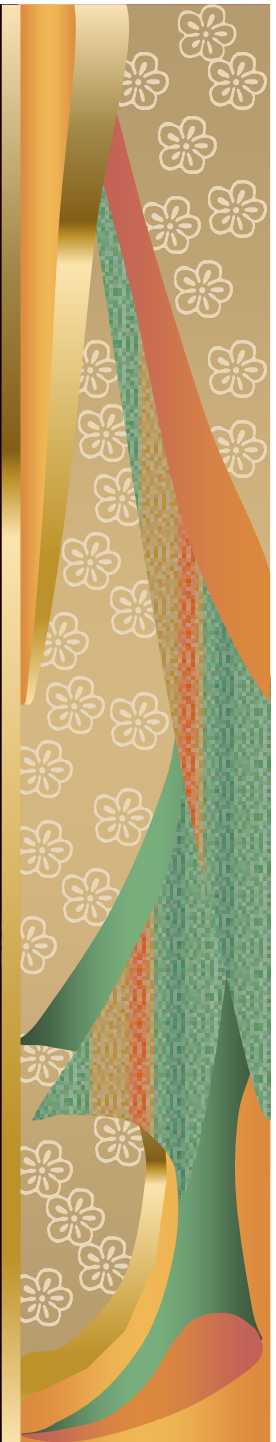


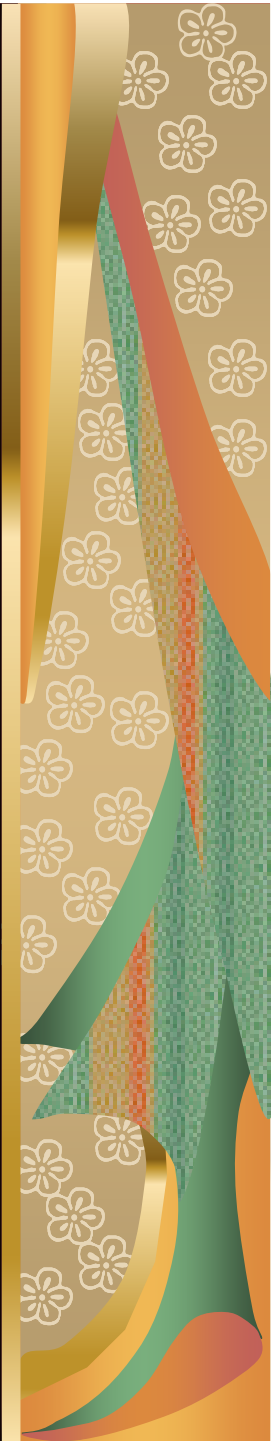
數位相機色彩管理

工業技術研究院 影像顯示科技中心
胡國瑞



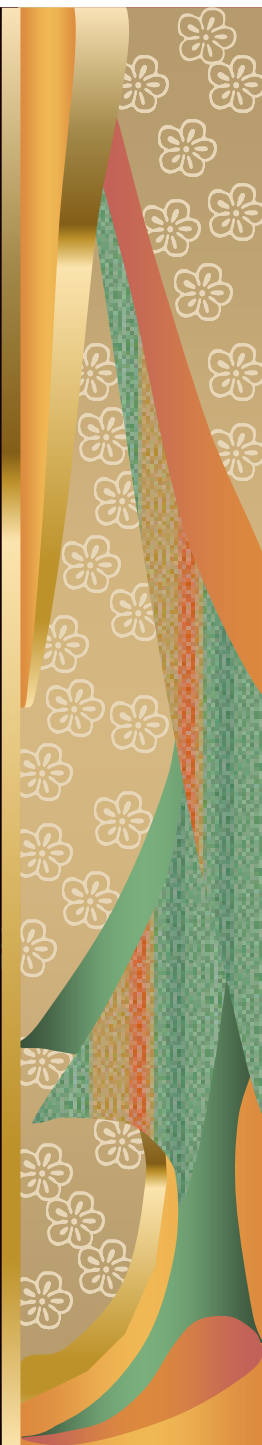
Outline

- 數位相機的基本架構
- 數位相機色彩校正基本模式
- 測試標準
- 數位相機色彩品質的評估法
- 結果與討論



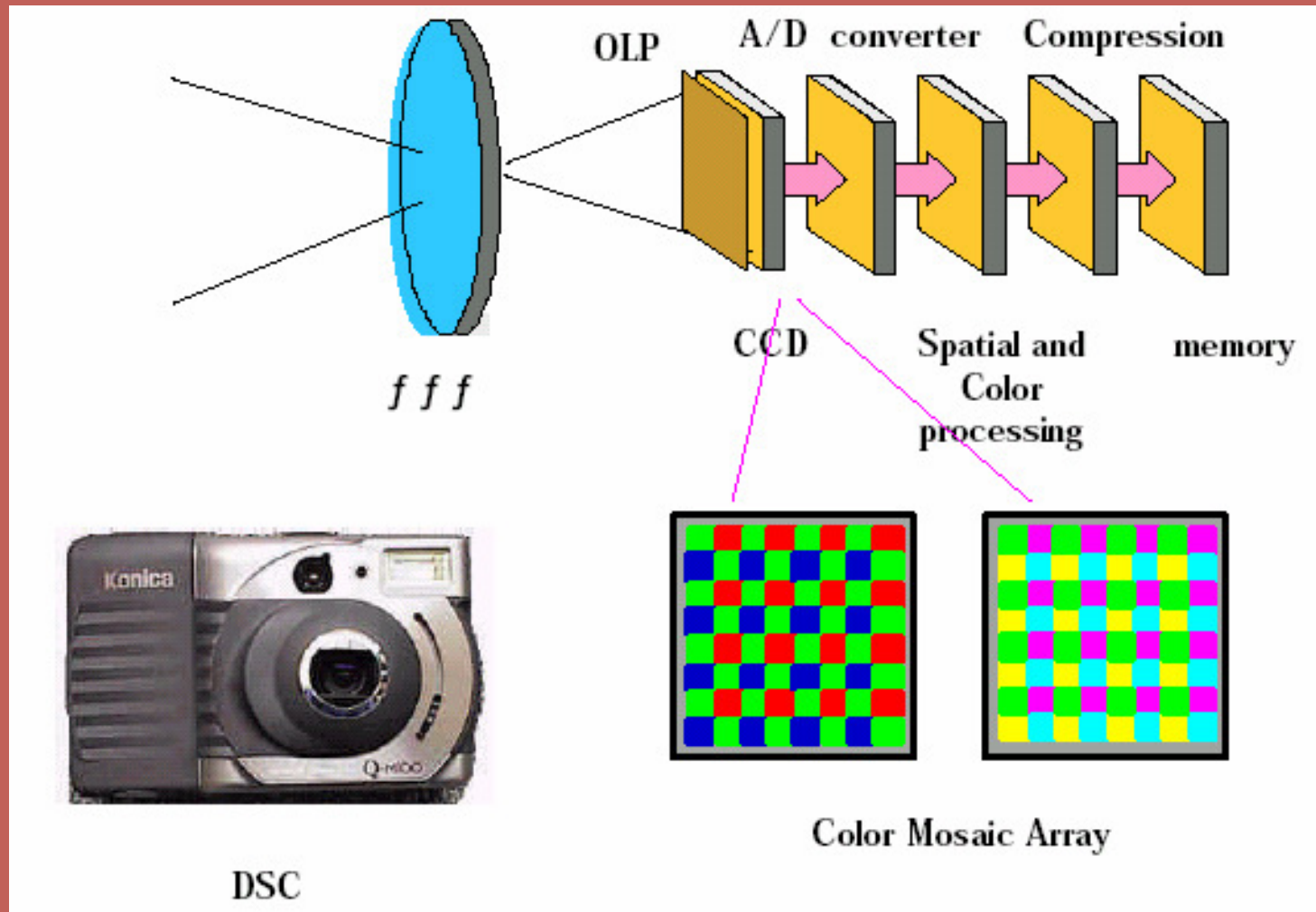
Outline

- 數位相機的基本架構
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數位相機的基本架構

Digital Still Camera



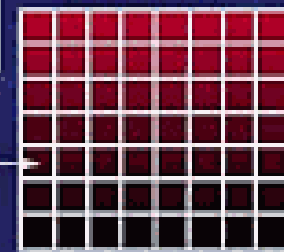
Sensor

- CCD

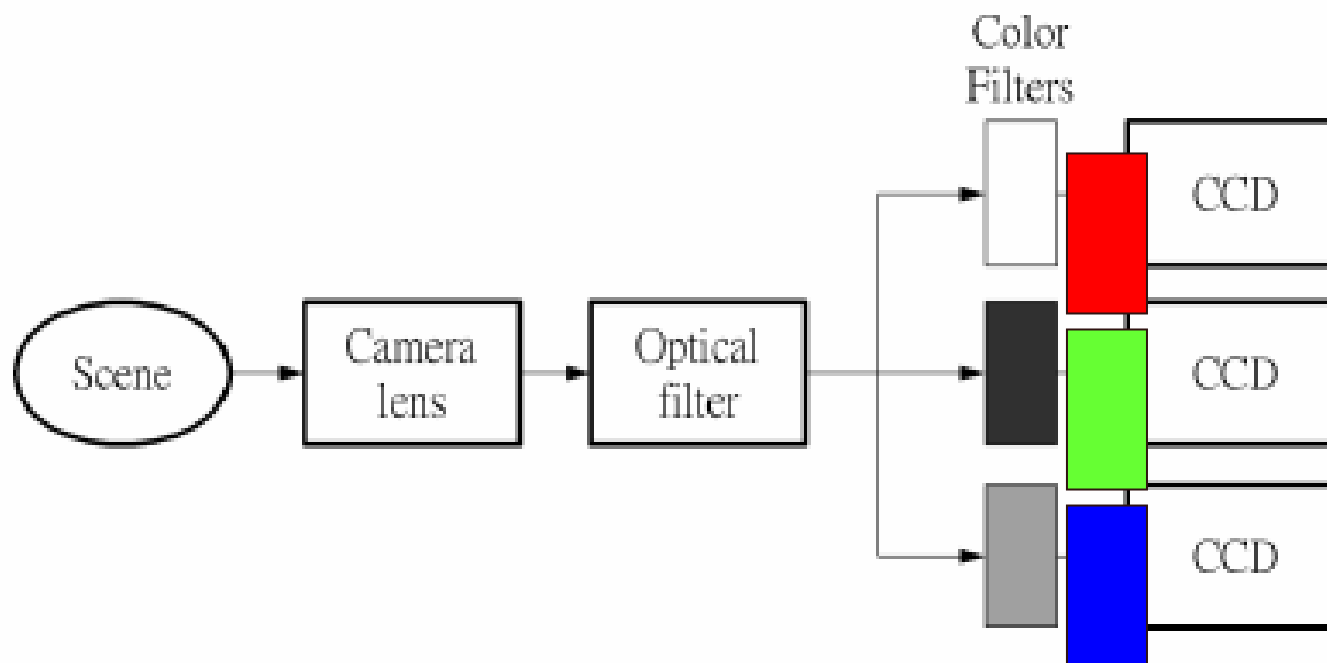
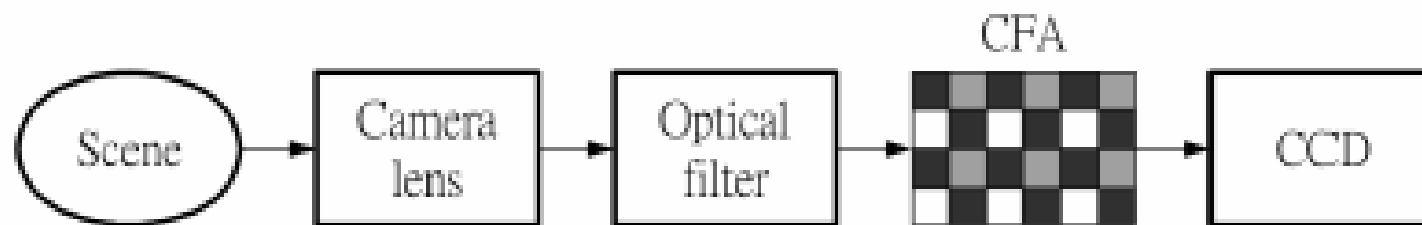
Linear Array CCD



