Contents

QUESTION 1 COMMENTING

```
% DO NOT REMOVE THE LINE BELOW
% MAKE SURE 'eel3135_lab03_comment.m' IS IN SAME DIRECTORY AS THIS FILE
type('eel3135_lab03_comment.m')
```

```
% USER DEFINED VARIABLES
w = 20;                                                 % Width of the Gaussian function
x = 0:1:79;                                             % Horiztonal Axis
y = 0:1:79;                                             % Vertical Axis

% ==> Creates a Gaussian-like 2D matrix based on specified width(w), generated
% using the exponential function to create a smooth decay from the center
% with a specified spread <==
z = round(exp(-1/w.^2*(((y.'-50)/1.5).^2+((x-20)).^2)));

% ==> Apply image processing systems to the matrix z.
% The first system (image_system1) samples and scales the image, while the
% second system (image_system2) applies a transformation based on the output
% of the first system <==
[xs,ys,zs] = image_system1(z,3,6);
za         = image_system2(zs,90,-4);

% PLOT RESULT WITH SUBPLOT
figure(1);
subplot(1,3,1);                                         % ==> Creates a subplot for the original image <==
imagesc(x, y, z);                                       % ==> Displays the original z image with specified x and y axes <==
axis square; axis xy;                                   % ==> Sets the aspect ratio to be equal and the y axis to increase up <==
title('Original')                                       % ==> Sets the title of the subplot <==

subplot(1,3,2);                                         % ==> Creates a subplot for the output of image_system1 <==
imagesc(xs, ys, zs);                                    % ==> Displays the processed image zs after applying the changes from image_system1 <==
axis square; axis xy;                                   % ==> Sets the aspect ratio to be equal and the y axis to increase up <==
title('After System 1')

subplot(1,3,3);                                         % ==> Creates a new subplot for image_system2 <==
imagesc(xs, ys, za);                                    % ==> Displays the processed image za after applying the changes from image_system2 <==
axis square; axis xy;                                   % ==> Sets the aspect ratio to be equal and the y axis to increase up <==
title('After System 2')


function [xs, ys, zs] = image_system1(z,Ux,Dy)
%IMAGE_SYSTEM1   ===> This function processes the input image z by sampling and scaling it.
% Inputs:
%   z  - Input image matrix
%   Ux - Upsampling factor in the horizontal direction
%   Dy - Downsampling factor in the vertical direction <===
```

```
% ==> Initializes the output matriz zs with zero restricted based on upscaling and downscaling specifications <==
zs = zeros(ceil(size(z,2)/Dy),ceil(Ux*size(z,1)));

% ==> Create the new vertical axis ys based on Dy <==
ys = 1:ceil(size(z,1)/Dy);
xs = 1:ceil(Ux*size(z,2));                                    % ==> Create the new horizontal axis xs based on the upsampling factor Ux. <==

% ==> Fill the output matrix zs by sampling the input matrix z.
% The input image is downsampled by Dy in the vertical direction and upsampled
% by Ux in the horizontal direction. <==
zs(1:end,1:Ux:end) = z(1:Dy:end,1:end);

end

function [za] = image_system2(z,Sx,Sy)
%IMAGE_SYSTEM2   ===> This function applies a transformation to the input image z.
% Inputs:
%   z  - Input image matrix
%   Sx - Shift in the horizontal direction
%   Sy - Shift in the vertical direction <===

% ====> Initialize the output matrix za with zeros, having the same size as z. <====
za = zeros(size(z,1), size(z,2));

for nn = 1:size(z,1)
        for mm = 1:size(z,2)
                % ====> Check if the current pixel (nn, mm) is within the bounds after shifting. <====
                if nn > Sy && nn-Sy < size(z,1) && mm > Sx && mm-Sx < size(z,2)
                        % ====> Assign the value from the shifted position in z to za, scaled by a factor of 1/2. <====
                        za(nn,mm) = 1/2*z(nn-Sy,mm-Sx);
                end
        end
end


end
```

