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BIOMETRIC KEYSTROKE RECOGNITION BASED ON HYBRID SVD AND WAVELET FOR FEATURE TRANSFORMATION

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Abstract: The main aim of this work is using keystroke biometric system as behavioral type of biometrics and improving the accuracy and dependability of the system. In this proposed we've pre-processed the data of dynamic keystroke by converting the feature to one dimensional vector. In feature extraction we've used a Wavelet Energy (WE) by implementing 2D dimensional Discreet Wavelet (2D-DWT) into four-level and computing the energy for the Singular Value Decomposition (SVD). SVD is computed on the result of wavelet and saved in a file for training information. Wavelet transform Daubchies “DBI” basic function has advantage that provide a good energy localization in the frequency domain as other wavelet transforms and then using Elman networks (Backpropagation) for training and testing the system and its useful in such areas as signal processing and prediction where time plays a dominant role.

Keywords: *Biometrics, Keystroke, Singular Value Decomposition, Wavelet DBI, Neural Network*

تشخيص لوحة المفاتيح للقياسات الحيوية مرتكز على نظام هجيني لتحليل القيم الفردية والموجات المنفصلة لمرحلة استخلاص الخصائص

الخلاصة: يعتبر عمل أنظمة القياسات الحيوية من أهم الأنظمة التي تعتمد على التعرف على إحدى المعلومات الشخصية الحيوية. وان الغرض الأساسي من النظام المقترح اعتماد لوحة المفاتيح كنوع من أنواع القياسات الحيوية التصرفية بالإضافة إلى تحسين دقة واعتمادية النظام. في المرحلة الأولى من المقترح تم إجراء المعالجة الأولية لبيانات الديناميكية المسجلة للوحة المفاتيح بتحويلها إلى متجه ذو بعد واحد. وفي المرحلة الثانية هي مرحلة استخلاص السمات حيث قمنا باستخراج طاقة المويجات (Wavelet Energy) وذلك باستخدام المويجات المنفصلة (Discrete Wavelet) ذات البعدين وبأربع بمستويات. بالإضافة إلى ذلك تم حساب تحليل القيم المفردة (SVD) لطاقة المويجات واعتماد الناتج الأخير كخصائص للمعلومات الأشخاص في مرحلة التدريب والاختبار. أن الدالة المستخدمة في المويجات المتحولة هي (DBI) ولها فائدة وذلك بإعطاء قيمة جيدة للطاقة الموقعية في المجال المتذبذب من دون الدوال الأخرى ،وبالتالي يجعل من استخدام خوارزميه الشبكة العصبية نوع أيلمان ذات فائدة وقوة في معالجة وتقليل الخطأ في البيانات

1. Introduction

A biometric system is basically a pattern recognition system that achieves recognition based on numerous features resulting from measurements of physiological or behavioral characteristics that a person has. Biometric characteristics categories as fingerprint, facial features, iris, voice, signature, and palmprint, finger - knuckle, gait, keystroke etc. are now generally used in security applications. These unimodal biometric systems are faced with a range of problems, noise in sensed data, non universality, inter - class similarities, and spoof attacks. Multibiometrics are a relatively new approach to overcome those problems. Besides enhancing matching accuracy, the multibiometric systems have numerous advantages over traditional unibiometricsystems[1].

Multibiometric systems depend on representing each client by multiple sources of biometric information. Based on the nature of these sources, a multibiometric system can be classified into one of six categories, Multi-sensor systems, Multi- algorithm systems, Multi-instance systems, Multi-sample systems, Multimodal systems and Hybrid systems.

Fusion in multimodal biometric systems can happen at three different levels, feature extraction level, matching score level and decision level. Each category of fusion has its advantages and disadvantages. Fusion at feature extraction level has two main issues, the incompatibility between different feature vectors and the difficulty of finding a good classifier for high-dimensional joint feature vectors. Fusion at the decision level is somewhat loosely joined system architecture, with each subsystem performing similar to a single biometric system. So the fusion at match score level is the most generally used fusion type [1].

2. Related works

Kolhandai Yesu et al. in 2012 [2], neural network was used for face recognition. The recognition method is a hybrid of local features and global features approaches to present a system with FRR of 2% and FAR of 2%. Yeong Gon Kim et al. in 2012 [3], SVM was used as classifier. Matching score result for face, left and right iris were fused and used as an input for support vector machine (SVM). This model achieved equal error rate (EER) of 0.131 %. Vinayak D. Shinde and Vijay M. Mane in 2012 [4], Multilevel wavelet transform was used. Three level and four level was used for feature extraction. Using distance measure, FAR was 15.91% and FRR was 6.82. Praveen N. In 2013 [5], used user speech for recognition.

