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Adaptive Pseudocoloring Method based on Color Image Scale for Emotional Art Image

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Abstract

Color can dramatically affect and arouse the emotions. In this paper, we propose a pseudocoloring method by applying the color psychology of color image scale to create an emotional art image. The proposed technique utilizes two key color groups, image segmentation, shape-preserving piecewise cubic Hermite interpolation with uniform lightness difference, Gaussian filter and morphological gradient to develop an adaptive color mapping of grayscale image. The key color groups of the desired emotion are extracted from the color image scale and the color map is generated from the interpolation results in CIELAB color space for each key color group to the segmented area. The simulation results show that the smooth gradient of key colors impressively transfers an implicative emotion of the image. In addition, soft transition between key color groups by smoothing at the edge of segmented area makes the image more artistic appeal. The emotional art image of the proposed pseudocoloring method could enrich the digital decoration and color therapy in both artifactual and natural images.

Keywords: Pseudocoloring, Color image scale, Emotional art image, Color gradient

I. INTRODUCTION

Pseudocoloring is a widely used technique to artificially assign colors for colorization of a grayscale image or modification of an existing color image. The technique is typically applied as a means of enhancing a visual appeal and highlighting specific features in the image. The color can be used to indicate the value of image data for qualitative and quantitative visualization. Pseudocoloring facilitates human interpretation in various applications of satellite, thermal and medical images. Many previous researches are both in applications of pseudocoloring [1]–[5] and pseudo coloring techniques [6]–[10]. For the research on the application of pseudocoloring, Sankaran et al. [1] utilize pseudocolor in visible-near infrared and thermal imaging for detection of Huanglongbing (HLB) disease in citrus trees. Several researchers work on applying pseudocolor for noninvasive diagnosis and industrial inspection. Li et al. [2] efficiently segment brain Magnetic Resonance (MR) image by using pseudocolor based segmentation with NAMS model (Non-symmetry and Anti-packing Model with Squares). In [3], adaptive pseudocolor enhancement method of radiographic testing (RT) image is proposed for a steam turbine manufacturing enterprise. The proposed method is based on the image processing in hue, saturation, and intensity (HSI) color space and the self-transformation of pixels. For pseudocoloring techniques, HSI and RGB color transformation are basically used which could be user-selected color mapping, linear or non-linear mapping, mathematically formulated transformation, histogram-based color mapping and function-based color mapping [6]. Other techniques are also developed to improve the efficiency for the specific purpose. In [7], nonlinear pseudocolor coding method based on gradient value is proposed to effectively highlight the disease areas in medical images. The automated pseudocoloring based on contourlet transform is developed in [8] for efficient Content Based Image Retrieval (CBIR. Moreover, multiple generative adversarial networks (Multi-GANs) [9] is recently introduced to create more realistic characteristics of the generated pseudocolor images. Pseudocoloring can be in the form of global and local color transfer between images [10]. The process generally involves histogram interpolation, luminance and texture matching. In this paper, we propose a new alternative application of pseudocoloring to automatically create an emotional art image. The proposed pseudocoloring method exploits the principle of color image scale with a unique image processing approach to convey the image impression. Our findings facilitate in the creation of emotive artwork for both professional and nonprofessional designers. The embellishment for more attractive and interesting design through the use of visual arts becomes less time and effort. The expressive art could also affect a person’s mood and enhance in healing the emotional problem in the color therapy.

II. RESEARCH METHODOLOGY

Color can evoke the emotions without awareness of subjects [11]. In this paper, we apply the color psychology by means of color image scale [12] to generate the emotional art image using pseudocoloring method. The proposed pseudocoloring technique begins with converting the emotion to key colors and then creates adaptive color mapping according to the content of grayscale image.

A. Emotion to Key Colors Conversion

The color image scale in [12] organizes the color combinations based on warm-cool and soft-hard axes and arranges them into 23 groups of emotions as illustrated in Figure 1. The color image chart shown in Figure 1 indeed consists of 160 key image words and their color combinations which will be applied in this stage. We select the desired emotion from these key image words and use its color combination to produce two tones of color groups. Each group has 4 to 6 key colors sorted in ascending order of lightness. Four emotions of romantic, pretty, sporty and dynamic are simulated in the experiment and their color combinations are shown in Figure 2.

