Bi-orthogonal Wavelet Based Comer Template Encoding Methodology

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Abstract: For performing feature extraction of iris, one of the strong biometric feature, encoding is the most important operation. Template formation or encoding in the proposed methodology is performed through convolving the normalized iris pattern with bi-orthogonal wavelets 3.5. The 2D normalized pattern is broken up into 1D-signals. The angular direction is taken rather than the radial which corresponds to columns of the normalized pattern, as the maximum independence occurs in the angular direction. Transformation of the segmented iris information into a normalized iris data is done using the bi-orthogonal tap. In the proposed method rather than utilizing the traditional Multi-Resolution Analysis (MRA) scheme, a novel lifting technique is explored for the construction of bi-orthogonal filters. The main advantage of this scheme over the classical construction methods is that it does not rely on the Fourier transform and results in faster implementation of wavelet transform.

***Keywords*—**Template Encoding, Bi-orthogonal Wavelets, Lifting Scheme.

I. INTRODUCTION

Calderbank et al. (1998); Daubechies and Sweldens (1998); Sweldens (1997); Sweldens (1995);have focussed that for accurate recognition of individuals, extraction of the most discriminating information must take place from an iris pattern being normalized. Encoding must be done of only the significant features of the iris so that comparisons between templates can be made. For creation of a biometric template most of the iris recognition systems make use of band pass decomposition of the iris image. A corresponding matching metric is required after template is generated in the feature encoding for providing a measure of similarity betwixt two iris templates. The metric should provide intra class comparisons to specify one range of values when comparing the templates generated from the same eye and inter class comparison when comparing another range of values when templates are created from different irises, providing distinct and separate values so that a decision can be made with high confidence whether two templates are from the same iris or from two different irises. A number of methods are available in literature for performing feature encoding, which are in the upcoming sections of the paper, followed by the proposed bi-orthogonal wavelet based comer template encoding methodology.

II. LITERATURE SURVEY

A number of traditional methodologies are available for carrying out encoding are listed below:

A. Wavelet Encoding

Wavelets can be used to decompose the data in the iris region into components that appear at different resolutions. Wavelets can be utilized as they have the advantage over traditional Fourier transform. Fourier transformation method allows matching of the features that occur at same position by localizing the feature data which does not provide a compact resolution of the image.

Therefore, in wavelet based encoding methods a number of filters referred as bank of wavelets are applied to the Two Dimensional (2D) iris region, one for each resolution of each wavelet (scaled version of some basis function). The output of applying the wavelets is then encoded for providing a compact and discriminating representation of the iris pattern.

B. Globar Filters

For providing an optimum conjoint representation of a signal in space and spatial frequency, Gabor filters are utilized which are constructed by modulating a sine/cosine wave with a Gaussian function to provide the optimum conjoint localization in both space and frequency.

A sine wave is perfectly localized in frequency but not localized in space. Quadrature pairs of Gabor filters provide decomposition of a signal with real part (a cosine modulated by a Gaussian) and an imaginary part (a sine modulated by a Gaussian) which are also referred as even symmetric and odd symmetric components respectively.

The frequency of sine/cosine wave of the filter specifies the centre frequency of the filter and the bandwidth is specified by the width of the Gaussian. 2D Gabor filters are utilized by Daugman (2002) for encoding iris data pattern represented over an image domain (x, y) as:

$$f(i,j) \quad \frac{1}{2} \exp[\ \frac{1}{2}(\frac{i'^2}{\ ^2} \quad \frac{j'^2}{\ ^2})]\cos(2\ F_u i')$$

where:

- i' = icos (θ_v + (jsin (θ_v
- j' = isin ((θ_v + jcos (θ_v
- F_u = frequency of the sinusoidal plane wave.
- λ and γ = standard deviations of Gaussian envelope along x and y directions respectively referred as scales.