Two methods were studied, a discriminative classifier, multilayer perceptron artificial neural network ANNs and Vector Quantization (VQ) based minimum Euclidean distance classifiers. EER for ANN ranged between (0.0576 -0.0997). While for Euclidean distance classifiers the EER ranged between (0.1753 - 0.2456) depending on the used cluster size. K.Geetha and V.Radhakrishnan in 2013 [6], Features of palm and fingerprint were extracted, and wavelet was used by Fusion at feature level was performed and SVM was used as classifier. The accuracy of the SVM classifier was 97.53%.

3. Wavelet decomposition

The best way to define discrete wavelet transform over a number of cascaded filters. The input image X is divided into low pass filter (L) and high pass filter (H). The result of these filters has subsampled. The final resulting of the lowpasssubbandy_L and high pass subbandy_H are shown in Figure 1. The original signal can be reconstructed by synthesis filters (L) and (H) which take the up sampled y_L and y_H as inputs. One of the Wavelet families which is Daubchies 1 (DB1) has been used during featuring extraction phase in this work.

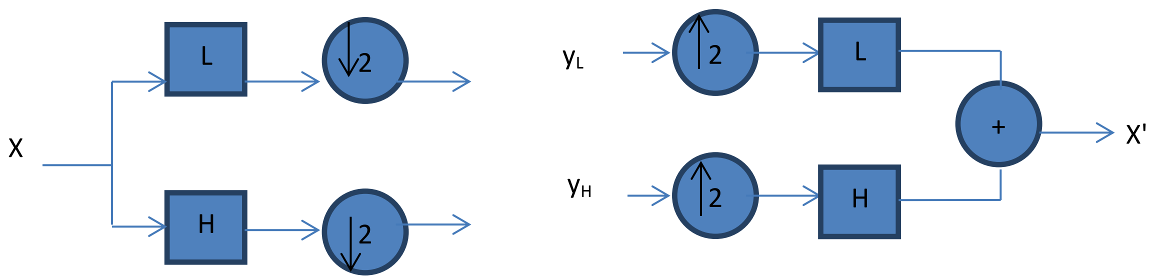

Figure 1. Wavelet Decomposition and Reconstruction process

The mathematical representations of yL and yH can be defined as:

$$y_L(n) = \sum_{i=0}^{t_L} L(i)X(2n-1) \qquad (1)$$

$$y_H(n) = \sum_{i=0}^{t_H} H(i)X(2n-1) \qquad (2)$$

Where t_L and t_H are the lengths of L and H respectively.

For a one dimensional vector, the approach of the 2D implementation of the discrete wavelet transform(DWT) is to achieve the one dimensional DWT in row direction or in column direction. In Figure 2. the LL is a coarser version of the original image and it holds the approximation information which is low frequency ,LH,HL, and HH are the high frequency subband containing the detail information. Further computations of DWT can be performed as the level of decomposition increases, the concept is illustrated in Figure 3. the second and third level decompositions based on the principle of multiresolution analysis show that the LL1 subband shown in Figure 3. is decomposed into four smaller subband LL4 ,LH4 ,HL4 ,and HH4[7,8].