QUESTION VARIABLES (DO NOT CHANGE)

```
x = 0:1:249;                                                                    % Horiztonal Axis
y = 0:1:249;                                                                    % Vertical Axis

% MAKE SURE 'ai_lines.png' is in the same directory!
z = imread('ai_lines.png'); z = mean(z,3);

% MAKE SURE 'frog.png' is in the same directory!
% UNCOMMENT TO USE "Natural" IMAGE
z = imread('frog.jpg'); z = mean(z,3);
```

2(a) WRITE FUNCTION (SEE END OF FILE)

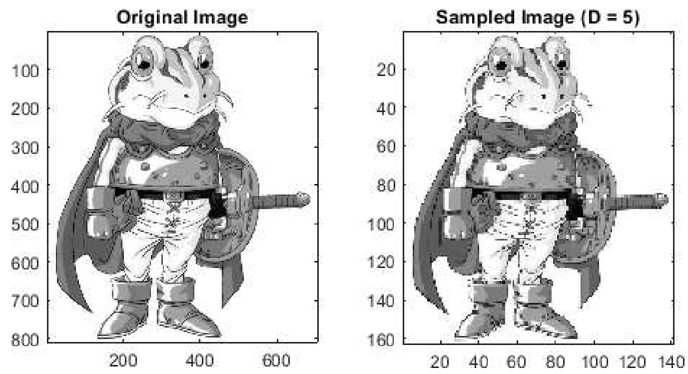
2(b) PEFORM SAMPLING

```
D = 5;
[xs, ys, zs] = sample(z,D);

figure;

subplot(1, 2, 1);
imagesc(z);
colormap(gray);
axis image;
title('Original Image');

subplot(1, 2, 2);
imagesc(zs);
colormap(gray);
axis image;
title(['Sampled Image (D = ', num2str(D), ')']);
```



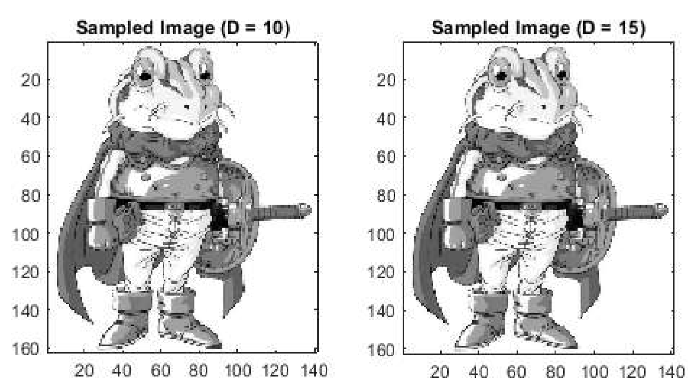
2(c) PEFORM SAMPLING

```
D1 = 10;
[xs1, ys1, zs1] = sample(z,D);

subplot(1, 2, 1);
imagesc(zs1);
colormap(gray);
axis image;
title(['Sampled Image (D = ', num2str(D1), ')']);

D2 = 15;
[xs2, ys2, zs2] = sample(z,D);

subplot(1, 2, 2);
imagesc(zs2);
colormap(gray);
axis image;
title(['Sampled Image (D = ', num2str(D2), ')']);
```



2(d) ANSWER QUESTION

```
% After applying sampling, specific regions of the images may appear to have different frequencies.
% This is often due to the presence of high-frequency components in the original image that are not
% captured when sampling at lower resolutions. For example, fine lines or edges may
% become blurred or lost, leading to a loss of detail and the appearance.
```

2(e) ANSWER QUESTION

```
% When using a natural image, aliasing manifests as unexpected patterns or distortions that were not
% present in the original image. This is because natural images often contain a wide range of frequencies,
% and sampling at too low a resolution can lead to misinterpretation of these frequencies, resulting in
% visual artifacts.
```

