The Image Quality Standard based on Human Visual System for the Spectral Sensitivity Crosstalk Depending on Lens F-number

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ABSTRACT

The color reproduction of an image sensor is one of the important characteristics which determine the performance of the image sensor. Recently, the pixel size of image sensor has become smaller due to the demand of large pixel count. So, small F-number lens is needed to improve the sensitivity. However, the crosstalk component of spectral sensitivity characteristics increases due to using the small F-number lens, and the color reproduction of the image sensor becomes worse. Therefore, we propose a color difference standard based on human visual characteristics to solve this problem due to the lens with small F-number. If the color difference corresponds to these standards, the color reproduction will be satisfied even if the crosstalk component of spectral sensitivity characteristics increases.

Keywords: color reproduction, small F-number lens, crosstalk component of spectral sensitivity characteristics, human visual characteristics

1. INTRODUCTION

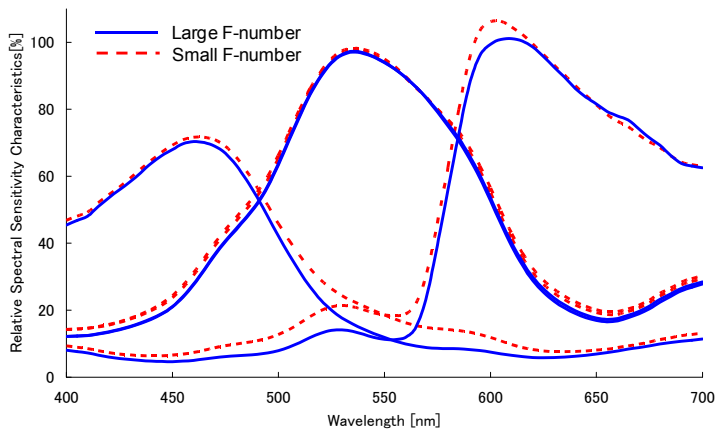
Image sensors in cellular phones, digital still cameras(DSCs), and digital video cameras are asked for performance improvement of sensitivity, SNR, resolution, dynamic range, and color reproduction. Recently, compact DSC with more than 16 mega pixel count has been commercialized. Due to large pixel count, pixel size becomes smaller, and small F-number lens is needed to improve the sensitivity. In case of small F-number lens, sensitivity of image sensor becomes worse than expected, because of the angular response characteristics of incident light of image sensor. As a result, the crosstalk component of spectral sensitivity characteristics increases, and the color reproduction of the image sensor becomes worse. So it is difficult to use the lens with small F-number. Fig.1 shows the crosstalk and color reproduction in the case of large and small F-numbers. The color difference of large and small F-number is 4.4 on CIEDE2000 standard. The value of this color difference is enough to make users feel a sense of discomfort.

Conventionally, the spectral sensitivity characteristics depending on the lens F-number were evaluated by only the amount of change of the crosstalk component. In fact, the acceptable level of the crosstalk component of the spectral sensitivity characteristics is not yet defined. Therefore, we propose a CIEDE2000[1][2][3] standard based on human visual characteristics to solve this problem due to the lens with small F-number. If the color difference corresponds to these standards, the color reproduction will be satisfied even if the crosstalk component of spectral sensitivity characteristics increases.

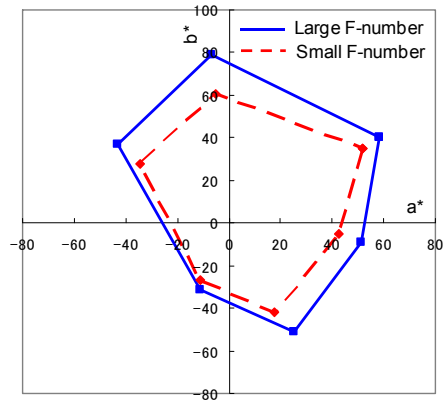
As a result, we have realized the image sensors which achieved the stable color reproduction thanks to designing the color filter using these standards that consist of JND(Just Noticeable Difference) and allowable limit.

