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Assessments Image Segmentation Using Genetic Algorithm

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Abstract. *Image segmentation is a crucial technique for processing images. It is a challenging task to process images, and the quality of the segmentation process affects the following assignments, which include classification, object recognition, feature extraction, and object detection. It's a significant phase of a system for computer vision. Image segmentation is the basic problem in many applications for image processing. Over time, image segmentation has gotten more challenging due to its extensive use in numerous applications. It is the procedure of segmenting the image into various areas by using a specific technique. There are many different ways for image segmentation. A new information parameter with a threshold basis for segmenting images using the genetic algorithm. Due to its ability to calculate the ideal number of segmentation regions, we employed the Genetic Algorithm. In this work, a novel approach built upon a genetic algorithm is used to solve the image segmentation problem by utilizing the thresholding concept. The suggested method uses a genetic algorithm to identify the evolutionary best segmented image based on a threshold that is based on new information. We presented the results of our experiments using the suggested method on various grayscale images in the last section. By using parameters used to evaluate image segmentation quality (PSNR, MSE, SC), we notice the results are good.*

Keywords: *Image segmentation, Genetic algorithm, thresholding.*

Digital image processing (DIP) is the employment of computer algorithms to perform analysis, segmentation, and enhancement of the image. It is motivated by three primary uses. The first is the improvement of visual information about human perception, which implies that whatever image you obtain, you want to increase the quality of the image so that it looks better. The second application is for autonomous machine applications, which have a variety of industrial uses, especially in the automation of assembly and quality control. third application is efficient storage and transfer of data. Image segmentation is among the foundational problems with image processing. It works on dividing images into multiple parts or sets based on selected image features. IS aims to simplify the image and alter its representation such that it is easier to comprehend, more significant, and simpler to evaluate [1]. Also, the purpose of IS to find boundaries and objects in the image, it results in a collection of the regions that communally cover the whole image. There is a similarity in some characteristics, like color, intensity, and texture, per pixel in the region. GA is a relatively recent paradigm for natural selection-based search. The most effective optimization method in a big solution space has been shown to be genetic algorithms. This

demonstrates how genetic algorithms' uses for image processing and other domains are growing in popularity. They are employed when conducting a thorough search for a solution would take a lot of the computing time. Genetic algorithms are used in image processing for a variety of tasks, such as classifying detected features, evolving filters, and edge detection.

Genetic algorithm is an optimization method that uses Darwinian criterion of population evolution of solving optimization problems based on natural selection. The process of natural selection is utilized for raise the effectiveness of group of possible solutions for meet an environment optimum. Genetic algorithm is based on the principle of (Survival of the fittest) [2]. Genetic algorithm's main premise is to replicate natural selection in order to find a good selection for an application**.** GA is used for search of close to ideal solutions where no specify technique is in place or if the specify technique requires a lot of computation. Genetic algorithm is a population-based algorithm that produces several solutions for each iteration." Population size is the total number of solutions for every iteration. Each chromosome is a representation of a solution, and each chromosome is composed of genes. Start with random solutions for the population size genetic algorithm. selects the optimal member solutions for mating following this in order to produce new solutions. The best solutions will be accepted for the following iteration, while the worst ones will be rejected. When the algorithm recursively finds solutions, these solutions get better until they eventually converge to nearly ideal solutions. The genetic operators of selection, crossover, and mutation are applied to each iteration to create a new population [3]. All the researched used genetic algorithm depending on the value of histogram of image for image segmentation while in this research, try to combine multi- threshold with GAs by searching the best threshold values to segment an image into foreground and background which depending on the varying lighting conditions. Genetic algorithms are a type of computational optimization method based on the ideas of genetics and natural selection. The genetic algorithm starts with the initial population of people, who are usually chosen at random. It then undergoes several generations of iterations. or epochs, in which the individuals undergo operations such as selection, crossover, and mutation. These operations mimic the processes of natural selection, reproduction, and genetic variation observed in biological evolution. During the selection phase, A fitness function that measures how well each solution resolves the issue is used to evaluate members of the current population. The survival of the fittest is simulated by selecting individuals based on their fitness values, which increases the likelihood of processing them further. Crossover, or recombination, is a genetic operator where two selected individuals exchange genetic information to create offspring. This operation is analogous to sexual reproduction, where genetic material from both parents is combined to produce genetically diverse offspring. Mutation introduces small random changes in the genetic information of selected individuals. This operation helps maintain genetic diversity within the population, allowing exploration of different regions of the solution space. A new population is formed, replacing the preceding generation, following the application of the genetic operators. This process is repeated until a termination condition is satisfied, like reaching a predetermined fitness level or going over a predetermined number of iterations, or for a fixed number of generations. Over the course of multiple generations, genetic algorithms explore the solution space, favouring solutions with higher fitness values. The algorithm can converge towards an optimal or near-optimal solution by iteratively applying selection, crossover, and mutation.

