Pattern Recognition Using the Concept of Disjoint Matrix of MIMO System

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Abstract: *In many applications, it is necessary to compare two or more images to identify the originality of them. For example, verification of fake logo of an organization or fake signature of an official can be considered in this context. The cross correlation and wavelet transform are widely used techniques to compare two images but they are low sensitive to awgn noise and very small change in the image. Different learning algorithms for example Principle Component Analysis (PCA) are prevalent for this purpose at the expense of process time. In this paper we apply the concept of uncorrelated MIMO channel of wireless link on different images such that received signal vector corresponding to the largest six eigen values will reflect the characteristics of the images. In this paper, three types of images: human face with background, fingerprint and human signature are considered for identification and the proposed model shows rigidity in identification of the image under rotation and noise contamination.*

Keywords: *Uncoupled MIMO links, eigenvalues, unitary matrix, noise and channel matrix.*

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1. Introduction

Pattern recognition is a vast growing field of image processing/computer vision in recognition of an object. For example, face recognition approach of [2, 7, 25] is designed to distinguish a specific identity from the unknown objects characterized by face images. An Efficient method for face recognition is based on Principal Component Analysis (PCA) explained in [4, 17, 20]. In PCA based face detection, few training images of same dimension are converted to vectors. The average vector and the difference vectors are then evaluated. Next the eigenvalues and eigenvectors are evaluated from difference vectors as explained in [8]. Converting the Eigen vectors into an image matrix provides eigenfaces. Next a weighting factor and corresponding weighting vector is computed. Finally, the Euclidian distance between weighting vectors of the training images and the test class provides the identity of face. Instead of group of pictures and their eigenfaces for training, a single image face recognition approach using Discrete Cosine Transform (DCT) is proposed in [6], where both the local and global features of face are extracted using both DCT and zigzag scanning from the coefficients of DCT. Here, images of size of 128×128 are taken from database and out of 16384 coefficients, only 64 are considered as the feature of the image. Similar analysis is found in [12], where additionally the co-ordinates of eyes are put manually to normalize the face. The accuracy of the system is found to be about 95% which depends on the number of DCT coefficients.

In image processing, Two-Dimensional (2D) wavelet transform is widely used with some threshold to preserve the most energetic coefficients for both denoising or compression of image even identification of an image. For this purpose, 2D filter bank [11] or wavelet packet transform [15, 19, 24] are widely used. Most widely used technique of pattern recognition is to select an image of $2^n \times 2^n$, where n is a positive integer. Discrete Wavelet Transform (DWT) is applied on the first column vector and the approximation coefficients vector which is just half the size of the original column vector evaluated. Actually, the approximate component is found simply from the convolution of the column vector and the impulse response of lowpass filter. The DWT is applied on the column vector recursively until a single point is found. If such operation is applied on each column vector then we will get a row vector for the image. Finally, DWT is applied on the row vector recursively until getting a vector of length 8 which actually the 8 minimum spectral points of the image. The resultant vector can be considered as a feature of an image as discussed in [1, 22].

Instead of the above conventional pattern recognition technique we will use a different approach to identify an image. Here we choose the eigen-decomposition technique of Multiple Input Multiple Output (MIMO) link of wireless communication. In wireless communication systems, the MIMO system enhances channel capacity without increasing the required bandwidth of the communication system [18, 26] since it can alleviate different types of fading in wireless communication system based on spatial diversity and spatial multiplexing techniques summarized in [5, 26]. Most of the researchers are interested to decompose the MIMO link based on eigen-decomposition and singular value decomposition [9]. Such analysis is necessary to find the strength of uncoupled link so that transmit antenna can be selected to provide more power. A modification of above decomposition is shown in [23] using Discrete Fourier Transform (DFT) which provides the scope of spectral control of signal. In this paper, we adopt the concept of MIMO link of $n_R \times n_T$ channel matrix, where we put the image of N×N against the channel matrix. The uncoupled transmitted and received signals are considered as the feature of the image.

The paper is organized as follows: section 2 provides the analytical model of MIMO link and the way of decomposition of mutual disjoint components, section 3 provides the results based on the concept of section 2, and finally, section 4 concludes the entire analysis.

2. Disjoint Links of MIMO Channel

A MIMO system consists of several transmit and receive antennas. We can consider a system with n_T transmit and n_R receive antennas. The channel of this system is defined by an $n_R \times n_T$ matrix, which is denoted by H, as a complex matrix. The transmitted signal is represented by an $n_T \times 1$ column matrix, denoted by symbol x, whereas the received signal is represented by an $n_R \times 1$ column matrix, denoted by symbol r.

