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A Review Paper on Image Segmentation Techniques Based on Colour and Texture Features

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Abstract. In image processing and computer vision, image segmentation plays a crucial role. It finds a place in many image applications. Texture and colour features and its combination are among the main features used in image segmentation. This paper presents the literature review for colour-based segmentation techniques and texture-based segmentation techniques. The main objective for this paper is to provide the recent trends of both the color and texture segmentation technique in image segmentation as well as presenting the most popular evaluation measurements used for image segmentation. At the end of this paper, the conclusion for future work and its direction is presented.

INTRODUCTION

In image processing and computer vision, image segmentation is crucial. In general, the process of image segmentation is referred to the technique of partitioning or clustering the pixel of an image into similar group or region. The goal of the image segmentation process is to make it easier to understand, interpret, and analyze an input image by simplifying its representation. Image segmentation has been used in many image processing tasks, such as boundary detection object localization and image recognition. Image segmentation has been applied in many application studies such as satellite images [1], medical image analysis [2], texture recognition [3], facial recognition [4], automatic number plate recognition [5], content-based image retrieval [6], and humans skin detection [7].

Innumerable image segmentation techniques have been proposed such as active contour [8], graph-cut-based [9], clustering-based methods [10], region merging methods [11], histogram thresholding [12] and region-based approaches [13]. However, no single method can be suitably used for all type of images [14]. In recent decades, several techniques of image segmentation have been presented [15]. In general, image segmentation techniques can be categorized into two main groups; unsupervised and supervised segmentation. In supervised segmentation technique, a top-down approach has been employed where certain properties in the image were labelled followed by a supervised segmentation process that learned the data based on the labelled properties [16]. On the other hand, the unsupervised segmentation is designed based on bottom-up approach. In this approach, no learning or training the data is needed [17],[18]. Both of these approaches are depicted in form of block diagram in Figure 1 [18].

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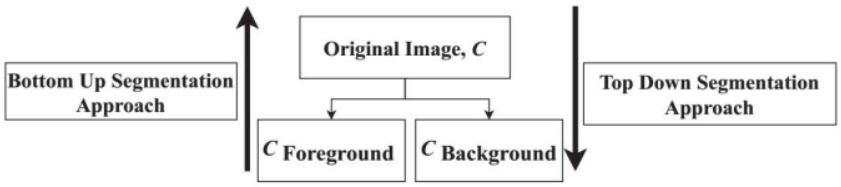

FIGURE 1. Block diagram of bottom-up and top-down approaches [18]

From the perspective of interactivity with the user, the algorithms of image segmentation can be classified into three main classes of method; manual, semi-automated and fully automated method. Users can utilize some computer processes, such as drawing tools, to isolate and segment one or more objects in the manual-based technique. In a semi-automated procedure, the user often selects specific locations or regions that will be utilized to collect data for the characterization of the segmented objects. Finally, the fully automated image segmentation method performs the segmentation process without any user interruption or intervention during the whole segmentation process. This fully automated process usually started by acquiring all necessary details of the image to form the basic information of the nature of the segmentation problem before the segmentation process taken place [19].

In image processing domain, image segmentation appears to be among the most complex issues. There have been many general-purpose image segmentation algorithms that have been develop in the past. All algorithms of segmentation are generally having their own advantages and limitations particularly with respect to performance, applicability, suitability, and computational cost. Thus, all of these qualities cannot be attained by just one segmentation algorithm. For this reason, the use of several techniques in combination appears to be the most effective, as this will exploit the strength of one technique and at the same time, avoid the issues related to each individual limitation. In addition, the image segmentation quality could be improved as well. In the recent years, there have been many applications that combined segmentation approaches, and this has greatly enhanced the strength of segmentation process [20]. Countless number of different approaches and algorithms for image segmentation has been introduced by many researchers in the past. This implies the need to compare these available techniques to determine which ones are better as opposed to others. For this purpose, considerable number of efforts has been made particularly in establishing the methods of performance evaluation [21].

IMAGE SEGMENTATION TECHNIQUE

In the past, there are many image segmentation techniques that have been introduced. The most common and widely used techniques in image segmentation will be discussed in the proceeding sections.

Region-based Segmentation

In region-based segmentation techniques, the pixels are segmented using similarity features such as points, edges, and lines. This segmentation technique assumes similarity in the level of intensity in accordance with a set of predetermined criteria. Some techniques such as region merging, splitting and region growing, belongs to this group. The image is segmented based on homogeneous regions. All pixels belong to one region connected to each other through certain properties. This technique is widely used due to its efficiency. However, one of its disadvantages is that it takes a long time to complete the algorithm [22].

