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Journal of the Korean Society
of Clothing and Textiles
Vol. 27, No. 12 (2003) p.1381~1389

# Evaluation of Colour Difference Between Cotton Dyed Fabrics and Reflection Print Images Using CAD Systems

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# CAD 시스템을 이용한 면염직물과 스캐닝 프린트 이미지간의 색차 평가

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(2003. 2. 28. 접수)

## Abstract

컴퓨터와 첨단영상매체의 발달로 디자인 분야에서도 컴퓨터를 사용하여 색을 자유롭게 선택할 수 있는 그래픽 소프트 웨어가 도입되고 있으나 영상정보의 색채 재현성과 영상입출력 장치의 다양화로 인한 색채 불일치에 대한 문제들이 극복해야할 시급한 과제로 부각되고 있다. 따라서, 색채 영상정보 입출력 장치의 색채구현 성능과 인간의 색채 인지 원리이론을 바탕으로 색보정 알고리즘이 발전하여 색보정 엔진의 개발이 국제적으로 활발히 진행되고 있는 연구 분야임에도 불구하고 국내에서는 그 연구사례가 상대적으로 극히 미비한 실정이며, 더욱이, CAD 시스템을 이용한 패션/텍스타일 디자인 분야에서는 이에 대한 연구가 거의 이루어지지 않고 있다. 본 연구에서는 염색 직물의 색을 CAD시스템을 이용하여 soft-copy로 재현하고 이것을 다시 hard-copy로 출력하여 물리적 측정치와 주관적 색채 인지도간의 일치도를 비교하고, 물리적, 주관적 색차의 한계치를 제시함으로써, 패션/텍스타일 디자인 CAD 시스템 운용에 기초가 되는 자료를 제공하려 하였다. 연구의 절차는 객관적 측정과 주관적 평가 두 단계로 나누어 진행되었다. 연구에 사용된 직물은 7가지 색상의 면 염직물로써, CAD시스템을 이용하여 각 직물당 5개의 soft-copy를 재현하고, 이것을 다시 hard-copy로 출력하여 spectrophotometer를 이용해 물리적 측정($\Delta E$, $\Delta L$, $\Delta c$, $\Delta h$)을 실시하였다. 또한 주관적 평가에는 20명의 의류학 전공 학생들이 참여하였다. 결과 분석에는 분산분석과 Friedman분석이 사용되었다. 연구 결과 색차 측정에 대한 물리적 측정치와 1차 주관적 평가치 사이의 일치도는 90.5%로 나타났으며, 2차 주관적 평가치와의 rank order는 거의 일치하는 것으로 나타났다. 또한 주관적 평가에서 피험자들은 색차인지에 있어 CIELAB 색채공간의 각각의 색요소 차이보다는 전체 색차에 더 영향을 받는 것으로 나타났다.

***Key wards:*** Design CAD system, Colour reproduction, Colour measurement, Colour-difference perception, Agreement; 디자인 CAD 시스템, 색채재현성, 색채 측정, 색차인지, 일치도

