Homework _MTF Curve

Problem solving exercise: A numerical method to calculate MTF based on measured slit and line spread function

(1) A LSF of an X-ray imaging system was determined by imaging a 0.01mm slit. The system is a 1024 by1024 pixels array, and the pixel pitch is 0.048 mm. The slit image is shown in Fig 1, and the corresponding line spread function (LSF) is in Fig. 2. The LSF dataset is attached (RawLSF1.txt).

Please calculate and plot the MTF of the system using Matlab. A flowchart and Matlab code are given as follows for your reference.

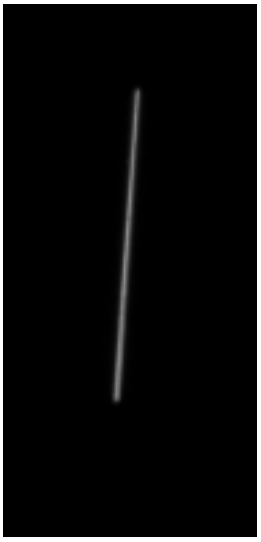


Fig. 1 A slit image

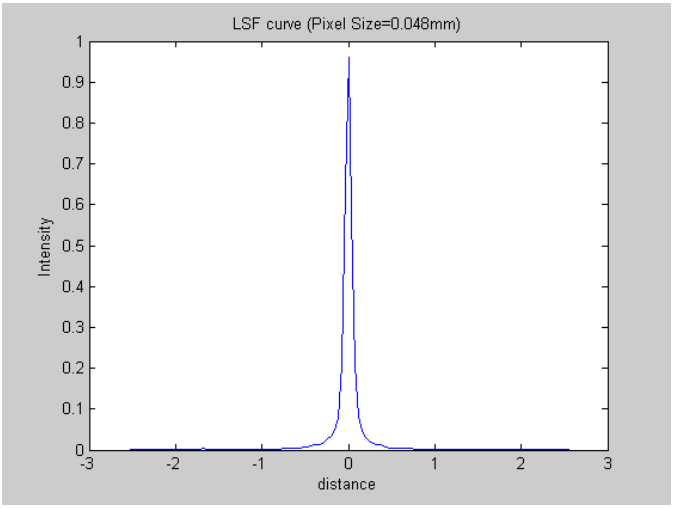
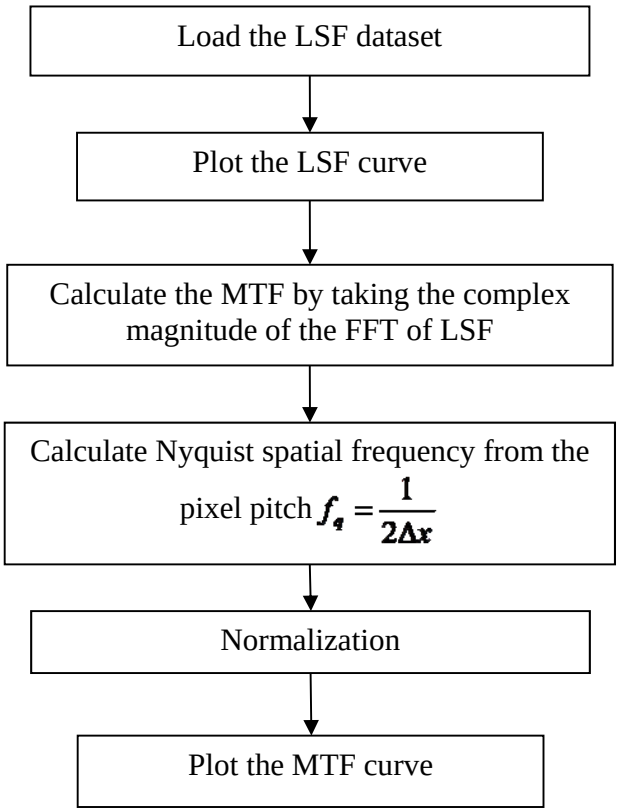


Fig. 2 Line spread function

(2) A LSF of another X-ray imaging system was also determined by imaging a 0.01mm slit. The system is again a 1024 by 1024 pixels array, but with different spatial resolution. The pixel pitch is 0.024 mm. The LSF dataset is attached (RawLSF2.txt).

