

ANEXOS

**CÓDIGO FUENTE DE LOS PROGRAMAS
DESARROLLADOS**

```

%*****
%*                                UNIVERSIDAD AUTONOMA DE LA CIUDAD DE MÉXICO                                *
%*                                Colegio de Ciencia y Tecnología                                          *
%*                                                                                                        *
%*                                TESIS                                                                    *
%*"Evaluación de algoritmos de interpolación polinomiales, adaptivos y                                *
%*   basados en redes neuronales para la superresolución de imágenes"                                *
%*                                                                                                        *
%*   Programa para evaluar el método de interpolación Bilineal                                        *
%*   con distancia deformada  $s'=s-k*A*s*(s-1)$                                           *
%*   Figuras 3.2, 3.3, 3.4, 3.5, 3.6 y 3.7                                                            *
%*                                                                                                        *
%*****

clear all;
clc

%*****
%*                                ABRIR IMAGEN ORIGINAL DE HR                                          *
%*****
[NombreImagen RutaImagen]=uigetfile({'*.jpeg;*.jpg;*.tif;*.png', 'Imagen JPEG (*.jpg, *.jpeg, *.tif,
*.png)'};
    '*.bmp', 'Imagen BMP (*.bmp)'},'MultiSelect','off');
if ~isequal(RutaImagen,0) && ~isequal(NombreImagen,0)
    PathCompletoImagen=strcat(RutaImagen,NombreImagen);
    Imagen=imread(PathCompletoImagen);
end

%*****
%*                                SI Zoom=2, INTERPOLACIÓN AL DOBLE DE RESOLUCIÓN                                *
%*****
Zoom = 2;

%*****
%*                                OBTENCION DE IMAGEN DEGRADADA DE BAJA RESOLUCIÓN                                *
%*****
ImagenLR=DimensionamientoLR(Imagen);

%*****
%*                                OBTENCION DE LA REJILLA DE ALTA RESOLUCIÓN INTERCALADA CON CEROS            *
%*                                SI ImRGB=1 SE TRATA DE UNA IMAGEN A COLOR                                *
%*                                SI ImRGB=0 SE TRATA DE UNA IMAGEN EN ESCALA DE GRISES                    *
%*****
sz=size(Imagen);
if length(sz)>2
    ImRGB=1;
else
    ImRGB=0;
end
if ImRGB==1
    G=DimensionamientoHR(ImagenLR(:,:,2),Zoom);
    B=DimensionamientoHR(ImagenLR(:,:,3),Zoom);

end
R=DimensionamientoHR(ImagenLR(:,:,1),Zoom);

figure(1)
imshow(uint8(ImagenLR));

```

```

%*****
%*          PROCESO DE INTERPOLACIÓN CON DISTANCIA DEFORMADA          *
%*****
Dim=size(ImagenLR);
m=Dim(1);
n=Dim(2);
s=0.5;
k=3;
L=256;
if ImRGB==1
    for i=1:m*Zoom
        for j=2:2:n*Zoom-3
            A = (abs(G(i,j+1))-abs(G(i,j+3)-G(i,j-1)))/(L-1);
            s = s-k*A*s*(s-1);
            G(i,j) = G(i,j-1)*(1-s)+G(i,j+1)*s;
            A = (abs(B(i,j+1))-abs(B(i,j+3)-B(i,j-1)))/(L-1);
            s = s-k*A*s*(s-1);
            B(i,j) = B(i,j-1)*(1-s)+B(i,j+1)*s;

        end
    end
    for i=2:2:m*Zoom-3
        for j=1:n*Zoom
            G(i,j) = G(i-1,j)*(1-s)+G(i+1,j)*s;
            B(i,j) = B(i-1,j)*(1-s)+B(i+1,j)*s;
        end
    end
    G(m,:)=G(m-1,:);
    B(m,:)=B(m-1,:);
    G(:,n)=G(:,n-1);
    B(:,n)=B(:,n-1);
end
for i=1:m*Zoom
    for j=2:2:n*Zoom-3
        A = (abs(R(i,j+1))-abs(R(i,j+3)-R(i,j-1)))/(L-1);
        s = s-k*A*s*(s-1);
        R(i,j) = R(i,j-1)*(1-s)+R(i,j+1)*s;
    end
end
for i=2:2:m*Zoom-3
    for j=1:n*Zoom
        R(i,j) = R(i-1,j)*(1-s)+R(i+1,j)*s;
    end
end
R(m,:)=R(m-1,:);
R(:,n)=R(:,n-1);

Interpol2(:, :, 1)=uint8(R);
if ImRGB==1
    Interpol2(:, :, 2)=uint8(G);
    Interpol2(:, :, 3)=uint8(B);
end
Interpol2(m*Zoom,:)=Interpol2(m*Zoom-1,:)/2;
Interpol2(:,n*Zoom)=Interpol2(:,n*Zoom-1)/2;
valor_psnr2 = Calcula_psnr(Imagen,Interpol2)
figure(2)
imshow(Interpol2)

```

```

%*****
%*                                UNIVERSIDAD AUTONOMA DE LA CIUDAD DE MÉXICO                                *
%*                                Colegio de Ciencia y Tecnología                                          *
%*                                                                                                      *
%*                                TESIS                                                                    *
%* "Evaluación de algoritmos de interpolación polinomiales, adaptivos y                                *
%*   basados en redes neuronales para la superresolución de imágenes"                                *
%*                                                                                                      *
%*   Programa para evaluar el método de interpolación bicúbica                                          *
%*   con distancia deformada  $s'=s-k*A*s*(s-1)$                                           *
%*   Figuras 3.2, 3.3, 3.4, 3.5, 3.6 y 3.8                                                            *
%*                                                                                                      *
%*****

clear all;
clc

%*****
%*                                ABRIR IMAGEN ORIGINAL DE HR                                          *
%*****
[NombreImagen RutaImagen]=uigetfile({
    '*.jpeg;*.jpg;*.tif;*.png', 'Imagen JPEG (*.jpg, *.jpeg, *.tif,
    *.png)';
    '*.bmp', 'Imagen BMP (*.bmp)'},'MultiSelect','off');
if ~isequal(RutaImagen,0) && ~isequal(NombreImagen,0)
    PathCompletoImagen=strcat(RutaImagen,NombreImagen);
    Imagen=imread(PathCompletoImagen);
end

%*****
%*                                SI Zoom=2, INTERPOLACIÓN AL DOBLE DE RESOLUCIÓN                                *
%*****
Zoom = 2;

%*****
%*                                OBTENCION DE IMAGEN DEGRADADA DE BAJA RESOLUCIÓN                                *
%*****
ImagenLR=DimensionamientoLR(Imagen);
%*****
%*                                OBTENCION DE LA REJILLA DE ALTA RESOLUCIÓN INTERCALADA CON CEROS            *
%*                                SI ImRGB=1 SE TRATA DE UNA IMAGEN A COLOR                                *
%*                                SI ImRGB=0 SE TRATA DE UNA IMAGEN EN ESCALA DE GRISES                    *
%*****
sz=size(Imagen);
if length(sz)>2
    ImRGB=1;
else
    ImRGB=0;
end
if ImRGB==1
    G=DimensionamientoHR(ImagenLR(:,:,2),Zoom);
    B=DimensionamientoHR(ImagenLR(:,:,3),Zoom);
end
R=DimensionamientoHR(ImagenLR(:,:,1),Zoom);

figure(1)
imshow(uint8(ImagenLR));

