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An Efficient Face Recognition System Using Transforms

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Abstract: Visual recognition is a process of authenticating a true identity of a person. It is one of the applications of Biometrics. This technique makes it possible to use a person's image to verify their identity. The proposed system includes three different modules such as compression, feature extraction and feature matching. The face recognition is performed in the compression domain. Three transforms are utilized for compression namely Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Fast Fourier Transform (FFT). Principle Component Analysis (PCA) and Euclidean distance algorithm is used for feature extraction and feature matching. By taking transform the image enters into compression domain and inverse transform is omitted. As a result, computational complexity, time consumption and storage space of the visual recognition system is reduced.

Key words: Biometrics, face recognition, compression domain, transforms, feature extraction

INTRODUCTION

Biometrics comes from the Greek word bios (life) and metrics (measure). It is the study of automated methods for uniquely recognizing humans based upon one or more intrinsic physical or behavioral traits. Biometric authentication refers to technologies that measure and analyses human physical and behavioral characteristics for authentication purposes. Examples of physical characteristics include fingerprints, eye retinas and irises, facial patterns and hand measurements while examples of mostly behavioral characteristics include signature, gait and typing patterns. Voice is considered as a mix of both physical and behavioral characteristics. However, it can be argued that all biometric traits share physical and behavioral aspects. A biometric system can operate in the following two modes. In verification mode, the system performs a one-to-one comparison of a captured biometric with a specific template stored in a biometric database in order to verify whether the individual is the person they claim to be. This process may use smartcard, username or ID number (PIN) to indicate which template should be used for comparison. Positive recognition is a common use of verification mode where the aim is to prevent multiple people from using same identity. In identification mode the system performs a one to much comparison against a biometric database in attempt to establish the identity of an unknown individual. The system will succeed in identifying the individual if comparison of the biometric sample to a template in the database falls within a previously set threshold. Identification mode can be used either for positive recognition (so that the user does not have to provide any information about the template to be used) or for negative recognition of the person where the system establishes whether the person is who she (implicitly or explicitly) denies to be. The latter function can only be achieved through biometrics since other methods of personal recognition such as passwords, PINs or keys are ineffective.

The first type of biometrics came into form in 1890, created by an anthropologist named Alphorns Bertillon. He built his system on the claim that measurement of adult bones does not change after the age of 20. The method consisted of identifying people by taking various body measurements like a person's height, arm length, length and breadth of the head, the length of different fingers and the length of forearms using callipers. However, the methodology was unreliable as non-unique measurements allowed multiple people to have same results, decreasing the accuracy and hence is no longer used.

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Literature survey: Face recognition has repeatedly shown its importance over the last 10 years or so. Not only is it a vividly researched area of image analysis, pattern recognition and more precisely biometrics but also it has become an important part of the everyday lives since it was introduced as one of the identification methods to be used in e-Passports. The relative usefulness of Independent Component Analysis (ICA) for Face Recognition has been represented and comparative assessments were made regarding ICA sensitivity to the dimension of the space where it is carried out and ICA discriminant performance alone or when combined with other discriminant criteria such as Bayesian framework or Fisher's Linear Discriminant (FLD) (Liu and Wechsler, 1999).

Face features are used as the required human qualities for automatic recognition in facial biometrics. The two subspace methods namely, Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) have been used in the technique. PCA has been used for dimension reduction and LDA as a discriminant (Chan *et al.*, 2010). From a practical implementation point of view, an important, yet often neglected part of any face recognition system is the image compression. In almost every imaginable scenario, image compression seems unavoidable. Just to name a few:

- Image is taken by some imaging device on site and needs to be transmitted to a distant server for verification/identification
- Image is to be stored on a low capacity chip to be used for verification/identification
- Thousands (or more) of images are to be stored on a server as a set of images of known persons to be used in comparisons when verifying/identifying someone

All of the described scenarios would benefit by using compressed images. Having compressed, images would reduce the storage space requirements and transmission requirements. Compression was recognized as an important issue and an actively researched area in other biometric approaches as well. Most recent efforts have been made in iris recognition and fingerprint recognition. Apart from trying to deploy standard compression methods in recognition, researchers even develop special purpose compression algorithms, e.g., a recent low bit-rate compression of face images. However, to use a compressed image in standard face recognition systems the image has to be fully decompressed. This task is computationally extensive and face recognition systems would benefit if full decompression could somehow be avoided. Working with partly decompressed images is commonly referred to as working in the compressed domain which would additionally increase computation speed and overall performance of a face recognition system. The aim of the proposed technique is to give an overview of the research performed lately in the area of image compression and face recognition with special concentration paid to perform face recognition directly in the compressed domain.

