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Research on the Integration of Ethnic Art Elements in Modern Housing Designs

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Abstract Based on the systematic collection and classification of highly representative ethnic element patterns, this paper applies computer image recognition and extraction technology to complete the task of extracting the representative elements of the patterns, so as to provide pre-study basic materials for the subsequent modern housing design. The extracted color features, texture features and organization features are applied to the modern housing design, and the design effect is evaluated with the help of hierarchical analysis algorithm and fuzzy comprehensive evaluation. The weight of livability A1 is 0.2708, and its subordinate secondary indicators exist ethnic characteristics space layout B3 (0.111) > living comfort B2 (0.0908) > B4 cultural atmosphere creation (0.04) > B1 living comfort (0.029), and the results of the evaluation of the effect of the housing design are (4.8791, 1.5293, 1.3133, 1.5134, and 0.7649), and based on the principle of maximum affiliation, it is concluded that the housing design effect of integrating ethnic art elements in a neighborhood is excellent. This study provides reference for traditional elements and modern housing design, and has theoretical guidance value for sustainable development of architecture.

Index Terms extraction technique, hierarchical analysis algorithm, fuzzy comprehensive evaluation, ethnic art elements, modern housing design, sustainable architectural development

I. Introduction

Housing, as a major part of the city, has always played a pivotal role in the city. From the point of view of housing science, cities are even the product of the differentiation of housing culture to a certain stage. As far as area is concerned, housing generally occupies a dominant position in cities, especially in China, which has a large population. Large-scale residential housing not only affects the cityscape, but also exerts influence on the city from various economic and social aspects [1]-[4]. Since entering the 1990s, China's urbanization process has accelerated, and the urbanization level was 28.85% in 1995, which has entered the accelerated stage according to the division of the urbanization process. In some big cities, it is the phenomenon of urban suburbanization, and the construction of suburbs is mainly based on residential housing, therefore, the planning and construction of residential housing largely determines the spatial and landscape structure of urban suburbs [5]-[8]. At the same time, due to the high speed development of urban construction driven by the economic transition, various places inevitably encountered a variety of problems in the renewal of old cities. Most of the old cities are dominated by traditional residences, and due to the relative economic lag, the serious lack of modern living facilities and the relatively poor living conditions, the renewal of old cities has become very urgent [9]-[11]. However, driven by the pursuit of high short-term profits in real estate development, the renovation of old housing and the planning of new housing have become oversimplified, resulting in the destruction of the original urban space, and ultimately leading to the loss of urban characteristics. Therefore, it is particularly important to consider the planning and construction of housing in a holistic way [12]-[14]. Ethnic art elements refer to the representative art forms, patterns, colors, materials, techniques and other elements originating from the traditional culture of each ethnic group. These elements reflect the history, culture, beliefs, lifestyle and aesthetic habits of the ethnic groups, and have unique artistic value and distinctive ethnic characteristics [15]-[17]. The innovative use of ethnic art elements in modern housing design can enrich the connotation of housing design, improve the cultural taste of housing, and enhance the ornamental, artistic and market competitiveness of housing [18]-[20].

The article is different from the traditional PS software to extract the national art elements, but this time the use of image pre-processing to accurately extract the national art elements that meet the requirements, to a great extent to ensure the effect of modern housing design, which is the main innovation point of this research. Through the browser query related literature, museum collection photos and other ways to collect national patterns, collect a total of 5000 patterns in line with national characteristics, which mainly consists of color, pattern, organization form

of the three components, symbolizing the cultural characteristics. Using computer image recognition and extraction technology, the extraction of each representative element of the pattern is completed, and the extracted ethnic elements are integrated into the modern housing design work. Evaluate the effect of extracting the ethnic art elements with the evaluation indexes to check whether the effect meets the modern housing design standards. Based on the principles of ethnic art elements, modern housing design requirements, and evaluation index system, we constructed the evaluation index system of modern housing design effect by integrating ethnic art elements, and used AHP hierarchical analysis method to get the results of weights of evaluation indexes, and established a fuzzy comprehensive evaluation model on this premise, and utilized the model to evaluate and analyze the effect of modern housing design.

II. Research on the application of national art elements to modern housing design

II. A. Ethnic art element extraction algorithm design

Ethnic art element extraction algorithm design is shown in Figure 1, on the basis of picture collection, key features arrangement and key technology theory analysis, this subsection mainly researches on ethnic element feature color extraction, pattern extraction and pattern organization form extraction, on the basis of systematic collection and classification screening of highly representative ethnic element patterns, using computer image recognition and extraction technology, according to the ethnic element pattern features The extraction of each representative element of the pattern is accomplished quickly and accurately, which provides the preliminary research base material for the subsequent modern housing design.

