Feature Extraction and Segmentation of Images

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I. Abstract

This project explores the development of a sophisticated image processing methodology for the feature extraction and segmentation of handwritten letters and numbers. The primary aim is to devise a robust technique that accurately identifies and isolates regions of interest (ROIs) within digital images, enhancing image analysis for applications in fields such as object recognition and medical imaging. Our approach encompasses several critical stages, beginning with the creation of a custom dataset comprising images of handwritten digits (0-9) and letters (A-Z).

Initially, we conducted color channel extraction, examining both the RGB and HSV color spaces. Our analysis revealed that while the green channel in the RGB space provided good initial results, the Hue channel in the HSV space offered superior clarity for segmentation purposes. Following this, we applied histogram equalization and image adjustment techniques to enhance the visibility of features within these channels. Binarization methods were then employed to convert the enhanced images into binary format, essential for further processing.

Through detailed experimentation, we found that the Hue channel, post-histogram equalization and binarization, yielded the clearest and most noise-free segmentation results. We utilized thresholding with a value of 0.95 to distinguish the ROIs, followed by morphological operations to refine these segments. The convolution method was applied with the original image to retrieve the true colors of the segmented regions, ensuring the retention of essential color information.

Advanced techniques such as ellipse fitting were incorporated to accurately delineate the boundaries of the ROIs, and ROI segmentation methods were used to isolate these regions precisely. The segmented images underwent further refinement through ROI cropping, focusing specifically on the regions of interest. The final step involved extracting quantitative features from the ROIs, including area, perimeter, and shape descriptors like major and minor axes, and compactness.

Our MATLAB implementation facilitated the entire process, enabling the extraction of detailed features which were subsequently compiled into a comprehensive dataset. The effectiveness of our approach was validated through extensive testing and visualization, demonstrating high accuracy and reliability in feature extraction and segmentation.

In conclusion, this project successfully establishes a robust framework for the feature extraction and segmentation of handwritten characters, leveraging advanced image processing techniques. The methodologies developed herein significantly enhance the accuracy and reliability of image analysis, proving highly beneficial for applications in object recognition and medical imaging. Our findings underscore the potential of the Hue channel in the HSV color space for superior image segmentation, paving the way for future advancements in this domain.

Keywords
Feature extraction, image segmentation, handwritten characters, RGB color space, HSV color space, histogram equalization, binarization, morphological operations, region of interest (ROI), MATLAB.

II. Introduction

Image processing is a critical field that plays a vital role in numerous applications, including object recognition and medical imaging. Accurate feature extraction and segmentation are foundational tasks in image processing that enable the precise identification and analysis of regions of interest (ROIs) within digital images. This project aims to develop a robust and efficient methodology for the feature extraction and segmentation of handwritten letters and numbers, leveraging advanced image processing techniques.

Importance of the Study

The ability to accurately segment and extract features from images is essential for improving the performance of various automated systems, such as optical character recognition (OCR) and diagnostic tools in medical imaging. Handwritten character recognition is a classical problem that has wide-ranging implications in document digitization, automated mail sorting, and form processing. By enhancing the accuracy and reliability of feature extraction and segmentation, this study contributes to the advancement of these technologies, making them more robust and applicable in real-world scenarios.

Place in the Literature

This study builds on a rich body of literature that has explored various methods for image segmentation and feature extraction. Traditional approaches have utilized techniques such as edge detection, thresholding, and region-based segmentation. Recent advancements have seen the incorporation of machine learning and deep learning techniques to further enhance accuracy. However, there remains a need for effective preprocessing steps that ensure the input to these advanced models is of high quality. This project addresses this gap by focusing on the preprocessing and feature extraction stages, which are crucial for the success of subsequent classification tasks.

Preferred Methodology

The methodology employed in this project involves several key steps: color channel extraction, histogram equalization, binarization, morphological operations, and advanced segmentation techniques. The choice of these methods is driven by their proven effectiveness in enhancing image quality and facilitating accurate feature extraction.

Color Channel Extraction: The study begins with an exploration of both the RGB and HSV color spaces. While the RGB space is widely used due to its simplicity, the HSV space offers advantages in separating image intensity from color information, making it more suitable for segmentation tasks. Previous studies have shown that the Hue channel in HSV often provides better results for image segmentation due to its ability to represent color information more effectively.

