GENETIC ALGORITHM IN IMAGE PROCESSING: METHODOLOGY AND APPLICATIONS

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Abstract

Genetic algorithms (GA) were developed to solve wide-range of optimization problems. It is one of the best-known Stochastic optimization algorithms based on Charles Darwin's theory of natural evolution. Genetic algorithms are commonly used to solve complex large-scale optimization problems in diverse fields. GA were first introduced in the early 1970's by John Holland based on natural genetics and selection. GA can be classified as a global search heuristic. GA comes from the larger class of evolutionary algorithms (EA) that are used to solve problems which do not already have a distinct and an efficient solution. EA use mechanisms based on biological evolution like inheritance, mutation, selection and crossover. GA have already been applied to find optimal solutions for complicated problems across disciplines such as biology, engineering, computer science and so on. In the field of computer science, Image processing is one of the diverse areas where GA have been used to solve various tasks like dense pixel matching. This paper discusses the methodology and applications of genetic algorithm in the area of Image processing. The process of image segmentation can be systematized as an optimization problem. In image segmentation, genetic algorithm perfectly solves the problem of parameter selection by efficiently determine the global maximum.

Keywords— *Genetic algorithm, Image processing, Image segmentation, Selection, Mutation, Crossover, Optimization algorithm.*

I. INTRODUCTION

Image segmentation is a major step in an image processing which includes the subsequent tasks such as object detection, feature extraction, object recognition and classification. These subsequent tasks depend on the quality of segmentation process where the images are divided

into constituent regions or objects. The process of subdivision is carried until the objects or region of interest in an image has been detected. Improving the probability of accurate segmentation is necessary since the accuracy of segmentation determines the level of efficiency of the analysis procedures. GA has the ability to determine the optimal number of regions of a segmentation result. This paper discusses the application of GA in the image processing tasks like image enhancement and segmentation. A sequence of population will be generated by GA using a selection mechanism which uses crossover and mutation as search mechanisms. GA depends on crossover whereas evolutionary strategies use mutation as a search mechanism to find better solutions.

II. IMAGE SEGMENTATION

Image segmentation is the process of segmenting a digital image into several non-overlapping regions or collections of pixels. The process of image segmentation gives the result which consist of a collection of regions and the association of those regions forms the entire image. Every pixel in an image is associated with one of the several regions. The process of partitioning regions or pixels can be done with uniform and homogeneous characteristics of a digital image. Image segmentation is used to find objects and boundaries like points, lines, curves, etc., in a digital image. This partitioning can be achieved by edge detection or region extraction. Each partitioned region is homogeneous, non-overlapped and connected. A segmentation process is said to be perfect only when it meets the following criteria:

1. Every pixel in the image is assigned to one of the regions.
2. A region is connected.
3. Each region is homogeneous with reference to any of the syntactic characteristics like color, intensity, texture, etc., and/or semantic characteristics.
4. A single homogeneous region cannot be produced by merging any of the adjacent regions.
5. No regions overlap.

1) Methods of Image Segmentation:

There are three major categories of image segmentation.

1. Thresholding
2. Edge-based segmentation
3. Region-based segmentation

Thresholding is the basic and most widely used method of segmentation. In thresholding, images are partitioned directly into regions depending on the similarity property for inclusion, region growing process should be stopped.

Region splitting and merging involves into subdivision of image into uniform disjoint regions. Initially the process starts by assuming the entire image as a single region. Then computes the similarity criteria to check if it satisfies the condition. If 'false', then the whole region is split into a quad region or quad tree (four smaller regions). Finally, similar smaller regions are merged to create the segmented result.

2) Applications of Image Segmentation:

The main objective of image segmentation is to make the image ease for better analysis. Image segmentation is the initial stage for image analysis. The segmented parts of similar properties are called 'image objects'. Image segmentation is a huge part of machine vision and has various applications in diverse industries. Some of the prominent fields are:

- Face, Iris and Fingerprint recognition for advanced security systems,
- Number plate and brake-light detection in traffic control system,
- Medical imaging such as diagnosis and treatment planning of various diseases, computer-guided surgery, to locate and identify cancer cells,
- In satellite images to locate objects like roads, forests, etc.,
- Crop/leaf disease detection in agricultural imaging.

Apart from this, image segmentation also used in the field of manufacturing and many other areas. In manufacturing sector, image segmentation is used to minimize the risk of human errors and also to make the testing process more efficient.

III. GENETIC ALGORITHM

The concept of population is an important aspect of GA. In contrast to traditional search methods, GA depends on the Gas compute finite-length strings by encoding the decision variable of a search problem. These strings of candidate solutions are referred to as chromosomes.

