EAI Endorsed Transactions
on Scalable Information Systems
Research Article EAI.EU

Digital Visual Design Reengineering and Application Based on *K*-means Clustering Algorithm

Lijie Ren[1,*] and Hyunsuk Kim[1]

[1]Hongik University, Seoul 100-744, Korea

Abstract

INTRODUCTION: The article discusses the key steps in digital visual design reengineering, with a special emphasis on the importance of information decoding and feature extraction for flat cultural heritage. These processes not only minimize damage to the aesthetic heritage itself but also feature high quality, efficiency, and recyclability.
OBJECTIVES: The aim of the article is to explore the issues of gene extraction methods in digital visual design reengineering, proposing a visual gene extraction method through an improved K-means clustering algorithm.
METHODS: A visual gene extraction method based on an improved K-means clustering algorithm is proposed. Initially analyzing the digital visual design reengineering process, combined with a color extraction method using the improved JSO algorithm-based K-means clustering algorithm, a gene extraction and clustering method for digital visual design reengineering is proposed and validated through experiments.
RESULT: The results show that the proposed method improves the accuracy, robustness, and real-time performance of clustering. Through comparative analysis with Dunhuang murals, the effectiveness of the color extraction method based on the K-means-JSO algorithm in the application of digital visual design reengineering is verified. The method based on the K-means-GWO algorithm performs best in terms of average clustering time and standard deviation. The optimization curve of color extraction based on the K-means-JSO algorithm converges faster and with better accuracy compared to the K-means-ABC, K-means-GWO, K-means-DE, K-means-CMAES, and K-means-WWCD algorithms.
CONCLUSION: The color extraction method of the K-means clustering algorithm improved by the JSO algorithm proposed in this paper solves the problems of insufficient standardization in feature selection, lack of generalization ability, and inefficiency in visual gene extraction methods.

Keywords: digital visual design reengineering, jellyfish optimization algorithm, k-means clustering algorithm, color gene extraction

Received on 29 February 2024, accepted on 11 March 2024, published on 14 March 2024

doi: 10.4108/eetsis.5233

*Corresponding author. Email: renlijie0921@gmail.com

1. Introduction

In the digital information age under the rise of digital media and communication carriers, static, fixed, two-dimensional plane carrier and visual style based on the traditional graphic design method is gradually replaced, digital visual design (Digital visual design) method based on graphic design, breaking the limitations of the traditional concept of graphic design creation, to realize the reconstruction of the design form of language [1]. Under the influence of modern design concepts, digital image design concepts, media forms, design techniques and aesthetic concepts, etc. have made great progress, facing the inflection point of the era of digital science and technology, the contemporary Chinese traditional cultural and creative design urgently needs the penetration of local digital design aesthetics theory and form [2]. Graphic aesthetic artifacts information decoding and feature extraction as a key link in digital visual design reengineering technology, not only minimize the damage to the aesthetic artifacts themselves, but also both high-quality, high-efficiency, cyclic reuse and other characteristics [3]. Therefore, the study of visual gene extraction, decomposition, condensation and reconstruction methods is an extremely urgent task for the digital visual design reconstruction of aesthetic cultural relics [4].

The extraction of visual design graphics mainly solves not only the aesthetic art problem of visual expression, but also pays more attention to the exploration of social function application and public integration under the development of digital media that needs to be solved by design communication [5]. Applying intelligent visual gene extraction methods to digital design reengineering problems, constructing a multi-system digital visual graphic gene extraction model, and carrying out intelligent digital design reengineering methods [6] are increasingly being paid attention to and researched by experts in the field [7]. Digital visual design reengineering graphic visual gene extraction methods are divided into color system extraction [8], graphic line body extraction [9], texture feature extraction [10] and other methods from the perspective of the type of gene extraction. Literature [11] proposes a color system extraction method based on K-means clustering algorithm, and constructs a color database of aesthetic artifacts; literature [12] adopts an image processing method, extracts the mural color system from the color three-channel, and puts forward a gene extraction method based on machine learning algorithms for the digital visual design recreation; literature [13] studies the color particles of the mural paintings, and through the particle swarm optimization algorithm Improved K-means clustering analysis of color features; Literature [14] uses deep learning methods to extract and learn graphic shapes, and constructs a digital reengineering model of multi-dimensional linear structure shapes; Literature [15] improves the K-means clustering method to digitally extract texture representations by using the peak density strategy, and at the same time, uses a self-coder neural network to construct the artifacts graphic texture expression model ; Literature [16] combines the gray wolf optimization algorithm, K-means algorithm and convolutional neural network method table mural texture aesthetics for feature extraction and reengineering representation; Literature [17] combines the color characteristics of aesthetic artifacts and line characteristics, to build a digital visual design reengineering evaluation system. For the analysis of the above literature, the existing graphic visual gene extraction methods have the following defects [18]: 1) digital visual design reengineering feature selection is not standard enough [19]; 2) gene extraction methods lack of generalization [20]; 3) gene extraction methods are not efficient enough.

K-means clustering algorithm is one of the machine learning and most popular divisive clustering algorithms which performs well in handling big data classification [21]. Swarm Intelligent Optimization Algorithm [22] designed algorithms or strategies for distributed interpretation problems by simulating the behavior of groups of insects, flocks of animals, flocks of birds and schools of fish. The K-means digital design reconstruction feature extraction method based on swarm intelligence optimization algorithm makes the digital design reconstruction accuracy increase, and its application to the digital design reconstruction problem of graphic artifacts has become a research hotspot for experts and scholars in the field [23].

Aiming at the problems existing in the current gene extraction and clustering method for digital visual design reengineering, this paper proposes a gene extraction and clustering method for digital visual design reengineering based on group intelligent optimization algorithm to improve K-means. The main contributions of this paper are (1) to clarify the visual gene decoding process by analyzing the process of digital visual design reengineering; (2) to optimize the K-means clustering center by using the swarm intelligent optimization algorithm, and to propose a gene extraction method based on the intelligent optimization algorithm to optimize the K-means clustering algorithm; and (4) to experimentally validate the effectiveness of this paper's proposed method, and at the same time, improve the accuracy of the clustering and real-time performance. .

