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Texture and pixel intensity characterization-based image segmentation with morphology and watershed techniques

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ABSTRACT

Image segmentation is an image processing technique that concentrated on finding and locating the parts of an image such as objects and boundaries. The purpose of locating these parts is for use in further processing analysis of an image such as recognition tasks, and content-based image retrieval. This paper introduces the segmentation procedure using a proposed template of features with watershed or morphology operations. Features template based on segmentation process conveys pixels' intensities property perceived by the threshold value of histogram representation and texture feature where the regions are characterized by their texture content using standard deviation (SD) filtering. Wiener filter and histogram equalization (HE) techniques are used as preprocessing operations to enhance the image quality. The edge detector operator is hybridized to boost the segmentation process. Some statistical metrics are used for assessing and analyzing the performance of the stages in the proposed work. As a result, this proposed template of features achieved more performance with watershed and morphology segmentation.

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1. INTRODUCTION

The partition of an image into separate regions, each with its own set of properties in terms of color, intensity, or texture is known as image segmentation. the purpose of this operation is to make the image more understandable for further analysis [1]. In the operation of image segmentation, two major classifications are regarded that defined as layer-based and block-based segmentation in an image. The approaches in the second classification are categorized based on two characteristics: discontinuity and similarity, and are divided into three groups: region-based strategies, edge-based or boundary-based procedures, and hybrid approaches [2]. Image segmentation is commonly used to define objects and edges in an image. The result of image segmentation is a set of segments consisting of the entire image or a set of contours extracted from the image. All pixels are connected to an area related to some computed property [3]. A variety of classical image segmentation algorithms such as watershed segmentation algorithm, active contour growth method, threshold-based segmentation method, regional growth methods, clustering algorithm, and segmentation method with Artificial neural network segmentation have been applied to image segmentation in recent years [4]. One of the more dominant methods and tools for image segmentation is watershed. This method is utilized for segmentation for the reason that it has the advantage of creating closed contoured regions and being able to display image details, but it has the problem of over-segmentation [5]. According to the watershed segmentation description and definition procedure, in the image that wants to achieve the segmentation process on it every local minimum in the image matches an isolated area in a result of this procedure of segmentation, the object contour region will be created at the end of this procedure. The identification of the number of regions depends on the number of local minima. For the reason, that noise and local inconsistency in the image that implements segment procedure on it, the number of local minima becomes more than the number of interest objects with applied significance in the image. That leads to false contours that interfere with the differentiation of the target contour of interest in the image. This is known as "over-segmentation" [6].

Many works are introduced to reduce this over-segmentation and improve watershed technique performance to get accurate objects of an image. Das and Ghoshal [7] introduced a proposed algorithm for segmenting an area of human skin from input color images utilizing a watershed technique with a modified morphological reconstruction as an open-closed marker. This process is implemented on the Cb component of the YCbCr space when the red, green, and blue (RGB) human face image is initially converted to this space, and the magnitude of the gradient of this Cb component was calculated using the Prewitt cut-off filter. Next, a segmentation process as proposed is applied. The results show that the proposed technique avoids the over-segmentation problem and provides a good segmentation result, comparable to that obtained by other algorithms. Lu *et al.* [8] created a segmentation method for medical tumor imaging, where the process relies on detecting gradient edges and controlling marked watersheds. the original image is first reconstructed and filtered by morphological opening and closing, then the object-related local minimum is extracted from the low-frequency components of the gradient image. The extracted mark is forced to use morphological reconstruction as the local minimum of the original gradient image, the achievement of adaptive correction of the gradient image, and finally the watershed segmentation.

Sardar *et al.* [9] suggested a methodology for image segmentation which is based on an adaptive process to select a Gabor filter using frequency content. Then extract the properties of the adaptive spectrum from the unique filters selected within the Gabor filters. The Gabor filter parameter is set to get the gradients of each property in the x and y directions, then the texture gradient image is taken into account when the combination of these properties is performed. and marker watershed technique performed on texture gradient image after selecting markers for different texture regions.

While Indriyani *et al.* [5] produced a method for image segmentation to determine the area of the road that is potholed. This algorithm includes six processes: smoothing, calculating gradient values, automatically determining minimum flood values, combining the catchment basins, deleting remaining catchment lines, and generating watershed curves. This study showed that this algorithm is effective in reducing the effects of over-segmenting.

Zhou and Yang [4] proposed a bone region segmentation algorithm. This segmentation process is performed depending on K-means clustering and an improved watershed algorithm for the purpose of breaking the over-segmentation and noise sensitivity caused by the implementation of the basic watershed technique. In the beginning, preliminary K-means clustering is implemented in the case when the noise is eliminated from the image by utilizing a Gaussian filter, then threshold separation using the Otsu approach is implemented. human body noise was eliminated by utilizing opening and closing morphological operations so, human skeletal areas were extracted, after morphological operations the watershed technique was applied, and afterward, similarity computing was achieved for obtaining integration and precise segmentation of human bone zones. The results of this algorithm appeared good feasibility of this algorithm to solve the over-segmentation of the original watershed algorithm and to segment bone regions of other human tissues.