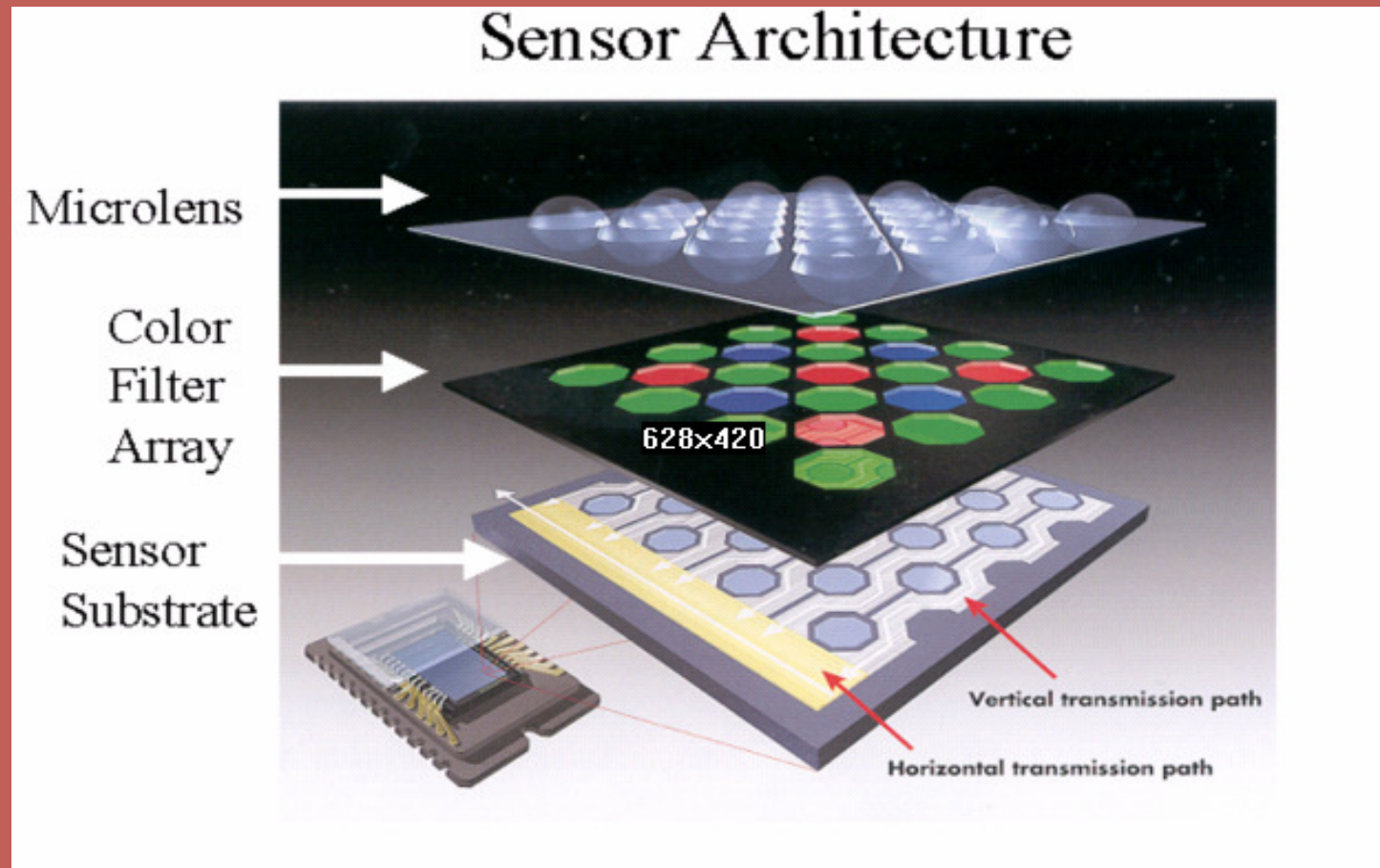
Area Array Image Sensor



Sensor

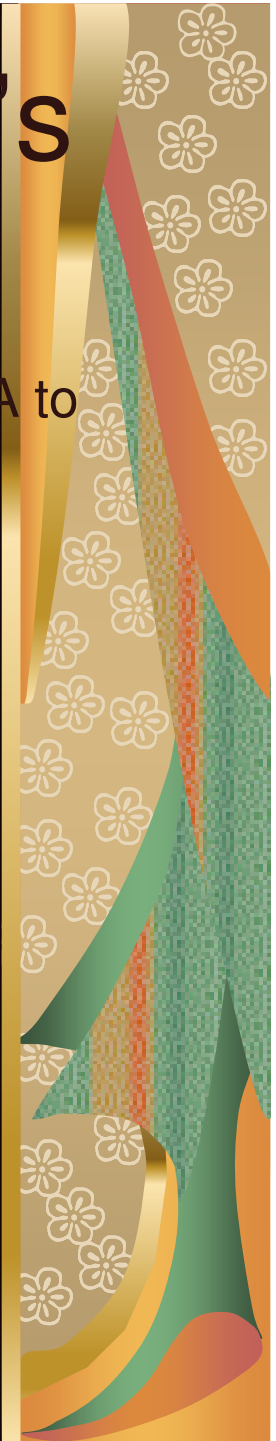


Demosaicing Algorithms for Digital Cameras

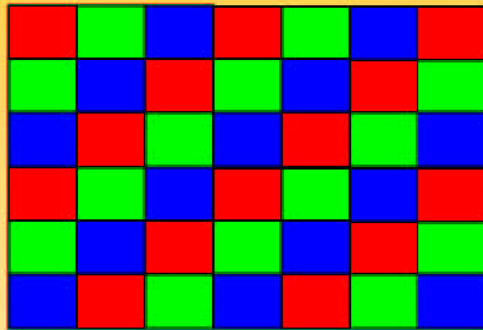


Why Use Color Filter Arrays

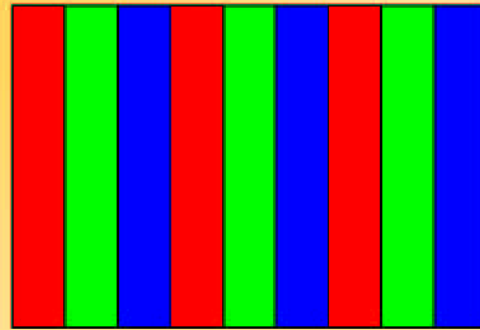
- Because the CCD is not spectrally sensitive, we need the CFA to create a full color image.
- Cut down the cost of the “single chip” digital camera.
 - Sensors are 10 - 25% of the total digital camera cost



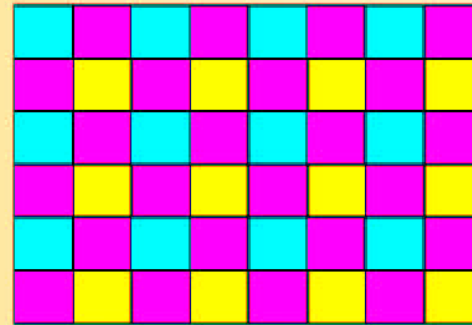
Color Filter Array



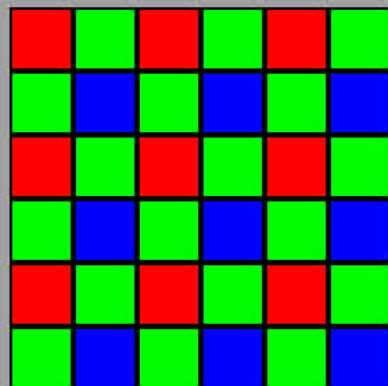
R-G-B Staggered CFA



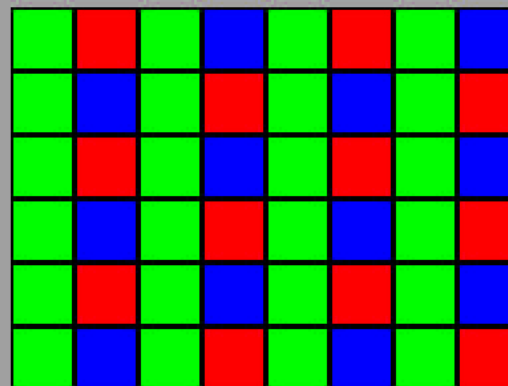
SONY Mavica CFA



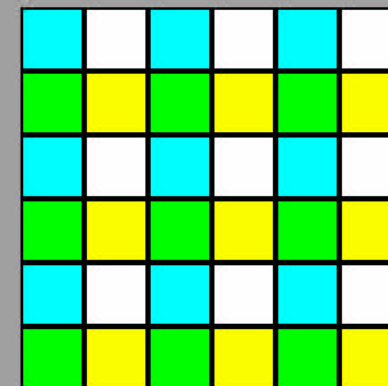
Subtractive CFA



Bayer/Kodak



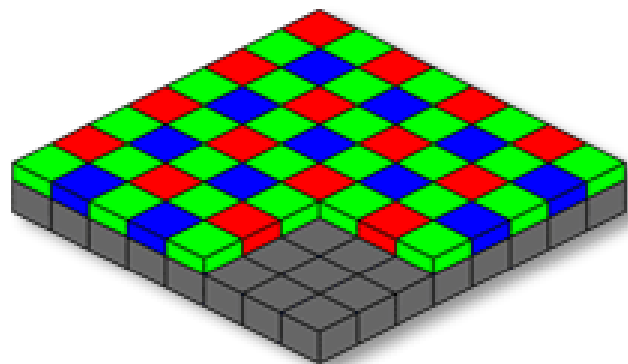
"New" SONY



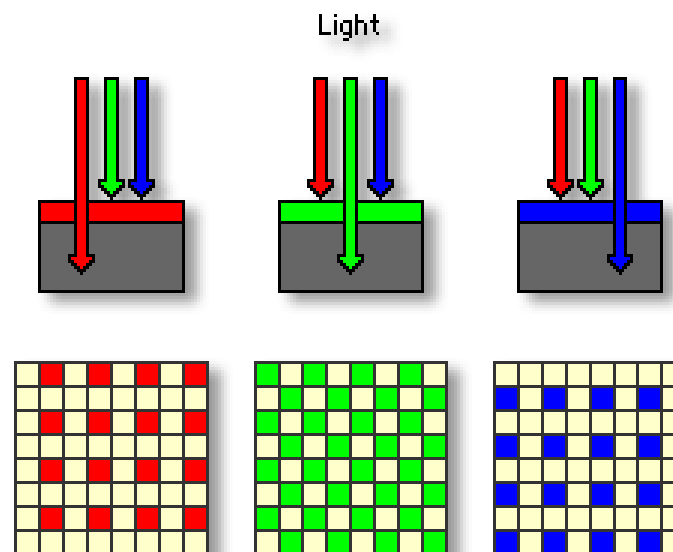
Hitachi

巴杉昌理員務工作切

Color Filter Array

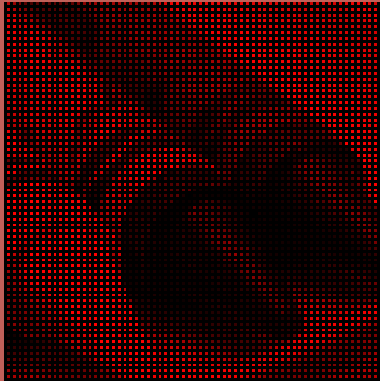


Color Filter Array Sensor



© 2003 Vincent Bockaert 123di.com

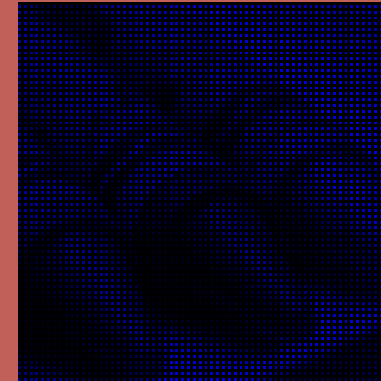
Color Filter Array



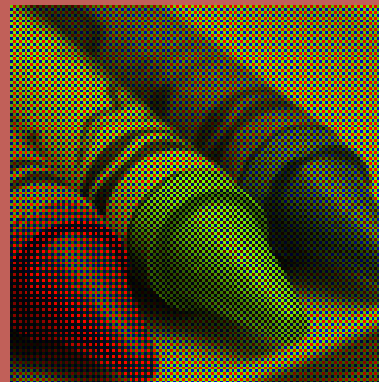
Red channel pixels
(25% of the pixels)



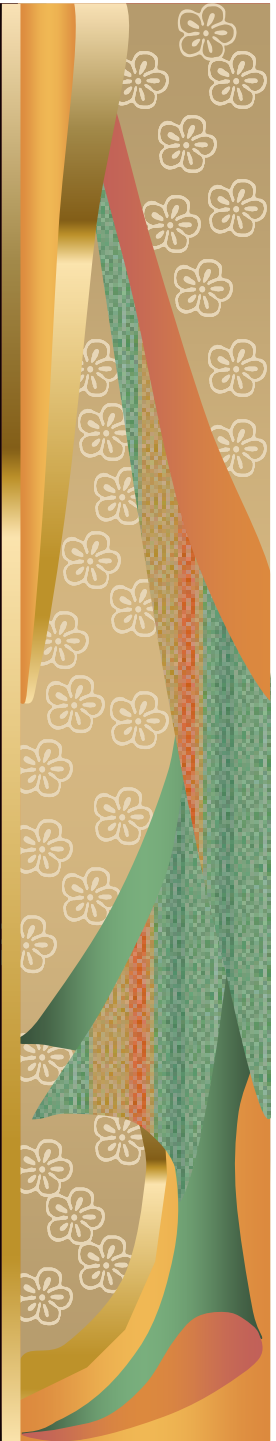
Green channel pixels
(50% of the pixels)



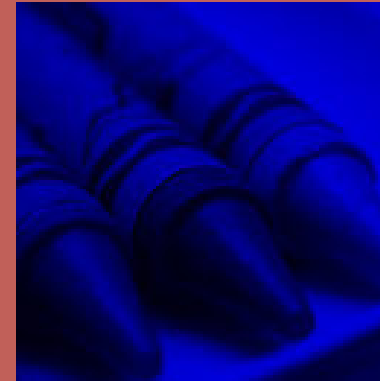
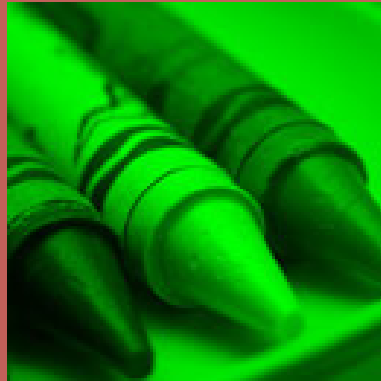
Blue channel pixels
(25% of the pixels)



Combined image

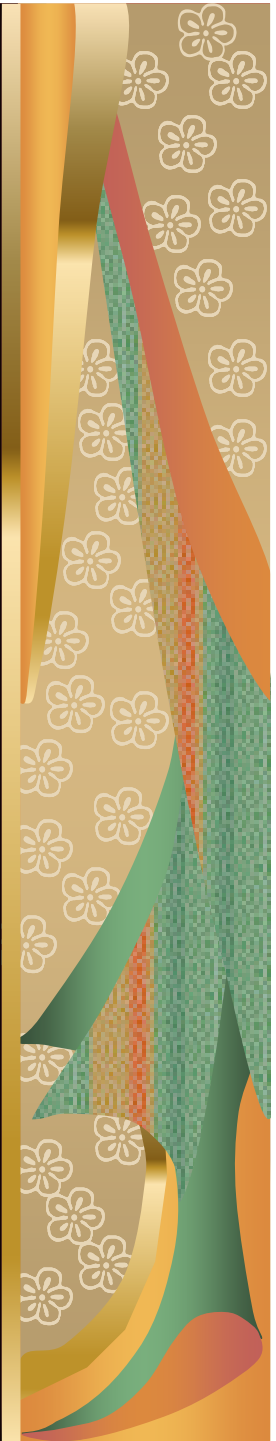


Color Filter Array



Combined image

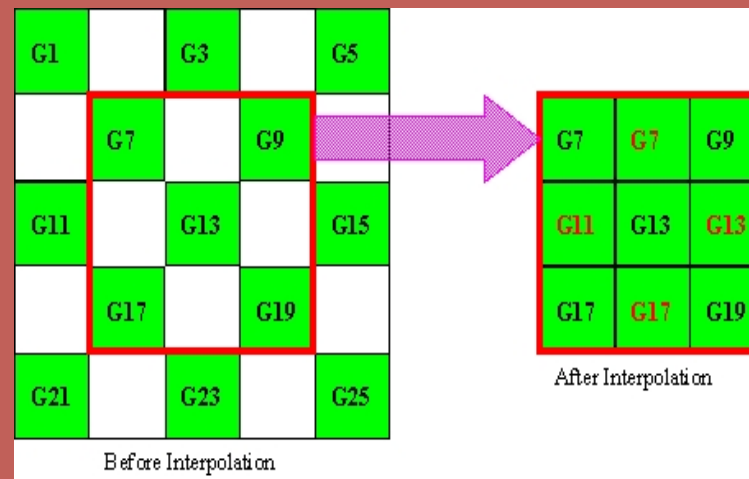
色彩管理實務工作坊



Non-Adaptive Algorithm

Nearest Neighbor Replication

- each interpolated output pixel is assigned the value of the nearest pixel in the input image. The nearest neighbor can be any one of the upper, lower, left and right pixels



Bilinear Interpolation

❏ Interpolation of **green** pixels : the average of the upper, lower, left and right pixel values is assigned as the G value of the interpolated pixel. For example : $G8 = (G3+G7+G9+G13) / 4$

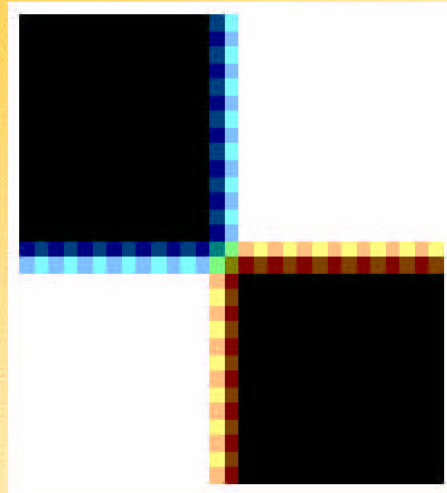
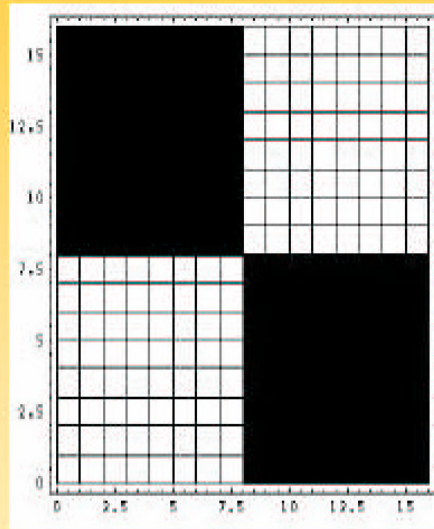
❏ Interpolation of **red/blue** pixels :