Please plot the LSF, and calculate/ plot the MTF of the system using Matlab.

Flowchart (MTF calculating)



MATLAB Program

```
%1. For pixel size = 0.048 mm
% 1.clear up the workspace and define the pixel size
clear;clc;close all;
DeltaX1=0.048;% pixel size = 0.048 mm
kkk=(-63:1:64);

% 2.load the LSF data from RawLSF.txt whose size is 128
load RawLSF1.txt;
distance = kkk*DeltaX1;% distance from each pixel to the slit line
LSF = RawLSF1(:)';% intensity of each pixel

% 3. plot the LSF curve
figure;
plot(distance,LSF);
title('LSF curve (Sampling Interval=0.048mm)');
xlabel('distance');
ylabel('Intensity');

% 4. calculate the MTF by taking the complex magnitude of the fft of LSF
MTF = abs(fft(LSF));
figure, plot(MTF);

%5. Shift MTF curve
MTF=fftshift(MTF);
figure, plot(kkk,MTF);

% 6. save the positive frequency part of the MTF
N=length(MTF);
MTF = MTF(floor(N/2)+1:N);

% 7. Normalize the MTF by dividing the MTF by its zero-frequency element
MTF = MTF/MTF(1);

figure, plot(MTF);

% 8. calculate the spatial frequency from the pixel size and the point
% number
f = (0:floor(N/2)-1)/(N/2)/(2*DeltaX1); % spatial frequency, linepair/mm
% the Nyquist frequency is set as the max frequency

% 9. plot the MTF vs frquency curve
figure;
plot(f,MTF,'-k');
xlabel('Spatial Frequency (linepair/mm)');
title('Modulation Transfer Function');
```

(1) MTF calculation with the pixel pitch (0.048 mm)

MTF calculation Using Matlab

Solution:

1. setup

[

```
%1. For pixel size = 0.048 mm
% 1.clear up the workspace and define the pixel size
clear;clc;close all;
DeltaX1=0.048;% pixel size = 0.048 mm
kkk=(-63:1:64);
```

]

```
>> whos
  Name         Size                Bytes  Class

  DeltaX1      1x1                     8  double array
  kkk          1x128                1024  double array

Grand total is 129 elements using 1032 bytes
>>
```

2. Load the LSF dataset

[

```
% 2.load the LSF data from RawLSF.txt whose size is 128
load RawLSF1.txt;
distance = kkk*DeltaX1;% distance from each pixel to the slit line
LSF = RawLSF1(:)';% intensity of each pixel
```

]

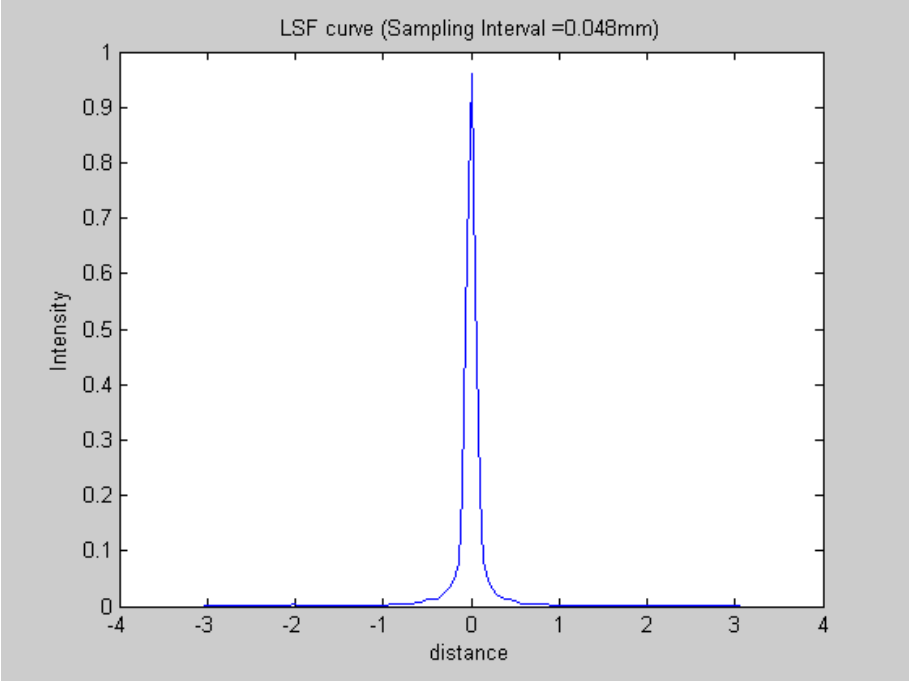
```
>> whos
  Name         Size                Bytes  Class

  DeltaX1      1x1                     8  double array
  LSF          1x128                1024  double array
  RawLSF1      128x1                1024  double array
  distance     1x128                1024  double array
  kkk          1x128                1024  double array

Grand total is 513 elements using 4104 bytes
>>
```

