Eng. & Tech. Journal, Vol.28, No13, 2010

Using Genetic Algorithm in Image Clustering

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Received on: 21/6/2009
Accepted on: 11/3/2010

Abstract

The aim of this work is to optimize gray scale image clustering using two traditional methods, these are thresholding technique and genetic algorithm (GA). The clustering optimization is achieved by applying three features (gray value, distance, gray connection) based thresholding technique and genetic algorithm. In this work clustering optimization includes segmenting the image to find regions that represent objects or meaningful parts of objects depending on the above mentioned three features which base on gray value of image and two standard mathematical theories these are chessboard distance and breshenham's algorithm. There are many recent researches in this subject some of them depending on gray value feature to clustering images, but in this research depended on three features which is making the clustering operation more accuracy.

استخدام الخوارزمية الجينية في التجميع العنقودي للصورة

الخلاصة

الهدف من هذا العمل هو الحصول على الأمثلية في التجميع العنقودي للصورة باستخدام طريقتين تقليديتين هما تقنية مقياس العتبة والخوارزمية الجينية. عملية الأمثلية في التجميع العنقودي تتحقق بتطبيق ثلاث خواص هي القيمة الرمادية, المسافة, الاتصال بالقيمة الرمادية بالاستناد إلى تقنية مقياس العتبة والخوارزمية الجينية. في هذا العمل عملية الأمثلية في التجميع العنقودي تتضمن تقطيع الصورة لإيجاد المناطق التي تمثل الأهداف أو أجزاء مهمة من الأهداف بالاعتماد على الخواص الثلاث السابقة والتي تستند على القيمة الرمادية للصورة وبالأستناد على نظريتين رياضيتين قياسيتين والتي هي مسافة رقعة الشطرنج وخوارزمية breshenham . يوجد العديد من البحوث الحديثة في هذا الموضوع البعض منها اعتمد على خاصية القيمة اللونية للتجميع العنقودي للصورة ولكن في هذا البحث اعتمدنا على ثلاث خواص والتي جعلت من عملية التجميع العنقودي اكثر دقة .

Notations

P(g)	Histogram Probability
GA	Genetic Algorithm
D_{chess}	Chessboard Distance
Max	Maximum Value
TD	Threshold Distance
Hig	Hight of Object
Wig	Width of Objec
Pix(i,j)	Pixel Coordinate
g(i,j)	Gray Value
ME	Misclassification Error

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https://doi.org/10.30684/etj.28.13.6
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1. Introduction

Images because the gray scale image can be represented by one function (one dimension). Image segmentation is one of the most important precursors for image processing-based applications and has a decisive impact on the overall performance of the developed system [1]. Robust image segmentation has been the subject for research for many years but the published research indicated that most of the developed image segmentation algorithms have been designed in conjunction with particular applications [5]. The segmentation process consists of separating a digital image into several disjoint regions, whose characteristics such as intensity, color, and texture are similar [6]. Typically, the goal of segmentation is to locate certain objects of interest in an image [1]. One important area of research is to perform image segmentation that evaluates the similarity of image regions that is defined in terms of color and texture and this information is used to automatically segment images into semantically meaningful parts[2]. Image segmentation techniques can be divided into three categories: 1) region-based method, 2) clustering methods and 3) boundary detection [10]. Clustering techniques are image segmentation methods by which individual elements are placed into groups; these groups are based on some measure of similarity within the group [15]. The major difference between these techniques and the other techniques is that the domains other than the rc-based image space (the spatial domain) may be considered as the primary domain for clustering. Some of these other domains include color spaces, histogram spaces, or complex feature spaces [14].

2. The modified System

To segment the image by partition it into objects and background, will proposed using two standard strategies with three features ***(gray value, distance, gray connection).*** These strategies are:

- Clustering based Thresholding with previous three features.
- Clustering based Genetic algorithm with previous three features.

2.1Clustering based Thresholding with *three features*

The easiest method of grouping pixels into classes is simply to threshold their gray values so that all pixels whose gray values are in a given range fall into the same class [8]. Most often, this method is used to segment an image so that the image object is separated from its background. While this approach is quite effective in many cases, a number of problems may arise. The most problem is of course that the choice of the threshold is difficult, and may lead to strange results [4]. A great help in choosing an appropriate threshold is the *image histogram* [13]. The histogram records the relative frequencies of each gray value. Image thresholding is a necessary step in image analysis and application [12].