## I. Introduction

There is a strong desire in fashion and textile industry for high colour-fidelity images reproduced using different imaging devices such as colour monitors, scanners and electronic printers. Particularly when fashion and textile designers create design using CAD system, self-luminous display image(soft copy) does not exactly match with reflection print image(hard copy). It is even more disappointing when the fabric isn't seen to match the original idea. The judgement of colour reproduction is highly subjective. Gardner(2000)has reviewed various types of colour reproduction based on colorimetry and has concluded that there is a need to predict changes in colour quantitatively so as to minimize observer dependencies. However, this is very difficult to achieve in practice for two reasons. First, there is a lack of understanding of the properties of human colour perception in the different viewing conditions used for original scenes and for different media, the latter often being very different from one another. Second, colour primaries and colouring technologies of devices used for colour reproduction are very different in different media. This is known as device dependency. Some researchers(Pointer & Arridge, 1998; Peter & Robert, 1997)have devised methods to calibrate imaging device primaries in terms of the CIE system(CIE, 1994). Hence a colorimetric match between colours presented on different media could be achieved. In colorimetric terms, colour matches are defined by multiple stimuli with identical tristimulus values. Since tristimulus values are a function of the interaction between a physical stimulus and the human visual system, it is necessary to consider two distinctly different types of colour matches, subjective and objective. Spectral colour matches, identified by physical stimuli with identical spectral radiant power distributions, are perceived as colour-matches by observers. Spectral colour-matches in colour reproduction are only possible when a single medium is used for both the original and the reproduction. Many literature references(Borbely, 2001; Cui, Luo & Rigg, 2001; Yebra, Garcia & Romero, 2001; Hawkyard, 1998; Lo, Luo & Rhodes, 1996)have supported the existence of subjective chromatic adaptation mechanisms when colour images are being viewed, which means that a hardcopy/softcopy image-matching model should account for both sensory and cognitive. Although the experiments(Kim & Um, 2001; Park & Kim, 1998; Luo & Gao, 1993; Zmura and Colantoni, 2001; Carreno & Fernando, 2001; Levkowitz, 2001; Field, 2001; Yebra, 2001; Melgosa, 2000)were carried out to quantify the colour-appearance with regard to computer aided colour matching in area such as graphic arts and desktop publishing, apparent evidence cannot be found of significant publications encompassing fashion/ textiles design CAD systems. Various sectors in fashion and textiles realize the importance of matching the created image and printed image, and also recognize that it is important that colour be expressed in numerical form in order for it to be measured and for colour formulas to be usable. Obviously, more experimental data is required to investigate relationships between subjective and objective evaluation of colour difference. This paper summarises experiments conducted to determine the objective and subjective difference threshold of colour difference evaluation using dyed fabrics and hardcopy images. And also it is revealed to identify the distortion occurring in colour perception in the process of fabric design to fabric scanning to printed images, especially when using the hardware normally used in educational institutions.

## II. Methodology

### 1. Experimental procedure

Two sets of preliminary experiments were conducted to obtain softcopies and hardcopies of assessing colour difference, and the viewing parameters to be included in the main set of experiments. Cotton dyed fabrics(100% cotton, plain weave, $57\times57/in^2$)of seven different colours were prepared to obtain softcopy images and hardcopies. The seven colours of fabric included red, magenta, blue, cyan, purple, salmon, yellow. The hardware used to obtain the softcopies were a Canon CLC-10 scanner, a digital 14" Mitac monitor. The hardcopy images were produced with a Mitsu G series(Model G370)printer. The fabrics were digitally scanned at a resolution of 300dpi. The reflection print images were generated from the scanned image data on the CAD system ENEAS. The first preliminary experiment was made by trained designers selecting up to five representations of the scanned colour on a monitor as in normal industry practice, thus total 35 reflection hardcopy images were obtained. The second preliminary experiment was designed to choose 3 printed copies closest to the original fabric. The main experimental set-up involved objective measurements and visual assessments.

## 2. Objective measurements

The original fabric samples and printed hardcopy images were objectively analysed on a reflectance spectrophotometer, Spectraflash 600(SF600). The spectrophotometer is an instrument that measures the amount of light that is reflected from a specimen at a number of wavelength in the visible spectrum in comparison to the amount reflected by a white standard that has been identically illuminated (McLaren, 1986).

Once the reflectance of a sample is known the colours can then be described in terms of their coordinates in a three-dimensional colour space. The coordinates are given numerical values so that other colours can be compared

