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Using Genetic Algorithms to Segment Images: A Review

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Keywords: Segmentation, Genetic Algorithm, Artificial intelligence, Artificial Neural Network, Image Processing.

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Abstract:

The genetic algorithm plays a pivotal role in image processing, particularly in the critical stage of image segmentation. The process of segmenting photographs is an essential method in the field. Identifying objects, extracting features for object recognition, and classifying are integral components of image processing. However, the effectiveness of these activities relies on the quality of the operations performed. The work at hand in the domain of image processing is notably arduous and intricate. The segmentation of photos cannot be consistently achieved through the utilization of a singular approach. Nevertheless, it is not possible to consistently classify photos into extensive categories. The complexity inherent in the image segmentation task necessitates careful consideration when determining a suitable set of parameters to employ. The arduous task of selecting picture parameters the picture segmentation problem encompasses various factors that contribute to the complexity of the selection process. An optimization problem is employed to efficiently locate the global maximum inside a given search space, with the problem being formulated as a Genetic Algorithm. Subsequently, the task of determining the most suitable segmentation criteria for an image is successfully overcome. The primary objective of this study was to investigate the viability of employing genetic algorithms within the domain of image segmentation.

Keywords: Segmentation, Genetic Algorithm, Artificial intelligence, Artificial Neural Network, Image Processing.

استخدام الخوارزميات الجينية لتقسيم الصور: مراجعة

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الخلاصة:

تلعب الخوارزمية الجينية دورًا محوريًا في معالجة الصور، خاصة في المرحلة الحرجة من تجزئة الصورة. تعد عملية تجزئة الصور الفوتوغرافية طريقة أساسية في هذا المجال. يعد تحديد الكائنات واستخراج ميزات التعرف على الكائنات وتصنيفها مكونات أساسية لمعالجة الصور. ومع ذلك، فإن فعالية هذه الأنشطة تعتمد على جودة العمليات المنفذة. العمل الجاري في مجال معالجة الصور شاق ومعقد بشكل خاص. لا يمكن تحقيق تجزئة الصور بشكل متسق من خلال استخدام نهج فردي. ومع ذلك، ليس من الممكن تصنيف الصور باستمرار إلى فئات واسعة النطاق. يتطلب التعقيد الكامن في مهمة تجزئة الصورة دراسة متأنية عند تحديد مجموعة مناسبة من المعلمات لاستخدامها. المهمة الشاقة المتمثلة في اختيار معلمات الصورة تشتمل مشكلة تجزئة الصورة على عوامل مختلفة تساهم في تعقيد عملية الاختيار. يتم استخدام مشكلة التحسين لتحديد موقع الحد الأقصى العالمي بكفاءة داخل مساحة بحث معينة، مع صياغة المشكلة كخوارزمية جينية. وبعد ذلك، تم التغلب بنجاح على مهمة تحديد معايير التجزئة الأكثر ملاءمة للصورة. كان الهدف الأساسي من هذه الدراسة هو دراسة جدوى استخدام الخوارزميات الجينية في مجال تجزئة الصورة.

الكلمات المفتاحية: التجزئة، الخوارزمية الجينية، الذكاء الاصطناعي، الشبكة العصبية الاصطناعية، معالجة الصور.

1. INTRODUCTION:

Image segmentation is a technique utilized to partition a digital image into multiple sections composed of pixels [1]. Please note that picture segmentation should not be mistaken for image partitioning both edge detection and region extraction techniques were employed to generate these regions. Upon undergoing division, the distinct elements comprising an image maintain their original color and texture properties. The outcome comprises several discrete segments that, when integrated, form the entirety of the visual representation. Identifying a reliable approach capable of accurately segmenting all photographs can pose a significant challenge. The task of determining the most suitable strategy for segmentation is also complex and demanding. The applicability of these technologies, originally designed for a certain image type, is limited when applied to different types of photographs. The categorization of segmentation techniques can be classified into three groups, as outlined in reference [2]:

A- Traditional algorithms refer to algorithms that are based on mathematical or methodological principles.
B- Approaches about artificial intelligence .

C- Methods for achieving optimal performance.