In an ideal case, for images having two classes, the histogram distribution has a deep and sharp valley between two peaks representing objects and background, respectively. Therefore , the threshold can be chosen as the bottom of this valley [7].

In its simplest form, thresholding means to classify the pixels of a given image into two groups(e.g. objects and background), one containing pixels with gray values above a certain threshold, and the other including those with gray values equal to and less than the threshold.This is called bi-level thresholding. In multilevel thresholding, one can select more than one threshold and use them to divide the whole range of gray values into several sub ranges. Most of the thresholding techniques utilize shape information of the histogram of the given image to determine appropriate threshold.

2.1.1Specification histogram& determine peaks & valley

In this principle, the shape of the histogram distribution of the original image is considered to determine the optimal threshold, histogram having two modes (two peaks and one valley) correspond to two classes in the given image. In this principle is proposed clustering technique to detect peaks and valleys corresponding to different modes of the histogram.

2.1.2Detect Objects and Background

By the following features, image can be classified into objects and background.

First: **By using gray value feature**

In this feature, used the optimal valley (minimum value in histogram that represent the threshold)that used to segment the image into objects and background, such that:

$$pix(i,j) = \begin{cases} 1 & g(i,j) \geq thr \\ 0 & g(i,j) < thr \end{cases}$$

This feature is considered as the default where the resent features (distance, gray connection features) are depend on the resulting of it.

Second: **By using distance feature**

This is the second feature is used to enhance the result of the first feature, where through this feature can be detecting the bounders of an object and eliminate all redundant gray values that are out of an object and the same gray value of object. In image processing have different types of distance measurements.

The two popular types are ***Euclidian distance, Chessboard distance***. Being the most popular type which makes the integer value decrease the time of computations [3], *the chessboard distance has been chosen* in the proposed system. Chessboard distance can be computed as the following equation:

$$D_{chess} = max(|X_2 - X_1|, |Y_2 - Y_1|) \ldots (1)$$

Third: **By using gray connection feature**

This feature is used to enhance the results of previous features where is used to eliminate a redundant the gray values that inside the object and different in gray value. After determined the bounders of an object, can be found the center of object. The gray connection feature, occurs when the line passes from the pixel that represent the center of object to the pixel in the bounders of object if all pixels between them have the same gray, this means that they are connected, if there are different gray between them can be changed to the same gray of object. Can be passing on all points of line using ***Breshenham's Algorithm*** for line. ***Breshenham's Algorithm*** is the basic "line drawing" algorithm used in computer graphics. This algorithm was developed to draw lines on digital plotters, but has found wide-spread usage in computer graphics. The algorithm is fast – it can be implemented with integer calculations only and very it is simple to describe.

2.2 Clustering based genetic algorithm with three features

The genetic algorithm is a method, which is suitable for solving an extremely wide range of problems. Recently, GA has been widely and successfully applied to optimization problems specifically in unsupervised classification of digital data sets [6]. In genetic algorithm (GA) applications, the unknown parameters are encoded in the form of strings, so called individuals(chromosomes), a chromosome is encoded with binary, integer or real numbers. Gray scale image data are usually represented by positive integers (0-255) [7]. In GA, a population is the set of individuals. The size of the population, n, will refer to the number of individuals in the population; each individual (one_dimensional array of gray value) involves the necessary information required for image clustering, where each individual should represent a complete solution to the problem. For any GA, a chromosome representation is needed to describe each individuals in the population. The representation scheme determines how the problem is structured in the GA and also determines the genetic operators that are used [6].

2.2.1 Individual representation and Initial Population

In this step, individual definition can be a structure of:

chrom(i)=(g_1, g_2 ...,g_L)

for i=1, 2,.., n.

chrom(i) is an array with fixed length(L) equal (5) that represent one background and four objects, (g) represent the gene on chromosome that contain the gray values (0-255) that represent the centers of clusters. In each generation the gray values of each chromosome are changed through computes the average of each cluster. Fig(1)depicts an individual representation. In the figure, $0 \le c_i \le 255$, and $1 \le i \le 5$. At the beginning of the GA cycle, the population of size n is randomly created.

