sfrmat 2.0 User's Guide

Peter Burns

pdburns@ieee.org

0. Changes

This version of *sfrmat*, (distributed as Matlab function, sfrmat2.m) includes several significant changes from the previous version 1.1. These include;

- **For three-record (R,G,B) image files, the Spatial Frequency Response (SFR) is reported for each color record, in addition to the previous combined luminance measure**
- **A color misregistration measure is reported for the row or column direction along the edge**
- **Several execution options are available, including a non-GUI (graphical user interface) selection, for those who wish to combine the *sfrmat2* procedure with their own programming.**

Suggestions for improvement and reporting of bugs are encouraged and can be sent to the above e-mail address.

1. Introduction[*]

sfrmat is a Matlab function that provides a spatial frequency response* (SFR) from a digital image file containing a slanted-edge feature. The specific edge-gradient algorithm follows the intent of the standard ISO 12233, developed by Technical Committee ISI/TC 42, for resolution measurements for electronic still pictorial cameras[1,2]. The same procedure is referred to in the final draft of standard ISO 16067, Spatial Resolution Measurements: Part 1 Scanners for Reflective Media[3]. The objective for developing this Matlab implementation of the procedure was to provide analysis software that can be easily used across several common computer operating systems.

The first version of this software was intended to provide equivalent results to those available using the Adobe PhotoShop plugin software[4] written by Eric Higgins and Andrew Juenger, and distributed by the Photographic Industry Manufacturers Association (PIMA)[†]. This capability is available using *sfrmat2*, however, additional flexibility has also been included.

The *sfrmat2* software consists of m-files, which are interpreted by the Matlab application as

---

[*] The term Modulation Transfer Function (MTF) is often used when describing spatial frequency performance of imaging systems. There are two reasons why the computation performed by *sfrmat2* is called SFR rather than MTF. The calculation does not explicitly account for the input object (scene) spatial frequency content, as would be done if a measure of the transfer of image detail were needed. A second reason is to avoid confusion with photographic MTF measured as per ANSI PH 2.39 standard.

[†] PIMA has been superceded by The International Imaging Industry Association (I3A).

instructions in its programming language. The main function, *sfrmat2*, calls several supporting functions, for reading and selecting data, processing, etc. These are supplied as part of this distribution, and are listed in the Appendix. Other functions which are called are either built into Matlab, or are supplied by The MathWorks in the Standard Toolboxes. *sfrmat2* does not call any functions from toolboxes that are available at additional cost, such as those for signal processing and statistics.

Matlab Versions

The software has been tested using the following Matlab versions;

Sun Unix: Matlab versions 5.3, 6.0

Windows 2000, Windows XP: Matlab version 5.3, 6.1

Macintosh: Matlab version 5.2

Trademarks

Matlab is a registered trademark of The MathWorks Inc., Photoshop is a registered trademark of Adobe Systems Inc., Macintosh is a registered trademark of Apple Computer, UNIX is a registered trademark of AT&T, Windows is a registered trademark of Microsoft Corp.

2. Copyright Information

By installing this software, you accept and agree to be bound by the terms of the software license agreement which appears below.

RECOVERING SUCH DATA OR PROGRAMS. I3A RESERVES THE RIGHT TO MAKE CORRECTIONS OR IMPROVEMENTS TO THE INFORMATION PROVIDED AND TO THE RELATED SOFTWARE AT ANY TIME, WITHOUT NOTICE.

By installing this software, you accept and agree to be bound by the terms of this agreement.