C. Log-Gabor Filters

As enumerated by Struc et al. (2009), to overcome disadvantage of the gabor filter (even symmetric filter will have a DC component (mean value of the waveform) whenever the bandwidth is larger than one octave), log gabor filter is utilized where zero DC component can be obtained for any bandwidth by using a gabor filter which is Gaussian on a logarithmic scale whose frequency response is given as:

$$G(f) = \exp\left(\frac{-\left(\log\left(\frac{f}{f_0}\right)\right)^2}{2\left(\log\left(\frac{\sigma}{f_0}\right)\right)^2}\right)$$

where:

- $f0$ = centre frequency.
- σ = bandwidth of the filter.

D. Zero-Crossing of the ID Wavelet

Boles and Boashash (1998) have utilized one dimensional wavelet for encoding iris data pattern.

$$\varphi(x) = d^2\theta(x) / dx^2$$

The wavelet transform of a signal f(x) at scale s and position is given by:

$$Wsf(x) = f * \left(S^2 \frac{d^2\theta(x)}{dx^2}\right)(x) = S^2 \frac{d^2}{dx^2}(f * \theta s)(x)$$

where:

- θs = (1/S) $\theta(x/s)$.
- Wsf(x) = proportional to the second derivative of f(x) smoothed by $\theta s(x)$.
- $f * \theta s(x)$ = zero crossings of the transform that correspond to points of inflection region.

E. Haar Wavelet

Lim et al. (2001) utilized Haar wavelet referred as the mother wavelet that computes a feature vector with 87 dimensions from multi-dimensional filtering. Each dimension has a real value ranging from -1.0 to +1.0. The feature vector is sign quantised so that any positive value is represented by 1 and negative value as 0. This results in a compact biometric template consisting of only 87 bits.

Lim et al. (2001) by comparison showed that the recognition rate of Haar wavelet transform is slightly better than Gabor transform by 0.9%.

F. Laplacian of Gaussian Filters

Wildes et al. (1994) developed a system that decomposes the iris region by application of Laplacian Gaussian filters:

$$\Delta G = \frac{1}{\iota\sigma 4}\left(1 - \frac{p^2}{2\sigma 2}\right) e^{-p^2/2\sigma^2}$$

where:

θ = It is the standard deviation of the Gaussian function

ρ = It is the radial distance of a point from the centre of the filter.

III. BI-ORTHOGONAL WAVELET BASED COMER TEMPLATE ENCODING METHODOLOGY

Template formation or encoding in the proposed methodology is performed through convolving the normalized iris pattern with bi-orthogonal wavelets 3.5. The 2D normalized pattern is broken up into 1D-signals. The angular direction is taken rather than the radial which corresponds to columns of the normalized pattern, as the maximum independence occurs in the angular direction.

Transformation of the segmented iris information into a normalized iris data is done using the bi-orthogonal tap. In the proposed method rather than utilizing the traditional Multi-Resolution Analysis (MRA) scheme, a novel lifting technique is explored for the construction of bi-orthogonal filters.

The main advantage of this scheme over the classical construction methods is that it does not rely on the Fourier transform and results in faster implementation of wavelet transform. Fig.1 and Fig. 2 depicts the basic concept of lifting scheme that starts with a trivial wavelet referred as the “Lazy wavelet”, which has the formal properties of basic wavelet but is not capable of performing the analysis.

A new wavelet having improved properties is gradually developed by adding a new basis function which is the main inspiration behind the name of the scheme. The lifting scheme can be visualized as an extension of the Finite Impulse Response (FIR) schemes where for any two-channel, FIR sub band transform can be factored into a finite sequence of lifting steps making the implementation of these lifting steps faster and efficient.

The bi-orthogonal filter family is shown in fig..3. Bi-orthogonal 3.5 tap is selected for encoding the iris information by adjusting the frequency content of the resulting coefficients to get a separated band structure. In the lifting scheme the filters are designed using the lifting steps as they are completely invertible.

