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## Face Recognition in compressed domain based on wavelet transform and kd-tree matching

By Menila James, Dr.S.Arockiasamy

*University of Nizwa*

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**GJCST Classification:** I.5.4, I.4.6



*Strictly as per the compliance and regulations of:*



# Face Recognition in compressed domain based on wavelet transform and kd-tree matching

Menila James<sup>a</sup>, Dr.S.Arockiasamy<sup>Ω</sup>

**Abstract** - This paper presents a novel idea for implementing face recognition system in compressed domain. A major advantage of the proposed approach is the fact that face recognition systems can directly work with JPEG and JPEG2000 compressed images, i.e. it uses directly the entropy points provided by the compression standards as input without any necessity of completely decompressing the image before recognition. The Kd-tree technique is used in the proposed approach for the matching of the images. This algorithm shows improvement in reducing the computational time of the overall approach. This proposed method significantly improves the recognition rates while greatly reducing computational time and storage requirements.

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## I. INTRODUCTION

Face recognition [1][2][3] is playing a key role in the research areas of pattern recognition and computer vision due to its capable applications such as personal identification, bankcard verification, automated surveillance etc. So far, various face recognition systems have been proposed but still research is going on in the field of face recognition as it has various inherent complexity associated with environmental changes and subject actions (facial expressions and head pose variations), etc. The performance of face recognition systems mainly varies corresponding to the environment where face images are taken. These Face recognition approaches normally use visible spectrum images for recognition because they provide clear representation of facial features and face texture to differentiate between two individuals.

With the growth of internet and multimedia, compression techniques have become the popular research area in the field of Image processing. But, there are very few researchers have concentrated on to investigate the effect of compression on face recognition, even though the images are mainly stored and/or transported in a compressed format. Image Compression is an area of face recognition which needs more attention since the adoption of face recognition as

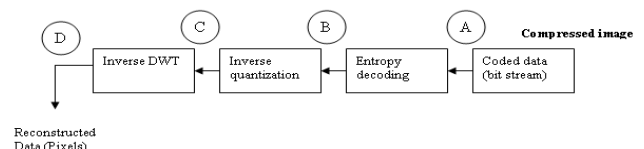
part of the e-passports which use face images as one of the three identifiers along with fingerprints and iris scans being the other two. Mainly, the compression of images are essential in face recognition due to the advantages such as ability to store compressed images on smart cards and low-capacity chips, easy to transmit image to a distant server for verification and improved computational speed [4]. Moreover, image acquisition equipment also often delivers the compressed images as its output. So, to work directly in existing compressed domain has its valid reasons as well. For the stored (or derived) image of the unknown individual to be identified it has to be compared to one or more images of known individuals. Decompressing all those images (including the unknown one) is very computationally intensive. Thus, avoiding full decompression process could be very advantageous when compared to the existing techniques [5].

## II. BACKGROUND

### Image Compression Technique Using Wavelets

The most widely used standard image compression techniques are JPEG [6] and JPEG2000 [7]. These image compression standards have been employed in face recognition systems in past few years. Usually, compression is vital for any reasonable implementation where a large quantity of images need to be stored. All modern image coders are considered to be transform coders. The Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) are examples of those transforms methods. Both JPEG and JPEG2000 have been using the general transform coding scheme as shown in Figure 1.

The input signal is first encoded as bit stream using an invertible transform, and then quantized and entropy coding has been done. The rate distortion unit controls the quantization to minimize the distortion within the available bit rate. These stages have an impact on the image quality achieved in terms of compression ratio. A better transform will provide improved compression performance [8].



**About<sup>a</sup>**- Senior Lecturer, Department of Computing, Muscat College, Sultanate of Oman.

menilajames@muscatcollege.edu.om

**About<sup>Ω</sup>** Head, Department of Information Systems, University of Nizwa, Sultanate of Oman.

arockia99@gmail.com

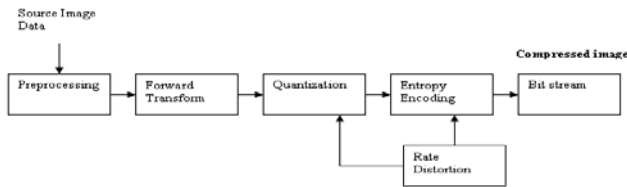


Figure 1: Block diagram of compression /decompression in transform coding

In decompression process, the data must be entropy decoded first, inverse quantized and then inverse transformed in order to reconstruct an original image. This resultant image may be with a poor quality due to information discarded during compression. In figure 1, point D represents image pixels and point A represents fully compressed domain. The resulting reconstructed images will have a checker-board or the smear effect.

