COLOR CAST DETECTION FOR SURVEILLANCE VIDEO USING ADDITIVE AND SUBTRACTIVE COLOR SYSTEM

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***Abstract*—To tackle color cast detection challenge, a new approach is proposed in this paper to detect color cast and estimate the extent of color cast using additive and subtractive color system. First, the proposed approach calculates bright and dark information and extreme intensity ratio, and then determines the type of bright and dark information according to extreme intensity ratio. Finally, the proposed approach determines color system type and cast variation channel, and estimates the extent of color cast using extreme intensity ratio and difference intensity. Experimental results show that the proposed approach is reliable and effective, as well as consistent to human's subjective evaluation.**

***Index Terms*—Color cast detection, extreme intensity ratio, cast variation channel.**

I. INTRODUCTION

Colors in surveillance videos are affected not only by the reflective properties of the object itself, but also by the influence of the environmental light source and photosensitive coefficient of the image capturing devices. Therefore, there is a difference in the colors between the obtained images and the real scenes, which is called the color cast. The color cast yields an unsatisfied visual perception. Many studies show that the color cast will result in degradation and make further image analysis and recognition difficult, such as vehicle recognition and tracking. It is of great necessity to conduct image color cast detection for video quality assessment.

Various methods have been developed in the literature, such as gray world [1, 2], white patch [3, 4], neural network [5, 6], histogram statistic algorithm [7] and the equivalent circle algorithm [8], and so on. They contain no approach to estimate the extent of color cast. Gray world method [1, 2] doesn't work if there is a dominant color object in images or images are collected in too dark or bright environment. White patch methods [3, 4] work well only in the circumstances of highlight or white area [9]. Neural network methods [5, 6] need prior knowledge and training costs too much time. Thus its performance depends on the quality of prior knowledge and the structure of neural network. Histogram statistic algorithm [7] is hard to get a comprehensive and accurate judgment because of the complexity and diversity of reasons that cause color cast. Equivalent circle algorithm [8] makes wrong judgments when the extent of color cast is too small.

In view of this, a new approach is proposed in this paper to detect color cast based on additive and subtractive color system. The proposed approach decides the types of color system in the images, including additive type, subtractive type and normal type, which outperforms previous methods. The proposed approach not only needs no assumption and no prior knowledge, but also implements color cast extent estimation and has a high accuracy.

The rest of this paper is organized as follows. The color cast detection and extent estimation is proposed in Section 2. Section 3 provides a parameter optimization of the proposed approach. Experimental results and comparison with other methods are presented in Section 4. Finally, Section 5 concludes this paper.

II. PROPOSED COLOR CAST DETECTION APPROACH

Three types of *color variation* (CV) are presented to describe the bias of color channels in the image [10]. They are additive variation, subtractive variation, and normal. First, the additive type represents that the intensity of one color channel is much larger than other two color channels, such as images of red cast, green cast and blue cast. Second, the subtractive type denotes the intensity of one color channel is much smaller than other two color channels like cyan cast, magenta cast and yellow cast. Third, the normal type suggests the intensity among color channels is balanced, such as normal images.

A red cast image is shown in Fig. 1(a), the histogram of which is presented in Fig. 1(d). The curve with solid line stands for red channel, the curve with dotted line indicates green channel, and the curve with dot chain line represents blue channel. The intensity of red is much larger than other two colors in Fig. 1(d), and the intensity of blue is much smaller than other two colors in Fig. 1(e), whereas the intensity of three channels is similar in Fig. 1(f). Based on the description of color variation, the color cast detection is achieved as follows.

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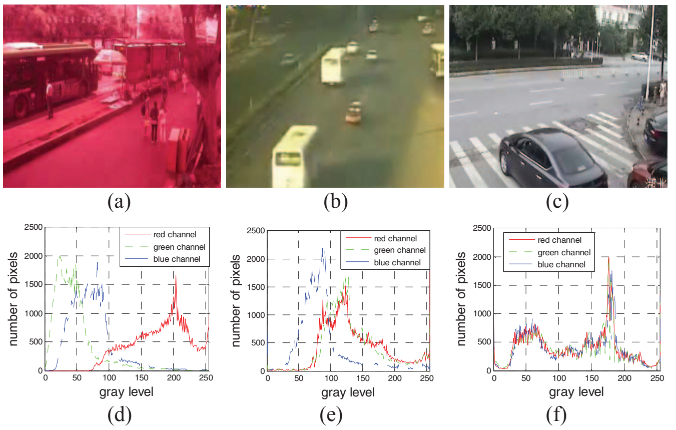


Fig. 1. Images and their histogram: (a) red cast image; (b) yellow cast image; (c) noncast image; (d) histogram of image (a); (e) histogram of image (b); (f) histogram of image (c).