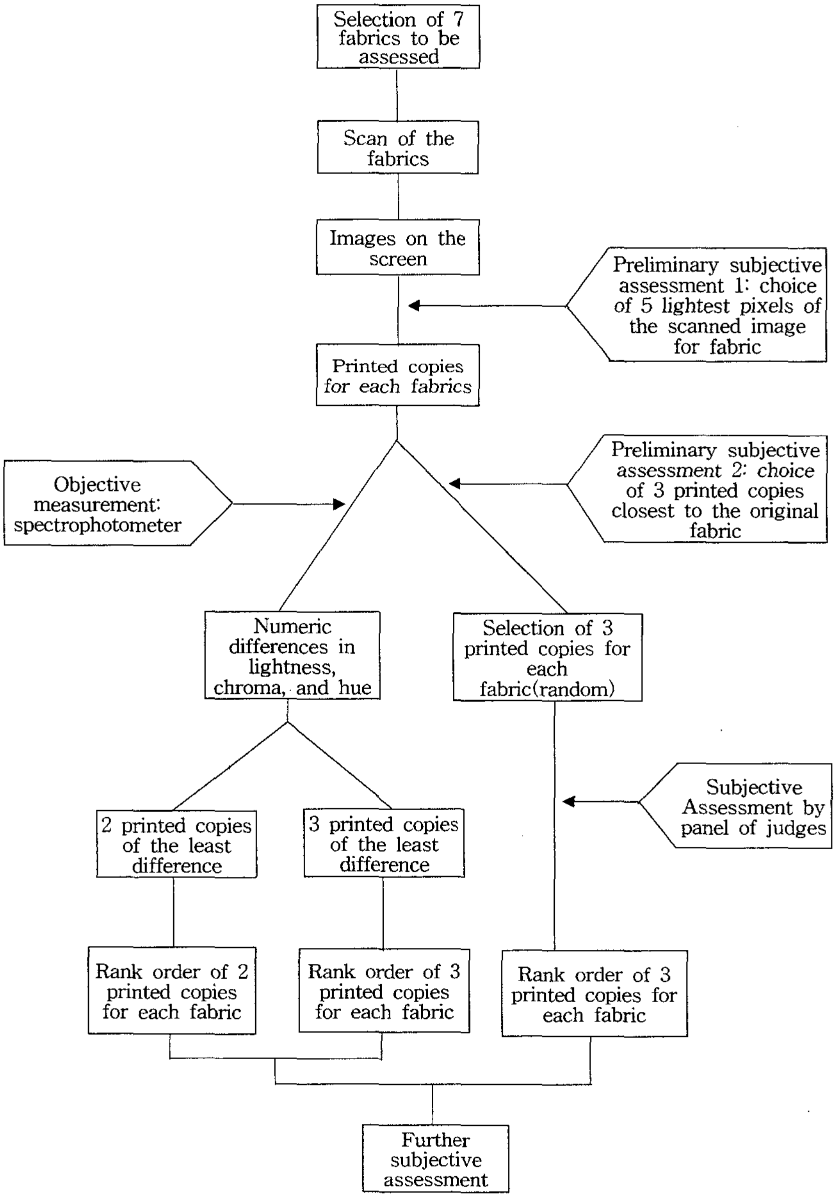

Fig. 1. Assessments Procedure

with them. Colour measurements from ten areas of the reflection hardcopy images were carried out randomly. As a result, in total 350 results of objective colour analysis were generated. It was anticipated that even though the spectrophotometer represents an accurate colour matching analysis, it is inevitable that there would still be some limitations in the comparison of two different materials. The variable properties which might affect the colour measuring are evenness of colour in the dyed fabric, moisture content of the fabric, and the type of weave. Non-uniform colour in printed paper and degree of luster are the main variables in the hardcopy images.

### 3. Subjective assessments

The first step of the subjective assessments was a pre-screening of the hardcopy images by researchers. Three samples from five reflection print images per colour were selected. Thus the main experimental set-up involved seven reference colours of dyed fabrics and 21 hardcopy images. For the main subjective assessment a panel of 20 students that were all senior in the dept. of fashion design & industry of university was used. These observers all had normal vision(CIE, 1994). The Veri Vide viewing cabinet, a viewing box specified in BS1006, was used to illuminate the hardcopy images and original reference colours. The viewing box contained lamps capable of producing the chromaticities of CIE Standard Illuminant D 65. Also, a uniform neutral-grey background with a luminance factor of 0.2 was used to encompass the white border for each reflection print image. This neutral-grey background was part of the adapting stimulus for each hardcopy image. For the illuminated reflection print uniform neutral background, a spectrally nonselective material(Munsell Value 5 neutral)with a luminance factor of 0.2 was chosen. Spectral nonselectivity ensured that the chromaticities of the grey background when illuminated in the center of the viewing box were the same as the reference white adapting stimulus. The binocular simultaneous matching(BSM) viewing technique is the most common method used practically. Each hardcopy image was viewed with both eyes and observers rapidly switched their adaptation when their binocular view changed from one hardcopy image to the other. The experiments were carried out in a darkened room. The outside of the colour matching box was completely masked by a black cloth. The hardcopy images were placed against a grey background with $L^*$ of approximately 50. This allows the observer's field of view to be field with the image and background without interference from other area. The physical sizes of each hardcopy image and reference fabric were the same(3cm×3cm). The simultaneous arrangement with two hardcopy images and a reference colour displayed side by side was used in this experiment. Each hardcopy image used had a white border, which was used as an anchor point(or reference white)for chromatic adaptation purposes. The experimental design was a classic paired comparison in which an ordinal judgement was made by the observers. An interval scale of the quality of the appearance match could be derived from these experiments based on the law of comparative judgments. each possible pair of images was viewed. With three images, there were 3 possible pairs[i.e., (n/2)(n-1)=3, where n=number of images]. Given images A-C, the possible pairs were AB, BC, AC. Observers viewed a pair of reflection print images and chose which one was a better match to the original fabric colour. The order of the pairs was randomized when presented to each observer. The Latin Square design was used as a design of experiment to eliminate the effect of order of the pairs. Each observer should made a choice between hardcopy image 1 and image 2 with the identity of these images only known to the experimenter. Observations were made and recorded for each image pair. Observers assessed the same pair twice. In total, 840 comparisons were made.

