TOD Test Method for Characterizing Electro-Optical System Performance

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ABSTRACT

Santa Barbara Infrared is working with TNO Human Factors Research Institute to develop the equipment and procedures necessary for a new standardized test method for characterizing electro-optical system performance. This method called Triangle Orientation Discrimination (TOD), offers a statistically more accurate and less subjective method of characterizing electro-optical system performance. TOD testing provides an excellent means of performing system level tests that characterizes spatial sensitivity in conjunction with target contrast, just as MRTD and MRC tests do, but in a more statistically accurate manner with less operator to operator variability. System design parameters and options will be discussed.

Keywords: TOD, Triangle Orientation Discrimination, Electro-Optical system performance, FLIR, infrared imaging, automated testing, IRWindows.

1. INTRODUCTION

The Triangle Orientation Discrimination procedure for testing electro-optical system performance was developed by the Bijl and Valeton[1,2] at TNO as an alternative to Minimum Resolvable Temperature Difference (MRTD) and Minimum Resolvable Contrast (MRC) testing. Santa Barbara Infrared, Inc. (SBIR) has always been an innovator in the field of electro-optical testing, and to that end we see the need for a common platform to continue experimenting with the TOD methodologies, including the development of a broader database of test results on a wide variety of equipment. To meet this need, a common set of comprehensive testing assets, as well as a flexible data collection and analysis software is being developed with TNO to create a flexible platform for performing the TOD test. and will be available to the electro-optical community.

The MRTD test[3] is widely used for characterizing infrared imaging systems, and the MRC test[4] is used for characterizing imaging systems in the visible spectrum. Both tests rely on a trained observer to resolve a periodic target by adjusting either the temperature (for an infrared imaging system) or luminance contrast (for a visible imaging system).

There are two general weaknesses with these tests. The first is their subjective nature. Responses from “trained” observers vary widely, due to variations between different observers, and due to varying physiological or psychological conditions of a single observer (such as fatigue or stress). Also, there’s no convenient way to verify an observer’s responses, and this limits the breadth of statistical analysis that can be applied to the results.

The second general weakness is the nature of the target used for MRTD or MRC tests. This target is a 3-bar or 4-bar pattern with a specific spatial frequency. A set of these patterns is selected so that their spatial frequencies bracket the region of interest. Unfortunately, the aliasing effects of sampling these test patterns become more severe in the spatial frequency range of interest. Also, the abstract nature of the patterns themselves does not easily correspond to natural targets encountered during normal operation. It's rare that a repeating set of vertical columns needs to be identified or targeted.

Both of these weaknesses are addressed in the TOD method. The core elements of the procedure are: the use of a triangular target (a closer abstraction or real world objects of interest to an observer); forcing the observer to identify the spatial orientation of the triangle (producing a verifiable result); and performing a large number of perception trials (generating a database that can be statically analyzed). Some of the specifics of the test are discussed in the next section.

2. TOD METHODOLOGY

The goal of the complete TOD test is to generate the TOD curve. The curve graphically characterizes the relationship between the size of an item and the contrast (thermal or visual) necessary for an observer to accurately resolve it. Figure 1 shows a set of triangle images oriented so the size of the image changes vertically and the contrast of the image changes horizontally. In the upper left, the orientation of each triangle is easily resolvable. In the lower right, it is very difficult to tell the orientation of the triangles. Between these two extremes, a curve can be drawn where the orientation of a triangle can be accurately identified a fixed percentage of the time (for example, 75%). Figure 2 is the TOD curve showing this relationship. This section will discuss the procedures and measurements taken to generate this curve.

The key component of the TOD test is the ability to discriminate the orientation of a triangle. Figure 3 shows the four orientations of a target (up, down, left, or right). For a single presentation, the observer is required to identify the orientation. One of the four orientations must be selected, even if the observer cannot clearly determine an orientation (i.e. they must make a guess). This is referred to as a four-alternative, forced choice method (4AFC).

What is important to keep in mind is that this is a statistical method. Many orientations are presented to the observer for a target of a specific size and at the same contrast (thermal or visible). Each response is scored as right or wrong, and the percent of correct responses for a given size and contrast is a data point in the overall characterization of the system under test (between pure guesswork of 25% and complete clarity at 100%). This large number of verifiable results allows for additional statistical analysis to be performed on the results, such as the Chi-Squared (X^2) confidence check, to verify the statistical significance of the data set.

