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Color Reduction in Hand-drawn Persian Carpet Cartoons before Discretization using image segmentation and finding edgy regions

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Abstract
In this paper, we present a method for color reduction in Persian carpet cartoons which increases both the speed and accuracy of editing. Carpet cartoons are in two categories: machine-printed and hand-drawn. Hand-drawn cartoons are divided into two groups: before and after discretization. The purpose of this work is color reduction in hand-drawn cartoons before discretization. The proposed algorithm consists of the following steps: image segmentation, finding the color of each region, color reduction around the edges and final color reduction with C-means. The proposed method requires knowing the desired number of colors in any cartoon. In this method, the number of colors is not reduced to more than about 1.3 times of the desired number. Automatic color reduction is done in such a way that the final manual editing done to reach the desired colors is very easy.

Keywords: *Color Reduction, Hand-drawn Cartoons, Segmentation, C-means, Persian Carpet.*

1. Introduction
True color images typically contain thousands of colors, and 24 bits are assigned to each pixel. Display, storage, transmission, and processing of these images are problematic. For this reason, color quantization is commonly used as a pre-processing step for various images. Applications of color quantization in image processing include: compression [1], segmentation [2], text detection [3], color-texture analysis [4], watermarking [5], and content-based retrieval [6]. The purpose of this research work is to reduce the number of colors in a hand-drawn carpet cartoon into a preset value.
Color quantization has many techniques in RGB, HSV, HSL, and other color spaces [7, 8]. The RGB color space was used in the current work.
The process of color quantization is comprised of two steps: palette design (selection of a small set of original image colors) and pixel mapping (replacing image colors with the color palette) [9]. Color quantization methods can be classified into two groups: image-independent method that determines a fixed palette regardless of any specific image [10] and image-dependent methods that determine an adaptive palette. The aim is to reduce the number of colors in the image with minimal distortion [9].
In another classification, quantization methods can be categorized into pre-clustering or divisive and post-clustering [1]. Pre-clustering methods are essentially based on the statistical analysis of the color distribution. They start with a single cluster that contains all colors of the image. This cluster is divided into K ones [9]. Known divisive methods include octree [11], median-cut [12], variance-based [13], center-cut [14], binary splitting [15], and rwm-cut[1] [16]. Agglomerative pre-clustering methods begin with N clusters that are the total number of colors in the image. These clusters are then joined until K clusters remain [17, 18].
Post-clustering methods first determine a basic palette and then improve it iteratively. These methods yield fetter results at the cost of increased computational time. These methods are dependent

[1] radius weighted mean cut

on the initial conditions; therefore, the initial palette is first constructed by a pre-clustering method and the result is improved by a post-clustering method [19]. Clustering algorithms utilized for color quantization includes C-means [20-22], min-max [23], competitive learning [24, 25], fuzzy c-means [26, 27], BIRCH [28], self-organizing map [29, 30], and divisive hierarchical clustering [31].

Some color reduction methods exploit the local properties around a pixel to find its color more precisely. Ant colony and self-growing and self-organized neural gas are examples of optimization methods utilized for this purpose [29, 32, and 33].

Patterns in a Persian carpet cartoon consist of uni-color parts or regions; therefore, segmentation-based methods are the best choices for color reduction in these cartoons. In what follows, some image segmentation methods are briefly explained.

Segmentation methods based on boundaries and edges work on the discontinuity of pixels whereas region-based methods work on similarity [34]. Also, there are hybrid methods derived from integration of the region-based and edge-based method information [35]. In this research work, a hybrid method is used.