The conventional procedures encompass several techniques such as utilization thresholds to identify unique histograms, performing region expansion or extraction, detecting edges and boundaries, and employing relaxation methods. The utilization of segmentation is derived from the discipline of artificial intelligence, wherein methodologies including Artificial Neural Networks are employed. This paper discusses the utilization of a Genetic Algorithm (GA) in optimization tactics. The parameters of segmentation algorithms and pixel-level segmentation have been modified due to the substantial impact of genetic algorithms on picture segmentation [3]. In the context of segmentation analysis, the utilization of genetic algorithms (GA) can facilitate the determination of an optimal number of segments to consider for attribute selection, including heuristic thresholds.

2. Related Works

Image segmentation can be done using a variety of algorithms. However, owing to various constraints, finding the best solution is difficult. [4] classifies the pixels' belonging and then uses area expansion to obtain the piece. [5] suggested linking the region details and color histogram for creating video databases based on artifacts. A genetic algorithm-based segmentation method was proposed in [6] to alter image characteristics triggered by variable environmental conditions. [7] describes a two-step approach to image segmentation. The authors suggested a graph-based approach in [8].

3. Image Segmentation

In the process of segmentation, the input image is divided into regions that do not overlap with one another [9]. Every region is the same and is linked together. When all the pixels conform to the homogeneity criterion, the areas are the same.

If there is a path between any two pixels that are located within the zone, then the zone is said to be connected. Using this method, an image can be divided into sections that have consistent and consistent features. The goal of picture segmentation is to reduce the complexity of an image's representation by converting it into a form of meaning that can be easily analyzed [10, 11].

3.1. Image Segmentation Using Gas

A proposed approach for estimating the solution area involves the utilization of a distance function that incorporates both local and global compute segments. This approach employs a genetic algorithm (GA).

To develop a proficient genetic algorithm (GA) for picture segmentation, it is imperative to focus on two main considerations as highlighted in previous research [12,13].

1- Identify the optimal symbol to symbolize each solution.
2- Establishing an optimal fitness posture depending on weight and health. Image segmentation algorithms typically include customizable parameters, which enable users to exert more precise control over the resulting output. The gas method can be broadly characterized as outlined in reference [14].

At the point when the seed supply is prepared for utilization, three factors come into play. The initial stage of the genetic cycle, as seen in Fig.1.

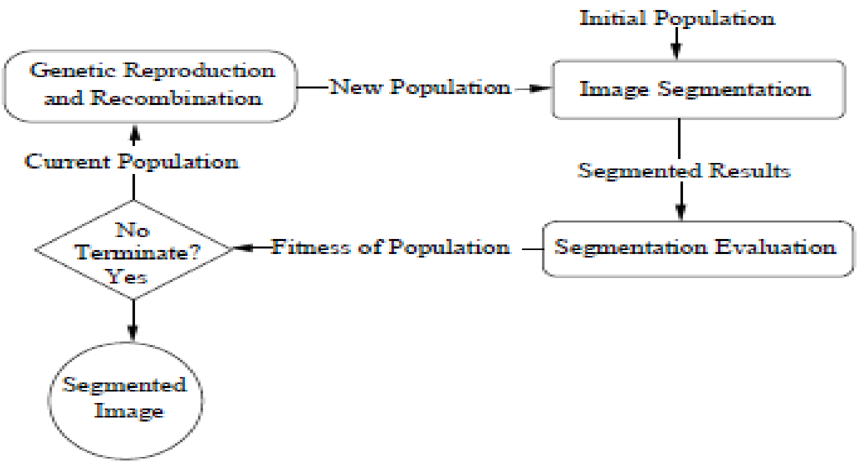

Fig1. Flow Chart of the Based Segmentation Method

The evaluation process assesses the quality of the result for each category of factors. If the maximal efficiency for the present population exceeds the previously indicated value, it is recommended to discontinue the method [15].

