# Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 13 (3): 451-457, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.451.457


# Face Recognition in Compressed Domain by Applying Wavelet Transform and Feature Vector Optimization

[1]Menila James, [2]S. Arockiasamy and [3]P. Ranjit Jeba Thangaiah
[1]Department of Computing, Muscat College, Oman
[2]College of Information Systems, University of Nizwa, Oman
[3]School of Computer Science and Engineering, Karunya University, Coimbatore, India

**Abstract:** In this study, a novel method for extracting feature vector in the form of entropy points from compressed images was proposed. This efficient approach for performing face recognition systems directly into wavelet based compressed domain which involve wavelet based image compression/decompression for feature extraction, an efficient feature optimization technique and a method for image classification. This is accomplished by stopping the decompression process after entropy decoding and utilizing the entropy points as input to recognition systems. During the experiments, firstly, a standard recognition algorithms used like principal component analysis, independent component analysis and kernel PCA for optimizing feature vector and kd-tree based method for image matching. Secondly, an improved version of canonical correlation analysis method is applied for feature projection. Finally, cascade forward neural network based algorithm for better matching of facial images for image classification. The experimental results proved that the proposed approach is effective in achieving face recognition in compressed domain with additional reduction of computational time and storage requirements.

**Key words:** Face recognition, compressed domain, entropy points, tree matching

## INTRODUCTION

Automatic face recognition is an extensively researched area in computer science along with other biometric techniques like fingerprint verification and voice recognition. Identification of person is the most important factor of security applications and smart interaction applications. Problems to be addressed in automatic face recognition are challenging due to the changes facial images undergo in real life like variations in facial expressions, illumination, occlusion etc. Researchers have used uncompressed high resolution still images for performing face recognition until recently even though compression was realized as an important issue in finger print verification and iris recognition previously (Rakshit and Monro, 2007; Funk *et al*., 2005).

Previously researchers had tried to implement face recognition in compressed domain with standard recognition systems such as Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) methods and Independent Component Analysis (ICA). A study on human recognition in wavelet domain was done by Curtis and Sabharwal (1997). 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. Chien and Wu (2002) had proposed a multi resolution wavelet transform based approach for face recognition. The authors had calculated the approximation band for recognition algorithms by applying two wavelet decompositions. Li and Liu (2002) performed a study using a combination of wavelet techniques and eigenfaces to extract features for face recognition. The experimental results show that using DWT coefficients as input to PCA given superior performance compared to standard PCA. Ekenel and Sankur (2005) study the effect of multi resolution analysis for face recognition by using wavelet decomposition to find the subbands which are least sensitive to variations due to expression changes and illumination conditions. Delac and Grgic (2007) and Delac *et al*. (2009) focused on the practicability of compressed images face recognition by using feature vector as input to various standard face recognition algorithms. Canonical Correlation Analysis (CCA) has stimulated the interest of researchers in the field of pattern recognition and signal processing recently which helps to relate two sets of observations by describing different aspects of appearance. Lee and Choi (2007) focused on CCA to give the high dimensional relationship between

**Corresponding Author:** Menila James, Department of Computing, Muscat College, Oman

two sets of multi-dimensional variables with a few pairs of canonical variables. Hotelling (1936) also was intended to define relations between CCA and two sets of one dimensional data sequences unlike PCA and LDA. Jelsovka *et al.* (2011) had conducted two dimensional face recognition based on CCA method and the obtained result showed high efficiency. Oh (2005) proposed a standard LDA method using radial basis function network in order to improve the robustness of the face recognition system. The authors had studied the effect of the combination of two compensating classifiers and testing ORL database which improve by 93.55 recognition rate. In James and Arockiasamy (2011) study first analysis of performing face recognition with partially compressed images using standard recognition systems PCA and ICA. The preliminary results observed there are largely expanded in the next studies by the same authors (James and Arockiasamy, 2012a,b) where the impact on face recognition using compressed images is analysed when canonical correlation based algorithms are applied for feature projection. Standard yale data sets were used for testing in these experiments.