2. PROPOSAL

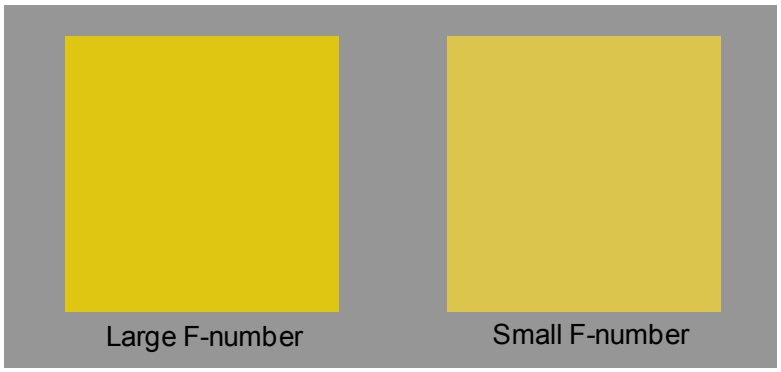
Mac Adam's ellipse is common in subjective



(a) Relative spectral sensitivity characteristics



(b) L*a*b* chromaticity diagram

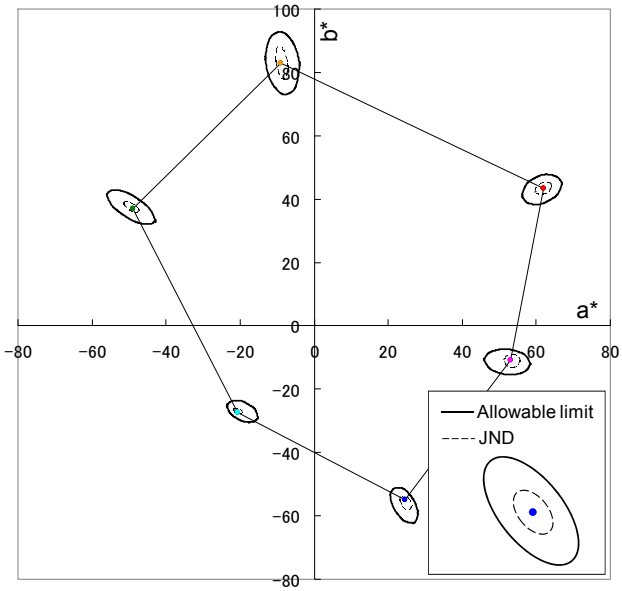


(c) Yellow color reproduction

Fig.1 Relation between F-number of the lens and Spectral sensitivity characteristics

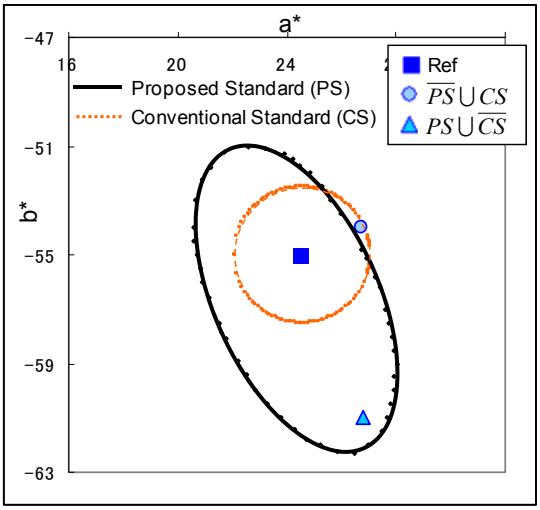
evaluation of color difference. It is well known that each Mac Adam's ellipse has a certain elliptical form and directivity, and it is not a perfect circle. However, Mac Adam's ellipse is xy chromaticity which is not uniform color space[4]. Then, the Euclidean mapping converted to CIEDE2000 chromaticity diagram from xy chromaticity diagram was investigated[5][6]. Furthermore, we investigated the standard of the uniform color difference with CIEDE2000. For reference six colors (Red, Green, Blue, Yellow, Magenta, and Cyan), we conducted two experiments: 1st experiment is JND of color difference, and 2nd experiment is allowable limit of color difference (the limit that the human eye can recognize and accept). Thirty observes participated in each experiment. All participants were from Sony in Japan. In Fig.2(a), the user interface composed of two images(the original and test image) are shown. We changed the hue and saturation of the original image and made a test image. The reflectance ratio of the background grey image is 18%. "Good" will be chosen if the color difference of two images can be undetected. "Acceptable" will be chosen if the color difference of two images can be detected and it can still be accepted. "Bad" will be chosen if unacceptable. Fig.2(b) shows the results of these experiments. If the color difference is within these proposed standards, the color reproduction will be satisfied.

