

Experimental demonstration №1

Subject: Statistical analysis of biological tissues polarization images

Objects:

Learning of main methods and principles of working with polarization images of biological tissues (BT) in the MatLab. Using of MatLab for statistical processing of polarization images of different type BT with different optical-geometric parameters.

Tasks to be done:

1. Assembling and adjusting optical scheme (Fig. 1) under the guidance of tutor.

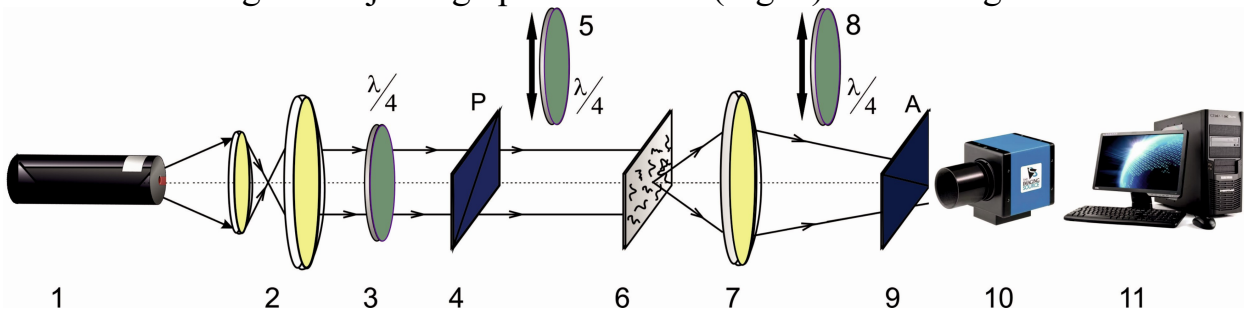


Fig. 1. Optical scheme of experimental setup. Here 1 – He-Ne laser; 2 – collimator; 3 – stationary quarter-wave plate; 5, 8 – mechanically movable quarter-wave plates; 4, 9 – polarizer and analyzer respectively; 6 – object of investigation; 7 – strain free objective; 10 – CCD camera; 11 – PC

2. Measuring of laser polarization images (in coaxial and crossed polarizer (4) and analyzer (9)) of normal and pathologically changed BT.
3. Using of MatLab program for statistical analysis of measured images (see Appendix 1). As the result of program working you will obtain statistic moments of the 1st-4th orders, namely average, dispersion, skewness coefficient and kurtosis coefficient.

$$R_1 = \frac{1}{P} \sum_{j=1}^P q_j \text{ - average value}$$

$$R_2 = \sqrt{\frac{1}{P} \sum_{j=1}^P (q - R_1)_j^2} \text{ ; - dispersion}$$

$$R_3 = \frac{1}{R_2^3} \frac{1}{P} \sum_{j=1}^P (q - R_1)_j^3 \text{ ; - skewness coefficient}$$

$$R_4 = \frac{1}{R_2^4} \frac{1}{P} \sum_{j=1}^P (q - R_1)_j^4 \text{ - kurtosis coefficient}$$

4. Making conclusions on the samples.

All necessary theoretical information will be carried out during the lectures.

Experimental demonstration №2

Subject: Investigation of Stokes vector parameters of laser radiation transformed by optically thin histological sections of biological tissues

Objects:

Learning of main methods and principles of calculation of Stokes parameters of laser field transformed by BT in the MatLab. Performing of statistical analysis of corresponding Stokes vector parameters.

Tasks to be done:

1. Assembling and adjusting optical scheme (Fig. 1) under the guidance of tutor.
2. Measuring of the Stokes vector parameters due to the following algorithm:

$$\begin{aligned}S_{i=1}^{0;45;90;\otimes} &= I_0^{0;45;90;\otimes} + I_{90}^{0;45;90;\otimes}; \\S_{i=2}^{0;45;90;\otimes} &= I_0^{0;45;90;\otimes} - I_{90}^{0;45;90;\otimes}; \\S_{i=3}^{0;45;90;\otimes} &= I_{45}^{0;45;90;\otimes} - I_{135}^{0;45;90;\otimes}; \\S_{i=4}^{0;45;90;\otimes} &= I_{\otimes}^{0;45;90;\otimes} + I_{\oplus}^{0;45;90;\otimes}.\end{aligned}$$

Upper indices correspond to the azimuths of polarization of the illuminating beam.

