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Color Image Models and its Applications to Document Examination

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ABSTRACT

The questimed document examination plays an important role in forensic science. In Chinese documents, such as business contracts, there are stamps and signatures (or fingerprints) over them. Sometimes, those patterns (stamps, signatures or fingerprints) may superimpose on each other. When the documents being served as evidences to court, the overlapped patterns become contentious usually. Even in the document examination, overlapped patterns may interfere with the examination work. It will be helpful if we can reduce the overlapping influence before processing the document examination.

The objective of image segmentation is to find regions that represent objects or meaningful parts of objects. The method for image segmentation is to find the measure of homogeneous regions of objects or to detect the boundaries between objects. In this paper, we review some color image models and explain how we apply the image segmentation method to analyze overlapped patterns in the document examination. Synthetic images and one real case image are used to show the capability of the image segmentation method.

Introduction

Documents have been used almost everywhere in the human society, especially in economic activities. In general, a document is composed of three major parts - writing, ink, and paper. Each part of a questioned document can be checked and identified along. However, since their characteristics may affect each other, we must consider three parts together when checking questioned documents. In Chinese documents, such as business contracts, there are stamps and signatures (or fingerprints) over them. Sometimes, those patterns (stamps, signatures or fingerprints) may superimpose on each other. When the documents being served as evidences to court, the overlapped patterns become contentious usually. Even in the document examination, overlapped patterns may interfere with the examination work. It will be helpful if we can reduce the overlapping influence before processing the document examination.

From the definition [1-3], a digital gray-level image, f(x, y), can be represented as

$$f(x,y)=\sum_{i=1}^{M}\sum_{j=1}^{N} g(i,j)\delta(x-i,y-j)\,, \qquad (1)$$

where M x N is the image size, *g(i, j)* is the original continuous(natural) image, and δ*(i, j)* is the delta function. Since a color image can provide more information than a gray-level image does, color image processing has been noticeable. For a digital color image, *f(x, y),* can be represented as

$$f(x,y)=(f_r(x,y),\, f_g(x,y),\, f_b(x,y)) \qquad (2)$$

where

$$f_k(x,y)=\sum_{i=1}^{M}\sum_{j=1}^{N} g_k(i,j)\delta(x-i,y-j)\,,\ k=r,g,b$$

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,represent red, green, blue components of color information (in the RGB model), respectively.

Digital images take the advantage of easy transmission, convenient storage, good stability, simple manipulation. As the acquisition of digital images is getting convenient, digital images have been extensively applied in various domains. The image processing techniques have been successfully applied in forensic science [4-9]. According to processing objectives, image processing technologies can be classified as: image enhancement, image restoration, image segmentation, image feature extraction and representation,..., etc. Usually, it is useful to divide the image into regions corresponding to objects of interest before further processing. The primary objective of image segmentation is to find regions that represent objects or meaningful parts of objects. The secondary objective of image segmentation is to find the boundaries of interested objects for recognition. The method for image segmentation is to find the measure of "homogeneous regions" of objects or to detect the boundaries between objects. "Homogeneous regions" refer to a group of "similar" pixels (pixels with neighboring positions, near gray-level values, near color values, textures or features).

In this paper, we review some color image models and explain how we apply the image segmentation method to analyze overlapped patterns in the document examination. Synthetic images and one real case image are used to show the capability of the image segmentation method.

Methods

Color image models

With the color format, a digital image can record and provide more information than the gray scale format image does.

Digital acquisition devices (such as scanners and digital cameras) can separate beams of light into three primary colors- red, blue, and green, through the assistance of spectroscopes and filters. In order to record the color information, we need at least three parameters (e.g. red, blue, and green) to represent a color.

We use the color model to represent the color information of digital images. Since we need three parameters to represent a color, those color models must be with a three dimensional format. The models use some mathematical functions to represent a point position (in the three dimensional space) that is assigned to a color. Some color models (RGB, CMY, YIQ, HSI, l1_l2_l3, and L*a*b) are summarized as follows [2,3,10]:

1. RGB color model

The three primary colors (red, green, and blue) and their combination in visible light spectrum are shown in Fig.1. With different weights, (R, G, B), their combination can indicate different colors. After normalizing the values of R, G, B, we can get the color cube (Fig.2). The colors on the diagonal line, from the origin to the coordinate (1,1,1) of the cube, means the gray-level values.