```

```

%*****
%*          PROCESO DE INTERPOLACIÓN CON DISTANCIA DEFORMADA          *
%*****

Dim=size(ImagenLR);
m=Dim(1);
n=Dim(2);
s=0.5;
k=3;
L=256;

if ImRGB==1
    for i=1:m*Zoom
        j=2;
        A = (abs(G(i,j+1)-G(i,j-1))-abs(G(i,j+3)-G(i,j-1)))/(L-1);
        s = s-k*A*s*(s-1);
        G(i,j) = G(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+G(i,j+1)*((1+s)^3-4*s^3)/6+G(i,j+3)*(s^3)/6;
        A = (abs(B(i,j+1)-B(i,j-1))-abs(B(i,j+3)-B(i,j-1)))/(L-1);
        s = s-k*A*s*(s-1);
        B(i,j) = B(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6 +
B(i,j+1)*((1+s)^3-4*s^3)/6+B(i,j+3)*(s^3)/6;
        for j=4:2:n*Zoom-4
            A = (abs(G(i,j+1)-G(i,j-1))-abs(G(i,j+3)-G(i,j-1)))/(L-1);
            s = s-k*A*s*(s-1);
            G(i,j) = G(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+G(i,j+1)*((1+s)^3-4*s^3)/6+G(i,j+3)*(s^3)/6;
            A = (abs(B(i,j+1)-B(i,j-1))-abs(B(i,j+3)-B(i,j-1)))/(L-1);
            s = s-k*A*s*(s-1);
            B(i,j) = B(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6 +
B(i,j+1)*((1+s)^3-4*s^3)/6+B(i,j+3)*(s^3)/6;
        end
        j=m*Zoom-3;
        A = (abs(G(i,j+1)-G(i,j-1))-abs(G(i,j+3)-G(i,j-1)))/(L-1);
        s = s-k*A*s*(s-1);
        G(i,j) = G(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+G(i,j+1)*((1+s)^3-4*s^3)/6+G(i,j+3)*(s^3)/6;
        A = (abs(B(i,j+1)-B(i,j-1))-abs(B(i,j+3)-B(i,j-1)))/(L-1);
        s = s-k*A*s*(s-1);
        B(i,j) = B(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6 +
B(i,j+1)*((1+s)^3-4*s^3)/6+B(i,j+3)*(s^3)/6;
    end
    for i=1:m*Zoom
        j=2;
        A = (abs(G(j+1,i)-G(j-1,i))-abs(G(j+3,i)-G(j-1,i)))/(L-1);
        s = s-k*A*s*(s-1);
        G(j,i) = G(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+G(j+1,i)*((1+s)^3-4*s^3)/6+G(j+3,i)*(s^3)/6;
        A = (abs(B(j+1,i)-B(j-1,i))-abs(B(j+3,i)-B(j-1,i)))/(L-1);
        s = s-k*A*s*(s-1);
        B(j,i) = B(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6 +
B(j+1,i)*((1+s)^3-4*s^3)/6+B(j+3,i)*(s^3)/6;
        for j= 4:2:n*Zoom-4
            A = (abs(G(j+1,i)-G(j-1,i))-abs(G(j+3,i)-G(j-1,i)))/(L-1);
            s = s-k*A*s*(s-1);
            G(j,i) = G(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+G(j+1,i)*((1+s)^3-4*s^3)/6+G(j+3,i)*(s^3)/6;

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        A = (abs(B(j+1,i)-B(j-1,i))-abs(B(j+3,i)-B(j-1,i)))/(L-1);
        s = s-k*A*s*(s-1);
        B(j,i) = B(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6) +
B(j+1,i)*((1+s)^3-4*s^3)/6)+B(j+3,i)*(s^3)/6;
    end
    j=n*Zoom-3;
        A = (abs(G(j+1,i)-G(j-1,i))-abs(G(j+3,i)-G(j-1,i)))/(L-1);
        s = s-k*A*s*(s-1);
        G(j,i) = G(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6)
+G(j+1,i)*((1+s)^3-4*s^3)/6)+G(j+3,i)*(s^3)/6;
        A = (abs(B(j+1,i)-B(j-1,i))-abs(B(j+3,i)-B(j-1,i)))/(L-1);
        s = s-k*A*s*(s-1);
        B(j,i) = B(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6) +
B(j+1,i)*((1+s)^3-4*s^3)/6)+B(j+3,i)*(s^3)/6;
    end
    G(m,:)=G(m-1,:);
    B(m,:)=B(m-1,:);
    G(:,n)=G(:,n-1);
    B(:,n)=B(:,n-1);
end
for i=1:m*Zoom
    j=2;
        A = (abs(R(i,j+1)-R(i,j-1))-abs(R(i,j+3)-R(i,j-1)))/(L-1);
        s = s-k*A*s*(s-1);
        R(i,j) = R(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6) +R(i,j+1)*((1+s)^3-
4*s^3)/6)+R(i,j+3)*(s^3)/6;
        for j=4:2:n*Zoom-4
            A = (abs(R(i,j+1)-R(i,j-1))-abs(R(i,j+3)-R(i,j-1)))/(L-1);
            s = s-k*A*s*(s-1);
            R(i,j) = R(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6)
+R(i,j+1)*((1+s)^3-4*s^3)/6)+R(i,j+3)*(s^3)/6;
        end
        j=m*Zoom-3;
        A = (abs(R(i,j+1)-R(i,j-1))-abs(R(i,j+3)-R(i,j-1)))/(L-1);
        s = s-k*A*s*(s-1);
        R(i,j) = R(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6) +R(i,j+1)*((1+s)^3-
4*s^3)/6)+R(i,j+3)*(s^3)/6;
    end
    for i=1:n*Zoom
        j=2;
            A = (abs(R(j+1,i)-G(j-1,i))-abs(R(j+3,i)-R(j-1,i)))/(L-1);
            s = s-k*A*s*(s-1);
            R(j,i) = R(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6) +R(j+1,i)*((1+s)^3-
4*s^3)/6)+R(j+3,i)*(s^3)/6;
            for j=4:2:m*Zoom-4
                A = (abs(R(j+1,i)-G(j-1,i))-abs(R(j+3,i)-R(j-1,i)))/(L-1);
                s = s-k*A*s*(s-1);
                R(j,i) = R(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6)
+R(j+1,i)*((1+s)^3-4*s^3)/6)+R(j+3,i)*(s^3)/6;
            end
            j=n*Zoom-3;
            A = (abs(R(j+1,i)-G(j-1,i))-abs(R(j+3,i)-R(j-1,i)))/(L-1);
            s = s-k*A*s*(s-1);
            R(j,i) = R(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6) +R(j+1,i)*((1+s)^3-
4*s^3)/6)+R(j+3,i)*(s^3)/6;
        end
        R(m,:)=R(m-1,:);

```

```

R(:,n)=R(:,n-1);

Interpol2(:,:,1)=uint8(R);
[ssimR2 ssim_map] = ssim_index(uint8(Imagen(:,:,1)),uint8(R));
ssim_3 = ssimR2;

if ImRGB==1
    Interpol2(:,:,2)=uint8(G);
    Interpol2(:,:,3)=uint8(B);
    [ssimG2 ssim_map] = ssim_index(uint8(Imagen(:,:,2)),uint8(G));
    [ssimB2 ssim_map] = ssim_index(uint8(Imagen(:,:,3)),uint8(B));

    ssim_3=(ssimR2+ssimG2+ssimB2)/3
end

valor_psnr2 = Calcula_psnr(Imagen,Interpol2)
figure(2)
imshow(uint8(Interpol2))

