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Survey of PCA, DWT, K-means and Novel K-means algorithm for Image Processing

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Abstract— Image processing is done by using various algorithms like PCA (Principle component analysis), DWT (Discrete Wavelet Transform), K-means and Novel K-means. These algorithms are used according to the requirements of the image processing methodology. In this paper a survey of these algorithms is proposed to usage in image processing techniques. It has been found that PCA outperform DWT in terms of MSE, PSNR and Fragility. In Novel K-means selection of initial seeds is based on variance, mean, median and mode parameters. This approach shows better performance yielding good PSNR and variable bit rate at a very low time complexity than K-means clustering approach.

Index Terms— DWT, K-means, Novel K-means and PCA.

1 INTRODUCTION

1.1 Discrete Wavelet Transform

Discrete Wavelet Transform DWT is multi-resolution decompositions that can be used to analyse signals and images. It describes a signal by the power at each scale and position. DWT has been proved to be a very useful tool for image compression in the recent years. Wavelet transform exploits both the spatial and frequency correlation of data by dilations (or contractions) and translations of mother wavelet on the input data. It supports the multi-resolution analysis of data i.e. it can be applied to different scales according to the details required, which allows progressive transmission and zooming of the image without the need of extra storage. Another encouraging feature of wavelet transform is its symmetric nature that is both the forward and the inverse transform has the same complexity, building fast compression and decompression routines. Its characteristics well suited for image compression include the ability to take into account of Human Visual System's (HVS) characteristics, very good energy compaction capabilities, robustness under transmission, high compression ratio etc.

The implementation of wavelet compression scheme is very similar to that of subband coding scheme: The first stage of the DWT converts an image into four sub-bands by applying low-pass and high-pass filters to the image followed by down-sampling by a factor of two. The resulting coefficients grouped into four zones, where H symbolizes high frequency data and L symbolizes low frequency data.

The advantage of wavelet transform, it is that divides the information of an image into decomposing images to approximate subsignals (LL) and detail subsignals (LH, HL, HH) parts as shown in Fig.2 . This enables to isolate and manipulate the data with specific properties. With this, it is possible to determine whether to preserve more specific details. For instance, keeping more vertical detail instead of keeping all the horizontal (LH), vertical details (HL) and diagonal (HH) of an image that has more vertical aspects. This would allow the image to lose a certain amount of horizontal and diagonal details, but would not affect the image in human perception.

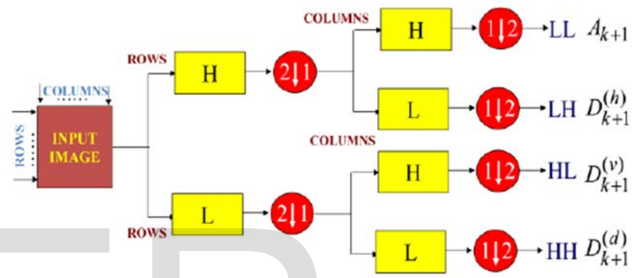

FIG.1: The Two-level Sub-band Decomposition Used in the DWT

There are a lot of wavelet filters like, Daubechies wavelets, Coiflets, biorthogonal wavelets, and Symlets. These various transforms are different in mathematical properties such as symmetry, number of vanishing moments and orthogonally [1].

1.2 Principle Component Analysis

PCA (Principle Component Analysis) is widely used in image processing, especially in image compression. Also, it is called the Karhunen-Leove transform KLT or the Hotelling transform. Principal components analysis PCA is a statistical procedure that allows finding a reduced number of dimensions that account for the maximum possible amount of variance in the data matrix. The PCA basis vectors are the eigenvector of the covariance matrix of the input data. This is useful for exploratory analysis of multivariate data as the new dimensions called principal components PCs. A reduced dimension can be formed by choosing the PCs associated with the highest eigenvalues. So, we can consider KLT as a unique transform which decorellates its input.