3. Plot the LSF curve

```
[
  figure;
  plot(distance,LSF);
  title('LSF curve (Sampling Interval =0.048mm)');
  xlabel('distance');
  ylabel('Intensity');
]
```

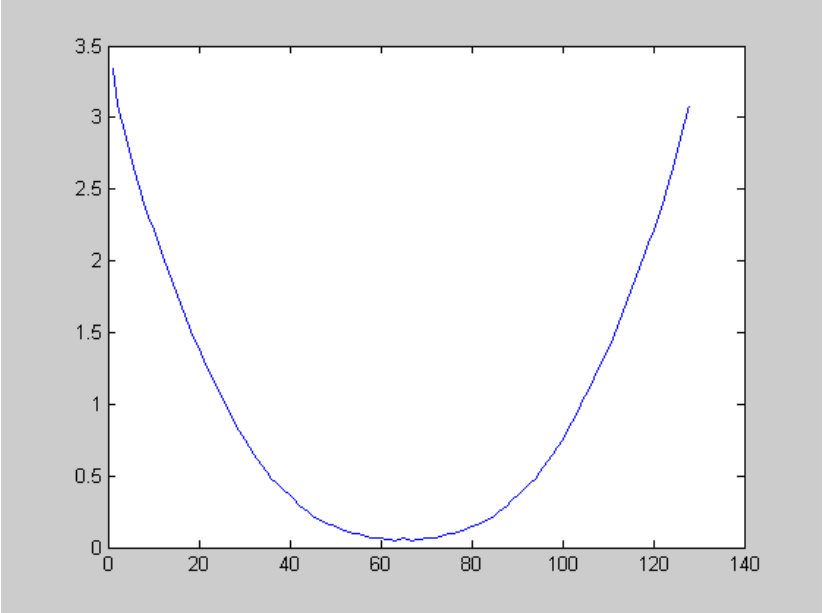


4. Calculate the MTF by taking the complex magnitude of the FFT of LSF

[

```
MTF = abs(fft(LSF));
Figure, plot(MTF);
```

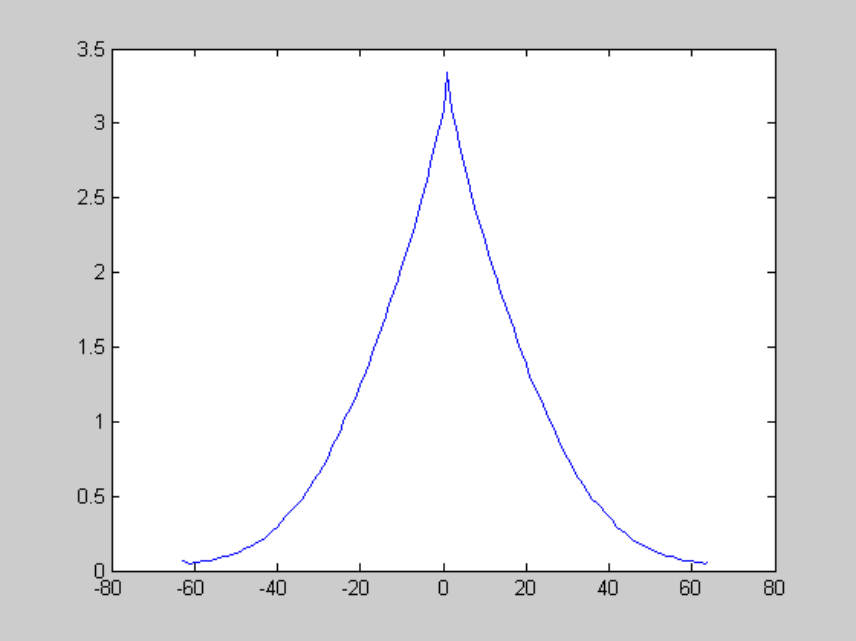
]



