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VQ-Codebook Enhancement using HGAPSO Algorithm

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A B S T R A C T

Linde–Buzo–Gray (LBG), a traditional method of vector quantization (VQ), makes a local optimal codebook, which has a lower PSNR value. Vector quantization (VQ) works best with the right codebook, so researchers came up with optimization methods to generate global codebooks. So, we came up with a hybrid optimization method called the Hybrid Genetic-PSO (HGAPSO) Algorithm to minimize on convergence time and computation by using the main features of both GA and PSO to find global optimal solutions. For the proposed technique, performance parameters like SSI, PSNR and MSE are used to figure out how well it works. The results of simulations are better when the HGAPSO algorithm is used.

Keywords: Vector quantization, Bat algorithm, PSO, Linde–Buzo–Gray.

Introduction

Because of improvements in medical engineering, digital acquisition of medical images tends to make the images clearer, which means that there is a lot more data to store [1]. So, in the current situation, data plays a very important role. The progress of technology is measured by how well people can control, send, and get information. Since sending images takes up most of the information measure, it takes more bandwidth to send them. Images need to be compressed so that they can be sent quickly and for less cost. Every year, the amount of information sent over the internet doubles, and most of it is images. If a system needs less bandwidth, it will save a lot of money and be easier to use.

In the Vector Quantization process, codebook training is important because a codebook affects the quality of image compression so much. Since Codebook training was so important, it gave many researchers a new boost, which led to a lot of new research on how to design Codebook using many different ideas [2]. Ayoobkhan et al. (2017) [4] showed a new method for lossy compression of medical images called PE-VQ. In this method, an artificial bee colony and genetic algorithms are used to build the codebook and find the best solutions. Prediction error and vector quantization are also used to effectively compress the images. It has been seen that, compared to the other algorithms, the proposed method can get a higher PSNR for a given compression ratio. Ahilan et al. 2019 [5] showed a method for lossless image compression based on classification and blending prediction. To find the area of interest, the optimization algorithm and multilevel thresholding are used together. Particle swarm optimization (PSO), Darwinian PSO (DPSO), and FODPSO are three different optimization algorithms that are used to find the best threshold value for medical image compression. Out of the three optimization algorithms, FODPSO gets the best results in terms of MSE, PSNR, and fitness value. Rani M.L.P et al. [6] has combined PSO and the firefly algorithm (FA) to make the global optimal codebook. In this method, the improved codebooks from PSO were optimised even more with FA, which led to high-quality images. The simulation shows that the PSNR has improved significantly by 1.2–6 dB. Rajpoot, et al.[7] made a codebook using an Ant Colony Optimization (ACO) algorithm, and the results were very interesting. This showed how much better the results were when ACO was mixed with LBG. Codebook is optimised by putting the vector coefficients in a two-way graph. Next, the ACO-LBG Algorithm describes a good way to put pheromones on the edges of the graph. Tsaia et al. [8] increased the speed of convergence of the ACO LBG algorithm by getting rid of the calculations that were already done. Particle Swarm Optimization (PSO) is also an adaptive swarm optimization method based on updating the global best (gbest) and local best (lbest) solutions. Many researchers have used PSO to solve optimization problems because it is easy to make improvements and quickly converges on the expected solution. The LBG algorithm's failings can be fixed with particle swarm optimization with vector quantization [9]. Compared to the LBG learning algorithms, the efficiency of evolutionary fuzzy particle swarm optimization algorithm [10] is a fast and reliable algorithm.

Image Compression using Vector Quantization (VQ)

Effective lossless and lossy compressions schemes can be attained by forming a single block (Grouping and encoding outputs of source). The blocks are viewed as vectors, and thus, it can be termed as ‘‘VQ’’ and it is a fixed to a fixed length method based on the principle of Block Coding’’. LBG has adopted a VQ modeling approach depending on a training model. The exploitation of the training sequence avoids the necessity for multidimensional integration, which is regarded as a major issue in modeling of VQ [3]. VQ is performed in 3 phases. They are, (a) Encoder, (b) Channel (c) Decoder. Its diagrammatic demonstration is revealed in figure 1.

