Performance Measure of Human Skin Region Detection Based on Hybrid Particle Swarm Optimization

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***Abstract*—This paper proposes an application of human skin region detection using Hybrid Particle Swarm Optimization (HPSO) algorithm. It consists of two steps. In the first step, the input RGB color image is converted into CIEL*a*b color space. Then this is clustered by the Hillclimbing segmentation with K-Means clustering algorithm, which will be useful to find the number of clusters and the local optimal solutions. In the second step, these local solutions are further improved by PSO algorithm using YCbCr explicit skin color conditions in order to find the global solution. This solution helps to detect the robust skin region. Finally the performance measure named Peak Signal-to-Noise Ratio (PSNR) is performed on the ground-truth skin dataset. The experimental results has shown the efficiency of the proposed method.**

***Index Terms*—3D histogram, color space, hillclimbing segmentation with k-means, particle swarm optimization, PSNR.**

I. Introduction

Applications of image segmentation can be found in a wide variety of areas such as remote sensing, vehicle and robot navigation, medical imaging, surveillance, target identification and tracking, scene analysis, product inspection/quality control etc. Image segmentation remains a long-standing problem in computer vision and has been found difficult and challenging for two main reasons: firstly, the fundamental complexity of modelling a vast amount of visual data that appear in the image is a considerable challenge; the second challenge is the intrinsic ambiguity in image perception, especially when it concerns so-called unsupervised segmentation. Hence, the proposed application focused on the cluster based segmentation which automatically determines the "optimum" number of clusters to the application of human skin region detection.

Skin region detection plays an important role in many applications of image processing. The applications are face detection, face recognition, gesture recognition, human body parts like hand, eye and lip detection and others. The important cue to detect the skin region is by skin color. So, color spaces play a major role to detect the skin region. Different color spaces like RGB, Normalized RGB, HSV, YCbCr [1],[2],[3],[4],[5] and CIEL*a*b [6] are mainly used. Since many recent proposals are based on the underlying idea of representing the skin color in an optimal color space by means of the so-called skin cluster. Color information is an efficient tool for identifying skin areas if the skin color model can be properly adapted for different lighting environments. This fact leads to avoid the use of RGB, because the red, green and blue components are highly correlated and dependent on lighting conditions. Hence, the proposed method is based on CIEL*a*b and YCbCr color spaces. Some of the skin color modeling techniques are skin detection rule, parametric skin distribution modeling, non-parametric skin distribution modelling [2] and edge based [4].

Optimization technique is very important in image segmentation applications. Since, this helps to minimize certain criteria (e.g., intra cluster centre). The optimization techniques are Simulated Annealing, Genetic Algorithms, Ant Colony Optimization algorithms and Particle Swarm Optimization. In that, PSO has been applied to many different applications of segmentation [1],[7],[8],[9], pattern classification and image analysis.

This proposed paper deals with 3D Histogram, dynamic cluster formation, local and global optimum solution. The local optimum solutions are determined by Hillclimbing segmentation with K-Means clustering algorithm of CIEL*a*b color image. Then these local solutions are further refined by the PSO algorithm, in order to find the global solution by YCbCr color space explicit skin color conditions.

The paper is structured as follows. In Section 2, literature review discussed. The Section 3, explain the formation of clusters and finding local solutions. The Section 4 describes the proposed HPSO algorithm. The Section 5 and 6, illustrates the performance measure and demonstrates the experimental results respectively. The conclusion and future work is discussed in the final section.

II. Literature Review

J. A. Nasiri, H. S. Yazdi and M. Naghibzadeh [1] proposed the chrominance based mouth detection approach using PSO rule mining. The high values of Cr and low values of Cb considered as the mouth region. PSO had been tuned to separate pixels properly.

Nils Janssen and Neil Robertson [2] used a non-parametric classification scheme based on a histogram similarity measure by various color spaces and the resolution of histograms. Also compared the results with three methods namely Gaussian, Bayesian and Thresholding.

A. Cheddad, J. Condell, K. Curran and P. Mc Kevitt [3] set hypothesis that "luminance inclusion does increase separability of skin and non-skin clusters". This approach used a new color space which contains error signals derived from differentiating the grayscale map and the

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non-encoded-red grayscale version and performed the reduction of space from 3D to 1D.