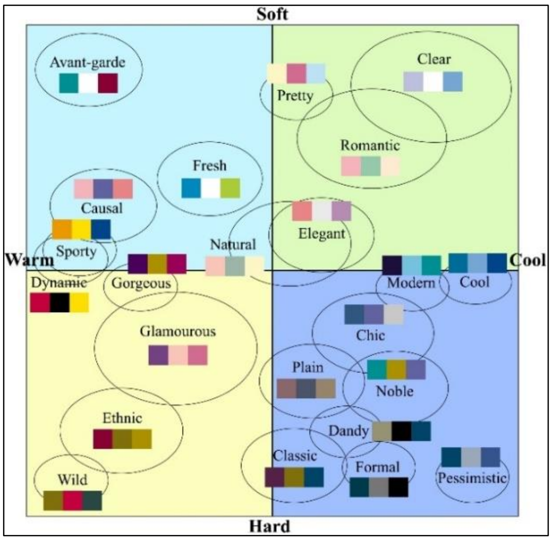


Figure 1: Color image chart.

Figure 2: Color combinations of the simulated emotions.

B. Adaptive Color Mapping

The overview of the proposed pseudocoloring technique is described in Figure 3. First, we segment the grayscale image into low intensity and high intensity using Otsu's thresholding method [13] which is an efficient way to perform automatic image thresholding. In this technique, the optimal threshold is determined by minimizing intra-class intensity variance, or more practically in computation, by maximizing inter-class variance. Therefore, the algorithm searches for the threshold $\boldsymbol{t}$ that maximizes the function of inter-class intensity variance $\sigma_b^2(t)$ described in (1).

$$\sigma_b^2(t) = W_0(t)W_1(t)[\mu_0(t) - \mu_1(t)]^2 \qquad (1)$$

Where $W_0(t)$ and $W_1(t)$ are the probabilities of the two classes separated by a threshold t, and $\mu_0(t)$ and $\mu_1(t)$ are means of these two classes.

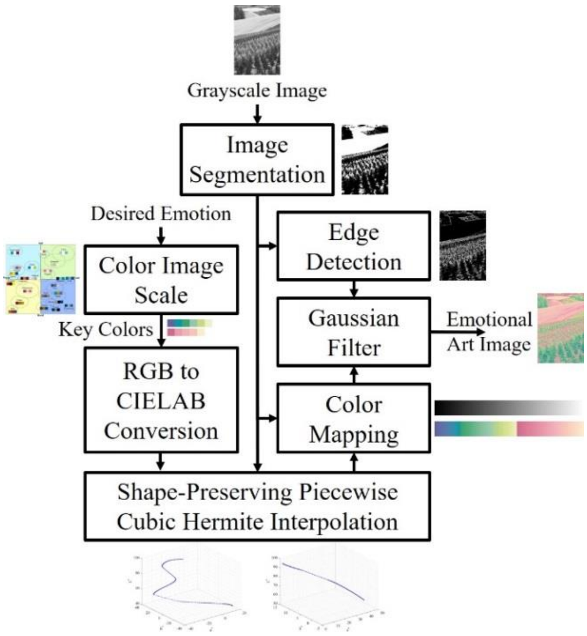


Figure 3: The overview of the proposed pseudocoloring technique.

The key colors obtained from the color image scale [12] are converted into CIELAB color space with CIE standard illuminant D65. The CIE 1976 L*a*b* is used because it is a standard device-independent color space and is modeled based on the sensitivity of the three types of cone cells in the human eye. Where L* is the luminance or brightness of the color and has the values in the range [0, 100] from black to white. a* is the amount of red or green tones with the values in range [-100, 100] or [-128, 127) from green to red/magenta while b* is the amount of blue varying to yellow tones in the range [-100, 100] or [-128, 127). Then the first key color group is mapped to the low intensity area and the second key color group is mapped to the high intensity one. The shape-preserving piecewise cubic Hermite (pchip) interoplation [14] with uniform lightness difference is used to expand each key color group to the intensity of the segmented area. The pchip interpolates using a piecewise cubic Hermite interpolating polynomial which has the advantages of smooth connection, preserving monotonicity and the shape of the data. Moreover, if the data is not smooth, pchip has no overshoots and less oscillation comparing to the cubic spline data interpolation. The color mapping algorithm is the relative luminance mapping between grayscale of segmented image and the results of the interpolation. Finally, Gaussian filter is applied at the edge between low intensity and high intensity areas to smooth the transition between two pseudocolor groups. The Gaussian smoothing kernel with standard deviation of 1 obtained from the 2-D Gaussian function shown in (2) is selected with the square filter of size 5×5 for soft blurring.