In this study, a novel generic face recognition system that performs robustly in direct compressed domain in spite of the facial appearance variations. In addition, further expanded by implementing face recognition of compressed images using Kernel PCA based feature projection method with and kd-tree matching. A numerous experiments conducted with AR data bases which contain more than 4000 facial images which involve image data sets with varying expression, illumination changes and partial occlusion.

## LITERATURE REVIEW

**Principal Component Analysis (PCA):** Alwakeel and Shaaban (2010) proposed Principal Component Analysis (PCA) as a tool to reduce the large dimensionality of the data space to a set of representative projection vectors for describing the data efficiently. In this method image elements used as random variables with Gaussian distribution and minimized second-order statistics which keep lower-order principal components and ignoring higher-order ones. Jolliffe (2002) proved that low-order components often contain the most important aspects of the data. The most representative vectors are the eigenvectors corresponding to the largest eigenvalues of the covariance matrix (Turk and Petland, 1991). In addition, PCA can be used for dimensionality reduction is data set by retaining those characteristics of the data which has successful applications that have been used in digital image processing and pattern recognition.

**Independent Component Analysis (ICA):** ICA is a generalization of PCA. For any non-Gaussian distribution, largest variances would not respond to PCA basis vectors. While PCA deals with second-order statistics (variance), ICA captures both second and higher order statistics and projects the data onto basis vectors that are statistically independent as possible. ICA implementation was done based on the algorithm proposed by Bartlett *et al.* (2002).

**Kernel Principal Component Analysis (KPCA):** Kernel PCA is an extension of PCA which firstly proposed as a nonlinear extension of PCA. Even though Principal Component Analysis performs very well in dimensionality reduction of data, the efficiency of PCA method is not that satisfactory for problems with high nonlinearity such as face recognition. Hence, KPCA is developed to handle the nonlinearity of face recognition problems (Timotius *et al.*, 2010). In Kernel PCA, a nonlinear kernel function is used for dimensionality reduction. The face images are first transformed from image space into a feature space though nonlinear mapping and then the principal components are computed in that feature space. By applying kernel method, the principal components are computed by high-order correlations of input pixels making up a facial image and hence performance is improved (Kim *et al.*, 2002).

**Canonical Correlation Analysis (CCA):** Canonical correlation analysis is a a powerful feature projection approach which suitable technique for exploring the relationships among multiple dependent and independent variables. CCA recognize and measure the relationship between two sets of variables. For this purpose, CCA uses two sets of linear combination of variables. A pair of linear combinations with greatest correlation among all pairs is determined subsequently. Hence, high dimensional association between two sets of variables with a few pairs of canonical variables is represented in by CCA (Kukharev and Kamenskaya, 2010). A detailed analysis of this method is given in our work presented in James and Arockiaswamy (2012b).

## PROPOSED METHOD

Figure 1 sows the main framework to perform face recognition in direct compressed domain which involve new approaches for image pre-processing and DWT based feature extraction in compressed domain, efficient methods for feature vector optimization and classification (Recognition) of images.

