

A Genetic Algorithm Based K-Means Algorithm For Compressing Images

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Abstract: *In this paper, an evolutionary approach based Genetic algorithm, is adopted to find the initial seeds of K-means for compressing images. Genetic Algorithm is a kind of optimization technique inspired by the natural process of evolution, well suited to find true and approximate solutions for hard problems even with little knowledge of search space. The proposed method shows enhanced performance in terms of image quality, when applied to test images.*

Keywords: Genetic Algorithm, K-Means, Image Compression, Evolutionary Computing.

1. Introduction

The recent rapid growth of digital image applications has led to the need for their efficient storage and transmission. Compression of images is achieved by eliminating the inherent redundancy and irrelevancy in images. Image compression can be lossy or lossless. Lossless compression methods account for exact recovery of the original image whereas lossy compression methods reproduce images with minor loss in quality. Many novel algorithms have been proposed based on advanced computing techniques such as Discrete Cosine Transforms, Wavelet transforms, Block Truncation Coding, Fractal Coding and Vector Quantization[1-5]. Image compression standards JPEG and JPEG 2000 are Transform based methods which produce high quality images but at the cost of high computation complexity[4]. Vector Quantization is a simple lossy compression technique which produces good quality images with high compression ratio [5-8]. Moreover its low computation complexity has attracted the attention of researchers eventually increasing its number of applications as well[9-11]. Several methods have been proposed for compressing images based on VQ. Two novel, two stage vector quantization algorithms that employ an innovative approach to VQ using number patterns as the codebook have been proposed which outperforms JPEG in producing high quality images[6-7]. This method has been extended for compressing color images as well[8].

K-means clustering is one of the most widespread clustering techniques and it is also used for generating optimal codebook based on Vector Quantization. It has quite a large number of applications in the fields of image and video compression [12-16]. It's an iterative method to find the cluster centroids for each iteration to get the closest seed.

The two fundamental steps of K-means algorithm are initialization of cluster centroids (seeds) and convergence criteria. The most vital factor that determines the performance of K-means is selection of initial seeds. Inappropriate selection of seeds will lead to poor convergence, ultimately affecting the quality of the codebook.

Hence, research has been geared towards developing novel methods for initial seeds selection for K-means Clustering[17-20]. Two new methods have been proposed in [19]-[20] which select the initial seeds based on proper blend of statistical parameters mean, median and mode. In this paper, a new method has been proposed for finding the initial seeds of K-means clustering using Genetic algorithm (GA). Genetic algorithms are a particular class of evolutionary algorithms first introduced by J.Holland [21]. The method uses techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover.

GA's are found to be good in finding optimal and near optimal solutions for many function optimization problems. Moreover, their robustness of search in large search spaces and domain independent nature has intensified their applications in several fields like pattern recognition, machine learning, VLSI design, etc [22].

The rest of the paper is organized as follows: Section 2 describes the proposed method with an outline of genetic algorithm and K-means algorithms, Section 3 presents the results and discussion of the performance of the proposed method and Section 4 concludes with the future enhancements

2. The Proposed Method (Genetic K-Means)

The proposed method starts with the generation of optimum cluster centroids (seeds) using Genetic Algorithm in the first phase. The second phase uses the seeds generated from the first phase as initial seeds for K-means clustering algorithm and generates the final codebook (set of cluster centroids).

2.1 Basic Genetic Algorithm

A typical genetic algorithm requires two things to be defined:

- A Genetic representation of the solution domain, and
- A Fitness function to evaluate the solution domain.

A standard representation of the solution is as an array of of symbols typically a binary string.

The evolution process of GA usually starts from a population of randomly generated individuals or solutions known as chromosomes and happens in generations. In each generation, the fitness of every individual in the population is evaluated and multiple individuals are selected from the current population with a probability proportional to their fitness. The fitness function is defined over the genetic representation and measures the *quality* of the represented solution. The selected individuals (chromosomes) are then modified by applying genetic operators such as crossover and mutation to form a new population. The crossover operator produces a new offspring by exchanging segments of two selected parent chromosomes across a crossover point. The crossover operation is performed with a crossover probability specific to the problem domain. The mutation operator flips selected positions in the chromosome with a mutation probability that is again problem specific. The new population is then used in the next iteration of the algorithm. The algorithm terminates either with the maximum number of generations or having achieved a desired fitness value .

The basic Genetic algorithm is presented below:

