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Signature Recognition using 2D Discrete Wavelet Transforms

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Abstract: Signature recognition is one of the most secure techniques used for person identification. Wavelet transforms possess an extra time localization property over Fourier transforms, despite both are frequency localized. That is why; it is more useful to analyze the one dimensional and two dimensional signals both. First of all the features of a signature are extracted and then matching is performed. We have proposed feature extraction technique using discrete wavelet transforms level-1 and matching of signatures are performed using some statistical parameters of discrete wavelet coefficients using matching percentage, sum of absolute difference, mean square error and city block distance.

Keywords: Signature recognition, discrete wavelet transform, matching percentage, sum of absolute difference and mean square error, city block distance.

I. INTRODUCTION

Person identification is a very common and important process in many government and private systems. The best way for this is the identification through signature made by a person. Several techniques are being used for the recognition of signature, but we are proposing a simple and effective technique for signature recognition using discrete wavelet transforms. It is very important to recognize whether a given signature is genuine or a forge. In online recognition system the pressure, speed, direction etc. of signature of any person is analysed. But in most of the cases in India, the signatures are generally off-line. Recognition of these offline signatures is a great challenge facing by our experts. In off-line signature verification, the digitization of signature written on paper is performed through their scanning [1]. In this process few dynamic information are missed which result as low accuracy. Despite this, the offline approaches are more general, simple and needed in many situations. Three types of forgery are being observed in handwritten signatures as skilled, unskilled and random forgery [2]. In skilled forgery, the signatures are deliberately written by any professional forgers, for this they make a lot of practices and expense long time to copy other's signatures. This type of forgery is very hard to detect and hence face a quite challenge.

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In unskilled forgery, the signer is not professional and experienced, he/she makes signature of any person in his own style after observing signature of that person for a short while. But in random forgery, the signer writes signature of any person by using the name of that person in his own style for the forgery called the simple or random forgery. Fourier transforms are replaced by wavelet transforms due to its advantages to analyze functions having discontinuities and sharp peaks. The wavelet transforms are frequently used to accurately analyze the finite, non-periodic and/or non-stationary signals.

The wavelet is a mathematical function that is able to decompose a function or signal into different scale components having different frequency range. The basic wavelet having finite length and fast decaying oscillating waveform is called mother wavelet. By dilation and translation of mother wavelet the daughter wavelets are generated. Continuous wavelet transforms work over every possible value of scale and translation, while discrete wavelet transforms work over specific values of scale and translation.

The main advantages of wavelet transforms are to provide better signal analysis due to multi-resolution analysis and additional time localized properties [4]. Due to these properties, the wavelet transforms are frequently applied for a vast number of applications in many areas of Physics and Engineering such as signal and image processing, climate dynamics, human behaviour and psychology, speech recognition, computer graphics, multi-fractal analysis and sparse coding.

In wavelet transform a signal or function is decomposed into mutually orthogonal set of wavelets which works as filters. When a signal is passed through these filters, it is divided in two bands. The low pass filter corresponding to an average operation extracts the approximation information of the signal, while the high pass filter corresponding to a difference operation, extracts the detail information of the signal [8].

In image processing, an analysis filter bank having a set of low pass and a high pass filter at each decomposition stage is generally used. Signature of any person is treated as image signal in wavelet transform aspects. This signature is image wavelet transformed and the corresponding discrete wavelet coefficients are obtained. In general, two dimensional transform is equivalent to two separate one-dimensional transforms. First of all, the image is filtered along x-dimension using low pass and high pass filters and decimated by two. The low pass filtered coefficients and high pass filtered are stored on the left and right part of the matrix respectively. Due to decimation process of the image analysis, the size of original and wavelet transformed image are same.

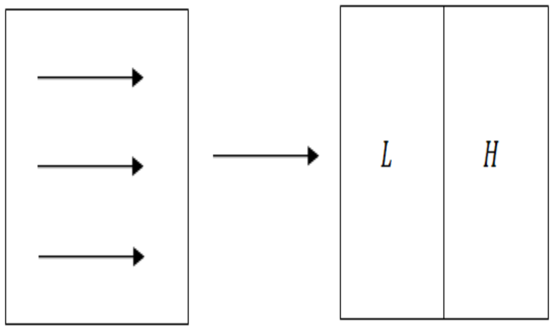

Fig. 1. Horizontal transform; 2 sub-band

After this operation the sub-image is filtered along the y-dimension and again decimated by two. After one level decomposition in x and y dimension, the image is divided into four sub-bands denoted by $LL1$, $HL1$, $LH1$, and $HH1$ where L represents to low and H to high.

