Volume 3, No. 1, Jan-Feb 2012
ISSN No. 0976-5697
International Journal of Advanced Research in Computer Science
RESEARCH PAPER
Available Online at www.ijarcs.info

Fuzzy Homogeniety Based Color Image Segmentation

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Abstract: Any entity can be subdivided into its constituent parts and vice versa (in some cases).Same is the case with digital images. Subdivision of an image into constituent regions or objects is SEGMENTATION. Image segmentation is important area in the field of image processing and computer vision. It is the first step in image analysis and pattern recognition and has wide applications such as in medical imaging, industrial automation and satellite imagery. Most of the work in image processing was done around gray images. But color provides more information than the gray tones. Various techniques have been proposed for color image segmentation based on different parameters. This paper aims at reviewing the existing color image segmentation techniques and proposes a new technique based on homogeneity principle. Segmentation of color image is based on two primary parameters: color space used and segmentation criteria: similarity or discontinuity. This paper aims at RGB images with segmentation criteria being homogeneity of pixels with its neighbouring pixels.

Keywords: segmentation, color space, pixels, homogeneity, histogram, homogram

I. INTRODUCTION

Digital image processing [1, 2] is a technique, which aims to bridge the gap between human perception and computer vision, which would act as the ultimate tool in our quest for artificial intelligence. Human eye can clearly make out no. of objects in an image, color variations and other attributes of image. Digital image processing aims at providing the same analyzing skill to the machine. This is done through image segmentation.

Real life objects are defined by the segments as surfaces and edges as the boundaries. Careful observation of real life situations, scenes and images reveal that the segments and their colors are most times closely related. More intelligent the segmentation and edge detection algorithms, more the detected components are appropriate and more appropriate is decision making in applications where it is used.

II. IMAGE SEGMENTATION

In Image processing three types of processes are considered:

a. Low-level process in which both input and output are images.
b. Mid-level process in which input is image and output is an attribute extracted from that image.
c. High-level process involves “making sense” of ensemble of recognized objects.

Image segmentation is a mid-level process [3].

Segmentation subdivides an image into its constituent regions or objects. Segmentation should stop when the objects of interest in an application have been isolated. Segmentation of nontrivial images is one of the most difficult tasks in image processing. Segmentation accuracy determines the eventual success or failure of computerized analysis procedures. For this reason, considerable care should be taken to improve the probability of rugged segmentation.

The image segmentation problem is basically one of psychophysical perception, and therefore not susceptible to a purely analytical solution. Any mathematical algorithm usually should be supplemented by heuristics which involve semantic information about the class of images under consideration. That is why there are hundreds of segmentation techniques in literature. But no single method can be considered good for all sorts of images and conditions, nor are all methods equally good for a particular type of image. Moreover, algorithms developed for one class of image may not always be applied to other classes of images. However, most of the segmentation methods developed for one class of images can be easily applied/ extended to another class of images.

III. COLOR IMAGE SEGMENTATION

A. Basics:

Color image segmentation attracts more and more attention. It has long been recognized that the human eye can discern thousands of color shades and intensities but only two-dozen shades of gray. The situation often occurs when the objects cannot be extracted using gray scale information but can be extracted using color information. Compared to gray scale, color provides additional information to intensity. It is seen that color is useful or even necessary for pattern recognition and computer vision.

In most of the existing color image segmentation approaches, the definition of a region is based on similar color. Hence color becomes an important parameter in color image segmentation. The major challenge in color image segmentation is the selection of color space.

B. Selection of color space:

The purpose of a color model/color space is to facilitate the specification of colors in some standard, generally accepted way. In essence, a color space is a specification of a coordinate system and a subspace where each color is represented by a single point. Most color spaces in use today are oriented either toward hardware or toward applications where color manipulation is the goal.

The most commonly used color spaces are:

a. RGB (Red, Green, Blue)
b. HSI (Hue, Saturation, Intensity)
c. CIE L*u*v*

Each color representation has its advantages and disadvantages. There is still no color representation that can dominate the others for all kinds of color images yet. Color is perceived by human as a combination of tri-stimuli R (red), G (green), and B (blue) which is usually called three primary colors. From RGB, we can calculate different kinds of color spaces by using either linear or nonlinear transformations. Several color spaces are employed for color image segmentation, but none of them can dominate the others for all kinds of color images. Selecting the best color space is still one of the difficulties in color image segmentation.

RGB is the most commonly used model for television system and pictures acquired by digital cameras. *RGB* is suitable for color display, but not good for color scene segmentation and analysis because of the high correlation among the R, *G*, and *B* components.

