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Measurement of Minimum Resolvable Contrast Based on BP Neural Network

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Abstract

Aiming at the MTF evaluation limitations in visible imaging system, this paper introduces the minimum resolvable contrast. On the basis of MRC theoretical, the paper obtains subjective and objective methods of MRC measurement. Then MRC measurement based on neural network is put forward, which does not depend on subjective judgment of person. BP neural network is established and trained. Therefore, the network can replace human eyes to judge test patterns with different spatial frequencies and contrasts. Sony camera with 500 megapixels is selected in the experiment. Results show that MRC values of the objective measurement at all frequencies are less than those of the subjective measurement. The MRC Measurement has good stability.

Keywords: *imaging quality; MRC; BP neural network; objective measurement*

1. Introduction

In visible region, the optical sensor and system are both mature so that the detecting systems with high sensitivity and resolving power can be developed. And the performances of those systems are stable and reliable, large numbers of visible imaging systems are used in the aerospace model. Most of models are still in the stage of developing. While nowadays the assessment merits about imaging quality of the visible imaging system are not sufficient and the equipments of measuring these merits are unsatisfied. No model has effective assessment merit and test equipment. Therefore the research on assessment and measurements for imaging quality of the visible imaging system plays an important role.

In modern optical imaging system, MTF (Modulation Transfer Function) is widely used to evaluate the imaging quality [1], but MTF deals strictly with the spatial resolving power and MTF has traditionally been a laboratory test because of its rigorous mathematical roots. In recent years MRC (Minimum Resolvable Contrast) is introduced to evaluate imaging quality of the visible imaging system. It can describe not only the power of resolving the detail of the system but also its sensitivity. MRC data are generally so easy to be got and processed that it is used in not only the laboratory but also each trial field.

Currently MRC parameter is obtained by judging four bar target pattern in visible imaging system with human eyes. This method needs human eyes to distinguish patterns so that it is inevitably with individual subjectivity and affected by the operation state of the observer. The results are sometimes as much as 50% of the errors. In order to obtain relatively objective results, it is necessary to take the average result of many observers, but it is clearly not a feasible option. On the other hand, for imaging systems of navigation, tracking, search and

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other automatic systems, observer is no longer a necessary part of the above imaging systems. Thus people try to find an objective measurement method of MRC and the research aim of the objective measurement method is to provide an objective judgment standard. The development of computer intelligent makes MRC objective measurement become a reality. Neural network simulates function of the brain and nervous system with the self learning ability. Based on the neural network, the computer can extract and recognize feature of images which are from visible imaging system and then it is self-learning. By describing and judging to the results, MRC parameters of the imaging system can be obtained objectively.

2. Theory of Measuring MRC

2.1. Principle

The principle of MRC measurement is that the test pattern with different spatial frequencies or different sizes is placed in the background. Then the contrast of test pattern is changed. When observer can just distinguish test pattern through visible imaging system, contrast of test pattern at this time is called as the minimum resolvable contrast of the imaging system in the spatial frequency or size [2]. Contrast of test pattern is defined as [3]:

$$C = \frac{L_{\text{target}}}{L_{\text{background}}} \tag{1}$$

where L_{target} and $L_{\text{background}}$ mean target brightness and background brightness of test pattern respectively.

Figure 1 shows two kinds of bar test patterns. MRC measurement needs different contrast and spatial frequency or different size of the test pattern which is provided through coordinating contrast controller and target generator. Optical collimation system can simulate that test pattern in the infinite project on visible imaging system.

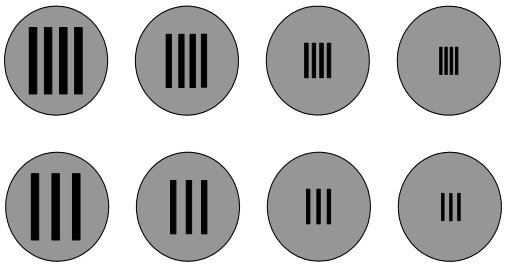


Figure 1. Two Kinds of Bar Test Patterns

2.2. Method of Measuring MRC

From the above principle, the measurement of MRC parameter needs observer. Thus measured results also depend on the observer and this method cannot realize MRC automatically measured.