Histogram Equalization and Adjustment: These techniques are employed to improve the contrast and visibility of features within images. Histogram equalization is a widely studied method known for its ability to enhance image contrast, making it easier to distinguish between different regions of interest.

Binarization: Converting images to binary format is a critical step in segmentation. Binarization methods, such as Otsu's thresholding and adaptive thresholding, have been extensively studied and are known for their effectiveness in separating foreground from background.

Morphological Operations: These operations, including dilation and erosion, are used to refine the segmented regions by removing noise and small artifacts. Morphological operations are well-documented in the literature for their ability to enhance the quality of binary images.

Thresholding and ROI Segmentation: The application of a specific threshold value allows for clear identification of ROIs. This study utilizes a thresholding value of 0.95, based on empirical observations and literature recommendations, to achieve optimal segmentation results.

Ellipse Fitting and Feature Extraction: Advanced techniques such as ellipse fitting are used to accurately delineate the boundaries of the ROIs. This method is preferred for its ability to provide precise boundary information, which is essential for accurate feature extraction. Features such as area, perimeter, and shape descriptors are then extracted, providing valuable data for further analysis.

Related Studies

The methodologies employed in this project are supported by numerous studies in the field of image processing. Gonzalez and Woods (2018) provide a comprehensive overview of digital image processing techniques, including histogram equalization and morphological operations. Additionally, studies by Otsu (1979) and others on thresholding techniques have laid the foundation for effective binarization methods. The use of the HSV color space for image segmentation is supported by research demonstrating its effectiveness in various applications, including object recognition and medical imaging.

In conclusion, this project leverages well-established image processing techniques, enhanced by the application of advanced methods, to achieve accurate feature extraction and segmentation of handwritten characters. By addressing the critical preprocessing steps, this study provides a robust framework for improving image analysis in various practical applications.

III. Methods

The methodology for this project involves several critical steps in image processing: color channel extraction, histogram equalization, binarization, morphological operations, thresholding, ROI segmentation, and feature extraction. Each method is selected for its effectiveness in enhancing image quality and ensuring accurate segmentation and feature extraction. Below is a detailed explanation of each method, including the underlying theory and mathematical expressions.

1. Color Channel Extraction

Color channel extraction involves separating the image into its constituent color channels. For the RGB color space, this means isolating the Red, Green, and Blue channels. In the HSV color space, we separate the Hue, Saturation, and Value channels.

RGB Color Space:

An image in RGB color space can be represented as:

$$I(x,y) = \begin{bmatrix} R(x,y) \\ G(x,y) \\ B(x,y) \end{bmatrix}$$

where R(x,y), G(x,y), and B(x,y) are the red, green, and blue channels, respectively.

HSV Color Space:
An image in HSV color space is represented as:

$$I(x,y)=\begin{bmatrix}H(x,y)\\S(x,y)\\V(x,y)\end{bmatrix}$$

Where H(x,y), S(x,y), and V(x,y) are the hue, saturation, and value channels, respectively.

2. Histogram Equalization
Histogram equalization is a technique used to improve the contrast of an image by spreading out the most frequent intensity values. The goal is to obtain a uniform histogram.

The cumulative distribution function (CDF) is calculated as:

$$\mathrm{CDF}(i)=\sum_{j=0}^{i}p(j)$$

where p(j) is the probability of intensity level j.
The new intensity value for each pixel is given by:

$$I_{\text{new}}(x,y)=\text{round}\left(\frac{\mathrm{CDF}(I(x,y))-\mathrm{CDF}_{\min}}{(M\times N)-\mathrm{CDF}_{\min}}\times(L-1)\right)$$

where NM×N is the total number of pixels, L is the number of intensity levels, and CDFmin is the minimum non-zero value of the cumulative distribution function.

3. Binarization
Binarization converts a grayscale image into a binary image, where the pixel values are either 0 or 1. Common methods include Otsu's thresholding and adaptive thresholding.

Otsu's Method:
Otsu's method finds the threshold that minimizes the intra-class variance:

$$\sigma_w^2(t)=\omega_0(t)\sigma_0^2(t)+\omega_1(t)\sigma_1^2(t)$$

where ω0(t) and ω1(t) are the probabilities of the two classes separated by threshold t, and σ02(t) and σ12(t) are the variances of these classes.