2. IMAGE SEGMENTATION METHODS

The methods are described below: -

1. Layer-Based Segmentation Methods: it is used for classifying and evaluating images based on segmenting and detecting objects. It combines the bank object detectors' output to explain the appearance, depth, and ordering.

2. Block-Based Segmentation Methods*:* This method depends on different characteristics discovered in the image. which are principally divided into three sets based on two properties: similarity and discontinuity: -

Discontinuity means a change in intensity while similarity means dividing the image into many regions depending on the criteria such as thresholding [4].

A. Edge Based Segmentation

It is one of the most significant low–level image processing stages that is used in several high-level analyses such as feature identification and motion estimation [5,6]. The edge-based segmentation serves as a border between two areas that are similar to one another which involves detection of the confines between different regions in the image [7,8]. Also, it relies on edges found in an image by edge-detecting operators [9]. The idea is to determine the sharp changes in image splendour which can catch the critical occasions and properties [10]. This method is the most often used method for detecting meaningful gray-level discontinuities [11]. Due to these confines will be interruptions between the selected feature's pixels (for example Intensity, texture, and color). It is generally used to specify objects which include: -

i. Gradient Operator that responds to discontinuities in intensity level and includes first-order derivatives. It has a positive leading edge and a negative following edge. Prewitt, Roberts, and Sobel operators are used to detect edges by determining the magnitude in the first derivative.

ii. Second Derivative Operator: whenever the lighter the negative side and the darker the side that is positive. It is particularly sensitive to an image's noise. However, it's highly helpful for extracting some secondary data, like Laplacian, and Gaussian detection edges by searching for zero-crossing [12].

(1)

B. Thresholding Based Segmentation

One of the most straightforward ways to segment images is to use thresholding. Because of its simplicity, thresholding is a direct way of extracting various portions from an image [13]. It plays an important role in image segmentation [8], for dividing images that have bright objects on dim backgrounds [14,15]. It can use to separate objects from the background by a chosen threshold value. Which depends on the change in gray-level values in the image. There are two methods for the chosen value of threshold, firstly, global thresholding, and local thresholding [16]. The local method is the one in which the threshold factor is considered on a small region. The original image is split up into several sub-images in local thresholding, and a threshold is set for each of the sub-images. The distribution of intensity of object and background pixel is distinguished enough, then can be used global thresholding on the entire images, where the global thresholding method is easy to implement and computationally less involved [17,18]. There are several methods for global thresholding, such as entropy-based thresholding, Otsu thresholding, iterative thresholding, and minimum error thresholding. [12,19].

i. Minimum Error Thresholding: This approach finds the ideal threshold by directly optimizing the average pixel classification error rate to minimize the likelihood of a classification error [20].