2. Analysis of digital visual design reengineering process

2.1. Digital Visual Re-engineering Process

Extracting, decomposing, condensing and recreating the visual genes with core features in the graphic artifacts under the framework of digital visual design dimension for new deduction exploration is the core feature of digital visual design recreating and application [24]. The schematic process of decoding and extracting planar features under the digital visual framework is shown in Figure 1.

(1) Digital visual graphic form abstraction

The computer digital technology platform can be used to assist in artistic creation by constructing objective objects. Computer vision can be used to extract visual elements and technical language for heterogeneous isomorphism, resulting in the extraction of digital visual symbol forms.

(2) Digital Visual Grammar Composition

The morphology of digital visual language can evolve into many different forms in the parametric adjustment changes, in the parametric adjustment changes, but the form produces a variety of morphological stochastic changes, especially contemporary digital technology and artificial intelligence driven to generate a variety of visual styles and art forms of derivative works.

(3) Analysis of digital interactive media

With the iterative development of image information technology and the birth of new visual media, presenting digital, virtual, interactive, derivative and other characteristics, digital design expands the extension of visual and experiential activities, breaking the traditional sense of visual information communication and access to a single way.

(4) Digital Aesthetic Processing

Digital technology has been applied to painting, three-dimensional installations, film art, augmented reality and virtual reality, and in the field of contemporary visual art there are digital artworks created by using digital technology to simulate the medium, blurring the aesthetic boundaries of different art mediums and forms.

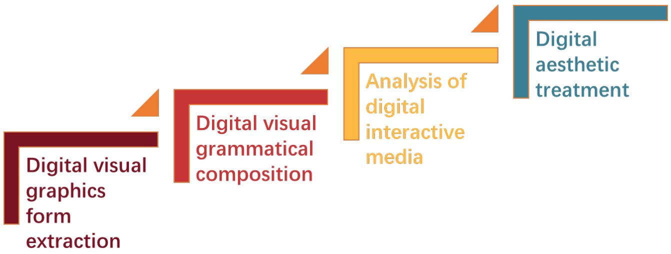


Figure 1. Decoding and extraction process of planar features in the framework of digital vision

2.2. The visual genetic decoding process of graphic digital design

Through on-site digital photography, scanning, extraction and other methods, using the digital era platform, through computer graphics and digital image processing methods, focusing on the technological processing, splitting and extraction of color genes. This paper takes Dunhuang mural as the research object to carry out the construction of digital design visual gene decoding model [25], as shown in Figure 2. As shown in Figure 2, Dunhuang mural input, first through image preprocessing and layer processing, using clustering methods to analyze and extract the main color set data set and tonal color data set, for local color, title color and successive generations of color and other issues, to obtain the color data set, to obtain the complete data set.

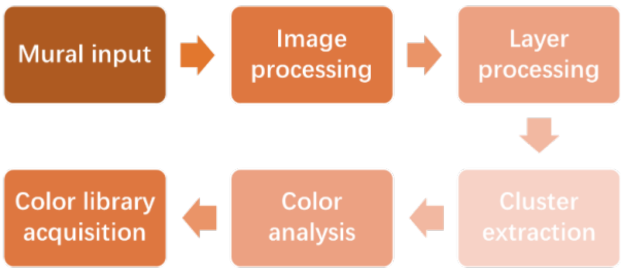


Figure 2. Decoding and extraction process of wall painting color digital gene

3. Related Technologies

3.1. K-means clustering algorithm

The K-means algorithm is the most popular divisive clustering algorithm, which performs well in dealing with large data classification [26]. The algorithm determines the clustering centers and the elements to which they belong by minimizing an objective function based on squared error. The aim is to keep the cluster centers as far away from each other as possible and associate each data point to the nearest cluster center. In the K-means algorithm, the Euclidean distance is commonly used as a similarity measure. A small distance indicates strong similarity, while a large distance indicates low similarity.

The objective function of the K-means algorithm is defined as follows:

$$J=\sum_{i=1}^{K}\left(\sum_{k}\left\|x_k-c_i\right\|^2\right) \tag{1}$$

where K is the number of clusters, C_i is the center of the cluster, and x_k is the *kth* data point in the *ith* cluster.

The exact procedure of the algorithm is as follows:

Step 1: Determine the total number of classified classes K and randomly select K cluster class centers $C=(c_1, c_2, \ldots, c_k)$.

Step 2: Compute the partition matrix. A data point belongs to the cluster whose center is closest to that data point. Therefore, the clusters are represented by a binary division matrix U. The elements in U are determined as follows:

$$u_{ij}=\begin{cases}1 & if\ \left\|x_j-c_i\right\|^2\le\left\|x_j-c_t\right\|^2, \forall t\neq i\\ 0 & otherwise\end{cases} \tag{2}$$

where u_{ij} denotes whether the *jth* data point belongs to the *i-th* cluster class.

Step 3: Update the cluster centers. Define each cluster class center c_i that minimizes the objective function as follows:

$$c_i=\frac{\sum_{j=1}^{N}u_{ij}x_j}{\sum_{j=1}^{N}u_{ij}} \tag{3}$$

where N denotes the number of samples.

Step 4: Compute the objective function using equation (1). Verify that the function converges or that the difference between two neighboring values of the objective function is less than a given threshold and stop. Otherwise repeat step 2.

3.2. Jellyfish optimization algorithm

(1) Inspired Mechanisms

Artificial jellyfish search optimization (JSO) is a bionic optimization algorithm proposed by Chou J S et al. in 2020 [27], which is based on three idealized behavioral rules:

1) Jellyfish either follow ocean currents or move around themselves within a colony, and these two modes of movement are controlled by time-controlled mechanisms;

2) In the ocean, jellyfish search for food and they are more likely to be attracted to locations where there is a large amount of food;

3) The amount of food found is determined by the objective function for that location and the corresponding location.

