User Guide for mitre_sfr Computer Program

The mitre_sfr computer program computes the spatial frequency response of an imaging system from the digital image of an edge target, following the technique defined in:
ISO 12233:2000, "Photography – Electronic still-picture cameras – Resolution measurements," First Edition, 2000-09-01
The mitre_sfr code is restricted to operation on 8 bits per pixel grayscale images input in TIFF, PGM, or raw format.

Procedure:

1) Construct Opto-Electronic Conversion Function (OECF)

If the imaging system has a nonlinear response to input energy, i.e., OECF curve is non-linear, then obtain or create the corresponding OECF file at discrete points.

- This file has one floating point pair of data values per line; first value is the input energy, second value is the corresponding output grey level
- Data is sorted on grey level, and linear interpolation is used for missing values.
- All pixel grey levels in the selected edge Region Of Interest (ROI) must be within the max & min grey level range of the OECF.
- Optional comment lines are allowed at the beginning of the data file; they must begin with the pound sign: #
- An OECF curve is not needed if the input/output response is linear

2) Define the Region Of Interest (ROI)

- View the softcopy image of the slanted edge target (using your image display software)
- Locate an area of slanted edge transition.
- Construct a ROI rectangle within the edge area with the following properties:
    - Vertical slanted edge: ROI width is less than height
    - Horizontal slanted edge: ROI width is greater than height
    - Only one edge allowed in the ROI, approximately centered
        - If one side of the edge requires a larger area to reach stability, the ROI should be expanded on the other side as well, so that the edge is approximately centered.
    - Black/white transition of edge must continue from end to end of the ROI
    - Where the edge transition crosses the ROI border cannot be less than 5 pixels from a corner of the ROI.
    - The edge transition should appear as a straight line within the ROI, and the ROI area should avoid image blemishes, nonuniformity, dust, etc.

  - Within the ROI, width of each side of slanted vertical edge, or height of each side of slanted horizontal edge, should be 20 to 60 pixels, measured from ROI center to ROI edge
  - ROI height for slanted vertical edge or width for slanted horizontal edge should be 80 to 300 pixels

- Identify the location and size of the selected ROI:
  - Record the (column, row) of upper left corner of ROI, the ROI width and height, or,
  - Record the (column, row) of the approximate center of the ROI (a point near the edge transition) and the ROI width and height
  - These measurements are in pixel units with coordinate reference: **upper left corner (col,row) of Entire image is (0,0) [not! (1,1)]** with columns in integer pixel steps increasing to the right, and rows in integer pixel steps increasing towards the bottom.

3) Determine the pixels per inch (ppi) scale:

- An accurate assessment of ppi might be obtained from any one of a variety of sources, depending on the type of imaging system and available information. For example, ppi might be computed from system design data, measurement of sensor element size, inspection of sensor 'spec sheets', or measurements on the edge image itself. In the latter case it is assumed that there is a fiducial mark on each side of the target edge, with known distance between, then the ppi scale would be given by:

pixels between fiducials in image / fiducial distance on target

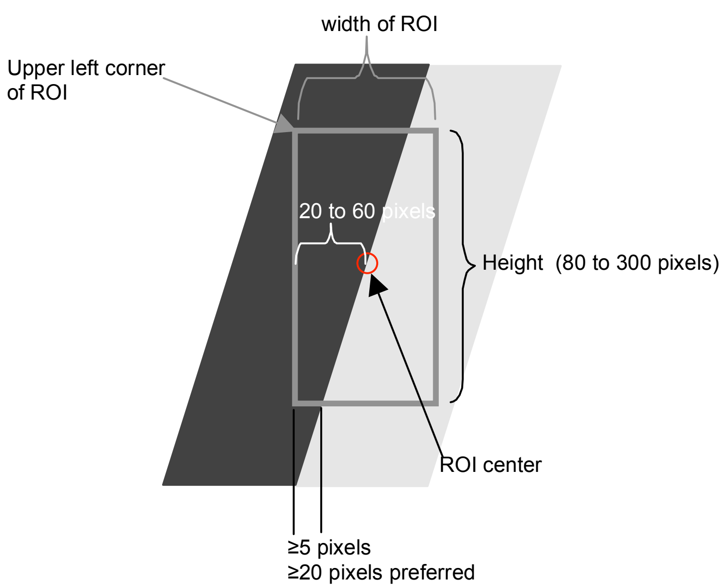
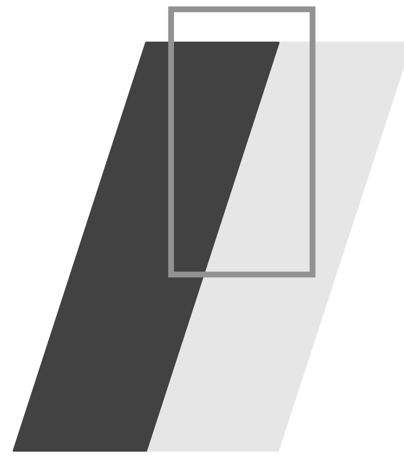
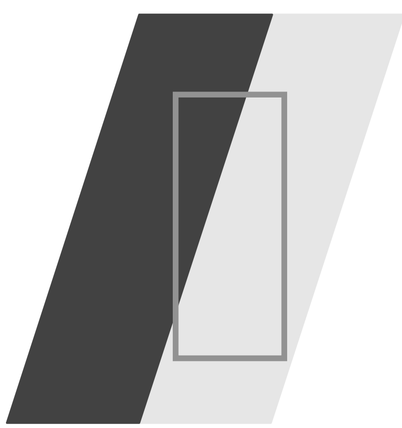


