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Hybrid Features of Mask Generated with Gabor Filter for Texture Analysis and Sobel Operator for Image Regions Segmentation Using K-Means Technique

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Abstract

*To make the image easily represented for more analysis and processing the segmentation procedure is required, where the image is portioned into its formed regions using some segmentation techniques based on features extraction. In this paper, a proposed procedure for finding the regions that formed the image is achieved based on hybrid features in two different components of different two colors spaces L*a*b* and RGB segmented by the k-means method. The hybrid features which comprise the mask segmentation are a combination of texture image characterization extracted by the Gabor filter and gradient image intensity by the Sobel operator after image quality enhancement by applying wiener filter noise reduction and contrast enhancement using Contrast limited adaptive equalization (CLAHE). Some statistical metrics are used for evaluating the performance of the proposed work stages.*

Introduction

The procedure that refers to separating or ordering the pixels involved in an image into sets of related characteristics is defined as image segmentation (Kwok et al.,2009). This procedure aims to categorize pixels with homogeneity depending on some features for example color, texture, and others. Much information exists in color features and it's possible for human vision to perceive thousands of color mixtures, and the comparative is made for intensity with grayscale or it made with black and white (binary) (Wicaksono et al.,2015). A specific color can be described through the color space by the primary components. The diversity of color spaces products from variances within these elementary components and several color spaces yielded from each other by transformation (Jungmann et al.,2014).

There are many types of color space. the RGB kind utilizes additive color and considers the furthermost generally used because of its significance, this color space is characterized by three chromatics which are "red (R), green (G), and blue (B)" (Ismael,2020). Also, there is another color space which considered a very common color space which is CIE (Commission International de lclairage) LAB. The CIELAB color space (denoted as CIE L*a*b* or infrequently abbreviated as "Lab" color space) which is considered by CIE (International Commission on Illumination) in 1976 (Rimiru et al.,2022). In this paper, the segmentation process proposed to apply two different color spaces based on the Gabor filter and gradient image intensity with the Sobel operator.

Many works have used the Gabor filter for the analysis of texture in the image segmentation process. The authors (Bharathi & Subashini, 2013) suggest a segmentation method where the

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Gabor filter is applied for image texture segmentation and then discriminates the textures with a diversity of colors as diverse textures and various images are considered based on these similar colors which are extracted and by employing k-means technique as color-based segmentation, when first and second-order statistical approaches are utilized for features extraction, then PNN is used as a classifier by passing these features to it. While the authors (Khan et al.,2009) proposed a segmentation method where the features of an image are determined using a Gabor filter through adaptively elected size, orientation, frequency, and phase for every pixel. Distinguishing features associated with the variation in brightness, color, texture, and position are detected for every pixel at the designated size of the filter. for gathering the pixels into diverse regions, the joint distribution features of pixels are represented by a mixture of Gaussians employing three variants of the expectation maximization (EM) algorithm.

The main problem is to find and detect segments (objects) that construct an image precisely. So, in this paper, the proposed procedure applied aims to allocate individual pixels to their consistent segment. In which the proposed feature space is extracted with a combination of texture features analyzed by the Gabor filter and gradient with the Sobel operator in two different color spaces components after performing quality enhancement operations by reducing noise with the Weiner filter and contrast has been enhanced by Contrast limited adaptive equalization (CLAHE), then the K-means is applied for segmenting similar pixels to detect individual objects (segments) that form an image. The rest of the paper is ordered as follows: the methodology with detailed stages is explained in section 2, then the obtained results are illustrated in section 3, and the evaluations of the proposed work stages are discussed in section 4 followed by a conclusion in section 5.

