



AFRL-HE-AZ-TP-2006-0004

**Graphical User Interfaces
For Digital-Image Frequency Analysis**

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December 2006

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE (DD-MM-YYYY) 15-12-2006		2. REPORT TYPE Technical Memorandum		3. DATES COVERED (From - To) 01-03-2006 to 01-04-2006	
4. TITLE AND SUBTITLE Graphical User Interfaces for Digital-Image Frequency Analysis				5a. CONTRACT NUMBER F-41624-97-F-5000	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER 62202F	
6. AUTHOR(S) Chi-Feng Tai, James P. Gaska, and George A. Geri				5d. PROJECT NUMBER 1123	
				5e. TASK NUMBER B1	
				5f. WORK UNIT NUMBER 23	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Link Simulation and Training 6030 S. Kent St. Mesa, Arizona 85212				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory Human Effectiveness Directorate Warfighter Readiness Research Division 6030 South Kent Street Mesa AZ 85212-6061				10. SPONSOR/MONITOR'S ACRONYM(S) AFRL; AFRL/HEA	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-HE-AZ-TM-2006-0004	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Frequency analysis plays an important role in the area of visual research. The application described in this technical memorandum provides a graphical user interface that simplifies loading, analyzing, and storing the results of common frequency analysis tasks. The application allows the user to load image files and compute: a 2-D discrete Fourier transform (DFT) of the image, a polar transform (orientation and radial spatial frequency) of the DFT, or a 1-D modulation verses spatial frequency plot produced by averaging over specified orientations of the polar transform. The outlined analysis can also be performed on a subsection of the input image. The subsection of the input image can also be multiplied by a Gaussian window to reduce edge effects.					
15. SUBJECT TERMS Digital images; Frequency Analysis; Graphical user interface; GUI; Image files; Visual Research					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UNLIMITED	18. NUMBER OF PAGES 12	19a. NAME OF RESPONSIBLE PERSON Dr Byron J. Pierce
a. REPORT UNCLASSIFIED	b. ABSTRACT UNCLASSIFIED	c. THIS PAGE UNCLASSIFIED			19b. TELEPHONE NUMBER (include area code)

GRAPHICAL USER INTERFACES FOR DIGITAL-IMAGE FREQUENCY ANALYSIS

Introduction

Frequency analysis plays an important role in the area of visual research. The application described in this technical memorandum provides a graphical user interface that simplifies loading, analyzing, and storing the results of common frequency analysis tasks. The application allows the user to load image files and compute:

- A 2-D discrete Fourier transform (DFT) of the image
- A polar transform (orientation and radial spatial frequency) of the DFT
- A 1-D modulation versus spatial frequency plot produced by averaging over specified orientations of the polar transform

The analysis outlined above can also be performed on a subsection of the input image. The subsection of the input image can also be multiplied by a Gaussian window to reduce edge effects.

Installing and running the application

This program is designed to run on a PC (Windows) with or without Matlab.

Running the application with Matlab

To run the application with Matlab, simply copy the entire folder, *m-codes*, (see attached CD) to any desired location on an end-user machine. The user can either change the current directory to *m-codes* or use the `setpath` command in Matlab to reference the application directory. Type “`guiFFT`” on the command line in Matlab to start the application.

Running the application without Matlab

To run the application without Matlab, it is necessary to first install Matlab runtime software. The runtime modules are installed by running *MCRInstaller.exe* which can be found on the attached CD. After installing the runtime modules, the application is started by double-clicking on *guiFFT.exe* located inside the folder labeled *StandAloneExecutable*. Running the application using Matlab is primarily of interest to Matlab programmers who wish to examine or modify the m-code. In addition, running the application using Matlab does not require installing the runtime modules.