2.2.2Objective Function

The evaluation function is the link between the GA and the task to be solved. An evaluation function takes a chromosome as input and returns a value or a list of values that represents a performance measure related to the task to be solved.

In this research, fitness function of individual can be evaluated according to the following measurement:

- The convergence ratio between gray values in chromosome and gray values in original image is *high*, where the number of gray values in the chromosome is convergence to the number of gray values in original image.
- The difference ratio in the chromosome itself, where the chromosome that contain more different gray values have *high* difference ratio.
- The features that proposed (the distance, and the gray connection) can applying when the number of gray values in chromosome be close to 90% from gray values in original image.

while the gray value feature applied in the beginning, in the distance feature should determined the number of gray values that be within the distance that represent radius
Of object. In the gray connection feature must determine the number of gray values which connected with object by gray value inside object.

2.2.3 Selection

In this reaserch tournament selection with size two, a pair of chromosomes is competed. The individual with highest objective function is copied into the mating pool. Repeating this process until the mating pool is filled with probably better chromosomes of *n* parents to be perturbed by the crossover operator to form new offspring.

2.2.4 Crossover operator

The uniform crossover was adopted in this research, where each bit in the first offspring is selected from parent1 with probability P and from parent2 with probability (1-P), the second offspring receives the bit not selected for the first offspring.

2.2.5 Mutation Operator

During mutation, all the chromosomes in the population are checked gene by gene and according to a predefined probability all values of a specific gene may be randomly changed. And in this step, can enhance solution to decrease misclassification of the selected chromosome which is selected from the first step by changing some chromosome value(gray value) that maximize fitness function. This depends on the value of the random number. Then compute fitness function for all chromosomes after mutation.

2.2.6 Stopping Criteria

The GA algorithm will be repeated until the values which represents the center of clusters are fixed (do not change) and the number of generation is finish.

3. Implementation & Results

This section experimentally tests the effectiveness of two strategies (clustering based thresholding technique and clustering based genetic algorithm) with three features (gray value, distance, and gray connection) for detect objects and background. A series of experiments and comparisons have been conducted to show the applicability of the proposed genetic algorithm and thresholding technique with previous three features for image clustering. Comparisons are made among two main algorithms: genetic algorithm and thresholding technique with previous three features.
This section is also concerned with parameters used in qualifying and quantifying the effectiveness of each of the implemented algorithms for strategies. In this research, genetic algorithm is heuristics and thus it does not ensure an optimal solution. In algorithms of modified system that depended on the gray value as default and used the histogram to execute the thresholding operation for clustering image into two clusters, one for objects and the other for background, where through the histogram can be found the peak values and from the peak value can be found two values of valley. The image set tested consists of three different images, as the following figures for two strategies. To illustrate accuracy in executing the algorithms of two strategies, will be take different image. They differ in the shape and the number of objects. For example the image in fig(2)-(a-1) includes three separated objects.

While in the image of fig(3)-(a-1) there are two separated uniform objects.

The image in fig(4)-(a-1) the object is non uniform and there are more details.

Through comparison between two strategies, can be noted that there are some errors, these errors are called misclassification errors which can be computed by the following equation:

$$ME = 1 - \frac{|B_O \cap B_T| + |F_O \cap F_T|}{|B_O| + |F_O|} \quad ....(2)$$

Where B_O and F_O denote the background and foreground of the original image and B_T and F_T denote the background and foreground of the test image. Misclassification errors are computed for each image and for two strategies. The two strategies, the thresholding and GA with their algorithms are used in the experiments.

In this research, several conclusions can be found. They will be grouped under a major theme.

- From system results, will be found that the algorithms used are good in the discernment of objects and background in an image that includes the object in spite of being the colors near to object's color and which are outside this object by using abundant features which are distance and gray connection.
- Through the results, the modified system proves that the GA is the best because employment it in clustering image can be good if used suitable operators(selection,crossover, mutation) when comparison it with the thresholding technique.
- In gray scale image, the GA is simple and fast when comparison with color
- Using the proposed features (gray value, distance, gray connection) with GA adding to it robust in objects isolation from background in image.