```

```

%*****
%*                                UNIVERSIDAD AUTONOMA DE LA CIUDAD DE MÉXICO                                *
%*                                Colegio de Ciencia y Tecnología                                              *
%*                                                                           *
%*                                TESIS                                                                      *
%* "Evaluación de algoritmos de interpolación polinomiales, adaptivos y *
%*   basados en redes neuronales para la superresolución de imágenes" *
%*                                                                           *
%*                                Programa para evaluar el método de interpolación O-MOMS                    *
%*                                con distancia deformada  $s'=s-k*A*s*(s-1)$                                 *
%*                                Figuras 3.2, 3.3, 3.4, 3.5, 3.6 y 3.9                                        *
%*                                                                           *
%*****

clear all;
clc

%*****
%*                                ABRIR IMAGEN ORIGINAL DE HR                                              *
%*****
[NombreImagen RutaImagen]=uigetfile({
    '*.jpeg;*.jpg;*.tif;*.png', 'Imagen JPEG (*.jpg, *.jpeg, *.tif,
    *.png)';
    '*.bmp', 'Imagen BMP (*.bmp)'},'MultiSelect','off');
if ~isequal(RutaImagen,0) && ~isequal(NombreImagen,0)
    PathCompletoImagen=strcat(RutaImagen,NombreImagen);
    Imagen=imread(PathCompletoImagen);
end

%*****
%*                                SI Zoom=2, INTERPOLACIÓN AL DOBLE DE RESOLUCIÓN                                *
%*****
Zoom = 2;

%*****
%*                                OBTENCION DE IMAGEN DEGRADADA DE BAJA RESOLUCIÓN                            *
%*****
ImagenLR=DimensionamientoLR(Imagen);
%*****
%*                                OBTENCION DE LA REJILLA DE ALTA RESOLUCIÓN INTERCALADA CON CEROS                *
%*                                SI ImRGB=1 SE TRATA DE UNA IMAGEN A COLOR                                    *
%*                                SI ImRGB=0 SE TRATA DE UNA IMAGEN EN ESCALA DE GRISES                        *
%*****
sz=size(Imagen);
if length(sz)>2
    ImRGB=1;
else
    ImRGB=0;
end
if ImRGB==1
    G=DimensionamientoHR(ImagenLR(:,:,2),Zoom);
    B=DimensionamientoHR(ImagenLR(:,:,3),Zoom);
end
R=DimensionamientoHR(ImagenLR(:,:,1),Zoom);

```

```

%*****
%*          PROCESO DE INTERPOLACIÓN CON DISTANCIA DEFORMADA          *
%*****

Dim=size(ImagenLR);
m=Dim(1);
n=Dim(2);

figure(1)
imshow(uint8(ImagenLR));

s=0.9;
k=3;
L=256;

if ImRGB==1
    for i=1:m*Zoom
        j=2;
        A = (abs(G(i,j+1)-G(i,j-1))-abs(G(i,j+3)-G(i,j-1)))/(L-1);
        s = s-k*A*s*(s-1);
        G(i,j) = G(i,j-1)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+G(i,j+1)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21))+G(i,j+3)*(-
(1/6)*((2-s)^3)+((2-s)^2)-(85/42)*(2-s)+(29/21));
        A = (abs(B(i,j+1))-abs(B(i,j+3)-B(i,j-1)))/(L-1);
        s = s-k*A*s*(s-1);
        B(i,j) = B(i,j-1)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+B(i,j+1)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21))+B(i,j+3)*(-
(1/6)*((2-s)^3)+((2-s)^2)-(85/42)*(2-s)+(29/21));
        for j=4:2:n*Zoom-4
            A = (abs(G(i,j+1)-G(i,j-3))-abs(G(i,j+3)-G(i,j-1)))/(L-1);
            s = s-k*A*s*(s-1);
            G(i,j) = G(i,j-3)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+G(i,j-1)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+G(i,j+1)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21))+G(i,j+3)*(-
(1/6)*((2-s)^3)+((2-s)^2)-(85/42)*(2-s)+(29/21));
            A = (abs(B(i,j+1)-B(i,j-3))-abs(B(i,j+3)-B(i,j-1)))/(L-1);
            s = s-k*A*s*(s-1);
            B(i,j) = B(i,j-3)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+B(i,j-1)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+B(i,j+1)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21))+B(i,j+3)*(-
(1/6)*((2-s)^3)+((2-s)^2)-(85/42)*(2-s)+(29/21));
            end
            j=m*Zoom-2;
            A = (abs(G(i,j+1)-G(i,j-3))-abs(G(i,j-1)))/(L-1);
            s = s-k*A*s*(s-1);
            G(i,j) = G(i,j-3)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+G(i,j-1)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+G(i,j+1)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21));
            A = (abs(B(i,j+1)-B(i,j-3))-abs(B(i,j-1)))/(L-1);
            s = s-k*A*s*(s-1);
            B(i,j) = B(i,j-3)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+B(i,j-1)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+B(i,j+1)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21));
            end
            s=0.5;
            for i=1:n*Zoom
                j=2;

```

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        A = (abs(G(j+1,i))-abs(G(j+3,i)-G(j-1,i)))/(L-1);
        s = s-k*A*s*(s-1);
        G(j,i) = G(j-1,i)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+G(j+1,i)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21))+G(j+3,i)*(-(1/6)*(2-
s)^3+(2-s)^2-(85/42)*(2-s)+(29/21));
        A = (abs(B(j+1,i))-abs(B(j+3,i)-B(j-1,i)))/(L-1);
        s = s-k*A*s*(s-1);
        B(j,i) = B(j-1,i)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+B(j+1,i)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21))+B(j+3,i)*(-(1/6)*(2-
s)^3+(2-s)^2-(85/42)*(2-s)+(29/21));
        for j=4:2:m*Zoom-4
            A = (abs(G(j+1,i)-G(j-3,i))-abs(G(j+3,i)-B(j-1,i)))/(L-1);
            s = s-k*A*s*(s-1);
            G(j,i) = G(j-3,i)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+G(j-1,i)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+G(j+1,i)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21))+G(j+3,i)*(-
(1/6)*((2-s)^3)+(2-s)^2-(85/42)*(2-s)+(29/21));
            A = (abs(B(j+1,i)-B(j-3,i))-abs(B(j+3,i)-B(j-1,i)))/(L-1);
            s = s-k*A*s*(s-1);
            B(j,i) = B(j-3,i)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+B(j-1,i)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+B(j+1,i)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21))+B(j+3,i)*(-
(1/6)*((2-s)^3)+(2-s)^2-(85/42)*(2-s)+(29/21));
        end
        s=0.5;
        j=m*Zoom-2;
        A = (abs(G(j+1,i)-G(j-3,i))-abs(G(j-1,i)))/(L-1);
        s = s-k*A*s*(s-1);
        G(j,i) = G(j-3,i)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+G(j-1,i)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+G(j+1,i)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21));
        A = (abs(B(j+1,i)-B(j-3,i))-abs(B(j-1,i)))/(L-1);
        s = s-k*A*s*(s-1);
        B(j,i) = B(j-3,i)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+B(j-1,i)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+B(j+1,i)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21));
    end

    G(Dim(1),:)=G(Dim(1)-1,:);
    B(Dim(1),:)=B(Dim(1)-1,:);
    G(:,Dim(1))=G(:,Dim(1)-1);
    B(:,Dim(1))=B(:,Dim(1)-1);
end
for i=1:n*Zoom
    j=2;
    A = (abs(R(i,j+1))-abs(R(i,j+3)-R(i,j-1)))/(L-1);
    s = s-k*A*s*(s-1);

    R(i,j) = R(i,j-1)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+R(i,j+1)*((1/2)*(1-s)^3-(1-s)^2+(s/14)+(13/21))+R(i,j+3)*(-(1/6)*((2-
s)^3))+((2-s)^2)-(85/42)*(2-s)+(29/21);
    for j=4:2:m*Zoom-4
        A = (abs(R(i,j+1)-R(i,j-3))-abs(R(i,j+3)-R(i,j-1)))/(L-1);
        s = s-k*A*s*(s-1);

        R(i,j) = R(i,j-3)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+R(i,j-1)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))

```

```

+R(i,j+1)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21))+R(i,j+3)*(-(1/6)*(2-
s)^3+(2-s)^2-(85/42)*(2-s)+(29/21));
end
j=m*Zoom-2;
A = (abs(R(i,j+1)-R(i,j-3))-abs(R(i,j-1)))/(L-1);
s = s-k*A*s*(s-1);

