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Review on Region-Based Segmentation Using Watershed and Region Growing Techniques and their Applications in Different Fields

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Abstract

In digital image processing and computer vision, segmentation operation for an image refers to dividing an image into multiple image segments, and the significant purpose of segmentation operation is to depict an image in a way so that the analysis process of the objects of interest is easier and more accurate. The region-based segmentation scheme act for finding similarities between adjacent pixels to detect each region that constructs the image. Similarity scales have based on different features, in a grayscale image, the scale may be referred to as textures and other spatial appearances, and also the variance in intensity of a region and so on. Significantly, many applications in different fields involved region-based segmentation for instance remote sensing, medical application, and others for recognizing interesting objects in an image. In this paper, two techniques for segmentation operation in region-based which are region growing and watershed are reviewed.

Introduction

Meaningfully, image segmentation is considered an elementary difficulty in the field of the analysis of an image. The significance of image segmentation has resulted in wide-ranging research and various introduced methods for instance intensity, color, texture, etc., in cooperation with automatic and interactive (Lalaoui et al., 2015). Two chief categories are considered in the operation of image segmentation which is known as layer-based and block-based segmentation in an image. The methods in the second category are considered on two characteristics, which are known as discontinuity and similarity in three groups, first, which are known as region-based approach, secondly, edge-based or boundary-based methodologies, and third, techniques in hybrids (Zaitoun & Aqel, 2015). The mechanism of separating the regions of an image as a set of pixels is referred to as the image segmentation procedure. The purpose of this separation in regions of an image is to make the depiction of it more significant and easier to analyze. The employing of this segmentation operation to the image for detecting its own objects and edges (Kaur et al.,2013). In this paper, a review of region-based segmentation with two techniques is introduced which are watershed segmentation and region growing along with details for each individual and their applications in different fields. The purpose of this review is to support researchers who try to extract image regions using these two techniques. This reviewed paper is presented as follows, section 2 briefs the theoretical background of watershed and region growing techniques, followed by a list of some

applications of these two techniques in section 3, and lastly, a conclusion is inferences in section 4.

Theoretical background

Watershed Transform

Watershed transformation has received a lot of interest in recent years as an effective means for morphological segmentation. The growth process starts from each regional minimum point, each of which constructs a particular region after transformation. The watershed algorithm successfully associations discontinuity and similarity characteristics. The chief shortcoming of watershed transform is over-segmentation and also considered sensitive to noise, and high computational difficulty makes it inappropriate for the real-time process (Singh, 2016). The watershed is the elevation line that divides various areas called catchment basins across different river organizations as shown in Figure 1 (Acharjya & Ghoshal, 2012). Extracting regions that are considered catchment basins that exist in topography has been considered the main idea of segmenting by watershed technique. Hence the lines constructed by the watershed are the boundaries of the catchment's basins (Bhatia & Saxena, 2007). This Transform is considered an exclusive procedure for segmenting operations that habits a kind of region-growing scheme created on an image gradient. The perception of this technique is founded on picturing an image in three scopes: two spatial organizes versus gray levels. Figure 2 illustrates the applying the Watershed Transform of Lena test image introduced in (Amoda & Kulkarni, 2013). The exploration of the regions which has high-intensity in their gradients is the purpose of this technique which divides the adjacent local minimum (basins) (Salman, 2006). For more mathematical details (Roerdink & Meijster, 2001).

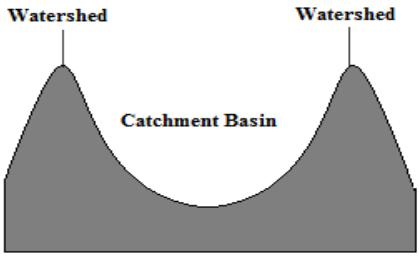

Figure 1. Watershed segmentation (Acharjya, & Ghoshal, 2012)

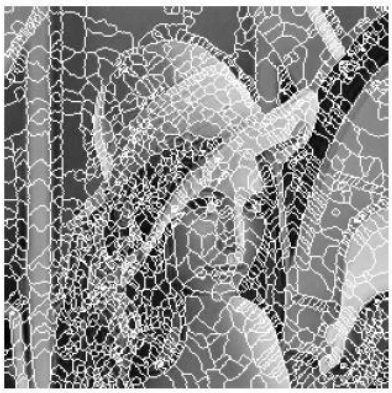

Figure 2. Watershed Transform of Lena test image (Amoda & Kulkarni, 2013)