First step:

- set transmission plane of analyzer 9 at an angle of $\Theta = 0^0$ and measure $I_0(m \times n)$
- set transmission plane of analyzer 9 at an angle of $\Theta = 90^0$ and measure $I_{90}(m \times n)$

Second step:

- set transmission plane of analyzer 9 at an angle of $\Theta = 45^0$ and measure $I_{45}(m \times n)$
- set transmission plane of analyzer 9 at an angle of $\Theta = 135^0$ and measure $I_{135}(m \times n)$

Third step:

- insert quarter-wave plate 8
- set transmission plane of analyzer 9 at an angle of $\Theta = 45^0$ and measure $I_{\otimes}(m \times n)$
- set transmission plane of analyzer 9 at an angle of $\Theta = 135^0$ and measure $I_{\oplus}(m \times n)$

3. Using of MatLab program for statistical analysis of measured Stokes vector images (see Appendix 2). As the result of program working you will obtain statistic moments of the 1st-4th orders, namely average, dispersion, skewness coefficient and kurtosis coefficient.

4. Making conclusions on the samples.

All necessary theoretical information will be carried out during the lectures.

Experimental demonstration №3

Subject: Calculation of coordinate distributions of Mueller-matrix elements of biological tissues histological sections

Objects:

Learning of main methods and principles of calculation of Mueller-matrix elements coordinate distributions of different types BT in the MatLab. Performing of statistical analysis of corresponding Mueller-matrix elements.

Tasks to be done:

1. Assembling and adjusting optical scheme (Fig. 1) under the guidance of tutor.
2. Measuring of Stokes vector elements for four different state of polarization of illuminating beam ($S_{i=1,2,3,4}^{0;45;90;\otimes}$, see Experimental demonstration 2).
2. Measuring of the Mueller-matrix elements coordinate distributions due to the following algorithm:

$$\begin{aligned}M_{11} &= 0.5(S_1^0 + S_1^{90}); & M_{31} &= 0.5(S_3^0 + S_3^{90}); \\M_{12} &= 0.5(S_1^0 - S_1^{90}); & M_{32} &= 0.5(S_3^0 - S_3^{90}); \\M_{13} &= S_1^{45} - f_{11}; & M_{33} &= S_3^{45} - f_{31}; \\M_{14} &= S_1^{\otimes} - f_{11}; & M_{34} &= S_3^{\otimes} - f_{31}; \\M_{21} &= 0.5(S_2^0 + S_2^{90}); & M_{41} &= 0.5(S_4^0 + S_4^{90}); \\M_{22} &= 0.5(S_2^0 - S_2^{90}); & M_{42} &= 0.5(S_4^0 - S_4^{90}); \\M_{23} &= S_2^{45} - f_{21}; & M_{43} &= S_4^{45} - f_{41}; \\M_{24} &= S_2^{\otimes} - f_{21}; & M_{44} &= S_4^{\otimes} - f_{41}.\end{aligned}$$

3. Using of MatLab program for statistical analysis of calculated Mueller-matrix images (see Appendix 3). As the result of program working you will obtain statistic moments of the 1st-4th orders, namely average, dispersion, skewness coefficient and kurtosis coefficient.

4. Making conclusions on the samples.

All necessary theoretical information will be carried out during the lectures.