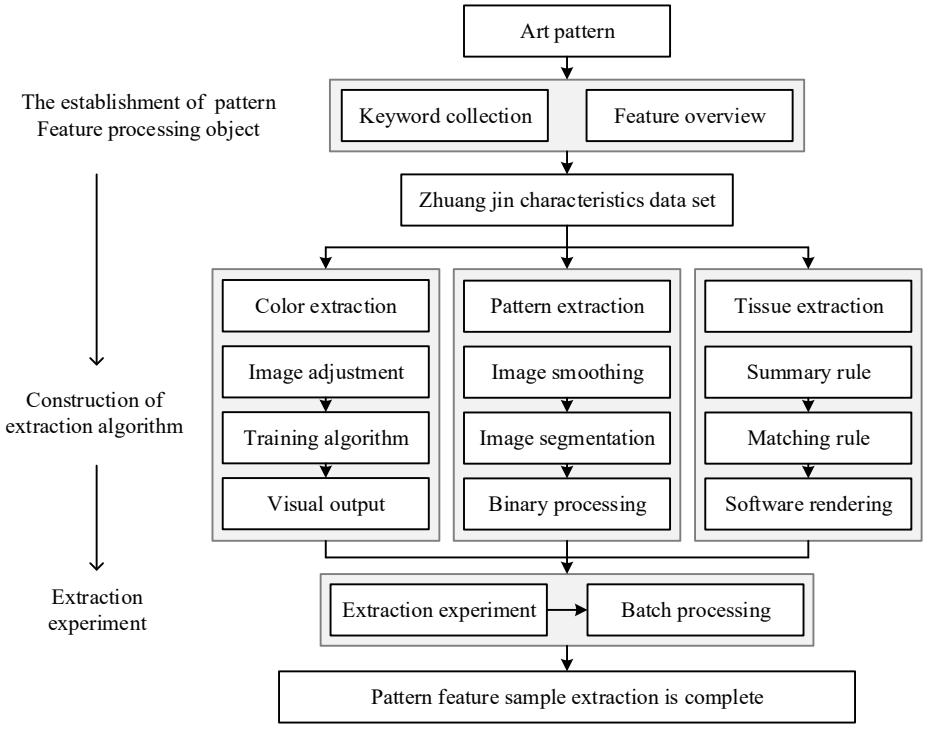


Figure 1: Ethnic art element extraction algorithm design

II. A. 1) Ethnic art picture collection

Due to the abundance of ethnic elements, a large number of undifferentiated processing of ethnic patterns will lead to a huge workload, and the construction of ethnic art elements dataset can solve this problem well. In the feature combing stage, mainly through the browser query related literature, museum collection photos and other ways on the collection of ethnic patterns, eliminating the pattern is not clear, the elements are not obvious, the source of the image is uncertain, collect a total of 5000 patterns in line with the national characteristics, analyze the preliminary search for the collection of ethnic patterns, and summarize the characteristics of the ethnic patterns. Pattern features are mainly composed of three elements: color, pattern, and organizational form, which symbolize cultural characteristics. The relationship of characteristic elements is shown in Fig. 2. The ethnic art elements intimately connect the relationship of shape, color and structure, forming a relationship of mutual achievement and integration and unique ethnic art value.

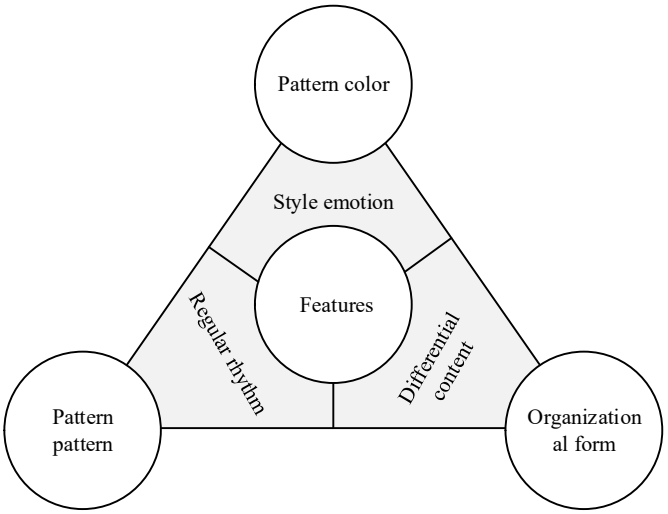


Figure 2: Characteristic element relation

II. A. 2) Color feature extraction

Color extraction in the color extraction of arbitrary samples as an example, through the K-means algorithm will be the main color of ethnic art images hexadecimal coding and occupancy ratio with a visual display.

Algorithm extraction platform to install PyCharm Community, Python 4.5. build OpenCV 4.9.0 computer vision library, computer operating system for Windows 8, CPU for Intel (R) Core (TM) i7-7700HQ CPU @ 3.60GHz, video memory for 16.00 GB.

The idea of the algorithm implementation is to pass the selected image into the K-means algorithm to extract the primary color hexadecimal encoding and occupancy, and match the query with the closest color from the color dictionary to draw the scale map. It is mainly divided into the following steps:

(1) Input image and the number of clusters i.e. the number of extracted colors.

(2) Image resizing.

(3) Training K-means algorithm to fit the model and predict the clusters [21].

(4) Cluster centers (RGB values) are matched from dictionary to query actual/closest color.

(5) Visualization output.

The extraction of ethnic characteristic colors provides color materials for ethnic pattern design, promotes subsequent research on the application of ethnic patterns in modern residential design, uses typical color matching to enhance the aesthetics and ornamental properties of the product, allows more ethnic elements to enter the public's field of vision, deepens the user's cognition of the ethnic elements, and helps to propagate the ethnic culture from the visual dimension.

II. A. 3) Texture Feature Extraction

In order to avoid the sample image blurring and complex texture interference and other reasons affecting the extraction effect during the texture extraction process, the relative total variation model (RTV) texture smoothing, Grabcut interactive image segmentation method, and Otsu algorithm are applied to extract the target texture from the image completely.

(1) Image Smoothing

In order to reduce the interference of its own organization texture on the pattern information processing, the relative total variation (RTV) model algorithm is applied in order to achieve the purpose of extracting the texture smoothing.Texture smoothing aims to smooth the texture in the image while retaining the prominent structures. The relative total variation formula at any point p in the image is as follows:

$$\sum_{p} \frac{\phi_x(p)}{\Psi_x(p)+\varepsilon} + \frac{\phi_y(p)}{\Psi_y(p)+\varepsilon} \tag{1}$$

where ε is a fixed constant and $\varepsilon > 0$, the main function is to ensure that the denominator is not 0 and to avoid errors in the calculation. Any point p in the image is divided into full and intrinsic variants of the window in the x, y direction:

$$D_x(f_p) = \sum_{q \in R(p)} h_{p,q} \cdot |(\partial_x f)_q| \quad (2)$$

$$D_y(f_p) = \sum_{q \in R(p)} h_{p,q} \cdot |(\partial_y f)_q| \quad (3)$$

$$L_x(f_p) = |\sum_{q \in R(p)} h_{p,q} \cdot (\partial_x f)_q| \quad (4)$$

$$L_y(f_p) = |\sum_{q \in R(p)} h_{p,q} \cdot (\partial_y f)_q| \quad (5)$$

where R_p is a rectangular region centered on p, q is any point in the variational region R_p, x, y is the partial differential of pixel point q in directions x and y, respectively, and $h_{p.q}$ is a weight function defined according to the spatial

$$h_{p,q} \propto \frac{exp(-((x_p - x_q)^2 + (y_p - y_q)^2))}{2\sigma^2} \quad (6)$$

p_x and p_y denote the horizontal and vertical coordinates of point p, respectively, and σ controls the spatial scale of the window.The RTV algorithm is modeled as:

$$\arg\min_f \sum_p \left[(f_p - S_p)^2 + \lambda \cdot RTV(f_p) \right] \quad (7)$$

In the above equation: S denotes the input ethnic pattern pattern, f denotes the image after the extracted structure, and λ is a fixed regularization parameter, i.e., the smoothing degree coefficient.

