Color Image Segmentation Features and Techniques: A Comparative Study

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ABSTRACT

Image segmentation is an important and interesting digital image pre-processing phase to enhance the performance of various pattern recognition and computer vision applications. Segmentation process enhance images analysis through the extractions of features from the relevance part of image only. In this paper, a comparative study between five different color segmentation techniques is performed. The experimental results of PSNR and MSE metrics show that K-means clustering algorithm has better results when compared to the other algorithms, but still need to be modified to deal with different types of sharp and smooth edges.

KEYWORDS

Image segmentation, HSV color space, K-means, Digital image processing.

1 INTRODUCTION

Image Segmentation as a pre-processing phase is an effective process in many fields such as computer vision, remote sensing, traffic control, health care, industry, pattern recognition, and video surveillance. The segmentation process involves splitting an image into a number of different regions in which each region has a set of pixels with high similarities but with high divergence in pixels from pixels in other regions. The splitting process is based on some extracted features that may include color, intensity, shape, depth, and/or texture gray-level. One or more features can be used to perform the segmentation process [1]. Several researchers have focused on gray-level features during the image segmentation process [2]. Segmentation underlie its importance in detecting specific part of an image that we are interested in, which is subsequently increases the response time of the application, and consequently increases the success of image analysis procedures. It can be done using several techniques based on the feature(s) that the application is using. Some of these techniques are based on: clusters, regions, threshold, salient, and/or Hybrid techniques. In this paper, different segmentation techniques and a comparative study between them are presented. These techniques are; Fuzzy C-Means, Region Growing, OTSU’s adaptive Thresholding K-means clustering, Masking with Watershed, and Hill-climbing with K-Means algorithms [1].

In some application areas such as computer vision and pattern recognition, gray level threshold segmentation method is not useful since it is difficult to detect the borders of some distorted images [3]. However, in such application areas, the usage of color information from images would be very useful in image analysis process. Therefore, more efforts are needed to improve on the methods of color image segmentations as a result of having larger features of rich information in such color images over gray images [3].

This paper is organized as the follows: section two presents the related literature review, section three presents the five different image segmentation algorithms to be compared, section three presents the image quality measures used in this study, section four presents the comparative study results between these segmentation algorithms, finally, the last section presents the conclusion of this study and the future work.
2 LITERATURE REVIEW

Previous work on image segmentation includes many proposed systems such as the work of Liu Yucheng who proposed a new fuzzy morphological system that is a fusion based image segmentation technique [4]. To smooth the image, this work uses the opening and closing morphological operations followed by the gradient operation on the image. In addition, they have solved the over segmentation drawback of Watershed algorithm. This system proved that the fusion approach saved the information details of an image and improved the speed of segmentation [5].

Fernando C. Monteiro proposed an image segmentation algorithm that is based on morphological watershed edge and region information using the spectral method [6]. It applies an enhancement of a preprocessing stage using bilateral filter to reduce the noise from an image, then preliminary segmentation is performed using region merging. Also, it had generated region similarity and then region based grouping using the Multi-class Normalized Cut method.

Weihong Cui Yi Zhang [7] image segmentation algorithm generates multi-scale image segmentation with an edge based auto threshold select method, then it calculates edge weighte. Minimum spanning tree and edge based threshold method are used to perform image segmentation. Experiments results have shown that this method maintained the object information and kept object boundaries while segmenting the image.

R. V. Patil claims that K-means image segmentation will provide better results if the number of clusters is estimated in an accurate manner based on edge detection [8]. Phase congruency is used to detect the edges. Then these edges with threshold and Euclidean distance are used to find the clusters. K-means is used to find the final segmentation of an image. Experiments results have showed that the number of clusters is accurate and optimal.

Anna Fabijanska [9] used Variance Filter for edge detection in the image segmentation process. This process finds the edge positions, then the Sobel Gradient filter with K-means is also used to extract the edges of an image. The effect of filtering in case of larger details images concluded that a small filtering window is preferred.

The following subsections present the five image segmentation algorithms that are used in our comparative study.