From the results, in some images one feature is enough for good classification (as image 1) while in other images are needed two or three features to obtain good classification (as image2) depending on the shape of the object, number of objects in the image.

The comparison between two strategies was also depending on the time of processing.

- Color images can be modeled as three-band monochrome image data, where each band of data corresponds to different color. Typical color images are represented as red, green, and blue or RGB images. In the original research are treated with gray scale images, which are referred to as monochrome, or one color images. Therefore when we are treatment with color images, should been take each band alone.

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Table (1) Experiment Parameter Settings
(used images with two clusteredand different sizes)

Images	Image Size
$Image_1$	120*180
$Image_2$	150*100
$Image_3$	240*160

Table 2 (a) The Parameters of proposed system (used distance feature)

Images	vertical distance of object			horizontal distance of object		
$Image_1$	Object1:24	Object2:30	Object3:24	Object1:84	Object2:62	Object3:54
$Image_2$	Object1:52	Object2: 44		Object1:52	Object2:44	
$Image_3$	81			77		

These values (vertical and horizontal distance of object) are used to determine the threshold distance and center of objects used to detect the object from background.

Table 2 (b) The Parameters of proposed system (used distance feature)

Images	Center coordinate of object					
	Cx			Cy		
$Image_1$	Object1:42	Object2:31	Object3:27	Object1:12	Object2:15	Object3:12
$Image_2$	Object1:26	Object2:22		Object1:26	Object2:22	
$Image_3$	119			78		

Table 2(c) The Parameters of proposed system (used distance feature)

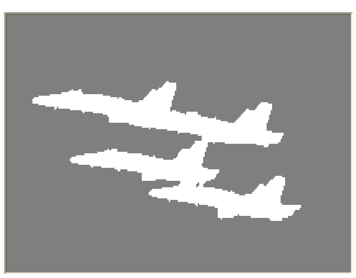
Images	Threshold distance value		
$Image_1$	Object1:84	Object2:62	Object3:54
$Image_2$	Object1: 52	Object2:44	
$Image_3$	81		

C_1	C_2	C_3	C_4	C_5

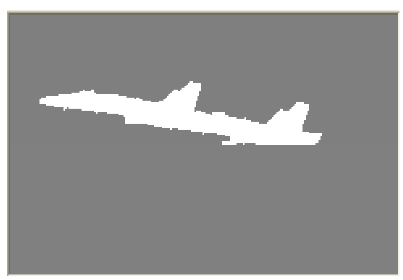
Figure (1) Chromosome Representation

(1)

1- Clustering based Thresholding with three features



(2)



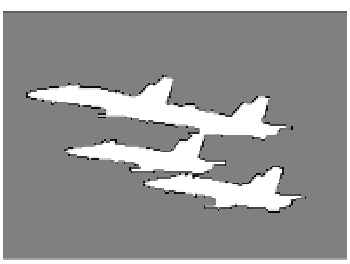
(3)

(4)

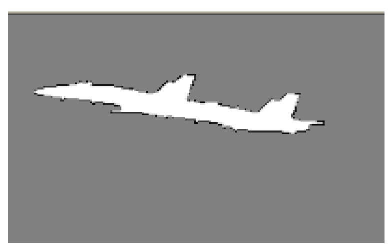
(5)

Figure (2-a):(1) image1, (2)clustering with gray value feature, (3) clustering with gray value & distance &gray connection features(object 1), (4) clustering with gray value & distance & gray connection features (object 2), (5) clustering with gray value & distance & gray connection features(object 3).