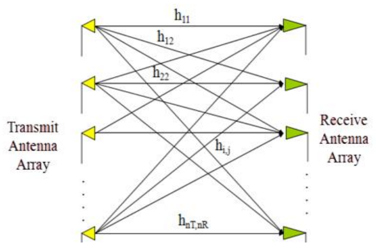


Figure 1. MIMO channel of wireless network.

The complex channel matrix, $H(n)$ of Figure 1 is expressed by the following $n_R \times n_T$ complex matrix: [13]:

$$\mathrm{H}(n)=\begin{bmatrix} h_{11}(n) & h_{12}(n)\ldots\ldots\ldots & h_{Nt1}(n) \\ h_{21}(n) & h_{22}(n)\ldots\ldots\ldots & h_{Nt2}(n) \\ \vdots & \vdots & \vdots \\ h_{Nr1}(n) & h_{Nr2}(n)\ldots\ldots\ldots & h_{NrNt}(n) \end{bmatrix} \quad (1)$$

The system equations can be expressed as the following matrix form [10]:

$$r(n)=H(n)\mathrm{x}(n)+n(n) \quad (2)$$

The $n_R \times 1$ vector denotes the complex noise vector as:

$$n(n)=\left[\tilde{n}_1(n), \tilde{n}_2(n), \ldots\ldots\ldots, \tilde{n}_{Nr}(n)\right]^T \quad (3)$$

To simplify the equation, we can suppress the dependence on time n by the following expression

$$r = Hx + n \quad (4)$$

Let us define a matrix:

$$Q=\begin{cases} HH^H; & n_R < n_T, \\ H^H H; & n_R \ge n_T. \end{cases} \quad (5)$$

The eigenvalues λ of Q is evaluated from:

$$det\left(\lambda I_m - Q\right)=0 \quad (6)$$

where $m=\min(n_R, n_T)$.

Let us define another two unitary matrices: matrix U and matrix V such that the columns of U are the eigenvectors of HH^H and that of V are the eigenvectors of $H^H H$.

Now the received signal vector can be rewritten as [3, 14]:

$$r = U\Lambda VHx + n \quad (7)$$

where Λ is an $n_R \times n_T$ non-negative diagonal matrix, U and V are $n_R \times n_T$ and $n_T \times n_R$ unitary matrices respectively.

The diagonal matrix Λ can be expressed as:

$$U^H H(VV^H)H^H U = \Lambda \quad (8)$$

Let us define new $n_T \times n_T$ diagonal matrix [D 0]. Here O is a null matrix and is added to maintain matching of matrix dimension. We can write the diagonal matrix as:

$$\Lambda = [D\ 0]\,[D\ 0]^H \quad (9)$$

Using Equations 4, 8, and 9, we have the following transformation of Equation (7):

$$r' = [D\ 0]\, x' + n',$$

Where, $r'=U^H r$, $x'=V^H x$, and $n'=U^H n$. By doing these, the n_R uncoupled parallel channels are shown in Figure 2.

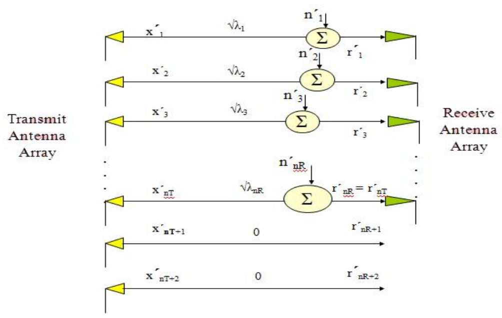


Figure 2. Equivalent uncoupled MIMO channel.

Numerical Example:

Given

x = [0.2+0.4i; 1.1-0.6i; 0.45-0.34i; 1.2+1.4i];

n = [0.001+0.02i; 0.003-0.005i; 0.04-0.003i; 0.0012-0.003i].

H = [0.23-0.12i -0.612+0.09i -0.71+0.12i 0.32+0.11i; 0.112-0.098i 0.16+0.23i 0.154-0.22i 0.32-0.23i; -0.53-0.12i 0.321-0.25i 0.56-0.076i 0.71-0.22i; 0.86-0.23i -0.887-0.099i 0.23+.76i 0.45-0.42i].