R(i,j) = R(i,j-3)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+R(i,j-1)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+R(i,j+1)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21));
end
for i=1:n*Zoom
j=2;
A = (abs(R(j+1,i))-abs(R(j+3,i)-R(j-1,i)))/(L-1);
s = s-k*A*s*(s-1);

R(j,i) = R(j-1,i)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+R(j+1,i)*((1/2)*(1-s)^3-(1-s)^2+(s/14)+(13/21))+R(j+3,i)*(-(1/6)*(2-
s)^3+(2-s)^2-(85/42)*(2-s)+(29/21));
for j=4:2:m*Zoom-4
A = (abs(R(j+1,i)-R(j-3,i))-abs(R(j+3,i)-R(j-1,i)))/(L-1);
s = s-k*A*s*(s-1);

R(j,i) = R(j-3,i)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+R(j-1,i)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+R(j+1,i)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21))+R(j+3,i)*(-(1/6)*(2-
s)^3+(2-s)^2-(85/42)*(2-s)+(29/21));
end
j=m*Zoom-2;
A = (abs(R(j+1,i)-R(j-3,i))-abs(R(j-1,i)))/(L-1);
s = s-k*A*s*(s-1);

R(j,i) = R(j-3,i)*(-(1/6)*(1+s)^3+((1+s)^2)-
(85/42)*(1+s)+(29/21))+R(j-1,i)*((1/2)*(s^3)-(s^2)+(s/14)+(13/21))
+R(j+1,i)*((1/2)*((1-s)^3)-((1-s)^2)+(s/14)+(13/21));
end
R(Dim(1),:)=R(Dim(1)-1,:);
R(:,Dim(1))=R(:,Dim(1)-1);

Interpol2(:,:,1)=uint8(R);
[ssimR ssim_map] = ssim_index(uint8(Imagen(:,:,1)),uint8(R));
if ImRGB==1
Interpol2(:,:,2)=uint8(G);
Interpol2(:,:,3)=uint8(B);
[ssimG ssim_map] = ssim_index(uint8(Imagen(:,:,2)),uint8(G));
[ssimB ssim_map] = ssim_index(uint8(Imagen(:,:,3)),uint8(B));
ssim_1=(ssimR+ssimG+ssimB)/3;
disp(ssim_1)
end
disp(ssimR)
valor_psnr2 = Calcula_psnr(Imagen,Interpol2)

figure(3)
imshow(Interpol2)

```

```

%*****
%*          UNIVERSIDAD AUTONOMA DE LA CIUDAD DE MÉXICO          *
%*          Colegio de Ciencia y Tecnología                      *
%*                                                              *
%*          TESIS                                              *
%* "Evaluación de algoritmos de interpolación polinomiales, adaptivos y *
%*   basados en redes neuronales para la superresolución de imágenes" *
%*                                                              *
%*          Programa para evaluar el método de interpolación Bilineal *
%*          con distancia ponderada  $a_0=1-\epsilon$  y  $a_1=1+\epsilon \cdot A_n$  *
%*          Figuras 3.20 y 3.21                                *
%*                                                              *
%*****

clear all;
clc

%*****
%*          ABRIR IMAGEN ORIGINAL DE HR                        *
%*****
[NombreImagen RutaImagen]=uigetfile({
    '*.jpeg;*.jpg;*.tif;*.png', 'Imagen JPEG (*.jpg, *.jpeg, *.tif,
    *.png)';
    '*.bmp', 'Imagen BMP (*.bmp)'},'MultiSelect','off');
if ~isequal(RutaImagen,0) && ~isequal(NombreImagen,0)
    PathCompletoImagen=strcat(RutaImagen,NombreImagen);
    Imagen=imread(PathCompletoImagen);
end

%*****
%*          SI Zoom=2, INTERPOLACIÓN AL DOBLE DE RESOLUCIÓN      *
%*****
Zoom = 2;

%*****
%*          OBTENCION DE IMAGEN DEGRADADA DE BAJA RESOLUCIÓN    *
%*****
ImagenLR=DimensionamientoLR(Imagen);
%*****
%*          OBTENCION DE LA REJILLA DE ALTA RESOLUCIÓN INTERCALADA CON CEROS *
%*          SI ImRGB=1 SE TRATA DE UNA IMAGEN A COLOR            *
%*          SI ImRGB=0 SE TRATA DE UNA IMAGEN EN ESCALA DE GRISES *
%*****
sz=size(Imagen);
if length(sz)>2
    ImRGB=1;
else
    ImRGB=0;
end
if ImRGB==1
    G=DimensionamientoHR(ImagenLR(:,:,2),Zoom);
    B=DimensionamientoHR(ImagenLR(:,:,3),Zoom);
end
R=DimensionamientoHR(ImagenLR(:,:,1),Zoom);

figure(1)
imshow(uint8(ImagenLR));

```

```

%*****
%*          PROCESO DE INTERPOLACIÓN CON DISTANCIA DEFORMADA          *
%*****

Dim=size(ImagenLR);
m=Dim(1);
n=Dim(2);
s=0.5;
epsilon=1;
L=256;
if ImRGB==1
    for i=1:m*Zoom
        for j=2:2:n*Zoom-3
            An = (abs(G(i,j+1)-G(i,j-1))-abs(G(i,j+3)-G(i,j-1)))/(L-1);
            a0 = 1-epsilon*An;
            a1 = 1+epsilon*An;
            G(i,j) = (1-s)*a0*G(i,j-1)+s*a1*G(i,j+1);
            An = (abs(B(i,j+1)-B(i,j-1))-abs(B(i,j+3)-B(i,j-1)))/(L-1);
            a0 = 1-epsilon*An;
            a1 = 1+epsilon*An;
            B(i,j) = (1-s)*a0*B(i,j-1)+s*a1*B(i,j+1);
        end
    end
    for i=2:2:m*Zoom-3
        for j=1:n*Zoom
            An = (abs(G(i+1,j)-G(i-1,j))-abs(G(i+3,j)-G(i-1,j)))/(L-1);
            a0 = 1-epsilon*An;
            a1 = 1+epsilon*An;
            G(i,j) = (1-s)*a0*G(i-1,j)+s*a1*G(i+1,j);
            An = (abs(B(i+1,j)-B(i-1,j))-abs(B(i+3,j)-B(i-1,j)))/(L-1);
            a0 = 1-epsilon*An;
            a1 = 1+epsilon*An;
            B(i,j) = (1-s)*a0*B(i-1,j)+s*a1*B(i+1,j);
        end
    end
    G(m,:)=G(m-1,:);
    B(m,:)=B(m-1,:);
    G(:,n)=G(:,n-1);
    B(:,n)=B(:,n-1);
end
for i=1:m*Zoom
    for j=2:2:n*Zoom-3
        An = (abs(R(i,j+1)-R(i,j-1))-abs(R(i,j+3)-R(i,j-1)))/(L-1);
        a0 = 1-(epsilon*An);
        a1 = 1+(epsilon*An);
        R(i,j) = (1-s)*a0*R(i,j-1)+s*a1*R(i,j+1);
    end
end
for i=2:2:m*Zoom-3
    for j=1:n*Zoom
        An = (abs(R(i+1,j)-R(i-1,j))-abs(R(i+3,j)-R(i-1,j)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        R(i,j) = (1-s)*a0*R(i-1,j)+s*a1*R(i+1,j);
    end
end
R(m,:)=R(m-1,:);

```

```

        R(:,n)=R(:,n-1);

Interpol2(:, :, 1)=uint8(R);

if ImRGB==1
    Interpol2(:, :, 2)=uint8(G);
    Interpol2(:, :, 3)=uint8(B);
end