ii. Iterative Thresholding: It specifies a fairly straightforward method that does not require extensive understanding of the image, additionally, it performs well against image noise. [20].
iii. Otsu's method: This technique can be categorized as one of the non-parametric, unsupervised methods for automatic threshold selection in image segmentation. [17,19]. It divides the image into several classes by determining a threshold that is dependent on the variation in pixel intensities within each class. [21]. The goal of the Otsu method is to determine the ideal value for the global threshold. Otsu's threshold selection method is straightforward to implement, but its main drawback is that it assumes a bimodal histogram. Although the Otsu method is the fastest, it requires a thorough optimization process and increases computation time. [22].
I. Entropy Thresholding: Although there are slight differences in definition, the entropy used as fuzziness measures is thought to be analogous to the entropy utilized in information theory. In a study, the author Fan et al. (1996) proposed a fast entropic method for automatically determining the global threshold by lowering the computational complexity. According to a study by Portes de (2004), an entropic thresholding strategy was modified from the nonextensive Tsallis entropy concept. Xiao's (2008) study proposed an entropic thresholding method based on the gray-level spatial correlation histogram. [17,19]. The performance of thresholding segmentation can be enhanced by some entropy-based image segmentation techniques [12]. However, they are still unable to distinguish edges from visual noise with clarity [23].

C.Region Based Segmentation

This is an additional method of segmenting images that divides an image into smaller areas based on certain guidelines, such as the requirement that every pixel in a region have the same gray level. [5,24]. a region-based method based on recurring patterns in the intensity values among a group of adjacent pixels [25,26]. This technique combines clustering, merging, splitting, and region growth.
i. Region Growing: Region growth is a commonly used technique for image segmentation, wherein adjacent pixels with comparable amplitudes are grouped to create a segmented area(3). In actuality, the growth pattern needs to be limited to yield acceptable results. [22].
ii. Region Splitting and Merging: separated the picture into several separate subregions. Afterward, each sub-region undergoes a merging and/or splitting process by the designated segmentation criteria. [5,24].
iii. Clustering: it is the arrangement of data in groups called clusters, per cluster contains more similar data to each other [27] Clustering applies in many areas (medical, geographic, agriculture). clustering is created based on the diversity of characteristics (size, color, texture) [5,25].

3. Genetic Algorithm

It is an Optimization method that uses the Darwinian criterion of population evolution for solving optimization problems based on natural selection [27]. In the 1970s, Holland proposed the GAs as a computer program to simulate the process of natural selection [28,29].
When no specified method exists or if the specified method is computationally complex, GA is used to find near-optimal solutions. [30]. The population size is the number of solutions produced by the population-based algorithm for each iteration. The solution is represented by a chromosome, with each chromosome being composed of genes [31]
Many parameters should be taken into consideration when using the Gas that are described below [31]: -
1. the chromosome and genes' representation, as poor representation may act to impede convergence.
2. Crossover and mutation are the two most widely used mechanisms for creating new solutions from existing ones

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3. How to identify fitness functions to select the most suitable individuals for mating and determine whether to accept or reject the recommendations.

The general steps in the GAs are as follows [28,32]:

1. Generate the initial population
2. Valuation of the fitness of the individual according to fitness function
3. Select the best individual for coupling
4. Apply crossover and mutation operations to generate offspring
5. Determine the fittest members of the current generation and the offspring by evaluating their fitness. They make up the next generation's population.
6. If the stop criteria are satisfied, stop; if not, go back to step 3.

4. Basic Genetic Algorithm Operation

The GAs consist of many operations that are described below [33]:-

1. Initial population: It begins by selecting an initial population at random for the given problem.

2. fitness function: The fitness function is entirely objective without human subjective being required. Fitness functions are used in place of natural selection and genetic material is represented by a string of bits in computers.

3. selection: The choice of individuals to create subsequent generations is crucial in roles in GAs. The probabilistic selection is made based on an individual's fitness, with the better individuals having a higher likelihood of being chosen.