[

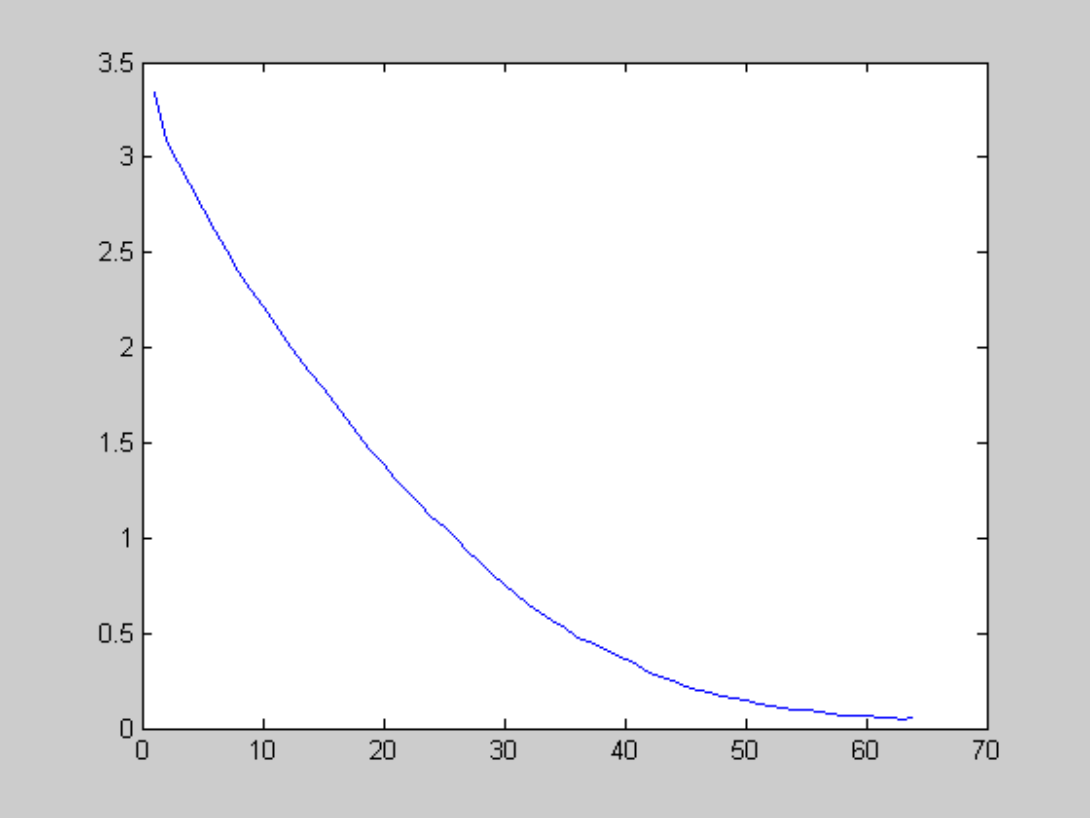
```
MTF=fftshift(MTF);
Figure, plot(kkk,MTF);
```

]



