Design and Implementation of Classification System for Satellite Images based on Soft Computing Techniques

Dr. Nabeel Hashem Kaghed, Dr. Tawfiq A. Abbas, Samaher Hussein Ali

nhkaghed@yahoo.com, tawfiqasadi63@yahoo.com, Samaher_hussein@yahoo.com

Department of Computer Science, University of Babylon, Iraq

Abstract

This paper presents a method to design programming system using hybrid techniques represented by soft computing to classify objects from the air photos and satellite images depending on their features with minimum acceptable error. These images usually consist of seven layers, while the work in this research focuses on dealing with three bands (red ,green and blue). This paper concerns with classifying five kinds of objects (urban area, forests, roads, rivers, football-stadiums). Accordingly, the database which describes that objects depending on their attributes were built. Then, the Evolution algorithm of type breeder genetic algorithm to procedure genetic clustering process to segment image which provides a number of clusters found in that image data set were used. To avoid the overlapping between clusters with other, one of the clustering validity measures called "Davies-Bouldin index" as fitness function of that algorithm was used. Moreover, four methods of the recombination, which are:(Discrete Recombination (DR), Extended Line Recombination (ELR), Extended Intermediate Recombination (EIR), Fuzzy Recombination(FR)) were discussed. Then, two types of features for each cluster which are visual features including(Pattern, Shape,Texture, Shadow, Associative), and statistical features represented by spectrum features that include (Intensity, Hue, Saturation) were extracted. After that, feed forward neural network from type error back propagation neural network to determine the class under which each feature vector belongs to was used. At the last stage, IF-Then rule to form several rules that govern each class attributes were used .

Keywords: Soft Computing, Remote Sensing, Clustering, Davies-Bouldin index, Breeder genetic algorithm, Building database, Back propagation neural network, Rule generation.

1. Introduction

Remote Sensing has provided an efficient method and perfect alternative of data acquisition for land use administration and land cover maps updating[1]. So," Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information". The following seven elements comprise the remote sensing process from the beginning to the end[2]:(1)Energy Source or Illumination.(2) Radiation and the Atmosphere.(3) Interaction with the Target.(4) Recording of Energy by the Sensor.(5) Transmission,Reception, and Processing.(6) Interpretation and Analysis.(7) Application.

Peddle, 1993[3] stated a procedure for analyzing modern and future remote sensing data sets to address the methodological limitations of conventional approaches to image processing and classification. Different scales of measurement factors that confound the use of conventional Maximum Likelihood (ML)and Linear Discriminate Analysis(LDA) Algorithms were provided.

Peterson, 1997[4] evaluated the effectiveness of digital image analysis in the production of land cover maps. Unsupervised and supervised classifications using 1993 Spot satellite imagery of Boca Raton, Florida were applied.

Schaale, 2000[5] presents standard techniques for the analysis of remote sensing imager data making use of the multispectral information only. These techniques are based on the inherent statistitics of the scene under investigation and they usually neglect the neighborhood of an analysed pixel, that is the context information.

Nikola, et al 2001[6] present a methodology for image classification of both spatial and spectral data with the use of hybrid evolving fuzzy neural networks.

Sanghamitra and Ujjwall, 2002[7] submit a method depending on the Genetic clustering technique to classify satellite image of a part of the city Calcatta. The image is in the multispectral mode having two bands :red and near infrared.

Leena and Jorma, 2003[8] present a classification method of the texture samples which was based on the k-nearest neighbor method. In this method a rock texture classification depended on textural and spectral features of the rock, where the spectral features were considered as some color parameters while the textural features were calculated from the co-occurrence matrix.

2. Soft Computing Techniques

Soft computing is an umbrella term for a collection of computing techniques.

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"Soft computing differs from conventional computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty and partial truth. In effect, the role model for soft computing is the human mind. The guiding principle of soft computing is: Exploit the tolerance for imprecision, uncertainty and partial truth to achieve tractability, robustness and low solution cost" [9].

And the term Soft Computing(SC) refers to a family of computing techniques that originally comprise five different partners: fuzzy logic, evolutionary computation, neural networks , probabilistic reasoning and hybrid system[10].