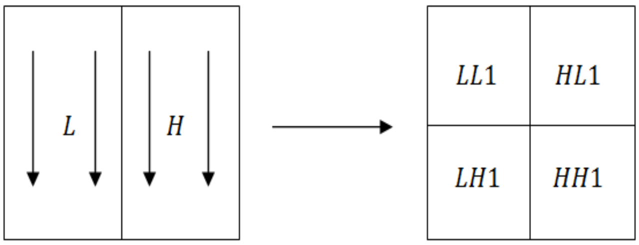

Fig. 2. Vertical transform; 4 sub-bands

II. DISCRETE WAVELET TRANSFORMS

The whole family of wavelets can be generated by single mother function by translating and scaling the mother wavelet, and expressed as:-

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) = T_b D_a \psi \qquad (1)$$

Where a and b are dilation or scaling parameter and translation parameter respectively and ψ (t) is real-valued function [3]. The continuous wavelet transform is represented as follows:-

$$W_{a,b} = \int f(t)\frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right)dt$$

$$= \int f(t)\,\psi_{a,b}(t)dt \qquad (2)$$

Taking $a = 2^{-j}$ and $\frac{b}{a} = k$, where j and k are integers, the discrete wavelet transform is defined as:-

$$W_{j,k} = \int f(t)\, 2^{j/2}\, \psi(2^j t - k)dt \qquad (3)$$

$$= \int f(t)\, \psi_{j,k}(t)dt$$

We get discrete wavelets as following:-

$$\psi_{j,k}(t) = 2^{j/2}\psi\,(2^j t - k)$$

A. Haar Wavelet

The Haar wavelet is discontinuous and resembles with a step function [5]. Its mother wavelet function ψ(t) is described as:-

$$\psi(\mathrm{t}) = \left.\begin{matrix} 1 \text{ for } 0 < t < 1/2 \\ -1 \text{ for } 1/2 < t < 1 \\ 0 \text{ Otherwise} \end{matrix}\right\} \qquad (4)$$

The scaling function $\phi(t)$ of Haar wavelet is described as:-

$$\phi(t) = \left.\begin{matrix} 1 \text{ for } 0 < t < 1 \\ 0 \text{ otherwise} \end{matrix}\right\} \qquad (5)$$

Its wavelet and scaling function can be shown in figure as follows:-

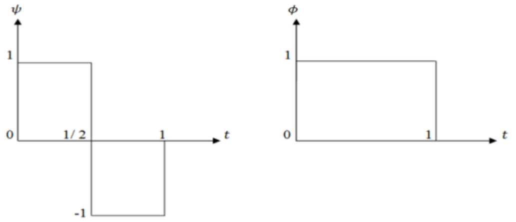

Fig. 3. Haar wavelet and scaling function

The Haar wavelet transform has low computing requirements in process of signal analysis and it is able to compact the signal and conserve its total energy too. Due to these properties of Haar wavelet transform, it is frequently used for image processing and pattern recognition.

B. Biorthogonal Wavelet

Biorthogonal wavelets represent to the family of compactly supported symmetric wavelets [6]. The symmetry of the wavelet filter coefficients is desirable because it results in linear phase of the transformed function. Biorthogonal wavelets exhibit the property of linear phase, so that they are very useful in signal and image processing.