Appendix 1

```
en='.bmp';
file = 'c:\'

[Z00,mapZ00]=imread([file, '0-0', en]);
[Z090,mapZ090]=imread([file, '0-90', en]);

Z00=double(Z00);
Z090=double(Z090);
%Convert an indexed image to an intensity image
Z00=ind2gray(Z00,mapZ00);
Z090=ind2gray(Z090,mapZ090);

figure (1);
subplot 121,imshow(Z00,[min(min(Z00)) max(max(Z00))],title(['Z00'],'Color','b');colorbar;colormap (gray);
subplot 122,imshow(Z090,[min(min(Z090)) max(max(Z090))],title(['Z090'],'Color','b');colorbar;colormap (gray);

%statistics
[dim1,dim2]=size(Z00);
STD2=std2(Z00);
Seredne=mean2(Z00);
Mx=mean2(Z00);
Dx=STD2^2;
MEDx = median(median(Z00));
MAX = max(max(Z00));
MIN = min(min(Z00));
Ax=skewness(skewness(Z00));
Ex=kurtosis(kurtosis(Z00))-3;

fid=fopen('Z00 - статистика.txt','w')
fprintf(fid,'Статистика для Z00(x,y)\n')
fprintf(fid,'\n')
fprintf(fid,'X-dimension of the matrix dim1=%14.7f\n',dim1);
fprintf(fid,'Y-dimension of the matrix dim2=%14.7f\n',dim2);
fprintf(fid,'Min. element of the matrix    =%14.7f\n',MIN);
fprintf(fid,'Max. element of the matrix    =%14.7f\n',MAX);
fprintf(fid,'Mean                        =%14.7f\n',Seredne);
fprintf(fid,'Math. waiting                    =%14.7f\n',Mx);
fprintf(fid,'S. K. V.                          =%14.7f\n',STD2);
fprintf(fid,'Dispersion                      =%14.7f\n',Dx);
fprintf(fid,'Assimetrie                          =%14.7f\n',Ax);
fprintf(fid,'Extcess                            =%14.7f\n',Ex);
fprintf(fid,'Median                            =%14.7f\n',MEDx);
fclose(fid);
movefile('Z00 - статистика.TXT','C:/MATLAB701/work/AAA');

%статистика
[dim1,dim2]=size(Z090);
STD2=std2(Z090);
Seredne=mean2(Z090);
Mx=mean2(Z090);
Dx=STD2^2;
MEDx = median(median(Z090));
MAX = max(max(Z090));
MIN = min(min(Z090));
Ax=skewness(skewness(Z090));
Ex=kurtosis(kurtosis(Z090))-3;

fid=fopen('Z090 - статистика.txt','w')
fprintf(fid,'Статистика для Z090(x,y)\n')
fprintf(fid,'\n')
fprintf(fid,'X-dimension of the matrix dim1=%14.7f\n',dim1);
fprintf(fid,'Y-dimension of the matrix dim2=%14.7f\n',dim2);
fprintf(fid,'Min. element of the matrix    =%14.7f\n',MIN);
fprintf(fid,'Max. element of the matrix    =%14.7f\n',MAX);
fprintf(fid,'Mean                        =%14.7f\n',Seredne);
fprintf(fid,'Math. waiting                    =%14.7f\n',Mx);
fprintf(fid,'S. K. V.                          =%14.7f\n',STD2);
fprintf(fid,'Dispersion                      =%14.7f\n',Dx);
fprintf(fid,'Assimetrie                          =%14.7f\n',Ax);
fprintf(fid,'Extcess                            =%14.7f\n',Ex);
fprintf(fid,'Median                            =%14.7f\n',MEDx);
fclose(fid);
movefile('Z090 - статистика.TXT','C:/MATLAB701/work/AAA');

figure (2)
subplot 121,imshow(Z00,[min(min(Z00)) max(max(Z00))],title(['Z00(x,y)'],'Color','b');
subplot 122,imhist(Z00);title('гистограмма Z00(x,y)','Color','b');

figure (3)
subplot 121,imshow(Z090,[min(min(Z090)) max(max(Z090))],title(['Z090(x,y)'],'Color','b');
subplot 122,imhist(Z090);title('гистограмма Z090(x,y)','Color','b');
```

