Face Recognition: A Fourier Transform and SVD Based Approach

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***Abstract*-Authentication based on a person's face is one of the most stringent measures to secure a place or system. In this report such a method has been proposed that successfully identifies a person. The proposed algorithm also identifies a person with emotions/varied face expressions. This algorithm first enhances the image and then computes its singular value decomposition(SVD) to yield a matrix containing singular values followed by its singular value decomposition which further yields a single numerical value, instead of a matrix, that has been employed to compare images. This report presents a method employing frequency domain transformation followed by Singular Value Decomposition of the test image which is used to compare it with the original image in the database. Experiments are performed with face images of Psychological Image Collection at Stirling(PICS) and the results are also shown.**

***Keywords*- Face recognition; Biometrics; Singular Value Decomposition(SVD)**

I. Introduction

Automatic face recognition has gained much importance in the past few years and intense research is taking place in this field to optimize it further to yield much better results. Various methods have been presented in the past to arrive at a satisfactory result. The need for an efficient face recognition technique dates back to years using password protected system. Then came the need for a better and secure systems as password protected systems could be easily hacked or deceived. The next phase belonged to simple Biometrics wherein fingerprints or retina were used for security; although they are still in use but the relative ease of obtaining a face biometric sample makes such systems enticing. This paper is concerned with the face recognition for varying expressions or under normal expression with a high success rate. Singular Value Decomposition (SVD) is a powerful tool not only for calculating the diagonal matrix containing singular values of a rectangular matrix but also for modal analysis [1],[2].
SVD is a projection based recognition technique. It requires less space and is also more efficient than Eigen face.

II. Face Recognition algorithm

There are numerous models to recognize a person using his face [3]–[15]. However, the model presented in this paper also yields useful results and a significant improvement in the accuracy over some of the conventional methods.

Discrete Fourier Transform (DFT) has been used to enhance the input image in the frequency domain.

Following are the steps involved for filtering an image in frequency domain:

1) f(x,y) is the image fed as input where f(x,y) is a grayscale image.

2) F(u,v) is obtained after performing fourier transform on f(x,y)

$$F(u,v)=\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)e^{-j2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)} \quad (1)$$

3) The third step involves linear filtering which makes use of convolution theorem.

$$f(x,y)*h(x,y) \longleftrightarrow H(u,v)F(u,v) \quad (2)$$

where the symbol "*" denotes convolution of two functions; f(x,y) being the image and h(x,y), the filter mask and F(u,v) and H(u,v) are their fourier transforms respectively.

4) The last step is to compute the inverse Discrete Fourier transform to return the processed image (G(u,v)) back to its original domain (into x and y coordinates) from Fourier domain,

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$$G(u,v)=H(u,v)F(u,v) \quad (3)$$

$$g(x,y)= \frac{1}{MN}\sum_{u=0}^{M-1}\sum_{v=0}^{N-1} G(u,v)e^{j2\pi(\frac{ux}{M}+\frac{vy}{N})} \quad (4)$$

