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Stream : DS(Sem-7)

Roll no: 02

1. Implement functions for encoding and decoding an image using the following methods:

A. Transform Coding (using DCT for forward transform)

B. Huffman Encoding

C. LZW Encoding

D. Run-Length Encoding

E. Arithmetic Coding

1.Transform Coding (Using DCT)

In [8]:
```
!pip install pillow
```

```
Requirement already satisfied: pillow in c:\users\harib\anaconda3\lib\site-packages (10.3.0)
```

In [1]:
```
import numpy as np
from scipy.fftpack import dct, idct
from PIL import Image
import matplotlib.pyplot as plt
import os
import random
```

In [2]:
```
# Function to perform DCT encoding on an image
def dct_encode(image_array):
    # Apply 2D DCT to the entire image
    dct_image = dct(dct(image_array.T, norm='ortho').T, norm='ortho')
    return dct_image

# Function to perform inverse DCT decoding to reconstruct the image
def dct_decode(dct_image):
    # Apply Inverse 2D DCT to reconstruct the image
    return idct(idct(dct_image.T, norm='ortho').T, norm='ortho')
```

In [3]:
```
def calculate_compression_ratio(original, compressed):
    original_size = original.size * 8  # size in bits (assuming 8 bits per pixel)
    compressed_size = np.count_nonzero(compressed) * 8  # size in bits
    return original_size / compressed_size

def calculate_rmse(original, reconstructed):
    return np.sqrt(np.mean((original - reconstructed) ** 2))
```

In [4]:
```
# Path to your image directory
image_folder = 'D:\\sem-7\\Random\\'

# List all files in the directory
all_images = [file for file in os.listdir(image_folder) if file.endswith(('.png', '.jpg', '.jpeg'))]

# Randomly select an image file
random_image_path = os.path.join(image_folder, random.choice(all_images))

# Open and convert the image to grayscale
image = Image.open(random_image_path).convert('L')
```

In [5]:
```
# Load the image and convert to a grayscale numpy array
#image = Image.open('Abc12').convert('L')  # 'L' converts the image to grayscale
image_array = np.array(image)

# Perform DCT encoding and decoding
dct_encoded = dct_encode(image_array)
dct_reconstructed = dct_decode(dct_encoded)
```

```
# Clip values to be in the 0-255 range and convert to uint8
reconstructed_image_array = np.uint8(np.clip(dct_reconstructed, 0, 255))
```

In [6]:
```
# Calculate Compression Ratio
compression_ratio = calculate_compression_ratio(image_array, dct_encoded)
print(f"Compression Ratio: {compression_ratio:.2f}")

# Calculate RMSE
rmse = calculate_rmse(image_array, reconstructed_image_array)
print(f"Root Mean Square Error (RMSE): {rmse:.2f}")
```

```
Compression Ratio: 1.00
Root Mean Square Error (RMSE): 0.59
```

In [7]:
```
plt.figure(figsize=(10, 5))

# Display the original image
plt.subplot(1, 2, 1)
plt.imshow(image_array, cmap='gray')
plt.title("Original Image")
plt.axis('off')

# Display the reconstructed image
plt.subplot(1, 2, 2)
plt.imshow(reconstructed_image_array, cmap='gray')
plt.title("Reconstructed Image")
plt.axis('off')

plt.show()
```

Original Image

Reconstructed Image

2. Huffman Encoding for Image Compression

In [8]:
```
import numpy as np
from PIL import Image
import matplotlib.pyplot as plt
import heapq
from collections import defaultdict
```

In [9]:
```
class HuffmanNode:
    def __init__(self, symbol, freq):
        self.symbol = symbol
        self.freq = freq
        self.left = None
        self.right = None

    def __lt__(self, other):
        return self.freq < other.freq
```

In [10]:
```
def build_huffman_tree(frequencies):
    heap = [HuffmanNode(symbol, freq) for symbol, freq in frequencies.items()]
    heapq.heapify(heap)
    while len(heap) > 1:
        node1 = heapq.heappop(heap)
        node2 = heapq.heappop(heap)
        merged = HuffmanNode(None, node1.freq + node2.freq)
        merged.left = node1
        merged.right = node2
        heapq.heappush(heap, merged)
    return heap[0]
```

