Realizing variable contrast technique in MRC measuring target using integrating sphere

Wenjuan Li (李文娟)[1,2], Chao Qi (齐 超)[1], and Jingmin Dai (戴景民)[1]

[1] *School of Electrical Engineering & Automation, Harbin Institute of Technology, Harbin 150001*

[2] *Electrical & Electronic Engineering College, Harbin University of Science and Technology, Harbin 150040*

Received March 11, 2004

In order to realize variable contrast in the minimum resolvable contrast (MRC) measuring target in the visible imaging system, a novel technique is presented, which adopts two integrating spheres to illuminate two sides of target respectively and the different contrasts can be achieved by regulating the luminance in two integrating spheres. This technique can make the contrast be regulated more conveniently. Based on this technique, the MRC measuring device is developed. This device can be used in all kinds of trial fields. The expanded uncertainty of measuring MRC is less than 3%.

OCIS codes: 120.4820, 220.4830, 350.7420.

The modulation transfer function (MTF) is widely used to evaluate the imaging quality in the modern optical imaging system, but the MTF deals strictly with the spatial resolution and has traditionally been a laboratory test because of its rigorous mathematical roots[1]. Another merit of evaluating the imaging quality is introduced to the visible imaging system, that is the minimum resolvable contrast (MRC) which is equivalent to the minimum resolvable temperature difference (MRTD) for infrared imaging systems[2,3]. MRC describes the resolution of a system in the presence of noise and the MRC measurement can be carried out in all kinds of trial fields because MRC data is generally easier to be got under less controlled conditions.

In order to measure MRC, standard periodic four-bar patterns with different contrasts are presented. The observer using the imaging systems for test can resolve the bars when he adjusts the luminance contrast to the lowest value. This value is the MRC which we want to measure. Usually the contrasts of the target are limited and fixed on the MRC measuring target. In this article, a novel technique for realizing variable contrast is presented.

Several groups of bar patterns with different spatial frequencies are used in the target for the MRC measurement. In order to obtain the different contrasts of each group of pattern, two lighting systems are adopted to uniformly illuminate the face and back of the target respectively. The face luminance is the target luminance and the back one is the background luminance. The contrast is defined as the ratio of the target luminance to the background luminance. Each luminance can be adjusted separately by the corresponding optical system. Based on the above technique, the patterns with different contrasts in certain spatial frequency are achieved more conveniently. According to this idea, the schematic diagram can be designed to realize the variable contrast in MRC measuring target as shown in Fig. 1.

The optical lighting system in Fig. 1 is achieved by the integrating sphere. An integrating sphere is a hollow sphere whose inner surface is coated with an approximately Lambertian reflector (such as magnesia, barium sulfate, etc.). The scheme of the integrating sphere is illustrated in Fig. 2. Suppose ϕ is the total luminous flux of the beam which injects into the sphere, S_3 is the area of the inner surface of the sphere illuminated by the beam. Diffuse reflection of the beam takes place for many times on the inner surface. The illuminance of any point M on the inner surface can be deduced and represented as[4]

$$E = \frac{\rho\phi}{4\pi R^2[1-\rho(1-f)]}, \tag{1}$$

where ρ is the diffuse reflection coefficient, R is the curvature radius of the wall of the sphere, f is the opening ratio, which is defined as

$$f = \frac{s_2}{s_1}, \tag{2}$$

where s_1 is the total inner area of the sphere, s_2 is the opening area of the sphere.

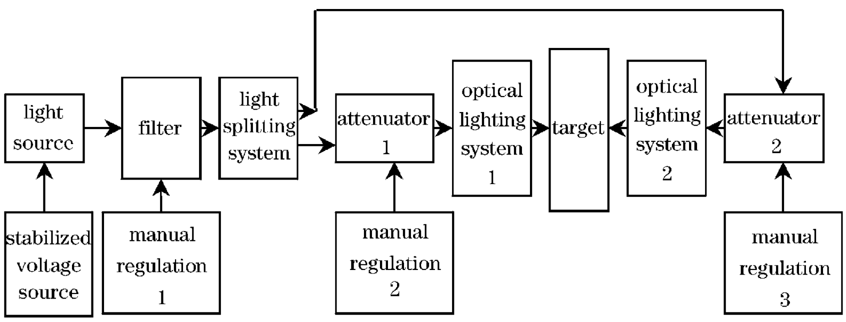

Fig. 1. Schematic diagram for realizing variable contrast.

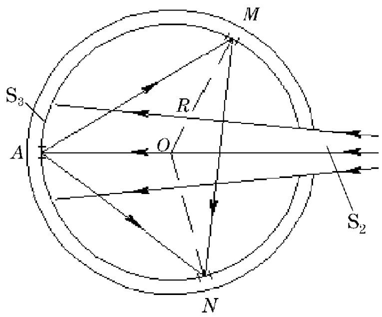

Fig. 2. Scheme of the integrating sphere.