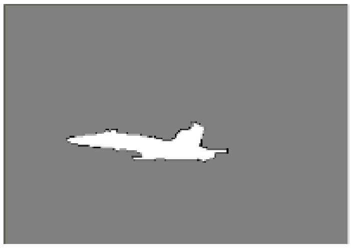
2. Clustering based GA with three features



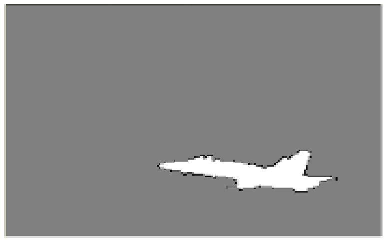
(2)



(3)



(4)

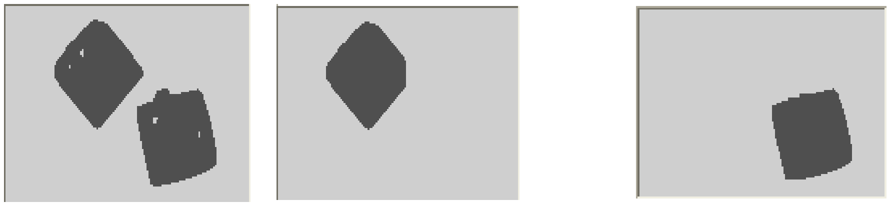


(5)

Figure(2-b):(2) clustering with gray value feature, (3) clustering with gray value & distance & gray connection features(object 1), (4)clustering with gray value & distance & gray connection features(object 2), (4) clustering with gray value & distance & gray connection features(object 3).

(1)

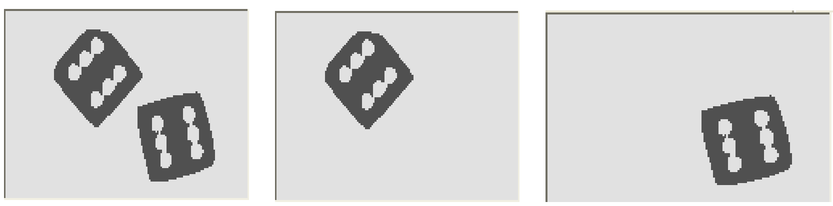
1- Thresholding based clustering with three features



(2) (3) (4)

Figure (3-a):(1) image2, (2)clustering with gray value feature, (3) clustering with gray value & distance & gray connection features(object 1), (4) clustering with gray value & distance & gray connection features(object 2).

2- Clustering based GA with three features

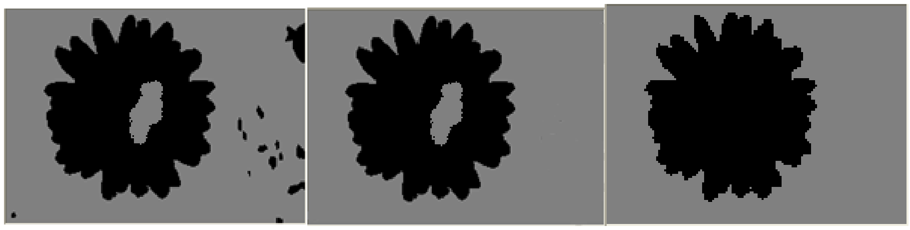


(2) (3) (4)

Figure (3-b): (2)clustering with gray value feature, (3) clustering with gray value & distance & gray connection features(object 1), (4) clustering with gray value & distance & gray connection features(object 2).

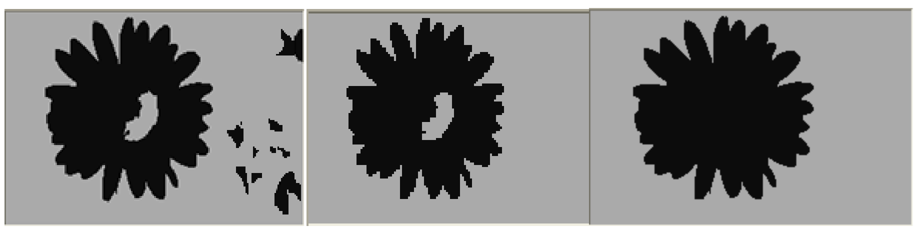
(1)

1- Clustering based Thresholding with three features



(2) (3) (4)

Figure(4-a):(1) image3, (2) clustering with gray value feature, (3) clustering with gray value & distance feature, (4) clustering with gray value & distance & gray connection features.



(2) (3) (4)

Figure (4-b) :(2) clustering with gray value feature, (3) clustering with gray value & distance feature, (4) clustering with gray value & distance &gray connection features.

