IRL #9: Progress Review

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Team G: EXCALIBR

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Individual Progress

Overview

Since I have complete color checker detection and segmentation last week, I move on to searching for the color mapping function.

Color Calibration

Color calibration is to measure and adjust the color response of a device (input or output) to a known state. We use an X-Rite ColorChecker Classic Card as our ground truth (The manufacture gives us the true color values) and aim at mapping the colors recorded by the cameras these ground truths.

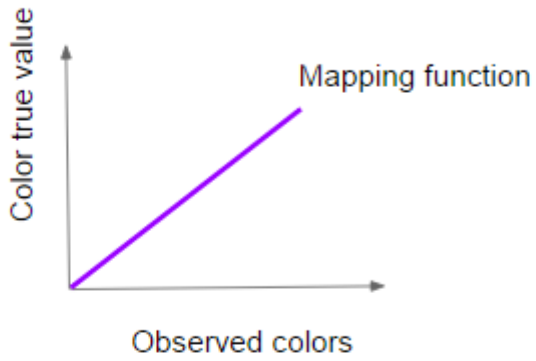


Figure 1. Mapping function (unreal): This graph is only for illustrating the concepts

CCFind

After Macduff algorithm failed in robust tests, I studied all the algorithms trying to build my own colorchecker detector. When I once again traced CCFind's code. I found that it did several downsampling in the code itself, which made me guess the reason it failed before is because of the image size. Therefore, I downsample my images first before applying CCFind on them. The results are good. Furthermore, since CCFind only use the contour information of the colorchecker, it would not be affected by bad lighting conditions.

Therefore, CCFind is the current algorithm used in my color calibration system.

Mapping function

First, I used different linear models to fit the data and calibrated the image with the mapping function model. However, I found that the linear model does not calibrate the image successfully. The result white color patch is the most apparent one. We can see that the white color patches in linear model results are not real white.

ColorChecker Information

Figure 2. The 1-24 in this image correspond to the 1-24 in the x-axis below

No.	Number		sRGB			CIE L*a*b*			Munsell Notation Hue Value / Chroma	
			R	G	B	L*	a*	b*		
1.	dark skin		115	82	68	37.986	13.555	14.059	3 YR	3.7 / 3.2
2.	light skin		194	150	130	65.711	18.13	17.81	2.2 YR	6.47 / 4.1
3.	blue sky		98	122	157	49.927	-4.88	-21.925	4.3 PB	4.95 / 5.5
4.	foliage		87	108	67	43.139	-13.095	21.905	6.7 GY	4.2 / 4.1
5.	blue flower		133	128	177	55.112	8.844	-25.399	9.7 PB	5.47 / 6.7
6.	bluish green		103	189	170	70.719	-33.397	-0.199	2.5 BG	7 / 6
7.	orange		214	126	44	62.661	36.067	57.096	5 YR	6 / 11
8.	purplish blue		80	91	166	40.02	10.41	-45.964	7.5 PB	4 / 10.7
9.	moderate red		193	90	99	51.124	48.239	16.248	2.5 R	5 / 10
10.	purple		94	60	108	30.325	22.976	-21.587	5 P	3 / 7
11.	yellow green		157	188	64	72.532	-23.709	57.255	5 GY	7.1 / 9.1
12.	orange yellow		224	163	46	71.941	19.363	67.857	10 YR	7 / 10.5
13.	blue		56	61	150	28.778	14.179	-50.297	7.5 PB	2.9 / 12.7
14.	green		70	148	73	55.261	-38.342	31.37	0.25 G	5.4 / 8.65
15.	red		175	54	60	42.101	53.378	28.19	5 R	4 / 12
16.	yellow		231	199	31	81.733	4.039	79.819	5 Y	8 / 11.1
17.	magenta		187	86	149	51.935	49.986	-14.574	2.5 RP	5 / 12
18.	cyan		8	133	161	51.038	-28.631	-28.638	5 B	5 / 8
19.	white (.05*)		243	243	242	96.539	-0.425	1.186	N	9.5 /
20.	neutral 8 (.23*)		200	200	200	81.257	-0.638	-0.335	N	8 /
21.	neutral 6.5 (.44*)		160	160	160	66.766	-0.734	-0.504	N	6.5 /
22.	neutral 5 (.70*)		122	122	121	50.867	-0.153	-0.27	N	5 /
23.	neutral 3.5 (.1.05*)		85	85	85	35.656	-0.421	-1.231	N	3.5 /
24.	black (1.50*)		52	52	52	20.461	-0.079	-0.973	N	2 /

Cie L*a*b* values use Illuminant D50 2 degree observer sRGB values for Illuminate D65.