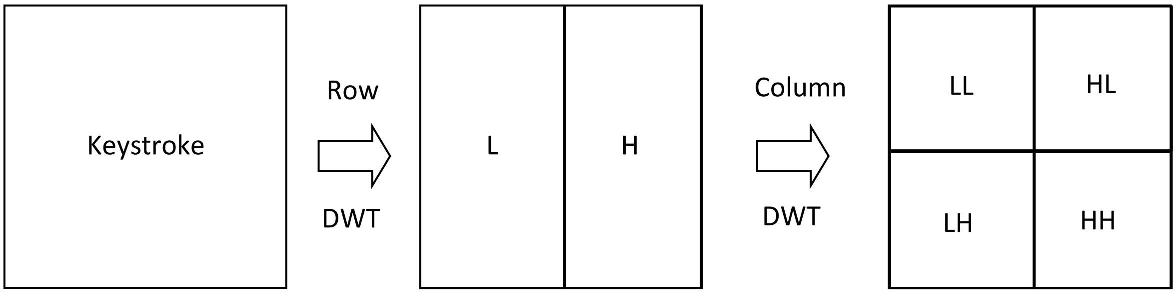

Figure 2. 2D row and column computation of DWT

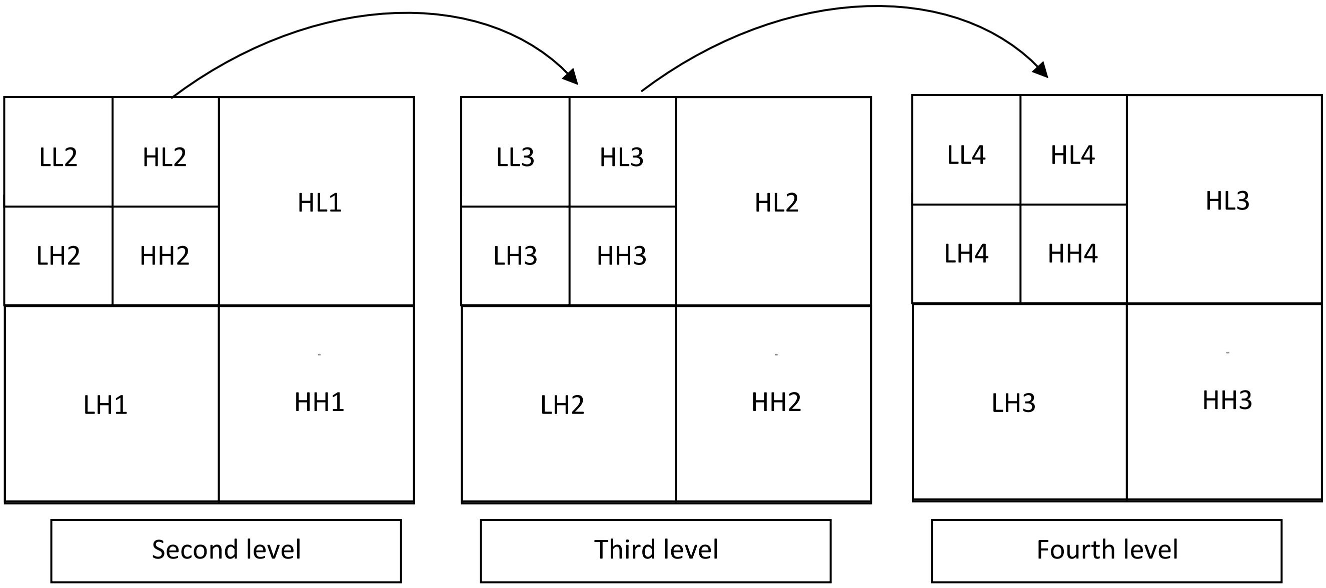

Figure 3. second, third and fourth level row and column decomposition.

The wavelet domain is a powerful and efficient technique for analyzing, decomposition, denoising, and compressing signals. In particular, the Discrete Wavelet Transform (DWT) breaks a signal into several time-frequency components that enables the extraction of feature desirable for signal identification and recognition.

4. Wavelet energy

Wavelet energy is a method for finding wavelet energy for 1-D wavelet decomposition. The wavelet energy provides percentage of energy corresponding to the approximation and the vector containing the percentage of energy corresponding details. The wavelet energy is computed as follows[9,10]:

$$WE(s_i) = \sum_{j=1}^{L_i} w^2(s_i, j)/L_i \qquad (3)$$

Where s_i is the scale, L_i is the total number of wavelet coefficient in scale, $w(s_i,j)$ is current wavelet coefficient in scale s_i.

Instead of the wavelet energy considered as quality assessment algorithm uses subband characteristics in wavelet domain. The existing metrics are analyzed a limitations are investigated. Image quality evaluation using wavelet energy computation uses a linear combination of high frequency coefficients after Daubechies wavelet transform. The probability density function of the enhanced image has relatively higher energy in wavelet domain compared to other transforms. Therefore, the wavelet energy metric is an effective and efficient metric to evaluate the quality of the enhanced image. The approximation wavelet energy coefficients provide the information on the global image enhancement and detailed wavelet energy coefficients provide statistics on the image details [11].