## III. Results and Discussion

### 1. Objective measurement

To measure the difference in colour between the original fabric samples and the printed images the CIE $L^*a^*b^*$(CIELAB) colour space was used. This is based upon CIE tristimulus values. CIE tristimulus values X, Y, Z are coordinates of colour perception. They are calculated by spectral multiplication and summation (integration) of the illuminant, object, and observer colour-match functions. In the CIELAB colour space $L^*$ indicates lightness and $a^*$ and $b^*$ are the chromaticity coordinates. The X, Y, Z colour system, which is transformed to CIELAB colour space, can then be used to interpret the measured colour using the three concepts of colour, L(lightness), C(chroma), H(hue).

Table 1 shows the difference in the lightness coordinate ($\Delta L$), the difference in the chroma coordinate($\Delta c$), and the difference in the hue angle ($\Delta h$) of the tested printed images compared with the original fabric samples under

**Table 1. Differences in overall colour(E), lightness(L), chroma(C) and hue(h) of hardcopy imagies obtained from the light source D65.(mean±standard deviation)**

| | | ΔE | ΔL | ΔC | Δh |
|---|---|---|---|---|---|
| Red | R1 | 30.77±0.16 | 5.01±0.03 | −28.93±0.19 | 9.26±0.16 |
| | R2 | 35.96±0.45 | 1.88±0.22 | −34.13±0.36 | 11.14±0.40 |
| | R3 | 31.55±0.33 | 4.67±0.11 | −29.73±0.30 | 9.49±0.29 |
| | R4 | 31.26±0.21 | 4.86±0.20 | −29.12±0.15 | 10.25±0.37 |
| | R5 | 36.95±0.59 | 2.80±0.22 | −35.39±0.52 | 10.41±0.47 |
| Magenta | M1 | 18.73±0.10 | 3.09±0.02 | −4.27±0.07 | 17.97±0.10 |
| | M2 | 18.31±0.08 | 2.86±0.03 | −4.02±0.13 | 17.63±0.11 |
| | M3 | 22.68±0.22 | 2.76±0.13 | −19.01±0.30 | 12.04±0.35 |
| | M4 | 19.05±0.12 | 1.83±0.09 | −8.69±0.15 | 16.85±0.09 |
| | M5 | 18.77±0.09 | 2.95±0.04 | −4.13±0.11 | 18.08±0.11 |
| Blue | B1 | 19.61±0.46 | −14.59±0.45 | −10.02±0.22 | 8.44±0.15 |
| | B2 | 24.62±0.35 | −19.32±0.36 | −10.09±0.34 | 11.45±0.15 |
| | B3 | 17.76±0.41 | −12.15±0.51 | −8.35±0.31 | 8.72±0.31 |
| | B4 | 22.74±0.27 | −19.34±0.38 | −4.67±0.10 | 11.00±0.26 |
| | B5 | 26.69±0.39 | −13.85±0.29 | −14.03±0.21 | 18.08±0.24 |
| Cyan | C1 | 32.47±0.29 | −20.78±0.54 | −8.73±0.22 | 23.37±0.14 |
| | C2 | 28.77±0.08 | −11.88±0.23 | −4.04±0.14 | 25.89±0.05 |
| | C3 | 27.65±0.19 | −11.85±0.19 | −0.77±0.22 | 24.97±0.13 |
| | C4 | 30.94±0.22 | −17.66±0.23 | −5.41±0.18 | 24.82±0.11 |
| | C5 | 35.02±0.07 | −25.98±0.34 | −9.24±0.31 | 27.09±0.16 |
| Purple | P1 | 12.81 0.35 | −10.69±0.40 | −0.36±0.02 | 7.02±0.03 |
| | P2 | 14.20 0.34 | −9.35±0.31 | −1.85±0.18 | 10.51±0.25 |
| | P3 | 11.84 0.27 | −7.21±0.22 | −8.11±0.08 | 4.73±0.23 |
| | P4 | 14.17 0.62 | −10.80±0.70 | −7.14±0.14 | 5.74±0.06 |
| | P5 | 16.94 0.53 | −14.73±0.46 | −10.22±0.21 | 15.63±0.26 |