HSI (hue, saturation, intensity) system is another commonly used color space in image processing, which is more intuitive to human vision. The *HSI* system separates color information of an image from its intensity information. Color information is represented by hue and saturation values, while intensity, which describes the brightness of an image, is determined by the amount of the light. *HSI* color system has a good capability of representing the colors of human perception, because human vision system can distinguish different hues easily.

CIE (Commission International de Eclairage) color system was developed to represent perceptual uniformity, and thus meets the psychophysical need for a human observer. It still has the same problem of singularity as other nonlinear transformations.

After studying the color schemes following observations can be drawn

a. None of the schemes is universally acceptable for all types of images and algorithms.
b. Most of the digital image technologies still generate and process in RGB form.
c. The conversion from RGB to other schemes is basically arithmetic in nature and accordingly requires computational overhead.

Hence in this work default color space RGB is used.

C. Techniques of color image segmentation:

Color image segmentation is based on gray level image segmentation approaches with different color representations [3, 4, 5, 6].

Color Segmentation approaches	=	**Monochrome segmentation approaches**	+	**Color schemes**
		Histogram thresholding Feature space clustering Region based approaches Edge detection approaches Fuzzy approaches Neural networks Physics based approach Combination of above approaches		RGB YIQ YUV HIS CIE ($L^*u^*v^*$) Hybrid color space

Segmentation approaches are categorized into four classes:

i. Pixel based segmentation
ii. Region/Area based segmentation
iii. Edge based segmentation
iv. Physics based segmentation

a. Pixel based segmentation approach includes Histogram based techniques, clustering in color space and fuzzy clustering methods.
b. Region based segmentation approaches, including region growing, region splitting, region merging and their combination, attempt to group pixels into homogeneous regions. These techniques work best on images with an obvious homogeneity criterion and tend to be less sensitive to noise because homogeneity is typically determined statistically. The region based approach is widely used in color image segmentation because it considers the color information and spatial details at the same time.
c. Edge based segmentation: In color images, the information about edge is much richer than that in monochrome case. In a color image, an edge should be defined by a discontinuity in a three-dimensional color space. The edges in the three components are kept independent, except that the spatial angles of the edges have to be the same.
d. Physics based segmentation approach aims to locate the objects' boundaries while eliminating the spurious edges of shadow or highlights in a color image. The existing physics based models are efficient only in image processing for the materials whose reflection properties are known and easy to model.

IV. RELATED WORK

A. Histogram based color image segmentation:

Histogram is a discrete function which gives no. of pixels having same gray level. In Histogram based color image segmentation, thresholding approach is used. The histogram is a plot of no. of pixels against gray values. Thus valley points of histogram give the minimum no. of pixels with that gray value. This value can be used as a threshold and the nearest peak value of histogram can be used as the region value. Thus finding the peak and valley point is critical in histogram based color image segmentation.

The algorithm for Histogram [7] based color image segmentation is as follows:

Algorithm 1

a. Input a color image
b. Separate the color components (R, G, B)
c. Find image histogram of the component images
d. Find local peaks and valleys of histogram for each component
e. Select peaks and valleys so that between two valleys there is a peak, others are neglected.
f. Use the modified peaks and valleys to segment each component image separately by algorithm 3.2

Algorithm 2

a. Consider two consecutive valleys say v1 and v2, there will be a peak point in between v1 and v2 say p1 then threshold will be v2 & region point will be p1.

b. Scan the image pixel by pixel and change the pixel value to p1 if it is between v1 and v2.

c. Repeat 1) and 2) till all valley points are exhausted.

B. Homogram based color image segmentation:

Homogram is also 1-D and gives occurrence of gray levels along with neighboring homogeneity values among pixels.

a. Fuzzy Homogeneity criterion: In terms of image processing, due to the deficiency of specificity and the fuzziness of boundaries, the advantages provided by fuzzy set theory are characterized by various definitions of membership functions associated with the pixels rather the definitions provided by the crisp set theory. The point of fuzzy logic is to map an input space to an output space, and the primary mechanism for doing this is a list of if-then statements called rules. All rules are evaluated in parallel, and the order of the rules is unimportant. In fuzzy logic, the truth of any statement becomes a matter of degree. A membership function associated with a given fuzzy set maps an input value to its appropriate membership value. Homogram takes into account spatial dependencies among pixels. The homogeneity of a pixel with its neighbor is a fuzzy set. The degree of homogeneity can be decided by the membership function. The property of homogeneity could be characterized by the homogeneity vectors h(t, θ,d) which sum the degree of homogeneity between two pixels with gray level t and its neighbors with different angle θ and neighboring distance d.