Peng *et al.* [6] suggested bubble image segmentation by means of an improved watershed algorithm built on optimal labeling and edge constraints. For acquiring different initial tags three algorithms were developed, and then the extracted content of different tags is combined to get the combined foreground tag. Used the fuzzy c-means (FCM) algorithm, morphological reconstruction method, and adaptive threshold method to extract and fuse the foam foreground markers. The extraction of the bubble boundary was implemented by the edge operator for decreasing the offset of the segmentation line, and the boundary priori condition is utilized as a restriction to fix the segmentation line. Ultimately, the optimal segmentation line is achieved through a combination of foreground markings and external constraints.

Rahali *et al.* [10] introduced an algorithm for Drosophila cell segmentation using a watershed based on two proposed foreground markers: the kernels, built using Fiji software, and the Obj.MPP markers, which were created using the object/pattern detection using a marked point process (Obj.MPP) framework and comparison are made with a basic marker-controlled watershed and proved that Obj.MPP markers are better than kernels. The results with the new markers appeared good performance in terms of quantitative and qualitative assessments.

Many works are developed and proposed different algorithms to improve watershed segmentation to get image segments accurately. In the literature, some of these works improved watershed performance based on markers, where internal and external markers are predefined. Marker identification has a great effect on the segmentation result, so some researchers proposed different techniques to modify markers. While the other researchers introduced proposals to improve the watershed by adding further processing steps.

The proposed work improves watershed and reduces its over-segmentation problem by proposing a new template of features that labeled the pixel intensities of image objects which considered the essential information contained inside pixels as well as a crucial attribute used for categorization and contains information about the local variability of pixel intensity value at the same time. In this proposed methodology the pixels intensities of image objects are detected and labeled on the base the objects in the image are separated into dissimilar sets depending on the intensity of the pixel [11], by this process false contours that interfere with the detection of the image's target contour of interest are reduced when applying watershed technique, and segmented accuracy is increased when local variability of pixel intensity value is extracted at the same time in this template of features. This step is achieved when preparing the image quality enhancement in a preprocessing stage which is regarded as a critical stage in raising method performance, and the segmentation is boosted by applying an edge detector. So, the watershed is improved in its segmentation performance as proved by metric evaluation along with displayed the resulting figures.

Also, the other contribution is to improve the performance of image object segmentation using this template of features based on morphology operations. The utilization of morphological operators has had a reproducible advantage for various image processing applications recently. This is mainly due to their capability to tackle many difficult challenges related to form. Segmentation, in addition to automated counting and testing, are the main areas of application. Morphology is a certain and crucial set of methods that can be treated mathematically precisely in the context of set theory [12]. So, by employing these morphology characteristics with the abilities of the proposed template of features and using appropriate structure element size after enhancing image quality and boosting the segmentation by edge operator an attempt to detect real pixel objects of the image is proposed and proved, and evaluated in the next sections. Many researchers used these morphology operations to get image segments in different applications such as in medicine and recognition. Aung *et al.* [13] using trypan blue-stained microscopic pictures of a breast cancer cell line, a computer-assisted cell counting technique was presented, in which live and dead cells were counted following image segmentation. A guided image filter was used to eliminate unwanted noise and clutter. To discriminate between living and dead cells, color space hue, saturation, and value (HSV) conversion and grayscale conversion were done. For image segmentation, picture thresholding and morphological operators were used.

Hassani *et al.* [14] an automated hybrid technique for lung segmentation that utilizes mathematical morphology and the region growth algorithm was suggested. The seed points are chosen automatically, with no user intervention. Furthermore, the structuring element employed in mathematical morphology operations is dynamic, changing shape and properties based on the input 2D lung CT slices.

Zainudin *et al.* [15] introduced an algorithm for the segmentation and detection of glaucoma. This algorithm described the utilization of color channel separation for pre-processing to eliminate noise for improved optic disc and optic cup segmentation. The optic disc and optic cup are then extracted from the fundus image using morphological processing and an adaptive thresholding approach. Finally, the segmentation and identification of glaucoma were effectively achieved.

Zhang *et al.* [16] produced a suggested algorithm for the segmentation of brain tumor images, a hybrid clustering technique coupled with morphological procedures was proposed. The approach initially removes the outside membrane using morphological procedures, which minimizes computing cost and the number of clustering rounds. The K-means++clustering technique is used during the clustering step.

The aim of this proposed method is to find the meaningful and homogenous regions (objects) that form the image and create the edge plot using improved watershed techniques or morphology operations. This proposed method achieved in stages are preprocessing stage, proposed features template generation stage, segmentation processes stage, and the extracted regions by the two techniques are emphasized by another technique when a canny detector is used and obtained the edge plot of the segmented image and apply it to the original one. The rest of the paper has been organized as follows: section 2 shows the basic concepts of methods used in this proposed work. In section 3 reveals the methodology in which the proposed work was followed in detail. The acquired results on experienced images are presented in section 4. Finally, a conclusion is in section 5, followed by a performance evaluation and discussion in section 6.

