Automatic White Balance for Digital Still Camera

White Balance Mechanism

- Whenever scene is captured by digital camera, the recorded image of the scene shows a distinct color cast depending on the light source.
- This color cast appears because of the color temperature of surrounding light source.

Color Temperature

- Low color temperature causes reddish color cast over the scene.
- High color temperature causes bluish color cast over the scene.

Effect of Color Temperature over the Captured Scene

Low color temperature → High color temperature

Reddish cast

White balanced

Bluish cast

Traditional White Balance Algorithms

- White balance methods based on the,
  - Gray World Assumption (GWA)
  - Perfect Reflector Assumption (PRA)
  - Fuzzy Rule Method (FRM)

Gray World Assumption

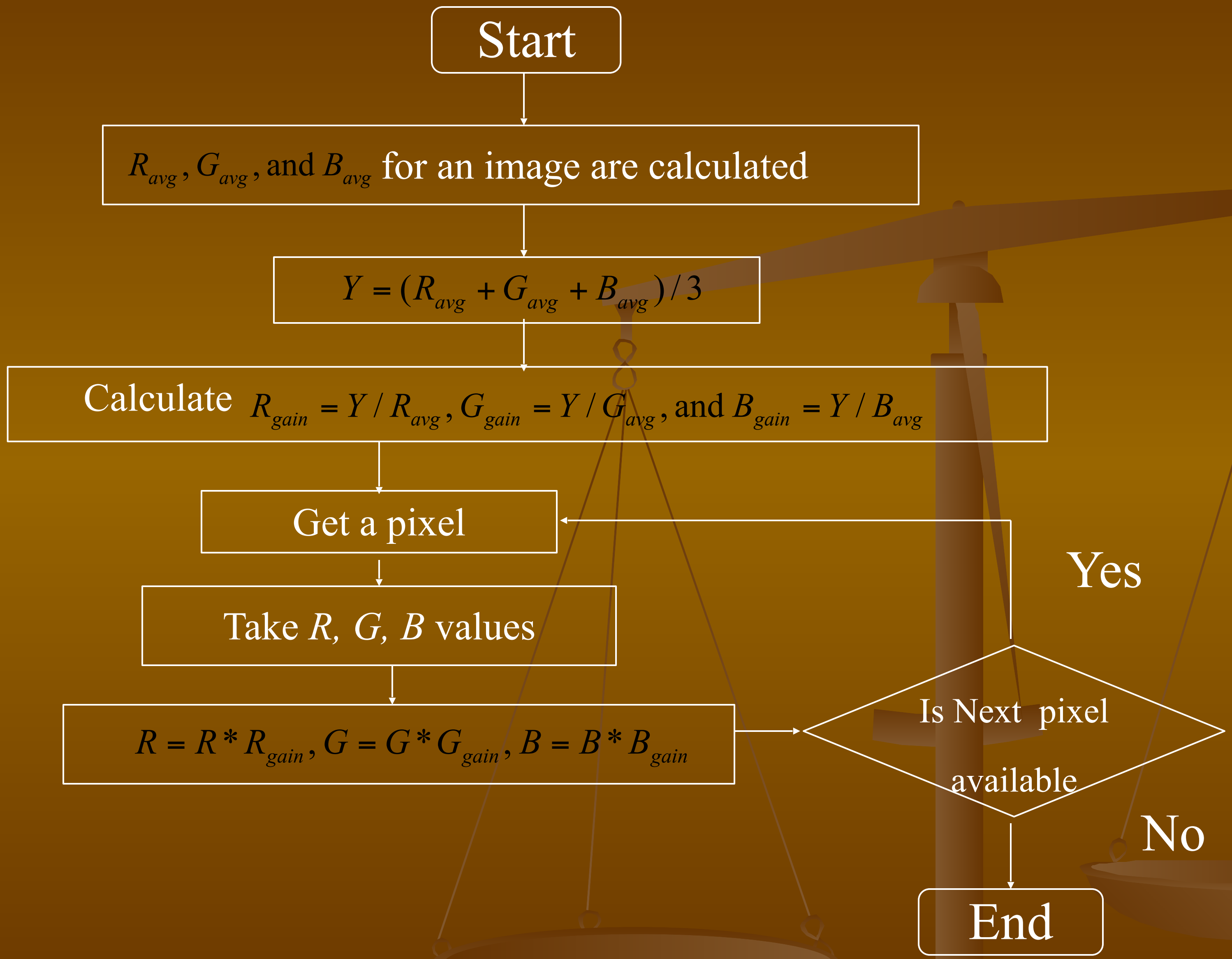
Basics:

- An image with sufficient amount of color variation, the average values of R, G, and B components of the image should meet a common gray value.

- As a result, effect of the special lighting cast can be removed by enforcing the gray world assumption on the image.

- Thus the image is much closer to the original scene.

Flow Chart for **Gray World Assumption**



Perfect Reflector Assumption

Basics:

- ❖ The glossy surfaces or specularity from an image are used for balancing the color variation.
- ❖ As glossy surfaces or specularity reflects the actual color of the light source that illuminates the scene, independently of the color of the surface.
- ❖ Therefore, the R, G, and B components of the brightest or most reflective spots are used to scale the R, G, and B values of all other objects (pixels) in the image in order to obtain the true colors of the original.

Flow Chart of **Perfect Reflector Assumption**

Start

↓

Find out the reference white point in an image.

↓

Compute the scale factors according to the reference white point.

↓

Adjust each pixel in an image by applying the scale factors to the respective component values.

↓

End

Disadvantages of Basic Methods

- Whenever there is lack of color variation the GWA gives strange results.

- In PRA, picking the brightest pixels is not suitable solution.

- Brightest pixels may belong to other color rather than white color.

"You should check your e-mails more often. I fired you over three weeks ago."

Fuzzy Rule Method

Working

- Convert the image from the RGB color space to the YC_rC_b color space
- Seize the color characteristics in the YC_rC_b color space for the white balance adjustment
- Perform some experiments to get related statistic results.

Experiments:

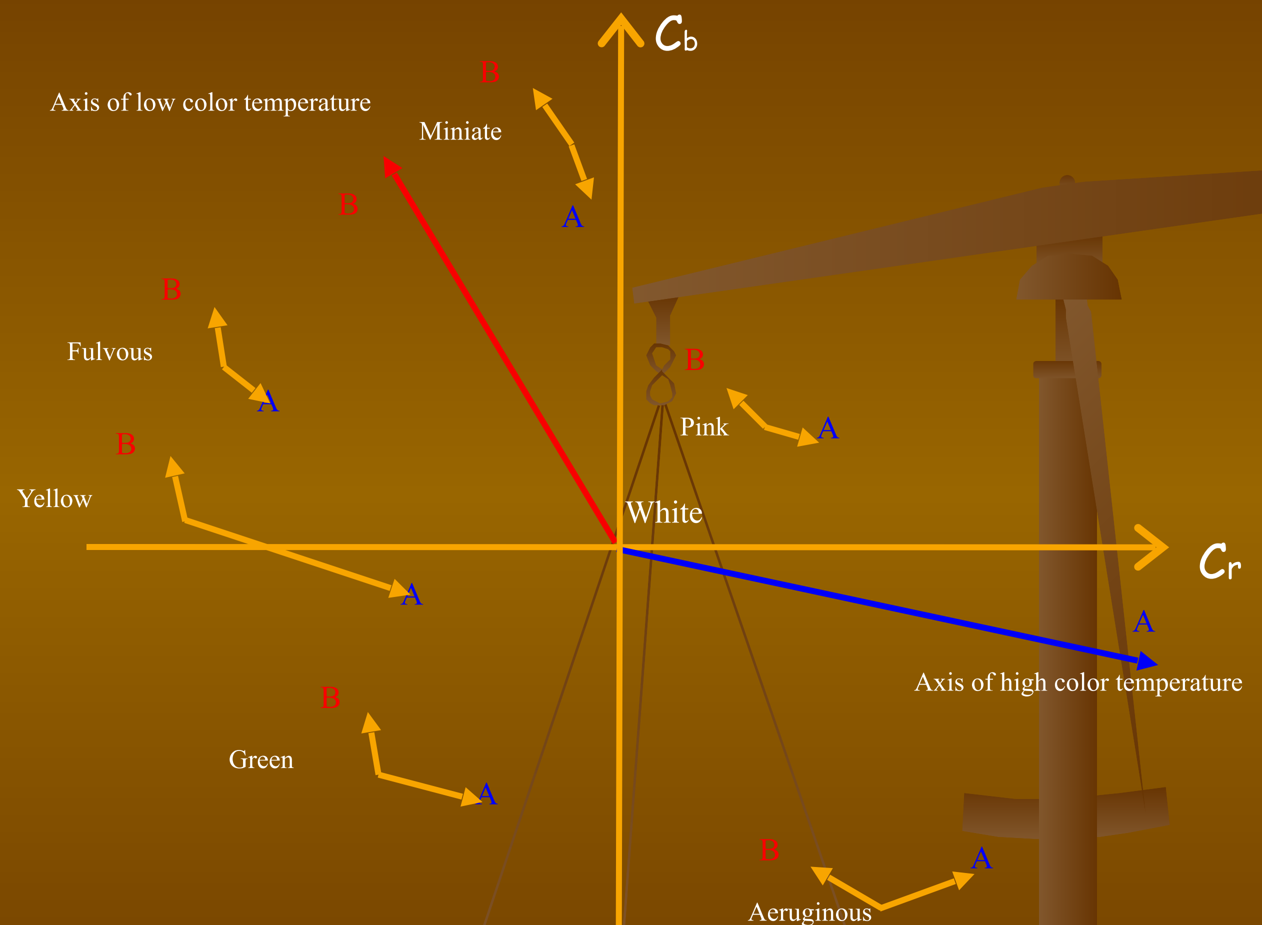
- Objects with various colors were illuminated with different light sources.

Light source used in this experiment with their code listed below.

Color Temperature (Kelvin)	6575	4289	2885	2264
Light Source	Daylight	Cool-white	INCa	Horizon

- The results are plotted on $C_r - C_b$ coordinates.

The Experimental Data of Colors under Different Light Sources



A: the deflected direction of high color temperature
B: the deflected direction of low color temperature

Experimental Results

- A dark color has less deviation from nominal position under different light sources, as opposed to the bright color, where the deviation is significant on the C_r and C_b components.

- When a white object is illuminated with different light sources, the slope of deflection, i.e. the ratio of C_r to C_b, $r = C_r/C_b$, is approximately between -1.5 and -0.5.

- At high luminance, the color components are easily saturated, while at low luminance, the color components become colorless.

Fuzzy Rules

- Automatic white balance algorithm is developed by using the above experimental results.
- A frame of image capture with CCD (Charge-Coupled Device) camera is divided into 8 segments for weighting.
- The averages of C_r and C_b components of all pixels within each segment are calculated, then weighted under fuzzy control means.

Fuzzy Rules (continued)

➢ Based on the experimental results fuzzy rules for weighting are described below:

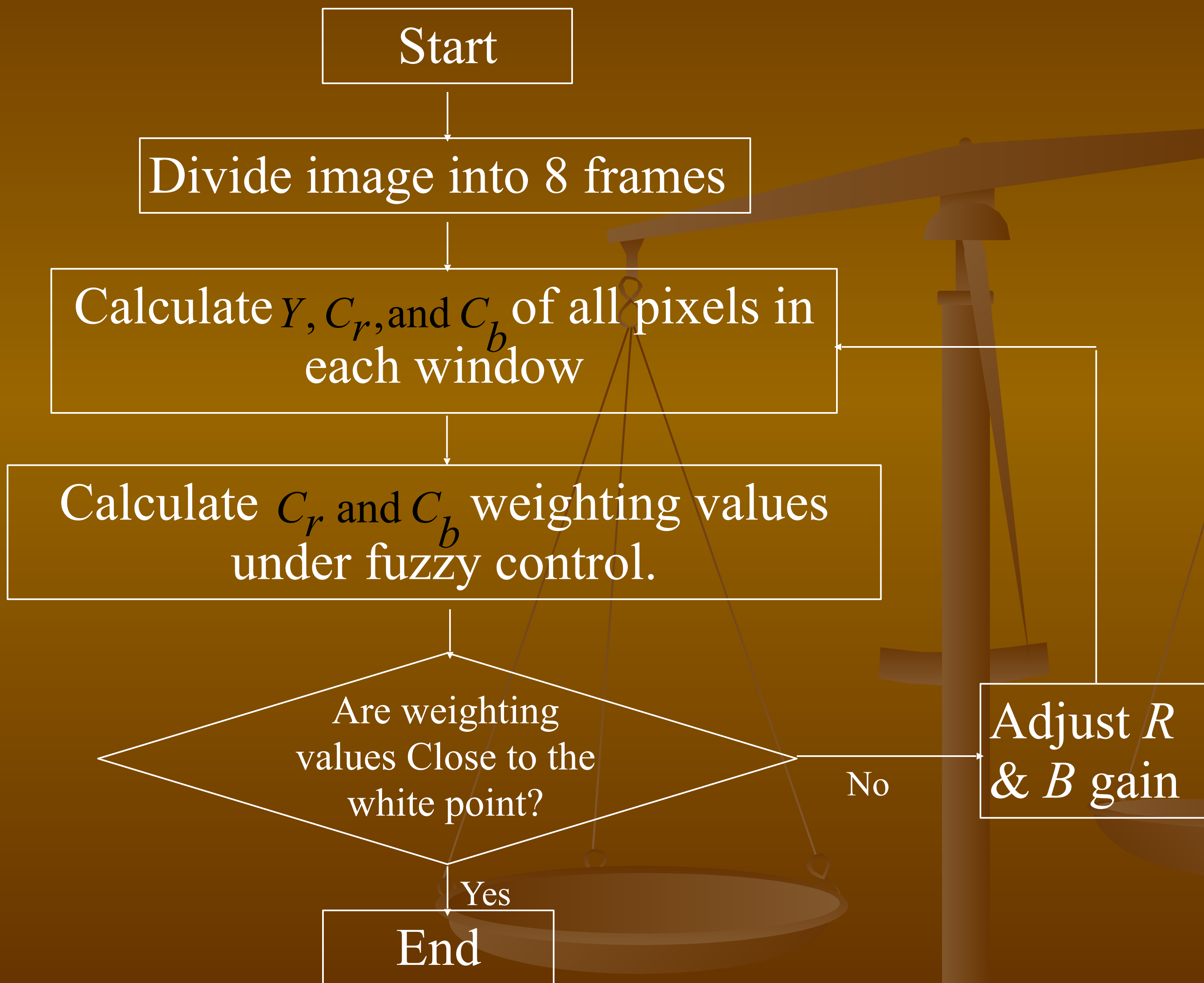
1. C_r and C_b weighted with small values under the conditions of high-end and low-end luminance.

