Charcoal Drawing Style and Color Effect of Children Face Images based on Structural Similarity Index and Color Image Scale

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Abstract

Many people love to capture and view children pictures to catch their cute moments. The smile and innocence of children's faces are very impressive. Therefore, this paper proposes an alternative method to create charcoal drawing style and color effect for children face images. The method applies the structural similarity index (SSIM) of image quality assessment to generate rich black tones automatically. The image is blurred with Gaussian filter to the appropriate level and compared with the original image to obtain the local SSIM values. The blurred level and the weight of neighborhood pixels for estimating local statistics in SSIM quality assessment is controlled by the threshold of the average SSIM value of image detail acquired from the preliminary experiment. The color effect is based on SSIM values and the knowledge of color image scale. The results reveal that the sophisticated intensity of lightness from SSIM map has the power to convey this expressive drawing style emotionally and naturally.

Keywords: Charcoal Drawing, Color Effect, Children Face Images, Structural Similarity Index, Color Image Scale

I. INTRODUCTION

Charcoal drawing is one of the amazing arts as it provides a profound and in-depth look to an image. The artists usually use vine charcoal and compressed charcoal with drawing techniques to create rich lines and shading for realistic and attractive work. The softness of charcoal drawing edge emphasizes on mass and movement rather than solid and linear precision. The artists can focus on large shapes and general contours and express more without getting stuck in details. Various art techniques and sketching experiences or skills are required to achieve the professional charcoal drawing. There have been several researches and tools that are available to assist in creating digital imitation of charcoal drawing. Some methods introduce the transformation of photo into pencil drawing first [1]-[3]. The photo can be adjusted manually or transformed automatically to charcoal drawing with realistic charcoal Photoshop action [4]-[5] or charcoal filter [6]. The thickness of the line and the line density or the degree of detail can be controlled to the desirable level. These methods facilitate in producing charcoal drawing with some manual tasks such as reducing noise, selecting subject, adjusting details and brush strokes. The results sometimes tend to be like graphical images. Previous researches have investigated in applying saliency maps for portrait sketching [7] and local image measurements of brightness, color and texture cues for detecting natural image boundaries [8]. These approaches can improve the drawing style and local boundary detection. However, they cannot fully generate charcoal drawing without additional effort. Current interesting apps are "my sketch" [9], "photo to sketch" [10] and "sketch master" [11] which completely convert photos into drawing sketches. The success depends on the content of image and tends to be lower for low image detail or image with weak texture. The natural of drawing style, i.e., not too photorealistic and not too artifactual, requires more improved. Therefore, we develop an alternative method to automatically create better charcoal drawing and color effect by introducing the structural similarity of image detail. The proposed method is self-generated charcoal drawing and colorizes by applying the color image scale to the structural similarity index (SSIM) information. Generally, the structural similarity index is used for image quality assessment by measuring the similarity between two images [12]. It has been used in a variety of fields, particularly in radiological medical images [13] and neural networks for image classification and super-resolution imaging [14]. This paper has extended the application of SSIM to an aesthetic aspect for children face images. Although the proposed method is not limited to the children face images, their cuteness to stimulate widely use of applications lead us to focus on children faces for practical applications. The natural charcoal drawing and color effect of children faces would contribute to an impressive design in versatile purpose such as T-shirt, tote and grocery bag for more enjoyable and enthusiastic use.

II. RESEARCH METHODOLOGY

We propose the method to automatically transform the image into charcoal drawing by using the structural similarity index (SSIM) [15]. The overview of the proposed method is illustrated in Figure 1. First, the original RGB image is smoothed with 2-D Gaussian filter. The Gaussian kernel coefficients are sampled from the 2-D Gaussian function described in (1). The initial standard deviation of 1 is used because the image begins to be perceived in blurriness for proceeding to the process of structural similarity measurement.