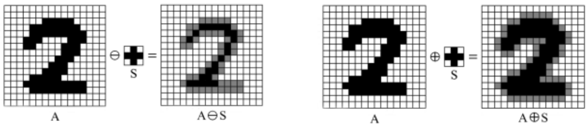
2. METHODS BACKGROUND

2.1. Morphology operations

Mathematical morphology is defined as a theory of geometrical structure analysis. It is considered an influential approach that's frequently employed in image processing to manage the extraction of image features that are useful in depicting area forms, such as borders and skeletons. Erosion, dilation, opening, and closing are the elementary morphological operators [14]. Dilation is a process that increases or condenses objects in an image. A shape known as a structuring element organizes the specified method and range of this thickening. While the purpose of erosion operation is to reduce the object size that exists in an image [12]. The definitions of erosion and dilation processes are demonstrated in (1) and (2) respectively and as shown in Figure 1, where Figure 1(a) defines erosion and Figure 1(b) demonstrates dilation. A has been assumed to refer to a binary object in an image and S means a structuring element [17]. Morphological operators are used to process binary images on the basis of their shape and characteristics. Different types of structuring elements can be used to encode the binary information according to the applications [18].

$$A \ominus \mathrm{S} = \{(\mathrm{i},\mathrm{j}) : \mathrm{S}(\mathrm{i},\mathrm{j}) \subset \mathrm{A} \tag{1}$$

$$A \oplus S = \cup_{(i,j)\in A} S'(i,j) \tag{2}$$



(a) (b)

Figure 1. Erosion and dilation processes in (a) erosion and (b) dilation [17]

2.2. Edge detection

The process has been divided the spatial domain known as edge detection, where the image is demarcated into important portions or regions. Pauses are sudden variations in pixel density and edges that mark the borders of objects in an image and object appreciation [19]. The origin of edges in an image is among two equivalent areas. Edge detection refers to a procedure or method for recognizing appropriate image boundaries [20]. Several gradient-based edge operators have been established in the last two decades. Edge detection is considered a fundamental stage of main importance in image analysis. Despite the diversity of these approaches, two broad groups may be distinguished: methods that utilize global analysis and methods that use local analysis. For edge detection, local analysis is the preferred method [21]. The first derivative of a Gaussian is the canny edge operator which closely approaches the operator that improves the product signal-to-noise ratio and localization [22].

2.3. Watershed transformation

The watershed transform is defined as a segmentation technique in mathematics morphology. In geography, a watershed is defined as the edge that splits regions channeled by a diverse river system. This transform is a morphological gradient-based segmentation method [23]. In this method, the image intensity plot is observed as a topographical landscape where the minimum intensity is the catchment basins and the hills are the watershed. The goal is to search for watersheds by growing area, and growing catchment basins from the previous fixed set of local minimums till each pixel in the image are related to one of the labeled catchment basins [24]. The principle of a watershed originated from geography. Assume a landscape has been inundated by rain. Rainwater obviously floods the steepest pathway and finally drops into a variety of attractive regions. Watersheds are the ordinary segmenting contours of the landscape since they are the dividing lines of these domains (called catchment basins). Watershed model dominates many benefits. This model is considered broad and appropriate to many segmentation difficulties, and it is able to yielded closed contours, which is an effective quality for follow-on processing operations, for instance, pattern recognition. Further more, current watershed techniques are typically computationally effective [25]. Watershed segmentation can be used to segment the connected cells, but need to use distance transform to pre-process the image to make it suitable for watershed segmentation. Distance transform is applied with $Euclidian$ distance as seemed in (3) [26].

$$d_{\mathrm{Euclidian}}\left([i_1, j_1], [i_2, j_2]\right) = \sqrt{(i_1 - i_2)^2 + ((j_1 - j_2)^2} \tag{3}$$

Where $([i_1, j_1], [i_2, j_2])$ refer to the two pixels.

3. METHOD

Figure 2, shows the proposed model of the segmentation process that contains five essential stages: reading RGB entered image and obtaining the grayscale, preprocessing stage, features template generation stage, segmentation processes, and hybrid with canny operator for outlining segmented regions. A detailed explanation for each stage's role is given in the following subsections.

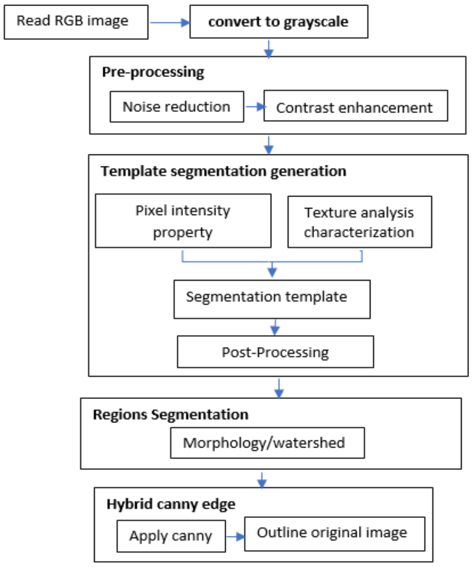


Figure 2. Proposel model

3.1. Reading the input RGB

The first stage of achieving the proposed model is reading input testing images. In this stage, the RGB input-tested image has been read where in an RGB color image a pixel color in an image is a mixture of three colors RGB, and then converted to a grayscale utilizing a representation of intensity information for each pixel value, which have an equal level of intensity for the main RGB colors. The conversation is performed for further processing.