From the above model, it can be seen that the degree of smoothing of the image by the relative full variational algorithm mainly depends on two parameters, the degree of smoothing coefficient λ, and the spatial scale parameter σ.

(2) Image Segmentation Processing

GrabCut is an interactive image segmentation algorithm based on graph cut implementation, which requires the user to manually mark the region to be segmented with a rectangle pattern pattern and pattern, pattern and organization of the connectivity is not high, through the GrabCut algorithm for selective localized segmentation of the ethnic pattern. The steps of the GrabCut algorithm are as follows:

(a) One or more rectangles T containing the target are defined in the image, with the outer region of the rectangle as the background region T_B and the inner region of the rectangle as the foreground region $TF = \varnothing, Tu = TB$.

(b) Initialize label $a_n = 0$ for any pixel n within T_B as a background pixel, and initialize label $a_n = 1$ for each pixel n within T_U as a “possible target” pixel.

(c) Clustering foreground region T_F and background region T_B into K classes by k-means clustering algorithm, respectively, to obtain K Gaussian models in GMM.

(d) Model the background and foreground by Gaussian mixture model (GMM) to obtain the initial values (π, μ, σ) of the two GMM parameters θ, where π is the weight, μ is the mean vector and covariance matrix σ.

(e) Calculate the GMM component of each pixel within the foreground T_U, i.e., the RGB value of the target pixel n is brought into each Gaussian component in the target GMM, and the one with the highest probability is the one that is most likely to be generated n, i.e., the k_n th Gaussian component of pixel n:

$$k_n := \arg\min D_n(\alpha_n, k_n, \theta, z_n) \quad (8)$$

(f) For a given image data Z, the GMM parameters are trained to learn.

$$\underline{\theta} := \arg\min_{\underline{\theta}} U(\underline{\alpha}, k, \underline{\theta}, z) \quad (9)$$

(g) Segmentation is performed by a maximum-minimum flow algorithm to obtain the minimum energy.

$$\min_{\{\alpha_n, n \in T_U\}} \min_k E(\underline{\alpha}, k, \underline{\theta}, z) \quad (10)$$

(h) Repeat (d) to (g) to optimize the GMM model and segmentation results until the energy E reaches a converged state, thus outputting a high quality image.

(3) Image binarization

Image binarization is a basic technique of image processing, which can retain enough feature information. The main core idea is to find the maximized gray level k, i.e. Otsu's threshold, and then divide the image into two colors, black and white, which are greater than the threshold and less than the threshold. The principle of the specific algorithm is as follows:

For a grayscale image F, think of it as an M × N matrix of pixels in the image with pixel values (0, 255), and let n_i be the number of pixels with gray level i, and p_i be the probability that the pixel has a gray level of i, then:

$$p_i = \frac{n_i}{n_0 + n_1 + \cdots + n_{255}} \tag{11}$$

$$\sum_{i=0}^{255} p_i = 1 \tag{12}$$

The segmentation thresholds for the foreground and background are denoted as k. According to the thresholds, the image is classified into two classes C_A (less than k) and C_B (greater than k), the probability that a pixel is classified into classes C_A and C_B is p_A, p_B, respectively, and the gray level means of the two classes are denoted as m_A and m_B, respectively, and the cumulative mean of the gray levels K is m. The global mean of the image is m_G.

Then there are:

$$p_A(k) \times m_A(k) + p_B(k) \times m_B(k) = m_G \tag{13}$$

$$p_A(k) + p_B(k) = 1 \tag{14}$$

According to the concept of variance, the expression for variance is:

$$\sigma^2 = p_A(k)(m_A(k) - m_G)^2 + p_B(k)(m_B(k) - m_G)^2 \tag{15}$$

Eq. (14) is obtained by bringing Eq. (16):

$$\sigma^2 = p_A(k) p_B(k)(m_A(k) - m_B(k))^2 \tag{16}$$

Among them:

$$p_A(k) = \sum_{i=0}^{k} p_i \tag{17}$$

$$p_B(k) = \sum_{i=k+1}^{255} p_i \tag{18}$$

$$m = \sum_{i=0}^{k} i p_i \tag{19}$$

$$m_G = \sum_{i=0}^{255} i p_i \tag{20}$$

$$m_A(k) = \frac{\sum_{i=0}^{k} i p_i}{p_A(k)} \tag{21}$$

$$m_B(k) = \frac{\sum_{i=k+1}^{255} i p_i}{p_B(k)} \tag{22}$$

Equation (17) can be deformed as:

$$\sigma^2 = \frac{(m_G * p_A(k) - m)^2}{p_A(k)(1 - p_A(k))} \tag{23}$$

The threshold k that maximizes the variance between classes can be obtained by traversing. After getting the maximum threshold value the image is segmented by binarization:

$$img(i,j)=\begin{cases}\max val & if\ \ img(i,j)>threshold\\ 0 & otherwise\end{cases} \tag{24}$$

After Otsu algorithm to get the binarized image, the target image is separated from the background color, and the final binarized result is presented in black and white to preserve the foreground target image to the maximum extent.

II. A. 4) Organizational form extraction process

Referring to the methods of rule summarization and minimum unit transformation in shape grammar to get the target figure, in the process of ethnic pattern organization form extraction, observing the minimum unit and using the transformation law, we can draw the pattern organization faster and realize the accurate extraction of ethnic pattern organization form. In this section, the organization form extraction process is mainly divided into the following five steps:

(1) Account for the law of ethnic pattern organization form to facilitate the subsequent extraction of ethnic pattern organization according to the law.

(2) Simplify the organization form and draw the smallest unit with the help of drawing tools.

(3) Analyze the organization of ethnic patterns and match the corresponding transformation laws.

(4) Transform the smallest unit according to the matching law.

(5) Compare with the original drawing to verify the accuracy of extraction, and the extraction of organizational patterns is finished.

II. B.Housing design incorporating ethnic elements

The above mentioned ethnic art elements are fully applied to modern housing design, and the specific contents of this section include the integration of ethnic color characteristics into modern housing design, the integration of ethnic texture characteristics into modern housing design, and the integration of ethnic organization characteristics into modern housing design, which will help to promote the sustainable development of architectural design.

