行政院國家科學委員會專題研究計畫 成果報告

不同色域壓縮模式對色彩影像於織物上色彩真實性影響之研究

研究成果報告(精簡版)

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計畫參與人員：助教-兼任助理人員：孫雪嘉

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行政院國家科學委員會補助專題研究計畫 ■ 成 果 報 告 □期中進度報告

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不同色域壓縮模式對色彩影像於織物上色彩真實性影響之研究

(The Effect of Various Color Gamut-mapping Models on the Color Fidelity of Color Images Printed on a Textile Fabric)

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摘要

隨著科技的發展，在數位印刷的領域上一直不斷的突破與進步，在印刷打樣上為了達到所見即所得的目標，通常使用到三個基本的色彩管理技術，那就是設備的從屬性質、色外觀、和色域對映，在以往打樣的研究在紙類上而非在布類上，本研究中以紙與布兩種媒材作為研究對象。本文說明將標準影像透過色彩校正處理，經由三種色域對映模式，裁切法、線性法、非線性法影像處理將之印製於相片紙與棉布上，同時測量影像與樣本之間的色差，最後使用心理物理實驗法分析打印之樣本，研究顯示布與紙兩者分別採用不同色域壓縮模式會有較佳的效果。

關鍵字：色彩校正、色域對映、色彩科學、數位印刷

ABSTRACT

With the development of the color science and technology in digital printing to reach the goal of what you see is what you get, three basic color management technologies in characterization of equipment, color appearance, and color gamut mapping were usually used. In the past the main printing researches were focus on paper material but not on textile. In this study, three kinds of color gamut mapping methods, cut, linear and nonlinear through the color correction, were used to process the standard images, and print them on paper and cotton substrates respectively. The difference between individual standard image and its output printed on one of the substrates tested was also estimated by measuring the color difference between the color samples randomly chosen on both original and out-put images respectively. Finally the category judgment method was used to analyze the color reproduction of the standard images printed in cross-medium. The results show that the factor of substrate has a significant effect on images processed using the gamut-mapping methods tested. The nonlinear one has the best performance in duplicating colors of standard images on the substrate of paper while the linear one the best on that of cotton fabric.

Keywords: color correction, gamut-mapping method, color science, digital printing

1.前言

近十年來，各種播媒體推陳出新地競相發展，使得影像與色彩在媒體之間之真實性更形重要。同時，色彩複製技術亦成為其中重要熱門之課題。“所見即所得”(What You See Is What You Get.", abbreviated as "WYSIWYG")**已成為國際上色彩相關產業所追求之目標。為達成此一目標，除了有好的電腦等硬體設備外，尚須要有精確的軟體功能，此重要的軟體功能即須要具備有一色外觀之預測功能。此功能可用以預測色樣本在不同光源條件下所呈現不同的色外觀。**

在色彩複製過程當中，需要針對影像做最佳的色彩校正，來重現原稿之色彩，為了達到 WYSIWYG 所見即所得的理想，通常需要經過三種色彩管理的核心技術，即設備的從屬性質、色外觀模式、以及色域對映模式。不同設備間色彩表現不一致的主要原因是跨範圍不同所導致的結果，另外，在色彩訊號的轉換上也是一項重要的因素，例如，一組 RGB 的彩色訊號經過掃描器、顯示裝置與印表機列印後，這三個階段所產生的顏色在視覺上均有著不同的表現，裝置與裝置之間也有不同的對映關係，因此，不同的媒體需要進行色彩修正以達成正確的色彩溝通。

Sara, (1984) 提出六項色域對映的方式：1、在 XYZ 色度空間中，找出和色域邊界距離最短的色彩，將之裁剪到色域邊界上。2、沿著明度軸中心點的力向作裁剪。3、沿著色相與明度不變的方向作裁剪，所以只有彩度發生改變。4、在色域對映中，定義出 26 個色點，透過這些色點和明度軸的連線，連接原始色點和色域壓縮後的色點。5、同 4，但改成朝著重心軸之壓縮方式。6、先對明度做線性壓縮，在對彩度作線性壓縮。另外成功的色彩複製，必須遵循以下的原則(依重要程度排列)。第一要有正確之色相。第二:要有正確之明度。第三:彩度與原稿須成正比。第四彩度與亮度須跟原稿接近。