We evaluate

r =

-0.5729 + 1.4296i

1.0791 + 0.1978i

1.5713 - 0.2012i

0.7200 + 1.1081i

U =

0.3620 + 0.2623i -0.1647 - 0.1681i -0.7509 - 0.3720i 0.0263 + 0.2047i

-0.0026 - 0.1564i 0.1840 + 0.0868i -0.2623 - 0.2052i -0.0323 - 0.9068i
-0.1678 - 0.2142i 0.4944 + 0.6960i -0.2446 - 0.1826i -0.0517 + 0.3182i
0.8376 0.4176 0.3061 -0.1738

V =
0.5369 + 0.0428i -0.1859 - 0.0882i -0.2561 + 0.3282i 0.5015 - 0.4926i
-0.5553 + 0.0367i 0.2847 + 0.3541i -0.2285 - 0.2482i 0.2688 - 0.5457i
-0.2136 - 0.5249i 0.3771 - 0.2273i -0.4464 + 0.4635i 0.0884 + 0.2509i
0.2812 0.7466 0.5465 0.2548

$$\Lambda = \begin{bmatrix} 3.2808 & 0 & 0 & 0 \\ 0 & 1.4094 & 0 & 0 \\ 0 & 0 & 0.4875 & 0 \\ 0 & 0 & 0 & 0.1645 \end{bmatrix}$$

$$D = \begin{bmatrix} 1.8113 & 0 & 0 & 0 \\ 0 & 1.1872 & 0 & 0 \\ 0 & 0 & 0.6982 & 0 \\ 0 & 0 & 0 & 0.4056 \end{bmatrix}$$

x′ =
1.1463 - 0.3709i
1.1710 + 0.4022i
-0.8752 - 0.4612i
1.2282 + 0.1279i

n′ =
0.0013 + 0.0140i
0.0370 - 0.0082i
0.0126 + 0.0125i
-0.0090 - 0.0050i

r′ =
-0.5163 + 2.1346i
1.4957 + 0.1729i
0.2989 + 0.6411i
0.4518 + 0.1911i

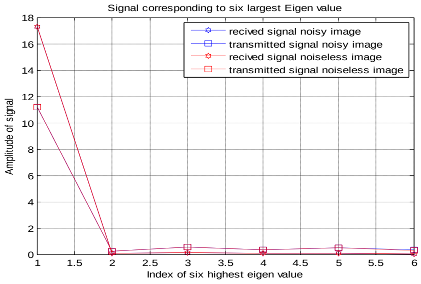
$r = (U^H)^{-1} r' =$
-0.5729 + 1.4296i
1.0791 + 0.1978i
1.5713 - 0.2012i
0.7200 + 1.1081i;

Which is same as the calculated previously. In result section we will consider x' and r' as the feature of the image.

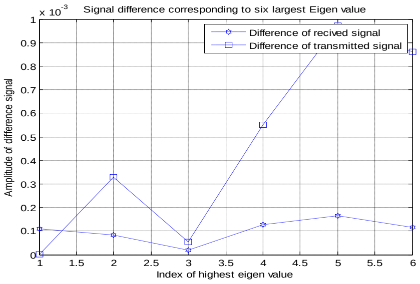
3. Results

In this section we consider three types of image as mentioned previously. Let us first test human image using the system model proposed in section 2. First of all we compare between an image shown in Figure 3.a and its noisy version with-12dB noise shown in Figure 3.b. The uncorrelated transmitted and received signals of six strongest paths are plotted in Figure 3.c. The graph has four legends but only two curves are visualized since two transmitted and two received vector pair points are so close that they seem to be overlapped. Then we plot the difference between the received and transmitted signal vectors of two images. Since, same images (one original and another it's noisy version) are used hence difference between the vectors at corresponding indices are found very small, i.e., close to zero.

a) Original image. b) Noisy image.



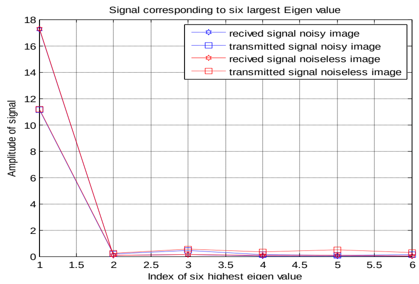
c) Uncorrelated transmitted and received signal vector of two images.



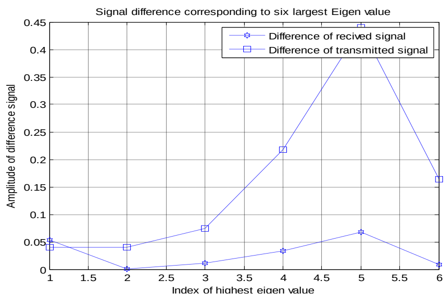
d) Difference of transmitted and received signal vectors.