❏ Interpolation of a **red/blue** pixel at a **green** position : the average of two adjacent pixel values in corresponding color is assigned to the interpolated pixel. For example : $B7 = (B6+B8) / 2$; $R7 = (R2+R12) / 2$

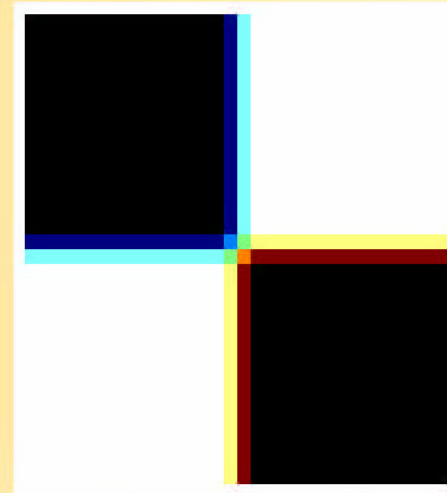
❏ Interpolation of a **red/blue** pixel at a **blue/red** position : the average of four adjacent diagonal pixel values is assigned to the interpolated pixel. For example : $R8 = (R2+R4+R12+R14) / 4$; $B12 = (B6+B8+B16+B18) / 4$

G1	R2	G3	R4	G5
B6	G7	B8	G9	B10
G11	R12	G13	R14	G15
B16	G17	B18	G19	B20
G21	R22	G23	R24	G25

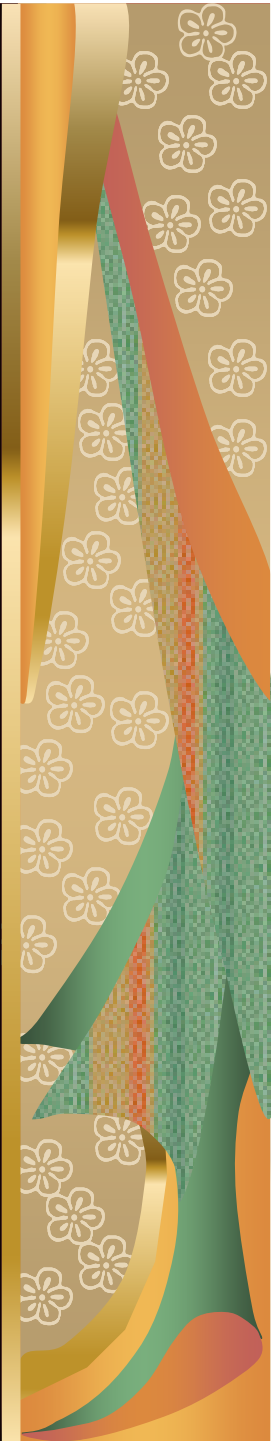
Interpolation



Simple Interpolation



Logical Interpolation



Edge Sensing Interpolation Algorithm

Interpolation of green pixels :

- First, define two gradients, one in horizontal direction, the other in vertical direction, for each blue/red position. For instance, consider B8 : define two gradients as following where $| \cdot |$ denotes absolute value

The algorithm then can be described as follows :

$$\Delta H = |G7 - G9| \text{ and } \Delta V = |G3 - G13|$$

If $\Delta H < T$ AND $\Delta V > T$,

$$G8 = (G7 + G9) / 2;$$

Else if $\Delta H > T$ AND $\Delta V < T$,

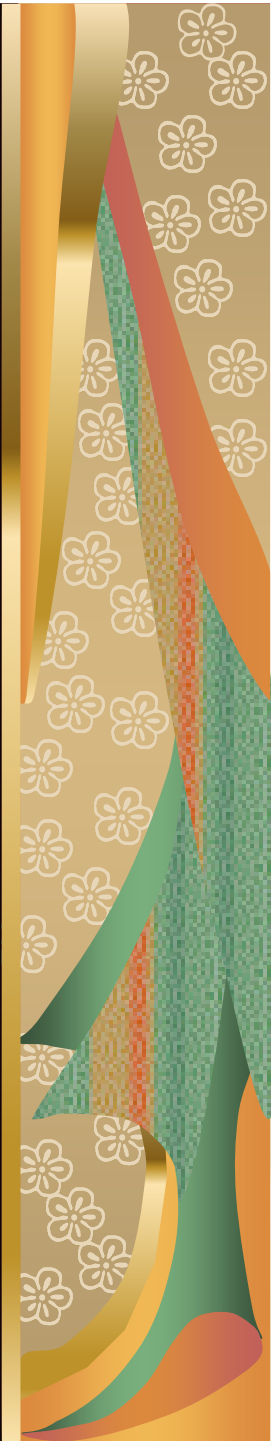
$$G8 = (G3 + G13) / 2;$$

Else

$$G8 = (G3 + G7 + G9 + G13) / 4$$

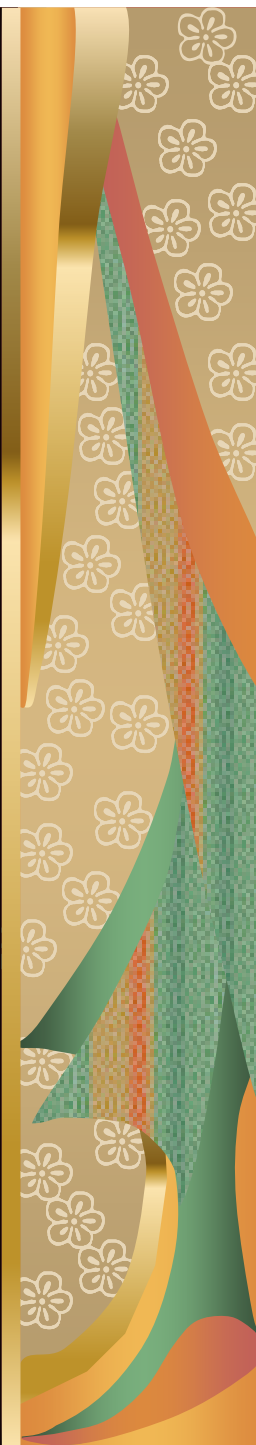
End

Interpolation of red/blue pixels : same as in Smooth hue transition interpolation in logarithmic exposure space.

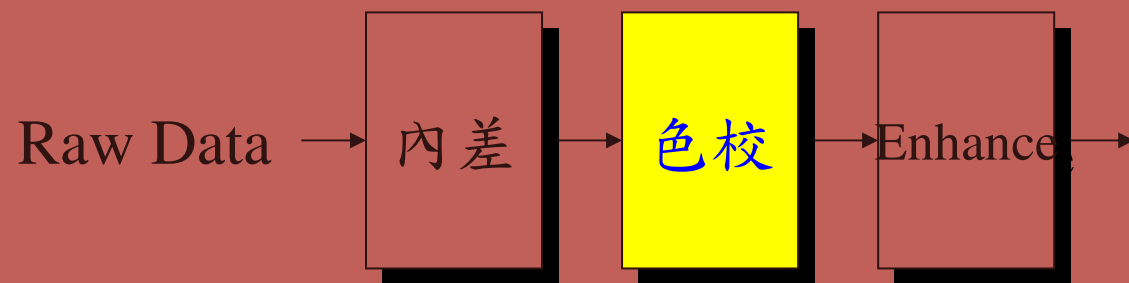


Outline

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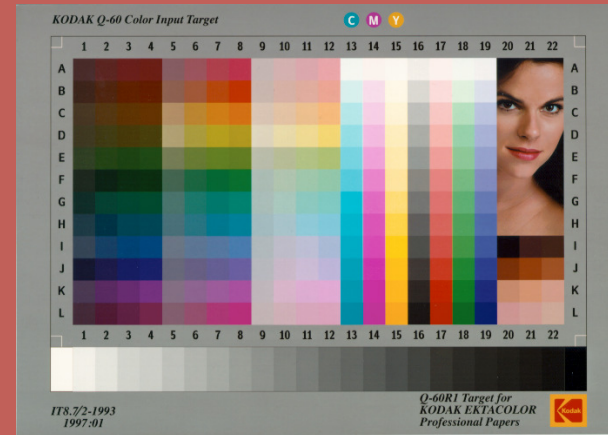
數位相機色彩校正基本模式