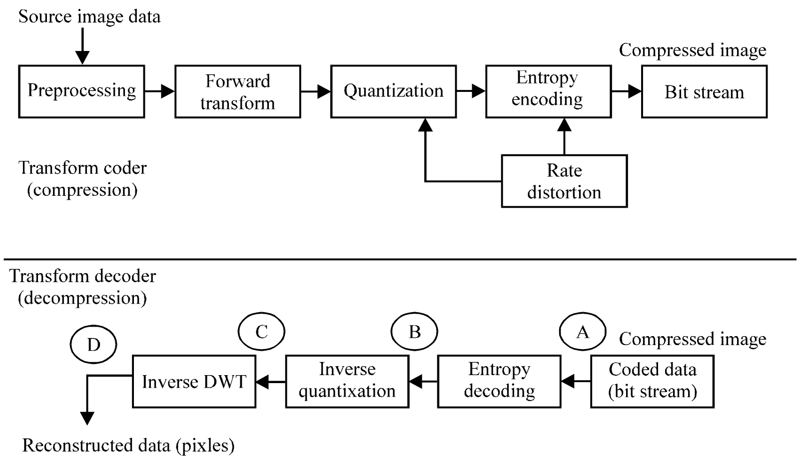


Fig. 1: Wavelet transform coder/decoder

Three classification algorithms are developed in the framework to be used for matching of images in the proposed approaches. A matching algorithm based on kd-tree technique is developed and used along with feature projection approaches based on PCA, ICA and KPCA. Mode based matching algorithm is used in experiments conducted with feature projection approach based on CCA. Also, a neural network based image classification algorithm is developed and applied for the face recognition approach based on canonical correlation analysis. The details of the algorithms are explained as follows:

**Pre-processing of images:** Pre-processing of images prior to Wavelet Transformation is essential. Pre-processing processes are performed on original images to maintain the size of the train and test image as same. The RGB image is converted into gray scale image and then cropped to size of 128×128 pixels. 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.

**Extracting entropy points as feature vector:** This stage is extracting features as DWT coefficients from the pre-processed image by applying Cohen Daubechies Feauveau (CDF) 9/7 wavelet on the image. All the preprocessed images used in the experiments were compressed according to JPEG2000 compression scheme with various compression ratios of 1, 0.5, 0.3 and 0.2 bpp (lower, moderate and higher compression levels). The proposed approach eliminates major part of the decompression phase as the decoding is interrupted after entropy decoding and all entropy points obtained are used as input to the proposed recognition method. Also, feature vector is extracted from image code block thus avoiding image decompression fully. During experiments the feature projection system is placed either at point B or at point A.

**Feature vector optimization:** In this stage, various algorithms based on PCA, ICA, Kernel PCA and improved canonical correlation analysis method are applied on features obtained in the previous stage for conducting experiments.

## EXPERIMENTAL SETUP

The block diagram of the experimental set up is given in Fig. 2. This diagram represents the exact description of the procedures carried out in the experiments. For the simulated experiments, the uncompressed face images were first transformed and then encoded using the EBCOT (Embedded block coding with optimal truncation) coding technique as per JPEG2000 compression standard. In the real time application the facial images will be captured through high resolution digital camera and will be stored in JPEG2000 compressed format. To test these images for face recognition, it needs to decode the code stream in order to extract the entropy points.

In the second part of the experiments the propose image labeling in the pre-processing stage before compression. The input image is cropped in such a way to extract only the particular components of the image. By doing this, the background of the image and hair patterns are been eliminated and hence the focus only will be in face. After this cropping process, a HIGH BOOST FILTERING as given by James and Arockiaswamy (2012b) is applied to improve the cropped image, so that it can

