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Intensity Preserving Cast Removal in Color Images Using Particle Swarm Optimization

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ABSTRACT

In this paper, we present an optimal image enhancement technique for color cast images by preserving their intensity. There are methods which improves the appearance of the affected images under different cast like red, green, blue etc but up to some extent. The proposed color cast method is corrected by using transformation function based on gamma values. These optimal values of gamma are obtained through particle swarm optimization (PSO). This technique preserves the image intensity and maintains the originality of color by satisfying the modified gray world assumptions. For the performance analysis, the image distance metric criteria of CIELAB color space is used. The effectiveness of the proposed approach is illustrated by testing the proposed method on color cast images. It has been found that distance between the reference image and the corrected proposed image is negligible. The calculated value of image distance depicts that the enhanced image results of the proposed algorithm are closer to the reference images in comparison with other existing methods.

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1. INTRODUCTION

Color cast removal is a challenging task under different illumination conditions. Image captured by digital camera are usually depend on various properties of the device and source of the illumination. The major adjustment is required on the color content and intensity of the image. The color cast is due to the color of ambient light which shows low or high contrast, over exposure or under exposure of some regions lead to the difference. These major causes are removed with the proposed approach.

The image enhancement may be carried out by increasing the image contrast. The contrast increment can be achieved by using various algorithms like histogram equalization, global histogram equalization etc [1]; [2]. In these methods generally, the image is enhanced but its information content gets reduced significantly [3].Buchsbaumet [4] has proposed the gray world assumption based method for color constancy in a degraded image. It meets the criterion of human visual system. Tang [5] have presented a method to enhance the color image by dividing it into chromaticity and intensity components. Kwok [16] avoids the color saturation by modifying the gray world assumption. Farid [7] proposed the gray image enhancement by using gamma correction. Monobe [8] used the knee transfer function based gamma correction. Finding an optimal value of gamma is always a difficult task.

Evolutionary algorithms have been used to perform image enhancement [9]; [19]; [11]. One of the main drawbacks of the previously used evolutionary algorithms is the lack of memory availability which limits its search and convergence ability. Guan [12] have discussed the application of GA to determine the gamma value. In the proposed method, we have used PSO for optimizing the gamma value used in image contrast enhancement. In comparison to GA, PSO [13] is simple and has less complexity as it does not require the selection, crossover and mutation operations that are involved in GA. PSO has fewer parameter and fast convergence rate as it does not use the survival of the fittest concept. The particle having lower fitness can survive during the optimization and potentially visit any point in the search space [14]; [15]; [16]; Kwok [17]; [18]. In the proposed method, the PSO is used for finding the optimal value of gamma by preserving mean intensity values. The method enhances the color images effectively and automatically without prior illumination knowledge.

In this paper a novel method is proposed which uses single fitness function. It utilizes the PSO and gives optimal value under non-linear conditions.

The paper is as organized as follow. The proposed fitness gamma correction method based on knee transfer function is introduced in Section 2. Section 3 discusses the PSO algorithm. Later in Section 4, the proposed algorithm is developed for color cast removal. The performance measures and results are discussed in section 5 section 6 respectively. Finally, conclusions drawn from the results obtained are mentioned in Section 7.

2. MODIFIED GAMMA CORRECTION BASED ON KNEE TRANSFER FUNCTION

In the present application we have considered Red (R) Green (G) and Blue (B) color model of color space. The mean value $\bar{R}$, $\bar{G}$ and $\bar{B}$ of red, green and blue channel respectively of a color image of size MxN is given by

$$\bar{\mathrm{R}} = \frac{1}{\mathrm{MN}} \sum_{\mathrm{i}=1}^{\mathrm{M}} \sum_{\mathrm{j}=1}^{\mathrm{N}} \mathrm{R}(\mathrm{i},\mathrm{j}) \tag{1}$$

$$\bar{\mathrm{G}} = \frac{1}{\mathrm{MN}} \sum_{\mathrm{i}=1}^{\mathrm{M}} \sum_{\mathrm{j}=1}^{\mathrm{N}} \mathrm{G}(\mathrm{i},\mathrm{j}) \tag{2}$$

$$\bar{\mathrm{B}} = \frac{1}{\mathrm{MN}} \sum_{\mathrm{i}=1}^{\mathrm{M}} \sum_{\mathrm{j}=1}^{\mathrm{N}} \mathrm{B}(\mathrm{i},\mathrm{j}) \tag{3}$$