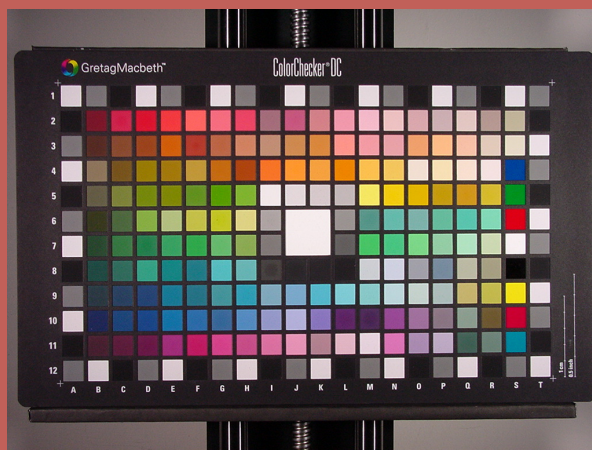
常用校正用色稿



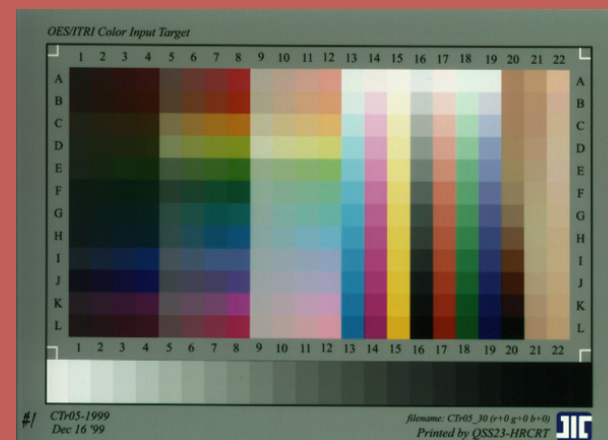
Macbeth Color Checker



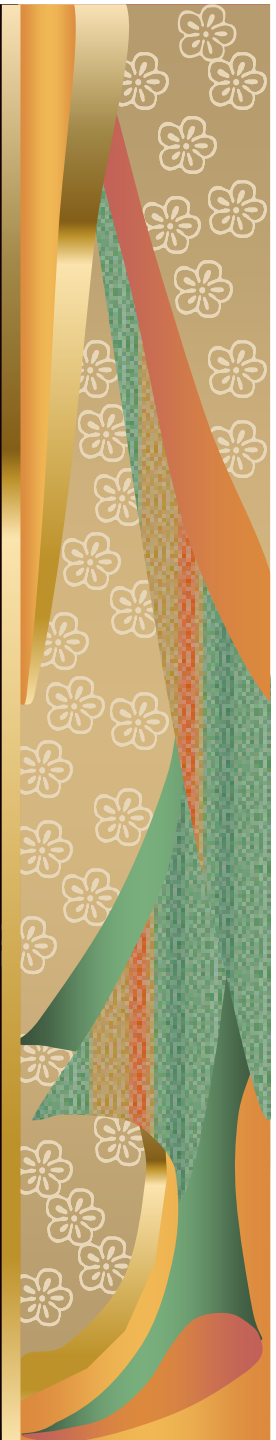
IT8 by Kodak



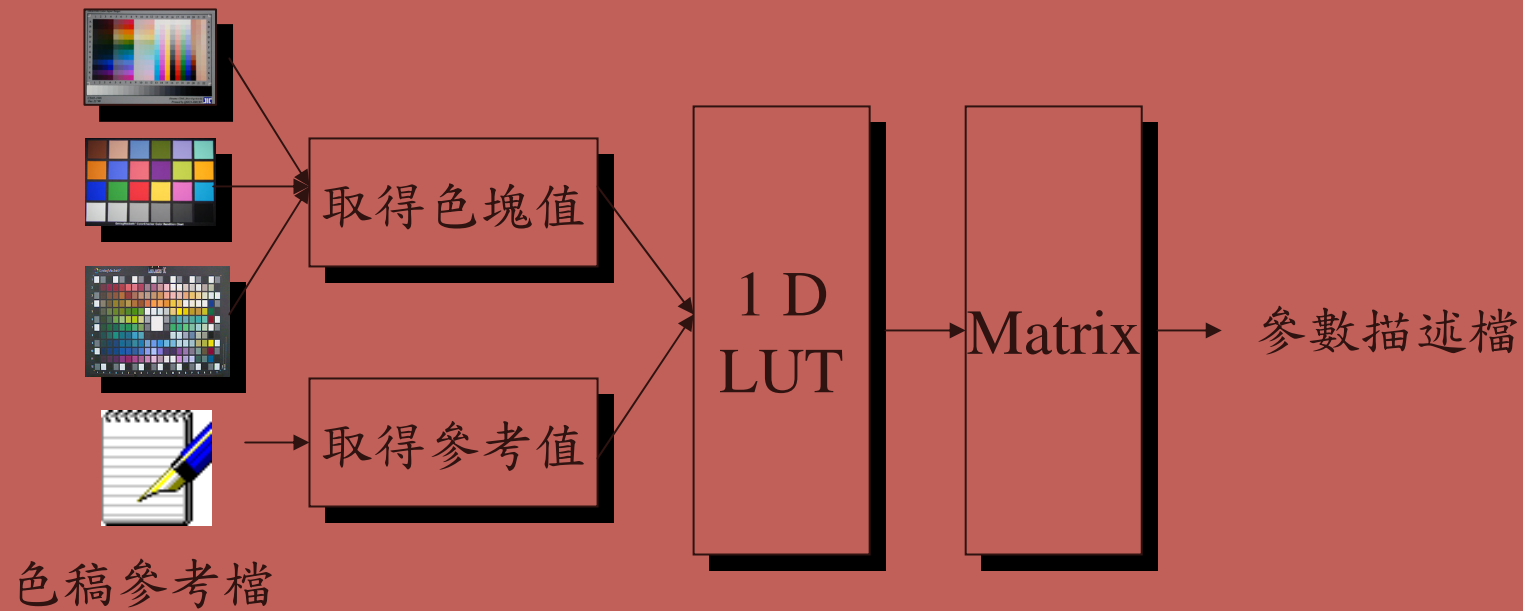
Macbeth Color CheckerDC



IT8.2 by ITRI

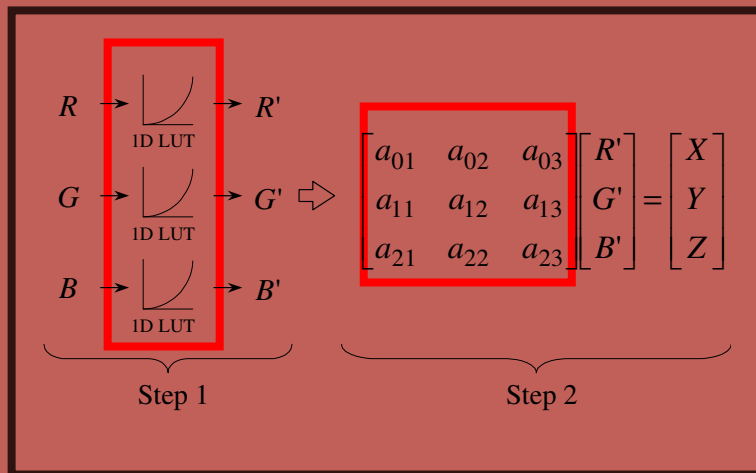


數位相機色彩校正基本模式

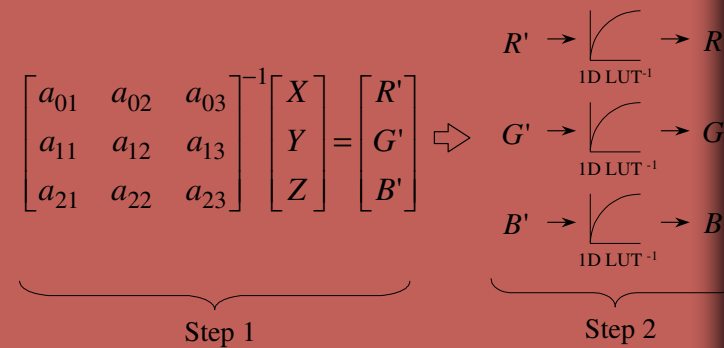


數位相機色彩校正基本模式

產生色校參數

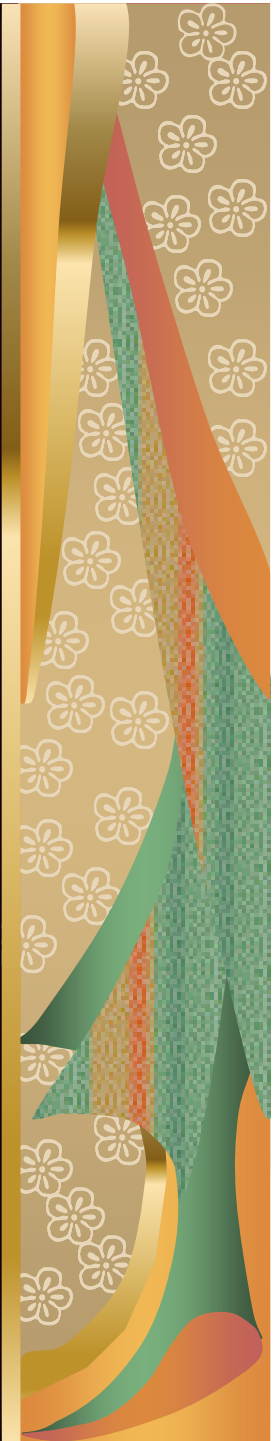
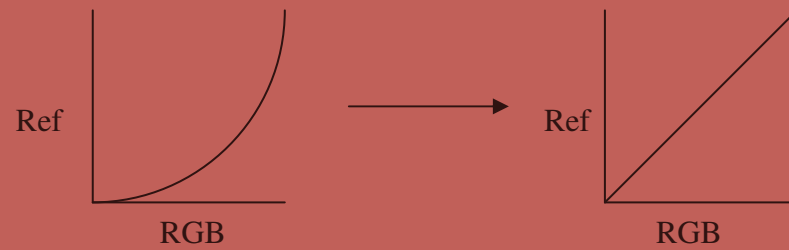


Forward Modal



Backward Modal

數位相機色彩校正基本模式



數位相機色彩校正基本模式

轉換矩陣

$$3 \times 3 \quad [X, Y, Z]^T = [M_{3 \times 3}] \times [R, G, B]^T$$

$$3 \times 4 \quad [X, Y, Z]^T = [M_{3 \times 4}] \times [1, R, G, B]^T$$

$$3 \times 6 \quad [X, Y, Z]^T = [M_{3 \times 6}] \times [R, G, B, RG, GB, RG]^T$$

$$3 \times 8 \quad [X, Y, Z]^T = [M_{3 \times 8}] \times [1, R, G, B, RG, GB, RG, RGB]^T$$

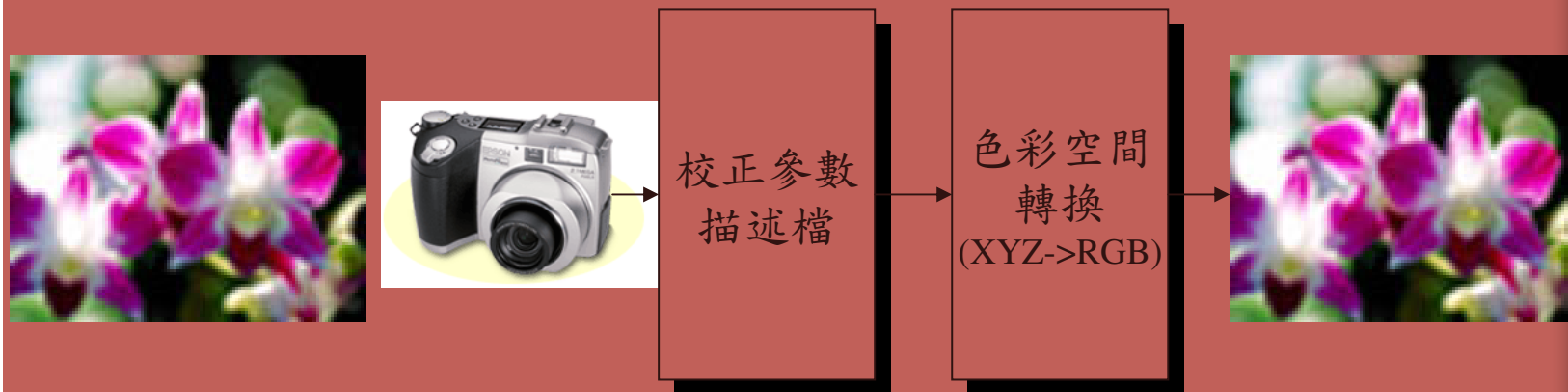
$$3 \times 9 \quad [X, Y, Z]^T = [M_{3 \times 9}] \times [R, G, B, RG, GB, RG, R^2, G^2, B^2]^T$$

$$3 \times 11 \quad [X, Y, Z]^T = [M_{3 \times 11}] \times [1, R, G, B, RG, GB, RG, R^2, G^2, B^2, RGB]^T$$

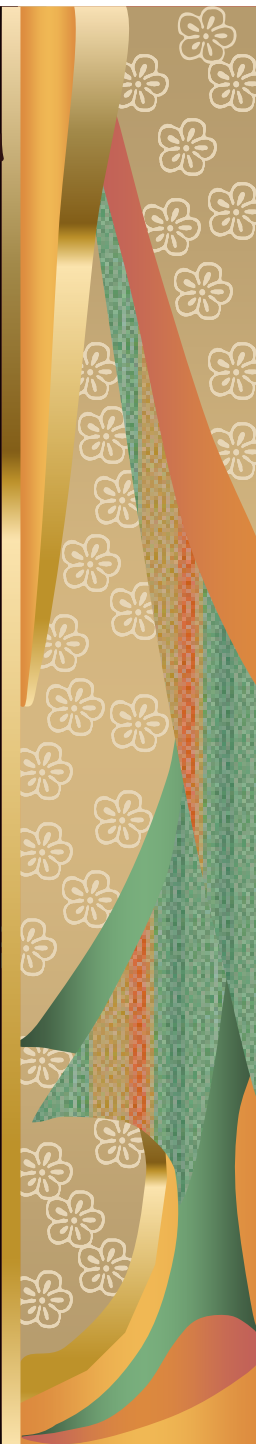
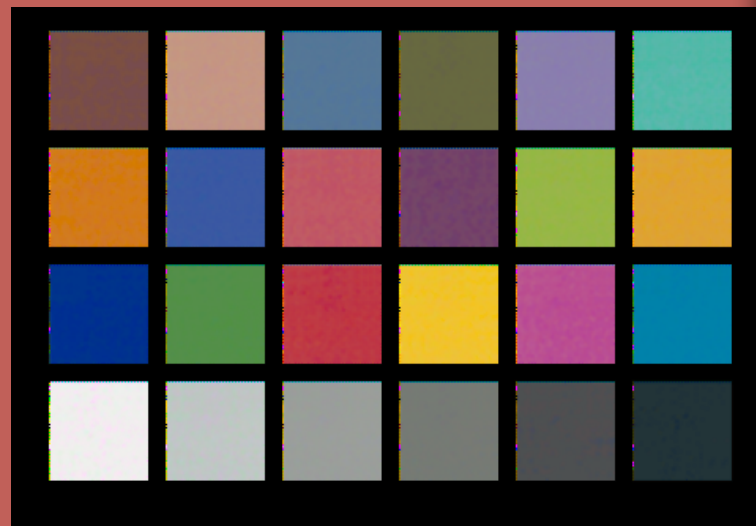
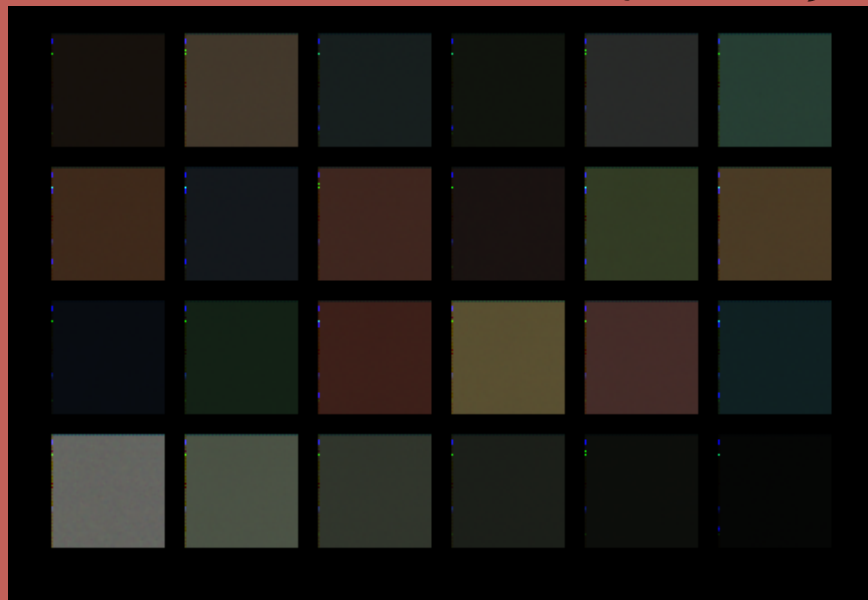
$$3 \times 14 \quad [X, Y, Z]^T = [M_{3 \times 14}] \times [1, R, G, B, RG, GB, RG, R^2, G^2, B^2, RGB, R^3, G^3, B^3]^T$$

$$3 \times 20 \quad [X, Y, Z]^T = [M_{3 \times 20}] \times [1, R, G, B, RG, GB, RG, R^2, G^2, B^2, RGB, R^3, G^3, B^3, RG^2, RB^2, GR^2, GB^2, BR^2, BG^2]^T$$

數位相機色彩校正基本模式

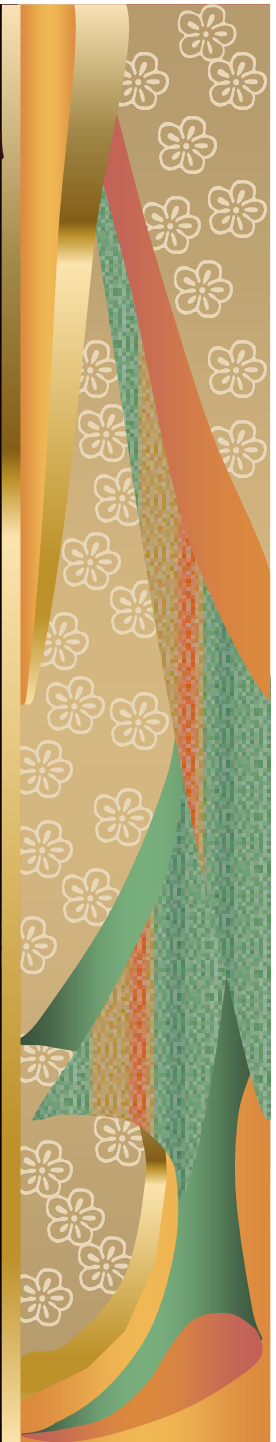


數位相機色彩校正基本模式



數位相機色彩校正基本模式

色彩校正



數位相機色彩品質的評估法

DSC/DVC 白平衡

■ 參考白估計：

■ 平均法(Grey World) [1938~86]

■ 極亮(大)值法(White-Patch retinex) [1971~]

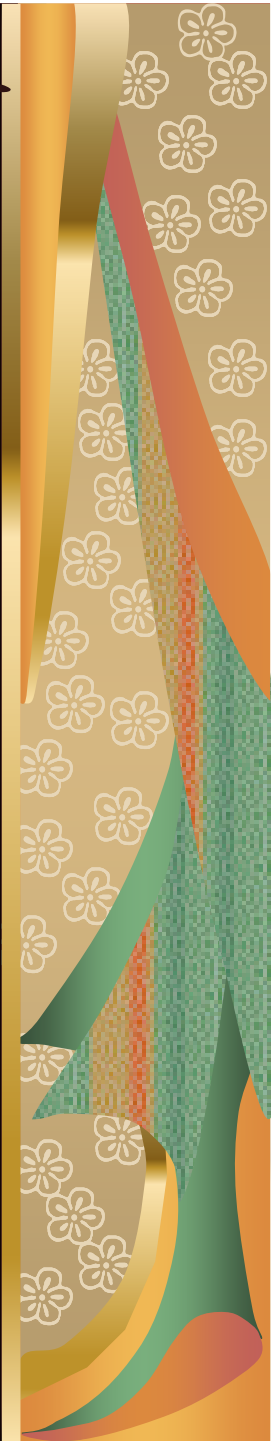
■ 色域比對法(Gamut Constraint) [1990~]

■ 光源色溫轉換 to D50：

■ von Kries adaptation

■ XYZ to sRGB:

■ <http://www.color.org>

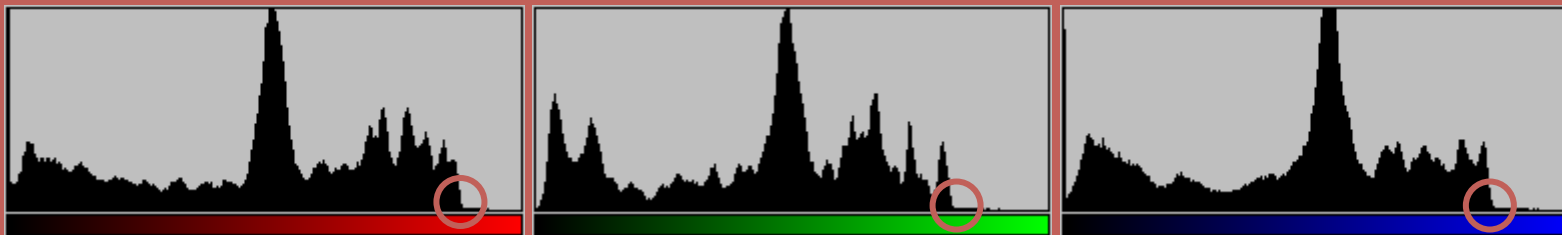


數位相機色彩品質的評估法

白平衡 (色溫估算)

Brightest Surface Method

- ❏ E.H. Land, "The retinex theory of color vision," Scientific American, pp. 108-129, 1977.
- ❏ J.J. McCann, J. A. Hall and E. H. Land, Color Mondrian Experiments: The Study of average spectral distributions, J. Opt. Soc. Am. A 67, 1380, 1977.