(2) Optimization Strategies

1) Population initialization

Randomly initialized populations are prone to defects such as slower convergence speed, not being able to jump out of the local optimal solution already poor population diversity. In order to improve the initialized population diversity, the initial position of jellyfish population adopts Logistic mapping method, and the specific mapping formula is as follows:

$$X_{i+1} = \eta X_i \left(1 - X_i\right) \quad (4)$$

$$0 \le X_0 \le 1 \quad (5)$$

where X_i denotes the logical chaos mapping value of the *ith* jellyfish location; X_o is used to generate the initial population, $X_0 \in \left(0,1\right)$, $X_0 \notin \left(0, 0.25, 0.5, 0.75, 1.0\right)$, $\eta = 0.4$.

2) Ocean current movement strategy

Jellyfish are attracted to the movement of ocean currents because of the large amount of nutrients present. The direction of the ocean currents is mainly determined by the average of the jellyfish population position versus the best position of the jellyfish. The specific modeling equations for ocean currents are as follows:

$$trend = \frac{1}{n_{pop}} \sum \left(X^* - e_c \mu\right) = X^* - e_c \frac{\sum X_i}{n_{pop}} = X^* - e_c \mu \quad (6)$$

This is known as $df = e_c \mu$:

$$trend = X^* - df \quad (7)$$

Where n_{pop} denotes the number of jellyfish populations, X^* denotes the best position in the current jellyfish population, e_c denotes the attractiveness factor, μ is the average position of the population, and df is the difference between the current best position of the jellyfish population and the average of the positions held by all jellyfish.

The jellyfish assumes that the dimensions obey a given normal distribution and that the $\pm \beta \sigma$ range of mean locations contains all jellyfish possibilities, then:

$$df = \beta \cdot \sigma \cdot rand^f \left(0,1\right) \quad (8)$$

where σ is the standard deviation of the distribution:

$$\sigma = rand^f \left(0,1\right) \quad (9)$$

Based on the calculations at σ , this gives

$$df = \beta \cdot rand^f \left(0,1\right) \cdot \mu \cdot rand^f \left(0,1\right) \quad (10)$$

A simplification of the above equation:

$$df = \beta \cdot rand^f \left(0,1\right) \cdot \mu \quad (11)$$

Let $e_c = \beta \cdot rand\left(0,1\right)$, which gives:

$$trend = X^* - \beta \cdot rand\left(0,1\right) \cdot \mu \quad (12)$$

Jellyfish location updated to:

$$X_i\left(t+1\right) = X_i\left(t\right) + rand\left(0,1\right) \cdot trend \quad (13)$$

assume (office)

$$X_i\left(t+1\right) = X_i\left(t\right) + rand\left(0,1\right) \cdot \left(X^* - \beta \cdot rand\left(0,1\right) \cdot \mu\right) \quad (14)$$

3) Jellyfish population movement strategies

Jellyfish populations have 2 types of movement, passive movement (type A) and active movement (type B). When the population is first formed, most jellyfish use type A movement; over time, more and more jellyfish use type B. Type A movement is the movement of jellyfish around their own position, with each jellyfish's corresponding position updated to:

$$X_i\left(t+1\right) = X_i\left(t\right) + 0.01 \times rand\left(0,1\right) \cdot \left(U_b - L_b\right) \quad (15)$$

where U_b and L_b denote the upper and lower boundaries of the search space, respectively.

B-movement randomly selects 2 jellyfish positions *i* and *j* to determine the direction of movement. When the amount of food at position j exceeds the amount of food at position i, the jellyfish at position *i* moves toward position *j*, and vice versa, away.The formula for B-movement is as follows:

$$X_i\left(t+1\right) = X_i\left(t\right) + Step \quad (16)$$

$$Step = rand\left(0,1\right) \times Direction \quad (17)$$

$$Direction = \begin{cases} X_j(t) - X_i(t) & f(X_i) \geq f(X_j) \\ X_i(t) - X_j(t) & f(X_i) < f(X_j) \end{cases} \tag{18}$$

4) Time control mechanisms

Ocean currents contain large amounts of nutrients that attract jellyfish to move around. Over time, more jellyfish gather in the currents to form jellyfish swarms. When the temperature or wind direction changes the current, jellyfish from the population move into another current and form a new jellyfish colony. To regulate jellyfish current movement and jellyfish intra-population movement, the JSO algorithm uses a time control function $c(t)$ and a constant threshold $c0$, where the time control function is a random value that varies with the number of iterations and takes a value in the range $[0,1]$. $c0$ It is set to 0.5. The specific formula for the time control function is as follows:

$$c(t) = \left| \left(1 - \frac{t}{Max_{iter}}\right) \cdot \left(2 \times rand(0,1) - 1\right) \right| \tag{19}$$

Where t denotes the specified number of iterations and Max_{iter} denotes the maximum number of iterations. When $c(t)$ exceeds $c0$, the jellyfish follows the ocean currents; when $c(t)$ is less than $c0$, the jellyfish adopts the intra-population movement of jellyfish. In addition, to switch between type A and type B motions, $1-c(t)$ is utilized to describe the type of jellyfish motion. When $1-c(t)<0.5$ is smaller than $1-c(t)<0.5$, jellyfish follow type B motion; as the number of iterations increases, the value of $c(t)$ changes from 0 to 1, the probability of decreases gradually, and jellyfish intrapopulation motion tends to be more and more like type A motion.

5) Strategies for dealing with transgressions

To prevent the jellyfish from moving beyond the search boundary, JSO uses an out-of-bounds processing strategy, i.e:

$$\begin{cases} X'_{i,d} = \left(X_{i,d} - U_{b,d}\right) + L_{b,d} & X_{i,d} > U_{b,d} \\ X'_{i,d} = \left(X_{i,d} - L_{b,d}\right) + U_{b,d} & X_{i,d} < L_{b,d} \end{cases} \tag{20}$$

where $X_{i,d}$ denotes the position of the ith jellyfish in the dth dimension, $X'_{i,d}$ denotes the updated position after checking the boundary constraints, and $U_{b,d}$ and $L_{b,d}$ are the upper and lower bounds in the dth dimension, respectively.