Methods

Figure 1 explains the main stages of the proposed model, which begins with the first stage where the RGB input image is read, then converted to L*a*b* color space. And the mask of features is constructed by combining the two extracted features after enhancing input image, and finally, the regions are extracted by the k-means technique. And the details are as follows:

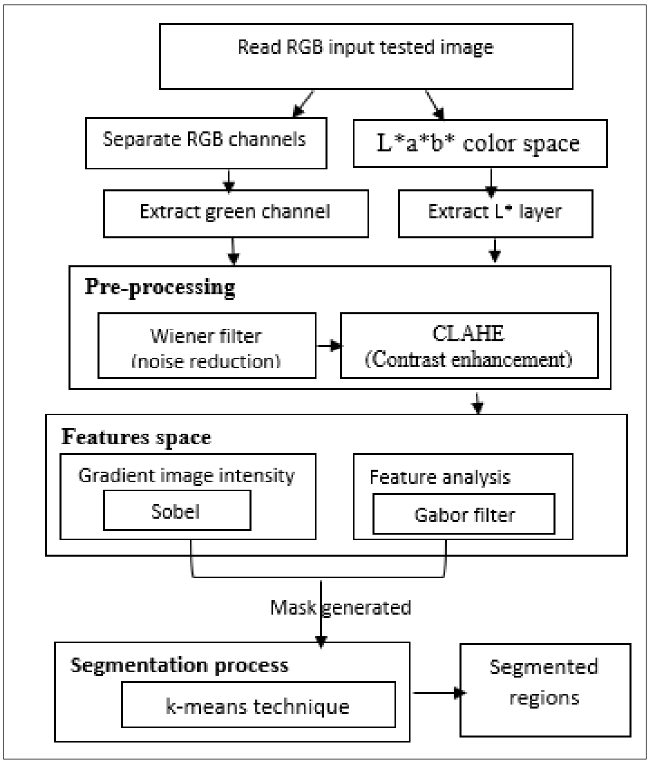

Figure 1. proposal model

First stage

Read RGB-tested input image

*Convert RGB image into L*a*b* color space*

The colors seem by human eyes able to be represented by the L*a*b* typical. Also, the L*a*b* color representation recompenses for the variation in the distribution of colors in the RGB color model the reason that the RGB representation has moreover transition color between blue and green (Zheng et al.,2018). So, L*a*b* color space is used in this stage, where the channel L* is considered from L* a* b* color space which depicts the value luminance grayscale of these input images. Where the more contrast channel from RGB color space is considered for texture analysis based on measuring the value of each channel contrast as explained in Table 1, and from this table green channel is more contrast for these input images than the red and blue channels. Statistical standard deviation (STD) metric is used for measuring the contrast value of each channel for each input image. Where STD refers to somewhat about the contrast by depicting the data separation by mean the high variance of an image refers to high contrast whereas the low variance of an image denotes low contrast (Sergyan,2008). the STD calculated in the below equations (Fazal-e-Malik, 2011).

$$\mu_j = \frac{1}{N}\sum_{i=1}^{N} x_{ji} \quad (1)$$

$$\sigma_j = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_{ji} - \mu_j)^2} \quad (2)$$

Second stage

Pre-processing stage is considered a vital stage in image processing for enhancing its quality for further analysis and processing. The improvement is achieved by noise reduction and contrast enhancement. Where in ***noise reduction*** the purpose of using a wiener filter is to separate out the noise which causes a signal to corrupt. In which statistical methods are used by it. Representative filters are considered for the anticipated frequency response (Shetti & Patil, 2017). And in ***contrast enhancement*** this step is prepared for enhancing the input-tested image quality by improving its contrast which is performed using Contrast limited adaptive equalization (CLAHE). CLAHE is considered an adopted adaptive histogram equalization. The enhancement function of this technique is implemented on completely neighborhood pixels and the conversion function is derived (Yadav et al., 2014).

Third stage

Two types of features are adopted for the segmentation process textures characterization extracted by Gabor filter, gradient intensity image with Sobel operator.

In ***Texture features*** Gabor filter is used for input-tested image texture analysis, The Gabor filter is defined as a linear filter that is utilized for the detection of an edge. The similarity of the Gabor filter's frequency and orientation depictions to those of the human visual system, is mainly suitable for texture depiction and discrimination (Bhattacharya & Bhattacherjee, 2013). Gabor filter is applied on L* and green components of L*a*b* and RGB color spaces respectively. ***Sobel operator*** where this operator is a discrete differentiation operator, which is calculating an estimation of the gradient image intensity function. This gradient is estimated at every point, and the direction of the biggest probable growth from light toward the dark has

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been equipped with the rate of variation in that direction. So, consequently, the image changes "abruptly" or "smoothly" are illustrated at that point, So, it demonstrates how expected this part of the image is to be an edge, and its masks are agreed as follows (Vincent & Folorunso, 2009):

$$\Delta x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad \Delta y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

Significantly, in this step Sobel operator is applied on L* and the green channel. And by combining these two features segmented mask has been generated.