Interpol2(m*Zoom,:)=Interpol2(m*Zoom-1,:)/2;
Interpol2(:,n*Zoom)=Interpol2(:,n*Zoom-1)/2;
valor_psnr2 = Calcula_psnr(Imagen,Interpol2)
figure(2)
imshow(Interpol2)

```

```

%*****
%*                                UNIVERSIDAD AUTONOMA DE LA CIUDAD DE MÉXICO                                *
%*                                Colegio de Ciencia y Tecnología                                              *
%*                                                                           *
%*                                TESIS                                                                      *
%* "Evaluación de algoritmos de interpolación polinomiales, adaptivos y *
%*   basados en redes neuronales para la superresolución de imágenes" *
%*                                                                           *
%*   Programa para evaluar el método de interpolación Bilineal      *
%*   con distancia ponderada  $a_0=1-\epsilon$  y  $a_1=1+\epsilon \cdot A_n$  *
%*   Figuras 3.20 y 3.21                                           *
%*                                                                           *
%*****

clear all;
clc

%*****
%*                                ABRIR IMAGEN ORIGINAL DE HR                                *
%*****
[NombreImagen RutaImagen]=uigetfile({
    '*.jpeg;*.jpg;*.tif;*.png', 'Imagen JPEG (*.jpg, *.jpeg, *.tif,
    *.png)';
    '*.bmp', 'Imagen BMP (*.bmp)'},'MultiSelect','off');
if ~isequal(RutaImagen,0) && ~isequal(NombreImagen,0)
    PathCompletoImagen=strcat(RutaImagen,NombreImagen);
    Imagen=imread(PathCompletoImagen);
end

%*****
%*                                SI Zoom=2, INTERPOLACIÓN AL DOBLE DE RESOLUCIÓN                                *
%*****
Zoom = 2;

%*****
%*                                OBTENCION DE IMAGEN DEGRADADA DE BAJA RESOLUCIÓN                                *
%*****
ImagenLR=DimensionamientoLR(Imagen);
%*****
%*                                OBTENCION DE LA REJILLA DE ALTA RESOLUCIÓN INTERCALADA CON CEROS *
%*                                SI ImRGB=1 SE TRATA DE UNA IMAGEN A COLOR                                *
%*                                SI ImRGB=0 SE TRATA DE UNA IMAGEN EN ESCALA DE GRISES            *
%*****
sz=size(Imagen);
if length(sz)>2
    ImRGB=1;
else
    ImRGB=0;
end
if ImRGB==1
    G=DimensionamientoHR(ImagenLR(:,:,2),Zoom);
    B=DimensionamientoHR(ImagenLR(:,:,3),Zoom);
end
R=DimensionamientoHR(ImagenLR(:,:,1),Zoom);

figure(1)
imshow(uint8(ImagenLR));

```

```

%*****
%*          PROCESO DE INTERPOLACIÓN CON DISTANCIA DEFORMADA          *
%*****

Dim=size(ImagenLR);
m=Dim(1);
n=Dim(2);
s=0.01;
epsilon=1;
L=256;

if ImRGB==1
    for i=1:m*Zoom
        j=2;
        An = (abs(G(i,j+1)-G(i,j-1))-abs(G(i,j+2)-G(i,j+1)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        G(i,j) = a_1*G(i,j-1)*(((2+s)^3-4*(1+s)^3+6*s^3)/6)
+a0*G(i,j+1)*(((1+s)^3-4*s^3)/6)+a1*G(i,j+3)*(s^3)/6;
        An = (abs(B(i,j+1)-B(i,j-1))-abs(B(i,j+2)-B(i,j+1)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        B(i,j) = a_1*B(i,j-1)*(((2+s)^3-4*(1+s)^3+6*s^3)/6)
+a0*B(i,j+1)*(((1+s)^3-4*s^3)/6)+a1*B(i,j+3)*(s^3)/6;
        for j=4:2:n*Zoom-4
            An = (abs(G(i,j+1)-G(i,j-1))-abs(G(i,j+2)-G(i,j+1)))/(L-1);
            a0 = 1-epsilon*An;
            a1 = 1+epsilon*An;
            a_1 = a0;
            a_2 = a1;
            G(i,j) = a_1*G(i,j-1)*(((2+s)^3-4*(1+s)^3+6*s^3)/6)
+a0*G(i,j+1)*(((1+s)^3-4*s^3)/6)+a1*G(i,j+3)*(s^3)/6;
            An = (abs(B(i,j+1)-B(i,j-1))-abs(B(i,j+2)-B(i,j+1)))/(L-1);
            a0 = 1-epsilon*An;
            a1 = 1+epsilon*An;
            a_1 = a0;
            a_2 = a1;
            B(i,j) = a_1*B(i,j-1)*(((2+s)^3-4*(1+s)^3+6*s^3)/6)
+a0*B(i,j+1)*(((1+s)^3-4*s^3)/6)+a1*B(i,j+3)*(s^3)/6;
        end
        j=m*Zoom-3;
        An = (abs(G(i,j+1)-G(i,j-1))-abs(G(i,j+2)-G(i,j+1)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a_2 = a1;
        G(i,j) = a_1*G(i,j-1)*(((2+s)^3-4*(1+s)^3+6*s^3)/6)
+a0*G(i,j+1)*(((1+s)^3-4*s^3)/6)+a1*G(i,j+3)*(s^3)/6;
        An = (abs(B(i,j+1)-B(i,j-1))-abs(B(i,j+2)-B(i,j+1)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a_2 = a1;
        B(i,j) = a_1*B(i,j-1)*(((2+s)^3-4*(1+s)^3+6*s^3)/6)
+a0*B(i,j+1)*(((1+s)^3-4*s^3)/6)+a1*B(i,j+3)*(s^3)/6;
    end
end

```

```

end
for i=1:m*Zoom
    j=2;
    An = (abs(G(j+1,i)-G(j-1,i))-abs(G(j+2,i)-G(j+1,i)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    G(j,i) = a_1*G(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*G(j+1,i)*((1+s)^3-4*s^3)/6+a1*G(j+3,i)*(s^3)/6;
    An = (abs(B(j+1,i)-B(j-1,i))-abs(B(j+2,i)-B(j+1,i)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    B(j,i) = a_1*B(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*B(j+1,i)*((1+s)^3-4*s^3)/6+a1*B(j+3,i)*(s^3)/6;
    for j= 4:2:n*Zoom-4
        An = (abs(G(j+1,i)-G(j-1,i))-abs(G(j+2,i)-G(j+1,i)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a2 = a1;
        G(j,i) = a_1*G(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*G(j+1,i)*((1+s)^3-4*s^3)/6+a1*G(j+3,i)*(s^3)/6;
        An = (abs(B(j+1,i)-B(j-1,i))-abs(B(j+2,i)-B(j+1,i)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        B(j,i) = a_1*B(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*B(j+1,i)*((1+s)^3-4*s^3)/6+a1*B(j+3,i)*(s^3)/6;
    end
    j=n*Zoom-3;
    An = (abs(G(j+1,i)-G(j-1,i))-abs(G(j+2,i)-G(j+1,i)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    G(j,i) = a_1*G(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*G(j+1,i)*((1+s)^3-4*s^3)/6+a1*G(j+3,i)*(s^3)/6;
    An = (abs(B(j+1,i)-B(j-1,i))-abs(B(j+2,i)-B(j+1,i)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    B(j,i) = a_1*B(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*B(j+1,i)*((1+s)^3-4*s^3)/6+a1*B(j+3,i)*(s^3)/6;
    end
    G(m,:) = G(m-1,:);
    B(m,:) = B(m-1,:);
    G(:,n) = G(:,n-1);
    B(:,n) = B(:,n-1);
end
for i=1:m*Zoom
    j=2;
    An = (abs(R(i,j+1)-R(i,j-1))-abs(R(i,j+2)-R(i,j+1)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    R(i,j) = a_1*R(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*R(i,j+1)*((1+s)^3-4*s^3)/6+a1*R(i,j+3)*(s^3)/6;

```

