

Accuracy of sRGB colour reproduction through a camera and a LCD imaging display

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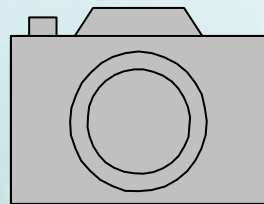
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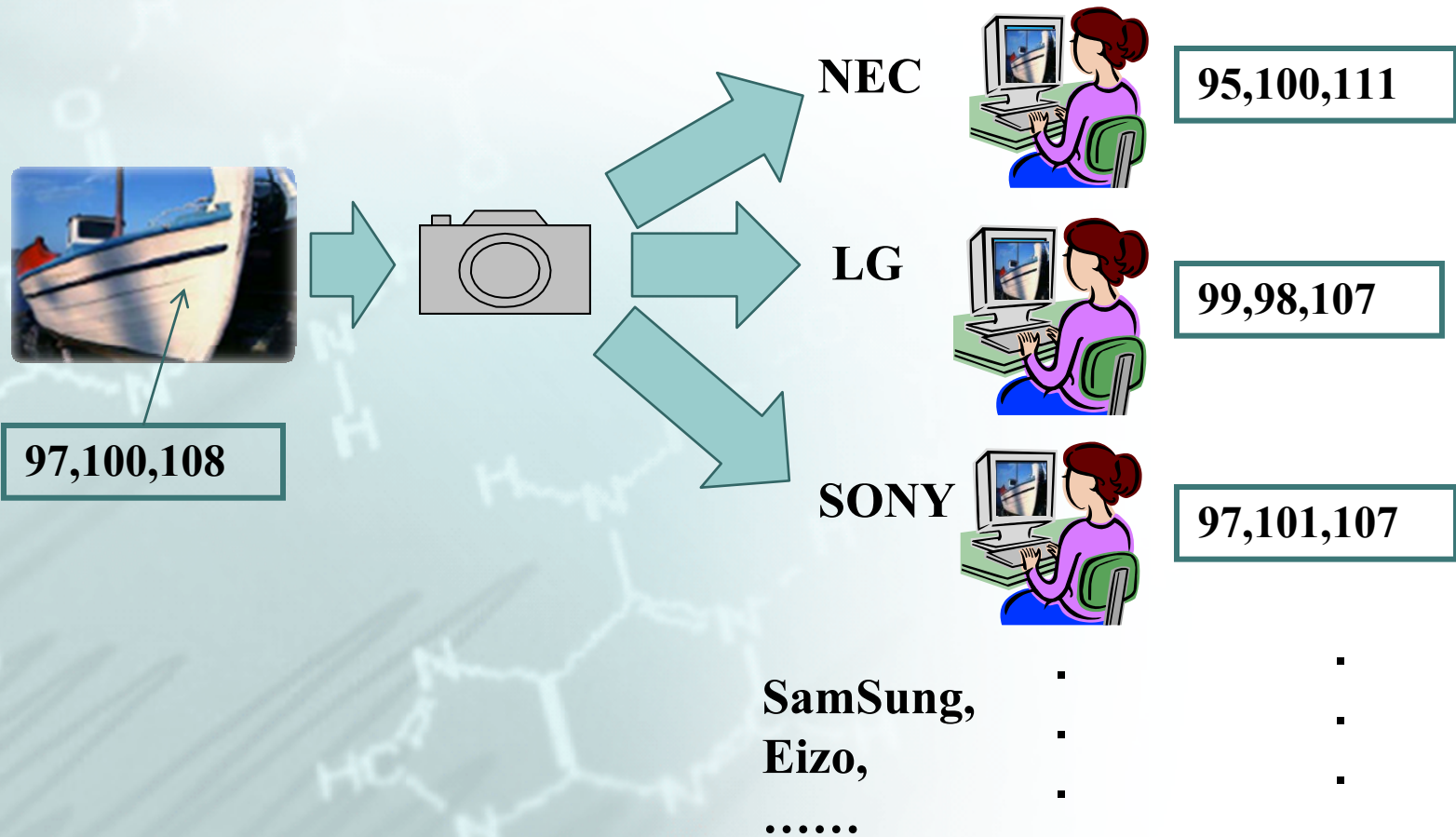
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4. Conclusion