Figure 3. Color ground truth

Experiments

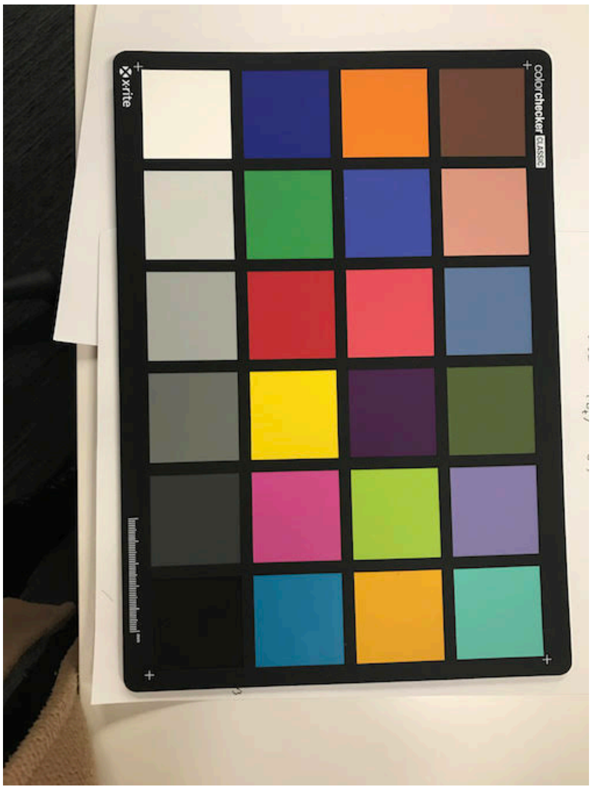


Figure 4. Input Image

Linear Model 1

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}_c = \begin{bmatrix} R \\ G \\ B \end{bmatrix}_T$$

Linear Model 2

$$\begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}_c = \begin{bmatrix} R \\ G \\ B \end{bmatrix}_T$$

Linear Model 3

$$\begin{bmatrix} 1 + a_{11} & a_{12} & a_{13} \\ a_{21} & 1 + a_{22} & a_{23} \\ a_{31} & a_{32} & 1 + a_{33} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}_c = \begin{bmatrix} R \\ G \\ B \end{bmatrix}_T$$

Polynomial 1

$$CalibratedR = \alpha_0 + \alpha_1 R + \alpha_2 G + \alpha_3 B + \alpha_4 R^2 + \alpha_5 G^2 + \alpha_6 B^2$$
$$CalibratedG = \beta_0 + \beta_1 R + \beta_2 G + \beta_3 B + \beta_4 R^2 + \beta_5 G^2 + \beta_6 B^2$$
$$CalibratedB = \gamma_0 + \gamma_1 R + \gamma_2 G + \gamma_3 B + \gamma_4 R^2 + \gamma_5 G^2 + \gamma_6 B^2$$

Calibrated results

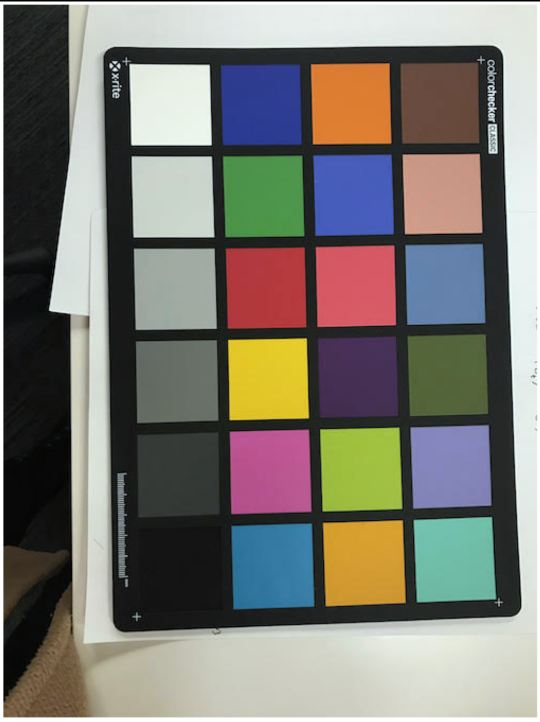
Polynomial Model1	Linear Model1
	
Linear Model2	Linear Model3
	

Figure 5. Calibrated Images

We can see that polynomial model has less errors and the white color is closer to the ground truth.