A.Y. Dawod, J. Abdullah and Md. J. Alam [4] also proposed the luminance based clustering. Edge detection could be used to construct a free-form skin color model. Gradient method by Sobel operator detected edges at finest scales and has smoothing action along the edge direction.

Qing-Fang Zheng and Wen Gao [5] proposed a fast adaptive skin detection approach that worked on DCT domain of JPEG image and classifies each image block according to its color and texture properties. The color and texture features adopted by YCbCr color space, since it is more valid than other color spaces for skin detection. The experiment carried out in two ways: first, the accuracy and efficiency of the method were compared with existing adaptive methods and non-adaptive method. Second, the advantage of using both color and texture features.

D. D. Gomez, C. Butakoff, B. K. Ersboll and W. Stoecker [6] proposed an unsupervised algorithm named Independent Histogram Pursuit for segmenting dermatological lesions. This method was used to find a suitable image-dependent linear transformation of an arbitrary multispectral color space to aid segmentation of dermatological images. The spectral bands was enhanced the contrast between healthy skin and lesion. Then the remaining N-1 combinations were estimated.

Chih-Cheng Hung and Li Wan [7] proposed the image classification by hybridization of Particle Swarm Optimization with the K-Means algorithm. This method was performed in two steps: in the first step, different PSO heuristics was optimized by the K-Means algorithm. In the second step, determined the reliability parametric values for different variants of PSO and K-Means algorithms.

Mahamed G.H. Omran, A. Salman and A. P. Engelbrecht [8] proposed a new dynamic clustering approach based on particle swarm optimization. Binary particle swarm optimization was used to automatically determine the optimum number of clusters. Then the chosen clusters were refined by K-Means clustering algorithm. The experiments were conducted by both synthetic images and natural images.

Yuhua Zheng and Yan Meng [9] proposed a robust tracking algorithm used an adaptive tracking window associated with five parameters. These parameters were optimized by a PSO algorithm. The fitness function for particles was calculated by appearance histogram.

The proposed paper used the concepts of YCbCr color space, CIEL*a*b color space, 3D Histogram, Hillclimbing K-Means clustering algorithm and PSO for finding a global solution. The above existing works clearly explained the importance of these concepts. The drawbacks identified by the existing works could be optimally reduced through combining these concepts. and also this is a good solution for the drawbacks mentioned in our previous works [10] and [11].

III. Cluster Formation and Finding Local Solutions

K-Means clustering algorithm is one of the simplest and efficient unsupervised learning algorithms for clustering problems such as image segmentation. Such efficient algorithm could be used here for identifying the number of clusters and the local solutions.

The input color image is first converted into CIEL*a*b color space. Since CIEL*a*b color space is human perception based color space. 3D histogram and histogram size (number of bins) (here 10) are used to find the histogram peaks. This is used to obtain the number of initial seeds for K-Means clustering algorithm. The results of K-Means clustering algorithm and the number of cluster are passed to PSO algorithm for further refinement, in order to obtain the global best solution. 3D histograms assume dependence of one channel on the other and which is more realistic. This could be the same implementation as in third color space discussed in [12] and [13]. Fig. 1 shows the sample labelled segmentation results of Hillclimbing segmentation with K-Means clustering algorithm. Fig. 2 shows the distribution of pixels in CIEL*a*b color space of the Fig. 1 labelled images.

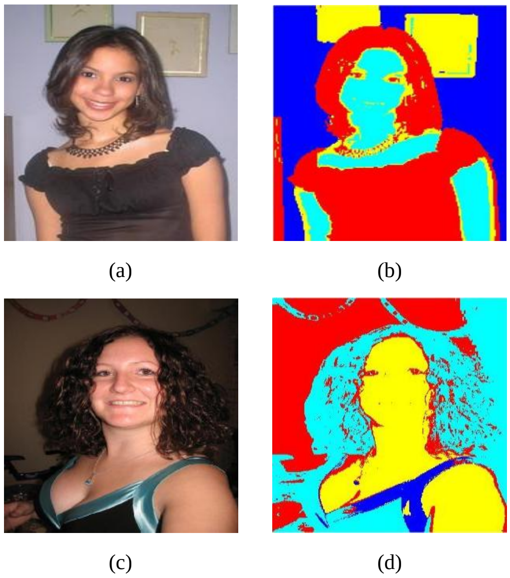


Fig. 1. Segmentation results of Hillclimbing segmentation with K-Means clustering algorithm (a), (c) Original image (b), (d) Segmented labelled image.