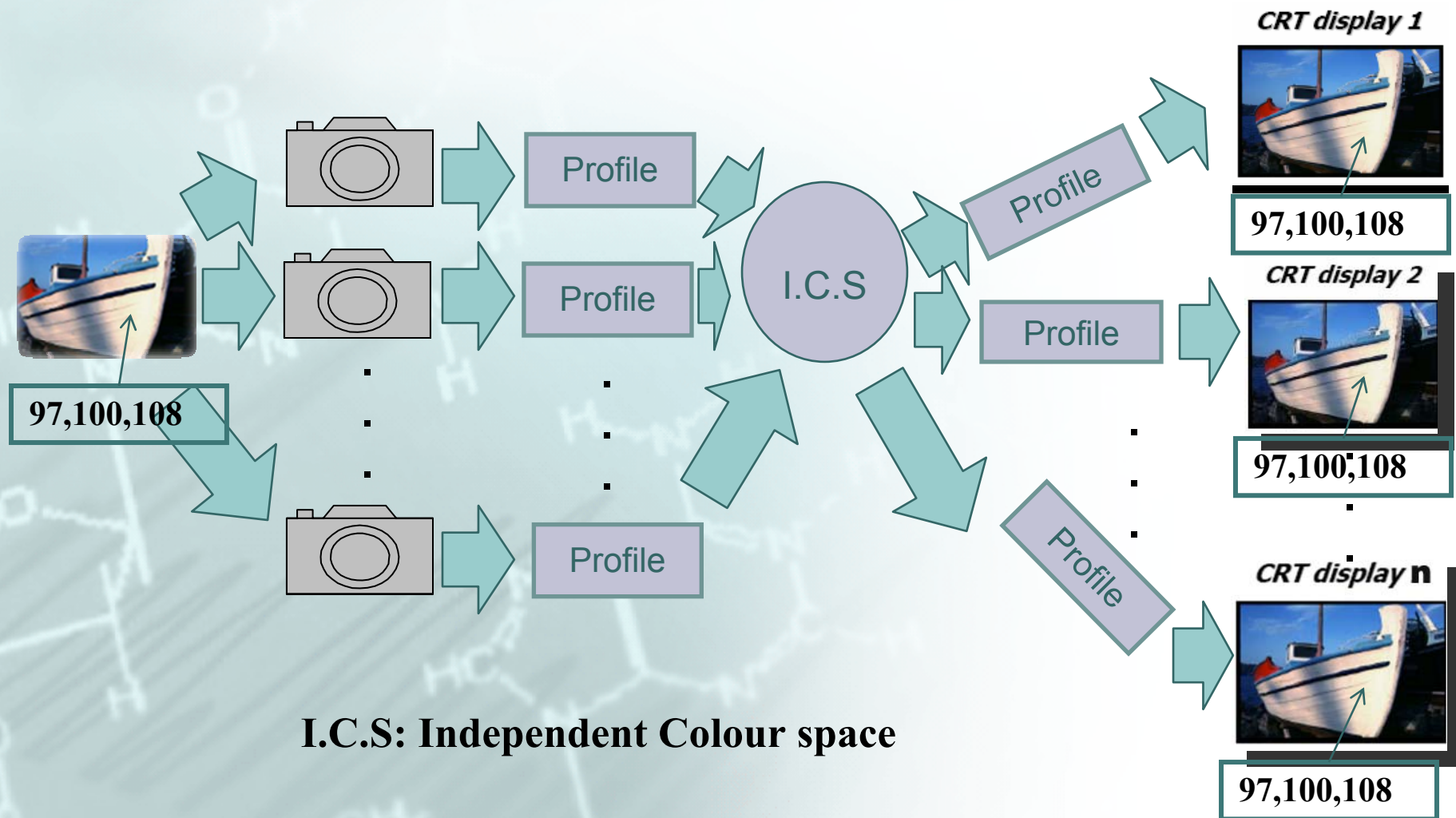
Accuracy of colour reproduction



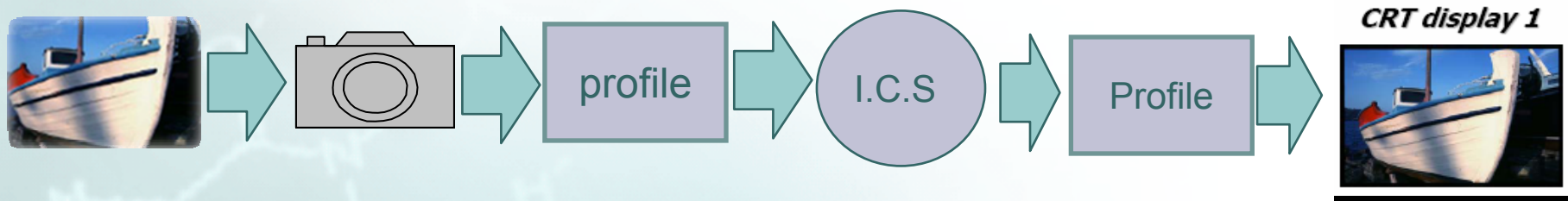
Accuracy of colour reproduction



Accuracy of colour reproduction



Accuracy of colour reproduction

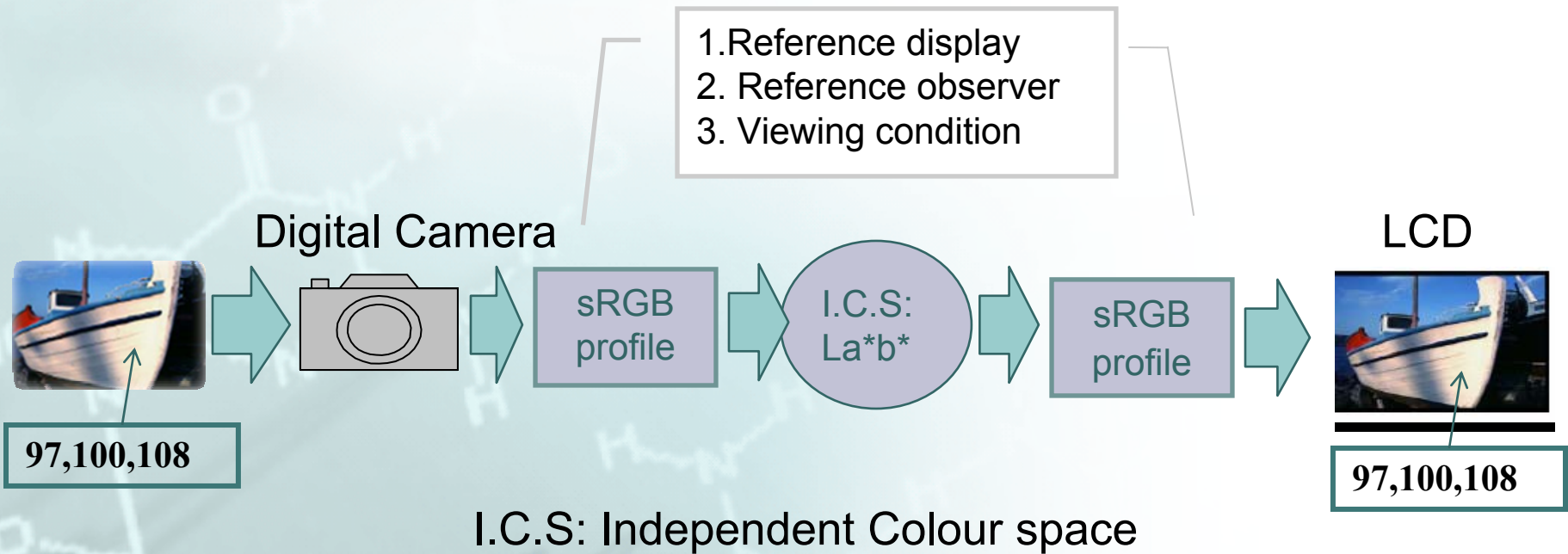


I.C.S: Independent Colour space

Methods [sharma]

- 1. Process profile (i.e. sRGB, SWOP)
- 2. Generic Profile (i.e Epson 2000P)
- 3. Custom Profile (i.e. Polynomial regression, GOG)

Accuracy of colour reproduction



sRGB Encoding

– Forward conversion

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

– Inverse conversion

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \\ \beta_{31} & \beta_{32} & \beta_{33} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

sRGB Encoding

Inverse transformation

Step 1:

$$R'_{sRGB} = (R_{8bit} - BDC) / (WDC - BDC)$$
$$G'_{sRGB} = (G_{8bit} - BDC) / (WDC - BDC)$$
$$B'_{sRGB} = (B_{8bit} - BDC) / (WDC - BDC)$$

BDC is a black digital count and a white digital count is WDC (8-bits/channel)

if $R'_{sRGB} G'_{sRGB} B'_{sRGB} \leq 0.04045$ or if $R'_{sRGB} G'_{sRGB} B'_{sRGB} > 0.04045$

$$R_{sRGB} = R'_{sRGB} \div 12.92$$

$$G_{sRGB} = G'_{sRGB} \div 12.92$$

$$B_{sRGB} = B'_{sRGB} \div 12.92$$

$$R_{sRGB} = \left[\frac{(R'_{sRGB} + 0.0055)}{1.055} \right]^{2.4}$$

$$G_{sRGB} = \left[\frac{(G'_{sRGB} + 0.0055)}{1.055} \right]^{2.4}$$

$$B_{sRGB} = \left[\frac{(B'_{sRGB} + 0.0055)}{1.055} \right]^{2.4}$$

sRGB Encoding