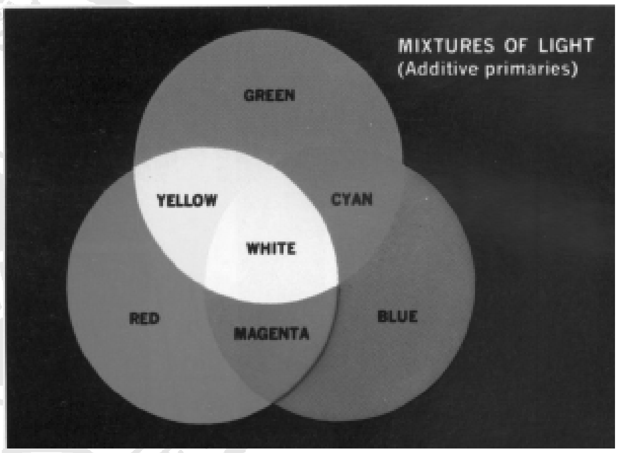

Fig. 1 RGB graph of the primary colors [2].

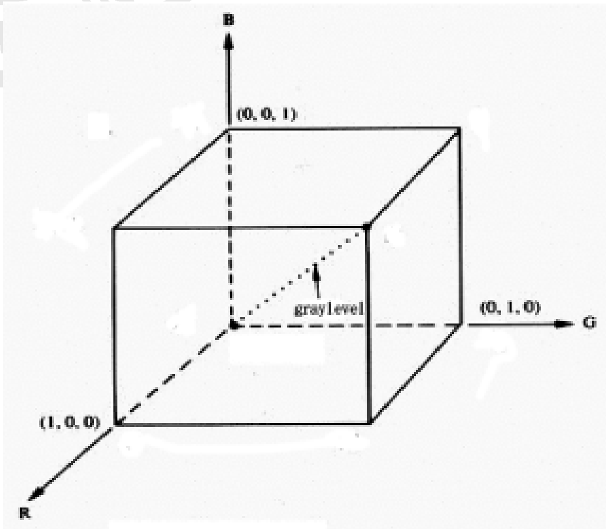

Fig. 2 RGB primary color cube [2].

2. CMY color model

The CMY color model is based on complementary colors- cyan, magenta, yellow. This color model can be expressed as

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}. \quad (3)$$

Fig. 3 shows the relationship of the component color of the CMY color model. The CMY color model is applied to the output devices, such as printers.

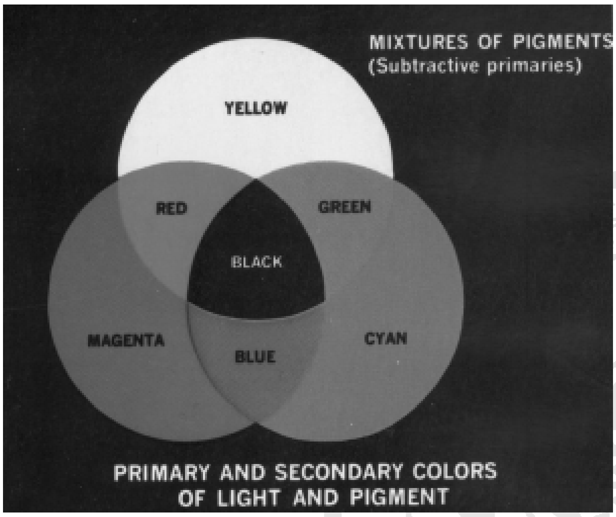

Fig. 3 CMY color model [2]

3. YIQ color model

The YIQ color model is designed to refer to the characteristics of the human's visual system. In the human's visual system, people are more sensitive to the lightness component than the hue component. So, the YIQ color model is set to separate colors into luminance (*Y*) and hue (*I* and *Q*). The relationship between YIQ and RGB is expressed as

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}, \quad (4)$$

where *Y* is the luminance, *I* and *Q* indicate the weights of hue.

The advantage of the YIQ color model is that we can deal with the luminance component independently. The YIQ color model is the standard model applied to the signal transmission of color TV sets.