Calculating a principal components analysis is relatively simple and depends on some characteristics associated with matrices eigenvalues and eigenvectors. To calculate the PCA we first estimate the correlation matrix or covariance matrix of the image array. The next step is to calculate the eigenvalues of the matrix. Each eigenvalue can be interpreted as the variance associated with a single vector. The next step is to calculate the eigenvectors associated with each eigenvalue. Each eigenvector represents the factor loading associated with a specific eigenvalue. By multiplying the eigenvector by the square root of

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the eigenvalue. This is all the information we need to begin to apply PCA. Finally, we need to select the number of eigenvectors needed to explain the majority data of the image. We simply select the eigenvectors associated with the largest eigenvalues to represent a sufficient amount of the image data [1].

1.3 K-means clustering

The k-means algorithm is an algorithm to cluster objects based on attributes into k partitions. The objective is to minimize total intra-cluster variance, or the squared error function.

$$V= \sum_{i=1}^{k} \sum_{x_j \in s_i} \left| X_j - \mu_i \right|^2 \quad (1)$$

where there are k clusters S_i, i = 1, 2,..., k and μ_i is the centroid or mean point of all the points in cluster S_i .The algorithm starts by partitioning the input points into k initial sets, either at random or using some heuristic data. It then calculates the centroid of each set and constructs a new partition by associating each point with the closest centroid. Then the centroids of each set are recalculated and the algorithm is repeated by alternate application of these two steps until convergence, which is obtained when the points no longer switch clusters (or alternatively centroids are no longer changed).

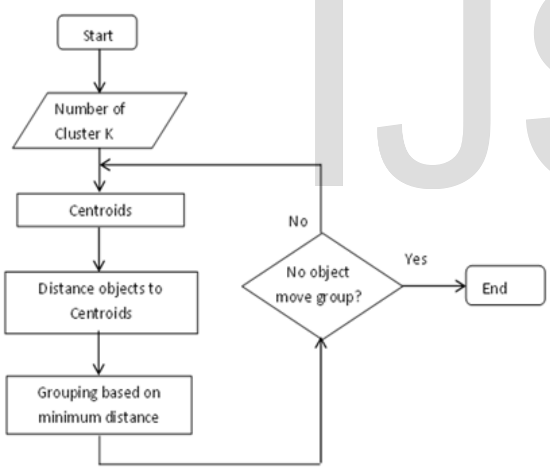

FIG.2: K-MEANS FLOWCHART

Despite its efficiency, t has drawbacks like apriori fixation of number of clusters and random selection of initial seeds. Inappropriate choice of initial seeds may yield poor results and leads to increase in computation time for convergence [4].

1.4 Novel K-means clustering

It adopts divide and conquer strategy by dividing the input data space into classes and apply K-means clustering. Novel K-means segments input image into K clusters and works in two phases as follows. In the first phase, the input vectors are divided into N classes based on the mean value of each vector. A training vector is assigned to a class C_I, if its mean value is less than or equal to the domain of C_I. This mean based grouping of input data speeds up convergence resulting in reduction of computation time.

K-Means algorithm is performed on each class of vectors with initial seeds. The number of initial seeds M in each class is proportional to its size. The initial seeds are selected with the right blend of statistical features (variance, mean, median and mode) of the class population [4].

2 EXPERIMENTAL ANALYSIS

The authors [2] proposed a survey on available video watermarking techniques, feasibility study on watermarking techniques meeting the requirements and the transformations that have also been explored for watermarking such as principal component analysis (PCA) and the recent trend to combine the DWT with other algorithms to increase robustness and invisibility. They also suggested that PCA is a linear transformation that chooses a new coordinate system for the data set. It has the advantage of high energy concentration and complete decorrelation which it is suitable for data hiding. PCA has been used in different ways in image and video watermarking methods. The performance analysis done on the image for watermarking technique using DWT and PCA was as given as in table 1.

TABLE 1[2]:
Performance analysis of different video watermarking techniques.