The proposed approach performs color cast detection in RGB color space. Firstly, let $\mathbf{H}_{\max}$ and $\mathbf{H}_{\min}$ respectively denote maximum intensity matrix and minimum intensity matrix of the image $\mathbf{I}$. Namely,

$$\mathbf{H}_{\max} = \max\left(\mathbf{I}^R, \mathbf{I}^G, \mathbf{I}^B\right) \quad (1)$$

$$\mathbf{H}_{\min} = \min\left(\mathbf{I}^R, \mathbf{I}^G, \mathbf{I}^B\right) \quad (2)$$

where $\mathbf{I}^R, \mathbf{I}^G, \mathbf{I}^B$ represent red, green and blue component of image $\mathbf{I}$, respectively. $\max()$ and $\min()$ denote the operator of maximum and minimum, respectively.

Let T_a be the amplitude tolerance, the bright information $\mathbf{L}_b$ and the dark information $\mathbf{L}_d$ of image $\mathbf{I}$ are defined by

$$\mathbf{L}_b^c(x,y) = \begin{cases} 1, & if\ \left(\mathbf{H}_{\max}(x,y) - \mathbf{I}^c(x,y)\right) < T_a \\ 0, & otherwise \end{cases} \quad (3)$$

$$\mathbf{L}_d^c(x,y) = \begin{cases} 1, & if\ \left(\mathbf{I}^c(x,y) - \mathbf{H}_{\min}(x,y)\right) < T_a \\ 0, & otherwise \end{cases} \quad (4)$$

where $c \in \{R, G, B\}$, x and y respectively donate row index and column index of the image $\mathbf{I}$. After $\mathbf{L}_b$ and $\mathbf{L}_d$ are calculated, they can be refined via the inverse procedure to remove the negative effects caused by pixels not matching the conception of color cast. The inverse procedure is given by,

$$\mathbf{L}_i(x,y) = \begin{cases} 1 - \mathbf{L}_i(x,y), & if\ \mathbf{L}_i(x,y) = (1,1,1) \\ \mathbf{L}_i(x,y), & otherwise \end{cases} \quad (5)$$

where $i \in \{b, d\}$.

The *extreme intensity ratio* (EIR) can be calculated by,

$$EIR_i^c = \frac{\sum_{x=1}^{M}\sum_{y=1}^{N} \mathbf{L}_i^c(x,y)}{M \times N} \quad (6)$$

where M and N are the height and width of image $\mathbf{I}$ individually. Moreover, $\mathbf{L}_i^c$ is the bright and dark information of RGB channels. EIR_i^c is the bright and dark intensity ratio of RGB channels and exactly is the mean of bright and dark information of RGB channels.

Fig. 2 presents some color cast image and their EIR. As shown in (f), each scale on the horizontal axis corresponds to three bars, which represent EIR of the R channel, G channel and B channel from left to right, in the bright EIR of an additive blue cast image (b), the rate of blue is far lager than red and green, which can be regarded as an extension of additive type from image to bright or dark information, and the corresponding dark EIR(g) is additive as well. However, in the bright EIR(m) of the image(j) which has subtractive yellow cast, the rate of blue is much smaller than red and green, which can be treated as an extension of subtractive type as well, while the corresponding dark EIR(n) is additive.