The triangle form is a much closer abstraction of what would be seen in a real world scene. Also, in the course of the TOD procedure, the triangle is repeatedly presented to the observer with a random shift of ½ the size of the target. Because of the large number of times the target is presented, this random shift deals with any aliasing problem in the response statistics.

A threshold graph records the accuracy of an observer's ability to resolve the triangle orientation as one of the two independent parameters is varied. For instance, Figure 4 holds the size of the target constant, while the contrast is varied (the x-axis on the curve). The observer's accuracy is recorded at several test contrasts.

The data in the threshold graph can be fit to a curve that is derived from the psychometric model of this perception test. The mathematical model is shown below.

$$P_{abgd}(x) = (1-d) - (1-?-\mathrm{d}) \cdot 2^{-(x/a)^{b}}$$

χ = stimulus strength (contrast or size)
α = threshold
β = steepness of psychometric function
γ = guess rate (= 25% for 4AFC)
δ = finger error (= 0.02)

This has the form of a Weibull curve. By fitting the experimental data to a Weibull curve, the accuracy of any contrast can be derived from the curve. The result from this threshold graph is the contrast for a single target size that will generate a specific accuracy. Figure 4 also shows the 75% accuracy line that establishes the contrast needed for the selected target size.

A separate threshold curve is generated at each target size of interest. The contrast needed for the desired accuracy at each target size is extracted from the curves and is plotted on the size vs. contrast graph. Fitting this data generates the final TOD curve. This is illustrated in Figure 5.

