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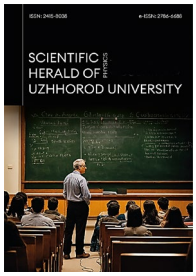

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Research on the extraction of RMB decorative pattern configuration and its innovative design: Analysis based on OpenCV calculator visual library and shape grammars

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Abstract

Relevance. The study addresses the potential application of configuration rules in creating decorative designs for RMB, focusing on improving design aesthetics and functionality.

Purpose. To analyze the feasibility of using configuration rules to enhance the design of Chinese currency.

Methodology. The study involved the analysis and synthesis of decorative patterns, the establishment of configuration rules, and the examination of their application in currency design.

Results. The findings demonstrate that configuration rules can effectively utilize existing patterns to improve Chinese currency design, providing opportunities for new design variations that align with modern aesthetic and functional requirements. The analysis revealed that Chinese currency patterns often embody cultural significance, historical events, and characters through complex geometric and abstract elements. Key features of the patterns were identified, highlighting the potential for more efficient use of configuration rules in design.

Conclusions. Configuration rules can successfully organize and enhance the decorative patterns in the Chinese currency. The study confirms the feasibility of applying these rules to create cohesive and culturally rich designs. Additionally, the integration of configuration rules can streamline the design process and ensure consistency in aesthetic quality.

Keywords: computer technology; image processing; syntactic structure extraction; monetary unit.

Introduction

The traditional process of creating decorative drawings is often complicated and time-consuming, and the level of skill and imagination of the artist can limit its results. The use of modern computer technology to automate this process can open up new design possibilities, making it easier and faster to create drawings. The use of such technologies can not only increase the speed and efficiency of the process but also create innovative and unique designs that meet modern market requirements. In addition, the design process is currently done manually, which can lead to limitations in the quality and variety of designs. The use of computer technology, such as artificial intelligence (AI) and image processing, can not only increase productivity and accuracy but also open new horizons in creating unique and innovative designs that meet the needs of the modern market. These technologies can become central in the development of currency design, contributing to its improvement and opening new opportunities for creativity and individual expression.

The study by J. Xie [1] showed that the use of AI technology contributes to the development of innovative design of intangible cultural heritage, through the analysis of characteristics and the use of formal grammar for design. Z. Mang [2] demonstrated that by analysing the symbolism, security, and visual design of the fifth series of the Chinese currency, its role in shaping the national image can be determined. Moreover, W. Guo [3] highlights the importance of developing ways to promote the RMB as an international reserve currency, which could affect the

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Chinese and global economies. In turn, N. Bodkhe et al. [4] demonstrated that the use of image processing in currency verification systems, including the analysis of its decorative patterns, could effectively detect counterfeit currency and improve the authentication of genuine banknotes. S.B. Kumar et al. [5] emphasised the significant potential of the OpenCV computer recognition library for the development of visual data processing applications with minimal computing time, which can contribute to the further development of computer recognition and AI. In addition, B. Ogechi Ogbuokiri and M. Raborife [6] determined that contextual bag grammars are effective in creating similar images as distractors in visual password schemes.

Additionally, A. Mashhour [7] showed that the structural foundations of organic forms could be successfully used to develop modern decorative designs and improve students' skills in using design tools. S. Fathima Chandhini et al. [8] created a computer recognition system based on the OpenCV library for accurate character extraction from documents and images, which can process a variety of input data, extract characters with high accuracy and efficiency, and confidently handle character processing. Moreover, C.J. Silva Costa and M.A. Costa Frade [9] emphasised that traditional and innovative methods should be used to reproduce decorative elements in relief plaster, ensuring compliance with the ethical principles of conservation and restoration. U.M. Sikharam et al. [10] noted a significant improvement in the efficiency of frequent pattern extraction algorithms using parallel processing within MapReduce, which can be useful for practitioners in the field of associative data analysis.

These authors have studied various aspects of innovative design, and the use of AI technologies, and analysed product development methods. However, this study addresses the possibility of using the methods of designing decorative patterns for the Chinese currency using configuration rules. To achieve this goal, the OpenCV library and shape grammars were used. The study aims to analyse the composition of RMB decorative patterns, collect digital images of the Chinese currency, use methods to extract patterns and establish configuration rules, systematise information about them and define classifications, and review RMB design methods and their application.

Materials and Methods

This study was conducted using the Windows 10 system, the Python 3.7 programming language, and the OpenCV 4.5.1 library of computer recognition functions and algorithms. First, the narrow and expand operations were used on the image, followed by the open and close operations on the image to improve the smoothness. In addition, morphological gradient operations were applied to sharpen and make the contours in the image more visible. The study examined the process of extracting patterns from a digital library and setting up configuration rules for their further use in design. This process involved analyzing the various decorative elements available in the digital library and selecting those that best met the research goals and objectives. After selecting the appropriate patterns, configuration rules were established that determined the way they were placed, interacted with and related to each other in the composition.

After that, the design of decorative patterns was analysed using innovative approaches and methods. The analysis identified key features and characteristics that determined and evaluated the aesthetic and cultural aspects of each pattern. Based on the analysis, new methods and strategies for the effective use of configuration rules in the design of the Chinese currency were explored. They were presented and described in detail, which were used to define their applicability in practice. Additionally, formulas and calculations were performed in the study. If the outline of a floral pattern is defined as, a closed curve made up of points, then (1):

$$a = [x_1, x_2, \dots, x_n], \tag{1}$$

where: a – designation of the floral pattern; n – number of dots.

If a ring pattern pixel is defined as a complex path made up of paths, then (2):

$$b = [y_1, y_2, \dots, y_e], \tag{2}$$

where: b – designation of the ring pattern; e – number of contours.