Figure 3. Comparison of images using MIMO with -12db noise.

a) Original image. b) Noisy image.



c) Transmitted and received signal of two images.



d) Difference of transmitted and received signal vector of two images.

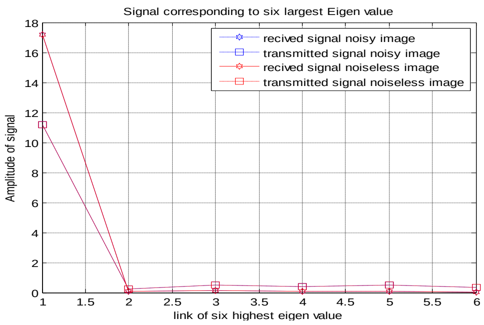
Figure 4. Comparison of images using MIMO with-40db noise.

Next we increase the noise level to -40dB shown in Figures 4.a and 4.b and similar operation is applied on the images. Now the difference is found significant compared to previous one but still less than 0.45 as shown in Figures 4.c and 4.d.

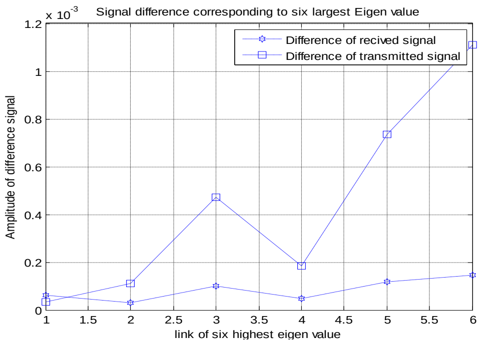
Now rotate the noisy image (-12dB) to 180^0 and the corresponding results are shown in Figures 5.a, 5.b, 5.c, and 5.d, where the difference between the transmitted vectors as well as received vectors are found close to zero. Therefore, the mode can recognise an image irrespective of rotation and noise level below some threshold.

a) Orifinal image.

b) Noisy image.



c) Transmitted and received signal of two images.



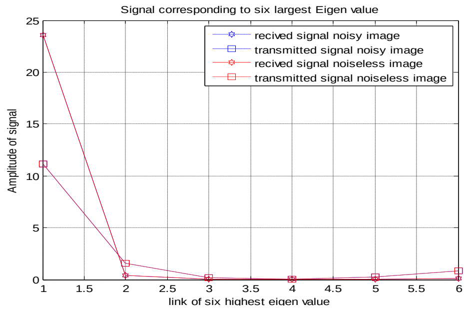
d) Difference of transmitted and received signal vector of two images.

Figure 5. Comparison of images using MIMO with 180 deg rotation.

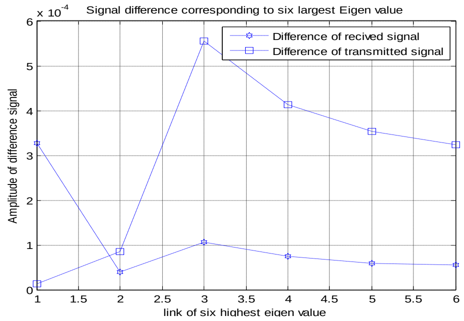
Next, we consider the image of fingerprint like [21] to test whether our proposed scheme can be applied in biometric identifications or not. First of all we choose a fingerprint of single core and its noisy version shown in Figures 6.a and 6.b. Both the equivalent transmitted and received signal pairs are overlapped and the difference is found in the order of 10^{-4} as shown in Figures 6.c and 6.d. Now, we take two different fingerprints one with single core another with double core shown in Figures 7.a and 7.b respectively. In this case, the variation of input and output signals is visualized from Figure 7.c which is 1000 times greater than the previous one.

a) Original image.

b) Noisy image.



c) Transmitted and received signal of two images.

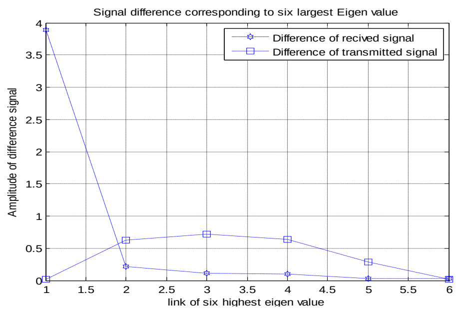


d) Difference of transmitted and received signal vector of two images.