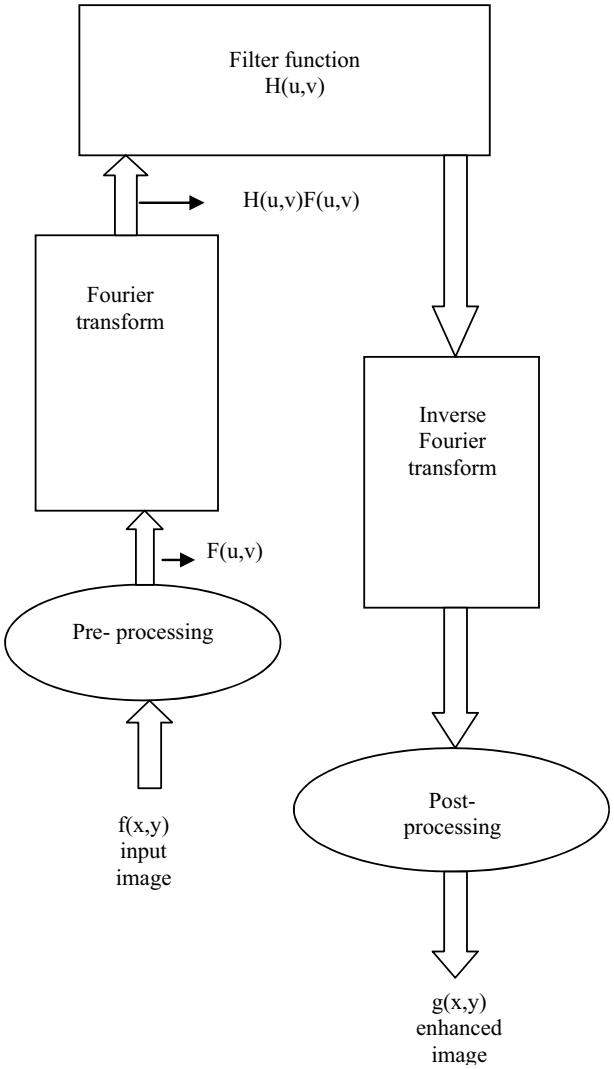

Figure 1. Steps for filtering in frequency domain

Following is a result obtained by using above mentioned filtering method:

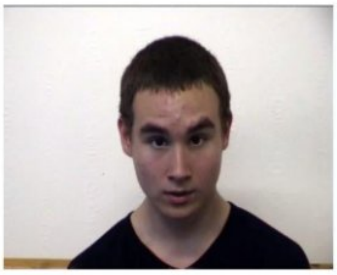

Figure 2[22]. Original face image from PICS image database

Figure 3. Processed image (using Matlab)

As it can be seen in the processed image that the target i.e. the person to be identified has been selected (a white boundary has been created on the outer boundaries of the target) and his features have been sharpened. Using this feature, one can easily Figure out the area of interest which can be further used for comparison.

The next step is to compare this image with the one already present in the database. This task is accomplished by using Singular Value Decomposition (SVD). The SVD is computed as:

a=svd(i) (5)

where i is the matrix whose SVD is to be calculated and is stored as a diagonal matrix containing singular values in another matrix "a".

The SVD [16] theorem states that the SVD of an M × N matrix is given by:

$$X = U\sum V' \quad (6)$$

where columns of U are the left singular vectors corresponding to the eigenvectors of $XX'$and $\sum$ is a diagonal matrix of singular values $\sigma_k$with singular values arranged in order of descending value $\sigma_1 > \sigma_2 > \cdots . \sigma_N$. The columns of matrix V represent the right singular vectors, or the eigenvectors of XX'=R, where R is the autocorrelation matrix of X. But in case of SVD, the calculation of R, the autocorrelation matrix is not essential as in case of Eigen Value Decomposition (EVD).

Further decomposing $\sum$ into its singular values would yield a single value. Following is the data obtained when these

operations were performed on a face image from PICS image database:

Computing the SVD of the sample image of Figure 1[22] yielded following data (information is shown at each step):

- After converting "h" (the variable in which the image was stored) from class unit8 to class double, its size was 576×720.
- Decomposing "h" into singular values returned a matrix g of same class i.e. class double but of size 576×1.
- Further decomposing "g" yielded a singular value of class double and 8 bytes size with its value as 1.2302e+05

III. Application of SVD and the results

SVD[19] is an important technique in signal processing. It is also employed for perturbation analysis [18] in the context of subspace decomposition. SVD also finds its use in denoising applications [17]. For reconstructing seismic transmission traveltime tomography [23], a combination of appropriate weighting matrices, variable regularization parameter are used along with SVD is used.
After using the DFT and filtering followed by inverse DFT, SVD (twice) is used to compute the singular value of the image matrix.
So , the proposed algorithm looks like following:

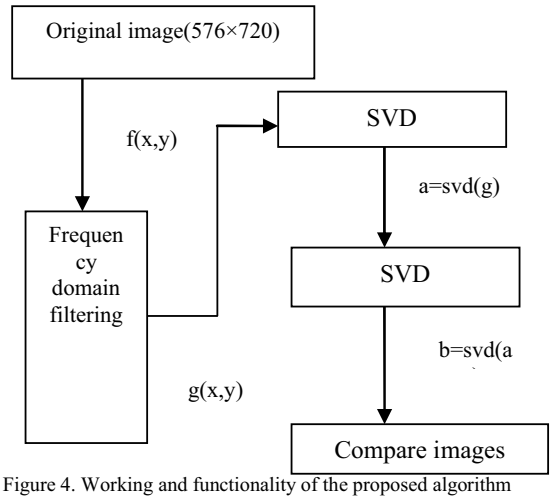

Figure 4. Working and functionality of the proposed algorithm

This algorithm was applied to various set of images containing varied expressions and was also tested on same image. Following is a set of results thus obtained on the images shown.