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad (2)$$

Where x and y are the distance from the origin in horizontal and vertical axes, respectively, and σ (sigma) is the standard deviation of the Gaussian distribution. Boundary padding uses replication of the nearest border pixel to avoid the artifacts around the boundary of the image.

For edge detection process, morphological gradient is applied to the binary image resulting from the image segmentation. The operation of morphological edge detection is described in (3) which is equal to the difference between dilation and erosion of the image.

$$Edge = (A \oplus SE) - (A \ominus SE) \qquad (3)$$

Where A is the resulting binary image of the image segmentation process and SE is the structuring element shown in Figure 4. The dilation and erosion of A by SE are denoted $A \oplus SE$ and $A \ominus SE$, respectively. The internal and external boundaries of the high intensity regions can be then extracted as the edge and smoothing areas between two key color groups.

0	1	0
1	1	1
0	1	0

Figure 4: The structuring element for morphological edge detection.

III. RESULTS AND DISCUSSION

The key colors and their lightness of simulated emotions are shown in Figure 5. The top row and the bottom row of each emotion depict the first group and the second group of key colors, respectively. The key colors in each group are arranged in an ascending order of lightness to prepare for the interpolation process as the lightness value shown in Figure 5. Figure 6 illustrates the example of grayscale image and binary image of segmentation process using Otsu's thresholding method. The low intensity pixels are in the black area while the high intensity pixels are in the white area of binary image. The example results of shape-preserving piecewise cubic Hermite (pchip) interpolation are demonstrated in Figure 7. The graphs show the interpolation results in CIELAB color space with uniform lightness difference for romantic and dynamic emotions of the image shown in Figure 6.

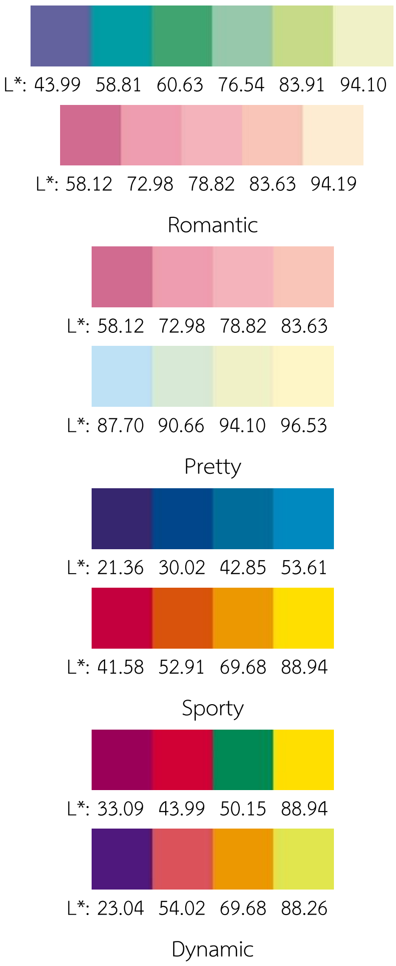


Figure 5: The key colors and their lightness (L*) of the simulated emotions (top: the 1st group of key colors; bottom: the 2nd group of key colors).

Figure 8 shows the color maps of all simulated emotions for the grayscale image shown in Figure 6. Figure 9 describes the edge between low intensity and high intensity areas of the segmented image in Figure 6. These edges are determined by using morphological gradient.