Appendix 2

```
en='.bmp';
file = 'c:\bic\'
zona = 'bic-'

[Z00,mapZ00]=imread([file, zona, '0-0', en]);
[Z045,mapZ045]=imread([file, zona, '0-45', en]);
[Z090,mapZ090]=imread([file, zona, '0-90', en]);
[Z0135,mapZ0135]=imread([file, zona, '0-135', en]);
[Z0180,mapZ0180]=imread([file, zona, '0-180', en]);
[Z0225,mapZ0225]=imread([file, zona, '0-225', en]);

Z00=double(Z00);
Z090=double(Z090);
Z045=double(Z045);
Z0135=double(Z0135);
Z0180=double(Z0180);
Z0225=double(Z0225);

%Convert an indexed image to an intensity image
Z00=ind2gray(Z00,mapZ00);
Z090=ind2gray(Z090,mapZ090);
Z045=ind2gray(Z045,mapZ045);
Z0135=ind2gray(Z0135,mapZ0135);
Z0180=ind2gray(Z0180,mapZ0180);
Z0225=ind2gray(Z0225,mapZ0225);

% Stokes vector calculation;
S10=Z00+Z090;
S20=Z00-Z090;
S30=Z045-Z0135;
S40=Z0180-Z0225;

S10=S10./max(max(abs(S10)));S20=S20./max(max(abs(S20)));S30=S30./max(max(abs(S30)));S40=S40./max(max(abs(S40)));

figure (1);
subplot(2,2,1),imshow(S10,[min(min(S10)) max(max(S10))],title(['S1 (на вході -
0)'],'Color','b');colorbar;colormap (jet);
subplot(2,2,2),imshow(S20,[min(min(S20)) max(max(S20))],title(['S2 (на вході -
0)'],'Color','b');colorbar;colormap (jet);
subplot(2,2,3),imshow(S30,[min(min(S30)) max(max(S30))],title(['S3 (на вході -
0)'],'Color','b');colorbar;colormap (jet);
subplot(2,2,4),imshow(S40,[min(min(S40)) max(max(S40))],title(['S4 (на вході -
0)'],'Color','b');colorbar;colormap (jet);

figure (2);
subplot(2,2,1),imshow(S10,[min(min(S190)) max(max(S190))],title(['S1 (на вході -
90)'],'Color','b');colorbar;colormap (gray);
subplot(2,2,2),imshow(S290,[min(min(S290)) max(max(S290))],title(['S2 (на вході -
90)'],'Color','b');colorbar;colormap (gray);
subplot(2,2,3),imshow(S390,[min(min(S390)) max(max(S390))],title(['S3 (на вході -
90)'],'Color','b');colorbar;colormap (gray);
subplot(2,2,4),imshow(S490,[min(min(S490)) max(max(S490))],title(['S4 (на вході -
90)'],'Color','b');colorbar;colormap (gray);

%statistics
[dim1,dim2]=size(S20);
STD2=std2(S20);
Seredne=mean2(S20);
Mx=mean2(S20);
Dx=STD2^2;
MEDx = median(median(S20));
MAX = max(max(S20));
MIN = min(min(S20));
Ax=skewness(skewness(S20));
Ex=kurtosis(kurtosis(S20))-3;

fid=fopen('S2 - статистика.txt','w')
fprintf(fid,'Статистика для S2(x,y)\n')
fprintf(fid,'\n')
fprintf(fid,'X-dimension of the matrix dim1=%14.7f\n',dim1);
fprintf(fid,'Y-dimension of the matrix dim2=%14.7f\n',dim2);
fprintf(fid,'Min. element of the matrix   =%14.7f\n',MIN);
fprintf(fid,'Max. element of the matrix   =%14.7f\n',MAX);
fprintf(fid,'Mean                        =%14.7f\n',Seredne);
fprintf(fid,'Math. waiting                =%14.7f\n',Mx);
fprintf(fid,'S. K. V.                      =%14.7f\n',STD2);
fprintf(fid,'Dispersion                    =%14.7f\n',Dx);
fprintf(fid,'Assimetricity                  =%14.7f\n',Ax);
fprintf(fid,'Extcess                        =%14.7f\n',Ex);
fprintf(fid,'Median                        =%14.7f\n',MEDx);
fclose(fid);
movefile('S2 - статистика.TXT','C:/MATLAB701/work/AAA/S2');
```