4. HSI color model

The HSI color model is also based on the characteristics of the human's visual system. *I* denotes the light intensity, *H* denotes the hue that indicates the measure of the color purity, *S* is the saturation (the degree of a color permeated the white color). If a color is with high saturation value, it means the color is with the low white color. The relationship between HSI and RGB can be described as

$$I = \frac{1}{3}(R+G+B), \quad (5)$$

$$H = COS^{-1}\left\{\frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{\frac{1}{2}}}\right\}, \quad (6)$$

$$S = 1 - \frac{3}{(R+G+B)}[\min(R,G,B)]. \quad (7)$$

5. I1_I2_I3

The I1_I2_I3 color model is also based on the human visual system. *I1* denotes the luminance, while *I2* and *I3* indicate the color information. When *I2* and *I3* are positive, the color tends to red and yellow, respectively. When *I2* and *I3* are negative, the color tends to green and blue, respectively. The relationship between I1_I2_I3 and RGB can be described as

$$I1 = \frac{1}{3}(R+G+B), \quad (8)$$

$$I2 = R - G, \quad (9)$$

$$I3 = \frac{1}{2}(R+G) - B. \quad (10)$$

*6. L*a*b*

Commission International del'Eclairage (CIE) proposed the L*a*b color model as the international standard of color survey in 1931. In 1976, this color model was revised and named CIE L*a*b. A color can be defined by a lightness component (*L*) and two color components (*a* and *b*). *a* shows the degree from green to red. *b* means the degree from blue to yellow. The composition of the L*a*b color model components is shown as Fig.4.

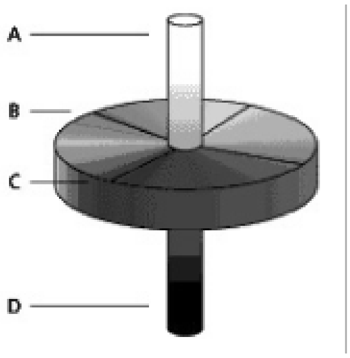

Fig. 4 The L*a*b color model diagram. A and D denote the lightness components, B and C describe the information of hue [2].

The relationship between I1_I2_I3 and RGB can be described as

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.618 & 0.177 & 0.205 \\ 0.299 & 0.587 & 0.144 \\ 0.000 & 0.056 & 0.944 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (11)$$

and

$$L^* = 25(100Y/Y_0)^{1/3} - 16, \quad (12)$$

$$a^* = 500[(X/X_0)^{1/3} - (Y/Y_0)^{1/3}], \quad (13)$$

$$b^* = 200[(Y/Y_0)^{1/3} - (Z/Z_0)^{1/3}]. \quad (14)$$

7. Digital color image file structures

In this paper, we use images with the digital color format BMP as our experimental samples. The BMP data format is summarized as below:

Filename: 'bmptest.bmp'
FileModDate: '13-Jun-2001 00:42:18'
FileSize: 12344
Format: 'bmp'
FormatVersion: 'Version 3 (Microsoft Windows 3.x)
Width: 64
Height: 64
BitDepth: 24
ColorType: 'truecolor'
FormatSignature: 'BM'
NumColormapEntries: 0
Colormap: []
RedMask: []
GreenMask: []
BlueMask: []
ImageDataOffset: 54
BitmapHeaderSize: 40
NumPlanes: 1
CompressionType: 'none'
BitmapSize: 0
HorzResolution: 11813
VertResolution: 11813
NumColorsUsed: 0
NumImportantColors: 0

From above date format, we can see this sample image size is 64*64 pixels or 12288 bytes (=64*64*3), the total file size is 12344 bytes. The file structure can be shown as Fig. 5.

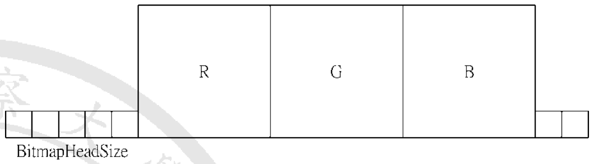

Fig. 5 BMP color image structure.

Color segmentation

In questioned document examination, overlapped patterns (such as signature and stamp) may interfere with the examination work. So, it will be helpful if we can reduce the overlapping influence before processing the document examination. Since those overlapped patterns have their own significant colors, it is convenient for us to segment them based on their color information.

From Fig.5, we can obtain the color information from the image file directly. As shown in Fig.6, we can extract three single color images (red, green, blue) from an original color image. Fig.7 shows an example. Fig.7 (a) is an original image. Fig.7(b)~(d) show red, green, and blue color component images, respectively.

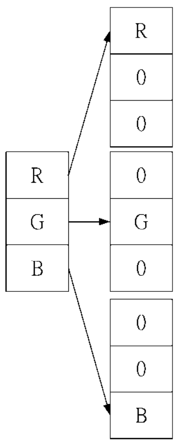

Fig. 6 The diagram of the color information extraction procedure.