| Salmon | S1 | 18.87 0.42 | −10.04±0.01 | −15.18±0.35 | 9.64±0.44 |
| | S2 | 19.92 0.23 | −10.42±0.32 | −9.31±0.24 | 17.42±0.03 |
| | S3 | 23.21 0.38 | −15.04±0.29 | −14.30±0.27 | 10.37±0.31 |
| | S4 | 27.47 0.35 | −17.47±0.31 | −19.01±0.23 | 9.37±0.56 |
| | S5 | 32.51 0.21 | −13.87±0.54 | −25.98±0.43 | 13.67±0.29 |
| Yellow | Y1 | 2.88 0.12 | −2.73±0.11 | −0.93±0.01 | 0.35±0.06 |
| | Y2 | 6.98 0.36 | −1.45±0.10 | −4.13±0.31 | 5.40±0.17 |
| | Y3 | 5.14 0.09 | −2.71±0.10 | −4.22±0.08 | 1.03±0.02 |
| | Y4 | 8.59 0.53 | −4.22±0.43 | −3.18±0.37 | 7.53±0.42 |
| | Y5 | 7.74 0.45 | −1.76±0.23 | −4.28±0.27 | 6.75±0.52 |

D65, stimulated daylight. ΔE is the numerical value given to the overall colour difference and is calculated as follows;

$$\Delta E^{*} =(\Delta L^{*2}\Delta c^{*2}\Delta h^{*2})^{1/2} \text{ or, } \Delta E^{*} =(\Delta L^{*2}\Delta a^{*2}\Delta b^{*2})^{1/2}$$

The smaller the E values, the nearer the samples were in colour to the originals. From Table 1 it is shown that yellow demonstrated the least change in overall colour difference, followed by purple and magenta. These are followed by blue, salmon while cyan and red demonstrated the most changes in overall colour difference. Analysis of the standard deviation between print samples of the same colour showed that magenta and cyan varied the least in overall colour difference, while purple and blue had the greatest variation in print0out copies. In all cases except yellow, the printed copy lost chroma, indicating that the colour of the original fabric was more vivid than the printed copy. This is perhaps due to the fact that the paper was not saturated densely enough with colour, so that the white background of the paper shone through. In all cases, the hue changed from fabric to printed copy but the greatest change was for cyan where a completely different hue from the original fabric sample was printed on paper. When the overall colour (ΔE) for each fabric was compared, R1>R4>R3>R2>R5 was the closest matching order for the original red fabric whilst M2>M1>M5>M4>M3, B1>B3>B4>B2>B5, C3>C2>C4>C1>C5, P3>P1>P4>P2>P5, S1> S2>S3>S4>S5, Y1>Y3>Y2>Y5>Y4 were the closest mat-ching order for the original magenta, blue, cyan, purple, salmon and yellow fabrics.

## 2. Comparison of results from the objective measurement and the preliminary subjective assessment

Table 2. printed copies selected as best matches to original fabrics

|  | From spectrophotometer |  |
|---|---|---|
| Red | R1 R3 R4 | B2<br>C1 |
| Magenta | M1 M1 M5 |  |
| Blue | B1 B4* B3 |  |
| Cyan | C3 C2 C4* |  |
| Purple | P3 P1 P2 |  |
| Salmon | S1 S2 S3 |  |
| Yellow | Y1 Y3 Y2 |  |

*The selection made by the spectrophotometer was not recognised by the panel of judges but replaced by the right column.