Inverse transformation

Step 2:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.4124 & 0.3576 & 0.1805 \\ 0.2126 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9505 \end{bmatrix} \begin{bmatrix} R_{sRGB} \\ G_{sRGB} \\ B_{sRGB} \end{bmatrix}$$

sRGB Encoding

- The method to sRGB colour space is developed based on a **cathode ray tube (CRT)** display.
 - **Sharma Abhay**, *Understanding color management*, 2004
- It continues to be implemented in liquid crystal displays (LCDs). It is also the most popular encoding transformation, found in most contemporary digital acquisition devices (such as scanner and digital cameras).

sRGB Encoding

- “... *well suited* to cathode ray tube(CRT), *flat panel displays*, television, scanners, *digital camera* and printing systems....”

- ISO 61966-2-1

Question

1. Reference display
2. Reference observer
3. Viewing condition

CRT display



sRGB
Encoding
Transformation

*Camera,
LCD display*



Question

- Is colour reproduction via sRGB encoding using a high end digital camera and an LCD 'correct'?
- If there are errors, where in the imaging chain do they occur?

Equipment Used

- **Camera:**

A full-frame (36×24mm) SLR professional Cannon-1Ds with a 28-135mm zoom lens



- **LCD :**

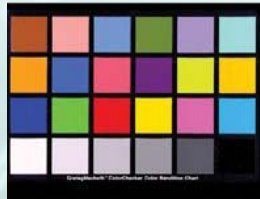
A 21 inch EIZO CG210 LCD



Equipment Used

- **Two Test targets :**

Macbeth ColorChecker chart (C.C.C) & Kodak Q-60



(ANSI standard T8. 7/2)