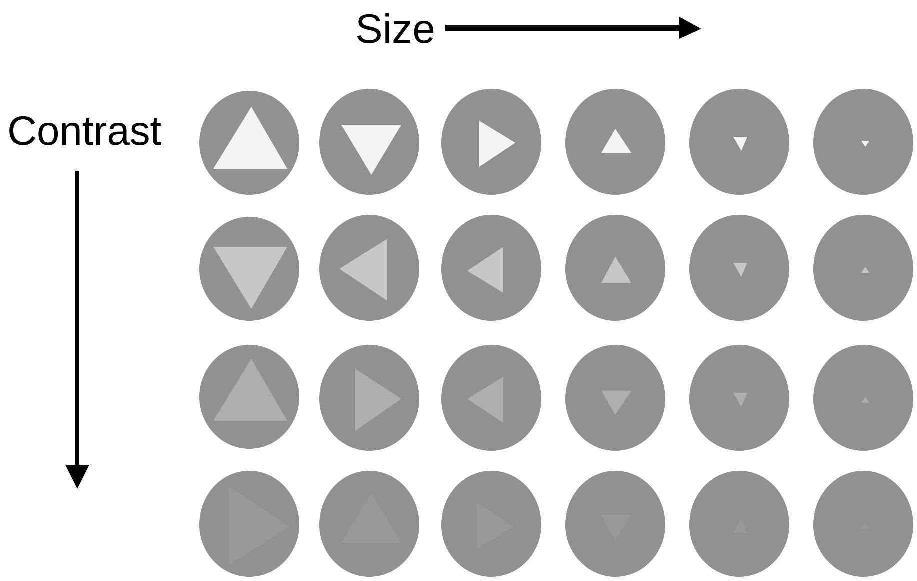

Figure 1 TOD Test Patterns Arranged by Size and Contrast

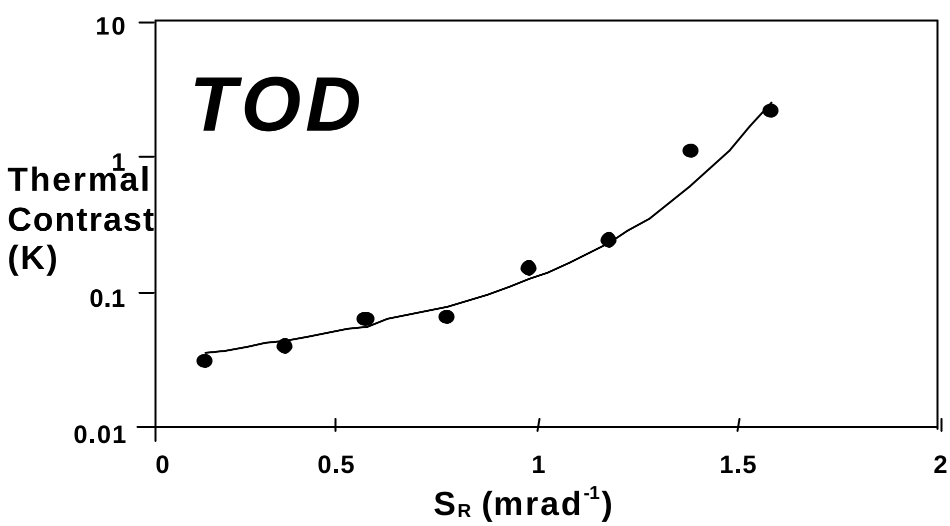

Figure 2 TOD Curve, Derived From Figure 1

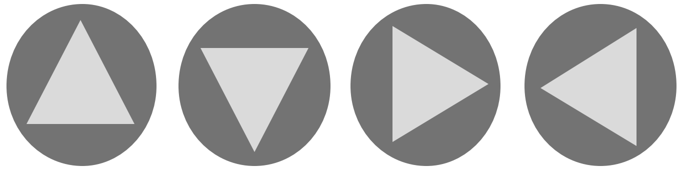

Figure 3 Triangle Orientations (up, down, right, left)