After that, we've performed 4-level wavelet decomposition. Hence the coefficient matrix for all the three levels were generated. The coefficient matrix were generated for the approximation, horizontal, vertical and diagonal details. Once the coefficient matrix were obtained, we calculated energy corresponding to each of the coefficient matrix, for two dimensional wavelet decomposition, the percentage of energy corresponding to the approximation, horizontal, vertical, and diagonal details.

5. Singular value decomposition svd

Singular Value Decomposition (SVD) is said to be a significant topic in linear algebra by many renowned mathematicians. SVD has many applied and theoretical values; special feature of SVD is that it can be achieved on any real number (m, n) matrix. Considering a matrix such A contains m rows and n columns, with rank such r where $r \leq n \leq m$. Then the matrix A can be factorized into three matrix as described below[12, 13,14]:

$$A = USV^T \qquad (4)$$

where matrix U is an mxm orthogonal matrix

$$U = [U_1, U_2, \dots, U_r, U_{r+1}, \dots U_m] \qquad (5)$$

column vectors Ui, for i=1,2,...,m, form an orthonormal set:

$$U_i^T U_j = \delta_{ij} = \begin{cases} 1 & i = j \\ 0 & i \neq j \end{cases} \qquad (6)$$

and matrix V is an mxn orthogonal matrix

$$V = [V_1, V_2, \dots, V_r, V_{r+1}, \dots V_m] \qquad (7)$$

column vectors V_i for i=1,2,...,n, form an orthogonal set:

$$V_i^T V_j = \delta_{ij} = \begin{cases} 1 & i = j \\ 0 & i \neq j \end{cases} \qquad (8)$$

here, S is an mxn diagonal matrix with singular values (SV) on the diagonal. the matrix S can be showed in following:

$$S = \begin{bmatrix} \sigma_1 & 0 & \dots & 0 & 0 & \dots & 0 \\ 0 & \sigma_2 & \dots & 0 & 0 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \sigma_r & 0 & \dots & 0 \\ 0 & 0 & \dots & 0 & \sigma_{r+1} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & 0 & 0 & \dots & \sigma_n \\ 0 & 0 & \dots & 0 & 0 & \dots & 0 \end{bmatrix} \qquad (9)$$

For i=1,2,...,n,σ are called singular values of matrix A.

6. Neural network learning

Neural networks has ability to solve complicated or imprecise data especially used to extract patterns of feature and solve too complex to be noticed by either humans or other computer techniques. A trained neural network considered as an "expert" in the classification of information. One of the most powerful method of learning called (Elman recurrent neural network)[7,8,9]. This method is proven highly successful in training of multilayered neural nets. The neural network is not just used to support for how it is doing on a task. Information about errors is also filtered back through the system and is used to adjust the connections between the layers, thus improving performance[15, 16].The ANN system consists of a high number of a thoroughly interconnected processing elements (neurons) also known as perception.

The perceptron has inputs that come either from the environment or is the output of other perceptions. Each input xj has a connection weight wj and the output y.

$$y = \sum_{j=1}^{d} w_j x_i + w_0 \qquad (10)$$

The error on the single instance pair with index t, (xt, rt), is

$$E^t(w|x^t, r^t) = \frac{1}{2}(r^t - y^t)^2 = \frac{1}{2}[r^t - (w^T x^t)]^2 \qquad (11)$$

and for j = 0, . . ., d, the online update is

$$\Delta w_j^t = \eta(r^t - y^t)x_j^t \quad (12)$$

Where η is the learning factor, which is gradually decreased in time for stochastic convergence.

The neural networks can be only one layer network (perceptron) or consist of a number of layers (multi-layer network). Furthermore, the geometrical connection can be either feedforward or backpropagation. There are different algorithms for adaptation of link weights. In backpropagation networks in addition to having a feed-forward connections, for the hidden layer there is also an error feedback connection from each of the previous neurons.

The Elman network is commonly a two-layered network. That has a recurrent feedback neural network and it can detect and generate a pattern that is varying with time. An Elman network consist of a number of context nodes placed in the input layer. These context nodes increase the activity of a hidden layer, at the input of the neural network, at the previous time step. This variation enables the Elman neural network to deal with conflicting patterns.

7. Quality metrics

There are some metrics have been used in our work to measure the quality of results. These metrics described as below.

- **MSE (Mean Square Error):** this metric used to measure the similarity of two data or signals by subtracting test data from the reference (trained) and it's defined as:

$$MSE = \frac{1}{M * N}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(x(i,j) - y(i,j)\right) \quad (13)$$

Where, M and N are the vector dimension, x(i,j) and y(i,j) position of data for both test and reference.