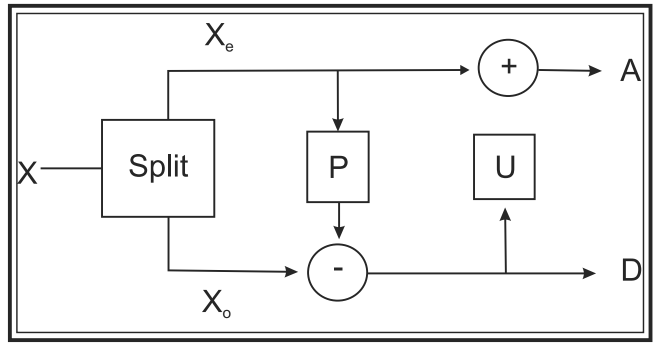

Fig. 1: Lifting Scheme for Bi-orthogonal Wavelets

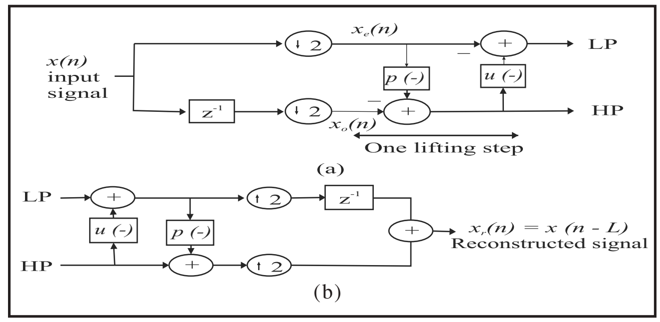

Fig. 2 (a): One Lifting step (b) Reconstructed Signal

Transformation of the data into a different and new basis is performed by the filters, where large coefficients correspond to relevant image data and small coefficients corresponds to the noise. Thresh-holding is performed once again and referred as image de-noising.

The data encoded by the wavelet is scalable and localized, making matching possible of the features at same location using various scales resulting in information of bit-stream of 1s and 0s referred as the “iris template”. For performing comparison band pass Gabor pre-filtering is performed for encoding the information and generating the filter using Gaussian filters.

Then utilizing this approximation for generating wavelet coefficients that are quadrature quantized, resulting in information of bit-stream of 1s and 0s. This is performed for all the iris images and the formulated bit-pattern is referred as the ‘iris template’ having angular resolution of 20, radial resolution of 200 and length as 8000 bits. The noisy parts of the image are located by

