

Application of genetic algorithms to minimization of the reproduction error of natural objects in calibrated CRT display using the GOG model

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ABSTRACT

We have applied a genetic algorithm to minimization the reproduction error of natural objects in a calibrated CRT display. The GOG model of calibrated CRT display provides the relative scalar values (R,G,B) of each channel-colour. With these values the CRT Display reproduces the colour of natural objects. The reproduced colour in the CRT display is different of the colour of natural object under the selected illuminant (D_{65}). We have perturbed each relative scalar values RGB with one increment ($\Delta R, \Delta G, \Delta B$) to minimize the reproduced colour error. We obtain these increments using a genetic algorithm. The genetic algorithm uses the relative scalar values (R,G,B) provided by the GOG model to generate the initial population and the colour difference ΔE_{94} of CIELAB system as merit function. We have applied a genetic algorithm to minimization the reproduction error of 24 natural objects of ColorChecker chart in the calibrated CRT display. The ColorChecker chart is uniform illuminated with 90π lx of illuminant D_{65} .

1. INTRODUCTION

The GOG (gain-offset-gamma) model describes with high accuracy the tristimulus values that the CRT display reproduces. For this application, the GOG model to CRT display used is:

Channel	Gain (g)	Offset (o)	Gamma (γ)	Gain-Offset equation
Red	1	0	2.5274	$g + o = 1$
Green	1	0	2.6279	$g + o = 1$
Blue	1	0	2.8293	$g + o = 1$

Table 1. Gain-offset-gamma values of the CRT display GOG model

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \frac{cd}{m^2} = \begin{bmatrix} 54.44 & 40.67 & 19.42 \\ 29.48 & 84.65 & 9.046 \\ 3.576 & 18.56 & 101.5 \end{bmatrix} \cdot \begin{bmatrix} \left(\frac{ND_R}{255}\right)^{2.5274} \\ \left(\frac{ND_G}{255}\right)^{2.6279} \\ \left(\frac{ND_B}{255}\right)^{2.8293} \end{bmatrix} \quad (1)$$

where ND_k are the digital counts in the display.

We need to apply the inverse problem to reproduce the colour of a natural object under a selected illuminant. In this case, we need to calculate which are the digital counts (ND_k) that reproduce the tristimulus values ($X_{std}, Y_{std}, Z_{std}$) of a natural object under the selected illuminant. The inverse GOG model is used to do this calculation. For our CRT display this model is:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} \left(\frac{ND_R}{255}\right)^{2.5274} \\ \left(\frac{ND_G}{255}\right)^{2.6279} \\ \left(\frac{ND_B}{255}\right)^{2.8293} \end{bmatrix} = \begin{bmatrix} 54.44 & 40.67 & 19.42 \\ 29.48 & 84.65 & 9.046 \\ 3.576 & 18.56 & 101.5 \end{bmatrix}^{-1} \begin{bmatrix} X_{std} \\ Y_{std} \\ Z_{std} \end{bmatrix} \quad (2)$$

The relative scalar values RGB for each channel must be between 0 and 1 to reproduce this colour in the CRT display.

The CRT display behaves as an additive reproduction device of the colour; therefore the spectrum of natural objects reproduced in the CRT display is a linear combination of the spectrum of three primary channels of the CRT display, where the scalar values of each channel are the relative scalar values (R, G, B) provided by the inverse GOG model (Eq. 2). The mathematical expression of the spectral colour (C) reproduced in the CRT display is:

$$C(\lambda_i) = R P_R(\lambda_i) + G P_G(\lambda_i) + B P_B(\lambda_i) \quad (3)$$

where λ_i are the wavelengths from 380 nm to 780 nm and $P_R, P_G,$ and P_B are the three spectral channels of the CRT display.

From the spectral colour (C) in the display we can calculate the tristimulus values of the reproduced colour (X_r, Y_r, Z_r). The mathematical expression to obtain these values in cd/m^2 is:

$$\begin{aligned} X_r &= 683 * 4 * \sum_{i=380}^{i=780} C(\lambda_i) \cdot \bar{x}(\lambda_i) \\ Y_r &= 683 * 4 * \sum_{i=380}^{i=780} C(\lambda_i) \cdot \bar{y}(\lambda_i) \\ Z_r &= 683 * 4 * \sum_{i=380}^{i=780} C(\lambda_i) \cdot \bar{z}(\lambda_i) \end{aligned} \quad (4)$$

We evaluate the reproduction error of CRT display by mean of the colour difference provided by CIELAB system between the tristimulus values ($X_{std}, Y_{std}, Z_{std}$) of a natural object under a selected illuminant and the tristimulus values (X_r, Y_r, Z_r) of the reproduced colour in the CRT display, using the white colour of the CRT display as the white reference.

2. METHOD

In this work we have applied a genetic algorithm to minimize the reproduction error of natural objects in a calibrated CRT display. For this purpose we have perturbed each relative scalar values RGB with one increment. Now, the mathematical expression of the spectral colour (C) reproduced in the CRT display is:

$$C(\lambda_i) = (R + \Delta R)P_R(\lambda_i) + (G + \Delta G)P_G(\lambda_i) + (B + \Delta B)P_B(\lambda_i) \quad (5)$$

Where R, G, B are the relative scalar values provided by the inverse GOG model (Eq. 2) and $\Delta R, \Delta G, \Delta B$ are the values introduced to minimize the reproduction error.

To look for the value of these increments we have adapted a genetic algorithm to colour reproduction using the relative scalar values R, G, B for generating the initial population. However, we have used the typical parameter ΔE of CIELAB system used to evaluate the colour difference as merit function. We have applied a genetic algorithm with this quality function described previously to minimization the reproduction error of 24 natural objects of ColorChecker chart in the CRT display.