Analyzing a Full Image

After starting the application, a window will be displayed on the screen as shown Figure 1. There is a *User Control Panel* (UCP) near the bottom of main window that allows the user to select the input image and initiate the frequency analysis. The left section of the UCP provides a preview of the input image. The size of the image in pixels is displayed below the figure. The user can instruct the program to simulate monitor gamma by using the check-box and the associated text box positioned below the preview image. If the Gamma box is checked, the numerical values of each image pixel are modified according to the following formula:

$$I_{out} = I_{In}^{Gamma},$$

where *Gamma* is the value entered into the gamma text box. If the gamma checkbox is unchecked, the values in the input files will be used for the frequency analysis.

The center section of the UCP lists the content of the current directory. Clicking on “..” will move the current directory up one level and clicking a folder icon will make that folder the current directory. The user can filter the type of image files displayed by using the pull-down menu below the directory listing. The user can preview an image by selecting (single-click) the filename in the folder list. The filename, “flowers.bmp,” is selected for preview in Figure 1. The program will only process files with the formats shown in Table 1. Selecting other files will cause “Invalid Type” to be displayed on the preview window.

The *Perform FFT* button initiates the data analysis. Upon completion, a message box will be displayed indicating that the analysis is complete along with the value of the gamma used (Figure 2). Select the **OK** button to dismiss the message box.

Format	Extension	Comment
Bitmapped Image	.bmp	Windows bitmapped image. It must be a 24-bit depth image.
Flexible Image Transport System	.fit	Format used for the transport, analysis, and archival storage of scientific data sets in the astronomical community. [Used by CCD cameras supplied by the Santa Barbara Instrument Group.]
Luminance Image	.lum	A simple binary format with the first two 16 bit words being the X and Y dimensions of the luminance array, followed by the array of single-precision (32 bit) floating point values. [Used by the Lumetrix IQCam CCD camera.]
Text image	.txt	A tab separated text file. A row of the text file should equal a row of the image.