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

Where x is the distance from the origin in the horizontal axis, y is the distance from the origin in the vertical axis, and σ (sigma) is the standard deviation of the Gaussian distribution. The filtered image or blurred image is achieved by convolving the 2-D Gaussian distribution function with the original RGB image in spatial domain. The filter size is $4\sigma+1$. Then, the original image and blurred image are converted into grayscale by eliminating the hue and saturation information while retaining the luminance. The formula used to convert RGB values to grayscale values is described in (2).

$$\text{Grayscale} = 0.2989R + 0.5870G + 0.1140B \quad (2)$$

Where R, G, B are the intensities of red, green and blue components, respectively.

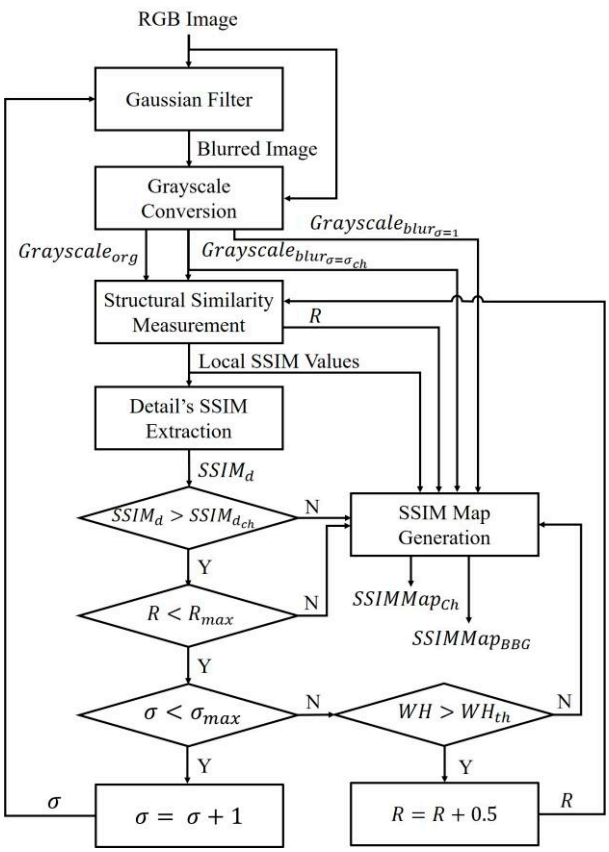

Figure 1 The overview of automatic charcoal drawing generation.

The outputs of this process are the grayscale of original image $(Grayscale_{org})$, the grayscale of blurred image at σ =1 $(Grayscale_{blur_{\sigma=1}})$, and the grayscale of blurred image at any σ $(Grayscale_{blur_{\sigma}})$. Next, we measure the similarity between original image and blurred image by computing the local structural similarity index (SSIM) values of $Grayscale_{blur_{\sigma}}$ compared to $Grayscale_{org}$. This quality assessment is based on the computation of multiplicative combination of luminance, contrast and structure and can be simplified as (3) [16].

$$SSIM(b,o) = \frac{(2\mu_b\mu_o+C_1)(2\sigma_{bo}+C_2)}{(\mu_b^2+\mu_o^2+C_1)(\sigma_b^2+\sigma_o^2+C_2)} \quad (3)$$

Where μ_b, μ_o, σ_b, σ_o, and σ_{bo} are the local means, standard deviations, and cross-covariance for images *b* (blurred image), *o* (original image). The standard deviation (R) of isotropic Gaussian function is initially set to 1.5 as the image begins to reduce in line sharpness. This is because the natural charcoal drawing prefers gray gradient to solid and sharp sketch. The value of R is used to weight the neighborhood pixels around a pixel for estimating local statistics. The value of C_1 is equal to $(0.01L)^2$ and the value of C_2 is equal to $(0.03L)^2$, where L is the dynamic range of the input image. The greater the value of SSIM is, the more similar the two images are. The value will become 1 when the two images are identical.