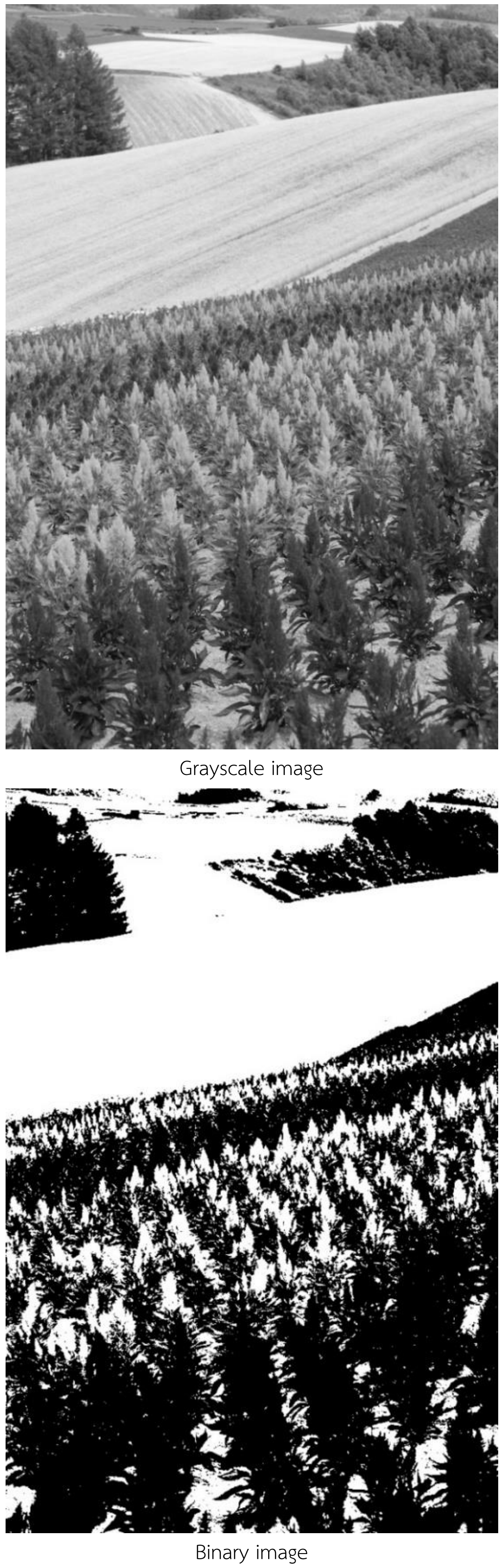
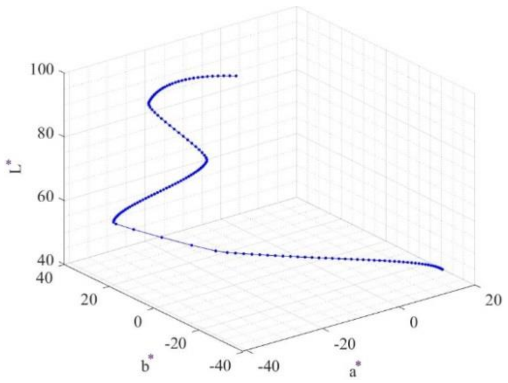
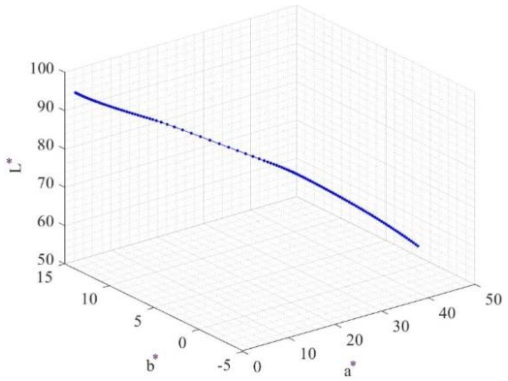


Figure 6: The example of grayscale image and binary image used in the experiment.