Table 1: Valid Image Formats

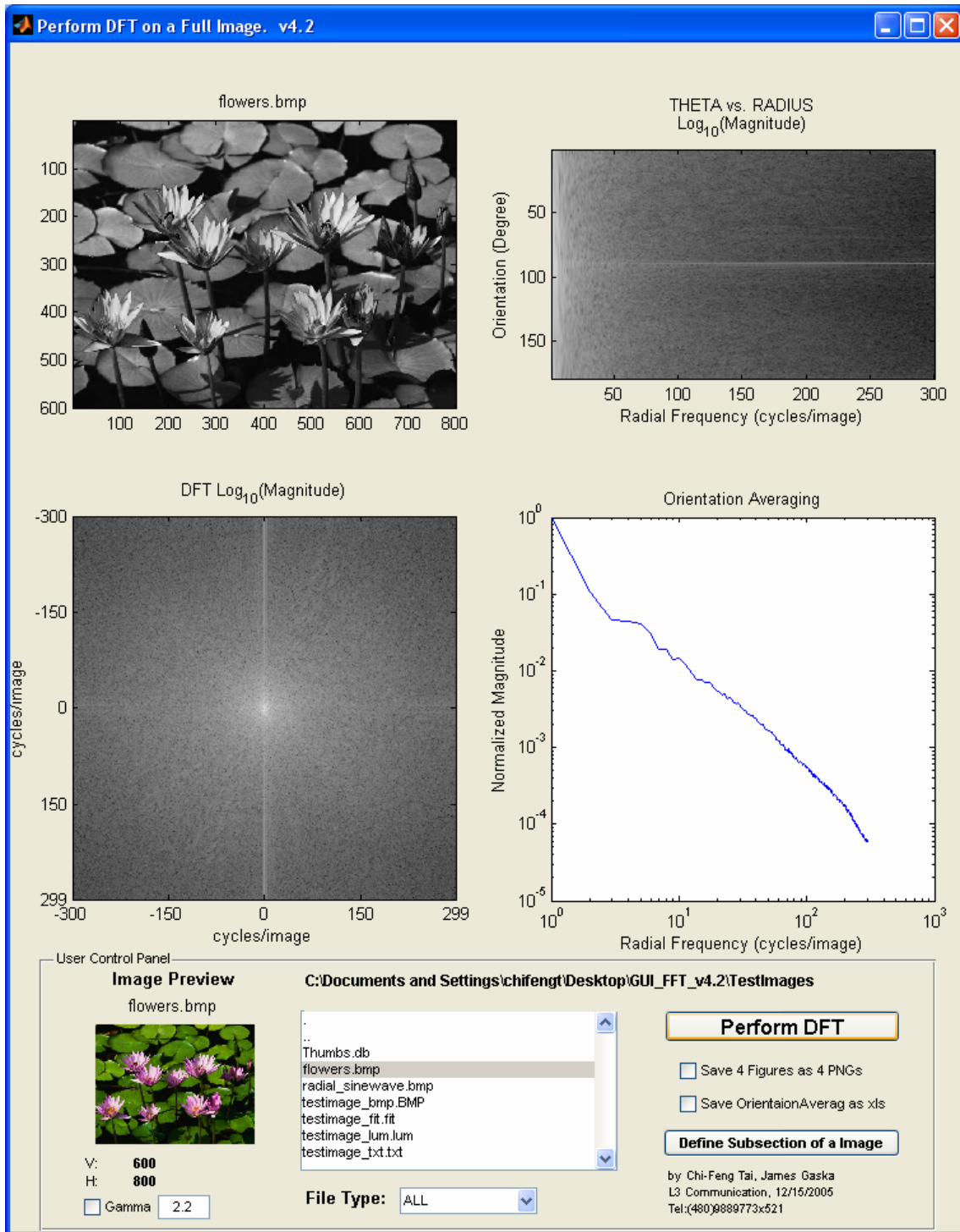


Figure 1: Perform FFT on a Full Image

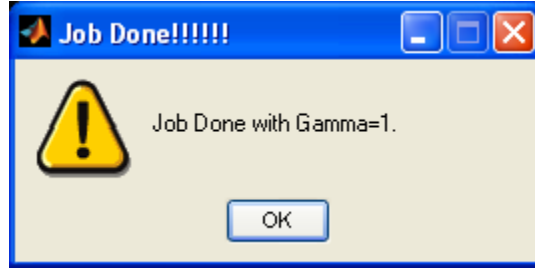


Figure 2: Job Done message box

The DFT is performed using the **FFT2** function supplied by Matlab:

$$F(p, q) = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} f(m, n) e^{-j(2\pi/M)pm} e^{-j(2\pi/N)qn} \quad \begin{array}{l} p = 0, 1, \dots, M-1 \\ q = 0, 1, \dots, N-1 \end{array}$$

where p and q are the indices of the DFT coefficients and m and n are the indices of the input image. The program displays the (Log_{10}) magnitude of the complex valued Fourier coefficients,

$$M(p, q) = \sqrt{F_{\text{real}}(p, q)^2 + F_{\text{imag}}(p, q)^2} .$$

Results of the analysis are shown in four figures that appear above the UCP (see Figure 1).

- 1) The input image in the upper left of the figure,
- 2) The magnitude of the 2-D discrete Fourier transform (DFT) of the image in the lower left of the figure,
- 3) A polar transformation of the magnitude of the DFT:

$$\theta = \arctan\left(\frac{q}{p}\right)$$

$$\text{frequency} = \sqrt{p^2 + q^2}$$

where θ is the angle between a radial line segment starting from the DC point (center point) of DFT and a line segment starting at DC and continuing along the positive horizontal axis. If a point on a line does not fall on a frequency bin, a bilinear interpolation is used to calculate the value for the point. Orientations were sampled in one degree increments and spatial frequency was sampled at the bin width of the DFT. Note that the first value of radial frequency will be DC value.