Figure 1: Recommended ROI properties

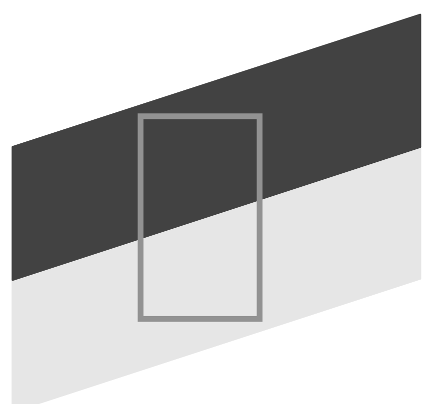
NG - part of ROI is off edge



NG - part of ROI is off edge



NG - edge transition does not intersect bottom of ROI



NG - ROI width < height on horizontal edge

Figure 2: Examples of ROI Selections that are Not Good

4) **Manual edge tilt angle (optional)**

If default mitre_sfr processing generates a poor estimate of the edge tilt angle, it is possible to override it with user specified edge information. Record the locations (columns and rows) of two well-separated points along the edge transition. For example, for a vertical edge, the two points where the edge transition crosses the upper and lower ROI boundaries could be used, although the selected points may also lie outside the ROI - see Figure 3. Zooming-in on the displayed image enables accurate location of the edge transition; you can use fractional column or row if the edge transition appears to lie between two pixels. Processing will assume a straight-line edge between these two points. The diagnostic image and/or verbose LSF output can help double check if the edge points define the expected edge transition.

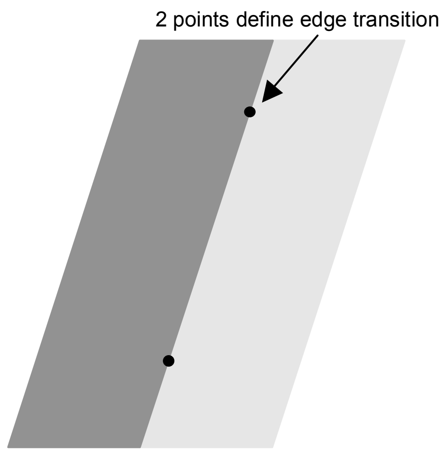


Figure 3: Two User-Defined Points on Edge Transition to Establish Edge Tilt Angle

5) **Run mitre_sfr**

- Multiple options can be selected from the runtime menu display; separate selected option letters by spaces or no space, but not by commas.
- The output file is named SFROUT.txt
  Data is always appended to this output file.
- There are two runtime alternatives:
  1) Command line:
     If input/output (OECF) is linear:
     > ./mitre_sfr image.tif linear ULcol ULrow width height ppi
     If input/output is nonlinear:
     > ./mitre_sfr image.tif OECF.txt ULcol ULrow width height ppi

     User will then be asked to select options (see description below).

  2) Interactive mode (from a terminal window):
     > ./mitre_sfr

- **Menu options:**
  - a Compute edge tilt angle from user entered points
  - b Auto-refine input region
  - c ROI defined by center point instead of UL corner
  - d Create diagnostic image (_box.tif)
  - e Verbose output
  - f Reverse image polarity
  - h Help & Program Notice
  - n Don't compare output to PIV spec

The default (no options) output contains the SFR and information about the ROI, OECF, and computed edge angle.

a – Edge angle and location is based upon user entered information rather than using ISO specified centroid approximation. User enters column and row information of two pixels on the edge (fractional values allowed). The two points should be well separated (not necessarily within ROI) and the edge should be linear between them; see Figure 3.

