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# Iris Feature Extraction and Recognition using Triplet Halfband Filterbank Designed with Euler Frobenius Polynomial

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***Abstract*—Iris Recognition has gained a great consideration for person authentication systems in various fields. Due to its high accuracy and uniqueness, iris recognition technology can be used in various domains of access control and security at borders. In this paper, new methodology for iris feature extractions based on triplet halfband filterbanks is proposed. Firstly, biorthogonal perfect reconstruction halfband filterbank is designed using Euler Frobenius halfband polynomial (EFHP). We use EFHP in three step lifting structure to determine analysis low-pass and high-pass filters. The lifting halfband kernels are designed using EFHP. The proposed filters are used to extract the iris features using discrete wavelet transform. The designed filters satisfy the linear phase and PR property. It has been shown that the proposed method efficiently captures the feature of Iris images which assures better recognition rate. Several examples are given on iris images to demonstrate the method.**

***Index Terms*—image processing, iris recognition, wavelet FBs**

## I. Introduction

A biometric system provides recognition of a person based on the basis of unique feature which is possessed by the person. There are various biometric systems that have been developed based on fingerprints, facial features, voice, retina, and iris. The demand for the iris recognition system is increasing daily. This system is known for its accuracy, uniqueness and reliability. It is the most robust identification and authentication features among all the others types of biometric features. The human iris remains unchanged through ones lifetime. Most commercial iris recognition systems use patented algorithms developed by Daugman [1]–[3].

The main motivation to consider Iris images as biometric trait is because because every individual human beings has a different iris patterns. The iris is a thin circular concentric ring like structure, which lies between the cornea and the lens of the human eye. The iris is an externally visible, yet protected organ whose unique epigenetic pattern remains stable throughout adult life. These features of the iris makes it very attractive for use as a biometric for identifying a person [4]. Different image processing transforms can be used to extract the unique iris pattern from a digital image of the iris, encode it into a biometric template, and can be stored in the form of database. This template consists mathematical representation of the unique information stored in the iris, and allows one to one comparisons between templates.

The iris recognition system consists of an automatic segmentation, and is also able to localize the circular iris and pupil regions excluding the eyelids, eyelashes and reflections. The iris region which was extracted is normalized into rectangular block with constant dimensions. Most of the biometric systems allow two modes of operation. An enrollment mode for adding templates to a database, and an identification mode, where a template is created for an individual and then a match is searched for in the database of existing templates. Highly unique features are the characteristics of a good biometric so that the chance of any two people having the same characteristic will be minimal, stable so that the feature are not time dependent, and be easily captured in order to provide ease to the user, and prevent mismatch of the feature.

The wavelet filterbanks (FBs) are popular in the signal and image processing applications, such as pattern recognition, compression, denoising, feature extraction, classification etc. Filterbanks can be classified into two types orthogonal or biorthogonal. The biorthogonal filterbanks are mostly chosen for the image processing applications, because it has linear phase criterion. The wavelet filters should have the properties such as tight frame bound ratio, regularity, high frequency selectivity etc. It is also important to deal with higher regularity measure in the filterbanks design and it is obtained by imposing zeros at $\omega = \pi$ or $z = -1$ (aliasing frequency) for the low-pass filters. The zeros are referred as vanishing moments (VMs). In theory, maximum VMs give the smoother scaling function which represents the complex signals accurately. Therefore, the selection of VMs is a desirable criterion to take into consideration for designing the PR FBs. In this direction several filterbank design methods have been proposed in [5]–[7]. The commonly used method for designing different wavelet FBs is by using factorization of halfband polynomials [8]. The well known biorthogonal FBs, such as spline wavelet FBs, CDF-9/7 [9] have been designed by the factorization method. The Lagrange halfband polynomial (LHBP) has been factorized to design filters. This polynomial has maximum number of zeros at $z = -1$, which give higher regularity measure [10]. Several directional filterbank designs are also proposed based on 2-D filters for iris recognition [11].

In this paper, we propose a methodology for iris feature extractions based on triplet halfband filterbanks. The iris images are transformed into normalized form using Daugman's model [12]. The normalized images give efficient and highly discriminating representation of the iris patterns, which can be used to extract unique features using discrete wavelet transform. We use newly designed biorthogonal filters in discrete wavelet transform to extract the iris features. The new Biorthogonal perfect reconstruction filters are designed using Euler Frobenius halfband polynomial (EFHP) [7]. We use three step lifting structure to determine analysis low-pass and high-pass filters. The lifting halfband kernels are designed using EFHP. The proposed filters are then used to extract the iris features using discrete wavelet transform. The designed filters satisfy the linear phase and PR property. It has been shown that the proposed method efficiently captures the feature of Iris images which assures better recognition rate.