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Produce an initial population of individuals
Evaluate the fitness of all individuals
while termination condition not met do
    select individuals with high fitness for reproduction
    recombine between individuals
    mutate individuals
    evaluate the fitness of the modified individuals
    generate a new population
End while

```

2.2 K-Means Clustering

The K-means algorithm is a extensively used VQ technique known for its efficiency and speed. This is an iterative clustering algorithm that generates a codebook which is a set of cluster centroids from the training data using an appropriate distance function suitable for the given application.

K-means comprises of four steps: initialization, classification, computational and convergence criteria. The objective is to minimize the total intra-cluster variance, or the squared error function E . The algorithm begins by selecting 'k' initial cluster centroids (seeds). Each data point is assigned to the nearest cluster based on distance measure. At the end of each iteration, new centroids for each cluster is computed by finding the mean of each cluster and this process is repeated until the convergence of criterion function [8]. The overall quality of clustering is the average distance from each data point to its associated cluster centroid. Typically, the K-means algorithm uses squared euclidean distance measure to determine the distance between an object and its cluster centroid[8]-[9].

2.3 Genetic K-Means Algorithm (GKM)

The input image is divided into 4x4 blocks and each 4x4 block is converted to 16-element vector. This set of vectors form the training set for construction of optimal codebook. The initial population of K vectors are chosen by applying the

roulette wheel selection operator of Genetic Algorithm. The Roulette wheel selection operator selects individuals from the population based on its fitness value. This algorithm uses the variance of each vector as its fitness value and the optimization criteria is maximization of variance. The initial population is then subject to application of genetic operators Crossover and Mutation. Next, crossover is performed on two randomly selected vectors from the initial population. The crossover points are chosen so as to lie between a given range $c1$ and $c2$. Good results are achieved for $c1=5$ and $c2=8$. Consequently mutation operation is performed depending on a specific mutation probability. Normally, a mutation probability 0.2 yields good convergence. The variance of each vector in the initial population is calculated and the fitness function is taken to be the global variance of selected vectors at the end of each iteration. The process is repeated until the fitness value is above the desired threshold or the maximum number of iterations is reached.

The steps of the proposed GKM algorithm is given as follows:

Phase I:

1. Divide the image into 4x4 blocks
2. Convert each block into 16-element vector
3. Divide the vectors into 'M' groups each having approximately equal number of vectors.
4. Pick 'N' vectors randomly from each group where $N=K/M$ which form the initial population of K vectors for applying k-means algorithm
5. Select vectors randomly from the initial population and apply crossover operation
6. Select the crossover points that lie within the given range $c1$ and $c2$
7. Apply Flip Bit mutation operation to selected individuals
8. Repeat steps 5 – 7 until good convergence or the maximum number of iterations is reached

Phase II

Perform K-means Clustering algorithm to generate the codebook using the K vectors resulting out of applying GA in the first phase

3. Results and Discussion

The performance of the proposed method is analysed by experimenting on compressing three different images of size 512 x 512 with 256 gray levels and 4x 4 initial block size. Our results clearly reveal that the proposed method yields good convergence with comparable image quality and compression ratio than the K-means random seeds selection method .The performance comparison of the proposed method GKM and K-means with random initialization of seeds are presented in Table 1.

Table 1. Performance Comparison of GKM and K-means

| Image | Performance Metrics | Method (K=200) | |
|-------|---------------------|----------------|-----|
| | | K-means | GKM |
| | | | |

| | | | |
|---------|----------------|-------|-------|
| Lena | PSNR | 32.72 | 32.91 |
| | Q | 0.681 | 0.707 |
| | bpp | 0.102 | 0.102 |
| | Time (in sec.) | 1500 | 142 |
| Lake | PSNR | 27.80 | 28.08 |
| | Q | 0.691 | 0.705 |
| | bpp | 0.125 | 0.103 |
| | Time (in sec.) | 206 | 172 |
| Peppers | PSNR | 30.8 | 31.29 |
| | Q | 0.635 | 0.691 |
| | bpp | 0.125 | 0.105 |
| | Time (in sec.) | 3160 | 195 |

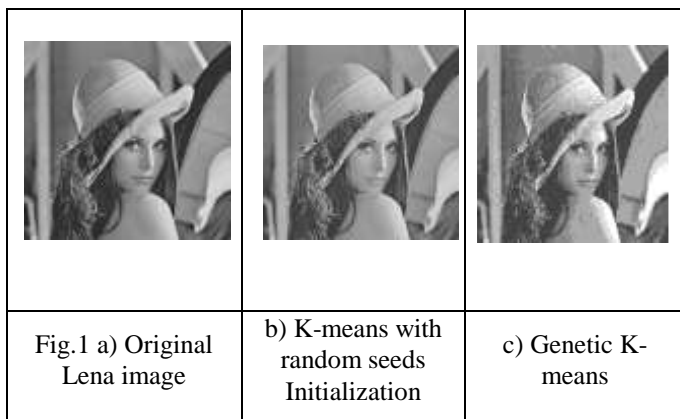
Image Quality is assessed by two important metrics *Mean Square Error (MSE)* and the *Peak Signal to Noise Ratio (PSNR)*. The MSE represents the cumulative squared error between the compressed image y_c and the original image y_o . The lower the value of MSE, the lower the error.

$$MSE = \frac{\sum(y_c - y_o)^2}{n} \quad (3)$$

PSNR is often used as a quality measurement between the original and the compressed image, measured in decibels, which is computed using the following equation:

$$PSNR = 20 \log_{10} \frac{255}{\sqrt{MSE}} \quad (4)$$

The higher the PSNR, the better the quality of the compressed, or reconstructed image. Table 1 shows that the proposed method GKM yields high PSNR value than K-means with random initialization of seeds. Moreover, GKM outperforms Random K-means even with low codebook size $C_n = 200$, thereby achieving good compression rate as well. The images of lena using the proposed method GKM and K-means have been shown in Fig. 1 for visual comparison.



4. Conclusion

In this paper, a novel method of K-means initial seed selection using Genetic K-Means has been proposed. Genetic Algorithm is a robust optimization technique based on evolutionary computing which is effectively used to find optimal initial seeds for K-means clustering for compressing images. Our

future work will be enhancing the performance further by applying genetic operators in different sequences and selecting the initial population using statistical parameters median and mode as well.

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Author Profile



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