3. Design of the Proposed System

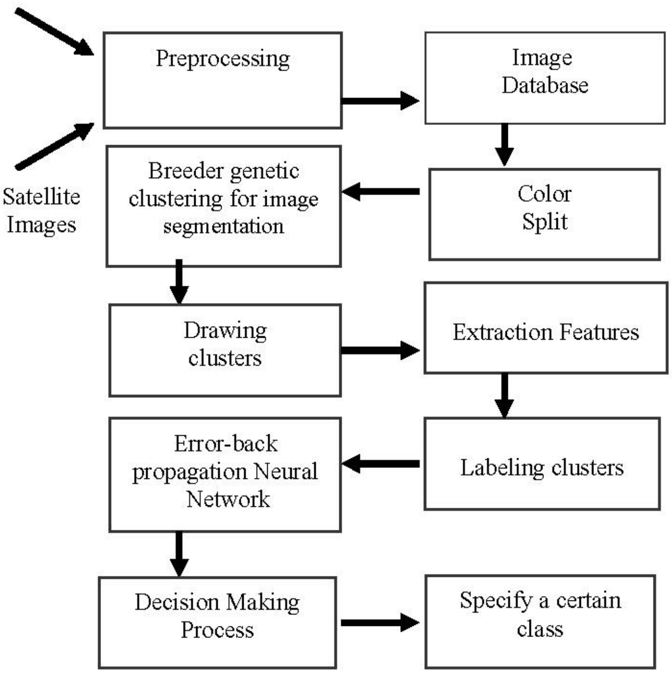
Analysis of remote sensing imagery involves the identification of various targets in an image, and those targets may be environmental or artificial features which consist of points, lines, or areas. Targets may be defined in terms of the way they reflect or emit radiation. This radiation is measured and recorded by a sensor, and ultimately is depicted as an image product such as an air photo or a satellite image.

The classification task of remote sensing imagery(i.e., air photo or a satellite image) is consider a very accurate and important mission because these imageries are able to present copious information, we can benefiting from in different domains.
Therefore, a suitable techniques to assure a correct classification to the objects in these images should be selected. Therefore, the proposed System combines many techniques, the first of which is the Evolutionary algorithm represented by breeder genetic algorithm that is recognized by the ability to solve the local minimum problem(premature saturation)because it starts with more than one solution. This increases the avoidance of falling in that problem. It uses truncation selection and this is suitable to find the optimal solution.
The second is feed forward neural network trained by error back propagation algorithm is used to find the class for each feature vectors. While the third technique IF-Then Rule which is used to form several rules, that govern each class attributes (i.e., specify a certain class attributes).
The proposed system is characterized by the following:- (1) it builds database describe each object.(2) It uses EA(combines between features of genetic algorithm (GA)and evolution strategies (ESs))represented by BGA. (3) It uses one of cluster validity algorithms represented by David-Bouldin index(DBI).(4) It uses dynamic length of the chromosome.(5) It works in two environments which are unsupervised(clustering)and supervised (classification). (6) it formulates rules that govern features for each class by using (IF -Then Rule). Figure(1) shows the block diagram of the proposed system.

3.1. Preprocessing

In this stage image acquisition that require ation their objects by proposed system that can ormed by using one of the remote sensing such as satellite or camera carried by air-planes .

Air Photos



Figure(1):A Block Diagram of Proposed System

3.2. Image Database

According to the proposed system, one needs to describe each object in the image depending on their features (attributes), where digital images were segmented into different objects, which are labeled with appropriate category names. This stage can be performed by two methods, the first method describes each object depending on statistical calculation and the second method depends on visual description in this work using both methods.
So far, five categories have been defined for the image description. These categories are necessary for describing an image scene. The definition of these categories are given database (has five attributes and five different objects) as shown in Table (1). And we use the binary values(0,1)to encoded the visual attributes as shown in Table(2).

3.3. Color Split Stage

Color split process is consider necessary in most application and this work deals with true color(red, green, blue)(i.e., natural color). The color image file consists of two parts: header part and data region part, where each pixel (element)in the image is represented by three byte characteristic colors(red , green, blue). Split process is achieved by reading each element in the image then saving three bytes for each element in three files.

3.4. Breeder Genetic Clustering for Image Segmentation

Breeder Genetic Algorithm (BGA) represents a class of random optimization techniques gleaned from the science of population genetics, which have proved their ability to solve hard optimization problems with continuous parameters. BGA which can be seen as a recombination between Evoluation strategies (ES)and Genetic Algorithm(GA), uses truncation selection which is very similar to the (u ,λ)strategy in ESs and the search process is mainly driven by recombination making BGA very similar to GAs. It has been proven that BGAs can solve problems more efficiently than GAs due to the theoretical faster convergence to the optimum and they can, like GAs, be easily written in a parallel form[11].