II. B. 1) Integration of color features into housing design

National color identity refers to the color orientation with national characteristics formed by people in a certain period or a certain stage. China in the traditional cosmology, philosophical thinking, social customs under the guidance of the final formation of the national representative color system, namely, “five-color system”, “five-color” refers to black, white, red (red), yellow, blue five colors, these five colors have been given a special These five colors have been given special meanings. In the historical development of traditional Chinese culture, the “five-color view” has been running through the national aesthetic sense of color, which has a great influence and is widely used in traditional Chinese architecture. Color is a more active visual factors in the housing space, often give people a first impression of the space environment, displayed in the housing space furniture, handicrafts, fabrics, and the room from all walks of life in the color selection, are the performance of the housing color content. Color brightness, saturation, hue differences will lead to differences in the sense of space and temperature of the housing, good color matching can let the user produce positive physical and psychological feelings. The integration of traditional colors into modern housing design must also follow the scientific principles of color, taking into account the nature of the space and the user's factors, appropriate selection.

The introduction of national color elements into modern housing space is a humanistic sense of modern space and traditional color fusion exploration, with the help of traditional color cultural connotations and national sentiments conveyed, can point out a new development path for modern Chinese housing design. For the use of traditional colors, should not only stay in the visual expression of the color itself, but also pay attention to the cultural meaning it conveys. In modern housing design, traditional colors can be incorporated as a cultural symbol, giving the space a deeper cultural value and symbolism.

II. B. 2) Integration of ethnic textural features into housing design

National texture element is a unique art form created by ancient working people, the traditional pattern texture is not a simple plane graphic, it contains a profound national spiritual connotation, is the generations of skilled craftsmen through the observation of things and imagination, the use of harmonic, borrowing metaphors, metamorphosis, comparison and other techniques to create. It is a philosophical aesthetic ideal to express thoughts and feelings, highlighting people's pursuit of a better life and expectations. Most of the traditional auspicious textures express the wishes of good luck, well-being, longevity, congratulations, etc., and thus are widely used in architecture,

which is widely used in modern housing design with rich forms and beautiful symbols, and has a strong decorative character, which is mainly embodied in the interface of the housing space and the design of the furnishings. The application in modern housing space is mainly reflected in the design of spatial interface and furnishings: the top surface and the ground are dominated by simple geometric texture. On the façade, there are many types of traditional textures, and the patterns can be complicated or simple, with colorful expressions, including partitions, decorative paintings, wood carvings, hanging screens, color paintings and so on. The use of texture in the furnishings should be simple, moderate, expressive principle, grasp its form and charm, focusing on the expression of the mood. In short, modern people advocate a minimalist home style, in the specific application of traditional texture, can be simplified by refining, abstract deformation, symbols reconstruction and other modern art techniques to transform, and then combined with new materials, new technologies for the performance, and ultimately create a modern aesthetic characteristics without losing the flavor of the national culture of the housing space.

II. B. 3) Integration of organizational features into housing design

The characteristics of national art organization form indicate that under the ancient natural environment and social and humanistic conditions, China formed a unique wooden frame load-bearing architecture, which is the most widely used, the most numerous and the most representative in China, and contains a rich variety of architectural organization features, such as columns, beams, purlins, rafters, arches, birdbaths, alizarin wells, windows, and so on. Traditional ceilings and algal wells are breathtaking in their complex structures and exquisite patterns, and are undoubtedly beautiful decorative materials for housing design. To reasonably incorporate them into modern housing design, it is necessary to grasp their cultural essence, including complex organizational forms, as well as profound cultural symbols, aesthetic values, etc., and apply them in conjunction with modern aesthetic concepts, design methods, and technological means. Made of gypsum board and finished with latex paint, the simple form is more in line with modern people's demand for moderate decoration of living space, while it also echoes with the ground chevron paving, improving the spatial sense of housing and decorative. Organizational form characteristics of beams, pillars and other components often appear as decorative objects in housing design. The beauty of the structure that fully demonstrates the characteristics of the national organizational form lies in its external characteristics on the one hand, the simplified ceiling structure of the ancient architecture, the simple color of the wood and the overall modern Chinese space coherence. On the other hand, it lies in the spiritual thinking triggered by its external features. This symbolic image integrates the ancient architecture and traditional living sentiment into the space, which makes people reverie on national culture and forms a kind of spiritual communication. Partition fan is used as a partition in modern housing is a relatively common application, based on the traditional application of the partition fan is its practical function, play the role of protection, lighting, ventilation, it is usually used as a practical partition in modern housing, used for space enclosure, division, etc., the form of colorful, some of which are the original form of the traditional partition fan, most of which are simplified after the The traditional partition fan retains the charm of the above hollowed-out pattern is exquisite and transparent, so that the space seems to be separated from each other, mutual penetration, through the openwork carving of the pattern can be seen vaguely another space, giving people a kind of implicit and elegant feeling of the space. The pattern of the partition is mainly based on the traditional lattice heart pattern, and each kind of lattice heart pattern shows a different expression. Partition fan by the processing of modern design techniques, simplify the form, change the color, change the material, etc., so that it is more natural to integrate into the modern housing space, play a role in planning and separation of space, so that the level of space and depth of view can be shown, in order to meet the functionality of the premise, but also in the role of fine crafts placed in the housing for people to enjoy, simple and beautiful pattern contains a good meaning, full of rich and elegant The simple but beautiful pattern contains a good meaning, full of rich and elegant ethnic flavor.

III. Analysis of examples of housing design incorporating ethnic elements

III. A. Analysis of the effect of extracting ethnic art elements

III. A. 1) Evaluation of Color Feature Extraction Effectiveness

(1) Evaluation index

The need to evaluate whether two images are similar in terms of color features, similar in terms of structure, and what is the image quality is often encountered in image processing. So far, there are many objective image quality evaluation indexes, including peak signal-to-noise ratio (PSNR), structural similarity index (SSIM), multi-scale similarity index (MSSIM), visual signal-to-noise ratio (VSNR), feature similarity index (FSIM), and gradient magnitude similarity deviation (GMSD), etc. Evaluation indexes are used to analyze the quality of the image from multiple perspectives. Peak signal-to-noise ratio PSNR and structural similarity SSIM for quantitative evaluation.