2. The average of C_r and C_b for each segment is weighted less for the dark colors than bright colors.

Fuzzy Rules (continued)

3. When a large object (say background) occupies more than one segment,
   - Its color will dominate that segment.
   - The $r = C_r/C_b$ value will be similar among the adjacent segments. In such situation, given weighting for that segment is small, in order to avoid over-compensation on the color of the picture.
   - The value r is very different from the adjacent segment and is between -1.5 to -0.5. The given weighting for that segment is very large.

Automatic White Balance Algorithm Based on Fuzzy Rule Method



GNURF

Chiou’s White Balance Method

Start

↓

White point detecting unit

↓

White balance judging unit

↓

White balance adjusting unit

↓

End

The components block diagram of Chiou’s white balance method.

Steps in White Point Detecting Unit

1. Detection of rough reference white point:
   - Convert the color space from RGB to YC_rC_b and determine the threshold CH_{th} (= 60) for chromaticity value($\sqrt{C_r^2 + C_b^2}$).
   - The pixel with chromaticity value less than or equal to the threshold CH_{th} , are picked up as rough reference white point

Steps in White Point Detecting Unit (continued)

2. Detection of precise reference white point:
   - Each color component threshold R_{th}, G_{th}, and B_{th} are determined by using percentile histogram method.
   - Next determine the thresholds, $AB_b\ (= 45)$, $AB_r\ (= 45)$, $R_l\ (= -1.25)$, and $R_u\ (= -0.75)$ in YC_rC_b color space.

Steps in White Point Detecting Unit (continued)

2. Detection of precise reference white point (continued):
   - The rough reference white pixels satisfying the following condition are picked up as precise reference white pixels

$$R \geq R_{th}, G \geq G_{th}, B \geq B_{th}$$

$$|C_r| \leq AB_r, |C_b| \leq AB_b$$

$$R_l \leq C_r / C_b \leq R_u$$

Steps in White Point Detecting Unit (continued)

3. The averages of rough reference white pixels are calculated as,

$$(\qquad) R_r, G_r, \text{ and } B_r$$

4. Finally the averages of precise reference white pixels are calculated as,

$$(R_p, G_p, \text{ and } B_p)$$

Steps in White Balance Judging Unit

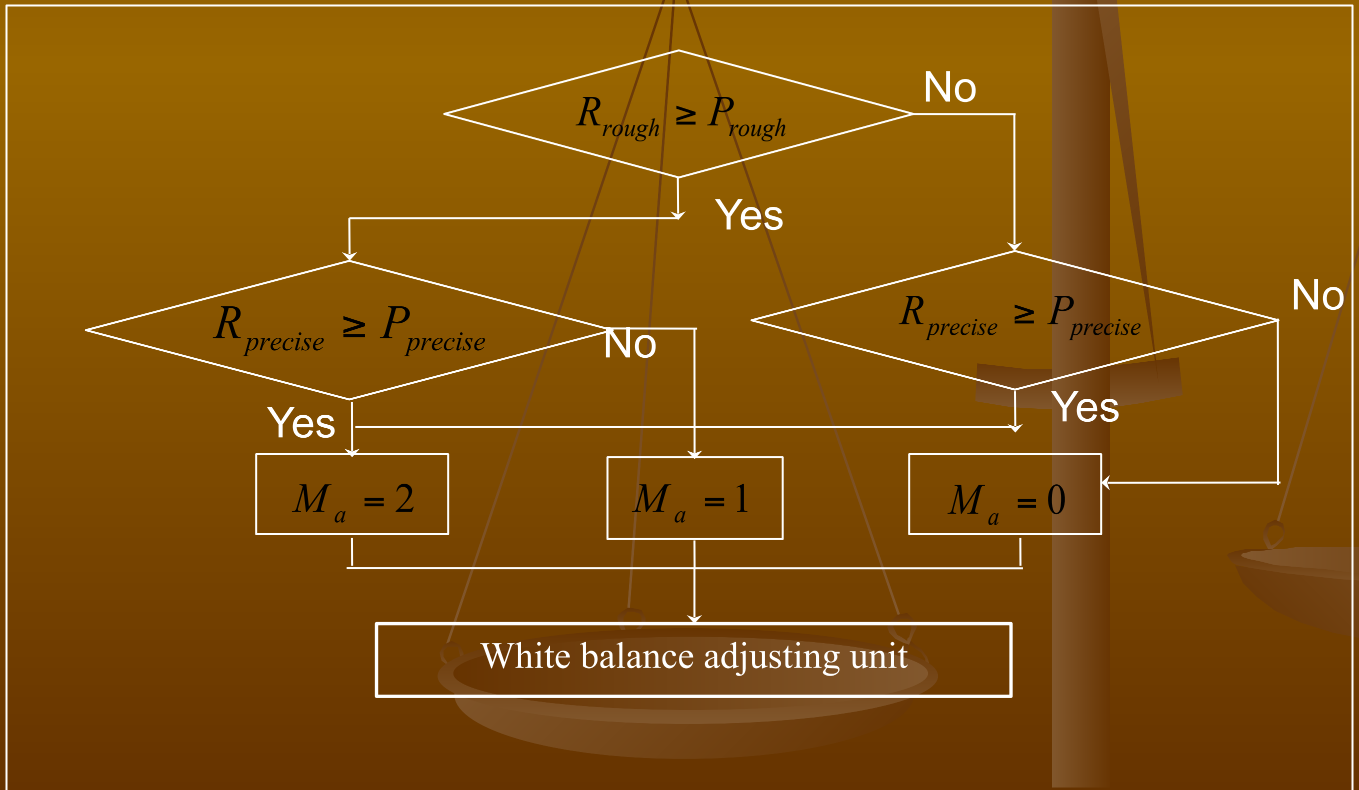
1. Pick up the reference white point data from the white point detecting unit.
2. Calculate R_{rough}, ratio of the rough reference white pixels to all pixels of an image and $R_{precise}$, ratio of the precise reference white pixels to all pixels of an image.

Steps in White Balance Judging Unit (continued)

3. Judge whether or not R_{rough} is equal to or larger than a P_{rough} value, defined as prescribed proportion (0.2).
4. Judge whether or not $R_{precise}$ is equal to or larger than a $P_{precise}$ value, defined as prescribed proportion (0.05).

Steps in White Balance Judging Unit (continued)

5. Set the mode M_a to the values 0,1, or 2 according to the conditions shown below.



Steps in White Balance Adjusting Unit

1. Calculate scale factors according to the rough reference white point as,

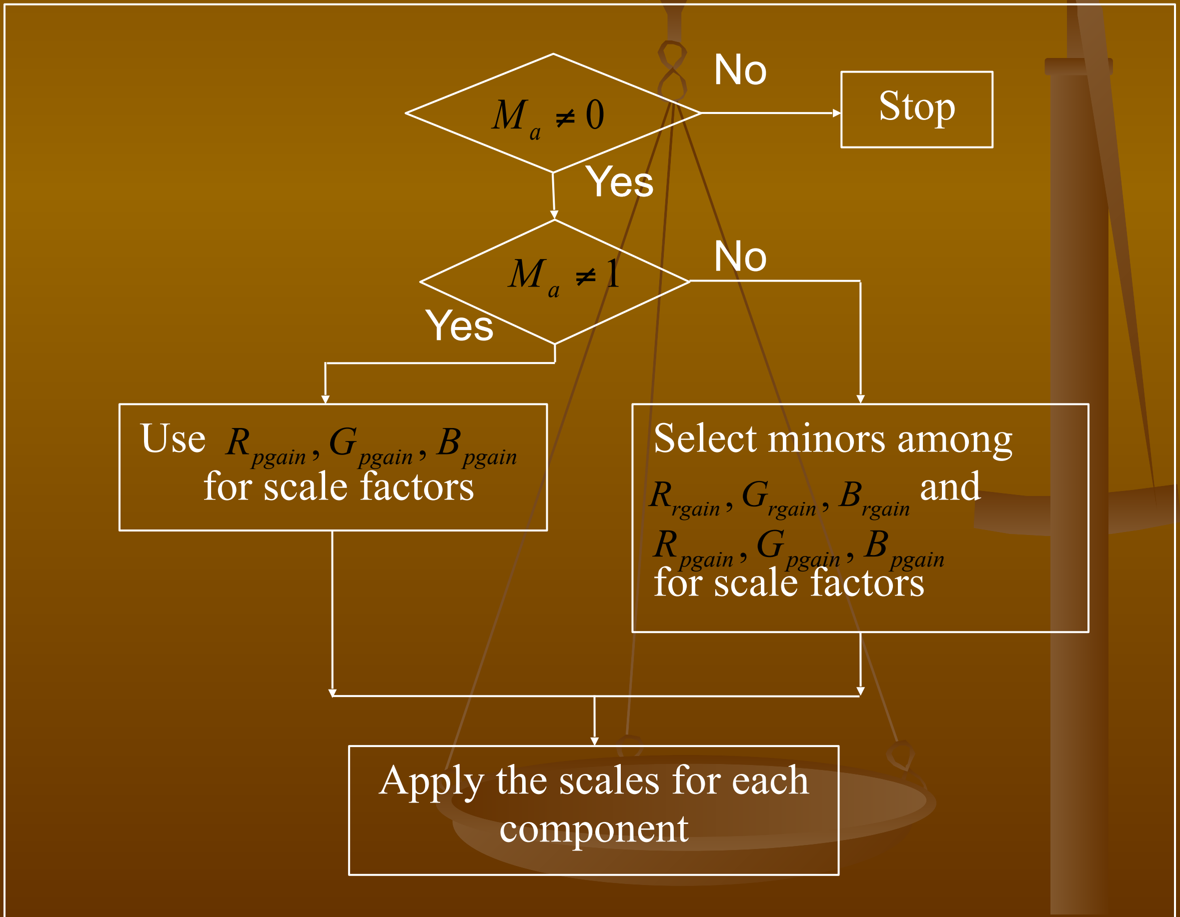
$$R_{rgain}, G_{rgain}, B_{rgain}$$

2. Calculate scale factors according to the precise reference white point as,

$$R_{pgain}, G_{pgain}, B_{pgain}$$

Steps in White Balance Adjusting Unit (continued)

3. Next, scale factors applied according to the mode M_a

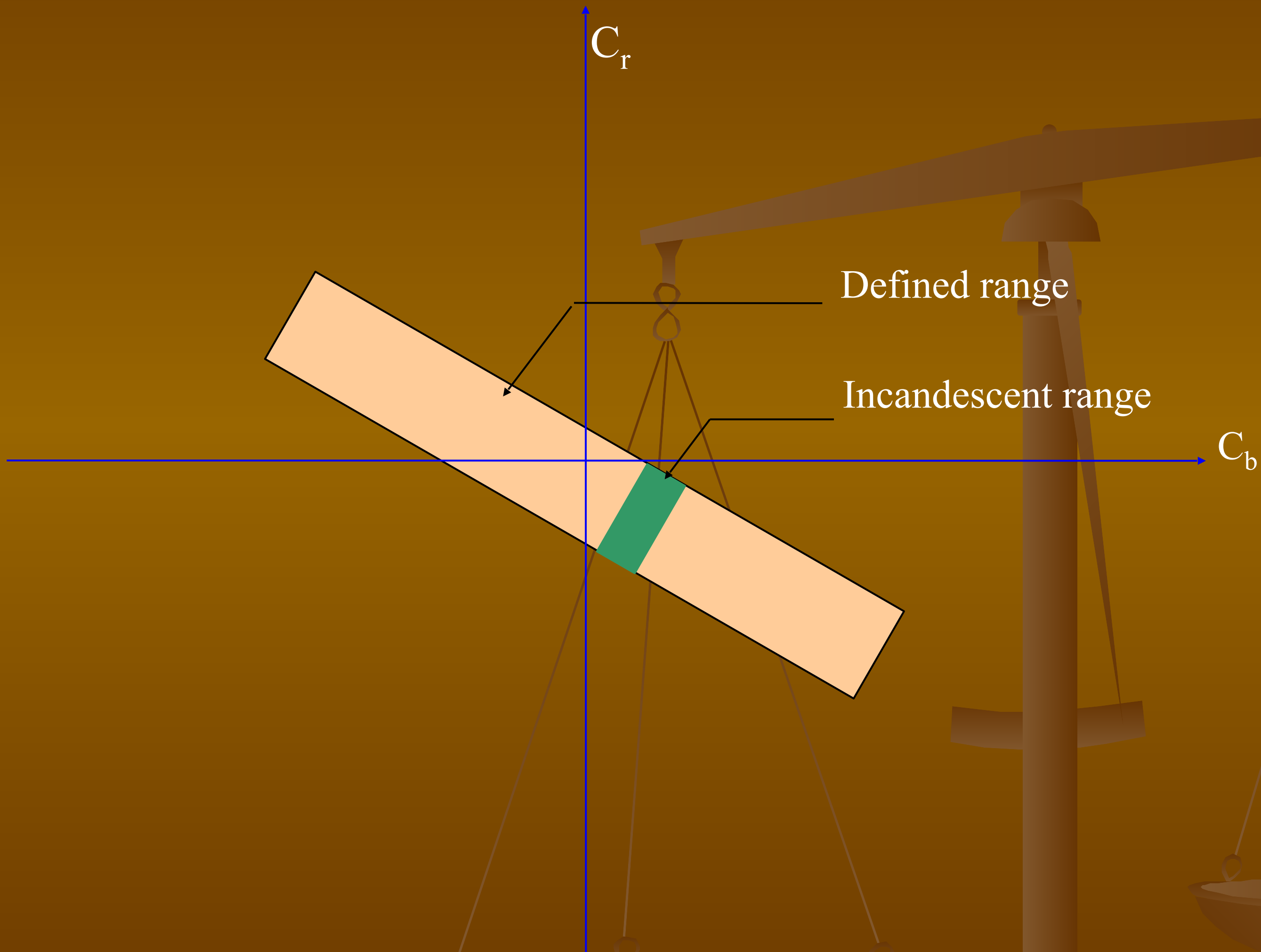



use mouse
to open
window

Drawbacks

- The main drawback of FRM and Chiou's method is consideration of such wide range for component. C_r and C_b
- This predefined range for white color is calculated by considering the extreme color temperature conditions.

