



Adaptive Image Segmentation Using a Genetic Algorithm

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Abstract: In this paper we present an Adaptive approach for image segmentation using genetic algorithm, a natural evolutionary approach for optimisation problems. In addition, method of implementing genetic algorithm has also been reviewed with a summary of research work on Adaptive approach for image segmentation techniques. We have proposed an efficient color image segmentation using Adaptive approach along with genetic algorithm. The advantage of the proposed method lies in its utilisation of prior knowledge of the RGB image to segment the image efficiently.

I. Introduction

Segmentation is the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics.

The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image (see edge detection). Each of the pixels in a region is similar with respect to some characteristic or computed property, such as color, intensity or texture. Adjacent regions are significantly different with respect to the same characteristic(s). Genetic Algorithms were invented to mimic some of the processes observed in natural evolution to solve the optimization problems. Genetic algorithm (GA) is a new technique for a search, based on principles of natural selection. Genetic algorithms are proven to be the most powerful optimization technique in a large solution space. This explains the increasing popularity of Genetic algorithms applications in image processing and other fields.

II. Work done in Genetic algorithm

Genetic algorithms are based on natural selection discovered by Charles Darwin. They employ natural selection of fittest individuals as optimization problem solver. A typical genetic algorithm requires:

1. A genetic representation of the solution domain.
2. A fitness function to evaluate the solution domain.

Optimization is performed through natural exchange of genetic material between parents. Off springs are formed from parent genes. Fitness of offspring is evaluated. The fittest individuals are allowed to breed only. In computer world, genetic material is replaced by strings of bits and natural selection replaced by fitness function. Mating of parents is represented by cross-over and mutation operations.

Given a clearly defined problem to be solved and a bit string representation for candidate solutions, a simple GA works as follows:

1. Start with a randomly generated population of n l -bit chromosomes (candidate solutions to a problem).
2. Calculate the fitness $f(x)$ of each chromosome x in the population.
3. Repeat the following steps until n offspring have been created:
 - a. Select a pair of parent chromosomes from the current population, the probability of selection being an increasing function of fitness. Selection is done "with replacement," meaning that the same chromosome can be selected more than once to become a parent.
 - b. With probability p_c (the "crossover probability" or "crossover rate"), cross over the pair at a randomly chosen point (chosen with uniform probability) to form two offspring. If no crossover takes place, form two offspring that are exact copies of their respective parents. The crossover rate is defined to be the probability that two parents will crossover in a single point. There are also "multi-point crossover" versions of the GA in which the crossover rate for a pair of parents is the number of points at which a crossover takes place.)
 - c. Mutate the two offspring at each locus with probability p_m (the mutation probability or mutation rate), and place the resulting chromosomes in the new population. If n is odd, one new population member can be discarded at random.
4. Replace the current population with the new population.
5. Go to step 2.

Genetic Algorithms were invented to mimic some of the processes observed in natural evolution to solve the optimization problems. Farmer and Shugars [24] categorized the applications of genetic algorithms used for image segmentation into two major classes:

1. Parameter selection, where genetic algorithms are used to modify the parameters of an existing image segmentation method to improve its output, i.e. application to segmentation parameter selection for improved segmented outputs.
2. Pixel-level segmentation, where genetic algorithms are used to perform region labelling, i.e. application to pixel-level segmentation involving region labelling.

Most image segmentation methods have many parameters for optimization, thus the first method is used more often. Bhanu *et al.* [25] used genetic algorithms for adapting four parameters of the Phoenix segmentation algorithm [26] for outdoor color imagery. Feitosa *et al.* [27] modified the region growing segmentation algorithm using a fitness function based on the similarity of resulting segments to a target segmentation provided by the user. Zingaretti *et al.* [28] applied genetic algorithms to unsupervised color image segmentation techniques, which resort to multi-pass thresholding during each pass of the algorithm. Pignalberi *et al.* [29] focused on range images, by segmenting outside surfaces of 3D objects. However, this method can also be applied to segmentation of 2D images as well.