Marker-controlled watershed transformations

To reduce the outcome of plain over-segmentation, Marker-controlled watershed transformations have been anticipated. Which is considered a strong and flexible way of separating objects with locked contours. Demarcated operation on the interior marker is implemented, also on an exterior marker (Kaur et al.,2013). The segmentation using this

method has been performed best when the foreground objects and the background locations are marked. Therefore, the procedure for implementing Marker controlled watershed is as follows: *first*, the function of segmentation has been calculated, *second*, foreground markers are computed, *third*, background markers are then calculated, and the function of segmentation is updated hence it contains the locations of foreground and background marker at minima. Lastly, the watershed technique of updated function is implemented (Hamdi, 2011). Directing the over-segmentation problem in the watershed technique is significant to detect valid regional minima. By considering the markers as the valid regional minima and wholly the invalid regional minima are deleted when choosing the markers. So, in this approach, the over-segmentation problem is decreased and Figure 3 shows an example of applying this process (Manda & Kim, 2019).

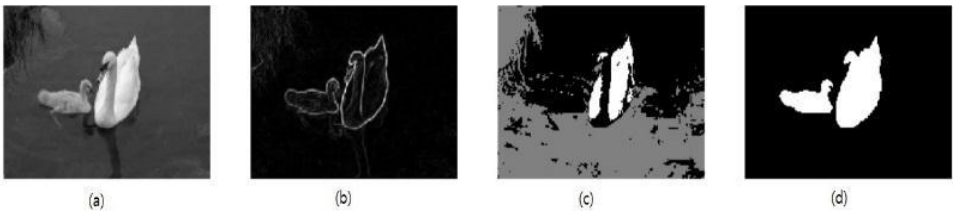

Figure 3. Illustrates Watershed segmentation using markers (Manda & Kim, 2019)

Distance Transform Approach

It is referred to as a procedure involved regularly in combination with the watershed transform for achieving the segmentation process. Which is defined as the distance metric between a piece pixel with the adjacent non-zero valued pixel (Seal et al.,2015). Various ways of describing the distance between two pixels $[i_1, j_1,]$ and $[i_2, j_2]$ in a digital image and Figure 4 demonstrates the use of distance transform with the watershed transform, also some regularly used DT functions for image processing are as follows (Chen et al.,2004):

Euclidean:

$$d_{\text{Euclidian}}([i_1, j_1], [i_2, j_2]) = \sqrt{(i_1 - i_2)^2 + ((j_1 - j_2)^2} \quad (1)$$

City block:

$$d_{cityblock} = ([i_1, j_1], [i_2, j_2]) = |i_1 - i_2| + |j_1 - j_2| \quad (2)$$

Chessboard:

$$d_{chessboard} = ([i_1, j_1], [i_2, j_2]) = \max(|i_1 - i_2| + |j_1 - j_2|) \quad (3)$$

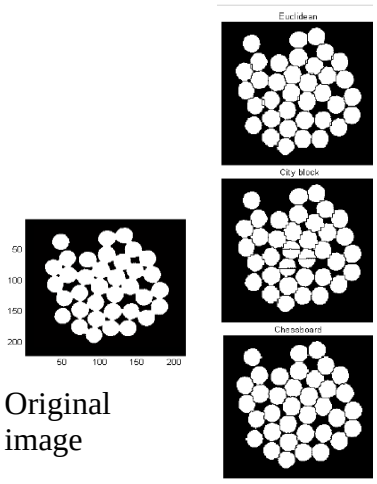

Figure 4. Watershed segmentation results for the chocolate beans with different DTs. (*Chen et al., 2004)*

Region Growing

This technique considers a region-based image segmentation. and also classified as a pixel-based figure segmentation procedure that contains different initial seed points. Examining adjacent pixels of initial "seed points" can adopt a decision on whether these neighborhood pixels have to be improved to the region (Yohannes & Utaminingrum, 2016). It's a well-known scheme. Depending on the similarity the growth starts with a pixel and continues to add pixels to the area, repeating until all the pixels belong to a certain area (Zaitoun & Aqel, 2015). This methodology is considered Statistical Region Merging (SRM), Seeded Region Growing (SRG), and Unseeded Region Growing (Jasim & Mohammed, 2021).