- **Measuring instruments:**

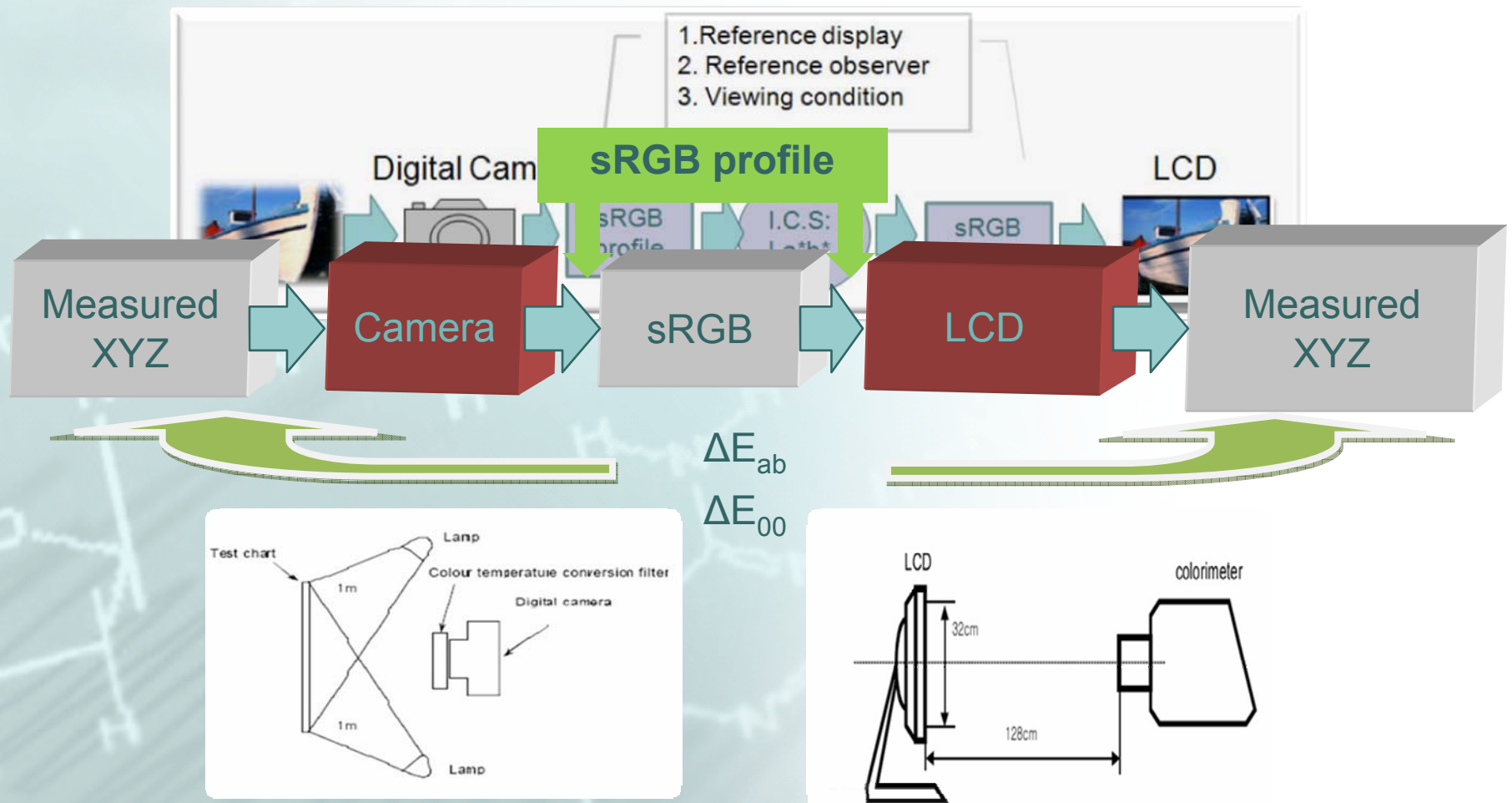
X-Rite spectrophotometer - for Kodak Q-60

Color-Eye 7000A spectrophotometer - for C.C.C

Minolta CS-200 colorimeter - for colour patch on LCD

C.C.C: Macbeth ColorChecker chart

Implement sRGB in imaging chain (Camera - LCD)



sRGB colour Errors

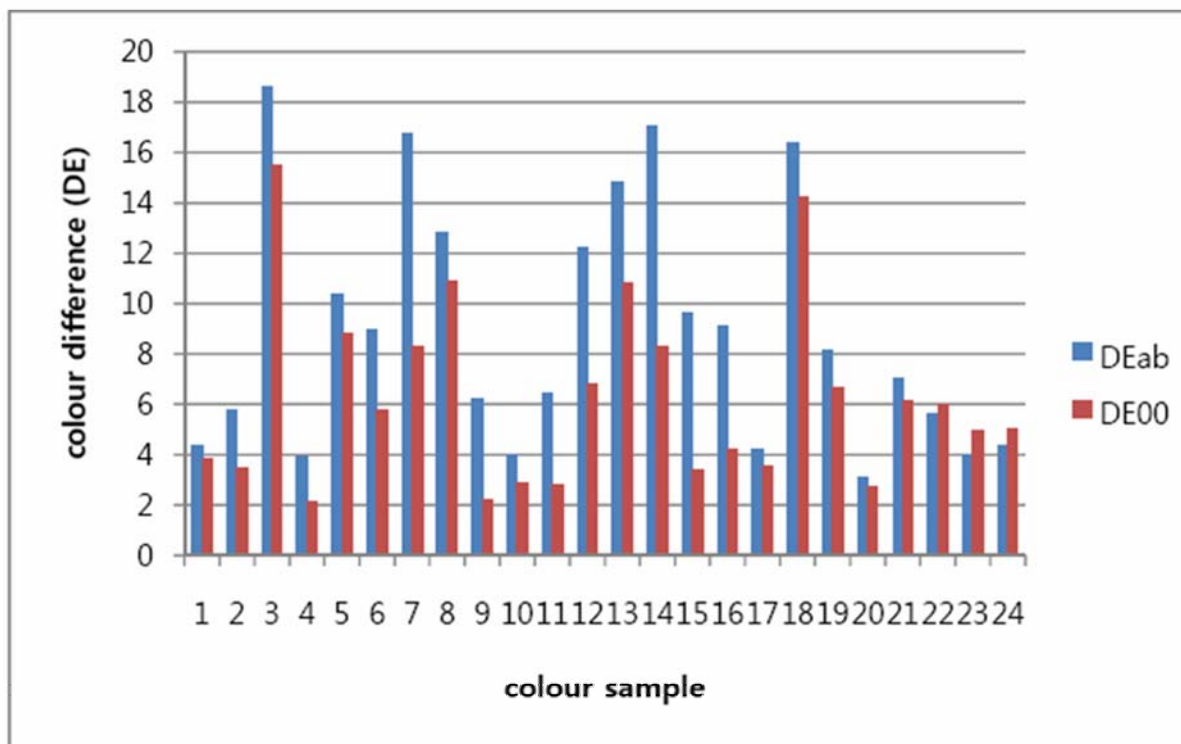
Whole system (camera-LCD)

