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The Comparative Study on Color Image Segmentation Algorithms

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Abstract

Image segmentation is the initial step in image analysis and pattern recognition. Image segmentation refers to partitioning an image into different regions that are homogenous or similar in some characteristics. Color image segmentation attracts more and attention because color image color images can provide more information than gray level images. Basically, color image segmentation approaches are based on monochrome segmentation approaches operating in different color spaces. This paper gives the comparative study of different color image segmentation algorithSams and reviews some major color representation methods.

Key word- *Color image segmentation, color spaces, edge detection, thresholding.*

1. INTRODUCTION

Color image segmentation is a process of extracting from the image domain one or more connected regions satisfying uniformity(homogeneity) criterion which is based on features derived from spectral components.These components are defined in a chosen color space model.

It has long been recognized that human eye can discern thousand of color shades and intensities but only two dozenshades of gray. Compared to gray scale, color provides information in addition to intensity. Color is useful or even necessary for pattern recognition and computer vision.

Color image segmentation attracts more and attention mainly due to following reasons.

1) color Images can provide more information than gray level images.
2) the power of personal computer is increasing rapidly, and PC's can be used to process color images now.

This paper is organized as follows: firstly different color spaces are discussed, then main image segmentation algorithms are classified, then advantages and disadvantages of different image segmentation algorithms are given. Finally, last section provide conclusion.

2. COLOR SPACES

Several color spaces such as RGB, HIS, CIE L* U* V* are utilized in color image segmentation. Selecting the best color space still is one of the difficulty in color image segmentation. According to the tristimulus theory color can be represented by three components, resulting from three separate color filters as follows:

$$\begin{bmatrix} R = \int_\lambda E(\lambda)\, S_R(\lambda)\, d_\lambda \\ G = \int_\lambda E(\lambda)\, S_G(\lambda)\, d_\lambda \\ R = \int_\lambda E(\lambda)\, S_B(S_R)\, d_\lambda \end{bmatrix}$$

Where, S_R ,S_R ,S_R are the color filters on the incoming light and λ is the wavelength.

Form R,G,B representation, we can derive other kinds of color representations by using either linear or nonlinear transformation.

2.1 Linear Transformations

2.1.1 YIQ

YIQ is used to encode color information in TV signal for American system. It is obtained from the RGB model by a linear transformation.

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.274 & -0.322 \\ 0.211 & -0.253 & -0.312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Where $0 \le R \le 1,\ 0 \le G \le 1,\ 0 \le B \le 1$.

2.1.2 *YUV*

YUV is also a kind of TV color representation suitable for European TV system. The transformation is

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.289 & 0.437 \\ 0.615 & -0.515 & -0.100` \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Where $0 \le R \le 1$, $0 \le G \le 1$, $0 \le B \le 1$.

2.1.3 $I_1I_2I_3$

$I_1 = (R+G+B)/3$, $I_2 = (R-B)/2$,
$I_3 = (2G-R-B)/4$

Comparing $I_1I_2I_3$ with 7 other color spaces (RGB, YIQ, HIS, Nrgb, CIE xyz, CIE(L*u*v*) and CIE(L*a*b*) , claimed that $I_1I_2I_3$ was more effective in terms of the quality of segmentation and computational complexity of the transformation.

2.2 Nonlinear transformations

2.2.1 Normalized RGB (N_{rgb})

The normalized color space is formulated as:

$r = R/(R+G+B)$ $g = G/(R+G+B)$
$b = B/(R+G+B)$

Since r+g+b=1 whe=n= two components are given , the third component can be determined.

2.2.2 HSI

Hue represents the basic colors, and is determined by dominant wavelength in the spectral distribution of light wavelength. The saturation is the measure of the purity of the color, and signifies the amount of white light mixed with the hue. I is the average intensities of R, G and B.
The HIS coordinates can be transformed from the RGB space as:

$H = \arctan(\mathrm{sqrt}(3)(G-B)/(R-G)+(2R-G-B))$
$S = 1 - \min(R,G,B)/I$
$I = (R+G+B)/3$

2.2.3 HSV

The HSV color space is similar to the HIS space while the value (V) component is given by an alternate transformation as the maximum of the RGB component.

$H = \arctan(\mathrm{sqrt}(3)(G-B)/(R-G)+(2R-G-B))$
$S = 1 - 3*\min(R,G,B)/(R+G+B)$
$V = \max(R,G,B)$

2.2.4 CIE Space

CIE (Commission International de 1'Eclairage) color system was developed to represent perceptual uniformity and thus meet the psychophysical need for a human observer. It has three primaries denoted as X,Y and Z. Any color can be specified by combination of X,Y,Z. The values of X,Y,ZZ can be computed by a linear transformation from RGB coordinates.