b - Allows program to determine the ROI; user inputs a preliminary ROI search area centered approximately on an edge pixel. The search will not use pixels outside this area. The code will check to see what size/location ROI gives the best line-fit based on maximizing R^2, and then uses this ROI for the SFR computations.

c - ROI defined by center point, width, height, instead of ULcorner, width, height

d - The diagnostic image shows where the selected ROI lies within the image; it stretches the scale by a factor of 4 in the measurement direction and shows where the best fit line lies in that area, and what pixels contribute to the SFR.

e - The verbose output adds the intermediate ESF and LSF profiles.

f - TIFF image header information generally contains the correct image polarity, which will then be correctly read by the TIFF reader in mitre_sfr. In some cases, however, the TIFF header may contain the wrong polarity information. The ESF listing in the verbose output mode can be used to verify that the expected polarity was read correctly: a black-to-white edge should have a smaller value at the beginning of the edge listing and a larger value after it. If the ESF shows the opposite trend, this option will force a polarity reversal.

n - By default the output SFR will be compared to the PIV 500 ppi MTF spec. Use this option to turn off the PIV spec checking.

- **Data input:**

  image filename - The input 8 bpp grayscale image can be in uncompressed TIFF, PGM, or raw format. If raw format, the number of header bytes, image width and height (in pixels) must be known and typed-in.

  OECF – if linear, press RETURN
  if nonlinear, type-in the OECF data filename

  pixels per inch – type-in ppi (floating point entry allowed)

  ROI size/location – default type-in: ROI ULcorner, width, height
  option c type-in: ROI center, width, height

- **Output Parameters**

The output is both written to the runtime display window and appended to the output file: SFROUT.txt

The SFR is reported in terms of modulation versus spatial frequency in cy/mm at the object plane (the input ppi is used to scale the frequency axis to the object plane). This SFR has been corrected for the small error incurred by computing the derivative of the discrete sampled ESF as finite differences.

Additional information is reported about the straight line that is fitted along the edge transition, i.e., R^2 of edge fit, edge tilt angle, number of rows per phase rotation, and number of phase rotations of the edge used in the SFR computation. If R^2 is not close to 1.0 then the diagnostic image should be examined to see if the edge has any noticeable curvature within the ROI (if it does, then define a new ROI within a straight portion of the edge). The computed edge tilt angle with respect to the vertical (for near vertical edge) or horizontal (for near horizontal edge) needs to be reasonably correct for an accurate assessment of SFR. If possible, crosscheck the computed tilt angle with its true value, if known from other sources. An inaccurate assessment of tilt angle in SFR could be due to high noise, edge curvature, edge non-uniformities, or artifacts/blemishes on the edge; the diagnostic image is useful to see if the edge fit is systematically good.

For a near vertical edge, including many edge rows in the assessment will give a more consistent SFR curve, as long as the edge fit continues to be reliable at both ends of the ROI. Rows where the edge fit moves away from the true edge location will contaminate the SFR with bad data, and give the impression that the edge is blurry. If the edge is linear, then additional rows of data tend to improve the edge fit, and hence the SFR. If the edge is not quite linear, then smaller measurement areas may be needed (with concurrent increase in ‘noise’ and less reliable line fit measurements). For the sake of consistency, at least 5 phase rotations are needed for accurate SFR computation. A warning is printed in the problem report area if the ROI isn’t large enough to rely on the

SFR results. When this occurs increase the maximum dimension to allow at least 5 row cycles. (Number of rows expected per cycle is listed in the output.)
The number of rows included in the SFR is listed, and the number of pixels on each side of the line fitted to the edge transition is listed.

Verbose ESF and LSF: The 4X over-sampled ESF and LSF curves are printed only in the vicinity of the edge. The x-values are in pixel units relative to the center of the best edge fit. With the type of discrete derivative used in mitre_sfr, i.e., [-1,1], the ESF is binned offset from the LSF (i.e., ESF x-values are actually 0.125 greater than reported). The LSF peak or centroid should be located near zero.

Diagnostic Image: The diagnostic image shows the original image with the ROI box and any user defined edge endpoints inscribed, plus a blowup of the ROI area. The ROI blowup is stretched by a factor of 4 in the across-the-edge direction, but has no zoom in the along-the-edge direction. Inscribed into the ROI blowup is the edge location used for the SFR computation (solid line) as well as dotted lines marking the edge of the pixels that actually contribute to the final SFR value. If the inscribed edge line has an angle different from the actual edge, then the computed SFR is suspect. If the angle of the edge line is good, but the location is slightly offset from the actual edge, then only slight variations in SFR are expected if the edge shifts. A serious offset of edge line from the true edge center should be investigated. Menu option ‘a’ can be used to force the edge line to lie in specific locations.