Region Growing Algorithm

Some steps are required for achieving region growth, and may be divided into four steps as explained below (Chaturvedi et al., 2016):

Step1: It is done by choosing in an image the set of seed pixels.

Step2: similarity criteria have been determined for instance gray level intensity or color, and the rule of stopped is configured.

Step3: Regional growth is done by mapping each seed to those pixels that are adjacent to it and have features previously determined that are similar to the seed pixels.

Step4: when no further pixels of additional criteria exist the growth of the region will be stopped.

Statistical Region Merging (SRM)

The significant norm of this referred technique is to express image segmentation by way of an inference problem. The dealing with an image as a seeming case of an unknown theoretical image, so the reconstruction has been required to implement on statistical regions. This technology carries benefits such as simplicity, and it has effectiveness in its computational (Emre Celebi et al., 2008). For more details in this technique in (Nock & Nielsen, 2004).

Seeded Region Growing (SRG)

This technique is considered a hybrid method. Where growth begins with an allocated seed, region growth is implemented by merging pixels into the adjacent seed region. The diversity in the output segments reasoned by SRG contains two inherent pixel-order dependencies. A first-order dependency is achieved when some pixels contain the same metrics of variance as their adjacent regions. And the second one is achieved when a single pixel contains the identical variance scale for some regions, Figure 5 is an example of using Seeded Region Growing proposed by (Shih & Cheng, 2005). This scheme begins with a fixed of *n* initial seeds *A*1, *A*2, . . ., *An*. The seed *Ai* is growing at each step when a certain pixel such as *x* is merged with adjacent seed region *Ai*. This technique is considered fast, and efficient with robustness. It has problems to labeling isolated pixels (Gómez et al., 2007).

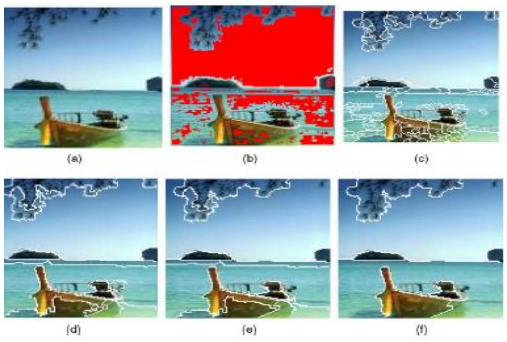

Figure 5. example of using Seeded Region Growing (Shih & Cheng, 2005)

Unseeded Region Growing

The defined UsRG method is recognized as a fully automated technology, which is built on the similarities of pixels in a range of space. This method has flexibility, is fully automated, and depends on modification limitations.

Unseeded Region Growing Algorithm

There are some steps to perform the Unseeded Region Growing technique, and the principal steps can be brief (Jasim & Mohammed, 2021):

Step 1: Initializes the split operation with region S_1 containing 1 pixel and then produces regions S_1, S_2, ..., S_n after accomplishment.

Step 2: To customize pixels, test the pixel difference scaling using average stats the value is executed.

Step3: Assign a pixel to a specific region, such as S_i, if a difference value exists < a specific threshold value; otherwise, this pixel is allocated to a new S_j.

Step 4: The above steps are repeated for the rest of the pixels.

Table 1 demonstrates the summary of the comparison of watershed and region growing techniques.

Table 1. Explain summary to comparison on region growing and watershed segmentation

Segmentation technique	Technique Properties	Methods	Methods description
Watershed	• picturing an image in three scopes: two spatial organizes versus gray levels • Use the perception of topological explanation. In this, density denotes basins with a hole at the minimum in terms of water infiltration • Suffer from over-segmentation and considered sensitive to noise	(1) Marker-controlled watershed	• Foreground objects and the background locations are marked. • A strong and flexible way of separating objects with locked contours, and reducing over-segmentation.
		(2) Distance Transform	• Defined as the distance metric between a piece pixel with the adjacent non-zero valued pixel. • Various ways of describing the distance between two pixels: Euclidean, City block, and Chessboard
Region Growing	• depending on a measure that is determined previously for collecting the whole image into sub-regions.	(1) Statistical Region Merging (SRM)	Statistical Region Merging is to express image segmentation
		(2) Seeded Region Growing (SRG)	Hybrid methods, growth begins with an allocated seed

	• Depending on a similarity the growth starts with a pixel and continues to add pixels to the area	(3) Unseeded Region Growing	Fully automated and depends on modification limitations

The applications of segmentation based-region in different fields

Some of the applications of watershed and region growing are as follows: Authors (Yohannes & Utaminingrum, 2016) introduce segmentation for building using region growing based on some variables in the region growing such as area and perimeter.