(3) Steps and Processes

According to the Seagull optimization strategy, the JSO pseudo-code is shown in Figure 3 with the following steps:

```
Algorithm 1 Jellyfish search optimization
Set parameters, including Max_iter and Npop;
Initialize population based on Logistic mapping method;
Calculate individual fitness value, and record current best individual;
For t = 1:Max_iter
    Calculate time control function;
    // Update population position
    if c(t) >= 0.5
        Follow the movement of ocean currents;
    else
        // Adopt the intra-population movement of the jellyfish;
        if 1-c(t) < 0.5
            Follow the B-type movement;
        else
            Follow the A-type movement;
        end
    end
    Check the boundary of position;
    Calculate individual fitness value;
end
Ouput best individual
```

Figure 3. Pseudo-code diagram of JSO algorithm

Step 1: Initialize the population position using Logistic mapping method, set the maximum number of iterations and other parameters;

Step 2: Calculate the fitness value and record the current optimal individual;

Step 3: Calculate the time control function;

Step 4: Jellyfish population position update. If the control parameter is greater than or equal to the threshold value of 0.5, the jellyfish follows the ocean current movement; if the control parameter is less than 0.5, the jellyfish adopts the jellyfish intra-population movement; if $1-c(t)<0.5$, the jellyfish follows the B-type movement; otherwise, it follows the A-type movement; and according to the movement strategy, the new position of the jellyfish population is calculated;

Step 5: Check the boundary conditions, calculate the fitness value and update the optimal individual;

Step 6: Determine whether the number of iterations reaches the maximum number of iterations. If the maximum number of iterations is reached, proceed to output the optimal solution and optimal value; otherwise, go to step 3.

4. Ideas of Digital Visual Design Reengineering Methods Based on Jellyfish Optimization Algorithm with Improved K-means Clustering

4.1. Decision-making variables

In order to increase the accuracy of K-means clustering method and improve the efficiency of digital visual design reengineering, this paper adopts JSO algorithm to improve K-means to cluster and extract the color genes of the key technology of digital visual design reengineering.The process of JSO algorithm is to find a set of optimal clustering centers by using JSO algorithm to make the distance from the center of clustering of all colors in the cultural relics' color digital library minimum, i.e., the similarity of the color collection is maximum. center distance is minimum, that is, the color collection similarity is maximum. Therefore, the K-means-JSO algorithm decision variable for cultural relics color set clustering center.

4.2. Objective function

According to the design of decision variables of K-means-JSO algorithm, this paper adopts the sum of intra-class distances as the fitness assessment function of JSO algorithm to optimize K-means clustering method, which is calculated as follows:

$$J = \sum_{j=1}^{K} \sum_{\forall s_j \in c_j} d\left(s_i, c_j\right)^2 \tag{21}$$

Where, $d\left(s_i, c_j\right)$ is the color similarity, which is calculated as follows:

$$d\left(s_i, c_j\right) = 1 - \cos\left(s_i, c_j\right) = 1 - \frac{s_i \cdot c_j}{\left\|s_i\right\| \cdot \left\|c_i\right\|} \tag{22}$$

In this case, the higher the color similarity, the value of cosine similarity is 1 and the value of distance between colors is 0. The lower the color similarity, the value of cosine similarity is 0 and the value of distance between colors is 1.

4.3. Methodology steps and flowchart

The steps of color gene extraction and cluster analysis for digital visual design reengineering by combining JSO algorithm and K-mean clustering algorithm are as follows:

Step 1: Acquire the dataset. Take images of flat artifacts and color correct the images;

Step 2: Initialize the population. Initialize the number of clustering categories K and randomly initialize the forest population according to different dimensions to obtain the jellyfish population $X = \left[X_1, X_2, \cdots, X_N\right]$;

Step 3: Calculate fitness values. Calculate the cosine similarity of each data object in the numerical new dataset hitting the K clustering centers represented by each individual of the initial jellyfish population, and then calculate the color similarity to assign that data object to the closest class cluster, directing the assignment of all the data to be completed, and finally calculating the sum of the intraclass distances of all the data objects in the individual class clusters of each jellyfish, i.e., the fitness function value;

Step 4: Position update. According to the optimization strategy of the JSO algorithm, the strategy of following the motion of the ocean currents and the motion within the jellyfish population is executed to perform the position update;

Step 5: Determine whether the K-means-JSO clustering algorithm reaches the maximum number of iterations or satisfies the convergence condition, if yes, output the optimal clustering center; otherwise, loop iterate step 3 to step 5;

Step 6: Output the clustering results and assign the corresponding data to the corresponding categories according to the final clustering results.

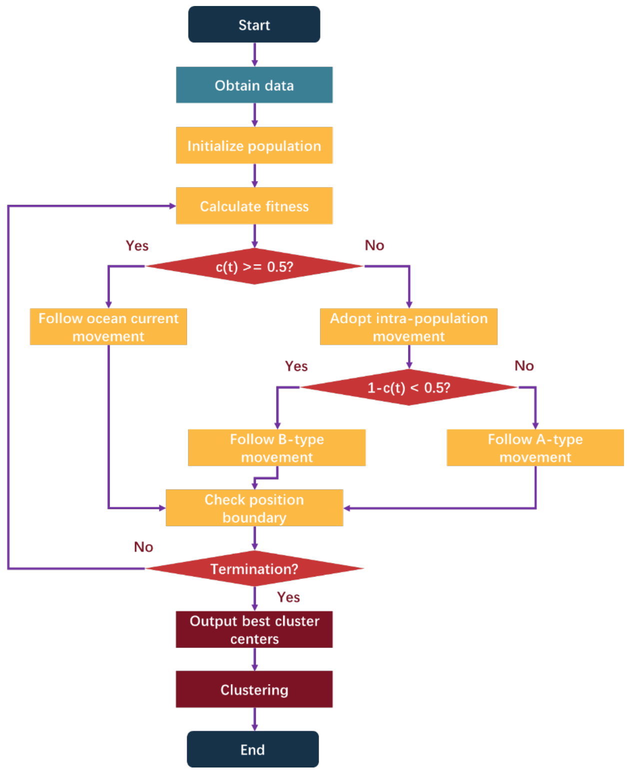


Figure 4. Optimized K-means based on JSO algorithm for color gene extraction for digital visual design reengineering