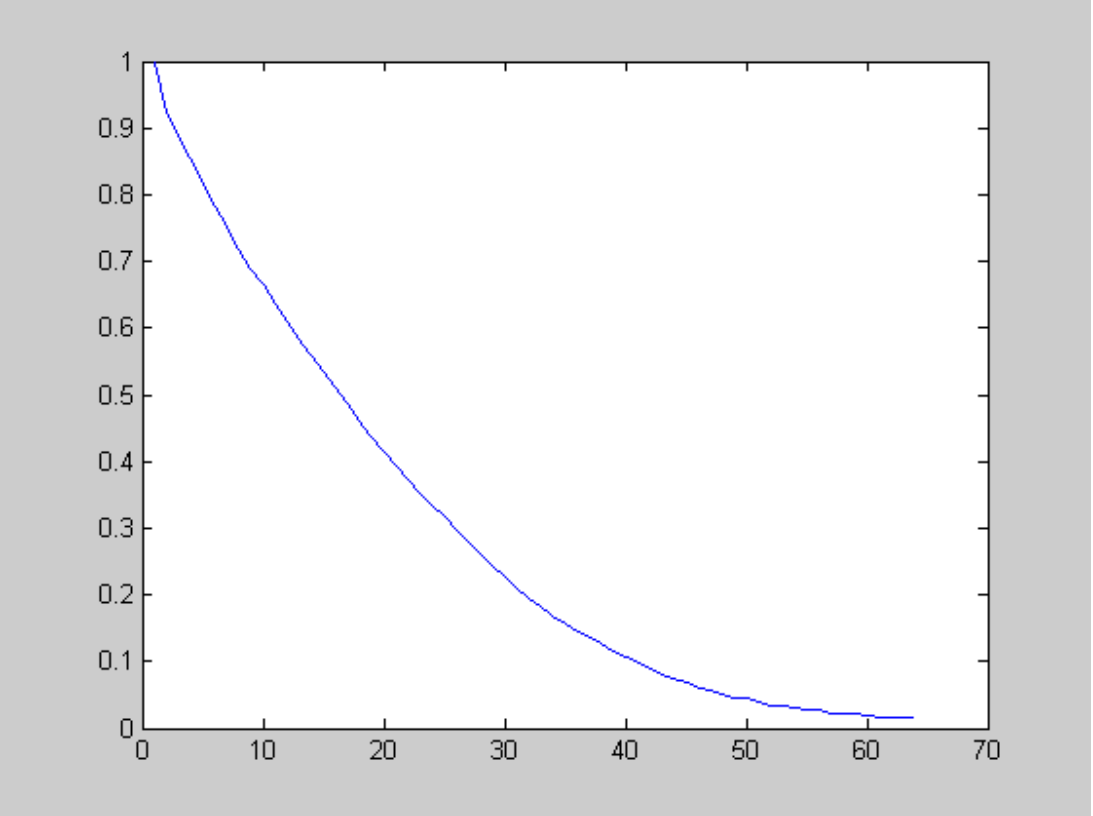
5. Save the positive frequency part of the MTF

```
N=length(MTF);
MTF = MTF(floor(N/2)+1:N);
figure, plot(MTF);
```



6. Normalization

MTF = MTF/MTF(1);
Figure, plot(MTF);



7. Determine frequency coordinate from sampling interval

$f_q = \frac{1}{2\Delta x}$.

For this case, the sampling interval equal to pixel pitch.