3.2. Preprocessing stage

Preprocessing is regarded as a critical stage in raising method performance. It's considered an essential step for enhancing the image to improve its quality for further analysis and processing. Two operations are performed in this stage for image quality improvement, noise reduction where the noise effect on information that extract from image, and contrast enhancement process in which the brightness variances are improved in an image object.

3.2.1. Noise reduction

Wiener filter is considered in this step. The Wiener filter is a popular image enhancement technique that is utilized in a variety of applications such as linear prediction, signal recovery, echo cancellation, channel equalization, and identification systems. The primary purpose of this approach is to recover the image while lowering the error value by reducing noise [27]. The Wiener filter is a statistically based filtering tool. The Wiener filter calculates the mean and variance of each pixel in such a way that [28].

$$\mu = \frac{1}{mn}\sum_{i}^{m}\sum_{j}^{n} a_{i,j} \tag{4}$$

$$\sigma^2\,(A) = \frac{1}{mn}\sum_{i}^{m}\sum_{j}^{n} a_{i,j}^2 - \mu^2\,(A) \tag{5}$$

Forming Wiener filter equation from combining mean equation and variance equation together:

$$W_{i,j} = \mu(A) + \frac{\sigma^2(A)-v^2}{\sigma^2}\left(a_{i,j} - \mu(A)\right) \tag{6}$$

where μ is local mean, σ^2 variance around each pixel, v^2 is the noise variance, $W_{i,j}$ is Wiener.

3.2.2. Contrast enhancement

Histogram equalization (HE) technique is used to enhance the contrast of an image by highlighting information within the low dynamic range of that gray-level image that resulted from the previous step. HE is an image enhancement technology that work in the spatial domain in the operate and handles image pixel intensity without explaining it to another domain (i.e., frequency domain). To improve visual contrast, the HE approaches redistributes image intensity equally over the whole grayscale range [29]. HE is as "representing of each pixel of the input image into an associated pixel of the organized output image is known as histogram". HE can be described as in (7) [30]:

$$p_n = \frac{no.of\ pixels\ with\ intinsity\ n_k}{total\ no.of\ pixels\ n} \tag{7}$$

where n=0, 1…L-1 is the range of the gray level values.

3.3. Segmentation template generation

At this stage, a segmentation features template used in morphological and watershed segmentation techniques was generated based on the combination of two types of feature extraction, where the first feature is the pixels' intensities of the grayscale of the enhanced image, and the second one is the texture feature analysis. Pixel intensity properties are considered an important feature and in this proposed template are extracted based on the threshold value of histogram representation. The objects in the image are divided into dissimilar sets based on the intensity of the pixel. One or more threshold values be able to do detection from each peak of the histogram that has been reflected in one or more regions in the image [11]. Also, it is important to consider texture information provided with an image by considering the grayscale components of an enhanced image. Statistical measure as the standard deviation (SD) of the 5-by-5 neighborhood around the consistent pixel is used to extract the texture feature which provides local variability of the pixel's intensity values information. Texture content in an image characterizing the regions on it is indicated as the texture analysis process, it's implemented by range filtering, SD filtering, and entropy filtering. The filtering operation is done using regular statistical metrics which depict the image texture. This depiction offers information on the local variability of the pixel's intensity values in an image [31]. The calculation of SD is as follows [32].

$$\mu_j = \frac{1}{N}\sum_{i=1}^{N} x_{ji} \tag{8}$$

$$\sigma_j = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_{ji} - \mu_j)^2} \tag{9}$$

Where μ_j is the mean, σ_j is the SD.

3.4. Morphological and watershed segmentation

In this stage, segmentation operation is done based on the proposed template of features using two techniques, the first segment is morphological operations with dilation and erosion applied for region segmentation with structure element 3×3 using the segmentation template which is generated in the previous stage, then the binarization operation is performed as a post-processing step on the morphology output using Otsu's method. Where the image pixel intensity is used in the Otsu method mechanism to discover the best threshold value. This is done when iterations have been performed for all possible values and the space of the pixel levels scale was calculated on threshold sides individually, that is, the pixels that lie in the background or foreground. The goal is to determine the threshold value where background spread and foreground summation are minima [33]. And the second one is a watershed segmentation using distance transform by measuring the distance from each pixel in template segmentation towards the adjacent non-zero valued pixel by (3). Then, the obtained watershed ridge lines are detected as segmented regions. Binarization operation using Otsu's method is applied to the features template before watershed segmentation.

3.5. Hybrid with edge detection

Another segmentation technique is hybridized with watershed and morphology operations to boost the extraction of the region. Where the canny edge detection is utilized for this purpose. Canny edge operator is applied to the segmented image that results from morphological operations or watershed and outlined regions of the original image.