Appendix 3

```
en='.bmp';
file = 'c:\bic\';
zona = 'bic-'

[Z00,mapZ00]=imread([file, zona, '0-0', en]);
[Z045,mapZ045]=imread([file, zona, '0-45', en]);
[Z090,mapZ090]=imread([file, zona, '0-90', en]);
[Z0135,mapZ0135]=imread([file, zona, '0-135', en]);
[Z0180,mapZ0180]=imread([file, zona, '0-180', en]);
[Z0225,mapZ0225]=imread([file, zona, '0-225', en]);

[Z450,mapZ450]=imread([file, zona, '45-0', en]);
[Z4545,mapZ4545]=imread([file, zona, '45-45', en]);
[Z4590,mapZ4590]=imread([file, zona, '45-90', en]);
[Z45135,mapZ45135]=imread([file, zona, '45-135', en]);
[Z45180,mapZ45180]=imread([file, zona, '45-180', en]);
[Z45225,mapZ45225]=imread([file, zona, '45-225', en]);

[Z900,mapZ900]=imread([file, zona, '90-0', en]);
[Z9045,mapZ9045]=imread([file, zona, '90-45', en]);
[Z9090,mapZ9090]=imread([file, zona, '90-90', en]);
[Z90135,mapZ90135]=imread([file, zona, '90-135', en]);
[Z90180,mapZ90180]=imread([file, zona, '90-180', en]);
[Z90225,mapZ90225]=imread([file, zona, '90-225', en]);

[Z1350,mapZ1350]=imread([file, zona, '135-0', en]);
[Z13545,mapZ13545]=imread([file, zona, '135-45', en]);
[Z13590,mapZ13590]=imread([file, zona, '135-90', en]);
[Z135135,mapZ135135]=imread([file, zona, '135-135', en]);
[Z135180,mapZ135180]=imread([file, zona, '135-180', en]);
[Z135225,mapZ135225]=imread([file, zona, '135-225', en]);

Z00=double(Z00);
Z090=double(Z090);
Z045=double(Z045);
Z0135=double(Z0135);
Z0180=double(Z0180);
Z0225=double(Z0225);

Z900=double(Z900);
Z9090=double(Z9090);
Z9045=double(Z9045);
Z90135=double(Z90135);
Z90180=double(Z90180);
Z90225=double(Z90225);

Z450=double(Z450);
Z4590=double(Z4590);
Z4545=double(Z4545);
Z45135=double(Z45135);
Z45180=double(Z45180);
Z45225=double(Z45225);

Z1350=double(Z1350);
Z13590=double(Z13590);
Z13545=double(Z13545);
Z135135=double(Z135135);
Z135180=double(Z135180);
Z135225=double(Z135225);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Convert an indexed image to an intensity image
Z00=ind2gray(Z00,mapZ00);
Z090=ind2gray(Z090,mapZ090);
Z045=ind2gray(Z045,mapZ045);
Z0135=ind2gray(Z0135,mapZ0135);
Z0180=ind2gray(Z0180,mapZ0180);
Z0225=ind2gray(Z0225,mapZ0225);

Z900=ind2gray(Z900,mapZ900);
Z9090=ind2gray(Z9090,mapZ9090);
Z9045=ind2gray(Z9045,mapZ9045);
Z90135=ind2gray(Z90135,mapZ90135);
Z90180=ind2gray(Z90180,mapZ90180);
Z90225=ind2gray(Z90225,mapZ90225);

Z450=ind2gray(Z450,mapZ450);
Z4590=ind2gray(Z4590,mapZ4590);
Z4545=ind2gray(Z4545,mapZ4545);
Z45135=ind2gray(Z45135,mapZ45135);
Z45180=ind2gray(Z45180,mapZ45180);
Z45225=ind2gray(Z45225,mapZ45225);

Z1350=ind2gray(Z1350,mapZ1350);
Z13590=ind2gray(Z13590,mapZ13590);
```

```
Z13545=ind2gray(Z13545,mapZ13545);
Z135135=ind2gray(Z135135,mapZ135135);
Z135180=ind2gray(Z135180,mapZ135180);
Z135225=ind2gray(Z135225,mapZ135225);
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
S10=Z00+Z090;
S20=Z00-Z090;
S30=Z045-Z0135;
S40=Z0180-Z0225;
```

```
S145=(Z450+Z4590);
S245=Z450-Z4590;
S345=Z4545-Z45135;
S445=Z45180-Z45225;
```

```
S190=(Z900+Z9090);
S290=Z900-Z9090;
S390=Z9045-Z90135;
S490=Z90180-Z90225;
```

```
S1135=(Z1350+Z13590);
S2135=Z1350-Z13590;
S3135=Z13545-Z135135;
S4135=Z135180-Z135225;
```

```
M11 = (S10 + S190)/2;
M11=M11./M11;
