Peter Haub (Germany, phaub@dipsystems.de) Dec. 2015 – May 2017

MTF_Measure

What is the plugin for?

MTF_Measure is an ImageJ plugin for evaluating the spatial frequency response of electro-optical systems by analysis of Siemens star resolution targets (Fig. 1). Detailed information regarding meaning and measurement of the modulation transfer function (MTF) and contrast transfer function (CTF) can be found in the literature [1-7].

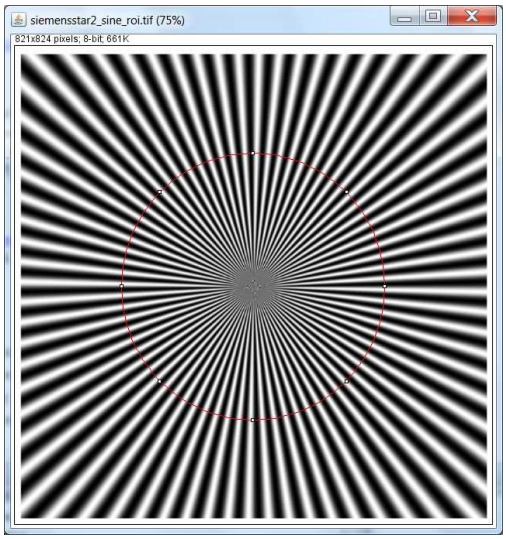

Fig. 1: Siemens Star resolution chart

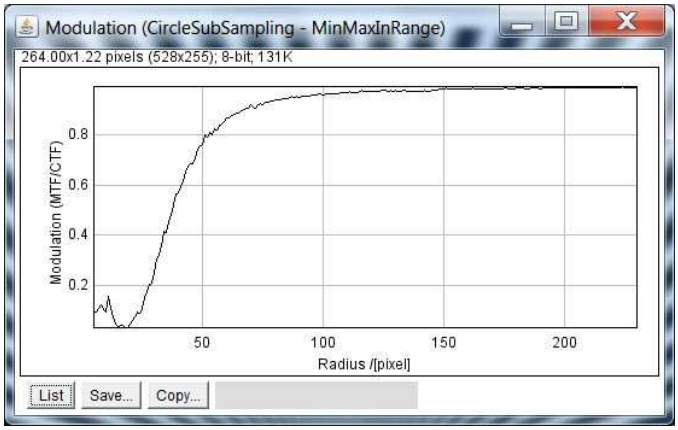

Fig. 2: Modulation transfer function

Installation

Download and unpack MTF.zip. Drag and drop MTF.jar and MTF_20170503.jar to the "ImageJ" window or copy both files manually into the ImageJ\plugins folder.

Usage

1- Open an image of a Siemens star resolution chart and select a circular area around the center of the star (use OvalRoi tool)

2- Start MTF_Measure from the ImageJ menu Plugins/MTF

3- Check and adapt the settings in the parameter window (Fig. 3) and press OK

Note 1:

The calculations are performed in 16bit grayscale images. Other types of images are automatically converted into 16bit images with an intensity scaling.

Note 2:

The plugin tries to determine the center of the Siemens star and the number of line pairs before the Setup dialog is displayed.

Check the determined parameters and correct them if necessary.

(To display the intermediate detection image (Fig. 4) hold SHIFT key down when starting the plugin by clicking onto <Plugins menu/MTF/MTF_Measure>. In a dialog the inner detection radius can be defined as relative reduction of the outer radius.

Settings

The following parameters can be adjusted to control the measurement:

N Line Pairs	Number of sectors in Siemens star chart
Center X / Center Y	Center of Siemens Star chart
GetPixel Mode	Pixel values on measurement circles are determined by: - Pixel access via Bresenham circle algorithm (no interpolation) - Bilinear pixel interpolation - Interpolation by pixel sub sampling (rectangular or circular)
SubSample Size	Sample size (0.3 pixel <= sample size <= 0.8 pixel) (only for rectangular and circular sub sampling)
SubSample Overlap	Sample overlap (in pixel fraction, only for rectangular and circular sub sampling)
useDenseBresenhamMode	8-connection Bresenham algorithm (instead of 4-connection)
GetModulation Mode	Modulation calculation mode
do2D	Analyze MTF/CTF in 2 dimensions
maxRadius (2D only)	maxRadius in Pixel (Roi dimensions will not be used)
phiRangeDeg (2D only)	Measurement angle range (in deg)
Save macro String	Macro String is save in USER di