4. EXPERIMENTAL RESULTS

4.1. Read test input images

The evaluation of the performance of this proposed method has been achieved by testing four input images which have diverse sizes and types, the first three input tested images are well-known standard pepper (512×512 pixel), Lena (256×256 pixel), Jelly beans (256×256 pixel) images respectively, and the fourth tested image is a satellite image (197×197 pixel) where the L1G product was acquired from the United States Geological Survey (USGS) website [34] and stored as the original 8-byte integer value. This satellite-tested image depicts an intensive study area consisting of the part of the euphrates river and its surrounding arable land. As explain in Figure 3, where Figures 3(a) to 3(d) illustrate tested input images and Figures 3(e) to 3(h) show their conversion to grayscale.

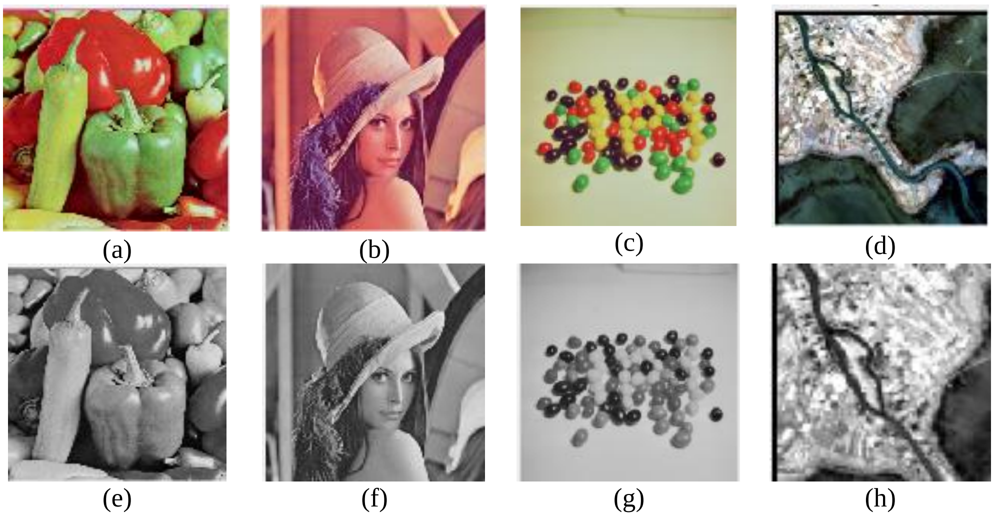
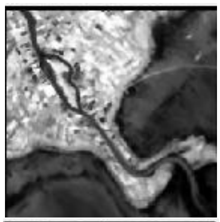
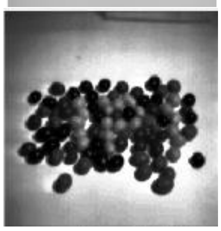
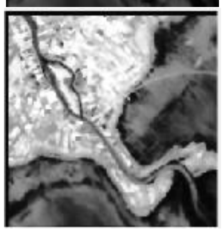


Figure 3. Original tested images and their grayscale (a), (e) Pepper, (b), (f) Lena, (c), (g) Jelly beans, and (d), (h) satellite image

4.2. Image preprocessing

Image enhancement plays a vital role in improving image quality before further processing, the image has been enhanced by removing noise and contrast enhancement. Table 1 clarifies the application of these enhancement operations on input tested images. The first row of the table explains noise removal where a Wiener filter is employed when converting each input image to its grayscale for decreasing the amount of noise that exists in a grayscale image with a window size of 3×3. This window size was determined depended on performance evaluation of the Wiener filter using statistical metrics with other window sizes, and the performance reveals that the 3×3 window is more performance than others and considered in this stage. While the second row of this table shows contrast enhancement where the HE technique is used for improving image visualization when the noise has been eliminated.

Table 1. Image enhancement by Wiener filter and HE

Tested image	Pepper	Lena	Jelly beans	Satellite image
Noise reduction				
Contrast enhanced				

4.3. Segmentation template generated

The template of features segmentation is created by combining pixel intensity property and texture features of an image. Where the pixel intensity image is calculated based on the threshold value explained in Table 2 from histogram representation. This table demonstrates the threshold value for each input tested image.

Table 2. Threshold value to detect interesting intensity regions

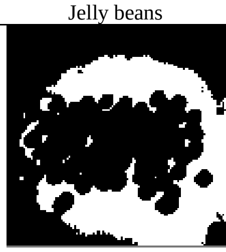
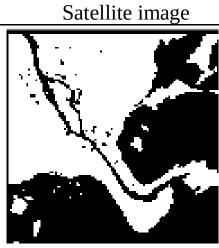
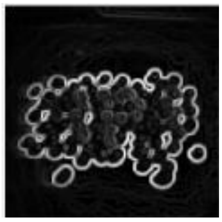
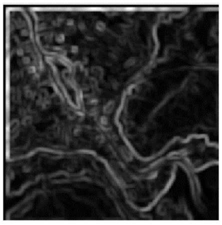
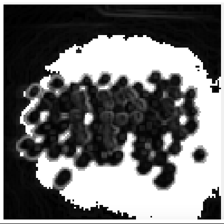
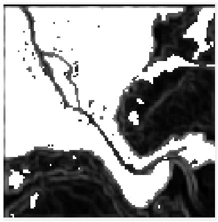
Tested image	Pepper	Lena	Jelly beans	Satellite image
Threshold value	values>95	values>140	values>170	values>130