- 4) A 1-D modulation verses spatial frequency plot produced by averaging, at a given spatial frequency, over all orientations of the polar transform data. The data in the plot are normalized to the DC value of the DFT.

Before clicking the *Perform FFT* button, the user should decide whether the results are to be saved. The four figures discussed above will be saved using the **Portable Network Graphics (PNG)** format if the relevant checkbox, in the right portion of the UCP, is checked. Likewise, the numerical values produced by orientation averaging will be saved as a Microsoft Excel file if the relevant checkbox is checked.

The final processing option available in the UCP is labeled *Define Subsection of a Image*. We will next describe the details of this process.

Analyzing a Selected Portion of an Image

The user can select a portion of the input image to be processed by clicking on the *Define Subsection of a Image* button in the UCP (again, see Figure 1). When this is done, a window entitled “*Define Rectangular Subsection for FFT Analysis*” is displayed (see Figure 3).

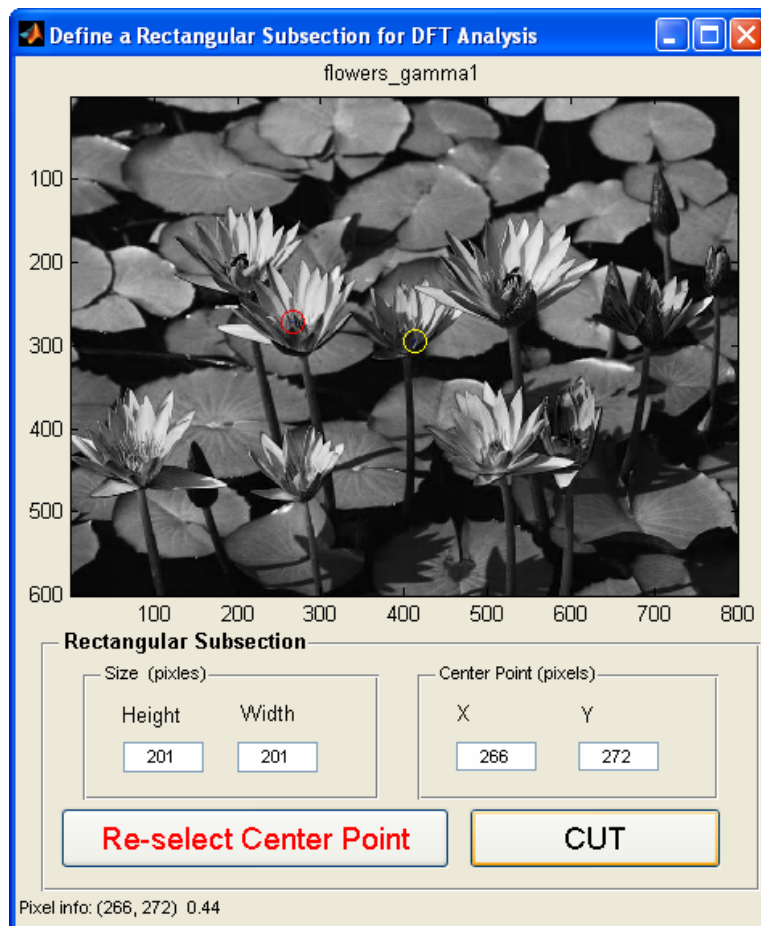


Figure 3: Define Rectangular Subsection to be cut out

The user can use the mouse to move the cursor to a desired location and click to specify that location as a center point for the rectangular portion of the image to be analyzed. The center point can also be specified by manually entering coordinates at the lower right of the window. The size of the portion of the image to be analyzed must be specified manually using the text boxes at the lower left of the windows. A yellow circle displayed on the image indicates the previous center point selected, and a red circle indicates the current center point. To change the location of the current center point, the user should press the button labeled *Re-select Center Point* and use either the cursor or manual entry to select a new location. If the center point is chosen near the edge or corner of the image and the size of the rectangular area is set too large, a window containing an error message will appear (see Figure 4). In that case, it will be necessary to either choose another center point or choose a different size for the rectangular area so that rectangular area will fit inside of image.