Subsequently, we segment the image detail by using global threshold from Otsu's method [17], [18] to the local SSIM values. The method finds the optimal threshold by exhaustive searching for the threshold that minimizes the intra-class intensity variance or, equivalently, maximizes the inter-class variance for fast calculation. The SSIM value of image detail called $\mathbf{SSIM}_d$ can be then extracted by averaging the local SSIM values of the image detail part. From the preliminary experiment, the most suitable SSIM value

of image detail for charcoal drawing ($\mathrm{SSIM}_{d_{ch}}$) is approximated to 0.3 with the maximum standard deviation of the Gaussian distribution (σ_{max}) of 30. The value of R is limited to 8 (R_{max}=8) for the best result of large image size. The initial value of R will be increased with step of 0.5 only when width or height of image (WH) is greater than 3,000 pixels (WH_{th}=3000). The process continues increasing the value of σ by step of 1 in image smoothing to decrease the value of SSIM_d until it reaches or nears 0.3 ($\mathrm{SSIM}_{d_{ch}}$). Then, we get σ_{ch} and SSIM map generation will be enabled and collects the data of $Grayscale_{blur_{\sigma=\sigma_{ch}}}$, $Grayscale_{blur_{\sigma=1}}$, R and local SSIM values for generating two SSIM maps, i.e., $\mathrm{SSIMMap}_{ch}$ and $\mathrm{SSIMMap}_{BBG}$. The charcoal drawing is the SSIM map called $\mathrm{SSIMMap}_{ch}$ which is the local SSIM values of $Grayscale_{blur_{\sigma=\sigma_{ch}}}$ compared with $Grayscale_{blur_{\sigma=1}}$ using the current R value. The use of small blurred image ($Grayscale_{blur_{\sigma=1}}$) is to reduce noise on smooth area such as facial skin.

For color effect, we divide into black background and light color background. $\mathrm{SSIMMap}_{BBG}$, which is the current local SSIM values, is used for black background. This is because dark tone background usually requires more detail for color drawing expression. In light color background, we apply the value of $\mathrm{SSIMMap}_{ch}$ directly. The SSIM maps for color effect in light color background and black background are summarized in (4) and (5), respectively.

$$SSIMMap_{ch} = SSIM\left(Grayscale_{blur_{\sigma=\sigma_{ch}}}, Grayscale_{blur_{\sigma=1}}\right) \quad (4)$$

$$SSIMMap_{BBG} = SSIM\left(Grayscale_{blur_{\sigma=\sigma_{ch}}}, Grayscale_{org}\right) \quad (5)$$

In the case that σ reaches its maximum value of 30 and SSIM_d is still greater than $\mathrm{SSIM}_{d_{ch}}$, the algorithm will check for the size of image. If image width and height are not greater than 3,000 pixels (WH_{th}), SSIM map generation will be enabled. But if image width or height is greater than 3,000 pixels, the value of R will be increased with step of 0.5 to reduce the sharpness of drawing in high resolution image until the value of SSIM_d reaches or nears $\mathrm{SSIM}_{d_{ch}}$. SSIM map generation will be then enabled. However, if the increased R reaches its maximum limit of 8, SSIM map generation will be also enabled.

Once we get two SSIM maps, we can apply the color image scale [19]-[22] which matches basic colors and color combinations to key image words to create the emotion throughout the colors. Figure 2 shows the color image chart [21] which organizes the color groups and image words according to warm-cool and soft-hard axes. The chart consists of 23 emotional groups and 160 key image words. Each emotional group has several key image words and each key image word has approximately 16 color combinations. Twenty-three emotional groups, e.g., pretty, romantic, dynamic, modern, classic, formal, are described in Figure 2. For example, emotional group of pretty has 6 key image words, i.e., pretty, endearing, childish, lovely, sweet and cute. Each of these key image words has its own color combinations and might have some colors in common. Figure 3 shows the example of 16 color combinations for key image word of cute. There are 4 key image words or emotions which are demonstrated as the examples in this research, i.e., two for black background and other two for light color background. The first two emotions of black background are daring and intense feelings. We use the color combinations of these key image words to produce the color effect. For daring image, $\mathrm{SSIMMap}_{BBG}$ creates the shade of pink tone by (6) - (8). In intense feeling, we calculate the output image by using (9) - (11).