We call this method as the MRC subjective measurement which depends on the subjective judgment of the observer to accomplish MRC measurement. Obviously, subjective measurement is influenced by the subjective state of observer, interpretation technology and

environment so that stability of results is poor and cannot realize MRC measured automatically. It is necessary to seek the objective measurement of MRC which does not

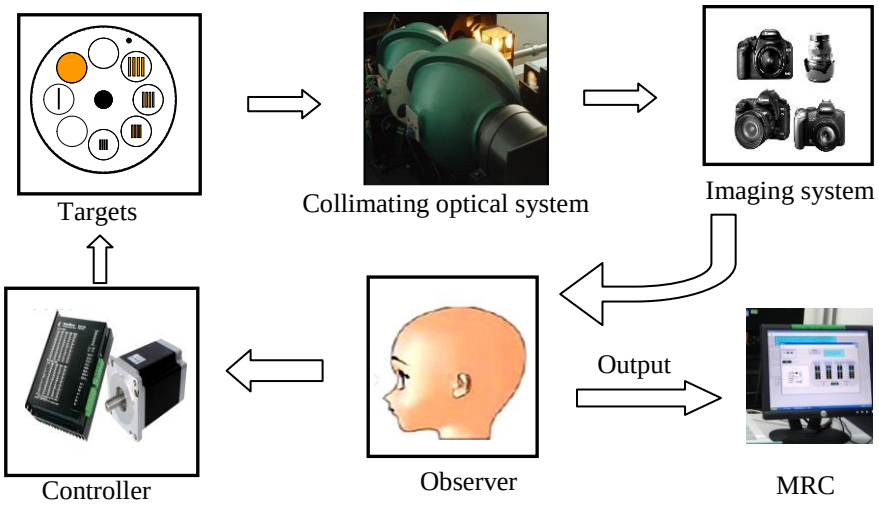


Figure 2. Schematic Diagram of Measuring MRC

depend on observation and judgment of human and take into consideration of the visual and psychological feeling of human, thus the automatic measurement of MRC can be realized with proper software. Figure 2 shows the schematic diagram of measuring MRC.

Through adjusting the target brightness and background brightness of the test pattern, the visible imaging system can record a lot different contrast of the test pattern. These images are inputted to the computer. The computer automatically find out the four bar image which is distinguished clearly by human eye. Then according to the relationship between the gray value and brightness value, the MRC is calculated. Because there is no direct intervention of human in the process of the MRC measurement, measurement results are objective. Therefore this approach is called as the objective measurement method of MRC.

Since the 1980, the intelligent control attracts more and more attention from scholars. The various intelligent control systems are gradually being known and applied to the control in all walks of life by scholars in order to meet the higher control requirements in complex systems such as the fuzzy control with fuzzy thinking of human, the neural network control simulating human neural network structure and function [4].

Thus we put forward the idea that test pattern with different contrasts are automatically discriminated and classified by letting the computer simulate the human vision. In order to find out patterns just distinguished, the technology of neural network is needed, which is named as the objective measurement MRC method based on neural network.

3. MRC measurement by Neural Network

As a high technique, the neural network has drawn wide attention in the recent years. Scientists in various fields have made a deep study of it and have achieved a lot of valuable research findings. It has been widely used in the image recognition. Usually the image recognition based on neural network needs feature extraction, and then the features extracted are delivered to the neural network classifier [5]. MRC of the image is measured by using neural network to identify.

3.1. Neural Network

The human brain is actually composed of many complicated neural networks on which human can understand information from the sense organ at high speed. The human brain has the very strong ability of learning and memory, such as recognizing each other's voice in noisy environment, having very strong learning ability and creative ability, learning from the environment. Hence it is hoped that the functions of it can be realized by simulating the human brain's structure and way of thinking. Artificial neural network is an analog of structure and way of thinking of the human brain and the artificial neuron based on neural network of is the simplification and simulation of the biological neuron. An artificial neuron can accept a set of input signals from other neurons in the system and the entire weighted sum decides the activation status of neuron.

