Title:
Research on the Pattern Extraction of Academy of Classical Learning's Buildings based on Image Enhancement Technology

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Introduction:
With the development of computer-aided design technology, the modern innovative application and dissemination path of traditional culture presents a trend of digitization, symbolization, cultural innovation, and productization. The extraction of cultural elements has the requirements of standardization. In terms of image enhancement, researchers have used image enhancement techniques such as Bilateral Filtering[1], CLAHE algorithm[2], and Gaussian filtering[3] to achieve ideal results. In terms of symbol and pattern extraction, researchers proposed a new pattern extraction algorithm based on grayscale, binary, and contour tracking methods[4]. They combined the morphological method with the Canny algorithm to achieve relatively complete extraction of patterns[5]. What's more, took hyperspectral imaging technology aided the extraction of patterns[6].

These researches have promoted the application and innovation of computer-aided design technology in traditional pattern extraction, but they still have certain limitations. First of all, the patterns extracted by some of the above research are relatively simple, and the extracted patterns are not complete enough to support designers in redesigning them. Besides, there is no systematic workflow for the extraction of traditional patterns. Due to the diverse carriers, complex patterns, and different shapes of the architectural decorative patterns of Yuelu Academy, it is impossible to rely on computer technology to extract them completely. However, with the changes of the times and the environment and natural and human factors, the architectural decorations have been worn, weathered, and even damaged. In addition, the architectural ornaments of Yuelu Academy are widely distributed on the roofs, ridges, cornices, bucket arches, etc. The above reasons limit the material shooting of the architectural decorations of Yuelu Academy, resulting in low image quality of some original photos, increasing the workload of image preprocessing, and the difficulty of pattern recognition and extraction.

Main Idea:
Aiming at the above problems, this paper proposes a systematic pattern extraction workflow, including material collection and analysis, image enhancement, and standardized pattern correction. It forms the extraction specification of architectural decorative pattern design elements. The image enhanced section uses the CLAHE algorithm combined with the Adaptive Bilateral Filtering algorithm to perform image enhancement processing on the original material to improve the human eye recognition obstacles caused by the complex light and background and assist the designer in pattern extraction. The standardized correction section uses the vector graphics tool Illustrator to standardize and correct different patterns in combination with the formal features of traditional patterns. The workflow is shown in Fig. 1.

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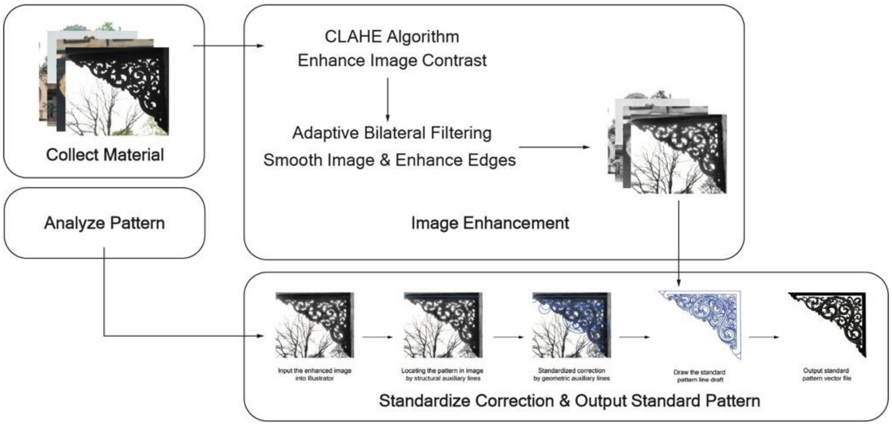


Fig. 1: The extraction workflow of traditional architectural decorative patterns.

<u>Collection and screening of original materials for architectural patterns:</u>
We selected six original materials with image quality problems as experimental samples. As shown in Fig. 2. The pattern features in the six samples were analyzed and classified, as shown in Tab.1.

Fig. 2: Experimental samples.

Fig. 2(a) is the underexposed image, Fig. 2(b)(c)(d)(e)(f) are the images with lower resolution, and Fig.2(f) is the pattern with the same color as the background.