	ΔE_{ab}			ΔE_{00}		
	Mean	Median	Max	Mean	Median	Max
C.C.C	8.911	7.579	18.602	6.224	5.403	15.524
Q-60	13.485	12.103	31.418	9.584	8.079	25.925

C.C.C: Macbeth ColorChecker chart

sRGB colour Errors

Whole system (camera-LCD)

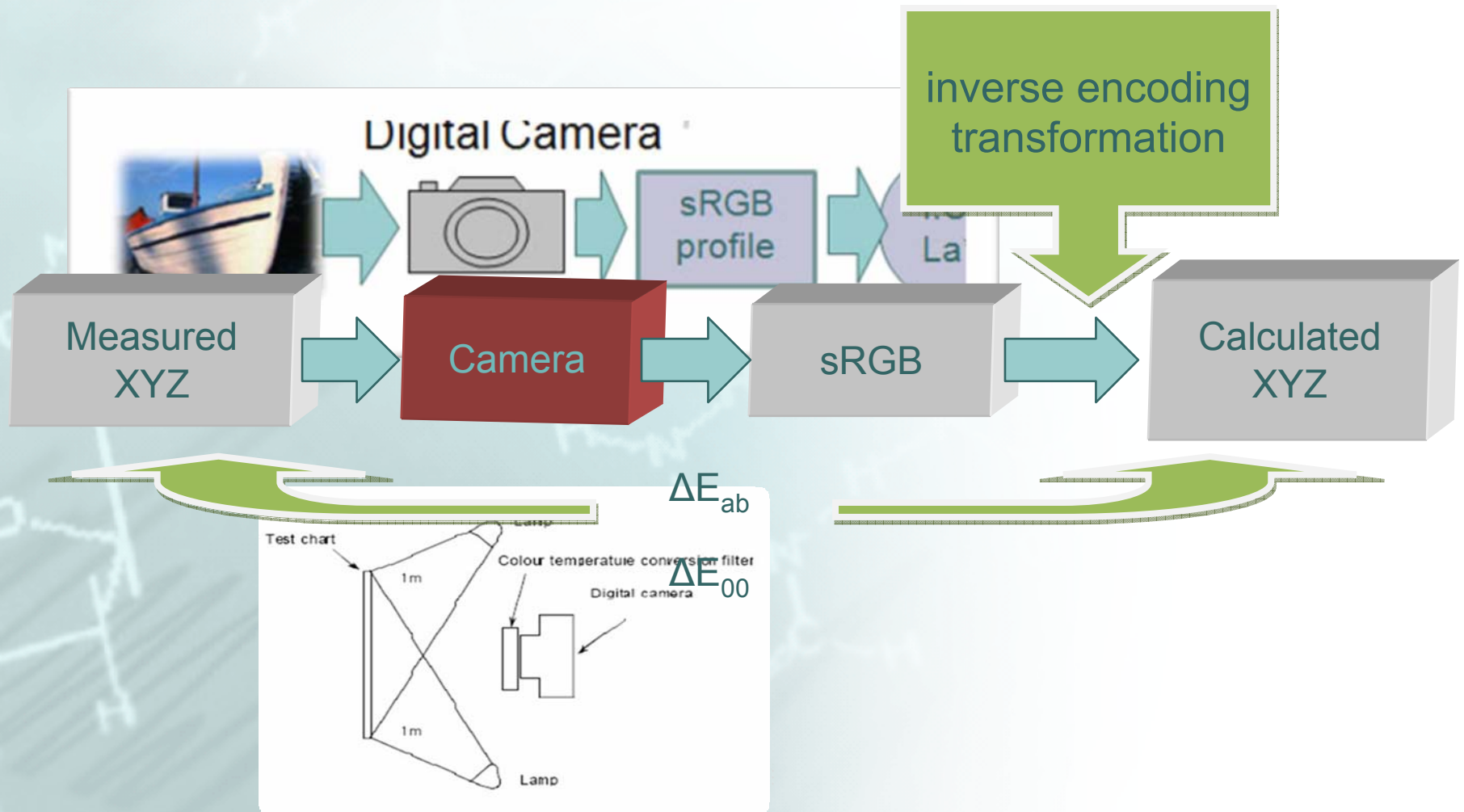


C.C.C: Macbeth ColorChecker chart

Errors

- 1. sRGB reproduction of digital camera
- 2. sRGB reproduction of LCD
- 3. sRGB encoding transformation