Now, will be compare between the previous strategies according to time consumption and misclassification ratio as shown in the following:

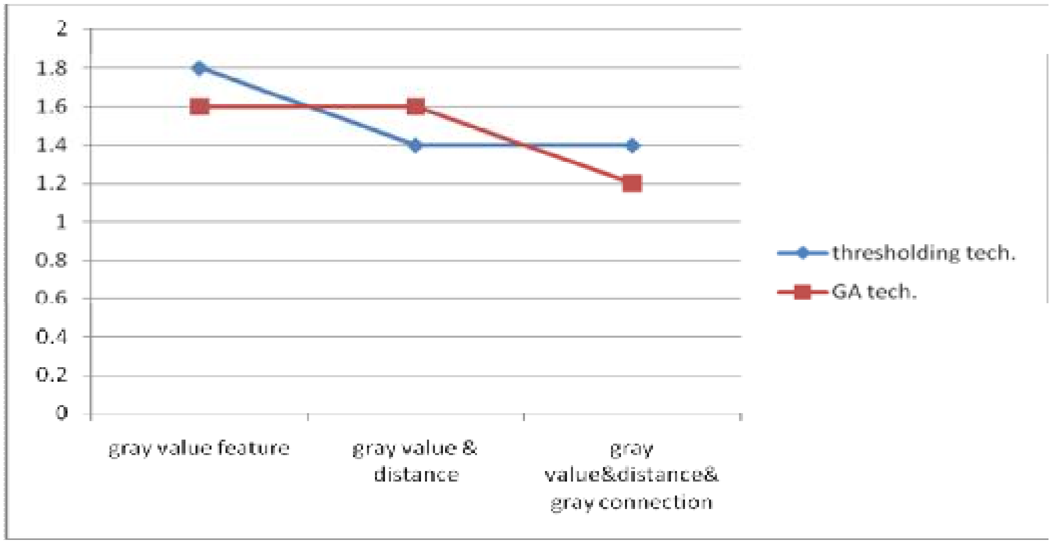


Figure (4) (a): comparison between two strategies by time (image1)

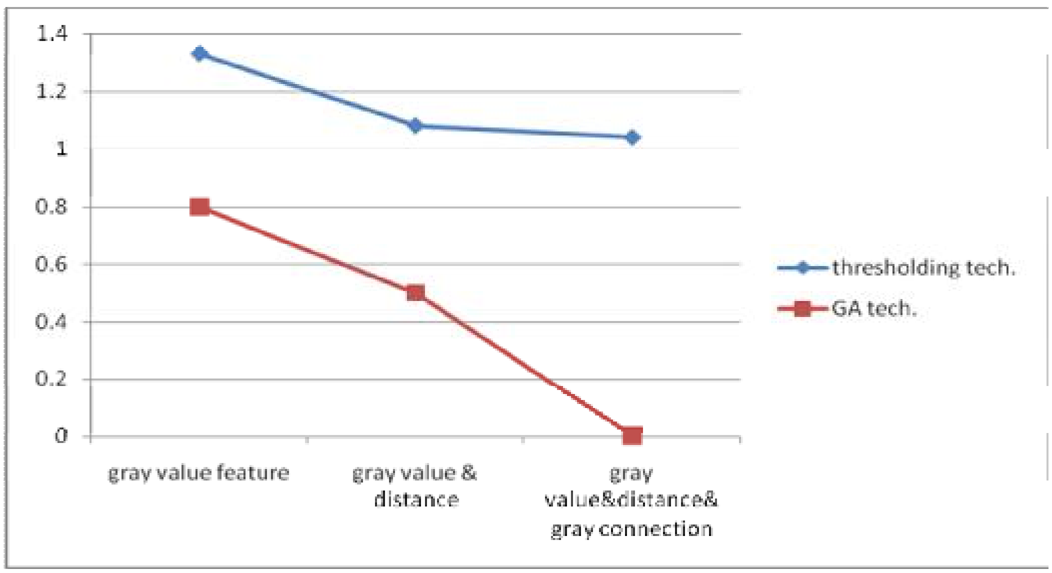


Figure (4) (b): comparison between two strategies by misclassification error (image1)