```

for j=4:2:n*Zoom-4
    An = (abs(R(i,j+1)-R(i,j-1))-abs(R(i,j+2)-R(i,j+1)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    R(i,j) = a_1*R(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*R(i,j+1)*((1+s)^3-4*s^3)/6+a1*R(i,j+3)*(s^3)/6;
end
j=m*Zoom-3;
An = (abs(R(i,j+1)-R(i,j-1))-abs(R(i,j+2)-R(i,j+1)))/(L-1);
a0 = 1-epsilon*An;
a1 = 1+epsilon*An;
a_1 = a0;
R(i,j) = a_1*R(i,j-1)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*R(i,j+1)*((1+s)^3-4*s^3)/6+a1*R(i,j+3)*(s^3)/6;
end
for i=1:n*Zoom
    j=2;
    An = (abs(R(j+1,i)-R(j-1,i))-abs(R(j+2,i)-R(j+1,i)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    R(j,i) = a_1*R(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*R(j+1,i)*((1+s)^3-4*s^3)/6+a1*R(j+3,i)*(s^3)/6;
    for j=4:2:m*Zoom-4
        An = (abs(R(j+1,i)-R(j-1,i))-abs(R(j+2,i)-R(j+1,i)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        R(j,i) = a_1*R(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*R(j+1,i)*((1+s)^3-4*s^3)/6+a1*R(j+3,i)*(s^3)/6;
    end
    j=n*Zoom-3;
    An = (abs(R(j+1,i)-R(j-1,i))-abs(R(j+2,i)-R(j+1,i)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    R(j,i) = a_1*R(j-1,i)*((2+s)^3-4*(1+s)^3+6*s^3)/6
+a0*R(j+1,i)*((1+s)^3-4*s^3)/6+a1*R(j+3,i)*(s^3)/6;
end
    R(m,:) = R(m-1,:);
    R(:,n) = R(:,n-1);

Interpol2(:,:,1) = uint8(R);
[ssimR2 ssim_map] = ssim_index(uint8(Imagen(:,:,1)),uint8(R));
ssim_3 = ssimR2;
if ImRGB==1
    Interpol2(:,:,2) = uint8(G);
    Interpol2(:,:,3) = uint8(B);
    [ssimG2 ssim_map] = ssim_index(uint8(Imagen(:,:,2)),uint8(G));
    [ssimB2 ssim_map] = ssim_index(uint8(Imagen(:,:,3)),uint8(B));

    ssim_3 = (ssimR2+ssimG2+ssimB2)/3
end
valor_psnr2 = Calcula_psnr(Imagen,Interpol2)
figure(2)
imshow(uint8(Interpol2))

```

```

%*****
%*          UNIVERSIDAD AUTONOMA DE LA CIUDAD DE MÉXICO          *
%*          Colegio de Ciencia y Tecnología                      *
%*                                                              *
%*          TESIS                                                *
%* "Evaluación de algoritmos de interpolación polinomiales, adaptivos y *
%*   basados en redes neuronales para la superresolución de imágenes" *
%*                                                              *
%*          Programa para evaluar el método de interpolación O-MOMS *
%*          con distancia ponderada  $a_0=1-\epsilon$  y  $a_1=1+\epsilon \cdot A_n$  *
%*          Figuras 3.14 y 3.15                                   *
%*                                                              *
%*****

clear all;
clc

%*****
%*          ABRIR IMAGEN ORIGINAL DE HR                          *
%*****
[NombreImagen RutaImagen]=uigetfile({'*.jpeg;*.jpg;*.tif;*.png', 'Imagen JPEG (*.jpg, *.jpeg, *.tif,
*.png)'};
    '*.bmp', 'Imagen BMP (*.bmp)'},'MultiSelect','off');
if ~isequal(RutaImagen,0) && ~isequal(NombreImagen,0)
    PathCompletoImagen=strcat(RutaImagen,NombreImagen);
    Imagen=imread(PathCompletoImagen);
end

%*****
%*          SI Zoom=2, INTERPOLACIÓN AL DOBLE DE RESOLUCIÓN      *
%*****
Zoom = 2;

%*****
%*          OBTENCION DE IMAGEN DEGRADADA DE BAJA RESOLUCIÓN    *
%*****
ImagenLR=DimensionamientoLR(Imagen);

%*****
%*          OBTENCION DE LA REJILLA DE ALTA RESOLUCIÓN INTERCALADA CON CEROS *
%*          SI ImRGB=1 SE TRATA DE UNA IMAGEN A COLOR            *
%*          SI ImRGB=0 SE TRATA DE UNA IMAGEN EN ESCALA DE GRISES *
%*****
sz=size(Imagen);
if length(sz)>2
    ImRGB=1;
else
    ImRGB=0;
end
if ImRGB==1
    G=DimensionamientoHR(ImagenLR(:,:,2),Zoom);
    B=DimensionamientoHR(ImagenLR(:,:,3),Zoom);
end
R=DimensionamientoHR(ImagenLR(:,:,1),Zoom);

figure(1)
imshow(uint8(ImagenLR));

```

```

%*****
%*          PROCESO DE INTERPOLACIÓN CON DISTANCIA DEFORMADA          *
%*****

Dim=size(ImagenLR);
m=Dim(1);
n=Dim(2);
s=0.01;
epsilon=1;
L=256;

if ImRGB==1
    for i=1:m*Zoom
        j=2;
        An = (abs(G(i,j+1)-G(i,j-1))-abs(G(i,j+2)-G(i,j+1)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a_2 = a1;
        G(i,j)=(a_1*G(i,j-1)*((-1/6)*(1+s)^3+(1+s)^2-
(85/42)*(1+s)+(29/21)))+(a0*G(i,j+1)*((1/2)*s^3-
s^2+(s/14)+(13/21)))+(a1*G(i,j+3)*((1/2)*(1+s)^3+(1-s)^2-
s/14+13/21))+(a2*G(i,j+5)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21));
        An = (abs(B(i,j+1)-B(i,j-1))-abs(B(i,j+2)-B(i,j+1)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a_2 = a1;
        B(i,j)=(a_1*B(i,j-1)*((-1/6)*(1+s)^3+(1+s)^2-
(85/42)*(1+s)+(29/21)))+(a0*B(i,j+1)*(1/2*s^3-
s^2+s/14+13/21)+(a1*B(i,j+3)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+(a2*B(i,j+5)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
        for j=4:2:n*Zoom-5
            An = (abs(G(i,j+1)-G(i,j-1))-abs(G(i,j+2)-G(i,j+1)))/(L-1);
            a0 = 1-epsilon*An;
            a1 = 1+epsilon*An;
            a_1 = a0;
            a_2 = a1;
            G(i,j)=(a_1*G(i,j-1)*((-1/6)*(1+s)^3+(1+s)^2-
(85/42)*(1+s)+(29/21)))+(a0*G(i,j+1)*(1/2*s^3-
s^2+s/14+13/21)+(a1*G(i,j+3)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+(a2*G(i,j+5)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
            An = (abs(B(i,j+1)-B(i,j-1))-abs(B(i,j+2)-B(i,j+1)))/(L-1);
            a0 = 1-epsilon*An;
            a1 = 1+epsilon*An;
            a_1 = a0;
            a_2 = a1;
            B(i,j)=(a_1*B(i,j-1)*((-1/6)*(1+s)^3+(1+s)^2-
(85/42)*(1+s)+(29/21)))+(a0*B(i,j+1)*(1/2*s^3-
s^2+s/14+13/21)+(a1*B(i,j+3)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+(a2*B(i,j+5)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
            end
        j=m*Zoom-5;
        An = (abs(G(i,j+1)-G(i,j-1))-abs(G(i,j+2)-G(i,j+1)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;

```