- **PSNR (Peak Signal Noise Ratio):** this metric used to measure the ratio between data variance and reconstruction error variance and it's defined as:

$$PSNR = 10\log_{10}\frac{(2^n - 1)^2}{\sqrt{MSE}} \quad (14)$$

- **Max Error**: it's defined as the maximum of the error by find difference between test data and reference as described below:

$$MAX\ Error = MAX\ x(i,j) - y(i,j) \qquad (15)$$

8. Proposed method

A block diagram of the basic stages for proposal work can be shown in Figure 4. These stages involve feature extraction and fusion, pattern recognition and the creation of template. Finally, identification is performed by matching with the trained features.

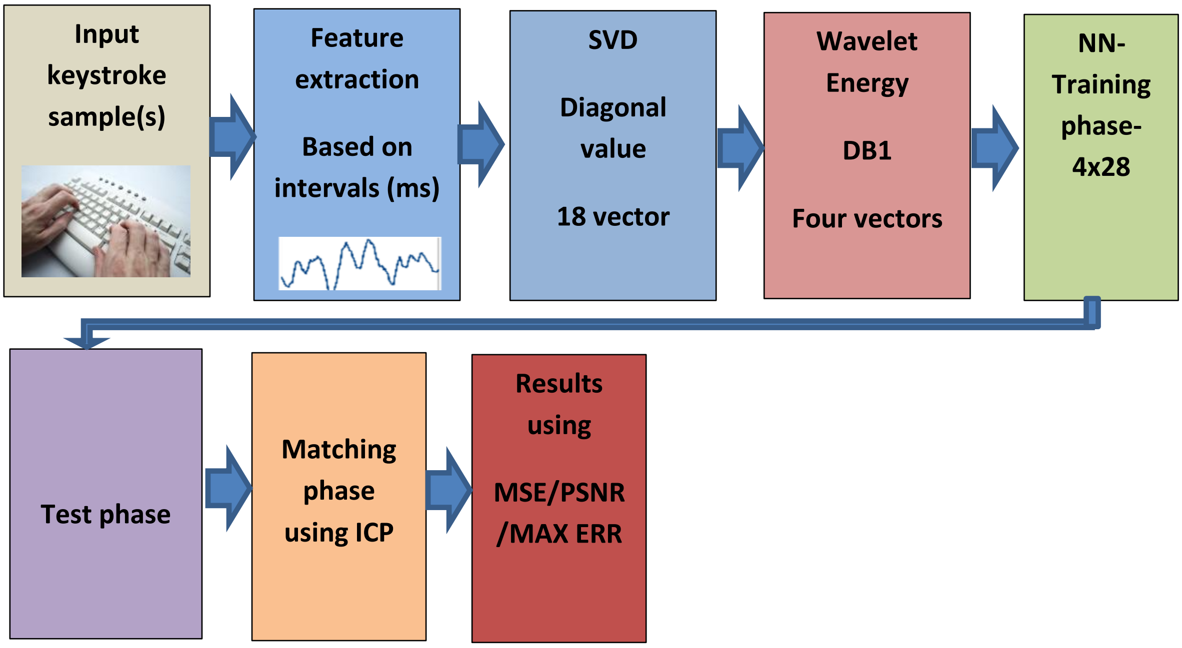

Figure 4. Block diagram of proposal work

In the proposed work, keystrokes samples have been recorded by typing word "in the name of God" and calculating the time among each letter as described in Table (1).

Table 1. Intervals in *ms* among each letter for each person

Samples	*Naeem*	*Hala*	*Usama*	*Bahaa*
Sample1	0.792089	0.518073	0.358614	1.155119
Sample2	1.052188	0.710766	0.296132	0.260039
Sample3	3.676216	3.020021	0.434293	0.823378
Sample4	0.262836	0.240714	0.23683	0.414273
Sample5	3.811974	0.446558	0.221622	1.21094
Sample6	0.954856	0.306667	0.211758	0.285025
Sample7	3.298788	0.632914	0.607311	1.366237
Sample8	0.994467	0.204149	0.186209	0.664466
Sample9	2.3372	0.94237	0.417038	0.855912
Sample10	0.548095	0.441176	0.36968	0.287266
Sample11	1.909615	0.455295	0.214197	1.003756
Sample12	0.775146	2.315599	0.592925	0.847692
Sample13	4.353999	0.546129	0.224515	0.699475
Sample14	0.829313	0.273008	0.256052	0.391036

Sample15	2.695493	0.843907	0.586095	0.653737
Sample16	2.036296	0.284759	0.512607	1.099444
Sample17	1.690447	0.372103	0.603197	0.439751
Sample18	1.132842	1.012985	0.727032	1.866206

The samples' feature mentioned above in Table 1. has been illustrated in graph as shown in Figure 4.