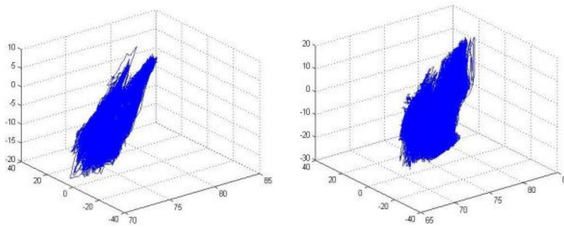


Fig. 2. Distribution of pixels in CIEL*a*b color space of Fig. 1 labelled images.

Table I shows the performance measures of automatic cluster formation by Hillclimbing segmentation with K-Means clustering algorithm.

TABLE I: Cluster Formation by HILLCLIMBING Segmentation with K-Means Cluster Algorithm

Input Image	Image Size	Number of Clusters	Duration (seconds)
Fig 1 (a)	170 x 235	4	0.689
Fig 1 (c)	450 x 600	4	4.796

IV. Proposed Hybrid Particle Swarm Optimization Algorithm

Particle Swarm Optimization was originally introduced by Kennedy and Eberhart [14], inspired by social behaviour of bird flocking or fish schooling.

In PSO, a swarm of individuals (called particles) fly through the search space. Each particle represents a candidate solution to the optimization problem. The position of a particle is influenced by the best position visited by itself and the position of the best particle in its neighborhood. When the neighborhood of a particle is the entire swarm, the best position in the neighborhood is referred to as the global best particle and the resulting algorithm is referred to as a *gbest* PSO. When smaller neighborhoods are used, the algorithm is generally referred to as a *lbest* PSO. The performance of each particle is measured using a fitness function that varies depending on the optimization problem [8]. It is a population based stochastic optimization technique in which individuals called particles change their positions and velocity with time. Also PSO is easy to implement for its simple particle updating operation. It is a new method which can solve most of global optimization problems.

Each particle in the swarm is represented by the following characteristics:

x_{id} : The *current position* of the particle.

v_{id} : The *current velocity* of the particle.

p_{id} : The *personal best position* of the particle.

The new velocity and position of each particle can be calculated using the current velocity and the distance from p_i to p_g as shown in the following formulas:

$$v_{id}^{k+1} = w \times v_{id}^{k} + c_1 \times rand() \times (p_{id} - x_{id}^{k}) + c_2 \times rand() \times (p_{gd} - x_{id}^{k}) \quad (1)$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1} \quad (2)$$

where $i = 1,2,...,n,\ d = 1,2,...,m.\ w, c_1, c_2 > 0,$ n is the number of particles in a group, m is the number of members in a particle, w is the inertia weight factor, c_1 and c_2 are acceleration constants, $rand$ are random numbers with the range $[0,1]$. The particles follow up the scent p_i and p_g to search in the goal searching space until the optimum result does not change again or reach the scheduled numbers.

PSO algorithm is used to optimize the objective functions that are mainly used to minimize within cluster distance (between pixel and the cluster mean) and to maximize among cluster distance (between cluster pairs). In this proposed paper, the number of clusters is not known priori. This is derived from the Hillclimbing segmentation with K-Means clustering algorithm and the details of the cluster formation is discussed in the previous section.

The detailed procedure for combining the K-Means clustering algorithm and PSO algorithm is outlined as follows:

1) The input RGB color image is converted into CIEL*a*b color space.
2) The CIEL*a*b color space components undergone the calculation of histogram in 3D, in order to find the histogram peaks.
3) This peak value is used as the number of clusters of K-Means clustering algorithm.
4) The return values, the number of cluster and cluster centres of K-Means clustering algorithm are passed to the proposed PSO algorithm.
5) The PSO algorithm uses the return values of K-Means and take the argument as RGB color image as in step 1. Here this original image can be converted into YCbCr color space.
6) The PSO algorithm used to find the global optimum solution from the initial solutions of K-Means clustering algorithm with the following explicit skin color conditions and prerequisites:
   - Population is derived from Hillclimbing segmentation with K-Means clustering algorithm.
   - Maximum and minimum chrominance values are assigned to Cb=125 & Cr=172 and Cb=75 & Cr=132 respectively.
   - The solutions of K-Means clustering algorithm are assigned to the best values of the proposed method.
   - The number of iteration is assigned to 100.
   - Individual weight and social weight of the particles is 2 each.
   - Inertial factor (w) is 1.
   - PSO algorithm stores the chrominance components previous best position of each particle and the best global position of particles by using equations (1) and (2).
7) The cluster of the skin region mapped to the original RGB components of the input image and other clusters are eradicated. Here all non-skin region color components are assigned to zero.

