

# Using Moiré Chroma for DSC On-line Focus Calibration

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## Abstract

Focus is an important part before capturing an image by DSC. After obtaining an optimized focus, image can have best contrast to evaluate. So far, many focus methods were built and they include maximum contrast search and object distance inverse calculation.<sup>1</sup> No matter which method is used, both can provide us best focus to capture. In this paper, another method to determine focus is moiré. Reason of moiré happened is related to sensor's pixel pitch and spatial frequency of capture target. When moiré happened and based on mosaic CFA (Color Filter Array), the captured image will result in special slanted line and some colored pixel.<sup>2</sup> In some focus test, moiré was known to be a method to determine focus, but it is inspected by human visual without any quantification. This paper tries to use chroma of moiré to make some experiment and to compare with contrast method. Therefore, focus can be determined simply by chroma calculation

## Introduction

### Application of Moiré

How moiré is generated? It is related to sensor's mosaic pattern and target spatial frequency. When spatial frequency (line pair per mm) is smaller than double of sensor's pixel pitch, moiré is naturally made. Not only slanted line will interface scene captured but also some colored pixels. This is due to mosaic pattern and it can be taken an example to explain how it works. (Figure 1 & 2)

When light pair fall on Bayer pattern,<sup>3</sup> two types of condition will show out (Figure 1 & 2). Figure 1 illustrates that dark light covers vertical R, G pixels. Then, all imaged data will be sent to image processing, interpolation, color correction...etc. The edge of bright and dark will generate vertical color area. The color is presented just like right picture of Figure 1. Because the color is mixed by almost G and B color (bright area), the resulted colored area presents cyan. Same to another condition, the color is mixed by R and G color, and thus its color is orange.

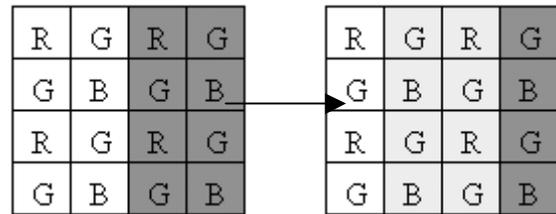


Figure 1. First type of colored pixel for line pair

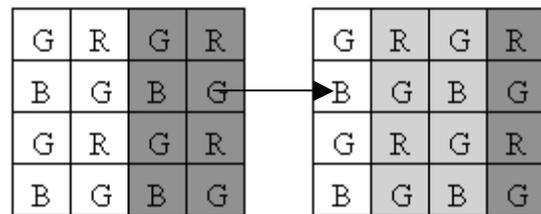


Figure 2. Second type of colored pixel for line pair

### Chroma of Moiré

It is known that focus determination can use by moiré, but it is just evaluated by visual inspection. Therefore, a method tries to get any quantification to determine by program without human visual inspection. Chroma is one character of moiré that can be taken a role of focus test.

When camera cannot focus target, the contrast and chroma of the image would be very low. However, the focal lens continues to move toward to search optimize focus, the contrast will greater and some slanted line, colored pixels also present in the captured image via moiré phenomenon. According to moiré sometimes sensitivity as focal length changed, the evaluation will test depend on focus controllable lens. Thus, all data are obtained by movable focusing lens and under one motor step increment moving.

### Calculation Method

#### Contrast Based

The most popular focus evaluation method is contrast-based algorithm. One simple algorithm of this method is to pick G value of each pixel (Figure 3), and then minus them

pixel by pixel in horizontal direction. All differenced data summarize to get a focus index. Continuously vary the focal length, some focus index will be calculated to draw a focus curve. (1)

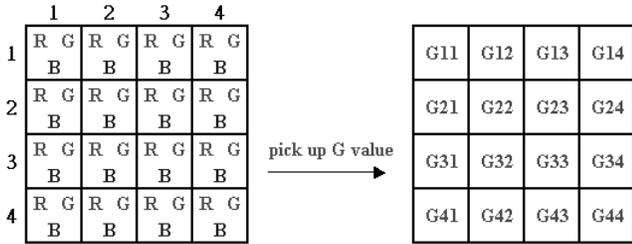


Figure 3. G pixel for simple calculation of contrast method

$$Focus\_Index = \sum ABS(G_{i,j+1} - G_{i,j}) \quad (1)$$

Combine all focus index for every focus position, best lens focusing position would be selected on the peak.