PSNR measures the degree of image distortion by calculating the error between the original image and the pixel points of the extracted image. The distortion between images is calculated using PSNR by first calculating the mean

square error (MSE) between the two images, the MSE is the mean difference in energy between the real image and the distorted image, the difference in energy between these two is the noise, hence PSNR is the ratio of peak signal energy to MSE. Two $m \times n$ monochrome images I and K, if there is a noise approximation between the two images, then their mean square error is defined as shown in equation (25):

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}\left[I(i,j)-K(i,j)\right]^2 \tag{25}$$

MSE is a common loss function, from MSE you can calculate the distortion of the two images, the image is stored in the computer occupies a maximum of $2^{bits}-1$ memory, so $PSNR$ the formula is shown below:

$$PSNR = 10 \cdot \log_{10}\left(\frac{MaxValue^2}{MSE}\right) = 10 \cdot \log_{10}\left(\frac{\left(2^{bits}-1\right)}{MSE}\right) \tag{26}$$

Peak Signal to Noise Ratio (PSNR) is often used to evaluate the degree of distortion of the processed image, the value of PSNR is negatively correlated with the degree of distortion of the image, when the value of PSNR is higher than 40 decibels it means that the processed image is very similar to the original image, in 30-40 decibels it means that the processed image has a small degree of distortion, and when the value of PSNR is between 20 and 30 decibels it means that the processed image is very different from the original image. 30 dB indicates that the processed image is more different from the original image. When the PSNR value is below 20 dB the image is severely distorted and unacceptable.

SSIM defines structural information from the perspective of image composition as an attribute that reflects the structure of objects in the scene independently of luminance and contrast, and models distortion as a combination of three different factors: luminance, contrast and structure. $SSIM$ calculates the similarity between image x and image y, then Eq. (27) is defined as:

$$SSIM(x,y) = \left[l(x,y)\right]^{\alpha}\left[c(x,y)\right]^{\beta}\left[s(x,y)\right]^{\gamma}, \alpha>0, \beta>0, \gamma>0 \tag{27}$$

The above equation is the mathematical definition of SSIM, where SSIM measures image similarity in terms of luminance, contrast and structure respectively, $l(x,y)$ is luminance comparison, $c(x,y)$ is contrast comparison and $s(x,y)$ is structure comparison. μ_x and μ_y represent the mean of image x, y, δ_x and δ_y represent the standard deviation of x, y, and δ_{xy} represents the covariance of x, y, respectively. c_1, c_2, c_3 are constants, respectively, to avoid systematic errors caused by a denominator of 0. Usually taken in the actual calculation process, it is usually set to a fixed value, so the calculation of SSIM is simplified as:

$$SSIM(x,y) = \frac{\left(2\mu_x\mu_y + c_1\right)\left(2\delta_{xy} + c_2\right)}{\left(\mu_x^2 + \mu_y^2 + c_1\right)\left(\delta_x^2 + \delta_y^2 + c_2\right)} \tag{28}$$

In general, SSIM has the following characteristics:

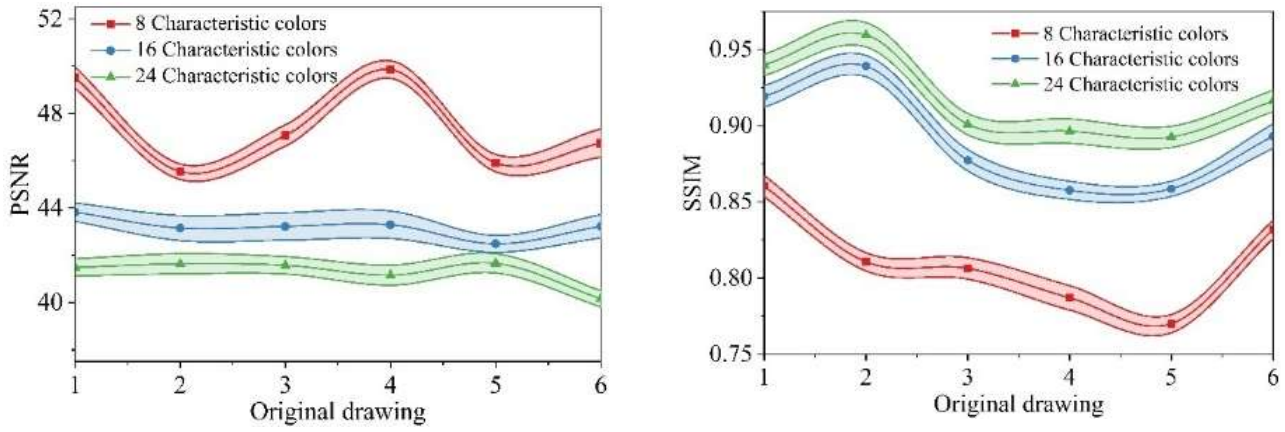
(a) $SSIM(x,y) = SSIM(y,x)$.

(b) The value domain of $SSIM$ is [0, 1], i.e., the closer the value converges to 1, the better the extraction effect.

(c) The SSIM value is 1 when the extraction effect is exactly the same as the original image.

(2) Analysis of results

Image reconstruction is performed using 8 feature colors, 16 feature colors and 24 feature colors extracted by K-means algorithm, and the K-means color extraction results are analyzed from the visual point of view, and the peak signal-to-noise ratio, PSNR, and the structural similarity index, SSIM, are used as the evaluation indexes for the similarity between the reconstructed image and the original image. Therefore, in this subsection, the similarity between the reconstructed image and the original image is calculated from two perspectives, PSNR and SSIM, and the values are recorded in order to compare with the reconstruction results of other algorithms. Taking six images in the collected image dataset as an example, the results of the extraction effect evaluation are shown in Fig. 3, where (a)~(b) are PSNR~SSIM, respectively. For different images in doing the same feature color extraction reconstruction, the data index fluctuates with the color of the original image, the SSIM of the same image increases with the extraction of the feature color, while the PSNR is the opposite. It can also be seen that the PSNR value of six images is higher than 40 dB indicating that the processed image is very similar to the original image, and the SSIM value is distributed in the range of 0.75 to 0.98, which is fully able to meet the requirements and standards of housing design and promote sustainable development of buildings.



(a)PSNR (b)SSIM

Figure 3: Extraction effect evaluation results

III. A. 2) Evaluation of Texture Feature Extraction Effectiveness

(1) Smoothing parameters

The two parameters that control the degree of image smoothing are smoothing coefficient λ and spatial scale parameter σ. Smoothing coefficient λ is generally taken between 0 and 0.05, only adjusting λ does not allow effective separation of noise and pattern, when increased alone λ may cause blurring of the image and unwanted texture is retained instead, so it is necessary to adjust in parallel with the spatial scale parameter σ. For some small-size image stains, the smoothing effect is more significant when σ is increased to 0~6, and the noise is eliminated. However, the detail part of the pattern is lost to a certain extent when $\sigma = 6$ is increased, so the spatial scale parameter σ is selected as 4. Meanwhile, with the increase of λ, the white part of the knife cuts in the image is smoothed, but the value of λ is too small, which will also make the smudged part of the image be retained, so the coefficient of the degree of smoothing λ is selected to be 0.02~0.04 when dealing with the shadow image.

