Texture analysis and gradient magnitude extracted features based active contour image segmentation

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Abstract: Image segmentation is a vital mechanism for extracting information from image-forming regions (objects) for supplementary processing. The segmentation process is employed in different applications such as object recognition and others. In this paper, the segmentation procedure is proposed using the active contour technique based on texture analysis with entropy and local standard deviation filtering, and another type of feature is gradient magnitude with a central difference operator when the enhanced process to the image quality is performed on a grayscale of the input image by reducing noise with Wiener filter and Histogram Equalization technique for contrast enhancement, canny edge operator is used for boosting segmentation process. The accuracy of the resulting regions' segmentation is evaluated in clean and noisy conditions using some statistical metrics.

Keywords active contour, histogram equalization, entropy filter, standard deviation filter, wiener filter

1. Introduction

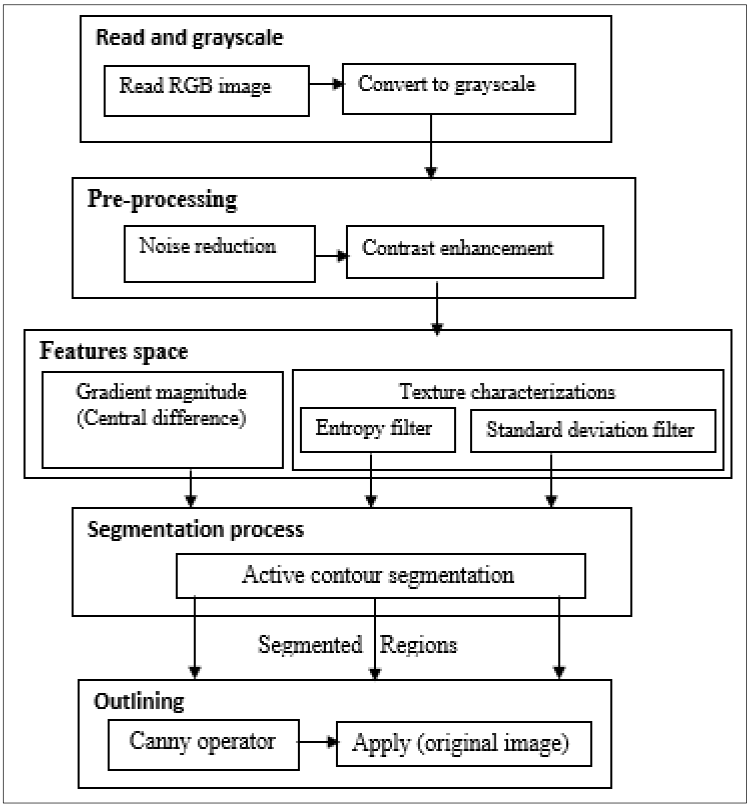
Image segmentation is considered to be the major matter when working in image processing and computer vision **(Bresson & Thiran, 2006)**. Partitioning an image into homogenous regions based on some criteria represents the image segmentation process **(Marfil et al, 2006)**. Significantly, the main challenge in this process of segmentation is to accurately determine the spatial extent of some object which can be denoted by the union of several regions **(Camilus & Govindan, 2012)**. Many methodologies have been existed employed for segmentation operations, and each one has its significance. It can be treated with these segmentation methodologies by considering two main approaches of segmentation which refer to region-based or edge-based approaches. By implementing each of these segmentation methodologies on various images the segmentation process has been performed. These segmentation methods can be classified into three classes, Stochastic Segmentation methods, Structural Segmentation, and Hybrid procedure **(Kaur & Kaur, 2014)**. There are many applications that employed Active Contour segmentation. Authors **(Pons et al, 2008)**, a novel procedure for unsupervised texture segmentation in which the combination of the set of characteristics is performed, and depending on an active contour technique devoid of edges by level set depiction and filtering approach for the associated component. While the authors **(Tatu & Bansal, 2015)**, proposed an unsupervised procedure for the segmentation of the texture depending on active contour. employ intensity covariance matrices of regions by way of describing characteristics of textures and detect regions with the furthermost inter-region unalike covariance matrices utilizing active contours. Also, in the same scope authors **(Cai et al, 2015)**, developed a level set segmentation structure directed by the image gradient function. where the borders and regions in the image are separated by utilizing the image gradient sample function.

