Parallel Genetic Algorithm for Color Image Segmentation

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Abstract

This paper presents a Parallel Genetic Algorithm (PGA) based on the distributed (island) paradigm to optimize color image segmentation. The goal of using PGA is to accelerate the process of segmentation. However, that is not the only motivation for parallelism. Even when speed is not primary factor, these distributed algorithms, and as we shall see through the results, often outperform GAs with single population. Some examples in color images are presented and overall results discussed.

Keywords: Color Image Segmentation; Parallel Genetic Algorithms; Clustering.

1. INTRODUCTION

Segmentation of an image entails the division or separation of the image into a set of disjoint regions whose characteristics such as intensity, color, texture, etc. are similar (Gonzalez, 1992; Russ, 1999; Partt, 2001). Image segmentation is a very important process because it is typically the first task of any automatic image understanding process, and all subsequent steps, such as feature extraction, classification, object detection, and recognition depend heavily on its results. The segmentation process is a complicated task because most of a available segmentation techniques use numerous control parameters that must be adjusted to obtain an optimal performance.

Recently, researchers have investigated the application of genetic algorithms into image segmentation. Perhaps the oldest work was proposed by Zingaretti *at el* (1997) to adopt a GA to determine the parameters set that optimize the output of an existing segmentation algorithm. Also, Stephan (1999) presented approach depended on GA, where this approach consists of two parts, one part depends on finding the optimal thresholds, wherein the second part uses edge-detection technique for finding the optimal edge with single pixel width. Another situation where GAs may be useful tools is illustrated by the work of Ramos and Muge (2000). In their work, the authors formulated the segmentation problem as an optimization problem and adopt hybrid GAs for clustering of single pixels represented by feature vector in feature space.

This paper presents a parallel GA based on the distributed (island) paradigm (Davison and Rasheed 1999) to optimize color image segmentation and also to speed up this process overall. In this paradigm, the population is divided into collection of subpopulations (islands) which evolve independently from each other on isolated continents, but each trying to minimize the same objective function. Once in a while some individuals (the best) migrate from one island to another according to a neighborhood topology (for example, hypercube topology). This migration allows subpopulations to share genetic material. The idea is that isolated environments, or competing islands, are more search-effective than a wider one in which all the members are held together.

The rest of the paper is organized as follows. The application of genetic algorithms in image segmentation is discussed in section 2. Section 3 describes the proposed approach. Section 4 deals with results. Finally, conclusion and future work are shown in section 5.

2.Genetic Clustering in Image Segmentation

The GAs (Goldberg, (1989); Mitchell, (1996)) are adaptive methods which use a model of natural selection that occurs in real life. In image segmentation, GAs can be used to search either in the parameters space of an existing segmentation algorithm or in the space of candidate segmentation. In both cases, an objective function, assigning a score to each segmentation, has to be specified.

In the present approach, we use the L*a*b* (CIE Lab) color space (Sangwine and Horne 1998) which was designed such that the perceived differences between single, nearly colors correspond to the Euclidean distance of the color coordinates. Using this color space will make feature vector of each pixel represented by three component (L*,a*,b*) and segmentation problem is simply reformulated as an unsupervised clustering problem, then genetic algorithms are used for finding the most appropriate and natural clusters with minimum distortion according to Eq.1:

$$distortion = \frac{1}{NK}\sum_{i=1}^{M}\sum_{x\in C_i}\left\| x - z_i \right\|^2$$

(1)

where N is the number of pixels in the image, M is the number of clusters, K is the number of features in feature vector (here is three : L*,a*,b*), and z_i is the cluster center of cluster C_i. By this reformulation, one can in fact guarantee that similar pixels will belong to the same color cluster.