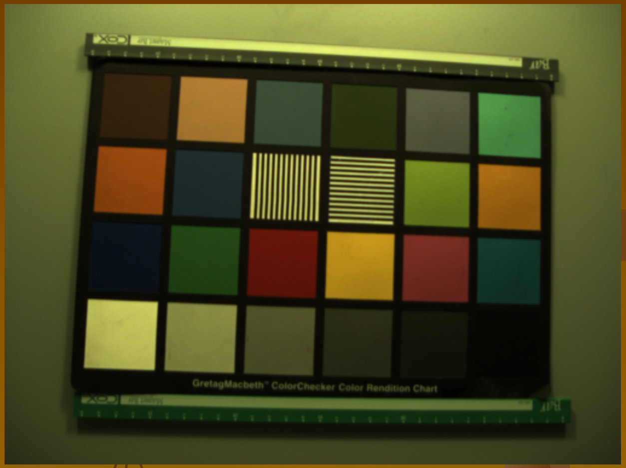
Example



Approximate comparison of white point's defined range in FRM and incandescent range.

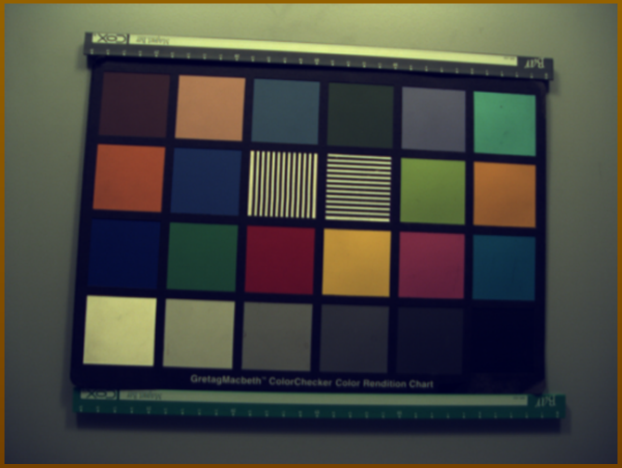
Example- FRM (continued)

Image taken under
Incandescent light source

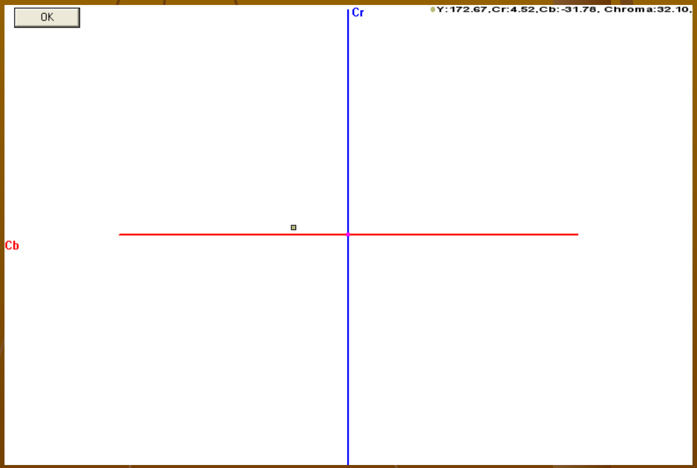


Average value of $\sqrt{C_r^2 + C_b^2}$
for achromatic
patches: 20.3078

Results after applying FRM



Average values of white color patch on C_r-C_b axis

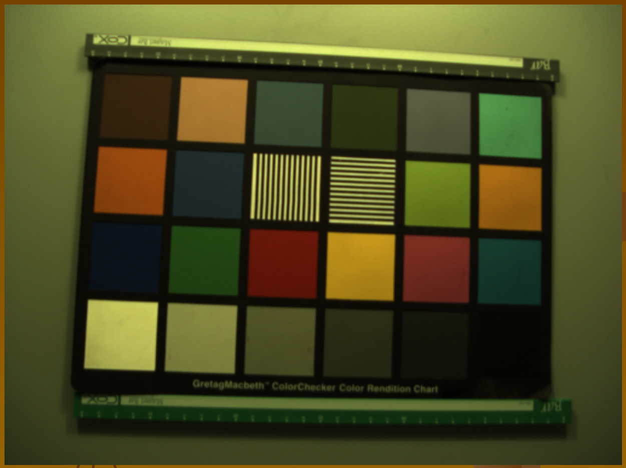


$$Y = 172.67$$
$$C_r = 4.52$$
$$Cb = -31.78$$

Average value of $\sqrt{C_r^2 + C_b^2}$ for achromatic patches: 14.594

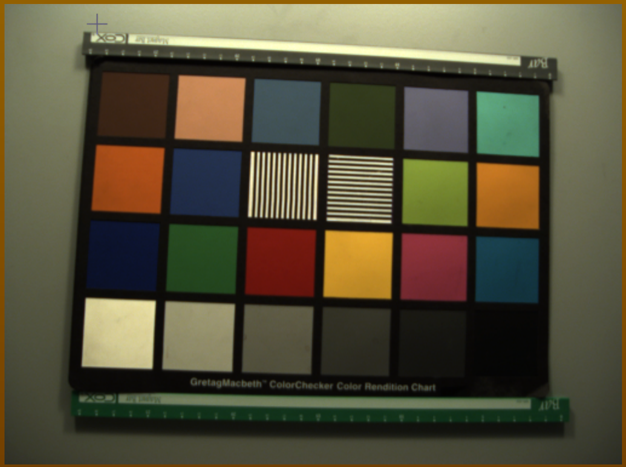
Example- Chiou's Method (continued)

Image taken under Incandescent light source

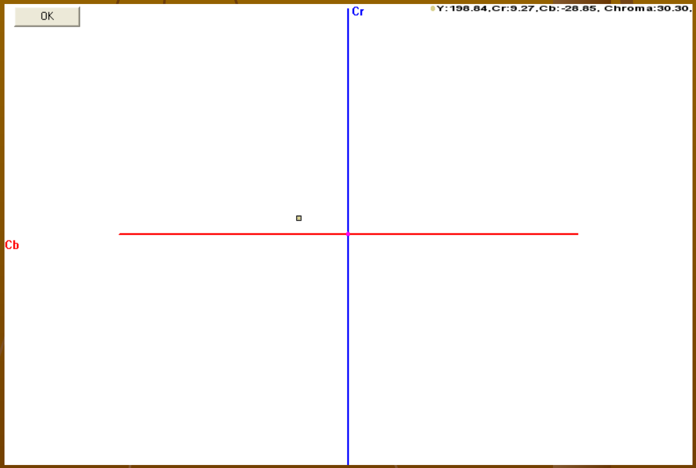


Average value of $\sqrt{C_r^2 + C_b^2}$ for achromatic patches: 20.3078

Results after applying Chiou's method



Average values of white color patch on C_r and C_b axis



$$Y = 198.84$$

$$C_r = 9.27$$

$$Cb = -28.85$$

Average value of $\sqrt{C_r^2 + C_b^2}$ for achromatic patches: 5.9706

Our Method for White Balance

- After detailed study of previously developed white balance methods we propose a new method.
- Main purpose of our method tries to define minimum range of the C_r-C_b values for white point detection.

Steps in Our Method

Start

↓

White Object Purification

↓

White Point Detection

↓

White Balance Adjustment

↓

End

White Object Purification

- For minimizing the C_r-C_b range some pre-processing is needed.
- After some pre-processing, color cast appeared due to the light source partially removed.
- In such a way white object will appear purely white.
- Finding the white object with small range of C_r-C_b values becomes easy.

White Object Purification (continued)

- Pre-process the image with histogram equalization.
- Histogram equalization is the image enhancement technique.
- Applying histogram equalization for each channel separately results in removing the color cast over the image.
- After removing the color cast, the task of detecting the white object from the original image becomes easier.

Flow Chart - White Object Purification

Start

↓

Store the original image data $I_{org}\ (R_{org}, G_{org}, B_{org})$

↓

Apply the histogram equalization to image $I_{Hist}\ (R_{Hist}, G_{Hist}, B_{Hist})$

↓

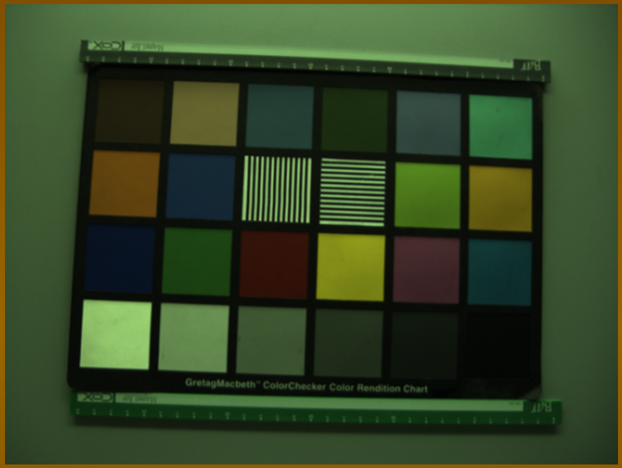
White Point Detection

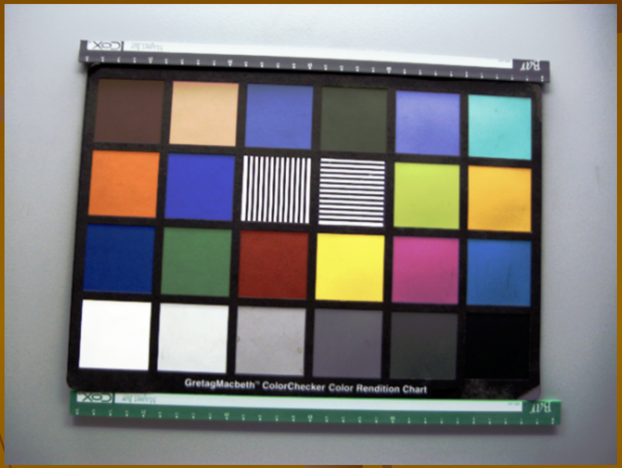
Results after White Object Purification

Original Images

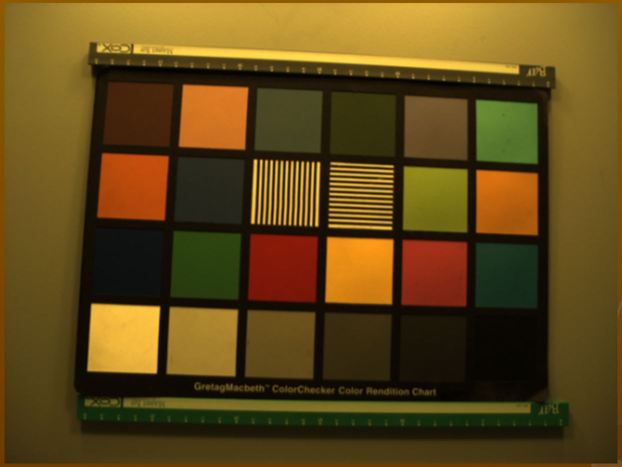
After Histogram Equalization

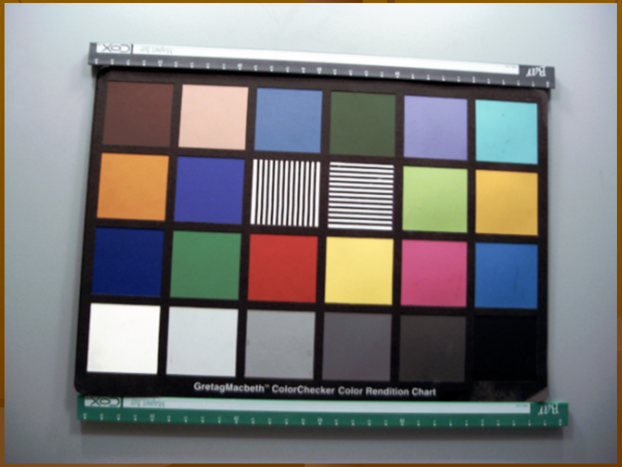
INC





HRZ





INC: Incandescent light source.
HRZ: Horizon light source.

"You have one of the company's most important roles, Larry. You're the guy everyone looks to when they need to feel superior to someone!"

White Point Detection

- Convert the $I_{Hist}(R_{Hist}, G_{Hist}, B_{Hist})$ data from RGB color space to YC_rC_b color space.
  $Y_{Hist}, C_{r\,Hist}, C_{b\,Hist}$
- In this step we find out the probably white pixels.
- The pixels satisfying the following conditions are selected as probably white pixels.

$$Y_{Hist} \geq 210, \text{ and}$$
$$-3 \leq C_{r\,Hist}, C_{b\,Hist} \leq +3$$

White Point Detection (continued)

- Find out the brightest pixel from the probably white pixels.
- The brightest pixel defined as a pixel, with maximum Y_{Hist}, and C_{rHist}, C_{bHist} are close to zero among all probably white pixels.