If a symmetrical pattern configuration is defined as a layout rule composed of partial patterns, then (3):

$$c = [z_1, z_2, \dots, z_f], \tag{3}$$

where: c – Symbol of a symmetrical pattern; f – number of partial patterns.

A raised pattern made up of pixels (4, 5):

$$g = \{b_1, c_1, b_2, c_2, \dots, b_k, c_k\}, \tag{4}$$

$$g = \left\{g_{a_1}, c_{a_1}, g_{a_2}, c_{a_2}, \dots, g_{a_k}, c_{a_k}\right\}, \tag{5}$$

where: g – designation of the enhanced pattern; k – number of pixels.

Expressions for expansion, reduction, opening and closing operations are as follows (6-9):

$$A \oplus B = \left\{z \mid [(\widehat{B})_z \cap A \neq \emptyset]\right\}, \tag{6}$$

$$A \ominus B = \{z \mid [(B)_z \subseteq A]\}, \tag{7}$$

$$A \circ B = (A \ominus B) \oplus B, \tag{8}$$

$$A \cdot B = (A \oplus B) \ominus B, \tag{9}$$

where: A – an image; B – a structural element.

An expression for the morphological gradient operation (10):

$$C = A \oplus B - A \ominus B, \tag{10}$$

where: A – the original image; B – the structural element; C – the image after the morphological gradient operation.

Assuming the presence of contours A and B, the contour is defined as (11, 12):

$$m_i^A = \text{sign}(h_i^A)\log h_i^A, \quad (11)$$

$$m_i^B = \text{sign}(h_i^B)\log h_i^B, \quad (12)$$

The difference between contour A and contour B is expressed as (13):

$$I(A,B) = \sum_{i=1}^{7}\left|\frac{1}{m_i^A} + \frac{1}{m_i^B}\right|, \quad (13)$$

where: $I(A,B)<0.02$.

The identified contours are classified, and a group of similar contours is formed (14):

$$Y = \{y_1, y_2, y_3, \ldots, y_n\}, \quad (14)$$

where: Y – group of contours.

The remaining dissimilar contours are classified into a set (15):

$$U = \{u_1, u_2, u_3, \ldots, u_n\}, \quad (15)$$

where: U – set of paths.

A formula for calculating the shortest distance between outer contours (16):

$$d_{min}(A_i, A_j) = \min_{x\in A_i, z\in A_j} \text{list}(x,z), \quad (16)$$

where: A_i, A_j – outer contours.

A formula for calculating the target centre position using zero- and first-order moments (17-20):

$$M_{00} = \sum_I \sum_J V(i,j), \quad (17)$$

$$M_{10} = \sum_I \sum_J i \times (i,j), \quad (18)$$

$$M_{01} = \sum_I \sum_J j \times (i,j), \quad (19)$$

$$i_c = \frac{M_{10}}{M_{00}}, j_c = \frac{M_{10}}{M_{00}}, \quad (20)$$

where: M_{00} – the moment of zero order; M_{10}, M_{01} – first-order moments; i_c, j_c – coordinates of the central point of the image.

In addition, information about the pattern features is formalized, and the primitive expression is as follows (21):

$$B = \begin{bmatrix} \text{RMB decorative patterns feature1}V_1 \\ \text{feature2}V_2 \\ \ldots\ldots \\ \text{feature nV}_n \end{bmatrix} = \begin{bmatrix} R_1 \\ R_2 \\ \ldots \\ R_n \end{bmatrix}, \quad (21)$$

where: B – primitive.

Form grammar was also employed, which utilizes changes to initial formation elements for subsequent output following a determined set of rules, where the newly generated elements demonstrate a certain degree of inheritance from the attributes of the original elements.

Results

Features of the configuration of decorative patterns of Chinese currency

Currency banknotes are an important part of every country's financial system. One of the key characteristics of banknotes is their decorative patterns, which are not only aesthetically pleasing but also of great historical and cultural significance for the country. The decorative designs of the Chinese currency consist of basic, border, and auxiliary designs. The main pattern is the main design of the currency unit, which includes a floral pattern such as chrysanthemums, and lotuses. A border pattern often contains a combination of decorative patterns, such as spherical patterns or ribbon patterns. Therefore, auxiliary designs usually consist of basic shapes, such as straight lines, curves, and concentric circles, which create a complex graphic structure of banknotes.

The composition methods of Chinese currency decorative patterns are divided into symmetrical composition, diverse and unified composition, and divided composition. In the first case, the decorative pattern of the Chinese currency has a unified and symmetrical face composition, which emphasizes balance and symmetry in the pattern (Figure 1). After selecting a thematic pattern, it is placed in the centre of the image or repeated continuously, symmetrically dividing the pattern along the central axis.

Figure 1. The method of symmetrical composition

Source: compiled by the author.

Furthermore, a varied and unified composition includes an organic distribution of patterns in a certain form, creating an image with rhythm and harmony, in contrast to a single and static composition (Figure 2).

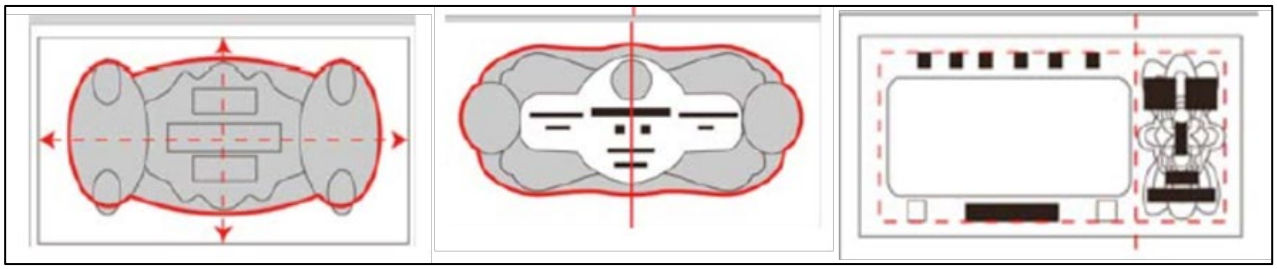


Figure 2. The method of diverse and unified composition

Source: compiled by the author.