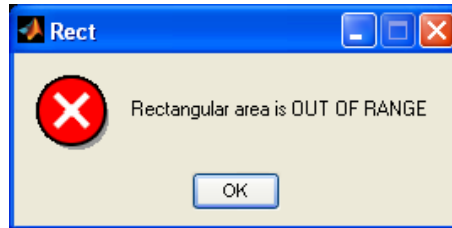


Figure 4: Image out-of-range warning box

After the desired center point and size are chosen, the rectangular area can be cut out by pressing the button labeled *CUT*. A GUI labeled *Perform FFT on Subsection of a Image* will appear and will include the image portion selected (see Figure 5). There are three checkboxes on this GUI. If the box labeled *Gaussian Window* is checked, a Gaussian of the form:

$$G = e^{-\left(\frac{1}{2} \frac{(x-x_0)^2}{s_x^2}\right)} e^{-\left(\frac{1}{2} \frac{(y-y_0)^2}{s_y^2}\right)}$$

will be multiplied with the image prior to calculation of the DFT. The standard deviations along the x and y dimensions (s_x , s_y) are chosen so that the pixel values at the edge of the image are approximately zero. This procedure, called data windowing, will have the effect of reducing spectral leakage which is the technical term used to describe the loss of amplitude of a given frequency to other frequency bins in the DFT.

As was the case with the analysis performed on the full image, the appropriate boxes must be checked in order to save the image (in this case both with and without the Gaussian window), the FFT output, the polar transform of the FFT output, and the spectrum obtained by orientation averaging. The results will be saved with names that are generated by the application, and which indicate the center point location, the size of the cut image, and whether the process is done with Gaussian window.

