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How Individual CMFs can Improve Soft-proofing

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RESEACH BACKGROUND



Previous Research

- **In 2023, we conducted an experiment to visually match a LED backlight monitor to halogen based projector.**
- **By applying a matrix based transformation of 2-degree Standard Observer CMFs, 8 participants were able to obtain a better visual match to the original 2-degree Standard Observer CMFs.**

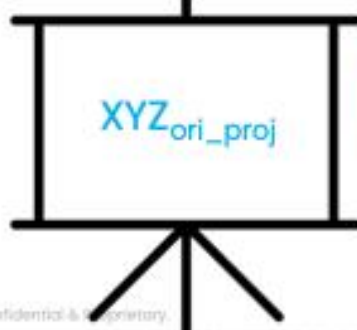
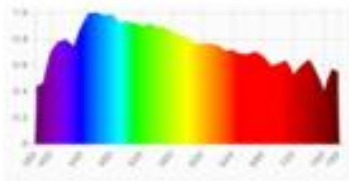


Previous Research

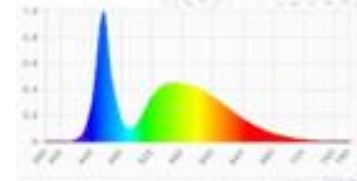
Experiment Design



2. Based on existing CIE Standard Observer (1931 or 1964), apply linear transformation to the original XYZ values:
 1. Measure colour using instrument and obtain XYZ values (XYZ_{ori}).
 2. Apply a transformation matrix to the XYZ_{ori} values. The XYZ values become the transformed XYZ values (XYZ_T).
 3. If $XYZ_{ori_proj} = XYZ_{T_mon}$ then the colour is **visually matched** on the two display devices.



$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$









HOW ABOUT SOFTPROOFING?



File Edit View Window Help
100% (RGB/8/4/EPSON_SCP-5000_SemiGloss_2023)Photoshop 2500, 119x2, 20241023.com



Type here to search



Proposed Experiment

- The same method was utilized in this experiment.
- How do we obtain the transformation matrix?
- In order to obtain the “**visually matching**” result, it is necessary to conduct psychophysical experiment to determine the “adjustment amount” for W, R, G, B, C, M, Y.
 - Observers were asked to match the monitor to the hardcopy proof visually
 - W: adjust RGB values.
 - R, G, B, C, M, Y: adjust Hue, Saturation and Lightness.



Experiment Overview

- 1. Individual CMFs were obtained by calculating the transformation matrix for each observer.**
- 2. Average CMFs were calculated from the 45 observers' individual CMFs.**
- 3. In addition, K-means clustering was applied to the dataset to generate three distinct CMFs for comparison.**
- 4. A validation experiment was conducted to verify the performance of the individual CMFs generated.**



EXPERIMENT PROCEDURE



Procedure

- 1. Calibrate the monitor to D50, and generate Display Profile.**
- 2. Use experiment software to adjust hue, saturation and lightness of the displayed image.**
- 3. Record the HSL values of each image.**
- 4. Repeat the adjustment for 3 times for each observer.**



Procedure

5. 45 observers participated the experiment:

- 24 male and 21 female
- Age ranges from 25 to 45 years old.

6. Each observers were asked to conduct 3 trials.

- There were $45 \times 7 \times 3 = 945$ judgements conducted in the experiment.



