

ISET – Calculating the System MTF using ISO-12233 (Slanted bar)

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ISET implements the ISO 12233 (Slanted bar) method for calculating system the Modulation Transfer Function (MTF). This document describes a step-by-step procedure for how to perform this calculation.

The system MTF summarizes how well an imaging system represents image contrast as a function of spatial frequency. The ISO 12233 method [1] uses a measurement (or simulation) of a slanted edge to calculate the MTF through each of the color channels. The method also combines the data from the separate color channels to compute a system luminance MTF.

The basic idea of this method, which is due to scientists at Kodak, is simple and elegant. The response in the vicinity of an edge is directly related to the line spread function (via a derivative). The line spread function is directly related to the MTF by a Fourier Transform. Hence, the method estimates the edge response to calculate the line spread, and then the MTF. Commonly, this method is limited because the digital samples in an imager make it difficult to assess the true system line spread – as one measures in slightly different position compared to the samples the line spread changes. The slanted bar method avoids this problem by combining the line measurements across different levels of the edge. These combined measurements provide, essentially, a super-sampled version of the edge and reduce the problems associated with the under-sampling by the digital imager.

Computing the system MTF

Step 1. First, you should set up the ISET simulation pathway. Choose the optics, sensor and processing parameters that you wish to evaluate. Note that the system MTF depends on all of these choices; the processing pipeline (including demosaicing and color balancing) influence the measured responses. Hence, they influence the system MTF.

Step 2. Now, create an input scene comprising a slanted bar. There are several ways to create this scene. You can use the Scene Window and create such a scene (“Scene Window | Scene | Patterns | Slanted bar (ISO 12233)”). Alternatively, you can simply begin in the Processor Window and use the “(Processor Window | Analyze | Create Slanted Bar”) pull-down. This will create a slanted bar in the in scene window and compute the resulting image, using the current parameters.

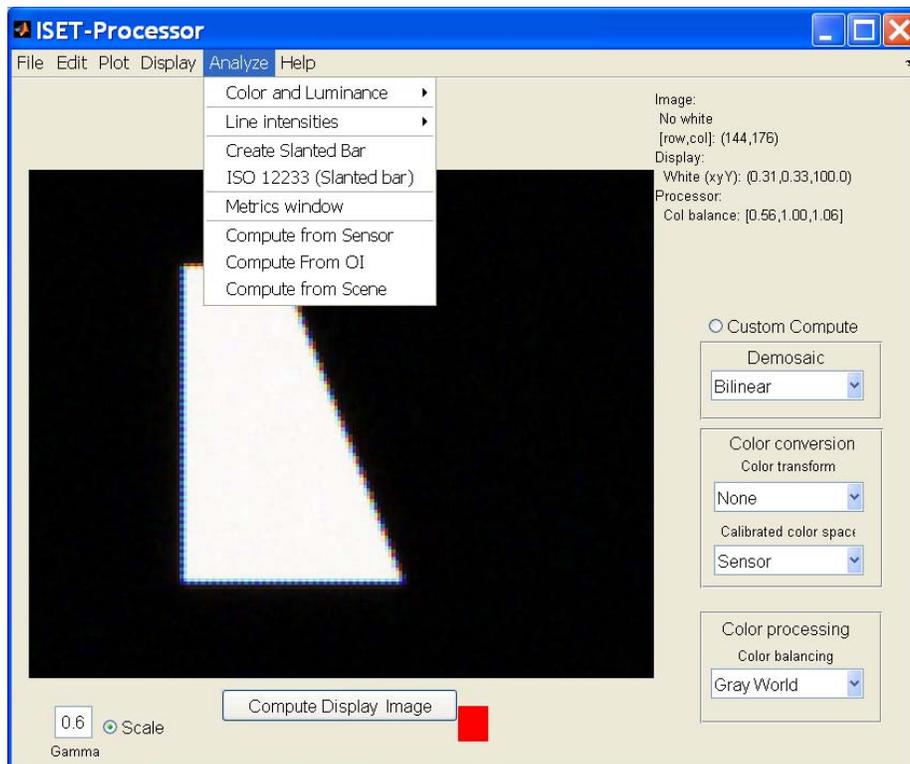


Figure-SlantedBar-1. You can create the system simulation of a slanted bar image directly from the ISET-Processor window. Choose “Analyze | Create Slanted Bar”. This will create a slanted bar scene and process the scene through the current optics, sensor and image processing settings.