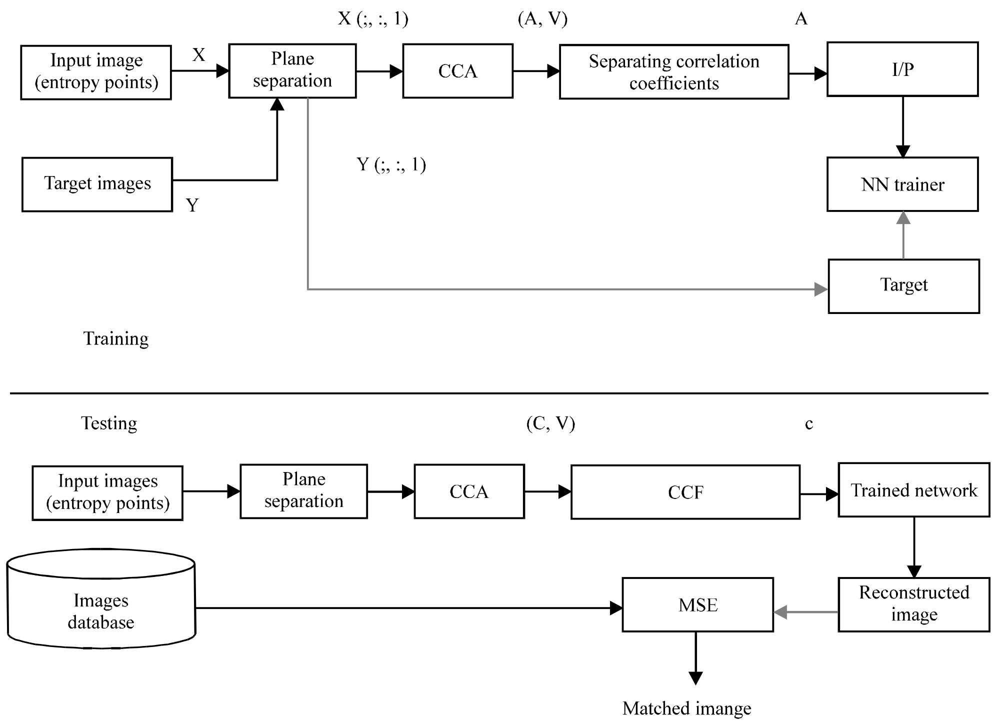


Fig. 2: Experimental setup for the training and testing session of enhanced CCA approach

improve the high frequency component in an image to much higher level. The recognition rate for image data sets with varying expressions is improved significantly. The other two image data sets (varying illumination and minor occlusion) also showed further improvement.

## RESULTS AND DISCUSSION

Various image data sets from the AR face database Martinez and Benavente (1998) was used in the experiments and this include images of individuals with varying expression (fb), varying illumination (fc) and partial occlusion (fd). The AR database was collected at the Computer Vision Center in Barcelona, Spain in 1998. It contains 4000 uncompressed colour images of 126 individuals (70 men and 56 women). The pictures were taken under strict conditions in order to ensure that settings are identical across subjects. Facial expression variations include normal, smile, anger, sad, sleepy and surprised impression. Illumination variations include lighting in the center, left and right position. Images of individuals with glasses and scarf are considered as partially occluded images. Two sets of experiments were conducted in compressed domain. In the first set of tests, entropy points are fed as input to PCA, ICA and KPCA instead of image pixels and a kd-tree based algorithm is applied for image classification. During the latter set of experiments, canonical correlation analysis based approach is used for feature vector optimization. In this second set of experiments for matching of images using two classification algorithms based on mode based matching and cascade forward neural networks are applied.

First set of experiments, the recognition algorithms based on PCA, ICA and KPCA were implemented in MATLAB following the description in studies (Alwakeel and Shaaban, 2010; Bartlett *et al*., 2002; Kim *et al*., 2002). In the pixel domain experiments, first PCA was performed on the uncompressed images which were cropped to 128×128 pixels. After performing PCA, top 40% of eigenvectors were kept and this subspace ws used for classification based on kd-tree as PCA face space and also as input to ICA algorithm. Finally, KPCA was performed in the experiments to calculate the features for the uncompressed face images. The results are noted in Table 1 (original images). All images used in experiments were compressed according to JPEG2000 compression standards, with various compression ratios 1, 0.5, 0.3 and 0.2 bpp. To compress images