The selections of three printed copies judged by the preliminary subjective assessment to be the closest matches to the original fabrics were compared with the results from the spectrophotometer. Table 2 shows the closest copies identified by the spectrophotometer and the choices made by the researchers.

The researchers did not rank their selection of printed copies, and therefore the comparison was on the basis of which copies were selected. In the case of red, R1, R3 and R4 were selected correctly. Also, in the case of magenta, M1, M2 and M5 were selected correctly. In terms of blue, B1 and B3 were selected correctly but B2 was selected instead of B4. The difference between these two copies was insignificant, and hence the human perception of the printed colours may have been indifferent. In the case of cyan, C2 and C3 were selected correctly, but C1 was selected instead of C4. For purple, salmon, yellow all three selected printed copies were identical to the results from the spectrophotometer. Overall, in 90.5% of all cases the choice by researchers was identical to that of the spectrophotometer.

## 3. Comparison of results obtained from the objective measurement and the subjective assessment

The paired comparison results were analyzed using Friedman analysis(Friedman 1937; Hollander and Wolfe, 1973). The raw data were collected and a frequency matrix was constructed.

In Table 3, each number represents the frequency that the image represented by the row is judged to be a better match to the reference colour than the image represented by the column. For example, the value of red for row 1, column 2 is 36 which indicates that the image of row(R1) is judged 36 times out of 40(the total number of judgements) to be a better match than the sample of column(R3).

The first step in the Friedman analysis was to compute the rank sum for each sample. The rank sums were obtained by adding the sum of the row frequencies to twice the sum of the column frequencies. The results of rank sum are given in Table 4.

**Table 3. Frequency matrix of the samples**

| Red | R1 | R3 | R4 |
|---|---|---|---|
| R1 | – | 36 | 32 |
| R3 | 2 | – | 8 |
| R4 | 20 | 22 | – |
| Magenta | M1 | M2 | M5 |
| M1 | – | 30 | 25 |
| M2 | 10 | – | 12 |
| M5 | 20 | 23 | – |
| Blue | B1 | B2 | B3 |
| B1 | – | 38 | 2 |
| B2 | 0 | – | 0 |
| B3 | 31 | 49 | – |
| Cyan | C1 | C2 | C3 |
| C1 | – | 18 | 5 |
| C2 | 21 | – | 16 |
| C3 | 41 | 19 | – |
| Purple | P1 | P2 | P3 |
| P1 | – | 32 | 33 |
| P2 | 8 | – | 2 |
| P3 | 14 | 31 | – |
| Salmon | S1 | S2 | S3 |
| S1 | – | 22 | 39 |
| S2 | 12 | – | 36 |
| S3 | 7 | 4 | – |
| Yellow | Y1 | Y2 | Y3 |
| Y1 | – | 42 | 32 |
| Y2 | 2 | – | 24 |
| Y3 | 3 | 17 | – |

**Table 4. Rank sum of the samples**

| | | | |
|---|---|---|---|
| Red | R1 | R3 | R4 |
| | 112 | 126 | 122 |
| Magenta | M1 | M2 | M5 |
| | 115 | 128 | 117 |
| Blue | B1 | B2 | B3 |
| | 102 | 174 | 84 |
| Cyan | C1 | C2 | C3 |
| | 147 | 111 | 102 |
| Purple | P1 | P2 | P3 |
| | 105 | 136 | 115 |
| Salmon | S1 | S2 | S3 |
| | 99 | 100 | 161 |
| Yellow | Y1 | Y2 | Y3 |
| | 84 | 144 | 132 |

On identical scale, the HSD(Meilgaard et al., 1997) for comparing two rank sums looks like this;

$$HSD = q_{a,t,\infty}\sqrt{pt/4} = 3.31\sqrt{40(3)/4} = 18.13$$

where HSD=Tukey's honestly significant difference, p=the number of times the basic design is repeated, t=the number of treatments.

In the case of red, the difference between R1 and R3 was smaller than 18.13, ie there was no statistically significant difference between R1 and R3, and also between R3 and R4, R1 and R4.