If the performance standards are not satisfied, the purpose of the genetic operators will be altered. Individuals who possess a significant degree of physical strength are considered suitable candidates for this endeavor. Within a given population, this phenomenon leads to the emergence of a subsequent generation of offspring that exhibits enhanced performance. Following the application of a revised population for the second iteration to divide the image, the cycle recommences. The term "generation" encompasses various stages within the iterative process, namely "Crossover," "Segmentation-Fitness," and "Mutation." Fig. 1 illustrates the ongoing process will persist until all requisite requirements have been fulfilled [16,17].

The measurement of distance position in this context is contingent upon the number of pixels and is influenced by both distress and spatial location. This interplay of factors contributes to the generation of similarity, as depicted in Fig. 2.

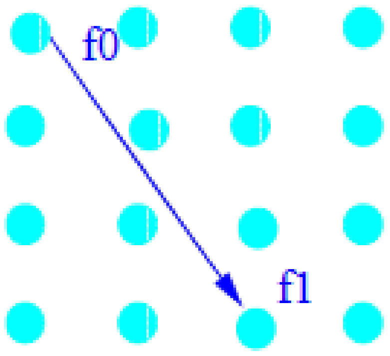

Fig2. The graph and the distance function

3.2.Genetic Algorithm Methodology

During a genetic algorithm, a collection of strings, often referred to as chromosomes, which represent potential solutions to an optimization problem, undergoes a progressive evolution towards improved solutions. In many cases, the phenomenon of evolution commences with a cohort of individuals that have arisen through autonomous reproductive actions, thereafter, progressing across successive generations. The generation of a new population is achieved through a process of random selection of individuals from the existing population, with the likelihood of selection influenced by their respective fitness levels. These selected individuals are then subjected to modifications, specifically through crossover and mutation techniques **[18].** Each successive cohort assesses the overall adaptability of everyone within the populace. Subsequently, the algorithm integrates the revised population in the future iteration. Typically, the termination of the process occurs when either the maximum number of generations has been attained or when the population has attained a satisfactory level of health. If the algorithm terminates when reaching a specific cumulative number of generations **[19-21],** it is uncertain whether a feasible solution has been obtained at that stage.

4. Segmentation Of the Image Using Genetic Algorithm

Farmer and Sugars **[22]** split the genetic algorithms used to segment images into two key groups for image segmentation.

1. Selection of parameters, where genetic algorithms are used to change the parameters of an existing system of image segmentation to maximize its performance.
2. Segmentation at the pixel level, using genetic algorithms to perform area marking.

Most methods of image segmentation have several parameters that need to be refined, and the first approach is therefore used more frequently**[23,24].**

5. Different Soft Computing Techniques Used for Image Segmentation

5.1. Fuzzy Clustering

Data points are divided into homogenous classes or clusters using clustering, which aims to make the items in the same cluster as similar as feasible and the items in separate classes as unlike as possible. Distance, connection, and intensity are a few variables that may be utilized as similarity indicators. In non-fuzzy or hard clustering, information is separated into distinct clusters, each of which contains exactly one data point. In fuzzy clustering, the data points may belong to many clusters, and for each point, membership grades that describe the degree to which the data points are a part of each cluster are assigned. An item can belong to many classes in variable degrees (referred to as memberships) according to the primary principle of fuzzy clustering. Numerous benefits may be seen in the membership produced by the fuzzy clustering method [25].

5.2. Possibility Fuzzy C Mean

The partition should exhibit two key characteristics: intra-cluster homogeneity, which implies that the data within each cluster should be as similar as possible, and inter-cluster heterogeneity, which implies that the data across different clusters should be as diverse as possible.

The assumption is made that the degree of typicality of a point within a fuzzy set (or cluster) is absolute. This degree is defined by the membership values assigned to that point among the other clusters existing in the domain under consideration [26]. The process of grouping is referred to as a probabilistic approach. In contrast, several clustering techniques employ a probabilistic constraint that mandates the summation of membership values for a given point to equal one. According to this constraint, it is stipulated that a given point can exclusively be assigned to a single cluster at any given moment. The PCM methodology diverges from other methods by not assuming probabilistic constraints. The Probabilistic Constraint Model (PCM) is founded on the concept of relaxing the probabilistic constraint [27], enabling the interpretation of the membership function or degree of typicality in a probabilistic fashion.