  $Y_{Hist}^{bright}, C_{rHist}^{bright}, C_{bHist}^{bright}$
- Selection of brightest pixel following such conditions avoids selecting other color pixel as brightest pixel rather than white.

White Point Detection (continued)

- Calculate the average of probably white pixels as,

$$Y^{avg}_{Hist}, C^{avg}_{rHist}, C^{avg}_{bHist}$$

- For finding the reference white pixels, select the maximum and minimum values between $Y^{bright}_{Hist}, C^{bright}_{rHist}, C^{bright}_{bHist}$ and $Y^{avg}_{Hist}, C^{avg}_{rHist}, C^{avg}_{bHist}$ as lower limit Y_l, C_{rl}, and C_{bl} and upper limit Y_u, C_{ru}, and C_{bu} respectively.

White Point Detection (continued)

- If pixel $Y_{Hist}, C_{r\,Hist}, C_{b\,Hist}$ data satisfy following condition then corresponding position pixel from $I_{org}(R_{org}, G_{org}, B_{org})$ data is selected as reference white pixel.

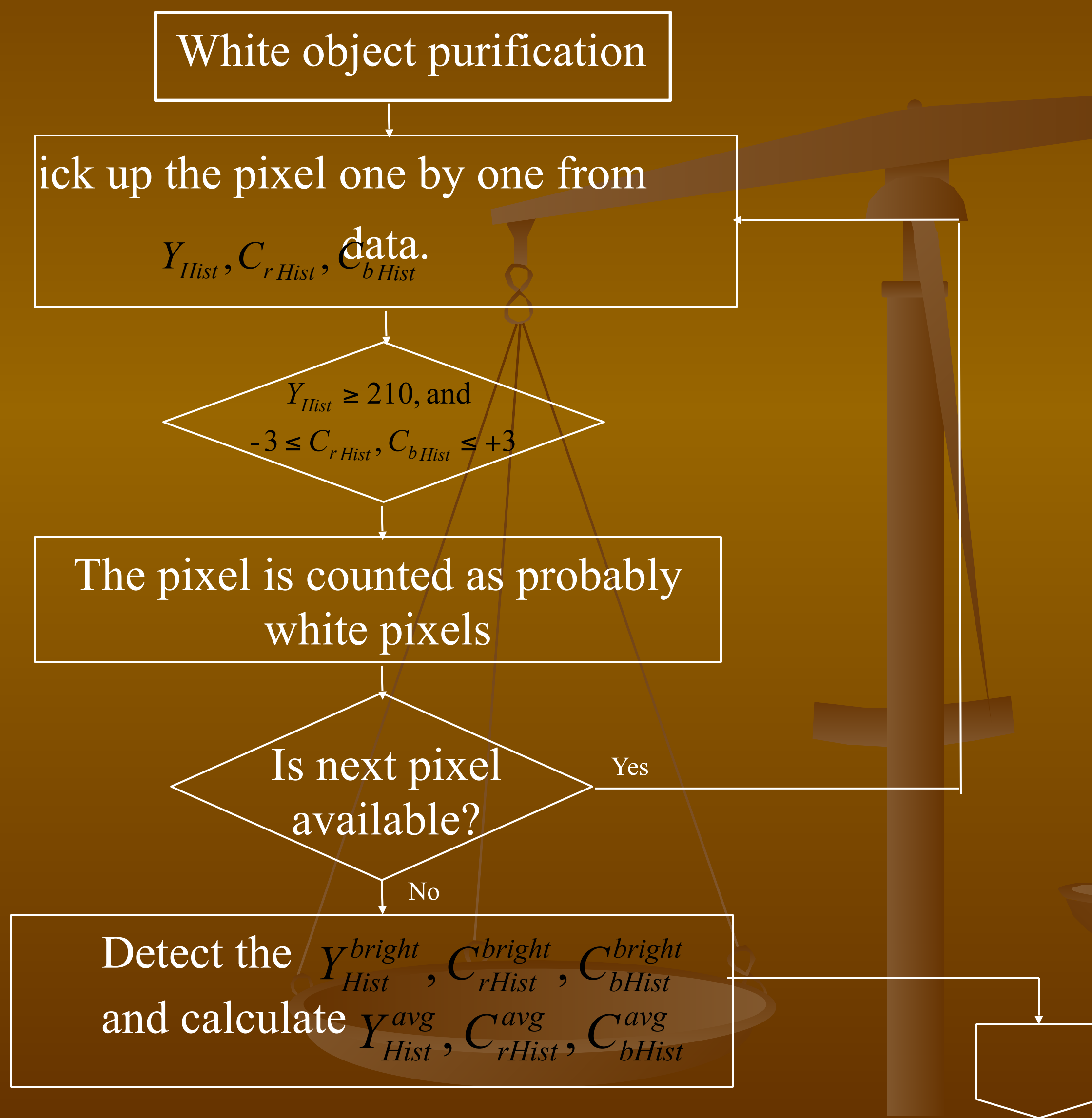
$$Y_l \le Y_{Hist} \le Y_u$$

$$C_{r\,l} \le C_{rHist} \le C_{r\,u}$$

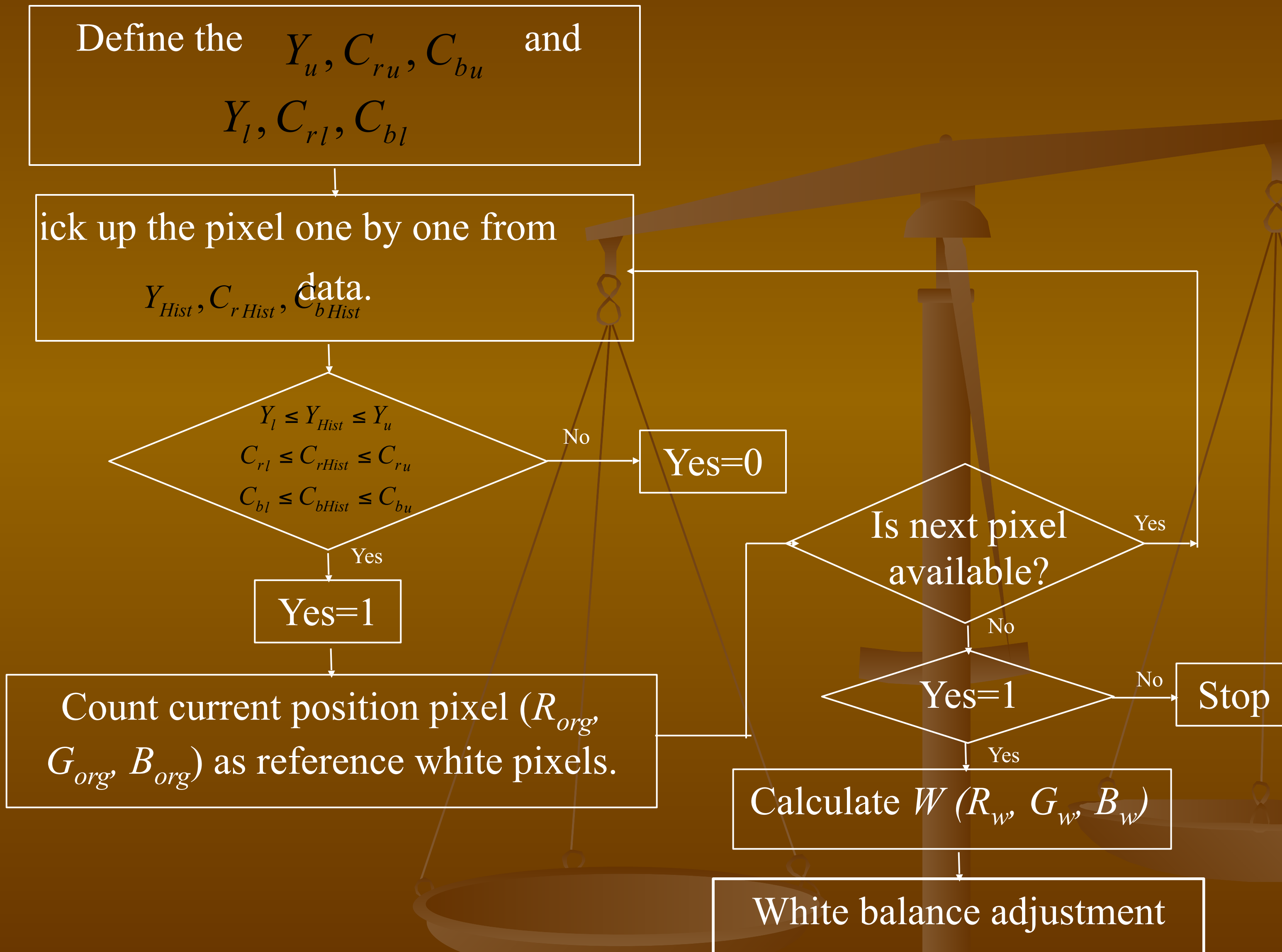
$$C_{b\,l} \le C_{bHist} \le C_{b\,u}$$

- Calculate the average of reference white pixels as $W(R_w, G_w, B_w)$.

Flowchart - White Point Detection



Flowchart - White Point Detection (continued)



White Balance Adjustment

- Calculate the scale factors according to the $W\,(R_w,\ G_w,\ B_w)$.

$$R_{scale} = Y_w / R_w$$
$$G_{scale} = Y_w / G_w$$
$$B_{scale} = Y_w / B_w$$

where,

$$Y_w = 0.299 * R_w + 0.587 * G_w + 0.114 * B_w$$

- Calculate the scale factors according to the GWA.

$$R_{GWA} = Y_{avg} / R_{avg}$$
$$G_{GWA} = Y_{avg} / G_{avg}$$
$$B_{GWA} = Y_{avg} / B_{avg}$$

White Balance Adjustment (continued)

- Set *colorcast* to 1,2 or 3 by using equations,

if $B_{Hist}^{avg} + 3 \geq G_{Hist}^{avg}$ and $B_{Hist}^{avg} > R_{Hist}^{avg}$ then $colorcast = 3$

if $G_{Hist}^{avg} + 3 > R_{Hist}^{avg} > B_{Hist}^{avg}$ then $colorcast = 2$

if $R_{Hist}^{avg} > G_{Hist}^{avg} > B_{Hist}^{avg}$ then $colorcast = 1$

else set $colorcast = 0$.

- Apply the appropriate scale factors to the all image pixels to get white balanced image.

Flow Chart - White Balance Adjustment

Calculate scale factors,

$R_{scale} = Y_w / R_w, G_{scale} = Y_w / G_w, B_{scale} = Y_w / B_w$ and

$R_{GWA} = Y_{avg} / R_{avg}, G_{GWA} = Y_{avg} / G_{avg}, B_{GWA} = Y_{avg} / B_{avg}$

Set the *colorcast* to 0, 1, 2 or 3

Colorcast = 3 — Yes → Apply the scale factors, $R_{factor} = R_{scale}, G_{factor} = G_{scale}$, and $B_{factor} = B_{GWA}$

No

Colorcast = 2 — Yes → Apply the scale factors, $R_{factor} = R_{scale}, G_{factor} = G_{GWA}$, and $B_{factor} = B_{scale}$

No

Colorcast = 1 — Yes → Apply the scale factors, $R_{factor} = R_{GWA}, G_{factor} = G_{scale}$, and $B_{factor} = B_{scale}$

No

Stop


You are here

Simulation Methods

- White balance method based on gray world assumption (GWM).
- White balance method based on perfect reflector assumption (PRM).
- Fuzzy rule method (FRM).
- Chiou's white balance method (CWBM).
- Our white balance method (Our Method).

Standard Light Sources

- The standard light sources used in our experiment with appropriate color temperatures

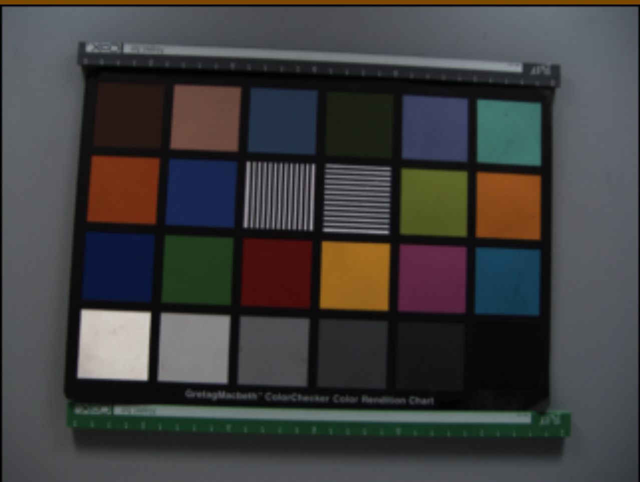
Light Sources	Color Temperature (Kelvin)
Daylight	6575
Cool White	4289
TL84	4100
Incandescent ‘A’	2884
Horizon	2264

Objective and Subjective Evaluation

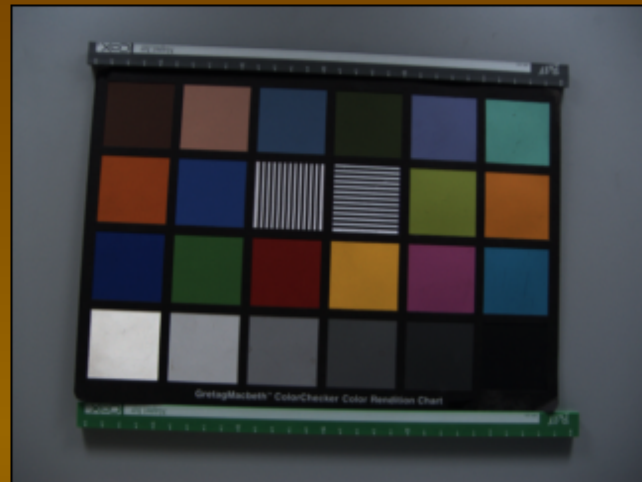
- For objective evaluation (C) we calculate average of chromaticity values, $C = \sqrt{C_r^2 + C_b^2}$ for the achromatic patches of the ColorChecker.
- For Subjective evaluation (S) we ask group of people to vote for the images generated by 5 simulations.