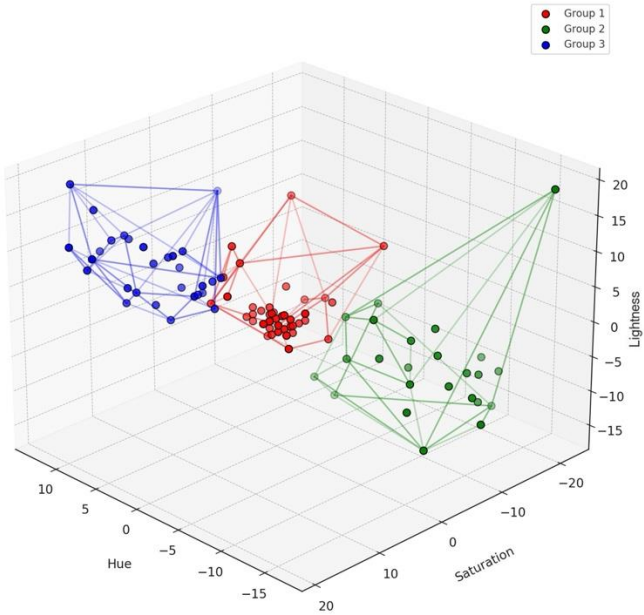


EXPERIMENT RESULTS

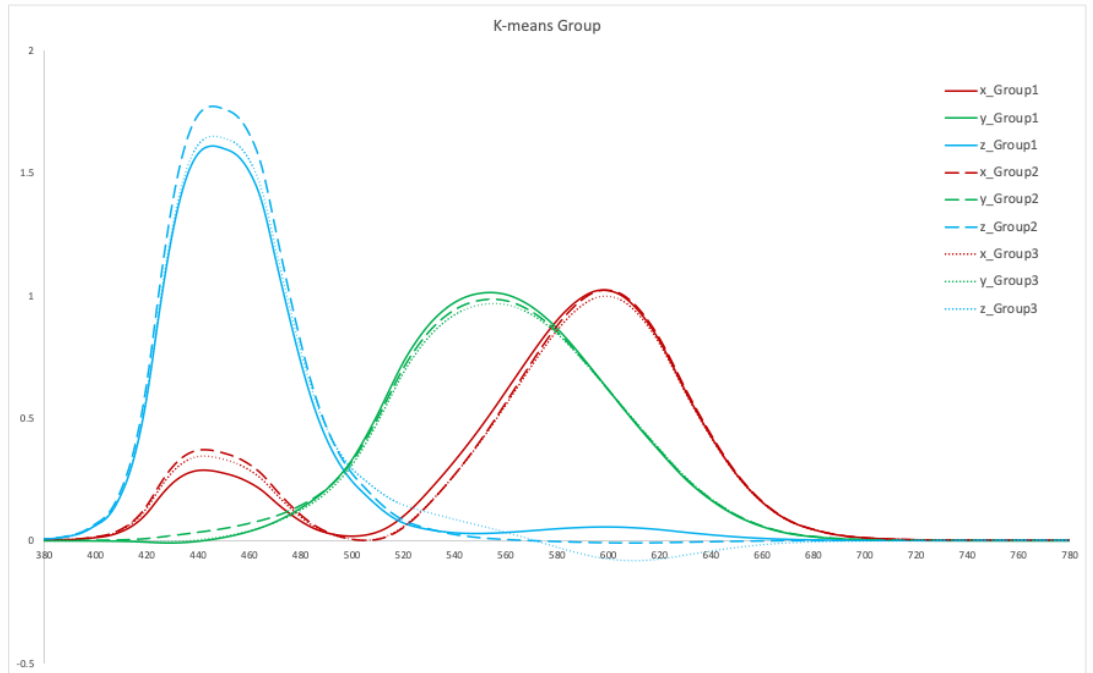


K-means Clustering Result

K-means Clusters with HSL



K-means Group





Matrices

Average

0.99735	0.01117	-0.0047
-0.00895	1.02252	-0.00596