As the BP Neural networks can theoretically map any non-linear relation, and it possesses some good properties such as self-learning, self-adapting and stronger robustness. Neural network is composed of a large number of neurons linked by the structure. Artificial Neural Network (ANN) is a structural mimic biological neural connection type system.

3.2. BP Neural Network Model

Back propagation neural network model has a hidden layer of three layers BP network. BP network consists of input layer nodes, the output layer nodes, and one or more layers of hidden layer nodes. There is no connection between the nodes in the same layer. Input parameters via the transfer function to the input layer node and the output of each input layer node is fed to each of hidden-layer nodes, which in turn is fed to output nodes [6].

The output of each layer directly influences the output value of under layer and affects the final output results indirectly. Currently, BP neural network has been very mature. By learning guided and the multiple compound operations to the simple nonlinear function, its capability of processing information is greatly enhanced.

Since 1940's Hebb proposed learning rule, people have proposed all kinds of learning algorithm. Error back propagation method (Back Propagation) that Rinehart put forth most widely affected. Today, BP algorithm still is the most important and the most efficient algorithm applied at Automatic control. In 1986, the back propagation learning algorithm (BP algorithm) is proposed by Rinehart. This algorithm can modify the network weight coefficient of each layer. Therefore, it is suitable for multi-layer network learning. BP algorithm is one of the most widely used in neural network learning algorithm and it is also the most useful learning algorithm in the field of automatic control and image recognition [7]. As is shown in figure 3 that classifier of BP neural network

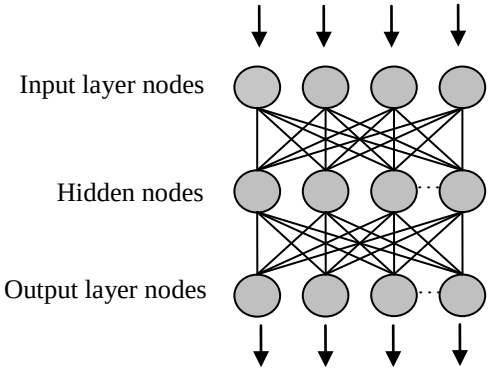
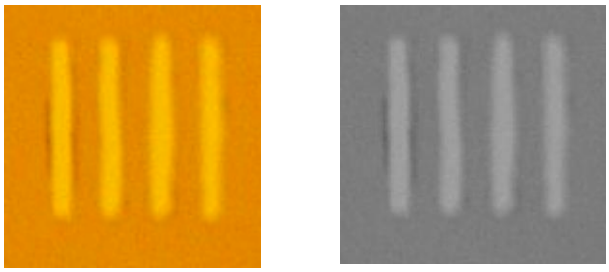


Figure 3. Three-BP Neural Network Classifiers Image

3.3. Image Processing

Improve image quality and advancing image recognition degree, it needs process image to distill interested information. Therefore, the process of image is a necessary. Image of after processing can be better to extract various characteristics. In this paper, image preprocessing methods have the image gradation processing, demising processing, image linearization operation and image segmentation [8]. Figure 4 shows the image grayscale processing.



Before processing After processing

Figure 4. Gray Processing

3.4. Feature Extraction

Feature extraction is the key problem in image recognition. Its basic task is how to find out the most effective characteristics from a number of characteristics. The heart of the neural network is to identify features of image for training [9]. MRC of image is not to say that features extracted are better, but the key is how to extract effective components identification. This article uses three characteristics that there are the image strips of target area, maximum gray value of target and the minimum gray value of background. According to the image grayscale distribution and boundary of the target image, histogram distribution and Fourier transform are analyzed [10].

3.5. Image of MRC Recognition

Image processing is finished automatically on computer. Compared with the traditional image discrimination of MRC, neural network recognition is performed automatically on

image processing and recognition by computer. Because there is no people distinguish image, thereby this method reduces the subjective error.

