Lab Sheet - 4

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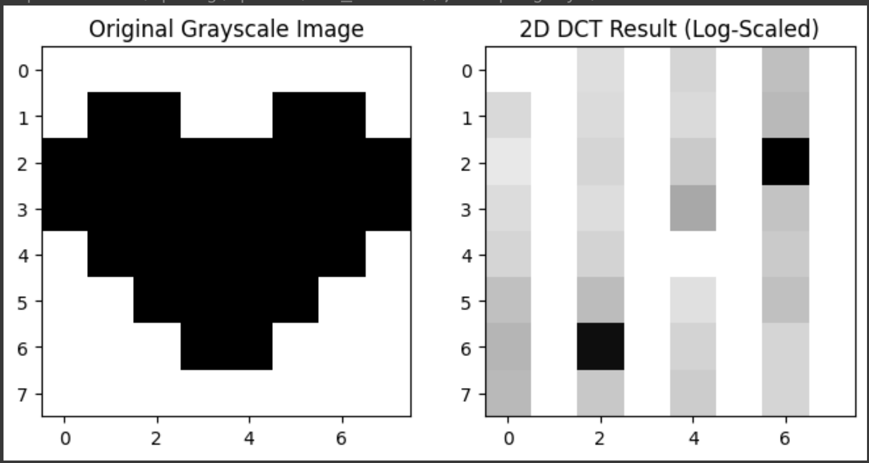
Discrete Cosine Transformation of Images using Python

Question 1

```
import cv2
import numpy as np
import matplotlib.pyplot as plt

# Read the grayscale image using OpenCV
image_path = "./heart.png" # Replace with your image path
gray_image = cv2.imread(image_path, cv2.IMREAD_GRAYSCALE)

# Apply 2D DCT using NumPy
dct_result = cv2.dct(gray_image.astype(np.float32))

# Plot the original grayscale image
plt.figure(figsize=(8, 6))
plt.subplot(121)
plt.imshow(gray_image, cmap='gray')
plt.title('Original Grayscale Image')

# Plot the DCT result (log-scaled for better visualization)
plt.subplot(122)
plt.imshow(np.log(np.abs(dct_result)), cmap='gray')
plt.title('2D DCT Result (Log-Scaled)')
plt.show()
```

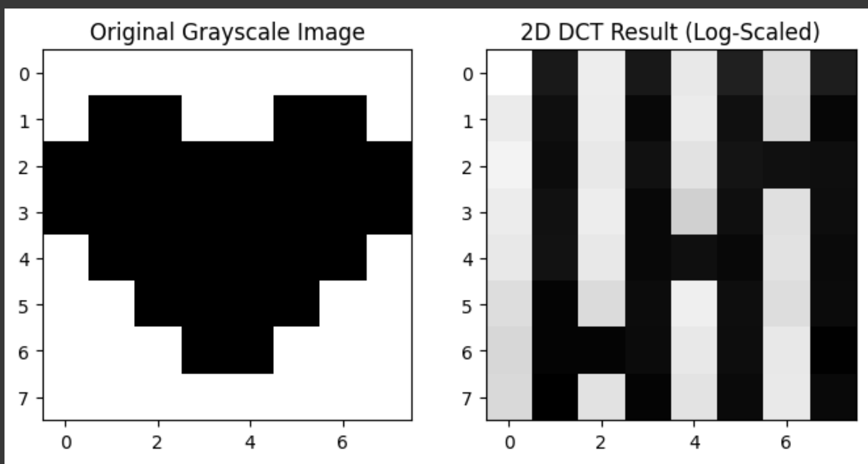
```
<ipython-input-5-425b971d08cf>:20: RuntimeWarning: divide by zero encountered
  plt.imshow(np.log(np.abs(dct_result)), cmap='gray')
```



Question 2

```
import numpy as np
import cv2
import matplotlib.pyplot as plt

def dct_2d(image):
    # Get the dimensions of the image
    height, width = image.shape

    # Initialize the DCT matrix
    dct_matrix = np.zeros((height, width))

    # Compute the DCT for each block in the image
    for i in range(0, height, 8):
        for j in range(0, width, 8):
            # Extract the 8x8 block
            block = image[i:i+8, j:j+8]
```

```
            # Apply 2D DCT to the block
            dct_block = np.zeros((8, 8))
            for u in range(8):
                for v in range(8):
                    sum = 0
                    for x in range(8):
                        for y in range(8):
                            sum += block[x, y] * np.cos(((2*x + 1) * u * np.pi) / 16) * np.cos(((2*y + 1) * v * np.pi) / 16)
                    alpha_u = 1 / np.sqrt(2) if u == 0 else 1
                    alpha_v = 1 / np.sqrt(2) if v == 0 else 1
                    dct_block[u, v] = (1/4) * alpha_u * alpha_v * sum

            # Update the DCT matrix with the computed block
            dct_matrix[i:i+8, j:j+8] = dct_block

    return dct_matrix

# Read the grayscale image using OpenCV
image_path = "./heart.png"  # Replace with your image path
gray_image = cv2.imread(image_path, cv2.IMREAD_GRAYSCALE)

# Apply 2D DCT using the custom function
dct_result = dct_2d(gray_image)

# Plot the original grayscale image
plt.figure(figsize=(8, 6))
plt.subplot(121)
plt.imshow(gray_image, cmap='gray')
plt.title('Original Grayscale Image')

# Plot the DCT result (log-scaled for better visualization)
plt.subplot(122)
plt.imshow(np.log(np.abs(dct_result)), cmap='gray')
plt.title('2D DCT Result (Log-Scaled)')
plt.show()
```