Region Growing

One of the most widely used approaches in the region-based segmentation technique is the region-growing method. Region growing methods work by collecting similar property of the pixels to form a region. In the beginning of the algorithm, a seed pixel is determined and then the pixels that are similar in characteristics are

combined to form a particular region. This method is based on accumulating pixels with similar characteristics, to form regions. Pixels are combined to build small sub-regions or large regions. These regions are formed based on several criteria [22].

Region Splitting and Merging

This technique is one of the easy-to-use techniques. It works on the premise of separating a picture into distinct parts, which can then be joined or divided to generate the final segmentation, which is governed by a pre-specified criterion. One of the disadvantages of this method is that it takes a long time for the segmentation process to complete [22].

Edge-based Segmentation Method

The edge-based segmentation method is one of the commonly used image segmentation techniques. It is based on the notion of adjusting the image's intensity by locating the edges, which are created by the contrast between two elements. The edge is the boundary between two objects or two elements in the input image [23]. The edge-based techniques such as active Canny, zero-crossing, point flow and edge flow, works by extracting the boundary of an object in an image by producing objects' contour [24].

Threshold-based Segmentation

Threshold-based image segmentation can be considered as one of the simplest and easiest approaches of image segmentation. It is a commonly used method by practitioners using because this method is straight forward and simple to implement. In this method, the region of the image is segmented by dividing them into a foreground and background based of certain predetermined threshold value. This method is effective especially when there is a clear contrast between the object(s) presented in the foreground of the image and its background environment. One of the obvious disadvantages of this method is that it does not give accurate results especially when the object and the background image have not clear boundary. The threshold-based segmentation can be grouped into three classes [25].

Global Threshold

This technique can be used if there is a large discrepancy between the object(s) or region(s) to be segmented from the background environment. By using this technique, a global threshold is calculated to segment the background and the objects of interest. The threshold value is estimated from the image density [26].

Local Threshold

The local threshold technique will divide the entire image into multiple little parts or several small regions that have similar properties. These small regions have characteristics that combine the constituent pixels. In other words, each region has a local threshold value. Subsequently, the filtering process is carried out to get rid of the intermittent grey levels after the thresholding process. The segmentation process in this method takes a slightly more time as compared to the global threshold technique. This method can be useful especially in the case of images containing various backgrounds [26].

Dynamic Thresholding

Some images contain many objects with distinct regions with varying intensity values, as well as threshold values that vary locally. Each pixel should be utilized to split the image, which is based on the grey level image's point values [26].

Clustering Approach

In the unsupervised segmentation category, clustering is commonly used approaches for image segmentation. The fuzzy c-mean and K-mean is the perhaps the most commonly used algorithms in clustering [26]. The clustering method works based on the principle of grouping the pixels where the cluster number is determined either by user or automatically determined by the algorithm [27].

K-Means Clustering

In the unsupervised segmentation category, clustering is commonly used approaches for image segmentation. The fuzzy c-mean and K-mean is the perhaps the most commonly used algorithms in clustering [26]. The clustering method works based on the principle of grouping the pixels where the cluster number is determined either by user or automatically determined by the algorithm [27].

Fuzzy C-Means Clustering

In 1973, Dunn introduced the fuzzy c-means algorithm (FCM) and subsequently improved in 1981 by Bezdek. This method is considered as one of the unsupervised segmentation methods. The problems with this method are related to the deviation from the centre of mass. The interference density may lead to poor segmentation results. FCM has proven to be a successful in many area of research especially in machine learning, image segmentation and pattern recognition [28].

Other Segmentation Techniques

Neural Network Based Segmentation

Neural networks are defined as a group of interconnected neurons, each cell normally deals with one piece of input data, often a single pixel of the image. Subsequently, mathematical operations are applied to the interconnected neurons processing the signals in a series of neuronal layers until the process of segmentation completed [29]. Conventional Neural Network (CNN) is a method used to segment images and to extract the features directly from pixel images with minimum pre-processing. Neural networks are based on the principle that each neuron corresponds to a specific pixel in the image, and a single pixel is assigned to a single neuron [30].

Watershed Based Segmentation

This method is based on topological principles, where the objects in the image are represented as holes and border. The watershed principle starts from fill the water in the hole, till reached the boundary. In this case the adjacent region can be combined together [23]. In watershed-based segmentation algorithms, an image is represented as topographic layers. This method treated the two-dimensional and three-dimensional images alike. The image is represented in the form of layers, valleys and slopes, and sometimes the concept of a plateau can be used. The basic idea of this method depends on determining the location of all basins that collect water, and each basin can be considered as an independent region from the rest of the objects in the image [31].

Partial Differential Equation-based Segmentation

The partial differential equation-based segmentations are frequently employed in time-sensitive situations. Basically, there are two types of partial differential equation-based segmentation been used, i.e. a nonlinear isotropic diffusion filter and a convex non-quadratic variation restoration. The advantage of this technique is the process of image segmentation can be considered fast. The output generally displays a blurred image. C–V Model, Mumford-Shah Model, Level Set Model, Active Contours are the examples of these techniques [23].