Figure 6. Comparison of same fingerptint images using MIMO.

a) Finger print of single core

b) Finger print of double core

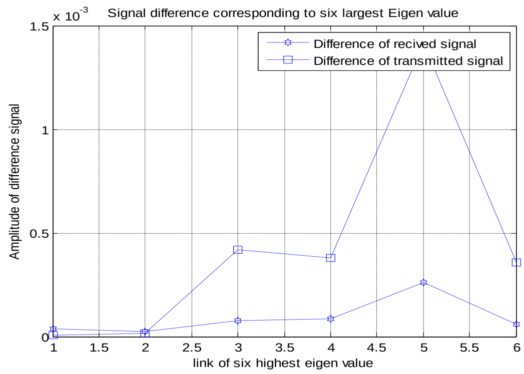


d) Difference of transmitted and received signal vector of two images

Figure 7. Comparison of different fingerptint images using MIMO.

Finally, we apply the concept in identification of image of signature. Two signatures of same person, where one signature is noisy shown in Figures 8.a and 8.b. In this case, difference between uncorrelated transmitted and received signals pair is in the order of 10^{-3} shown in Figure 8.c. When two different signatures with one noisy is selected then the difference is found almost 700 times of previous case shown in Figures 9.a, 9.b, and 9.c.

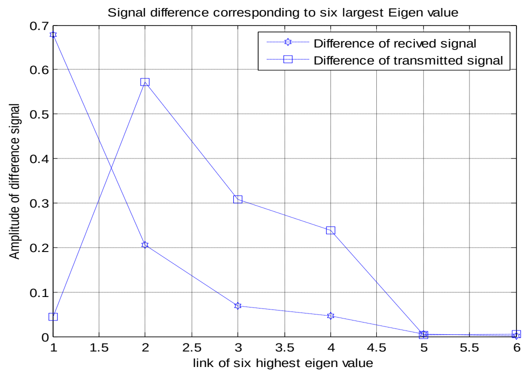
a) Original image. b) Noisy image.



c) Difference of transmitted and received signal vector of two images.

Figure 8. Comparison of same signature images using MIMO.

a) Original image. b) Noisy image.



c) Difference of transmitted and received signal vector of two images.

Figure 9. Comparison of different fingerprint images using MIMO.

4. Conclusions

In this paper, the concept of disjoint MIMO channel matrix is adopted to analyze the range of similarity of two images. Our analysis reveals that different categories of images like human faces, fingerprints, human signatures etc. can be recognized above -20dB noise level. We can also apply the proposed scheme in identification of letters of any language like [16]. Here we have selected only six links correspond to largest eigenvalues and the corresponding transmitted and received signal vectors. We can extent the work including more disjoint links to observe the condition of signal vector but the process time will be much higher for large number of uncoupled links. We can improve the proposed model using the concept of learning system of pattern recognition. For example, average value of transmitted /received vectors of several images from database will be taken as the reference vector. The Euclidean distance between the reference vector and the vector of test image will identify the category of the image.

References

[1] Alam M., Basak S., and Islam I., "Fingerprint Detection Applying DWT on ROI," *International Journal of Scientific and Engineering Research*, vol. 3, no. 6, pp. 1-5, 2012.

[2] Azeem A., Sharif M., Raza M., and Murtaza M., "A Survey: Face Recognition Techniques under Partial Occlusion," *The International Arab Journal of Information Technology*, vol. 11, no. 1, pp. 1-10, 2014.

[3] Bahrami H. and Le-Ngoc T., "Eigenstructures of MIMO Fading Channel Correlation Matrices and Optimum Linear Precoding Designs for Maximum Ergodic Capacity," *EURASIP Journal on Advances in Signal Processing*, vol. 2007, no. 1, pp. 1-9, 2007.

[4] Belhumeur P., Hespanha J., and Kriegman D., "Eigenfaces vs. Fisher Faces: Recognition Using Class Specific Linear Projection," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 19, no. 7, pp. 711-720, 1997.

[5] Bolcskei H., Gesbert D., and Paulraj A., "On the Capacity of OFDM-Based Spatial Multiplexing Systems," *IEEE Transactions on Communications*, vol. 50, no. 2, pp. 225-234, 2002.

[6] Chadha A., Vaidya P., and Roja M., "Face Recognition Using Discrete Cosine Transform for Global and Local Features," *in Proceeding of the International Conference on Recent Advancements in Electrical, Electronics and Control Engineering*, Sivakasi, pp. 502-505, 2011.

