Fraunhofer IOSB

Fraunhofer-Institut für Optronik, Systemtechnik und
Bildauswertung IOSB, Ettlingen

Assessment of Thermal Imagers according to the Triangle Orientation Discrimination (TOD) Method at IOSB

Uwe Adomeit, 30. Juni 2020

Note:

Triangle Orientation Discrimination (TOD) is a development by the Netherlands TNO Human Factors Research Institute. It measures imager performance by judging the orientation of an equilateral triangle. Bijl and Valeton published the concept in "Triangle orientation discrimination: the alternative to minimum resolvable temperature difference and minimum resolvable contrast" Optical Engineering 37(7), 1976-1983 (1998) and "Validation of the new triangle orientation discrimination method and ACQUIRE model predictions using observer performance data for ship targets" Optical Engineering 37(7), 1984-1994 (1998). Bijl, P., Valeton, J. M., "Guidelines for accurate TOD measurement," Proc. Of. SPIE 3701, 14-25 (1999) describes their proposed measurements process. Corrections for some of the formulas in this paper give Bijl et al in "TOD predicts target acquisition performance for staring and scanning thermal imagers" Proc. Of. SPIE 4030, 96-103 (2000). These two papers form the basis for the measurement process described here. Newest publication at time of writing that includes an overview on the actual status is Bijl and Hogervorst „EO system design and performance optimization by image-based end-to end modelling" Proc. Of SPIE 11001, 110010G (2019).

Validity:

1. The TOD applies for well and under sampled thermal imagers. The applicable spectral range is 3 µm to 14 µm or parts of this range.

Definition:

2. TOD is the temperature difference that allows an observer to identify the orientation of an equilateral triangle with a probability of 75 % (without guess rate correction). This temperature difference depends on the size of the triangle, the environmental temperature and the position of the triangle relative to the detector (phase).

Measurement Conditions:

3. The triangle target mounts on a turntable positioned in front of a blackbody. The turntable allows 360° rotation of the target. An aperture hides the target during the rotation.

4. The blackbody allows positive and negative temperature differences ΔT between the triangle and the background.

5. A 2.5 m focal length, 0.3 m diameter off axis collimator projects the triangle on the imager under test. In doing so optical axis of imager under test and projection correspond. The position of the triangle relative to the detector is adjustable in small steps relative to the imager's instantaneous field of view.

6. Environmental temperature, which also corresponds to the triangle background temperature, is within 22±2 °C unless otherwise specified. Room illumination is set to a level that does not distract the observer from its task. Typically, a low level is used to increase the observer's contrast sensitivity. Alterations according to the observer's demands are allowed.

7. Imager gain is set manually using an as high as possible one for the measurement. It is kept so during the measurements. Imager brightness is adjusted before and during the measurements by the observer to optimize results. However, no alterations are allowed within the measurement of a single triangle.

8. Measurements are performed at the display that belongs to the imager. If no display is belonging to the imager in test, an IOSB standard monitor is used instead. Contrast and brightness of the monitor are adjusted before the measurements to give optimum performance. A suited video generator is used for this purpose. No alterations are allowed during the measurements. The observer is allowed to alter the distance of his eye from the monitor to give optimized results wherever applicable.

Measurement Process:

9. A temperature difference is selected where it should be possible to correctly identify the triangle orientation. The aperture is closed and one of the four triangle orientations automatically randomly selected and set by the turntable. The aperture reopens and the observer tells the observed or guessed triangle orientation. Temperature, real and observed triangle position are recorded.

10. The process aperture closed – random orientation – aperture opened is repeated twelve times. For each change of orientation, a random phase shift is also conducted.

11. For a given triangle this is conducted for temperature differences changing from positive to negative contrast. Highest and lowest temperature difference should enable orientation identification with at least 90 % probability. In-between these two extremes six to ten temperature differences are aimed for.

12. The measurements are conducted as fast as possible to minimize drift influence.

13. The measurement is repeated with smaller triangles. It stops when a triangle is presented which at high contrast gives less than 80 % probability of orientation identification.

14. Measurements typically are taken at a minimum of six triangle sizes distributed approximately uniformly over the useful range of the imager.

Measurement Exploitation:

15. From the recorded data, the probability of correct orientation identification is calculated for each triangle size and temperature combination as ratio of correct responses to number of stimuli.

16. From this calculation for each triangle size a curve results that shows the probability of correct orientation identification P versus temperature T. On each of these curves a Gaussian function (A and B are the fit parameters)

$$P(T) = 0.98 - 0.73 \cdot e^{-0.5 \cdot \left[\left(\frac{T-A}{B}\right)^2\right]}$$

is fitted. The fits are checked using a chi-Test. If the test fails, the measurement is excluded from further analysis. The inverse function allows calculating the temperature $\Delta T_{0.75}$ at which 75 % probability is achieved.

17. The Reciprocal Angular Subtense (RAS) describes the triangle size. It interprets as a kind of spatial frequency. RAS is calculated from the triangle edge dimension a in angular units according to

$$RAS = \frac{2}{\sqrt[4]{3}} \cdot \frac{1}{a}$$

Result:

18. The $\Delta_{T0.75}$ temperature difference versus RAS is the TOD-curve.