TEXTURE IMAGE SEGMENTATION TECHNIQUE

Texture is one of the most basic elements in visual recognition and perception. It has been employed for many applications. In human vision, it is easy to distinguish between one texture to another, but it is not the case when it is processed using a computer. At this moment, there is no exact definition of image texture. However, in general, it can be defined as a measure of roughness, orientation, and uniformity. Texture is used in many applications in various fields, where it can be applied in the different area of applications such as medical field, remote sensing and face recognition.

Texture based segmentation technique used texture features for segmenting an image. There are various methods that have been introduced in the past to extract texture features. In general, texture-based segmentation method can be divided into six approaches; statistical, transform-based, graph-based, model-based, entropy-based and learning-based approaches. Table 1 shows the different classes of methods for texture extraction [32].

PERFORMANCE EVALUATION FOR IMAGE SEGMENTATION

Basically, there are no fixed and standard criteria for the evaluation of segmented image. There are two primary types of evaluation methods for segmented images in the literature: objective evaluation and subjective evaluation. In the objective evaluation method, the evaluation is generally done through each method, sometimes independently. In the subjective evaluation method, the evaluation process needs human to determine the performance of the method. As a result, in this later case, the evaluation differs from person to person because each person has their own subjective criteria for evaluating the segmentation results based on the degree of congruence between the manually segmented images produced by the human evaluator and the images produced by the algorithms. The following paragraphs explain more detail on this matter. The methods are commonly used in the evaluation processes shows in Figure 2 [33].

TABLE 1. Texture classes and feature extraction methods

Classes	Methods	
Statistical approaches	• Grey level co-occurrence matrix • Local mapped patterns-based approaches • Local energy pattern • Variogram • Tamura features • Local binary pattern and variants • Shape index histograms	• Grey level run-length matrix • Autocorrelation-based approaches • Histogram of gradient magnitudes • Deterministic walk • Weber local descriptor
Transform-based approaches	• Filter banks: Law's texture features • Fourier transform-based approaches • Gabor decomposition-based approaches • Wavelet-based approaches	• Shearlet-based approaches • Contourlet-based approaches F Locally encoded transform feature histogram (LETRIST)
Model-based approaches	• Complex network-based approach • Mosaic models • Random field models	• Fractal-based measures • Gravitational model • World decomposition
Graph-based approaches	• Local graph structures • Graph of tourist walk approach	• Shortest paths in graphs
Learning-based approaches	• Vocabulary learning methods • Extreme learning machine-based methods	• Deep learning methods
Entropy-based approaches	• Two-dimensional sample entropy • Two-dimensional distribution entropy	• Two-dimensional multiscale entropy

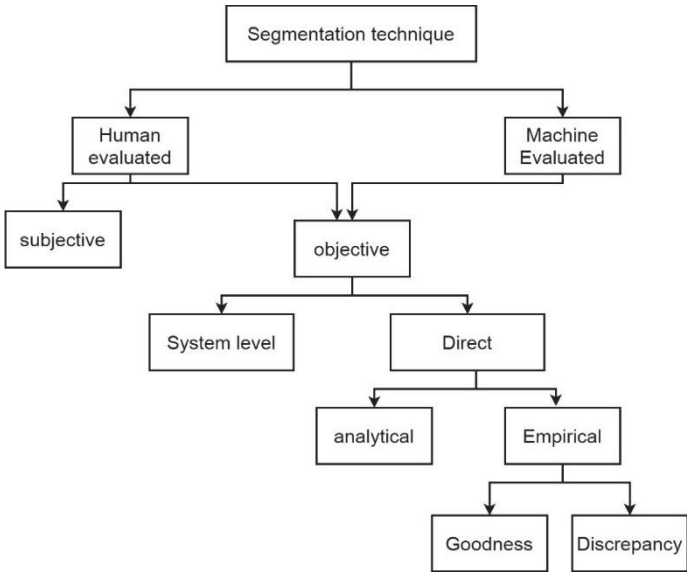

FIGURE 2. Image segmentation performance evaluation method

Subjective Methods

One of the most appropriate methods of evaluation for image segmentation is subjective methods. This method is popular because human evaluators are the ones who determine the validity and accuracy of the segmentation. The main disadvantage of this method is that human differ in the method of evaluation for the same image and thus it is time consuming process [34].

Direct Evaluation and Indirect Evaluation

The direct evaluation is the algorithm's appraisal of itself. During the process of image segmentation, users may apply easy and simple algorithm. There are a set of factors that are necessary to be decided before certain algorithm is selected to be used. These factors include the speed of the algorithm and the accuracy produced by the algorithm. In the case of indirect evaluation, a graph of the segmentation results can be applied, then the segmentation process is judged, thus obtaining the segmentation results indirectly [34].