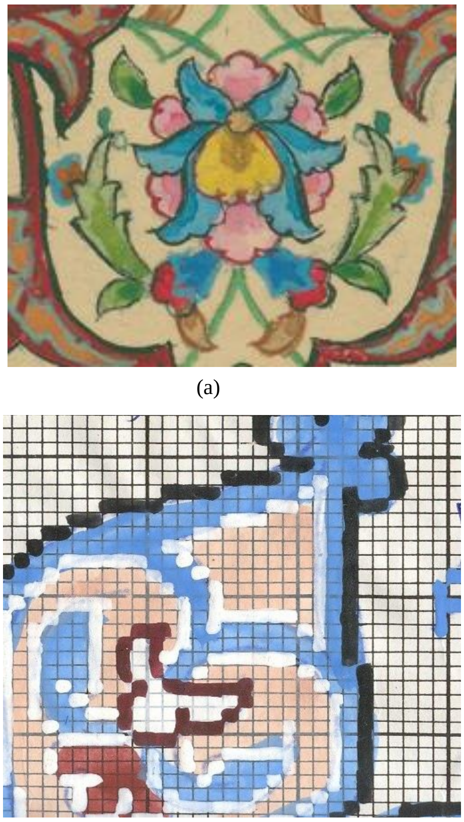
From the perspective of user's assistance, there are three ways to set a color palette depending on the application: 1) the palette is found without knowing any default number of colors, 2) number of desired colors is set by the user, 3) the palette is provided by the user. In all three ways, several methods for color reduction and quantization have been proposed [19, 28]. In our work, the number of colors is preset by the user.

Considering that the color reduction of carpet cartoons is a new topic, in this paper, a brief description of this topic is provided in Section 2. In Section 3, the proposed method is described. In Section 4, the details of dataset are described. Then in Section 5, the experimental results are analyzed and a comparison with the results obtained by commercial software is provided. Finally, in Section 6, the conclusion is derived.

2. Principles of automatic reading of carpet cartoons

Carpet cartoons are divided into two categories: a) hand-drawn by traditional methods, and b) machine-printed by computerized methods.

Hand-drawn cartoons are divided into two categories: a) before discretization, and b) after discretization. Two samples of carpet cartoons before and after discretization are shown in figure1. The design of a carpet cartoon after discretization is done on a graph paper.



(a)

(b)

Figure 1. (a) Typical carpet cartoons before discretization; (b) Typical carpet cartoons after discretization.

The purpose and innovation of this work is the color reduction of hand-drawn carpet cartoons before discretization, which has never been done before, in order to ease the production of digital cartoons. The production of digital cartoons is of great help in establishing carpet cartoon libraries, preservation and restoration of old carpet cartoons, and automatic discretization and semi-automatic editing of cartoons.

The main concern in color reduction in conventional images is the minimization of a perceived difference between the original and quantized images. A typical conventional carpet cartoon has a palette of 10 to 15 colors. The main concern here is to have pure uni-color regions, while the fact that the quantized color of a region is close to the desired one is of less importance.

There are some commercial software products available, which assist the designer in the process of developing a carpet cartoon. However, this process is still very time- consuming and expensive. In the Iranian market, Booria [36] and Nqshsaz [37] are the most important commercial products for designing carpet cartoons. These applications reduce the number of colors to 256 perfectly. However, a further reduction in colors to tens of colors makes errors-hard to fix manually.

In the recent years, some algorithms have been proposed for color reduction in carpet cartoons [19, 38-40]. However due to the challenging problems, in particular for hand-drawn cartoons, the results are far from satisfactory. For example, color reduction with optimized C-means method [19] on part of a hand-drawn cartoon is shown in section 5 (Figure 17).

As shown in figure 2, there are two main problems to reduce color in hand-drawn carpet cartoons.

1- Varying saturation of a specific color in different parts of a hand-drawn cartoon.
2- Scanning with 256 or more colors.

The method proposed in this paper tries to solve both problems.

Figure 2. A typical hand-drawn carpet cartoon before discretization scanned by 300 dpi.

3. Proposed algorithm

The proposed algorithm consists of the following steps. 1) Image segmentation: in this step, edge detection is performed using Canny operator and edge linking is done where every closed boundary makes a separate segment. The resulting regions are of two kinds, edgy regions around the pattern edges, and plain regions including intra-pattern and background regions. 2) Finding the color of each plain region. 3) Color reduction of edgy regions with connected components labeling. 4) Final color reduction with C-means: in this step, color reduction with high accuracy is performed.