X		0.607	0.174	0.200	R
Y	=	0.299	0.587	0.114	G
Z		0.000	0.066	1.116	B

There are a number of CIE spaces can be created once the XYZ tristimulus coordinates are Known. CIE (L* a* b*) space and CIE (L* u* v*) space are two typical examples. They can be obtained through nonlinear transformation of X,Y,Z values:

i) CIE(L* a* b*) is defined as:

$L^* = 16(Y/Y_0)^{1/3} - 16$
$a^* = 500\,[(X/X_0)^{1/3} - (Y/Y_0)^{1/3}]$
$b^* = 200\,[(Y/Y_0)^{1/3} - (Z/Z_0)^{1/3}]$

where fraction $Y/Y_0 > 0.01$, $X/X_0 > 0.01$ and $Z/Z_0 > 0.01$

(X_0,Y_0,Z_0) are (X,Y,Z) values for standard white.

ii) CIE (L* u* v*) is defined as:

$L^* = 116(Y/Y_0)^{1/3} - 16$
$u^* = 13\,L^*(u' - u_0)$
$v^* = 13\,L^*(v' - v_0)$

Where $Y/Y_0 > 0.01$, Y_0, u_0 and v_0 are the values of standard white and
$u' = 4X/(X+15Y+3Z)$, $v' = 6Y(X+15Y+3Z)$

3. CLASSIFICATION OF COLOR SEGMENATATION ALGORITHMS

Image segmentation is a process of dividing an image into different regions such that each region is, but the union of any two adjacent regions is not, homogenous. A formal definition of image segmentation is as follows[1]: If p( ) is a homogeneity predicate defined on groups of connected pixels, then segmentation is a partition of the set F into connected subsets or regions (S_1, S_2,……..,Sn) such that

$$U^n_{i=1}\ S_i = F \text{, with } Si \cap Sj = \Phi \quad (i \neq j)$$

The uniformity predicate $P(S_i)$ = true for all regions, S_i, and $P(S_i \cup S_j)$ = false, when $i \neq j$ and S_i and S_j are neighbors.

Most of segmentation algorithms are based on two characters of pixel gray level: discontinuity around edges and similarity in the same region. There are three main categories in image segmentation : A. Edge-based segmentation ; B. Region-based segmentation; C. Special theory based segmentation.

4. EDGE-BASED SEGMENTATION

In a color image, an edge should be defined by discontinuity in a three dimensional color space and is found by defining a metric distance in some color space and using discontinuities in the distance to determine edges. Another way to find an edge in a color image is by imposing some uniformity constraints on the edges in the three color components to utilize all of the color components simultaneously, but allow the edges in the three color components to be largely independent.

For each color space, edge detection is performed using the gradient edge detection method. The color edge is determined by the maximum values of 24 gradient values in three components and eight directions at a pixel. There are three most commonly used gradient based methods: differential coefficient technique , Laplacian of Gaussian and Canny technique. Among them Canny technique is most representative one.

5.REGION-BASED SEGMENTATION

Edge-based segmentation partition an image based on abrupt changes in intensity near the edges whereas region-based segmentation partition an image into regions that are similar in according to a set of predefined criteria. Thresholding, region growing, region splitting and region merging are the main examples of techniques in this category.

A. *Thresholding Methods*

Thresholding techniques are image segmentations based on image-space regions. The fundamental principle of thresholding techniques is based on the characteristics of the image[2]. It chooses proper thresholds T_n to divide image pixels into several classes and separate the objects from background. When there is only a single threshold T, any point (x,y) for which f(x,y)>T is called an object point; and a point (x,y) is called a background point if f(x,y)<T. T is given by:
T = M[x , y , *p*(x,y) , f(x,y)], based on this equation thresholding technique can be divided into global and local, thresholding techniques.

1) *Global thresholding:* When T depends only on f(x,y) and the value of T solely relates to the character pixels, this thresholding technique is called global thresholding techniques. There are number of thresholding techniques such as: minimum thresholding, Otsu, optimal thresholding, histogram concave analysis, iterativw thresholding, entropy-based threshholding.

2) *Local thresholdin:* If threshold T depends on both f(x,y) and p(x,y), this thresholding is called local thresholdind. Main local thresholdind techniques are simple statistical thresholding, 2-D entropy-based thresholding, histogram transformation thresholding etc.