Viggiano, (1992) 有以下七個色域對映的原則。1、原稿白點對映至複製品白點。2、原稿黑點對映至複製品黑點。3、進行一致性的壓縮模式。4、保持灰色平衡。5、色相保持不變。6、彩度表現儘量接近原稿。7、彩度與明度使用同一壓縮率。

呂雅雯 (2003) 研究中指出以 CARISMA 法使用的非線性之方式優於剪裁法，透過階調複製之非線性壓縮，接近輸出設備的色域範圍。

根據(Chen，2002)研究發現，3-DMA 色域對映法比 CARISMA 來的佳，然而在(闕家彬，2003)研究指出使用 3-DMA 色域對映法，以非線性壓縮法 NLM(Non-linear Compression)，配合複數集中壓縮方向(Multiple focal points)為最佳，次好的為線性壓縮法 LM(linear Compression)，配合複數集中壓縮方向(Multiple focal points)。

本研究擬以三種壓縮方式做為色域對映的方法，即複數集中壓縮方向配合使用裁切法 CM、線性壓縮法 LM、非線性壓縮法 NLM，來對影像做處理。

2.實驗

2-1 印材種類、性質

以下將印材分為紙與織品兩類。塗佈型的用紙主要使用於彩色印刷。不同比例的黏結劑、定著劑及其他添加物，將影響印墨的吸收速度、吸收容量、網點徑、網點形狀、印字濃度、色彩性、耐水性等。

表 1 噴墨印刷用紙特性

	特性			
分類	色濃度	印墨吸收性	網點徑	顆粒
A 非塗佈紙 吸收型（上膠）	○	極早	大	○
B 非塗佈紙 吸收型（無上膠）	△	極早	中	○
C 非塗佈紙 非吸收型（無上膠）	△	遲	小	△
D 非塗佈紙 非吸收型（微上膠）	△	極遲	小	×
E 塗佈紙	◎	早	中	○
F 塗佈紙	◎	稍遲	小~中	◎

紙有以下特性：1.物理性質(Physical Properties)：如基重、厚度、密度、透氣度、平滑度、油墨吸收性、尺守安定性、捲曲。2.強度性質

(Strength Properties)：如抗張強度、頂破強度、抗撕裂力、耐折力、剛挺度。3.光學性質(Optical Properties)：如白度、光澤度、不透明度、紙張顏色。4.化學性質(Chemical Properties)：如PH 值、紙張含水量與.相對濕度表面強度、上膠與抗水性。5.電子性質(Electrical Properties)：包括電子介質強度、紙張導電能力、紙張絕緣能力。6. 微觀性質 (Microscopical Properties)：如纖維長度、纖維結構。(鄭茂提，1998)

常見的織品有棉(Cotton)、尼隆、(Nylon)、 聚酯纖維 (PET)，棉、尼龍透過選定的墨水，可用無版印花的方式印之於表面上。聚酯纖維比其他任何纖維適合作熱昇華適合作熱昇華轉印，有下列特性：1. 聚酯纖維於熱昇華轉印有優越的顏色再現性。2.聚酯纖維的耐熱性好，熱轉印後不會損害薄層織物之特具物性(如手感、光澤)。(陳明和，1999)，本研究擬選出一種塗布紙與一種織品，做為未來實驗的被印材料。

2-2 心理學實驗法

以色彩科學來說，心理學實驗有兩種模式(Thurstone，1927)，以視覺的判斷方法來選出最好的複製結果。第一種模式為為喜好色的評比模式(Preference)，讓觀測者選出自己喜好的影像或顏色，這種方式的觀測者不一定要具有專業色彩知識即可進行實驗。第二種模式是正確色的評比模式(Accuracy)，觀測者根據正確性來選出最接近原稿的複製影像或色彩，此時觀測者就需要對色彩學有專業的知能，才能給予複製品較精準嚴刻的評估。

上述兩種方法，皆使用配對比較法 (Pair-Comparison Method) 。(Thurstone，1927)。觀測者需要以原始影像作為參考體，從兩張經過不同色域對映技術的複製品中，選出和原始影像擁有最接近的色外貌再現效果的複製影像。評選時，每個比對組是以隨機的方式取出，觀測者並不曉得評比的是哪兩種色域對映模式的影像。評選的結果，以數字紀錄下來。這些數據，經過平均值與標準差的計算之後，求得一指標 Z 值(z-score)，Z 值越高，表示該複製品具有較好的色彩再現品質。