Color reduction steps in hand-drawn carpet cartoons are shown in figure 3.

In what follows, we describe the details of each color reduction step.

3.1. Image segmentation

In this step, color image is converted to grayscale, and edges are detected by canny operator (Figure 4).

In figure 4, some of the image boundaries have rupture. This rupture will cause a problem in area separation. Therefore, it is required to decrease the boundary ruptures. Then the intensity of pixels bigger than zero will be replaced by 255. Edge linking is carried out by blurring on image of edges. In continuation, the boundaries with one horizontal and vertical pixel distance will be connected till the image area separation gets done clearly and completely (Figure 5).

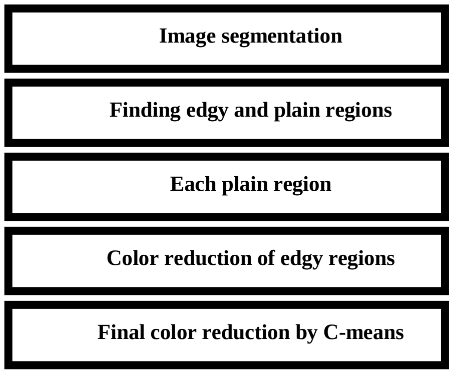


Figure 3. Proposed steps for color reduction in before-discretization carpet cartoons.

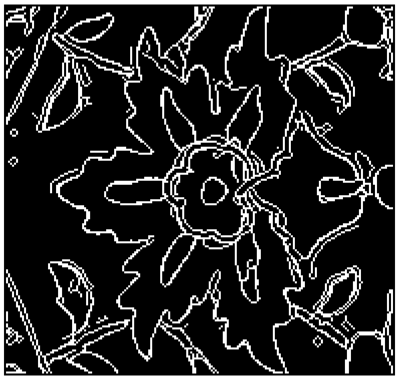


Figure 4. Edge detection by Canny operator on carpet cartoon in figure 2.

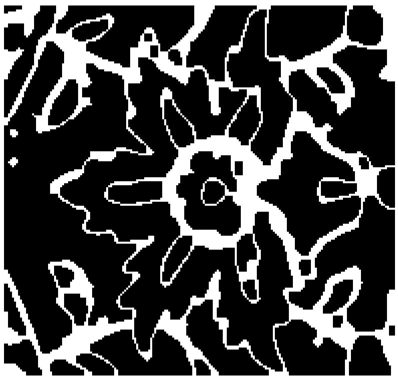


Figure 5. Blurring on edge image in figure 4.

Pattern boundaries are shown in white in figure 6. The image segmentation steps are shown in figure 7.

3.2. Finding color of each plain region

In this step, the color of each plain region is determined by the average color of its pixels for one time. If the difference between the average color and the color of any pixel is more than 10, that pixel is excluded and the average color of the remaining pixels is taken as the color of that region.

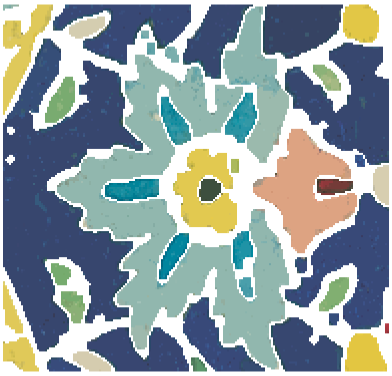


Figure 6. Final result of finding edgy regions, shown in white.

Converting color image to grayscale

Edge detection by canny operator

Edge linking by blurring

Edge linking by connecting to each

Figure 7. Steps of image segmentation.

After determining the color of each region, the number of colors in the image could be up to the number of plain regions. Using C-means algorithm, the number of palette colors is reduced to three times the number of colors preset by the user. The color distance between any region color and the palette colors is calculated. If this value is less than 15, the palette color is given to that segment; otherwise, the color does not change.