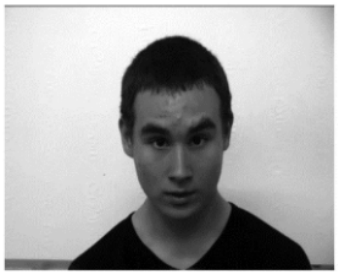
Figure 5[22]. Test image from PICS image database


Figure 6[22]. Test image from PICS database

When Figure 5 was used as security image in the database and Figure 6 as test image for matching, the proposed algorithm yielded a value 678.1048 which is the difference between singular values of the two images based upon this algorithm (can be considered as an offset). Another test was performed on two different persons with same posture which showed following result:

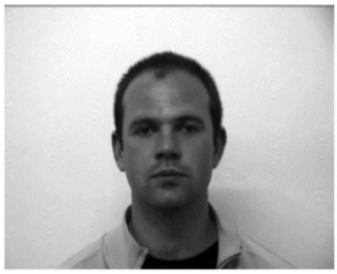
Figure 7[22]. Test image from PICS database

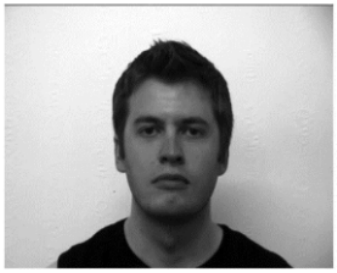

Figure 8[22]. Test image from PICS database

When Figure 7 was used as a database image to match images and face image of Figure 8 was used to compare, the singular value (difference between the two images) obtained was 5.0121e+03. Similarly, such test was performed on various images and a singular value of 800 was found to be appropriate to be used as a threshold value. The algorithm's implementation will display a message "Images match" when the singular value of the test image lies within the range ±800 of the image in the database being used as original image.
When used on varied expressions, this method also matched the images under test.

Figure 9[22]. Test image from PICS database

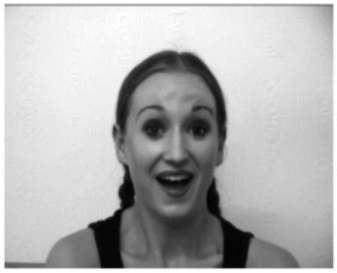

Figure 10[22]. Test image from PICS database

As the change of expression can be seen in the image, this algorithm still recognized the face with the difference in singular value being just 196.5086.

Figure 11[22]. Test image from PICS database

And when Figure 11 was used instead of fog 10, the result was somewhat higher but still within the reaches of the threshold value and was found to be 506.7386.
Following are processed images of Figures 9 and 11 that were used for comparison.

Figure 12. Processed image for Figure 9

Figure 13. Processed image for Figure 11.

IV. Conclusion

Face recognition method is a transition from the currently in use biometric system[20] employing, hand, fingerprint or retina. There have also been developments in the field of hidden biometrics[21] but the idea of using an MRI or an X-Ray as a security identification seems to be a comparatively expensive approach. Although various successful methods for face recognition have already been developed e.g. Line Edge mapping [14], Multi Modal Approach [10] etc., but my

algorithm has also shown successful results for various sets of face images. When the same image, which was already in the database, was used for recognition, the singular value obtained or the offset was 0. But this algorithm can only be used for matching human faces and it needs to be optimized further in order to make it universally acceptable .

References

[1] S. Ahmed and E.P. Li, "Modal Analysis of Microstrip Lines Using Singular Value Decomposition Analysis of FDTD Simulations", IEEE Transactions on Electromagnetic Compatibility, Vol. 50, No. 3, pp. 687-696, August 2008

[2] J.B.Fahline, R.L.Campbell and S.A.Hambric, "Modal Analysis Using the Singular Value Decomposition", February 2004

[3] Z. Zhang, D. Yi, Z. Lei and S. Z. Li, "Regularized Transfer Boosting for Face Detection Across Spectrum", IEEE Signal Processing Letters, Vol. 19, No. 3, pp. 131-134, March 2012

[4] R. M. Ramadan and R. F. Abdel-Kader, "3D Face Compression and Recognition Using Spherical Wavelet Parametrization", International Journal of Advanced Computer Science and Applications, Vol. 3, No. 9, 2012

[5] S. Z. Li, R. F. Chu, S. C. Liao and L. Zhang, "Illumination Invariant Face Recognition Using Near-Infrared Images", IEEE Transactions On Pattern Analysis and Machine Intelligence, Vol. 29, No. 4, pp. 627-639, April 2007