(a) User interface

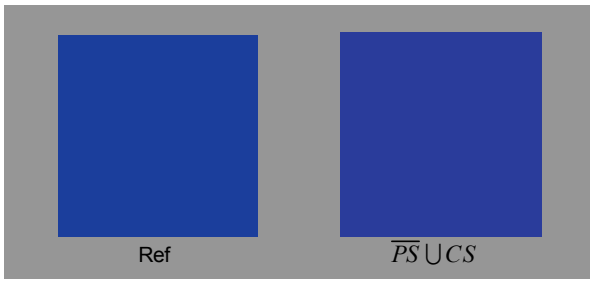


(b) The ellipse of Sony original color standard

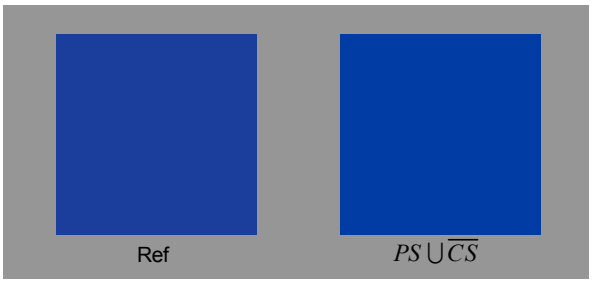
Fig.2 The experiment of color difference



(a) L*a*b* chromaticity diagram of PS and CS



(b) The comparison image of reference and CS



(c) The comparison image of reference and PS

Fig.3 The comparative result of the proposed standard(PS) and conventional standard(CS)

3. RESULTS

Generally speaking, conventional standard of color difference for SNR10[7] is defined by the perfect circle limit for each color saturation and hue. However, we defined the appropriate standard for each color. As a result, it could provide the correct standard, so the limit is accurate. Fig.3(a) shows the proposed standard and the conventional standard of allowable limit of color difference of Blue. Fig.3(b) shows the image in the case of not meeting the proposed standard but meeting the conventional standard. The color difference of these images is not desirable. On the other hand, Fig.3(c) shows the image in the case of not meeting the conventional standard but meeting the proposed standard. The color difference of these images is permissible. Therefore, if the proposed standard is applied, the image sensor with desirable color reproduction is realizable. Furthermore, SNR10 is improved thanks to the small gain of color matrix(CM) as Fig.4 shows. The values of SNR10 of the conventional standard and the proposed standard are shown in Table 1.

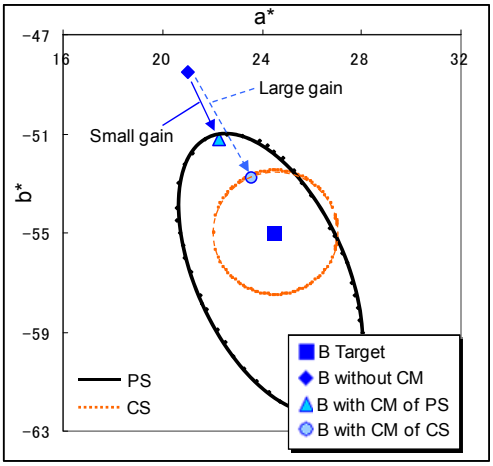


Fig.4 The comparison gain of PS and CS

Table.1 SNR10

Standard	SNR10
Conventional	45 lx
Proposed	40 lx

4. CONCLUSIONS

In this paper, we proposed the evaluation method of the acceptable level of the crosstalk component of the spectral sensitivity characteristics. We have realized the image sensors which achieved the stable color reproduction thanks to designing the color filter using these standards (JND and allowable limit). Furthermore, the standard of this color difference is applicable to other evaluations. For example, it can be used for evaluation of adjustment of different color temperatures, and evaluation of the color matrix performance for improved color reproduction.

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