The method of divided composition means division by geometric shapes with corresponding patterns within each shape (Figure 3). The patterns correspond to changes in the outer contour of the geometric shape, reflecting the rationality and order of the structure.

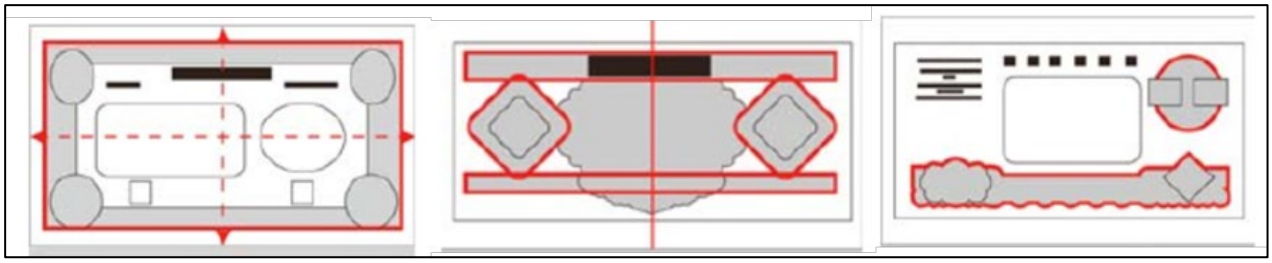


Figure 3. The method of divided composition

Source: compiled by the author.

The concept of configuration comes from architecture and is used to represent the relationships between components and the whole. Regarding the composition of RMB decorative patterns, it is necessary to provide relevant descriptions through observation, and then demonstrate the pattern around which the symmetrical and visual patterns using different configurations are different (Figure 4).

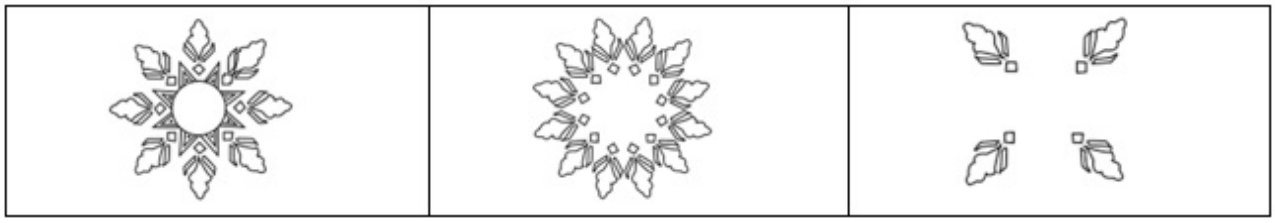


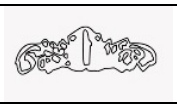
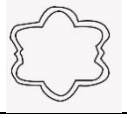
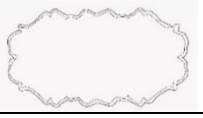
Figure 4. Floral, ring and symmetrical patterns

Source: compiled by the author.

In the aforementioned example, the first flower pattern is the one around the solar explosion (Formula 1), then the ring flower pattern (Formula 2), and then the symmetrical flower pattern (Formula 3). In general, pixels are the basic unit for creating visual patterns, and their combinations are formed by employing a range of configuration rules. To provide a better determination of the hierarchical relationship between the decorative patterns of the Chinese currency, a hierarchical expression model for RMB patterns was developed. In this way, pixels are transformed and combined according to configuration rules to create a pattern. The pixels that make up the pattern are located at different levels in the tree structure. The root part represents the general pattern, while the branches and leaves are raised following the configuration rules. A raised pattern is defined as composed of a certain number of pixels (Formula 4), where the pixels form a pattern. Such a pattern can also be described as a set of enhanced patterns (Formula 5), where the patterns are composed according to configuration rules. The hierarchical model of

pixel expression (Table 1) is divided into basic patterns (Y), additional patterns (F), and edge patterns (B).

Table 1. Example of sub-image selection results

20 RMB	Pixel level	Subpixels A	Subpixels B	Subpixels C
	Supplementary pattern F	FZ1: 	FZ2: 	FZ3: 
	Border pattern B	BK1: 	BK2: 	BK3: 
	Embellish a m X	XS1: 	XS2: 	

Source: compiled by the author.

Thus, the characteristics of the composition of RMB decorative patterns were considered. Different methods of composition were used to create distinctive effects, and the pattern expression model determined their hierarchy and interconnection. This approach not only analyzed the patterns themselves but also compared them in terms of their structure and components.

Removal of patterns and configuration rules

In this study, digital images of Chinese currency decorative patterns were collected using image collection devices. However, due to the inherent refractive index of currency materials, noise can occur in images caused by factors such as lighting and equipment. Noise can distort some of the details of patterns, so it is necessary to post-process images to reduce the effects of noise and restore clarity to the details. Mathematical morphology provides certain tools for this, such as dilation, corrosion, and opening and closing operations, which preserve the main features of images and get rid of unnecessary elements. The dilation operation is a method of combining elements of a set by vector addition, which can be used to identify local maximum values and increase the number of selected areas in the image (Formula 6). It transfers the structural element B to the edge region of image A, centered at the origin of B, and the intersection with the edge creates an extended image (Figure 5).