3. Installing sfrmat2

a. Decompress the *sfr2.zip* distribution file and store the resulting Matlab m-files in a directory (folder) of your choice, e.g.,

computer/user/matlab/sfr2 under UNIX, or
computer:applications:matlab:sfr2 for Macintosh
C:\folder\sfr2 for Windows.

b. Make this directory accessible to Matlab, by adding it to your Matlab search path. Windows and Macintosh versions of Matlab have Path Browsers for viewing and editing the search path. You can also use commands such as,

addpath to add a directory to your search path
rmpath to remove a directory from your search path
path2rc to save the current Matlab path so it will become the default path whenever you run Matlab

c. Check to see if you have done the above correctly by typing the following at the Matlab prompt,

```
>> which sfrmat2
```

If the file is not found the response will be

```
>> sfrmat2 not found
```

and you will need to modify you search path as in steps a and b.

4. Running *sfrmat2*

4.1 Input Image Data

sfrmat is used to analyze a slanted or rotated edge feature as stored as an image file, such as JPEG, TIFF, etc. The Matlab function *imread* is used, and more information can be found by typing,

```
>> help imread
```

at the command window prompt.

Figure 1 shows acceptable orientations of the edge feature. After input file selection, the Region of Interest (ROI) Graphical User Interface (GUI) is displayed. A feature such as one of Fig. 1 can be chosen from a digital image that contains a larger image.

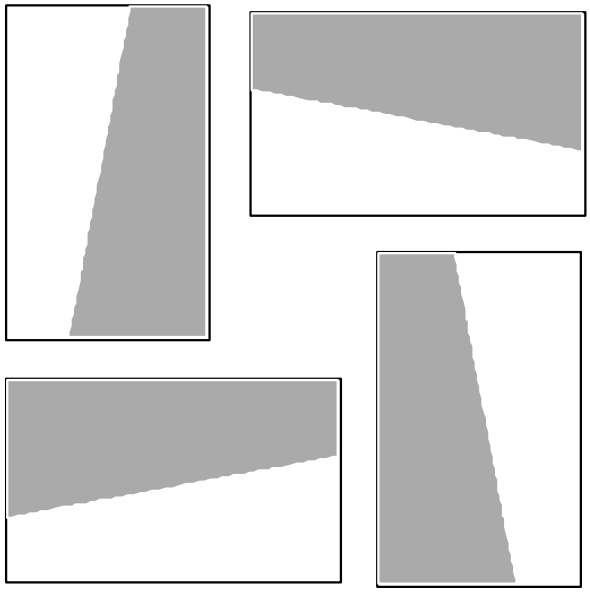

Figure 1: Acceptable edge-feature orientations

4.2 Running sfrmat2

To run *sfrmat2*, type the name of the function type,

```
>> sfrmat2
```

Figure 2 shows a listing given after the *help* command,

```
>>help sfrmat2
```

is executed.

```
sfrmat2:  Slanted-edge and color mis-registration analysis
   [status, dat, fitme, esf] = sfrmat2(io, a, del);
        From a selected edge area of an image, the program computes
        the ISO slanted edge MTF. Input file can be single or
        three-record file. Format can be JPEG or TIF. The image is
        displayed and a region of interest (ROI) can be chosen, or
        the entire field will be selected by not moving the mouse
        when defining an ROI. Either a vertical or horizontal edge
        feature can be selected.
   Input arguments:
        io (optional) integer [1-4] controls computation, and
        reporting of output
        a (optional) an nxm or nxmx3 array of data     (used with io=4)
        del (optional) sampling interval in mm or dpi  (used with io=4)
           If dx < 1 it is assumes to be sampling pitch in mm
           If io = 4 (see below, no GUI) and del is not specified,
           it is set
           equal to 1, so frequency is given in cy/pixel.
   Returns:
```

```
      status = 0 if normal execution
      dat = computed sfr data in 2 (freq, sfr) or 5 columns.
      fitme = coefficients for the linear equations for the fit to
              edge locations for each color-record
      esf   = supersampled edge spread function vector
  Usage:

      sfrmat2(0) = ISO Plugin type output (no color registration,
                   single luminance SFR), with prompts for I/O
      sfrmat2(1) = ISO output + edge location(s)

      sfrmat2
      sfrmat2(2) = (default) R,G,B,Lum SFRs + edge location(s)

      sfrmat2(3) = only edge location(s)
      [status, dat, fitme] = sfrmat2(4, array, a, del)
                 returns SFRs and edge locations to the variables
                 [[status, dat, fitme] without plotting or other
                 output. Input 'array' is an nxm or nxmx3 array of
                 data. No Graphical User Interface (GUI) is used with
                 this option.
  Needs: ahamming, cent, centroid, clipping, deriv1, findedge,
         getoecf, getroi, inbox1, inbox3, inputdlg, project, results,
         rotatev, splash, isarray

  Author: Peter Burns, peter.burns@kodak.com
          12 August 2003
  Copyright (c) International Imaging Industry Association
**************************************************************
```