Accuracy of sRGB reproduction of digital camera



sRGB colour Errors

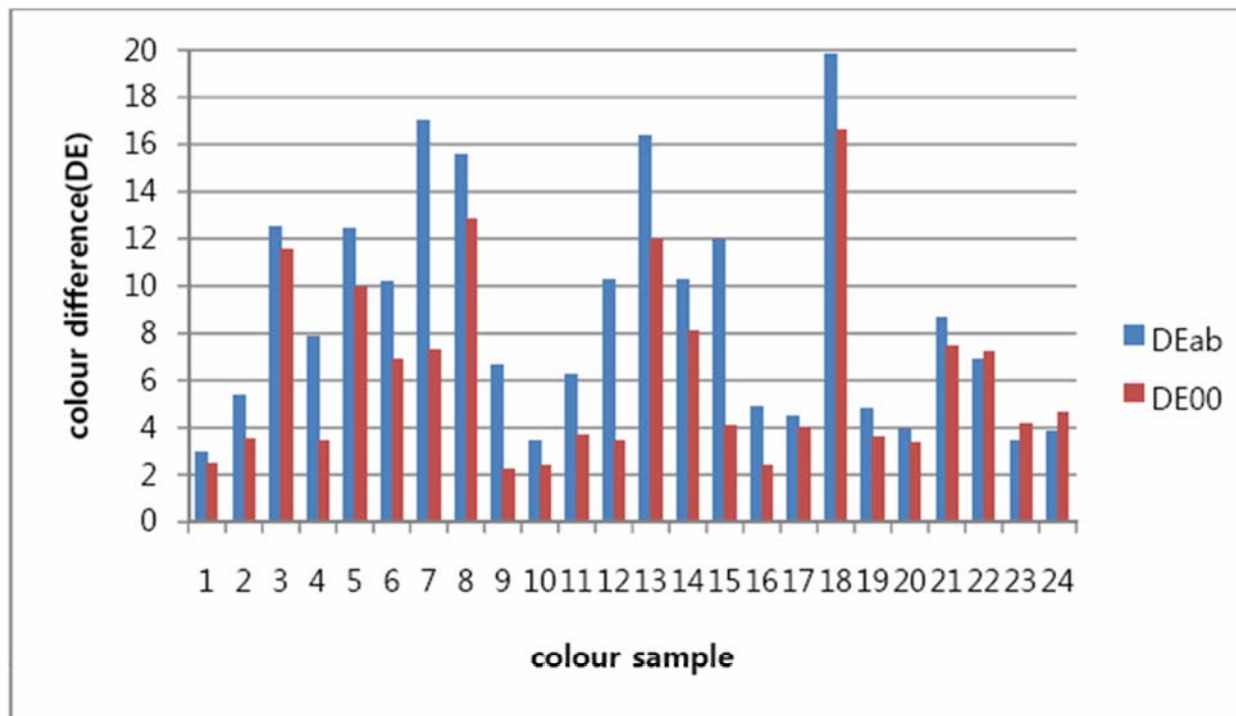
Only digital camera

	ΔE^*_{ab}			ΔE_{00}		
	Mean	Median	Max	Mean	Median	Max
C.C.C	8.730	7.394	19.806	6.125	4.116	16.569
Q-60	13.112	11.742	34.407	9.517	7.679	27.826