The second feature of a segmentation template is a characterization of image texture content computed by using a SD filter, and it can afford statistics of the local changeability of the density values of pixels in an image by applying 5×5 neighborhood size around interesting pixels in an enhanced image by the SD for each pixel on it. Neighborhood size is determined depending on the performance evaluation by measuring region homogeneity. Considering (I) has the size with $w \times h$, then homogeneity of (I) is considered as in (10) [35].

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

Hence, the segmented template conveys information about the pixel intensity property of the regions and the local changeability of the pixel density values in an image that exists in texture content depiction. Table 3 demonstrates the images computed based on intensity and texture analysis filtering and the resulting one.

Table 3. Segmentation features template generated for each input image

Feature	Pepper	Lena	Jelly beans	Satellite image
pixels intensities property image				
Standard deviation filtering image				
template (features combination)				

4.4. Segmentation operation

Table 4 demonstrates the extracted region with the two proposed segmentation techniques. Where the first and second rows of this table describe the implementation of morphology with dilation and erosion operations respectively to each input tested image, where the last one shows the applied of watershed method. To boost segmentation operation canny edge operator is applied to the segmented image that results from morphological operations or watershed and outlined regions of the original image as seen in Table 5, canny applied on dilation and erosion showed in the first and second columns, and on watershed in third one.

Table 4. Illustrates segmentation operations with morphology and watershed

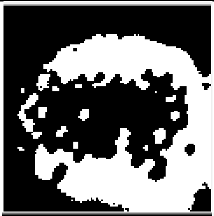
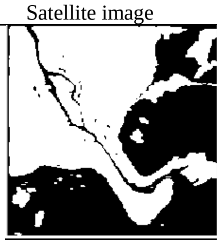
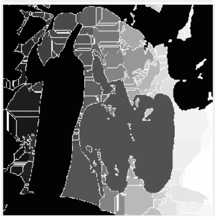
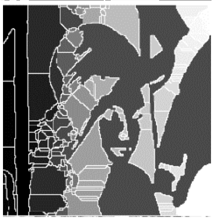
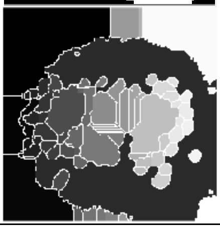
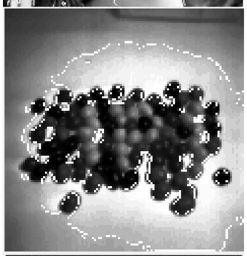
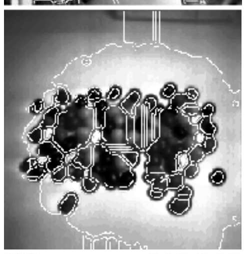
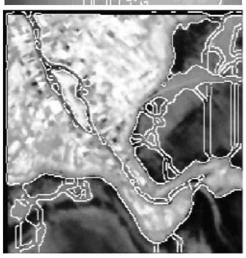
Tested image	Pepper	Lena	Jelly beans	Satellite image
Dilation				
Erosion				
watershed				

Table 5. Outline segmented regions on the original one

	Dilation	Erosion	Watershed
Pepper			
Lena			
Jelly			
Satellite image			

5. PERFORMANCE EVALUATION AND DISCUSSION

5.1. Noise reduction

Statistical metrics peak-signal-to-noise ratio (PSNR), signal-to-noise ratio (SNR), and structural similarity index measure (SSIM) are used to judge the effect of noise reduction by Wiener filter, Table 6 exposed the accurate performance of applying noise reduction from the values of PSNR, SNR, and SSIM for each input image pepper, Lena, Jelly beans, and satellite image. These metrics are quantifying the image of applying a Wiener filter concerning the grayscale of the original one and from these metrics' values, the noise is reduced in an accurate performance. SNR and PSNR are calculated as in (11) and (12) respectively [36].

$$SNR = 10log_{10} \sum_{x=1}^{m} \sum_{y=1}^{n} \frac{f(x,y)^2}{(f(x,y)-g(x,y))^2} \tag{11}$$

Where f (x, y) de-noise image, g (x, y) is an image that contains noise, and the image size is $m \times n$. The higher the SNR the improved the noise decrease influence.

$$PSNR = 10log_{10} \sum_{x=1}^{m} \sum_{y=1}^{n} \frac{m\times n\times 255\times 255}{\left(f(x,y)-g(x,y)\right)^2} \tag{12}$$

Where PSNR is the peak signal-to-noise ratio in decibels (dB). Also, the higher PSNR enhanced the noise reduction influence.