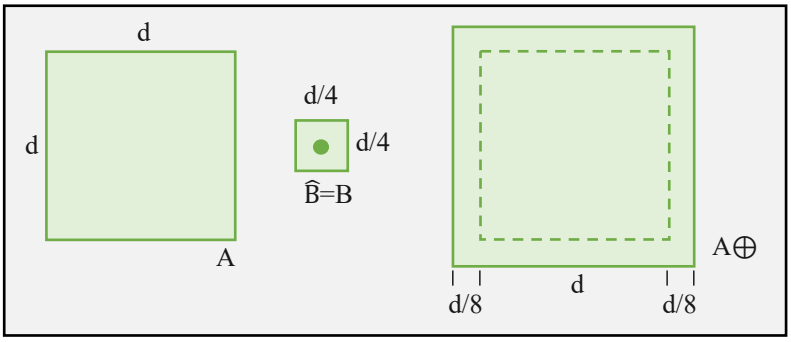


Figure 5. Schematic diagram of the expansion operation

Source: compiled by the author.

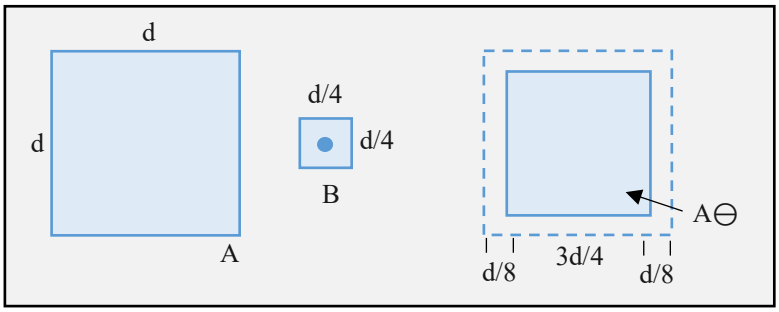
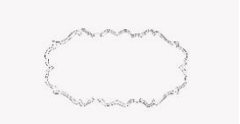


Figure 6. Schematic diagram of the reduction operation

Source: compiled by the author.

The opening (Formula 8) and closing (Formula 9) operations are a combination of expansion and contraction. Discovery first performs a reduction of the image and then expands it based on the corrosion image. Closing first expands it and then shrinks it. Moreover, the morphological gradient operation (Formula 10) defines the contour of an object in the image, considering its outliers and dips. This makes it possible to highlight the difference between highlights and depressions in an image that shows the edges of objects. It is also worth considering the removal of RMB decorative patterns by user interaction. Based on the visual perception of the Chinese currency's decorative patterns, users select one or more patterns to be included in the main pattern. Depending on personal preferences, choosing an additional pattern can have several different outcomes (Table 2).

Table 2. Example of sub-image selection results

Original pattern	**Manual extraction**	**Main pattern Y**	**Secondary pattern F**		**Border pattern B**	
	Outcome 1	YT1: 	FT21: 	FT22: 	BT31: 	
	Outcome 2	YT1: 	FT21: 	FT22: 	BT31: 	BT32: 

Source: compiled by the author.

Next, the creation of a hierarchy where the user distributes the selected additional patterns into levels based on their subjective assessment is necessary. For instance, if T1 is the only one in the main pattern Y, then YT1 is itself a higher level of the pattern and can move to the next step. If T1 is not the only one, additional patterns similar to T1 are selected, and a hierarchical model is built from the bottom up based on the user's choice. The user then codes and names the selected additional patterns sequentially from the top to the bottom level and from left to right. After that, the steps are repeated until the user has coded and named all the necessary additional patterns, exited the rule extraction mode, and generated the appropriate configuration rules for the patterns (Figure 7).

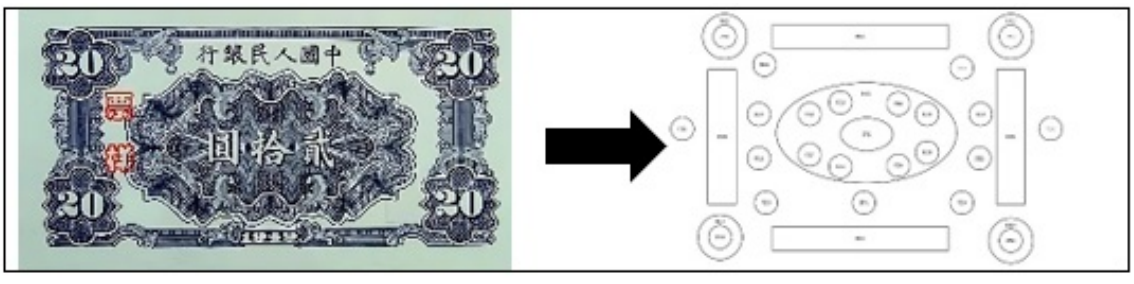


Figure 7. Example of configuration extraction results

Source: compiled by the author.

Thus, the composition of decorative patterns on Chinese banknotes is complex, as it contains many similar contours. Manually selecting similar paths requires many operations and time and can lead to clusters of similar paths. Therefore, it is necessary to classify the contours of decorative patterns of currency by similarity and distance. Similar contours usually share common features such as ordered arrays, symmetry, and rotation, while distance can indicate clustering or have special meaning. In this paper, Hu's moments were used to extract similar contours, which were proposed by Ming Kuei Hu to express the geometric features of images (Formulas 11-13). In other words, this work is based on the invariance property of the Hu matrix to extract and separate similar contours in patterns. The identified similar contours are divided into classes to form a group of similar contours (Formula 14). The rest of the detected contours that are not similar are classified as a set of contours (Formula 15). At the same time, the process of clustering contours is based on Hu moments (Figure 8).