Table 1: Comparison of recognition rate

| | Original image | | | 1 bpp | | | 0.5 bpp | | | 0.3 bpp | | | 0.3 bpp | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feature | fb | fc | fd | fb | fb | fd | fb | fc | fd | fb | fc | fd | fb | fc | fd |
| PCA (Euclidean) | 79.04 | 47.09 | 36.05 | 77.05 | 48.02 | 37.02 | 79.00 | 49.00 | 35.01 | 79.06 | 50.01 | 34.03 | 80.02 | 51.08 | 33.00 |
| ICA (Euclidean) | 83.00 | 68.02 | 44.00 | 83.02 | 68.00 | 46.07 | 83.05 | 67.08 | 42.05 | 83.07 | 67.03 | 41.09 | 83.01 | 56.00 | 35.04 |
| PCA kd-tree | 81.00 | 48.04 | 39.00 | 79.00 | 49.02 | 40.02 | 79.02 | 50.08 | 41.01 | 81.04 | 51.04 | 38.02 | 81.06 | 52.02 | 36.06 |
| ICA kd | 83.09 | 69.00 | 45.02 | 83.09 | 69.00 | 48.01 | 84.02 | 68.04 | 49.06 | 84.05 | 68.02 | 41.07 | 82.03 | 56.04 | 39.00 |
| Kernel PCA (kd-tree) | 81.15 | 50.79 | 39.21 | 79.18 | 51.11 | 43.01 | 80.12 | 48.67 | 43.72 | 81.92 | 45.32 | 37.42 | 79.32 | 41.92 | 35.82 |

Table 2: Comparison of recognition rates in compressed domain for various image data sets

| | Original image | | | 1 bpp | | | 0.5 bpp | | | 0.3 bpp | | | 0.2 bpp | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feature technique | fb | fc | fd | fb | fc | fd | fb | fc | fd | fb | fc | fd | fb | fc | fd |
| PCA (Euclidean) | 79.04 | 47.09 | 38.06 | 77.04 | 48.02 | 37.02 | 79.00 | 49.00 | 35.01 | 79.06 | 50.01 | 34.03 | 80.02 | 51.08 | 33.00 |
| ICA (Euclidean) | 83.00 | 68.02 | 44.00 | 83.02 | 68.00 | 48.07 | 83.05 | 67.08 | 42.05 | 83.07 | 67.03 | 41.09 | 83.01 | 56.00 | 38.04 |
| PCA kd | 81.00 | 48.04 | 39.00 | 79.00 | 49.02 | 40.02 | 79.02 | 50.08 | 41.01 | 81.04 | 51.04 | 38.02 | 81.06 | 52.02 | 36.06 |
| ICA kd | 83.09 | 69.00 | 45.02 | 83.09 | 69.00 | 48.01 | 84.02 | 68.04 | 49.06 | 84.05 | 68.02 | 41.07 | 82.03 | 56.04 | 39.00 |
| Kernel PCA (kd | 81.15 | 50.79 | 39.21 | 79.01 | 51.01 | 43.00 | 80.12 | 48.67 | 43.72 | 81.09 | 45.03 | 37.04 | 79.03 | 41.09 | 35.08 |
| CCA with mode based matching | 77.78 | 79.22 | 53.39 | 77.90 | 31.20 | 55.24 | 78.85 | 81.74 | 61.76 | 71.52 | 72.20 | 48.07 | 69.92 | 63.38 | 46.14 |
| CCA+ANN dassifier | 78.82 | 79.53 | 68.22 | 79.03 | 81.45 | 68.90 | 79.99 | 83.83 | 64.90 | 76.82 | 78.70 | 60.28 | 74.82 | 74.32 | 48.83 |
| CCA+ANN labeling | 80.24 | 80.84 | 58.28 | 81.21 | 81.76 | 83.21 | 81.76 | 88.90 | 67.31 | 78.64 | 78.31 | 64.76 | 78.16 | 77.69 | 68.68 |
| Kernel PCA with feature | 76.18 | 42.79 | 88.21 | 66.78 | 84.68 | 29.82 | 68.89 | 32.46 | 27.58 | 60.61 | 81.88 | 26.37 | 43.20 | 30.68 | 24.67 |
| CCA+ANN classifier with feature vector | 78.82 | 79.63 | 68.22 | 62.60 | 69.72 | 46.24 | 60.22 | 68.86 | 44.94 | 47.87 | 62.78 | 43.86 | 40.14 | 46.90 | 39.20 |

PCA: Principal Component Analysis, ICA: Independent Component Analysis, fb: Varying Expression, fc: Varying Illumination, fd: Partial Occlusion

using JPEG2000 standard, JPEG2000 toolbox in MATLAB was used. The compressed images were partially decompressed to extract the transform coefficients. The compression/decompression of images were required as the uncompressed images from the AR Face database was used in the experiments.