In pixel-level segmentation, genetic algorithms find use in region labelling depending on the characteristics of constituent pixels. Peng *et al.* [1] represented each pixel in an image by a chromosome, which labels a region. Vitorino Ramos, Fernando Muge [11] applied k-Means unsupervised clustering methods into Genetic Algorithms, for finding the optimal or sub-optimal data partition, which requires a non-trivial search because of its intrinsic NP-complete nature thereby obviating any user-intervention in the segmentation process. They focussed on the demonstration of the efficiency of Genetic Algorithms to automatic and unsupervised texture segmentation [21]. Chun and Yang [22] used a fuzzy fitness function to account for the associated uncertainty in their proposed genetic algorithm based segmentation technique. Gong and Yang [23] represented the original and segmented images by means of quad-trees. They defined a two pass genetic algorithm based optimization system similar to the method by Zingaretti *et al.* [28]. In the first pass, genetic algorithms minimize an energy function. In the second pass, fine tuning of the segmentation method is carried out. Zingaretti *et al.* [28] proposed unsupervised colour image segmentation using genetic algorithm. This is another case of parameters of an existing image segmentation method being tuned by genetic algorithms. A key difference in this method is that it performs multi-pass thresholding. Different thresholds are adapted during each pass of genetic algorithms. This approach successfully segmented a wide variety of images, with the exception of images that were highly textured [8][9][17].

Pignalberi *et al.* [29] used genetic algorithms for the optimization of parameters in an image segmentation algorithm. In this case, they focused on range images, where a pixel is coloured depending on the distance between the object and a sensor. This method segments out surfaces of 3D objects, but could be applied to segmentation of 2D images. Tianzi Jiang, Faguo Yang, Yong Fan, and David J. Evans proposed a parallel genetic algorithm [6] for cell image segmentation under severe noise. A priori knowledge about cell shape is incorporated in their method. The segmentation results of noisy human thyroid and small intestine cell images demonstrate that the proposed method is very successful in segmenting images of elliptically shaped cells.

Genetic algorithms have been used to solve a wide variety of problems. In image processing, genetic algorithms have successfully been used for feature extraction, object recognition, knowledge based segmentation and image classification.

III. Classification

The objective of the classification process is to categorize all pixels in a digital image into one of several classes. The intent of image classification is to identify and present, as a unique gray level (or color), the features occurring in an image in terms of the object.

Image classification is perhaps the most important part of digital image analysis. It is pleasant to have a "pretty picture" or an image, showing a magnitude of colors illustrating various features. Classification is a computational procedure that sorts images into groups or classes according to their similarities.

Images represented by $N \times N$ arrays of intensity values can be considered as points in an $N \times N$ -dimensional space. From the viewpoint of distance metric: points that are close to each other in that space represent images that are similar while from the color point of view: points having almost similar intensity values are considered to be belonging to same class.

There are two different approaches to classification: supervised and unsupervised. Both make use of the similarity measure, but one (supervised) classifies a set of images according to their similarity with certain pre-given images that can be considered as references or templates, the other (unsupervised) classifies the images according to their intrinsic grouping or clustering within the set.

Supervised Classification

With supervised classification, we identify examples of the information of interest in the image. These comprise what we call training set. Supervised classification uses the information obtained from training samples to classify an image. With the assistance of the training samples it becomes easy to extract the desired classes. When completing a supervised classification it is critical that a accurate and complete set of class definitions are created. These classes are typically created with a specific goal or target in mind. The more well defined the classes the less the ambiguity and inconsistency within the classification. Supervised classification has advantages such as generation of information classes, self-assessment using training sites and it also enables training sites to be reusable.

Unsupervised Classification

Unsupervised classification is a method which examines a large number of unknown pixels and divides into a number of classes based on natural groupings present in the image values. Unlike supervised classification, unsupervised classification does not require analyst-specified training data. The basic premise is that values within a given class should have similar gray whereas data in different classes should be comparatively well separated, i.e. have very different gray levels.

The classification process is performed by assigning a scalar value to each pixel estimating the importance of that image location based on the threshold. The HSV (Hue-Saturation-Value) value of the input RGB image is exploited in accordance with a threshold range. Color based classification utilizes color feature of the input image. As an image may contain strong, light or medium variations of a pure color therefore if we were to consider all these variations the segmentation would be using information that was not required. To solve this problem a threshold range is provided to include within it the variations of the color and assign it to a single class instead of making several classes out of it.