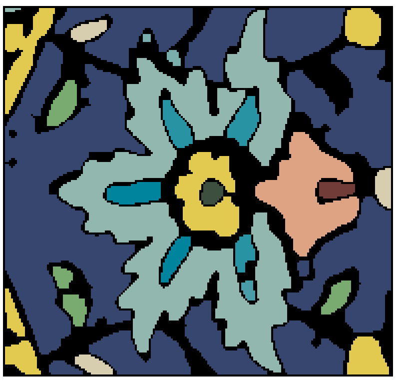


Figure 8. Finding color of each plain region in figure 2; and color reduction from 550 to 30 by C-means algorithm.

3.3. Color reduction of edgy regions

After finding the colors of plain regions, the colors of edgy regions are determined by a connected component labeling described in figure 9. In what follows, the basis of this method is described.

Image segmentation methods are divided into three groups:

- Thresholding Methods
- Boundary/Edge-based methods
- Region-based methods

The purpose of all these methods is segmentation with a high accuracy. However, it might be caused by problems in segmentation [34]:

- The segmented region might be smaller or larger than the actual one.
- The edges of the segmented region might not be connected.
- Pseudo-edges are created and real edges are missing.

In many segmentation methods based on the threshold, the threshold is determined by both general and local. The method does not have a high accuracy, because determining the exact threshold is difficult. But instead, the method has a high speed.

In edge-based methods, the number of regions is assumed to be equal to the number of closed borders. Also the gradient and laplacian algorithm is used to identify the boundary [34].

Accuracy of region-based methods is useful for segmentation. In these methods, similar regions are connected according to criteria such as color, texture and intensity. In this section, region growing and clustering are common methods. In this paper, segmentation around the edge is done by region-based methods with connected components labeling.

In this method, the Euclidian color distances of each pixel from neighboring pixels, are compared with a threshold value. If this distance is less than the threshold, the color of the neighboring pixel is replaced with the color of the central one.

A 5 by 5 window is considered and the threshold value is set by (1) where decreases as physical distance increases.

$$thershold = 15 * e^{\frac{-|x+y|}{2}} \quad (1)$$

In the above equation, x and y are the Euclidian distance of the neighboring pixel from the central one. Note that after this step, there is another one to reduce the color. Therefore, the threshold value is considered small.

Figure 10 shows a sample of color reduction for edgy regions.

3.4. Final color reduction by C-means algorithm

At the end, color reduction for the entire image is done by C-means. To ensure that the desired colors are preserved, color reduction is limited to 40-50% more than the desired number of colors, preset by the user.

The final result of color reduction is shown in figure 11. In this figure, the colors should be reduced to 16, while to keep the desired colors, the algorithm is set for 24 colors.