As the transform coefficients that represent higher frequencies are more and more discarded (or are rounded to lower precision) with higher compression rates, the images become more and more low-pass filtered. This is clearly observed in the JPEG2000. For example at 0.2 bpp, the finer details of the face (like wrinkles) were eliminated in the reconstructed image. Thus it is observed that, low-pass filtering can greatly affect the recognition results [9].

The magnitude of compression is mainly calculated by *compression ratio*, expressed in the form of *bits per pixel* (bpp). The performance of the compression technique can be effectively measured by Peak Signal to Noise Ratio (PSNR), and calculated as:

$$PSNR = 20 \log \left( \frac{2^n - 1}{RMS} \right) \text{ [dB]}$$

where  $n$  is the number of bits per pixel in the original image and RMS is the Root Mean Square Error defined as:

$$RMS = \sqrt{\frac{1}{N} \sum_{i=1}^N (I_i - I'_i)^2}$$

where  $I_i$  is pixel value in the original image,  $I'_i$  is corresponding pixel value in the reconstructed image and  $N$  is the total number of pixels in the image.

The basic image compression technique usually takes high computational time for stored image of the unknown individual and it can be recognized if it is compared to one or more images of known individuals. Moreover, decompressing all those images will be very difficult; this leads to a novel idea of image compression technique which will avoid the difficult position in the decompression domain.

### III. RELATED WORK

In Ekenel, H.K. et al. [10], the face recognition system that can be deployed for real-life smart interaction applications have been described. This system is capable of developing a fast and robust fully automatic face recognition system. The algorithm is mainly based on the appearances of local facial regions that are represented with the coefficients of discrete cosine transform. There are three fully automatic face recognition systems have been formulated based on this algorithm. The first device is the "Door monitoring system" which is formulated based on this algorithm that records everything which is entering into the room and identifies the subjects. The second device is "portable face recognition system" which recognizes the user of a machine. The third system "3D face recognition system" which operates fully automatic face recognition on 3D range data.

Rabab M. Ramadan et al. [11] have presented Face recognition comprises of many applications which are ranging from security access to video indexing by content. Here they described about the VQ-based automatic face recognition system and which analyze the feature selection effects, codebook size and feature dimensionality on recognition performance in the VQ-based framework. In specific, the DCT-based feature vectors are examined in such a system. Directly the recognition can be performed on the bit stream of the DCT based compressed images. The system comprises of three parts: a preprocessing step which is accomplished to segment the face, then the feature selection process and finally the classification. A database which comprises of 500 images could be recognized with high accuracy.

In a study conducted by Delac in 2007 [12], the feasibility of implementing face recognition algorithms directly into JPEG2000 compressed domain was examined and CDF 9/7 wavelet was used in the study. The Standard face recognition algorithms PCA, ICA and LDA were fed with CDF 9/7 wavelet and also FERET database was used. It was proved that no significant drops were observed and the authors claimed that face recognition algorithms can be directly implemented in JPEG2000 compressed domain. The authors also recommended further research for finding a way to intelligently extract feature vectors within compression scheme or finding another mechanism for image matching in order to improve recognition performance. This proposed method continues the study reported in this paper.

## IV. PROPOSED METHODOLOGY

The proposed methodology uses the entropy points as the input to the face recognition system as in PCA. The original image is transformed using the DWT and quantization and entropy coding is done on the coefficients. The proposed approach eliminates major part of the decompression phase.

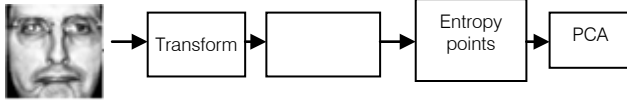


Figure 3: Face Recognition in Compressed Domain

It is very vital to define the compressed domain as it plays a key role in this research. The Compressed domain is any point in the compression / decompression procedure after transform and before inverse transform.