C.C.C: Macbeth ColorChecker chart

sRGB colour Errors

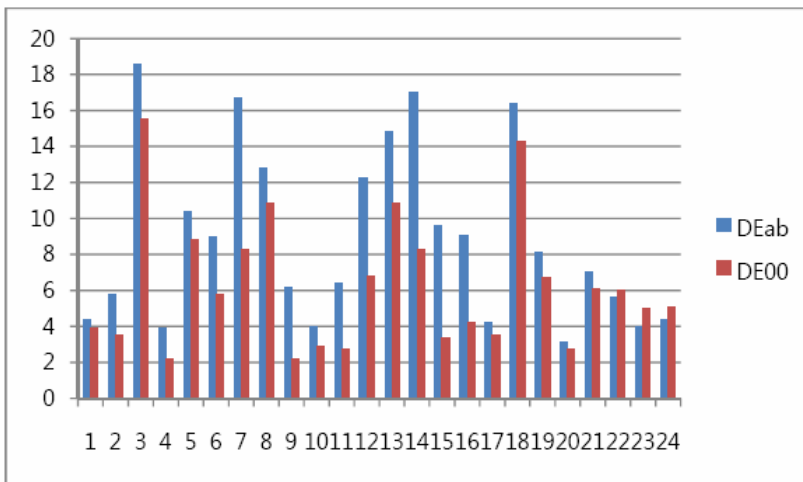
Only digital camera



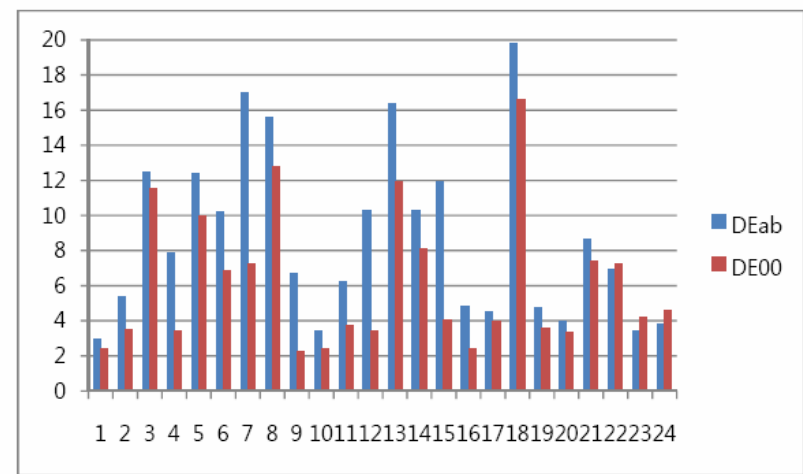
C.C.C: Macbeth ColorChecker chart

sRGB colour Errors

Compare between imaging chain and digital camera-only



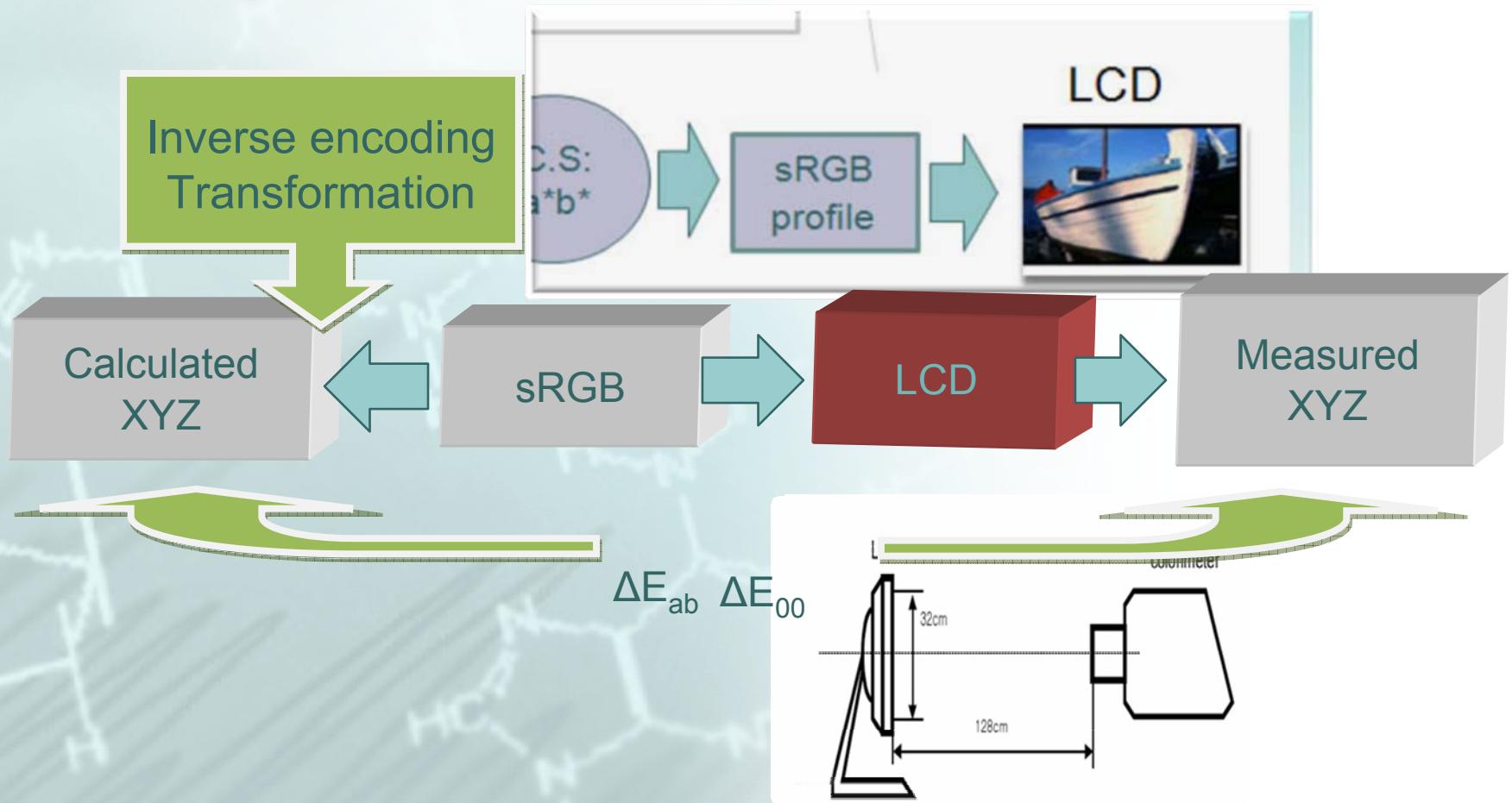
Camera-LCD



camera

C.C.C: Macbeth ColorChecker chart

The accuracy of sRGB Reproduction of LCD

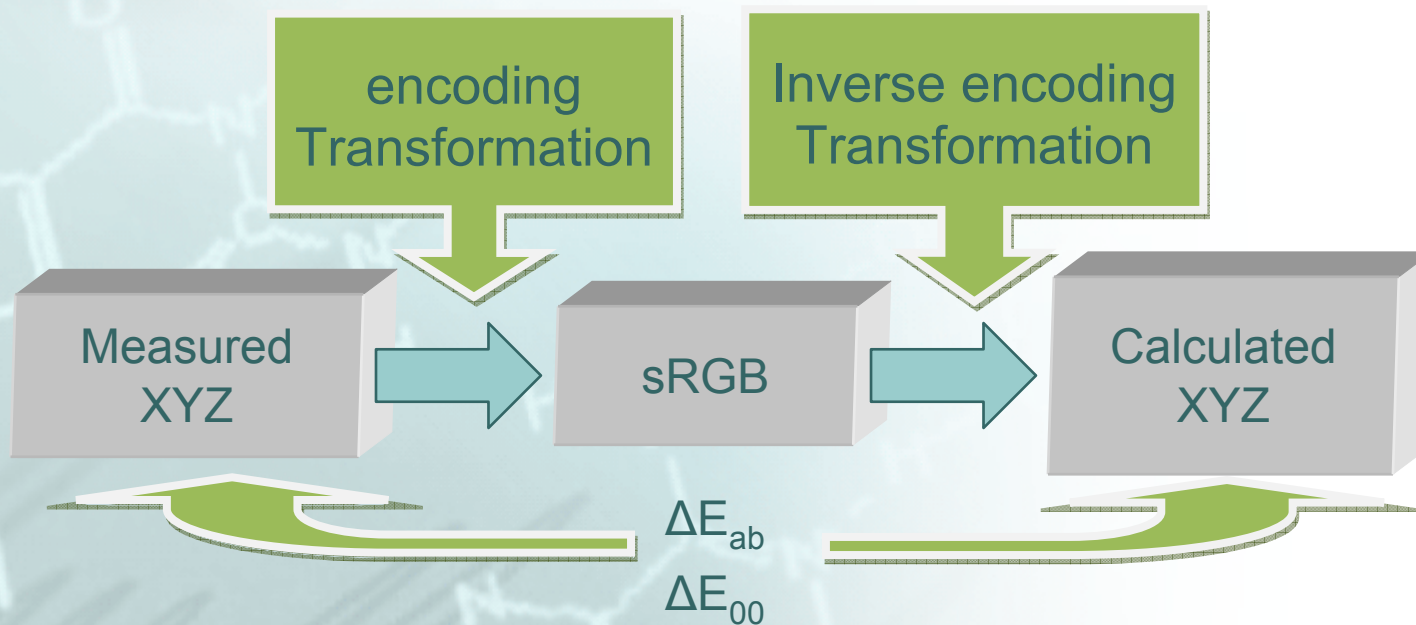


sRGB colour Errors

Only LCD

	ΔE_{ab}			ΔE_{00}		
	Mean	Median	Max	Mean	Median	Max
42 Patches	1.572	0.538	7.210	0.521	0.201	2.172

The accuracy of sRGB encoding transformation



sRGB colour Errors

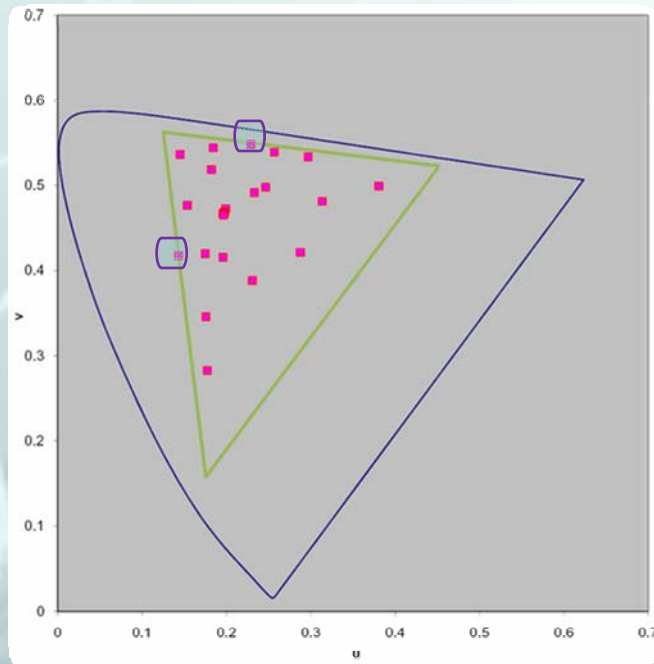
The accuracy of sRGB encoding transformation

	ΔE^*_{ab}			ΔE_{00}		