0.00429	0.00324	0.98685

Chris

1.0064	0.0059	0.00937
-0.03893	1.0297	0.01305
-0.0068	0.00901	0.98823

K-means1

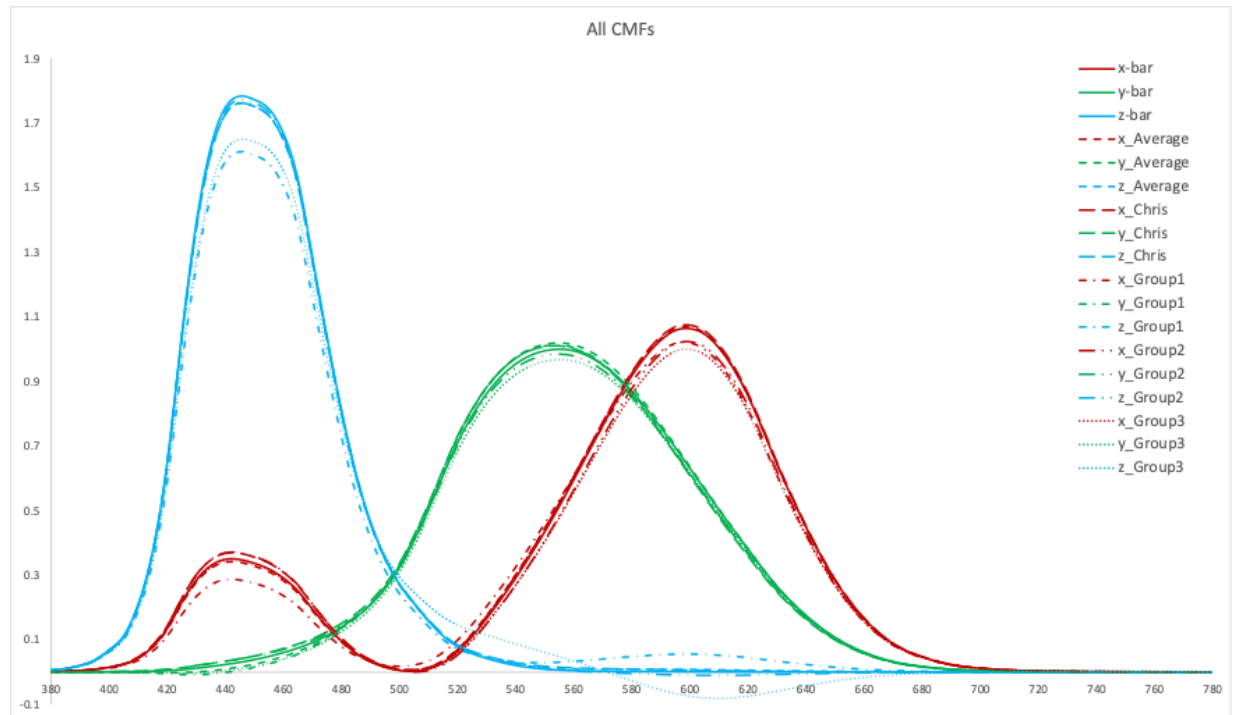
0.92439	0.05876	-0.02164
-0.03143	1.02909	-0.00851
0.05247	-0.002	0.89287