Clustering [12]is a popular unsupervised pattern classification technique which partitions the input space into K regions based on some similarity or dissimilarity metric.

The number of partitions or clusters may or may not be known a priori. Let the input space S be represented by n points $\{x_1,x_2,\dots,x_n\}$, and the K clusters be represented by $C_1, C_2, \dots, C_K$, then

(i) $C_i \neq 0$ for i=1,2, … , K

(ii) $C_i \cap C_j = 0$ for i=1,2, …, K and j=1,2, ..., K , i≠j

(iii) $\bigcup_{i=1}^{K} C_i = S$

In this section, an attempt has been made to use breeder genetic algorithms for automatically clustering an image data set. This includes determination of number of clusters as well as appropriate clustering of the data. The methodology is explained first followed by the description of the implementation results. The main befit from using breeder genetic clustering technique is to find a number of clusters and to provide the best seed for each cluster. A Flowchart of the method is provided in figure (2).

3.4.1. Representation of Solution

The chromosomes are make up of numbers (representing the coordinates of the centers drawing from image dataset and bias components of color R,G,B) as well as the don't care symbol '#'. The value of K_i is assumed to lie in the range $[K_{min}; K_{max}]$, where K_{min} is chosen to be 2 unless specified otherwise. The length of a string is taken to be K_{max}(i.e., K_{max} represents a number of higher peaks in image histogram) where each individual gene position represents either an actual center or a don't care symbol.

3.4.2. Population Initialization

For each string i in the population (i=1,2,…, p, where p is the size of the population), a random number K_i in the range $[K_{min}; K_{max}]$ is generated. This string is assumed to encode the centres of K_i clusters. For initializing these centres, K_i points are chosen randomly from the data set of image. These points are distributed randomly in the chromosome.

3.4.3. Fitness Function

The fitness of a chromosome is computed using the Davies–Bouldin index. This index is a function of the ratio of the sum of within-cluster scatter to between-cluster separation[13],[14] The scatter within C_i , the ith cluster, is computed as

$$S_{i,q} = \left(\frac{1}{|C_i|} \sum_{S \in C_i} \left\{ \|x - z_i\|_2^q \right\} \right)^{1/q} \quad (1)$$

where, z_i is the centroid of C_i , and is defined as

$$Z_i = 1/n_i \sum_{x \in C_i} X \quad (2)$$

and n_i is the cardinality of C_i (i.e., the number of points in cluster C_i). The distance between cluster C_i and C_j is defined as(3), ,[15],[16].

$$d_{ij,t} = \left\{ \sum_{S=1}^{p} |z_{is} - z_{js}|^t \right\}^{1/t} = \|z_i - z_j\|_t \quad (3)$$

Specifically, Si,q used in this article, is the average Euclidean distance of the vectors in class i to the centroid of class i. While dij,t is the Minkowski distance of order t between the centroids that characterize clusters i and j(i.e., in this work ,we use t=4). Subsequently we compute

$$R_{i,qt} = \max_{j,\, j \neq i} \left\{ \frac{S_{i,q} + S_{j,q}}{dij\ ,i} \right\} \quad (4)$$

The Davies–Bouldin (DB) index is then defined as

$$DB = \frac{1}{R} \sum_{i=1}^{k} R_{i,qt} \quad (5)$$

The objective is to minimize the DB index for achieving proper clustering. The fitness function for chromosome j is defined as 1/DBj, where DBj is the Davies–Bouldin index computed for this chromosome, where the maximization of the fitness function will ensure minimization of the DB index.

3.4.4. Breeder Genetic Operations

The following breeder genetic operations are performed on the population of strings for a number of generations.

Truncation Selection

is artificial selection method in which only the best individuals-usually a fixed percentage of total population size p are selected and the gene pool to be recombined and mutated is entered . as the basis to form a new generation, usually truncation ratio lies in rang[10 %, 50%].The BGA selection mechanism is then deterministic (i.e., there are no probabilities), extinctive (the best elements are guaranteed to be selected and the worst are guaranteed not to be selected).And 1-elitist (the best element is always to survive from generation to generation)[17].