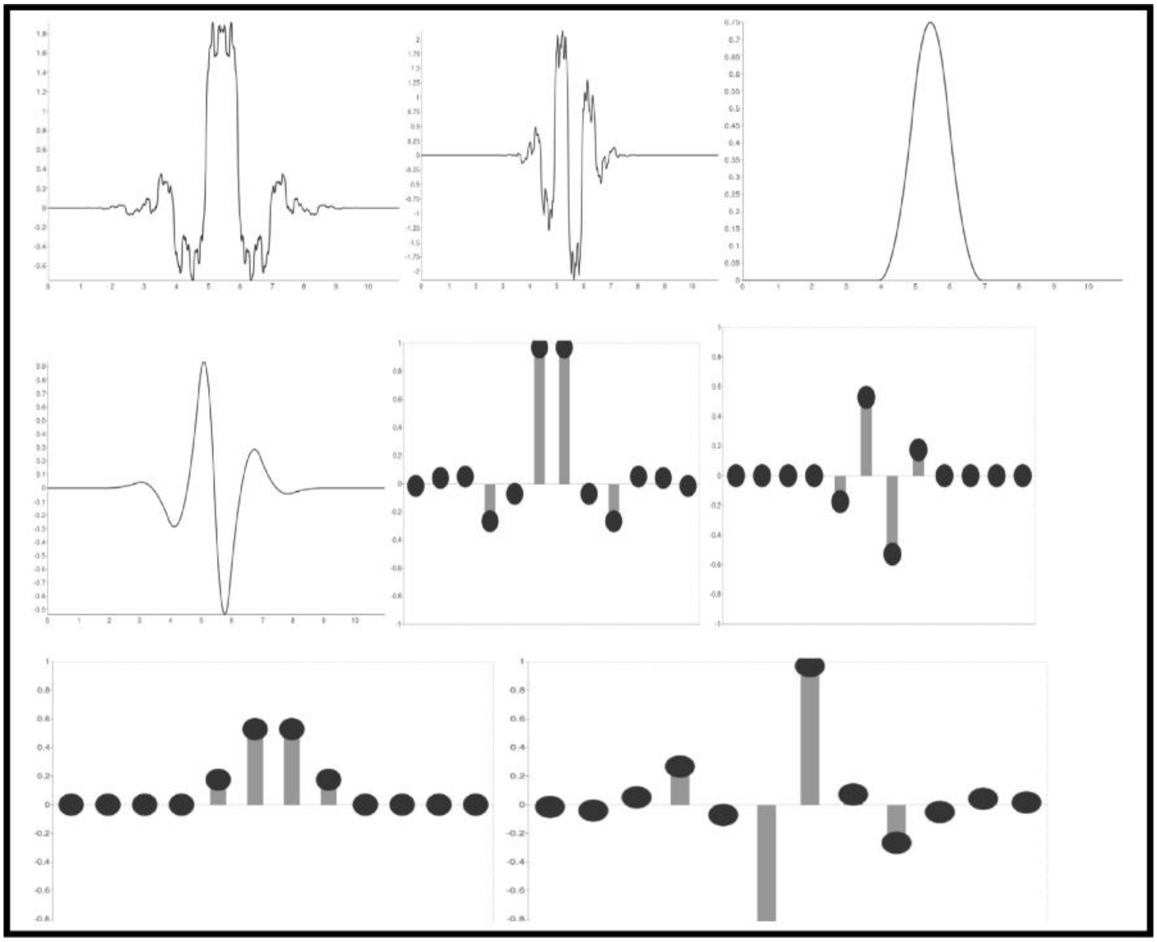

Fig. 3: Bi-orthogonal Wavelet 3.5 and its Related Coefficients

the mask template that is formed along with the iris template. For performing wavelet analysis in this particular study, the digital iris images are encoded using wavelets to formulate the iris template.

The intensity values at known noise areas in the normalized pattern are set to the average intensity of surrounding pixels to prevent influence of noise in the output of the filtering.

Phase quantization at the output of filtering is then done to four levels, where two bits of data for each phasor are produced then the output of phase quantization is chosen to be a grey code, so that when going from one quadrant to another, only 1 bit changes hence, minimizing the number of bits disagreeing.

IV. SIMULATION STUDY

Algorithm below describes bi-orthogonal wavelet based encoding using lifting scheme. Flowchart of fig. 4 depicts the feature extraction method.

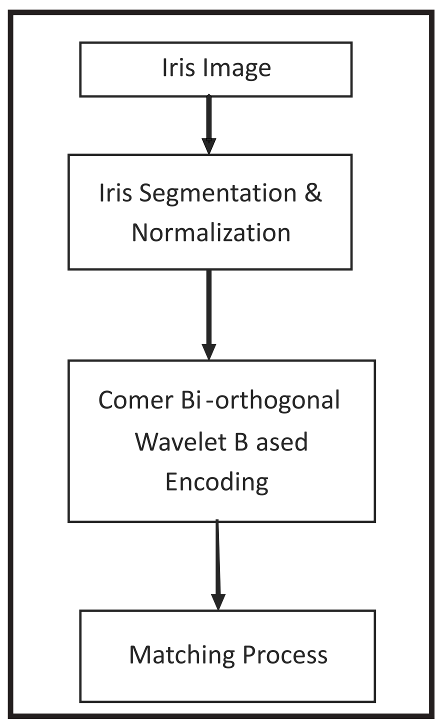

Fig. 4: Depicting Feature Extraction Method through Flowchart

```
function [data_stream,mask_stream] = fun_bin_stream(ract_iris)
ract_iris = double(ract_iris);
els = {'p',[-0.125 0.125],0};
lsbiorInt = liftwave('bior3.5');
lsnewInt = addlift(lsbiorInt,els);
[CA,CH,CV,CD] = lwt2(ract_iris,lsnewInt);
[THR,SORH,KEEPAPP] = ddencmp('den','wv',ract_iris);
C = [CA CH; CV CD];
C1 = abs(C);
C_data = (C1 >= THR).*C;
max_val = max(C_data(:));
```