Pattern Type	*Figure Number*	*Pattern Name*	*Location*	*Pattern Form*	*Pattern Elements*
Plant Pattern	(a)	Vol-Grass Pattern	He Xi Platform's Bracket of Beams and Columns	Corner Fit	Roll Grass
	(b)	Peach Pattern	Yuelu Academy Tablet's Bracket	Shape Fit	Peach, Peach Blossom
	(c)	Peony Pattern	He Xi Platform's Ridge	Two-sided Continuous	Peony, Roll Grass
Animal Pattern	(d)	Chi Wen	Ji Quan Pavilion's Ridge	Single Equilibrium	Dragon
Geometric Pattern	(e)	Geometric Pattern	He Xi Platform's Stone Fence	Symmetrical Individual	Circle, Curve
Combined Pattern	(f)	Kirin Pattern	Da Cheng Hall's Ridge	Equilibrium Fit	Kirin, Bookcase, Roll Grass
	(g)	San-yuan-ji-di Pattern	He Xi Platform's Eaves Brace	Shape Fit	Longas, Magpie, Stone

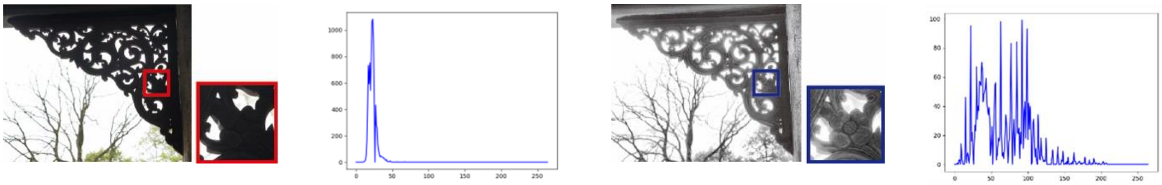
Tab. 1: Analysis and classification of pattern characteristics of experimental samples.

The pattern extraction workflow mainly relies on python8, MATLAB and illustrator, and other tools for experiments and research, divided into image enhancement, pattern standardized correction, and extraction. It is an interactive workflow relying on computer image technology and computer-aided design tool.

Image Enhancement

The image enhancement adopts the combination of the CLAHE algorithm[2] and Adaptive Bilateral Filtering[7], which enhances the pattern edge recognition and pattern details and reduces the interference of strong image noise on pattern recognition so that the image can achieve better human eye recognition.

The CLAHE algorithm clips the histogram with a pre-defined threshold before calculating the cumulative histogram function (CDF) around the pixel. It evenly distributes the cut part to the rest of the histogram. To achieve the purpose of increasing the image contrast while limiting the noise amplitude. The CLAHE algorithm process the six selected images to present more details, as shown in Fig. 3.



(a) Input image (b) Enhanced result

Fig. 3: Comparison of the original image and CLAHE algorithm enhanced results.

After enhancement, the image gray value is uniformly stretched by the local contrast limit, as shown in Figure 3(a). The dark areas of the image are significantly improved, offering more pattern details, as shown in Fig. 3(b).

The adaptive bilateral filtering algorithm is used for smoothing the processed image, reducing part of the noise amplified by contrast enhancement. The algorithm uses the bilateral filter window size and image noise variance to obtain the spatial image variance and grayscale variance adaptively, then adaptively brings the optimal image smoothing parameters according to different photos.

Fig. 4: Overall process and result of ABF.

Figure 4(a) is the input image, (b) is the image after CLAHE algorithm enhancement, (c) is the result of the ABF algorithm smoothed, and (d) are close-ups of regions.

Standardized Correction and Extraction of Patterns

This section needs to be done manually, relying on the visual recognition ability of the extractor, and proposes a method of using geometric auxiliary lines to locate and extract details of patterns in images.

Using the vector graphics tool Illustrator to draw auxiliary lines according to the composition of different patterns, the smoothness of the lines, and the integrity of the patterns, standardize and correct the patterns on the enhanced image, and extract the patterns by vectorization. Pattern standardized correction and extraction are mainly divided into five steps. As shown in Figure 5.

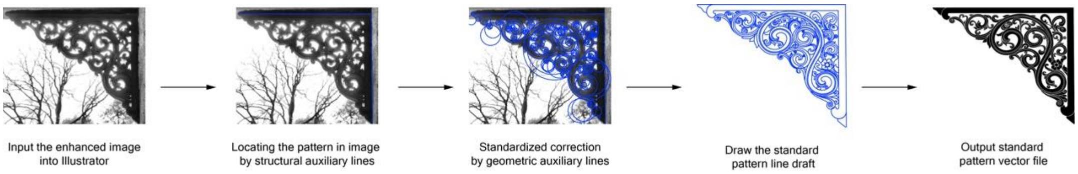


Fig. 5: Workflow of pattern standardized correction and extraction.

