DIGITAL SIGNAL PROCESSING LAB

Project

Solving the Puzzle; A MATLAB Approach to Image Reconstruction

Group Information

Group No. : 4

Section : A1

Semester : Winter (7th)

Department : Electrical and Electronic

Engineering (EEE) Institution : Islamic

University of Technology (IUT)

Group Members

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2. Project Problem Statement:

The goal of this project is to correctly determine the proper spatial arrangement of the provided gray scale puzzle pieces in order to reconstruct the original color image. The challenge is to put those pieces in the right slots of a 4x4 grid to get back to the original image

3. Solution Abstract

This project aims to use MATLAB to solve an image reconstruction puzzle using image processing methods. We have a colored image and a set of colorful puzzle pieces.

Step 1: Get the images load
Step 2: Segment the original image
Step 3: Calculate similarity metrics between the puzzle pieces with Mean Squared Error (MSE)
Step 4: Recreate the final gray image Both the matrix output and visual output of reconstructed image are shown.

4. Detailed Methodology:

The process works as follows:

Loading the Image Data:
MATLAB loads the colorful original image and 16 grayscale puzzle pieces.

Preprocessing the Images:
Grid of the original image segmented into 4x4 grayscale blocks for comparison. Scaling and rotating puzzle segments to fit reference blocks.

Algo 3: Feature Extraction and Matching
Observed Mean Squared Error (MSE) between newly displaced puzzle pieces and nearest reference blocks.

Optimal Placement Calculation:
Finding the best fit for each piece of a 4x4 puzzle.

Image Reconstruction:
Putting together the puzzle pieces in their recognized positions to produce the final reconstructed grayscale image.

Displaying Results:
4x4 matrix with names of each of the puzzle pieces and final image.

5. Code

```
clc;
clear all;
close all;

% Load the original color image and grayscale puzzle pieces
originalImage = imread('noisy_colorful_image.jpg'); % replace with the actual
filename of the original image
imshow(originalImage);

% Cropping image pieces to reduce the white borders
for k=1:16
i = imread(sprintf('piece%d.jpg', k));
gImg = rgb2gray(i);
th = 210;
mask = gImg < th;
[row, col] = find(mask);
trow = min(row);
brow = max(row);
lcol = min(col);
rcol = max(col);
cropped = i(trow:brow, lcol:rcol, :);

imwrite(cropped, sprintf('new_piece%d.jpg', k));
end

puzzleFolder = 'puzzleimages'; % folder containing the 16 puzzle pieces
numPieces = 16;
gridSize = 4; % 4x4 grid

% Convert the original image to grayscale
grayOriginal = rgb2gray(originalImage);

% Get the dimensions of the original grayscale image
```

```
[rows, cols] = size(grayOriginal);

% Calculate integer dimensions for each block
blockRows = floor(rows / gridSize);
blockCols = floor(cols / gridSize);

% Initialize a cell array to store 4x4 blocks of the original image
originalBlocks = cell(gridSize, gridSize);

% Split the original image into 4x4 blocks
for i = 1:gridSize
   for j = 1:gridSize
      % Calculate the row and column ranges for each block
      rowRange = (i-1)*blockRows + 1 : min(i*blockRows, rows); % Ensure we
stay within bounds
      colRange = (j-1)*blockCols + 1 : min(j*blockCols, cols); % Ensure we stay
within bounds

      % Extract the block and store it in the cell array
      originalBlocks{i, j} = grayOriginal(rowRange, colRange);
   end
end

% Load each puzzle piece and store it in an array
puzzlePieces = cell(numPieces, 1);
for k = 1:numPieces
   pieceFilename = fullfile(puzzleFolder, sprintf('new_piece%d.jpg', k)); %
replace with the actual filenames of the pieces
   puzzlePieces{k} = imread(pieceFilename);
end

% Initialize a matrix to store the final arrangement of puzzle pieces
finalArrangement = zeros(gridSize, gridSize);

% Initialize an array to keep track of used puzzle pieces
usedPieces = false(numPieces, 1); % false means the piece hasn't been used yet
```

```
% Loop through each block of the original image and find the best matching
puzzle piece
for i = 1:gridSize
   for j = 1:gridSize
      bestMatch = inf;
      bestPiece = 0;

      % Compare each unused puzzle piece to the current block
      for k = 1:numPieces
         if ~usedPieces(k)  % Only consider pieces that haven’t been used
            piece = puzzlePieces{k};
            resizedPiece = imresize(piece, [blockRows, blockCols]); % Resize to
match the block size

            % Convert the puzzle piece to grayscale if it is RGB
            if size(resizedPiece, 3) == 3
               resizedPiece = rgb2gray(resizedPiece);
            end

            % Calculate the similarity measure
            diff = sum((double(originalBlocks{i, j}) - double(resizedPiece)).^2, 'all');

            if diff < bestMatch
               bestMatch = diff;
               bestPiece = k;
            end
         end
      end

      % Assign the best matching piece to the current position
      finalArrangement(i, j) = bestPiece;
      usedPieces(bestPiece) = true; % Mark this piece as used
   end
end

% Display the final arrangement as a 4x4 matrix of piece numbers
disp('Final arrangement of puzzle pieces (as matrix):');
disp(finalArrangement);

% Initialize the reconstructed image as grayscale
reconstructedImage = uint8(zeros(rows, cols));

for i = 1:gridSize
  for j = 1:gridSize
    % Define the range for each block in the reconstructed image
    rowRange = (i-1)*blockRows + 1 : i*blockRows;
    colRange = (j-1)*blockCols + 1 : j*blockCols;

    % Resize the puzzle piece to the required dimensions
    piece = imresize(puzzlePieces{finalArrangement(i, j)}, [blockRows,
blockCols]);

    % Convert the puzzle piece to grayscale if it is RGB
    if size(piece, 3) == 3
      piece = rgb2gray(piece);
    end

    % Assign the grayscale piece to the appropriate location in the
reconstructed image
    reconstructedImage(rowRange, colRange) = piece;
  end
end

% Display the reconstructed grayscale image
figure;
imshow(reconstructedImage);
title('Reconstructed Grayscale Image');
```