There are several types of selection which are explained below [34]:

A. Roulette Wheel selection

B. Rank selection

C. Elitism Selection

4. Crossover

A. One-point crossover

Chromosome1	11011 00100110110
Chromosome2	11011 11000011110
Offspring1	11011 11000011110
Offspring2	11011 00100110110

B. Two-point crossover

Chromosome1	11011 00100 110110
Chromosome2	10101 11000 011110
Offspring1	11011 11000 110110
Offspring2	10101 00100 011110

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C . Uniform crossover

Parent 1

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Parent2

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

Offspring1

1 0 0 0 1 1 0 1 0 1 0 0 1 0 0 1 1 1 1 0 1

Offspring2

0 1 1 1 0 0 1 0 1 0 1 1 0 1 1 0 0 0 0 1 0

5. Mutation: Mutation is the process of altering a gene's value within a chromosome. The number of rows of the chromosome is changed at random and we are most likely to select the first of them[35].

There are several types of mutation:

i.Flip Bit Mutation: Choose one or more genes, then reverse the values so that 1s become 0s and vice versa.

1	0	1	1	0	1

1	1	1	1	0	1

ii. Swap Mutation: Choose two chromosomes and swap the values of those genes.

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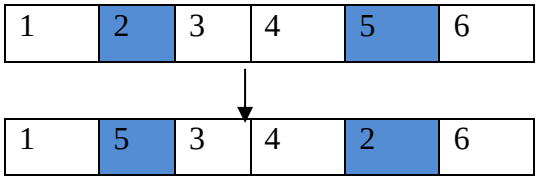
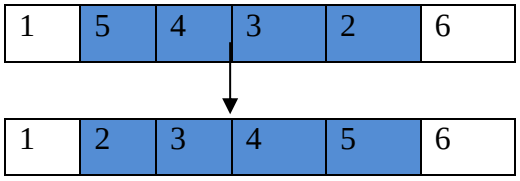
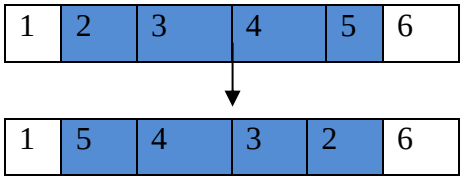


iii. Inversion Mutation: choose a portion of genes and flip their sequence



I. Scramble Mutation: Choose a portion of genes and jumble their values. The chosen genes might not be adjacent.



3. RESULTS AND DISCUSSION

3.1. RESULTS

We displayed our findings on a computer system with computer specifications Version 10.0, Build 19045 of Windows 10 Pro, 64-bit. Also, the system is designed using MATLAB(R2016ar). We have used a variety of gray level images of various sizes to demonstrate our suggested image segmentation technique. The framework presented here uses a faster genetic algorithm with a threshold to address a new set of segmentation criteria. In several applications involving image processing, measuring visual quality is crucial. In order to quantify image quality, we have employed some fundamental metrics like peak signal to noise ratio, mean square error, and structural content. The undistorted reference signal and error signal determine the image's quality signal. execute the GA for the different image files selected from the three datasets (Pakistani-license-number-plates-Dataset, Retinal-Vessel-Segmentation Dataset, Convid19-Xrays Dataset) and a classical images file as show in figure (1,2,3,4). Image segmentation with excellent

results was demonstrated by the algorithm segmented results and a set of sample input images are displayed in table 1 and table 2:-

3.2. DISCUSSION

Different images of gray level image are tested with suggested a new information parameter based on thresholds for image segmentation using genetic algorithms. We are aware that segmentation divides the regions from the target image, and that the intensity of pixels within a region is shared. To separate the object from the background, we therefore used threshold. The fitness values of genetic algorithm are found out for different segments values for different images. To evaluate the performance of algorithm researchers selected a set of image from Retinal-Vessel-Segmentation Datasets ,Pakistani-license-number-plates-datasets, Covia-19 dataset, Classical image. In many image processing applications, visual quality measurement is crucial. Therefore, we have used some basic "Image Quality Measures like, MSR , PSNR, SC. We can define Mean Square Error(MSR) is The quantitative assessment of the error signal's strength is done through quality measures. Because MSE is easy to implement and has a straightforward mathematical structure, it is widely used. Greater values of Mean Square Error indicate lower image quality, while lower values of Mean Sequar Error indicate higher image quality.