5.3. Artificial Neural Network

An artificial neural network (ANN) is a kind of information processing that emulates the operations of biological neural systems, such as the human brain. The narrative structure of the data processing system assumes a vital role within this paradigm. The system has numerous interconnected processing units, commonly referred to as neurons, which collaborate to address a diverse range of problems. An artificial neural network (ANN) can be tailored to suit specific applications, such as pattern recognition or data categorization, by undergoing a process of learning [28]. Neural networks possess the ability to acquire novel talents through the process of monitoring and assimilating pre-existing ones. Autonomous systems lack the capacity for programming, rendering them impervious to instruction. It is imperative to use caution and thoughtful deliberation while choosing samples to prevent time wastage and, more significantly, to avert potential network malfunctions resulting from subpar input. The presence of a disadvantage compels the network to independently seek a resolution to the issue, potentially yielding unanticipated outcomes.

5.3.1 Supervised approach

For segmentation, supervised methods require expert human input. As a result, human professionals carefully choose the training data that will be utilized to segment the photos. Suprevised approaches are based on the manual selection of training pictures by operators or people with competence.

Divide them up into n regions. Using the chosen photos as training images, the suggested architecture is trained by assigning labels to each area. After that, the technique may segment comparable pictures. Regions are given labels based on the knowledge contained in the neural network architecture that is being.

5. 3.2. Unsupervised procedures

Semi- or completely automated unsupervised approaches are available. The findings should be independent of humans; however, user intervention may be required at some point in the process to enhance the effectiveness of the approach. Without the help of an operator, an unsupervised approach mechanically divides the pictures. The technique divides the picture into k smaller parts, and then automatically labels each of those sections [29].

6. Technique Of Genetic Algorithm

The objective of a Genetic Algorithm is to identify the optimal solution to an optimization problem through the iterative improvement of a population of strings (chromosomes) that represent potential solutions to the problem. Evolution generally initiates with the formation of novel social collectives and proceeds across subsequent generations [30]. The process of determining the fitness of everyone in a population involves randomly selecting multiple individuals from the current population, applying crossover and mutation operations to these individuals to generate a new population in each generation, and subsequently calculating the average fitness of these individuals. The algorithm's future iterations incorporate the newly obtained demographic data. The termination of the method occurs when either a specific threshold for population fitness is attained or a predetermined number of generations have been generated [31] The determination of whether a viable solution has been obtained is contingent upon the algorithm's termination due to reaching its maximum number of generations.

Genetic or evolutionary algorithms employ the fundamental principles of natural evolution to effectively choose the optimal resolution for a Solver problem. In the context of a genetic algorithm, the problem at hand is typically represented as a series of bit strings. However, in an evolutionary algorithm, the problem is approached by directly utilizing the choice variables and problem functions to find a solution. Both algorithms are classified as "algorithms." On evolutionary algorithms, many commercial Solver products are built. There are a few ways in which "evolutionary" optimization techniques differ from "classical" methods [25]. Operations That Are Random vs. Deterministic Population Compared to Single Ideal Response Utilizing "Survival of the Fittest" to choose the best solutions, creating new solutions through mutation, combining solutions through crossover, and so on. Five phases comprise basic GA (**Fig. 3**):

Start with a population of N chromosomes that was produced at random, where N represents the population's size and l represents the chromosome x's length. Find the fitness value of each chromosome x in the population by calculating its function (x). Continue doing this until N progeny are produced: Using the value of the fitness function, choose a pair of chromosomes at random from the current population. Create an offspring with the crossover and mutation operations, where i = 1, 2, ..., Fresh population should replace the existing one. Move on to step 2 in 5. As shown in **Fig. 3**, a straightforward GA process.