Recombination

Any operater combining the genetic material of the parents is called a recombination operator. In BGAs recombination is applied unconditionally. let $\vec{x}$ =(x_1,x_2,…..,x_n), $\vec{y}$ =(y_1,y_2,…..,y_n) be two selected gene-pool individual $\vec{x}$, $\vec{y}$ such that $\vec{x} \neq \vec{y}$ .Let $\vec{z}$ =(z_1,z_2,…..,z_n)be the result of recombination and $1 \leq i \leq n$. The following are some of the more common possibilities to obtain an offspring[18]. During recombination each cluster centre is considered to be an indivisible gene. Four types of recombination process are discussed in this work:-

A. Discrete Recombination(DR)

$$Z_i \in \{x_i, y_i\} \quad (6)$$

chosen with equal probability

B. Extended Line Recombination(ELR)

$$Z_i = x_i + \alpha(y_i - x_i) \text{ , where } y_i \geq x_i \quad (7a)$$

$$Z_i = y_i + \alpha(x_i - y_i) \text{ , where } y_i < x_i \quad (7b)$$

With α uniformly random chosen in [-d,1.0+d] where d is a parameter for the BGA and $d \geq 0$ (typical d=0.25).

C. Extended Intermediate Recombination(EIR)

$$Z_i = x_i + \alpha_i (y_i - x_i) \text{ , where } y_i \geq x_i \quad (8a)$$

$$Z_i = y_i + \alpha_i (x_i - y_i) \text{ , where } y_i < x_i \quad (8b)$$

With αi uniformly random chosen in [-d,1.0+d] the difference with ELR being that in this latter case we choose a new α_i for each i.

D. Fuzzy Recombination(FR)

In this method we use polynomial function as a membership function.

$$F(z) = \frac{1}{\sqrt{2\pi}} \exp(-Z^2/2) \quad (9)$$

Mutation

Each position in a chromosome is mutated with probability Pr(Ψ)=1/n so that, on average, one gene is mutated for each individual, as follows: If the position of gene is '#' then it remains '#' else it becomes new cluster center by applying the discrete mutation equation(10):-

$$z_i' = z_i \pm \text{searchinterval}_i \text{ .Const. } \sum_{j=0}^{k-1} Qi \text{ . } 2^{-j}. \quad (10)$$

In the above formula k is a parameter originally related to the machine precision, (i.e., the number of bits used to represent a real variable in the machine). We are working with (e.g. 24, 32, and 64). And const determines the maximum half–width of the interval centered in zi in which z_i' can be. In this work the searchinterval is represented the width and height of the image and const represented half-width, half-height of image. Furthermore each Qi equal (zero) before mutation and is mutated to(one) with probability (1/k), so on average just one of the elements in the sum with be non-zero after mutation. A practical assumption is that we deterministically flip just one and only one of these bits, so that the above formula becomes

$$z_i' = z_i \pm \text{searchinterval}_i \text{ . const. } 2^{-j} \text{ .} \quad (11)$$

where $0 \leq j \leq k-1$

Selection the Best Chromosome

The best string having the largest fitness(i.e., smallest Davies-Bouldin index value)see up the last generation provides the solution to the clusters count problem. We have up implanted elitism at each generation by preserving the best string see up to that generation in a location outside the population. Thus on termination, this location contains the centers of the final clusters that represent the image after clustering process and also provide a number of clusters.

Table(1) : Explain image database

Object	Pattern	Shadow	Texture	Shape	Association
Urban	U	Y	R	K,U	S,R,P
Road	Non	N	R	U	C
Forest	Non	Y	R	U	W,V
River	Near	N	S	U	V,B
Football-stadium	U	Y	R	K	Sc,Ca

Where:-
Pattern:U=uniform,Near=near-uniform,Non=nonuniform
Shadow:Y=yes, N=no.
Texture:S=smooth, R=rough.
Shape: K=known, U=unknown
Association: S=school, R=road,P=playgrounds,C=car, W=water,V=vegetation,B=bridges,Sc=scrolls,Ca=car-attitude.