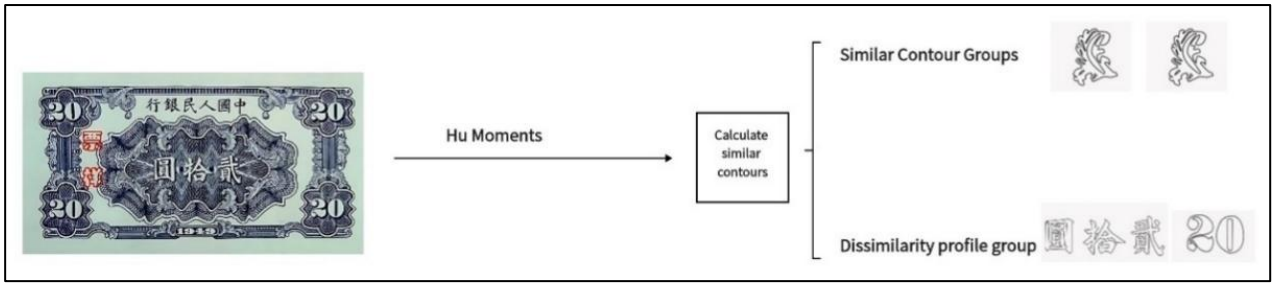


Figure 8. Clustering process based on Hu's contour

Source: compiled by the author.

Unsimilar contours tend to be spatially close to each other, forming a subgroup of contours that is visually and metaphorically different. A convolutional hierarchical clustering method was used to separate clusters of contours, which allows to distinction of clustered contours from dissimilar contours and building a hierarchical expression model for dissimilar contours. The shape of a cluster path is usually related to its shape and is measured by the shortest distance from the edge of the path (Formula 16). By combining the different groups of paths in a uniform hierarchical way and measuring the shortest distance between the edges of the paths, cluster classes and independent classes can be obtained, and a hierarchical expression model can be created based on the clustering results (Figure 9).

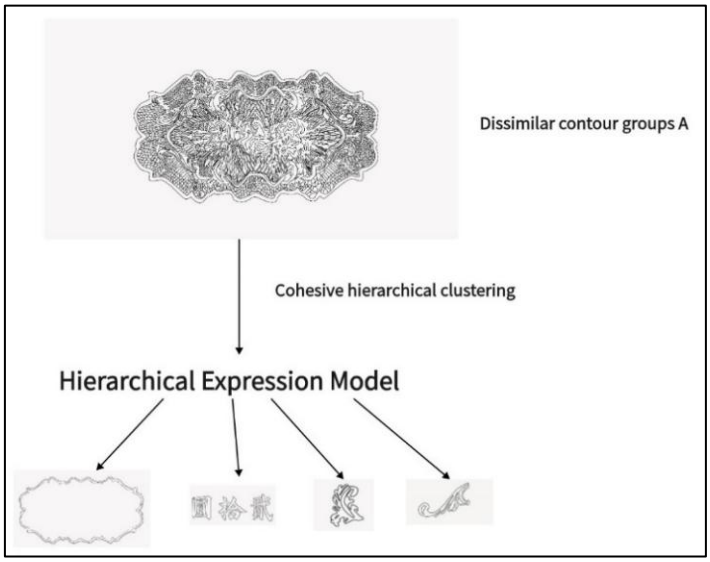


Figure 9. Hierarchical representation model for heterogeneous contours

Source: compiled by the author.

When using Hu's moments to select similar contours, the central coordinates of the image must be calculated, for which the zero and first moments are used (Formulas 17-20). Considering each subsample in the image as coordinate points, the entire image is made up of these points, which are connected. The topological structure of points and lines is also known as configuration rules. Thus, each RMB decorative pattern is marked in turn, creating a

database of configurations and expressing a topological structure (Figure 10).

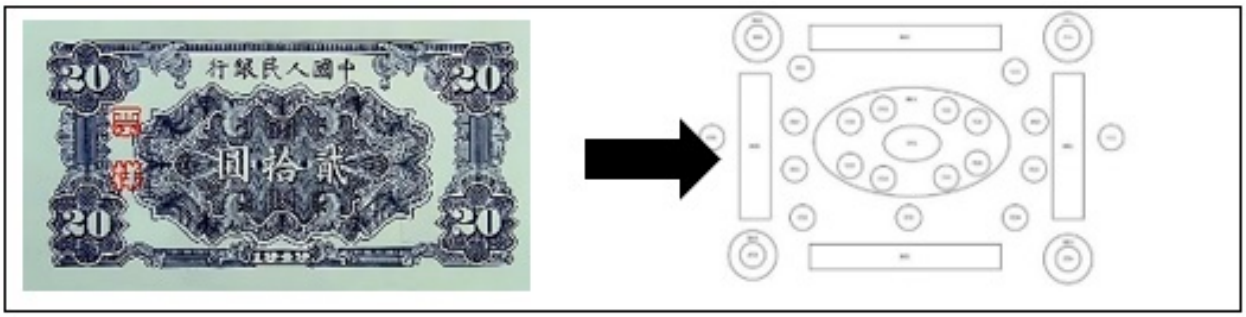


Figure 10. An example of a topological image

Source: compiled by the author.

To summarize, various methods were used to extract patterns and configuration rules for images of decorative elements of Chinese currency. By processing digital images using mathematical morphology, noise reduction and restoration of pattern details are achieved. Operations such as dilation, corrosion, opening and closing were applied to preserve the main features of the images and to get rid of unnecessary elements. In addition, the application of Hu's moments was used to effectively identify similar contours, and the method of convolutional hierarchical clustering was used to further divide the contours into clusters and build a hierarchical expression model. This approach established a topological structure of points and lines known as configuration rules, which reflects the organization of decorative patterns in Chinese banknotes.

Innovative design of Chinese currency decorative patterns

By analyzing the literature for this study, the information on decorative patterns of Chinese currency was systematized and the types of classification were identified (Figure 11). In addition, the collected images of decorative patterns of Chinese currency were coded in this paper.

