13.4856	14.3485
Shanghai	Cultural and creative industry added value (100 million yuan)	2267.9485	2565.4856	2833.0485	3021.4869	/
	Proportion in GDP(%)	11.2969	11.5459	8.9485	12.1485	/
Guangdong	Cultural and creative industry added value (100 million yuan)	2706.5485	3015.4865	3551.4285	3648.9685	4256.4485
	Proportion in GDP(%)	4.7485	4.8684	5.2485	5.0485	5.2648
Jiangsu	Cultural and creative industry added value (100 million yuan)	2232.4584	2705.8985	3013	3148.3455	3485
	Proportion in GDP(%)	4.3495	5	/	4.9485	/
Zhejiang	Cultural and creative industry added value (100 million yuan)	1583.1858	1880.4869	2184.8845	2493.4485	3245
	Proportion in GDP(%)	4.4648	5	5.4985	5.8598	5.8547

IV. A. 2) Cultural orientation

Table 2 shows the statistical results of purchase factors and purposes, 71.6485% of the respondents in the purchase of Shuangdun carved cultural and creative products are more inclined to the product contains a beautiful symbolism, 55.4185% of the people pay more attention to the cultural connotation of the product, which indicates that the purchase of Shuangdun carved cultural and creative products in the minds of most consumers is not just an item, its symbolic significance and cultural significance in the minds of consumers occupy an important position, and more than 80% of the respondents know more about the traditional Shuangdun carving. This shows that although most people are more interested in traditional Chinese culture, but the understanding of regional traditional culture is still relatively lacking, it can be seen that the development of cultural and creative products is absolutely necessary, not only to help protect the regional traditional culture, but also to help enrich the supply of cultural and creative products, to provide consumers with more choices.

More than 75% of the buyers buy cultural and creative products for memorial memorial collection of cultural. Creative products are the combination of traditional cultural elements and modern design products, which not only have practical and artistic value, but also carry a rich historical and cultural connotation.

“Non-heritage” has been regarded as a valuable source of inspiration for cultural and creative industries, and vice versa. The creative industry also provides a broad space for the inheritance and development of “non-heritage”. The combination of these two is inevitable and scientific and reasonable. The combination of these two is inevitable and scientific, and such a combination will not only give the cultural and creative products a “sense of responsibility” for cultural heritage, but also stimulates the consumers' deep sense of cultural heritage. “Sense of mission”, designed in line with the Shuangdun carved regional traditional culture visual symbols, can not only expand the Shuangdun carved intangible cultural heritage of the dissemination of the scope and influence, but also substantially support the protection of intangible cultural heritage, which further stimulates the public to the intangible cultural heritage of the conscious awareness of protection.

Table 2: Purchase factors and purpose statistics

Purchase factor	Proportion
Moderate price	43.3485
Beauty	49.5485
Functionality	53.3485
Good meaning	71.6485
Cultural connotation	55.4185
Collection value	40.0488
Unique ideas	29.5458
Other	2.5498
Purchase purpose	Proportion
Memorial collection	76.6485
Gift	57.9696
Practicality	44.5365
Other	1.6485

IV. B. Cultural and Creative Products

IV. B. 1) Factors Influencing Purchasing Desire

Table 3 shows the influencing factors of respondents' purchase of cultural and creative products. Among the types of cultural and creative products, stationery and daily necessities are very popular, occupying 52.9485% and 51.3485% respectively, which indicates that Shuangdun carving buyers are more inclined to purchase cultural and creative products closely related to daily life. Their purchasing choices are both practical and cultural connotations related. Meanwhile, their intention in purchasing apparel and accessories is close to the rear, accounting for 46.6485%. Among the styles of cultural and creative products, the China Chic product style tops the list with 52.3485%, which shows the rise and popularity of the national tide culture in recent years, while the retro style and simple fashion style are also favored by nearly half of the interviewees, and in addition, the secondary yuan style has an audience of 39.7498%, indicating the influence of the animation culture among the young groups. In the price of cultural and creative products, most respondents preferred to choose cultural and creative products with a price of 50 to 100 yuan, accounting for 44.7485%, indicating that cost-effectiveness is an important factor for consumers to consider.

Table 3: The respondents bought the influence factors of the product

Variable	Options	Proportion
Type of cultural product	Stationery office	52.9485
	Dress accessories	46.6485
	Digital electronics	37.7858
	cosmetics	29.1658
	Food class	34.4856
	Life goods	51.3485
	Other	4.6485
Style of cultural and creative products	Vintage	49.6488
	Cute cartoon	31.4858
	Monster wind	26.1485
	Two-dimension cultural products	39.7498
	China Chic Products	52.3485
	Contracted fashion	40.7848
	Other	2.6485
Price	Below 50 yuan	30.1485
	50 ~ 100 yuan	44.7485
	100 ~ 500 yuan	18.8485
	Above 500 yuan	6.2545

IV. B. 2) Analysis of observations and recommendations

Table 4 shows the opinions and suggestions of the respondents, most of the respondents think that the main problems faced by the current Shuangdun carved cultural and creative products are creative varieties of cultural and creative single, homogenization is serious, accounting for 72.6667% of the proportion, in addition to the cultural and creative development of the importance of ornamental and light utility, the market demand is limited and the cultural and creative market promotion lack of lack of professional market operation is also a factor hindering the development of cultural and creative market, each accounted for 53% and 53.3333% each.