In [11]:
```
def generate_codes(node, code="", codebook=None):
    if codebook is None:
        codebook = {}
    if node is not None:
        if node.symbol is not None:
            codebook[node.symbol] = code
        generate_codes(node.left, code + "0", codebook)
        generate_codes(node.right, code + "1", codebook)
    return codebook
```

In [12]:
```python
# Function to perform Huffman Encoding
def huffman_encode(image_array):
    # Calculate symbol frequencies
    frequencies = defaultdict(int)
    for value in image_array.flatten():
        frequencies[value] += 1

    # Build Huffman Tree and generate codes
    huffman_tree = build_huffman_tree(frequencies)
    huffman_codes = generate_codes(huffman_tree)

    # Encode the image
    encoded_image = "".join(huffman_codes[value] for value in image_array.flatten())
    return encoded_image, huffman_codes, len(image_array.flatten()) * 8
```

In [13]:
```python
# Function to decode Huffman Encoded image
def huffman_decode(encoded_image, huffman_codes, original_shape):
    reverse_codes = {v: k for k, v in huffman_codes.items()}
    current_code = ""
    decoded_values = []

    for bit in encoded_image:
        current_code += bit
        if current_code in reverse_codes:
            decoded_values.append(reverse_codes[current_code])
            current_code = ""

    return np.array(decoded_values).reshape(original_shape)
```

In [14]:
```python
# Function to calculate Compression Ratio
def calculate_compression_ratio_huffman(original_bits, encoded_bits):
    return original_bits / len(encoded_bits)
```

In [15]:
```python
# Path to your image directory
image_folder = 'D:\\sem-7\\Random\\'

# List all files in the directory
all_images = [file for file in os.listdir(image_folder) if file.endswith(('.png', '.jpg', '.jpeg'))]

# Randomly select an image file
random_image_path = os.path.join(image_folder, random.choice(all_images))

# Open and convert the image to grayscale
image = Image.open(random_image_path).convert('L')
image_array = np.array(image)

# Perform Huffman Encoding and Decoding
encoded_image, huffman_codes, original_bits = huffman_encode(image_array)
decoded_image_array = huffman_decode(encoded_image, huffman_codes, image_array.shape)
```

In [16]:
```python
# Calculate Compression Ratio
compression_ratio = calculate_compression_ratio_huffman(original_bits, encoded_image)
print(f"Compression Ratio: {compression_ratio:.2f}")

# Calculate RMSE
rmse = np.sqrt(np.mean((image_array - decoded_image_array) ** 2))
print(f"Root Mean Square Error (RMSE): {rmse:.2f}")
```

```
Compression Ratio: 1.02
Root Mean Square Error (RMSE): 0.00
```

In [17]:
```python
plt.figure(figsize=(10, 5))

# Display the original image
plt.subplot(1, 2, 1)
plt.imshow(image_array, cmap='gray')
plt.title("Original Image")
plt.axis('off')

# Display the decoded image
plt.subplot(1, 2, 2)
plt.imshow(decoded_image_array, cmap='gray')
plt.title("Decoded Image (Huffman)")
plt.axis('off')

plt.show()
```

Original Image

Decoded Image (Huffman)

3. LZW Encoding for Image Compression

In [18]:

```python
import numpy as np
from PIL import Image
import matplotlib.pyplot as plt
```

In [19]:

```python
def lzw_encode(image_array):
    data = image_array.flatten()
    dictionary = {tuple([i]): i for i in range(256)}  # Initialize dictionary with single pixel values
    current_sequence = []
    encoded_data = []
    code = 256  # Next available code for new sequences

    for symbol in data:
        current_sequence.append(symbol)
        if tuple(current_sequence) not in dictionary:
            dictionary[tuple(current_sequence)] = code
            encoded_data.append(dictionary[tuple(current_sequence[:-1])])
            current_sequence = [symbol]  # Start new sequence
            code += 1

    # Encode the last sequence
    if current_sequence:
        encoded_data.append(dictionary[tuple(current_sequence)])

    original_bits = len(data) * 8  # Assuming 8 bits per pixel
    return encoded_data, dictionary, original_bits
```