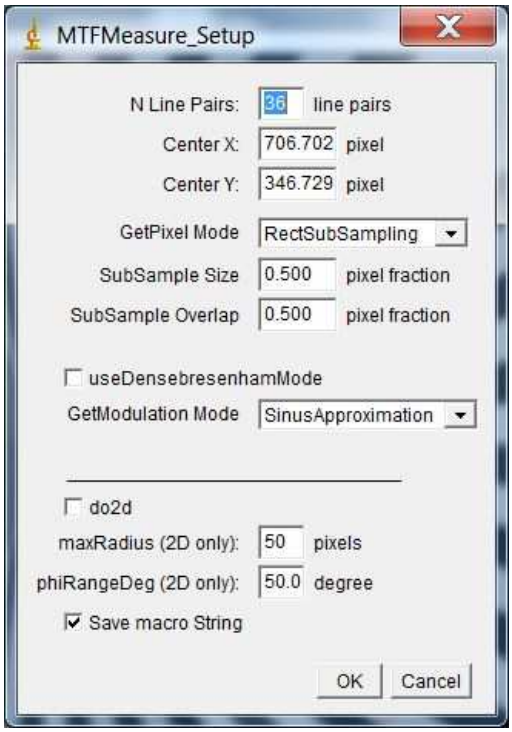

Fig. 3: MTF_Measure setup dialog

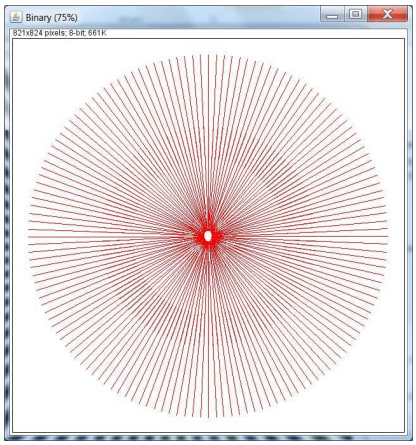

Fig. 4: Center detection

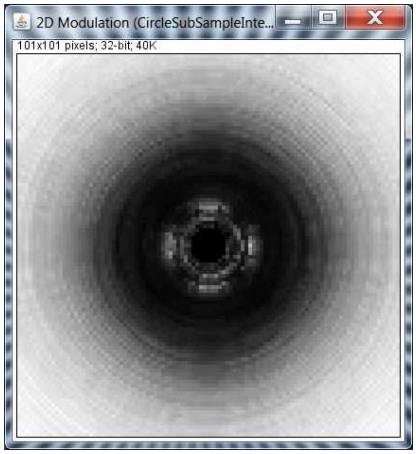

Fig. 5: 2D Modulation transfer function

Results

In the **1D mode** the MTF/CTF is determined over the full circle (2π). The mean modulation values are display in an ImageJ plot (Fig 2). The values can be access and copied from the plot window for further processing (Fig. 6).

The maximum measurement radius will be derived from the OvalRoi selection.

The theoretical Nyquist frequency equivalent radius is display in the IJ.log window.

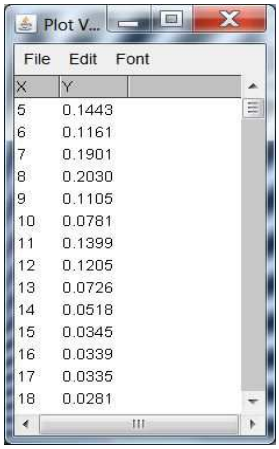

Fig. 6: 1D modulation values

In the **2D mode** the modulation values are display as intensity values in a 32bit floating point image (Fig. 5, 7).

MTF profiles can be displayed by using the ImageJ 'Plot Profile' function (Fig. 8).

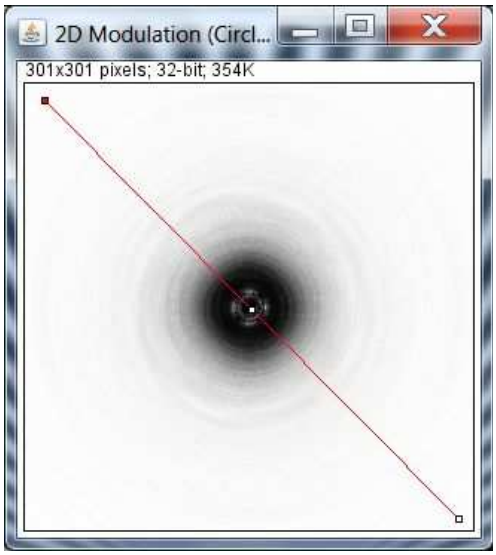

Fig. 7: 2D modulation image with line selection

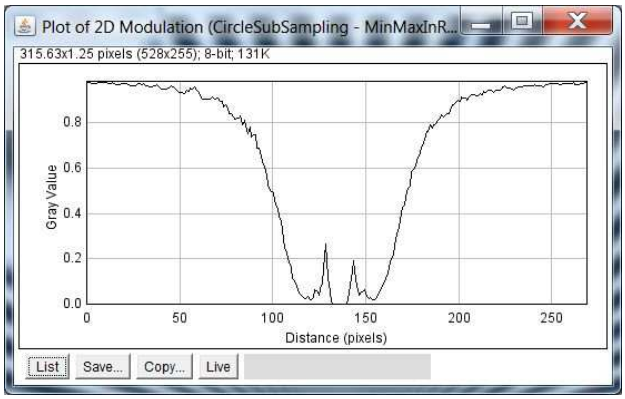

Fig. 8: Intensity profile (from selection in Fig. 6)