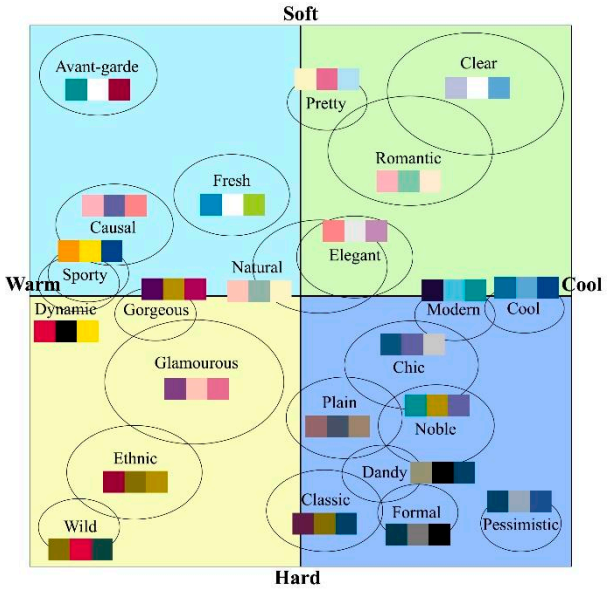

Figure 2 Color image chart.

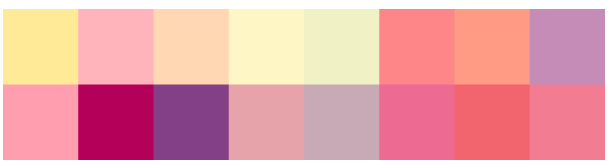

Figure 3 Color combination for key image word of cute.

Daring image

$$\mathrm{R} = 209 - \mathrm{SSIMMap}_{BBG} \quad (6)$$

$$\mathrm{G} = 107 - (2 \times \mathrm{SSIMMap}_{BBG}) \quad (7)$$

$$\mathrm{B} = 144 - \mathrm{SSIMMap}_{BBG} \quad (8)$$

Intense image

$$\mathrm{R} = 255 - (3 \times \mathrm{SSIMMap}_{BBG}) \quad (9)$$

$$\mathrm{G} = 0 \quad (10)$$

$$\mathrm{B} = 255 - \mathrm{SSIMMap}_{BBG} \quad (11)$$

Where R, G, and B are the red, green, and blue channels of output image, respectively.

The other two emotions of light color background are classic and stylish feelings. In this case, we reverse the value of $\mathrm{SSIMMap}_{ch}$ and subtract it from the setting background color shown in (12) - (13). The calculation for each color channel can be described in (14) - (15).

$$[R_{bc} \quad G_{bc} \quad B_{bc}]_{classic} = [240 \quad 246 \quad 218] \quad (12)$$

$$[R_{bc} \quad G_{bc} \quad B_{bc}]_{stylish} = [209 \quad 201 \quad 223] \quad (13)$$

Where R_{bc}, G_{bc}, and B_{bc} are the setting background color in red, green, and blue channels, respectively.

$$\mathrm{R} = R_{bc} - (1 - \mathrm{SSIMMap}_{ch}) \quad (14)$$

$$\mathrm{G} = G_{bc} - (1 - \mathrm{SSIMMap}_{ch}) \quad (15)$$

$$\mathrm{B} = B_{bc} - (1 - \mathrm{SSIMMap}_{ch}) \quad (16)$$

Where R, G, and B are the red, green, and blue channels of output image, respectively.

With the proposed method, it is possible to create natural charcoal drawings of children faces and color effects of daring, intense, classic and stylish images automatically.

For the evaluation, we select the conventional tools that can generate charcoal drawings by one or few clicks and compare the results with the proposed method. These tools consist of apps, website and software which are My sketch, Photo to sketch, Sketch master, Photoshop filter and Photo funny. Ten images are tested and the respondents will be asked to select the best charcoal drawing from 6 tools with the reason by using online questionnaire.