For $M \times N$ image with G= {1, 2, L} the angular fuzzy homogeneity vector is defined as

$$h(t,\theta,d) = \{ \sum \delta z (|t-r|) \quad t = g(i;j);\ r = g(k;l);\ t; r \in G; \quad 1 \le i \le M;\ 1 \le j \le N; \quad [(i;j);(k;l)] \in (X \times Y) \times (X \times Y) \quad |j(i;j) - (k;l)| = d \text{ along the } \theta \text{ direction}\}$$

Where, θ = {0 °, 45 °, 90 °, 135 °, 180 °, 225 °, 270 °, 315 °}

And

$$\delta_z(x) = Z(x,a,b,c) = \begin{cases} 1 & 0 \le x \le a \\ 1 - 2 \times \left(\frac{x-a}{c-a}\right)^2 & a \le x \le b \\ 2 \times \left(\frac{x-c}{c-a}\right)^2 & b \le x \le c \\ 0 & c \le x \le L-1 \end{cases}$$

Due to the symmetric nature, these eight fuzzy homogeneity vectors could be reduced to four. The average of the resulting four angular fuzzy homogeneity vectors gives homogeneity vector h (t, d)[8].

$$h(t,d) = \frac{1}{4}[h(t,0°,d) + h(t,45°,d) + h(t,90°,d) + h(t,135°,d)]$$

The "homogram" can be obtained by normalizing the above four angular fuzzy homogeneity vectors

$$H(t,d) = \frac{1}{4}\left[\frac{h(t,0°,d)}{(M-1)N} + \frac{h(t,45°,d)}{(M-1)(N-1)} + \frac{h(t,90°,d)}{M(N-1)} + \frac{h(t,135°,d)}{(M-1)(N-1)}\right]$$

Here homogeneity value of each pixel is calculated and normalized to obtain the homogram H (g) by counting the uniform pixels corresponding to a given intensity and d=1.

***b. The advantages of using Fuzzy Homogeneity criterion*:**

i. Homogeneity vectors take account of the spatial gray-tone dependence; thus, using homogeneity vectors has a better noise tolerance.

ii. From the extracted feature, the fuzzy region width could be determined automatically.

iii. Because the fuzzy region width is decided by the feature of the image, it could be adjusted according to the nature of the image.

V. FUZZY HOMOGENEITY BASED COLOR IMAGE SEGMENTATION

The disadvantage of most segmentation approaches is that the *a priori* probabilistic knowledge of an image is necessary. The spatial ambiguity among pixels has inherent vagueness rather than randomness; therefore, the conventional methods might not work well. We propose fuzzy homogeneity vectors to handle the grayness and spatial uncertainties among pixels, and to perform multilevel thresholding.

The new approaches, based on the fuzzy entropy framework and the extension of the maximum entropy principle, have been studied. They do not require the *a priori* knowledge of the number of clusters. The degree of uncertainty of an image is specified by the entropy of a fuzzy set instead of by the conventional probability measure. These approaches are effective for images whose histograms have noise spikes or no clear peaks and valleys

The fuzzy entropy function [9] is defined as,

$$E(F) = \frac{1}{\ln 2}\sum_{g=1}^{L} S_n(\delta_s(g))H(g)$$

S_n is the Shannon entropy of fuzzified image [10, 11]. The image is fuzzified using S membership function as shown below

$$\delta_s = S(g,a,b,c) = \begin{cases} 0 & 0 \le g \le a \\ 2 \times \left(\frac{g-a}{c-a}\right)^2 & a \le g \le b \\ 1 - 2 \times \left(\frac{g-c}{c-a}\right)^2 & b \le g \le c \\ 1 & c \le x \le L-1 \end{cases}$$

A color image segmentation algorithm based upon the fuzzy homogeneity is proposed. Each color component is transformed into corresponding fuzzy domain to obtain the image model. To improve the histogram segmentation results, the homogram, which is based on the homogeneity values of the pixels, is defined. Both global and local information are taken into account while calculating the homogeneity features of the fuzzified image.

The proposed method is divided into two stages. At the first stage, fuzzy homogeneity approach is applied to three color components to find thresholds for each color component, and then the segmentation results for the three color components are combined to partition the color space into several clusters. Some of these clusters may only contain too few pixels and should not be considered as proper clusters. Also there might be some clusters that are very close to each other, and they should be merged. This problem will be solved at the second stage using the region merging approach.