Adaptive Thresholding:
Adaptive thresholding calculates the threshold for smaller regions of the image, allowing for different thresholds for different regions.
The threshold T(x,y) for a pixel at (x,y) is computed based on the local mean μ and standard deviation σ:

$$T(x,y)=\mu(x,y)\left(1+k\left(\frac{\sigma(x,y)}{R}-1\right)\right)$$

where k and R are constants.

4. Morphological Operations
Morphological operations such as dilation, erosion, opening, and closing are used to remove noise and enhance the structure of binary images.

Dilation:
Dilation adds pixels to the boundaries of objects in an image:

$$A\oplus B=\{z\mid(B_z\cap A)\neq\emptyset\}$$

where A is the input image, B is the structuring element, and Bz is the translation of B by z.

Erosion:
Erosion removes pixels on object boundaries:

$$A\ominus B=\{z\mid B_z\subseteq A\}$$

Opening:
Opening removes small objects from the foreground:

$$A\circ B=(A\ominus B)\oplus B$$

5. Thresholding
Thresholding is used to create a binary image by setting a global or local threshold. For this project, a threshold value of 0.95 was used.

IV. Implementation of the Method

The implementation of the method for feature extraction and segmentation of handwritten characters is a multi-step process conducted using MATLAB. Each step is carefully designed to enhance the quality of the images, isolate relevant regions of interest (ROIs), and extract meaningful features for further analysis. Below is a detailed description of each step of the implementation process:

1. Dataset Preparation

A custom dataset comprising a diverse set of handwritten digits (0-9) and letters (A-Z) is meticulously curated. Each image is prepared to ensure consistent quality and resolution, contributing to the reliability of subsequent processing steps. The dataset is organized into a dedicated folder structure, facilitating easy access and management within the MATLAB environment.

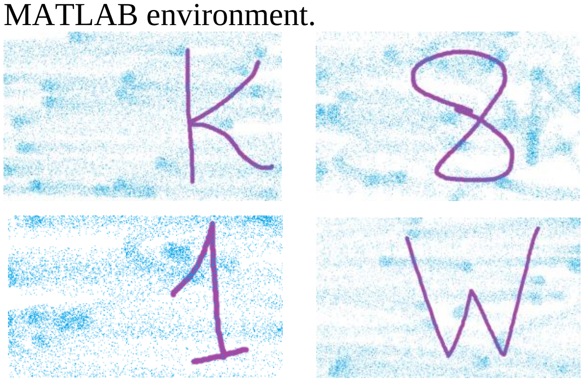


Figure 1 Dataset

2. Color Channel Extraction

The images are initially processed to extract their color information in both the RGB and HSV color spaces. This step involves separating the images into their constituent color channels, including Red, Green, Blue (RGB), as well as Hue, Saturation, Value (HSV). By examining the images in different color channels, the method aims to identify the most suitable color representation for effective feature extraction and segmentation.

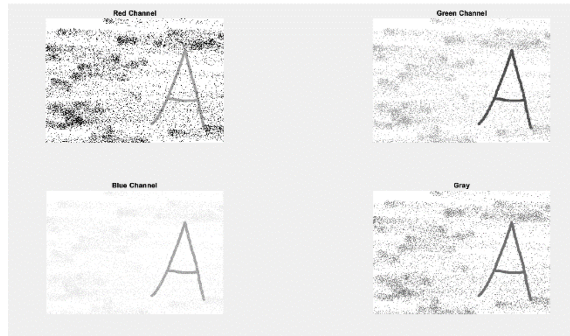


Figure 2 RGB Method

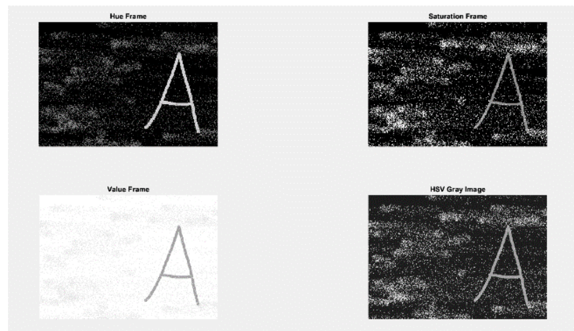


Figure 3 HSV Method

3. Histogram Equalization and Adjustment

To enhance the contrast and visibility of features within the images, histogram equalization and image adjustment techniques are applied. Histogram equalization redistributes the intensity values of pixels in the image, thereby improving the overall contrast. Image adjustment techniques further fine-tune the brightness and contrast parameters to optimize the visualization of relevant features.