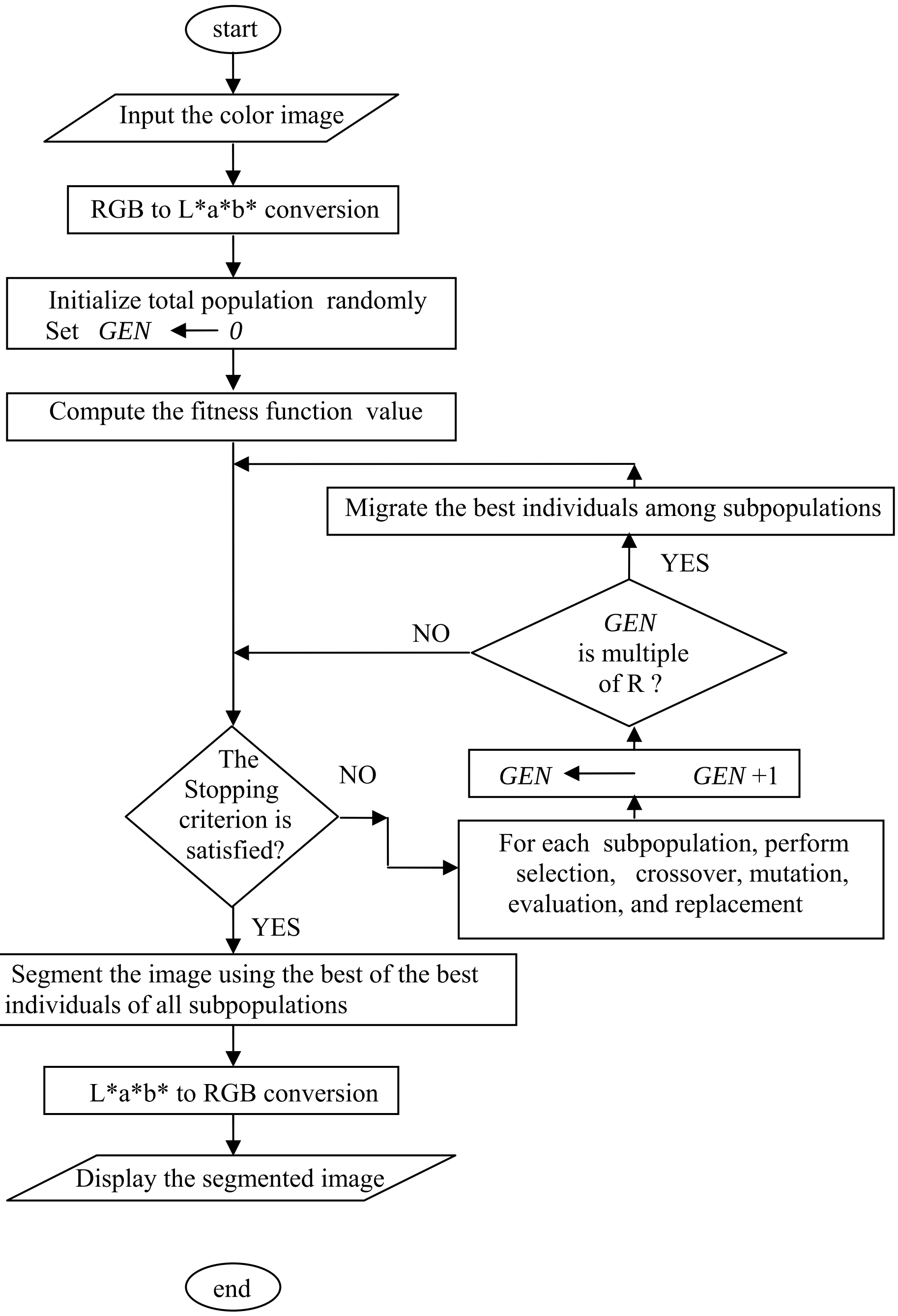
3. Proposed Approach

Here, parallel genetic algorithm is used to optimize image segmentation process. This PGA adopted the island model in which the total population is divided into subpopulations each evolve independently from each other. Using the Steady-State Genetic Algorithm (SSGA) (Michalewicz, (1996); Schmidt and Stidsen, (1997) rather than simple genetic algorithm, a few individuals are replaced in every iteration. The fitness is the inverse of the expectation of distortion. Each gene in the chromosome represent cluster center. The proposed algorithm, outlined in Fig. 1, consists of the following steps:

1. Initialization:- Randomly assign pixels(represent cluster center) to every individual of the population. A chromosome is composed of M cluster center. Separate the population into G subpopulations. G sets of P individuals are generated in this step, where P is the size of each subpopulation. Without loss of generality, set $G=2^n$.
2. Evaluation:- The fitness of every individual in each subpopulation is evaluated in this step.
3. Migration:- Subpopulations are communicated by migration, where the top best B individuals(called migration rate) of jth subpopulation are sent to the qth subpopulations to substitute B individuals in each receiving subpopulation in place of the worst ones for every R generation(s), i.e., receive some information from the other subpopulations, but keep the same population size. Here, it is used the hypercube topology for communication, where $q = j \oplus 2^i$, j=0,1,…,G-1, and i =0,1,…,n-1.
4. Selection:- It is used ternary tournament selection for selecting the parents. In this method three individuals are randomly chosen from the subpopulation and then select the best of these as a first parent. This process is repeated for selecting the appropriate set of parents.
5. Crossover:- The uniform crossover technique is used to produce two children from the selected parents for each subpopulation. In some probability (*0.5*), the crossover is take placed by exchanging genes of parents randomly to produce two children.
6. Mutation:- The genes (cluster center) in the chromosome are mutated according to mutation probability. The mutation is only operated by assigning pixel, randomly selected, from the image in place of gene in the chromosome.
7. Replacement:- Triple tournament replacement technique is used for replace the best new child in place of the worst of three individuals which are randomly selected from the subpopulation.

8. Stopping criterion:- The parallel genetic algorithm will be iteratively performed on an input image until stopping criterion is satisfied. The stopping criterion would check the current generation number, the search is terminated if the total number of generations exceeds a predefined constant.

After termination, the optimal clusters centers are generated from the best individual



for all subpopulations and the image is segmented accordingly.