## II. Proposed FBs Design using Euler Frobenius Polynomials (EFP) and Lifting Scheme

In this section, we give design for two channel wavelet filterbanks using Euler Frobenius polynomial. The detailed design is given [13].

### A. *Background of two channel Filterbanks*

Fig. 1 shows the general structure for two channel bi-orthogonal filterbanks. The four filters that form two channel filterbanks are analysis low-pass ($H_0(z)$), analysis high-pass ($H_1(z)$), synthesis low-pass ($F_0(z)$) and synthesis high-pass ($F_1(z)$). The two channel FBs is called PR FBs if it satisfy the following equation

$$H_0(z)F_0(z) + H_0(-z)F_0(-z) = cz^l \tag{1}$$

where, $l$ is the amount of delay. The PR condition can always

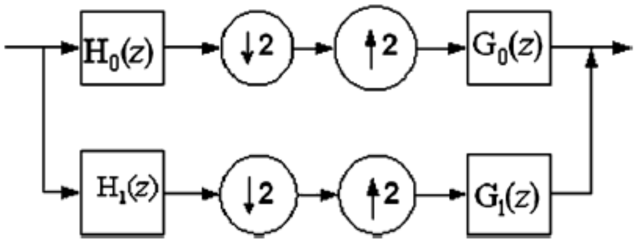


Fig. 1. A general structure of two-channel filterbanks.

be met if alias cancellation is achieved. This can be achieved by selecting the following analysis and synthesis high-pass filters as

$$H_1(z) = z^{-1}F_0(-z) \quad \text{and} \tag{2}$$

$$F_1(z) = zH_0(-z) \tag{3}$$

The product filter is defined as $P(z) = H_0(z)F_0(z)$. This product filter is related to special class halfband filters.

### B. *Design of Euler Frobenius Halfband polynomial*

The Euler Frobenius Polynomials (EFP) are well known and have been used in the design of spline wavelets. The main advantage of using EFP is that, its coefficients are integers and polynomial is symmetric. Also, these coefficients are determined recursively. The generalized Euler Frobenius Polynomials (EFP) are defined as

$$\mathcal{E}_f(z) = \sum_{i=0}^{m} \hat{e}(i+1)z^{-i} \tag{4}$$

where $m$ represents the order of EFP and coefficients are obtained by

$$\hat{e}(i+1) = \sum_{\ell=0}^{i}(-1)^{\ell}\binom{m+2}{\ell}(i+1-\ell)^{m+1}. \tag{5}$$

In this work, we have used EFP to design the required halfband polynomial. The odd-length EFP are combined with VMs (zeros at $z = -1$) and introduced some independent parameters $\beta_i$ so as to convert them into halfband polynomial. This new polynomial is called as Euler Frobenius halfband polynomial (EFHP) and given by

$$P(z) = (1+z^{-1})^{\eta}\mathcal{E}_f(z)\sum_{i=0}^{L}\beta_i z^{-i} \tag{6}$$

where, $\eta$ represents the number of VMs. The $m^{th}$ order *EFP* is represented by $\mathcal{E}_f(z)$. The product filter $P(z)$ have order $K = \eta + m + L$. The order of free polynomial is $L = K/2 - 1$. The free parameters $\beta_i$ are formulated such that the PR condition given in equation (1) is satisfied. The required $K^{th}$ order kernel of the lifting scheme is given by

$$\hat{T}(z) = z^{K/2}P(z) - 1 \tag{7}$$

We consider above equation to design the lifting kernels.

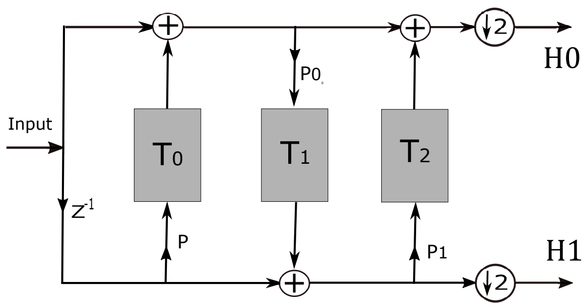


Fig. 2. A general structure of three step lifting.