```

        a2 = a1;
        G(i,j)=a_1*G(i,j-1)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*G(i,j+1)*(1/2*s^3-
s^2+s/14+13/21)+a1*G(i,j+3)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*G(i,j+5)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
        An = (abs(B(i,j+1)-B(i,j-1))-abs(B(i,j+2)-B(i,j+1)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a2 = a1;
        B(i,j)=a_1*B(i,j-1)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*B(i,j+1)*(1/2*s^3-
s^2+s/14+13/21)+a1*B(i,j+3)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*B(i,j+5)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
    end
    for i=1:m*Zoom
        j=2;
        An = (abs(G(j+1,i)-G(j-1,i))-abs(G(j+2,i)-G(j+1,i)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a2 = a1;
        G(j,i)=a_1*G(j-1,i)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*G(j+1,i)*(1/2*s^3-
s^2+s/14+13/21)+a1*G(j+3,i)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*G(j+5,i)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
        An = (abs(B(j+1,i)-B(j-1,i))-abs(B(j+2,i)-B(j+1,i)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a2 = a1;
        B(j,i)=a_1*B(j-1,i)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*B(j+1,i)*(1/2*s^3-
s^2+s/14+13/21)+a1*B(j+3,i)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*B(j+5,i)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);

        for j= 4:2:n*Zoom-5
            An = (abs(G(j+1,i)-G(j-1,i))-abs(G(j+2,i)-G(j+1,i)))/(L-1);
            a0 = 1-epsilon*An;
            a1 = 1+epsilon*An;
            a_1 = a0;
            a2 = a1;
            G(j,i)=a_1*G(j-1,i)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*G(j+1,i)*(1/2*s^3-
s^2+s/14+13/21)+a1*G(j+3,i)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*G(j+5,i)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
            An = (abs(B(j+1,i)-B(j-1,i))-abs(B(j+2,i)-B(j+1,i)))/(L-1);
            a0 = 1-epsilon*An;
            a1 = 1+epsilon*An;
            a_1 = a0;
            a2 = a1;
            B(j,i)=a_1*B(j-1,i)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*B(j+1,i)*(1/2*s^3-
s^2+s/14+13/21)+a1*B(j+3,i)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*B(j+5,i)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
        end
        j=n*Zoom-5;

```

```

        An = (abs(G(j+1,i)-G(j-1,i))-abs(G(j+2,i)-G(j+1,i)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a_2 = a1;
        G(j,i)=a_1*G(j-1,i)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*G(j+1,i)*(1/2*s^3-
s^2+s/14+13/21)+a1*G(j+3,i)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*G(j+5,i)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
        An = (abs(B(j+1,i)-B(j-1,i))-abs(B(j+2,i)-B(j+1,i)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a_2 = a1;
        B(j,i)=a_1*B(j-1,i)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*B(j+1,i)*(1/2*s^3-
s^2+s/14+13/21)+a1*B(j+3,i)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*B(j+5,i)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
    end
    G(m,:)=G(m-1,:);
    B(m,:)=B(m-1,:);
    G(:,n)=G(:,n-1);
    B(:,n)=B(:,n-1);
end
for i=1:m*Zoom
    j=2;
    An = (abs(R(i,j+1)-R(i,j-1))-abs(R(i,j+2)-R(i,j+1)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    a_2 = a1;
    R(i,j)=a_1*R(i,j-1)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*R(i,j+1)*(1/2*s^3-
s^2+s/14+13/21)+a1*R(i,j+3)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*R(i,j+5)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
    for j=4:2:n*Zoom-5
        An = (abs(R(i,j+1)-R(i,j-1))-abs(R(i,j+2)-R(i,j+1)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a_2 = a1;
        R(i,j)=a_1*R(i,j-1)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*R(i,j+1)*(1/2*s^3-
s^2+s/14+13/21)+a1*R(i,j+3)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*R(i,j+5)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
    end
    j=m*Zoom-5;
    An = (abs(R(i,j+1)-R(i,j-1))-abs(R(i,j+2)-R(i,j+1)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    a_2 = a1;
    R(i,j)=a_1*R(i,j-1)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*R(i,j+1)*(1/2*s^3-
s^2+s/14+13/21)+a1*R(i,j+3)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*R(i,j+5)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
end
end

```

```

for i=1:n*Zoom
    j=2;
    An = (abs(R(j+1,i)-R(j-1,i))-abs(R(j+2,i)-R(j+1,i)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    a2 = a1;
    R(j,i)=a_1*R(j-1,i)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*R(j+1,i)*(1/2*s^3-
s^2+s/14+13/21)+a1*R(j+3,i)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*R(j+5,i)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
    for j=4:2:m*Zoom-5
        An = (abs(R(j+1,i)-R(j-1,i))-abs(R(j+2,i)-R(j+1,i)))/(L-1);
        a0 = 1-epsilon*An;
        a1 = 1+epsilon*An;
        a_1 = a0;
        a2 = a1;
        R(j,i)=a_1*R(j-1,i)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*R(j+1,i)*(1/2*s^3-
s^2+s/14+13/21)+a1*R(j+3,i)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*R(j+5,i)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
    end
    j=n*Zoom-5;
    An = (abs(R(j+1,i)-R(j-1,i))-abs(R(j+2,i)-R(j+1,i)))/(L-1);
    a0 = 1-epsilon*An;
    a1 = 1+epsilon*An;
    a_1 = a0;
    a2 = a1;
    R(j,i)=a_1*R(j-1,i)*(-(1/6)*(1+s)^3+(1+s)^2-
85/42*(1+s)+29/21)+a0*R(j+1,i)*(1/2*s^3-
s^2+s/14+13/21)+a1*R(j+3,i)*(1/2*(1+s)^3+(1-s)^2-
s/14+13/21)+a2*R(j+5,i)*(-1/6*(2-s)^3+(2-s)^2-85/42*(2-s)+29/21);
end
    R(m,:)=R(m-1,:);
    R(:,n)=R(:,n-1);

Interpol2(:,:,1)=uint8(R);
[ssimR2 ssim_map] = ssim_index(uint8(Imagen(:,:,1)),uint8(R));
ssim_3 = ssimR2;

if ImRGB==1
    Interpol2(:,:,2)=uint8(G);
    Interpol2(:,:,3)=uint8(B);
    [ssimG2 ssim_map] = ssim_index(uint8(Imagen(:,:,2)),uint8(G));
    [ssimB2 ssim_map] = ssim_index(uint8(Imagen(:,:,3)),uint8(B));

    ssim_3=(ssimR2+ssimG2+ssimB2)/3
end

valor_psnr2 = Calcula_psnr(Imagen,Interpol2)
figure(2)
imshow(uint8(Interpol2))

```

```

%*****
%*          UNIVERSIDAD AUTONOMA DE LA CIUDAD DE MÉXICO          *
%*          Colegio de Ciencia y Tecnología                      *
%*                                                                *
%*          TESIS                                                *
%* "Evaluación de algoritmos de interpolación polinomiales, adaptivos y *
%*   basados en redes neuronales para la superresolución de imágenes" *
%*                                                                *
%*          Programa para evaluar el método de interpolación basado *
%*                  en redes neuronales                          *
%*                  Figura 3.16                                   *
%*                                                                *
%*****

clear all;
clc

%*****
%*          ABRIR IMAGEN ORIGINAL DE HR                          *
%*****
[NombreImagen RutaImagen]=uigetfile({'*.jpeg;*.jpg;*.tif;*.png', 'Imagen JPEG (*.jpg, *.jpeg, *.tif,
*.png)';
    '*.bmp', 'Imagen BMP (*.bmp)'},'MultiSelect','off');
if ~isequal(RutaImagen,0) && ~isequal(NombreImagen,0)
    PathCompletoImagen=strcat(RutaImagen,NombreImagen);
    Imagen=imread(PathCompletoImagen);
end