FIGURE 1. The proposed parallel genetic algorithm approach to color image segmentation

4. Experimental Results

Experiments were carried out to test the performance the proposed approach to color image segmentation. Four test color images, *skin cancer*, *child*, *peppers_mon*, and *synthetic* are used to evaluate the performance of the proposed approach. The four test color images are represented in the RGB color space and each of the RGB components is identically represented by 8 bits.

Since the image *synthetic* has four different objects, the aim was to search for 4 color clusters. For the same reason, the *skin cancer* segmentation was implemented with 2 clusters, *child* with 5 clusters, and finally the *peppers_mon* into 3 clusters. The parameter values used in the parallel genetic algorithm for the subpopulation size P, the number of subpopulations G, the number of generations N_g, the crossover rate Pc, the mutation rate Pm, the number of top best for migration B, and the number of generations for migration R are 50, 8,1000, 0.75, 0.1, 1, and 50 respectively.

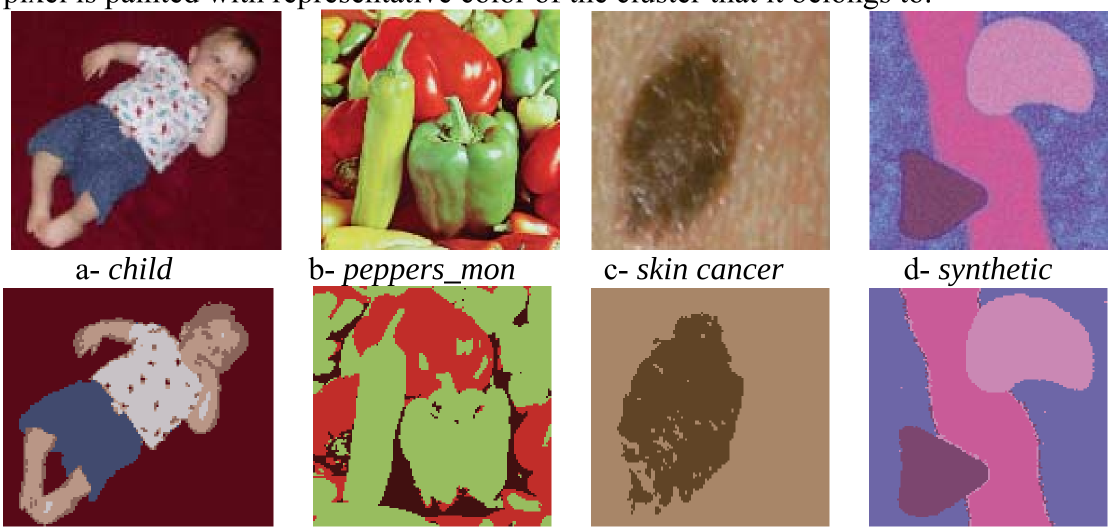
The efficiency of the proposed method can be measured by two different ways:(1) objective measure and (2) a subjective casual visual inspection of the images. In this study, the distortion can be used as the objective measure of the proposed approach. The distortion values for the four test color image by SSGA (sequential version) and PGA for comparison are listed in Table 1.

TABLE 1. The distortion values for four segmented test color images by the PGA & SSGA.

Population size is 400 for SSGA and the other parameters(Pc, Pm, N_g) are the same as in PGA.

Test Images	**SSGA**	**PGA**
Skin cancer	2.046	2.029
Peppers_mon	5.549	5.409
Synthetic	1.718	1.661
Child	1.803	1.727

On the other hand, As a subjective measure of the efficiency of the segmentation process, the original test images and their corresponding segmented images by the proposed approach are illustrated in Fig.2. The segmented images are such that each pixel is painted with representative color of the cluster that it belongs to.



a- *child* b- *peppers_mon* c- *skin cancer* d- *synthetic*

e f g h

FIGURE 2- Test images by proposed method. (a-d) and (e-h) Original and segmented images respectively.

5. Conclusions and Future Work

In this work, we have described a parallel genetic approach to color image segmentation. It is aimed at segmentation of natural images, in which the color and texture of each segment does not typically exhibit uniform statistical characteristics. The proposed approach uses the island model of genetic algorithm that globally searches for a good segmentation.

The performance of the proposed algorithm has been demonstrated on a group of images with different complexities. Experimental results (Fig. 2.) exhibit a promising performance for the proposed method. In fact, the final segmentation images are consistent with what is observed visually. However, some problems may be raised in some images. The main reason is that the problem is by itself difficult (with large search space).

Based on the experimental results obtained in Table 1., it is found that the parallel genetic algorithm is not only to accelerate the speed of running time, but also to produce improved image segmentation, where that the distortion values of the segmented images by the proposed approach are always smaller (better) than that of the segmented images by SSGA for comparison. Great improvements appear to be possible without requiring substantial modifications of the structure.

In addition, future works will focus on determining the number of clusters automatically by using variable chromosome length and alternative evaluation function to select the best.

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