4. Measurement Experiment and Results

The training requires repeated various parameters about neural network that Make fast convergence speed and get learning efficiently but also ensure accuracy. It needs to performing normalization to the characteristic data in order to ensure that network convergence and avoid larger magnitude of input/output data prediction error is larger.

The input vectors of BP network are 50 groups of vector and the output are 1 ~ 50. After choosing the characteristic vector, BP network of three layers is structured and trained. Considering the convergence speed and accuracy, training parameters are ultimately determined by Table 1.

Table 1. Training Parameters

Input layer	Hidden layer	Output layer	Training goals	Learning rate	Momentum factor
3	7	1	0.3	0.05	0.9

Neural network training is actually a constantly process of adjusting weight and threshold value. Because training time and the number of neural network are not the same. In order to get a better network, weight and threshold value are determined though a large number of experiments. Table 2 shows the weight and threshold value of neural network.

Table 2. Weight and Threshold

Input weights	-2.744	-0.267	0.359	Input bias	1.912
	0.894	-0.323	0.052		-0.467
	1.343	0.457	0.007		1.457
Layer weights	23.673	-39.179	-3.501	Layer bias	-10.28
	5.487	2.3316	-2.307		-2.146
	2.602	-5.906	-4.828		-1.578
	48.09	-125.482	3.146		14.610
	22.109	11.029	2.246		9.412
	-4.161	-8.031	-0.727		-4.855
	89.139	119.94	-1.642		15.191

Objective measurement MRC in visible imaging system is based on digital images of test patterns measured by the imaging system measure. Intensity of pixels in digital images is designated by the grayscale, but the MRC calculation requires the actual brightness of digital image. Thus it is need to find out the relationship between gray level and the brightness in the digital image. The different imaging systems have many relationships between the brightness and the gray, but the relationship is the only one in the same imaging system. In order to find out the relationship between brightness and gray level in imaging system, different brightness of the images are used which are recorded by the imaging system. It should record the corresponding brightness value. And then the grayscale of the key pixel in digital image is

also recorded. Finally the model of brightness and grayscale is calculated by using curve fitting method in imaging system.

Sony camera under 500 megapixels has been carried on the experiment. Figure 5 shows the brightness and gray value.

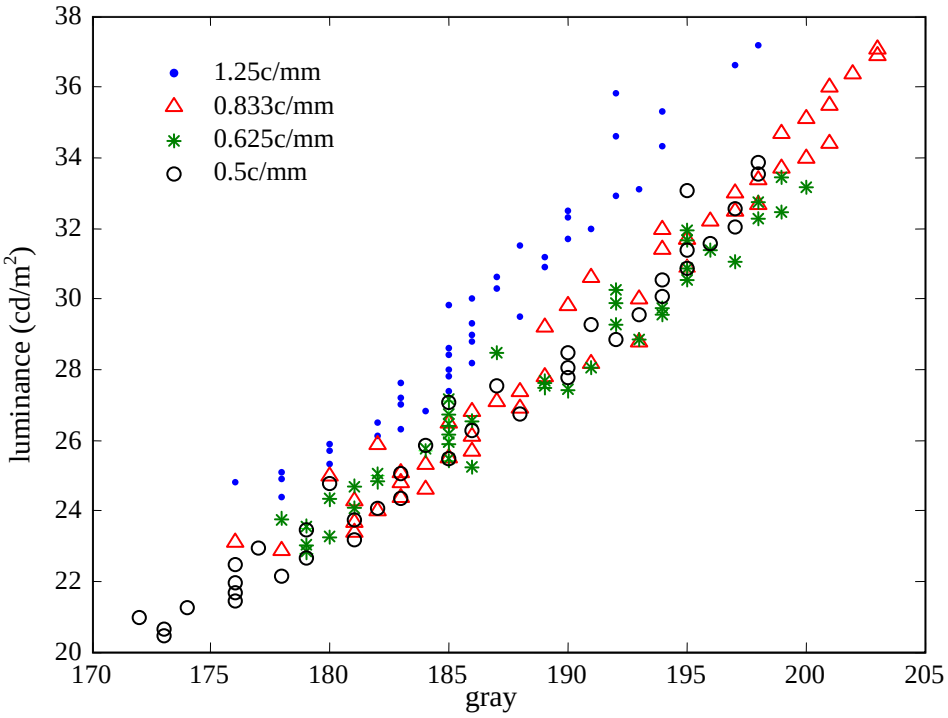


Figure 5. Brightness and Gray Relation of SONY Camera

Table 3 illustrates the results of MRC measurement in Sony camera.