Gray World Theory

■ Testing color{ R', G', B' }

■ Original color{ R, G, B }

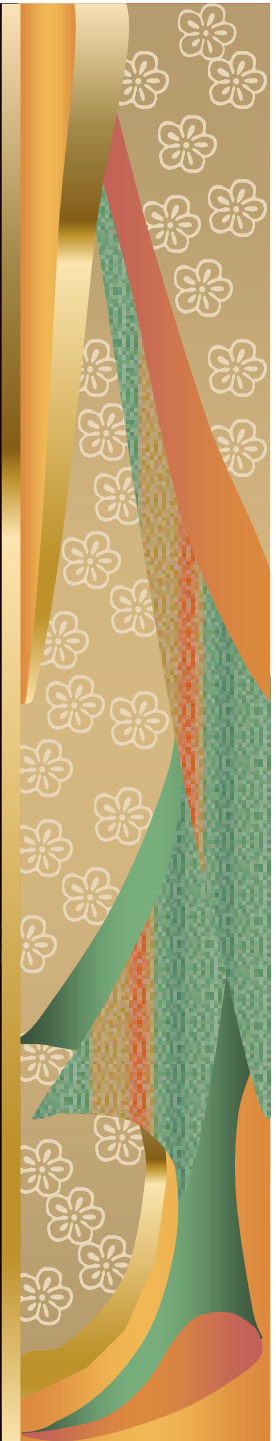
■ $\text{Gray}' = (R' + G' + B')$

■ $\text{Gray} = (R + G + B)$

■ According to $\text{Gray} = \text{Gray}'$

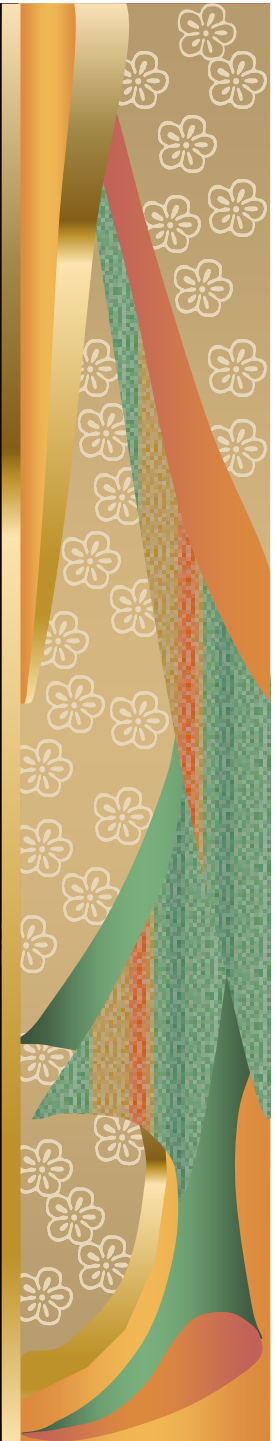
■ Than

$(R = R' / \text{Gray}', G = G' / \text{Gray}', B = B' / \text{Gray}')$



Gray World Theory

- Assume that the illumination is uniformly distributed within scene
- Human perception of color is the average of three channels named as gray. (not necessary be real gray)
- Estimated gray is used as scale the testing color to recover the original color.

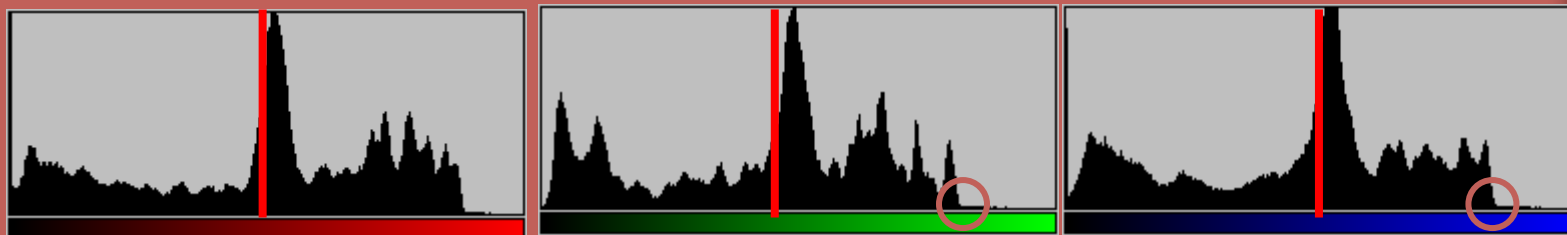


數位相機色彩品質的評估法

白平衡 (色溫估算)

Gray-World

- ❶ R. M. Evans, "Method for correcting photographic color prints," US Patent 2,571,697(1951).
- ❷ G. Buchsbaum:1980, "A spatial processor model for object color perception," J. Franklin Institute, 310:126, 1980



數位相機色彩品質的評估法

光源色溫轉換

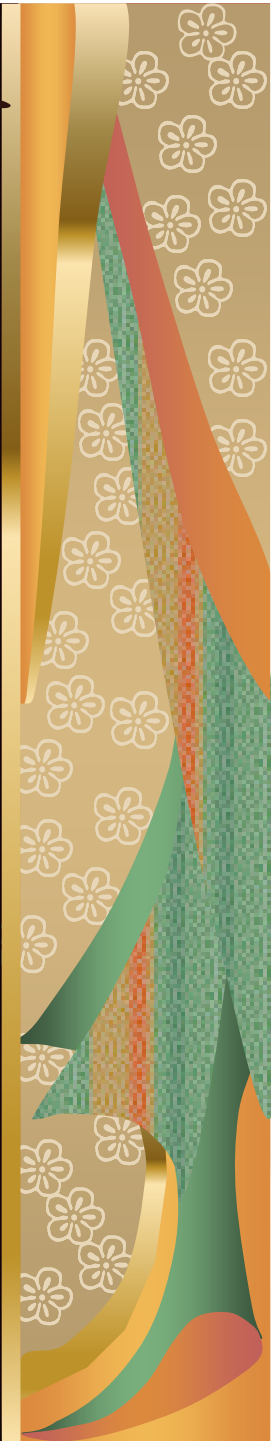
von Kries adaptation

$$\frac{X_A}{X_{A,W}} = \frac{X_{D50}}{X_{D50,W}} = \text{色度反射率}$$

$$\Rightarrow X_{D50} = X_A \frac{X_{D50,W}}{X_{A,W}}$$

$$\Rightarrow Y_{D50} = Y_A \frac{Y_{D50,W}}{Y_{A,W}}$$

$$\Rightarrow Z_{D50} = Z_A \frac{Z_{D50,W}}{Z_{A,W}}$$



數位相機色彩品質的評估法

標準光源的三刺激值

標準光源	三刺激值		
	X	Y	Z
A	109.85	100.00	35.58
B	99.09	100.00	85.31
C	98.07	100.00	118.23
D50	96.42	100.00	82.49
D55	95.68	100.00	92.14
D65	95.04	100.00	108.89
D75	94.96	100.00	122.61

D50



A

C

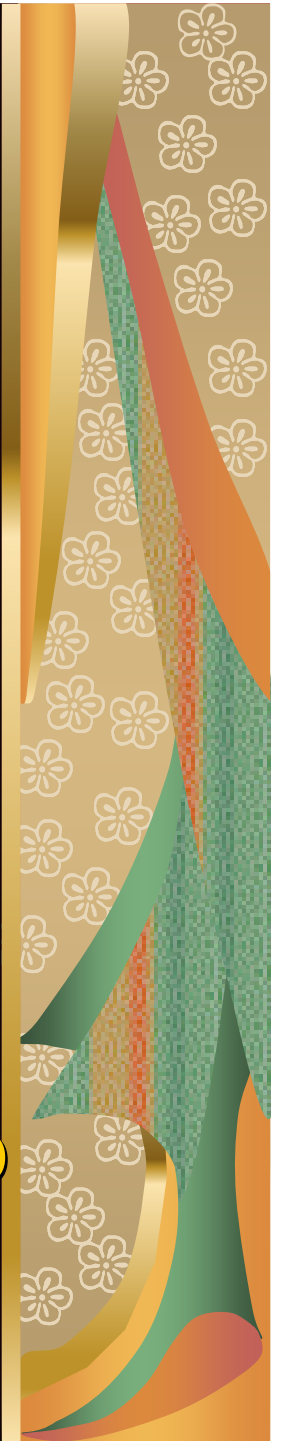


D65

D75



D50



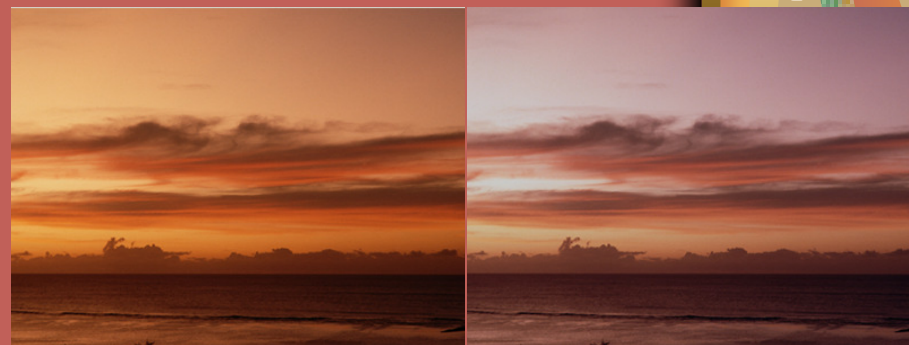
數位相機色彩品質的評估法

結果比較分析



Original

BFS



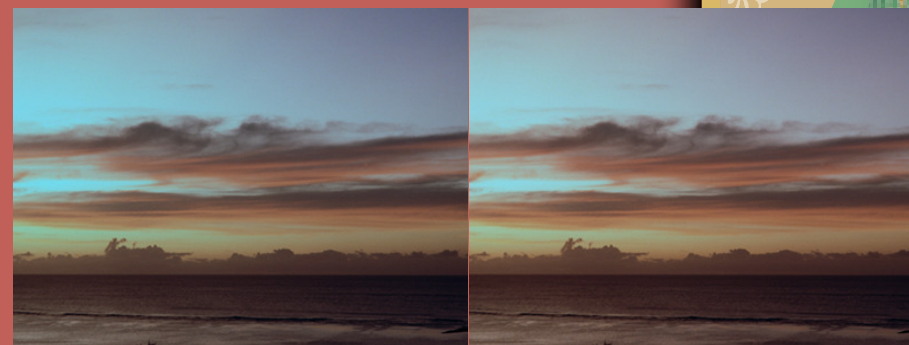
Original

BFS



GW

OES

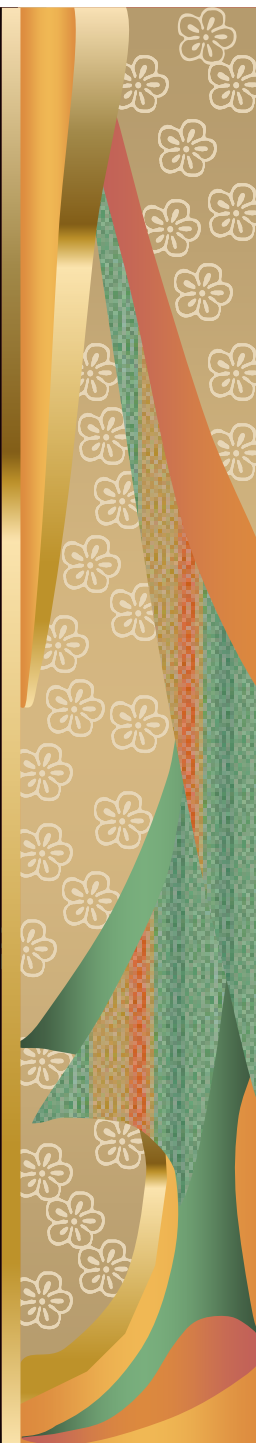


GW

OES

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測試標準

ISO/TC42/WG18

(Photography – Electronic Still Picture Imaging)

ISO 12231: 1997 名詞定義與解釋

ISO 12232 :1998 ISO Speed 曝光時間與速度

ISO 12233 : 解析度的測試

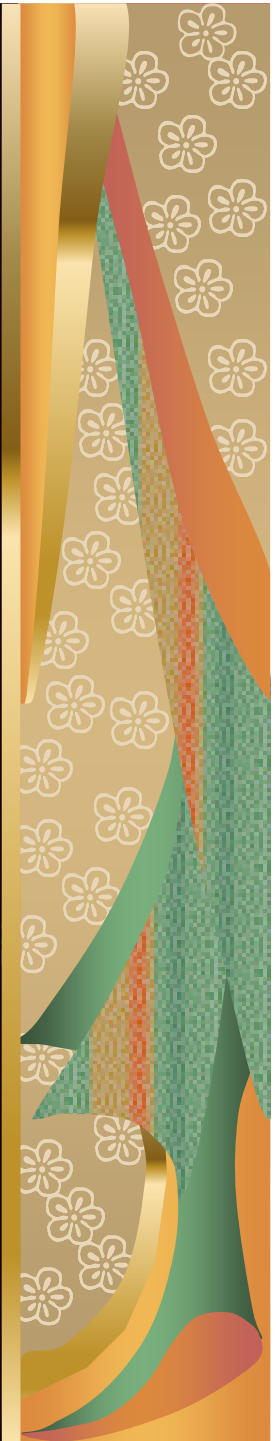
ISO /FDIS 14525 :光電轉換函數的量測 (OECF)

ISO/DIS 12234-1 : Part1 : removable memory reference model

ISO/DIS 12234-2 : Part2 :影像檔格式 – TIFF/EP

ISO/CD 15739 : 雜訊量測 Noise Measurements

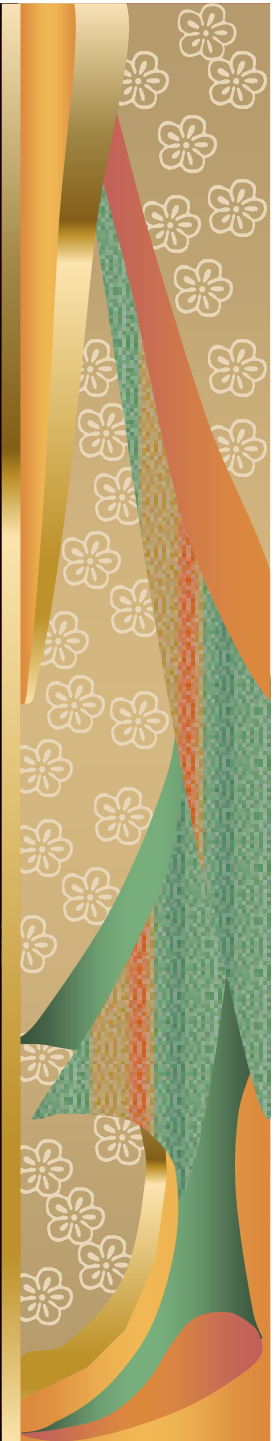
ISO/WD 16067 : 空間解析度的量測 Part 1: Scanners for reflective media



ISO/TC42/WG18 (Photography – Electronic Still Picture Imaging)

ISO/WD 17321 : 測試條件與色彩轉換 (如: 測試色稿、光源與色彩空間轉換)