It is made up of three blocks, and each one has a different working model. Block 1 in the encoder section is constituted of creating image vectors, indexing, and making a codebook. Image vectors are made by dividing the image into blocks that don't overlap and are instant. Creating an effective codebook is still the most important thing to do in VQ. It has a set of code words whose size is the same as the size of the block that doesn't overlap. A scheme is thought to be better if the codebook it makes is good. After the codebook is made, each vector will be given a number from the index table that will be used as its index. This information is sent to the receiver. At the receiver, the indexed numbers are broken down with the help of the receiver index table. At both the sender and the receiver, the codebook is almost the same. The received index numbers are given to the code words that go with them, and they are set up so that the size of the input image and the size of the reconstructed image are the same.

The main goal of the design of the codebook is to lower the bit rate during the process of encoding and decoding images for compression. In the traditional method, the LBG algorithm is used to make a local optimal codebook.

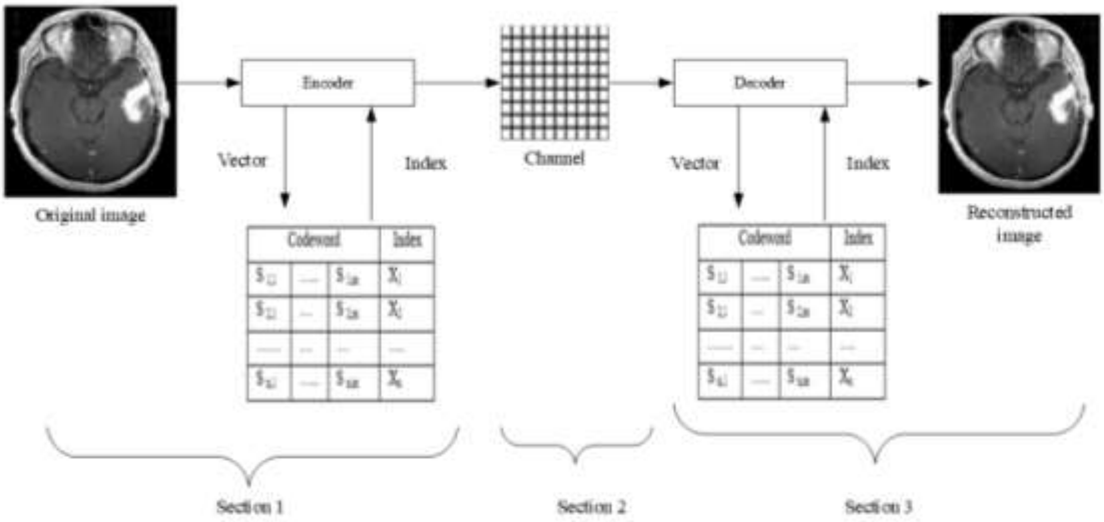


Fig. 1 - The overall process of VQ

Code book generation

The most frequently used VQ algorithm is generalized by Lloyd Algorithm (GLA) also called Linde – Buzo – Gray (LBG) algorithm. LBG are used for mapping function to partition training vectors in N clusters. The mapping function is defined as RK → CB. Where RK is the randomly generated codebook and CB is the codebook size. It generates a local codebook with minimum distortion.

The steps in LBG algorithm are given below,

Step 1: Initially, a random codebook with size of Nc and distortion D1=1 are taken

Step 2: Partition the input image training set/code vectors into clusters using the K-means clustering with nearest neighborhood condition

• Compute the Euclidean distance between first row vector of input image and all row vectors in the codebook. Each and every row vector of input image is represented $x_i= \{ x_{i1}, x_{i2}, \ldots x_{iL}\}$, where i = 1, 2, 3 … and code word of the codebook is denoted as $c_j=\{c_{j1}, c_{j2}, \ldots c_{jL}\}$, where j = 1, 2, …Nc.