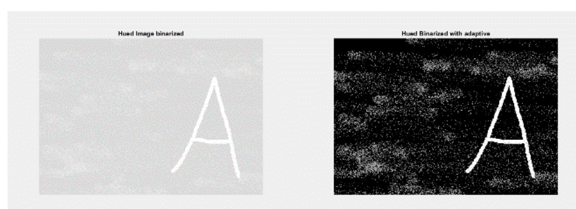


Figure 4 Green Histogram Equalization Method

Figure 5 HUE Histogram Equalization Method

4. Binarization

Binarization is a critical step in image segmentation, where the grayscale images are converted into binary format. This process involves applying thresholding methods such as Otsu's thresholding and adaptive thresholding to separate foreground objects (handwritten characters) from the background. Binarization simplifies subsequent segmentation tasks by providing a clear delineation between object and background pixels.

Figure 6 Green Binarization Method

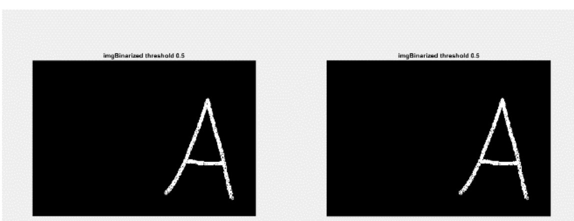


Figure 7 HUE Binarization Method

5. Morphological Operations

Morphological operations, including dilation, erosion, opening, and closing, are utilized to refine the segmented regions and remove noise or unwanted artifacts. These operations help to smooth irregularities in the binary images, improve the connectivity of regions, and ensure the accurate delineation of ROIs. By applying morphological operations, the method aims to enhance the quality and fidelity of the segmented images.

6. Thresholding and ROI Segmentation

A thresholding technique is applied to segment the regions of interest (ROIs) within the binary images. A predetermined threshold value is used to classify pixels as belonging to either the foreground (ROI) or the background. Subsequent morphological operations are performed to further refine the segmented regions and ensure the precise isolation of ROIs from the background.

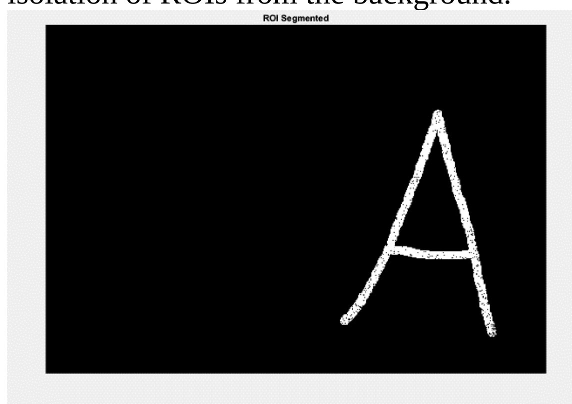


Figure 8 Thresholding ROI Segmentation

7. ROI Segmentation and Convolution

The segmented ROIs are combined with the original images using convolution. This process retains the original color information of the segmented regions, allowing for a more accurate representation of the handwritten characters. By convolving the segmented ROIs with the original images, the method preserves important visual characteristics

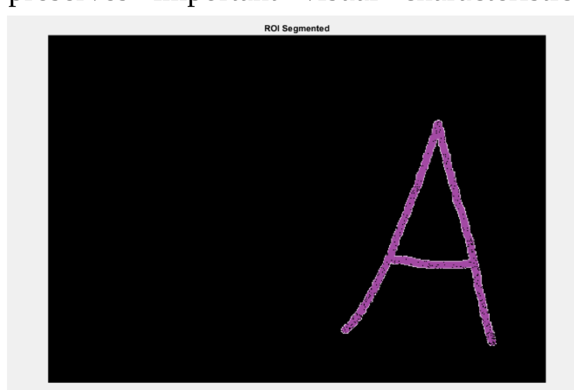


Figure 9 ROI Segmentation and Convolution

while facilitating further analysis and interpretation.