Step 3. Once the image is created in the ISET-Processor window, you are ready to invoke the ISO 12233 settings. To do this, simply choose the “Processor Window | Analyze | ISO 12233 (Slanted bar)” pull-down menu. This will begin a simple interaction in which you select a modest sized rectangular region within the edge of the slanted bar. The rectangular region that you select will be indicated by a dashed line. Simply hold down the left mouse button and drag the mouse across the image to select the region.

If you do not like your selection, simply repeat the process. The computation does not take very long. You may wish to repeat the process a few times just to make sure that the response region was large enough to guarantee a stable MTF estimate.

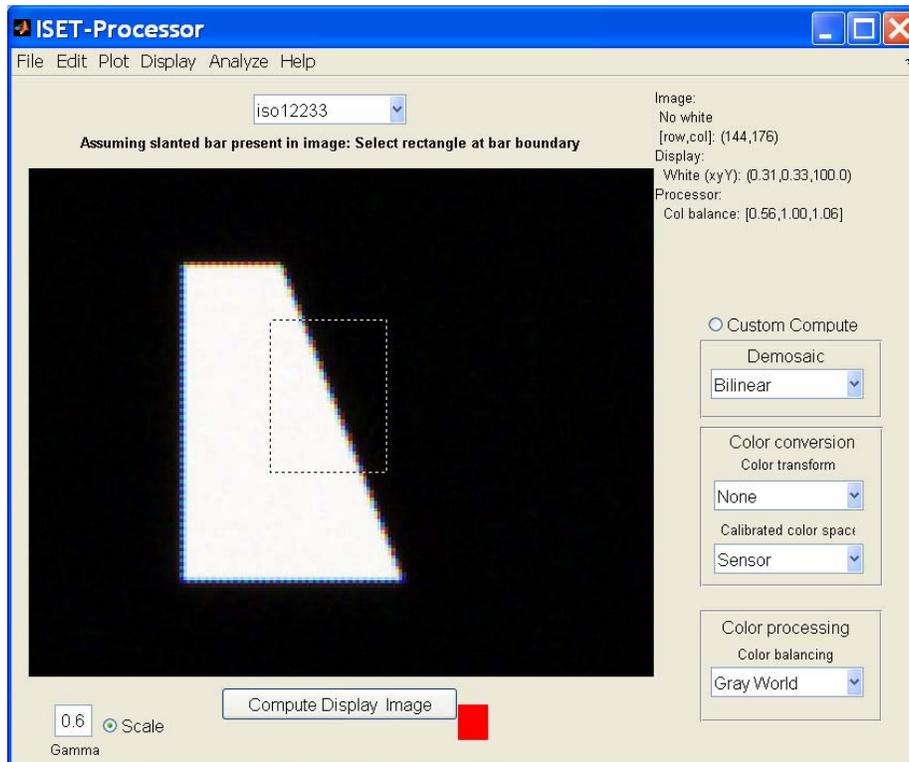


Figure SB-2. Hold down the left mouse button and drag the mouse to define a rectangle centered on the slanted edge. The region you select will be indicated by the dotted rectangle, as shown above. The horizontal lines across this region will be combined into a single system edge response. From this edge response, a line spread and then MTF response will be calculated for each color channel. In addition, a system luminance response, based on combining the three color channels, will also be calculated.

Step 4. The calculated MTF functions values, along with some summary values, are shown in an ISET graph window (Figure SB-3).

The horizontal axis represents spatial frequency in cycles per millimeter along the sensor surface. The vertical axis represents the contrast reduction (called spatial frequency reduction or SFR in the ISO standard). The graph contains four colored lines representing the contrast reduction as a function of spatial frequency in the red, green and blue channels (shown by the corresponding colors). These are the color MTFs. The luminance MTF is represented by the black line. This shows the MTF calculated from the weighted sum of the color channels using the default values: $Luminance = 0.3R + 0.6G + 0.1B$.

