Human Face Recognition in wavelet compressed domain using Canonical Correlation Analysis

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ABSTRACT
This paper explores the possibility of implementing face recognition systems directly into wavelet based compressed domain. This is accomplished by stopping the decompression process after entropy decoding and providing the entropy points to face recognition systems as input. A novel approach for efficient face recognition in compressed domain has been implemented using 2-dimensional Canonical Correlation Analysis. CCA is a powerful multivariate analysis method and hence a powerful feature projection approach for compressed facial images based on CCA is proposed. Matching of image data is done by Mode based Matching method. The experimental results proved that the proposed method considerably improves the recognition rates and also reduce the computational time and storage requirements.

General Terms
Image Processing, Face Recognition, Compression.

Keywords
Face recognition, compressed domain, wavelet transform, Canonical Correlation Analysis (CCA).

1. INTRODUCTION
Automatic Face recognition as a biometric method is an extensively researched area in Computer Science and turned out to be one of the most flourishing applications of image processing [1]. Face recognition is a biometric technology which recognizes the human by his/her face. Performing human face recognition is a complex and highly challenging problem due to variety of parameters like illumination, pose, expression, aging image occlusion etc. [2, 3]. As a biometric method, face recognition acquires the qualities of both high precision and low intrusiveness [4]. It has the very huge accuracy of a physiological approach without being intrusive [5].

Uncompressed high resolution still images were used in face recognition research until recently. With the growth of internet and multimedia, compression techniques have become the popular area in the field of image processing. More research work is to be done in order to explore the effect of image compression in face recognition as mostly face images are stored and transported in compressed format. Compression is an area of face recognition which needs more attention since face recognition is accepted as an element of e-passports which in turn use face images as an identifier.

Compression of images are essential in face recognition due to major 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 also of improved computational speed [6]. Moreover, the output of the image capturing equipments is mostly compressed images. For identification, the query image is to be compared with one or more images of known individuals. This process is time consuming as decompression of images is very computationally extensive. Thus, avoiding full decompression process is very advantageous when compared with the existing techniques as it solves the real time implementation needs such as storage requirements and computational speed [7].

This paper is discussed in five sections. Section II presents related work analysed for face recognition in compressed domain and section III discusses the proposed methodology. Experimental results are listed in section IV and section V finally concludes and suggests the scope for future enhancements.

2. RELATED WORK
A study on human recognition in wavelet compressed domain was done by Sabharwal and Curtis [8]. Daubechies 2 wavelet was used in this experiment. The obtained filter coefficients were used as input to the standard classification technique PCA. Increase in recognition rate was noticed compared to PCA with uncompressed facial images.

Multi resolution analysis to the face recognition performance was examined by Ekenel and Sankur [9] by applying Daubechies 4 wavelet decomposition on recognition algorithms PCA and ICA. The main purpose of this study was to find out the subbands that are least sensitive to the variation in expression and illumination. In the experiments with images taken in different illumination conditions shown good performance score when DWT coefficients were used. On the other hand testing with images of varying expressions shown no major difference when DWT coefficients were used.

In studies conducted by K. Delac in 2007[10] and later in 2009[11], the feasibility of performing face recognition algorithms in JPEG2000 compressed domain was examined. The standard face recognition algorithms PCA, ICA and LDA were fed with CDF 9/7 wavelet which is an element of JPEG2000 compression standard. Experiments were conducted with standard FERET database and 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 recommend further research for finding a method that extract feature vectors more efficiently within compression scheme or finding another mechanism for image matching for better recognition performance.

Recently the Canonical Correlation Analysis (CCA) stir up the interest of biometrical experts in human recognition as a method which helps to relate sets of observations describing different aspects of appearance. CCA gives a high dimensional relationship between two sets of multi dimensional variables with a few pairs of canonical variables [12]. It was intended to describe relations between two sets of one dimensional data sequences. This method has been widely used in several fields such as signal processing [13] and

pattern recognition. Compared to Principal Component Analysis (PCA) [14] and Linear Discriminant Analysis (LDA) [15], CCA can deal with two sets of data. Two dimensional face recognition based on CCA is implemented by Dominic and Robert [16] and was tested on 20 subjects from FERET database. Test results of this approach gave a very good recognition rate for FERET database.

These papers encouraged us to explore the possibility of using JPEG2000 compression scheme and Canonical Correlation Analysis for performing face recognition in fully compressed domain which is fast and accurate.

3. PROPOSED METHODOLOGY

The proposed methodology to perform face recognition in compressed domain uses wavelet transform based compression scheme, Canonical correlation analysis based feature projection technique and Mode based Matching method for matching of images.

Describing compressed domain is very important as it plays a key role in this research. Any point in the compression/decompression scheme after transform coding and before inverse transform is defined as compressed domain according to Delac [1].