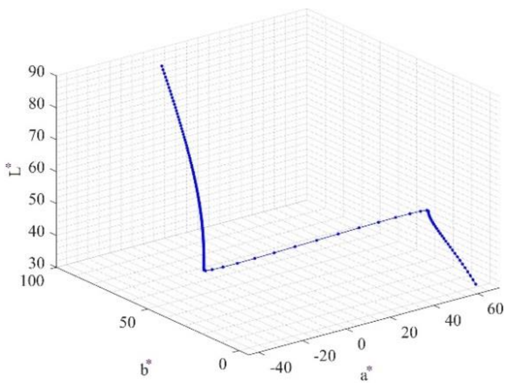


The 1st key color group

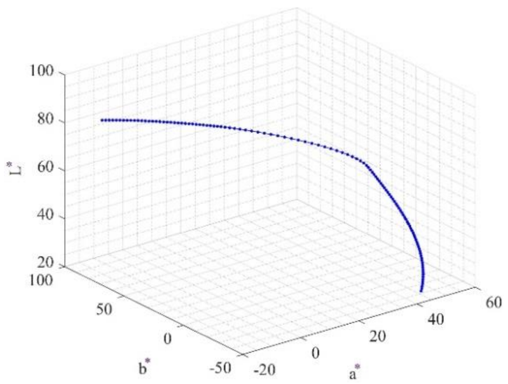


The 2nd key color group

Romantic



The 1st key color group



The 2nd key color group

Dynamic

Figure 7: The results of pchip in CIELAB color space of the image shown in Figure 6.

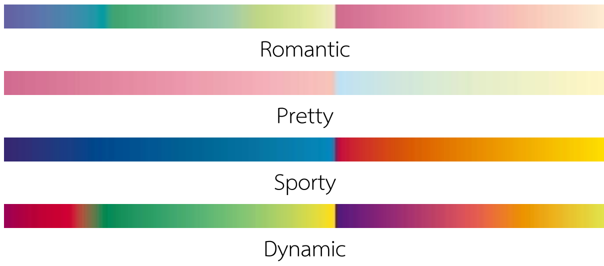


Figure 8: Color maps of all simulated emotions for the image shown in Figure 6.

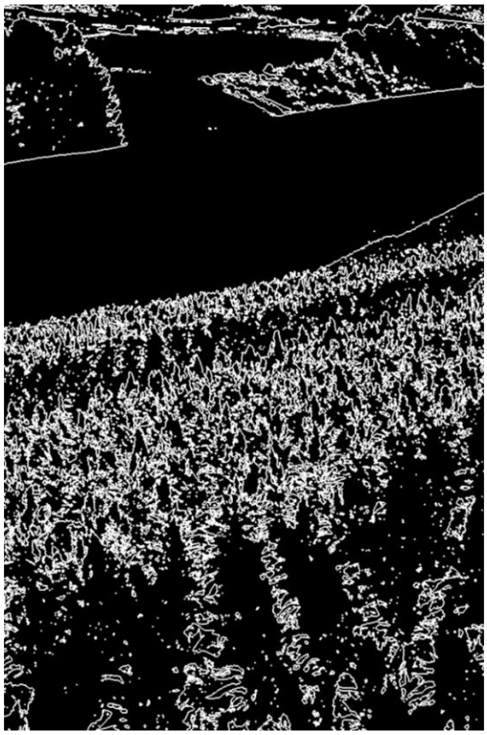
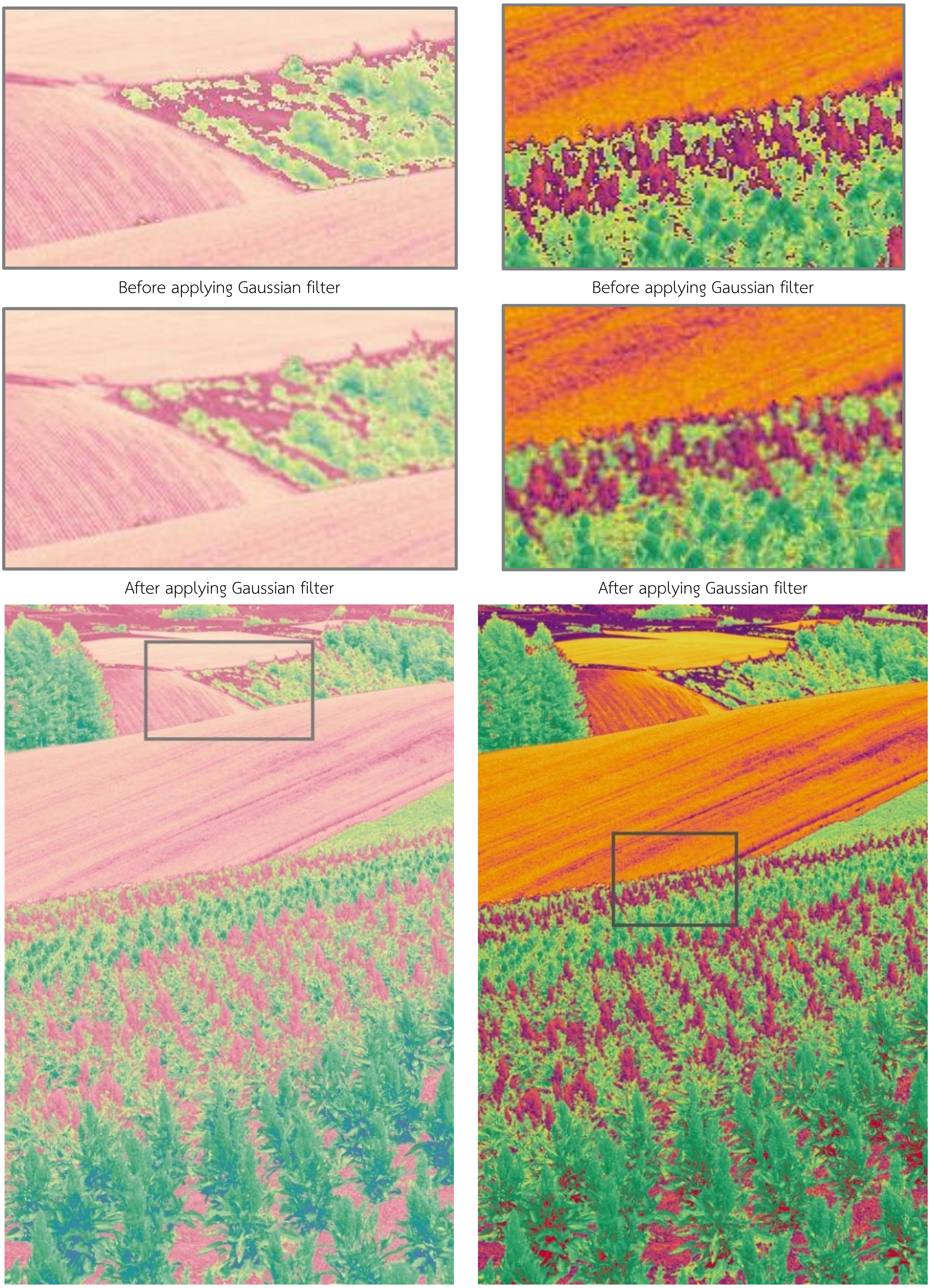