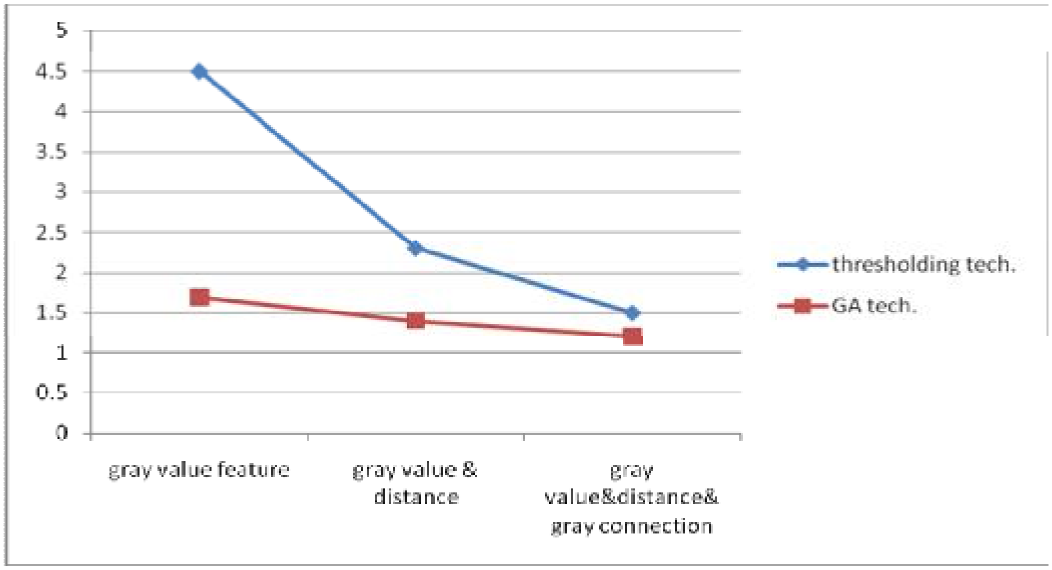


Figure (5) (a): comparison between two strategies by time (image2)

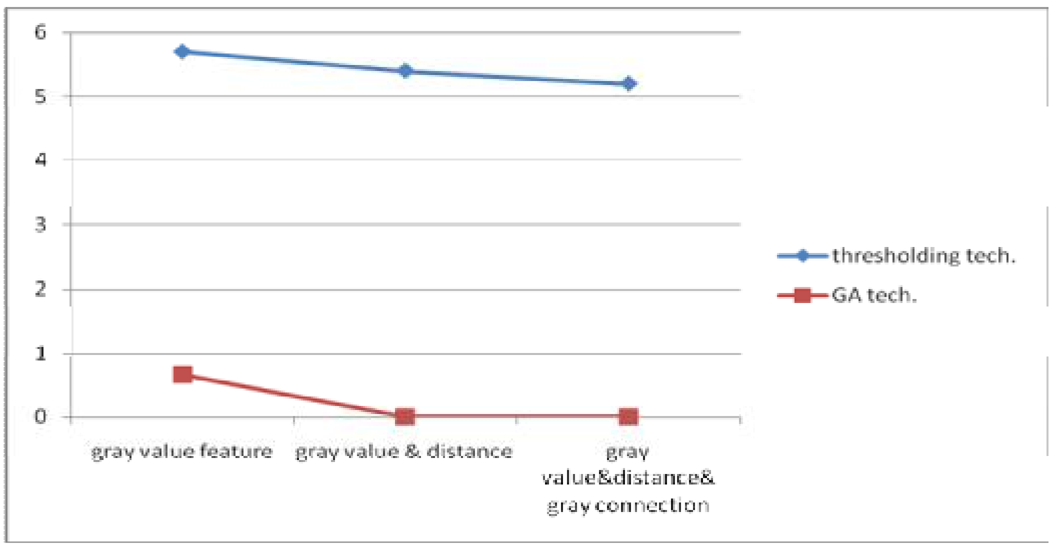


Figure (5) (b): comparison between two strategies by misclassification error (image2)