The clear approach to transport face recognition into the compressed domain is to stop the decompression process before the inverse transformation and to utilize coefficients as input to face recognition approaches. The inverse quantization as well as the inverse transformation is removed.

There is no change in the performance when using the inversely transformed coefficients. When the inverse quantization is eliminated some additional computation time was saved. For the experimental observation, all the coefficients available after the entropy decoding were used. In case of the normalized 128 x 128 sized images, all 1195 coefficients per image were used as input to PCA [13].

### Improved Matching by Kd tree

The K-dimensional tree (kd-tree) is a space-partitioning data structure for organizing points in a k-dimensional space. This method is a widely used data structure in various applications like exploration which involves multidimensional search key (e.g. range searches and nearest neighbor searches). The kd-tree methods are considered as a special case of BSP trees. In this proposed approach, kd tree is used for improved matching of the face recognition algorithms.

**Kd-tree Algorithm:** Given a list of  $n$  points, the following algorithm will construct a balanced kd-tree containing those points.

Algorithm Build Kd tree ( $P$ ,  $depth$ )

Input: A set of points  $P$  and the current  $depth$ .

Output: The root of a kd-tree storing  $P$ .

1. If  $P$  contains only one point
2. then return a leaf storing this point
3. Else if  $depth$  is even
4. then Split  $P$  into two subsets with a vertical line  $l$  through the median  $x$  coordinate of the points in  $P$ . Let  $P_1$  be

the set of points to the left of  $l$  or on  $l$ , and let  $P_2$  be the set of points to the right of

$l$ .

5. Else Split  $P$  into two subsets with a horizontal line  $l$  through the median  $y$ -coordinate of the points in  $P$ . Let  $P_1$  be the set of points below  $l$  or on  $l$ , and let  $P_2$  be the set of points above  $l$ .

6.  $V_{left} \leftarrow \text{BUILDKDTREE}(P_1, depth+1)$

7.  $V_{right} \leftarrow \text{BUILDKDTREE}(P_2, depth+1)$

8. Create a node  $V$  storing  $l$ , making  $V_{left}$  the left child of  $V$ , and make  $V_{right}$  the right child of  $V$ .

9. Return  $V$

### Complexity

- Constructing a static kd-tree from  $n$  points takes  $O(n \log^2 n)$  time if an  $O(n \log n)$  sort is used to calculate the median at each level. The complexity is  $O(n \log n)$  if a linear median-finding approach.
- Inserting a new point into a balanced kd-tree takes  $O(\log n)$  time.
- Removing a point from a balanced kd-tree takes  $O(\log n)$  time.
- Querying an axis-parallel range in a balanced kd-tree takes  $O(n^{1-1/k} + m)$  time, where  $m$  is the number of the reported points, and  $k$  the dimension of the kd-tree.

Thus from the complexity information, it is found that compared to Euclidean distance which was used in earlier studies for recognition purpose, the proposed kd-tree matching technique takes less time.

## V. EXPERIMENTAL SETUPS AND RESULTS

### Database and protocol

To implement the proposed idea, a Standard FERET data [13] set is utilized in this paper for evaluating the proposed technique which includes the data partitions for recognition tests, as represented in [14]. This dataset contains 1,196 images and also four sets of query images that are matched to the dataset images in identification phase. The fb probe set consists of 1,195 images of subjects obtained at the same time as dataset images with the only dissimilarity being that the subjects were told to suppose a various facial expression.

The fc probe set consists of 194 images of subjects with various illumination cases. The dup1 (duplicate I) set consists of 722 images taken somewhere between one minute and 1,031 days after the dataset image was obtained, and dup2 (duplicate II) set is nothing but a subset of dup1 which consists of 234 images obtained at minimum 18 months after the dataset image was obtained. Every image in the data

set is of size  $384 \times 256$  pixels and represented in grayscale.

### Preprocessing

There are several well known appearance-based subspace face recognition algorithms like Principal Component Analysis (PCA) [15], Linear Discriminant Analysis (LDA) [16] and Independent Component Analysis (ICA) [17].