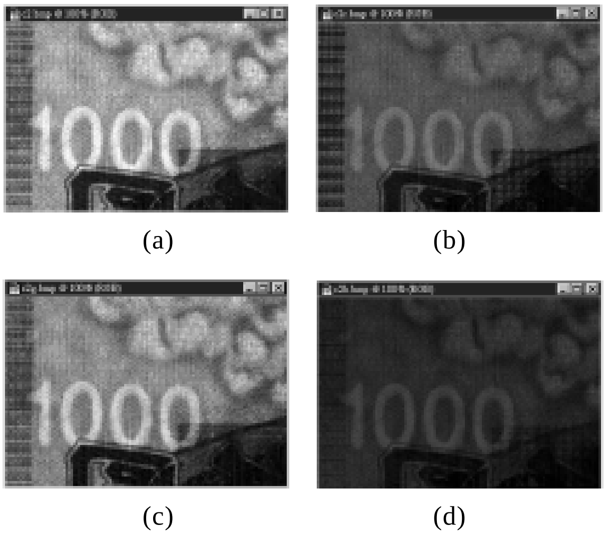

Fig. 7 (a) An original image; (b) the red color component image; (c) the green color component image; (d) the blue color component image.

Experimental Results

Synthetic images

There are four kinds of pens used in our experiments: (1)Sakura XPGB(T) Ballsign; (2)simbalion marking pen alcohol base NO.600; (3)UNIBALL fine delux waterproof UB-177; and (4)Lion NO.100.

There are two kinds of red stamp: (1) Japan Sunrise stamp pad (major ingredients: pigment, resin, comb-sesame oil); (2) Liberty brand stamp pad (major ingredients: dyes, water-glue, glycerin, and activity).

We use regular A4 copy papers and two writing order: stamp-first and signature-first. All 16 samples are list in the table 1. All samples are scanned with the UMAX Astra 2400S scanner under 300 dpi resolution and saved as bmp format files.

filename	Write status	Pen kind	Stamp kind
B4-1-2	Stamp first	Sakura XPGB(T) Ballsign	Sunrise stamp
B4-2-2	Stamp first	simbalion marking pen alcohol base NO.600	Sunrise stamp
B4-3-2	Stamp first	UNIBALL fine delux water-proof UB-177	Sunrise stamp
B4-4-2	Stamp first	Lion NO.100	Sunrise stamp
B4-5-2	Stamp first	Sakura XPGB(T) Ballsign	Liberty stamp
B4-6-2	Stamp first	simbalion marking pen alcohol base NO.600	Liberty stamp
B4-7-2	Stamp first	UNIBALL fine delux water-proof UB-177	Liberty stamp
B4-8-2	Stamp first	Lion NO.100	Liberty stamp
B4-9-2	Signature first	Sakura XPGB(T) Ballsign	Sunrise stamp
B4-10-2	Signature first	simbalion marking pen alcohol base NO.600	Sunrise stamp
B4-11-2	Signature first	UNIBALL fine delux water-proof UB-177	Sunrise stamp
B4-12-2	Signature first	Lion NO.100	Sunrise stamp
B4-13-2	Signature first	Sakura XPGB(T) Ballsign	Liberty stamp
B4-14-2	Signature first	simbalion marking pen alcohol base NO.600	Liberty stamp
B4-15-2	Signature first	UNIBALL fine delux water-proof UB-177	Liberty stamp
B4-16-2	Signature first	Lion NO.100	Liberty stamp

Table 1 Sample types.

In Fig.8, we extract three components (red, green, blue) from the original image. We can separate the signature (ink) from the stamp with them. Fig.9(a) and (b) show the extracted signature and stamp, respectively. The other experimental results are shown in the appendix.

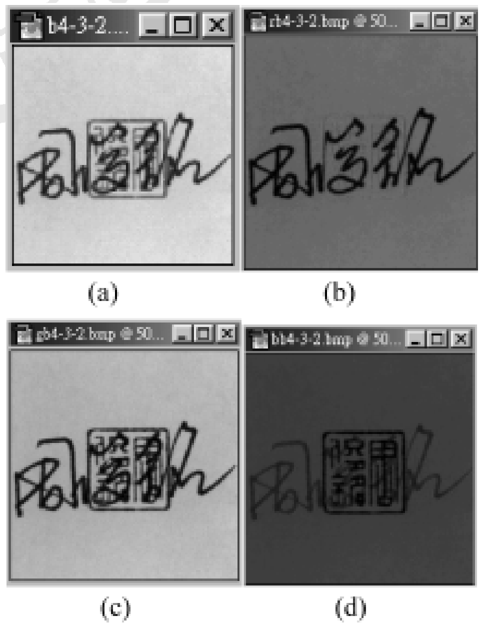

Fig. 8 (a) An original image; (b) the red color component image; (c) the green color component image; (d) the blue color component image.