[6] I. Dagher and R. Nachar, "Face Recognition Using IPCA-ICA Algorithm", IEEE Transactions On Pattern Analysis and Machine Intelligence, Vol. 28, No. 6, pp. 996-1000, June 2006

[7] W. S. Zheng, J. H. Lai and P. C. Yuen, "GA-Fisher: A New LDA-Based Face Recognition Algorithm With Selection of Principal Components", IEEE Transactions on Systems, Man and Cybernetics-Part B: Cybernetics, Vol. 35, No. 5, pp. 1065-1078, October 2005

[8] C. Garcia and M. Delakis, " Convolution Face Finder: A Neural Architecture for Fast and Robust Face Detection", IEEE Transactions On Pattern Analysis and Machine Intelligence, Vol. 26, No. 11, pp. 1408-1423, November 2004

[9] J.Chen, R. Wang, S.Yan, S.Shan, X.Chen and W.Gao, "Enhancing Human Face Detection by Resampling Examples Through Manifolds", IEEE Transactions on Systems, Man and Cybernetics-Part A: Systems and Humans, Vol. 37, No. 6, pp. 1017-1028, Novemberber 2007

[10] P. Vadakkepat, P. Lim, L. C. De Silva, L. Jing and L. L. Ling, "Multimodal Approach to Human-Face Detection and Tracking", IEEE Transactions on Industrial Electronics, Vol 55, No. 3, pp. 1385-1393, March 2008

[11] H. Sellahewa and S. A. Jassim, "Image-Quality-Based Adaptive Face Recognition", IEEE Transactions on Instrumentation and Measurement, Vol. 59, No. 4, pp. 805-813, April 2010

[12] N. K. Baloch, M. h. Yousaf, W. Ahmad and M. I. Baig. "Algorithm for Efficient Management: Face Recognition based approach", International Journal of Computer Science Issues, Vol. 9, No. 4, pp. 146-150, July 2012

[13] S. Muruganantham, T. Jebarajan, "An Efficient Face Recognition System Based on the Hybridization of Pose Invariant and Illumination Process", International Journal of Computer Science Issues, Vol. 9, No. 1, pp. 228-237, July 2012

[14] Y. Gao and M. K. H. Leung, "Face Recognition Using Line Edge Map", IEEE Transactions On Pattern Analysis and Machine Intelligence, Vol. 24, No. 6, pp. 764-779, June 2002

[15] P. Mohanty, S. Sarkar, R. Ksaturi, P. J. Phillips. "Subspace Approximation of Face Recognition Algorithms: An Empirical Study", IEEE Transactions on Information Forensics and Security, Vol. 3, No. 4, pp. 734-748, December 2008

[16] F. W. Mauldin Jr., D. Lin and J. A. Hossack, "The Singular Value Filter: A General Filter DesignStrategy for PCA-Based Signal Separation in Medical Ultrasound Imaging", IEEE Transactions on Medical Imaging, Vol. 30, No. 11, pp. 1951-1964, November 2011

[17] S. K. Jha and R. D. S. Yadava, "Denoising by Singular Value Decomposition and its Application to Electronic Nose Data Processing", IEEE Sensors Journal, Vol. 11, No. 1, pp. 35-44, January 2011

[18] J. Liu, X. Liu and X. Ma, "First-Order Perturbation Analysis of Singular Vectors in Singular Value Decomposition", IEEE Transactions on Signal Processing, Vol. 56, No. 7, pp. 3044-3049, July 2008

[19] M. Sharif, S. Anis, M. Raza and S. Mohsin, "Enhanced SVD based Face Recognition", Journal of Applied Computer Science and Mathematics, No. 12(6), 2012

[20] J. C. Yang, "Biometrics Verification Techniques Combing with Digital Signature for Multimodal Biometrics Payment System", International Conference on Management of e-Commerce and e-Government, 2010

[21] A. Nait-Ali, "Hidden Biometrics: Towards Using Biosignals and Biomedical Images for Security Applications", 7th International Workshop on Systems, Signal Processing and their Applications, 2011

[22] Psychological Image Collection at Stirling(PICS) face images, pics.stir.ac.uk

[23] L. P. Song and S. Y. Zhang, "Singular Value Decomposition-Based Reconstruction Algorithm for Seismic Traveltime Tomography", IEEE Transactions on Image Processing, Vol. 8, No. 8, pp. 1152-1154, August 1999