SSIM is demarcated in expressions of the mean pixel values, $\mu_{x,}$ and with μ_y, and σ_x and σ_y which are considered as pixel value SD at spots x and y and covariance (cross-correlation) σ_{xy} of x and y through the following [37].

$$l(x,y) = \left(2\mu_x\mu_y + C1\right)/(\mu_x^2 + \mu_y^2 + C1) \tag{13}$$

$$c(x,y) = \left(2\sigma_x\sigma_y + C2\right)/(\sigma_x^2 + \sigma_y^2 + C2) \tag{14}$$

$$r(x,y) = (\sigma_{xy} + C3)/(\sigma_x\sigma_y + C3) \tag{15}$$

Where C1, C2, and C3 are constants, when (μ_x^2+μ_y^2), (σ_x^2+σ_y^2), or $\sigma_x\sigma_y$ is near to zero. The $\mathrm{l(x,y)}$ indicator is associated with variances in illumination, $\mathrm{c(x,y)}$ with contrast modifications, and $\mathrm{r(x,y)}$ with organization differences between x and y. The common formula of the SSIM indicator is demarcated as in (16):

$$SSIM(x,y) = [l(x,y)]^{\alpha}.[c(x,y)]^{\beta}.[r(x,y)]^{\gamma} \tag{16}$$

where α, β, and γ are parameters that describe the qualified significance of each element. SSIM (x, y) ranges from 0 (completely different) to 1 (identical areas).

Table 6. Wiener filter performance evaluation

Tested Image	PSNR	SNR	SSIM
Pepper	36.643	30.907	0.900
Lena	37.602	31.945	0.930
Jelly beans	43.195	40.169	0.991
Satellite image	30.760	24.588	0.922

5.2. Contrast enhancement

The SD and root mean square error (RMSE) are statistical metrics used to evaluate HE technique performance for enhancing the contrast of an image in this step. SD is a measure of how the data is spread concerning the mean. The SD exposes somewhat the contrast of an image, where the value of SD is high which refers to the high contrast of an image, if there's a low SD value that means the low contrast in an image [32]. As seen in Table 7 the SD values of an image with enhanced contrast are higher SD values than the other one, also the values of RMSE reveal that the image processed by HE is more accurate in visibility than the compared image, which means its contrast has been improved other than the original one.

Table 7. Contrast performance evaluation with SD, RMSE

Tested image	SD (input image)	SD (Enhanced contrast)	RMSE
Pepper	53.436	74.694	23.844
Lena	47.342	74.865	28.736
Jelly beans	37.729	74.647	71.510
Satellite image	70.933	74.588	29.593

5.3. Segmentation operation

The proposed segmentation operation for the two processes is evaluated based on region (objects) homogeneity. The process of image segmentation is demarcated as a technique of dividing an image into homogeneous regions [38]. Object homogeneity of the segmented image is measured using (10).

Let's discuss the effect of the proposed template on morphology segmentation, Table 8 illustrates the comparison of region homogeneity based on texture and pixel intensity features each individually using the same segmentation steps with the segmentation based on proposed features using morphology operations. From the values of this table and as explained in Figure 4, the proposed combination feature template segmentation has its effect on finding the regions that form the image accurately and homogeneity. Also, the dilation with the proposed feature is more homogenous in output regions.

Table 8. Comparison morphology regions homogeneity based on feature type with SD filtering window size

Test image	Texture feature (5×5)		Pixel intensity feature		Proposed feature template		
	Dilation	Erosion	Dilation	Erosion	Dilation (5×5)	Erosion (5×5)	Dilation (3×3)
Pepper	654.7686267850928	443.0175379017312	3822.267353849135	3526.333337286905	4473.363951341467	3976.720074890466	4281.110732981614
Lina	416.4299780539195	260.9969905466975	1138.307085699794	870.759451330971	1549.290967575678	1140.729977480196	1438.132752621065
Jelly	350.3994443543226	226.0018795800566	685.3033657642909	597.9841661948027	1031.249903863452	831.659694877026	949.3244077640182
Satellite image	392.3893178784643	269.1906424507967	970.0765367899465	788.6917167811714	1359.334128049272	1063.901486552061	1252.885596349259

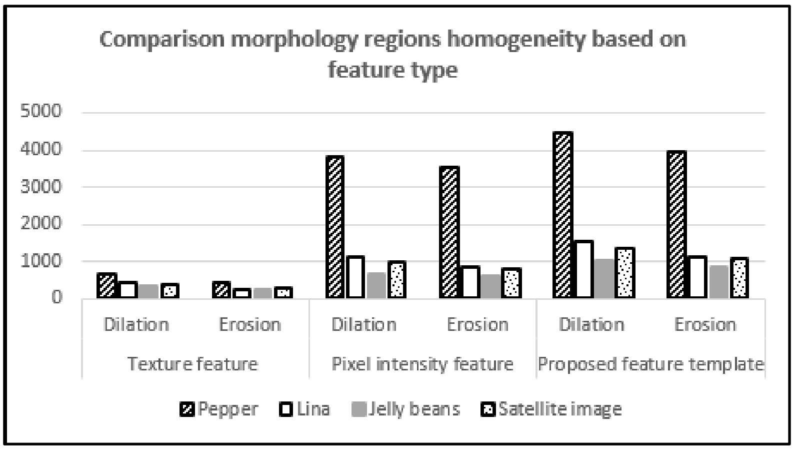


Figure 4. Comparative morphology region's homogeneity segmentation based on the feature type (5×5 SD filtering)

Also, the effect of the proposed feature templates on watershed segmentation. Watershed algorithm is considered more efficient method for achieving segment process on image, but this technique has a problem of over-segmentation [22]. Table 9 shows the evaluation of watershed segmentation using region homogeneity measure based on SD filtering window size (5×5) and comparing it with (3×3).