The main problem is to locate the regions that construct the image accurately. In this proposed work three extracted features are based active contour technique to find the regions that construct an image. Two based features are texture characterization analyzed by entropy and standard deviation filters, and the third feature is gradient magnitude with the central difference operator. The comparison is made in segmented region homogeneity based on these three features by the active contour technique using statistical metrics. Also, the segmented regions are evaluated in noisy conditions, and the comparison is made for these segmented regions. The rest of the paper is presented as follows: section 2 explains the methodology of this proposed work, section 3 demonstrates the experimental results and discussion followed by the performance evaluation of the stages of the proposed work in section 4, and finally, the conclusion is presented in section 5.

2.Methodology

Figure 1 explains the model of the proposed work which consists of five stages, which begin with reading tested input image and converting to grayscale, pre-processing operations, features space, then the segmentation process flowed by outlining operation. The details of each stage are as follows:

Figure.1. proposed model flowchart



First stage: Read RGB input-tested images and convert them to grayscale to get information from the pixel intensity value.

Second stage: pre-processing operations are performed for enhancing the input-tested image quality for further processing. The noise is reduced by the wiener filter and the contrast is enhanced by the histogram equalization (HE) technique. The calculation of the wiener filter is presented as follows **(Siddeq & Yaba,2009)**.

$$\mu = \frac{1}{n^2}\sum_{z=1}^{n}\sum_{w=1}^{n} f(z,w) \tag{1}$$

$$\sigma^2 = \frac{1}{n^2}\sum_{z=1}^{n}\sum_{w=1}^{n} f^2(z,w) - \mu^2 \tag{2}$$

$$d(z,w) = \mu + \frac{\sigma^2 - Noise}{\sigma^2}(f(z,w) - \mu) \tag{3}$$

Where μ is the local mean, σ^2 local standard deviation, $d(z,w)$ is de-noised coefficients.

HE can be characterized as in equation 4 (Kaur & Rani,2016).

$$p_n = \frac{no.of\ pixels\ with\ intinsity\ n_k}{total\ no.of\ pixels\ n} \tag{4}$$

Where n is considered as the range of the values of the Gray level, n= 0, 1,…L-1.

Third stage: Segmentation features space. In this stage, two types of features are based on locating the regions that construct an image which explain as follows:

- **Texture feature**: the description of the image texture of the input-tested image is performed by applying two filters to extract two types of features. the first feature is created by applying an entropy filter on an enhanced grayscale image to characterize image regions by texture content. Various applications have employed entropy in the image for instance filtering, segmentation, and getting precise information. The mechanism of an entropy filter is to change the values of pixels' intensity with entropy values, where Shannon's Entropy algorithm is performed in which a structured element according to a specific size is predefined to be locally assessed **(Espinosa et al., 2021)**. According to the entropy equation 5 **(Sayed, 2016)**.

$$e = -\sum_{i=0}^{L-1} p(x_i) log_2\, p(x_i) \qquad (5)$$

where xi represents the intensity of the pixels, $p(x_i)$ is the probability distribution function (PDF) of the intensity levels in the window, and L refers to the intensity level number that exists in the window.

Standard deviation (STD)filtering provides the second characterization of image texture used in this stage. Standard deviation is calculated in equations 6,7 **(Fazal-e-Malik, 2011)**.

$$\mu_j = \frac{1}{N}\sum_{i=1}^{N} x_{ji} \qquad (6)$$

$$\sigma_j = \sqrt{\frac{1}{N}\sum_{i=1}^{N} (x_{ji} - \mu_j)^2} \qquad (7)$$

Where μ_j is the mean, σ_j is the standard deviation.

- **Gradient magnitude**: in digital images, the root means square of image directional gradients alongside two orthogonal directions is demarcated as the gradient magnitude. For calculating the gradient, image convolution is performed with a linear filter, there are some examples of this filter Sobel, Roberts, and Prewitt filters or some certain mission **(Xue et al., 2014)**. In this step derivative operators of gradient magnitude are considered to generate features of segmentation in which a central difference and computed as in equations 8,9 **(Thanh et al., 2019)**.

$$\frac{\partial u}{\partial x_1} = \frac{u(i+1, j) - u(i-1, j)}{2} \qquad (8)$$

$$\frac{\partial u}{\partial x_2} = \frac{u(i, j+1) - u(i, j-1)}{2} \qquad (9)$$

Where $u(\boldsymbol{x})$ is assumed to be an entered image with the value of $\boldsymbol{x}=(x_1,x_2)$, and i, j are spatial steps that represent the width and height of an image.

Fourth stage*:* Active contour models are a creative method used for the purpose of image segmentation, and there are two kinds: parametric active contour and geometric active contour models **(Iqbal et al, 2020)**. these models' objective is to detect and extract the border of a part that exists in an image. The central idea to calculate it comprises the description of a curve as the minimizer of a function. Which referred function is consisting of a sum of energies to achieve a trade-off between the consistency of the shape and the contours demarcated by the gradient of the image **(Pierre et al, 2021)**. In this stage, the segmentation operation is implemented by the active contour technique using features space generated in the previous stage, where the interest regions of each tested image are extracted according to the texture's characterization of the regions and their gradient magnitude of them.