### C. Lifting Scheme

The proposed filters are constructed via three-step and four-step lifting structure. Fig. 2 shows the lifting structure for analysis filters. It is parametrized with three and four halfband filters. The analysis filterbank can be expressed in the polyphase matrix form

$$\mathcal{R} = \begin{bmatrix} H_{0even} & H_{0odd} \\ H_{1even} & H_{1odd} \end{bmatrix}. \tag{8}$$

From polyphase matrix, we can find the filters $H_0$ and $H_1$ as

$$H_0(z) = H_{0even}(z^2) + z^{-1} H_{0odd}(z^2) \tag{9}$$
$$H_1(z) = H_{1even}(z^2) + z^{-1} H_{1odd}(z^2). \tag{10}$$

*Three-Step Lifting Scheme::* The analysis and synthesis low pass filters constructed with three lifting steps are given by

$$H_0(z) = C_0\{\frac{1+p}{2} + \frac{1}{2}\hat{T}_1(z)(1 - p\hat{T}_0(z))\} \tag{11}$$
$$F_0(z) = C_1\{(\frac{1+p\hat{T}_0(z)}{1+p} + \frac{1-p}{1+p}\hat{T}_2(z) \times (\frac{1+p}{2} - \frac{1}{2}\hat{T}_1(z)(1+p\hat{T}_0(z)))\} \tag{12}$$

where, the kernels $\hat{T}_0(z)$, $\hat{T}_1(z)$ and $\hat{T}_2(z)$ are designed from $K^{th}$ order proposed halfband polynomial. The aim is to design lifting kernels $\hat{T}(z)$ with good frequency selectivity and regularity. The high-pass filters are obtained by using equation (3). The lifting parameter $p$ is the degree of freedom which provides the flexibility for choosing the magnitude at $\omega = \pi/2$.

### D. Choice of lifting parameters

Note that the filters and kernels obtained from above equations are noncausal filters. Therefore, the causal kernels $T_i(z)$ are obtained by applying $\kappa/2$ delays as:

$$T_i(z) = z^{-\kappa/2} P_i(z) - 1. \tag{13}$$

The parameters $p_0$, $p_1$ and $p_2$ are determined by examining the passband and stopband response the analysis low-pass filter ($H_0(z)$) and high-pass filter ($H_1(z)$) as: $p_0 = p_1 = (1+p)/2$ and $p_2 = (1-p)/(1+p)$. The free parameter $p_i$ can be used provide flexibility for shaping the frequency response of the resulting filters and its value is set in the range of $0 < p < 1$ . With the appropriate value of $p$, we can set the frequency response of designed filters to any desired value at $\omega = \pi/2$. Particularly, when $p = \sqrt{2} - 1$, the frequency response magnitude at $\pi/2$ is $1/\sqrt{2}$ for both analysis and synthesis low-pass filters.

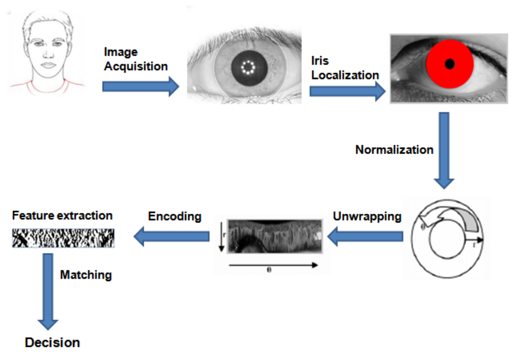


Fig. 3. Steps for iris recognition

## III. Proposed Methodology for Efficient Iris Feature Extraction using Biorthogonal Wavelet Filters

The Figure 1 shows the steps to be followed for iris recognition. The system is divided into enrollment and authentication modules. The enrollment process consists of iris acquisition, segmentation, normalization, and extraction of features from the iris image. These features are stored in the database as reference. During the recognition (decision) process, the test iris feature is compared with stored features. The first stage in iris recognition is dealing with segmentation of iris. The main aim of this process is to localize the pupil (inner) and the scleric (outer) borders. The shape can be assumed either elliptical or circular in shape for two detected borders. It is required to compensate for variations in pupil size and the acquired image capturing distances. This is done by translating the region of the iris which is segmented into a defined length and polar coordinates system which are dimensionless. This stage is mostly implemented by the method proposed by Daugman [14]. The feature extraction methods in the iris recognition system can be divided into three main categories: texture analysis based methods [15], phase-based methods [16], zero-crossing method [17]. In the final stage, a comparison between the signatures of the iris is made, which produces a numerically non-similar value. If the obtained value is greater than the specified value or threshold, the system generates output as not-matched, In another case, the output is matched which means that both features/signatures were taken from the iris of the same eye.