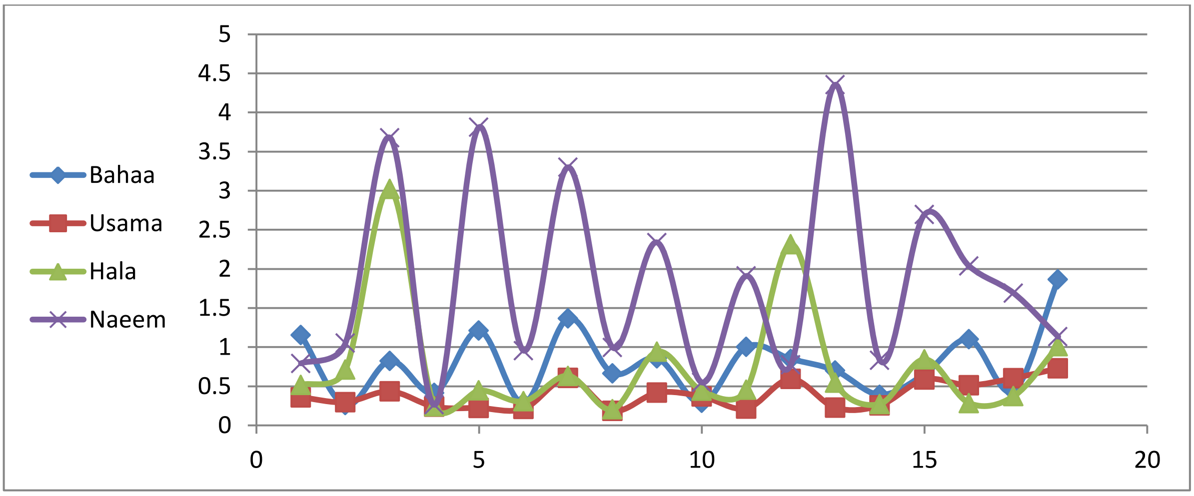

Figure 4. Recorded data for one sample for each person

In this paper, the dataset has contents of ten samples for four persons, seven of these samples for each person have prepared for training phase, and rest of the samples used for testing phase. For feature extraction, we have used SVD for given processed keystrokes to find singular vectors of keystroke matrix.

SVD technique can be measured as an algebraic feature and the algebraic features usually characterize intrinsic properties. The first property of SVD is that: the singular values are unique, but the matrices U and V are not unique. By applying (SVD) to a sample of the keystroke (m_r b_y m_c),

$$[U\ S\ V]=U\sum V(KS_n) \qquad (16)$$

where U is an m_r by m_r dimension orthogonal matrix (U=U-1), $\sum$ is an m_r by m_c diagonal matrix (0 except on its main diagonal) and V is an m_c by m_c orthogonal matrix (V=V-1). The diagonal entries of sum are the singular values of keystroke sample (KS). The result of SVD has shown in Figure 5.

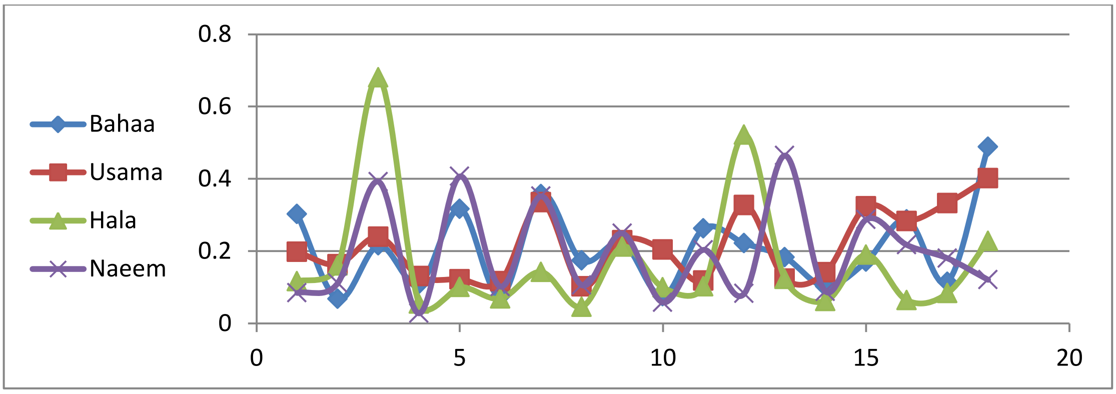

Figure 5. The results of SVD for one dataset.