Table 4: Respondents' opinions and Suggestions

Options	Microscope	Proportion
The development of wen development attaches importance to the ornamental and the light practicality, the city	159	53%
Field demand	150	50%
A low development level and a shortage of attractiveness	218	72.6667%
The creative species is single and homogenous	160	53.3333%
The marketing of wen created a lack of professional marketing	80	26.6667%
Other	300	/

IV. C. User satisfaction

The questionnaire was distributed through online mode, and 310 questionnaires were collected, excluding 10 invalid questionnaires that did not meet the requirements, and finally 300 valid data were obtained, with an effective rate of 96.7742%. Figure 6 shows the user satisfaction feedback results of Shuangdun engraved cultural and creative design practice, which is the user satisfaction results feedback of Shuangdun engraved serialized cultural and creative design practice by users, with an overall satisfaction of 4.0581, and the satisfaction values of each dimension are, in descending order, innovativeness (4.1993), practicability (4.1318), recognizability (4.1245), cultural expressiveness (4.0392), aesthetics (3.9371), and purchase desire (3.9168).

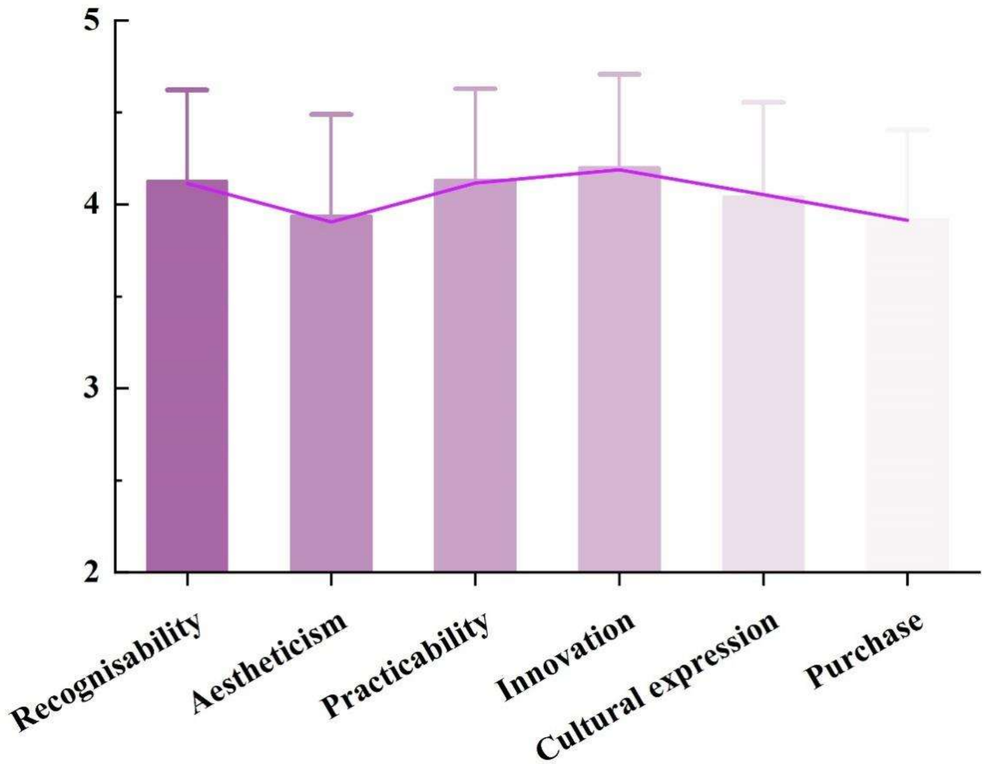

Figure 6: The text creates the user satisfaction feedback knot

V. Conclusion

The intelligent analysis of Shuangdun engraved symbols and the practice of cultural and creative product design in this paper verifies the important value of artificial intelligence technology in the digital inheritance of cultural heritage. By constructing an image feature extraction model based on the principle of perceptron, the automated recognition and analysis of 7300-year-old pottery incised symbols is successfully realized, which provides an effective technical path for the digital research of ancient cultural symbols.

Market validation results show that the cultural and creative products designed based on the intelligent algorithm have gained good user recognition, with an overall satisfaction score of 4.0581, and the innovative dimension is particularly outstanding, with a satisfaction score of 4.1993, fully reflecting the role of technological innovation in promoting the inheritance of traditional culture. Consumer behavior analysis shows that more than half of the respondents preferred national trend style design, accounting for 52.3485%, reflecting the important position of traditional cultural elements in modern aesthetics. The practicality and commemorative value of cultural and creative products are highly recognized by consumers, and 76.6485% of the purchasers chose cultural and creative products for commemorative collection, reflecting the unique role of cultural symbols in emotional expression and cultural identity.

This study not only provides new ideas for the protection and inheritance of Shuangdun culture, but also provides referenceable experience for the digital research and application of other Neolithic cultural heritage. The deep integration of technology and culture opens up a new model for the development of cultural and creative industries, and provides important support for the innovative development of traditional culture in the digital era.

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