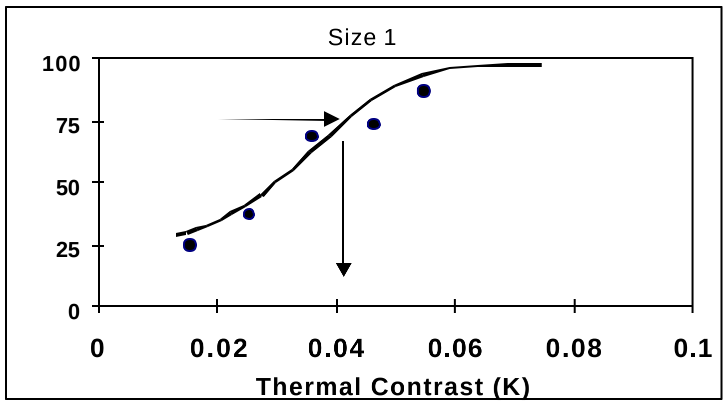

Figure 4 Threshold Measurement for Fixed Size

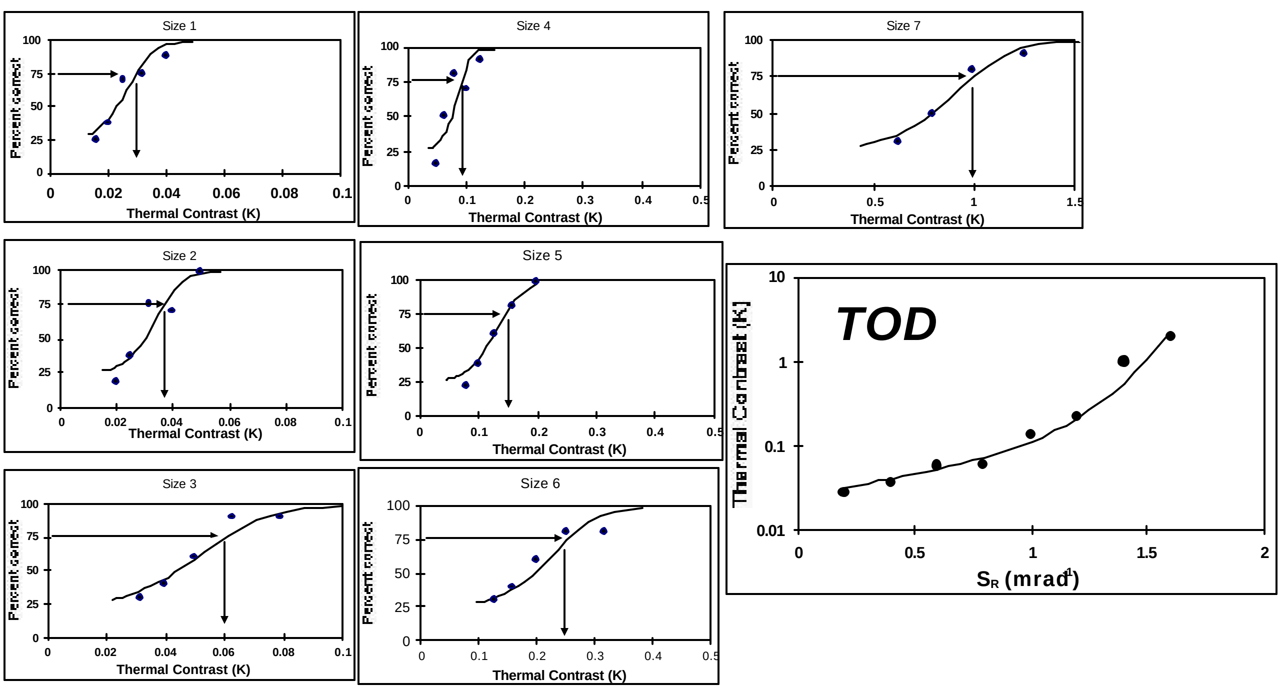

Figure 5 Threshold Graphs Used to Create TOD Graph

3. IMPLEMENTATION

There are two components to the implementation of the TOD testing. The first is the hardware, specifically the assets used for displaying the triangle images to the unit under test, and for altering their size, contrast, and orientation. The second component is the software system used to control the hardware during the test, execute the test procedure, collect the test data, reduce the data and display the results, and store the data in a database for future analysis.

SBIR is developing the hardware assets for the TOD test based on the traditional equipment used for testing electro-optical imaging devices. Figure 6 shows the traditional emissive IR target projector system. It consists of an extended area blackbody located behind a target that is at the focus of a collimating projector. The Unit Under Test (UUT) looks into the exit aperture of the collimator and focuses on the target. Since the target is a cutout, the feature appears at the temperature of the blackbody, and the background around the feature is at the ambient temperature of the room. Precisely controlling the temperature difference between the blackbody and the ambient temperature varies the contrast of the target.

At the focus, traditionally there is either a fixed target plate or a wheel that can select between alternative targets. For the TOD testing, there is a plate with sets of triangular cutouts mounted in a two-axis motion control table, and a shutter that can block the view of the target. Each target set consists of a triangle size in each of the four orientations. Multiple sets, bracketing the sizes of interest, can be placed on a single target plate. The two-axis motion control system moves the selected target size and orientation into the collimator's focus and the shutter limits the time the observer can view the target. Anti-aliasing offsets are controlled by the motion-control system. This mechanism fits into the existing target space without the need for altering any of the other components.

An alternative configuration is the reflective IR system (Figure 7). In this configuration, the target is changed to a cutout in a reflective surface. The feature cutout still passes the energy from a blackbody (the target blackbody), but the background reflects the radiant energy of a second blackbody (the background blackbody). This allows contrast to be controlled by varying both the target temperature and the background temperature. Controlling the background temperature moves the contrast measurement into different response regions of the sensor in the UUT, allowing greater control of the parameters of the test.

This reflective source configuration allows the system to be used in the visible spectrum by replacing the blackbodies with extended area visible sources (integrating spheres), as shown in Figure 8. Each visible source can be independently set to control the contrast of the target, and as for the IR configuration, controlling the background radiance allows the contrast measurement to take place in different regions of the sensor response curve.

The TOD software is incorporated into the **IRWindows™ 2001** test system. **IRWindows™** is an integrated test platform for performing tests on infrared imaging systems. Individual asset control, image analysis, automated test execution, data collection, data reduction, results display, and data archiving are performed by the system and packaged within a user interface that is intuitive and flexible. Individual tests can be quickly configured for use in a laboratory, or test suites can be easily developed for repeated use in a production environment. Reports can be automatically generated and printed during testing, or created later from the stored database. With the new release of the **IRWindows™ 2001** expansion upgrade, visible and laser system test support has been added.