Main focus is on the influence that degraded image quality (due to compression) has on recognition accuracy. As depicted in Fig. 1, the compressed data is usually stored in a database or is at the output of some imaging equipment. The data must go through entropy decoding, inverse quantization and inverse transformation (IDCT in JPEG or IDWT in JPEG2000) before it can be regarded as an image. Such a resulting decompressed image is certainly degraded due to information discarding during compression. Point A thus represents image pixels and any recognition algorithm using this information works in spatial or pixel domain. Any recognition algorithm using information at points B, C or D is said to be working in compressed domain and is using transform coefficients rather than pixels at its input.

Nonlinear feature extraction via Locally Linear Embedding (LLE) has attracted much attention due to their high performance. A novel approach has been proposed for face recognition to address the challenging task of recognition using integration of non-linear dimensional reduction and 95% of recognition rate could be obtained using the method (Abusham *et al.*, 2008). In the FRVT 2000 evaluation report, the effects of JPEG compression on face recognition were evaluated (Blackburn *et al.*, 2000). They proposed a real-life scenario: Images of persons known to the system (the gallery) were taken in near-ideal conditions and were uncompressed; unknown images (the probe set) were taken in uncontrolled conditions and were compressed at a certain compression level. Prior to experimenting, the compressed images were uncompressed (thus returning to pixel domain), introducing compression artifacts that degrade image quality. They used standard gallery set and probe set of the FERET database for their experiments.

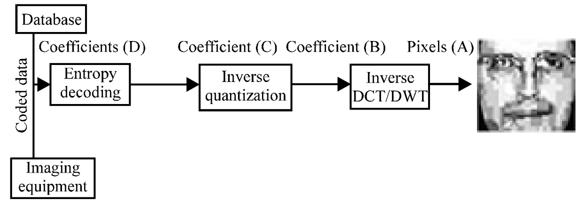

Fig. 1: Block diagram of decompression procedure in JPEG

Face verification was performed on images compressed to 0.5 bpp by standard JPEG2000 and showed that high recognition rates can be achieved using correlation filters. CMU PIE database was used and two experiments were performed to test illumination tolerance of the MACE filters-based classifier when JPEG2000 decompressed images are used as input. Their conclusion was also that compression does not adversely affect performance (Wijaya *et al*., 2005). The first detailed comparative analysis of the effects of standard JPEG and JPEG2000 image compression on face recognition was performed (Delac and Grgic, 2007). Compression effects on a wide range of subspace algorithm-metric combinations (PCA, LDA and ICA with L1, L2 and COS metrics) were tested.

Similar to other studies, it was also concluded that compression does not affect performance significantly. The conclusions were supported by McNemar's hypothesis test as a means for measuring statistical significance of the observed results. As in almost all the other studies mentioned so far some performance improvements were noted but none of them were statistically significant. The next study by the same researchers (Delac *et al*., 2005) analyzed the effects that standard image compression methods (JPEG and JPEG2000) have on three well-known subspace appearance-based face recognition algorithms: PCA, LDA and ICA. McNemar's hypothesis test was used when comparing recognition accuracy in order to determine if the observed outcomes of the experiments are statistically important or a matter of chance.