K-means2

0.97016	-0.01438	0.01763
-0.00959	0.9896	0.00812
-0.01495	0.0088	0.99652

K-means3

0.94288	-0.00617	0.00851
0.0068	0.96276	-0.0116
-0.13801	0.11356	0.95021





Images - Red

2 Degree



Individual



Average



K-means 1



K-means 2



K-means 3





Images - Green

2 Degree



Individual



Average



K-means 1



K-means 2



K-means 3





Images - Blue

2 Degree



Individual



Average



K-means 1



K-means 2



K-means 3





Images - Cyan

2 Degree



Individual



Average



K-means 1



K-means 2



K-means 3





Images - Magenta

2 Degree



Individual



Average



K-means 1



K-means 2



K-means 3





Images - Yellow

2 Degree



Individual



Average



K-means 1



K-means 2



K-means 3



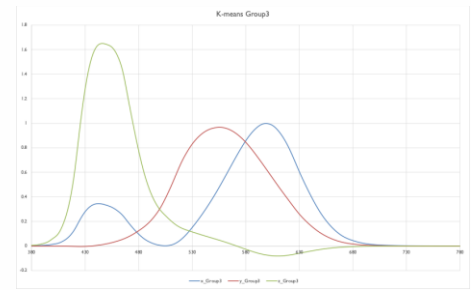
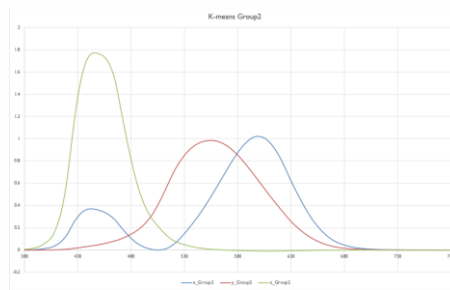
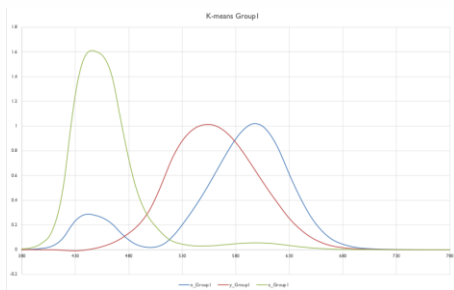
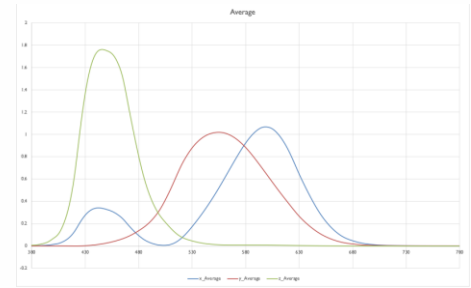
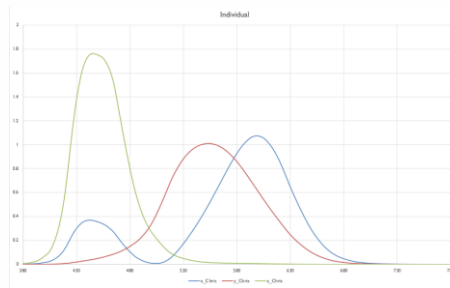
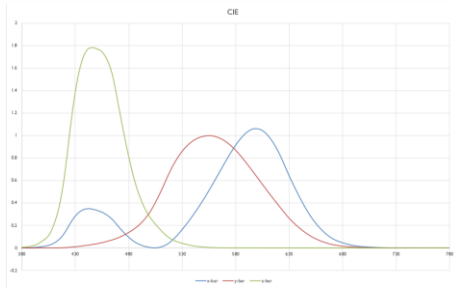


VALIDATION EXPERIMENT



Purpose

- **Need to determine which set of CMFs delivers better softproofing matching performance.**





Procedure

1. Apply the transformation matrices into Display Profiles using CHAD tag.
2. Apply printer profile to the 6 experiment images (Red, Green, Blue, Cyan, Magenta, and Yellow).
3. 5 observers (color experts) were asked to evaluate the images.

Display Profile

CHAD

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$




Procedure

- 3. Ask observers to evaluate under which Display Profile, the image showing on the monitor matches the hardcopy proof in the viewing booth the best.**
 - Conducted in a dark room.
 - Hardcopy proof viewed under D50, and monitor calibrated to D50.
 - Each hardcopy proof was evaluated 3 times randomly.
 - Display Profile was shown randomly.