Where i and j denotes the indices of pixel position. The mean intensity of an image is given by

$$\Xi = (\bar{\mathrm{R}} + \bar{\mathrm{G}} + \bar{\mathrm{B}})/3 \tag{4}$$

R channel, G channel and B channel are normalized in such a way that each channel has its value lying in the range [0, 1]. Gamma correction is a nonlinear adjustment method used for color correction. We define the modified gamma correction method based on knee transfer function (say for red channel)is obtained by modifying the conventional knee curve as given by

$$\mathrm{I} = \begin{cases} \frac{1}{256\times256} \sum_{\mathrm{i}=0}^{255} \sum_{\mathrm{j}=0}^{255} \mathrm{R}(\mathrm{i},\mathrm{j})^{\gamma}, \text{if } \bar{\mathrm{R}} < \mathrm{t} \\ \frac{1}{256\times256} \sum_{\mathrm{i}=0}^{255} \sum_{\mathrm{j}=0}^{255} (\mathrm{a_1 R^3(i,j) + a_2 R^2(i,j) + a_3 R(i,j) + a_4})^{\gamma}, \text{elsewhere} \end{cases} \tag{5}$$

where I is the output intensity level after the gamma correction and t denotes the threshold level for each channel which is taken as 0.35^{γ} in our case. The normalized values are raised to the power of γ as $\hat{\mathrm{R}} = \bar{\mathrm{R}}^{\gamma}$,$\hat{\mathrm{G}} = \bar{\mathrm{G}}^{\gamma}$, and $\hat{\mathrm{B}} = \bar{\mathrm{B}}^{\gamma}$ after comparing the mean values for each channel with the threshold value and are a function ofγ. If $\gamma > 1$ then average intensity value increases and vice versa. There are methods like gray world assumption which assumes mean value for correction factor. Here, mean intensity of each channel is decrement or increment for optimal value of gamma and equal to the aggregated mean intensity of the image.

In case the mean value of channel is found higher than the selected threshold value 't', then the approximate conventional knee curve transforms the intensity from linear curve to the cubic curve at the same selected threshold level. Depending upon intensity values of the given image gamma changes according to the condition as in equation (5). For high intensity values we maintain the local contrast by using cubic function. Simultaneously, the gamma correction for high intensity images maintains the local contrast and removes the color cast present in the image. The a_1, a_2, a_3 and a_4 mentioned in equation (5) are constants and get evaluated using the equation (11), (12), (13) and (14).

In order to determine the coefficients a_1, a_2, a_3 and a_4, the following conditions are imposed

$$\mathrm{I(t)} = \mathrm{a_1 t^3 + a_2 t^2 + a_3 t + a_4 = t} \tag{6}$$

$$\mathrm{I'(t)} = \mathrm{3a_1 t^2 + 2a_2 t + a_3 = 1} \tag{7}$$

$$\mathrm{I(m)} = \mathrm{a_1 m^3 + a_2 m^2 + a_3 m + a_4 = sm} \tag{8}$$

$$I'(m) = 3a_1m^2+2a_2m+a_3=s \tag{9}$$

where I' is the first derivative of I, denotes the maximum input level, and denotes the differential coefficients of the conventional knee curve at the maximum input level are given by

$$s = \frac{1-k}{t-k} \tag{10}$$

Where k denotes the intensity level at knee point of the conventional knee curve. We get the coefficient values are as follows