Image database chosen for the experiments was the gray scale portion of the FERET database along with accompanying protocol for face identification including standard image gallery and probe sets. Image compression was performed using standard JPEG and JPEG2000 coder implementations and all experiments were done in pixel domain (the images are compressed to a certain number of bits per pixel and then uncompressed prior to use in recognition experiments). The first thing that can be concluded from the studies reviewed in the above text is that all the researchers agree that compression does not deteriorate recognition accuracy even up to about 0.2 bpp. Some papers even report a slight increase in performance at some compression ratios, indicating that compression could help to discriminate persons in spite of the inevitable image quality degradation. There are three main experimental setups used in surveyed studies:

- Training set is uncompressed; gallery and probe sets are compressed
- Training and gallery sets are uncompressed; probe sets are compressed
- All images used in experiment are compressed

One of the first works done on face recognition in compressed domain was done by Schneier and Abdel-Mottaleb (1996). Binary keys of various lengths, calculated from DCT coefficients had been utilized within the JPEG compression scheme. Another very important contribution to the subject was made as follows: in the first part, a detailed overview of PCA and JPEG compression procedure was given and a way to combine those two into a unique recognition system working in compressed domain had been proposed. Then, an interesting mathematical link between Euclidean distance in feature space derived from uncompressed images, feature space derived from compressed images and correlation of images in original space was provided. Loading and partly decompressing the compressed images (working in compressed domain) is still faster than just loading the uncompressed image (Seales *et al*., 1998).

Image Fourier transforms is the classical algorithm which can convert image from spatial domain to frequency domain. Because of its good concentrative property with transform energy, Fourier transform has been widely applied in image coding, image segmentation, image reconstruction. Radix-4 Fast Fourier Transform (Radix-4 FFT) has been adopted for image coding, advantage of Fourier transform for image compression has been discussed (Hu *et al*., 2011). DCT coefficients were used as input to Hidden Markov Models (HMM) for classification (Eickeler *et al*., 1999). Compressed image is entropy decoded and inversely quantized before features are extracted from the coefficients. Related research using DCT was performed but standard JPEG compression scheme was not followed (Hafed and Levine, 2001). But DCT over the whole image was performed and top 49 coefficients were kept to be used in a standard PCA recognition setup. In their experiment, compared to using uncompressed images, a 7% increase in recognition rate had been reported.

The observed increase in recognition rate was around 2%. Surprisingly, recognition rates were increasing with the increase of the number of decompositions. Garcia *et al*. (2000) performed one standard wavelet decomposition on each image from the FERET database and observed increase in recognition rate. Similarly, the HH subband after three decompositions was used as input to PCA and recognition rate slightly increased (Feng *et al*., 2000). One of the first explorations of using features directly in the JPEG2000 domain had been performed (Xiong and Huang, 2002). Two wavelet decompositions were used to calculate the approximation band and then to be used in face recognition (Chien and Wu, 2002). The performance was slightly better than standard PCA.

Using all the DWT coefficients after decomposition as input to PCA yields superior recognition rates compared to standard PCA (Li and Liu, 2002). Using Daubechies wavelet and PCA and ICA, the sub bands that are least sensitive to changing facial expressions and illumination conditions were found. PCA and ICA were combined with L1, L2 and COS metrics in a standard nearest neighbour scenario. In the experiment with images with different illumination conditions, a considerable improvement was observed when DWT coefficients were used instead of pixels (over 20% higher recognition rates for all tested methods) (Ekenel and Sankur, 2005).

A new Euclidean distance for images called Image Euclidean Distance (IMED) has been suggested (Wang *et al*., 2005). IMED can be applied to image recognition since unlike the traditional Euclidean distance, IMED takes into account the spatial relationships of pixels. The main advantage of this distance measure is that it can be fixed in most image classification techniques such as SVM, LDA and PCA. A highly efficient audio-visual recognition system in compression domain has been proposed for face recognition system in videos (Wong *et al*., 2011). The multiband feature fusion method is used to select the wavelet subbands that are invariant to illumination and facial expression variations.

Face recognition system: The general system records face images through a digital video camera and analyses facial characteristics like the distance between eyes, nose and mouth and jaw edges. These measurements are broken into facial planes and retained in a database, further used for comparison. Face recognition can be done in two ways. In the first method, Face appearance employs Fourier transformation of the face image into its fundamental frequencies and formation of Eigen faces, consisting of Eigen vectors of the covariance matrix of a set of training images. The uniqueness of the face is captured without being oversensitive to noise such as lighting variations. In the other method, face geometry models a human face created in terms of particular facial features like eyes, mouth and layout of geometry of these features is computed. Face recognition is then a matter of matching patterns. There are four steps in face recognition process as depicted in Fig. 2.

Face recognition system in compression domain: The needs for image compression becomes apparent when number of bits per image are computed resulting from typical sampling rates and quantization methods.

