COMPARISON OF TRUE COLOR AND E-COLOR ON INDIGENEOUS TEXTILE

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Abstract: This paper aims at investigating variations of color display on computer screens or websites compared with color of the real products. We focus on displaying indigo-dyed fabric image which is one of the famous textile products of Thailand. Eighty-five college students participated in our experiments to test the similarity of color of indigo fabric images displayed on computer screens comparing with the real fabrics. Totally 138 images of indigo fabrics with variation in textures were collected and used in our experiments. The colors of the indigo fabrics were in blue tone but had different shades. Each participant had to evaluate similarity of color of all 138 fabric images against color of the real fabrics. Each image was evaluated three times per one participant on separate days. According to statistical analysis, we found that the colors of indigo fabric images displayed on computer screens were significantly different from the true colors of the real indigo fabrics. The colors of all test images on the computer screens were lighter than the true colors. The preliminary image enhancement results showed that a power-law transformation can alleviate the color deviation problem. It has high potential to be used as an image processing technique for eliminating e-color deviation problem automatically in order to increase color accuracy viewed on the computer screens.

Keywords: indigo-dyed fabric, indigo textile, e-color, true color, e-business, Internet, digital image processing

1.   Introduction

Although the Internet is an important tool for business nowadays, most of the Internet shoppers do not trust the e-colors or the colors they see on their computer screens. Consequently, those Internet shoppers may not decide to purchase products because the true colors of the products are in doubt. In particular, to display textile products on web sites, their authentic characteristics depend on accurate color web display. Therefore, accurate color information is an important part of the communication message embodied in textile products displayed on web sites. In this paper, we aim at investigating variations of color display on computer screens or websites comparing with color of the real fabric products. We perform experiments on indigo-dyed fabric. The indigo-dyed fabric is one of the unique regional cultural fabric products of Thailand. It is a famous product of Skon Nakhon province [1],[2],[3]. Nowadays, it becomes a high-quality product of Thailand because the product development is consistent, and it is environmentally friendly [1],[2],[4]. However, there are some limitations in terms of marketing due to limited distribution channels [5]. The internet is a promising way to be used as a new distribution channel, but it has limitations related to color display as mentioned above. If we can increase color accuracy viewed on the computer screens or websites, the Internet can be used to expand marketplaces for textile business dramatically. In this paper, we intend to seek for a proper image enhancement technique for displaying accurate color of fabric images, in particular, indigo fabrics. The paper is organized as follows: Section 2 introduces techniques of digital image enhancement, Section 3 explains experiments performed on indigo-dyed fabric images, Section 4 summarizes experimental results, and Section 5 is conclusions.

2. Digital Image Enhancement

Digital image enhancement is a basic technique of digital image processing used to improve quality of images for human perception. It also is used to provide better quality of input images for further steps of automated image processing. Digital image enhancement techniques have been commonly used in various applications when the quality of images is important. Although, there are several algorithms used for image enhancement [6],[7],[8],[9],[10], they can broadly be divided into two categories: Spatial Domain Method, and Frequency Domain Method. The enhancement operations are performed in order to modify some attributes in the input image, for example, brightness, contrast, distribution of the grey levels or colours, etc. Consequently, the pixel values of the output image (*g*) will be modified according to a transformation function (*T*) applied on the pixel values on the input image (*f*). One of the basic transformation functions is the power law transformation as defined in Eq. (1).

$$g = T(f) = c\,f^{\,r} \tag{1}$$

where *c* and *r* are positive constants. The graphical representation of the power-law transformation is illustrated in Figure 1.
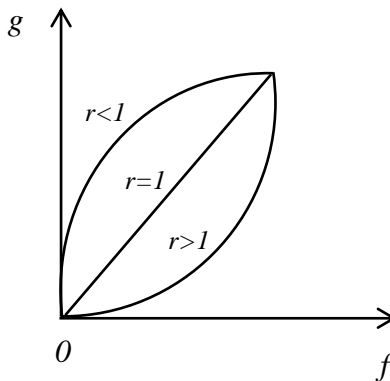

Figure 1: Graphical representation of the power-law transformation.