$$a_1 = \frac{(s-1)t+(2-m-ms)}{(t-m)^3} \tag{11}$$

$$a_2 = \frac{2(1-s)t^2+(ms+2m-3)(t+m)}{(t-m)^3} \tag{12}$$

$$a_3 = \frac{st^3+(s-4)mt^2+(6-m-2ms)mt-m^3}{(t-m)^3} \tag{13}$$

$$a_4 = \frac{(1-ms)t^3+(ms+2m-3)mt^2}{(t-m)^3} \tag{14}$$

Similarly, we can perform the same correction for other remaining channels

3. PARTICLE SWARM OPTIMIZATION

The PSO algorithm implementation can be summarized as
Step 1: Initialize all particles randomly according to the solution space satisfying the computational load or iterations required to obtain the optimum solution as shown in Table 1
Step 2: loop: For each particle, obtain the fitness function in D variables do:
Step 3: Set the value as the maximum value between the current value and existing value.
Step 4: Identify the particle in the neighborhood with the best success so far, and assign its index to the variable t.
Step 5: Update the particle velocity using

$$v_i^{t+1}=W^t.v_i^t+c_1.r_1.(pbest_i^t-X_i^t)+c_2.r_2.(gbest^t-X_i^t) \tag{15}$$

Where r_1 and r_2 are random values generated in the range [0, 1].
Step 6: Update the particle position using

$$X_i^{t+1}= X_i^t+v_i^{t+1} \tag{16}$$

Step 7: If a criterion (i.e. usually a sufficiently good fitness or a maximum number of iterations) is met, then terminate the loop.

Table 1. PSO Parameters

Parameters	Values
Population size	100
Max iteration	200
W_{max}	0.9
W_{min}	0.4
c_1	2
c_2	2

4. FITNESS FUNCTION FOR OPTIMIZATION

In this work, the mean intensity Ξ calculated from the normalized values of R, G, and B channel of color cast test image has to be preserved in the enhanced color image. The correction factor is optimized in the proposed case for each pixel value. The intensity value changes for each pixel channel in the image. We applied this factor for cast image which is not based on the any assumption. A parameterized transformation function be defined in order to remove the color cast present in a test image as $\bar{R}^{\gamma}$, $\bar{G}^{\gamma}$ and $\bar{B}^{\gamma}$. The transformation function contains the parameters γ which is a real valued lying between 0 and 10 such that the mean intensity of distorted image gets preserved. The amount of color cast adjustment is a typical task by using conventional approach. This is accomplished by evaluating the optimal value using PSO for pixel value in each channel. Now our aim is to find out the optimized set of real values of $\gamma = \gamma_{ij}$,i and j are the pixel locations in an image for each channel by using PSO which produces an acceptable output as per the fitness function. Here, the fitness function J for each channel is proposed as

$$\mathrm{J} = \mathrm{I} - \Xi \tag{17}$$

Similarly, we can define the fitness function for G and B channels. The proposed algorithm firstly initializes P number of particles. This means that the position vector of each particle X has one component of γ. Further, using this parameter value in each generation, the particle removes the color cast using the intensity transformation function defined for each channel as $\bar{R}^{\gamma}$. Transformation function changes the value of each pixel in the test image according to the parameter values. The values of gamma modify the intensity of each pixel and also preserve the intensity of image. These gamma values removes color cast up to some extent and produced a number of color corrected images. Fitness values of all the corrected images generated by all the particles are calculated. These pbest and gbest locations are given by fitness values according to the fitness function defined in equation (17). The is the best solution of a particular particle that it has achieved so far, it is also referred to as cognitive component which update their behavior only as per their own experience and another best value which is called as referred as social component are explained by equation (15). In this component, each individual ignore its own experience and update their behaviour according to the previous best particle in the neighbourhood of the group. This cognitive component combines with social component by the updating formula given in equation (15) and equation (16) and calculates the new velocity of each particle. When the process is completed, the color corrected image is created by the position of the particles as it provides the maximum fitness value. Further, using this parameter value in each generation, the particle removes the color cast using the intensity transformation function defined for each channel as $\mathrm{R}(\mathrm{i},\mathrm{j})^{\gamma}$

Algorithm: Color correction algorithm using PSO

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1. Input: A color image X = R, G, B of size M x N pixels
2. Obtain the normalized value of each channel $\bar{R}$,$\bar{G}$,$\bar{B}$ using equation (1), (2) and (3).
   Compute the mean intensity value Ξ using the equation (4).
3. Define PSO parameters: particles P_n, iterations itr_n
4. Firstly consider the red channel and obtain the modified red channel I after applying the transfer function using equation (5).
5. Compute the set of γ values that optimizes the fitness function given in equation (17) using PSO technique,
   at each pixel location for the selected channel as input (i.e. obtain M x N values).
6. Apply the resulted gamma values and obtain the enhanced corrected R channel.
7. Repeat the above mentioned steps for G and B channel.
8. Obtain the enhanced corrected channels i.e. $\mathrm{G}_{channel}$ and $B_{channel}$.