**Chroma of Moiré**

After taking a picture, transfer all RGB data with each pixel to Lab color space and then calculate chroma value by a and b (figure 4). Drawing histogram to obtain chroma and compare with specification what we will set, its horizontal axis represents chroma value and vertical axis is pixel numbers. In Lab color space, the nearer neutral axis represents the more monochromatic. Therefore, we can set one value to be threshold. If chroma is over than threshold, integrate the pixel counts of over threshold, and it is a focus index of moiré. (2)

$$Focus\_Index = \sum C_{i,j} \text{ As } C_{i,j} > threshold \quad (2)$$

**Chart Design**

Siemens star chart is modified for this test. When line pair generates moiré, the line width should be near one pixel pitch size. Therefore, this line pair of chart would be designed as a little bit below and greater one-pixel pitch. In this paper, it was designed to meet 0.8 to 2-pixel pitch. And its related dimension is describe below: (Figure 5)

This paper uses a digital camera with zoom lens to implement moiré test. This zoom lens wide focal length is 7.6mm, and sensor pixel pitch is 3.125um. If the object distance is set to 600mm, the line pair on chart has to be calculated first. With magnifying power, the line width would be 0.24671mm and line pair would be double, 0.49342mm. Then, the line width compare to pixel variation, 0.8 to 2 pixels pitch, can be design to 0.19737mm to 0.49342mm (Figure 6). Due to this line width variation, the test chart can be drawn in donut style and its internal diameter is 60mm, external diameter is 150mm.

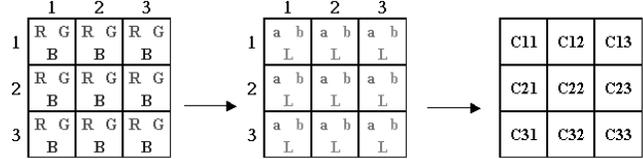


Figure 4. RGB transfer to Lab to get focus index for moire

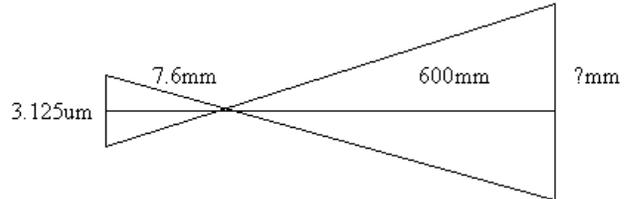


Figure 5. "?" is the line width we need

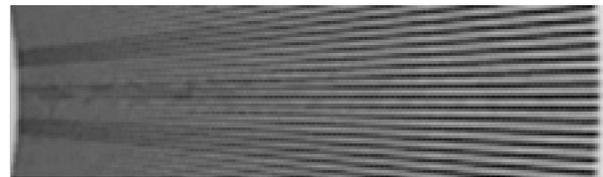


Figure 6. A piece of captured image of test chart

**Experiment**

Test setup is to put camera ahead from chart about 600mm and then snap an image by vary different focus motor step. In this test, one camera with zoom lens was choosing to implement it (Figure 7). The experiment procedure list below:

1. The best focus step can be determined by its auto focus calculation (focus step 275), and so that the best focus step is obtained and set to be a reference.
2. Move motor and snap images with a margin steps. The main idea is to search the peak chroma in these steps.

After all images download into PC, we cut out certain part which cover all the donut, and start running chroma of moiré program. If we can know the location where colored pixels presented, the time of program running will save.

**Result**

Via color space transformation, RGB can be transfer to Lab easily and then calculate chroma. Figure 8 is about chroma histogram of each image. X-axis is focus related step, and its step zero is related to absolute step of 260 (275 minus 15). Y-axis is chroma value. Z-axis is normalized pixels numbers and it is calculated by each pixel numbers of certain chroma divide by total pixel ones. In Figure 8, chroma of moiré can be presented obviously. If there were no colored pixels generate by moiré, a great part of pixel numbers would tend to neutral axis (chroma histogram value equal to zero). However, from Figure 8, some colored pixels generated by moiré and it makes chroma histogram curve tend to move to the direction of larger value, even reaches to 27.