Fifth stage*:* canny edge operator is applied for boosting segmentation process by outlining the segmented regions in an original tested input image.

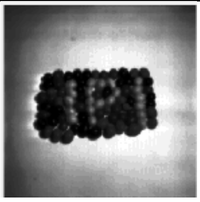
3.Expermental Results and discussion

The assessment of this proposed work is performed with a set of well-known standard images Tree (256×256 pixels), Jelly beans (256×256 pixels), and Pepper (512×512 pixels). So, these tested images are read, then pre-processing stage is applied with noise reduction and contrast enhancement as illustrated in Table 1, and the details are as follows:

- **Pre-processing stage**

  Two operations are done in this stage, firstly, noise is reduced using a wiener filter with a window size of (3×3), this window size is determined based on wiener filter performance evaluation with PSNR and SNR. Then the contrast for each input image is enhanced using HE as the second step.

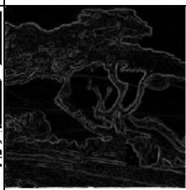
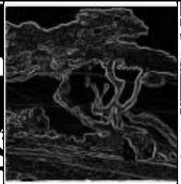
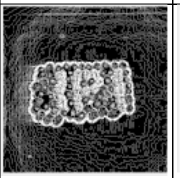
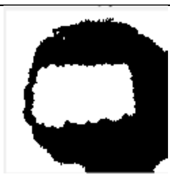
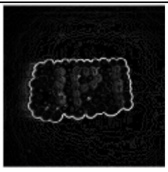
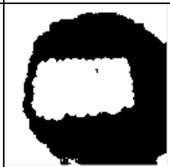
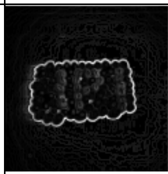
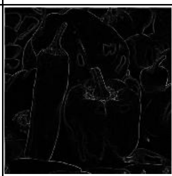
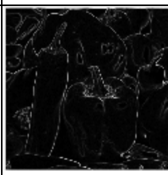
Table.1. shows original tested images, grayscale, enhanced

	Original image	**Grayscale**	**Noise reduction**	**Contrast enhancement**
Tree				
Jelly beans				
Pepper				

- **Features space and segmentation process**

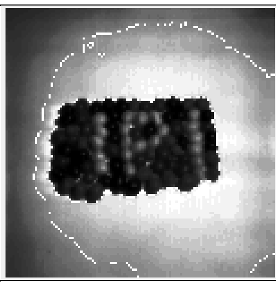
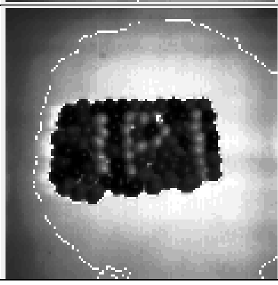
  Each texture of the input image is analysed using a texture filter, which means entropy and standard deviation filters, in which the characterization of image regions by their texture contents is considered using a window size of 3×3 for each one. Window size is determined by trial and error. Also, the gradient magnitude of central differences is extracted. Then the active contour segmentation is applied to each type of extracted feature. Table 2 demonstrates the images of each resulting active contour segmented region with each feature.

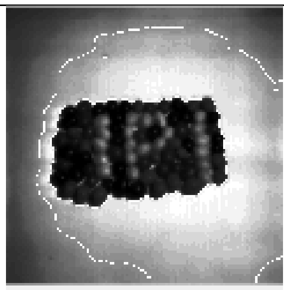
Table.2. Texture analysis (3×3) neighbour size and grand magnitude with active contour

Image	Entropy filter	Active contour (Entropy filter)	Gradient magnitude	active contour (gradient magnitude)	Standard deviation filter	Active contour (texture by STD filter)
Tree						
Jelly beans						
Pepper						

- Outline the original image by applying canny edge detection as explained in Table 3.

Table.3. applying canny of active contour segmented image on a grayscale of original image

Process	Tree	Jelly beans	pepper
Active contour (texture by Entropy filter)			
active contour (Gradient magnitude)			

Active contour (texture by STD filter)			

4. Performance evaluation and discussion

The accuracy of the stages of the proposed work is evaluated utilizing some statistical metrics and the details are as follows:

- **Noise reduction**

  PSNR and SNR **(Resham et al., 2021)** are statistical metrics used in this stage for wiener filter performance evaluation. A 3×3 neighboring size is considered in this filtering process, and from Table 4, the wiener filter works in accurately and the noise is reduced.