We can see the ColorChecker chart at Figure 1. The ColorChecker is uniform illuminated with 90π lx of illuminant D65.



Figure 1. The ColorChecker chart

3. RESULTS

We have applied a genetic algorithm actions described previously to minimization the reproduction error of 24 natural objects of ColorChecker chart (Fig. 1) in the CRT display. We can see the spectrum of three primary channels of the CRT display.

In table 2 we can see the relative scalar values R, G, B values provided by the CRT display GOG model. The increment values ΔR , ΔG , ΔB provided by the genetic algorithm. The colour difference ΔE_{94} of CIELAB system obtained without increment values. The colour difference $N-\Delta E_{94}$ of CIELAB system obtained with increment values. For this CRT display the use of increment values (ΔR , ΔG , ΔB) reduce de value of the colour different ΔE of CIELAB system for all natural objects around 12%.

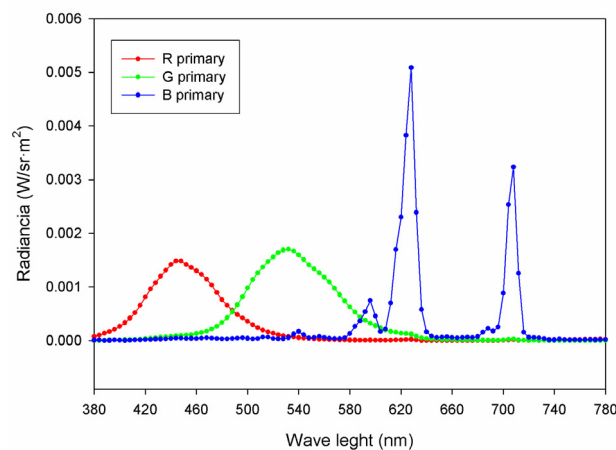


Figure 2. The spectrum of three primary channels of the CRT display

COLOUR	R	G	B	ΔE_{94}	ΔR	ΔG	ΔB	N- ΔE_{94}
Dark Skin	0.177	0.080	0.060	29.62	-0.0095	0.0034	0.0067	25.32
Light Skin	0.543	0.299	0.257	31.64	-0.0112	0.0022	0.0073	23.18
Blue Sky	0.154	0.220	0.404	30.69	0.0086	-0.0047	-0.0051	26.06
Foliage	0.110	0.155	0.047	16.20	-0.0021	0.0059	0.0018	14.90
Blue Flower	0.244	0.226	0.514	25.08	0.0037	-0.0048	-0.0026	22.54
Bluish Green	0.180	0.537	0.450	22.86	0.0049	-0.0056	-0.0031	20.01
Orange	0.664	0.166	0.030	58.65	-0.0072	0.0103	0.0145	52.33
Purplish Blue	0.074	0.118	0.462	44.57	0.0056	-0.0031	-0.0082	39.63
Moderate Red	0.495	0.080	0.139	38.84	-0.0063	0.0015	0.0093	35.11
Purple	0.110	0.041	0.191	13.08	0.0018	-0.0037	-0.0018	12.56
Yellow Green	0.399	0.501	0.026	33.89	-0.0049	0.0058	0.0068	29.98
Orange Yellow	0.784	0.311	0.011	58.64	-0.0084	0.0092	0.0177	52.34
Blue	0.036	0.054	0.371	46.00	0.0071	-0.0060	-0.0125	42.31
Green	0.088	0.308	0.059	6.16	-0.0010	0.0012	0.0021	5.53
Red	0.430	0.028	0.059	47.67	-0.0126	0.0045	0.0065	43.97
Yellow	0.839	0.556	-0.019	53.25	-0.0078	-0.0066	0.0218	48.75
Magenta	0.495	0.077	0.361	12.25	-0.0053	0.0032	0.0039	11.56
Cyan	-0.017	0.273	0.434	59.94	0.0331	0.0089	-0.0156	54.67
White	0.911	0.885	0.983	3.79	-0.0029	0.0011	0.0001	3.65
Neutral 8	0.603	0.580	0.659	3.44	0.0003	-0.0001	-0.0001	3.28
Neutral 6.5	0.379	0.361	0.410	2.84	0.0002	-0.0002	-0.0001	2.76
Neutral 5	0.206	0.198	0.223	2.32	0.0001	-0.0001	-0.0002	2.22
Neutral 3.5	0.099	0.093	0.106	1.80	-0.0004	0.0001	0.0003	1.72
Black	0.036	0.033	0.038	1.30	-0.0002	0.0001	0.0001	1.29

Table 2. The relative scalar values R, G, B values provided by the CRT display GOG model. The increment values ΔR , ΔG , ΔB provided by the genetic algorithm. The colour difference ΔE_{94} of CIELAB system obtained without increment values. The colour difference N- ΔE_{94} of CIELAB system obtained with increment values.

4. CONCLUSIONS

We have applied a genetic algorithm to minimization the reproduction error of natural objects in a calibrated CRT display. We have perturbed each relative scalar value RGB provided by The GOG model of calibrated CRT display with one increment (ΔR , ΔG , ΔB) to minimize the reproduced colour error. We obtain these increments using a genetic algorithm. The genetic algorithm uses the relative scalar values (R,G,B) provided by the GOG model to generate the initial population and the colour difference ΔE_{94} of CIELAB system as merit function. We have applied a genetic algorithm to minimization the reproduction error of 24 natural objects of ColorChecker chart in the calibrated CRT display. The ColorChecker chart is uniform illuminated with 90π lx of illuminant D_{65} . For this CRT display the use of increment values (ΔR , ΔG , ΔB) reduce de value of the colour different ΔE of CIELAB system for all natural objects.

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