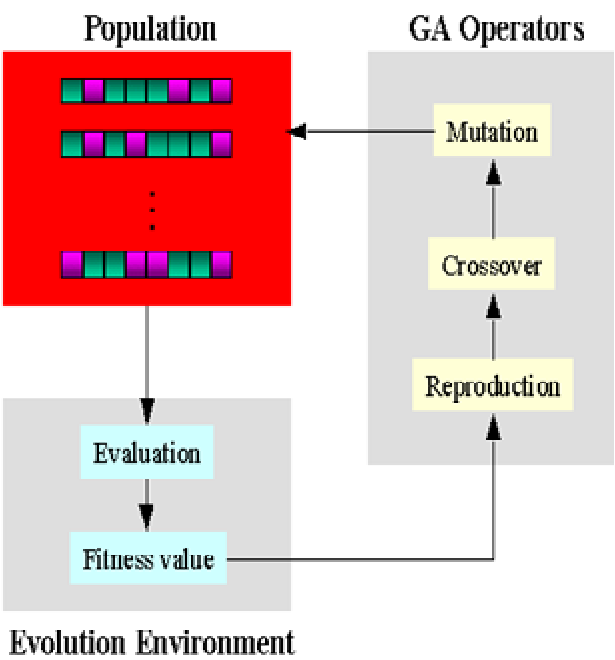

Fig 3: Genetic Algorithm process

a. Mutation

Periodically, an evolutionary algorithm will introduce random mutations or other modifications to a subset of the population. Consequently, a new set of alternatives for resolving the issue will arise. The formulation of this technique was derived from the examination of how DNA mutations contribute to the natural evolution of organisms. This phenomenon may be perceived positively or negatively about the existing population. There exist numerous potential approaches for implementing a "mutation," and the Evolutionary Solver utilizes three separate mutation protocols. The Evolutionary Solver employs a strategy known as "repair" to address issues by iteratively incorporating minor modifications into the algorithm. In instances where the probable outcome of a mutation appears unlikely, there exists a method that may, on occasion (but not consistently), render it conceivable. There exist numerous potential mutation operators, a few of which are outlined below:

1. Flipping.
2. Exchanging.
3. Reversing.

b. Crossover

An evolutionary algorithm attempts to combine components of existing solutions to generate a new solution with some of the traits of each "parent"; this attempt is motivated by the function of sexual reproduction in the development of biological organisms. In a "crossover" procedure that is motivated by the crossover of DNA strands that takes place during the reproduction of biological organisms, the components of current solutions are mixed. The Evolutionary Solver uses various variants of two separate crossover techniques since there are numerous alternative ways to do a crossover operation, much like with mutation, some of which are significantly better than others. The numerous crossing methods include:

- .Crossover at a single point,
- Crossover at two points.
- Multipoint/N-point crossover.
- Consistent crossover.
- Three-point crossover

The word "crossover probability" denotes a statistical measure employed to ascertain the frequency at which crossover operations are performed. In the absence of genetic recombination between parental sets, offspring can be seen as exact replicas of their parents in terms of genetic composition. If there is a genetic exchange between two individuals, the resulting progeny will possess chromosomes derived from both parental sets. If the probability of genetic recombination is 100%, then the offspring will exhibit identical traits. If the population size reaches zero, all the chromosomes present will be utilized to generate a new generation. The process of chromosome crossing over is undertaken with the anticipation that the resultant chromosome will exhibit superiority over its parental counterparts, owing to the incorporation of beneficial segments from the original chromosomes [26].

c. Selection

The evolutionary algorithm undergoes a selection process wherein individuals deemed to possess higher fitness levels are retained within the population, while those with lower fitness levels are eliminated. The influence exerted by natural selection on the process of evolution served as a source of inspiration for the development of this technique. In the context of addressing a constrained optimization issue, the efficacy of a solution is contingent upon its adherence to the problem's constraints, as well as its alignment with the value of the problem's objective function. The process of selection guides the evolutionary algorithm towards progressively enhanced solutions as it traverses the search space. The subsequent examples illustrate prevalent techniques employed in the process of selection.

- Tournament entry.
- Randomly choosing.
- Boltzmann selection
- Stochastic unbiased sampling
- Picking a rank.
- Choice of the roulette wheel.

Using a competitive neural network is a superior approach to fuzzy clustering approaches when comparing the aforementioned 5 ways of picture segmentation. The use of genetic algorithms is another alternative method for segmenting images. The complexity of the problem is decreased using genetic algorithms. of image segmentation, genetic algorithms are employed as function optimizers to change the parameters of already-existing segmentation algorithms. GAs are probabilistic and casualty tools, but they may not evolve in the same way when used on the same issue. More system knowledge and more fuzzy logic and ANN approaches were required. More mathematics as compared to GAs [27].