(2) Analysis of pixel number selection

The accuracy of pixel segmentation has a great impact on GrabCut segmentation, which determines the effect of the final target segmentation to a certain extent. Therefore, in order to objectively analyze the impact of the number of pixel segmentation on image segmentation accuracy and time, and to obtain the optimal number of pixels, this paper designs an evaluation index - boundary tightness - to evaluate the pixel segmentation accuracy. Taking the segmentation result when the number of pixels is $n = 800$ as an example, η is the ratio of the number of correct pixels contained in the edge field of the pixel target to the number of easily categorized pixels of the actual segmented target. That is:

$$\eta = \frac{T \cap C}{C} \tag{29}$$

where T is the number of correct complete target pattern pixels and C is the number of pixels closest to the edge of the target pattern after segmentation.

A comparison of the segmentation results with different number of pixels is shown in Fig. 4, where the horizontal axis is the number of pixels and the vertical axis is the boundary tightness and the running time, respectively. The results show that with the increase of the number of pixels, the running time ranges from 0.4221 to 0.4329s, except for the running time at n=100, which is within 0.420s. At n>600, the running time tends to increase, but there is no significant increase in its boundary tightness η. It is concluded that the segmentation effect is most significant and less time-consuming at n=600, when the boundary tightness $\eta = 0.968$. From the experimental results, it can be seen that although the higher the number of pixel segmentation the higher the accuracy, but after reaching a certain number, the segmentation accuracy is difficult to be increased, and on the contrary, it will lead to the lengthening of the running time. Therefore, when performing pixel segmentation, the number of segmentation should be chosen reasonably according to the size of the image being processed.

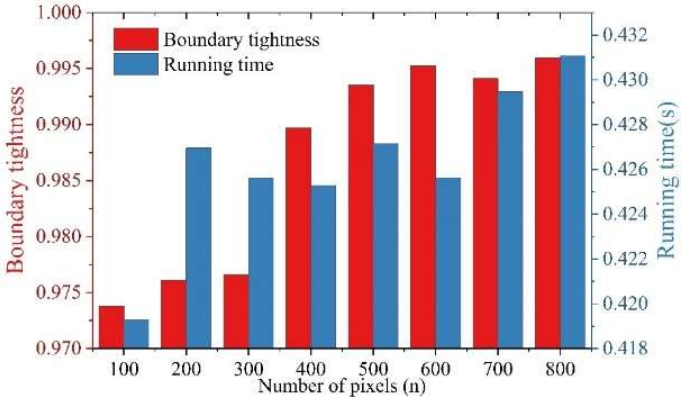


Figure 4: Comparison of segmentation results under different pixel numbers

(3) Image segmentation results

In order to quantitatively and objectively evaluate the experimental segmentation results of the algorithm proposed in the article, this paper uses the target pattern manually keyed out by the PS software as the reference object for correct segmentation to assess the segmentation accuracy of the target pattern by adopting the segmentation accuracy evaluation metric-Pixel Accuracy (PA), which is the ratio of the number of correctly categorized pixels to the number of categorized pixels obtained from all the experiments. That is:

$$f_{PA} = \frac{TP}{TP + FP} \tag{30}$$

where TP is the number of correctly classified pixels and FP is the number of incorrectly classified pixels.

Similarly six images are selected from the collected data set as samples for this study, and the number of pixels in the six images is uniformly set to 800, and the image segmentation results are represented in the form of confusion matrix, and the image segmentation results are shown in Fig. 5. It can be seen that the number of correctly classified pixels TP is above 763-782, and the pixel accuracy PA can be calculated to be >0.95. From the experimental results, it can be seen that the algorithm in this paper can obtain a clearer and more accurate target contour with less noise and the effective edge of the target pattern can be extracted to the maximum extent only by simple interactive operation. Make it better serve the modern housing design, to achieve the sustainable development level of architectural design.

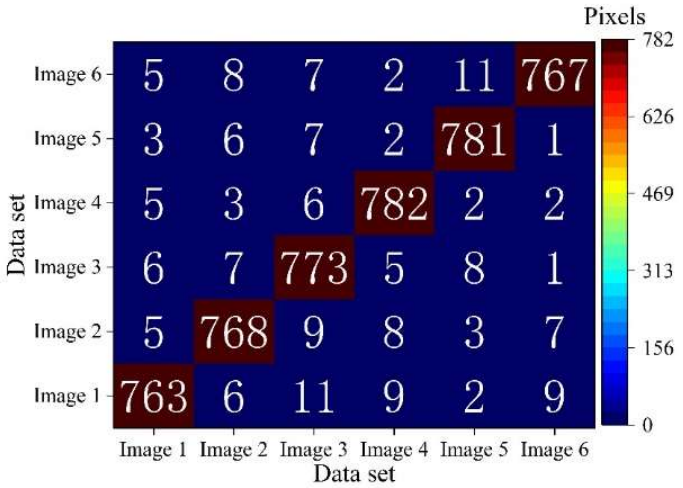


Figure 5: Image segmentation result

III. A. 3) Assessment of the effectiveness of organizational form feature extraction

This subsection evaluates the effect of organizational form feature extraction based on shape grammar with the help of a scale. The scale “Effectiveness of Organizational Form Feature Extraction Based on Shape Grammar” is designed in the form of reading References, with a total of 50 question items, and 30 experimenters are organized

for the test, which includes people without any design experience, school students and designers with design background. The experimental intention was explained to the experimenters and they were allowed to browse the 6 images in the dataset, so that they could systematically understand the ethnic organizational form features, and then the experimenters scored the scheme on the scale, and the results of the assessment of the organizational form feature extraction effect are shown in Table 1, in which the range of the scale scores is from 1 to 5. It can be seen that the mean values of the assessment of the organizational form extraction effect for images 1 to 6 are 3.809, 3.789, 3.796, 3.766, 3.586, 3.809, indicating that the 30 test subjects have a better assessment of the effect of organizational form feature extraction based on shape grammar, which provides valuable material support for modern housing design and thus accelerates the pace of sustainable development of buildings.