III. RESULTS AND DISCUSSION

We did the experiment to verify the proposed method with 80 children face pictures of various sizes. Due to the copyright of image, only some results can be shown. Figure 4 shows the original images and charcoal drawings which consist of high, medium, and low details. The pixel resolution of each picture is illustrated in Table 1.

Original image: My Good Images/Shutterstock.com

Charcoal drawing

kid1.jpg (high detail)

Original image: Anna Om/Shutterstock.com

Charcoal drawing

kid2.jpg (medium detail)

Original image: Kiselev Andrey Valerevich/Shutterstock.com

Charcoal drawing

kid3.jpg (low detail)

Figure 4 Example results of charcoal drawings.

Table 1 The pixel resolution of images in Figure 4

Image name	Dimensions (width × height)
kid1.jpg	1300 × 876
kid2.jpg	1300 × 1300
kid3.jpg	1300 × 868

We can see that the algorithm will automatically adjust for any image details and image sizes to reach or near the average SSIM value of image detail for charcoal drawing $(\mathrm{SSIM}_{d_{ch}})$. The results show the natural charcoal drawing, particularly in eye part. Rich shading of grayscale makes the image an interesting and attractive look.

Figure 5 shows the comparison result between 5 conventional tools and the proposed method from 35 respondents. The numbers of respondents who select the image result of each tool for each image as the best charcoal drawing are described. The image results of the proposed method are most selected as the best charcoal drawing which is about 70% of tested images. The second rank is the image results of "My sketch" app which is selected about 50% of tested image. For other tools, they are selected as the best charcoal drawing about 0-20% of tested image. The results are summarized in Table 2. In some images, the most selected results of drawing tools are equal so 2-3 tools are considered to produce the best charcoal drawing in these images. The reasons that the respondents select the charcoal drawing of the proposed method are proper line gradation, appropriate image detail, impression of charcoal drawing style. Figure 6 shows the example result of each tool for tested image number 7 which the proposed method gives the highest number of selected respondents. The proposed method performs quite well in low texture image because of the delicate gray gradation of apparent detail. Figure 7 shows the example results for tested image number 4 which the proposed method is ranked third among others. From our discussion with the respondents, it might be because some respondents prefer sharp line as their favorites. When the image detail is high as in the tested image number 4, the line sharpness effects more to the personal preference. In this case, the other tools can make more impressed for them. However, an art expert suggests that the natural charcoal drawing should not be artifactual or the line is not too sharp. Therefore, our algorithm tries to preserve the natural line gradation.

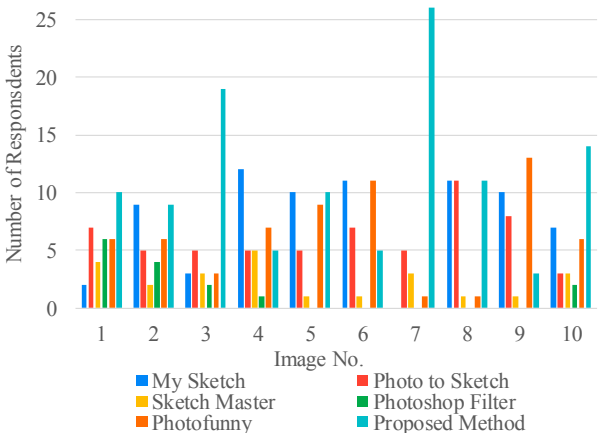

Figure 5 The comparison result of the numbers of respondents who select the image result of each tool as the best charcoal drawing.

