Design of a minimum resolution contrast detection system

Ji-Quan Li1*, Hai-Ping Li1, Jing-Wen Li1 and Hou-You Zhou1
1HuNan HuaNan Opto-Electro-Sci-Tech Co., LTD, HuNan, Changde, 415007, China
*Corresponding author’s e-mail: jiquan_li@163.com

Abstract. Aiming at TV camera equipment, a minimum resolution contrast detection system is designed. The system quantitatively controls the brightness of the target background in a closed loop mode, simulates a test pattern with adjustable contrast for the system to be tested under an infinite uniform background, and uses image processing technology and Johnson criteria to replace the traditional human eye observation to complete the objective judgment of the minimum resolution contrast, thus realizing the quantitative measurement of the minimum resolution contrast evaluation parameter of the television camera system. This detection system can realize continuous reading and adjustable brightness ranging from 0.02 to 4.45× 104 cd/m2, and the control precision can reach less than 0.003 cd/m2, thus satisfying the measurement of the minimum resolution contrast of the television camera system within 180mm of the light-transmitting aperture.

1. Introduction
Television camera system is one of the main imaging equipments for target detection and tracking, so it is very important for TV camera system to test and evaluate the target detection ability under low contrast. In the past, the performance test of TV camera system was carried out with various tests to ensure that the equipment went to the test base under the condition of field[1]. Due to the limitation of external weather, visibility, low efficiency and long time consuming, it is necessary to design a set of measuring devices which can be used in indoor measurement to meet the needs of measurement[2].

At present, the Minimum Resolution Contrast (MRC) is introduced into the evaluation parameters of the visible light imaging system, which synthesizes the sensitivity and noise of the system[3]. The target spatial frequency and the visual characteristics of human eyes can reflect the limit performance of photoelectric imaging system more comprehensively. Based on the principle of MRC measurement, a target generator is designed, which consists of a double integral sphere structure target source and a reflective collimation system. Combining with digital image processing technology and Johnson criterion, the MRC measurement of television camera system is realized.

2. Testing principle of MRC
In traditional MRC measurement, the test target is placed in a uniform background, the imaging system is used to image, and the human eye is used as the receiving system to observe. When the observer happens to be able to distinguish the target from the background of the test pattern, the contrast between the target and the background is the minimum discernible contrast of the system to be tested at the corresponding spatial frequency[4].

The traditional testing method takes the human eye as the receiving system. The test results are greatly influenced by the human factors such as the observer's psychology, visual acuity and so on, and lack of objectivity. Therefore, based on the traditional testing method, the system uses objective
recognition algorithm to automatically distinguish the target pattern, to determine the limit detection ability of the television camera system to the low contrast target under different illuminance. Finally, the MRC value of the test result is outputted. The schematic diagram is shown in figure 1.

![Figure 1. Schematic diagram of the experimental device](image)

It can be seen from the diagram that the detector is mainly composed of adjustable contrast target source, optical collimation system, luminance control unit, data acquisition and processing unit. In the process of measurement, the television camera system is placed on the multi-dimensional adjusting platform[5]. The target generator composed of the adjustable contrast target source and the optical collimation system provides the test target pattern with continuous variation of the contrast for the system to be tested. The test pattern is received by the system to be tested, the pattern of the test target is distinguished by the data acquisition and processing system, and the control command is generated. The background brightness of the target is adjusted by the closed-loop control method[6]. The contrast control of the test target pattern is realized, and the MRC of the system is obtained.

3. System Design

3.1. Design of Target Generator

In the design process, in order to control the brightness of the target and background accurately, the system adopts two uniform light sources as the basic structure, including two high uniformity integration spheres, wide spectrum light source, optical target (positive and negative four bar target) and so on. Through the adjustable contrast target source and the optical collimation system, the management of the optical path and the adjustment of the beam are realized, and the simulation of the target pattern is completed. The structure diagram is shown in figure 2.

![Figure 2. Schematic diagram of the target generator](image)

The brightness uniformity of the light source will directly affect the accuracy of the measurement[7]. As an ideal diffuse reflection source, the integral sphere has good Lambert cosine characteristics, good stability, and large uniform spot. Therefore, the system chooses the integral sphere with uniform exit brightness as the light source.
In order to meet the requirements of the field of view and reduce the volume of the instrument, the design adopts a reflective structure. The primary mirror is an off-axis paraboloid mirror and the secondary mirror is a plane mirror. The structure is shown in figure 3. Compared with the traditional parabola, there is no center occlusion, the image quality is good, the transmittance is high, and the field of view is relatively large, so the measurement of wide spectrum can be realized.

![Figure 3. Collimation optical system structure diagram, 1. Main mirror, 2. Secondary mirror, 3. Beam closing mirror, 4. Positive four-bar target, 5. Negative four-bar target, 6. Target integration sphere, 7. Background integral sphere](image)

3.2. Luminance control system design
The luminance control system realizes the closed-loop feedback control of the integrated sphere output brightness through the luminous flux control unit and the luminance monitoring unit, as shown in figure 4.