1 Original



4 K-means 1



2 Individual



5 K-means 2



3 Average



6 K-means 3





1 Original



4 K-means 1



2 Individual



5 K-means 2



3 Average

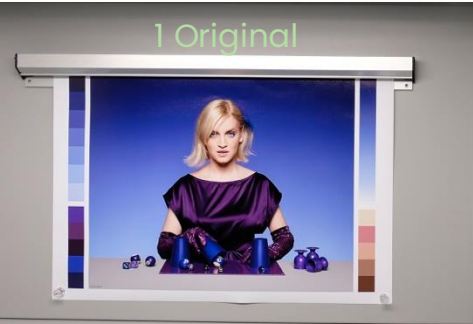


6 K-means 3





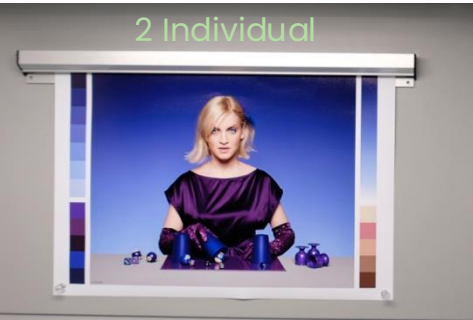
1 Original



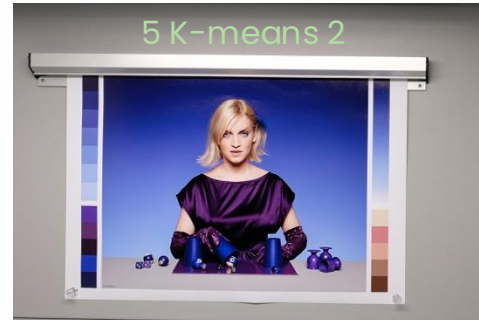
4 K-means 1



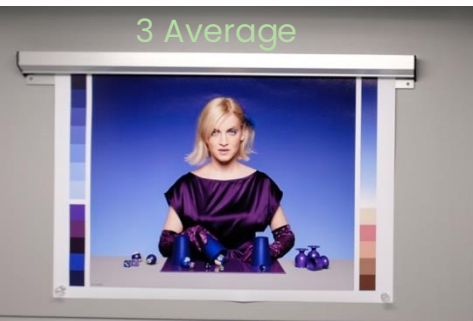
2 Individual



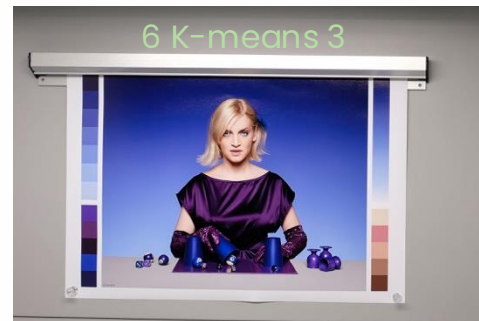
5 K-means 2



3 Average



6 K-means 3





1 Original



4 K-means 1



2 Individual



5 K-means 2



3 Average



6 K-means 3





1 Original



4 K-means 1



2 Individual



5 K-means 2



3 Average



6 K-means 3





1 Original



2 Individual



3 Average



6 K-means 3



Preliminary Experiment Result

Observer	R	G	B	C	M	Y
A	4	1	2	6	4	1
B	4	2	2	5	5	1
C	2	1	5	5	4	1
D	2	2	5	6	5	1
E	4	1	5	5	4	1

1. Original Image	2. Individual CMFs	3. Average CMFs	4. K-means Cluster 1	5. K-means Cluster 2	6. K-means Cluster 3
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Preliminary Findings

- 1. The Validation Experiment Result has shown that CMFs other than 2-degree Standard Observer deliver better matching results, except **yellow** and **green**.**
- 2. K-means cluster results have a high percentage (50%) of being selected.**
 - It is feasible to use categorial observer CMFs rather than actual individual observer CMFs.



Futuer Work

- **More observers will be asked to participate in the Validation Experiment.**
- **Investigate in separating more categories will help the matching result or not.**
- **Using less saturated colours to conduct the experiment.**
- **Experiment with monitors with different backlight technologies: OLED, mini LED, micro LED, etc...**



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Thank you!