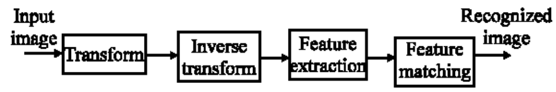

Fig. 2: Block diagram of the traditional face recognition system

Lossless versus lossy compression: In lossless compression schemes, the reconstructed image, after compression is numerically identical to the original image. However, lossless compression can only achieve a modest amount of compression. Lossless compression is preferred for archival purposes and often medical imaging, technical drawings, clip art or comics. This is because lossy compression methods, especially when used at low bit rates, introduce compression artifacts. An image reconstructed following lossy compression contains degradation relative to the original. Often this is because the compression scheme completely discards redundant information. However, lossy schemes are capable of achieving much higher compression. Lossy methods are especially suitable for natural images such as photos in applications where minor loss of fidelity is acceptable to achieve a substantial reduction in bit rate. The lossy compression that produces imperceptible differences can be called visually lossless. Future values and the difference is coded. Since, this is done in the spatial domain, it is relatively simple to implement and is readily adapted to local image characteristics.

MATERIALS AND METHODS

In the proposed system, the whole process of the face recognition is done exclusively in compression domain and the different steps involved in the process are as shown in Fig. 3. Proposed system has three main blocks they are:

- Compression domain
- Feature extraction
- Feature matching

Initially, the compression of images is done using the transforms and the image now enters the frequency domain (in compressed form). The types of transforms chosen are namely Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Fast Fourier Transform (FFT). The image is now compressed and is sent to the next stage for feature extraction which is done using PCA. Finally feature matching is done using Euclidean distance algorithm which checks whether the given test image is present in the database or not without decompression being performed.

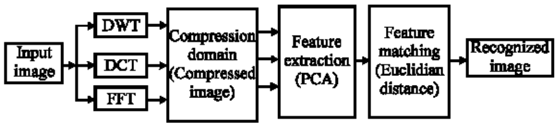

Fig. 3: Block diagram of proposed system

Discrete cosine transform: Compressing an image is significantly different than compressing raw binary data. DCT has been widely used in signal processing of image. The one-dimensional DCT is useful in processing one-dimensional signals such as speech waveforms. For analysis of two Dimensional (2D) signals such as images, a 2D version of the DCT data is needed, especially in coding for compression for its near-optimal performance. JPEG is a commonly used standard method of compression for photographic images. The name JPEG stands for Joint Photographic Experts Group, the name of the committee who created the standard. JPEG is the lossy compression technique of images. The objective is to reduce redundancy of the image data in order to be able to store or transmit data in an efficient form. The best image quality at a given bit-rate (or compression rate) is the main goal of image compression. The main objectives of using the compression based techniques are reducing the image storage space, reducing the computational complexity, easy maintenance and providing high level of security.

A Discrete Cosine Transform (DCT) expresses a sequence of finitely many data points in terms of a sum of cosine functions oscillating at different frequencies. DCTs are important to numerous applications in science and engineering, from lossy compression of audio and images (where small high-frequency components can be discarded) to spectral methods for the numerical solution of partial differential equations on, it turns out that cosine functions are much more efficient. In particular, a DCT is a Fourier-related transform similar to the Discrete Fourier Transform (DFT) but using only real numbers. DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry (since the Fourier transform of a real and even function is real and even) where in some variants the input and output data are shifted by half a sample. There are eight standard DCT variants of which four are common. DCT can be explained by the following equation:

$$y = \mathrm{dct}\,(x)$$

Returns the unitary discrete cosine transform of x:

$$y(k) = w(k)\sum_{n=1}^{N} x(n)\cos\frac{\pi(2n-1)(k-1)}{2N}, \quad k = 1,\ldots,N \tag{1}$$

$$w(k) = \begin{cases} \dfrac{1}{\sqrt{N}} & k = 1 \\ \dfrac{2}{\sqrt{N}} & 2 \le k \le N \end{cases}$$

Where:

n = Time domain variable
k = Frequency domain variable
N = The length of x

Discrete wavelet transform: Wavelet transform decomposes an image into a set of different resolution sub-images, corresponding to the various frequency bands. This results in a multi-resolution representation of images with localization in both spatial and frequency domains which is desirable in image compression. Wavelets have non-uniform frequency spectra which facilitate multi-scale analysis. The multi-resolution property of the wavelet transform can be used to exploit the fact that the response of the human eye is different to high and low frequency components of an image. DWT can be applied to an entire image without imposing the block structure thereby blocking artifact is reduced.