Output: overall enhanced brightness preserving color corrected image Y=$R_{channel}, G_{channel}, B_{channel}]$

Transformation function changes the value of each pixel in the test image according to the parameter values. Fitness values of all the corrected images generated by all the particles are calculated. These and locations are determined according to the fitness function defined in equation (17). When the process is completed, the color corrected image is created by the position of the particles as it provides the maximum fitness value.

5. PERFORMANCE MEASURE

CIELAB metric [19] estimates accuracy of the color reproduction in comparison to the original when analyzed by a human observer. The CIELAB metric is suitable for measuring color difference of large uniform color targets. CIELAB is based on one channel for Luminance (L) and two color channels (a and b). The a-axis starts from green (-a) to red (+a) and the b-axis starts from blue (-b) to yellow (+b). The Luminance (L) starts from the bottom to the top of the three-dimensional model. The $\Delta\mathrm{E_c}$ and $\Delta\mathrm{E_e}$ metric are given by

$$\Delta\mathrm{E_c} = \sqrt{\Delta\mathrm{L_c^2} + \Delta\mathrm{a_c^2} + \Delta\mathrm{b_c^2}} \tag{18}$$

where $\Delta L_c = L_{cast} - L_{original}$
$\Delta a_c = a_{cast} - a_{original}$
$\Delta b_c = b_{cast} - b_{original}$

$$\Delta E_e = \sqrt{\Delta {L_e}^2 + \Delta {a_e}^2 + \Delta {b_e}^2} \tag{19}$$

where $\Delta L_e = L_{enhanced} - L_{original}$
$\Delta a_e = a_{enhanced} - a_{original}$
$\Delta b_e = b_{enhanced} - b_{original}$

Parameters $L_c,\ a_c\ and\ b_c$ is the difference in the cast and test image coordinates of L, a, and b of CIELAB color space and $L_e,\ a_e\ and\ b_e$ are the coordinates L, a, and b of enhanced image in CIELAB color space. is the Euclidean distance for measuring the difference between colors. Smaller value of indicates that the enhanced test image is closer to the reference image.

6. RESULTS AND DISCUSSIONS

The proposed method has been successfully implemented using MATLAB 7.10. We have been tested 50 images under a diversified illumination conditions and the results of sample images (viz. Building, Stanford Tower, House, Mandrill, Village, Tree, Two men, Lena) are illustrated in the paper. We tested the proposed algorithm against gray world assumption and Kwok method [17] using CIELAB ΔE metric.

The cast images and images obtained from the Gray world corrected approach; Kwok method and the proposed method have been shown in Figures 1-8. The reference image is the original image without any bad illumination effect. The distorted images are obtained by adding color cast to them. The distorted images are corrected by using gray world approach, Kwok approach and the proposed corrected approach. The image distances are calculated using equation (18), equation (19) and summarized in Table 2.

In Figures 1-8, (a) shows the original image; (b), (c) and (d) show the red, green and blue cast of an image; (a), (e), (f), (g) represent the gray world corrected image of (b), (c) and (d) respectively; (h), (i) and (j) show the result of the Kwok corrected images of (b), (c) and (d) respectively; (k), (l) and (m) show the result of the proposed approach corrected images of (b), (c), and (d) respectively.