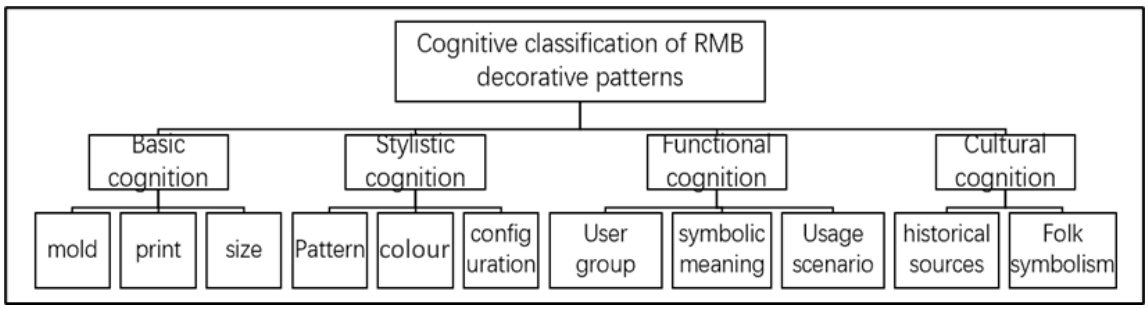


Figure 11. RMB knowledge classification

Source: compiled by the author.

It is worth emphasizing the externality, which is a formal model used to analyses and solve problems. Primitives, which are the logical components of extensiology, include elements of matter, elements of substance, and elements of relations. For the OpenCV calculator to understand the configuration and relevant features of RMB decorative patterns created by humans, and to achieve the recognition and design of such patterns, this study uses the basic theory of extensibility to transform the language. Vectorised samples of RMB decorative patterns become the object of study, and cultural connotations (such as author, history, style), visual graphics, encoding information, and hierarchical information are used as features. The information about pattern features is formalized and expressed in a primitive form (Formula 21).

Using the theory of primitives, a pattern representation model was created, which, combined with the collection of RMB decorative patterns, created a digital library of resources. From this library, representative patterns were selected for vectorisation, which was used to create a digital library of vectorised decorative patterns. In the process of reusing configuration rules, the user first selects a configuration rule from the resource library and then selects sub-templates from the database to fill in the corresponding configuration nodes (Figure 12). When filling in subpatterns into nodes, the user addresses their preferences and uses the hierarchical information of the main pattern, auxiliary pattern, and border pattern.

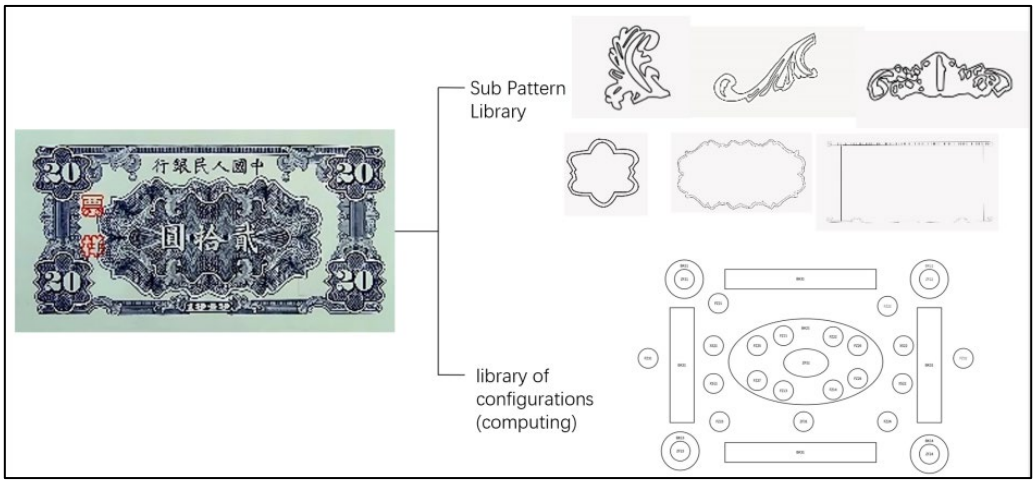


Figure 12. Selecting configurations and sub-patterns

Source: compiled by the author.

To avoid overlap during filling, the identification matrix method is used, where the initial value of 0 is changed to 1, indicating the presence of a pattern in the corresponding position, informing that other patterns can no longer fill this position. Finally, once completed, users can make local adjustments to the overall pattern to achieve the desired results.

Overview of methods for creating RMB design and their application

The study of innovative methods for creating decorative designs for Chinese currency through configuration rules is a relevant task, as it ensures the efficient use of existing patterns to create new and updated designs. These methods play an important role in preserving the cultural heritage of the RMB and contribute to the development of modern design, reflecting traditional and innovative aspects of culture. The first method collects and classifies data on decorative yuan patterns. It involves the systematic collection of various data related to decorative examples of the Chinese yuan. In turn, this process involves collecting information from field research, as well as analyzing literature and other available sources that contain information on various aspects of decorative designs.

Once the data is collected, it is classified for further use in the design process. This stage involves organizing and structuring the information obtained according to certain criteria, such as cultural aspects, historical context, style and other characteristics. The classification was used to systematize the data and make it available for further use when studying new designs and analyzing decorative samples. Thus, the method of collecting and classifying data on decorative yuan designs is an important step in the process of analyzing innovative design methods, as it provides systematization and structuring of the information necessary for further analysis and creative use in the process of creating new decorative designs.

Another method is to build a digital library of resources for decorative yuan designs. This method aims to create an important tool for researching and reviewing new decorative examples of the Chinese yuan. It involves the creation of a digital library that includes a variety of resources necessary for analysis and the creative process. The main element of this library is vectorised images of representative decorative samples, which ensure the accuracy and quality of the original drawings. The digital library is created to provide access to a variety of resources necessary for the further design and analysis of new decorative designs. It becomes the basis for further research, analysis and creative process in the field of decorative art.