Table 1: Evaluation of organizational form feature extraction effect

N	Image1	Image2	Image3	Image4	Image5	Image6
1	4.031	3.998	3.833	4.159	3.314	4.031
2	3.656	4.154	3.209	3.162	3.174	3.656
3	3.222	3.464	3.948	4.364	3.118	3.222
4	4.354	4.362	3.824	4.247	3.343	4.354
5	4.175	3.24	4.39	3.458	3.339	4.175
6	4.08	4.355	3.233	3.16	4.41	4.08
7	4.089	3.754	3.797	3.491	3.375	4.089
8	3.614	4.451	3.173	3.554	3.085	3.614
9	3.794	3.135	3.223	4.435	3.487	3.794
10	3.397	3.601	3.946	3.156	3.842	3.397
11	3.381	3.826	3.481	3.908	3.933	3.381
12	3.354	3.394	3.944	4.38	3.4	3.354
13	4.195	3.444	3.056	3.887	3.311	4.195
14	4.09	3.704	3.686	3.505	3.322	4.09
15	4.064	3.228	3.057	3.003	3.17	4.064
16	3.411	4.002	4.329	3.3	4.196	3.411
17	3.288	3.934	4.346	3.607	3.095	3.288
18	4.141	3.184	4.449	4.028	3.615	4.141
19	3.083	3.874	4.195	3.854	3.913	3.083
20	3.609	3.708	4.5	3.219	3.536	3.609
21	3.775	4.302	4.178	3.064	3.359	3.775
22	4.294	3.76	4.359	4.457	3.75	4.294
23	4.063	3.566	3.177	3.504	3.141	4.063
24	4.416	4.193	3.66	3.83	4.243	4.416
25	3.086	3.903	4.293	4.159	4.043	3.086
26	4.436	3.475	3.739	4.255	4.383	4.436
27	3.081	3.753	4.149	3.868	3.69	3.081
28	4.12	3.803	3.329	4.263	4.026	4.12
29	4.367	4.279	3.855	3.929	3.742	4.367
30	3.617	3.836	3.524	3.783	3.223	3.617
Mean	3.809	3.789	3.796	3.766	3.586	3.809

III. B. Assessment of the effectiveness of modern housing design

III. B. 1) Development of an evaluation indicator system

Based on the principles of national art elements, modern housing design requirements, and evaluation index system, an evaluation index system for the effect of modern housing design incorporating national art elements was constructed, and the evaluation index system is shown in Table 2. It can be seen from Table 2 that the evaluation index system consists of 3 first-level indicators (livability A1, aesthetics A2, low-carbon environmental protection A3) and 12 second-level indicators (living comfort B1, natural lighting and ventilation B2, national characteristic space layout B3, cultural atmosphere creation B4, appearance design B5, interior decoration B6, color matching B7, detail treatment B8, energy-saving material use B9, renewable energy utilization B10, green vegetation configuration B11, and traditional and modern technology combination B12).

Table 2: Evaluation index system

Title	Primary index	Symbol	Secondary index	Symbol
Modern housing design effect	Habitability	A1	Living comfort	B1
			Natural lighting and ventilation	B2
			Spatial layout of national characteristics	B3
			Cultural atmosphere construction	B4
	Aesthetic	A2	Appearance design	B5
			Interior decoration	B6
			Color matching	B7
			Detail processing	B8
	Low carbon and environmental protection	A3	Use of energy-saving materials	B9
			Renewable energy utilization	B10
			Green vegetation allocation	B11
			Traditional technology is combined with modern technology	B12

III. B. 2) Analysis of evaluation indicator weights

AHP hierarchical analysis method for the more complex and difficult to quantify the problem of gradual decomposition of the composition of factors and indicators, through the affiliation between the indicators to decompose the construction of hierarchical hierarchical structure, the construction of the two-two matrix judgment scoring for the quantification of the indicators, to obtain the results of the weight of the evaluation indicators [22], [23].

Evaluation index weights are analyzed as shown in Table 3. It can be seen that the weight of livability A1 is 0.2708, and its subordinate secondary indicators, the existence of national characteristics of spatial layout B3 (0.111) > residential comfort B2 (0.0908) > B4 cultural atmosphere creation (0.04) > B1 residential comfort (0.029), the rest of the aesthetics A2, low carbon and environmental protection A3 weight describes the analysis, the same reason.

Table 3: Evaluation index weight

Title	Symbol	Weighting	Symbol	Weighting
Modern housing design effect	A1	0.2708	B1	0.029
			B2	0.0908
			B3	0.111
			B4	0.04
	A2	0.4063	B5	0.11
			B6	0.1251
			B7	0.0878
			B8	0.0834
	A3	0.3229	B9	0.0773
			B10	0.0801
			B11	0.0947
			B12	0.0708

III. B. 3) Fuzzy integrated evaluation

Fuzzy comprehensive evaluation method is defined as a comprehensive evaluation method based on fuzzy mathematics, describing the fuzzy boundaries in terms of the degree of affiliation, and being able to transform qualitative evaluation into quantitative evaluation. Under the premise of determining the weights of the indicators, a fuzzy comprehensive evaluation model is established [24].

Taking a housing design project integrating ethnic art elements in a neighborhood as a research sample, 10 well-known designers were invited to evaluate its design effect, and the corresponding evaluation affiliation degrees, excellent, good, moderate, poor, and poor, were also set, and assigned values of 5, 4, 3, 2, and 1, respectively. The sample was evaluated and analyzed using the fuzzy comprehensive evaluation model, and the fuzzy comprehensive evaluation results are shown in Table 4. According to the data performance in the table, the evaluation results of the housing design effect are (4.8791, 1.5293, 1.3133, 1.5134, 0.7649), and based on the principle of maximum affiliation, it is summarized that the housing design effect of integrating the elements of

national fine arts in a certain district is excellent, which not only ensures the internal space of the housing and aesthetics, but also manifests the spirit and culture of the nation.

Table 4: Fuzzy comprehensive evaluation results

Secondary index	Excellence	Good	Intermediate	Range	Poor
B1	0.145	0.058	0.029	0.029	0.029
B2	0.3632	0.0908	0.1816	0.1816	0.0908
B3	0.444	0.222	0.111	0.222	0.111
B4	0.2	0.04	0.08	0.04	0.04
B5	0.66	0.22	0.11	0.11	0
B6	0.7506	0.2502	0.1251	0.1251	0
B7	0.439	0.0878	0.1756	0.0878	0.0878
B8	0.3336	0.1668	0.0834	0.1668	0.0834
B9	0.3865	0.0773	0.0773	0.1546	0.0773
B10	0.4005	0.0801	0.0801	0.1602	0.0801
B11	0.4735	0.0947	0.1894	0.0947	0.0947
B12	0.2832	0.1416	0.0708	0.1416	0.0708

IV. Conclusion

This paper uses image preprocessing technology to extract ethnic art elements, applies the extracted features to modern housing design activities, and analyzes examples of modern housing design incorporating ethnic art elements with the help of intelligent algorithms.