Similarly in case of magenta, observers could not perceive a difference of colour among M1, M2 and M5 because the differences between M1 and M2, M2 and M5, and M1 and M5 respectively were smaller than 18.13. In the case of blue, B3 was significantly better matched to the reference colour and thus more desirable than the group formed by B1 or B2. In the case of cyan, C3 was significantly better matched than C1, and also there was no statistically significant difference between C2 and C3. In the case of purple, observers perceived that P1 was the closest sample to the reference colour, also subjects judged that P3 was significantly better matched than P2. In the case of salmon, S1 and S2 were significantly better matched than the original colour of fabric and thus more desirable than the group formed by S3. Namely, observers could not perceive a difference of colour between S1 and S2 because the differences were smaller than 18.13. In the case of yellow, subjects perceived that Y1 was the closest sample to the reference colour, also observers judged that Y2 and Y3 were not different significantly. Table 5 shows the rank order of printed copies being closer to the original fabrics.

**Table 5. Rank order**

| | Spectrophotometer | Panel of judges |
|---|---|---|
| Red | R1>R4>R3 | R1=R3=R4 |
| Magenta | M2>M1>M5 | M1=M2=M5 |
| Blue | B3>B1>B2 | B3>B1>B2 |
| Cyan | C3>C2>C1 | C3>C2=C1 |
| Purple | P3>P1>P2 | P1=P3>P2 |
| Salmon | S1>S2>S3 | S1=S2>S3 |
| Yellow | Y1>Y3>Y2 | Y1>Y3>Y2 |

As discussed above, of seven colour, B3, C2, C3, P1, P3, S1, S2 and Y1 are perceived to be significantly better matched by a panel of 20 judges. As also demonstrated by the results from the spectrophotometer, Y1 is the best matches and therefore most of the results are identical.

### 4. Comparison of results obtained from the objective measurement and the further subjective assessment

Further subjective assessment was made to ascertain which element of colour($\Delta L$, $\Delta c$ and $\Delta h$)is the main factor affecting colour assessment. The rank order of the results from further subjective assessment, however, exactly matched the results from the spectrophotometer. The further subjective assessment results indicate that colour perception of colour mainly depends upon overall colour difference($\Delta E$) rather than any individual factors such as $\Delta L$, $\Delta c$ or $\Delta h$.

## IV. Conclusion

The following conclusions were drawn from the experiments combining subjective assessment and objective measurement to ascertain quantitatively the distortion occurring in the process of fabric scanning to print-out.

The results obtained from the spectrophotometer demonstrated that all printed copies changed their hues in various degrees and lost their chroma and lost their lightness except red and magenta. When the results from the spectrophotometer and preliminary subjective assessment were compared it was shown that in 90.5% of cases the selection made by subjective assessment of printed copies having the closest matches to the original fabrics agree with the results obtained from the spectrophotometer. Comparing the rank order given by the panel of judges for the printed copies perceived as closest to the original fabrics to the results given by the spectrophotometer were in agreement. It was also found from further subjective assessment that the perception of colour by designers mainly depends upon overall colour differences rather than any individual factors such as lightness, chroma or hue. The above conclusions drawn from the combined objective measurement and subjective assessment suggest that the designers may be able to select the printed images showing the closest matches to the original fabrics if the correct selection procedures are used. There are, however, two major selecting procedures in which errors could occur. The first of these erroneous procedures is the selection of colour on the monitor. As it is entirely up to designers to select the lightest pixels, a wide range of errors can occur. Unfortunately, there is no objective method to measure the colour quantitatively in this very first step of selecting a colour image(soft image) on a monitor. Further research into the measurement of the soft image is thus required. The second erroneous procedure is when hardcovers are printed out. each printer is able to produce a certain number of colours which will vary according to the particular technology. Either the colour can be matched automatically by the computer to the particular printer, or the designer does it by means of a colour book which relates to the colours available. Different papers used to print hardcopies also have a dramatic effect on how colours are printed.

Colour management is the most problematic area when dealing with CAD in fashion/textile industries and educational institutions. Two strategies can be pursued to achieve more accurate colour matching using CAD systems; further research to identify the optimized combination of subjective assessment and objective measurement; and integrating the spectrophotometer and CIELAB colour assessment standard into CAD systems.

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