Table.4. wiener filter evaluated with PSNR, SNR

Tested image	PSNR	SNR
Tree	31.0940	26.2343
Jelly beans	43.1960	40.1691
Pepper	36.6437	30.9071

- **Contrast enhancement**

  The standard deviation (STD) reveals to a certain extent the contrast of an image, in which the high value of STD denotes the high contrast, and the low image contrast is represented with a low STD value **(Fazal-e-Malik, 2011)**, so it is used in this step for evaluating the performance of HE for contrast enhancement as seen in Table 5.

Table.5. histogram equalization evaluated by STD

Tested image	STD (gray)	STD (enhanced)
Tree	67.4662	74.9964
Jelly beans	38.2768	74.6478
Pepper	53.8793	74.6942

- **Segmentation process**

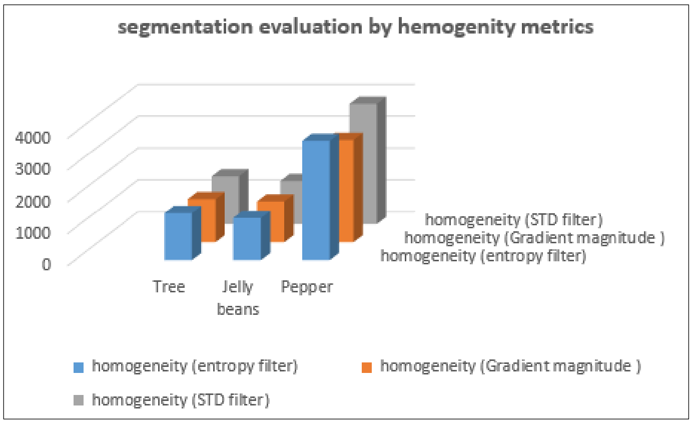
  Active contour segmentation operation with the three proposed features texture analysis with entropy filter, standard deviation filter, and gradient magnitude is evaluated based on the accuracy of the region homogeneity. From Table 6 and Figure 2, the active contour segmentation with texture features extracted by standard deviation filtering is more homogeneity than others, then the segmented-based texture characteristics extracted by entropy filter, and the segmentation with gradient magnitude in less homogeneity. Considering image (I) has the size with w×h, then homogeneity of image (I) is considered as in equation (10) **(Salman & Mohammed, 2021)**.

$$\text{Homogeneity (I)} = \sum_{i=0}^{w-1}\sum_{j=0}^{h-1}\frac{I(i,j)}{1+(i-j)} \tag{10}$$

Table.6. segmentation evaluation using homogeneity measure

Tested image	Region homogeneity entropy filter (3×3)	Region homogeneity Gradient magnitude	Region homogeneity STD filter (3×3)
Tree	1476.012925083569	1351.952178702612	**1501.989542476663**
Jelly beans	1321.496979383979	1279.121944681417	**1355.46057564935**
Pepper	3747.618303254659	3212.287820223055	**3776.278155810821**

Figure.2. Comparative in segmentation evaluation by hemoginty measure



- **Noisy condition**

  The robustness of active contour segmentation with each of the proposed features is evaluated in noisy conditions. So, the salt and pepper noise are added to the grayscale original image with a noise density of 0.02. Table 7 illustrates the additive noise to the grayscale image.

Table.7. additive salt and pepper noise to the grayscale input tested image

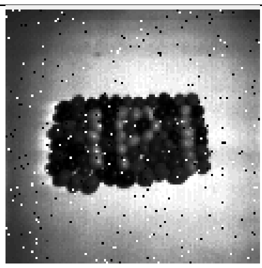
Tree	Jelly beans	Pepper
		

Table 8 and Figure 3 illustrate the computed PSNR, SNR, and RMSE for the grayscale of the input-tested image shown in Table 1 and with the grayscale of the additive noise image which is illustrated in Table 7. From this table, the Jelly beans image is more affected by additive noise while the Tree image is less affected.