The homogram considers both the occurrence of the gray levels and the neighboring homogeneity value among pixels. Therefore, it employs both the local and global information. Fuzzy entropy is utilized as a tool to perform homogram analysis for finding all major homogeneous regions at the first stage. Then region merging process is carried out based on color similarity among these regions to avoid over segmentation.

First, each cluster whose number of pixels is less than a predefined threshold is merged into its closest cluster until no such clusters exist; then region merging is performed iteratively by combining the two closest regions each time until the distances of all the pairs of regions are greater than a specified global threshold.

A. Algorithm for homogram based segmentation:

The algorithm for fuzzy homogeneity based color image segmentation can be put in three parts:

a. Determine the fuzzy region width using fuzzy homogeneity vectors.
b. Compute the fuzzy entropy function, using H (g), and *w*
c. Obtain multi-level thresholds using fuzzy entropies

i. Determine the fuzzy region width using fuzzy homogeneity vectors.

a. Compute homogeneity vectors, h(t, θ)
b. Normalize h to get homogram H(g)
c. Find local maxima of Homogram H_{max} (g_1), H_{max} (g_2), $H_{max}(g_k)$
d. Find the fuzzy region width *w*

Let $w_i = g_{i+1} - g_i$ i=1, 2,……k-1

$w = \max \{w_1, w2, \ldots\ldots\ldots\ldots w_{k-1}\}$

ii. Compute the fuzzy entropy function, using H (g), and *w*

a. Construct the S fuzzy membership function δ_s(g,a,b,c) where b is the cross point and the interval [a,c] is fuzzy region
b. Calculate fuzzy entropy E using S membership function, homogram and fuzzy region width. E $\in$ [0 1]

iii. Obtain thresholds using fuzzy entropy

a. Search for local maxima of fuzzy entropy such that E (g) > max {E (g-1), E (g+1)} and corresponding gray values are stored.
b. If distance between successive local maxima is greater than *w*/2 then only it is considered else neglected.
c. Use the gray values as thresholds to segment color images

B. Peak finding algorithm:

a. Let p be the array whose peaks are to b found Three values are considered at a time p(i,) p(i-1), p(i+1)
b. If ith value is greater than the other two values then it taken as peak value.
c. The above step is iteratively performed till we get a minimal peak set.
d. The minimal peak set is checked for optimality by a correction function.
e. If difference of two consecutive peaks is greater than min of minimal peak set or if it is greater than some small integer, select the peak else neglect.

C. Merging algorithm:

Two clusters are merged if following conditions are met

a. No. of pixels in one cluster are very less as compared to max no. of pixels in any cluster.
b. Two clusters are very close and their no. of pixels are small

VI. EXPERIMENTAL RESULTS

A. Histogram Vs Homogram:

Histogram is a 1-D feature space which gives occurrence of gray values. Homogram is also 1-D and gives occurrence of gray levels along with neighboring homogeneity values among pixels.

HIB (Histogram based segmentation approach) does not take into account the spatial dependencies among pixels. To improve the histogram segmentation results, the homogeneity histogram, which is based on the homogeneity values of the pixels HOB (Homogram based segmentation approach), is defined. Both global and local information are taken into account while calculating the homogeneity features of the fuzzified image. Only the homogeneous objects will contribute to homogeneity analysis.

B. Result Analysis:

Table I. The result of merging on histogram segmented images:

Image	No. of clusters (Before merging)	No. of clusters (After merging)
House.jpg	63	22
Lenna.jpg	151	61
Butterfly.jpg	33	15
Ascent.jpg	72	26
Tulip.jpg	153	54
Radiance.jpg	146	16

Table II. The result of merging on homogram segmented images:

Image	No. of clusters (Before merging)	No. of clusters (After merging)
House.jpg	61	22
Lenna.jpg	152	63
Butterfly.jpg	57	21
Ascent.jpg	76	26
Tulip.jpg	144	45
Radiance.jpg	199	26