The dimension of diagonal of singular values *s* is the same size of the keystroke sample, in this case apply (four level) db1to achieve one dimensional DWT in row direction. Then, holds the approximation information of singular value be decomposed into four smaller subbandLL4 ,LH4 ,HL4 ,and HH4.

Wavelet energy is compute in the find process using a linear combination of high frequency coefficients after a Daubechies wavelet transform. All the four-levels details coefficients are squared and summed up into one energy feature for each level.

Wavelet energy has been illustrated in graph as shown in Figure 6.

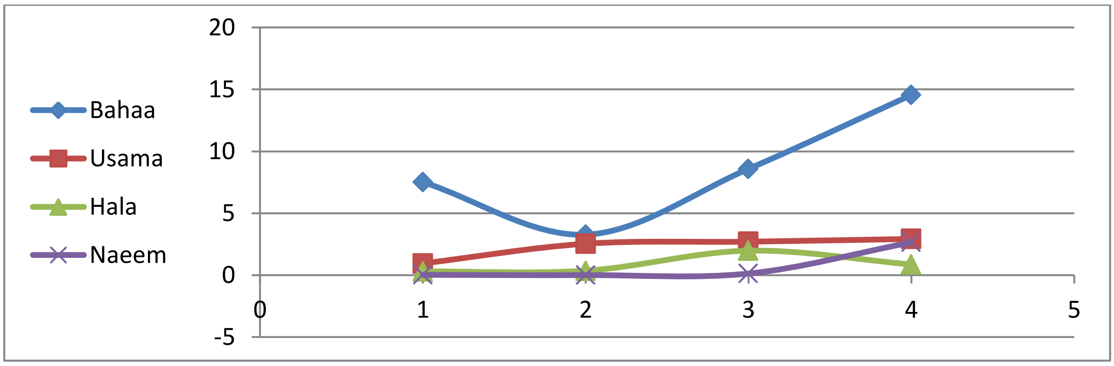

Figure 6. Wavelet energy results for one dataset

At this point we will have 40 fused vectors. Four vectors for each sample and for each person. The fused feature vectors will be used as an input for the neural network. In this case the neural network will have (28) input. The output is template of the pattern of the feature vectors that was learned by the neural network for all of the (28) vectors and this came by take (7) samples for (4) persons. For this module, Elman neural network will be used. This neural network is a recurrent neural network. The training function that will be used is the gradient descent with momentum and adaptive backpropagation learning. The transfer functions for the input layer and the hidden layers will be tan –sigmoidand pureline transfer functions. The number of hidden neurons trials. Figure 7. shows the illustration of proposed design of Neural Network.

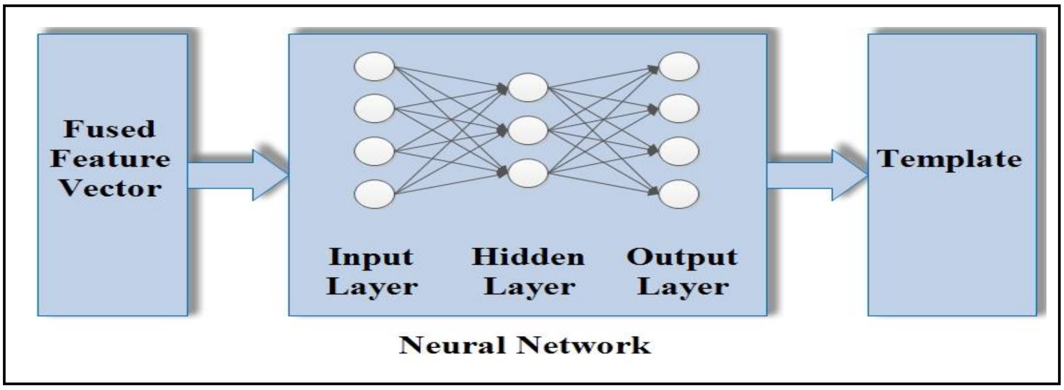

Figure 7. Proposed design of Neural Network

Training the neural network with the fused feature will result a (4 x28) output pattern template. The template size for this module will be small and will not take a lot of memory space. This is the advantage of using wavelet decomposition to reduce the vector size. Training neural network is required only once. After the training process, the template will be saved for future matching. When testing the module the neural network will be used to learn the pattern of the input feature vector based on its prior learning.