• Note down these distances and find the minimum all distances and that index of minimum distance of codebook index is placed in the first index value of input image. It means that corresponding index of code word in codebook is nearer to the input image vector.

• This repeats for all the remaining rows in the image.

Step 3: Once all the input image vectors are completed, the centroids of the region of partition is computed as in step 2

The distortion d (x, Cj) between the input image vector x and code book Cj=1,2,3…Nc is calculated at encoder block. The index of the code word vector/codebook with nearest neighbour rule is transmitted to the decoder if distortion is less. The index table of all vectors of input image is transmitted to the receiver.

Methodology

There is no assurance that the final codebook generated through LBG algorithm will be globally optimum. In this approach the final codebook will optimized using HGAPSO algorithm. However, evolutionary algorithms such as the Genetic Algorithm and PSO, which are well recognized for their strong global optimization, can handle such a problem. The proposed methodology combines the traditional LBG with HGAPSO for global and local optimal search. Both Genetic Algorithm & PSO are iterative mechanisms based optimization techniques. The Hybrid Genetic and PSO scheme proposed is based on the cascaded architecture. Where both GA and PSO operate on the same population and GA creates a perfect model for PSO from which particles in PSO are guided to evolve the model. Genetic Algorithm operations together with well-diversified PSO particle knowledge will improve the search efficiency of both PSO and Genetic Algorithm and prevent the algorithm from converging prematurely. With this arrangement PSO and Genetic Algorithm divide the same number of iterations evenly. Initially, LBG algorithm is used to generate the codebook with minimum distortion or any stopping condition is satisfied. For Genetic Algorithm, the codebook generated using LBG algorithm is used to define the chromosome genes. The genetic algorithm comprises three operations such as Tournament selection, the Arithmetic crossover and the uniform mutation. The genetic algorithm evaluates each individual in the population based on fitness function and the individual with the least fitness are replaced with the best performing individuals through crossover and mutation operations. The search space in PSO consists of population of the particles that corresponds to individuals in genetic algorithm. In each iteration, the PSO uses the solution given by the genetic algorithm to update the particles in the search space to find best P_{best} and g_{best}. The genetic and PSO algorithms stops its execution if the distortion can't be further reduced or any stopping condition is satisfied. The best solution obtained is stored as the coodbook for further compression and decompression.

Algorithm:

Step 1: Run the LBG algorithm by initializing the size of the codebook and generate minimum distortion codebook. Save the codebook for optimization.

Step 2.1: Initialize the Genetic Algorithm to generate model for PSO using selections, crossover and mutation operator. Assign the codebook generated as the individuals of GA randomly

Step 2.2: Use the model of Genetic Algorithm as input to PSO and evaluate.

Step 2.3: Repeat

Step 2.4: If no more improvement with usage of Genetic Algorithm and PSO is achieved or any stopping condition achieved.

Step 2.5: Stop the algorithm.

Step 3: Save the optimized codebook for further compression and decompression.

Step 4: End

Results

In this paper, experiments have done for the design of enhanced codebook for the efficient compression of images. These experiments have done on the gray scale medical images of brain image collected from BraTS dataset 2018. For evaluation of the results, the original data is compared with the compressed data.

The various quality metrics describes the performance of compression techniques are given below. The excellence of proposed approach for image compression is compared with other optimization techniques using the quality parameters i.e. PSNR, MSE, SSIM.

MSE: It gives the measure of degradation of reconstructed image quality as compared to the initial image. It is outlined in equation given below.

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}[I(i,j) - I'(i,j)] \quad (1)$$

Where M × N is the total number of pixels in the image. I (i, j) is the input image. I′(i, j)is output decompressed image.