Table 2 The percentage of tested images for each tool that the image result is selected as the best charcoal drawing

Tool	Selected Image Result as the Best Charcoal Drawing in Percentage
My Sketch	50%
Photo to Sketch	10%
Sketch Master	0%
Photoshop Filter	0%
Photofunny	20%
Proposed Method	70%

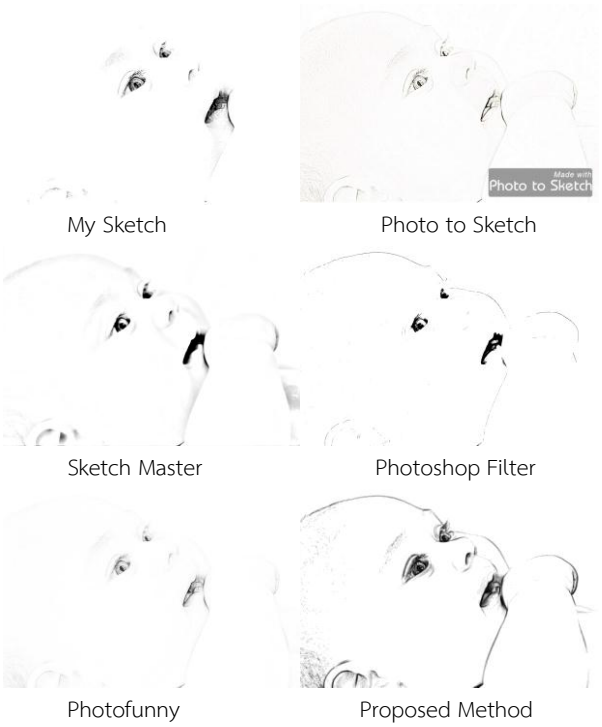

Figure 6 The image result of each tool for tested image no. 7.

Figure 7 The image result of each tool for tested image no. 4.

The example results for color effect of daring and intense feelings are shown in Figure 8. In the case of black background, $\mathrm{SSIMMap}_{BBG}$, which is the local SSIM values of $Grayscale_{blur_{\sigma=\sigma_{ch}}}$ compared to

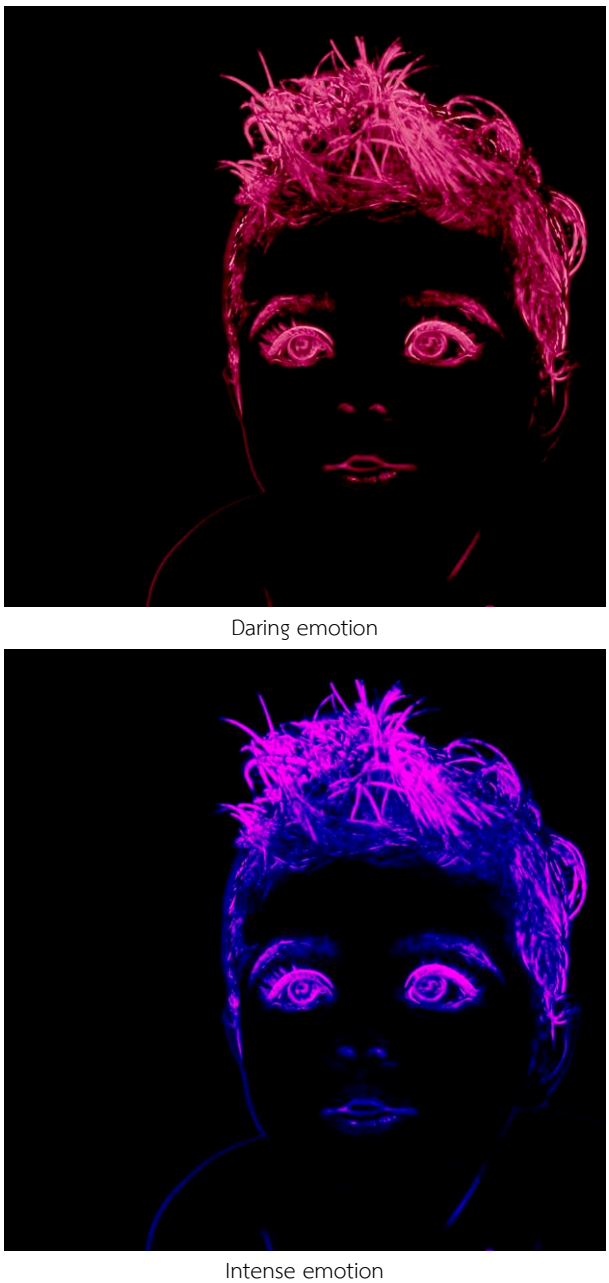

Figure 8 Example results for color effect of black background of kid2.jpg.