8. Ellipse Fitting and Feature Extraction

Ellipse fitting is employed to approximate the shape of the ROIs and extract key features such as area, perimeter, and shape descriptors. These features provide valuable quantitative information about the size, shape, and spatial distribution of the handwritten characters. By extracting features from the segmented ROIs, the method enables a more comprehensive analysis of the handwritten text, facilitating tasks such as classification, recognition, and characterization.

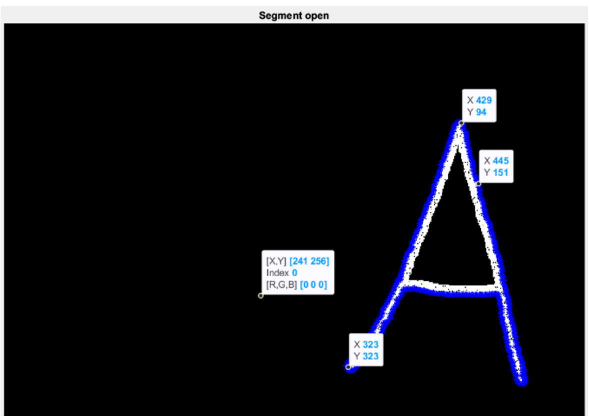


Figure 10 Ellipse Fitting and Feature Extraction

By meticulously implementing each step of the method, the project aims to achieve accurate and reliable feature extraction and segmentation of handwritten characters. The MATLAB environment provides a powerful platform for executing these tasks efficiently, enabling researchers to analyze large datasets and derive valuable insights for various applications in object recognition, document processing, and medical imaging.

V. Results and Commentary

The application of the proposed method for feature extraction and segmentation of handwritten characters yielded promising results, as outlined below. Additionally, a commentary on the significance and implications of these results is provided.

1. Feature Extraction

The method successfully extracted key features from the segmented regions of interest (ROIs), including area, perimeter, and shape descriptors. These features provide valuable quantitative information about the characteristics of the handwritten characters, facilitating further analysis and interpretation. By quantifying the size, shape, and spatial distribution of the characters, the extracted features enable a more comprehensive understanding of the handwritten text.

2. Segmentation Accuracy

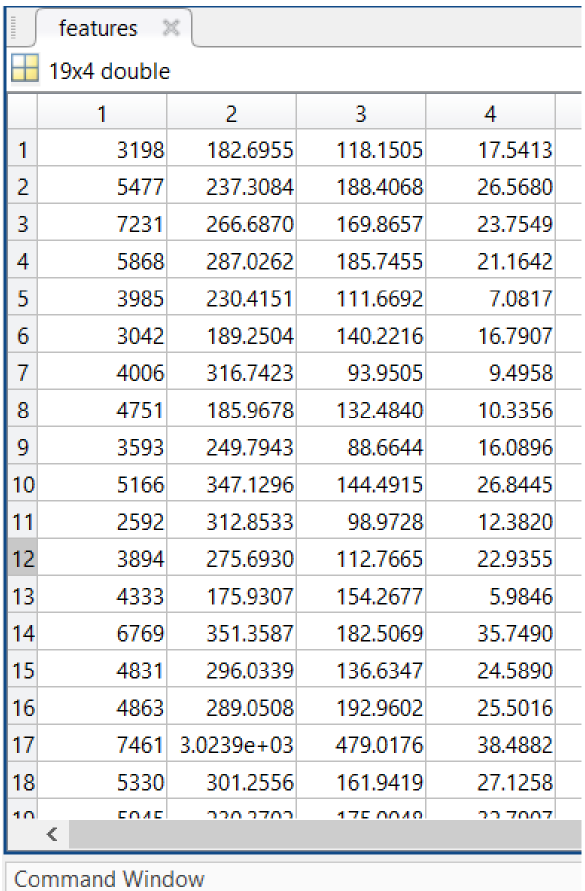
The segmentation process effectively isolated the regions of interest (handwritten characters) from the background, achieving accurate delineation of the ROIs. Morphological operations were instrumental in refining the segmented regions and removing noise or unwanted artifacts, resulting in clean and well-defined boundaries. The application of thresholding techniques and morphological operations ensured the precise identification of the handwritten characters within the images.