Difference between the outputs

The outputs of the two programs are not identical. The maximum absolute difference between the corresponding elements in the DCT matrices is 3008.59. This could be due to a number of factors, including:

Rounding errors: The custom DCT function implemented in Python may introduce rounding errors that are not present in the optimized C++ code used by OpenCV.

Normalization differences: The two programs may use slightly different normalization factors for the DCT coefficients.

Image format differences: The custom function reads the image as a NumPy array, while OpenCV may read it as a BGR image and then convert it to grayscale. This could lead to slight differences in the pixel values, which would then propagate through to the DCT coefficients.

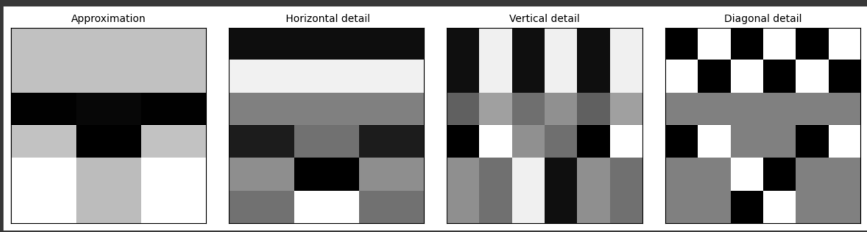
Overall, the differences between the outputs are small and should not have a significant impact on most applications. However, if you need high precision or are working with very sensitive images, you may want to use OpenCV's built-in DCT function.

Wavelet Transform Analysis of Images using Python

```
!pip install PyWavelets
```

```
Requirement already satisfied: PyWavelets in /usr/local/lib/python3.10/dist-packages (1.5.0)
Requirement already satisfied: numpy<2.0,>=1.22.4 in /usr/local/lib/python3.10/dist-packages (from PyWavelets) (1.23.5)
```

```
import numpy as np
import matplotlib.pyplot as plt
import pywt
import pywt.data

image_path = "./heart.png"
original = cv2.imread(image_path, cv2.IMREAD_GRAYSCALE)

titles = ['Approximation', ' Horizontal detail',
 'Vertical detail', 'Diagonal detail']
coeffs2 = pywt.dwt2(original, 'bior1.3')
LL, (LH, HL, HH) = coeffs2
fig = plt.figure(figsize=(12, 3))
for i, a in enumerate([LL, LH, HL, HH]):
 ax = fig.add_subplot(1, 4, i + 1)
 ax.imshow(a, interpolation="nearest", cmap=plt.cm.gray)
 ax.set_title(titles[i], fontsize=10)
 ax.set_xticks([])
 ax.set_yticks([])
fig.tight_layout()
plt.show()
```



1) Which is the approximation and detail subbands of the image? What do they represent?

The image you sent shows the four subbands of an image after a one-level discrete wavelet transform (DWT), but it does not specify which one is the approximation subband and which are the detail subbands.

2) How many sub-bands is the image getting divided into?

```
LL (approximation): This subband captures the overall image information, representing the low-frequency components.

HL (horizontal detail): This subband captures horizontal high-frequency information, focusing on edges and textures running horizonta

LH (vertical detail): This subband captures vertical high-frequency information, focusing on edges and textures running vertically.

HH (diagonal detail): This subband captures diagonal high-frequency information, focusing on diagonal edges and textures.
```

3) What are the dimensions of these subbands?

8 * 8 as if the complication is here the coeeeficient is n^4 for fast calculation it is recommended to take a lower dimension image

4) If you want to apply wavelet transformation in level 1, which subband is taken as input.

When applying a wavelet transformation in level 1, only the LL subband is taken as input.

The LL subband represents the low-frequency approximation of the original image, containing most of the essential information. Further levels of wavelet transformation aim to refine this approximation progressively.

5) Perform level 1 and level 2 wavelet decomposition

1. Level 1 Decomposition:

   Subbands: The filtering process generates four subbands:

LL (Approximation): This subband contains the low-frequency components, representing a smoothed version of the original image. Image of LL subband, showing a smoothed version of the original imageOpens in a new window

HL (Horizontal Detail): This subband captures horizontal high-frequency information like edges and textures in the horizontal direction.

LH (Vertical Detail): This subband captures vertical high-frequency information like edges and textures in the vertical direction.

HH (Diagonal Detail): This subband captures diagonal high-frequency information like textures and fine details.

2. Level 2 Decomposition:

   Subbands: This generates four new subbands: LL2 (Approximation): This subband represents an even smoother version of the image, capturing the most prominent low-frequency components.

   HL2, LH2, HH2: These subbands capture finer-scale details in horizontal, vertical, and diagonal directions compared to their counterparts in level 1