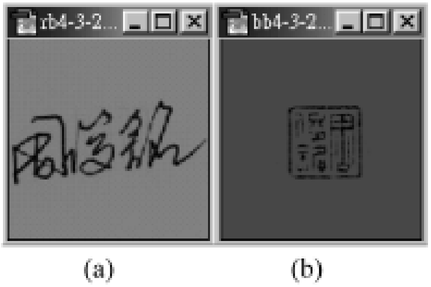

Fig. 9 (a) The enhanced image of Fig. 8(b); (b) the enhanced image of Fig. 8(d).

Real case image

We use a sample from a real criminal case. The segmentation result is shown in Fig.10. Fig.10(b) and (c) show the extracted writing and fingerprint, respectively.

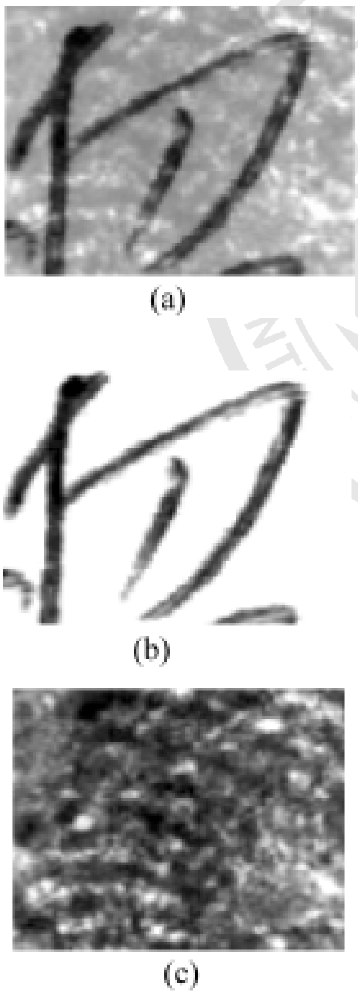

Fig. 10 (a) An original image; (b) the blue color component image (writing); (c) the red color component image (fingerprint).

CONCLUSIONS

In this paper, we review some color image models and explain how we apply the image segmentation method to analyze overlapped patterns in the document examination. Synthetic images and one real case image are used to show the capability of the image segmentation method. In the near future, we will try other color models and find their capability for aiding the processing of forensic sciences.