(1) The PSNR values of the six images in the dataset are higher than 40 dB indicating that the processed images are very similar to the original images, and the SSIM values are distributed in the range of 0.75~0.98, which means that the extracted color features can fully meet the requirements and standards of housing design. The pixel accuracy of image segmentation PA>0.95 indicates that the relative total variation model (RTV) texture smoothing, Grabcut interactive image segmentation method, and Otsu algorithm, can allow the effective edges of the target pattern to be extracted to the maximum extent, so that it can better serve the modern housing design.

(2) Livability A1 subordinate secondary indicators, the existence of ethnic characteristics of the spatial layout B3 (0.111) > residential comfort B2 (0.0908) > B4 cultural atmosphere creation (0.04) > B1 residential comfort (0.029), the evaluation results of the effect of the housing design of a neighborhood is (4.8791, 1.5293, 1.3133, 1.5134, and 0.7649), indicating that its design effect evaluation grade is excellent, making the building design sustainable development level further body.

References

[1] Ji, F., & Zhou, S. (2021). Dwelling is a key idea in traditional residential architecture's sustainability: A case study at yangwan village in suzhou, China. Sustainability, 13(11), 6492.

[2] Węgrzyn, J., & Kania, K. (2024). Heterogeneous preferences for sustainable housing: evidence from Poland. Journal of Housing and the Built Environment, 39(2), 749-767.

[3] Hasu, E., Tervo, A., & Hirvonen, J. (2017). Lifestyles and housing design: case Finnish townhouse. NA, 29(1).

[4] Karjalainen, M., Ilgın, H. E., Metsäranta, L., & Norvasuo, M. (2021). Suburban Residents' Preferences for Livable Residential Area in Finland. Sustainability 2021, 13, 11841.

[5] Askarizad, R. (2018). Influence of Socio-Cultural Factors on the Formation of Architectural Spaces (Case Study: Historical Residential Houses in Iran). Creative City Design, 1(1), 29-36.

[6] Nielsen, H. H. (2024). Housing double binds: Social sustainability in municipal policy plans. Nordic Journal of Wellbeing and Sustainable Welfare Development, 3(2), 85-99.

[7] Hagbert, P., & Malmqvist, T. (2019). Actors in transition: Shifting roles in Swedish sustainable housing development. Journal of Housing and the Built Environment, 34(3), 697-714.

[8] Hamnett, C. (2021). Urban housing in contemporary China: A commentary. Cities, 108, 102968.

[9] Chen, J., Wu, Y., Guo, F., & Wang, H. (2018). Domestic property and housing class in contemporary urban China. Journal of Housing and the Built Environment, 33, 91-109.

[10] Ling, Y., & Zhang, F. (2024). For the greater good: modern China's struggle on housing shortage. City, Territory and Architecture, 11(1), 12.

[11] Xiaoming, W. (2017). What the 'housing problem'shows about today's China. Cultural Studies, 31(6), 837-856.

[12] Haque, N. U., & Khurshid, N. (2023). Construction without real estate development. The Pakistan development review, 62(1), 1-14.

[13] Yu, K. H., & Hui, E. C. M. (2018). Housing construction and uncertainties in a high-rise city. Habitat International, 78, 51-67.

[14] Kaklauskas, A., Zavadskas, E. K., Lepkova, N., Raslanas, S., Dauksys, K., Vetloviene, I., & Ubarte, I. (2021). Sustainable construction investment, real estate development, and COVID-19: a review of literature in the field. Sustainability, 13(13), 7420.

[15] Bao, Q. T., Dinh, T. N., & Quang, K. M. (2024). Impacts of Culture on Traditional Housing Architecture of Ethnic Minority in the Vietnamese Northern Mountains. Journal of Design and Built Environment, 24(2), 01-18.
[16] Xiuyun, L. (2023). Innovation and Research of Ethnic Art Elements in Contemporary Design. Frontiers in Art Research, 5(6).
[17] SHILDERKHANOV, B. K., ISSAKHOV, N. Z., POPOV, Y. G., MYRZAHMETOVA, S. T., KOSTSOVA, A. A., TROFIMOV, V. P., ... & Myrzakhmetov, A. (2018). Compositional Features of Ethnic Interior Design. Astra Salvensis, (12).
[18] Zheng, S. O. N. G. (2022). Suggestions and Reflections on Inheritance Strategy of Traditional Residence Construction Technique of Ethnic Minorities in Western Hubei. Journal of Landscape Research, 14(5).
[19] Pane, S. F. (2022). CROSS-CULTURAL CREATIVITY: AESTHETICS IMPLEMENTATION OF MODERN ETHNIC STYLE INTERIOR DESIGN IN DUTCH COLONIAL HOUSE. In Prosiding Seminar Internasional-ICDAD (International Conference Dialogue on Art and Design) (Vol. 1, pp. 71-82).
[20] Chen, C. (2024). Algorithm and Tool Development for Creative Generation of Graphic Design of Folk Houses and Ancient Buildings Integrating Cultural and Creative Elements. Scalable Computing: Practice and Experience, 25(6), 4729-4736.
[21] Xiuqi Huang,Hong Tao,Haotian Ni & Chenping Hou. (2025). Debiasing weighted multi-view k-means clustering based on causal regularization. Pattern Recognition111195-111195.
[22] Muluken Tilahun Desbalo & Asregedew Kassa Woldesenbet. (2024). Enhancing strategic decision-making in built asset management through BIM-Enabled asset information modelling (AIM) for public buildings in Ethiopia: A fuzzy-AHP analysis. Heliyon(23),e40824-e40824..
[23] Himan Khodkam,Razieh Pourdarbani,Hadi Ghaebi & Mario Hernandez Hernandez. (2024). Investigating The Environmental Impacts Of Different Approaches Of Agricultural Waste Management Using Ahp Technique. Acta Technologica Agriculturae(4),242-250.
[24] Yunlong Lv. (2025). Integrating motion sensors based on deep neural networks into training and monitoring systems using a fuzzy comprehensive evaluation method. Computers and Electrical Engineering109890-109890.