Wavelet transform has become an important method for image compression. Wavelet based coding provides significant improvement in picture quality at high compression ratios mainly due to better energy compaction property of wavelet transforms. Wavelet transform partitions a signal into a set of functions called wavelets. Wavelets are obtained from a single prototype wavelet called mother wavelet by dilations and shifting.

Sub-band decomposition: Sub-band coding is a procedure in which the input signal is divided into several frequency bands and it can be implemented through filter bank. A filter bank is a collection of filters that partitions an image dyadically at the frequency domain. The filter bank consists of low-pass and high-pass filter. When the signal passes through these filters, it splits into two bands. The low-pass filter which corresponds to an averaging operation, extracts the course information of the signal. The high-pass filter which corresponds to a differencing operation, extracts the detail information of the signal. The output of the filtering operation is then decimated by two.

A 2D transform is achieved by performing two separate 1D transforms. Frist the image is filtered along the row and decimated by two. It is then followed by filtering the sub-image along the column and decimated by two. This operation splits the image into four bands, namely, LL, LH, HL and HH, respectively as shown in Fig. 4.

Fast Fourier Transform (FFT): A Fast Fourier Transform (FFT) is an efficient algorithm to compute the Discrete

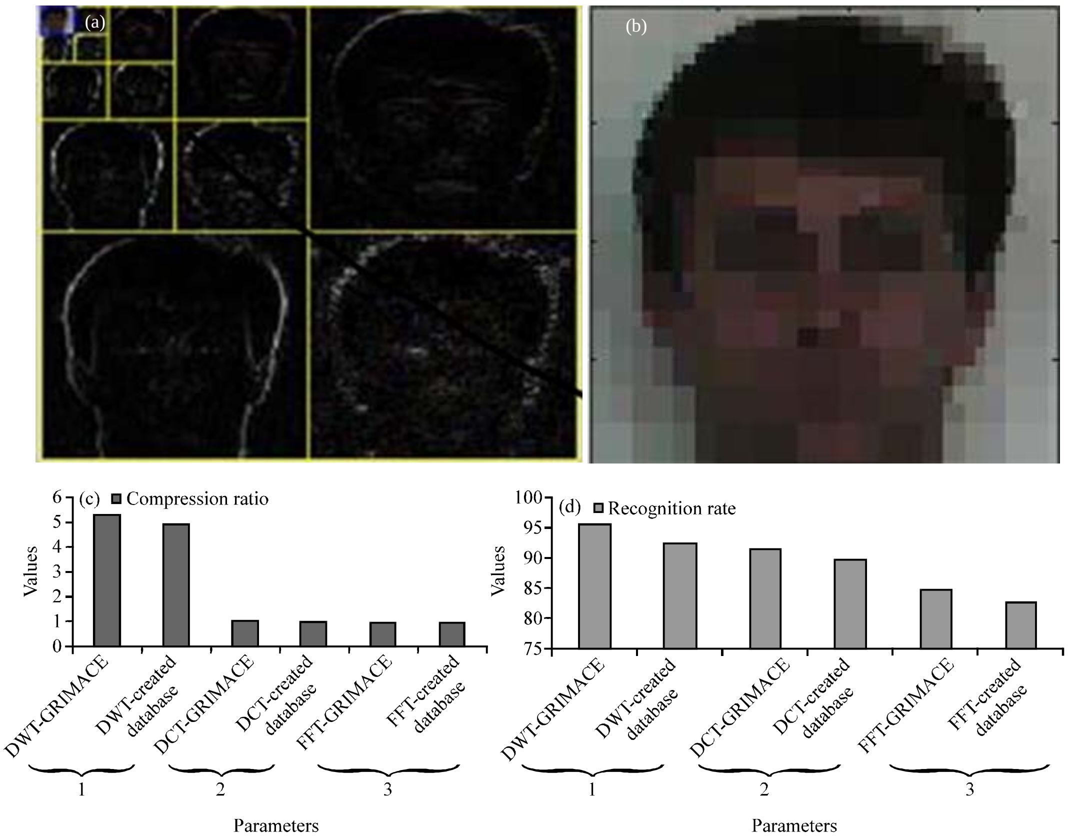

Fig. 4: Simulation results and compression performance; a) sub-band decomposition; b) DWT compressed image; c) comparison of compression ratio for different transforms; d) comparison of recognition rate with compression for different transforms and databases