Table.8. PSNR, SNR, RMSE between clean and noisy image

Tested image	PSNR	SNR	RMSE
Tree	**19.9415**	**15.0818**	**25.6722**
Jelly beans	10.7648	7.7378	73.8485
Pepper	18.4747	12.7382	30.3950

Figure.3. clean and additive noise of grayscale images evaluation, (a) PSNR, SNR, (b) RMSE

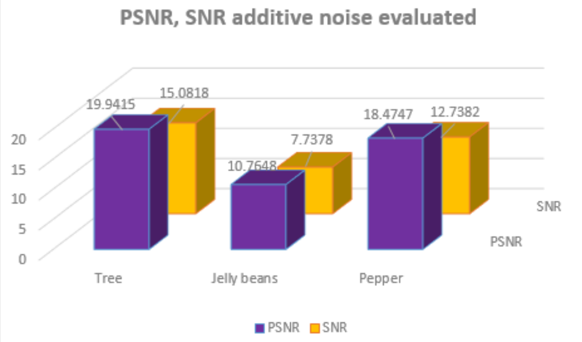
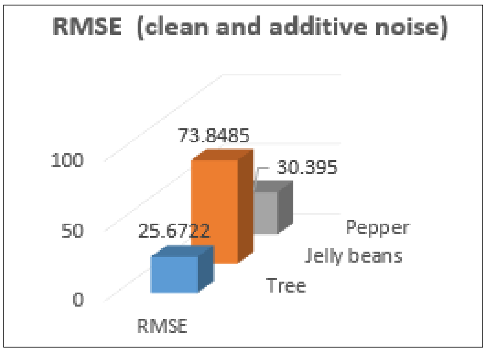
(a)	(b)
	

Table 9 demonstrates the application of the proposed active contour with these three features in additive noise salt and pepper conditions.

Table.9. active contour regions segmented with salt & pepper noise effect

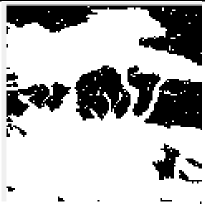
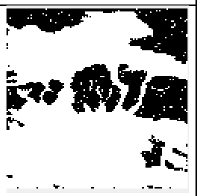
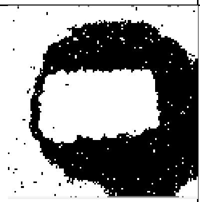
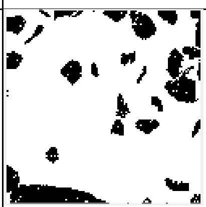
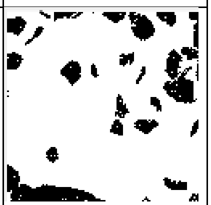
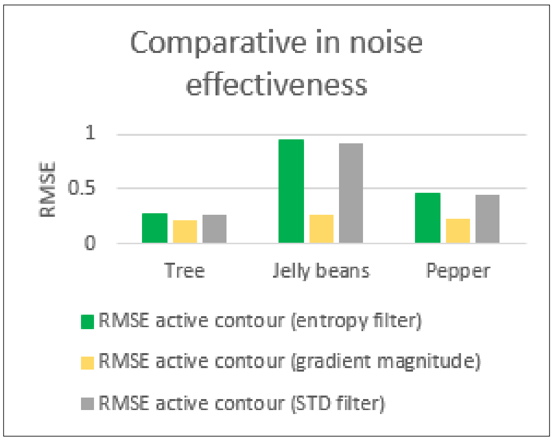
Tested image	Active contour (texture by Entropy filter)	Active contour (Gradient magnitude image)	Active contour (texture by STD filter)
Tree			
Jelly beans			
Pepper			

Table 10 and Figure 4, show the computed RMSE of the active contour segmented regions based on texture features with entropy, STD filters, and gradient magnitude in clean and noisy conditions that are explained in Tables 2 and 9 respectively. From this table, the active contour segmented region with gradient magnitude achieved more robustness in noisy conditions with these input-tested images although it performed with less homogeneity in clean conditions, and active contour segmented with texture features is more affected by additive noise.

image	RMSE active contour (entropy filter)	RMSE active contour (gradient magnitude)	RMSE active contour (STD filter)
Tree	0.2689	**0.2139**	0.2592
Jelly beans	0.9411	**0.2587**	0.9199
Pepper	0.4503	**0.2274**	0.4451

Table.10. Comparative of active contour (entropy filter, STD filter, gradient magnitude) with RMSE (clean, noisy)

Figure.4. RMSE (clean, noisy) for comparative segmentation



5.Conclusion

Three types of features are extracted from input-tested images after performing an enhancement process on image quality by reducing noise and contrast enhancement using the Wiener filter and Histogram Equalization technique respectively. Then using these extracted features to find the regions that form the image using the Active Contour procedure. From the previous sections, the segmented regions based on texture features analyzed by standard deviation are more homogenous than other regions that active contour segmentated with entropy filter and gradient magnitude. And when evaluating these segmented regions in noisy conditions it reveals that the proposed active contour with gradient magnitude is more robust than others in spite of it being less homogenous in clean conditions.

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