	Mean	Median	Max	Mean	Median	Max
C.C.C	0.194	0.000	4.655	0.096	0.000	2.306
Q-60	0.846	0.003	17.501	0.356	0.002	7.877

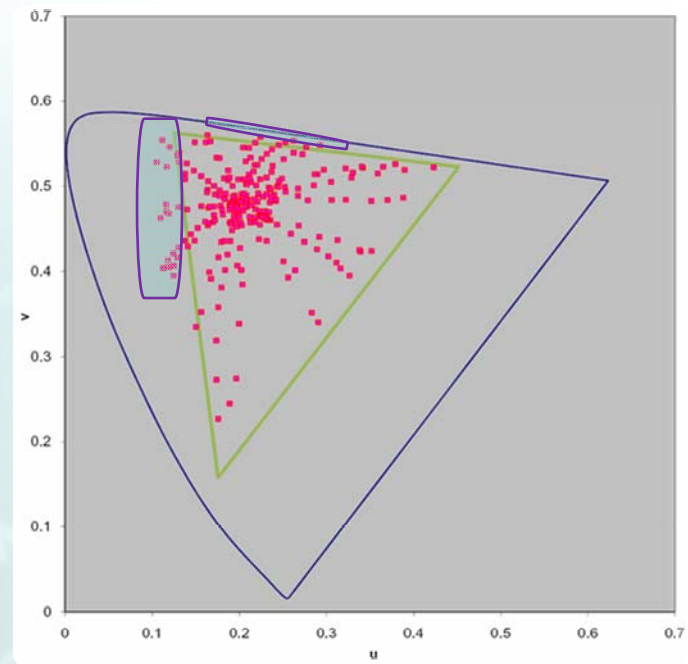
C.C.C: Macbeth ColorChecker chart

sRGB colour Errors

The accuracy of sRGB encoding transformation



Macbeth ColorChecker chart



Kodak Q-60

Conclusion

- 1. The sRGB encoding gave inaccuracies in colour reproduction in the imaging chain used.
- 2. The digital camera gave errors in colour reproduction.
- 3. In the errors found in the digital camera, there should be the encoding errors.
- 4. The LCD showed good sRGB colour accuracy.
- 5. Clipped colours in sRGB encoding transformation also produced errors.

Further work

- Ongoing work has shown that custom profile methods result in smaller errors.