2.1 Otsu’s Adaptive Thresholding K-mean Clustering

V.Jumb, M.Sohani, and A.Shrivas proposed a color image segmentation technique that initially converts the RGB input image to HSV color space [1]. It starts by extracting the V channel of the HSV color space. They found that the Separation Factor (SF) had a significant affect on image segmentation through the V channel of the HSV color space thresholding. If the SF is initialize to zero, then no edges would be detected, hence, SF will be increased slowly until it reaches near one in order for the main edges to be detected. To find the optimal separation factor, Otsu [10] used the notion of maximum classes variance to maximize the variance between classes.

Also, Otsu defines \( N \), the number of classes of segmentation, to be initially equal to two, this means to start from two classes one for foreground and the other for background. The \( N \) value will be increased each time the SF value is increased until it reaches one. In this method, objects are grouped based on their minimized variance. The first K-mean clustering method initializes the two class centres randomly which are called centroids, then by calculating the value of the histogram bin distance between each image pixel and its class centroid, each image pixel is then reassign to its closest class centroid. This
calculation is further done on the same group to adjust centroids positions. Finally, morphological processing is used as an enhancement step for better image segmentation.

2.2 Fuzzy C-means

Literature cites that different transformations have been used on biomedical and remote sensing images in order to extract or discover some of their anticipated features. It is almost concluded that more research is needed to come up with more realistic classifiers of features that represent more accurately the physical process [11]. Segmentation evaluation techniques can be either supervised or unsupervised. Optimal supervised segmentation of remote sensing images can not be achieved [12].

T.Saikumar, et. al [11] algorithm do not employ any training data in color features extraction process. Initially, it uses decorrelation stretching to enhance color separation of satellite images and then using the Fuzzy C-means algorithm to cluster the regions of an image into five different classes. The color space (L*a*b*) is used instead of the HSV method. Also, the C-means clustering is used instead of K-means. Finally, the decorrelation stretching is applied to enhance the image color separation that would result in the conversion of the RGB color into a color Space (L*a*b*).

The L*a*b* color space has three layers; a luminosity layer 'L*', a chromaticity-layer 'a*' that specifies which color is within the red-green axis, and a chromaticity-layer 'b*' that specifies which color is within the red-green axis and blue-yellow axis [13].

Fuzzy C-Means clustering process is used to classify the colors in the 'a*b*' space. This classification separates groups of objects based on the distance metrics that computes how close any two objects to each other and based on the specified number of clusters to be portioned. Each object in this clustering is treated as having its own space location, clustered objects are considered to be close to each other and far away from other objects in other clusters. Then using the Euclidean distance metric the objects are classified into three clusters. Finally, Fuzzy C-means clustering returns an index of the object’s cluster in their input to be used to label each pixel in the image and to produce a color segmented image [11].

2.3 Region Growing

A.Kumar, P.Kumar discussed how widely used and important is the color image segmentation in various application areas such as in multimedia applications. For an effective scan process of large number of images that may or may not contain text, it would be much better to store and sort them in a directory. Color and texture based are considered to be the most two important features of information retrieval, also, it is very useful in indexing and management of data, so new research should focus on color image segmentation [3].

The Watershed Method (WS) is used in a proposed method that is called region-based segmentation algorithm [14]. This method solves the problems existed in current algorithms in which they are either facing the problems of features extraction or over expanding the applicability of the image segmentation algorithm. This method is actually used originally in geography: In which a landscape that has been flooded with water and its dividing lines are determined using watersheds. In such a situation, an image is labeled in a way that all points of a given swamp spot are assigned a unique label. Then the region growing method is applied to collect all similar pixels to form a region. Labeling of the image is done by uniquely labelling all points of a given swamp spot that are different from the labelling done by the catchment basins. Also, this method initially, selects a starting seed pixel, then group to this seed all its similar neighbors and in a continuous manner each new pixels plays the
role of a new seed pixel until no more pixels can be added [13].