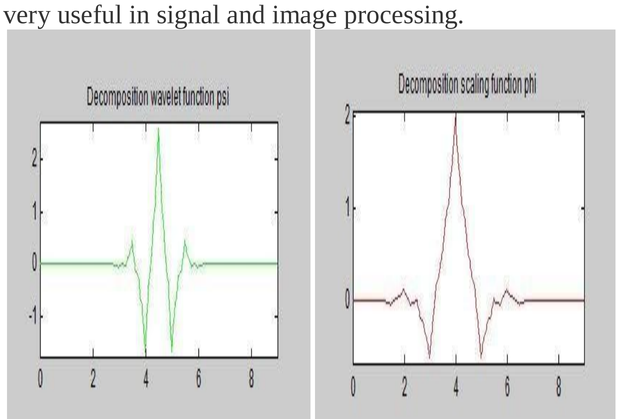

Fig. 4. Biorthogonal wavelet and scaling function

C. Multiresolution Analysis

A multiresolution analysis (MRA) is a recursive method of performing the discrete wavelet transforms [7]. It is introduced by Mallat and consists of a sequences $V_j : j \in \mathbb{Z}$ of closed subspaces of $L^2(\mathbb{R})$. The Lebesgue space is space of square integrable functions, satisfying the properties as follows:-

1) $V_{j+1} \subset V_j \qquad : j \in \mathbb{Z}$

2) $\cap_{j\in\mathbb{Z}} V_j = \{0\}$, $\cup_{j\in\mathbb{Z}} W_j = L^2(\mathbb{R})$,

3) For every, $L^2(\mathbb{R}), f(x) \in V_j \Rightarrow f\left(\frac{x}{2}\right) \in V_{j+1}$, $\forall\ j \in \mathbb{Z}$.

4) There exists a function $\phi(x) \in V_0$ such that $\{\phi(x-k): k \in \mathbb{Z}\}$ is orthonormal basis of V_0.
here the function $\phi(x)$ is known as scaling function of given MRA and property 3) implies a dilation equation as follows:-

$$\phi(x) = \sqrt{2}\ \sum_{k\in\mathbb{Z}} h_k\ \phi(2x-k)$$

where h_k is called low pass filter, defined as:-

$$h_k = \int_{-\infty}^{\infty} \phi(x)\phi(2x-k)\,dx$$

The wavelet function $\psi(x)$ can be expressed as follows:-

$$\psi(x) = \sqrt{2}\ \sum_{k\in\mathbb{Z}} g_k\ \phi(2x-k)$$

where, $g_k = (-1)^{k+1} h_{1-k}$ Any signal can be expressed in terms of bases of V_j space such that,

$$V_j = V_{j+1} \oplus W_{j+1},\ \forall j \in \mathbb{Z}$$

where W_{j+1} is the orthogonal complement of V_{j+1} in V_j ($V_{j+1} \perp W_{j+1}$). By iteration, we can write,

$$V_j = W_{j+1} \oplus W_{j+2} \oplus W_{j+2} \dots\dots\dots$$

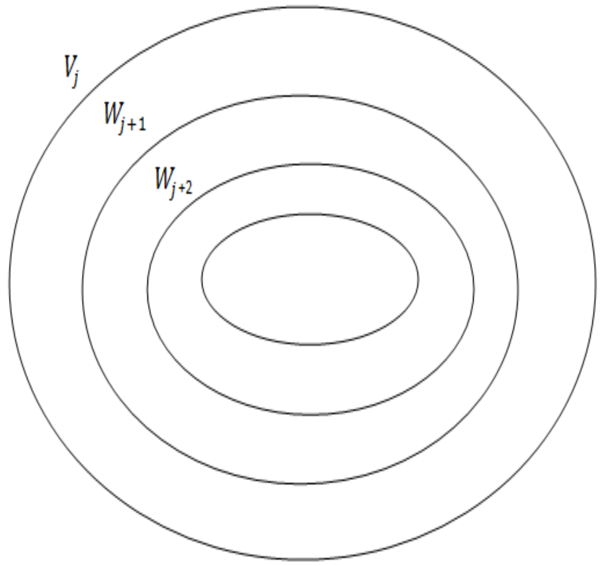

Fig. 5. Decomposition of signal space

2D Wavelet Transform

In 2D-wavelet transform of an image, the scaling and wavelet functions are described as,

$$\phi_{j,m,n}(x,y) = 2^{-j/2}\phi(2^{-j}x-m, 2^{-j}y-n)$$

$$\psi^i_{j,m,n}(x) = 2^{-j}\psi^i(2^{-j}x-m, 2^{-j}y-n),$$

for $1 \le i \le 3$. The wavelet functions $\{\psi^1_{j,m,n}, \psi^2_{j,m,n}, \psi^3_{j,m,n}\}$ are orthonormal basis of the subspace of details,

$$W_j^2 = (V_j \otimes W_j)\ (W_j \otimes V_j\ ) \oplus (W_j \otimes W_j\ ) \text{ at scale } j.$$