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$$MSE = \sum_{r=1}^{r} \sum_{c=1}^{c} (x(r,c) - x'(r,c))^2/(r*c) \ldots\ldots (1)$$

Where: X: is the original image ,X": is the segmented image ,(r, c) are the row and column. Peak Signal To Noise Ratio (PSNR) It is another image quality measure. PSNR is expressed in decibels (DB). If the Peak Signal To Noise Ratio has a small value, it means the image quality is bad. If the Peak Signal Noise Ratio has a large value, it means the image quality is good

$$PSNR = 10*\log(255*255)/MSE \ldots.(2)$$

Structural Content (SC) It is a correlation-based measurement that determines the similarity between two image signals.

$$SC = \sum_{r=1}^{r} \sum_{c=1}^{c} x(r,c)^2 \div \sum_{r=1}^{r} \sum_{c=1}^{c} x"(r,c)^2 \ldots\ldots (3)$$

Where: X: is the original image, X": is the segmented image, (r,c) row and column.

4. CONCLUSIONS

This paper discusses image segmentation and the various techniques used in computer vision and image processing, among other fields. Genetic algorithm is able to identify a suboptimal multi-threshold segmentation solution. Not every segmentation issue can be solved by this method. The The tendency of the implemented solution to segment small areas, such as edges, is a drawback. These areas shouldn't be considered because they aren't necessary for segmentation. Since the genetic algorithm can only process grayscale images, we always convert each image before beginning any work on it.

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Figure and tables

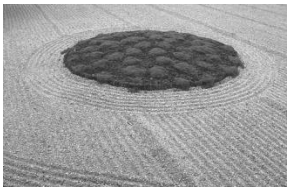
a.  b.  c. 

Fig.1.(a. Original image b. Gray level image c. Image segmentation)

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a.  b.  c. 

Fig.2.(a. Original image b. Gray level image c. Image segmentation)

a.  b.  c. 

Fig.3.(a. Original image b. Gray level image c. Image segmentation

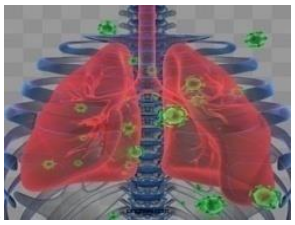
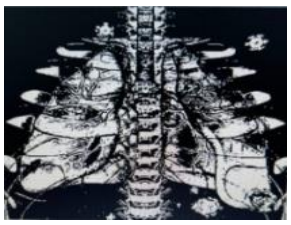
a.  **b.**  **c.** 

Fig.4. (a. Original image b. Gray level image c. Image segmentation

Table 1: In this table used different value of Probability of crossover=0.7, Probability of mutation=0.2, Probability of selection=0.1 , the size of population=10
Number of iteration=20, and different value of the number of threshold. As show in the table down.

N_threshold	PSNR	MSE	SE	Execute time(second)
9	46.6091	1.4196	1.2162	22.430
7	46.9528	1.3116	1.4766	10.039
5	46.7862	1.3629	1.3393	8.456
3	45.6823	1.7573	0.7970	5.964

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From Table 1 we notice that the best results of PSNR=(46.9528), MSE=(1.3116) when the threshold value is (7) , SC=(0.7970) when the threshold value is(3). we also notice that the execution time decreases when we reduce the threshold value .

Table 2: In this table we used different value of probability of crossover=0.03, probability of mutation=0.2, probability of selection=0.95, the size of population=20, the number of iteration= 40 and different value of the number of threshold. As show in the table down.

.

N_threshold	PSNR	MSE	SE	Execute time(second)
9	46.0353	1.6201	0.9243	28.624
7	46.5288	1.4461	1.1667	23.060
5	46.5867	1.4269	1.2020	21.822
3	46.7862	1.3629	1.3393	17.714

From Table 2 we notice that the best results of PSNR=(46. 7862), MSE=(1.3629) when the threshold value is (3), SC=(0.9243) when the threshold value is (9). Also, we note that the execution time of the genetic algorithm increases when the population size and the number of iterations increase.