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Survey on Skin Colour Segmentation Techniques

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***Abstract*— Segmentation of non-rigid complex structures is of great significance in the field of Vision Based Applications. There are many techniques available to segment the non-rigid bodies like hand, face, etc. These techniques are very useful in applications of Human Computer Interaction, Virtualization, Sign Language Recognition Systems, etc. The results from segmentation are used to identify the regions that are further processed and analysed to fit their application needs. Segmentation techniques have been broadly classified into two types – Parametric & Non – Parametric. The aim of this paper is to provide a survey of the various techniques used for parametric pixel based skin colour segmentation. The paper also provides the understanding of the segmentation techniques that are particularly most suited in a particular scenario over the other techniques.**

I. Introduction

Segmentation is the process of partitioning the image into the multiple segments to make easier the further processes of feature extraction, image analysis, etc. Segmentation remains a challenging task despite the advances in detection and tracking techniques. The first for any vision based application is the process of segmentation, where the regions of interest are extracted from the background pixels. There are several natural constraints that have taken into consideration while performing the process of segmentation. There are many issues to skin color segmentation

1. Skin color varies across different persons
2. Skin color intensity changes under varying illumination conditions
3. Different cameras display different color intensities for the same intensity, etc.

Segmentation algorithms available today are classified into three types – (1) Classical algorithms (2) Genetic Algorithms (3) Algorithms combining the approach of soft computing and neural networks. The aim of any segmentation technique is to partition the image into perceptually similar regions [1]. Every segmentation algorithm addresses two problems, the criteria for good segmentation and the method for achieving effective partitioning [2]. There are several methods by which segmentation can be performed and they are particularly termed into three types based on their approaches as(1) Thresholding (2) Region based and (3) Edge Based Segmentation. In thresholding method, the pixels intensity are categorized into ranges. If the pixel intensity falls into a particular range, the pixel gets segmented. In edge-based segmentation, an edge filter is applied on the image and based on the output obtained from the filter , the pixel can be classified as an edge or a non-edge pixel. Region Based Segmentation operates iteratively by grouping together the pixels which are neighbors and similar intensity values.

Section (II) illustrates the various methods of segmentation used to separate there required regions of interest from the background pixels. Section (III) elucidates the results obtained and the conclusion.

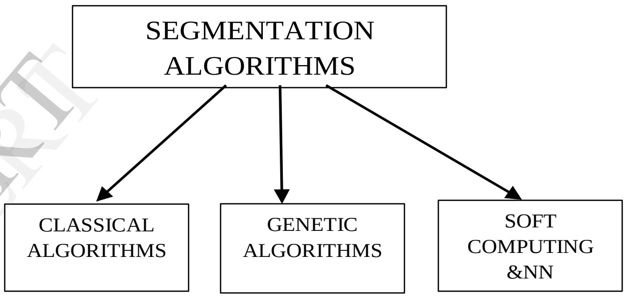

Fig – 1 Classification of Segmentation Algorithms

II. Segmentation Techniques

A. Background Subtraction

Initially image is captured without any hand gestures. Then the gestures are made. Now an image is captured again. When the initial image is subtracted from the image with hand gestures, the hand region alone is obtained. Then applying rules on the colour model selected skin region can be segmented

B. Skin Colour Segmentation Based on Histogram Analysis

The Histogram of the images are computed. The histogram analysis defines the maximum and minimum threshold for identifying the skin color regions. Based on the color frequency distribution the threshold is fixed and the skin color regions are segmented [3]. One of the major disadvantages of the histogram based method is that it is difficult to identify significant peaks and valleys in the images.

C. Skin Color Segmentation - Thresholding in HSV Space

The segmentation techniques are completely dependent on the chosen color space. Skin color based segmentation is apparently simple task with the only decision to make is the color space. Results obtained from segmentation are dependent on the color space chosen. In the HSV color the hue and the luminance component are separated and hence HSV color space a much sought out space for skin color based segmentation. The threshold for skin color are

$$\left.\begin{array}{l} H > 5 \;\&\&\; H < 17 \\ S > 38 \;\&\&S < 50 \\ V > 51 \;\&\; V < 242 \end{array}\right\} \quad \text{Eq. (1)}$$