From Table 1 pixel domain are shown as recognition rate of original images and results for experiments as per existing methodology (Delac *et al*., 2009) are given in first two rows (PCA Euclidean and ICA Euclidean). From one glance itself it is clear that the proposed approach experience no significant performance drop for all image data sets. The results for ICA are comparatively better when compared to other approaches. The comparison of Normalized Recognition Rate (NRR) of the image probe sets for the proposed methods in compressed domain (PCA, ICA and KPCA) to that of same in pixel domain is done. The computational time of the proposed approach using the kd tree method is compared with the existing techniques described by (Delac *et al*., 2009) using nearest neighbour algorithm which apply Euclidean distance method. The kd-tree takes very less computation time when compared to the recognition rate of the existing approaches which uses Euclidean matching.

Second set of experiments, canonical correlation Analysis based feature projection method was performed on the original uncompressed 128×128 images and the results for all AR database data sets were noted Table 2 (original images) using the three different image data sets. Significantly better results are observed for the CCA based method for images with varying illumination and partial occlusion in the first set of tests. The recognition rate of images with varying expressions is also improved by applying labeling of images in the second part of the experiments.

Normalized recognition rate is used to compare the results obtained in compressed domain to pixel domain of fc probe set for the various approaches are given above in Fig. 3. The curves marked “NRR after decompression” show result obtained in experiments where face images were first compressed to a certain compression ratio and then uncompressed before using them in recognition. These results show how NRR changes at various compression ratios when image degradation caused by compression procedure.

Comparison of the proposed methods with existing nearest neighbour algorithm which uses Euclidean distance method for matching is given in Fig. 4. All the proposed methods showed significant reduction in computational time when compared to the existing recognition method which uses nearest neighbour algorithm for matching of images.