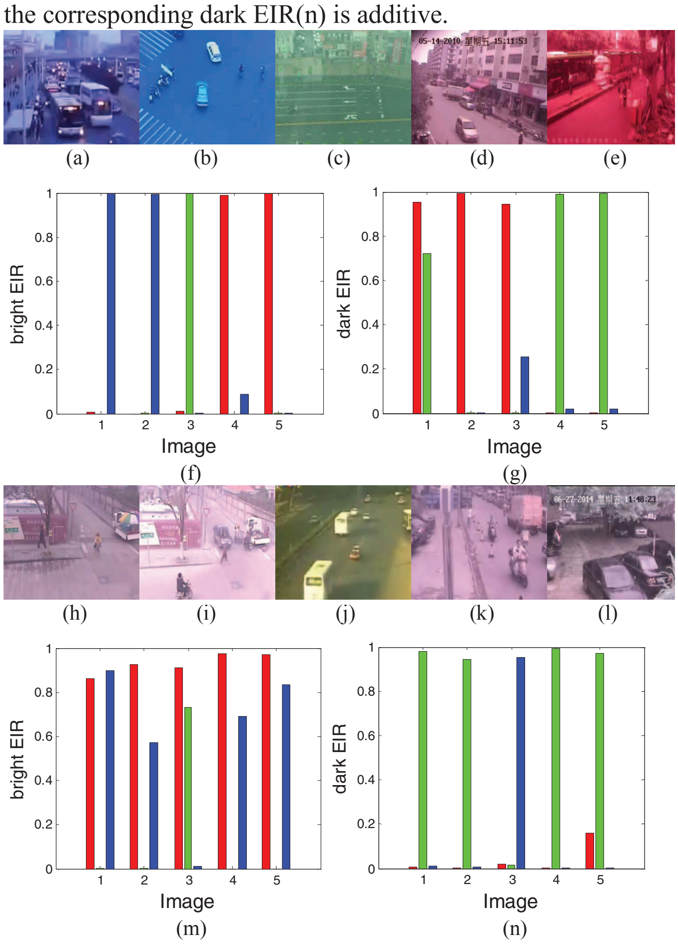


Fig. 2. Examples of color cast image and their EIR: (a)~(e) are examples of additive cast image; (f) the bright EIR of the additive examples; (g) the dark EIR of the additive examples; (h)~(l) are examples of subtractive-cast image; (m) the bright EIR of the subtractive examples; (n) the dark EIR of the subtractive examples.

It is observed over a great number of images including both color cast images and noncast images that, in an image, if the bright EIR is additive or stable as the stretch of normal when talking about CV, while the dark EIR is subtractive, the image has additive cast. If the bright EIR is not additive while the dark EIR is additive, the cast of the image is subtractive. Otherwise, the image is out of color cast.

Obtained from (6), EIR_b is a 1-by-3 vector, of which each elements are between 0 and 1. Supposed *ratio value* (RV) denoted by RV_k is the values of EIR_b in descending order, thus the first order inverse difference ΔRV_k and the second order inverse difference $\Delta^2 RV_k$ can be calculated by,

$$\Delta RV_k = RV_k - RV_{k+1} \tag{7}$$

$$\Delta^2 RV_k = \Delta RV_k - \Delta RV_{k+1} \tag{8}$$

where $k = 1, 2$.

In this paper, four states are supposed to describe the difference between three numbers. They are (i) *superior*, it represents the largest number is much bigger than middle one, e.g. $\Delta RV_1 > T_1$; (ii) *inferior*, it means the smallest number is much smaller than the middle like $\Delta RV_2 > T_2$; (iii) *balance*, it describes the three numbers are close to each other, such as, $\left|\Delta^2 RV_1\right| < T_3$; (iv) *similarity*, it shows the second numeric is near to the largest one or the smallest one, e.g. $\Delta RV_2 < T_4$. $T = \{T_1, T_2, T_3, T_4\}$ is a set of thresholds predefined. Therefore, three-numerical trend can be described by superior, inferior, balance, similarity, or their combination.

Define predicate

$\mathrm{STA}(obj, p)$: obj has the property p .

E.g. $\mathrm{STA}(\Delta RV_2, \text{inferior})$ means ΔRV_2 has the property inferior, i.e. the smallest is much smaller than the middle one. Summarizing the criteria for judging the type of bright or dark information as follows,

$$\mathbf{L}_i \in \begin{cases} add, & \textit{if}\ \mathrm{STA}(\Delta RV_{i,1}, sup) \wedge \mathrm{STA}(\Delta RV_{i,2}, sim) \\ sub, & \textit{if}\ \mathrm{STA}(\Delta RV_{i,1}, sim) \wedge \mathrm{STA}(\Delta RV_{i,2}, inf) \\ sta, & \textit{if}\ \mathrm{STA}(\Delta^2 RV_{i,1}, bal) \end{cases} \tag{9}$$

where add, sub, sta respectively donate additive, subtractive and stable types of bright or dark information which go back to the three types of color variation, *sup,sim,inf,bal* stand for four states, i.e. superior, similarity, inferior and balance. Thus the type of CV in an image is available by,

