A Modified Objective Discrimination Model for Triangle Orientation Discrimination Threshold Measurements

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Abstract—**By adding the mechanism of temporal integration and internal noise into the framework of the previous proposed basic objective discrimination model (ODM), a modified ODM for triangle orientation discrimination threshold measurements is achieved. Validation experiments results show that the performance curves of the modified ODM fit those of the civilian observers well. The correlation coefficients between data from the modified ODM and civilian observers are over 0.9, indicating that the modified ODM can predict the human performance well and can be used for TOD curves measurements instead of civilian observers.**

I. Introduction And Background

THE traditional standard ways to characterize IRIS, such as the MRTD and MRC methods which work well for linear systems，are not suitable for advanced staring imaging systems since nonlinear effects are induced. As an alternative, Triangle orientation discrimination (TOD) method newly proposed by the Human Factors Research Institute in Netherlands is good to characterize advanced staring imaging systems because of its inherent characteristics and good laboratory and field performance[1-3]. As the TOD measurement is a heavy workload and time-consuming task, it is necessary to develop a kind of machine to do the TOD measurement in place of civilian observers for human-effects-free results. We name such a machine as Objective Discrimination Model (ODM) for TOD threshold measurement.

In our previous work[4], the basic framework of the ODM has been set up. In the ODM, main effects of visual system are included, and it also takes orientation perceptiveness into account. The ODM works well for TOD measurements especially when tested under relative large size triangle patterns. But as temporal integration and internal noise are not considered in it, the ODM suffers from a relative poor discrimination performance when works on small size and low contrast triangle patterns. In this paper, new parts are added into the ODM for temporal integration and internal noise modeling.

II. Basic ODM Framework

The ODM consists of two parts, a vision model and a decision model, as shown in Fig.1. The vision model, which is based on the main characters of Human Visual System (HVS), simulates the course of response and process of the HVS on the input light signal. Decision model performs the information processing and makes decisions of the triangles' orientations.

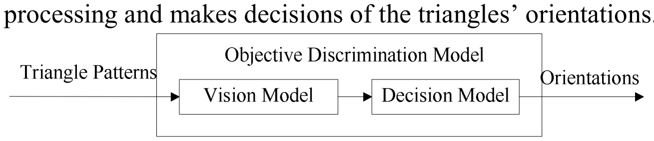

Fig.1 The diagram of the ODM

Three important characters are included in the vision model: nonlinearity, contrast sensitivity and multi-channel structure. The diagram of the vision model is shown in Fig.2. The nonlinear response of human eyes to brightness is modeled according to Weber-Fechner's law. Contrast sensitivity is modeled by contrast sensitivity function. And the multi-channel structure is described as a bank of two-dimensional Gabor filters specific in spatial frequency and orientation[5]. Since the filters' outputs represent spatial and directional features of the input signal, we name the set of the perceptual channels outputs as the visual character vector (VCV) of the input signal.

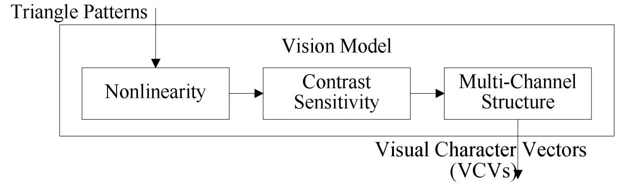

Fig.2 The diagram of the vision model

Decision model compares the VCV of the input triangle pattern with those of the standard triangle patterns and then makes a decision of its orientation according to a correlation criterion. Correlations are analyzed in two levels, single feature level and VCV level. Cross-correlation techniques are used for correlation scores calculation. The input triangle pattern is judged to have the same orientation as the standard triangle pattern with the largest correlated score.