9. Simulation results

The design of NN has input layer, hidden layer consists of 100 neurons, and output layer consists of 30 neurons. The number of training set samples for each person is (3 samples), and used Log-sigmoid transfer function takes the inputs and transfer the output into the range 0 to 1, and the recognition rate is (97.995) by whole tested sample. In the proposed work, has been design an application using Matlabto design a module for biometric keystroke processing. The application design has contents phases (preprocessing, feature extraction, training, and testing) as shown in Figure 8.

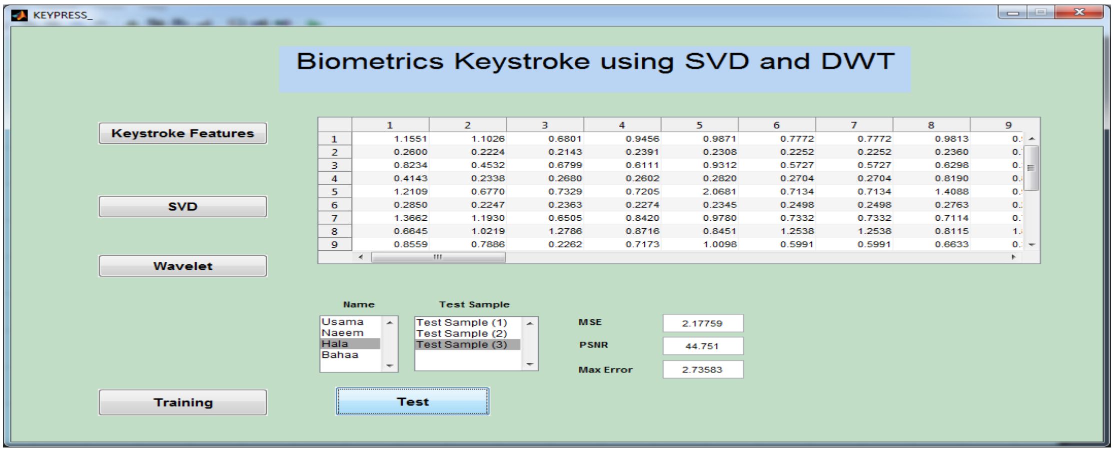

Figure 8. Application design of proposed work

During experimental work, we have evaluate of the module by analyzing results through two phases training and testing by using three metrics measurement for performance (MSE, PSNR, and Max Error). We have tested our work by taking two samples for each person, and processed these samples in same way for training phase. After processing step, a feature extract by applying SVD and coefficient energy of DWT. In matching phase, we've used Iterative Closest Point (ICP) to find the closest match of test feature with whole features of trained data and find MSE, PSNR, and Max error for matched samples as described in Table 2.

Table 2. Measurement metrics to performance proposed work

Name	*MSE*	*PSNR*	*Max Err*
bahaa	2.7323	43.7655	3.1719
bahaa	4.8086	41.3107	3.0137
hala	4.2702	41.8263	3.5976
hala	0.3506	52.6831	0.9917
Naeem	1.7482	45.7049	2.1928
Naeem	0.2264	54.5821	0.7191
Usama	2.408	44.3142	1.9917
Usama	2.5385	44.085	2.5723

10. Conclusions

Biometrics become an important issue in security as an authentication because it has unique biological characteristics (behavior and/or physical). In this work, keystroke characteristics have been analyzed and processed with two methods (SVD and Wavelet DB1). SVD has used to reduce dimensionality of features of keystroke samples, where the Discrete Wavelet has used to transform the diagonal results of SVD and find the coefficient energy of each level (4 levels) where the energy become (4 values). The recognition phase focused on creates, trains and evaluates our work using Neural Network – backpropogation. In the testing step, the proposed to use closest neighbor matching algorithm for the extracted feature of test sample to the feature in the database (trained dataset). Finally, we've evaluate our work by using metrics measurements (PSNR, MSE, and MAX ERR),

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