Figure 2: Help *sfrmat2* listing.

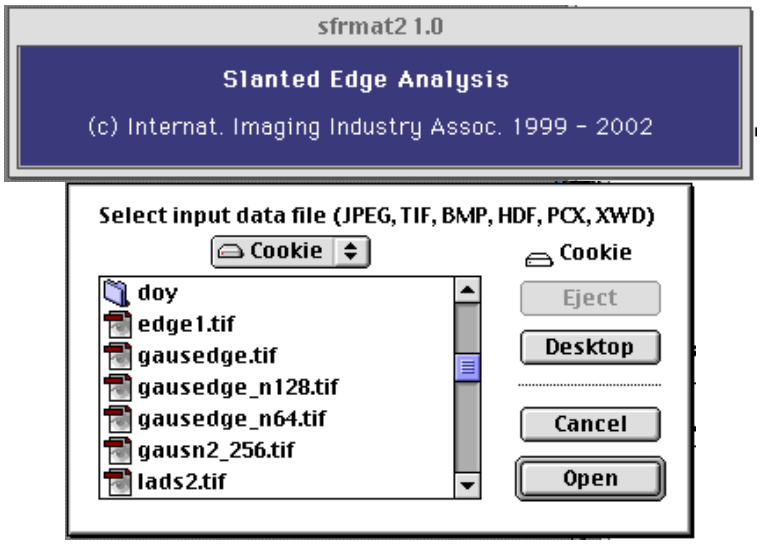

Figure 3: Dialog for selection of input data file, and copyright-version notice

After the execution of *sfrmat2*, the following dialog for input data file selection and copyright-version notice are displayed simultaneously, as shown in Fig. 3[‡]. After file selection, both of these will close. This is followed by the display of the Data Sampling and Weights dialog, of Fig. 4. If OK is selected in this window, the default values will be used.

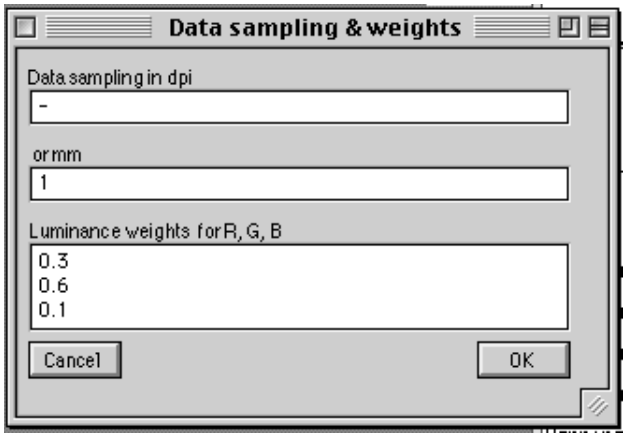

Figure 4: Window for selection of input sampling and luminance weights. Selection of OK results in the default values (shown) being used.

Figure 5 shows the next window, for selection of the region of interest, the data used for the SFR and color registration computation. **The short sides of the ROI rectangle should intersect the edge**. Start by pressing the (left) mouse button at any corner and move the mouse while still pressing the button. When you have defined the ROI rectangle release the button. (Currently you only get one try at this procedure per *sfrmat2* execution.) A vertical (shown) or horizontal edge can be chosen for analysis. See also Fig.1.