Visual Results under Standard Light Sources

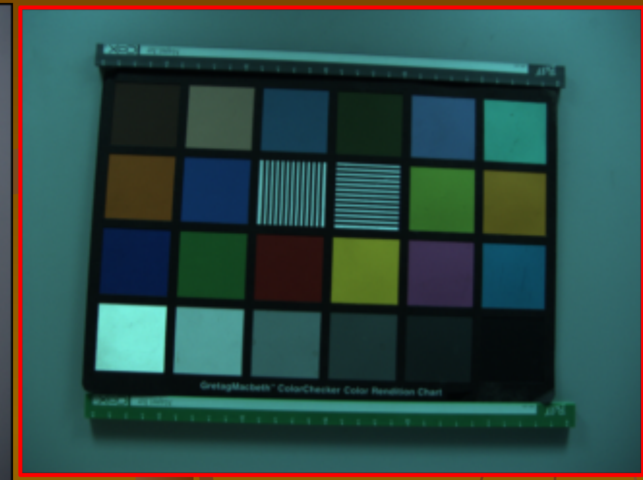
Visual Results – under Daylight Source (a)



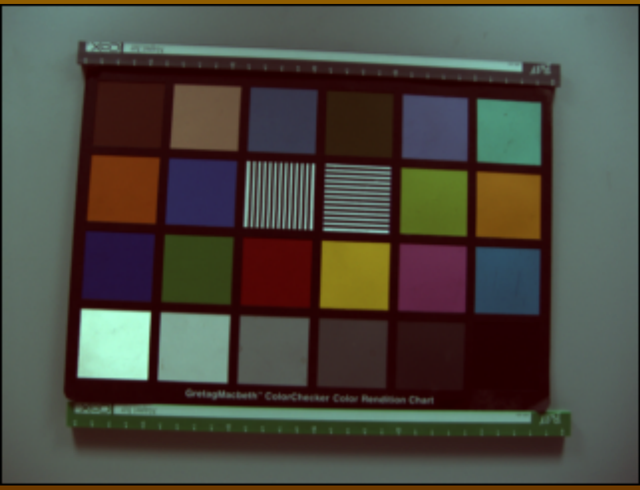
GWM (C= 1.7194, S=4)



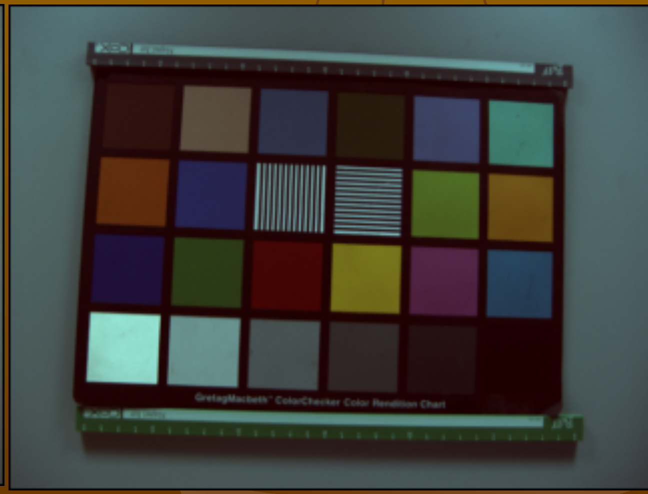
PRM (C= 2.0605, S=1)



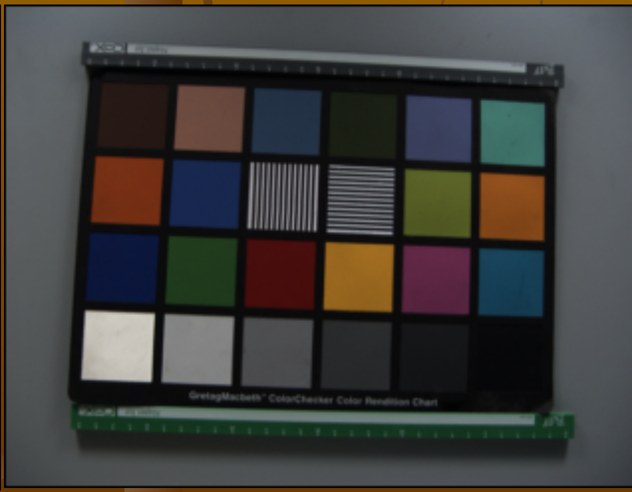
Original (C=23.4772)



CWBM (C= 4.7731, S=1)

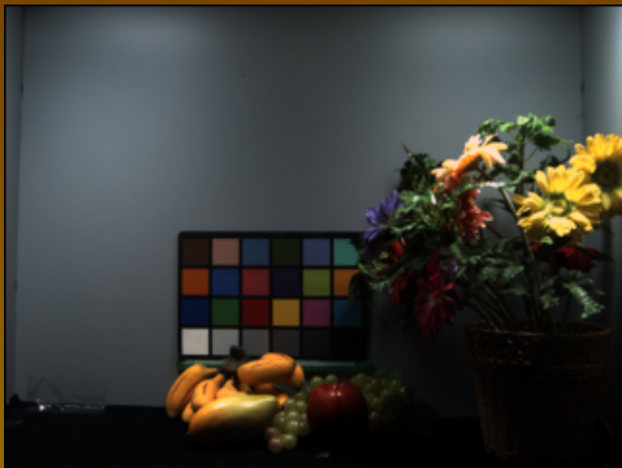


FRM (C= 15.6298, S=0)



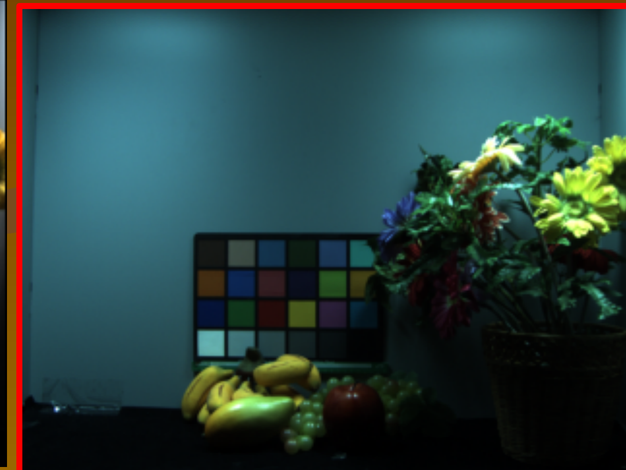
Our Method (C= 1.7142, S=5

Visual Results – under Daylight Source (b)

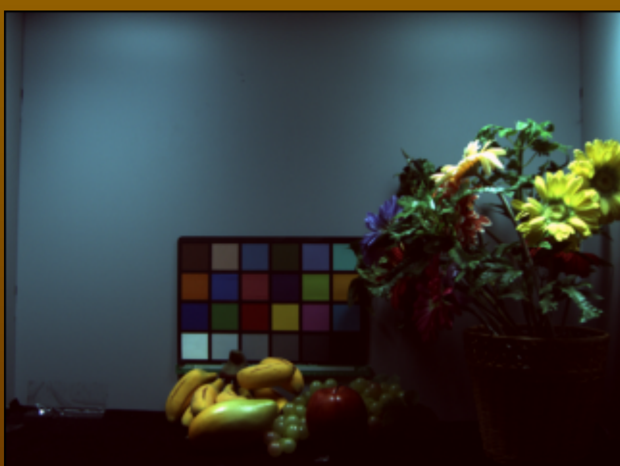


Our Method (C=1.3674, S=3)

GWM (C=1.2698, S=3)

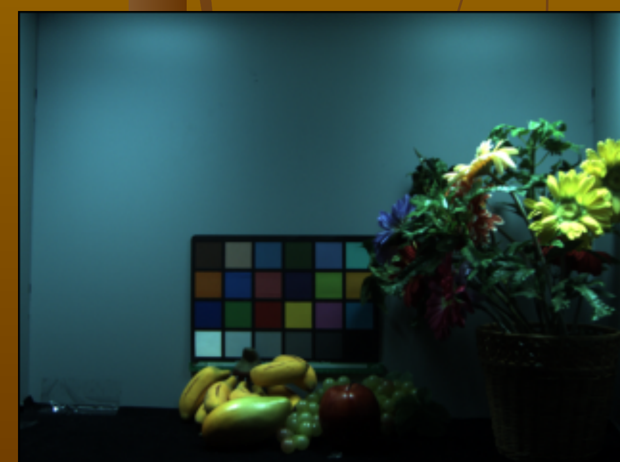


Original (C= 15.6510)



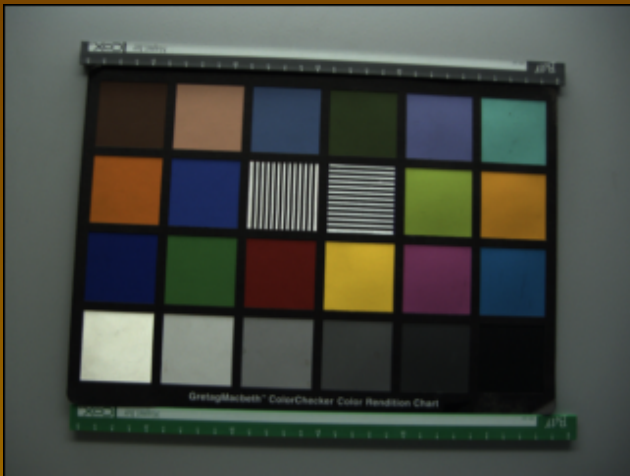
FRM (C=11.1508, S=0)

CWBM (C=9.9731, S=3)

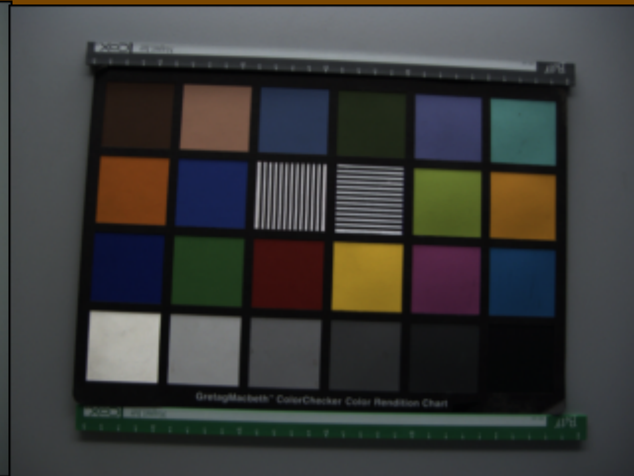


PRM (C=15.651, S=0)

Visual Results – under Cool White Source (a)

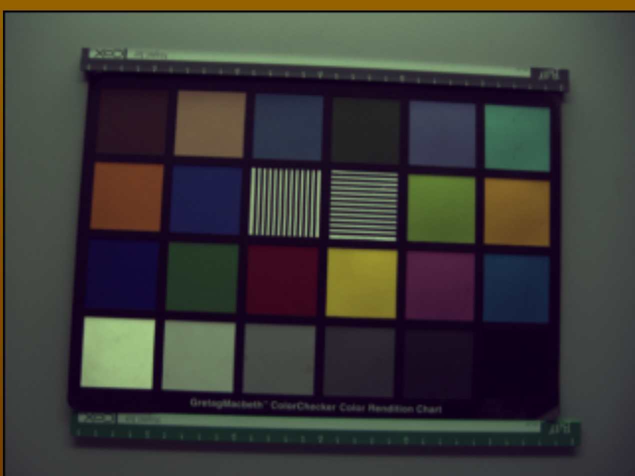


CWBM (C=3.6829, S=6)



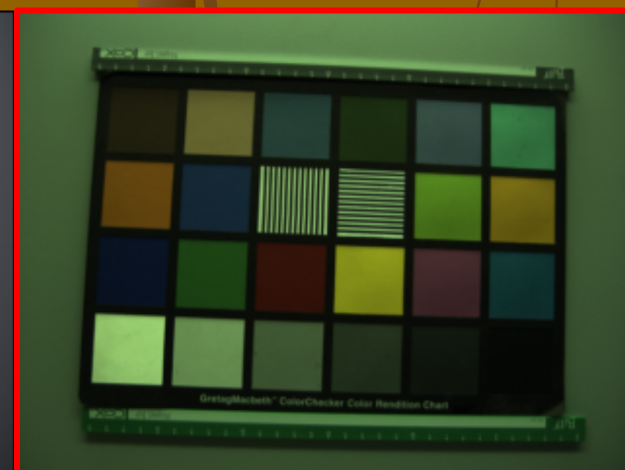
Our Method (C=1.4229, S=3)

PRM (C=1.4231, S=1)



FRM (C=11.5053, S=0)

GWM (C=1.4302, S=2)



Original (C= 16.5733)

Visual Results – under Cool White Source (b)

CWBM (C =6.2603,S=2)

FRM (C =7.0493,S=0)

PRM (C =7.7072,S=0)

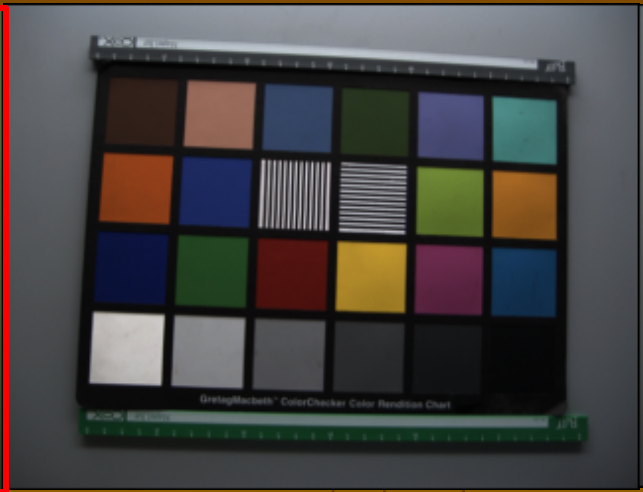
Our Method (C =3.8024,S=3)