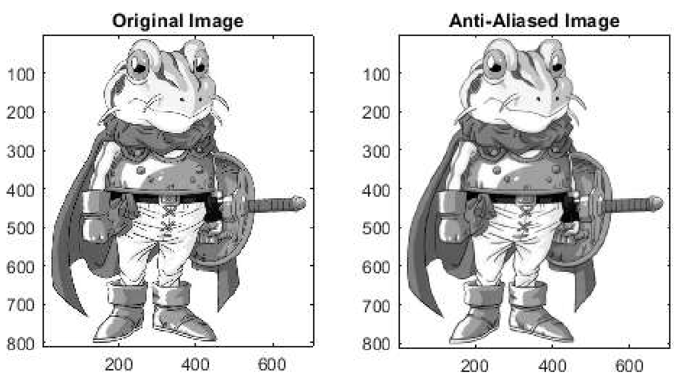
3(a) WRITE FUNCTION

3(b) PERFORM ANTI-ALIASING (NO SAMPLING)

```
zaa = antialias(z);

subplot(1, 2, 1);
imagesc(z);
colormap(gray);
axis image;
title('Original Image');

subplot(1, 2, 2);
imagesc(zaa);
colormap(gray);
axis image;
title('Anti-Aliased Image');
```



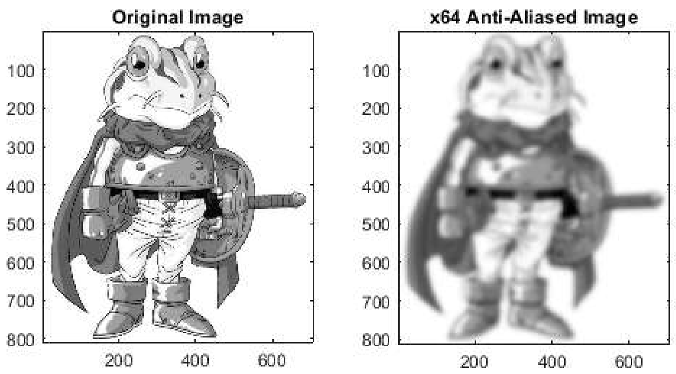
3(c) PERFORM ANTI-ALIASING x64 (NO SAMPLING)

```
z64 = z;

for i = 1:64
    z64 = antialias(z64);
end

subplot(1, 2, 1);
imagesc(z);
colormap(gray);
axis image;
title('Original Image');

subplot(1, 2, 2);
imagesc(z64);
colormap(gray);
axis image;
title('x64 Anti-Aliased Image');
```



3(d) PEFORM ANTI-ALIASING (WITH SAMPLING)

```
[zaas, ~, ~] = sample(zaa, 15);
[z64s, ~, ~] = sample(z64, 15);

subplot(1, 2, 1);
imagesc(zaas);
colormap(gray);
axis image;
title('Sample Anti-Aliased Image');

subplot(1, 2, 2);
imagesc(z64s);
colormap(gray);
axis image;
title('Sample Anti-Aliased Image (64x)');
```

3(e) ANSWER QUESTION

```
% The anti-aliasing filter smooths the image by averaging the pixel values in the neighborhood of each pixel.
% This reduces high-frequency components that can cause aliasing when the image is sampled. In real-world
% applications, this is useful for improving image quality and reducing artifacts in images that will be
% displayed at lower resolutions.
```

3(f) ANSWER QUESTION

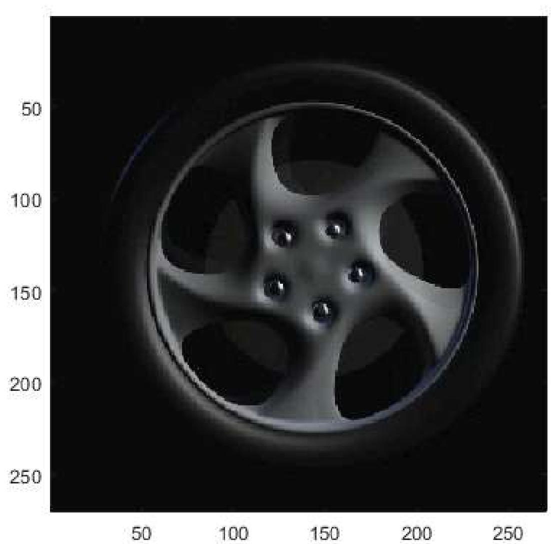
```
% When using a natural image, the anti-aliasing filter helps to reduce the jagged edges and artifacts that
% can occur due to high-frequency details. The effect is more pronounced in natural images, where fine details
% can lead to significant aliasing artifacts when sampled.
```