The text in the legend at the upper right shows various summary quantities. These are (a) the Nyquist sampling frequency of the sensor array (cycles/mm), (b) the spatial frequency at which the luminance MTF reaches 0.5 (Mtf50), and (c) the area under the luminance MTF that falls to the right of the Nyquist frequency (Percent alias). The Nyquist frequency is indicated graphically by a small vertical blue line plotted on the horizontal axis.

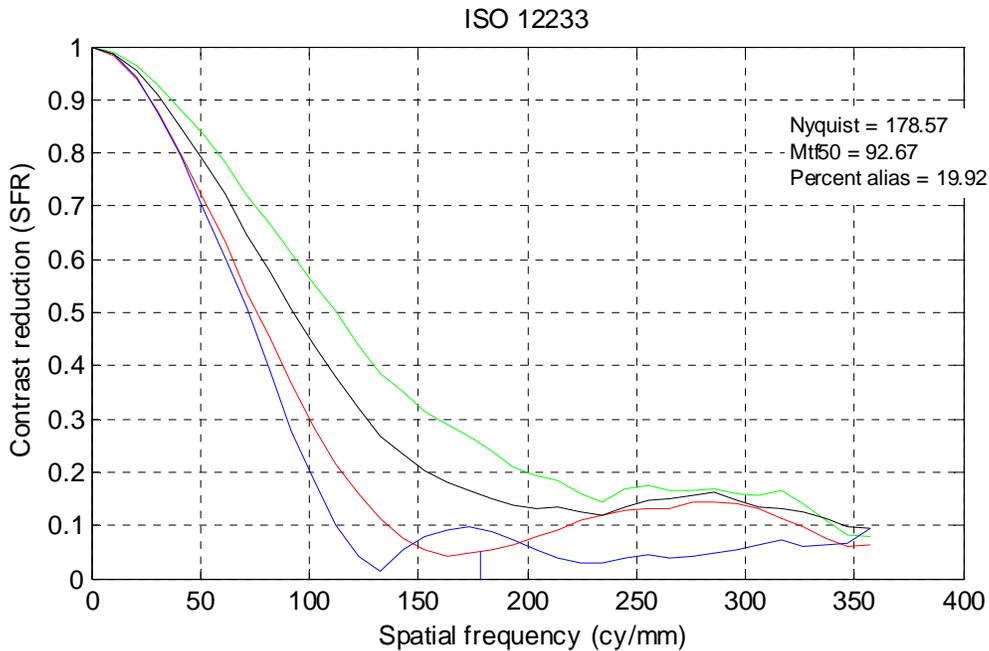


Figure SB-3. The results of the ISO 12233 calculation are shown in an ISET graph window. The curves show the reduction in contrast as a function of spatial frequency (in cycles/mm).

The ISET function `ielSO12233` is used to compute these MTF functions.

As is true commonly for the ISET graph window, the values plotted in the window are stored in the userdata slot within the window. So, to obtain the numerical values for the curves, use

```
d = get(gcf, 'userData');
```

The returned structure contains the following data slots

```
d =
```

```
        freq: [36x1 double]
        mtf: [36x4 double]
    nyquistf: 178.5714
        mtf50: 92.6706
aliasingPercentage: 19.9211
```

These correspond to the values plotted in the window.

Example calculations

As a final example, we illustrate how to analyze the MTF on data from a standard camera. As an example, we acquired an image using a Nikon D70 camera (Figure SB-4). The image was of an ISO spatial test chart, and we cropped a small portion of it that contained a slanted bar. Note that we oriented the slanted bar so that the bright side is on the left and the bar is slanted from left to right.