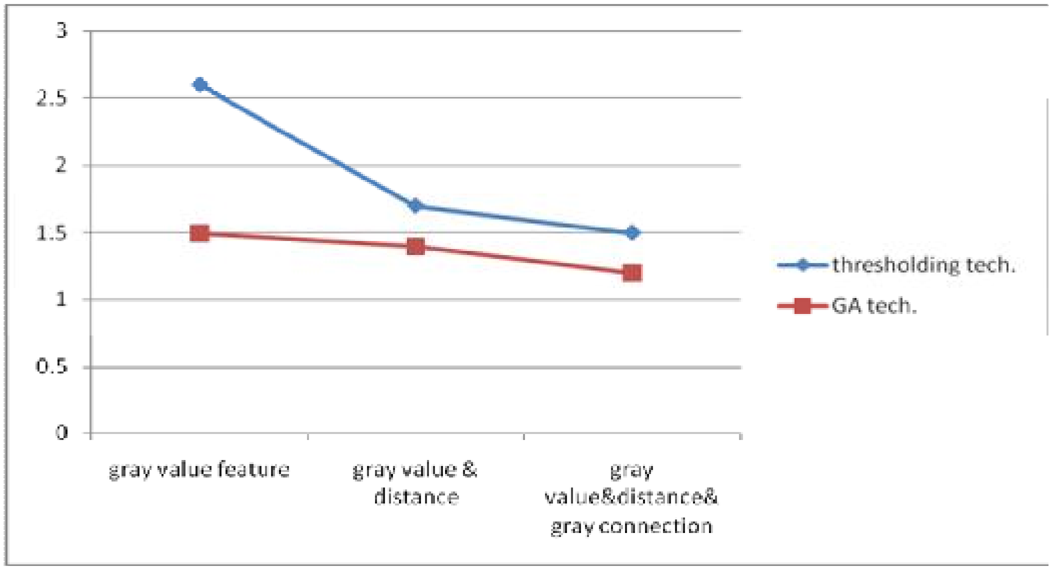


Figure (6) (a): comparison between two strategies by time (image3)

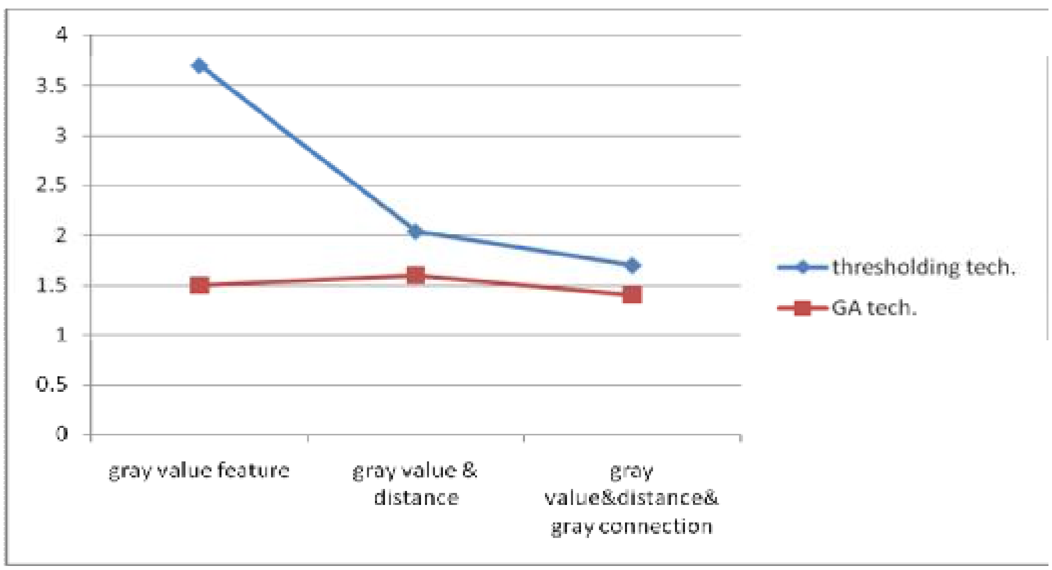


Figure (6) (b): comparison between two strategies by misclassification error (image3)