Figure 1 shows the cast building images, the clouds are not appearing to be bluish in color and grass color changes in appearance from the original or reference image in different cast conditions. When we apply the gray world corrected algorithm and Kwok correction technique on the cast building images then, the resulting images shown in Figure 1(e), (f) and (g) become dark which significantly reduces the color originality

The enhanced images obtained by using Kwok method shown in Figure 1 (h), (i) and (j), depict that color correction has been achieved to some extent. The effect of color cast still remains in the enhanced images. The images obtained by proposed method show that the blue color clouds and green color grass resembles the visual appearance as it is in the reference image. The same results depict from the value i.e. 0.0475, 0.0421 and 0.0521 for red cast, green cast and blue cast respectively (near to 0) as mentioned in Table 2

The cast Stanford Tower image in Figure 2, enhanced by gray world algorithm and Kwok method lacks a good visual appearance while the proposed algorithm removes darker portion of the image. This ensures that the proposed method has good perceptibility with the reference image. Further, the results are supported by value 0.013, 0.019 and 0.019 for red cast, green cast and blue cast respectively. In the cast House image Figure 3, visual analysis reveals that the image enhanced by proposed method is better than other two existing methods. The proposed algorithm maintains the originality of roof color and tree leaves as compared to the gray world correction algorithm. The House image enhanced by Kwok method is brighter but color cast is not completely removed.The same results are confirmed from the obtained value of CIELAB color space metric mentioned in Table 2.

In a mandrill gray world enhanced image shown in Figure 4, the color of the nose doesn't appear to be red as in the original mandrill image and the green cast are removed to some extent. If we analyze the results produced by Kwok method we can observe that they are close to the reference image in red and blue cast but not with the green cast image. Therefore, the proposed method has acquired the originality of the color by removing the cast.

Similarly, in Figures 5, 6, 7 and 8 the good perceptible quality enhanced image has been achieved using the proposed approach. The enhanced images obtained from the proposed algorithm are near to the original or reference image whereas the gray world correction algorithm does not give good result when there is a large contribution of one color. The quantitative results of the Figures 1-8 are given in Table-2. This table shows that the statistical parameter of the proposed approach provides the best performance as compared with other methods.

Table 2. Comparative results for grayworld, Kowk and Proposed method
(Distance Metric)

Reference image	Test image	Ec (Test Image)	Ee (Grayworld)	Ee (Kowk method)	Ee (Proposed approach)
Image-1(Building)	Red cast	0.1704	0.1186	0.0761	0.0475
	Green cast	0.1868	0.1353	0.0875	0.0421
	Blue cast	0.2189	0.1694	0.0768	0.0521
Image-2(Stanford Tower)	Red cast	0.1825	0.0987	0.0232	0.0131
	Green cast	0.2400	0.1649	0.0721	0.019
	Blue cast	0.2340	0.1271	0.0640	0.0190
Image-3(House)	Red cast	0.1746	0.1113	0.5680	0.0131
	Green cast	0.2070	0.1186	0.1089	0.0182
	Blue cast	0.2332	0.1264	0.1504	0.0181
Image-4(Mandrill)	Red cast	0.2039	0.1251	0.0611	0.0490
	Green cast	0.2461	0.1510	0.0746	0.0450
	Blue cast	0.2790	0.1349	0.0785	0.0490
Image-5(Village)	Red cast	0.2050	0.1050	0.0725	0.0470
	Green cast	0.2227	0.1745	0.0426	0.0450
	Blue cast	0.2316	0.1499	0.0817	0.0630
Image-6(Tree)	Red cast	0.1742	0.1085	0.0391	0.0320
	Green cast	0.2050	0.1459	0.0450	0.0320
	Blue cast	0.2140	0.1552	0.0583	0.0410
Image-7(Two men)	Red cast	0.1360	0.1086	0.0813	0.0540
	Green cast	0.1781	0.1212	0.0921	0.0600
	Blue cast	0.1832	0.1316	0.0881	0.0600
Image-8 (Lena)	Red cast	0.2342	0.1212	0.0164	0.0121
	Green cast	0.3151	0.1768	0.0196	0.0113
	Blue cast	0.3210	0.1144	0.0150	0.0131

7. CONCLUSION

The paper has presented gamma correction approach for color image enhancement as well as preserving the mean intensity of the image. The particle swarm optimization algorithm is used to obtain an optimal gamma value by preservation of intensity value and maximizing the information content. The results have shown that the proposed approach performs better than the gray world approach and the recent Kwok method as well. In addition, the proposed method removes the color cast completely. The effectiveness of the proposed approach is quantitatively measured by distance metric ΔE of CIELAB color space.