IV. Work done in Adaptive approach

The conventional flow of image segmentation process followed by classification assumed that the segmentation process has been able to successfully extract the object of interest. This traditional segmentation can also be viewed as a filter operating on the image independently of the classifier similar to the filter methods for feature selection. It is critical to recognize that current image segmentation algorithms are primarily open-loop in nature, as noted by Bhanu [5][3] implying that the existing segmentation algorithms are fundamentally complex spatial filters, operating “blindly” on the incoming image with no context regarding the object being segmented. It is thus an unrealistic approach to assume to obtain the required object segmented correctly without any semantic information regarding the class of objects in the scene. Hence obtained segmented map has been done correctly.

M.E. Farmer and Anil K. Jain [12] proposed in their paper a closed-loop framework for image segmentation, which uses the object classification subsystem as an integral part of the segmentation process. They proposed wrapping the segmentation and the classification together and using the classifier to determine the metric for selecting the best segmentation. In the Adaptive methods for feature selection [12], the classifier is an integral part of the selection process and serves as the metric to decide the best feature set. In the same way, the segmentation and classification are wrapped together, and the classification accuracy is used as the metric to determine the best segmentation. The Adaptive -based methods [18] employ some inductive classification algorithm(s) to evaluate the goodness of subset of features being selected. The performance of this approach relies on two factors: the strategy to search the space of all possible feature subsets; and the criterion to evaluate the classification accuracy of the selected subset of features. The purpose of feature selection [19] is to find the ‘good’ features by just selecting one representative feature subset from all features. The Adaptive approach of feature selection aims to find the minimum discriminative features to reach the high classification accuracy.

V. Adaptive Image segmentation using Genetic optimization technique

A. Proposed Algorithm

To improve segmentation results using prior knowledge, We implemented classification algorithm on the input image to enhance the results of the color based segmentation using genetic algorithm. In classification algorithm the RGB image is classified into n classes, each class representing a color according to the threshold. The obtained value of number of classes is taken as input to image segmentation.

The proposed algorithm of image segmentation using genetic algorithm is as stated below.

1. Initialize the population in predetermined number of rounds.
2. Randomly generate the cluster set.
3. Each pixel of the image is labelled to the generated cluster number using Euclidean distance criterion.
4. Evaluate the fitness function for each chromosome in every round.
5. Apply crossover between the best chromosomes produced during each round and the reproduced chromosome moves to next generation.
6. Repeat step 2 to 5 till fixed number of generations that is the termination criterion is reached.

7. The input image is segmented over the cluster set that has maximum fitness value.

Genetic algorithms employ natural selection of fittest individuals as optimization problem solver. Since in nature competition among individuals for scanty resources results in the fittest individuals dominating over the weaker ones. In proposed scheme, the same idea is applied on image data. Taking a RGB (Red, Green, Blue) image as an input image of size $M \times N$. The basic steps of the GA based clustering algorithm for clustering image data are as follows:

A.1 String representation

Each chromosome represents a solution which is a sequence of K cluster centres. For an N dimensional space, each cluster centre is mapped to N consecutive genes in the chromosome. For image datasets each gene is an integer representing an intensity value of the three components Red, Green and Blue.

A.2 Population initialization

Population is initialized in rounds randomly considering values that fall within $n-3$ to $n+3$ range where n is an input from the classification algorithm and in each round the best chromosome survives for the next round processing.

A.3 Fitness computation

The fitness computation is accomplished in two steps. First, the pixel dataset is clustered according to the centres encoded in the chromosome under consideration, such

that each intensity value $x_i(r,g,b)$ of colour image combined with three component red, green and blue (24 bit), $i = 1, 2, \dots, mxn$ is assigned to cluster with center $z_j(r,g,b)$, $j = 1, 2, \dots, K$.

$$\|x_i(r,g,b) - z_j(r,g,b)\| < \|x_i(r,g,b) - z_p(r,g,b)\|, p = 1, 2, \dots, K, \text{ and } p \neq j.$$

The next step involves adjusting the values of the cluster centers encoded in the chromosome, replacing them by the mean points of the respective clusters.

A.4 Selection

Initially the fittest chromosome in every round of population generation is moved to next generation, in the subsequent processing the fittest chromosome directly holds the 40% of the entire population and the rest of the population is hold by the chromosomes in the decreasing order of their fitness value.

A.5 Crossover

A single point crossover is performed by a probability of P_c . Algorithmically, a random point between the two chromosomes is selected randomly from the length of chromosome having less number of genes and the crossover is performed.