M12 = (S10 - S190)/2./M11;
M13 = (S145 - M11)/M11;
M14 = (S1135 - M11)/M11;
```

```
M21 = (S20 + S290)/2./M11;
M22 = (S20 - S290)/2./M11;
M23 = (S245 - M21)/M11;
M24 = (S2135 - M21)/M11;
```

```
M31 = (S30 + S390)/2./M11;
M32 = (S30 - S390)/2./M11;
M33 = (S345 - M31)/M11;
M34 = (S3135 - M31)/M11;
```

```
M41 = (S40 + S490)/2./M11;
M42 = (S40 - S490)/2./M11;
M43 = (S445 - M41)/M11;
M44 = (S4135 - M41)/M11;
```

```
[dim1,dim2]=size(M11);
%M11=M11./max(max(abs(M11)));M12=M12./max(max(abs(M12)));M13=M13./max(max(abs(M13)));M14=M14./max(max(abs(M14)));
%M21=M21./max(max(abs(M21)));M22=M22./max(max(abs(M22)));M23=M23./max(max(abs(M23)));M24=M24./max(max(abs(M24)));
%M31=M31./max(max(abs(M31)));M32=M32./max(max(abs(M32)));M33=M33./max(max(abs(M33)));M34=M34./max(max(abs(M34)));
%M41=M41./max(max(abs(M41)));M42=M42./max(max(abs(M42)));M43=M43./max(max(abs(M43)));M44=M44./max(max(abs(M44)));
```

```
for k=1 : dim1
    for j=1 : dim2
```

```
        if M11(k,j)>1;
            M11(k,j)=1;
        end;
        if M12(k,j)>1;
            M12(k,j)=1;
        end;
        if M13(k,j)>1;
            M13(k,j)=1;
        end;
        if M14(k,j)>1;
            M14(k,j)=1;
        end;
```

```
        if M21(k,j)>1;
            M21(k,j)=1;
        end;
        if M22(k,j)>1;
            M22(k,j)=1;
        end;
        if M23(k,j)>1;
            M23(k,j)=1;
        end;
        if M24(k,j)>1;
            M24(k,j)=1;
        end;
```

```
        if M31(k,j)>1;
            M31(k,j)=1;
        end;
        if M32(k,j)>1;
```

```

        M32(k,j)=1;
    end;
    if M33(k,j)>1;
        M33(k,j)=1;
    end;
    if M34(k,j)>1;
        M34(k,j)=1;
    end;
    if M41(k,j)>1;
        M41(k,j)=1;
    end;
    if M42(k,j)>1;
        M42(k,j)=1;
    end;
    if M43(k,j)>1;
        M43(k,j)=1;
    end;
    if M44(k,j)>1;
        M44(k,j)=1;
    end;
%*****
    if M11(k,j)<-1;
        M11(k,j)=-1;
    end;
    if M12(k,j)<-1;
        M12(k,j)=-1;
    end;
    if M13(k,j)<-1;
        M13(k,j)=-1;
    end;
    if M14(k,j)<-1;
        M14(k,j)=-1;
    end;

    if M21(k,j)<-1;
        M21(k,j)=-1;
    end;
    if M22(k,j)<-1;
        M22(k,j)=-1;
    end;
    if M23(k,j)<-1;
        M23(k,j)=-1;
    end;
    if M24(k,j)<-1;
        M24(k,j)=-1;
    end;

    if M31(k,j)<-1;
        M31(k,j)=-1;
    end;
    if M32(k,j)<-1;
        M32(k,j)=-1;
    end;
    if M33(k,j)<-1;
        M33(k,j)=-1;
    end;
    if M34(k,j)<-1;
        M34(k,j)=-1;
    end;
    if M41(k,j)<-1;
        M41(k,j)=-1;
    end;
    if M42(k,j)<-1;
        M42(k,j)=-1;
    end;
    if M43(k,j)<-1;
        M43(k,j)=-1;
    end;
    if M44(k,j)<-1;
        M44(k,j)=-1;
    end;
end;
end;

M22=abs(M22);
M33=abs(M33);
M44=abs(M44);

%*****
%*****

figure(1);
subplot(2,2,1),imshow(M11,[min(min(M11)) max(max(M11))],title(['M11'],'Color','b');colorbar,colormap(jet);
subplot(2,2,2),imshow(M12,[min(min(M12)) max(max(M12))],title(['M12'],'Color','b');colorbar,colormap(jet);
subplot(2,2,3),imshow(M13,[min(min(M13)) max(max(M13))],title(['M13'],'Color','b');colorbar,colormap(jet);
subplot(2,2,4),imshow(M14,[min(min(M14)) max(max(M14))],title(['M14'],'Color','b');colorbar,colormap(jet);

```