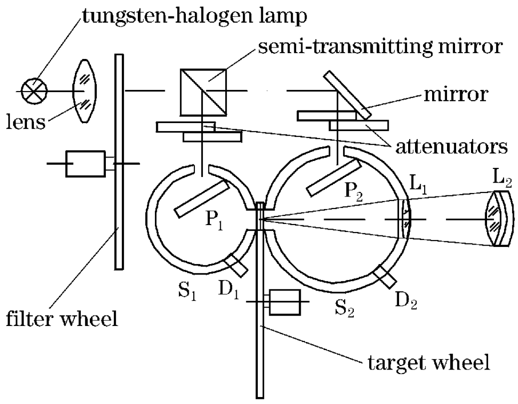

Fig. 3. Optical scheme for realizing variable contrast.

Equation (1) shows that the illuminance of any point of the inner sphere is proportional to the total luminance flux falling onto the sphere. So the integrating sphere can be used to carry out the uniform illumination.

According to the principle of the integrating sphere and the above design idea, the optical scheme is proposed to realize the variable contrasts measurement in MRC measuring target and shown in Fig. 3.

Because the MRC measurement is in visible region, the metal tungsten-halogen lamp with high stabilization is chosen as the light source. In order to improve the accuracy of the MRC measurement, the lamp is supplied by the large current source with high stabilization. The beam which the lamp sends out is collimated by the lens and arrives at the semi-transmitting mirror through the filter. The reflected light goes through the attenuator and falls into the integrating sphere S_1 whose diameter is 150 mm; the diameter of the right opening of S_1 is 25 mm; P_1 is a light baffle whose function is to prevent the light of the first radiation from directly reflecting to the exit; D_1 is a photoelectric detector; S_2 is another integrating sphere whose spherical diameter is 200 mm. S_2 has the same structure as S_1. S_2 has two openings. The left opening, whose diameter is also 25 mm, coincides with the opening of S_1 and the two spheres are very close to each other. A target wheel is inserted between them. There are several patterns for measuring MRC in this wheel. The diameter of the right opening of S_2 is 50 mm. P_2 is a light baffle too. D_2 is another detector. The inner surfaces of two integrating spheres are coated with barium sulfate. Two surfaces of the target are also coated with barium sulfate so that they are the same with the integrating spheres and have no influence on the contrast. L_1 and L_2 are two groups of lenses and form a collimating system whose focal plane superposes on the surface of the target. Each luminance of two sides of the target can be adjusted by regulating the supply current of the lamp and each attenuator. The target luminance and background luminance can be sensed by each detector. Therefore it is easy to obtain different contrasts of the target.

Table 1. Experimental Data of MRC of CCD Camera

Spatial Frequency	MRC			
(cycle/mm)	No.1	No.2	No.3	No.4
0.500	1.007	1.006	1.007	1.003
0.625	1.015	1.013	1.017	1.018
0.833	1.044	1.060	1.058	1.057
1.250	1.088	1.088	1.087	1.089

This technique uses two integrating spheres to achieve variable contrasts of the target. It has the following characteristics: 1) it is easy to make the target for measuring MRC; 2) the target luminance and background luminance can be separately adjusted; 3) the target luminance and background luminance can be kept constant; 4) the influence of the stray light (such as sunlight) on the contrast can be suppressed; 5) the corresponding device can be used in every trial fields.

Based on this technique, the MRC measuring device is developed. Using this device we measured the MRC of F707 charge-coupled device (CCD) camera (5 M pixels, Sony). Table 1 shows four groups of experimental data measured by different people. The results indicate that MRC rises with the increase of the spatial frequency and approximates to one, which means that the target luminance is nearly equal to the background luminance; thereby the influence of the transmission of the target on the MRC is very small, even can be neglected.

The uncertainty of measuring MRC is caused by the uncertainties of calibrating the values of the luminance, the detecting system, and the people. The uncertainties of calibrating the values of the luminance and the detecting system are approximately estimated by the maximal measurement deviation of the target luminance and background luminance. According to the experimental data, the uncertainties of the target luminance and background luminance are both about 1%. Based on the data in Table 1, the uncertainty brought by the people is calculated to be about 1%. The expanded uncertainty of measuring MRC is less than 3%.

W. Li's e-mail address is lwenjuan@163.com.

References

1. M. J. Jenquin, Proc. SPIE **2470,** 380 (1995).
2. P. Biji and J. M. Valeton, Opt. Eng. **37,** 1976 (1998).
3. P. Biji and J. M. Valeton, Opt. Eng. **38,** 1735 (1999).
4. D. T. Su, *Optical Testing Technology* (in Chinese) (Beijing Institute of Technology Press, Beijing, 1996) p. 38.