$$\mathbf{I} \in \begin{cases} add, & term\,1 \\ sub, & term\,2 \\ nor, & otherwise \end{cases} \tag{10}$$

$$term\,1: \mathrm{STA}(\mathbf{L}_b, add) \vee (\mathrm{STA}(\mathbf{L}_b, sta) \wedge \mathrm{STA}(\mathbf{L}_d, sub))$$

$$term\,2: (\neg\mathrm{STA}(\mathbf{L}_b, add) \wedge \mathrm{STA}(\mathbf{L}_d, add))$$
$$\vee (\mathrm{STA}(\mathbf{L}_b, sub) \wedge \mathrm{STA}(\mathbf{L}_d, sta))$$

where nor denotes normal type in color variation.

After the detection of image color cast, *channel of cast variation* (CCV) can be know as maximum channel in bright EIR of additive cast image and maximum channel in dark EIR of subtractive cast image, whereas there is no cast variation channel in a noncast image.

After color cast detection, the extent of color cast can be estimated as follows. It can be perceived that there are differences among the intensity of color channels through observation. The difference is defined as *difference intensity* (DI). It can be calculated by,

$$DI_i^c = \frac{\sum_{x=1}^{M}\sum_{y=1}^{N} \Delta_i^c(x, y)}{M \times N} \tag{11}$$

where Δ_i^c can be computed by,

$$\Delta_i^R(x, y) = \Delta RG_i(x, y) + \Delta RB_i(x, y) \tag{12}$$

where Δ_i^R denotes the sum of intensity difference between red channel and the rest channels, ΔRG_i and ΔRB_i defined as,

$$\Delta RG_i(x, y) = \begin{cases} \mathbf{I}^R(x, y) - \mathbf{I}^G(x, y), & \textit{if}\ \mathbf{L}_i^R(x, y) = 1 \\ 0, & otherwise \end{cases} \tag{13}$$

$$\Delta RB_i(x, y) = \begin{cases} \mathbf{I}^R(x, y) - \mathbf{I}^B(x, y), & \textit{if}\ \mathbf{L}_i^R(x, y) = 1 \\ 0, & otherwise \end{cases} \tag{14}$$

Likewise, an extension to G, B color channels and bright, dark information can be calculated.

The *extent of color variation* (ECV) is proposed to quantize the intensity variation. Prior to the computation of ECV, let's first get mixed RV and DI of a color cast image called MRV and MDI based on EIR and DI used for color cast detection.

$$MRV = \sum \lambda_i^c EIR_i^c \tag{15}$$

$$MDI = \sum \lambda_i^c DI_i^c \tag{16}$$

where λ_i^c denotes the weights λ . Moreover, λ depends on the type of CV and EIR. For instance, λ_i^c ought to be distinctively high if its corresponding channel is CCV. After that, the *difference intensity ratio* (DIR) can be obtained by sigmoid function,

$$DIR = \frac{1}{1 + e^{-(MDI - a)/b}} \tag{17}$$

where a and b represent position and scale parameters based on the luminance of image which will be discussed in section 3. Eventually the calculation of ECV is given by,

$$ECV = DIR \times MRV \tag{18}$$

The overall framework of the proposed algorithm is summarized in Fig. 3 and described as follows.

Step1: Given an image, bright and dark information are calculated by (3) and (4), and EIR is calculated by (6), then decide the type of bright and dark information are decided by (9), and CV type is determined by (10). Finally, CCV judgment is performed.

Step2: DI is calculated by (11). Then combine RV is combined by (15) and DI by (16). After MDI is normalized by (17), the ECV is computed by (18).

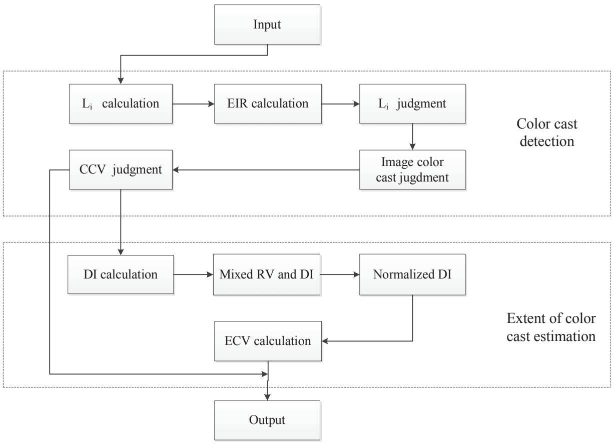


Fig. 3. The overview of the proposed approach

III. OPTIMIZATION OF THE PROPOSED APPROACH

There are 4 schemes to calculate *MRV* and *MDI* before deciding which one is the optimal. The difference of four schemes lies in the difference of weights λ. As mentioned above, λ relies on the type of CV and EIR. Re-sorting EIR in descending order firstly, then, the first weight is given by,