2.4 Hill-Climbing with K-means Algorithm

S. Kochra and S. Joshi had identified salient regions as the regions that have more power contrast than their surrounding regions [15]. This identification is applicable in various image segmentation processes such as object based adaptive content delivery, smart image resizing, image retrieval, and adaptive based image compression. Another definition of saliency of an image is referred to it’s local contrast [16][17].

This work can be summarized as follows; given an image as input, the goal is to get a set of visually coherent segments. This is done by computing the image color histogram then starting with a non-zero bin color histogram and moving uphill until a peak is reached. This iteration process involves a comparison between the number of pixels in the current and neighbouring bins histograms. If they have different number of pixels, the algorithm moves uphill towards the neighbouring bin that have the higher number of pixels, if they have the same number of bins the algorithm continues checking the next immediate neighbouring bin until it finds a pair of neighbouring bins that have different number of bins. This process is repeated until a bin is reached that has no more possible uphill movements. Such a pin is then called a peak. Each identified peak represents a cluster in the input image and all neighbouring pixels that have the same peak forms a cluster in the image [15].

2.5 Masking with Watershed Algorithm

Md. Rahman, and Md. R. Islam presented an improved modified method that is based on calculating regions of an image using watershed [18]. This improvement is done to smooth images through a convolution function, selecting adaptive masking operation, threshold, and local minimum information. Their work starts from a RGB image, then it extracts each of the color channels; red (R), green (G), and blue (B) as a dynamic threshold selection process to determine the adaptive threshold based on Gray-threshold function. For an N-dimensional convolution, an N-dimensional grid space is generated. For smoothing purposes, they applied image normalization into an N-dimensional convolution image on the three colors through masking operations that are applied during cell and nucleus making.

The Impose Minima is then used to create a new minima in the image using the adaptive selecting threshold operation at some chosen location. The Minima function uses nucleus-masking and adaptive image masking for morphological processing based on the morphological image color channels R, G and B in which watershed transformation algorithm is applied. Finally, the labelling process is done based on thresholding to determine the background and foreground in the generated segmented image [18].

3 MEASURES of IMAGE QUALITY

In order to evaluate the quality of processed images, some measures of digital image degradation are used. There are two types of measures that are used in the literature; subjective and objective. It has been reported that subjective evaluation measures are expensive and time consuming [1]. However, objective evaluation measures such as Mean Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity (SSIM) have been most commonly used to evaluate the quality of images.

MSE is defined as the accumulative square error between the original and the compressed image. Whereas, PSNR is defined as the measure of peak error. If I(x,y) is the original image, then I'(x,y) is the decompressed version of this image with dimensions of M and N. Specifically, the Mean Square Error (MSE) value is calculated by the summation of all square differences of all pixels divided
by the total pixels count. The lower the value of MSE is the better [18]. Hence, MSE and PSNR are defined mathematically as follows in equation 1 and 2:

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

(1)

\[
PSNR = 20 \cdot \log_{10} \left( \frac{255}{\sqrt{MSE}} \right)
\]  

(2)

A high value of PSNR is better since it indicates that the Signal to Noise ratio is higher where the 'signal' is the original image and the 'noise' is the error in rebuilding this image. Therefore, a scheme that has a lower MSE value and has a higher PSNR value is a good schema [19].

4 COMPARISON OF SEGMENTATION ALGORITHMS

In this section, we present a performance comparative study between the five color image segmentation algorithms presented earlier in this paper. These algorithms are; Hill-climbing with K-means (HKM) algorithms, Fuzzy C-Means clustering (FCM), OTSU’s adaptive Thresholding K-means clustering (KMC), Region Growing (RG), and Masking with Watershed Algorithm (MWS).

The OTSU’s adaptive Thresholding K-means clustering algorithm had been applied to different types of images’ edges and it had produced good results. Hill-Climbing algorithm is easy to implement [1]. Masking with Watershed has a better performance than all other algorithms which means it can perform on real-time applications [18]. Fuzzy C-Means Clustering try to reduce the computational time [11].