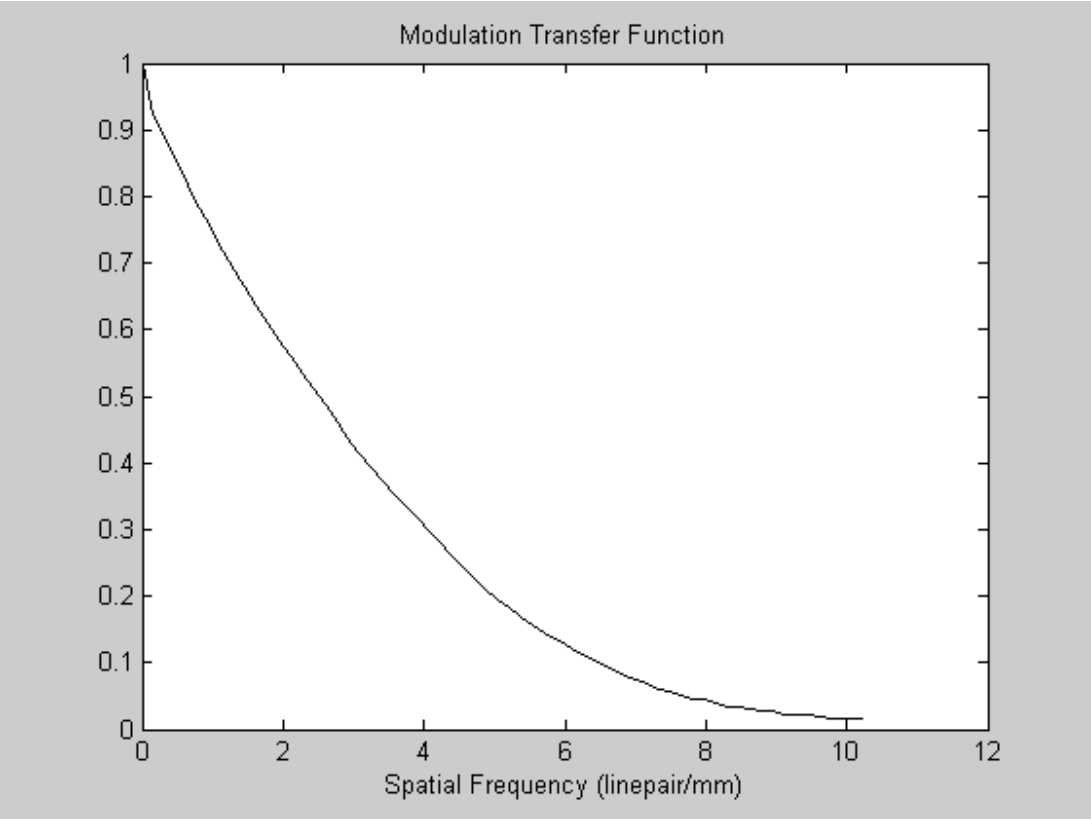
f = (0:floor(N/2)-1)/(N/2)/(2*DeltaX1);

It means:

0 point	0 lp/mm
64th point	$f_q = \frac{1}{2\Delta x}$
other point	linear equation

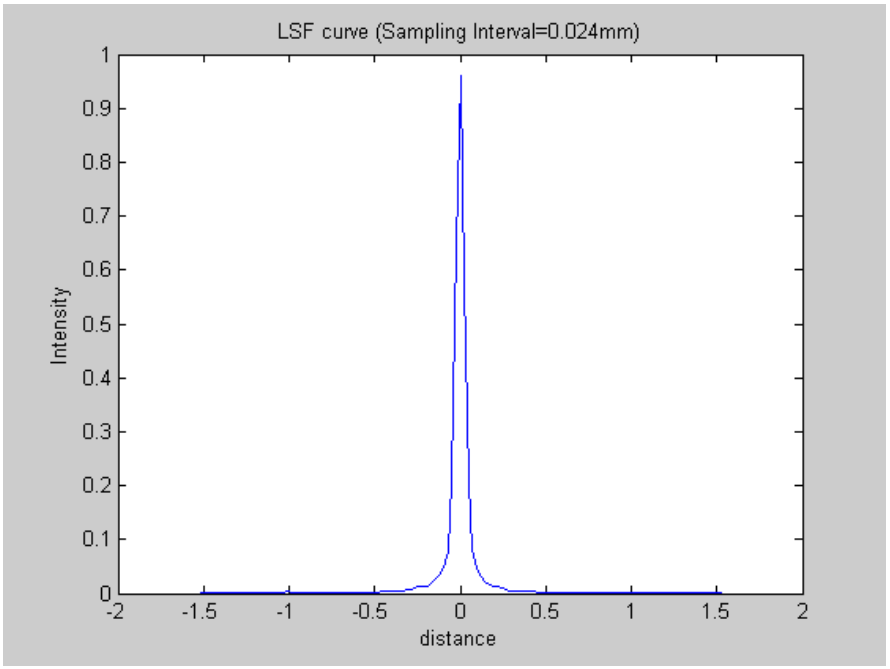
8. Plot the MTF curve

```
figure;
plot(f,MTF,'-k');
xlabel('Spatial Frequency (linepair/mm)');
title('Modulation Transfer Function');
```



(2) MTF calculation with the pixel pitch (0.024 mm)

LSF curve



MTF curve