2-3 觀測環境

在進行實驗時，Barco 螢幕以其內建的標準校正模式進行過校正，每次校正為 15 分鐘，每八個小時校正一次，在 sRGB 螢幕的白點，設定為 CIE 標準照明 D65 的色度，最大的亮度約 80 cd/m^2，觀測箱的設定亦為 6500K 之色溫，除了螢幕與對色箱之外，環境處於一昏暗的情況下。受測者約距離螢幕及對色箱約 37 公分，樣本分紙與棉布兩類，5 種模式各 8 張標準影像。紙張與棉布各 40 個樣本。

3.結果與討論

色差結果分析

表 2 平均色差分析表

種類	布				紙			
色差模式	L*a*b*	CMC	CIE94	CIE00	L*a*b*	CMC	CIE94	CIE00
膝型(K)	19	17	9	15	15	9	6	13
非線性(N)	17	15	9	13	10	6	4	8
線性(L)	18	16	9	14	11	7	5	9
裁切法(C)	16	11	6	11	15	10	6	12
未校色(O)	21	17	9	16	15	12	7	12

色差取四捨五入至整數位，由色差總體比較表可發現在紙張上之色差平均上比布來的小，然而在紙類上，非線性與線性與裁切法色差變動不大，在布類上的色差變動稍大，以未校色方面來說布類與紙類有明顯之差異，以 CIE 94 色差計算上為最小，其次是 CMC，然而在布類的 CMC 色差計算平均大於在紙類上的 CMC 色差計算。

心理學評比級數

實驗中有 8 張影像、5 種模式，紙與布兩類，共 80 張圖。實驗進行使用雙眼同時視覺法，對各種模式所產生的圖，隨機排列，與原圖做比對，實驗中一共有 15 位觀測者，每位觀測者實驗次數為兩次。
經由範疇比較法分析之後，將統計之數據加以計算成 Z 值，或是經由查表得出 Z 值，最後再轉成真值 Scale value，可以用來評估各個模式之表現。

紙類測試影像結果：

表 3 紙類總體 S 值、排名與評比級數

統計排名 / 模式	總和	平均	排名	評比級數
N	10.922	2.7305	1	1（極相似）
L	8.332	2.083	2	2（較相似）
C	6.002	1.5005	2	2（較相似）
K	5.112	1.278	4	3（相似）
O	3.512	0.878	5	4（較不相似）

邊界值分別為 0、0.942、1.436、2.264

由表 3 中可以得知使用非線性的色域對映模式有較高的 S 值，排名為第一，評比級數為 1 (極相似)，比其他模式有較好的色彩表現能力，在裁切法和膝部兩種模式有互相交集之部分，因此對於紙類上這兩種模式具有相似的色彩表現效果。

布類測試影像結果：

表 4 布類總體 S 值、排名與評比級數

統計排名 / 模式	總和	平均	排名	評比級數
N	4.926	1.2315	2	3（相似）
L	7.526	1.8815	1	2（較相似）
C	4.096	1.024	2	3（相似）
K	3.726	0.9315	4	4（較不相似）
O	3.446	0.8615	4	4（較不相似）

邊界值分別為 0、1.014、1.476、2.736

由表格 4 中可以得知使用線性的色域對映模式有較高的 S 值，排名為第一，評比級數為 2 (較相似)，比其他模式有較好的色彩表現能力，在裁切法和膝部和未校色三種模式上有互相交集之部分，因此對於布類上這三種模式具有相似的色彩表現效果。

4.結論

由本研究中可以歸類下列幾點結果：

在紙類上色域對映的效果符合期望，以非線性壓縮為最佳的色域對映模式，其次是線性壓縮法、最後是裁切法。

在過去研究以非線性的壓縮方法在紙類上整體 S 值和整體排名為最高，可以有較佳的色外貌表現能力，但在布類上卻不見得可以同樣適用。

以電腦繪圖影像來說，色彩對映技術對於複雜影像上的效果會來的明顯，水果圖即為電腦的繪圖影像，在紙類與布類中水果圖結果顯示非線性與裁切法兩者真值(S 值)很接近，表示兩者色外貌很相近。