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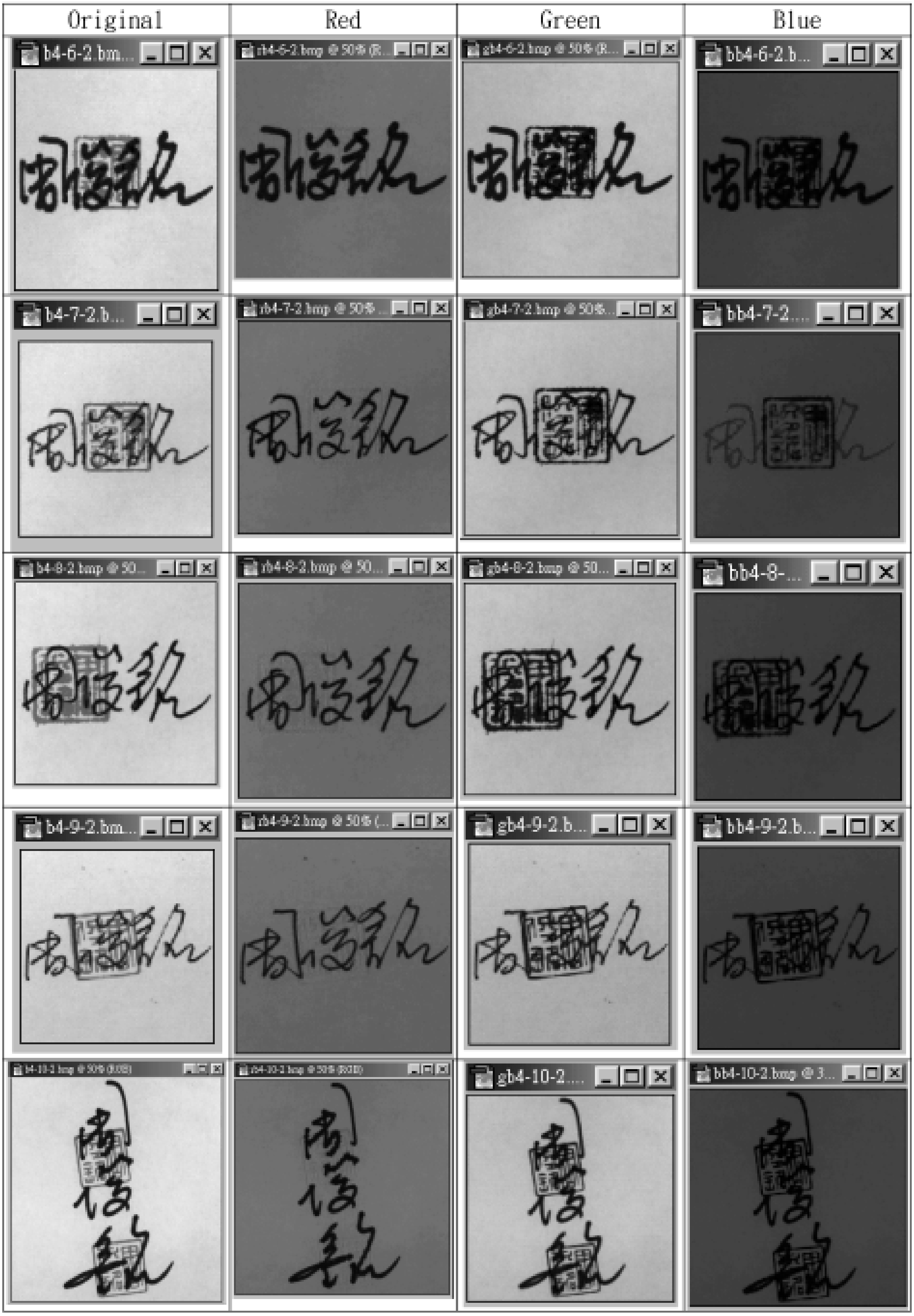
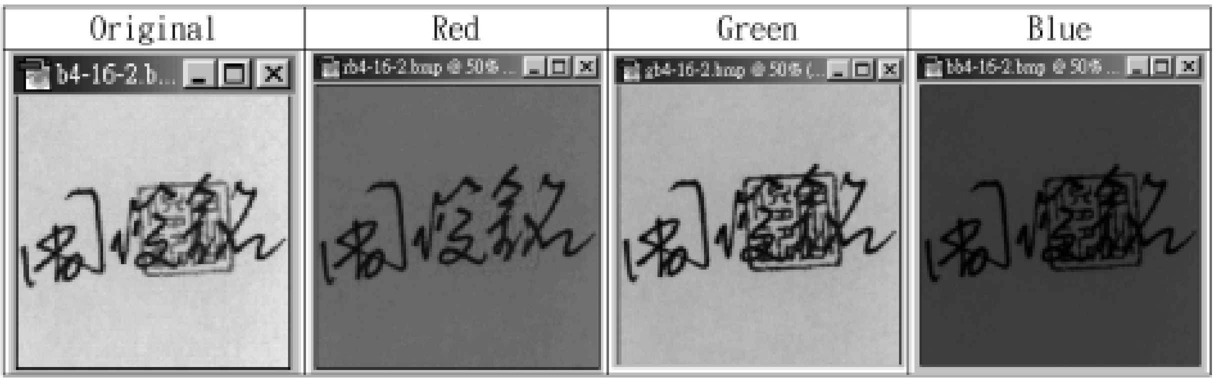
Appendix:


Original
Red
Green
Blue


Original
Red
Green
Blue
b4-11-2.bmp @...
bb4-11-2.bmp ...
b4-12-2.bm...
bb4-12-2.bm...
b4-13-2.bmp ...
bb4-13-2.bmp ...
b4-14-2.bmp ...
bb4-14-2.bmp ...
b4-15-2.bmp @ 5...
rb4-15-2.bmp @ 5...
gb4-15-2.bmp @ 5...


Original
Red
Green
Blue
b4-16-2.b...