The Lebesgue space $L^2(\mathbb{R}^2)$ can be expressed as:-

$$L^2(\mathbb{R}^2) = \oplus_j W_j^2$$

Discrete wavelet transforms with a cascade of filtering with $\bar{h}$ and $\bar{g}$ is followed by sub-sampling process. The LL1, HL1, LH1 and HH1 are each $M/2 \times N/2$ submatrices. The trend LL1 corresponds to scaling coefficients, while the fluctuations HL1, LH1 and HH1 correspond to wavelet coefficients for each of the three kinds of wavelet basis functions. The trend LL1 corresponds to the scaling coefficients for the scaling basis $\{\phi_{j,M-1}(x)\phi_{k,M-1}(y)\}$ and occupies the upper left quadrant of the image wavelet transforms.

III. METHODOLOGY

We are developing a signature recognition system, in which we are using seven signature samples as in figure (6) out of which two samples are of same person.

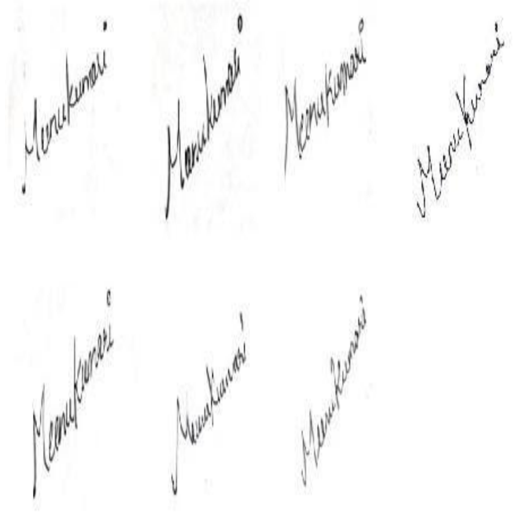

Fig. 6. Signature samples

In this system, we give one sample as test image that is to be compared with six samples that are stored in image database. Following are the steps of proposed work:

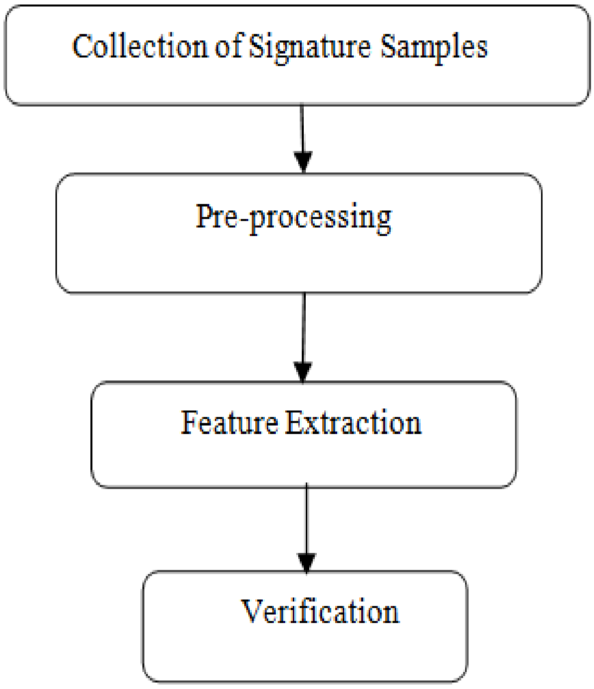

Fig. 7. Step flow chart

2D wavelet transforms of **test** signature and database signatures are performed using Haar and Biorthogonal 2.4 wavelet, level 1. The wavelet coefficients are obtained belonging to subspace LL1 which correspond to the approximation of image, The statistical parameters matching percentages, sum of absolute differences, mean square error, and city block distance of wavelet coefficients level 1 of test signature and database signatures are determined and compared.

IV. RESULT AND DISCUSSION

With help of the wavelet coefficients belonging to sub space LL1 aforesaid statistical parameters are determined which are very helpful in signature recognition.