Table (2): Encoding image database

Object No.	Pattern U near non	Shadow Y N	Texture S R	Shape K U	Association S R P C W V B Sc Ca
1	1 0 0	1 0	0 1	1 0	1 0 0 0 0 0 0 0 0
1	1 0 0	1 0	0 1	1 0	0 1 0 0 0 0 0 0 0
1	1 0 0	1 0	0 1	1 0	0 0 1 0 0 0 0 0 0
1	1 0 0	1 0	0 1	0 1	1 0 0 0 0 0 0 0 0
1	1 0 0	1 0	0 1	0 1	0 1 0 0 0 0 0 0 0
1	1 0 0	1 0	0 1	0 1	0 0 1 0 0 0 0 0 0
2	0 0 1	0 1	0 1	0 1	0 0 0 1 0 0 0 0 0
3	0 0 1	1 0	0 1	0 1	0 0 0 0 1 0 0 0 0
3	0 0 1	1 0	0 1	0 1	0 0 0 0 0 1 0 0 0
4	0 1 0	0 1	1 0	0 1	0 0 0 0 0 1 0 0 0
4	0 1 0	0 1	1 0	0 1	0 0 0 0 0 0 1 0 0
5	1 0 0	1 0	0 1	1 0	0 0 0 0 0 0 0 1 0
5	1 0 0	1 0	0 1	1 0	0 0 0 0 0 0 0 0 1

3.5. Drawing Clusters

After selecting the best solution(chromosome) and finding the final clusters that represents image, return to spatial domain of image through representing each element(pixel)in image by special color of cluster center related to it. In this work , we use Mean Relative Error(MRE) measure of each picture element to measure the performance of clustering process .

$$\text{MRE}=\frac{\sum_{X=1}^{W}\sum_{Y=1}^{H}\frac{|f(x,y)-g(x,y)|}{f(x,y)}}{W*H} \quad (12)$$

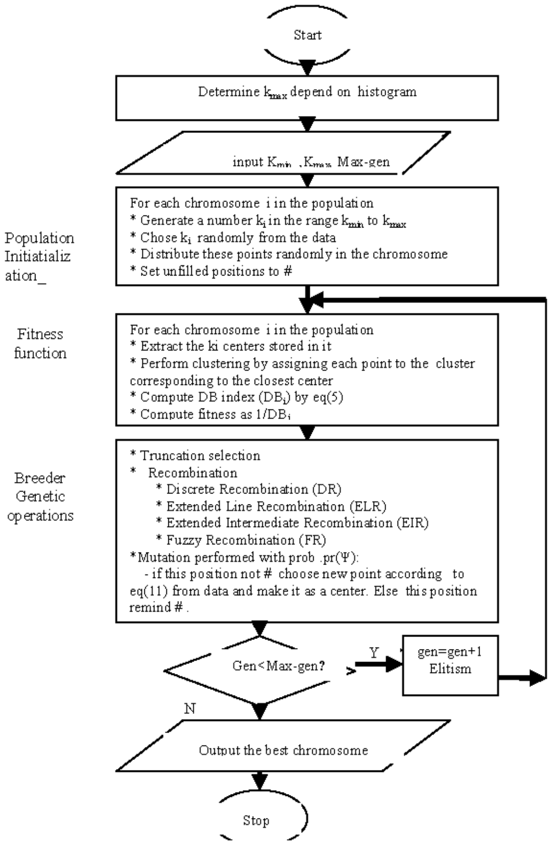


Figure (2) :Flowchart of Breeder Genetic Clustering for Image Segmentation

3.6. Features Extraction

In order to make an automated classification between different objects, some classifying features have to be extracted from the objects. In this part of this work we introduce two feature types, visual features and spectrum –based features.

3.6.1. Visual Description

Recognizing objects is the key to interpretation and information extraction. Observing the differences between objects and their backgrounds involves comparing different targets based on any, or all, of the visual elements of (shape, pattern, texture, shadow, and association). Visual interpretation using these elements is often a part of our daily lives, whether we are conscious of it or not Identifying targets in remotely sensed images based on these visual elements allows us to further interpret and analyze. The nature of each of these interpretation elements is described below[2].

Shape refers to the general form, structure, or outline of individual objects. **Pattern** refers to the spatial arrangement of visibly discernible objects. **Texture** refers to the impression of "smoothness" or "roughness" of image features is caused by the frequency of change of tone in photographs. **Shadow** is also helpful in interpretation as it may provide an idea of the profile and relative height of a target or targets which may make identification easier. **Association** takes into account the relationship between other recognizable objects or features in proximity to the target of interest.