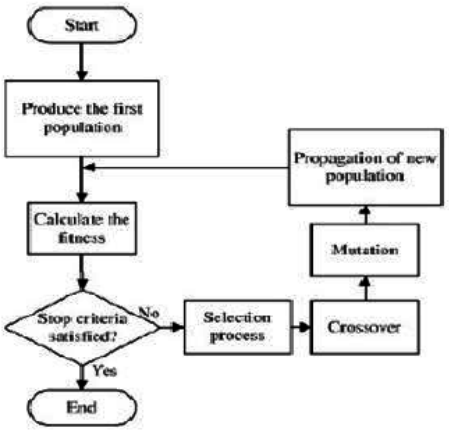

Fig 1. Block diagram of Genetic Algorithm

GA proceeds with an initial set of random solutions called population.

- Each individual in the population which represents a solution to the problem is called a chromosome.
- Chromosomes evolve through subsequent iterations, which are referred as generations, using the fitness function.
- New chromosomes, called offspring, are formed by either

  a. Merging two chromosomes from the current generation using a crossover operator (or)

  b. Modifying a chromosome using a mutation operator.

- A new generation is formed by selecting the good solutions according to the fitness value and eliminate the worse ones so as to keep the population size constant.
- Fitter chromosomes have higher possibilities of being selected.
- After several generations, the algorithm converges to the best chromosome that represents the optimal solution.

1) Search space:

The collection of all possible feasible solutions or values forms a search space. Each solution can be assigned by its value of the fitness function. A set of points which yields an optimal solution lies in the search space. The primary goal of optimization is to locate that point or the set of points in the search space. Finding either maximum or minimum describes the optimal solution.

2) Genetic Algorithm Methodology:

The population of binary strings is the basic principle of GA. Using genetic operators such as crossover and mutation, the following algorithm produces the subsequent generation from the current population. This process repeats until termination criteria is reached.

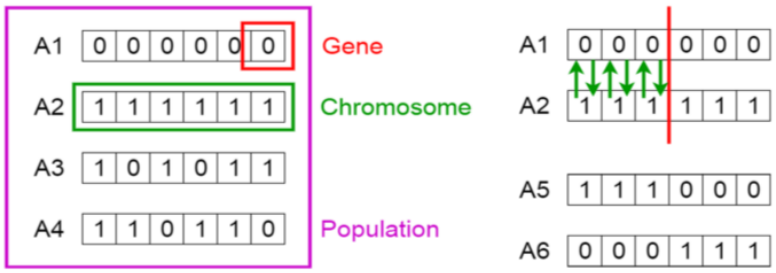

Fig 2. Population evolution

```
function ga()
{
Initialize population;
Compute fitness function;
while (fitness_value!=termination criteria)
{
        Selection;
        Crossover;
        Mutation;
        Compute fitness_function;
}
}
```

a) Fitness function:

To implement natural solution and to evolve good solutions, there is an objective function of mathematical model to find better solutions over the worse ones. Fitness function, which is the function to be optimized, provides the mechanism for generating each string. The fitness value is used for ranking any solution over the other solutions. A fitness function value is assigned to each solution based on the similarity to the optimal solution of the problem.

b) Selection:

The main objective of the selection operator is to preserve the good solutions and eliminate the worse one in a population while keeping the population size constant. Selection operator selects

the fitter solutions and discards the weaker ones. In GA, a fitter string receives a higher number of offspring so that the chance of surviving in the consequent generation gets increased. Hence the major steps in selection operation are:

- Identify the good solutions in the population.
- Make multiple copies.
- To place the multiple copies of good solution in the population, it eliminates the bad solutions from the population so as to keep the population size constant.

There are various methods to implement selection in GA:

1. Tournament selection
2. Roulette wheel selection
3. Proportionate selection
4. Rank selection
5. Steady state selection, etc.,

c) Crossover:

After selection, a pair of strings or selection point are chosen randomly from the population for the crossover operation. This operator is used to generate new solutions from the existing solutions available in the matting pool. A probability of crossover is introduced by selecting two individuals randomly and are recombined with a probability, Pc, which lies in the range of 0 to 1. A uniform random number, r, is generated. The two randomly selected individuals will go for crossover if ($r \leq Pc$). Otherwise, the two offspring are simply the copies of their parents, that is, the strings remain unaltered.