紙張與棉布因為材質的不同，是否壓縮方法可以改善因為材質的變因所造成之視覺影響，有待後人改善壓縮之模式。

本研究所採用的乃是 CIE L*a*b* 色彩空間，然而新的色外貌模式也是影響的因素之一，未來如能加以考量為因素可使實驗具備完善。

對於壓縮點的取法如有新的演算法，可將更有效率的改善壓縮效能。

計畫成果自評

原計畫中擬採用色彩心理物理學之實驗法以及不同材料之基材對不同色域壓縮法之特性做進一步的分析與研究，以獲得不同色域壓縮法在跨媒材達成 WYSIWYG 目標之檢驗資料與跨媒材之色域資料。研究成果即如原計畫完全相符，而且也完全達成預期目標。諸此資料即可以作為建立色彩影像複製技術整合之基礎，進而有利於色彩產業電腦化技術之進一步相關性研究與發展，及有助於達成”所見即所得”國際上色彩相關業界所追求之目標，並提昇國內各色彩產業之競爭力。

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參與國際會議心得報告及發表之論文

心得報告：

本計畫主持人於 2009 年九月 7~9 日參加在日本 Ueda 舉行的第十屆亞太紡織會議(The 10th Asian Textile Conference ATC-10)並發表論文一篇。所發表之論文即利用本計畫所得成果爲基礎，推廣其多方面應用之一，即在於流行色彩影像與樣本印製與其趨勢分析之應用。與會各國學者在此方面均未有在此方面之相似文章發表，並獲得很多學者之關注、好奇與興趣，足見我國在此方面之研發成果至少居於亞太地區之領先地位，值得再加以鼓勵國內學者持續努力進一步的發展。

所發表之論文如次頁起所示：

Investigating the Application of Fashion Color Using a New Color Image Space

Wen-Guey Kuo[1] Yung-Pong Tsai [1] Shang-Ming Lin [2] Chi-Chu Hung[3] Hsuan-Yu Hung[3]

[1] Department of Textile Engineering, Chinese Culture University, Taipei, Taiwan, R.O.C.
[2] Department of Materials and Textiles, Oriental Institute of Technology, Taipei, Taiwan, R.O.C.
[3] Mei Cha Mei Finishing Co. Ltd., Taoyuan, Taiwan, R.O.C.

ABSTRACT Accumulating eight-year color images of fashion apparels as fundamental samples, this article is proposed to discuss the application of vogue colors, and the relativity between the apparel-color image presented and original one. Therefore, both color psychophysical and new color-image estimation methods were used in this research. The results show that the spring-summer (SS) fashion apparels do not have too sweeping change in their own hues between 2001 and 2008, but those color appearances are more brilliance. It means that SS fashion apparels have the lively characteristic. In addition, the Autumn-winter (AW) samples were not much difference from the SS ones in hue. Meanwhile, the former has lower brightness than the latter, giving the warm feeling. A phenomenon was found that some designers might design products according to their own subjectivity, resulting in not agreeing with the relative mutual recognitions of most consumers.

Keywords: color image space, color appearance, color psychophysical method, spring-summer clothes

INTRODUCTION

In recent three decades, a lot of efforts of working on colour were completed. But, all systematical studies on colour have just started for several centuries. Meanwhile, these studies were mostly concentrated on colour physics, colour product design, and colour psychology but colour image scales were conducted. In addition, it has become a more and more important and interested subject to integrate the humanities and science since the late of last century. Referring to the correspondence between colour and sound, Gombrich says in the last chapter of his book Art and Illusion[1]: "Can the world of the mind, of the dream, be explored by experiments that result in accepted conventions as was the world of the waking eye? Much of our assessment of twentieth-century art may depend on our answer to this question, for though not all, or even most, of it is concerned with synesthesia proper, all or most of it tries to represent the world of the mind where shapes and colours stand for feelings." Just as Kandinsky[2] proposed investigating the subject at the theoretical level, Gombrich suggested focusing attention on the structural relationships in the system rather than on the similarity of the elements, being his conviction that "the problem of synesthetic equivalences will cease to look embarrassingly arbitrary and subjective if … we fix our attention not on likeness of elements but on structural relationships within a scale or matrix"[1], and followed by Sebba[3] and Lee and Kuo[4]. Furthermore, Kobayashi[5] and Kuo[6] then focused on the relationship between colour and colour image. Meanwhile, it has become an important subject to integrate both humanities and science technology. A new color image space HRU with one kind of merit color image scales (WIP)[7] was derived using the psychophysical method, magnitude estimation method by Kuo, to overcome the shortcomings of the NCD such as the color image of common works could not be precisely quantified by the NCD, even incomprehensibly expressing the magnitude of the strength of a specific color image in comparing two colors. Meanwhile, the communication would be difficult between the CIEL*a*b* color space and the NCD. Therefore, the applications of the NCD would be limited. Therefore, an application of the new color image space to investigate the tendency of the fashion colors employed by designers was also described in this study. Also, the results of this study would be advantage to the application in the reproduction technology of color images.