Analytical Evaluation and Empirical Evaluation

One of the direct evaluation types is analytical evaluation. The algorithms are evaluated using an analytical evaluation technique based on theoretical knowledge. If there are two algorithms with a significant difference in computational complexity or implementation speed, this method is applied. Basically, there are two types of analytical evaluation that is the qualitative evaluation and the quantitative evaluation. As for the empirical evaluation, it is considered indirect evaluation method where some specific processes for quantitative evaluation is been applied. The empirical evaluation can be divided into two main categories; supervised and unsupervised evaluation. An empirical evaluation is considered one of the most widespread methods. It provides an accurate result.

Supervised and Unsupervised Evaluation

In the supervised evaluation method, the algorithm is assessed by comparing the final image to a hand-segmented reference image known as the ground truth (GT). The similarity between the segmented image and the GT image is used to determine segmentation quality. One of the benefits of the supervised approach is that a direct

comparison of the GT and segmented images yields correct evaluation findings. However, providing a manually segmented image is complex and takes more time. In addition, for natural images, it is not easy to provide a reference image. Therefore, it is difficult to determine which reference images is more appropriate to be used in the comparison process. In contrast to the supervised evaluation method, the main characteristic of unsupervised method is that they do not require reference images. Thus, the evaluation process is quantitative and objective. Manual reference images are difficult to provide for all types of images and difficult to provide in all applications. Therefore, images can be evaluated using an unsupervised approach because reference images are not available. Supervised approaches are considered more accurate than unsupervised approaches [34].

Evaluation Parameter of Image Segmentation

Table 2 summarizes the most used evaluation metrics.

TABLE 2. The most commonly used evaluation metrics for evaluating segmented image.

Segmentation Evaluation Measure	Description
Probability Random Index (PRI)	Measures the similarity between the segmented results and the ground truth by analyzing the associations between pairs of pixels.
Variation of Information (VoI)	Measures the amount of randomness in one segmentation that is present between two segmentations
Global Conssitency Error (GCE)	Computes the error between two segmentation regions .
Boundary Displacement Error (BDE)	Measures the average displacement error which is present between the segmented image boundary pixels and the adjacent boundary pixels in the ground-truth segmentation
F	Measures the average squared color error of the segments, penalizing over-segmentation by weighting proportional to the square root of the number of segments.
F’	The evaluation was proposed to improve the F evaluation, because F was found to have a bias towards over-segmentation, which is the characteristic of producing many more regions than desired within a single real-world object.
Q	The Q evaluation improves upon F' by decreasing the bias towards both over-segmentation and under segmentation.
E	Measure the uniformity of pixels. Entropy is a measure of the disorder within a region.
Z	This evaluation is based on the internal and external contrast of the regions measured in the neighborhood of each pixel.
Rand index	Calculates the normalized sum of the pairs of pixels that have the same label relationship in both the segmented result and the GT image.
Normalised Probabilistic Rand (NPR)	NPR is a modification of the PR Index that is normalized with respect to a baseline common to all images contained in the data set.
Distance Distribution Signatures (DBS)	DBS is a discrete function whose distribution characterizes the distance discrepancies between the segmented boundary pixels and the GT boundary pixels.
Hamming distance (HD)	Calculates the total area of overlap between all regions that belong to the GT and segmented image.
Precision (P)	P is a fraction of boundary pixels from the segmented image that matches those in the GT data.
Recall (R)	R is a fraction of boundary pixels that belongs to the GT data for which a match was found in the segmented image.

Segmentation Evaluation Measure	Description
F-Measure	A weighted harmonic mean of combined precision and recall values.
Pratt Figure of Merit (FOM)	A measure of the global behavior of the distance between a segmentation and its reference segmentation.
Receiver Operating Characteristics (ROC)	Depicts the trade-off between the hit rate (recall) and the false alarm rate.

CONCLUSION

The research in image segmentation has been carried out in this era since the last three decades. Variation of objects, background images, colour and texture in natural images has increased the complexity of this task. Many algorithms have been developed to handle with different image classes. Wide application of image segmentation has drawn the attention of researchers to come up with various methods of image segmentation. This paper has presented and discussed various image segmentation techniques that have been used in many application studies. It provides a general brief overview of the most commonly used image segmentation techniques in the literature. As a conclusion, no one method is suitable for all applications. Depending on the nature of the problem to be solved, each method has its own set of advantages and disadvantages. This paper presented the most common methods used for segmentation based on color and texture, the proper method depends on the natter of image and the nature of the problem. It is anticipated that in the future, a more specific method will be introduced to tackle specific type of image segmentation problem.

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