The power-law transformation [6],[8] is useful for general-purpose contrast manipulation. It has been applied to various applications [7],[11],[12]. For a dark input image, an output image is accomplished by using a power-law transformation with *r* less than 1 (fraction exponent). For an input image having a washed-out appearance, the output image is obtained by using a power-law transformation with *r* greater than 1. The power-law function can generate a family of possible transformation curves obtained by varying the *r* parameter. Therefore, it can be applied easily for any type of image for better contrast and highlighting in order to get a meaningful output for any purpose. The power-law transformation is also used in a variety of devices such as computer monitors, printers, and image acquisition devices. The exponent in the power-law equation is referred to as *gamma*. Therefore, the power-law transformation is also called as

gamma correction. To reproduce colors to display on a computer screen accurately, it also requires knowledge of gamma correction because changing the value of gamma changes not only the brightness but also the R, G, B components in a color image. In this paper, we intend to seek for a suitable set of gamma value for accurately displaying color of indigo-dyed textile images on computer screens.

3. Experiments

Experiments were performed to evaluate the similarity of colors on images of fabrics and the real fabrics through a visual comparison task. The participants were exposed to a sequence of the original 138 indigo fabric images which were displayed in the centre of computer screens. Each participant was asked to compare the similarity of e-color and true color of each piece of indigo fabrics. In each test, 138 images were presented one image at a time. Each participant performed the test three times on separate days. The size of image is 512 pixels (width) by 512 pixels (height). There are 5 levels (1, 2, 3, …, 5) of similarity scores [13], where 5 indicates the most similarity, and 1 the least similarity. After that the original images were transformed by the power-law transformation to get three copies of each image that are most similar to each of the 138 real fabrics. Then, participants performed similarity evaluations again in the same way as explained above.

3.1. Participants

The participants are 85 college students consisting of 50 females and 35 males. The average age of the participants was 19.50 years (ranging from 16 to 25 years). All participants had normal visual acuity. And all participants had basic level of computer literacy and had experiences with the Internet and Web technology. Before performing the task, the participants were explained and presented with a set of instructions. They also received practice trials to familiarize with the test.

3.2. Apparatus and Materials

To ensure adequate and equal testing environment to all participants, the viewing conditions were arranged with the same parameter values. The experiments were presented on 17" LCD Lenovo. The screen resolution was 2048 x 1536 pixels. The refresh rate was 60 Hz. And chromatic resolution was 32 bit.

3.3. Image Data

We had collected a number of indigo-dyed fabrics from Sakon Nakhon Province which is the most famous area of indigeneous woven fabrics of Thailand. Indigo-dyed fabric images were taken under the same camera settings and environments. The camera was tuned to get the fabric images that are most similar to the real fabrics, especially, the colour attribute. All of the images had the same size of 512 x 512 pixels. There are totally 138 images for testing. Figure 1 shows some examples of the indigo-dyed fabric images used in our experiments.

Figure 1: Examples of indigo fabric images used in experiments.

4. Results

The average similarity scores from all of the test images are shown in Table 1. Most of them (81.2%, 112 images of 138 images) are at a good level [13], in the range of [4.0, 4.5) points out of 5 points. One image, as shown in Figure 2, can achieve 5 points.

Table 1: Average similarity score of the original indigo fabric images vs. the real ones

No	Range of average Similarity Score	No. of images	
		(images)	(%)
1	[1, 1.5)	0	0
2	[1.5, 2.0)	0	0
3	[2.0, 2.5)	0	0
4	[2.5, 3.0)	0	0
5	[3.0, 3.5)	0	0
6	[3.5, 4.0)	10	7.2
7	[4.0, 4.5)	112	81.2
8	[4.5, 5.0)	15	10.9
9	[5.0, 5.0]	1	0.7
Total		**138**	**100**

Figure 2: *The image that gets the highest score of similarity (5 points out of 5 points from all subjects) when compared with the real fabric.*

Table 2 shows the optimal values of the exponent of the power-law transformation used for improving quality of the test images. The gamma values in the range of [1.5, 2.0) and [2.0, 2.5) are suitable for most of the test images (around 66.7%, 92 images of 138 images). The smallest exponent is 1.3 and the largest exponent is 4.2. Details of values of the exponent (gamma) in the low-value range, and the high-value range that are used in the power-law transformation (gamma correction) are summarized in Tables 3 and 4 respectively. Results clearly show that all of the test images displaying on computer screens are lighter than the true colors, i.e., gamma values greater than one are proper for all images (see Table 2). The group of fabric images that has the smallest color deviation is the ones in Table 3, and the group that has the highest color deviation is the ones in Table 4. From a closer inspection of the results, we found that we can classify the indigo fabric images into 3 categories of color tones as follows: 1) classic dull blue, 2) vivid blue, and 3) dark blue. The color of the indigo fabric images in the classic dull blue is closed to the real one when displaying on a computer screen and the suitable gamma value is in the range of [1, 1.5). For the ones in the vivid blue tone, and the dark blue tone, their colors displaying on computer screens are remarkably different from the real ones. The suitable ranges of gamma value are [1.5, 3.0), and [3.0, 4.5) for the vivid blue tone, and the dark blue tone respectively. Examples of indigo fabric images in the three categories before and after enhancement by using the power law transformation are shown in Figures 3, 4, and 5 respectively.