The HRU New Color Image Space

The new color image scales WIP mentioned as above can be used to quantify the magnitude of three color-image factors for various colors. And, there are six elements (i.e. semantic differential pairs of words) having similar meaning

tendency with each other included in each of the three color image scales WIP as depicted in last study proposed by Kuo.[7] Therefore, the term of one element having the least mean variation in terms of the unit of correlation of variation (CV) within observers among the six ones contained in one specific color image scale W., I. or P. may be chosen and used to represent the term of one axis of the new color image space because this term would have the most synesthesia between color sensation and word expression of people. As a result, the elements Hard-Soft (having the mean coefficient of variation 25), Relaxed-Tense (27) and Ugly-Beautiful (26) were obtained and employed as the three polar axes of the new color image space HRU (abbreviated by means of the first letter of each element chosen). In the new color image space HRU, each color has three coordinates: Hard or Soft with the coordinate value －H or ＋H, Relaxed or Tense －R or ＋R, and Ugly or Beautiful －U or ＋U. The H axis represents the color image polar axis Hard-Soft, +H means that observers have softer color image for a specific color while -H harder; the R axis the Relaxed-Tense, +R tenser while -R more relaxed; the U axis the Ugly-Beautiful, +U more beautiful while –U uglier.

EXPERIMENTAL

Nine hundred and four color fashion images where each modal wore a fashion dress having single color were accumulated from the Spring-Summer (abbreviated as SS) and Autumn-Winter (abbreviated as AW) fashion shows helt in Milan within 2001 to 2008 repectively as the samples tested in this study. All colors of these fashion dresses were obtained on a professional monitor using a image-processing software Photoshop CS3 in CIEL*a*b* color coordinate unit. Then, three color-coodinate values L*, a* and b* of the fashion dress in each color image tested were further transfered into the corresponding color image-scale values H, R and U using the transformation equations derived by Kuo[8] below.

$$H = 1.3667\,L^* - 66.06 \quad (1)$$

$$R = (-6\times10^{-6})\,h^{*3} + 0.0044\,h^{*2} - 0.9383\,h^* + 41.05 \quad (2)$$

$$U = 0.424\,C^* - 9.9428, \quad (3)$$

where the symbols contained in these equations (1) to (3) indicate respectively: H, R and U the coordinate values of the three axes Hard-Soft, Relaxed-Tense and Ugly-Beautiful in the HRU color image space; L*, C* and h* the three color attributes of the CIEL*a*b* color space. Finally, those transfering results can be further used to analyze the tendency of the fashion colors used by designers.

RESULTS and DISCUSSIONS

The color fashion-address images accumulated were firstly analyzed in terms of three color coordinates L* a* b* of CIEL*a*b* color space. As shown in Table 1 analysis by the lightnesses of samples divided into three ranges of L* < 30, 30 <L*> 50 and L* > 50, the results indicate that the lightnesses of fashion colors used for AW vogues within 2001and 2008 by the designers in Milan were distributed into two main parts of L* < 30 and L* > 50 that may emphasize on both important image meanings of warmness and energy while for SS vogues L* > 50 on liveliness. In addition, Figs. 1 and 2 show that most fashion colors for AW and SS vogues within 2001and 2008 in Milan have the same tendency. That is, all thsee fashion colors used by designers have not much change in hue, principally located within red, pink and orange ranges with the exception of grey series, strictly speaking, those color ranges are belong to the same hue series.

According to the analysis results in terms of the new color image space HRU, ploting the color-image coordinate values of the AW and SS vogue samples onto the RU color-image coordinate diagram as shown on the Figs. 3 and 4 respectively, it can be found that for AW vogue samples, people would have the feeling of relaxed but little ugly as well as hard responses while free and plain as well as soft for SS ones.

CONCLUSIONS

In this study, totally nine hundred and four color fashion images about fashion dresses having single color were accumulated from SS and AW fashion shows helt in Milan from 2001 to 2008 repectively as the samples to examine their color images using a new color image space. Thes results can be concluded as follows: AW vogues within 2001and 2008 by the designers in Milan were distributed into two main parts of L* < 30 and L* > 50 that may emphasize on both important image meanings of warmness and energy while for SS vogues L* > 50 on liveliness. Strictly speaking, all thsee fashion colors used by designers have not much change in hue. Finally, AW vogue samples give people the feeling of relaxed but little ugly as well as hard responses while SS ones free and plain as well as soft.