5. Analysis of results

In order to verify the accuracy and timeliness of the color gene extraction model proposed in this paper, five analysis algorithms are selected for comparison with Dunhuang murals as the analysis data, and the specific parameters of each algorithm are set as in Table 1.The experimental simulation environment is Windows 10, CPU is 2.80GHz, 8GB memory, and the programming language Matlab2022a.

Table 1 Parameter settings for each method

arithmetic	parameterization
K-means-ABC	The number of clusters K=10; the number of ABC populations is 50 and the number of iterations is 200; Limit=20
K-means-GWO	The number of clusters K = 10; the number of GWO populations is 50 and the number of iterations is 200; the control parameter a decreases linearly from 2 to 0
K-means-DE	The number of clusters K = 10; the number of DE populations is 50 and the number of iterations is 200; the crossover probability is 0.9 and the variance probability is 0.1
K-means-CMAES	The number of clusters K = 10; the number of GWO populations is 50 and the number of iterations is 200
K-means-WWCD	Number of clusters K = 10; number of GWO populations is 50, number of iterations is 200; r = 0.6, n = 60, s = 0.6, K = 0.5, J = 0.1
K-means-JSO	Number of clusters K = 10; JSO algorithm population is 50, number of iterations is 200; c0 = 0.5

5.1. Description of experimental results

(1) Color extraction for single murals and elemental units

For a single mural work, the color clustering results based on the K-means-JSO algorithm are shown in Figure. 5 and Figure. 6. As shown in Figure 5, the main RGB colors in the picture 10 are layered, and the 10 main color information in the mural is extracted, and through the 2D picture orientation of the clustered colors, the color percentage and the main distribution points of each color in each position in the mural are determined. From Figure 6, it can also be seen that the algorithm can clearly get the color ratio and aesthetic tone of the mural from the color block ratio.

(a) Mural images

(b) Distribution of cluster color positions

Figure 5. Distribution of major colors in the picture

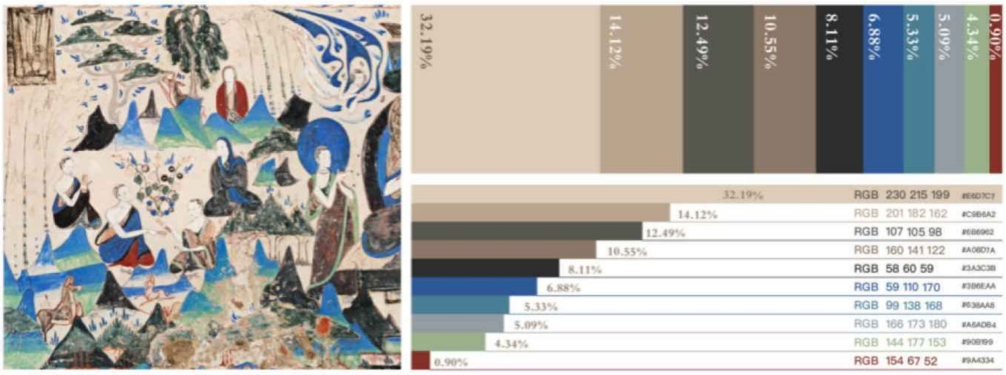


Figure 6. Histogram of the color weights of the main color, secondary color and tonal color ground

The clustering results of this experiment, which unfolds the design extension and visual creation of a single visual element, are shown in Figure 7. As can be seen from Figure 7, the method proposed in this paper can ensure accurate and clear color extraction.

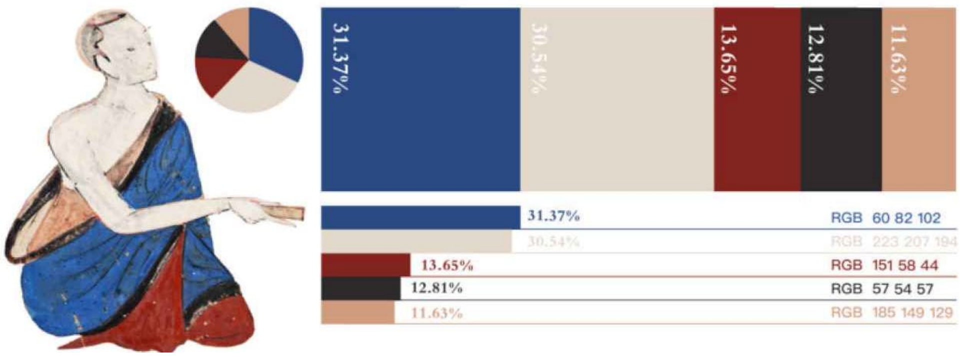
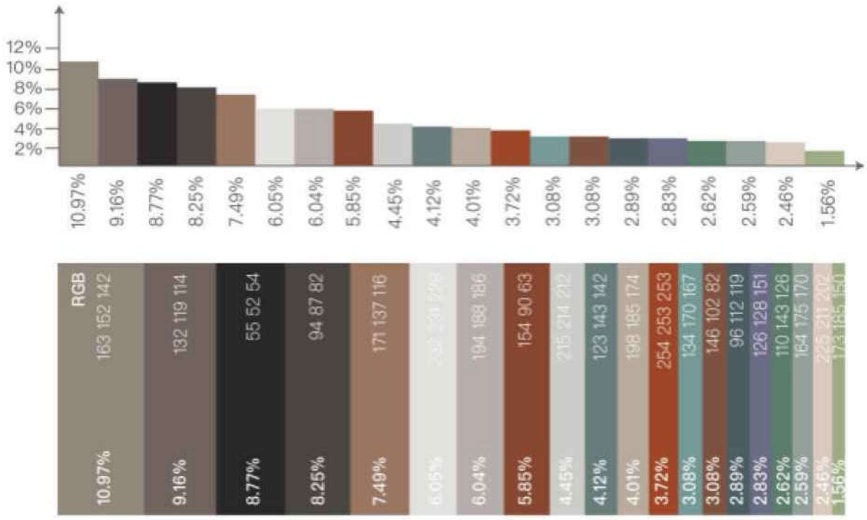