Table 9. Watershed with proposed features evaluation by homogeneity measure based on SD filtering size

Method | Tested image	Pepper	Lena	Jelly beans	Satellite image
Watershed (3×3)	832516.6351468597	174263.4086695805	75784.59934031933	71801.07203168809
Watershed (5×5)	**859411.9523190653**	**185815.6380512393**	**77996.99495397232**	**79232.63340306004**

Figure 5 shows the watershed segmentation based on texture and pixel intensity each individually. As seen in Figure 5(a) the segmentation based on texture feature presents over-segmentation more than the segmentation based on the proposed template of features that are illustrated in Table 5. Also, Figure 5(b) shows the watershed segmentation based on the property of pixel intensity, and Table 10 illustrates the region homogenous measure of this segmentation although it closes from segmentation by proposed features in reducing over-segmentation, but by comparing the values of Tables 9 and 10, the segmentation of the regions based on pixel intensity only is less homogenous than the segmentation with the proposed features template.

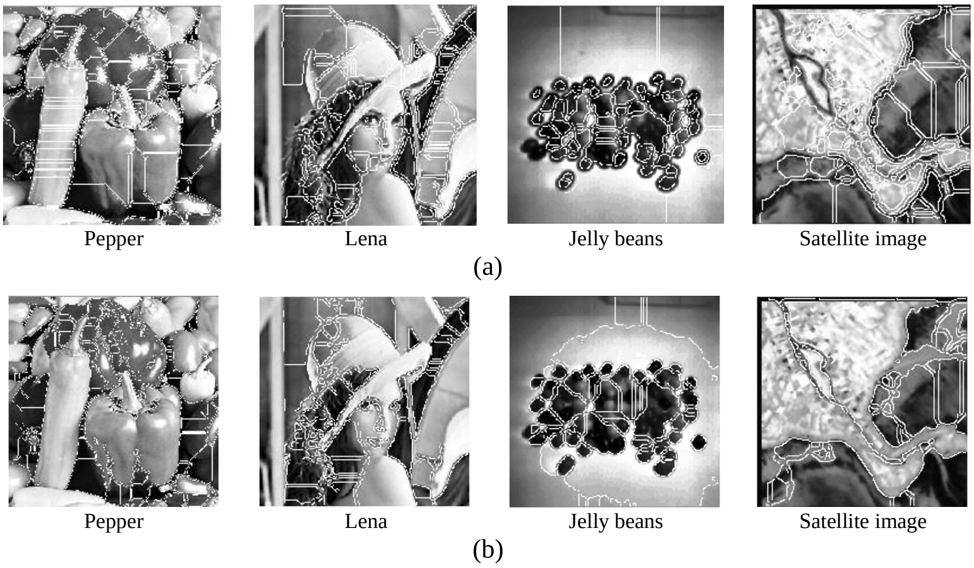


Figure 5. Watershed segmentation based on (a) texture feature and (b) pixel intensity

Table 10. Watershed segmentation evaluation with homogeneity measure based on pixel intensity feature

Pepper	Lena	Jelly beans	Satellite image
857458.6619493781	184122.1806719585	76273.95074715147	71808.58227736509

So, the proposed procedure works accurately with more homogeneity and in reducing over-segmentation. Since the proposed feature template labeled the pixels' intensities of objects which means the more informative intensities via the threshold of the histogram of an enhanced image, and at the same time contains information about the local variability of pixel intensity value. Hence this features combination improved the segmentation by watershed technique and morphology operations with dilation and erosion segmentation performance.

6. CONCLUSION

This work shows two proposed procedures of segmentation to find regions that form images accurately and homogeneity. A combination of features is based to segment an image with dilation and erosion morphology and watershed techniques. Image quality is enhanced using Wiener filter and HE technique as preprocessing step. Also, the proposed procedures are advancing their segmentation by hybridizing with the canny operator. Some statistical metrics are used to evaluate the performance of preprocessing steps and based on these metrics the HE and Wiener filter in accurate performance are achieved. The performance evaluation is achieved for the two proposed procedures based on region homogenous measure, and the comparison is made to see the effect of the proposed features template on finding regions and plotting boundaries. The two proposed procedures have their effects on the tested input images to find interesting homogenous objects (segments) in an image, and when using more than one feature the segmentation operation becomes more performance to find meaningful regions of an image.

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