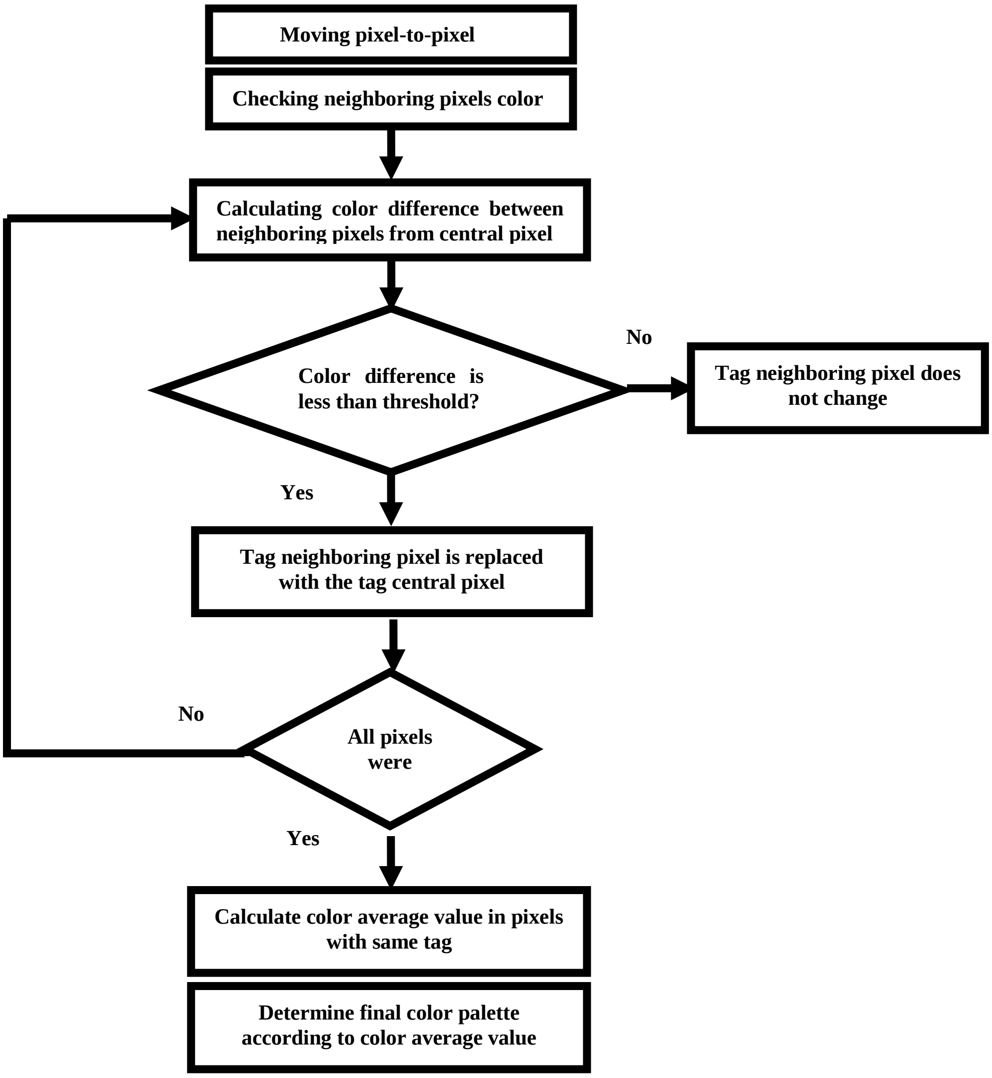


Figure 9. Flowchart for color reduction of edgy regions.

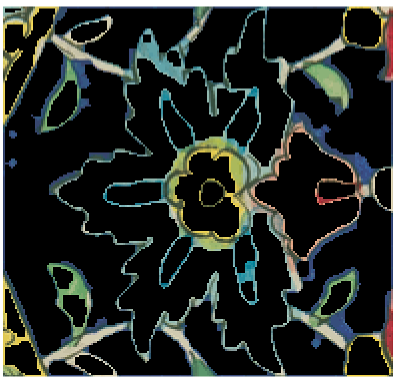


Figure 10. Color reduction of edgy regions of figure 2.

3.4. Final color reduction by C-means algorithm

At the end, color reduction for the entire image is done by C-means. To ensure that the desired colors are preserved, color reduction is limited to 40-50% more than the desired number of colors, preset by the user.

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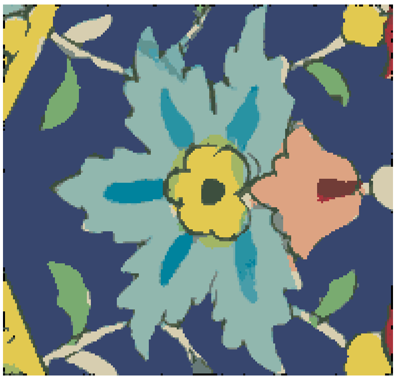


Figure 11. Final reduction of colors for image of figure 2.