Figure 7. Analysis of the proportion of color of single element of mural painting

(2) Color extraction for murals of the same subject matter

In order to further verify the color extraction generalization of the K-means-JSO algorithm, this paper generalizes the color extraction of the same theme mural, and the specific results are shown in Figure 8. As can be seen from Figure 8, the same theme mural color extraction will be a single color into different levels of "color scale", not only to enhance the three-dimensional effect of the mural itself, but also to make a single color luminance changes gradually with other contrasting complementary colors to produce integration.

(a) Mural images



(b) Color distribution and weave analysis

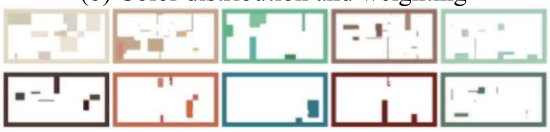
Figure 8. Overall color distribution and color value analysis of murals with the same subject matter

(3) Digital Color Extraction of Mural Paintings of Various Periods in Spatio-Temporal Dimension

In order to further analyze the effectiveness of the K-means-JSO algorithm from the time dimension, this paper analyzes the color extraction of the representative murals of the early Tang Dynasty, and the specific results are shown in Figure 9. As can be seen from Figure 9, the murals of the early Tang Dynasty are mainly in earthy yellow and white as the base color, with lime green and painted red as the main hues, the saturation and level changes are more soft and delicate, and the overall visual rhythm is richer.

(a) Color distribution of mural images

(b) Color distribution and weighting



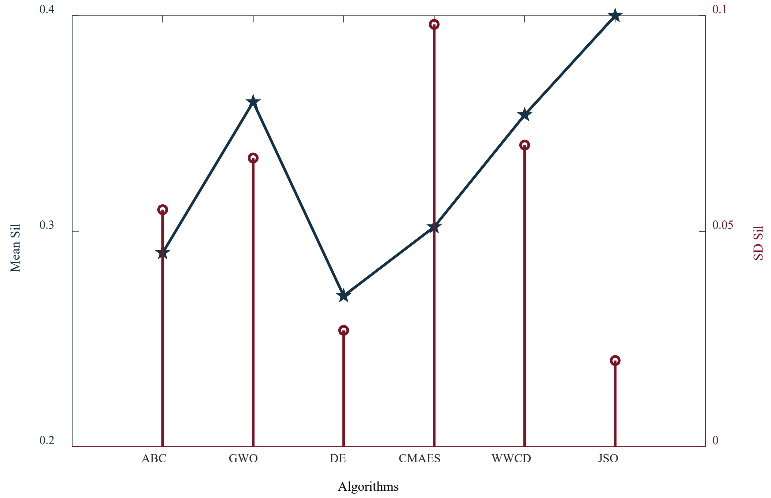
(c) Two-dimensional picture plane colors

Figure 9. Overall color distribution and color value analysis of murals with the same subject matter

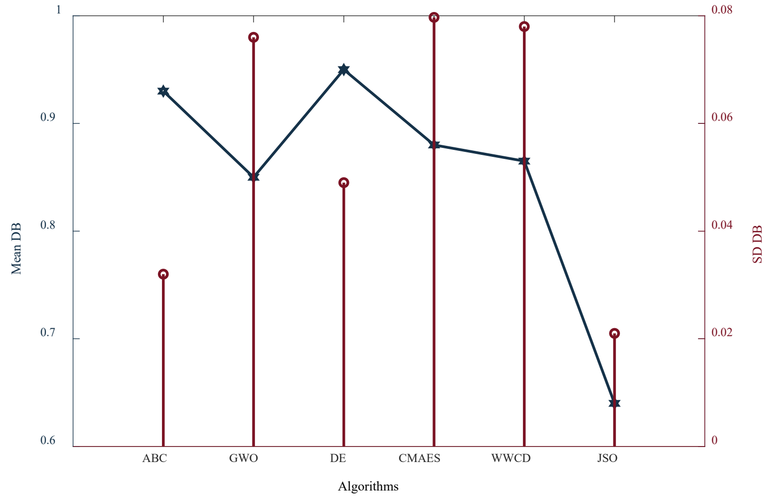
5.2. Performance comparison

In order to verify the superiority of the digital visual design recreation color extraction method based on the K-means-JSO algorithm, K-means-JSO is compared with five other models, and the clustering results of each model are shown in Figure 10, Figure 11, and Figure 12.