ISO 15740 : 影像轉換協定 **Picture Transfer Protocol(PTP)**

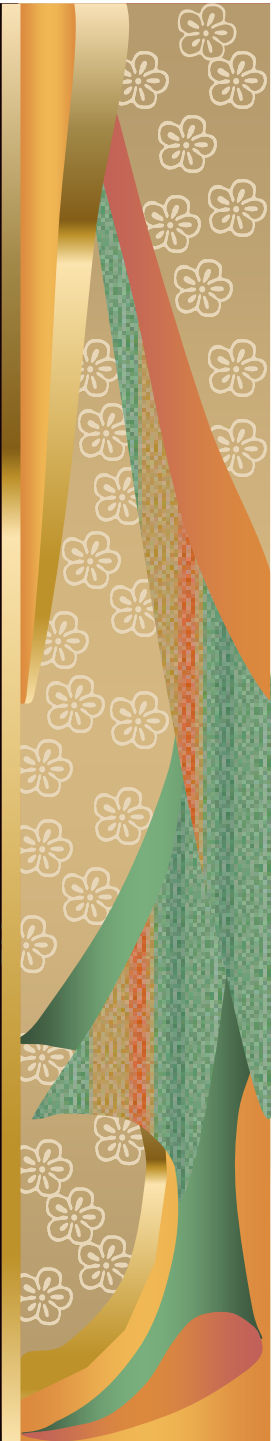


ISO Standard documents being developed for image quality

ISO Number	Title	Technical committee	Draft Number
ISO 16067	Photography – Electronic scanners for photographic images – Spatial resolution measurements :Part1 Scanners for reflective media(SRF , MTF)	ISO/TC42/WG18	Working Draft 5.2
ISO 14524/DIS	Photography – Electronic still picture cameras -Methods for measuring opto-Electronic conversion function(OECF)	ISO/TC42/WG18	DIS
ISO 15739	Photography – Electronic still picture cameras Noise measurements	ISO/TC42/WG18	Working Draft 5.2
ISO 17321	Graphic Technology and Photography – colour characterization of digital still cameras using colour targets and spectral illumination	ISO/TC42/WG18 ISO/TC42/WG3	Working Draft 3.1
ISO 12233:1999E	Photography – electronic still picture cameras – Resolution measurements	ISO/TC42/WG18	FDIS

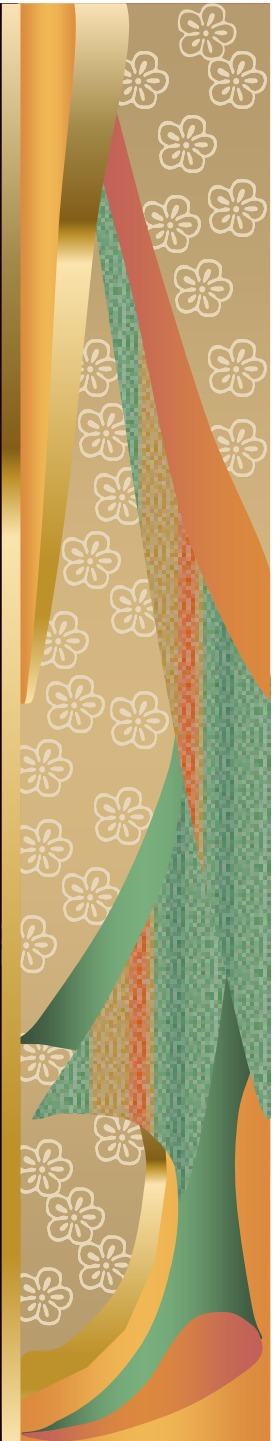
Outline

- 數位相機的基本架構
- 數位相機色彩校正基本模式
- 測試標準
- 數位相機色彩品質的評估法
- 結果與討論



數位相機色彩品質的評估法

1. Color Reproduce (CR) 色彩再現性
2. Color Rendering Index 演色性指數
3. Auto White Balance 自動白平衡
4. MTF (解析度)
5. SNR (雜訊比)
6. Uniformity (均勻度)
7. Dynamic range (動態範圍)
8. Veiling Flare (炫光)



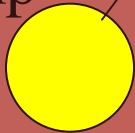
數位相機色彩品質的評估法

Matt black wall or black surround

Test Chart

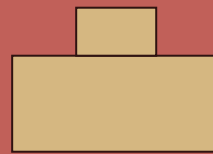
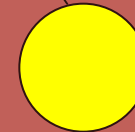
Distance is adjusted to
frame the test chart

lamp



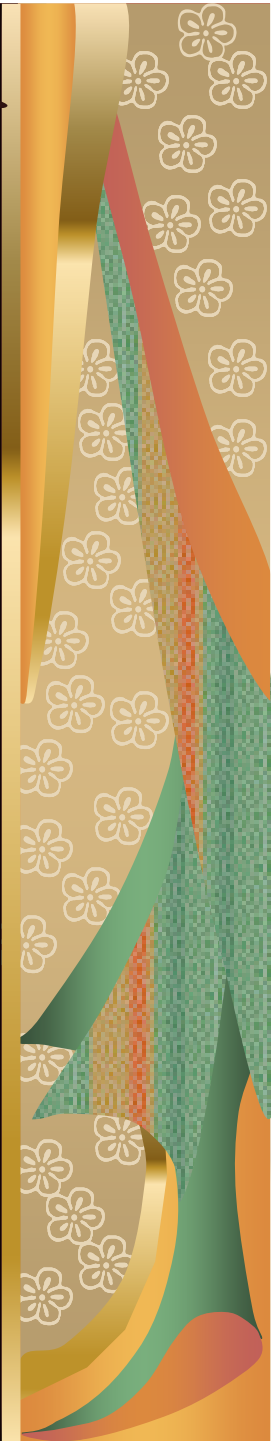
Baffles to prevent direct
illumination of the camera
lens by the lamps

lamp



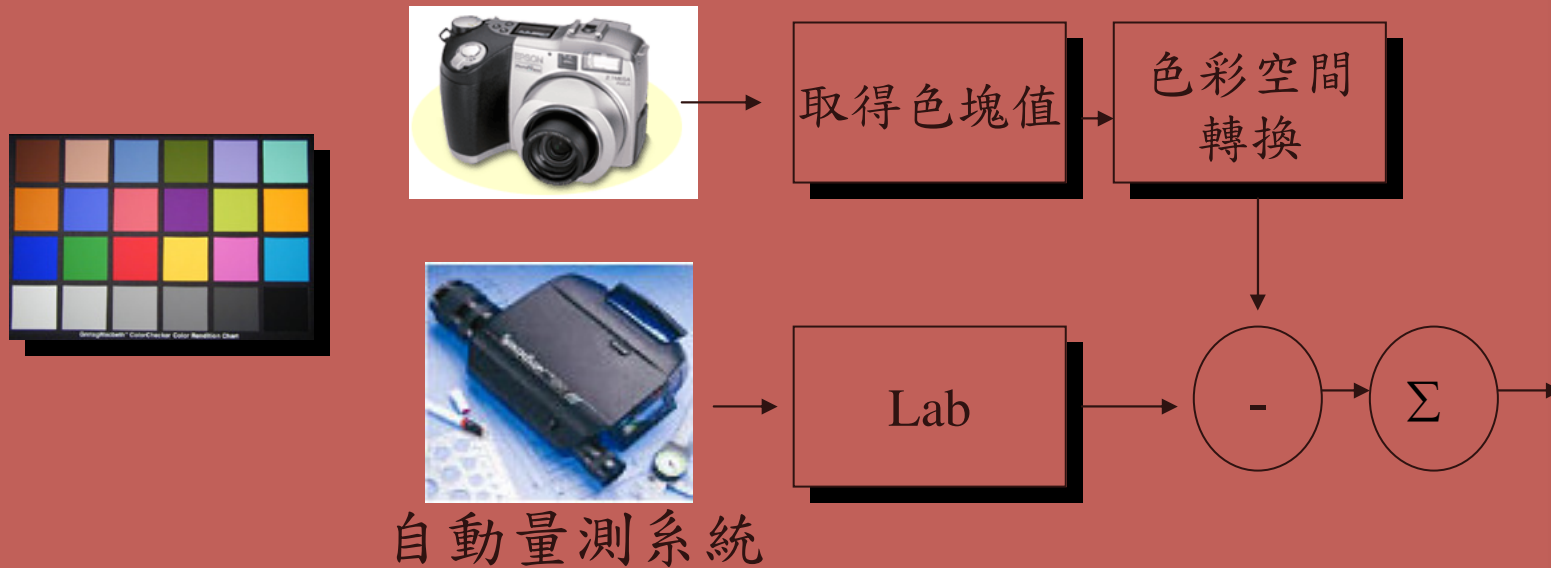
Electronic still picture camera

Lamp : 均勻光其要求低於 $\pm 10\%$ 的變化



數位相機色彩品質的評估法

Color Reproduce



$$\Delta E_{ab} = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

數位相機色彩品質的評估法

CIE
1976

$$L^* = 116 (Y / Y_n)^{1/3} - 16$$

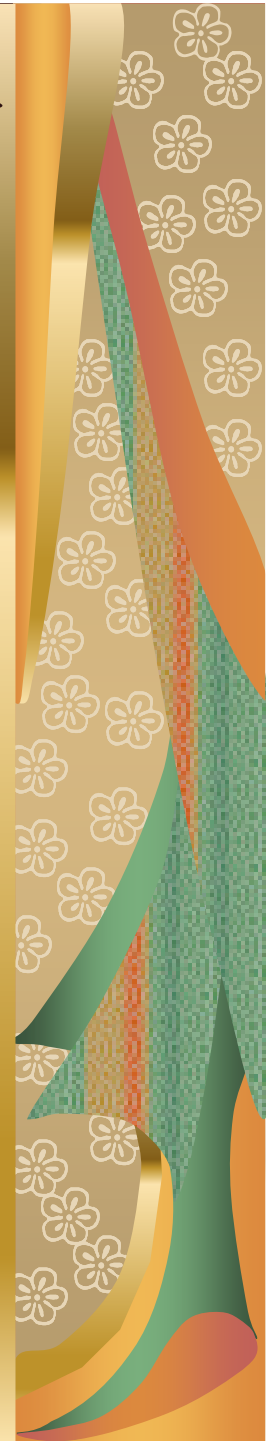
$$a^* = 500 \left[(X / X_n)^{1/3} - (Y / Y_n)^{1/3} \right]$$

$$b^* = 200 \left[(Y / Y_n)^{1/3} - (Z / Z_n)^{1/3} \right]$$

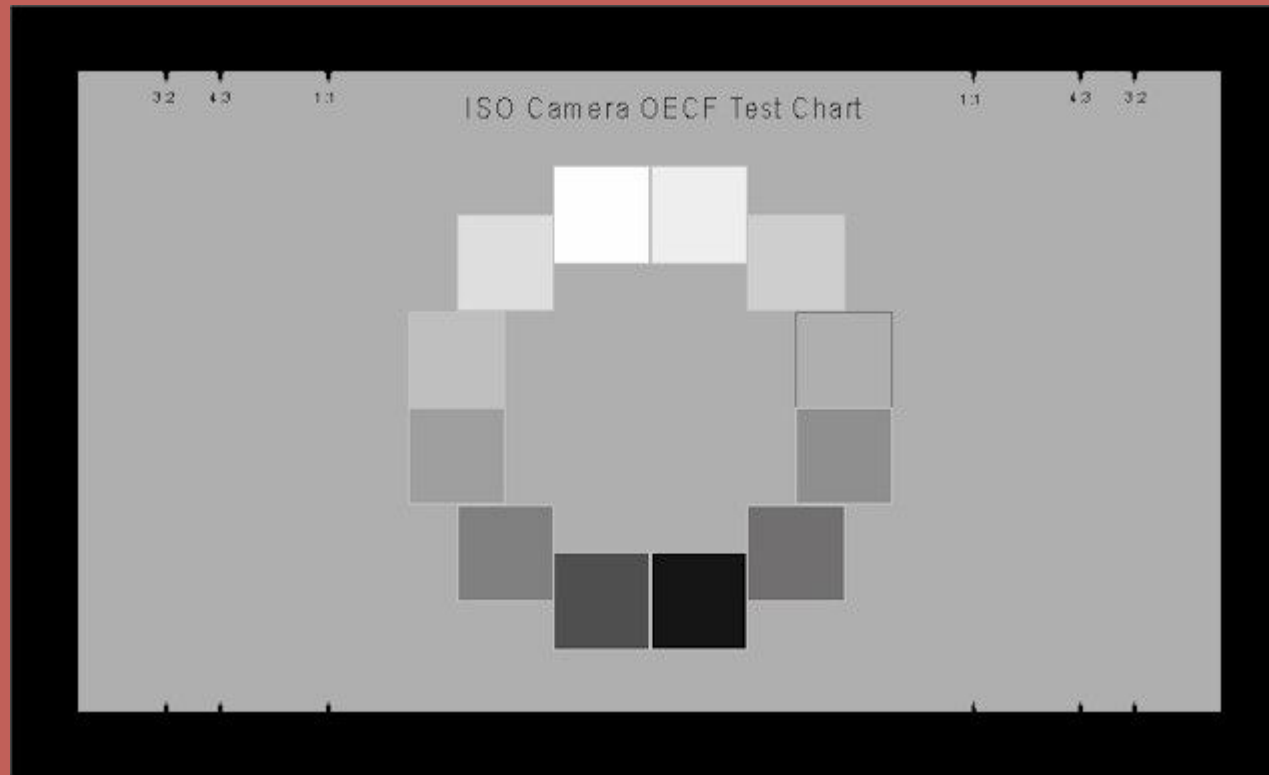
Color Difference 色差：

$$\Delta E_{ab} = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

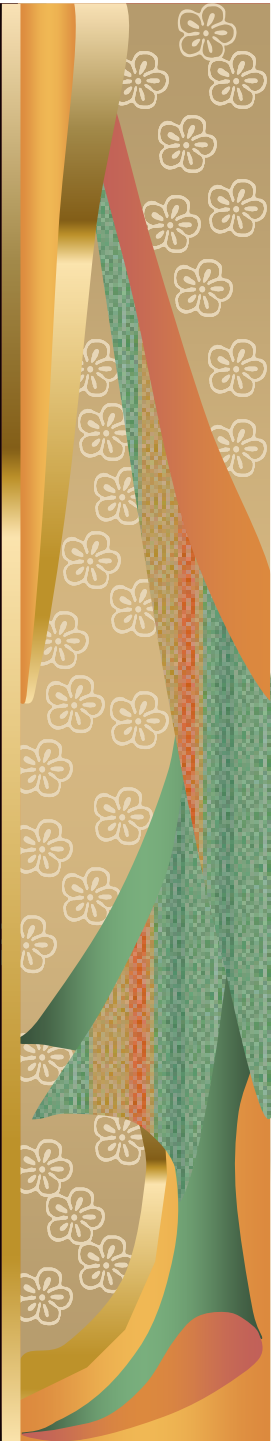
X_n, Y_n, Z_n 為參考白值



數位相機色彩品質的評估法

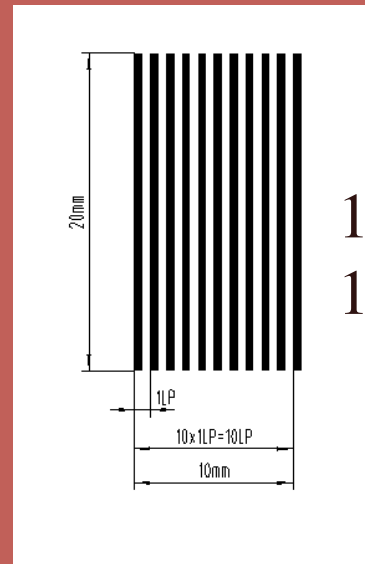


ISO Camera Contrast Chart ISO14524
12 gray levels ranging from 0.10 to 2.30 density