The pattern standardized correction part can maximize the smoothness of the pattern lines and repair the damaged pattern edges. What's more, the operation of this method is simple and easy to use, which reduces the difficulty of pattern extraction to a certain extent.

Drawing of auxiliary lines mainly draws corresponding structural auxiliary lines and geometric auxiliary lines according to different pattern features to cut and connect the lines to extract the complete pattern.

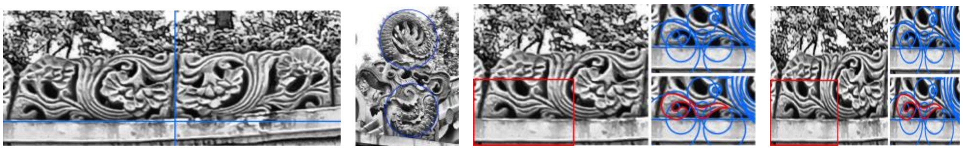


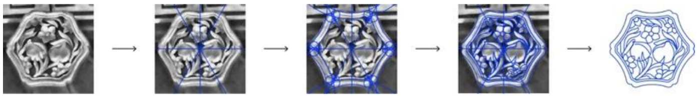
Fig. 6: Locating the patterns by structural auxiliary lines and restorations by geometric auxiliary lines.

The pattern included in Fig.6(a) is a regular pattern with specific rules, and straight lines are used to locate the patterns. Fig.6(b) is an irregular pattern with many curves, and circular auxiliary lines are used to locate the patterns. The patterns in Fig. 6(c)(d) have occlusion and deformation caused by the shooting angle, drawing circular auxiliary lines according to the edges of the pattern and using the pathfinder tool in Illustration to cut and connect the curves to extract the pattern produces the line drafts of architectural decorative patterns.

The output of patterns vector files is necessary for facilitating designers to innovate and commercialize traditional architectural decorative patterns systematically. According to the visual characteristics of the human eye[8], the pattern lines draft is colored with black and white color which is a high degree of recognition by the human eye to distinguish the main pattern and auxiliary pattern of the pattern, the foreground, and background, as well as the main body and details of the pattern.

<u>Results:</u>

According to the analyses of the architectural decorative patterns of Yuelu Academy in the previous article, image enhancement and pattern extraction are performed on typical samples, Fig.2(a) and Fig.2(b) according to the pattern extraction workflow proposed in this paper. The extraction process and results are shown in Tab.4.

Sample	*Extraction Flow*	*Result*
(a)		
(b)		

Tab. 2: The extraction process and results of typical samples.

Conclusion and Future Directions:

This paper proposes a workflow for extracting architectural decorative patterns based on image enhancement technology and computer-aided design tools, including image enhancement and pattern standardization correction and extraction. The extraction results of typical pattern samples show that this workflow can batch enhance architectural decoration image materials, enhance their recognition and extract standard patterns. To a certain extent, this workflow can effectively reduce the equipment and material sampling environment requirements for the on-site acquisition of architectural decorative patterns and improve the availability of original materials. On this basis, geometric auxiliary lines can quickly locate the patterns in the image and reduce the difficulty of detail extraction. The features and innovations of this research are as follows: (1) A systematic, standardized, and efficient workflow based on computer-aided design technology is proposed for the problem of insufficient systematisms and low efficiency in the extraction of architectural decorative patterns. The innovative application of the CLAHE algorithm and adaptive bilateral filtering optimizes the problems of inefficiency and limited expertise produced by using PS to preprocess images. At the same time, it is proposed to use computer-aided design tools to draw geometric auxiliary lines for standardized correction and extraction of patterns, which significantly reduces the time cost and difficulty of pattern extraction. (2) This process simplifies the work of pattern extraction to drawing, cutting, and connecting simple geometric auxiliary lines, which breaks the limitation of professional ability. Even non-design researchers can quickly get started and perform pattern extraction. In addition, this pattern standardization extraction process is universal and applies to the digitization of all complex traditional patterns.

At present, this workflow still requires manual participation. In future research, researchers can try to realize automatic pattern extraction through edge recognition, curve fitting, machine learning, and other technologies based on the auxiliary line extraction method proposed in this paper.

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