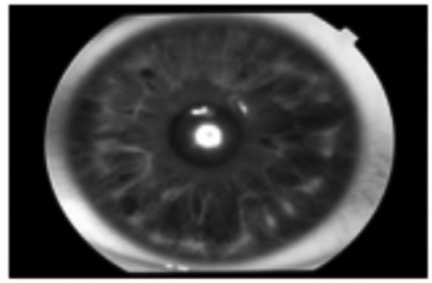

Fig. 5: Iris Template

```
min_val = min(C_data(:));
C_data_norm = (C_data - min_val)/(max_val - min_val);
```

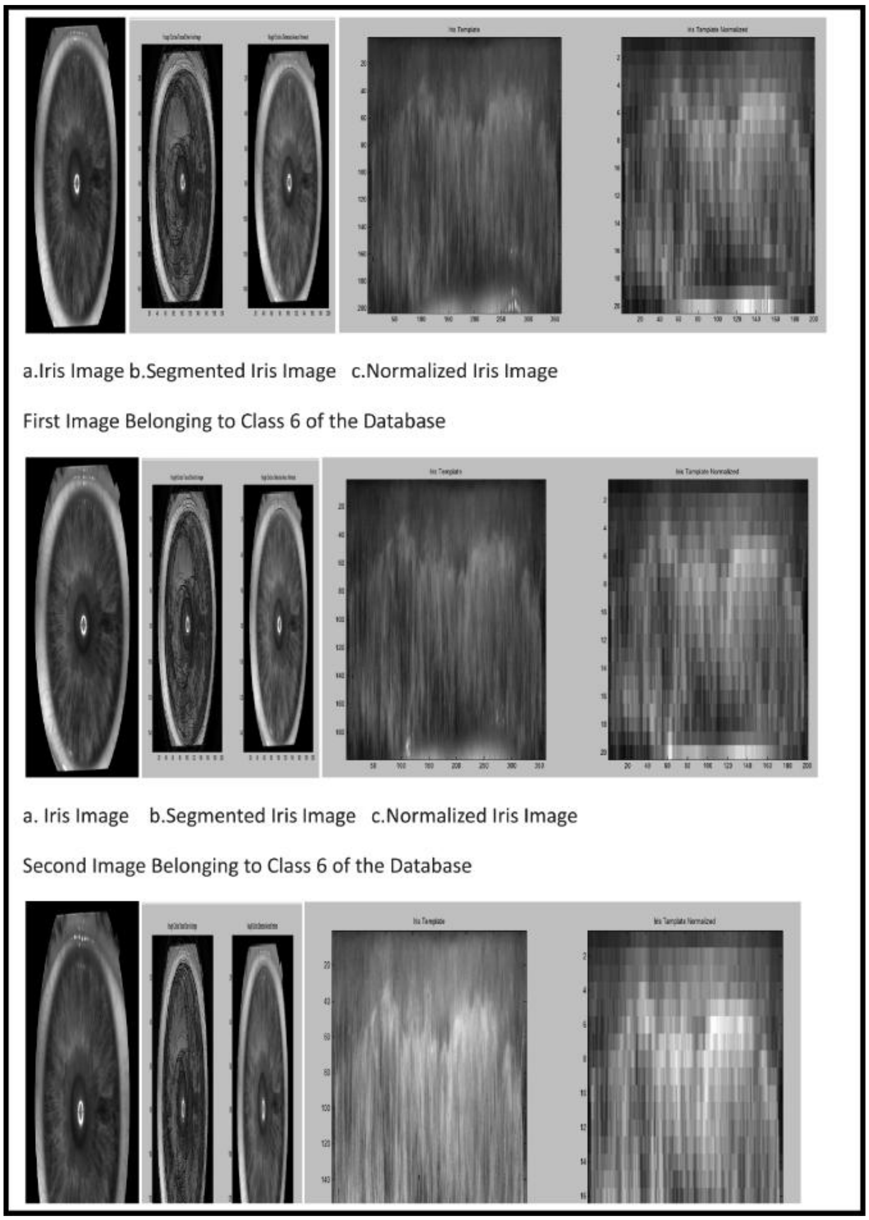

Fig. 6: Segmented and Normalized Iris Image

```
C_data_quant = round(C_data_norm*3);
rep = [0 0;0 1;1 0;1 1];
for i = 1:size(C_data_quant,1)
    for j = 1:size(C_data_quant,2)
            C_data_quant_new(i,2*(j-1)+1:2*j) =
rep(C_data_quant(i,j)+1,:);
    end
end
C_noise = (C1 < THR).*C;
max_val = max(C_noise(:));
min_val = min(C_noise(:));
C_noise_norm = (C_noise - min_val)/(max_val -
min_val);
C_noise_quant = round(C_noise_norm*3);
for i = 1:size(C_data_quant,1)
    for j = 1:size(C_data_quant,2)
            C_noise_quant_new(i,2*(j-1)+1:2*j)=
rep(C_noise_quant(i,j)+1,:);
    end
end
data_stream = C_data_quant_new(:);
mask_stream = C_noise_quant_new(:);
end
```

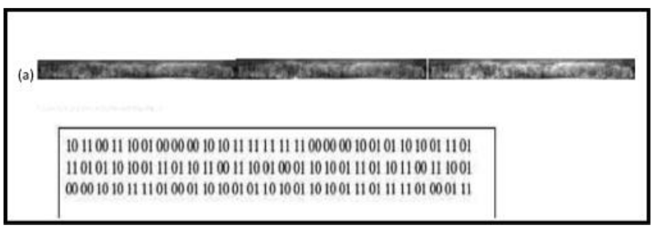

Fig. 7 (a): Iris ImageTemplates Generated After Encoding Process (b) Code of Iris Template Being Generated

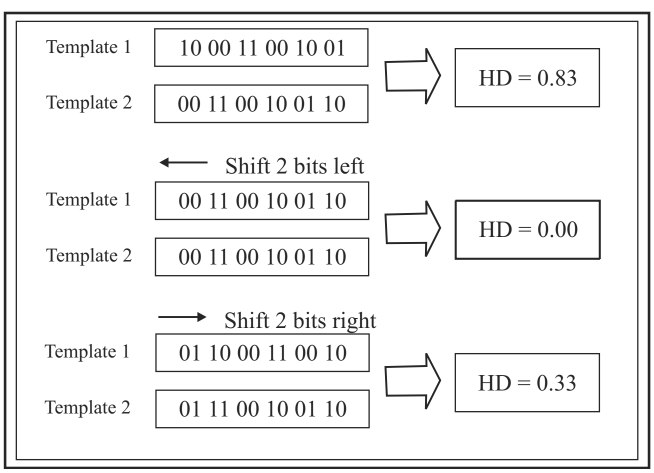

Fig. 8: Encoded templates undergo matching through Hamming Distance(HD) Calculation

V. RESULTS AND DISCUSSIONS

Iris template taken for further encoding is shown in fig. 5. Successful encoding depends on the segmented and normalized operations which are depicted in fig.6. Iris templates generated after comer bi-orthogonal wavelet based encoding process are shown in figure.7. Bitwise iris templates contain number of bits of information. The total number of bits in the template = 2 * the angular resolution times the radial resolution * number of filters utilized.Fig.8 depicts encoded templates undergoing matching operationthrough Hamming Distance (HD) calculation which is the final stage of feature extraction.

VI. CONCLUSIONS

Feature encoding is implemented through convolving the normalized iris pattern with Bi-orthogonal wavelets 3.5 by breaking the 2D normalized pattern into a number of 1D-signals. In the proposed method rather than utilizing the traditional Multi-Resolution Analysis (MRA) scheme, a novel lifting technique is explored for the construction of bi-orthogonal filters. The main advantage of this scheme over the classical construction methods is that, it does not rely on the Fourier transform and results in faster implementation of wavelet transform.The feature encoding processproduces a bitwise template containing number of bits of information.

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