[7] Dagher I., Sallak N., and Hazim H., "Face Recognition using the most Representative Sift Images," *International Journal of Signal Processing, Image Processing and Pattern Recognition*, vol. 7, no. 1, pp. 225-236, 2014.

[8] Dashore G. and Cyril R.., "An Efficient Method or Face Recognition Using Principle Component Analysis," *International Journal of Advanced Technology and Engineering Research*, vol. 2, no. 2, pp. 23-28, 2012.

[9] Dong Q., Song J., Jiang S., and Ma Y., "Eigenvalue-Based Memoryless MIMO Channel Decomposition," *in Proceeding of International Conference on Image Analysis and Signal Processing*, Hangzhou, pp. 1-4, 2012.

[10] Goldsmith A., Jafar S., Jindal N., and Vishwanath S., "Capacity Limits of MIMO Channels," *IEEE Journal on Selected Areas in Communications*, vol. 21, no. 5, pp. 684-702, 2003.

[11] Gonzalez R. and Wood R., *Digital Image Processing*, Pearson education, 2013.

[12] Hafed Z. and Levine M., "Face Recognition Using the Discrete Cosine Transform," *International Journal of Computer Vision*, vol. 43, no. 3, pp. 167-188, 2001.

[13] Haykin S. and Moher M., *Modern Wireless Communications*, Pearson Education, 2005.

[14] Khan M., Cho K., Lee M., and Chung J., "A Simple Block Diagonal Precoding for Multi-User MIMO Broadcast Channels," *EURASIP Journal on Wireless Communications and Networking*, vol. 1/95, pp. 1-8, 2014.

[15] Kharate G. and Patil V., "Color Image Compression Based On Wavelet Packet Best Tree," *IJCSI International Journal of Computer Science*, vol. 7, no. 2, pp. 31-35, 2010.

[16] Kumar K., "Algorithm to Identify Kannada Vowels using Minimum Features Extraction Method," *International Journal of Innovative Technology and Exploring Engineering*, vol. 2, no. 2, pp. 79-84, Jan. 2013.

[17] Martinez A. and Kak A., "PCA vs. LDA," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 23, pp. 228-233, 2001.

[18] Paulraj A. Gore D., Nabar R., and Bolcskei H., "An Overview of MIMO Communications-A Key to Gigabit Wireless," *Proceedings of IEEE*, vol. 92, no. 2, pp. 198-218, 2004.

[19] Sethi J., Mishra S., Dash P., Mishra S., and Meher S., "Image Compression Using Wavelet Packet Tree," *ACEEE International Journal On Signal and Image Processing*, vol. 2, no. 1, pp. 41-43, 2011.

[20] Shah J., Sharif M., Raza M., and Azeem A., "A Survey: Linear and Nonlinear PCA Based Face Recognition," *The International Arab Journal of Information Technology*, vol. 10, no. 6, pp. 536-545, 2013.

[21] Suwarno S., Subanar, Harjoko A., and Hartati S., "Fingerprint Image Segmentation Using Haar Wavelet and Self Organizing Map," *International Journal of Advanced Computer Science and Applications*, vol. 4, no. 9, pp. 28-31, 2013.

[22] Thaiyalnayaki K., Karim S., and Parmar P., "Finger Print Recogni-tion Using Discrete Wavelet Transforn," *International Journal of Computer Applications*, vol. 1, no. 24, pp. 96-100, 2010.

[23] Tohidian M., Amindavar H., and Reza A., "A DFT-Based Approximate Eigenvalue and Singular Value Decomposition of Polynomial Matrices," *EURASIP Journal on Advances in Signal Processing*, vol. 93, pp. 2-16, 2013.

[24] Wang D., Miao D., and Xie C., "Best Basis-Based Wavelet Packet Entropy Feature Extraction and Hierarchical EEG Classification for Epileptic Detection," *Expert Systems with Applications*, vol. 38, no. 11, pp. 14314-14320, 2011.

[25] Zhao W., Chellappa R., Rosenfeld A., and Phillips P., "Face Recognition: A Literature Survey," ACM Computing Surveys, vol. 35, no. 4, pp. 399-458, 2003.

[26] Zheng L. and Tse D., "Diversity and Multiplexing: A Fundamental Tradeoff in Multiple-Antenna Channels," *IEEE Transactions on Information Theory*, vol. 49, no. 5, pp. 1073-1096, 2003.

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