Figure 9: The edge between low intensity and high intensity areas of segmented image in Figure 6.

Figure 10 shows pseudocolor images of romantic and dynamic emotions comparing before and after applying Gaussian filter at the edge in the gray box area. It can be seen that smooth transition between two tones of key color groups makes the image softer and more artistic while still keeping texture and detail in other areas. The wide regions in pink tone of romantic and orange tone of dynamic remain the sharp details. The final results of pseudocolor images for pretty and sporty emotions of image in Figure 6 are shown in Figure 11.

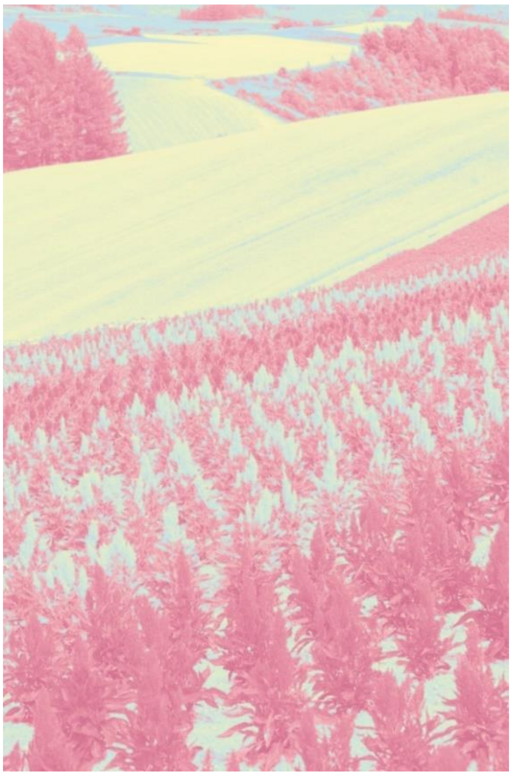


Before applying Gaussian filter | Before applying Gaussian filter

After applying Gaussian filter | After applying Gaussian filter

Pseudocolor image of romantic emotion | Pseudocolor image of dynamic emotion

Figure 10: The comparison results of pseudocolor images before and after applying Gaussian filter at the edge.