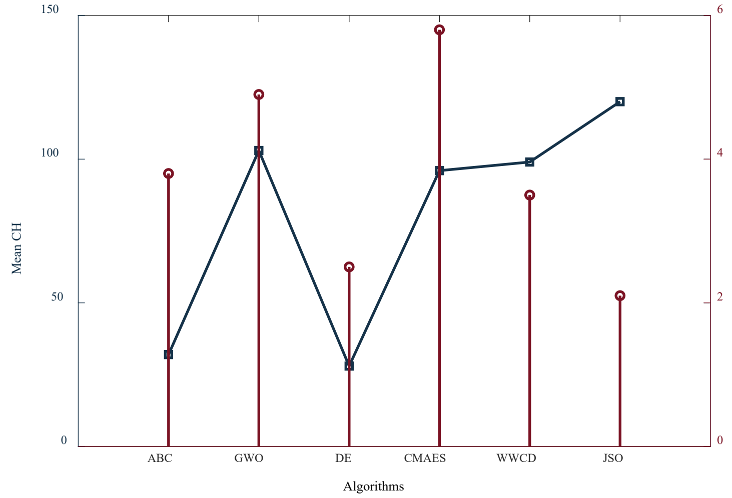
Three intrinsic assessment methods are used in this section, including the Silhouette (Sil) assessment index, the Davies-Bouldin (DB) assessment index, and the Calinski-Harabaz (CH) assessment index.The Sil assessment index, or the profile coefficient, has a value closer to 1, which indicates that the clustering is more reasonable; closer to -1, which indicates that the current samples should be divided to other classes; closer to 0, indicating that the samples should be on the boundary.DB index is mainly the ratio of the distance of the samples within a cluster to the center of clustering to the distance of the center of clustering between clusters, and the smaller the value indicates the better the clustering result.CH index is defined as the ratio of the degree of separation to the tightness, and the larger the value, the better the clustering result. Figure 10 gives the comparison results of Sil, DB, and CH evaluation indices based on each algorithm. From Figure 10(a), it can be seen that the mean value of Sil of the color extraction method based on the K-means-JSO algorithm is better than other algorithms, and the standard deviation of Sil is smaller than other algorithms; the mean value of Sil of the color extraction method based on the K-means-JSO clustering algorithm for visual design recreation is the largest, and then in order of magnitude, it is K-means-DE、K-means-ABC、K-means-GWO、K-means- WWCD, and K-means-CMAES algorithms; it can be seen that K-means-JSO clustering is better than the other algorithms. From Figure 10(b), it can be seen that the DB mean of the color extraction method based on the K-means-JSO algorithm is better than the other algorithms, and the DB standard deviation is smaller than the other algorithms; the DB mean of the visual design recreation color extraction method based on the K-means-JSO clustering algorithm is the smallest, and then in order, the DB mean of the K-means-GWO, K-means-WWCD, K- means-CMAES, K-means-ABC, K-means-DE; DB standard deviation of visual design reengineering color extraction method based on K-means-JSO clustering algorithm is the smallest, and then in the order of K-means-ABC, K-means-DE, K-means-GWO, K-means-WWCD, K- means-CMAES; it can be seen that K-means-JSO clustering is better than other algorithms. From Figure10(c), it can be seen that the CH mean of the color extraction method based on the K-means-JSO algorithm is better than the other algorithms, and the CH standard deviation is smaller than the other algorithms; the CH mean of the color extraction method based on the K-means-JSO clustering algorithm for visual design recreation is the largest, and then in the order of K-means-GWO, K-means-WWCD, K- means-CMAES, K-means-ABC, K-means-DE; the standard deviation of CH of the visual design reengineering color extraction method based on the K-means-JSO clustering algorithm is the smallest, and then in the order of K-means-DE, K-means-ABC, K-means-WWCD, K-means-GWO, K- means-CMAES; it can be seen that K-means-JSO clustering is better than other algorithms.



(a) Analysis of Sil results



(b) Analysis of DB results



(c) Analysis of CH results

Figure 10. Clustering performance results of digital visual design recreation color extraction methods based on each algorithm

As can be seen from Figure 11, the clustering time mean of the digital visual design recreation color extraction method based on the K-means-GWO algorithm is the smallest, and the time standard deviation is the smallest; in terms of the clustering time mean, in descending order, they are K-means-GWO, K-means-JSO, K-means-ABC, K-means-WWCD, K- means-DE, K-means-CMAES; in terms of standard deviation of clustering time, from small to large, they are K-means-JSO, K-means-DE, K-means-ABC, K-means-GWO, K-means-WWCD, and K-means-CMAES in the order of smallest to largest. it can be seen that, although K-means- JSO algorithm digital visual design recreation color extraction method clustering time is not the best, but it satisfies real-time and is the best in terms of robustness.

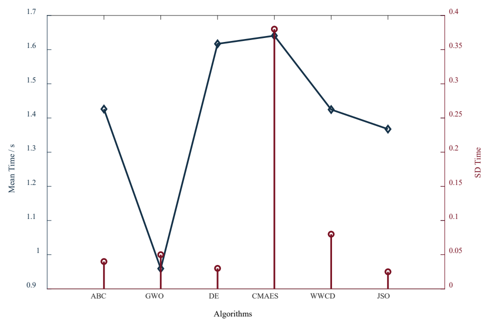


Figure 11. Clustering time comparison results of digital visual design recreation color extraction methods based on each algorithm

From Figure 12, it can be seen that the color extraction optimization curve based on the K-means-JSO algorithm converges faster than the K-means-ABC, K-means-GWO, K-means-DE, K-means-CMAES, and K-means-WWCD algorithms, and the convergence accuracy is better than the other algorithms.

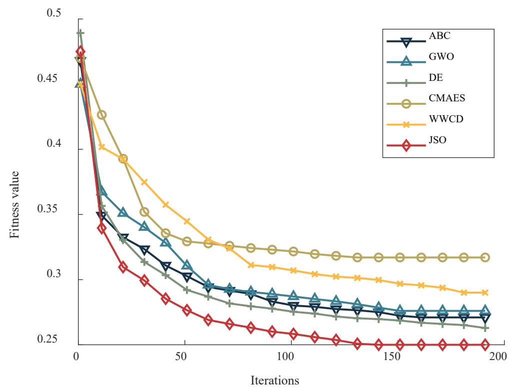


Figure 12. Results of the number of convergence iterations for each optimization algorithm to improve the DBN network

6. Conclusion

In order to improve the color extraction and robustness of digital visual design reengineering, this paper proposes a color extraction method based on JSO algorithm to improve K-means clustering algorithm and applies it to digital visual design reengineering problem. The method proposes a gene extraction and clustering method for digital visual design reconstruction by analyzing the process of digital visual design reconstruction and combining the color extraction method based on JSO algorithm to improve K-means clustering algorithm. Using Dunhuang mural shooting photos to analyze the proposed method has a comparison, and the following conclusions are obtained:

(1) By comparing different intelligent optimization algorithms to improve the K-means clustering method, the JSO algorithm has better convergence speed, extraction accuracy, and clustering time than other algorithms;

(2) From the data analysis of single element, single mural, mural of the same subject, and mural of each period, it is verified that the color extraction method based on K-means-JSO algorithm is effective in the application of digital visual design reconstruction.