$Grayscale_{org}$, is selected. This is because it can produce more sophisticated detail which is good for appealing exhibit on dark tone background. Black and pink shade colors are used to present daring

expression. The pink shades appear in relative to the image detail. For intense emotion, black and two tones of blue and purple are used. The shading between two color tones is naturally proportional to the image detail. From the comments of an art expert to the color effect of black background, the color appearances are definitely transferred into the detail of image so the color tone and its gradation extremely touch the feeling of viewer. However, an art expert also suggests that the algorithm should adaptively keep the main outline of subject in image that might be sometimes difficult to see on the black background.

Classic emotion

Stylish emotion

Figure 9 Example results for color effect of light color background.

Table 3 The pixel resolution of images in Figure 9

Image name	Dimensions (width × height)
kid4.jpg	3077 × 3077
kid5.jpg	5900 × 3938

The example results of light color background are shown in Figure 9. In Figure 9, we try some images of Figure 4 with larger size described in Table 3. Because of the light color, the image is sensitive to noise or undesired detail. Therefore, the $\mathrm{SSIMMap}_{ch}$, which is the local SSIM values of $Grayscale_{blur_{\sigma=\sigma_{ch}}}$ compared to $Grayscale_{blur_{\sigma=1}}$, is used and changes the background to the selected color. The use of small blur (σ=1) instead of original grayscale helps in reducing noise on the smooth area. In this case, from the color image scale in [19]-[21], the light green background is used for classic feeling and the light purple background is used for stylish feeling. The applying of SSIM map makes a smooth transition between charcoal drawing and light color background. For light color background, an art expert comments that the gray shading can be easily and comfortably seen. Therefore, additional adaptive algorithm might not be required in this case.

The results of charcoal drawing and color effect shown in Figure 4, 8, and 9 can be viewed at http://tiny.cc/c5e3lz. It is recommended to view the picture in full image size for the best perception. From the experimental results, we also recommend to use the good quality of lightness of input image with at least 800 pixels of minimum image size for the good result. Front light, which evenly illuminates the subject from behind the camera or from the camera itself with no or little shadow, are most suggested. According to the results of four emotions, the user can further apply the concept of using SSIM map to other colors or color combinations or more creative color effects. Figure 10 shows some practical applications of the proposed charcoal drawing and color effect on T-shirt and grocery

bag. However, any originative ideas are welcome to broaden the practical use and experience of these impressive charcoal drawings.

Grocery bag

T-shirt

Figure 10 Examples of practical applications for the proposed charcoal drawing and color effect.

IV. CONCLUSION

This paper proposes a photograph based charcoal drawing method and color effect for children face images. The method is based on local structural similarity index (SSIM) values of blurred image at charcoal drawing level compared with small blurred image or original image. The SSIM map presents which elements of the image carry high detail and reflects in delicate gradation from black to gray to white for visual attention. The charcoal drawings are produced automatically and naturally without any required skill or artistic knowledge. For color effect, the picture is filled with black background and color shading lines or using the selected light color background. Rich tonal values of SSIM map convey sort of intensity to explore smooth and delicate expression. The applying of SSIM map with color image scale can produce emotional color effect impressively with minimal colors and it could be further developed for more creative and appreciative designs and applications. The fine adaptive algorithm to SSIM map is our future challenge to enhance the color appearance of charcoal drawing on dark tone background. Moreover, landscape, cityscape, fine-art photography and close-up shot are very interesting to apply with our method in the future to fulfill the creative vision and expression for video production, multimedia and printing media.

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