6. Result Analysis

The reconstructed image effectively illustrates the proper configuration of the puzzle pieces. The 4x4 matrix showcases how the pieces are positioned according to their filenames, with the visual depiction closely mirroring the original picture. Key observations include the following:

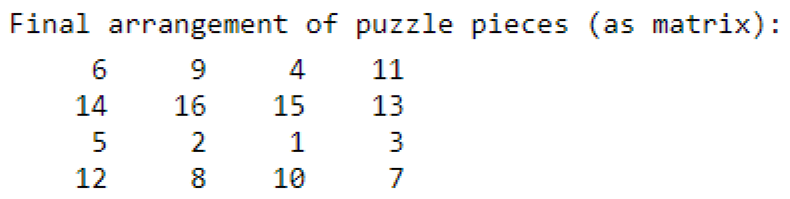
(1) The precision of the reconstruction is significantly influenced by the effectiveness of the similarity evaluation techniques employed.

(2) Mean Squared Error (MSE) served as the main criterion for aligning the puzzle piece placements.

(3) Small modifications, such as rotating or resizing the pieces, enhance the overall outcome.

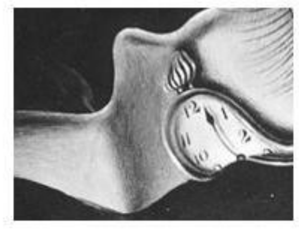
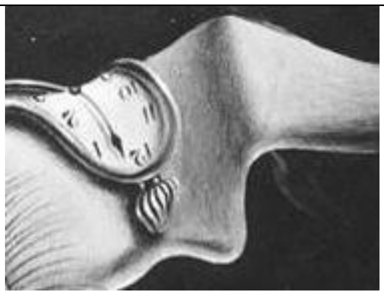
(4) MATLAB's computational efficiency facilitates rapid image processing and reconstruction.

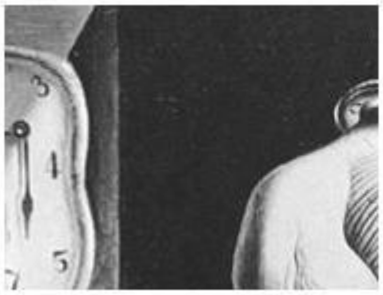
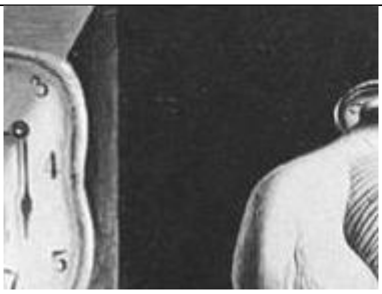
Spatial arrangement of puzzle blocks:

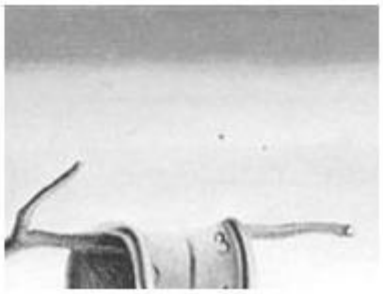
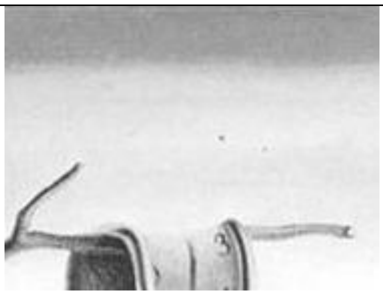