Pretty

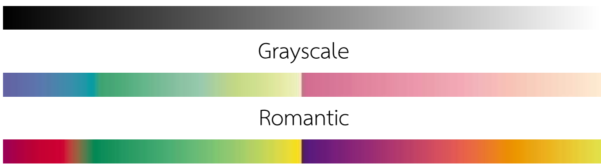
Sporty

Figure 11: The results of pseudocolor images for pretty and sporty emotions of the image shown in Figure 6.

Figures 12 and 13 show other examples of emotional art images and color maps using the proposed pseudocoloring method. In our technique, the color map will adaptively change according to the image content and keep smooth lightness variation to enhance the visual quality of sequential colors. The lightness of pseudocolor is also consistent with the grayscale. The gradient of key colors and the soft transition between key color groups bring significantly emotional art and impressed images as shown in the example results of Figures 10 to 13.

Grayscale image with low texture

Romantic Dynamic



Dynamic

Color maps

Figure 12: The example results of emotional art images with low texture and color maps.

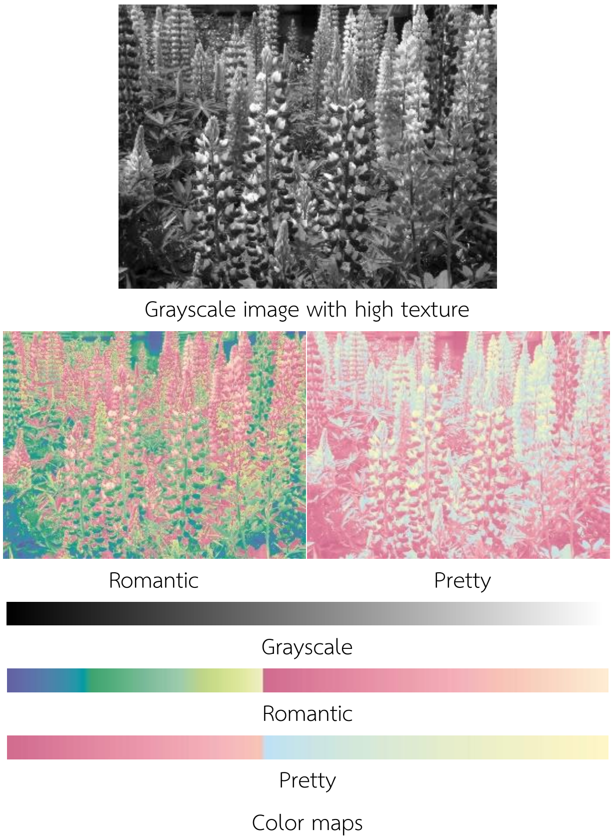


Figure 13: The example results of emotional art images with high texture and color maps.

Although romantic emotion can map to both images in Figures 12 and 13, in practice we recommend the emotion of high color variation (i.e., dynamic) for low texture image in Figure 12 and low color variation (i.e., pretty) for high texture image in Figure 13. This is to balance the visual perception of color and image detail for the best result. In addition, the emotional perception of an art image is quite complicated. Therefore, the objective evaluation should be investigated more in the future.

IV. CONCLUSION

In the proposed pseudocoloring method, we create an emotional art image by applying the color image scale and a particular approach of image processing. The grayscale image is segmented using Otsu's thresholding method and adaptively mapped to the interpolated key colors extracted from the color image scale. We preserve smooth lightness variation in the interpolation and smooth transition between segmented areas of different color tones by using Gaussian filter. Four emotions of romantic, pretty, sporty and dynamic are simulated in the experiment as a guideline for further application. The results of smooth gradients of emotive colors can convey an impressive emotional art image.

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