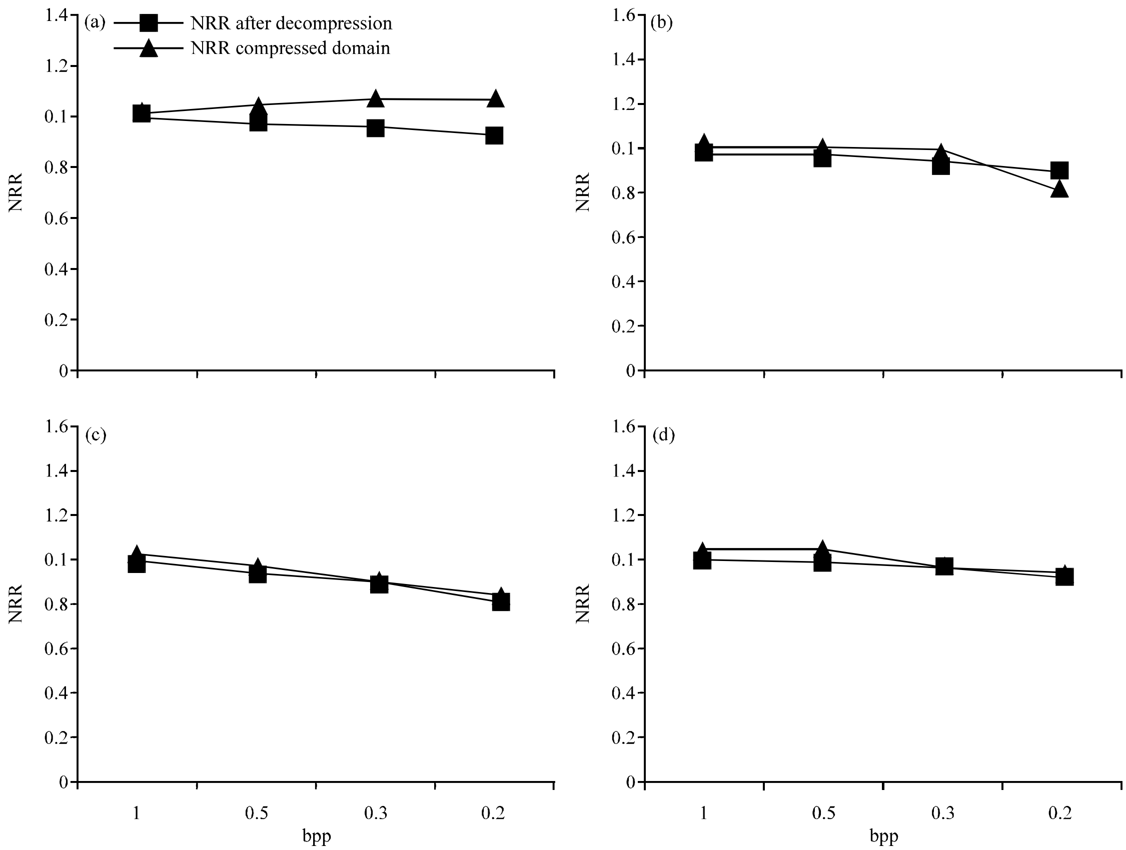


Fig. 3: NRR evaluation of fc probe set in compressed domain, (a) PCA kd-tree, (b) ICA kd-tree, (c) KPCA kd-tree (d) CCA with ANN classified

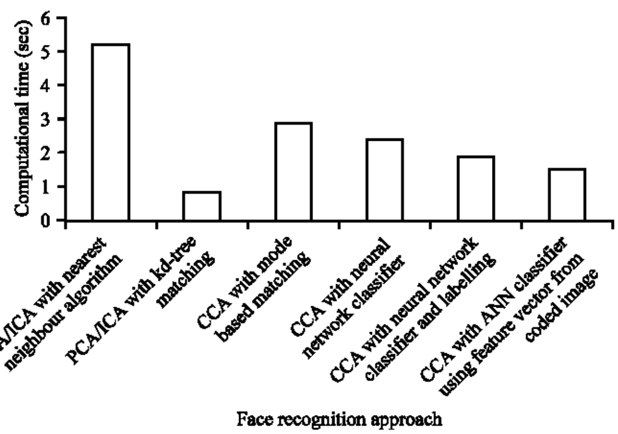


Fig. 4: Comparison of computational time of the proposed approaches

## CONCLUSION

The main advantage of this new approach is significant saving in computational time as it excludes the computationally most expensive phases of image decompression. Since, this method uses the arithmetic decoded data as feature vector, significant reduction in time is achieved. An average of 1.54 sec only is taken for recognition when compared to methodologies applying DWT coefficients and entropy points as feature vector for which the computational time was 5.2 and 2.87 sec, respectively. Even though the recognition rate is reduced when compared with previous approaches using entropy points, it is proved that face recognition is possible in direct compressed domain hence avoiding the decompression process completely. Future research will include finding a method for intelligently extracting feature vector from compressed image therefore completely excluding decompression of images in face recognition. Also, an algorithm for three dimensional face recognition in compressed domain which avoid the pitfalls of 2D face recognition algorithms in recognizing images with varying expressions, illumination and occlusions. Translation of the proposed methodology into video based face recognition is also recommended as the focus of this research work was face recognition from still images.

## REFERENCES

Alwakeel, M. and Z. Shaaban, 2010. Face Recognition based on haar wavelet transform and principal component analysis via levenberg-marquardt backpropagation neural network. Eur. J. Sci. Res., 42: 25-31.