The clear approach to carry out face recognition in compressed domain is to utilize the coefficients extracted before inverse transformation as input to face recognition systems. Both the stages inverse quantization and inverse transformation is avoided. 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 as the decoding is interrupted after entropy decoding and all DWT coefficients obtained are used as input to the classification method. Computational time is greatly saved by avoiding the inverse transformation which is computationally the most expensive phase in decompression scheme. Computation time was further saved by eliminating inverse quantization phase. All the coefficients extracted after entropy decoding was kept for the experimental observation. For a normalized image of 128x128 sizes, all the 16384 coefficients are to be fed as input to the face recognition system based on CCA.

3.1 Canonical Correlation Analysis

CCA is a multivariate analysis method used to identify and measure the association between two sets of variables [17]. It measures the linear relationship between two multi dimensional variables. CCA has various applications in pose estimation [18] and face matching. It is useful to find two sets of basic vectors, one for x and one for y, such that the correlation between the projections of the variables onto these basic vectors is maximized. CCA is useful to find wx and wy which are two pairs of vectors such that the correlation between the projections of the variables is maximized onto the basic vector:

$x = w_x{}^T x$ and $y = w_y{}^T y$. Projections x and y are known as canonical variables [19]. CCA maximize the function:

$$p = \frac{E w^T{}_x C_{xy} w_x}{\sqrt{w^T{}_x C_{xx} w_x w^T{}_y C_{yy} w_y}}$$

whereby E represents empirical operation. For two random variables X and Y, the total covariance matrix is a block matrix where Cxx and Cyy are the within-sets covariance matrices of x and y respectively and Cxy=CyxT is the between- sets covariance matrix [20].

The canonical correlations between x and y can be found by solving the eigenvalue equations:

$$p^2 w_x = C_{xx}{}^{-1} C_{xy} C_{yy}{}^{-1} C_{yx} w_x$$

$$p^2 w_y = C_{yy}{}^{-1} C_{yx} C_{xx}{}^{-1} C_{xy} w_y$$

Where eigenvalues p^2 are the squared canonical correlations and eigenvectors w_x and w_y are the normalized canonical correlation vectors [21].

Algorithm used in the proposed methodology:

1. Get the image data from the compressed domain after entropy decoding
2. Separating single coloured plane from RGB planes of the true colour image in order to reduce the processing time.
3. Finding identity matrix in the same size of image data from previous step.
4. Apply Canonical Correlation Analysis for the image data and identity matrix which is generated previously
5. Repeat the above steps for both test and train images
6. Finally get the two canonical correlations for train and test data
7. Difference between two square root of canonical correlation are taken (M)
8. If there are 20 image data in a database then we will obtain 20 different ‘M’.
9. Square each ‘M’
10. Mode of this squared value is obtained for mapping purpose
11. Using the above result find the region where MODE data is available.

Euclidean distance method for matching of images possess only 50% of the result and another matching algorithms like kd-tree matching is not suitable for this feature projection technique based on CCA. Hence mapping of the image data are done by means of finding Mode method.

4. EXPERIMENTAL SETUP AND RESULTS

The experiments were performed on standard Yale database which consist of images of individuals taken under different conditions and also at different points of time. The test image data sets are fb (images with facial expression variations), fc (images with different illumination) and fd (partially occluded images).

There are various ways to evaluate the efficiency for face recognition systems. Recognition Rate (RR) is used as a main means of measuring the accuracy of recognition in this research. In order to compare the recognition results in spatial domain and compressed domain, Normalized Recognition Rate (NRR) is used. NRR will be greater than 1 if the

recognition rate is higher in compressed domain than in pixel domain. NRR will be less than one if the recognition rate is lower in compressed domain than in pixel domain. Comparison of computational time is used as another important performance measure.

Preprocessing processes are performed on original images to maintain the size of the train and test image as same. Each and every image is cropped to size of 128x128 and elliptical masking is utilized to mostly remove the background. Also images are originally transformed to obtain the eyes at the fixed points and histogram equalization was done to have better background intensity.

All the preprocessed images used in the experiments were compressed according to JPEG2000 compression scheme with various compression ratios of 1bpp, 0.5bpp, 0.3bpp and 0.2bpp.

The proposed approach eliminates major part of the decompression phase as the decoding is interrupted after entropy decoding and all DWT coefficients obtained are used as input to the proposed classification method (CCA) presented in section III. The coefficients after entropy decoding phase is enough to carry out the face recognition process and hence the recognition system is positioned after the entropy decoding phase in the proposed work (Figure1).

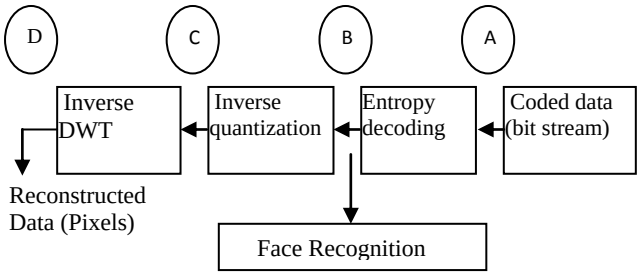

Figure 1: Positioning of face recognition system in decompression scheme

Train and test images are transformed as vectors using the equations in section III. Face recognition is performed by measuring the canonical correlation coefficient between the test face and all train images. Results for face recognition of the various experiments conducted on various image data sets at different compression ratios are shown in the figures given below.