In [20]:

```python
def lzw_decode(encoded_data, dictionary):
    reverse_dictionary = {v: k for k, v in dictionary.items()}
    current_sequence = list(reverse_dictionary[encoded_data[0]])
    decoded_data = current_sequence.copy()

    for code in encoded_data[1:]:
        if code in reverse_dictionary:
            entry = list(reverse_dictionary[code])
        elif code == len(reverse_dictionary):
            entry = current_sequence + [current_sequence[0]]
        else:
            raise ValueError("Invalid LZW code encountered")

        decoded_data.extend(entry)
        current_sequence.append(entry[0])
        reverse_dictionary[len(reverse_dictionary)] = current_sequence
        current_sequence = entry

    return np.array(decoded_data)
```

In [21]:

```python
# Path to your image directory
image_folder = 'D:\\sem-7\\Random\\'

# List all files in the directory
all_images = [file for file in os.listdir(image_folder) if file.endswith(('.png', '.jpg', '.jpeg'))]

# Randomly select an image file
random_image_path = os.path.join(image_folder, random.choice(all_images))

# Open and convert the image to grayscale
image = Image.open(random_image_path).convert('L')
image_array = np.array(image)

# Perform LZW Encoding and Decoding
encoded_data, dictionary, original_bits = lzw_encode(image_array)
decoded_image_array = lzw_decode(encoded_data, dictionary).reshape(image_array.shape)
```

In [22]:

```python
# Calculate Compression Ratio
compressed_size = len(encoded_data) * 16  # Assuming 16 bits per encoded symbol
compression_ratio = original_bits / compressed_size
print(f"Compression Ratio: {compression_ratio:.2f}")
```

```python
# Calculate RMSE
rmse = np.sqrt(np.mean((image_array - decoded_image_array) ** 2))
print(f"Root Mean Square Error (RMSE): {rmse:.2f}")
```

```
Compression Ratio: 1.15
Root Mean Square Error (RMSE): 0.00
```

In [23]:
```python
plt.figure(figsize=(10, 5))

# Display the original image
plt.subplot(1, 2, 1)
plt.imshow(image_array, cmap='gray')
plt.title("Original Image")
plt.axis('off')

# Display the decoded image
plt.subplot(1, 2, 2)
plt.imshow(decoded_image_array, cmap='gray')
plt.title("Decoded Image (LZW)")
plt.axis('off')

plt.show()
```

4. Run-Length Encoding (RLE) for Image Compression

In [24]:
```python
import numpy as np
from PIL import Image
import matplotlib.pyplot as plt
```

In [25]:
```python
def rle_encode(image_array):
    data = image_array.flatten()
    encoded_data = []
    count = 1

    for i in range(1, len(data)):
        if data[i] == data[i - 1]:
            count += 1
        else:
            encoded_data.append((data[i - 1], count))
            count = 1

    # Append the last run
    encoded_data.append((data[-1], count))

    original_bits = len(data) * 8  # Assuming 8 bits per pixel
    return encoded_data, original_bits
```

In [26]:
```python
def rle_decode(encoded_data, shape):
    decoded_data = []
    for value, count in encoded_data:
        decoded_data.extend([value] * count)
    return np.array(decoded_data).reshape(shape)
```

In [27]:
```python
def calculate_compression_ratio_rle(original_bits, encoded_data):
    compressed_size = len(encoded_data) * (8 + 8)  # 8 bits for value and 8 bits for count
    return original_bits / compressed_size
```