GWM (C =1.7156, S=4)

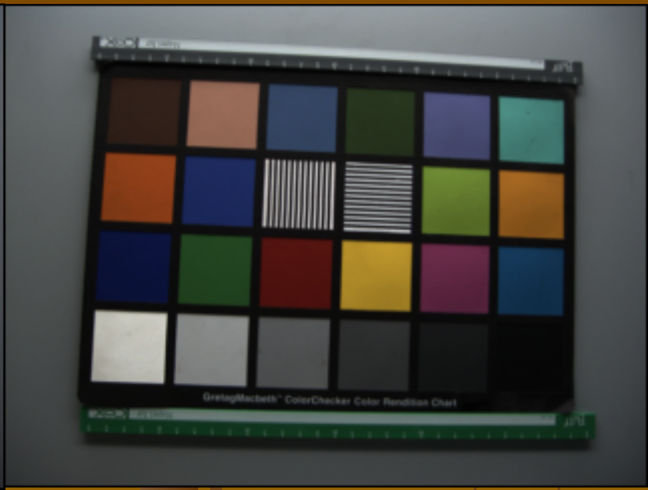
Original (C= 9.3234)

Visual Results – under TL84 Source (a)

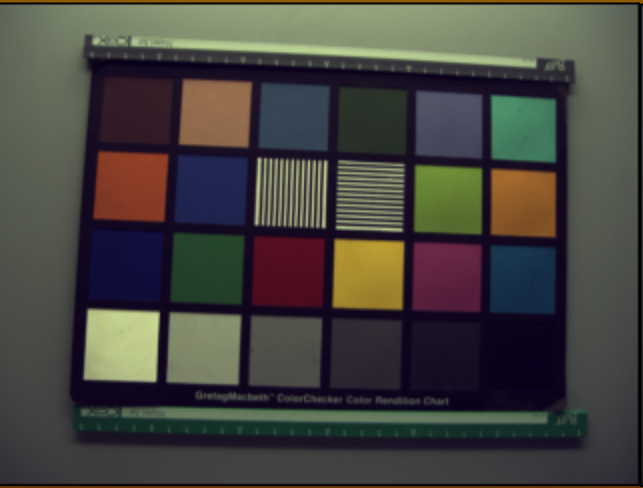
Original (C= 16.3563)



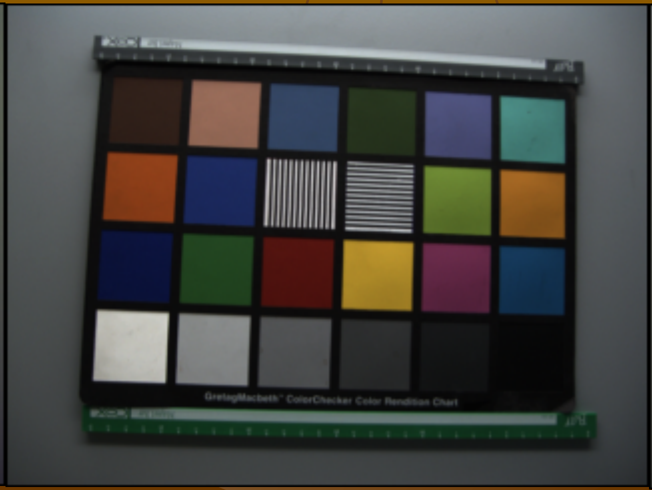
GWM (C =1.4756, S=7)



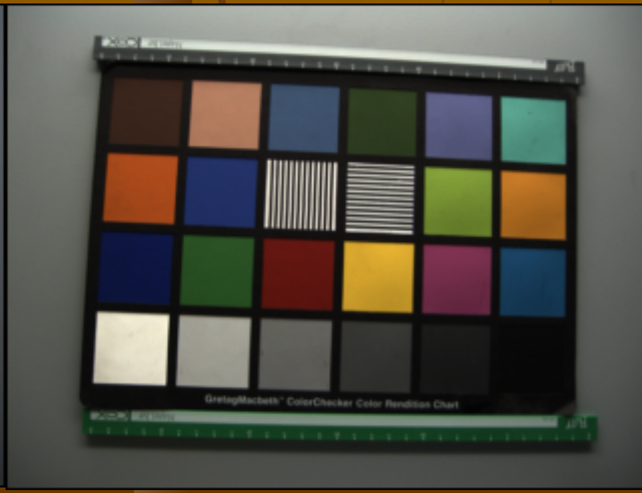
PRM (C =1.4201, S=0)



FRM (C =11.669, S=0)



Our Method (C =1.2949, S=3)



CWBM (C =3.9995, S=0)

Visual Results – under TL84 Source (b)

FRM (C =10.9939, S=0)

CWBM (C =3.9915, S=0)

Our Method (C =3.9754, S=5)

GWM (C =1.5297, S=5)

PRM (C =4.9923, S=0)

Original (C= 9.6106)

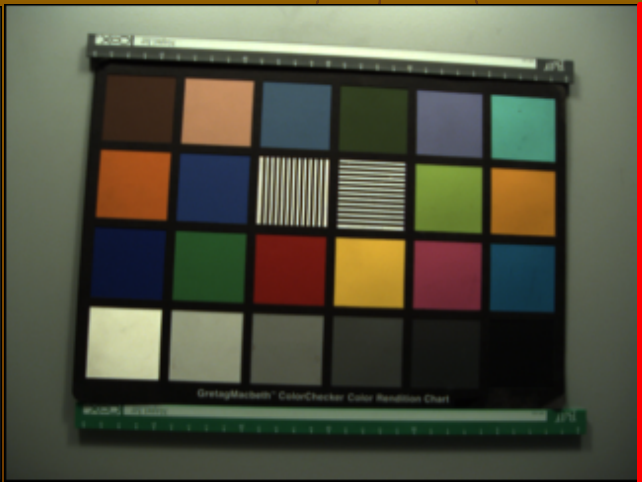
Visual Results – under Incandescent 'A' Source (a)

Our Method (C =2.0867, S=4)

GWM (C =1.0546, S=3)

PRM (C =3.4472, S=0)

FRM (C =14.4021, S=0)



CWBM (C =7.6653, S=2)

Original (C= 20.0768)

Visual Results – under Incandescent ‘A’ Source (b)

Original (C= 10.5618)

PRM (C =9.4584, S=1)

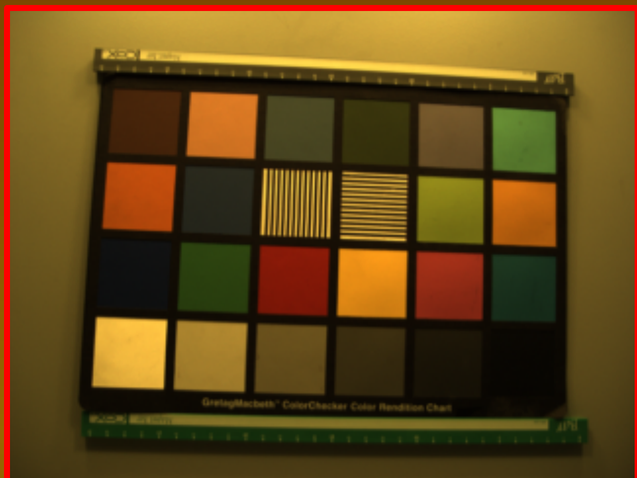
GWM (C =1.0141, S=4)

FRM (C =7.6004, S=1)

CWBM (C =5.9789, S=2)

Our Method (C =1.0851, S=5)

Visual Results – under Horizon Source (a)



Original (C= 33.196)

GWM (C =0.6593, S=4)

Our Method (C =0.7632, S=4)

FRM (C =22.2877, S=0)

CWBM (C =17.2691, S=2)

PRM (C =8.6694, S=0)

Visual Results – under Horizon Source (b)

Original (C= 19.9194)

FRM (C =13.3672, S=0)

PRM (C =9.4737, S=0)

CWBM (C =9.3502, S=3)

GWM (C =1.5718, S=3)

Our Method (C =2.3116, S=4)

Visual Results under Natural and Household Light Sources

Visual Results – Greenery

Captured outdoor at 5.30 pm under no-sunny climate

Original (C= 20.7315)

Our Method (C =9.1162, S=7)

PRM (C =20.7315, S=2)

FRM (C =20.9088, S=0)

CWBM (C =21.1899, S=0)

GWM (C =25.1198, S=0)

Visual Results – Steps

Captured indoor at 11.00 am under sunny climate

Original (C= 20.0944)

Our Method (C =2.9776 , S=3)

PRM (C =5.7905 , S=2)

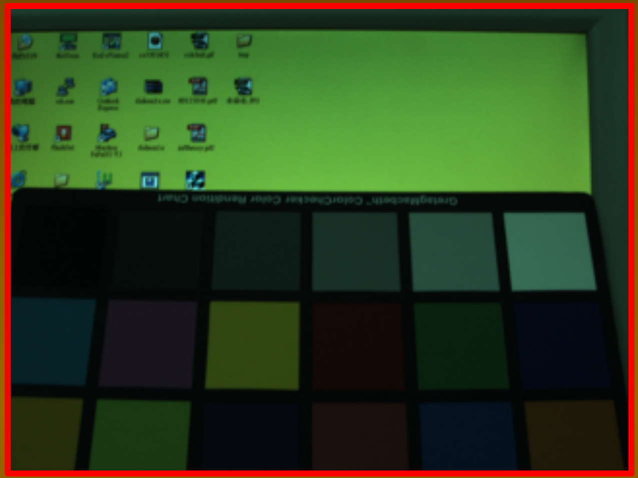
FRM (C =19.2823, S=1)

CWBM (C =17.9334 , S=4)

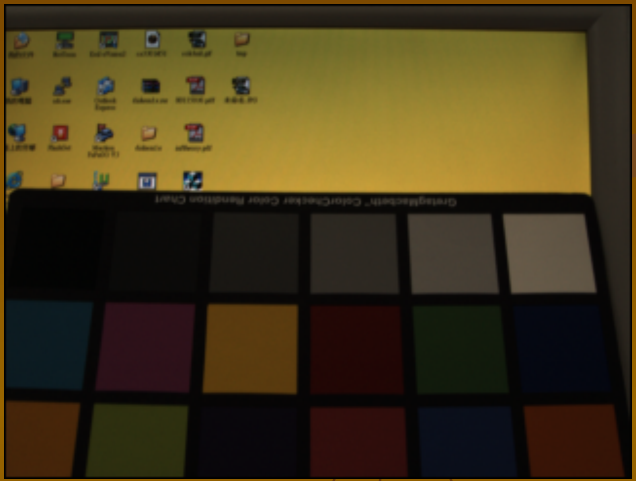
GWM (C =16.3632 , S=1)

Visual Results – LCD

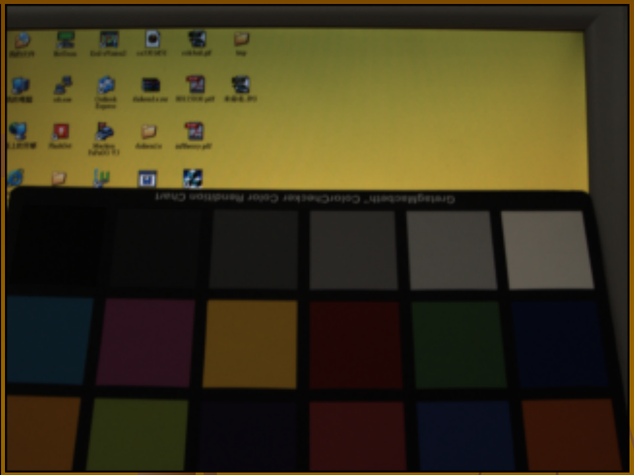
Captured under LCD (Liquid Crystal Display) light



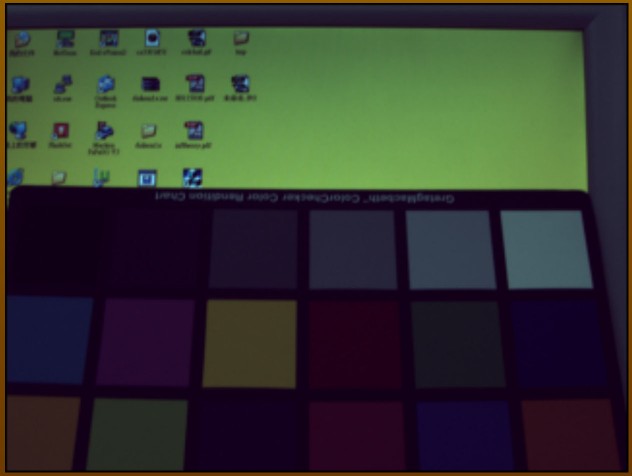
Original (C = 10.5008)



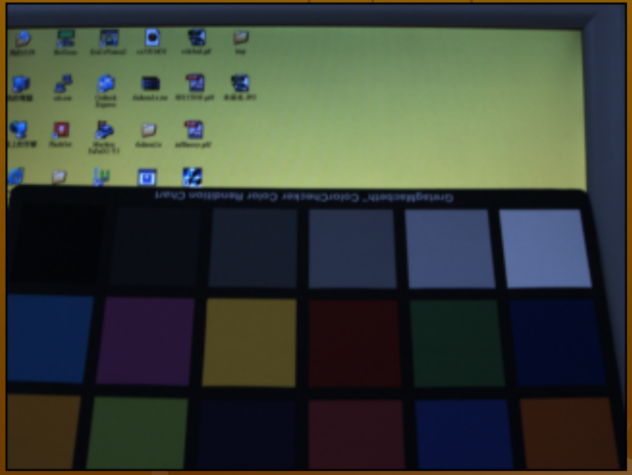
PRM (C=5.004, S=1)



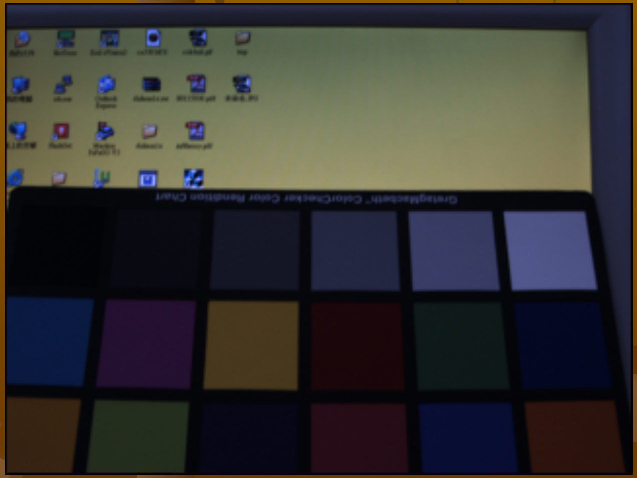
Our Method (C=2.5085, S=5)



FRM (C=11.8503, S=0)



CWBM (C=13.9504, S=3)



GWM (C=12.8298, S=0)

Visual Results – Fog

Captured indoor at 3.00 pm under sunny climate with little fog.