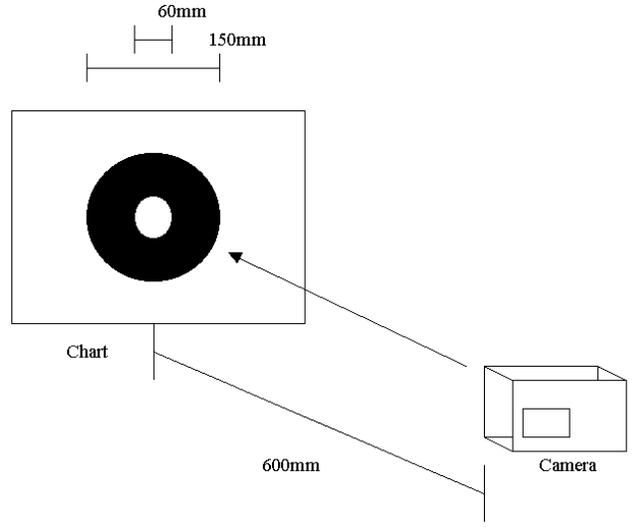


Figure 7. Experiment setup

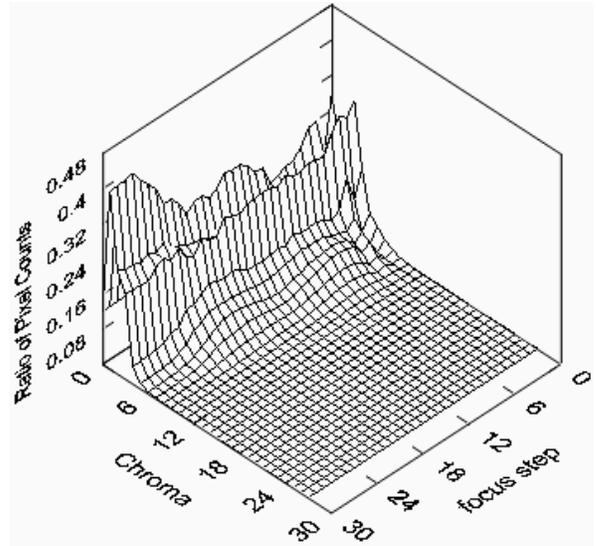


Figure 8. Histogram diagram of colored pixels

In this test, it also want to compare these two method whether can be put together to understand difference between with each other. Figure 9 presents this two-method combination. X-axis is absolute step and Y-axis is normalized by each value dividing by maximum value. In addition, this value is calculated from individual algorithm. This output also shows us which step is the best focus. Obviously, it presents two curves which black line formed by moiré and gray one formed by contrast have the same trend to form a peak. Moire's peak is 267 steps and Contrast's peak is 270 step, they only have three steps difference. It is obvious to say chroma of moiré can have similar result with contrast method but curve of moiré is not total smoothly. The non-smooth curve is caused by some reasons that need to be overcome.

Colored pixel is sensitive to environment illuminant and any careless shake the experiment setup would make the numbers of colored pixels change. This phenomenon may cause the focus cure has related peak to affect the result if the margin steps is not enough for calculation.

## Conclusion

This paper provides us quantification of applying moiré to determine focus position of lens, and can be communicate with other people by the same thinking. This also assists R&D people to evaluate lens focus determination more approaching human visual. In the future, we believe it would be applied to focus determination and other technologies, as if fast image processing can reduce calibrated time, will be built.

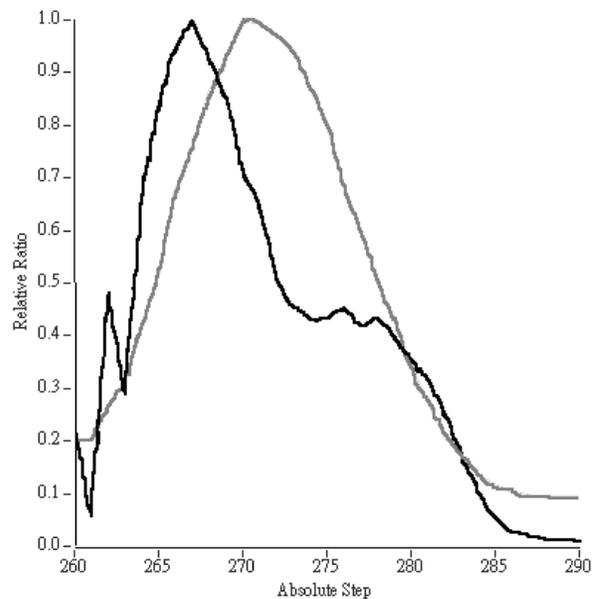


Figure 9. Focus curves of Moiré and Contrast based method. Black line is Moire method and gray line is Contrast method

## Reference

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### **Biographies**

**Wen-Lung Chou** worked for ITRI Taiwan from 1990 to 1997. He ever studied in color science from University of Derby, UK. He is currently working in image quality issue at Tekom Technologies, Inc. His research interests include image color science, image capture system calibration method and digital image processing.

**Ethan Tu** received his BS degree in 1998. He is currently working in image quality issue at Tekom Technologies, Inc. His research interests include digital still camera's AF and color correction algorithm.

**John Liu** is currently working in image integration at Tekom Technologies, Inc for several years. His research interests in DSC's SW & HW integration and provide proper direction in solving problem.