D. Skin Color Segmentation -Thresholding in RGB- HSV-YCbCr Space

The RGB color space is an additive color space and also used one of the most commonly used color space. The RGB space has high correlation between channels, lot of non-uniformity and also there is a dominant mixing of the chromaticity and the luminance information. [4] Hence the use of the RGB space alone is not suitable for color based recognition [5]. To overcome this problem the normalized RGB has been introduced to obtain the chromaticity information for more robust results. [6][7][8][9].

$$R^N = \frac{R}{R+G+B} \quad \text{Eq. (2)}$$

$$G^N = \frac{G}{R+G+B} \quad \text{Eq. (3)}$$

$$B^N = \frac{B}{R+G+B} \quad \text{Eq. (4)}$$

In the above equations, R^N, G^N *and* B^N represent the normalized values of R, G and B respectively. These normalized values will satisfy the Eq. (4).

$$R^N + G^N + B^N = 1 \quad \text{Eq. (5)}$$

The following are the equations used for the conversion of pixel intensities from RGB to HSV.

$$Max = Maximum\,(R^N, G^N, B^N) \quad \text{Eq. (6)}$$

$$Min = Minimum(R^N, G^N, B^N) \quad \text{Eq. (7)}$$

$$H = \begin{cases} 0 & \text{If Max = Min} \\ 60 * \frac{G^N - B^N}{Max - Min} & \text{If Max} = R^N \\ 60 * \frac{B^N - R^N}{Max - Min} & \text{If Max} = G^N \\ 60 * \frac{R^N - G^N}{Max - Min} & \text{If Max} = B^N \end{cases} \quad \text{Eq. (8)}$$

$$S = \begin{cases} 0 & \text{If Max = 0} \\ \frac{Max - Min}{Max} & \text{Otherwise} \end{cases} \quad \text{Eq. (9)}$$

$$V = Max \quad \text{Eq.(10)}$$

The following matrix is used to convert intensities from RGB color space to YCbCr Color Space.

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 0.257 & 0.504 & 0.098 \\ -0.148 & -0.291 & 0.439 \\ 0.439 & -0.368 & -0.071 \end{bmatrix} * \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad \text{Eq. (11)}$$

In this chosen method [10] for skin color segmentation the pixel intensity if tested for skin color in HSV, RGB and YCbCr Color space. Only if the pixel is found to be a skin color pixel in all the color spaces it is taken as a skin color pixel or else it is identified as background pixel.

The thresholding conditions for the skin color classification in the various color spaces are as follows:

In the RGB space, the following rule put forward by Peer et al [11], determines the skin color under uniform daylight.

$$\left.\begin{array}{l} (R > 95)\&\&(G > 40)\&\&(B > 20) \\ \text{AND} \\ \{MAX(R,G,B) - MIN(R,G,B)\} > 15 \\ \text{AND} \\ (|R - G| > 15) \\ AND\ (R > G) AND\ (R > B) \end{array}\right\} \quad \text{Eq.(12)}$$

For skin color under flashlight, a lateral rule for detection is given by

$$\left.\begin{array}{l}(R > 220) AND (G > 210) AND (B > 170)\\ \text{AND}\\ (|R - G| \leq 15) AND (R > B) AND (G > B)\end{array}\right\} \quad \text{Eq. (13)}$$

To take note of both the conditions, the above two rules are combined using the logical operator, OR.

In YCbCr space, the following thresholding conditions are applied.

$$\left.\begin{array}{l}Cr \leq 1.5862 * Cb = 20\\ Cr \geq 0.3448 * Cb + 76.2069\\ Cr \geq -4.5652 * Cb + 234.5652\\ Cr \leq -1.15 * Cb + 301.75\\ Cr \leq -2.287 * Cb + 432.85\end{array}\right\} \quad \text{Eq. (14)}$$

In [12] the thresholds for the YCbCr was improved by including the parameters for Y and Cb.

$$\left.\begin{array}{l}Y > 80\\ 85 < Cb < 135\end{array}\right\} \quad \text{Eq. (15)}$$

In the HSV space, the conditions for skin color are:

$$\left.\begin{array}{l}H < 25\\ H > 230\\ S > 38\\ S < 250\\ V > 51\\ V < 242\end{array}\right\} \quad \text{Eq. (16)}$$

The above two condition are combined using a Logical operator OR. If the pixel intensity falls under all the above threshold conditions, then the pixel intensity will be classified as a skin color intensity. The results obtained from the segmentation are further acted upon by morphological operations are used to eliminate the presence of noise in the results.