The Original FERET images are initially transformed spatially to obtain the eyes at the fixed points depending on a ground truth file of the eye coordinates provided with the original FERET data. Each and every image is then cropped to size of  $128 \times 128$  pixels and an elliptical mask was utilized to mostly to remove the background. At last, image pixel values were histogram equalized to the sort of values between 0 and 255. These preprocessing processes are performed on each image earlier to carry out the experiments even before compression.

In training the PCA algorithm, a subset of classes that there are three images per class was utilized. It is identified that there are 255 such classes which represent 255 various persons, thus the training set contain total of 675 images with 3 images per person ( $M = 675, c = 225$ ).

The outcome of this process is that this percentage of overlie has on the performance of this algorithm requires additional examination. The result of PCA algorithm according to the theory is ( $M - 1 = 674$ ) meaningful eigenvectors. The FERET suggestion is assumed and reserved the top 40% of those, consequence in 270-dimensional PCA subspace  $W$  (40% of  $674 = 270$ ). It was obtained that 97.85% of energy was preserved in those 270 eigenvectors.

The performance of the proposed approach compared to the existing image compression algorithms were evaluated by the performance measure called the Normalized Recognition Rate (NRR).

In Figure 3, it shows the graphical representation of the NRR of the proposed method compared to the existing method. It is clearly observed from the graph that the proposed approach shows the improvement in the NRR compared to the existing recognition technique.

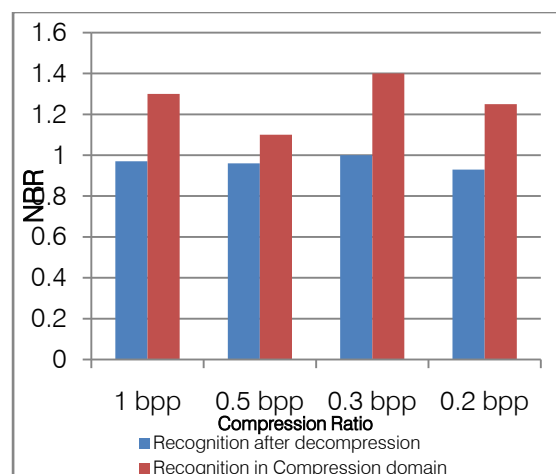


Figure 3: NRR evaluation of the proposed approach

The computational time of the proposed approach using the kd tree method is compared with the existing techniques in figure 4. The kd-tree takes very less computation time when compared to the recognition rate of the existing approach.

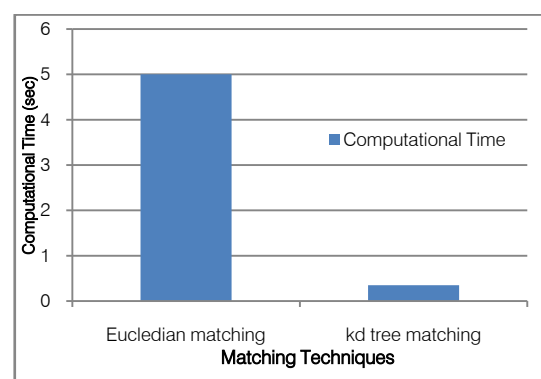


Figure 4: Comparison of the Computational Time

## VI. CONCLUSION

This paper presents systematic approach of implementing face recognition methods directly in compressed domain. All the aspects that can occur in such circumstances, ranging from the effects of compression on recognition rate to technical implementation issues like computational time and storage requirements savings were analyzed.

The experimental results proved that implementing the standard recognition method such as PCA directly in compressed domain will not deteriorate recognition results. All the experimentation results in compressed domain illustrated in this paper were compared to the results in pixel domain i.e. using either uncompressed or fully decompressed images.

Moreover, the proposed approach uses the kd-tree method for the face recognition comparison. This algorithm effectively reduces the computational time to a very great extent. Thus the proposed approach provides



significantly improved performance in terms of both computational time and NRR.

The scope for further improvement of this work will consist of analyzing the influence of proposed methodology on the result of performance for known face recognition algorithms using Linear Discriminant Analysis (LDA) and Independent Component Analysis (ICA). This could be implemented by testing on various images from different databases for generalization.

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