We have tested all of these algorithms on Berkeley Segmentation Database [20], the Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) have been calculated between images in order to assess their segmentation performance. The PSNR is calculated based on the segmentations of a color texture image. To be fair and to perform accurate comparison, we had selected some images that have been tested by all of these algorithms and compared the results obtained by each of them on these images alone. Table 1 presents the results of PSNR and MSE by each of the five algorithms on each of these selected images. These results are also depicted in Figures 1 and 2.

<table>
<thead>
<tr>
<th>Image</th>
<th>Metric(dB)</th>
<th>KMC</th>
<th>FCM</th>
<th>RG</th>
<th>HKM</th>
<th>MWS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beach</td>
<td>PSNR</td>
<td>58.69</td>
<td>52.58</td>
<td>52.35</td>
<td>57.92</td>
<td>57.92</td>
</tr>
<tr>
<td></td>
<td>MSE</td>
<td>0.08</td>
<td>0.36</td>
<td>0.15</td>
<td>0.39</td>
<td>0.11</td>
</tr>
<tr>
<td>Bird</td>
<td>PSNR</td>
<td>60.18</td>
<td>54.48</td>
<td>52.26</td>
<td>54.89</td>
<td>59.04</td>
</tr>
<tr>
<td></td>
<td>MSE</td>
<td>0.06</td>
<td>0.23</td>
<td>0.39</td>
<td>0.21</td>
<td>0.08</td>
</tr>
<tr>
<td>Building</td>
<td>PSNR</td>
<td>57.20</td>
<td>56.53</td>
<td>52.26</td>
<td>56.37</td>
<td>58.08</td>
</tr>
<tr>
<td></td>
<td>MSE</td>
<td>0.12</td>
<td>0.14</td>
<td>0.39</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>Car</td>
<td>PSNR</td>
<td>57.15</td>
<td>55.32</td>
<td>53.58</td>
<td>55.21</td>
<td>55.59</td>
</tr>
<tr>
<td></td>
<td>MSE</td>
<td>0.12</td>
<td>0.19</td>
<td>0.29</td>
<td>0.20</td>
<td>0.18</td>
</tr>
<tr>
<td>Flower</td>
<td>PSNR</td>
<td>58.69</td>
<td>58.10</td>
<td>51.72</td>
<td>53.21</td>
<td>58.93</td>
</tr>
<tr>
<td></td>
<td>MSE</td>
<td>0.13</td>
<td>0.08</td>
<td>0.44</td>
<td>0.31</td>
<td>0.08</td>
</tr>
</tbody>
</table>
Table 2. MSE and PSNR Average Performance of the Five Segmentation Algorithms

<table>
<thead>
<tr>
<th>Image</th>
<th>KMC</th>
<th>FCM</th>
<th>RG</th>
<th>HKM</th>
<th>MWS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSNR</td>
<td>58.38</td>
<td>55.40</td>
<td>52.43</td>
<td>55.52</td>
<td>57.91</td>
</tr>
<tr>
<td>MSE</td>
<td>0.10</td>
<td>0.2</td>
<td>0.33</td>
<td>0.25</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Table 2 shows that OTSU’s adaptive Thresholding K-means clustering algorithm (KMC) has the best in PSNR values, and lowest MSE value, this means that the KMC algorithm has better performance than the other four segmentation algorithms.

Figure 3 presents an example of an image to be segmented, whereas Figure 4 presents the result of segmentation of this image produced by each of the five compared algorithms [1][18].

5 CONCLUSION AND FUTURE WORK

Extracted color information in image segmentation is very useful and interesting in enhancing image analysis during image preprocessing phase for several applications such as computer vision and pattern recognition. Gray level threshold segmentation is not practical for images that have complex objects, so improving the methods that perform segmentation on color image is an important step due to the larger features of rich information in color images over gray images.

In this paper, a comparative study between five different color segmentation algorithms was performed. Result showed that K-means
clustering algorithm do a better job, but still need to be modified to deal more with different kind of sharp and smooth edges.

Finally, more work is needed to be done as future research to come up with a better performance measures to accurately reflect the actual differences between various segmentation techniques.

REFERENCES