E. Active Contour Based Segmentation

Active Contour Based Segmentation method involves the drawing of a random shape around the region of interest. On every iteration till the energy function is minimized to zero, the shape is tightens around the region of interest [13]. The method is highly suitable to obtain segmented regions of non-rigid objects. However shape complexity of the object determines the number of iterations required to segment the object. The energy function is as follows [14]

$$E(T) = \int_0^1 E_{internal}\,(v) + E_{image}\,(v).\,ds \quad \text{Eq. (17)}$$

F. K-Means Clustering

K- Means clustering[15] is one of the most simplest clustering algorithm used to partition the image into 'k' clusters and the this value of 'k' is to be specified by the user based on the application.

Let $X = \{x_1, x_2, \ldots x_n\}$ be a set of 'N' pixels. $V(x_i)$be the property vector of x_i. The steps followed for the K-means Algorithm is as follows

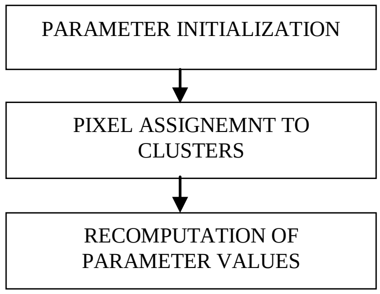

Fig 2 – K-Means Clustering Algorithm

In the first step, the means of K-clusters are assigned to potential property vectors. Assignment is done based on the distance computation between the vectors and the pixel is assigned to the cluster with the closest mean. The means of each of these clusters are again recomputed based on the property vector of all the pixels in the cluster. The second and third steps are repeated until no pixel moves from one cluster to the other.

G. Motion Based Segmentation

In a sequence of frames or in a video, the motion of an object can be used to segment the object region. The motion vectors are computed for every pixel in the frame. The motion vectors are analyzed and the group of pixels moving along the same direction are segmented. [16] These pixels are grouped together using different clustering techniques. This technique fails when the region of interest to be segmented does not move.

H.Adaptive Skin Color Segmentation using GMM

The Single Gaussian model has been used successfully to represent distinct object features in many real world problems. However these single models requires the components to vary smoothly around the mean value. In [17][18], it has been shown that a combination of randomly occurring independent models can be used. The probability density function of GMM can be seen a weighted sum of Gaussians [19]

$$P(x;\theta) = \sum_{i=0}^{n} \alpha_i\, G(x; \mu_i \alpha_i) \quad \text{Eq. (18)}$$

α_i is the weight of the *i-th* component, x is the sample input, G is the Gaussian probability density function with the parameters standard deviation and mean and 'n' is the number of components. Model Parameter estimation is done using the EM Algorithm. The skin color intensities are modelled as Gaussians and by measuring the probability of whether each pixel belongs to skin intensity or not, the skin color and non-skin color pixels can be separated.

III. Conclusion

The results of skin colour segmentation varies according to illumination conditions, the type of camera used, the colour space used for segmentation, etc. The survey of colour models [20] gives an overview of the colour models that can be used for skin colour segmentation. The Table -1 illustrates the working of the various methods under the conditions of Illumination and Background. In the below table (Yes – the method works under varying conditions of illumination , Partial Invariance – works under varying illumination but affected by other skin coloured objects, No – Variant to lighting conditions) The background of the scenario can either be complex or uniform and the method's working depends on it.

Sl.no	Technique	Illumination Invariant	Background
1.	Background Subtraction	Yes	Uniform
2.	Segmentation Based on Histogram Analysis	Partial Invariance	Complex
3.	Thresholding Using HSV	Partial Invariance	Complex
4.	Thresholding using HSV-RGB-YCbCr	Yes	Complex
5.	Active Contour Based Segmentation	Yes	Complex
6.	K- Means Clustering	Yes	Complex
7.	Motion Based Segmentation	Yes	Complex
8.	Adaptive Skin Colour Segmentation using GMM	Yes	Complex

Table – 1 Tabulating the Working of Different Segmentation Algorithms under varying conditions

Based on Table – 1, the different algorithms can be employed to segment different skin colour regions based on their application. In the recent times are lot of skin colour classifiers are being used to make the system invariant to varying lighting and background conditions.

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