Fourier Transform (DFT) and its inverse. There are many distinct FFT algorithms involving a wide range of mathematics from simple complex number arithmetic to group theory and number theory. A DFT decomposes a sequence of values into components of different frequencies. This operation is useful in many fields but computing it directly from the definition is often too slow to be practical. An FFT is a way to compute the same result more quickly. Computing a DFT of N points in the simple way using the definition, takes O (N2) arithmetical operations while an FFT can compute the same result in only O (N log N) operations. The difference in speed can be substantial, especially for long data sets where N may be in the thousands or millions in practice the computation time can be reduced by several orders of magnitude in such cases and the improvement is roughly proportional to N/log (N). This huge improvement made many DFT-based algorithms practical; FFTs are of great importance to a wide variety of applications from digital signal processing and solving partial differential equations to algorithms for quick multiplication of large integers. FFT can be explained by the following equations:

$$X(k)=\sum_{j=1}^{N}x(j)w_N^{(j-1)(k-1)}$$
$$x(j)=(\frac{1}{N})\sum_{k=1}^{N}x(k)w_N^{-(j-1)(k-1)} \qquad (2)$$

where, $W_N = e^{2\pi i/N}$. Feature extraction is performed using PCA algorithm. PCA involves a mathematical procedure that transforms a number of possibly correlated variables into a number of uncorrelated variables called principal components, related to the original variables by an orthogonal transformation. This transformation is defined in such a way that the first principal component has as high a variance as possible and each succeeding component in turn has the highest variance possible under the constraint that it be orthogonal to the preceding components. PCA is sensitive to the relative scaling of the original variables.

The major advantage of PCA is that the Eigen face approach helps in reducing the size of the database required for recognition of a test image. Euclidean distance algorithm is used for feature matching. A new Euclidean distance for images which is called Image Euclidean Distance (IMED) is utilised. Unlike the traditional Euclidean distance, IMED takes into account the spatial relationships of pixels. Therefore, it is robust to small perturbation of images.

RESULTS AND DISCUSSION

In the proposed method, images from the databases namely GRIMACE and the database created under real time are taken for testing. For example, an input image with the size of 200×180×3 (4.22 kB) is taken from the GRIMACE database. Sample images are shown in Fig. 5. For testing the algorithm, a database has been created using the set of images in the real time. The database contains 600 images of 100 persons, i.e., 6 image per person. In the train set 2 images per person are kept and in the test set 4 compressed images with different posture, illumination and facial expression for each person is kept. Three transforms are utilized for compression namely Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), Fast Fourier Transform (FFT) and the feature extraction is done separately for each transform in compression domain using Principal Component Analysis (PCA) and the feature matching is done using Euclidean distance algorithm. The recognition rate is high with the false recognition rate being low.

Fig. 5: GRIMACE database

Table 1: Comparison of compression ratio and recognition rate for different transforms and different databases

Transforms	Compression ratio	Recognition rate (%)
DWT-GRIMACE	5.421	96
DWT-created database	5.060	94
DCT-GRIMACE	1.125	93
DCT-created database	1.057	91
FFT-GRIMACE	1.048	85
FFT-created database	1.027	83

The simulation results and their performance evaluation are shown in Fig. 4 and Table 1 shows the comparison of compression ratio and recognition rate for different transforms and different databases. From the above comparisons best compression ratio is obtained in discrete wavelet transform and the best recognition rate also occurs in discrete wavelet transform for both the GRIMACE and created database.

CONCLUSION

Experimental results show that the proposed system achieves good recognition rate even though the recognition is performed in the compression domain. The technique has been tested with different databases (GRIMACE database and a database that has been created using real time images, captured under different lighting conditions with various posture and expressions.

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