Table 3. Results of MRC Measurement in Sony Camera

Spatial frequency (c/mm)	Objective measure MRC	Subjective measure MRC			
		No. 1	No. 2	No. 3	No. 4
0.500	1.003	1.007	1.006	1.007	1.003
0.625	1.011	1.015	1.013	1.017	1.018
0.833	1.022	1.044	1.060	1.058	1.057
1.250	1.046	1.088	1.088	1.087	1.089

Compared with the subjective measurement results, the MRC of objective measurements are less than those of the subjective measurements at all frequencies. It accords with the fact that computer can see more clearly than people. The MRC results by the objective measurement method do not depend on subjective factors of human. Furthermore this method can realize automatic measurement of MRC.

5. Conclusions

This paper introduces the minimum resolvable contrast based on that index MTF which is insufficient in evaluating the imaging quality to the visible imaging system. This paper also expounds the MRC measurement principle and the subjective measurement method. Then the objective measurement method of MRC is proposed based on neural network. BP neural network is established and trained repeatedly, thus image used by MRC measurement is identified automatically. Sony camera with 500 megapixels is selected in the experiment. On the basis of the just distinguished image, the relationship between the brightness and gray level is measured, and then MRC measurement is completed automatically. Measurement results are superior to those of the subjective measurement. Therefore MRC results do not depend on the subjective judgment of person, which provides terms to evaluate the visible imaging system objectively.

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References

[1] Y. Hua, Z. Yonghong, J. Wenchun and L. Ying, "Output response of CCD and MTF test of CCD camera", Optical Technology, vol. 5, no. 27, **(2001)**.
[2] L. Wenjuan, "Research on Measurement Technique for Imaging Quality Assessment merits of visible imaging system", Harbin Institute of Technology, **(2005)**.
[3] Y. Zhou, W. Jin, Z. Gao, G. Liu and J. Zhang. "Minimum Resolvable Contrast (MRC) Study for CCD Low-light-level Imaging System", Proc. SPIE, ; China, Beijing, **(2002)** June, pp. 591-597.
[4] C. Zixing, C. Haiyan and W. Shiyong, "Recent Advancesin Research of Intelligent Control Engineering. Control Engineering of China", vol. 1, no. 10, **(2003)**.
[5] P. Shumin and W. Junning, "Methods of Image Recognition Based on Neural Networks." Electronic Science and Technology, vol. 1, no. 32, **(2005)**.
[6] M. Yingke1, G. Zhicheng, W. Liming and Y. Bo, "Prediction of Leakage Current of Outdoor Insulators Based on BP Artificial Neural Network", Proceedings of the CSEE, vol. 27, no. 27, **(2007)**.
[7] M. Bortman and M. Aladjem, "A growing and pruning method for radial basis function networks", IEEE transactions on neural networks, China, Beijing, **(2009)** August, pp. 1039-1045.
[8] Q. Chengqun, "A License Plate Recognition System Based on MATLAB Image Processing", Mechanical Engineer, vol. 8, no. 87, **(2008)**.
[9] X. Feng, L. Jiangang and S. Youxian, "Application of Neural Network in Image Processing", Information and control, vol. 4, no. 32, **(2003)**.
[10] T. Wuqin, L. Yongshun, H. Chaochao, Y. Hua and F. Xiang, "Processing method of IR image based on mathematical morphology and wavelet transform", Optics and Precision Engineering, vol. 1, no. 15, **(2007)**.