While the suggestion (Xu et al, 2018), is a novel stage-wise convolutional network, then applying an orientation-based region-growing process. Where the goal of this proposed network is to automatically learn the discriminatory features of pulmonary vessels. the lung segmentation is performed in the first stage and the main vessel segmentation module is achieved in the second stage.

In the work (Jiang et al.,2019), breast tumor segmentation is achieved as a classification problem in the neutrosophic set (NS) domain. every pixel of the BUS image is characterized using the measure of similarity and the value of homogeneity computed in the NS domain. The chosen seed regions are performed by the adaptive Otsu-based threshold method and morphology operations. Then finding tumor regions is implemented by the adaptive region growing method.

Also, authors (Li et al.,2019), a process using region growing is suggested for accomplishing the separation on the background of 3D SAR image by employing the plural and the spatial information.

The suggestion in (Brilliant et al., 2020) attempts to discover the image segmentation model by means of the region growing method to segment Landsat (land satellite) images to identify land cover variations.

While the authors (Yang et al., 2020) suggest an individual tree segmentation process depending on the marker-controlled watershed process and 3-D spatial distribution analysis from airborne LiDAR point clouds.

the study by (Chen et al., 2020), suggested an automated cone photoreceptor cell segmentation and determination scheme using morphological treatment and watershed procedures for adaptive optics scanning laser ophthalmoscope images.

The suggestion by (Chen et al. 2020) segments a specific tooth utilizing a multi-task 3D fully convolutional network (FCN) and marker-controlled watershed. Where FCN is employed at once to expect the probability of tooth region and the tooth surface probability.

Authors (Xue et al.,2021) cultivated land borders have been located and detected depending on remote sensing images which have high resolution, an improved watershed technique for segmentation has been suggested by combining pre- and post-improvement processes.

Table 2 shows a summary of applications mentioned above to the watershed and region growing segmentation.

Table 2. a summary of watershed and region growing applications

Technique	Reference	Application
Region growing	(Yohannes & Utaminingrum, 2016)	Building segmentation
	(Xu et al, 2018)	Pulmonary Vessel Segmentation

	(Jiang et al.,2019)	breast tumor segmentation
	(Li et al.,2019)	3D SAR image
	(Muhamad et al.,2020)	Landsat (land satellite) images
Watershed	(Yang et al., 2020)	tree segmentation
	(Chen et al., 2020)	cone photoreceptor cell
	(Chen et al., 2020)	segment individual tooth
	(Xue et al.,2021)	cultivated land boundaries

In this work, the segmentation procedure achieved with region-based segmentation using watershed transform and region-growing technique is reviewed. And from the previous sections and as explained in Table 1, with the technique properties, watershed segmentation suffers from over-segmentation, and this problem is reduced when the Marker-Controlled Watershed transformations technique is used for the segmentation procedure Which is represented as a strong and flexible method of extracting objects with locked contours. Also, it's considered sensitive to noise.

Region Growing technique, based on the similarity then the growth starts with a pixel and continues to add the other pixels to the interested region. Different metrics are used for similarity and each one has its efficiency in its application. Region Growing technique is implemented with three methods Statistical Region Merging (SRM), Seeded Region Growing (SRG), and Unseeded Region Growing.

And as demonstrated in the previous section and Table 2, different applications are based on these two techniques such as different medical applications and remote sensing and others by using different features for analysis image characterizations.

Conclusion

Two techniques of region-based segmentation which are Watershed and region growing are reviewed, so the observation from previous sections is that the segmentation process has a significant role in image processing applications because depicts an image in a way that makes the analysis process of the objects of interest easier and more accurate. Watershed transform has been used in two methods which are one based on distance and second Marker-Controlled watershed that is reduced the over-segmentation problem of watershed. The significance of using watershed and region growing for finding the regions that form the image precisely has appeared when using them in different applications such as medical, remote sense, and others. Each of these segmentation techniques has its efficient performance in each application.

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