PSNR: It defined as follows

$$PSNR = 10\,log_{10}(\frac{255\times255}{MSE}) \quad (2)$$

SSIM: It is a quality assessment metric predicted on the computation of luminance, contrast and structural terms.

$$l(i,j) = \frac{2\mu_i\mu_j + c_1}{\mu_i^2 + \mu_j^2 + c_1} \quad (3)$$

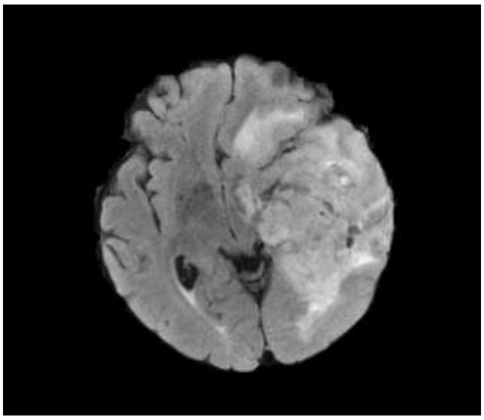
$$c(i,j) = \frac{2\sigma_i\sigma_j + c_1}{\sigma_i^2 + \sigma_j^2 + c_1} \quad (4)$$

$$s(i,j) = \frac{\sigma_{ij} + c_3}{\sigma_i\sigma_j + c_3} \quad (5)$$

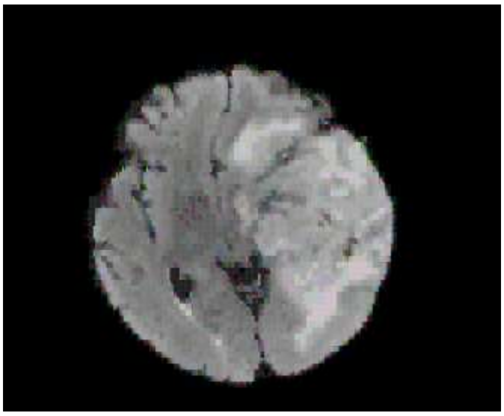
$$SSIM = \frac{(2\mu_i\mu_j + c_1)(2\sigma_{ij} + c_2)}{(\mu_i^2 + \mu_j^2 + c_1) + (\sigma_i^2 + \sigma_j^2 + c_2)} \quad (6)$$

c_1, c_2, c_3 are the regularization constant terms for the luminance, contrast, and structural terms. i, j are mean intensity values and i, j are the standard deviation values of two images. ij is the covariance of the two images.

Figure 2 represents original MRI image and the corresponding decompressed image of proposed brain MRI image.



(a) Original image



(b) Decompressed image

Fig 2- (a) Input image (b) Decompressed image of proposed approach

Table 1- Quality evaluation metrics with different code book sizes using proposed approach

Codebook size	**PSNR**	**MSE**	**SSIM**
8	45.1269	15.9763	0.99835
16	48.2364	15.6156	0.9983
32	51.2015	15.7789	0.9977
64	54.2379	15.6844	0.99741
128	57.216	15.8011	0.99743
256	60.2215	15.8185	0.99741
512	63.2306	15.8231	0.99749
1024	66.2364	15.8393	0.99755

Table 2- Comparison of PSNR values

Codebook	**LBG**	**Proposed**
8	30.16	45.1269
16	34.26	48.2364
32	35.89	51.2015
64	40.75	54.2379
128	38.65	57.216
256	36.79	60.2215
512	42.11	63.2306
1024	50.01	66.2364

CONCLUSION

Efficient image compression techniques are becoming very vital in areas like pattern recognition, image processing, system modeling, data mining, etc. Compression techniques have become the most concentrated area in the field of medical. Image compression is a technique of efficiently coding digital image to reduce the number of bits required in representing an image. The present research work proposes the optimal technique for image compression using vector quantization. Code book generation using vector quantization is the principal step in this work. The present research work uses effective optimization technique named HGAPSO algorithm for the optimization of code book generated from LBG algorithm. To attain better quality of the image.

The performance of the proposed approaches is evaluated on the basis of parametric standards like SSI, MSE and PSNR value. The performance is compared to the standard approaches like LBG. It is clearly observed from the experimental results that the proposed approach has superior performance. For performance evaluation, BRATs dataset were used.

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