Fourth stage

The k-means clustering technique is known as utmost frequently used clustering process for its easiness and fast computation. It has been implemented by gathering a k-number group of data (Dhanachandra & Chanu, 2017). This technique comprises two phases, where the centroid is initialized in the first phase and the second one determines in which cluster the data point belongs by defining the distance of the nearest centroid (Dhanachandra et al.,2015). Therefore, this technique is used in this segmentation stage to segment the regions of the input image.

Results and Discussion

The performance of the proposed method was evaluated by testing three input images with different sizes, the first two input-tested images are well-known standard Jelly beans (256×256 pixel), and Tree (256×256 pixel), and the third tested image is a satellite image (602×602 pixel) The Landsat 7 satellite images yielded are distributed as 8-bit images with 256 grey levels complete eight spectral bands. This tested image is demonstrating an image with geometric details.

Read tested input images as shown in Figure 2.

(a) (b) (c)

Figure 2. tested images, (a) Jelly beans, (b)Tree, (c) satellite image

Convert RGB image into L*a*b* color space, then extracted the value of L* channel from L*a*b* color space, and green channel from RGB color space. Table 1 explains the measure of the contrast of each channel in RGB color space using STD.

(a) (b) (c)

*Figure 3. L*a*b* color space, (a) Jelly beans, (b) Tree, (c) Satellite image*

Table 1. channels contrast measure using (STD)

Channel	Jelly beans	Tree	Satellite image
Red	48.0863	63.6229	60.2200
Green	**53.9611**	**74.6078**	**60.2273**
Blue	50.4223	71.6078	59.5569

Figure 4 explains the resulting images by applying image quality enhancement with noise reduction and contrast improvement. A wiener filter is applied on the grayscale of L* and the Green component of the input image for reducing the amount of noise present in a grayscale image with a window size of 3×3. Then CLAHE is applied for contrast enhancement.

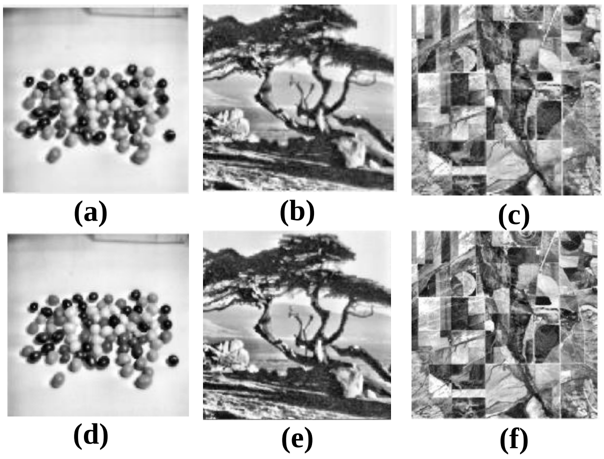
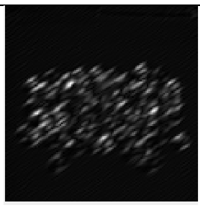
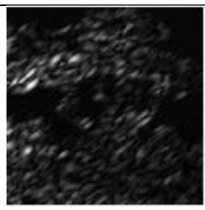
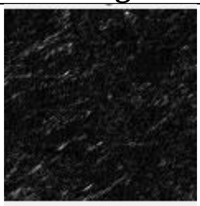
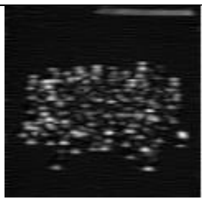
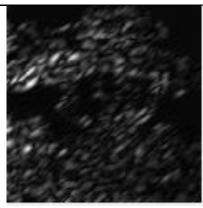
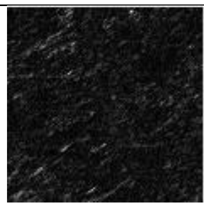