4. Dataset

Dataset for carpet cartoons was collected during five years from different sources [36, 37, 41]. In this work, 170 pieces of 17 carpet cartoons were used. The cartoons were from Kerman, Isfahan, Tabriz, Kashan and Qom.

- Size of each piece is between 300 by 300 and 1000 by 1000 pixels.
- The cartoons were scanned with 300 dpi.
- Color space of carpet cartoons is RGB.
- The number of colors in each piece is between 7 and 15.

90 pieces were used during the design of the method, and the remaining 80 pieces were used for the test. The ground truths for the test set were made by labeling the pixels in a semi-automatic manner, and were used to evaluate the proposed method.

As noted in Section 2, some pixels, about 5% of the total ones, are wrong in the original cartoons. In the proposed method, each region is homogeneous. Hence, the pixel color is corrected. However, if the correction does not happen, the error is not caused by the algorithm, and therefore is ignored.

5. Qualitative evaluations of results

In this Section, the results of the proposed method are examined on different carpet cartoons and compared with some conventional methods for color reduction. In our method, the final colors and number of colors are not exactly the same as the desired ones, so a quantitative evaluation is difficult. In this comparison, replacing the original colors with the similar ones is not considered as fault.

Color reduction for a sample image of the test set is shown in figure 12. The image has 522 * 524 pixels. The ground truth has 13 colors.

(a)

(b)

Figure 12. (a) A piece of a 13-color hand-drawn carpet cartoon before-discretization. (b) Resulting image produced with 18 colors.

Layer Pilot is general-purpose commercial software for color reduction of typical images. Color reduction in this software is semi-automatic [42]. In this software, the desired palette is specified by the user. The result of the color reduction by Layer Pilot is shown in figure 13. Our proposed algorithm is customized for carpet cartoons, and therefore, outperforms general-purpose software like Layer Pilot.

Part of a hand-drawn cartoon from Kerman with 15 colors is shown in figure 14.a. The colors are 5 kinds of greens, 2 gray, 2 kinds of blues, black, white, red, yellow, orange and beige. In this figure, the colors should be reduced to 15, while not to miss any desired color; the algorithm is set for 21 colors. If the colors are reduced to 15, errors resulting from merging similar colors are created. The color reduction into 15 is shown in figure 14.b. The color reduction into 21 is shown in figure 14.c.

Figure 13. Result of color reduction by Layer Pilot on figure 12.

For error analysis of figure14.b, each region is in white in figure15. In this figure, the grade color is known with the number of color. For example, dark blue and bright blue are known with blue 1 and blue 2. As seen, yellow and orange, 2 greens, white and part of beige are merged and 3 original colors are missed. Also, green 1 and white and part of gray 2, parts of green 2 and green 3 and gray 1 are merged. Gray 2 is divided into 2 colors and beige into 3 colors. In the proposed algorithm, to ensure that the desired colors are preserved, color reduction is limited to 40% more than the original number of colors.

For error analysis of figure14.c, each color is shown in figure16 by color white. As you can see, white and part of gray 2, parts of green 2 and gray 2 are merged and one color is removed. Also, gray1 and 2, green 1, 2 and 5 are divided into 2 colors and beige is divided into 3 colors. Dividing one color into 2 colors or more is not considered as error.

(a) (b) (c)

Figure 14. (a) A piece of a 15-color hand-drawn carpet cartoon. (b) Resulting image produced with 15 colors. (c) Resulting image produced with 21 colors.

(1) black (2) blue 1 (3) blue 2

(4) red

(5) gray 1

(6) parts of gray 2

(7) merging green 1, white and parts of gray 2

(8) merging yellow and orange

(9) parts of green 1

(10) merging parts of green 2, green 3 and gray 1

(11) green 4

(12) green 5

(13) parts of beige

(14) merging white and part of beige

(15) major part of beige

Figure 15. Each color of figure 14b is shown in white, separately.