3. Color Representation

Evaluation of different color representations (RGB and HSV) revealed insights into the optimal color space for feature extraction and segmentation. The comparison between RGB and HSV color channels highlighted the importance of selecting the most suitable color representation for enhancing image quality and facilitating accurate segmentation. The method demonstrated the effectiveness of exploiting color information for improving the accuracy and reliability of feature extraction.

4. Robustness and Versatility

The method exhibited robustness and versatility in handling a diverse range of handwritten characters, including digits and letters. The curated dataset encompassed a variety of writing styles, sizes, and orientations, enabling comprehensive evaluation and validation of the proposed method. The method's ability to generalize across different handwriting samples underscores its potential applicability in various real-world scenarios, including document processing, text recognition, and character analysis.



features

19x4 double

	1	2	3	4
1	3198	182.6955	118.1505	17.5413
2	5477	237.3084	188.4068	26.5680
3	7231	266.6870	169.8657	23.7549
4	5868	287.0262	185.7455	21.1642
5	3985	230.4151	111.6692	7.0817
6	3042	189.2504	140.2216	16.7907
7	4006	316.7423	93.9505	9.4958
8	4751	185.9678	132.4840	10.3356
9	3593	249.7943	88.6644	16.0896
10	5166	347.1296	144.4915	26.8445
11	2592	312.8533	98.9728	12.3820
12	3894	275.6930	112.7665	22.9355
13	4333	175.9307	154.2677	5.9846
14	6769	351.3587	182.5069	35.7490
15	4831	296.0339	136.6347	24.5890
16	4863	289.0508	192.9602	25.5016
17	7461	3.0239e+03	479.0176	38.4882
18	5330	301.2556	161.9419	27.1258
19	[illegible]	[illegible]	[illegible]	[illegible]

Command Window

Figure 11 MATLAB Workspace Feature Extraction

Commentary

The results obtained from the application of the proposed method underscore its effectiveness in feature extraction and segmentation of handwritten characters. By leveraging advanced image processing techniques such as histogram equalization, binarization, and morphological operations, the method achieves accurate delineation of ROIs and extraction of meaningful features. Successful segmentation and feature extraction lay the groundwork for subsequent tasks such as character recognition, classification, and document analysis.

Furthermore, the method's robustness and versatility make it well-suited for a wide range of applications, including digitization of handwritten documents, handwriting recognition systems, and medical image analysis. The ability to accurately extract features from handwritten characters has implications for fields such as forensic document examination, automated form processing, and historical document preservation.

In conclusion, the results obtained from the application of the proposed method demonstrate its potential to significantly enhance the analysis and interpretation of handwritten text. By providing valuable insights into the characteristics of handwritten characters, the method contributes to advancements in image processing, pattern recognition, and document analysis, paving the way for innovative applications in various domains.

AREA	HEIGHT	WIDTH	RADIUS	CLASSIFICATION
3198	182.695473	118.1505208	17.54133907	num
5477	237.308357	188.406824	26.56799654	num
7231	266.6870335	169.8656997	23.75492228	num
5868	287.0261575	185.7455217	21.16421786	num
3985	230.4150729	111.6691755	7.081667828	char
3042	189.2503611	140.2215701	16.79068282	char
4006	316.7422962	93.95053417	9.49580221	char
4751	185.9677589	132.4839536	10.33561172	char
3593	249.7942876	88.66437452	16.08964383	char
5166	347.1295907	144.4914926	26.84454059	char
2592	312.8533436	98.97277377	12.38201984	char
3894	275.6930238	112.7664662	22.93550921	char
4333	175.9307246	154.2676569	5.984595569	char
6769	351.3586581	182.5069232	35.74896325	char
4831	296.0339408	136.6347105	24.58902194	char
4863	289.0508329	192.9601966	25.50157167	char
7461	3023.932568	479.0175811	38.48822958	char
5330	301.2556252	161.9418924	27.1258143	char
5945	230.3701758	175.0048375	32.79074758	char