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Table 1. Analysis on the lightnesses of vogues within 2001and 2008 by the designers in Milan tested.

L* : Lightness; AW: Autumn-Winter;Spring-Summer

L* Range	L*<30	30<L*<50	L*>50
AW	40.48%	21.66%	37.86%
SS	23.97%	18.80%	57.23%

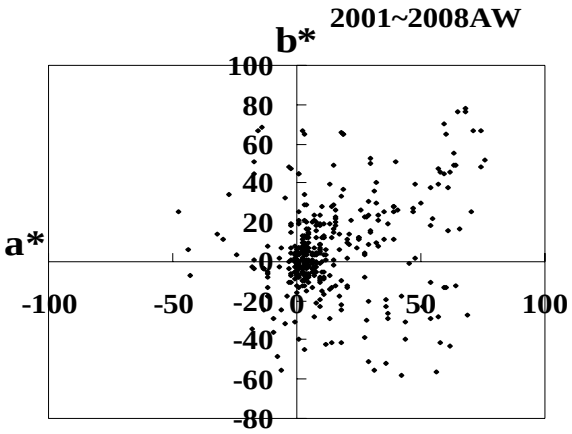

Fig. 1. AW vogue samples within 2001and 2008 in Milan are ploted on the CIEa*b* chromaticity diagram.

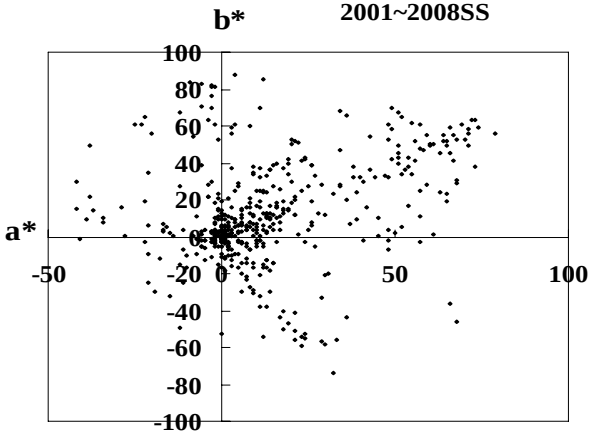

Fig. 2. SS vogue samples within 2001and 2008 in Milan are ploted on the CIEa*b* chromaticity diagram.

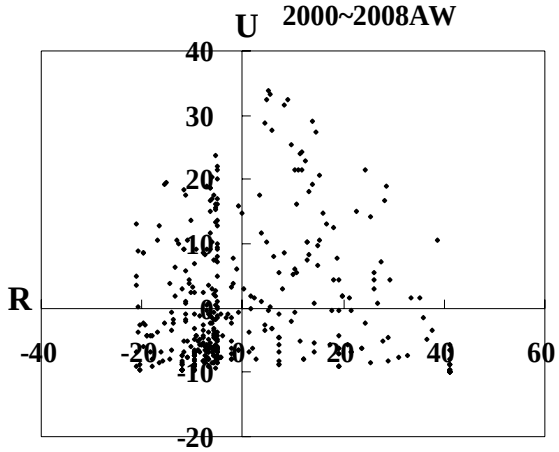

Fig. 3. AW vogue samples within 2001and 2008 in Milan are ploted on the RU color-image coodinate diagram.

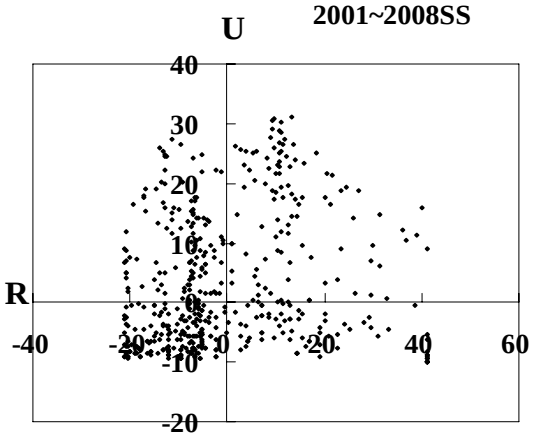

Fig. 4. SS vogue samples within 2001and 2008 in Milan are ploted on the RU color-image coodinate diagram.