QUESTION 4 VARIABLES (DO NOT CHANGE)

```
% DO NOT REMOVE THE LINE BELOW
% MAKE SURE 'wheel_video.mp4' is in the same directory!
vid = VideoReader('wheel_video.mp4'); z = read(vid,[1 Inf]);

% The variable z is now a 4 dimensional array, with dimensions 1 and 2 the
% m by n pixels in each color frame. The third dimension is the red,
% green, and blue colors in the image. The fourth dimension represents time

% HERE IS EXAMPLE CODE TO DISPLAY AND SAVE THE VIDEO AS AN MP4
figure(1);
for i = 1:min(size(z, 4),30*4)   % Only show 4 seconds max
    tic; imagesc(uint8(z(:,:,:,i))); axis square; tm = toc;
    pause(1/30-tm);              % Try to sync to 30 frames per second
end
v = VideoWriter('output_video','MPEG-4');
open(v); writeVideo(v,uint8(z)); close(v)
```



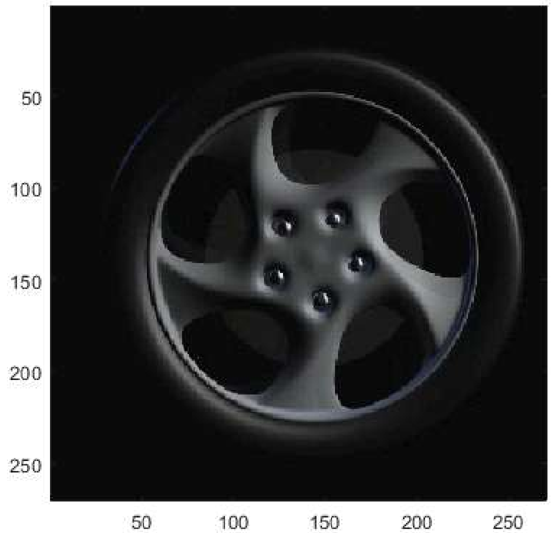
4(a) WRITE FUNCTION

4(b) MAKE SAMPLED VIDEO

```
Dx = 5;
Dy = 3;
Dt = 2;

sampled_video = video_sample(z, Dx, Dy, Dt);

for i = 1:min(size(z, 4),30*4)   % Only show 4 seconds max
    tic; imagesc(uint8(z(:,:,:,i))); axis square; tm = toc;
    pause(1/30-tm);              % Try to sync to 30 frames per second
end
v = VideoWriter('sampled_video','MPEG-4');
open(v); writeVideo(v,uint8(sampled_video)); close(v);
```



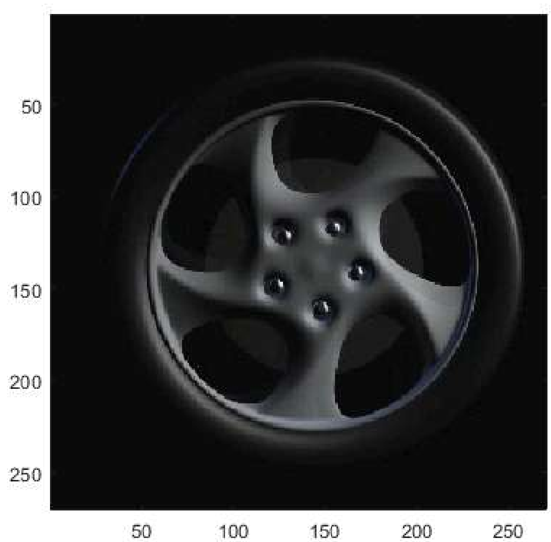
4(c) ANSWER QUESTION

```
% The choice of Dt is based on the frequency of the wheel's rotation. Since the wheel spins at 0.375 Hz,
% and we observe it repeating at 1.875 Hz due to the spokes, we need to sample at a rate that captures
% this motion without introducing aliasing. A sampling rate of 8 frames per second (Dt) is chosen to ensure
% that we capture enough frames to represent the motion without significant distortion.
```