$$\lambda_{b,add}=(1,0,0),\lambda_{b,sub}=\frac{1}{2}(1,1,0),\lambda_{b,nor}=\frac{1}{3}(1,1,1),$$

the other three are zeros. Where b and d corresponds to bright and dark EIR, and add, sub, nor correspond to additive, subtractive and normal of CV. Likewise, the second is

$$\lambda_{b,add}=(1,0,0),\lambda_{b,sub}=(1,1,0),\lambda_{b,nor}=\frac{1}{3}(1,1,1),$$

the third is

$$\lambda_{d,add}=(1,0,0),\lambda_{d,sub}=(1,0,0),\lambda_{b,nor}=\frac{1}{3}(1,1,1),$$

the fourth is

$$\lambda_{b,add}=(1,0,0),\lambda_{d,sub}=(1,0,0),$$
$$\lambda_{b,nor}=\frac{1}{3}(1,1,1),\lambda_{d,nor}=\frac{1}{3}(1,1,1).$$

Fig. 4 shows the roc curves of 4 methods where a is set to 30, and b is 20. Compared with the four curves, there is no difficult to conclude 4th scheme with the area under curve of 0.9873 is the best result, i.e. the strategy 4 is the number one.

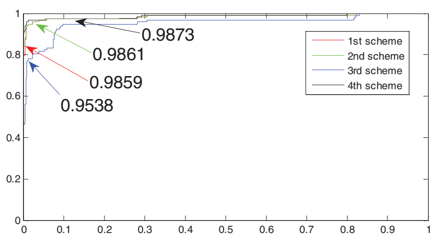


Fig. 4. The ROC curves of four methods to compute *MRV* and *MDI* .

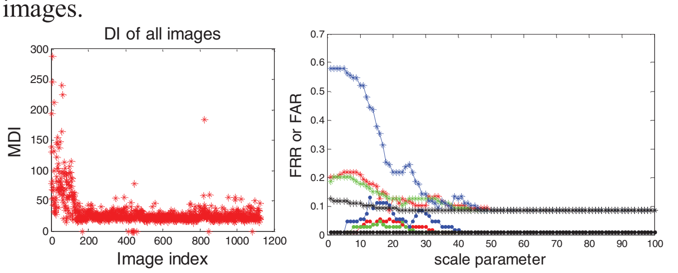
It is mentioned that the discussion of the ways to compute ECV is under a precondition that a and b are set to 30 and 20, respectively. However, the two parameters have some influence on ultimate results.

It has been illustrated that a represented position parameter, and b was scale parameter. Fig. 5 (a) shows a distribution of MDI. It can be observed from the Fig. 4(a), previous MDI is generally higher than the latter, since the previous is calculated based on color cast images while the latter based on normal images. Most of MDI cutlers between 10 and 50, consequently, a is set to 30 as an approximation. Fig. 5 (b) describes the trend of *false accept rate* (FAR) and *false reject rate* (FRR) obtained from the 4 schemes mentioned above with a range of b from 1 to 100 while a is fixed to 30, where FAR and FRR are given by formulations as follows,

$$\begin{aligned}FAR &= falseNum/norNum\\ FRR &= missNum/castNum\end{aligned} \tag{19}$$

where *falseNum* is number of false detection images, *missNum* is number of miss detection images, *norNum* is number of normal images, and *castNum* is number of color cast images.

In Fig.5 (b), the lines from red, green, blue to black are corresponding to schemes from 1st to 4th, and four lines above are curves of FRR, while below are FAR. Both in FRR and FAR, curves' colors from up to down are blue, red, green and blake. FRR is universally higher than FAR owing to the fact that cast samples are about 7.3 times bigger than normal samples. What can be known from Fig.5 (b) is that FRR and FAR gradually converge with the growth of b. As for the 4th scheme, b prefers to at least 20. It might require some minor adjustment to the two parameters in the process of very dark images.