![Figure 4. Luminance control schematic diagram](image)

The light source produces a certain color temperature light incident to the electric slit, and the electrically controlled slit controls the flux of light into the integral sphere, and the luminance in the integral sphere is monitored in real time by the optical fiber luminance meter. The collected monitoring data is uploaded to the processor through the control interface. The processor compares the luminance value in the collected integral sphere with the set luminance value. When there is an error between the actual brightness and the set luminance value, the processor emits instructions to control the electric slit and adjust the flux into the sphere until the brightness is the same as the set value. Through the above process, the two sets of light sources and targets are controlled to generate the required target and background respectively.
3.3. MRC Objective Evaluation

Because the periodic bar pattern is intuitionistic and easy to make, it can reflect the resolution details, and is often chosen as the test target. A four bar target with a ratio of 7:1 between light and dark phase is used as the target test target and the background test target[8]. The schematic diagram is shown in figure 5.

![Figure 5. Test target schematic](image)

In the same group of experiments, the target position and the background target position are fixed, so the test pattern with large brightness difference can be obtained as the template pattern, and the image processing algorithm is used to preprocess the template image. The location information of the target background in the template pattern is obtained. A new test pattern is obtained by adjusting the brightness of the target background by the brightness control system, and the luminance information at the target and the background position of the test pattern is obtained by using the position information of the template pattern. Thus, the contrast of the pixels of the target area in the test pattern is calculated. Combined with the human eye threshold and the Johnson criterion, the objective judgment of the minimum resolution contrast of the camera system is completed.

4. System performance analysis

4.1. Performance Analysis of Target Generator

The system uses 150W halogen tungsten reflector as the light source, and the luminance of the integral sphere can reach 13000fl@3000K. It satisfies the variation of the spectral range of 0.3-0.9 μm. The illumination at the outlet is better than 5×104 lux. The irradiance is 315.85 W/m2sr which makes the background brightness change in the range of 0~38 W/m2sr from morning to dusk, and the maximum background radiance is better than 50 W/m2sr.

The collimating optical system adopts a reflective system, and the primary mirror adopts an off-axis parabolic mirror. The focal length of the system is 1500 mm, the aperture of light is 180 mm, and the center of the optical system is not blocked. Therefore, the system can meet the test of optical system within 180mm.

4.2. Accuracy Analysis of Luminance Measurement

The accuracy of luminance measurement is related to integral sphere, optical attenuator (electric knife slit) and luminance meter. The optical fiber luminance meter of OL Company can be used to accurately measure the integrated sphere brightness of color temperature in the range of 2000K-3000K, and the accuracy of its detection is ±0.02%. If the upper limit 200cd/m2 is calculated according to the requirement of luminance, the maximum error of measurement precision is 0.04cd/m2. According to the formula, the variation range of target contrast can be calculated to be 0 ~ 99.7%, which can meet the target requirement of 0 ~ 20%.

The electric cutting edge slit is controlled by step motor, and the motor is subdivided to realize high precision control of luminance. When the subdivision driver is divided into two subdivision, the slit moves 0.5mm at 400 steps. The experimental results show that the control precision of the pulse brightness per unit pulse is 0.003cd/m2. Combined with the measurement error of luminance ±0.04cd/m2, the control accuracy of luminance can be up to ±0.003 cd/m2.

5. Conclusions

In this paper, a minimum resolution contrast detection system for TV camera equipment is designed. Based on the minimum resolution contrast detection technology, the background brightness of the target
is quantitatively controlled by closed loop method. In order to simulate the test pattern of different contrast in the uniform background of infinity, and using image processing technology, Johnson criterion is used instead of traditional human eye observation to make objective judgment of minimum resolution contrast. The quantitative measurement of threshold contrast evaluation parameters of television camera system is realized. The measuring system can realize the continuous reading of 0.02ng 4.45×104cd/m2, and the control precision can be less than 0.003cd/m2, which can meet the minimum resolution contrast measurement of TV camera system in 180mm.

References

[1] Clement D. (1994) Prediction and measurement of minimum resolvable contrast for TV sensors. Proceedings of SPIE - The International Society for Optical Engineering, 2223.
[2] L.W. Zhou. (2004) Target detection and recognition. Beijing Institute of Technology Press.
[3] S. Liu. (2016) MRC Model of Imaging system and Experimental study on its Measurement. Beijing Institute of Technology.
[4] Miller F P, (2010) Vandome A F, Mcbrewster J. Minimum Resolvable Contrast. Alphascript Publishing.
[5] Liang C, Li W, Yun W. (2012) Design and TracePro Simulation of Variable Contrast Target in MRC Measurement. International Conference on Measurement, Information and Control, pp:533-537.
[6] Li Wenjuan, Qi Chao, Dai Jingmin. (2004) Realizing variable contrast technique in MRC measuring target using integrating sphere. Chin Opt Lett, 2(9): 524−527.
[7] Zhou Yan, Jin Weiqi, Gao Zhiyong, et al. (2002) Minimum Resolvable Contrast(MRC)Study for CCD Low Light Level Imaging System. Proc SPIE, 4925: 591-597.
[8] Jianyong Zhang, Weiqi Jin, Shengcai Li, Yan Zhou. (2005) Optimum spectral band design of the night vision system based on MRC. Proc. SPIE, 5633: 479-485.