Macro Call

MTF_Measure can be called with the ImageJ command, e.g.

```
IJ.run("MTF Measure","np=36 xc=706.702 yc=346.729 modegetpixel=2 samplesize=0.5 sampleoverlap=0.5
modegetmodulation=0 maxr2d=50 phirangedeg=50.0 enlargefactor=50 usedensebresenhammode=false
do2d=false showplot=true");
```

MTF_Measure can also be called via Java code, e.g.

```
String options = "np=36 xc=706.702 yc=346.729 modegetpixel=2 samplesize=0.5 sampleoverlap=0.5
modegetmodulation=0 maxr2d=50 phirangedeg=50.0 enlargefactor=50 usedensebresenhammode=false
do2d=false showPlot=false";
MTFMeasure MTF = new MTFMeasure();
double[] a = MTF.calcMTF(options);
```

An example plugin MTF_MacroTest.java is stored in the MTF_20170503.jar.

Create_Star

With the plugin MTF\MTF_CreateStar a Siemens star resolution charts can be generated either with rectangular (Fig. 10) or sinusoidal profile (Fig. 11).

A linear gray scale is display below the star chart. The gray scale is adapted to the lowest and highest intensity value in the star.

The calculation is based on a numerical integration of function values with the advantage to be able to study and control the rendering process (of rectangular sampling of a polar coordinate function).

The following parameters can be adjusted in the setup dialog (Fig. 9):

N Line Pairs	Number of sectors in Siemens star chart
Image Half Width	Width of the chart image (specified by width/2)
Phase offset	Phase angle of the profile
Amplitude	Intensity I of white lines (I_{max} = A * nSubSamples * 2)
SubPixel Sampling	Number of sub samples per pixel
	(determines the accuracy of the pixel intensity calculation)
Sinus Modulation	Switch between rectangular and sinusoidal intensity profile

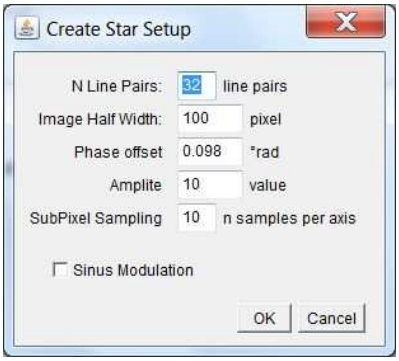

Fig. 9: MTF_CreateStar setup dialog

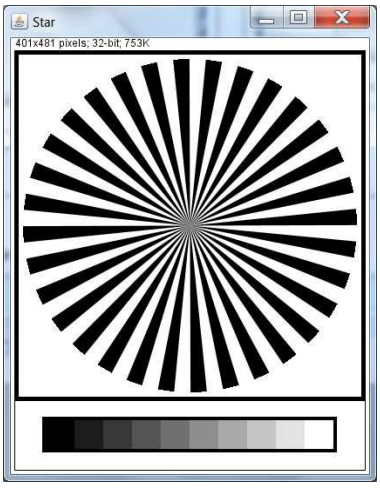

Fig. 10: Siemens star (rectangular profile)

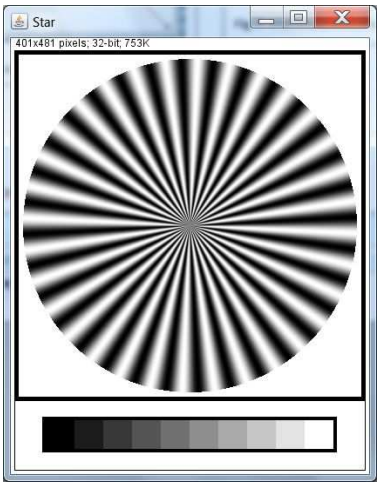

Fig. 11: Siemens star (sinusoidal profile)

License

Future

Planned Improvements:

- Pixel Subsampling
- GetModulation functions
- Save Preferences

Literature

[1] Hecht, E. Optics (4th edn, Addison-Wesley, 2002).

[2] Holst, G.C. Testing and Evaluation of Infrared Imaging Systems (2nd edn, JCD Publishing, 1998).

[3] Holst, G. C. CCD Array Cameras and Displays. (Bellingham, 1998).

[4] Goodman, J. Introduction to Fourier Optics (2nd edn, McGraw-Hill, 1996).

[5] Birch, G. C., Griffin, J. C. Sinusoidal Siemens star spatial frequency response measurement errors due to misidentified target centers. *Optical Engineering* 54.7 (2015).

[6] Loebich, C. et al. Digital camera resolution measurement using sinusoidal siemens stars, Proc. SPIE 6502, 65020N (2007).

[7] Optical transfer function (Wikipedia article) ; https://en.wikipedia.org/wiki/Optical_transfer_function, (Accessed: 03rd Dec 2015).