3.6.2. Features based on the spectrum

The light ,which is reflected by the object, forms a spectrum. The visible part of the spectrum of light is located between 0.4 and 0.7 um. Characterizations of the light is related to science of color. All colors are seen as variable combination of the three primary colors, red(R), green(G), and blue(B).

Combination of three primary colors is useful in spectrum measurement, when the visible part of the spectrum is considered. However to extract the spectrum information from the object, the consideration should be done in HSI(Hue, Saturation, Intensity)model. In the HSI-model hue(H) describes pure color in terms of the dominant wavelength (e.g., red, orange, yellow, ect.), whereas the saturation(S) gives the measure of degree to which a pure color is diluted by white light(e.g., pink is diluted red), intensity(I) is decoupled from the color information of the object [19][20][21]. In this work we use hue, saturation and intensity information as following:-

$$H = COS^{-1}\left\{\frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{1/2}}\right\} \quad (13)$$

$$S = 1 - \frac{3 * \min(R, G, B)}{(R + G + B)} \quad (14)$$

$$I = \frac{1}{3}(R + G + B) \quad (15)$$

3.7. Labeling the Cluster

According to the system design, one needs to determine a label for each cluster, and thus they are labeled with appropriate category name (i.e., one of the five objects described in Table(1)), this is called image object labeler(IOL),[22].This stage can be achieved by procedure comparison process between the features that is found for each cluster and image database(i.e., The main benefit from this stage is to determined the desired output for each class).Then we use this information to train error back-propagation neural network.

3.8. Error back propagation neural network

After we get the number of clusters expected in the image dataset and the feature vectors that represent each cluster we can train error back-propagation neural network.

First, we need to determine the structure of network (i.e., number of nodes in input layer, number of nodes in hidden layer and number of nodes in output layer) and also the initial values of weights. Where a supervised ANN uses a set of training examples or records in this work, number of records equal to number of actual clusters result from breeder genetic clustering and number of attributes in each record equal to 21(i.e., visual and spectrum attributes). In this work we use unipolar Sigmoidal as activation function .

The output class vector c_j, (j=1,2, ...,j), j is the number of different possible classes. If the output vector belongs to the $class_k$ then the element is equal to 1 while all the other elements in the vector are zeros. Therefore, the proposed number of output nodes in the output layer of ANN is j(i.e. in this work j=5). The ANN is trained on the encoded vectors of the input attributes and the corresponding vectors of the output classes. The training of the ANN is processed until the convergence rate between the actual and the desired output will be achieved. The convergence rate can be improved by changing the number of epochs, the number of hidden nodes, the learning rate, and the momentum rate.

3.9. Decision Making process

After verification of one of the stopping criterion to error back propagation algorithm such as verified cost function condition or exceeding the number of epochs to maximum number of learning epochs without reaching network error to a value less than the required value, we can say that the error –back propagation is complete there work.

IF cost function condition is verified this means network can train itself on input pattern to it and recognizing this pattern (i.e., the network successful in training process). While if the second condition verified (i.e., the network does not reach to an acceptable error and exceeds number of epochs) this means the network fails in the training process and recognition the input pattern.

3.10. Specify a Certain Class

There are several methods to specify a certain class. One of these methods depends on use IF-Then Rule, such as images are described in terms of many characteristics and a rule is given which specifies the attributes that determine membership of the target class[23]. The resultant of testing each image is add to image database to extended it.

4. Conclusions

This paper introduces a method to classify objects for

remote sensing imagery characteristics by the follow: The advantage of applying soft classifiers is that the small classes will not vanish with the use of maximum likelihood. To receive an acceptable classification result, the training areas need to be spectrally separable. This can be done with clustering or expert knowledge, and the proposed system verifies this by applying breeder genetic clustering. The bitmap format is suitable for the system since it deals with the image as multiple objects image in which each object is represented by a certain color. The randomly estimation of the number of the clusters that are found in the image may lead to

error in classification process. Therefore, the proposed system can solve this problem by determining it automatically. The proposed system confirms the ability to perform correct classification process of the objects of the images that are used in the testing process, despite of the different parameters for each image and the different objects found in that image. Forming several rules that govern each class attributes by using IF-Then Rule format makes the system more precise because the features extracted from each class which are used to train ANN are congruent to the conditions of this rule, while the resultant classes from ANN are congruent to the actions of this rule. In other words the extracted rules are used to justify the inferred decisions.

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