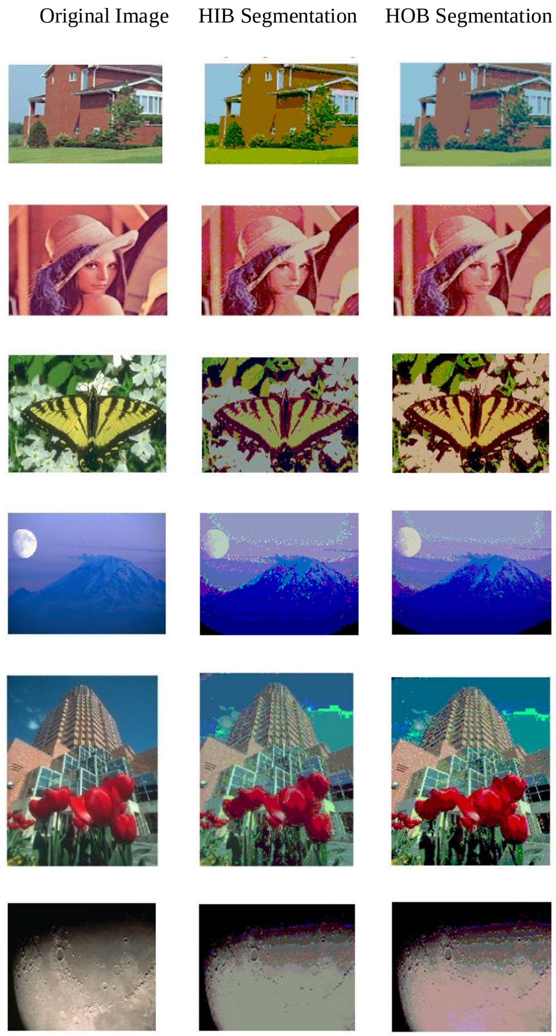
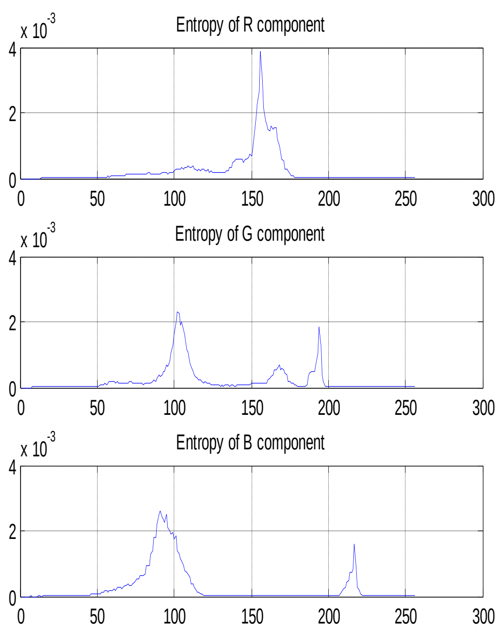


Figure: 1

Entropy function for house.jpg



Entropy function for Ascent. Jpg

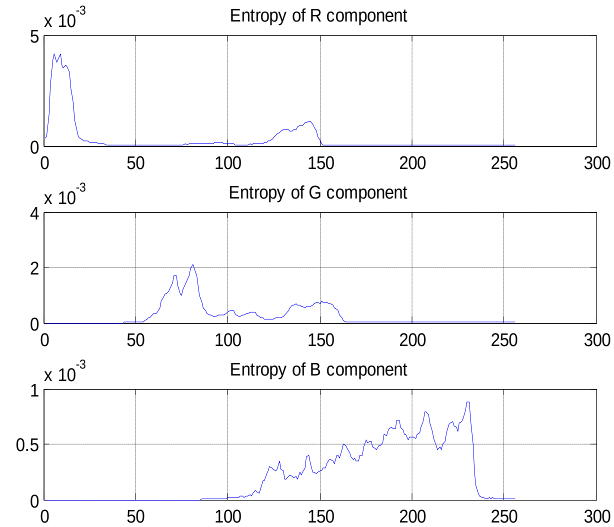


Figure: 2

VII. CONCLUSION

In histogram segmentation approaches finding peaks and valleys become difficult if the components are not distinctly spaced. In the proposed method entropy function is used to find thresholds, which is a measure of uncertainty. Hence finding peaks and valleys (ultimately threshold finding) becomes easier.

Since histogram-based method does not consider the spatial dependencies among pixels, there are some isolated pixels remain and some areas with uniform intensity are wrongly segmented.

Homogram analysis is used to extract all major homogeneous regions at the first stage and the region merging process is performed iteratively based on color similarity among these regions to solve the problem of over segmentation.

The experimental results show that the HOB tends to be more effective to find homogeneous regions and to extract the homogeneous regions with gradual shading in color images than HIB does.

Since the proposed approach considers both intensity and space information of the pixels by fuzzy homogeneity vectors, the image is better segmented.

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