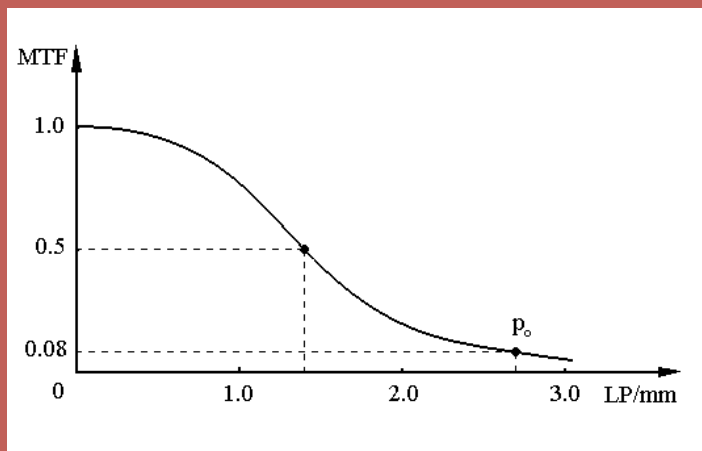


數位相機色彩品質的評估法

MTF



1PL/mm
10PL/cm



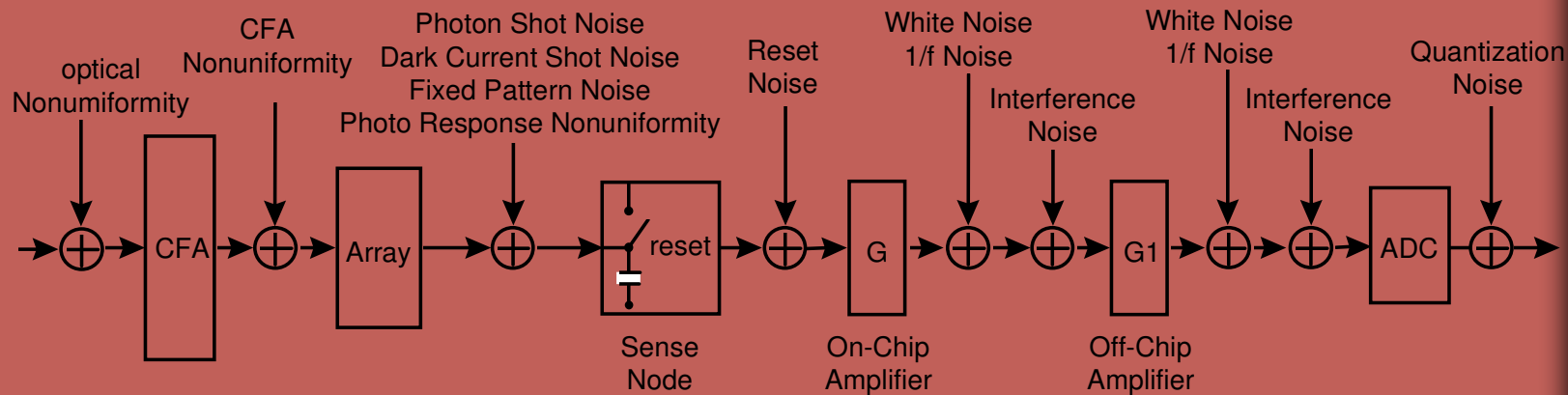
MTF值與分辨率的關係是：
分辨率越小，MTF越大

$$MTF = \frac{I_2 - I_1}{I_2 + I_1}$$

I_2 最大灰度

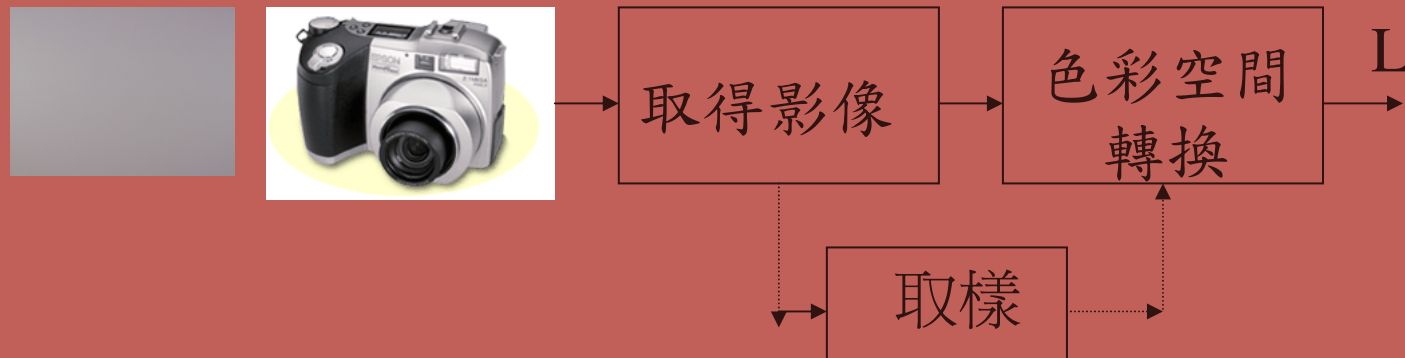
I_1 最小灰度

數位相機色彩品質的評估法



數位取像系統的信號與雜訊源

數位相機色彩品質的評估法



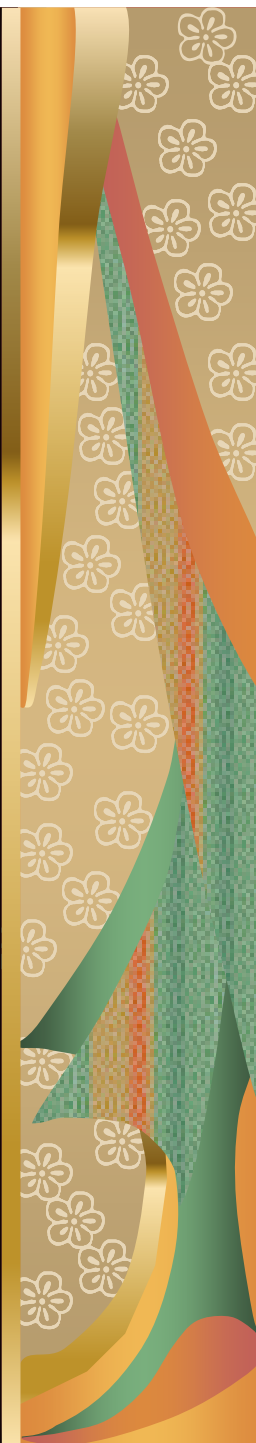
$$PSNR = 20 \log\left(\frac{100}{L_{rms}}\right) \quad Uniformation = 1 - \left(\frac{L_{max} - L_{min}}{L_{mean}}\right)$$

$$L_{rms} = \sqrt{(L - L_{mean})^2}$$

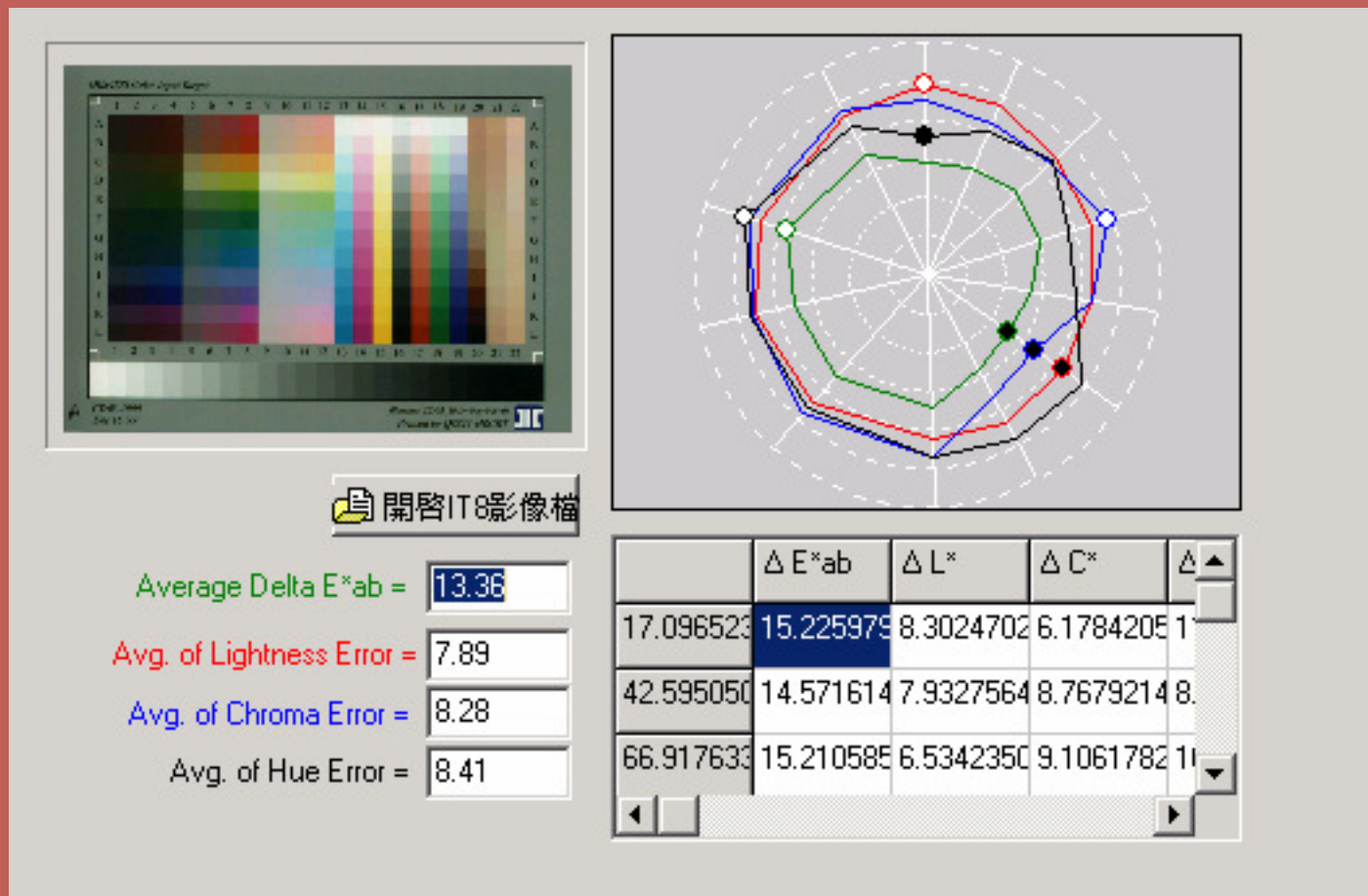
$$L_{mean} = \frac{1}{mn} \sum^m \sum^n L$$

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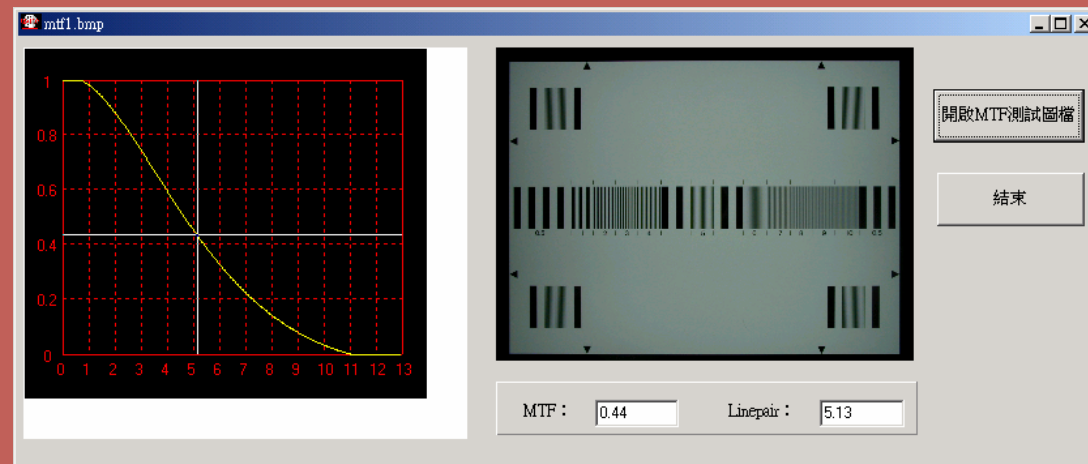
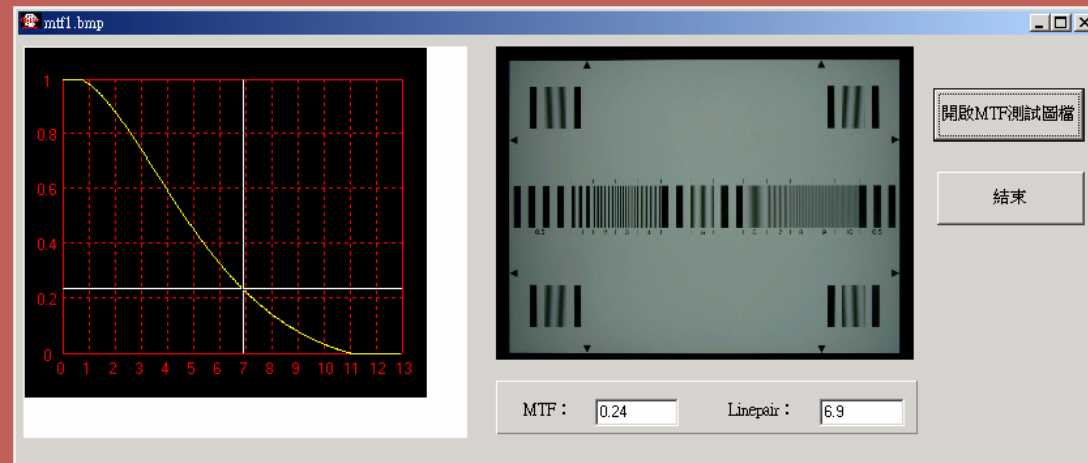