Table 2: *The optimal gamma values of the power-law transformation for all 138 test images.*
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No	Range of gamma value	No. of images	
		(images)	(%)
1	<= 1.0	0	0
2	(1.0,1.5)	21	15.2
3	[1.5, 2.0)	58	42.0
4	[2.0, 2.5)	34	24.7
5	[2.5, 3.0)	19	13.8
6	[3.0, 3.5)	2	1.4
7	[3.5, 4.0)	2	1.4
8	[4.0, 4.5)	2	1.4
9	[4.5, 5.0)	0	0
10	>= 5.0	0	0
Total		**138**	**100**

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Table 3: *The optimal gamma values for indigo fabric image enhancement in the range of* [1.0, 1.5)

No	Gamma value	No. of images	Image ID
1	1.10	0	-
2	1.20	0	-
3	1.30	7	K241012, K242012, K261011, K271022, K331012, K591011, K621012
4	1.40	11	K191012, K191021, K193011, K231022, K251022, K271012, K282012, K291011, K311012, K581012, K641013
5	1.45	3	K651013, K671012, K803013

Table 4: *The optimal gamma values for indigo fabric image enhancement in the range of* [3.0, 5.0)

No	Gamma value	No. of images	Image ID (gamma value)
1	[3.0, 3.5)	2	K481013 (3.3), K531011 (3.0)
2	[3.5, 4.0)	2	K161013 (3.7), K691013 (3.6)
3	[4.0, 4.5)	2	K441013 (4.2), K471011 (4.0)
4	[4.5, 5.0)	0	-

(a) K242010   *(b) K261010*   *(c) K271020*

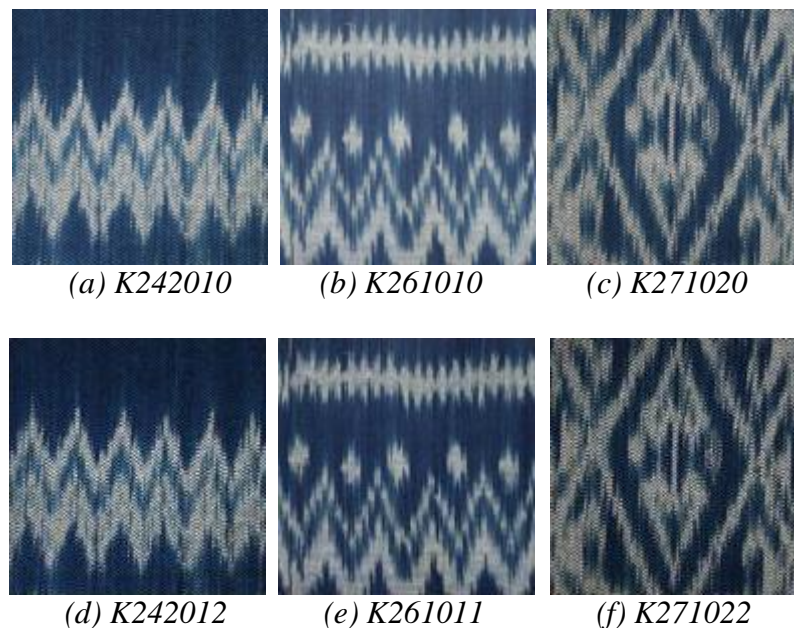*(d) K242012*   *(e) K261011*   *(f) K271022*