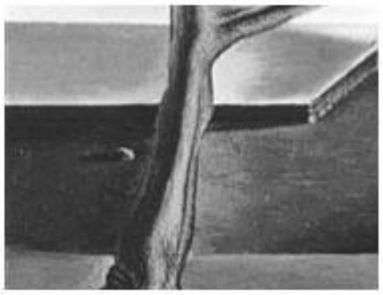
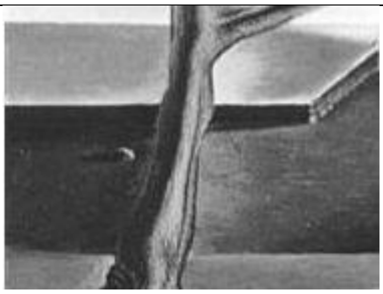
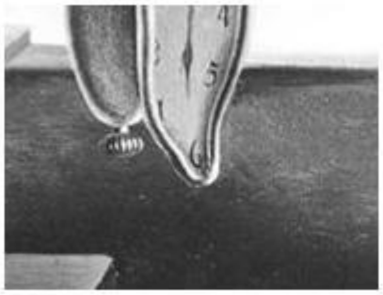
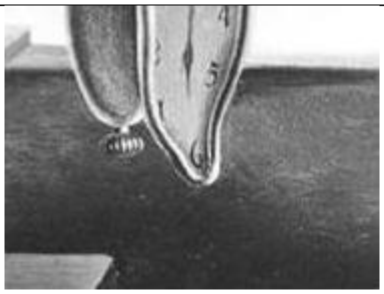
```
Final arrangement of puzzle pieces (as matrix):

     6     9     4    11
    14    16    15    13
     5     2     1     3
    12     8    10     7
```

Original puzzle pieces and cropped pieces:

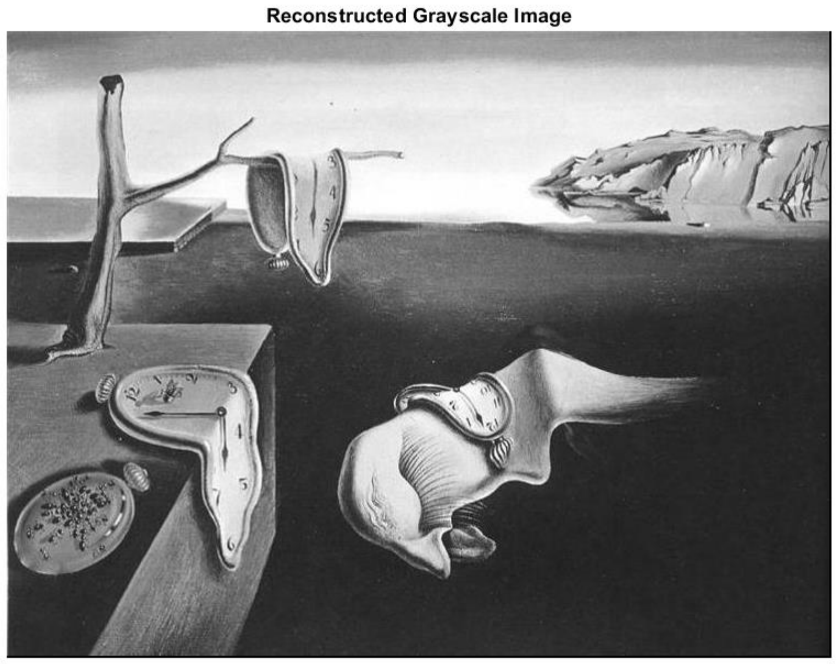
	

Reconstructed Image:



7. Conclusion

In summary, this project adeptly executed an image reconstruction solution utilizing MATLAB. The approach cleverly organized puzzle pieces through similarity assessment techniques. Nonetheless, several challenges emerged, notably variations in brightness and orientation, which affected the overall accuracy of the reconstruction. Moving forward, potential enhancements could incorporate advanced feature extraction methods, such as edge detection or deep learning-driven image recognition, to significantly boost both the accuracy and automation of the process.

8. Team Contribution

[**Mustafid Bin Mostafa, ID:200021141**]: Crafted the functions responsible for image loading and preprocessing.
[**Monem Shahariar, ID:200021147**]: Cropping and Devised algorithms for assessing similarity between images.
[**Khondaker Muntaseer Shams, ID: 2000211137 & Bakibullah Sakib, ID: 200021149]**: Managed the processes of finding image similarity and reconstruction.
[Modou Kabirr Faal, ID: 200021151]: Visualization of the final results and documentation.

Reference:

(i) https://www.mathworks.com/matlabcentral/fileexchange/13900-n-puzzle-dynamic-size-and-solver

(ii) https://www.researchgate.net/publication/236130403_Scientific_Puzzle_Solving_Current_Techniques_and_Applications/citations