[†]Fig.s 4-6 show Macintosh graphics. Other Matlab versions will differ in appearance, but have the same functions.

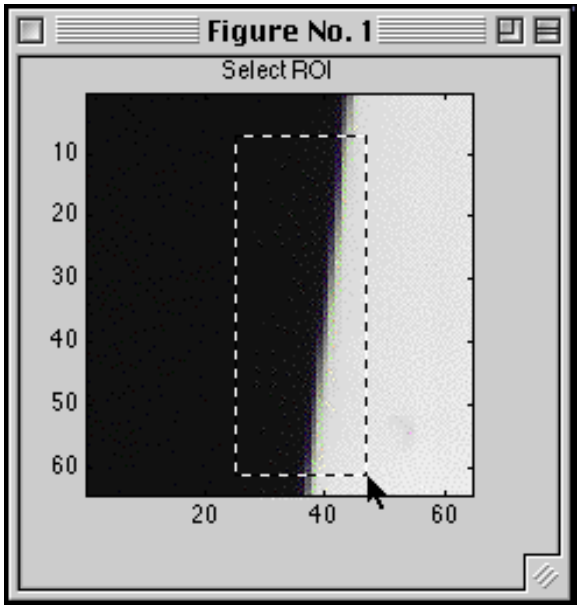

Figure 5: Display of input image file for selection of ROI with computer mouse. A correct selection is shown, but a click without moving the mouse results in the entire file being selected.

The next input requested is for the (optional) selection of an opto-electronic characteristic function (OECF) look-up table. This is shown in Fig. 6. This is for the transformation of the input image data via one-dimensional tables (three one-dimensional tables for a color image). This is described in reference 6, and is assumed available. The format of this table is the same as that needed for the ISO PhotoShop plugin software. Selecting Cancel results in no transformation being applied. Two example OECF look-up table files, lut1.dat and lut3.dat are supplied with software distribution file.

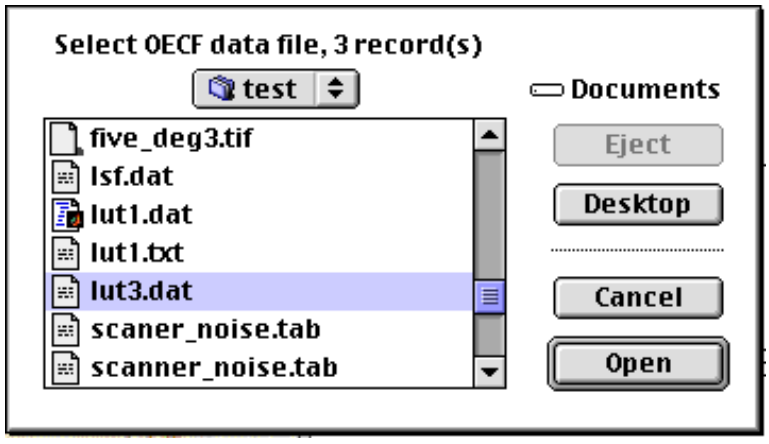

Figure 6: Dialog for selection of OECF file. Selecting Cancel results in no transformation.

Execution ends with a plotting of the computed spatial frequency plot, as shown in Fig. 7, and a dialogue for the naming of an (optional) output file. The output is a text file summarizing the analysis, shown in Fig. 8. Selecting Cancel results in no file being written.