6. SPECIAL–THEORY BASED SEGMENTATION

Numerous special-theory based segmentation algorithms derive from other fields of knowledge
such as wavelet transformation, morphology, fuzzy mathematics, genetic algorithm, artificial intelligence and so on.

A. Fuzzy Techniques

Fuzzy set theory provides a mechanism to represents and manipulate uncertainty and ambiguity. Fuzzy operators, properties, mathematics, and inference rules have found considerable applications in image segmentation.[3,4,5,6]. Prewitt first suggested that the output of image segmentation should be fuzzy subset rather than ordinary subsets. In fuzzy subsets, each pixel in an image has a degree to which it belongs to a region or a boundary, characterized by membership value.

Recently, there has been an increasing use of fuzzy logic theory for color image segmentation [7 ,8]. For color images colors tend to form clusters in color space which can be regarded as a natural feature spcace.

B. Physics based techniques

Physics based segmentation techniques involve physical models to locate the objects' boundaries by eliminating the spurious edges of shadow or highlights in a color image. Among the physics models, "dichromatic reflection model" [9] and "approximate color-reflectance model (ACRM)"
[10] are the most common ones.

C. Neural Network technique

Neural network based segmentation is totally different from conventional segmentation Algorithms. In this algorithm, an image is firstly mapped into a neural network where every neuron stands for a pixel. Then , we extract image edges by using dynamic equations to direct the state of every neuron towards minimum energy defined by neural network [11]. Neural network based segmentation has three basic characteristics: 1) highly parallel ability and fast computing capability, which make it suitable for real-time application; 2) unrestricted and nonlinear degree and high interaction among processing units, which make this algorithm able to establish modeling for any process; 3) satisfactory robustness making it insensitive to noise. However, there are some drawbacks for neural network based on segmentation, such as: 1) some kinds of segmentation information should be known beforehand; 2) initialization may influence the result of image segmentation; 3) neural network should be trained using learning process beforehand, the period of training may be very long, and we should avoid overtraining at the same time.

7. Table. Monochrome image segmentation techniques

Segmentation Technique	Method Description	Advantages	Disadvantages
Histogram Thresholding	Requires that the histogram of an image has a number of peaks, each correspond to a region.	It does not need a prior information of the image. And it has less computational complexity	1)Does not work well for an image without any obvious peaks or with broad and flat valleys; 2)Does not consider the spatial details, so cannot guarantee that the segmented regions are contiguous.
Region-Based Appraoches	Group Pixels into homogeneous regions. Including region growing, region splitting, region merging or their combination.	Work best when the region homogeneity criterion is easy to define. They are also more noise immune than edge detection approach.	1)Are by nature sequential and quite expensive both in computational time and memory; 2)Region growing has inherent dependence on the selection of seed region and the order in which pixels and regions are examined; 3)The resulting segments by region splitting appear too square due to the splitting scheme.
Edge Detection Approach	Based on the detection of discontinuity, normally tries to locate points with more or less abrupt changes in gray level.	Edge detection technique is the way in which human perceives objects and works well for images having good contrast between regions.	1)Does not work well with images in which the edges are ill-defined or there are too many edges; 2)It is not a trivial job to produce a closed curve or boundary; 3)Less immune to noise than other techniques.
Fuzzy Approaches	Apply fuzzy operators, properties, mathematics, and inference rules, provide a way to handle the uncertainty inherent in a variety of problems due to ambiguity rather than randomness.	Fuzzy membership function can be used to represent the degree of some properties or linguistic phrase, and fuzzy IF-THAN rules can be used to perform approximate inference.	1)The determination of fuzzy membership is not a trivial job; 2)The computation involved in fuzzy approaches could be intensive.
Neural Network Approaches	Using neural networks to perform classification or clustering	No need to write complicated programs. Can fully utilize the parallel nature of neural networks.	1)Training time is long; 2)Initialization may effect the result; 3)Overtraining should be avoided.

8. CONCLUSSION

In this paper, we classify and discuss color spaces and main segmentation algorithms. An image segmentation problem is basically one of psychophysical perception, and it is essential to supplement any mathematical solutions by a prior knowledge about the picture knowledge. Most gray level image segmentation techniques could be extended to color image, such as histogram thresholding, region growing, edge detection and fuzzy based approaches. They can be directly applied to each component of a color space, then the results can be combined in some way to obtain final segmentation result.

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