數位相機色彩品質的評估法

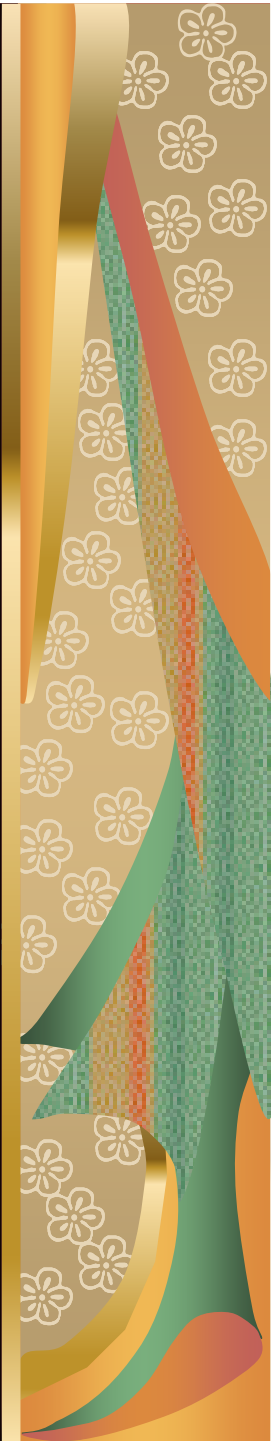


結果與討論

MTF

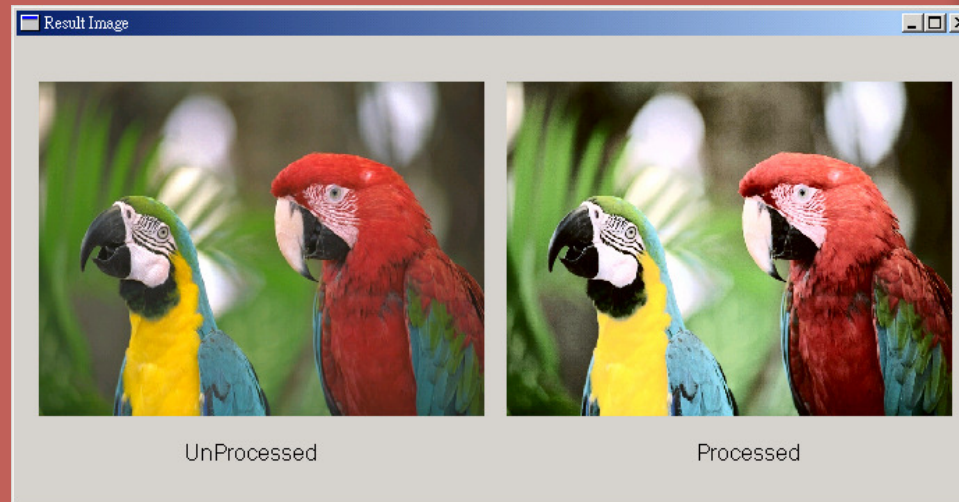
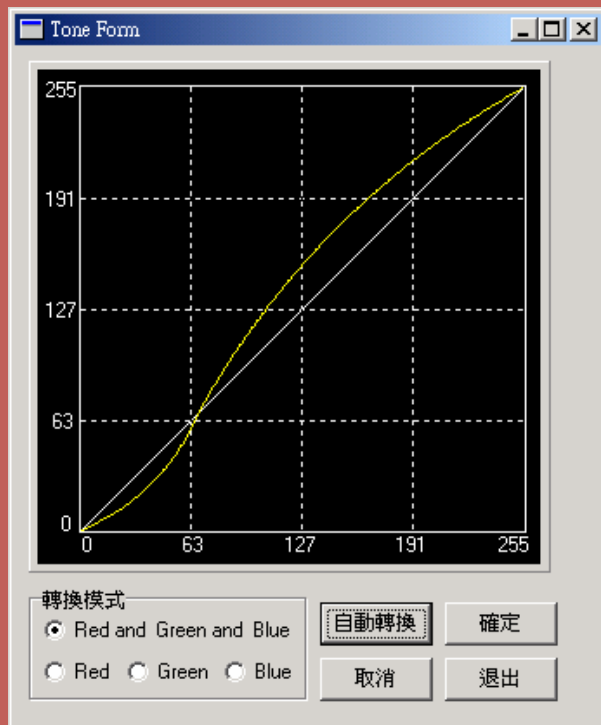


色彩管理實務工作坊

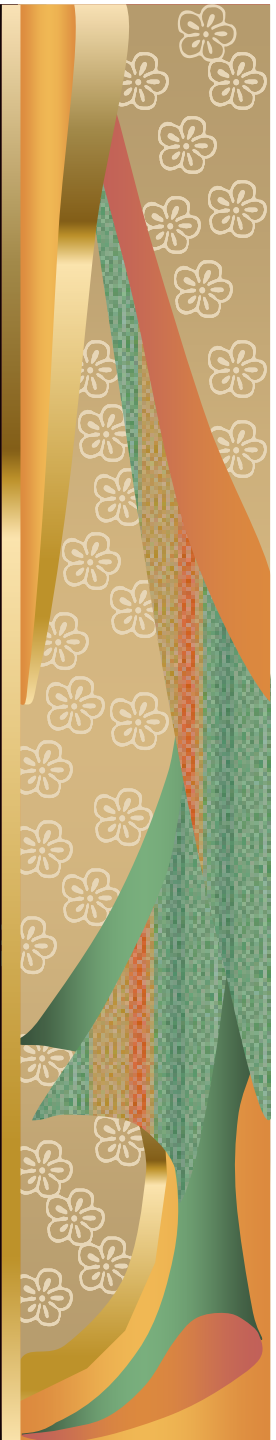
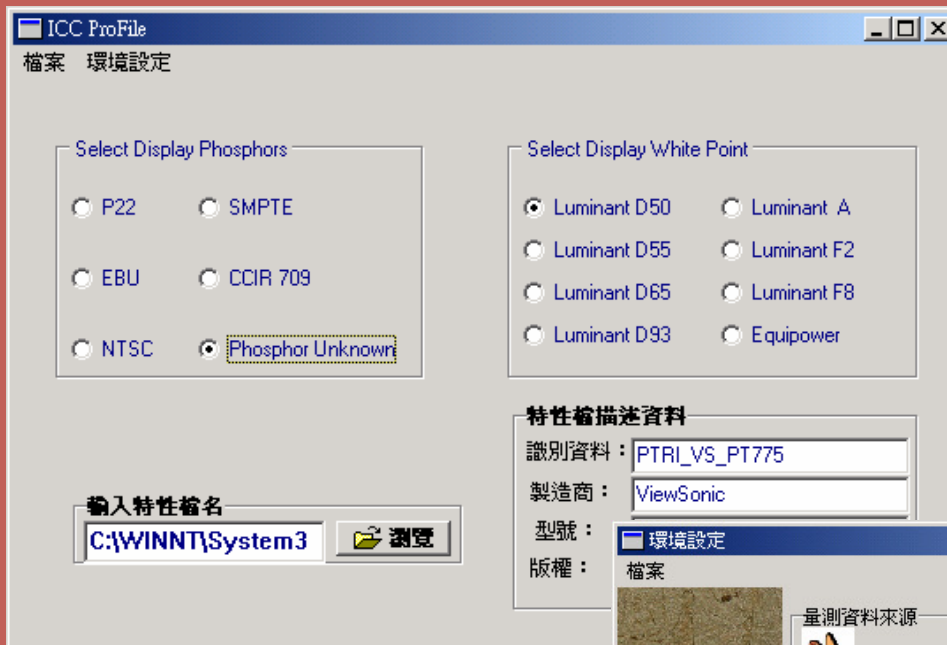


結果與討論

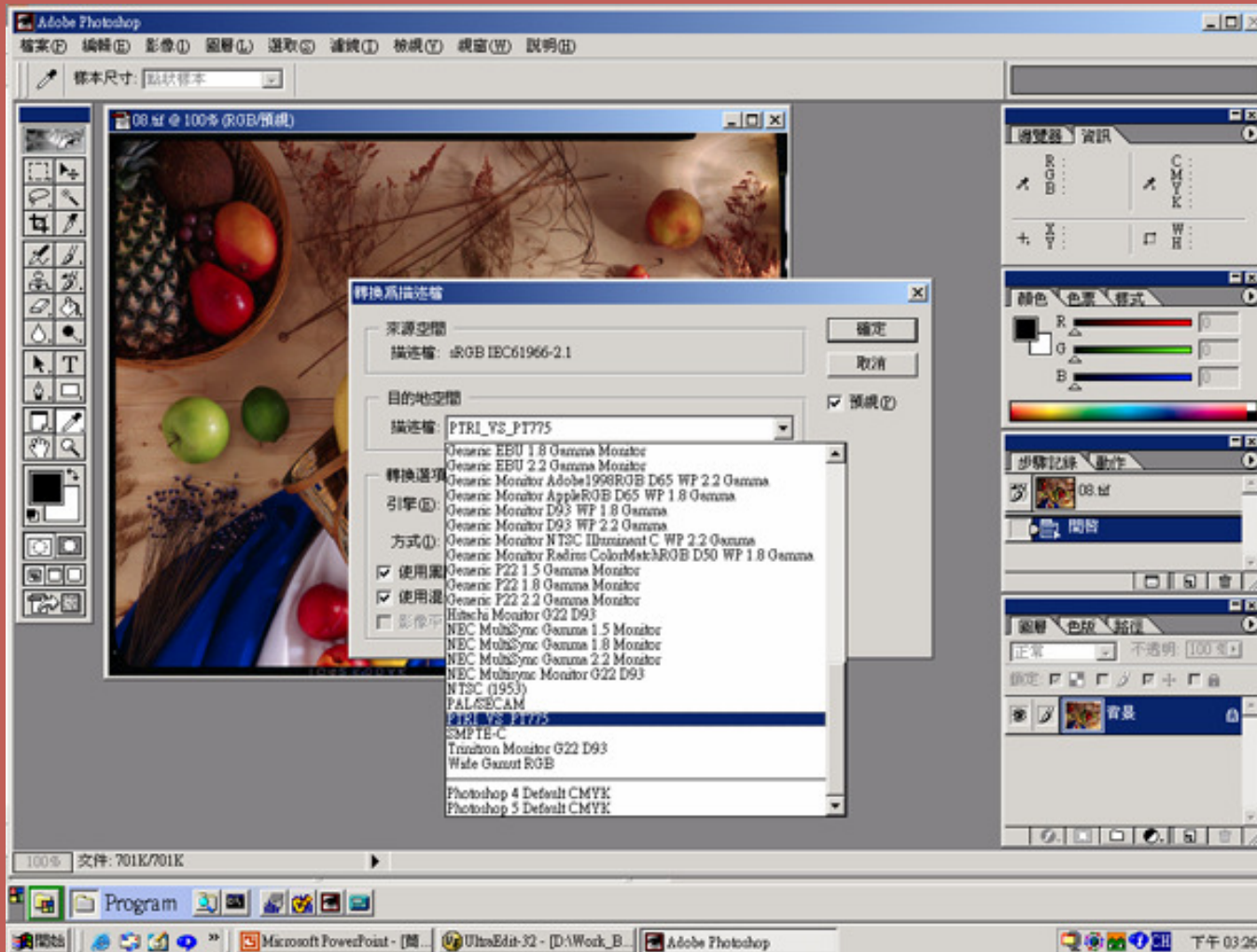
色調處理



結果與討論



結果與討論



結果與討論

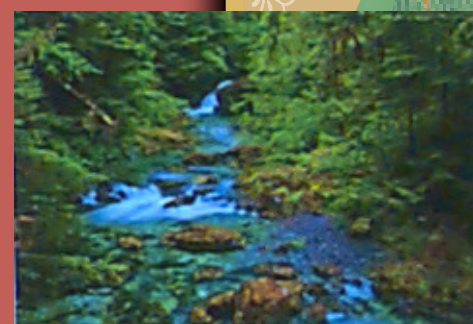
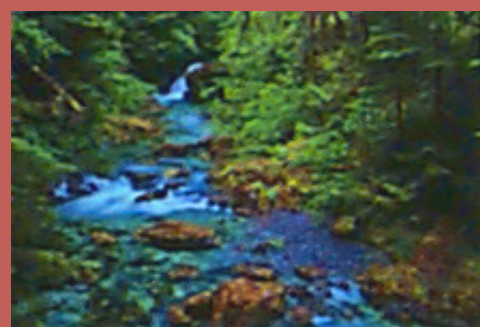
ICC描述檔操作(III):應用於不同顯示器時色彩 之一致性

EIZO 顯示器

ViewSonic 顯示器

EIZO 顯示器

ViewSonic 顯示器



未經ICC描述檔色彩校正

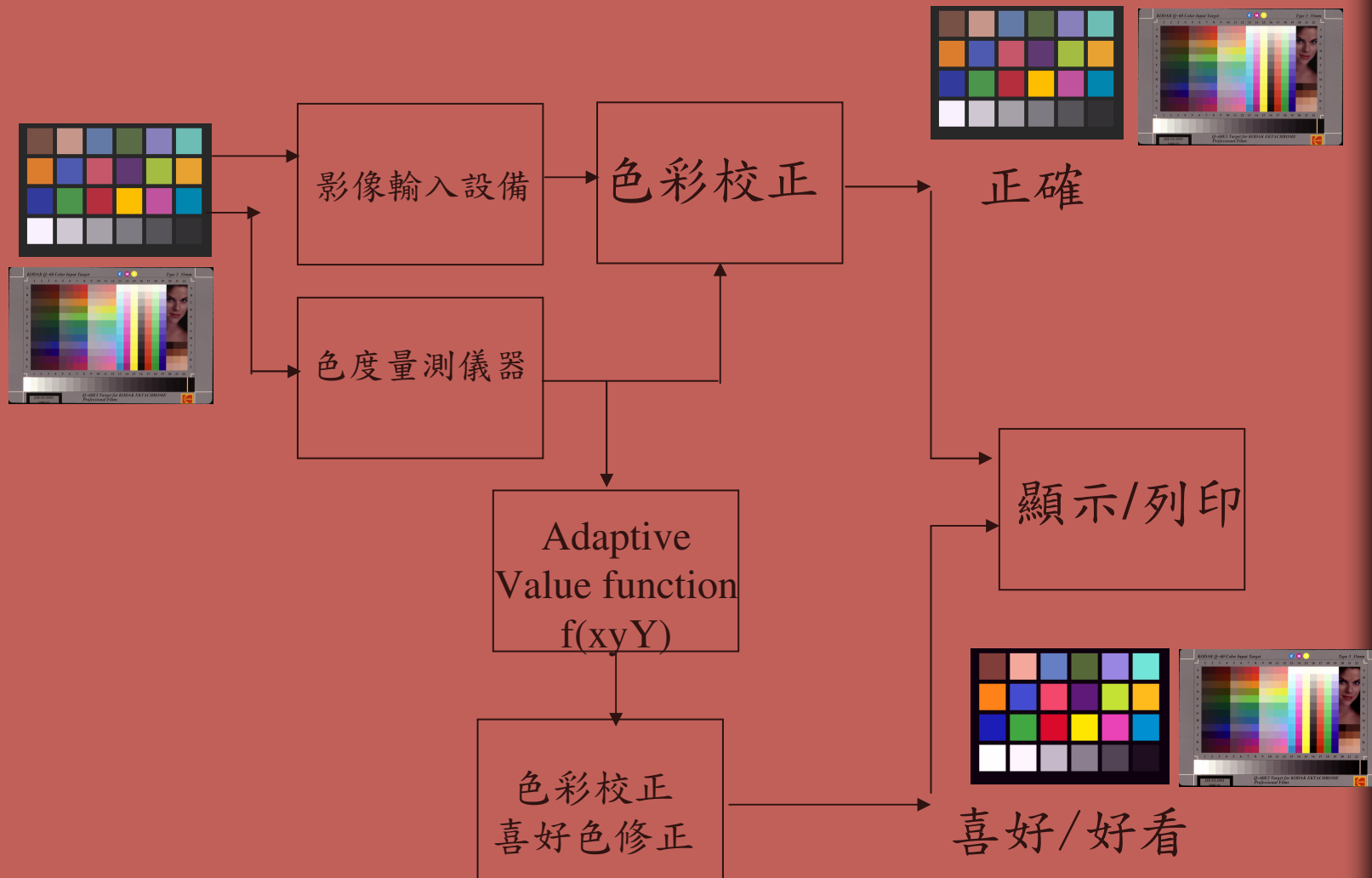
(同一影像檔在不同顯示器上, 顏色差異較大)

色彩管理實務工作坊

經ICC描述檔色彩校正後

(同一影像檔在不同顯示器上, 顏色逼近)

結果與討論



Thank you attention

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Tel : 03-5918410