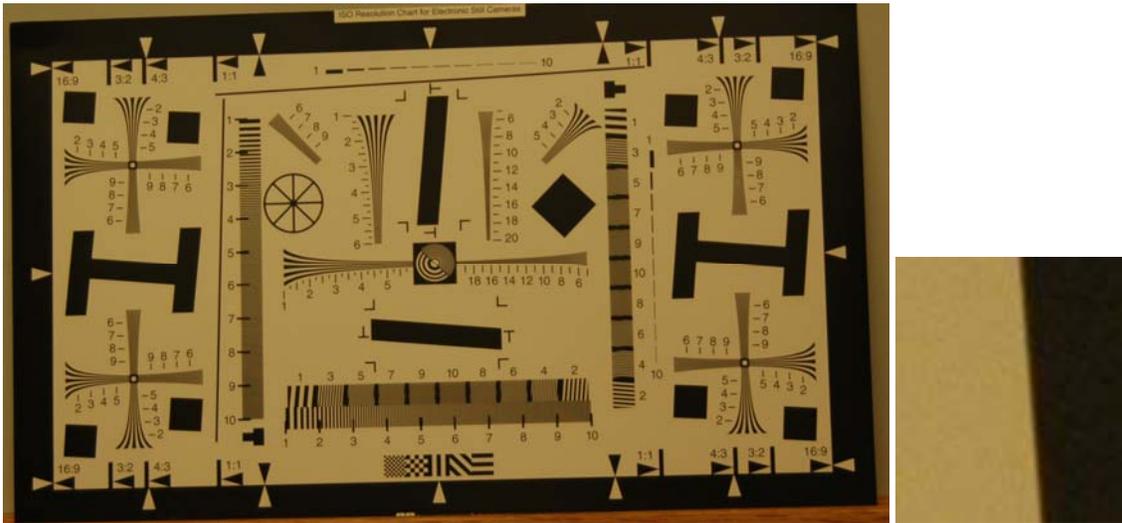


Figure SB-4. An image of an ISO Resolution Chart acquired with a Nikon D70 camera. We extracted a small portion, shown on the right, of a slanted bar edge. This portion is stored in the ISET-Data\processor directory. You can read this image into the ISET-Processor window using the "ISET-Processor | File | Load Image Data" pull-down option.

After loading the slanted bar data into the ISET-Processor window, we have a screen as shown in Figure SB-5. These data show a slanted bar from the processed Nikon D70 image. In this way, ISET can analyze data acquired from real devices in addition to simulated data.