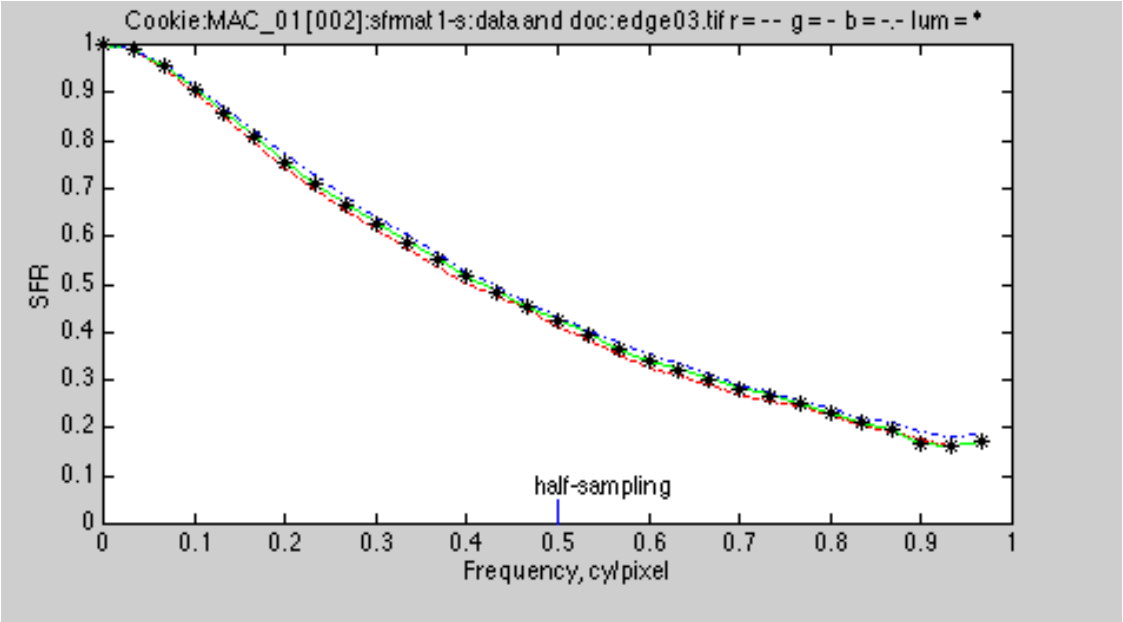

Figure 7: Example of plotted SFR result.

```
>> sfrmat2_dist
            ** sfrmat: version 2.1 (12 AUGUST 2003) **
        (c) Internat. Imaging Industry Assoc. 1999 - 2003
                          on Solaris 2

Select ROI with right mouse button, no move = all


Edge location(s) and slopes =
   16.2241   10.3047
   16.2589   10.2977
   16.2236   10.2744

Misregistration, with green as reference (R, G, B, Lum) =
   -0.0347
    0.0000
   -0.0353
* Writing results to file: /home/burns/matlab/sfrmat2/data/test3.dat
* sfrmat2 finished  *
```

Figure 8a: Example Command window dialogue for *sfrmat2* execution

```
% Output from Matlab function sfrmat2.m
```

```
 % Analysis:  Spatial Frequency Response
% 05-Aug-2002 09:07:55
% Image/data evaluated:  /home/burns/matlab/sfrmat2/data/edge03.tif
% This output file: /home/burns/matlab/sfrmat2/data/test3.dat
% Selected region: (1, 1), to (30, 176)
% OECF applied: lut3.dat
% Edge location, slope, misregistration (second record, G, is reference)
%   16.224     10.305      -0.035
%   16.259     10.298       0.000
%   16.224     10.274      -0.035
% Frequency     SFR-r       SFR-g       SFR-b       Lum
   0.000       1.0000      1.0000      1.0000      1.0000
   0.033       0.9879      0.9890      0.9891      0.9887
   0.067       0.9525      0.9569      0.9593      0.9558
   0.100       0.9023      0.9096      0.9158      0.9078
   0.133       0.8497      0.8604      0.8712      0.8579
   0.167       0.7961      0.8106      0.8229      0.8072
   0.200       0.7441      0.7592      0.7737      0.7557
…
   1.833       0.0061      0.0057      0.0042      0.0055
   1.867       0.0037      0.0050      0.0039      0.0045
   1.900       0.0031      0.0037      0.0024      0.0033
   1.933       0.0030      0.0023      0.0018      0.0024
   1.967       0.0014      0.0012      0.0009      0.0012
   2.000       0.0003      0.0000      0.0003      0.0000
```