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(a) Reference image

(b) Red cast

(c) Green cast

(d) Blue cast

(e) Gray corrected Red cast

(f) Gray corrected Green cast

(g) Gray corrected Blue cast

(h) Kwok corrected Red cast

(i) Kwok corrected Green cast

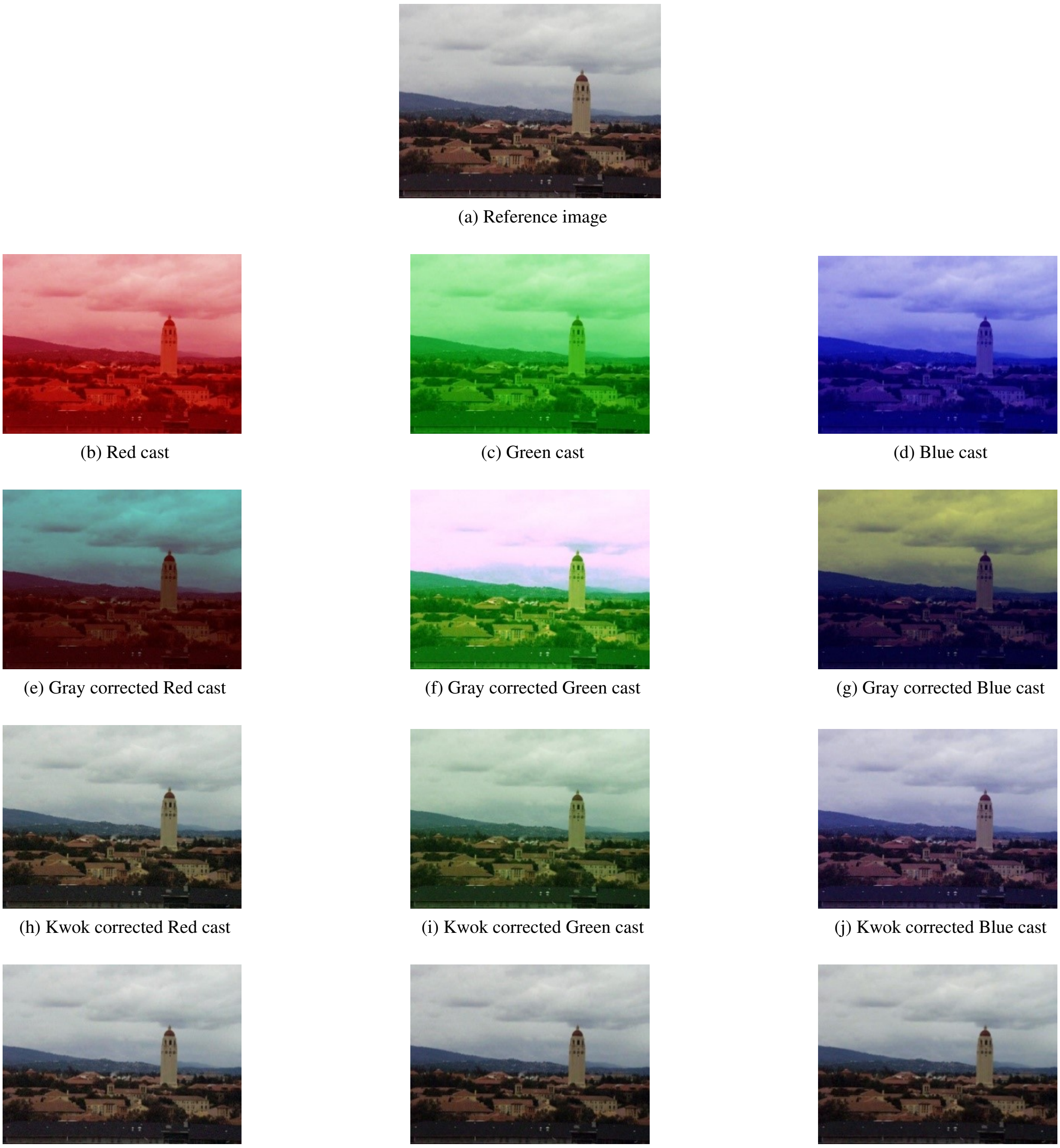
(j) Kwok corrected Blue cast

(k) Proposed approach corrected Red cast

(l) Proposed approach corrected Green cast

(m) Proposed approach corrected Blue cast

Figure 1. Image-1:Building



(a) Reference image

(b) Red cast

(c) Green cast

(d) Blue cast

(e) Gray corrected Red cast

(f) Gray corrected Green cast

(g) Gray corrected Blue cast

(h) Kwok corrected Red cast

(i) Kwok corrected Green cast

(j) Kwok corrected Blue cast

(k) Proposed approach corrected Red cast

(l) Proposed approach corrected Green cast

(m) Proposed approach corrected Blue cast

Figure 2. Image-2:Tower

(a) Reference image

(b) Red cast

(c) Green cast

(d) Blue cast

(e) Gray corrected Red cast

(f) Gray corrected Green cast

(g) Gray corrected Blue cast

(h) Kwok corrected Red cast

(i) Kwok corrected Green cast

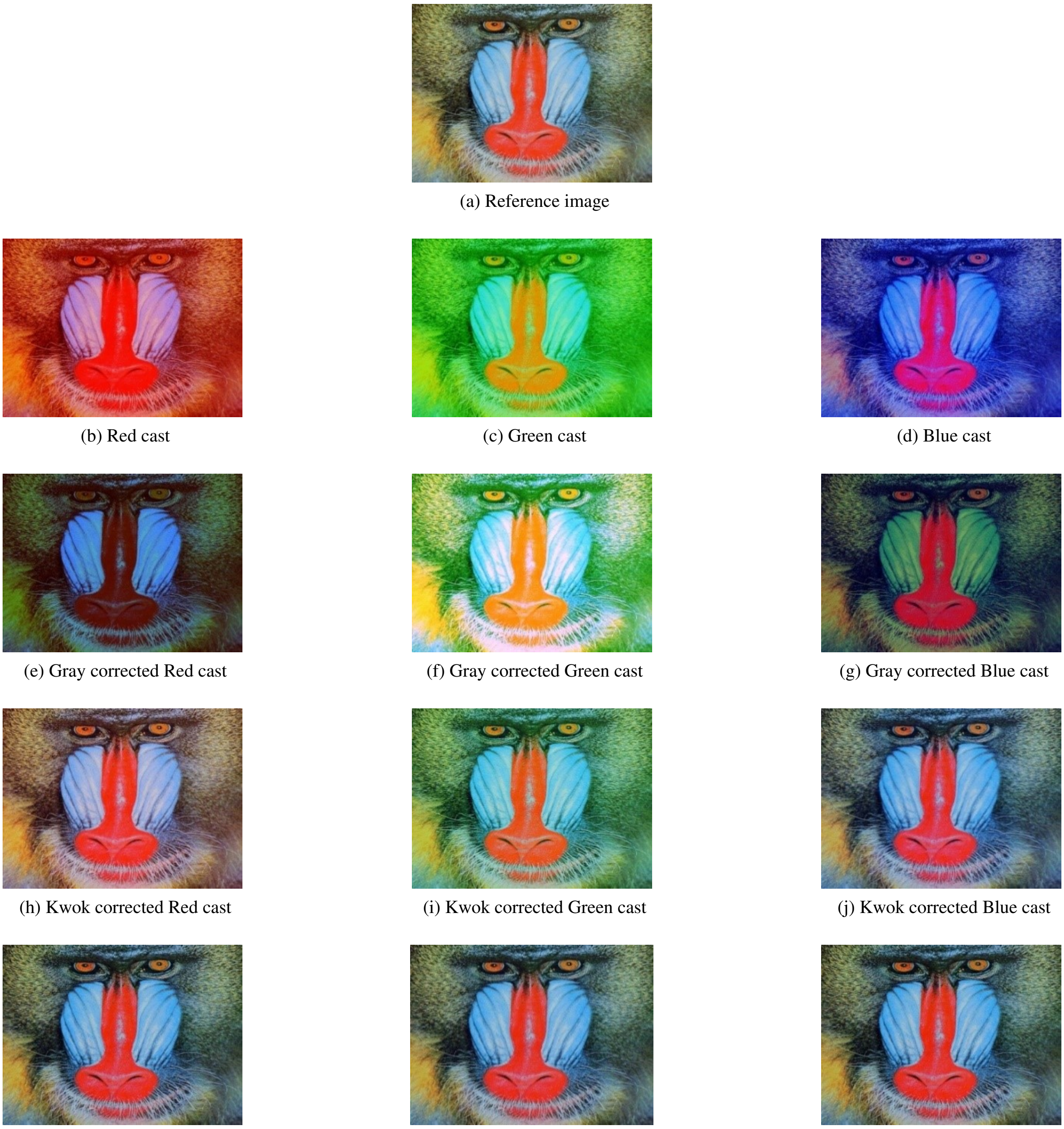