	PCA	DWT
Robustness	Good	Good
Imperceptibility	Good	Good
Fragility	Good	Average
PSNR	Good	Good
Normalized correlation	Good	Good
Tamper-resistance	Good	Average

Other experiments [3] were performed based on 10 image sets. Each image set consisted of 11 images obtained by fusion using each of the algorithms. The images were, typically, multi focal and multi spectral images. The performance of the different fusion algorithms are evaluated as stated in table 2.

TABLE 2[3]:
Image metrics readings for one image set.

	PCA	DWT
MSE	177.17	244.79
PSNR	25.64	24.24
Average Difference	-9.51	-14.39
Structural Content	0.85	0.83
Normalized Cross Correlation	1.08	1.09
Maximum Difference	84	84
Normalized Absolute Error	0.09	0.12
Laplacian Mean Squared Error	0.2	0.1
Structural Similarity Image Metric	95.24	96.06

	means				

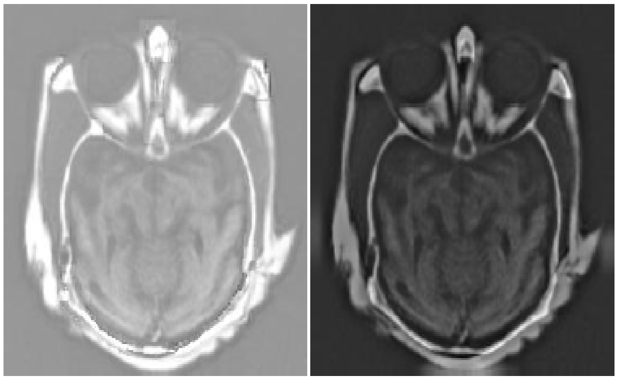

FIG.3: FIG. FUSED IMAGE BY SELECT MINIMUM METHOD (LEFT) AND PCA METHOD (RIGHT).

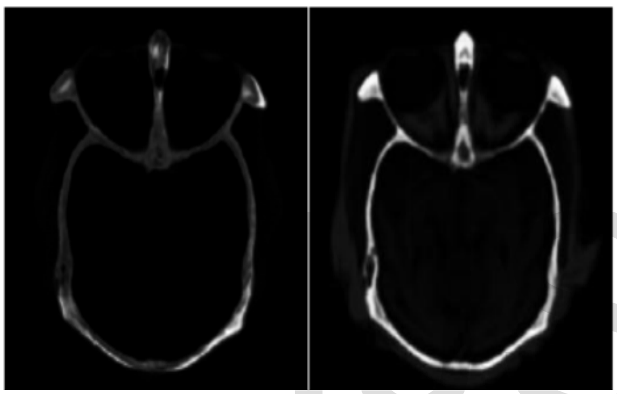

FIG.4: Fused Image by Select Morphological Pyramid Method (left) and DWT with Haar Method (right)

Author [4] proposed method is a two phase scheme that enhances the performance of K-means vector quantization algorithm for compressing images**.** In the proposed method, they have explored the possibility of application of statistical parameters for choosing the initial seeds for K-means algorithm. The selection of initial seeds depends on the statistical features of input data set (variance, mean, median and mode parameters).

TABLE 3 [4]:
Comparative Performance of K-means and Novel K-means

Image	Method	Break-Even Point (N)	Computation time	Bit rate	PSNR
Barbara	K-means		2075	0.125	28.2
	Novel K-means	4	322	0.123	25.18
Boat	K-means	-	362	0.125	31.4
	Novel K-means	8	150	0.121	31.3
Peppers	K-means		3160	0.125	31.4
	Novel K-means	8	762.59	0.119	31.322
Couple	K-means		1196	0.125	28.898
	Novel K-	8	699	0.124	28.908

3 CONCLUSION

This survey paper discusses various compression algorithms for image processing such as PCA, DWT, K-means and Novel K-means. It has been found that PCA provide better results than DWT in terms of MSE, PSNR. Also Novel K-means outperforms traditional K-means with random choice of initial seeds significantly in terms of computation time with comparable PSNR and bit rate.

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