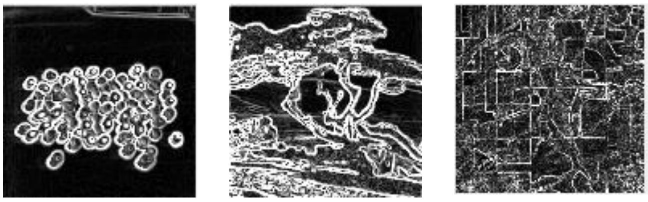
Figure 4 enhanced image (a)-(c) on green, (d)-(f) on L, (a) Jelly beans, (b) Tree, (c) satellite image*

Segmented Mask generated as explained in Table 2, the texture features that are extracted from the values of L* grayscale and green component of color spaces L*a*b* and RGB respectively using the Gabor filter. Gabor filter is dependent on some parameters which have an effect on the performance of texture characterization, these are wavelength W and orientation θ. In this work, the considered orientations are θ=0, 90, 125 with wavelengths 2, 4. And based on the information content measured by entropy value the Gabor parameters are determined which achieved in more accuracy as explained in Table 6.

Table 2. Gabor features extracted from L* value and Green channel

Feature	**Jelly beans**	**Tree**	**Satellite image**
Gabor filter magnitude (L*)			
Gabor filter magnitude (Green)			

The second feature is gradient image intensity with the Sobel operator as seen in Figure 5

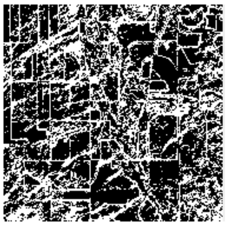
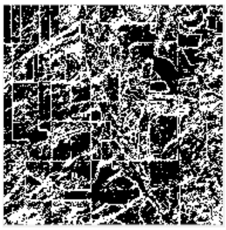


(a) **(b)** **(c)**

Figure 5. Sobel operator, (a) Jelly beans, (b) Tree, (c) satellite image

The segmented regions are obtained by applying the K-means technique on a segmented mask that was generated in the previous step as explained in Table 3.

Table 3. K-means segmentation on input images in L* and Green layers

process	**Jelly beans**	**Tree**	**Satellite image**
k-means (L*)			
k-means (green)			

Performance evaluation

The evaluation operations are performed for each stage of the suggested model as illustrated in the following:

Pre-processing stage is evaluated using statistical metrics such as PSNR which was formulated as in equations 3,4 (Bora & Gupta,2014) and SNR for wiener performance assessment, and histogram representation for CLAHE performance as seen in Tables 4 and 5.

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) \qquad (3)$$

Where, MAX_I is the greatest probable pixel value inside image.

$$MSE = \frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y) - I']^2 \qquad (4)$$

where, the original image is denoted by I(x,y), and I'(x,y) demarcated as its noisy with image size M,N.

Signal to noise ratio in an image is calculated as (Raj& Venkateswarlu,2012)

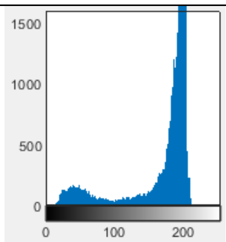
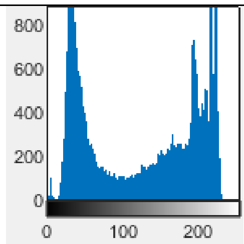
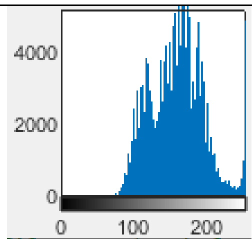
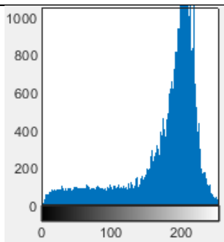
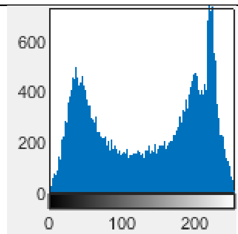
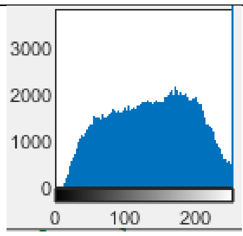
$$SNR = \frac{\mu}{\sigma} \qquad (5)$$

Where μ is refer to the rate of information that contained within the signal and σ is denote to the standard deviation of the signal.