Figure 8b: Example for output file format used to save results

5. Common Problems and How to Avoid Them

5.1 Region of Interest Selection

Successful spatial frequency response analysis requires that the input image data is supplied in a specific way. These requirements are generally the same as those for the Photoshop plugin analysis software. When selecting the region of interest, as shown in Fig. 5, the short sides of the selection rectangle (defined in a 'rubber band' operation) should both intersect the edge. Fig. 9 shows several incorrect selections to be avoided.

5.2 Low Contrast Edge

If the input edge image data is of low contrast (low-high signal difference across edge) this will usually result in an unreliable SFR measurement. *sfrmat2* tests whether the difference is less that 20% of the average signal level, and reports a warning in the Matlab Command Window,

---

** WARNING: Edge contrast is less than 20%, this can **
lead to high error in the SFR measurement.

Execution continues after this warning.

5.3 Edge Angle too Large or Too Few Lines of Data

If the angle of the input edge data is too large, or too few lines (for vertical edge, or pixels for a horizontal edge) are chosen, this can cause errors during the 'binning' operation used to construct the supersampled edge profile. *sfrmat2* attempts to account for this and continues after reporting the following warning.

```
** WARNING **
Zero count(s) found during projection binning. The edge
angle may be large, or you may need more lines of data.
 Execution will continue, but see Users Guide for info.
```

If this is seen, you are advised to repeat the procedure using a different edge or ROI.

5.3 Data clipping

If input data are clipped at either low or high signal levels, this will usually corrupt the calculated SFR, due to the artificially 'sharp' features that are introduced[7]. A simple test for signal clipping is included when *sfrmat2* is executed. If more that 0.5% of the pixel values are either at 0 or the maximum signal level, then a warning is given to the monitor screen, but execution continues. Note that signal clipping can also occur at other than these (e.g., 0, 255) levels, e.g., during digital image acquisition.