(j) Kwok corrected Blue cast

(k) Proposed approach corrected Red cast

(l) Proposed approach corrected Green cast

(m) Proposed approach corrected Blue cast

Figure 3. Image-3:house



(a) Reference image

(b) Red cast

(c) Green cast

(d) Blue cast

(e) Gray corrected Red cast

(f) Gray corrected Green cast

(g) Gray corrected Blue cast

(h) Kwok corrected Red cast

(i) Kwok corrected Green cast

(j) Kwok corrected Blue cast

(k) Proposed approach corrected Red cast

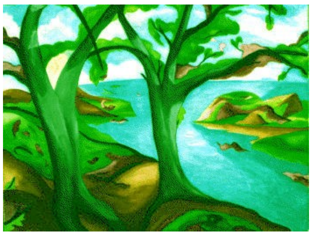
(l) Proposed approach corrected Green cast

(m) Proposed approach corrected Blue cast

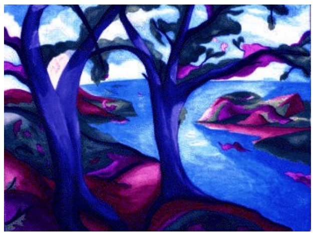
Figure 4. Image-4:Mandrill

(a) Reference image

(b) Red cast



(c) Green cast



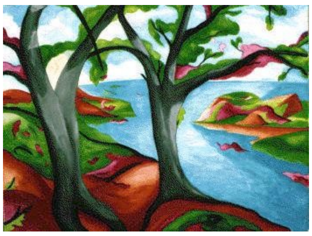
(d) Blue cast

(e) Gray corrected Red cast

(f) Gray corrected Green cast

(g) Gray corrected Blue cast

(h) Kwok corrected Red cast



(i) Kwok corrected Green cast

(j) Kwok corrected Blue cast

(k) Proposed approach corrected Red cast

(l) Proposed approach corrected Green cast

(m) Proposed approach corrected Blue cast

Figure 5. Image-5:Tree

(a) Reference image

(b) Red cast