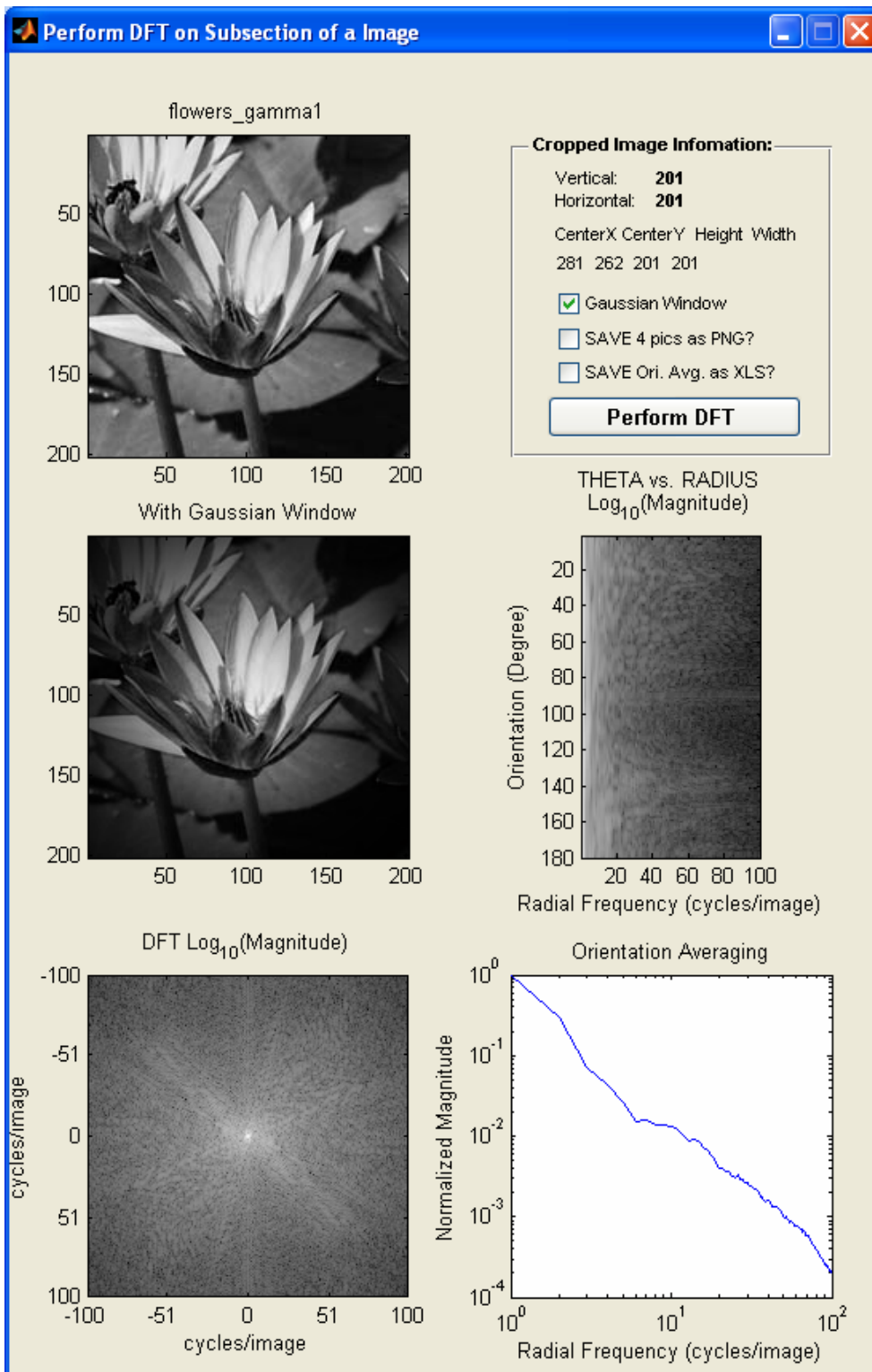


Figure 5: Perform FFT on Subsection of a Image

Key Method Used

1. Gamma:

```
newlum = oldlum.^gamma
```

2. Orientation Averaging:

```
nPAD=min(size(lum)); %lum is the input image data
z=evennumber(nPAD);
if z==1
    center = nPAD/2+1;
    step=nPAD/4;
    Rho=nPAD/2; %length of radius
else
    center=(nPAD+1)/2;
    step=round((nPAD+1)/4);
    Rho=center; %length of radius
end
%-- Polar transformation and interpolation (i is in degree)
for i = 1:180 %i is in degree
    Theta = i*pi/180;
    [x,y]=pol2cart(Theta,Rho);
    %% [x,y,value]=improfile(I,[vXstart,vXend],[vYstart,vYend],N
    equally spaced points,'Interpolation Method');
    if i < 90
        [cx,cy,c]=improfile(fft2_Im,[center,center+x-1],[center,center-
        y],Rho,'bilinear');
    elseif i==90
        [cx,cy,c]=improfile(fft2_Im,[center,center],[center,center-
        y],Rho,'bilinear');
    else
        [cx,cy,c]=improfile(fft2_Im,[center,center+x],[center,center-
        y],Rho,'bilinear');
    end
    % Matrix of Theta vs. Radius
    radius_line(i,:)=c; % bin 1 is the DC
end
```

3. Gaussian:

```
s=size(handles.lumcrop);
h1=fspecial('gaussian',[s(1) 1],s(1)/3);
h2=fspecial('gaussian',[1 s(2)],s(2)/3);
h=h1*h2;
h=h./max(max(h)); %Normalized
```

Contents of the Attached CD

The CD's contents are:

1. an electronic copy of this document in PDF format,
2. a folder that contains Matlab m-codes of this program,
3. a folder that contains all the stand-alone executable files,
4. a folder that contains the files `flower.bmp`, `radial_sinewave.bmp`, and the testimage in `.lum`, `.txt` and `.fit` formats,
5. *MCRInstaller.exe*.