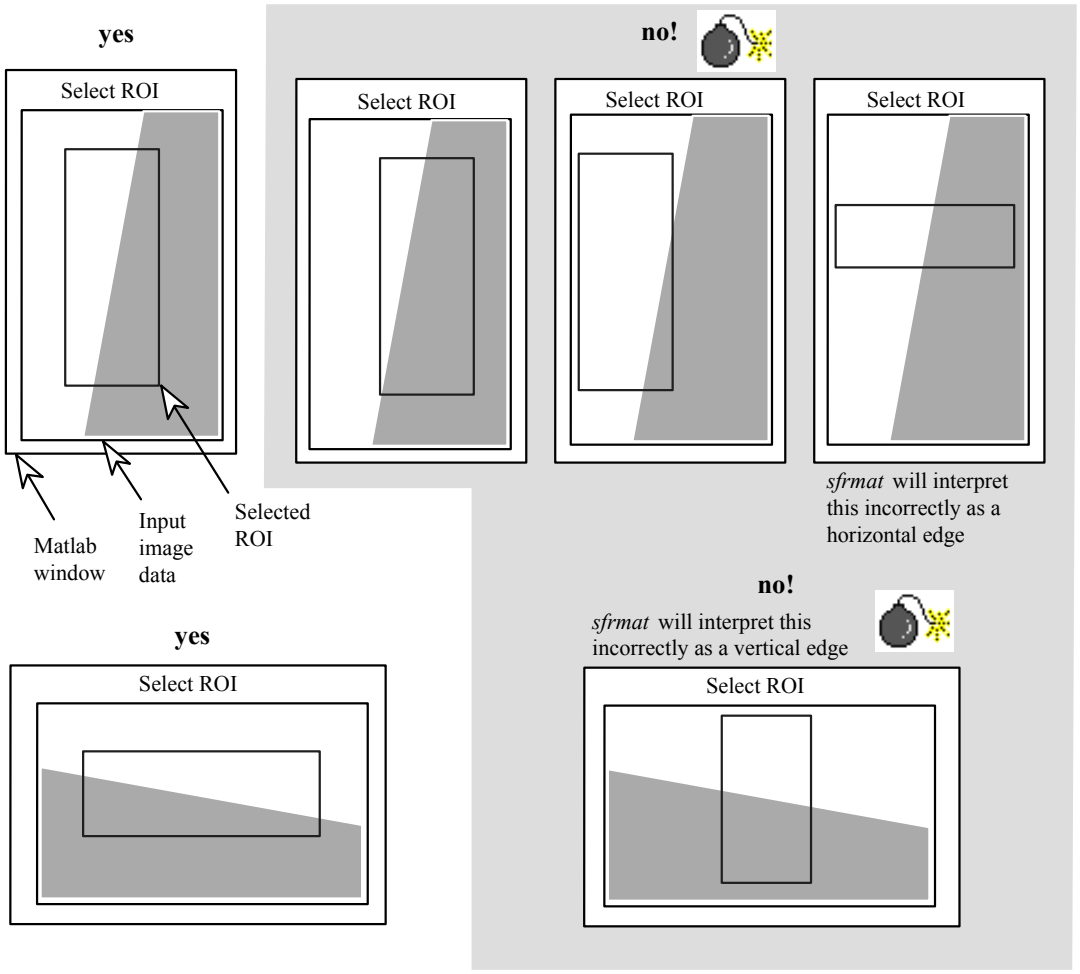

Figure 9: Correct and incorrect selection of the Region of Interest for *sfrmat2* analysis.

6. Acknowledgements

Many thanks to Don Williams for his suggestions during collaborations on both spatial frequency response[6,7] and color registration measurement[5] derived from slanted edges. I am also grateful to Ken Parulski and Jack Holm for encouragement to develop the Matlab software and for useful background information about the ISO standards developed through PIMA and now I3A.

7. References

1 ISO 12233 International Standard, Photography - Electronic Still Picture Cameras - Resolution measurements.

2. T. A. Fischer and J. Holm, 'Electronic still picture Camera Spatial Frequency Response Measurement,' Proc. of IS&T Annual Conf./ICPS 1994, vol. 2, pp. 626-630 (1994).
3. ISO 16067 Working Draft 3.1, Photography - Electronic still picture cameras – Spatial resolution measurements: Part 1 Scanners for reflective media, draft available from I3A Internet site, `http://www.i3a.org/`
4. ISO Imager Analyser Photoshop Plugin, previously available from PIMA Internet site.
5. P. D. Burns and D. Willliams, 'Using Slanted Edge Analysis for Color Registration measurements,' *Proc. PICS Conference*, IS&T, 51-53, 1999.
6. P. D. Burns, 'Slanted-Edge MTF for Digital Camera and Scanner Analysis,' *Proc. PICS Conf.*, IS&T, 135-138, 2000.
7. P. D. Burns and D. Williams, Refined Slanted-Edge Measurements for Practical Camera and Scanner Testing, *Proc. PICS Conf.*, IS&T, 191-195, 2002

Appendix I: Listing of Files Supplied with *sfrmat2* Distribution

Contents of *sfr2.zip* file

This Users Guide
- sfrmat2.pdf

Matlab files:
- sfrmat2.m
- ahamming.m
- cent.m
- centroid.m
- clipping.m
- deriv1.m
- findedge.m
- getoecf.m
- getroi.m
- inbox1.m
- inbox3.m
- isarray.m
- inputdlg.m
- project.m
- results.m
- rotatev.m
- splash.m

In **Data** directory/folder:

Example OECF look-up tables
- lut1.dat — for single-color (monochrome) image data
- lut3.dat — for three-color (R, G, B) image data

Example data files
- edge01.tif — monochromes single-record image file
- edge03.tif — R, G, B image file