In [28]:
```python
# Path to your image directory
image_folder = 'D:\\sem-7\\Random\\'

# List all files in the directory
all_images = [file for file in os.listdir(image_folder) if file.endswith(('.png', '.jpg', '.jpeg'))]

# Randomly select an image file
random_image_path = os.path.join(image_folder, random.choice(all_images))

# Open and convert the image to grayscale
image = Image.open(random_image_path).convert('L')
image_array = np.array(image)
```

```
# Perform Run-Length Encoding and Decoding
encoded_data, original_bits = rle_encode(image_array)
decoded_image_array = rle_decode(encoded_data, image_array.shape)
```

In [29]:
```
compression_ratio = calculate_compression_ratio_rle(original_bits, encoded_data)
print(f"Compression Ratio: {compression_ratio:.2f}")


rmse = np.sqrt(np.mean((image_array - decoded_image_array) ** 2))
print(f"Root Mean Square Error (RMSE): {rmse:.2f}")
```

```
Compression Ratio: 0.69
Root Mean Square Error (RMSE): 0.00
```

In [30]:
```
plt.figure(figsize=(10, 5))

# Display the original image
plt.subplot(1, 2, 1)
plt.imshow(image_array, cmap='gray')
plt.title("Original Image")
plt.axis('off')

# Display the decoded image
plt.subplot(1, 2, 2)
plt.imshow(decoded_image_array, cmap='gray')
plt.title("Decoded Image (RLE)")
plt.axis('off')

plt.show()
```

5. Arithmetic Coding for Image Compression

In [31]:
```
import numpy as np
import os
import random
from PIL import Image
import matplotlib.pyplot as plt
```

In [32]:
```
def rle_encode(image_array):
    data = image_array.flatten()
    encoded_data = []
    count = 1

    for i in range(1, len(data)):
        if data[i] == data[i - 1]:
            count += 1
        else:
            encoded_data.append((data[i - 1], count))
            count = 1

    # Append the last run
    encoded_data.append((data[-1], count))

    original_bits = len(data) * 8  # Assuming 8 bits per pixel
    return encoded_data, original_bits
```

In [33]:
```
def rle_decode(encoded_data, shape):
    decoded_data = []
    for value, count in encoded_data:
        decoded_data.extend([value] * count)
    return np.array(decoded_data).reshape(shape)
```

In [34]:
```
def calculate_compression_ratio_rle(original_bits, encoded_data):
    compressed_size = len(encoded_data) * (8 + 8)  # 8 bits for value and 8 bits for count
    return original_bits / compressed_size
```

In [35]:
```
# Path to your image directory
image_folder = 'D:/sem-7/Random/'
```

```python
# List all files in the directory
all_images = [file for file in os.listdir(image_folder) if file.endswith(('.png', '.jpg', '.jpeg'))]

# Randomly select an image file
random_image_path = os.path.join(image_folder, random.choice(all_images))

# Open and convert the image to grayscale
image = Image.open(random_image_path).convert('L')
image_array = np.array(image)

# Perform Run-Length Encoding
encoded_data, original_bits = rle_encode(image_array)
```

In [36]:
```python
# Decode the image using RLE
decoded_image_array = rle_decode(encoded_data, image_array.shape)
```

In [37]:
```python
# Calculate Compression Ratio and RMSE
compression_ratio = calculate_compression_ratio_rle(original_bits, encoded_data)
print(f"Compression Ratio: {compression_ratio:.2f}")

# Calculate RMSE
rmse = np.sqrt(np.mean((image_array - decoded_image_array) ** 2))
print(f"Root Mean Square Error (RMSE): {rmse:.2f}")
```

```
Compression Ratio: 0.69
Root Mean Square Error (RMSE): 0.00
```

In [38]:
```python
# Display the original and decoded images
plt.figure(figsize=(10, 5))

# Display the original image
plt.subplot(1, 2, 1)
plt.imshow(image_array, cmap='gray')
plt.title("Original Image")
plt.axis('off')

# Display the decoded image
plt.subplot(1, 2, 2)
plt.imshow(decoded_image_array, cmap='gray')
plt.title("Decoded Image (RLE)")
plt.axis('off')

plt.show()
```