(c) Green cast

(d) Blue cast

(e) Gray corrected Red cast

(f) Gray corrected Green cast

(g) Gray corrected Blue cast

(h) Kwok corrected Red cast

(i) Kwok corrected Green cast

(j) Kwok corrected Blue cast

(k) Proposed approach corrected Red cast

(l) Proposed approach corrected Green cast

(m) Proposed approach corrected Blue cast

Figure 6. Image-6:Village

(a) Reference image

(b) Red cast

(c) Green cast

(d) Blue cast

(e) Gray corrected Red cast

(f) Gray corrected Green cast

(g) Gray corrected Blue cast

(h) Kwok corrected Red cast

(i) Kwok corrected Green cast

(j) Kwok corrected Blue cast

(k) Proposed approach corrected Red cast

(l) Proposed approach corrected Green cast

(m) Proposed approach corrected Blue cast

Figure 7. Image-7:Two men

(a) Reference image

(b) Red cast

(c) Green cast

(d) Blue cast

(e) Gray corrected Red cast

(f) Gray corrected Green cast

(g) Gray corrected Blue cast

(h) Kwok corrected Red cast

(i) Kwok corrected Green cast

(j) Kwok corrected Blue cast

(k) Proposed approach corrected Red cast

(l) Proposed approach corrected Green cast

(m) Proposed approach corrected Blue cast

Figure 8. Image-8:Lena