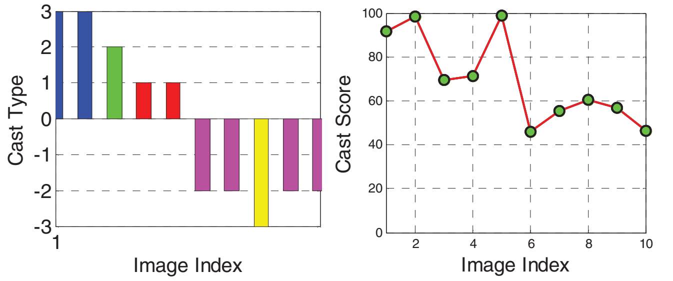
(a) (b)

Fig. 5. The relationship between the two parameters with other features: (a) the relationship between position parameters and MDI; (b) the relationship between scale parameters and FRR, FAR.

IV. EXPERIMENTAL RESULTS

The proposed approach is evaluated using an image database consisting of 120 color cast images and 990 normal images from surveillance videos. It is worthwhile mentioning that the proposed method is dedicated to non-reference surveillance video.

Fig. 6 shows results of ten raw images in Fig. 2. In (a), 7 numbers on the vertical axis from -3 to 3 respectively represent yellow cast, magenta cast, cyan cast, no cast, red cast, green cast, and blue cast. Fig. 6 (b) draws ECV of the ten images, it proves the similarly of proposed approach with the human eye behavior.



(a) (b)

Fig. 6. The results of proposed approach: (a) cast type detection of the ten images(in Fig. 2); (b) ECV the ten color cast images.

Table 1 shows an accuracy comparison with [10], what can be obviously seen is that the method proposed works better and have a higher accuracy.

TABLE I. PERFORMANCE EVALUATION BETWEEN THE PROPOSED APPROACH AND REFERENCE [10].

	Proposed approach	**Ref. [10]**
FAR	0.5%	1.7%
FRR	9.17%	11.7%

V. CONCLUSIONS

A distinctive scheme for color cast detection using additive and subtractive color system has been proposed in this paper. The proposed approach exploits the extreme intensity ratio and bright and dark information of the image to achieve the color cast and cast variation channel detection, and then estimates the extent of color cast via extreme intensity ratio and difference intensity. Experimental results show the proposed approach is capable of achieving color cast detection and the extent of color cast estimation.

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REFERENCES

[1] D. Forsyth, "A novel algorithm for color constancy." International Journal of Computer Vision, vol. 5, pp. 5–35, August 1990.

[2] H. Kawamura, S. Yonemura, J. Ohya, and N. Matsuura. "Illuminant color estimation by hue categorization based on gray world assumption." Proc. SPIE, vol. 7873, pp. 185–221, February 2011.

[3] G. D. Finlayson, D. Graham, P. M. Hubel, and S. Hordley. "Color by Correlation." Color & Imaging Conference, vol. 6, pp. 6–11, 1997.

[4] Kim, Sujung, W. J. Kim, and S. D. Kim. "Automatic white balance based on adaptive feature selection with standard illuminants." International Conference on Image Processing, pp. 485–488, 2008

[5] V. C. Cardei, B. Funt, and K. Barnard. "Estimating the scene illumination chromaticity by using a neural network." Journal of the Optical Society of America A, vol. 19, pp. 2374–2386, 2002.

[6] Q. Zhu, J. Chen, and L. Feng. "Study on Auto-Focusing Technique in Digital Still Camera Based on Image Analysis." Journal of Jiangsu University of Science & Technology, 2003.

[7] S. Chen, and J. Bi. "Automatic Color Cast Detection Algorithm for Surveillance Video Sequence Based on Color Histogram Characteristic." Lecture Notes in Computer Science, pp. 280–287, 2011.

[8] L. Feng and H. Jin. "Approach to detect digital image color cast based on image analysis." Journal of Jiangsu University, 2004.

[9] F. Li, and H. Jin. "An approach of detecting image color cast based on image semantic." Machine Learning and Cybernetics, 2004. Proceedings of 2004 International Conference on IEEE, vol. 6, pp. 3932–3936, 2004.

[10] D. Zhu, L. Chen, J. Tian, and X. Huang. "A Two-Stage Blind Image Color Correction Using Color Cast Estimation." Communications in Computer & Information Science, pp. 72–80, 2014.