The creation of a digital library allows researchers, designers and artists to effectively use available resources for an innovative creative process. It provides wide access to information and materials, which increases productivity and quality of work in the field of decorative design. Equally important is the method of using configuration rules for sample processing. It involves the use of configuration rules to explore and analyze the placement of subsamples in the master sample. The main idea is to determine how the subsamples are arranged within the main sample and in what order, they are arranged relative to each other.

Once the configuration of the selected sample is detected from the digital library, other samples are selected to fill in the corresponding sample elements. This process is based on analyzing existing configuration rules and selecting the best patterns to create a new design. The use of configuration rules ensures a logical and balanced composition of a decorative sample, which is an important aspect in the process of its creation. This method not only analyses but also actively applies existing configuration rules to create new, unique designs. The use of configuration rules simplifies and speeds up the design process, as well as allows for greater flexibility and creativity in shaping decorative patterns. Moreover, it is worth addressing the method of local optimisation of sample design, which is focused on making local adjustments to the design of samples based on the user's requirements and wishes. After creating a new sample design, the user can make certain changes to achieve the

desired result, which makes this method quite flexible and adaptive.

During the local optimization process, the user can make various changes, such as changing the size, colour, shape, or location of sample elements. These changes can be made using a special interface or editing tools provided to the user. Local design optimization allows users to actively interact with the process of creating decorative samples, including their personal preferences and needs. This method can be used to customise sample designs quickly and efficiently. This approach creates individual and unique decorative designs that meet the needs and requirements of the user. The application of these methods will effectively use existing decorative designs to create new yuan designs that meet user requirements and reflect the cultural and historical characteristics of the Chinese currency.

Discussion

The results of this study have shown that configuration rules are successfully applied to create new decorative designs for Chinese currency. They can be used to effectively use existing patterns that reflect traditional aspects to create an aesthetically pleasing and functional design.

While the findings of this study pointed to the importance of currency design for the perception and use of currencies, the results of a study by S. Catherine et al. [11] showed that in the metaverse, currency design plays a key role in determining their aesthetics and functionality. The study by L. Tambunan et al. [12] showed that the use of OpenCV improves the accuracy and efficiency of visual data analysis, which is also confirmed by the results of this work. Moreover, this study found that the use of OpenCV provides for faster and more accurate extraction and processing of decorative elements, which significantly improves the quality and variety of designs created. In contrast to the results of the study by Y.V. Teja [13], which indicated that image processing can effectively detect counterfeit currency, this study used image processing techniques specifically to optimise the design of decorative RMB samples. In addition, this paper investigates the possibilities of using the obtained methods to create unique designs, and the results of M.A. Otitoju et al. [14] indicated that changing the design of currency can increase its security and reduce the level of counterfeiting.

It is necessary to address the design of not only paper currencies, as in this study, but also digital currencies. As such, C. Bilgen et al. [15] analysed the design of the Sand Dollar digital currency using the Central Bank Digital Currency (CBDC) Tree framework, finding that this currency focuses on socio-political and legal aspects, promoting financial inclusion and modernising the financial system. F. Syarifuddin [16] determined the optimal design of the CBDC digital currency using a Strength, Weakness, Opportunity, Threat (SWOT) meta-analysis and proposed a hybrid architecture with anonymity tracing to ensure an efficient payment system and financial inclusion. Thus, this research attempted to complement existing approaches to currency design by focusing on automation and innovation in the creation of decorative patterns.

In addition, the results of the study showed the high efficiency of using automated methods to create decorative patterns for currency, which can significantly reduce the time and resources required to develop new designs. In comparison with the study by E. Diniz et al. [17], which proposed principles of currency design that consider the goals of the currency, its functioning processes and the assessment of its impact on sustainable development, this study focused on automating the process of creating decorative patterns for currencies using electronic libraries and shape grammars. This study also focused on creating unique and high-quality designs for paper currencies, whereas C. Bilgen [18] analysed the design of CBDC digital currency through a systematic literature review and determined that the successful implementation of CBDC requires an interdisciplinary approach for the future world of digital finance. In summary, this study has suggested innovative automation methods that can be useful for improving the design processes of both paper and digital currencies.

The conclusions of this study confirmed the relevance and effectiveness of the use of new technologies in solving problems in the field of decorative design of Chinese currency. In comparison with the study by S. Sweetline Shamini et al. [19], which emphasised the effectiveness of the system for recognising counterfeit paper banknotes, this paper extends this understanding. It presents the results of using a methodology that applied computer recognition algorithms in the field of decorative design, where the problem of counterfeiting also exists, in the context of the Chinese currency. Furthermore, since the results of the study by Y. Yusmerita et al. [20] demonstrated an increase in students' creative results in the field of design, the study showed not only the effectiveness of new design methods but also their potential use for creating unique decorative samples of Chinese currency.

Thus, the conclusions of the studies are valuable, as they pointed to the potential of new design methods in the field of Chinese currency, which may open up new opportunities for the development and improvement of this methodology. Thus, this study fits into the general context of applying the latest methods in design and technology to solve practical problems, including various problems in this area. This study in the context of the OpenCV library application is identified not only as a method for studying decorative samples of Chinese currency. Compared to the work of S. Desai et al. [21], which is devoted to the development of a system for identifying banknotes, this study goes beyond the usual methods of detecting counterfeit notes, aiming to create designs with unique traditional symbols of the Chinese Yuan.