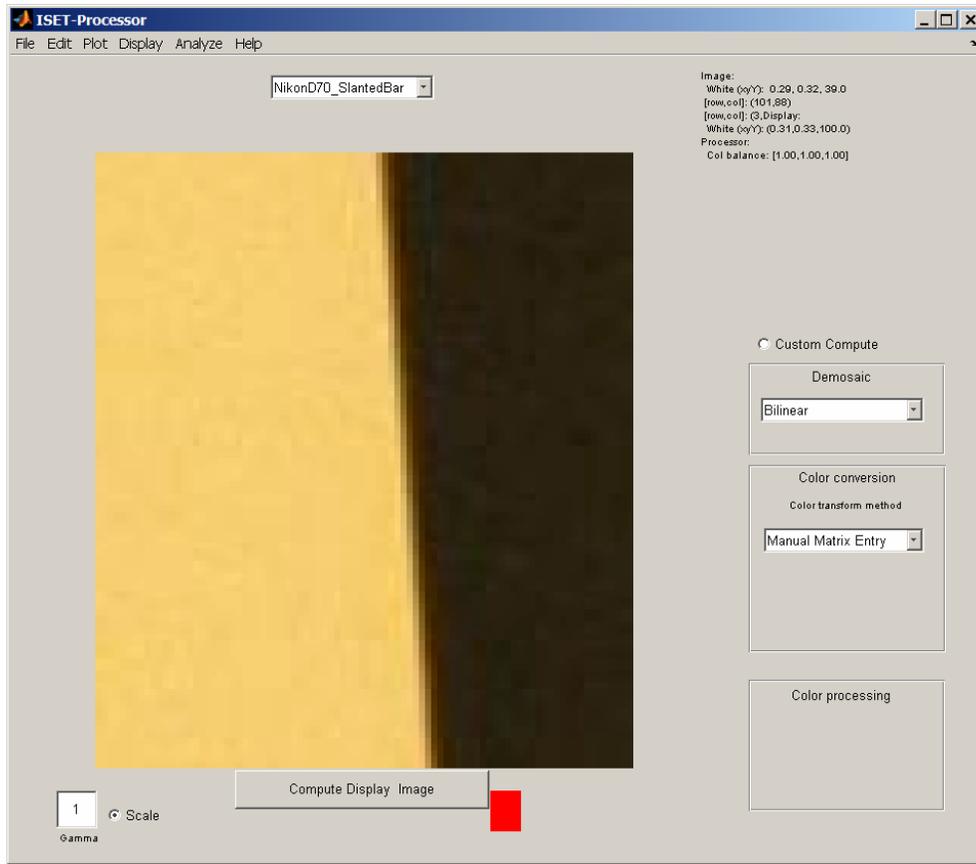
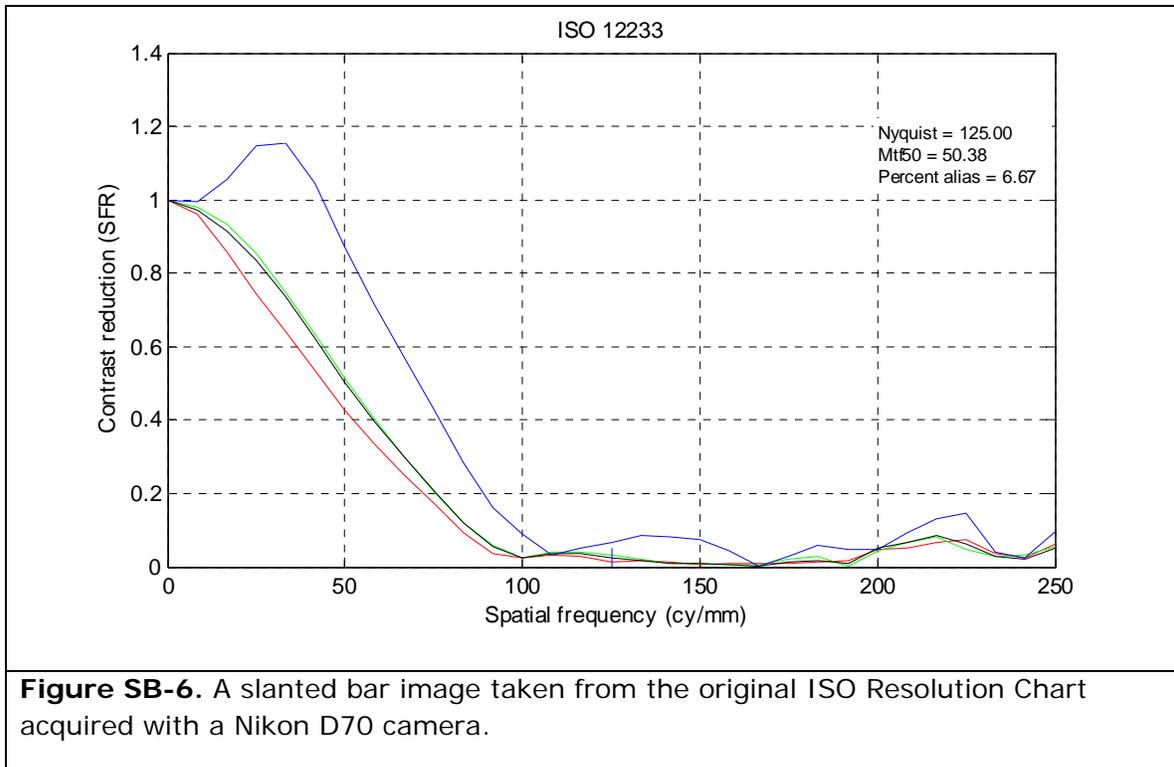


Figure SB-5. A slanted bar image taken from the original ISO Resolution Chart acquired with a Nikon D70 camera.

We then set the parameters in the ISET-Sensor window to correspond to our understanding of the Nikon D70 pixel geometry. Using the pull-down command "ISET-Processor | Analyze | ISO 12233 (Slanted bar)" we produce the summary plot shown in Figure SB-6. The colored lines correspond to the three color channels, and black is the luminance estimate.

Notice that the blue channel has a peak above zero, which is typical of image processing that sharpens the channel. The amount of aliasing is relatively low indicating a good match between the lens and the sensor sampling. Finally, the Nyquist limit for this camera (with a 7.9micron pixel) is calculated to be 125 cycles/mm.



References

- [1] Williams, D. and Burns, P. D, Low-Frequency MTF Estimation for Digital Imaging Devices using Slanted Edge Analysis, *Proceedings of the SPIE*, Volume 5294, 2004. (http://www.i3a.org/downloads_iso_tools.html)