III. Modification of the ODM

As seen form the ODM above, spatial integration is automatically included in the ODM by multi-channel structure modeling and VCVs correlation scores. But the ODM does not possess the ability of temporal integration. And as small size and low contrast triangle pattern may be included in TOD tests, effect of internal noise of HVS on TOD tests should be considered. We modify the ODM by adding temporal integration and internal noise modeling into the ODM. The new structure of the vision model is shown in Fig.3.

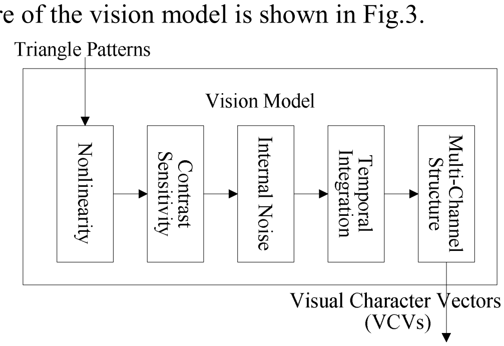

Fig.3 The diagram of the modified vision model

Temporal integration can be modeled by the integration of pictures. We adopted a model as follow. If I is the picture

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showed to civilian observers, then corresponding picture "showed" to the modified ODM is I':

$$I' = wI + \sum_{i=1}^{N-1} \frac{1-w}{N-1} I_i \tag{1}$$

Where w is the right coefficient for I . I_i is a picture in which there is a triangle pattern with the same size, contrast and IRIS modulation level as the one in I . In another word, I and I_i are "twins". The coefficient for I_i is $(1-w)/(N-1)$. Since I is more important than I_i, w should be larger than $1/N$.

The internal noise is assumed to have a Gauss distribution. By adding a white Gauss noise to each pixel of the triangle pattern picture, the effect of internal noise is included into the vision model.

IV. VALIDATION EXPERIMENTS AND RESULTS

By utilizing 1000 pictures of triangle patterns generated by a staring sensor model, validation experiments for the ODM were held. Results are presented in Fig.4 with $N = 3$ and $w = 0.6$. mODM represents the modified ODM.

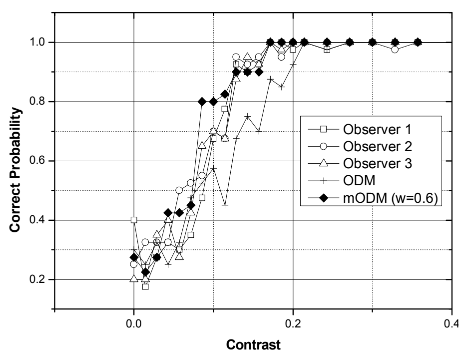

Fig.4 TOD tests results of ODMs and civilian observers
(Triangle pattern size: $3.6mrad$)

Table 1 shows the correlation coefficients between the results from the civilian observers, the original ODM and the modified ODM.

Table. 1 Correlation coefficients

	Observer 1	Observer 2	Observer 3	ODM	mODM (w=0.6)
Observer 1	1.0000	0.9709	0.9753	0.9345	0.9637
Observer 2	0.9709	1.0000	0.9776	0.9482	0.9628
Observer 3	0.9753	0.9776	1.0000	0.9476	0.9816
ODM	0.9345	0.9482	0.9476	1.0000	0.9184
mODM (w=0.6)	0.9637	0.9628	0.9816	0.9184	1.0000

As we can see from the data above, after the employment of mechanism of temporal integration, the performance of the modified ODM improves greatly and matches those of the civilian observer much better.

The degree of performance improvement is a function of w . This is obvious. The more w is close to $1/N$, the higher the SNR of I' will be, and the higher the improvement will be. While the more w is close to 1, the more the SNR tends to remain unchanged, and the less the improvement will be.

The performance of the modified ODM is also impacted by N , the number of integrated pictures. Different N results in different SNR . The larger the N is, the higher the SNR will be. Since TOD tests are random processes, w and N could not be determined before enough tests have been done. We present the temporal integration model in this paper and the determination of w and N will be left for future work.

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