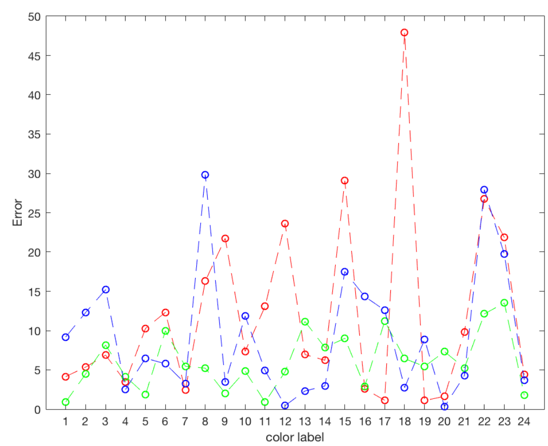
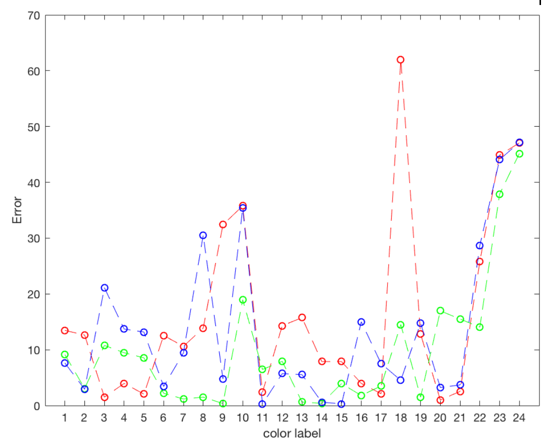
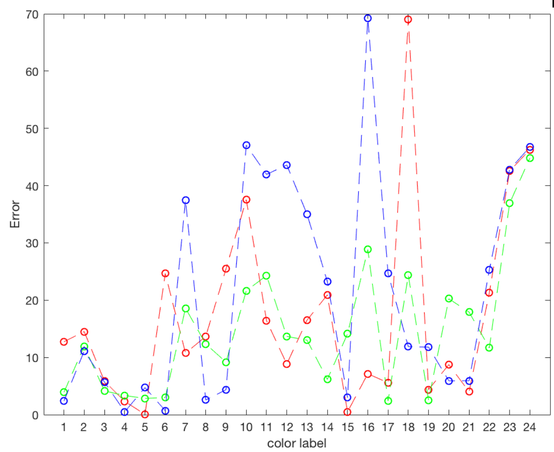
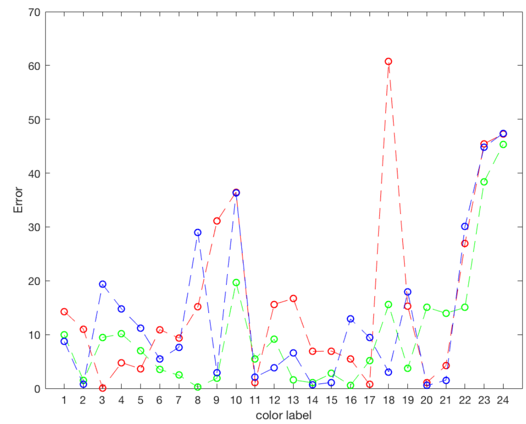
Polynomial Model 1	Linear Model 1
	
Linear Model 2	**Linear Model3**
	

Figure 6. Distances between calibrated images and X-rite ground truth

Challenge

1. PR08 goal: A mapping model is not easy to find. I might need to do some researches in previous similar studies. However, it is not clear that if mapping models differ from camera to camera→ Finished
2. It can be seen that the error in polynomial model is not really small. I might need to try using the Lab color space instead of RGB.
3. The color detection and segmentation algorithm robustness should be improved.

Teamwork

Yiqing Cai	Generate one of the best path for robot arm (go through as least

	positions as possible to cover FOVs of all cameras)
Huan-Yang Chang	Simulation system setup, Robot arm manipulation
Siddharth Raina	Sensor noise calibration plan development
Sambuddha Sarkar	Works on Blender. Generate virtual calibration target and render the virtual images of the target.

References

[1] https://en.wikipedia.org/wiki/Color_calibration

[2] https://en.wikipedia.org/wiki/Flood_fill