Bartlett, M.S., J.R. Movellan and T.J. Sejnowski, 2002. Face recognition by independent component analysis. IEEE Trans. Neural Networks, 13: 1450-1464.

Chien, J.T. and C.C. Wu, 2002. Discriminant wavelet faces and nearest feature classifiers for face recognition. IEEE Trans. Patt. Anal. Mach. Intell., 24: 1644-1649.

Curtis, W.S. and C.L. Sabharwal, 1997. Human Face Recognition in the Wavelet Compressed Domain, Smart Engineering Systems. In: Smart Engineering Systems: Neural Networks, Fuzzy Logic, Data Mining and Evolutionary Programming, Dagli, C.H., M. Akay, O. Ersoy, B.R. Fernandez and A. Smith (Eds.). ASME Press, New York, USA pp: 555-560.

Delac, K. and M. Grgic, 2007. Face Recognition. I-Tech Education and Publishing, Vienna.

Delac, K., M. Grgic and S. Grgic, 2009. Face recognition in JPEG and JPEG2000 compressed domain. Image Vision Comput., 27: 1108-1120.

Ekenel, H.K. and B. Sankur, 2005. Multiresolution face recognition. Image Vision Comput., 23: 469-477.

Funk, W., M. Arnold, C. Busch and A. Munde, 2005. Evaluation of image compression algorithms for fingerprint and face recognition systems. Proceedings of the 6th Annual IEEE Information Assurance Workshop, June 15-17, 2005, United States Military Academy, West Point, NY., USA., pp: 72-78.

Hotelling, H., 1936. Relations between two sets of variates. Biometrika, 28: 321-377.

James, M. and S. Arockiasamy, 2011. Face recognition in compressed domain based on wavelet transform and kd-tree matching. Global J. Comput. Sci. Technol., 11: 28-34.

James, M. and S. Arockiasamy, 2012a. Human face recognition in wavelet compressed domain using canonical correlation analysis. Int. J. Comput. Appl., 37: 36-40.

James, M. and S. Arockiaswamy, 2012b. Face recognition in compressed domain by applying canonical correlation analysis based feature vector optimization and neural network matching. Int. J. Comput. Sci. Network Secur., 12: 77-84.

Jelsovka, D., R. Hudec and M. Breznan, 2011. Face recognition on FERET face database using LDA and CCA methods. Proceedings of the 34th International Conference on Telecommunications and Signal Processing (TSP), August 18-20, 2011, Budapest, pp: 570-574.

Jolliffe, I.T., 2002. Principal Component Analysis. 2nd Edn., Springer-Verlag, New York, USA.

Kim, K.I., K. Jung and H.J. Kim, 2002. Face recognition using kernel principal component analysis. IEEE Signal Process. Lett., 9: 40-42.

Kukharev, G. and E. Kamenskaya, 2010. Application of two-dimensional canonical correlation analysis for face image processing and recognition. Pattern Recogn. Image Anal., 20: 210-219.

Lee, S.H. and S. Choi, 2007. Two-dimensional canonical correlation analysis. IEEE Signal Process. Lett., 14: 735-738.

Li, B. and Y. Liu, 2002. When eigenfaces are combined with wavelets. Knowledge-Based Syst., 15: 343-347.

Martinez, A.M. and R. Benavente, 1998. The AR face database. CVC Technical Report No. 24, June 1998.

Oh, B.J., 2005. Face recognition using radial basis function network based on LDA. World Acad. Sci. Eng. Technol., 7: 225-259.

Rakshit, S. and D.M. Monro, 2007. An evaluation of image sampling and compression for human iris recognition. IEEE Trans. Inform. Forensics Secur., 2: 605-612.

Timotius, I.K., I. Setyawan and A.A. Febrianto, 2010. Face recognition between two person using kernel principal component analysis and support vector machines. Int. J. Electr. Eng. Inform., 2: 53-61.

Turk, M. and A. Pentland, 1991. Eigenfaces for recognition. J. Cognitive Neurosci., 3: 71-86.