NombreImagen = NombreImagen(:,:,1);
NombreImagen = double(NombreImagen)/255;
[M,N] = size(NombreImagen);
h = [.5,.5];
ImagenLR = filter(h,1,NombreImagen');
ImagenLR = ImagenLR(1:2:N,:);
ImagenLR = filter(h,1,g');
ImagenLR = ImagenLR(1:2:M,:);
SNR = input('SNR en dB?');
ruido = im2col(ImagenLR,[M/2,N/2],'distinct');
n_var = var(ruido)/10^(SNR/10);
ImagenLR = imnoise(ImagenLR,'gaussian',0,n_var);
Resp = input('1 Bilineal, 2 Bicubica and 3 Bicubica O-Moms');

tic
if (Resp ==3)
    f = spline_coeff(ImagenLR);
    fs = ImagenLR;
end;
f = ImagenLR;
a = -1/2;
[M,N] = size(f);
Temp1 = zeros(M,N);
x = f(:,N-1:N);
x = rot90(x,2);
y = f(:,1);

```

```

f = [y,f,x];
L = 256;
l1 = 1;
l2 = 1;
l3 = 1;
l4 = 1;
k = 3;
k1 = 1.5;
s = 1/2;
net_ip = zeros(2,2000);
if(Resp ==2)|(Resp ==3)
    net_ip = zeros(4,2000);
end
net_op = zeros(1,2000);
counter = 1;
for i = 1:M
    for j = 2:N+1
        A = (abs(f(i,j+1)-f(i,j-1))-abs(f(i,j+2)-f(i,j)))/(L-1);

        switch Resp
            case 1
                tt = l2*f(i,j)*(1-s)+l3*f(i,j+1)*s;
                net_ip(:,counter) = [f(i,j);f(i,j+1)];
            case 2
                tt = l1*f(i,j-1)*(a*s^3-2*a*s^2+a*s)+l2*f(i,j)*((a+2)*s^3-
(3+a)*s^2+1)+l3*f(i,j+1)*(-(a+2)*s^3+(2*a+3)*s^2-a*s)+l4*f(i,j+2)*(-
a*s^3+a*s^2);
                net_ip(:,counter) = [f(i,j-1);f(i,j);f(i,j+1);f(i,j+2)];
            case 3
                tt = l1*f(i,j-1)*((3+s)^3-4*(2+s)^3+6*(1+s)^3-
4*s^3)/6+l2*f(i,j)*((2+s)^3-4*(1+s)^3+6*s^3)/6+l3*f(i,j+1)*((1+s)^3-
4*s^3)/6+l4*f(i,j+2)*s^3/6;
                net_ip(:,counter) = [f(i,j-1);f(i,j);f(i,j+1);f(i,j+2)];
            end
            net_op(:,counter) = tt;
            counter = counter+1;
        end
    end
end
net_ip = net_ip(:,1:counter-1);
net_op = net_op(:,1:counter-1);
net = newff(minmax(net_ip),[2 1],{'logsig', 'logsig'},'trainscg');
net = feedforwardnet(13);
net = init(net);
net.performFcn = 'mse';
net.trainparam.epochs = 20000;
net.trainparam.show = 10;
net.trainparam.goal = 1e-10;
net.trainparam.min_grad = 1e-7;
net = train(net,net_ip,net_op);
for i = 1:M
    for j = 2:N+1
        switch Resp
            case 1
                y = [f(i,j);f(i,j+1)];
            case 2
                y = [f(i,j-1);f(i,j);f(i,j+1);f(i,j+2)];
            case 3

```

```

        y = [f(i,j-1);f(i,j);f(i,j+1);f(i,j+2)];
    end
    Temp1(i,j-1) = sim(net, y);
end
end
M
N
Temp1 = Temp1(:,1:N);
Temp2(1:M,1:2:2*N) = f(1:M,2:N+1);
if (Resp ==3)
    Temp2(1:M,1:2:2*N) = fs(1:M,1:N);
end
Temp2(1:M,2:2:2*N) = Temp1(1:M,1:N);
Temp2 = (Temp2>= 0).*Temp2;
f = Temp2';
imshow(f)
figure
if (Resp ==3)
    f = spline_coeff(g);
    fs = g;
end
ss = f;
clear Temp1,Temp2;
a = -1/2;
[M,N] = size(f);
Temp1 = zeros(M,N);
x = f(:,N-1:N);
x = rot90(x,2);
y = f(:,1);
f = [y,f,x];
L = 256;
s = 1/2;
k = 3;
k1 = 1.5;
l1 = 1;
l2 = 1;
l3 = 1;
l4 = 1;
N
net_ip = zeros(2,2000);
if (Resp ==2)|(Resp ==3)
    net_ip = zeros(4,2000);
end
net_op = zeros(1,2000);
counter = 1;
for i = 1:M
    for j = 2:N+1
        A = (abs(f(i,j+1)-f(i,j-1))-abs(f(i,j+2)-f(i,j)))/(L-1);
        switch Resp
            case 1
                tt = l2*f(i,j)*(1-s)+l3*f(i,j+1)*s;%bilinear
                net_ip(:,counter) = [f(i,j);f(i,j+1)];
            case 2
                tt = l1*f(i,j-1)*(a*s^3-2*a*s^2+a*s)+l2*f(i,j)*((a+2)*s^3-
(3+a)*s^2+1)+l3*f(i,j+1)*(-(a+2)*s^3+(2*a+3)*s^2-a*s)+l4*f(i,j+2)*(-
a*s^3+a*s^2); %Bicubic
                net_ip(:,counter) = [f(i,j-1);f(i,j);f(i,j+1);f(i,j+2)];

```

```

        case 3
            tt = 11*f(i,j-1)*((3+s)^3-4*(2+s)^3+6*(1+s)^3-4*s^3)/6+12*f(i,j)
            *((2+s)^3-4*(1+s)^3+6*s^3)/6+13*f(i,j+1)*((1+s)^3-
            4*s^3)/6+14*f(i,j+2)*s^3/6;% B-Spline
            net_ip(:,counter) = [f(i,j-1);f(i,j);f(i,j+1);f(i,j+2)];
        end
        net_op(:,counter) = tt;
        counter = counter+1;
    end
end
net_ip = net_ip(:,1:counter-1);
net_op = net_op(:,1:counter-1);
%net = newTemp1(minmax(net_ip),[2 1],{'logsig','logsig'},'trainscg');
%net = init(net);
%net.performFcn = 'mse';
%net.trainparam.epochs = 20000;
%net.trainparam.show = 10;
%net.trainparam.goal = 1e-10;
%net.trainparam.min_grad = 1e-7;
net = train(net,net_ip,net_op)
for i = 1:M
    for j = 2:N+1
        switch Resp
            case 1
                y = [f(i,j);f(i,j+1)];
            case 2
                y = [f(i,j-1);f(i,j);f(i,j+1);f(i,j+2)];
            case 3
                y = [f(i,j-1);f(i,j);f(i,j+1);f(i,j+2)];
        end
        Temp1(i,j-1) = sim(net, y);
    end
end
ss = Temp1;
clear Temp2;
Temp1 = Temp1(:,1:N);
Temp2(1:M,1:2:2*N) = f(1:M,2:N+1);
if (Resp ==3)
    Temp2(1:M,1:2:2*N) = fs(1:M,1:N);
end;
Temp2(1:M,2:2:2*N) = Temp1(1:M,1:N);
toc
Temp2 = (Temp2>= 0).*Temp2;
Temp2 = min(Temp2,1);
size(Temp2')
size(NombreImagen)
error = Temp2'-NombreImagen;
[M1,M2] = size(NombreImagen);
MSE = sum(sum(error(3:M1-2,3:M2-2).^2))*255^2/((M1-4)*(M2-4))
PSNR = 10*log(sum(sum(ones(size(error))))/sum(sum(error.^2)))/log(10)
imshow(Temp2');
figure
imshow(1-error);

```