Table -I: Comparison of Matching Percentage of test and database signatures

Matching percentage		
Signature Sample	**Haar**	**Biorthogonal 2.4**
S1- S2	73.2666	71.2921
S1-S3	66.9678	63.2889
S1-S4	61.4258	57.7515
S1-S5	69.4824	66.9693
S1-S6	67.8711	65.7501
S1-S7	70.4346	68.6539

From table 1, it is clear that matching percentage for S1 and S2 using Haar and Biorthogonal 2.4 wavelet transforms are maximum and 73.2666 & 71.2921 respectively.

Table-II: Comparison of Sum of absolute difference of test and database signatures

Sum of absolute difference		
Signature Sample	**Haar**	**Biorthogonal 2.4**
S1- S2	522096	578283
S1-S3	611136	665799
S1-S4	685872	760648
S1-S5	590752	636937
S1-S6	674896	651240
S1-S7	595424	741794

From table 2, it is clear that the sum of absolute difference for S1 and S2 using Haar and Biorthogonal 2.4 wavelet transforms are minimum and 522096 & 578283 respectively.

Table- III: Comparison of Mean square error of test and database signatures

Mean Square error		
Signature Sample	**Haar**	**Biorthogonal 2.4**
S1- S2	662.7366	701.1694
S1-S3	835.7593	737.2454
S1-S4	906.8875	972.3706
S1-S5	741.2988	756.2222
S1-S6	886.7937	835.4468
S1-S7	800.8269	967.0383

From table 3, it is clear that the mean square error for S1 and S2 using Haar and Biorthogonal 2.4 wavelet transforms are minimum and 662.7366 & 701.1694 respectively.

Table- IV: Comparison of Cityblock distance of test and database signatures

Cityblock distance		
Signature Sample	**Haar**	**Biorthogonal 2.4**
S1- S2	1.9764e+03	2.1855e+03
S1-S3	2.6924e+03	2.9520e+03
S1-S4	2.2622e+03	2.4372e+03
S1-S5	2.6307e+03	2.9334e+03
S1-S6	2.2809e+03	2.4741e+03
S1-S7	2.2627e+03	2.4873e+03

From table 4, it is clear that the city block distance for S1 and S2 using Haar and Biorthogonal 2.4 wavelet transforms are minimum and 1.9764 $x10^3$& 2.1855 $x10^3$ respectively.

V. CONCLUSION

In above tables the statistical parameters as matching percentage, sum of absolute differences, city block distance and mean square of the wavelet coefficients of the first quadrant of the image decomposition are given. It is clear that by Haar and biorthogonal 2.4 wavelet transform these statistical parameters are extremum for two samples of signature of the same person. Therefore, we can say that wavelet transform technique provides simple and accurate framework for signature recognition.

REFERENCES

1. M.Tarek, T. Hamza, E. Radwan ‘‘ Off-line Handwritten Signature Recognition Using Wavelet Neural Network’’, International Journal of Computer Science and Information Security, vol.8, no. 6, 1-9, 2010.
2. P. G. Patil, R. S. Hegadi, ‘‘Offline Handwritten Signatures Classification Using Wavelets and Support Vector Machines’’, International Journal of Engineering Science and Innovative Technology (IJESIT), vol 2, no. 4, July 2013
3. A. Kumar and M. Kumari, ‘‘Image compression by discrete wavelet transforms using global thresholding’’, International Journal of Advance Research and Innovation, Special issue, pp. 1-5,2016.
4. E. Hernandez and G. Weiss ‘‘A First Course on Wavelets, CRC Press, New York’’, 1996.
5. A. Kumar, U. K. Rawat and P. Singh, ‘‘Spectral analysis of ground level nitrogen dioxide and sulphur dioxide’’, Progress in Nonlinear Dynamics and Chaos, vol.6, no.1, pp.11-17, 2018.
6. B.B.S. Kumar and P.S. Satyanarayana, ‘‘Image Analysis Using Biorthogonal Wavelet’’, International Journal of Innovative Research And Development, vol. 2, no.6, pp. 543-565, 2013.
7. S.G. Mallat, ‘‘A theory for multi resolution signal decomposition: the wavelet representation’’, vol. 11, no.7,pp. 674-693, 1989.
8. S.G. Mallat, ‘‘A wavelet tour of Signal Processing’’, Academic Press, New York. 1998.

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