(1) black

(2) blue 1

(3) blue 2

(4) red

(5) part of gray 1

(6) part of gray 1

(7) part of gray 2

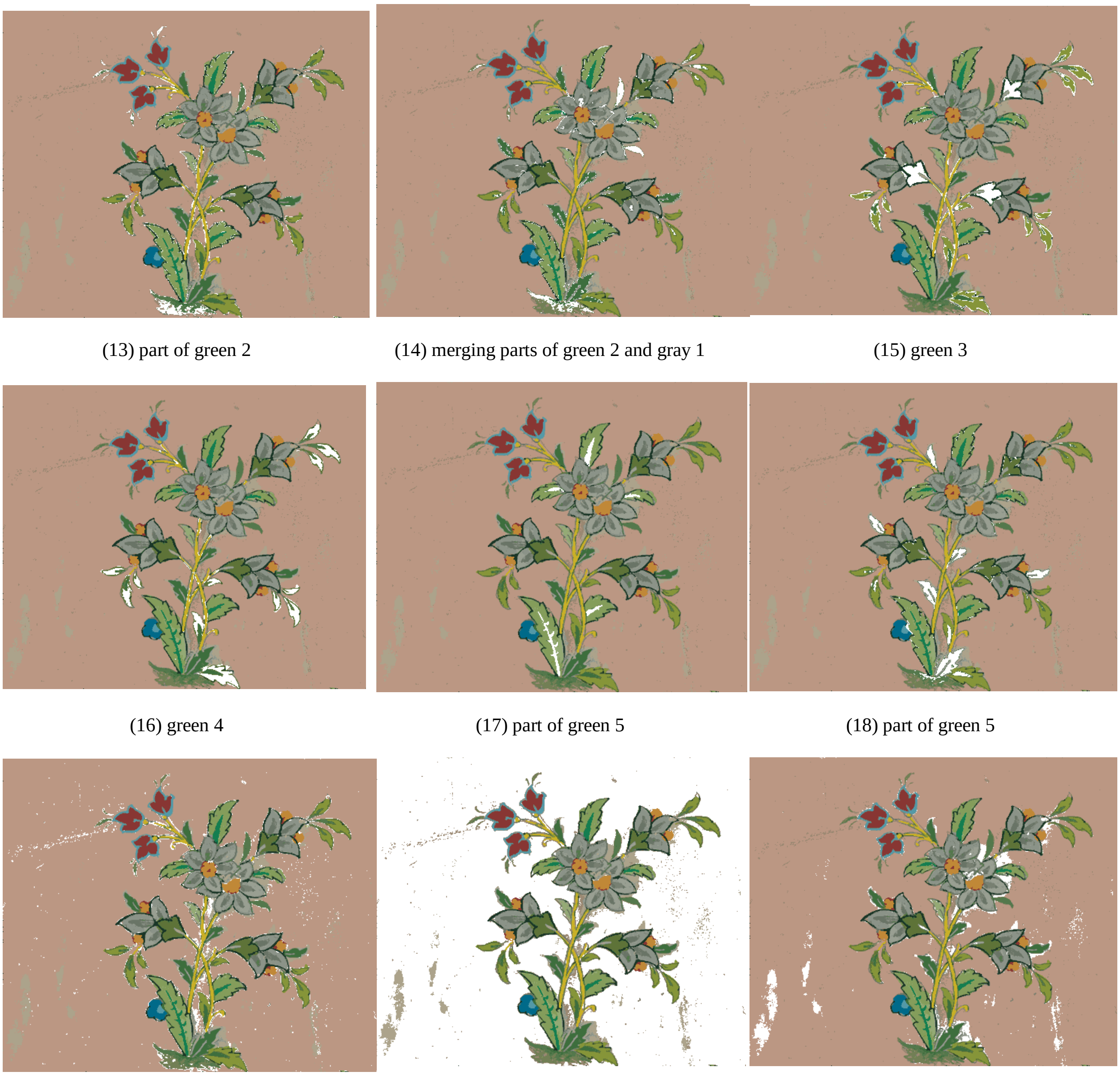
(8) merging white and part of gray 2

(9) yellow

(10) orange

(11) part of green 1

(12) part of green 1



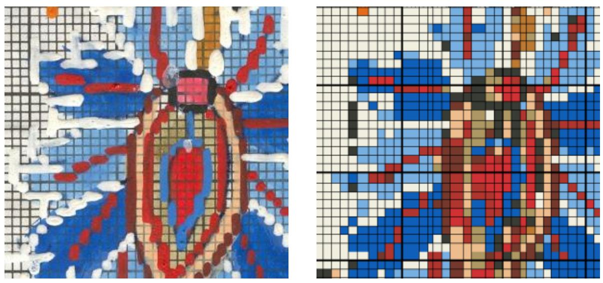
(13) part of green 2 (14) merging parts of green 2 and gray 1 (15) green 3

(16) green 4 (17) part of green 5 (18) part of green 5

(19) part of beige (20) part of beige (21) merging white and part of beige

Figure 16. Each color of figure 14c is shown in white, separately.

As mentioned in the previous sections, the previous methods have been designed for color reduction in machine-printed carpet cartoons and, due to the different conditions, are not efficient for hand-drawn cartoons. The methods are optimized to suit the color reduction in machine-printed carpet cartoons, and the methods are not accurate in other applications. Color reduction with the optimized C-means method [19] on part of a hand-drawn cartoon is shown in figure 17. As you can see, this result is not good for color reduction in hand-drawn cartoon.



(a) (b)

Figure 17. (a) A piece of hand-drawn carpet cartoon. (b) Image obtained by method of reference [19].

6. Conclusions

Using our proposed color reduction method, users will spend less time to convert hand-printed carpet cartoons, before discretization, into digital carpet cartoons.

Our method consists of several steps, experimentally tuned for the problem in hand. Performance of the method would have been very low if not using an appropriate technique in each step. Hence, in every part of the work, a technique is used highly appropriate for the carpet cartoons.