Since the JSO algorithm can easily fall into local optimum, how to improve the optimization performance of the JSO algorithm and apply it to the K-means-JSO model will be the next step.

References

[1] Teng Z .Innovative design analysis of visual communication based on\ndigital technology[J].

[2] Macdonald I. Window on the weather: a case study in multi-platform visual communication design, with a relationship to Design Thinking: [J].Visual Communication, 2023, 22(2):365-386.

[3] Zboinska M A, Dumitrescu D, Billger M , Amborg E. Colored skins and vibrant hybrids: Manipulating visual perceptions of depth and form in double -curved architectural surfaces through informed use of color, transparency and light[J].Color Research and Application, 2022(4):47.

[4] Liu Y, Liang C, Xu H , Wang F, Hao Y, Dong J. Digital Art Pattern Design Based on Visual Material Colouring Intelligent Programming System[J]. Mathematical Problems in Engineering: Theory, Methods and Applications, 2022(8):2022.

[5] Ballentine B. Digital Humanities and Technical Communication Pedagogy: a Case and a Course for Cross-Program Opportunities[J]. Design Quarterly, 2022.

[6] Miller M, Daniel Fürst, Hauptmann H , Keim D A, Mennatallah E. Augmenting Digital Sheet Music through Visual Analytics[J].Computer Graphics Forum. Journal of the European Association for Computer Graphics, 2022(1):41.

[7] Lin T, Yang Y , Beyer J , Pfister H. Labeling Out-of-View Objects in Immersive Analytics to Support Situated Visual Searching[J].IEEE transactions on visualization and computer graphics, 2023.

[8] Luo W. Role of video sensors in observing visual image design in the construction of smart cities[J]. Journal of electronic imaging, 2022.

[9] Song Z. How to Present the Evolution of Visual Images in the Context of Digital Media Art[J]. Arts Studies and Criticism, 2023.

[10] Neuroscience C I. Retracted: Restaurant Interior Design under Digital Image Processing Based on Visual Sensing Technology[J]. Computational intelligence and neuroscience, 2022.

[11] Ponka M, Grobelny J, Michalski R. Conjoint Analysis Models of Digital Packaging Information Features in Customer Decision-Making[J]. International Journal of Information Technology & Decision Making, 2023, 22(05):1551-1590.

[12] Lian L , Yan Y , Lv Z .Digital Visual Sensing Design Teaching Using Digital Twins[J].Advances in civil engineering, 2022(1):2022.

[13] Murtarelli G , Romenti S , Valentini C .The impact of digital image-based features on users' emotions and online behaviours in the food industry[J]. British food journal, 2022(1):124.

[14] José Coelho Rodrigues.Business models for the digital transformation of audiovisual archives[J].International journal of entrepreneurial behavior & research, 2022.

[15] Cao W , Wang Z , Liu X , Zhou Z, Zhang Y, He S. Bioinspired MXene-Based User-Interactive Electronic Skin for Digital and Visual Dual-Channel Sensing[J] . . Nano Express: English Edition, 2022(007):014.

[16] Bashirzadeh Y , Mai R , Faure C .How rich is too rich? Visual design elements in digital marketing communications[J]. International journal of research in marketing, 2022(1):39.

[17] Haefeli L M, Neves L M , Zin A , Costa A C C, Vasconcelos Z F M D, Pinto M. Portable wide-field digital imaging for screening of neonatal visual impairment causes in Rio de Janeiro, Brazil: a budget impact analysis[J].BMJ open, 2022, 12(6):e056498.

[18] Talebi S , Wu S , Al-Adhami M , Shelbourn M, Serugga J.The development of a digitally enhanced visual inspection framework for masonry bridges in the UK [J].Construction innovation: information, process, management, 2022.

[19] Campbell J L. Identifying Digital Rhetoric in the Telemedicine User Interface[J]. Journal of technical writing and communication, 2023.

[20] Pineda R. Automated Design of Salient Object Detection Algorithms with Brain Programming[J]. Applied Sciences, 2022, 12.

[21] Ding X, Wu Z, Li M. Clustering Merchants and Accurate Marketing of Products Using the Segmentation Tree Vector Space Model[J].Mathematical Problems in Engineering: Theory, Methods and Applications, 2022(11):2022.

[22] Gao Zhihui, Han Meng, Liu Shujuan, Li Ang, Mu Dongliang. A review of efficient usable itemset mining methods based on intelligent optimization algorithms[J]. Computer Applications, 2023, 43(6):1676-1686.

[23] Zhang F, Ye W , Lei G , Liu Y, Wang X. SOH estimation of Li-ion battery based on FA-BPNN-K-means optimization algorithm[J].J. Comput. Methods Sci. Eng. 2022, 22:1209-1222.

[24] David O , Sarkar S , Kammerer N , Nantermoz C, De Chamisso F M, Meden B. Digital assistances in remote operations for ITER test blanket system replacement: an experimental validation[J].Fusion engineering and design, 2023.

[25] Meng K, Liu F , Zhou T .Application of 3D Digital Image Processing Technology in Modern Packaging Design[J].Advances in multimedia, 2022(6):2022.

[26] Velmurugan T, Santhanam T. Computational Complexity between K-Means and K-Medoids Clustering Algorithms for Normal and Uniform Distributions of Data Points[J].

[27] Farhat M, Kamel S , Atallah A M , Khan B. Optimal Power Flow Solution Based on Jellyfish Search Optimization Considering Uncertainty of Renewable Energy Sources[J].IEEE Access, 2021, 9:100911-100933.