PRM (C=24.6286 , S=0)

CWBM (C=14.5046 , S=3)

FRM (C=16.8369 , S=0)

Original (C = 24.6286)

Our Method (C=7.9345 , S=5)

GWM (C=15.7073, S=1)

Visual Results – Cat

Captured indoor at 10.00 am under household light source.

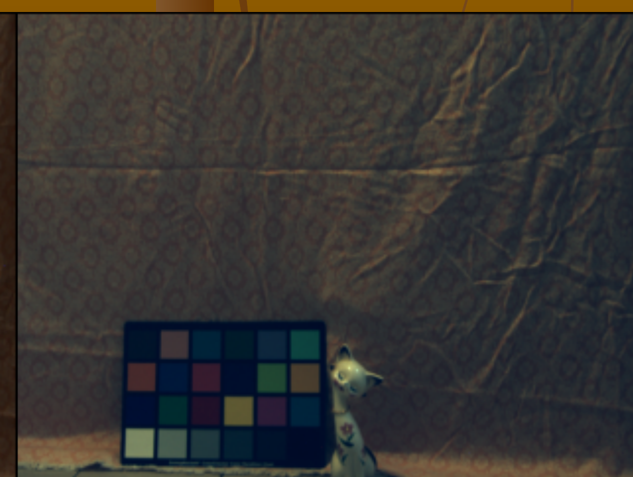
GWM (C=19.3405, S=1)

CWBM (C =19.3868 , S=2)

Original (C = 15.5105)

PRM (C =6.3096 , S=1)

Our Method (C =2.6452 , S=6)



FRM (C =16.2237 , S=1)

Comparing the Situation with and without Macbeth ColorChecker

Original Image- Dolls

Indoor: taken under household lighting conditions

(a): with Macbeth ColorChecker

C= 11.2114

(b): without Macbeth ColorChecker

Result of our method

(a) C=4.384

S=2

(b) S=3

(a)

Result of GWM

(a) C=7.9422

S=3

(b) S=1

(b)

Result of PRM

(a) C=7.1047

S=1

(b) S=1

Result of FRM

(a) C=9.496

S=1

(b) S=0


(a)

Result of CWBM

(a) C=9.9728

S=6

(b) S=7


(b)

(a)

Original Image- Football

Indoor: taken under cloudy weather conditions

(a): with Macbeth ColorChecker

C= 19.164

(b): without Macbeth ColorChecker

(b)

Result of Our Method

(a) C=1.7266

S=5

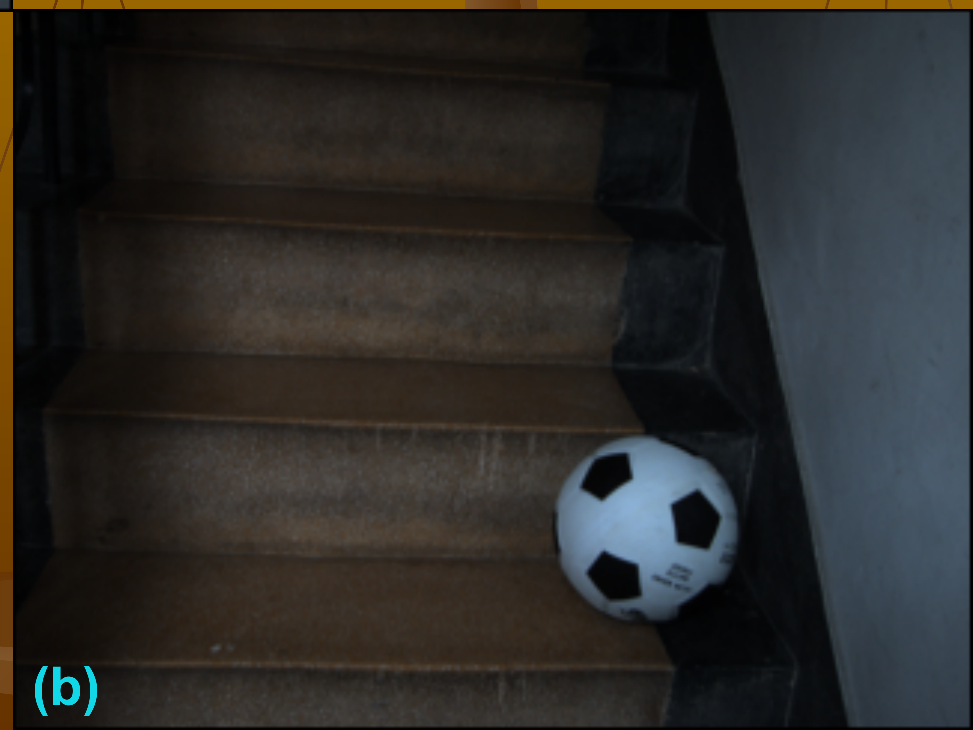
(b) S=5

Result of GWM

(a) C=12.1265

S=1

(b) S=2

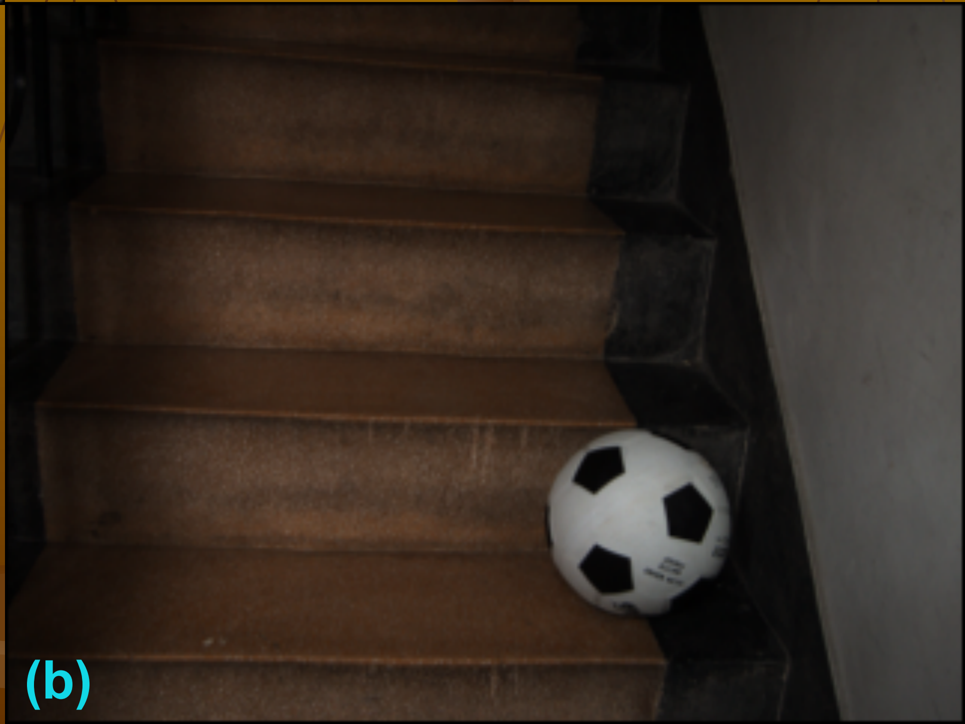


Result of PRM

(a) C=2.4542

S=3

(b) S=3



Result of FRM

(a) C=16.5689

S=1

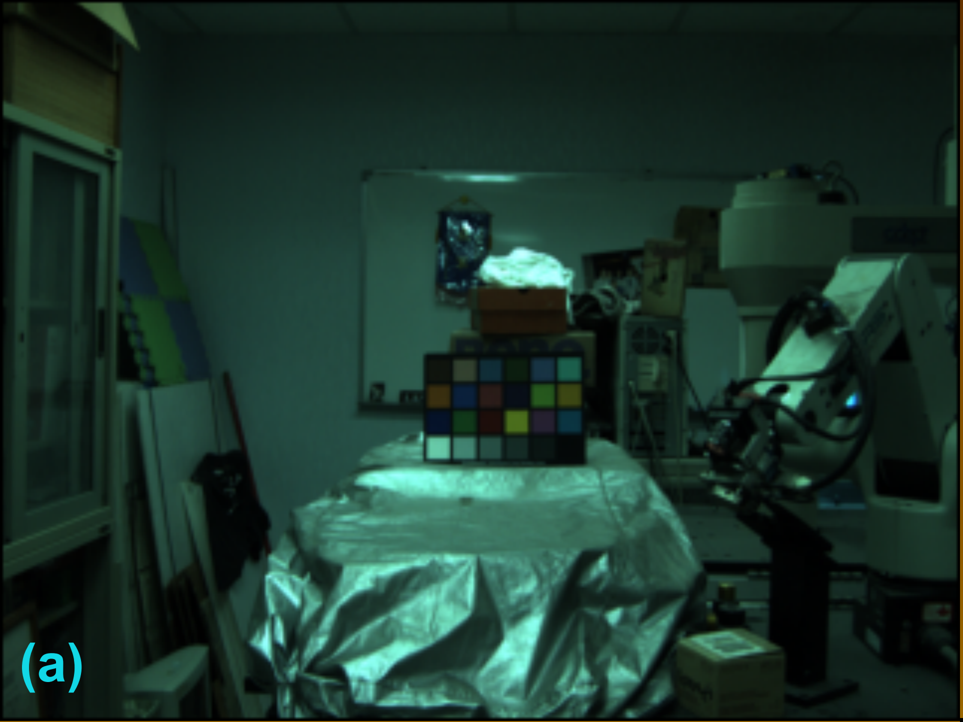
(b) S=1

Result of CWBM

(a) C=9.1797

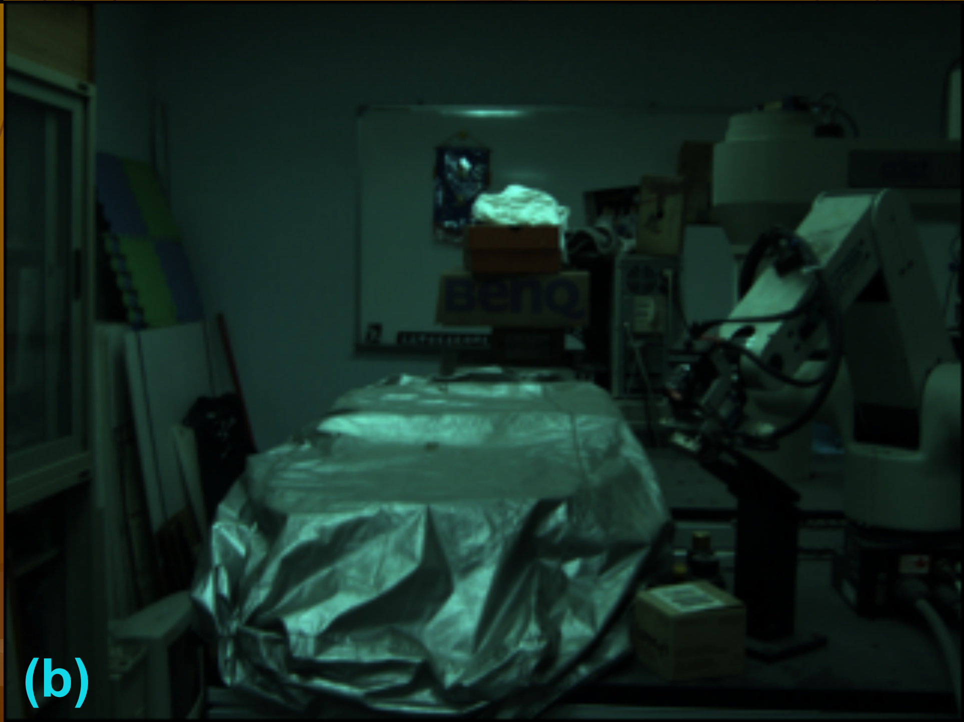
S=3

(b) S=3


(a)

Original Image- Lab

Indoor: taken under household lighting conditions
(a): with Macbeth ColorChecker
C= 19.2308
(b): without Macbeth ColorChecker


(b)