Steps of our method included image segmentation, finding the color of each plain region, color reduction of edgy regions with connected components labeling, and final color reduction with C-means.

In our method, the final colors and number of colors were not exactly the same as the desired colors. Since the quantitative evaluation was difficult, the qualitative evaluation of the results was selected.

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نشریه هوش مصنوعی و داده کاوی

کاهش رنگ در نقشه‌های دستی فرش ایرانی پیش از نقطه‌گذاری به کمک ناحیه‌بندی تصویر و یافتن نواحی مرزی

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چکیده:

در این مقاله، روشی برای کاهش رنگ در نقشه‌های فرش پارسی ارائه شده است. این کاهش رنگ، سرعت و دقت ویرایش نقشه‌های فرش را افزایش می‌دهد. نقشه‌های فرش شامل دو دسته‌ی چاپی و دستی هستند. نقشه‌های دستی به دو گروه پیش از نقطه‌گذاری و پس از نقطه‌گذاری تقسیم می‌شوند. هدف از این مقاله، ارائه‌ی روشی جهت کاهش رنگ در نقشه‌های فرش پیش از نقطه‌گذاری است. الگوریتم پیشنهادی از مراحل زیر تشکیل شده است: بخش‌بندی تصویر، یافتن رنگ هر ناحیه، کاهش رنگ در اطراف لبه‌ها و کاهش رنگ نهایی با روش C-میانگین. در روش پیشنهادی، تعداد رنگ‌های هر نقشه توسط کاربر به الگوریتم داده می‌شود. در این روش، تعداد رنگ‌های نهایی حداقل ۱٫۳ برابر تعداد رنگ‌های تعیین شده توسط کاربر هستند. حاصل کار به صورتی است که ویرایش دستی برای رسیدن به تعداد رنگ اصلی بسیار آسان است.

کلمات کلیدی: کاهش رنگ، نقشه‌های دستی، بخش‌بندی، C-میانگین، فرش پارسی.