Finally the segmented image is converted into gray scale image and performed the performance measure with PSNR by using MCG skin ground-truth dataset.

V. Performance Measure

The performance measurement for image segmentation, the well known Peak Signal-to-Noise Ratio (in dB) which is classified under the difference distortion metrics is applied on the skin region detected by the proposed method and the ground-truth of skin images. It is defined as:

$$PSNR = 20\log_{10}\left(\frac{255}{RMSE}\right) \quad (dB) \quad (3)$$

where RMSE is the root mean-squared error, defined as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(I(i,j) - \hat{I}(i,j))^2}{MxN}}$$

Here I and $\hat{I}$ are original and segmented images of size is MxN respectively.

PSNR is often expressed on a logarithmic scale in decibels (dB). PSNR values falling below 30 dB indicate a fairly low quality. However, a high quality image should strive for

40dB and above [15]. The PSNR value is calculated between the gray converted image of the proposed segmented image and the ground-truth of skin image [16].

VI. Experimental Results

This proposed method was implemented by Matlab7.0 on a 2.4GHz Pentium IV machine running on 256MB RAM. Experiments were conducted by the images of MCG skin ground-truth dataset, different country people and various illuminations, totally 385 images. These images have different numbers of clusters with varying complexities. The proposed PSO algorithm parameters are empirically set as follows: Nc is derived from the number of clusters of K-Means clustering algorithm and w=1, c1=c2=2.

Fig. 1 (b) and Fig. 1 (d) shows the labelled cluster image formed by Hillclimbing segmentation with K-Means clustering algorithm, which is same as discussed in [12] and [13]. This clustering algorithm could be useful to find the number of cluster and to find the local optimal solution of the input images.

Then these solutions are further refined by the proposed PSO algorithm by YCbCr color space explicit skin color conditions. The skin region cluster identified by the proposed method, which is explained in the step 6 of the previous section. The experiments on Hillclimbing segmentation with K-Means clustering algorithm and PSO algorithm are intended to show the effectiveness of the results of the classification. Finally the performance measure of PSNR is calculated between the gray converted segmented result and MCG skin ground-truth dataset. The experiment could be carried out by the MCG ground-truth skin dataset, skin different illumination and lighting condition images, people from various country and small skin patch images. Fig. 3 and Fig. 4 show the skin region pixels distribution of the Fig. 1 Original images and the experimental result of the proposed method respectively.

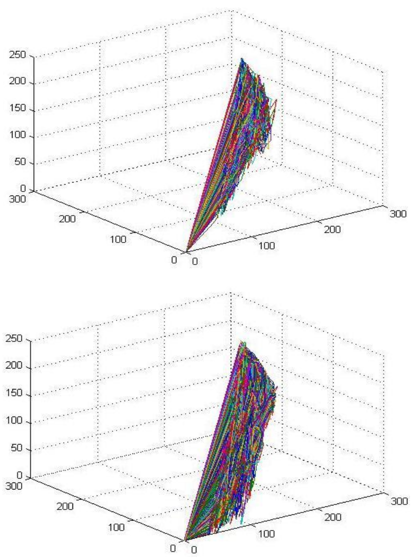


Fig. 3. Skin region pixels distribution of the proposed method of Fig. 1 Original images.

Hence the results are more robust and also overcome the drawbacks mentioned in our previous works [10] and [11]. Fig. 4 (d), (f) and (l) are the best sample results, to prove the proposed method is more robust than the existing work.