A.6 Termination Criterion

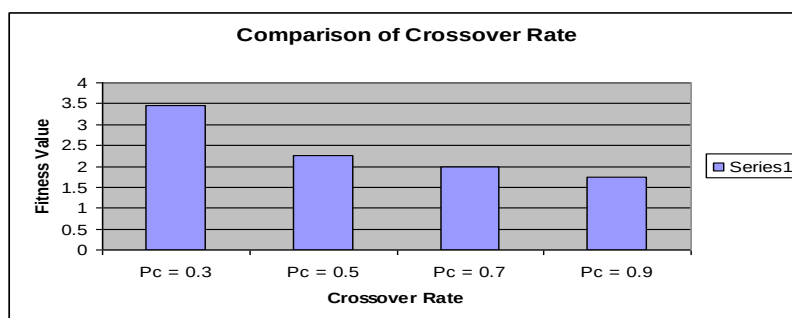
We perform the population generation, fitness computation, crossover and selection for a predetermined number of generations, thus the algorithm is computed for the fixed number of generations and the best solution seen in the entire generation proceeds to final result.

VI. RESULTS

Segmentation is the process of partitioning a digital image into multiple segments (sets of pixels, also known as super pixels). The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics.

Table 4.1 Comparison of different crossover rate

Image	Crossover Rate			
	$P_c = 0.3$	$P_c = 0.5$	$P_c = 0.7$	$P_c = 0.9$
lenna	3.4505	2.2576	1.9915	1.7444



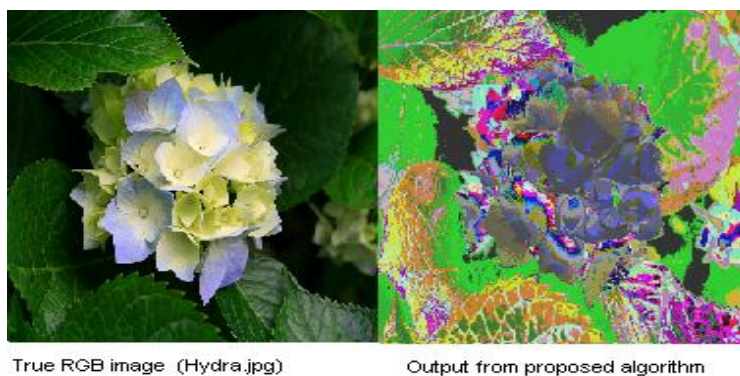
#Fitness Value shown here is the min-sum (shown as 3.4505e+006)

Table 4.2 Comparison on different generations

Image	Generations			
	Ngen=10	Ngen=100	Ngen=500	Ngen=1000
hydra	3.7182	2.4823	2.0860	1.5018

#Fitness Value shown here is the min-sum (shown as 3.7182e+007)

The outputs obtained are:



VII. CONCLUSION

The paper overviewed various researches in the field of image segmentation and to categorise them with respect to the image segmentation process. The design of a segmentation system must address issues of efficiency in

addition to that of effectiveness. There is no universal theory on image segmentation till now. They are strongly application dependent, in other words, there are no general algorithms that are good for all images. We have successfully used prior knowledge i.e. color through the classification algorithm and used it to segment the image efficiently on the basis of classes defined. The accuracy of the classifier in the classification algorithm can be measured to further improve the segmentation. Subsequently, image segmentation results can be utilized in feature extraction and object recognition phases of image processing and computer vision.

VIII. FUTURE WORK

After reviewing a set of papers on image segmentation these conclusions were drawn. [10] proved through experiments good performance of GA and plans to further extend its applicability. In [15] emphasis is on further advancing the use of genetic algorithm to improve color image segmentation techniques. [2] promoted to use prior knowledge based segmentation. The prospects and problems revealed in above cited papers can be resolved by integrating the segmentation processing with a classification process to provide the required semantic information and thus have appropriate results. The Adaptive framework for feature selection wraps the selection process inside the classifier in order to determine the best possible segmentation. Besides Adaptive , Genetic Algorithm is proposed to provide optimal solution from large amount of multidimensional data in minimum possible time to achieve all the prospects mentioned in [2][11][4][7][14] [15].Therefore by taking together the features of Adaptive framework and genetic algorithm, proficient segmented image can be achieved.

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