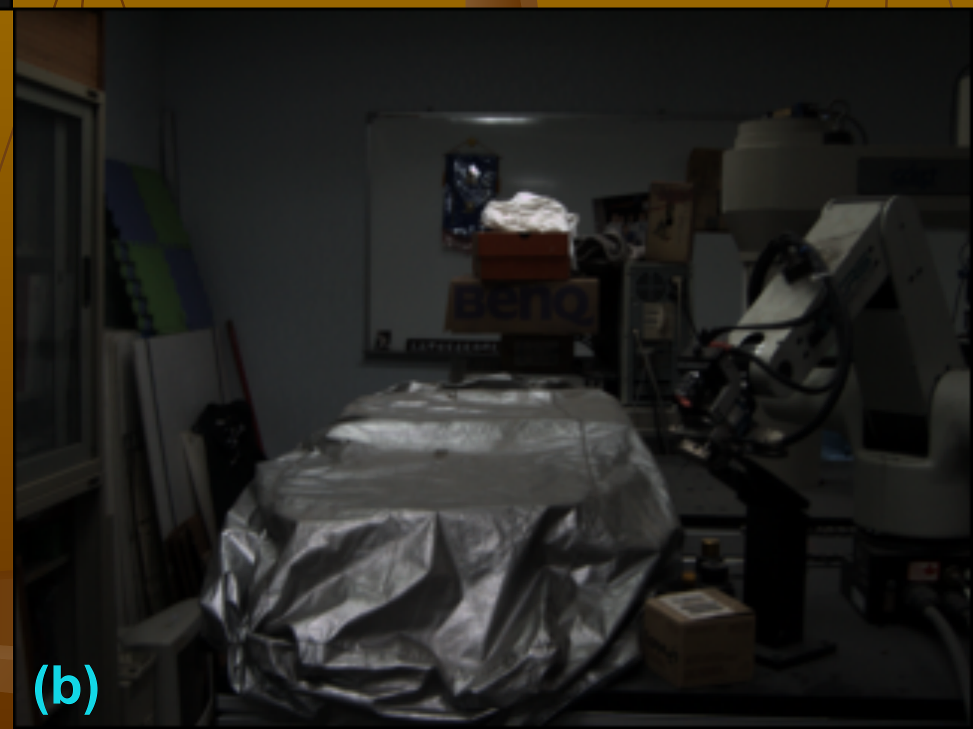
Result of Our Method

(a) C=1.33

S=7

(b) S=7

(a)



(b)

Result of GWM

(a) C=2.1064

S=7

(b) S=6

(a)

Result of PRM

(a) C=15.107

S=0

(b) S=1

(b)

Result of FRM

(a) C=13.2566

S=1

(b) S=1

Result of CWBM

(a) C=8.6913

S=1

(b) S=1

Original Image- Pots

Outdoor: taken under sunny climate

(a): with Macbeth ColorChecker

C=19.0996

(b): without Macbeth ColorChecker

(a)

(b)

Result of Our Method

(a) C=15.0289

S=7

(b) S=7

Result of GWM

(a) C=26.3661

S=1

(b) S=1

Result of PRM

(a) C=19.0996

S=3

(b) S=2


(a)


(b)

Result of FRM

(a) C=21.0041

S=1

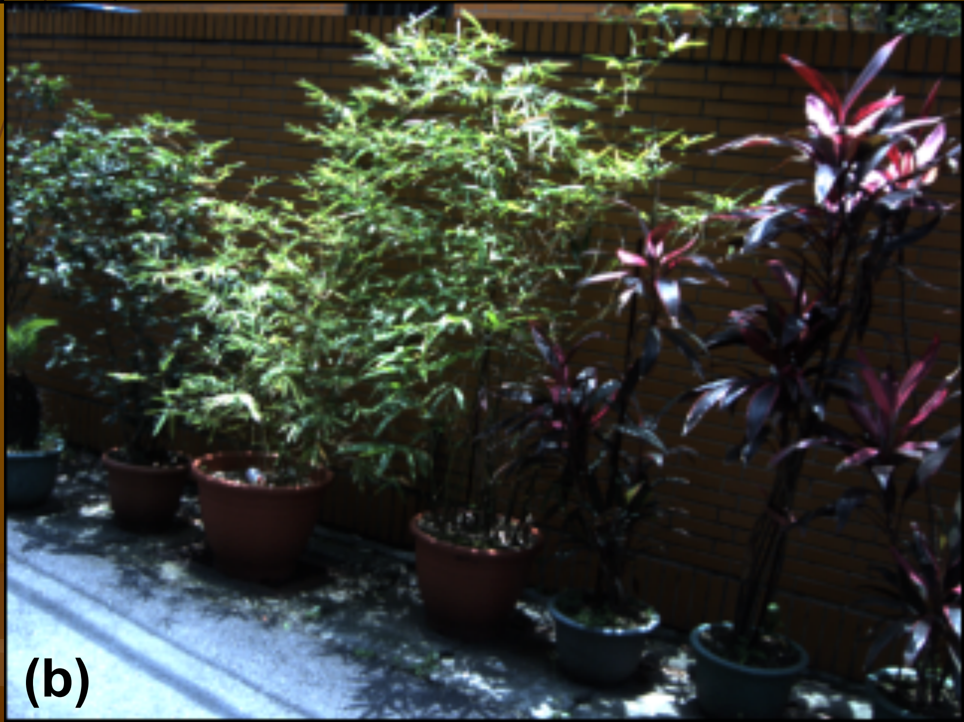
(b) S=1

Result of CWBM

(a) C= 23.3468

S=3

(b) S=2



Original Image- Building

Outdoor: taken under cloudy climate

(a): with Macbeth ColorChecker

C= 23.0667

(b): without Macbeth ColorChecker

(a)

(b)

Result of Our Method

(a) C=10.2176

S=8

(b) S=6

Result of GWM

(a) C=21.1726

S=2

(b) S=2

Result of PRM

(a) C=23.0667

S=0

(b) S=0

Result of FRM

(a) C=23.0157

S=1

(b) S=2

Result of CWBM

(a) C=21.2065

S=4

(b) S=4

Results – Objective and Subjective Evaluation

IMAGE		Original	SIMULATION				
			GWM	PRM	FRM	CWBM	Our Method
Daylight	(a)	23.4772	(4) 1.7194	(1) 2.0605	(0) 15.6298	(1) 4.7731	(5) **1.7142**
	(b)	15.6510	(3) **1.2698**	(0) 15.651	(0) 11.1508	(3) 9.9731	(3) 1.3674
Cool White	(a)	16.5733	(2) 1.4302	(1) 1.4231	(0) 11.5053	(6) 3.6829	(3) **1.4229**
	(b)	9.3234	(4) **1.7156**	(0) 7.7072	(0) 7.0493	(2) 6.2603	(3) 3.8024
TL84	(a)	16.3563	(7) 1.4756	(0) 1.4201	(0) 11.669	(0) 3.9995	(3) **1.2949**
	(b)	9.6106	(5) **1.5297**	(0) 4.9923	(0) 10.9939	(0) 3.9915	(5) 3.9754
Inc. ‘A’	(a)	20.0768	(3) **1.0546**	(0) 3.4472	(0) 14.4021	(2) 7.6653	(4) 2.0867
	(b)	10.5618	(4) **1.0141**	(1) 9.4584	(1) 7.6004	(2) 5.9789	(5) 1.0851
Horizon	(a)	33.196	(4) **0.6593**	(0) 8.6694	(0) 22.2877	(2) 17.2691	(4) 0.7632
	(b)	19.9194	(3) **1.5718**	(0) 9.4737	(0) 13.3672	(3) 9.3502	(4) 2.3116
Greenery		20.7315	(0) 25.1198	(2) 20.7315	(0) 20.9088	(0) 21.1899	(7) **9.1162**
Steps		20.0944	(1) 16.3632	(2) 5.7905	(1) 19.2823	(4) 17.9334	(3) **2.9776**
Cat		15.5105	(1) 19.3405	(1) 6.3096	(1) 16.2237	(2) 19.3868	(6) **2.6452**
LCD		10.5008	(0) 12.8298	(1) 5.004	(0) 11.8503	(3) 13.9504	(5) **2.5085**
Fog		24.6286	(1) 15.7073	(0) 24.6286	(0) 16.8369	(3) 14.5046	(5) **7.9345**

( ): Subjective evaluation (number of votes).

Results – Objective and Subjective Evaluation (continued)

IMAGE		Original	SIMULATION				
			GWM	PRM	FRM	CWBM	Our Method
Dolls	**(a)**	11.2114	(3) 7.9422	(1) 7.1047	(1) 9.496	(6) 9.9728	(2) **4.384**
	(b)	——	(1) ——	(1) ——	(0) ——	(7) ——	(3) ——
Football	**(a)**	19.164	(1) 12.1265	(3) 2.4542	(1) 16.5689	(3) 9.1797	(5) **1.7266**
	(b)	——	(2) ——	(3) ——	(1) ——	(3) ——	(5) ——
Lab	**(a)**	19.2308	(7) 2.1064	(0) 15.107	(1) 13.2566	(1) 8.6913	(7) **1.33**
	(b)	——	(6) ——	(1) ——	(1) ——	(1) ——	(7) ——
Pots	**(a)**	19.0996	(1) 26.3661	(3) 19.0996	(1) 21.0041	(3) 23.3468	(7) **15.0289**
	(b)	——	(1) ——	(2) ——	(1) ——	(2) ——	(7) ——
Building	**(a)**	23.0667	(2) 21.1726	(0) 23.0667	(1) 23.0157	(4) 21.2065	(8) **10.2176**
	(b)	——	(2) ——	(0) ——	(2) ——	(4) ——	(6) ——

( ): Subjective evaluation (number of votes).

Picture taken from airplane

Original

GWM

PRM

FRM

CWBM

Our Method

References

[1] R. S. Burns, Billmeyer, and Saltzman's Principals of Color Technology, Wiley-Interscience. New York, NY, 2000.

[2] PhotoIsland, "'Striped' Sensor Arrays," http://arctic.photoisland.com/servlet/com.arcsoft.NewsInfo?com=arcsoftPI&aw p=buyguid.html,2004.

[3] P. Green, Understanding Digital Color, GATFPress, Sewickley, PA, 1999.

[4] F. Al-Turkait, "Specular Reflection," http://ise.stanford.edu/class/psych221/projects/99/fahad/Spec_Ref_Intro.html, 1999.

[5] J. Chiang, "Gray World Assumption," http://ise.stanford.edu/class/psych221/projects/99/jchiang/intro2.html, 1999.

[6] V. Kunin, "The sunset over the Pacific," http://www.ebi.ac.uk/~kunin/camera/ocean.jpg, 2004.

[7] Y. C. Cheng, W. H. Chan, and Y.Q. Chen, "Automatic White Balance for Digital Still Camera," IEEE Transactions on Consumer Electronics, Volume 41, pp. 460-466, 1995.

[8] T. S. Chiou, "Automatic White Balance for Digital Still Camera," Master Thesis, Department of Computer Science and Information Engineering, National Taiwan University, Taiwan, 2000.

[9] R. C. Gonzalez and R. E. Woods, Digital Image Processing, Prentice-Hall, New Jersey, 2002.

Thank You

Questions & Answers

Failure of Histogram Equalization

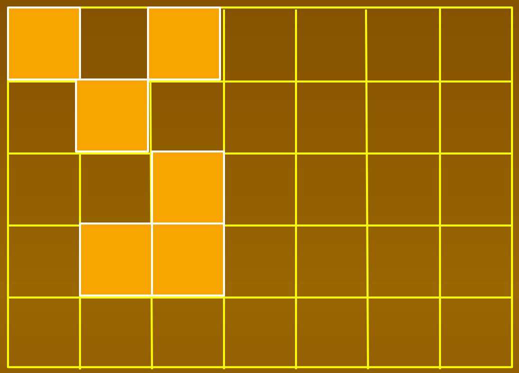
Original Image

After Histogram Equalization

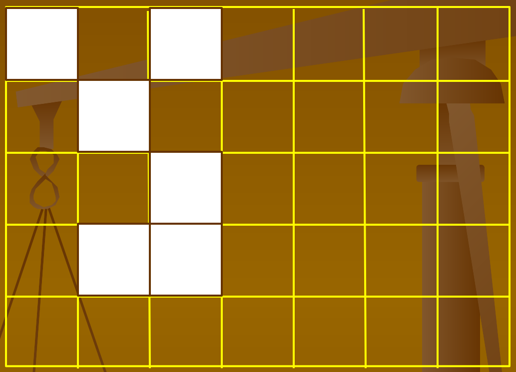
Weather condition: Little cloudy but sunny

Details

Original Image Pixel Data



Histogram Equalized Image Pixel Data



Pixels satisfying condition,

$$Y_l \leq Y_{Hist} \leq Y_u$$

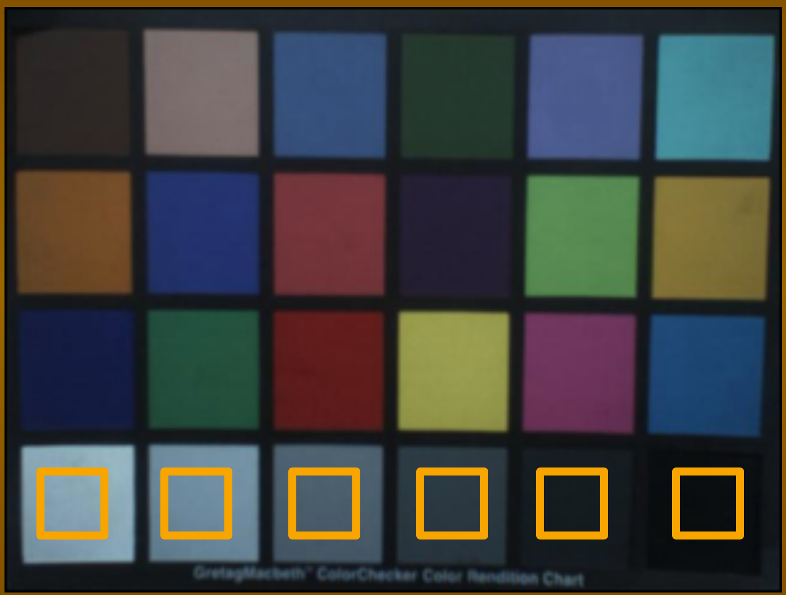
$$C_{rl} \leq C_{rHist} \leq C_{ru}$$

$$C_{bl} \leq C_{bHist} \leq C_{bu}$$

Corresponding position pixels are selected as reference white pixels

Drawback- PRA

Experiments



Daylight Source (6575 °K)

Horizon Light Source (2264 °K)