4(d) MAKE SAMPLED VIDEO

```
Dt = 1; % Adjust to make wheel move backwards
backward_video = video_sample(z, Dx, Dy, Dt);

for i = 1:min(size(z, 4),30*4)   % Only show 4 seconds max
    tic; imagesc(uint8(z(:,:,:,i))); axis square; tm = toc;
    pause(1/30-tm);              % Try to sync to 30 frames per second
end
v = VideoWriter('backward_video','MPEG-4');
open(v); writeVideo(v,uint8(backward_video)); close(v);
```



4(e) ANSWER QUESTION

```
% The choice of Dt in this case is to create a backward motion effect. By sampling at a lower frame rate,
% we can create the illusion of the wheel moving in reverse. However, care must be taken to ensure that
% the sampling rate does not introduce aliasing artifacts that could distort the perceived motion.
```

ALL FUNCTIONS SUPPORTING THIS CODE %%

```
function [xs, ys, zs] = sample(z, D)
%SAMPLE   ===> Samples the image z by a factor of D
    % Inputs:
    %   z - High-resolution image
    %   D - Sampling factor
    % Outputs:
    %   xs - New horizontal axis
    %   ys - New vertical axis
    %   zs - Sampled image <===

% ==> Add code here <==
% zs = zeros(ceil(size(z,2)/D),ceil(D*size(z,1)));                     % Initializes output matrix zs with zeros restricted by D
%
% % Create new axes ys and xs based on D
% ys = 1:ceil(size(z,1)/D);
% xs = 1:ceil(D*size(z,2));
%
% % Fill matrix by sampling input matrix z
% zs(1:end,1:D:end) = z(1:D:end,1:end);

% SAMPLE: Samples the image z by a factor of D
    zs = z(1:D:end, 1:D:end); % Sample every D pixels
    [rows, cols] = size(zs);
    xs = 0:D:(cols-1); % New horizontal axis
    ys = 0:D:(rows-1); % New vertical axis

end

function zaa = antialias(z)
%ANTIALIAS   ===> Applies a simple averaging filter to the image z
    % Input:
    %   z - High-resolution image
    % Output:
    %   zaa - Anti-aliased image <===

% ==> Add code here <==
% Initialize output matrix with zeroes same size as z
% zaa = zeros(size(z,1), size(z,2));
% [row, col] = size(zaa);
%
% for x = 1:size(z,1)
%       for y = 1:size(z,2)
%         zaa(x, y) = (1/9) * (z(x-1, y-1) + z(x-1, y) + z(x-1, y+1) + ...
%                                 z(x, y-1) + z(x, y) + z(x, y+1) + ...
%                                 z(x+1, y-1) + z(x+1, y) + z(x+1, y+1));
%
%         % ====> Check if the current pixel (nn, mm) is within the bounds after shifting. <====
%               if x > col && x-col < size(z,1) && y > row && y-row < size(z,2)
%                       % ====> Assign the value from the shifted position in z to za, scaled by a factor of 1/2. <====
%             zaa(x,y) = 1/2*z(x-row,y-col);
%         end
%       end
% end

[rows, cols] = size(z);
    zaa = zeros(rows, cols);

    for x = 2:rows-1
        for y = 2:cols-1
            zaa(x, y) = (1/9) * (z(x-1, y-1) + z(x-1, y) + z(x-1, y+1) + ...
                                 z(x, y-1) + z(x, y) + z(x, y+1) + ...
                                 z(x+1, y-1) + z(x+1, y) + z(x+1, y+1));
        end
    end
    zaa(1, :) = z(1, :); % Copy the first row
    zaa(end, :) = z(end, :); % Copy the last row
    zaa(:, 1) = z(:, 1); % Copy the first column
    zaa(:, end) = z(:, end); % Copy the last column

end

function zs = video_sample(z, Dx, Dy, Dt)
%VIDEO_SAMPLE   ===> Samples the video x in space and time
    % Inputs:
    %   x - Input video
    %   Dx - Horizontal sampling factor
    %   Dy - Vertical sampling factor
    %   Dt - Temporal sampling factor
```

```
    % Output:
    %   z - Sampled video <===

% ==> Add code here <==

zs = z(1:Dy:end, 1:Dx:end, :, 1:Dt:end); % Sample in space and in time

end
```

Published with MATLAB® R2024a