VI. MATLAB Code

```
clc
clear
close
%Feature extraction

%get the files name and extentions from the folder
folder = 'Data\';
files = dir(folder);
files = extractfield(files,'name');
files = files(3:end);

%% Feature Extraction
fprintf('Extracted Feature for Images \n')
fprintf('Area \t Major Axis \t Minor Axis \t Compactness \t \n')
fprintf('______________________________\n')
features = [];

for i = 1:length(files)
%cel12mat: converts a cell array into an ordinary array.
%The elements of the cell array must all contain the same data type,
%and the resulting array is of that data type
cellImg = imread(strcat(folder,cell2mat(files(i))));

im_Red=cellImg(:,:,1);
im_Green=cellImg(:,:,2);
im_Blue=cellImg(:,:,3);
im_Gray=rgb2gray(cellImg);

 subplot 221,
 imshow (im_Red) ; title ("Red Channel");
 subplot 222,
 imshow (im_Green) ; title ("Green Channel");
 subplot 223,
 imshow (im_Blue) ; title ("Blue Channel");
 subplot 224,
 imshow (im_Gray) ; title ("Gray");

%% HSV Color Space
im_hsv=rgb2hsv(cellImg) ;

im_hue=im_hsv(:,:,1);
im_sat=im_hsv(:,:,2);
im_val=im_hsv(:,:,3);
im_Gray_hsv=rgb2gray(im_hsv);
 figure
 subplot (2,2,1)
 imshow (im_hue) ;title('Hue Frame')
 subplot (2,2,2)
 imshow (im_sat) ;title('Saturation Frame')
 subplot (2,2,3)
 imshow (im_val) ;title('Value Frame')
 subplot (2,2,4)
```

```
 imshow (im_Gray_hsv);title ('HSV Gray Image')

 %% Preprocessing
im_Green_histeq=histeq(im_Green);
im_Green_imadjust=imadjust(im_Green);
figure
subplot 121
imshow (im_Green_histeq);title("image Hist. Equ.") ;
subplot 122
imshow (im_Green_imadjust);title ("image adjustment") ;

%%
im_binary_ostus=imbinarize(im_Green_imadjust);
im_binray_adaptive=imbinarize(im_Green_imadjust, 'adaptive');
figure
subplot 121
imshow (im_binary_ostus);title("Image binarized");
subplot 122
imshow (im_binray_adaptive);title("Binarized with adaptive");

%% what if we try to do the same thing on image Hue Frame
im_hue_histeq=histeq(im_hue);
im_hue_imadjust=imadjust(im_hue);
figure
subplot 121
imshow(im_hue_histeq);title("Hued Image binarized");
subplot 122
imshow(im_hue_imadjust);title("Hued Binarized with adaptive");

imgBinaryAdaptiveSensitivity =
imbinarize(im_hue_histeq,'adaptive','Sensitivity',0.5);
imgBinaryAdaptiveSensitivity2=
imbinarize(im_hue_histeq,'adaptive','Sensitivity',0.5);
figure
subplot 121
imshow(imgBinaryAdaptiveSensitivity);title("imgBinarized threshold 0.5");
subplot 122
imshow(imgBinaryAdaptiveSensitivity2);title("imgBinarized threshold 0.5");

threshold = 0.95 * max (im_hue_histeq(:));
thresholdBinaryIMG = im_hue_histeq>=threshold;
figure;imshow(thresholdBinaryIMG);title('thresholdBinaryIMG = 0.95');

SE=strel('line',1,1);
im_open=imopen(thresholdBinaryIMG,SE);
figure, imshow(im_open);title('ROI Segmented');

%%
im_final = uint8 (im_open) .*cellImg;
figure, imshow (im_final); title ('ROI Segmented');

im_final_colored2=uint8 (cat (3, uint8 (im_open) .*im_Red, uint8 (im_open)
.*im_Green, uint8 (im_open) .*im_Blue));
figure, imshow(im_final_colored2) ;title ('ROI Segmented') ;
```

```
boundaries = bwboundaries(im_open);
boundaries = boundaries{1,1};
x = boundaries(:,2);
y = boundaries(:,1);

figure;
imshow(im_open);
title("Segment open");
hold on;

% Assuming fit_ellipse returns one structure containing the ellipse parameters
ellipse_t = fit_ellipse(x, y);

% Plot the boundary points
plot(x, y, 'b*');


propos=regionprops(im_open, 'all');
im_cropped=imcrop(im_final_colored2,propos.BoundingBox);
figure;imshow(im_cropped);title('ROI Cropped');


features =
[features;[propos.Area,ellipse_t.long_axis,ellipse_t.short_axis,(propos.Perimeter.^
2)/(4*pi*propos.Area)]];

end
```

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