Table 4 wiener filter assessment

Image	PSNR	SNR
Jelly beans	40.1568	37.0441
Tree	30.2052	25.3900
Satellite image	40.8380	36.9559

Table 5 comparative on CLAHE performance using histogram representation

<table>
<tr><th>Process</th><th>Jelly beans</th><th>Tree</th><th>Satellite image</th></tr>
<tr><td>Before enhanced</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Enhanced</td><td>
</td><td>
</td><td>
</td></tr>
</table>

The evaluation of k-means regions segmentation is performed based on the entropy value measuring, the accuracy of these regions segmented with texture analysis using the Gabor filter depends on some parameters like theta and wavelength which has an effect on the performance of segmentation as shown in Table 6. The entropy is calculated as following (Kwok et al.,2009).

$$H_r = -\sum g_r^{-k} \log_2(g_r^{-k}) \qquad (6)$$

Where g_r^{-k} demarcated as normalized histogram or possibility distribution of assumed color space.

Table 6. K-means segmentation evaluation based on entropy metric

Input image	Gabor parameters		Entropy (L*)	Entropy (Green)
	θ	W		
Jelly beans	0	2	0.3226	0.8074
		4	0.3254	0.8075
	90	2	0.7977	0.3627
		4	0.7140	**0.8419**
	125	2	0.6801	0.8039
		4	**0.7999**	0.8080
Tree	0	2	0.9434	0.9540
		4	0.9672	0.9746
	90	2	0.9305	0.9412
		4	0.8711	0.8688
	125	2	0.9418	0.9515
		4	**0.9742**	**0.9841**
	0	2	0.9178	0.9306
		4	0.9149	0.9302

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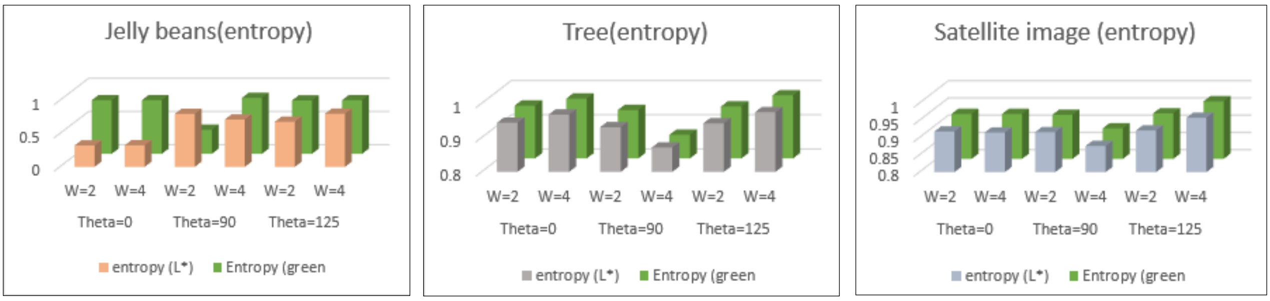
Satellite image	90	2	0.9160	0.9280
		4	0.8758	0.8887
	125	2	0.9209	0.9321
		4	**0.9575**	**0.9669**



(a) (b) (c)

Figure 6. K-means segmentation evaluation based on entropy metric

Conclusion

A Hybrid of two types of features is proposed with two different components of two different color spaces based on the k-means clustering method. These two types are texture features extracted by the Gabor filter, where the second feature is detected depending on the Sobel operator after enhancing the input-tested image for improving its quality. The information content by entropy metrics is utilized for the assessment of k-means segmentation. From the previous sections and tables for these input-tested images, the segmentation applied on the green component of RGB color space with the highest entropy value than the segmentation on the L* channel, which means the color space component has an effect on segmentation performance. also, the segmentation based on texture analysis by the Gabor filter is affected by the values of its parameters.

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