This opens the possibility of using the banknote design method proposed in this paper as an effective measure to prevent counterfeiting, as unique traditional symbols can complicate the process of counterfeiting banknotes and facilitate their detection. In contrast to M.H. Gouri and M. Kumar [22], who highlighted the importance of the OpenCV library in computer recognition and machine learning for visual data analysis, this study showed the possibility of extending this potential to the field of decorative design. It also focused on the recognition of unique cultural elements, which is important for the development of innovation in design and cultural heritage.

This study has proposed a new approach to the creation of decorative yuan designs that allow for the preservation and dissemination of valuable cultural heritage by modern technologies in the field of cultural design. Compared to the work of D.R. Prayudya and S. Al-Ayubi [23], who proposed a central bank digital currency design that is in line with Islamic principles, using SWOT analysis to identify the strengths, weaknesses, opportunities and threats of such a design, this study used a different analysis, which consisted of applying methods for pattern extraction and establishing configuration rules. In comparison with the work of I. Telalbasic [24], which proposed the design of an alternative digital currency for entrepreneurs in the early stages of business development, this study was aimed at improving the methods of analysis and development of visual elements of currencies.

This focus allows for improving the quality, efficiency, and originality of banknote design, enhancing accessibility, transparency, and economic efficiency. In this study, digital libraries and shape grammars are used to develop currency design, allowing for the creation and analysis of decorative patterns. In contrast to the work of S.R. Samaei and E. Behdadfar [25], which presents a design reconstruction system using AI and machine learning that uses various models to recreate existing or create new designs based on learned patterns. As in the present study, H.M. Kumar [26] used image processing methods and electronic libraries to recognise graphic forms and text. However, while the present study automated the process of creating decorative pattern designs, the aforementioned work created electronic design symbols from technical documents and other images.

Based on the use of the form grammar and the OpenCV library, this work allows for real-time tracking and analysis of objects in cultural design. Similar to the results of A.A. Johani [27], who showed that currency is directly related to culture and strongly influences people's cultural identity, the results of this study indicated the importance of using decorative patterns that reflect cultural and historical features in the design of Chinese currency. The authors' results are also confirmed by B. Blazhev [28], who emphasised that AI could automate certain design processes, improve work efficiency and create new graphic elements. Compared to the study of K. Ueda and C. Hay [29], which considered the impact of digital currency design on the central bank and the economy, addressing the unique features of each system, this study focused on the creation of currency design.

It is worth agreeing with the conclusions of this paper, as they studied an important aspect of the impact of currency design on government institutions. In comparison with the work of H. Deng [30], investigated the international integration of the digital yuan, this study focused on the impact of design on cultural heritage and the promotion of international recognition of the Chinese currency through its cultural aspects. These findings are important, as the study could have a significant impact on the perception of the currency and its role in the world.

In general, the study revealed that the use of the form grammar and the OpenCV library opens new opportunities for creating decorative samples of the Chinese yuan, which contributes to the preservation and dissemination of valuable heritage. This highlighted the importance of using analytical methods in contemporary cultural design research and showed the potential for further application in various fields.

Conclusions

The study examined methods for creating designs for decorative samples of the Chinese yuan using configuration rules, the OpenCV visual library, and shape grammar. The study determined that this approach provides efficient use of existing patterns to create new decorative designs that meet market needs and help speed up the production process. Furthermore, the analysis of decorative patterns of the yuan revealed traditional symbols that can be successfully integrated into modern design.

In terms of qualitative indicators, the study demonstrated the potential effectiveness of design methods. For instance, the use of configuration rules has improved design efficiency and increased the diversity of the designs created, which is an important step in further improving these methods. In addition, an approach was used that included processing the original image using morphological operations, as well as applying Hu's moments and a hierarchical clustering method to extract configuration rules. This created an innovative design system for Chinese yuan decorative patterns, which effectively improves design productivity and implements an intelligent method of generating modern designs based on traditional patterns.

The results obtained indicate the importance of using computer recognition and programming technologies for the development of traditional art. According to the results of the study, it is necessary to emphasise the importance of high-quality datasets for the successful implementation of the approach, as well as the need for careful design of data models for the effective study and adaptation of the characteristics of decorative samples. Another important step was to determine the optimal loss function that would improve the model's performance. Future research opportunities include expanding the pattern database and improving image processing algorithms for a greater variety of designs.

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None.

Conflict of Interest

None.

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Дослідження з вилучення конфігурації декоративного візерунка юаня та його інноваційного дизайну: Аналіз на основі візуальної бібліотеки калькулятора OpenCV та граматик фігур

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Анотація

Актуальність. Дослідження розглядає потенційне застосування правил конфігурації у створенні декоративних дизайнів для юанів, зосереджуючись на покращенні естетики та функціональності дизайну.

Мета. Проаналізувати доцільність використання правил конфігурації для покращення дизайну китайської валюти.

Методологія. Дослідження включало аналіз та синтез декоративних патернів, встановлення правил конфігурації та вивчення їх застосування в дизайні грошових знаків.

Результати. Отримані результати демонструють, що правила конфігурації можуть ефективно використовувати існуючі патерни для покращення дизайну китайських грошових знаків, надаючи можливості для нових варіацій дизайну, що відповідають сучасним естетичним та функціональним вимогам. Аналіз показав, що патерни китайських грошових знаків часто втілюють культурне значення, історичні події та символи через складні геометричні та абстрактні елементи. Виявлено ключові особливості візерунків, що підкреслюють потенціал для більш ефективного використання правил конфігурації в дизайні.

Висновки. Правила конфігурації можуть успішно організовувати та вдосконалювати декоративні візерунки на китайських грошових знаках. Дослідження підтверджує доцільність застосування цих правил для створення цілісних і культурно багатих дизайнів. Крім того, інтеграція правил конфігурації може впорядкувати процес проектування та забезпечити стабільність естетичної якості.

Ключові слова: комп'ютерні технології; обробка зображень; виділення синтаксичної структури; грошова одиниця.