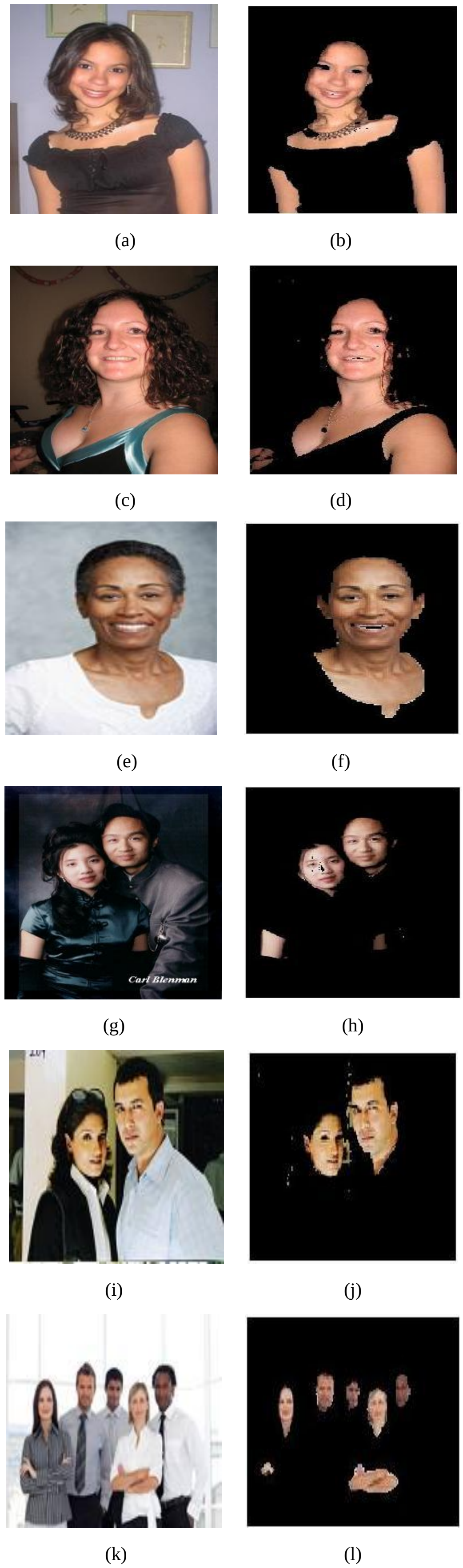
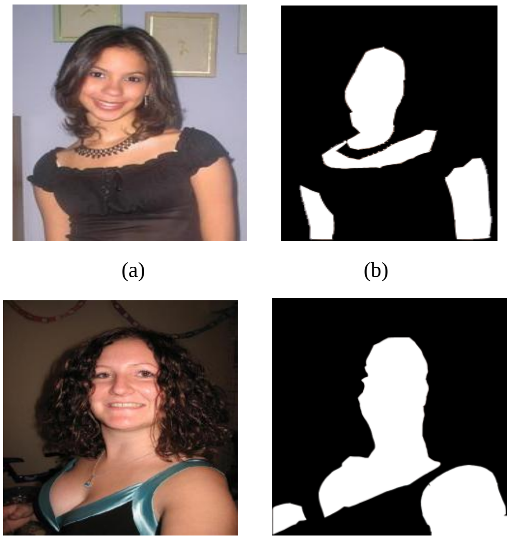


Fig. 4. Experimental results of the proposed PSO algorithm (a), (c), (e), (g), (i), (k) Original image (b), (d), (f), (h), (j), (l) The proposed PSO algorithm based skin region segmented image.

The PSNR values calculated by the proposed method for Fig. 4 (b) and (d) is illustrated in Table II and the corresponding skin ground-truth images is shown in Fig. 5 (b) and Fig. 5 (d).

TABLE II: PSNR VALUES.

Input Image	PSNR Value
Fig 5 (a)	41.14
Fig 5 (c)	41.14



(a) (b) (c) (d)

Fig. 5. Skin ground-truth image (a), (c) Original image (b), (d) MCG skin ground-truth image.

VII. CONCLUSION AND FUTURE WORK

In this paper, a new skin region detection algorithm based on PSO was proposed. Dynamic formation of clusters by Hillclimbing segmentation with K-Means clustering algorithm and the chrominance based global solution of the skin cluster found by PSO algorithm makes the process more robust to detect the skin region. The performance measure and experimental results show that our method is satisfactory for skin region detection. These satisfactory results were based on the segmentation quality, duration of execution, dynamic cluster formation, less frame buffer usage and optimal global solution. Also the segmented results will be useful to many computer vision applications like Face detection, Face recognition, Gesture recognition and etc. Future work will extend the experiments on low-resolution images with texture and spatial information instead of the chrominance values.

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