Therefore, based on a comparison of all available soft computing techniques, genetic algorithms are the most accurate way to segment a picture since they can handle complicated color images, which is extremely helpful nowadays as most photographs are colorful.

d. Randomness

First, it uses some random sampling. It is therefore nondeterministic, and even if your model hasn't changed, different executions of the procedure may have slightly different results. The linear, nonlinear, and integer Solvers, which are also part of the Premium Solver, are deterministic techniques; they consistently provide the same answer if you begin with the same values in the decision variable cells.

e. Population

Moreover, in contrast to conventional optimization methods that often retain only the best solution obtained thus far, an evolutionary algorithm maintains a population of viable solutions. While it is possible to identify a single or a limited number of options as the "best," the rest of the population serves as "sample points" in different areas of the search space. These points may contribute to the emergence of a more optimal solution in the future. The utilization of a population of solutions in the evolutionary algorithm serves the purpose of circumventing the potential entrapment at the present local optimum, enabling the algorithm to explore the possibility of a superior optimum that may lie beyond the scope of the current solution.

7. Method of Genetic Algorithm

The Genetic Algorithm consists of the steps below [32]:

Step 1: Pick an initial population of people.
Step 2: Assess everyone's health in that population.
Step 3: Repeat before termination of this generation (time limit, satisfactory fitness attained, etc.):

a-Select the best-fit reproductive individuals.
b-Breeding new individuals to give birth to offspring via crossover and mutation operations.
c-Evaluating the individual health of new people.
d-Substitute new people into the least-fit population.

The fact that GA tries to solve problems through evolution is both a benefit and a drawback. Natural life moves away from unfavorable situations rather than toward a good solution, therefore evolution is not unidirectional. It can lead to a species' evolution reaching a stalemate. We may be unaware that GA is providing a sub-optimal answer. A big phenomenon is the convergence principle. in GA For example, to begin a GA search by providing user input and receiving results, certain values are retrieved that are the best answer at the time. This proved to be a significant setback as well [33]. However, the produced result may not be optimum, and better outcomes in real life may be achievable. circumstance the reason for this is that there may be a local optimal point in a GA search process, and if you descend to that point, you won't be able to search for the global optimal. Which is exactly what we need. Convergence is the property of descent inside the local optimum space. This is a flaw in the GA search mechanism. [34-36].

8. Conclusion

The utilization of the Genetic Algorithm offers numerous advantages when seeking the optimal solution. This essay aims to elucidate the advantages associated with the implementation of hybrid algorithms. Numerous studies have consistently demonstrated that this strategy is the most effective method for optimizing a wide range of variables. The evolutionary algorithm streamlines the process of conducting a comprehensive search for the optimal solution across a multitude of criteria. Besides the fitness function, other parameters like as the chromosomal encoding scheme and the incorporation of genetic operators may influence the outcome of the optimization process. Conversely, by selecting the parameters judiciously, it is possible to enhance the quality of the image segmentation. Considerable discourse has transpired over the comparative advantages of non-conventional image segmentation algorithms, such as fuzzy, competitive neural networks, and evolutionary algorithms, in contrast to their more established counterparts. When comparing fuzzy and competitive neural networks, it becomes evident that fuzzy neural networks demonstrate superiority in the context of picture segmentation, whereas competitive neural networks are more effective for fuzzy clustering. Another viable option for image segmentation is the utilization of genetic algorithms. Genetic algorithms are employed to mitigate the intricacy of an issue that might otherwise pose significant challenges in its resolution. Genetic algorithms are widely recognized as function optimizers due to their application in refining the parameters of pre-existing segmentation algorithms, hence playing a crucial role in the image segmentation procedure. Furthermore, this study proposes the utilization of hybrid algorithms, such as genetic algorithms (GAs) and artificial neural networks (ANNs), to enhance the aesthetic quality of segmentation results and reduce processing durations.

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