Figure 2 shows the graphical representation of the NRR evaluation of the proposed method. It is clearly observed from the graph that the proposed approach outperforms the recognition in pixel domain.

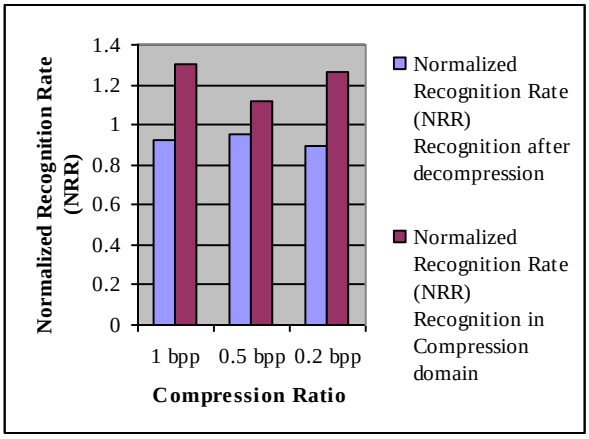

Figure 2: NRR evaluation of the proposed method

In Figure 3, the computational time of the proposed approach is compared with the existing recognition systems which uses Euclidean distance method and kd-tree matching respectively for matching of images [11][22]. The proposed method takes less time with a significant improvement in recognition rate.

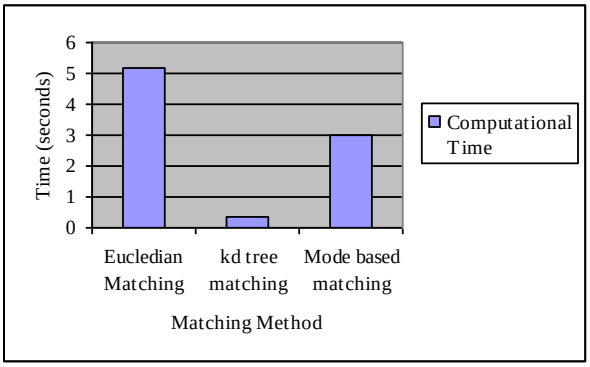

Figure 3: Comparison of the computational time

Recognition rates for various image data sets obtained by using entropy points as input to various recognition systems PCA, ICA and the proposed new classification method based on CCA is given Figure 4 and Table 1. The proposed method gives significantly better results for probe sets fc and fd when compared to PCA and ICA.

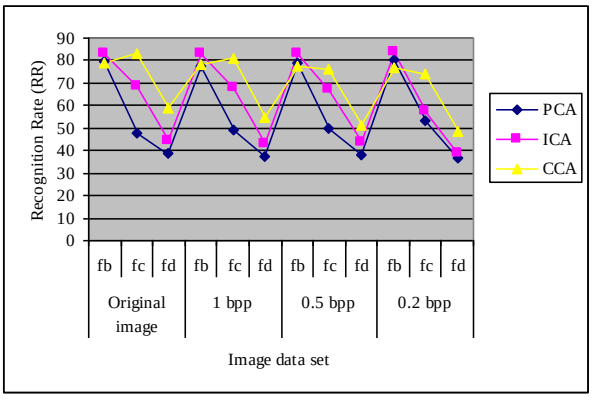

Figure 4: Comparison of Recognition Rates

Table 1: Comparison of recognition rates in compressed domain for various image data sets

Feature Projection Technique	Original image			1 bpp			0.5 bpp			0.2 bpp		
	fb	fc	fd	fb	fc	fd	fb	fc	fd	fb	fc	fd
PCA	79.4	47.9	38.5	77.8	49.0	37.1	79.0	50.0	38.2	80.5	53.6	36.6
ICA	83.0	68.6	44.3	83.0	68.0	42.9	82.8	67.5	43.5	83.6	57.5	38.9
CCA	78.6	83.0	59.0	78.0	81.0	55.0	77.4	76.0	51.0	77.0	74.1	48.4

5. CONCLUSION

This paper presents a new approach for implementing face recognition systems directly in JPEG2000 compressed domain. The effect of compression on recognition accuracy is observed and also issue like achieving computational time savings is examined in the new method. Canonical correlation based new algorithm is proposed for better feature projection. Transform coefficients available after entropy decoding is used as input to the new CCA based recognition method.

Numerous experiments have been done using the standard recognition methods PCA, ICA and the proposed method in compressed domain. The results obtained confirmed that the proposed method based on CCA is the superior method in terms of total Recognition Rate (RR) and Normalized Recognition Rate (NRR) with a comparatively less computational time when compared to the previous approaches.

The suggestion for future enhancement is to develop a new method for extracting feature vector from entropy coded image thus completely eliminating the decompression phase in face recognition. Also a method to enhance the proposed method using neural networks for better recognition of images with varying expressions is to be developed. Translation of the proposed methodology into video based face recognition is also recommended as the focus of this research work is Automatic Face Recognition from still images.

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