IRWindows™ encapsulates each type of test in its own module. The TOD test is provided in its own module, and so can be performed along with the other tests such as Signal Transfer Function (SiTF), Noise Equivalent Temperature Difference (NETD), Modulation Transfer Function (MTF), or even the traditional MRTD and MRC. By encapsulating the TOD test into its own module, all the existing features of the **IRWindows™ 2001** system are available, including the ability to save alternative test configurations, placing the TOD test into test suites, and results analysis.

Because the basic user interface is consistent across all the **IRWindows™** tests, the TOD test module instead focuses on the specific issues involved in the test execution. The TOD test requires performing a lot of individual perception trials, and so the test can take a long time to perform. One way to speed things up is to perform an adaptive test, where the next component of a trial (perhaps the next contrast level to be measured) changes depending on the previous measurement. By decreasing the number of measurements taken outside the critical performance areas, the total time taken for the test can be reduced, without affecting the accuracy of the result.

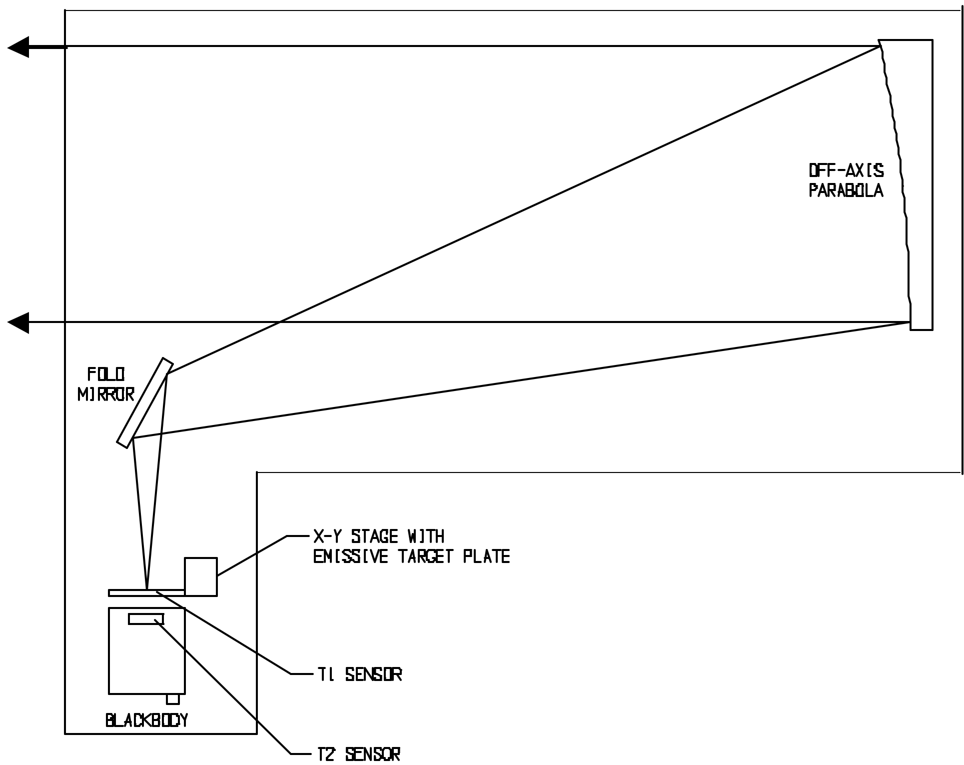

Figure 6 Emissive Infrared Target Projector

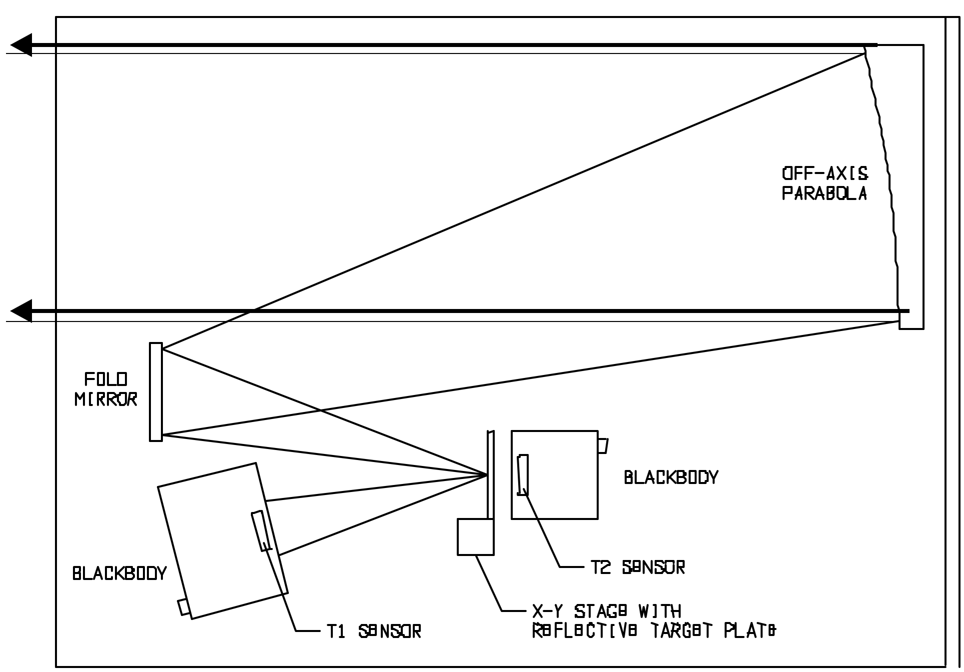

Figure 7 Reflective Infrared Target Projector

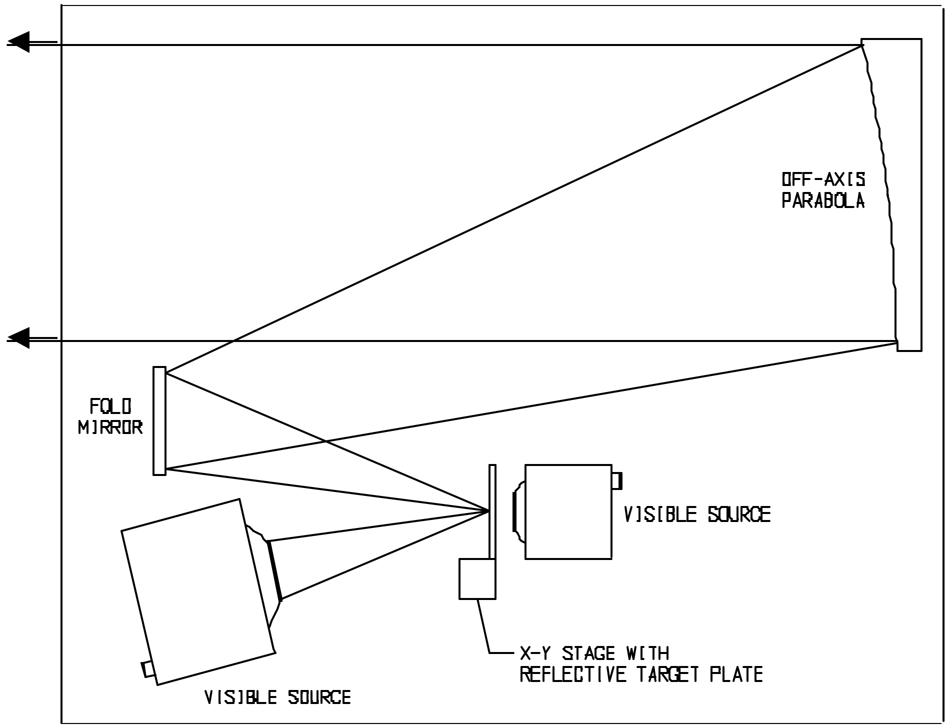

Figure 8 Reflective Visible Target Projector

4. CONCLUSION

Although TNO has made great strides in developing the TOD test as a reliable measure of a system's performance, one of the obstacles to the general acceptance of the test is the difficulty for independent laboratories to develop the equipment and procedures necessary to perform the test. By making a relatively inexpensive platform easily available, SBIR and TNO intend to see multiple sites begin verifying the accuracy and repeatability of the TOD test on a variety of platforms. This expanded database of results can also be used in the developing TOD performance prediction models, further establishing the performance test as an alternative to MRTD and MRC tests.

5. REFERENCES

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