Figure 3: *Examples of images in the category of classic dull blue: (a)-(c) original images (before enhancement), (d)-(f) output images (after enhancement).*
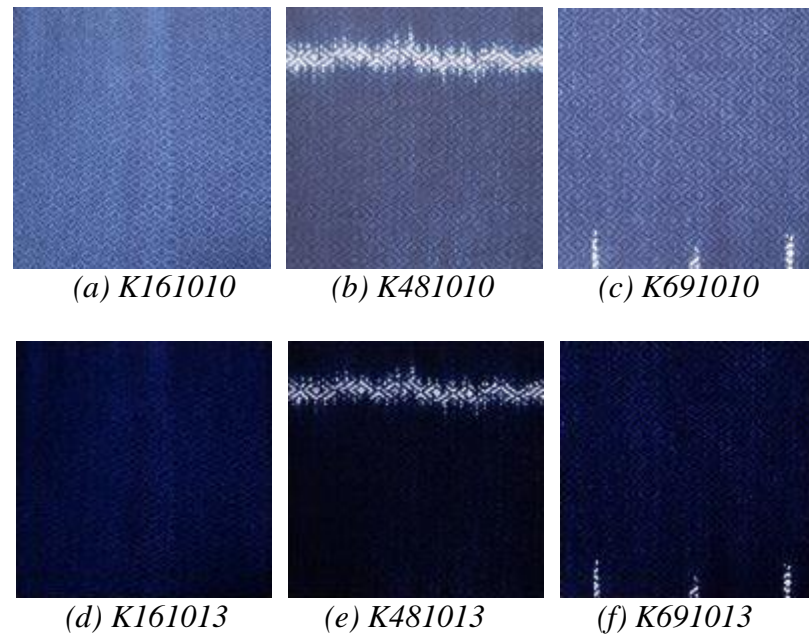
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(a) K161010	*(b) K481010*	*(c) K691010*
(d) K161013	*(e) K481013*	*(f) K691013*

Figure 4: *Examples of images in the category of dark blue: (a)-(c) original images (before enhancement), (d)-(f) output images (after enhancement).*
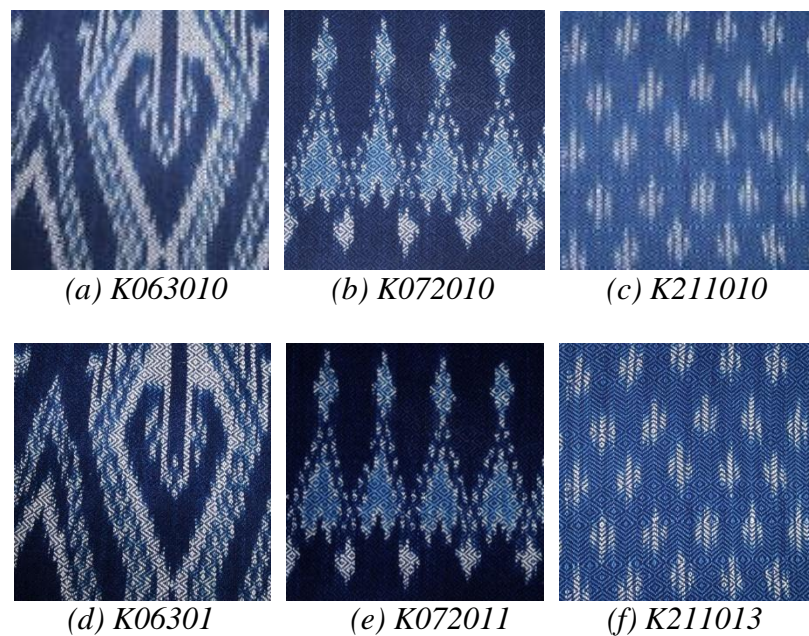

(a) K063010	*(b) K072010*	*(c) K211010*
(d) K06301	*(e) K072011*	*(f) K211013*

Figure 5: *Examples of images in the category of vivid blue: (a)-(c) original images (before enhancement), (d)-(f) output images (after enhancement).*

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5. Conclusions

In this paper, we had investigated variations of color display on computer screens compared with color of the real products. We had performed experiments on displaying of indigo fabric images. Eighty-five college students consisting of fifty female and thirty-five male participated in our experiments to test the similarity of color of indigo fabric images displayed on computer screens compared with the real fabrics. The participants had evaluated similarity of color of all test images against the real fabrics. In general, colors of all test indigo images on the computer screens were lighter than the true colors. In particular, the colors of dark blue tone of indigo fabric images had more deviation than others. According to statistical analysis, we found that the indigo fabric images can be classified into 3 categories in order to select the proper gamma values for improving color attribute to be similar to the real ones. The three categories are as follows: 1) classic dull blue, 2) vivid blue, and 3) dark blue. The proper gamma value ranges are [1, 1.5), [1.5, 3.0), and [3.0, 4.5) for the categories of classic dull blue, vivid blue, and dark blue respectively.

The image enhancement results showed that the power-law transformation can effectively alleviate the color deviation problem. It has high potential to be used as a technique for automatically eliminating e-color deviation problems in fabric image displaying in order to increase color accuracy viewed on the computer screen, and ultimately increase customer satisfaction and reliability on e-business related to textile products on the Internet.

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