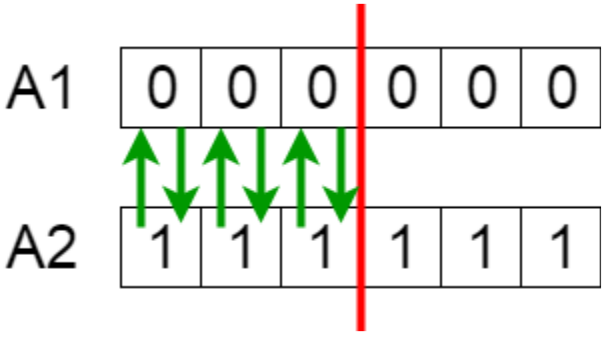

Fig 3. Exchange of population in crossover

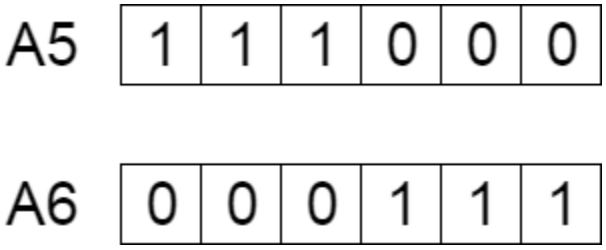

Fig 4. New offspring

d) Mutation:

Strings are subjected to mutation process after crossover or recombination operation. Mutation operator involves the process of bit-flip, where every bit with low probability in a binary string is changed, that is, changing 0 to 1 or vice versa. The bit-flip mutation can be done with a certain probability, Pm (mutation rate), known as the mutation probability just like Pc which controls the probability of crossover. Mutation takes place to maintain diversity in the population and to avoid premature convergence. Mutation operator is considered as a secondary mechanism of GA.

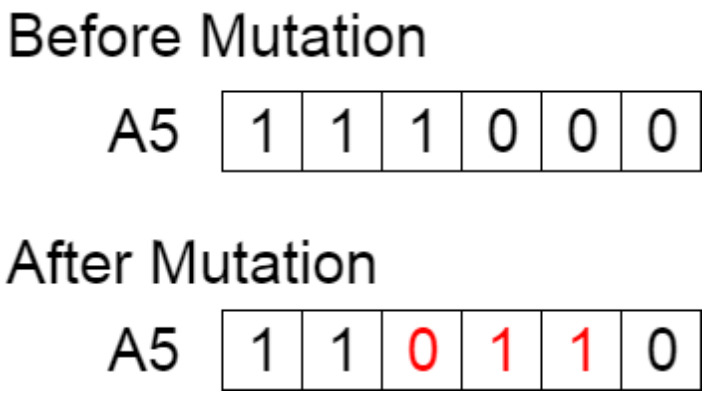

Fig 5. Before and after mutation

3) Genetic algorithm in Image segmentation:

Even though there are different algorithms for image segmentation as above, GA is good at producing optimal solutions by taking potentially large search spaces while traditional algorithm involves a step-by-step procedure to solve a problem. GA is based on the principle of natural selection and genetics to produce optimal solutions. GA mainly focused on the principle of "survival of the fittest". The most important difference between genetic algorithm and traditional methods is that GA employs a population of points at one time compared to traditional methods which is a single point approach. A typical GA involves a genetic

representation and a fitness function to evaluate the solution space. Once these functions are defined, GA starts to initialize a population randomly and it is enhanced by a repeated process of operators like selection, crossover and mutation.

Image segmentation using GA can be achieved by using two major classes namely parameter selection and pixel-level segmentation. Parameter selection is the most commonly used approach. In this method, parameters of an existing image segmentation method are modified to obtain effective result. To preform the task of region-labeling, pixel-level segmentation method is used.

Procedure for image segmentation using GA:

1. Compute statistical quantities of an image which includes histogram, 3D-surface plot, distance between points, etc.,
2. Generate initial population.
3. Start segmentation using initial parameters.
4. Calculate the segmentation quality measures.
5. Do until termination criteria is reached
    a. Select individuals using reproduction operator.
    b. Generate new population using the operators – crossover and mutation.
    c. Segmenting image using new parameters.
    d. Compute segmentation quality measures.
    End.
6. Update the search space.

IV. CONCLUSION

Image segmentation is a more challenging problem both for the solution of appropriate algorithm and for obtaining accuracy. GA which is proved to be the most powerful optimization technique that allows us to obtain the global optimum solution in image processing.

Optimization is achieved by the natural exchange of genetic material between parents. The result of the optimization depends on the chromosome encoding scheme, genetic operators such as crossover and mutation and also the fitness function. Although it considers a large search space, a much smaller number of points is required to obtain the result. However, to obtain accurate solutions, length of the strings needs to be increased regardless of increasing computation time.

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