### A. Step 1: Iris Segmentation/Localization

The most relevant method/procedure for iris segmentation was proposed by J. Daugman [18] in 1993. This method is consisted of the basis of the majority of functioning systems. Daugman introduced an integro-differential [19] operator to find the outer boundary and iris. The equation(1) is Daugman's intergro-differential operator.

$$max_{(r,xp,yp)}\left|G_{\rho}(r)*\frac{\partial}{\partial r}\right|\int_{r,x0,y0}\frac{I(x,y)}{2\pi r}dS \tag{14}$$

Here $I(x,y)$,$r$, $G\rho(r)$ and $s$ are the eye image, radius, Gaussian smoothing function and the contour of the circle respectively. The function of this operator is to search for the circular path where the change in x and y position to get the perfect location of eyelids. The main objective of this method is maximizing the equation so that we are able to identify the iris boundaries. The operator detects the pupil region of eye and the center of the pupil is considered to draw a circular region. The region includes the iris also, the process of detecting features starts from here itself. Preprocessing of the image is necessary so that undesirable features are added while the acquisition of the image like noise, reflection,eyelashes, eyelids, etc are removed before actual processing of the image. Iris segmentation can be also done by gradient-based binary image edge-map after which Hough transform is applied. This method is the most commonly used method for circle detection. In the next stage normalization of image takes place.

### *B. Step 2: Iris Normalization*

After successful segmentation the next stage is normalization. There are variations in the captured iris image. The variation may be in the form of the size of the pupil and the change in the distance and also the angle of capturing the image. The images with variations are difficult to process, as the size of the iris in the captured image can have complex variations. Due to this complex variation, the process of recognition becomes more difficult. A well-captured image of the iris that is capable of recognition must be invariant. Invariant here means it should be a perfect image, which qualifies acceptable size, the orientation of patterns and, positioning. The above described invariant factors can be achieved through, the conversion of the captured iris images into a double dimensionless polar coordinate system. The variables which are required for the conversion process are polar($\theta$) and radial(r). The rubber sheet model refer fig.2 provides each point on the iris image, the assignment is independent of its size and the dilation of the pupil region. There are pair of real coordinates and angles.The real coordinate system has (r, $\theta$), r here is on the unit interval [0, 1]. The other used angle system lies between [0, $2\pi$]. The relation between the iris image (x,y) and polar coordinates can be shown in for of the equation(2) below.

$$I(x(r,\theta),(y,\theta)) \rightarrow I(r,\theta) \tag{15}$$

where x(r,$\theta$) and y(r,$\theta$) are linear combinations of pupil boundary coordinates (xp($\theta$), yp($\theta$)) and the other region including the limbus boundary also the outer circumference of the iris (xs($\theta$), ys($\theta$)) which surround the detected area in the region of iris. Mathematically equation (3 & 4) the stages of this methods are as follows:

$$x(r,\theta) = (1-r)*x_p(\theta) + (1-r)*x_s(\theta) \tag{16}$$

$$y(r,\theta) = (1-r)*y_p(\theta) + (1-r)*y_s(\theta) \tag{17}$$

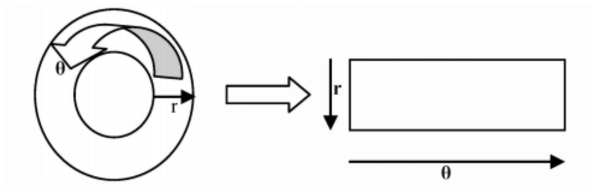


Fig. 4. Rubber sheet model [24]

### *C. Step 3: Iris Feature Extraction*

The image of the iris has been processed through the above-stated steps segmentation and normalization, now it will be used for feature extraction. As discussed above major methods used for feature extraction and approach towards recognition. The methods are phase-based, zero-crossing and texture analysis. Haar wavelet is most commonly used for the feature extraction process.

### *D. Step 4: Iris Matching*

Iris features are extracted in above step. Now the final step is to match the processed image with an input image. There are various methods that can be used for matching of iris features. The feature comparison/matching is usually done by distance metrics. Hamming distance is the most widely used method.The other methods used are Euclidean and Weighted Euclidean distance.

The above steps can be summarized as follows:

**Step 1:** Image acquiring, the primary section, is one among them key challenges iris recognition since we require a high-quality image of the iris whereas remaining noninvasive to the human operator.

**Step 2:** Segmentation/Localization process is required for isolating the iris region from the pupil and other noise that are undesirable.

**Step 3:** Normalization is employed to convert and the segmented image into rubbersheet model which can be stored in the form of database of a persons eye.

**Step 4:** Finally, it's time to extract the foremost discriminating feature within the iris pattern so a comparison between templates is often done. Therefore, the obtained iris region is encoded wavelets to construct the iris code.

## IV. Experimental Results

In this section evaluates the proposed method/approach using CASIA database [25]. The above proposed method is applied with iris recognition algorithms of J. Daugman.

### *A. Database*

CASIA Iris Image Database (CASIA-Iris) developed by the research group which were released to the international biometrics community and were updated from CASIA-IrisV1 to CASIA-IrisV3 since 2002. About More than 3,000 users from about 70 countries uses this database. This database in fig.4 provides excellent work on iris recognition has been done based on these iris image databases. There are also other database available online for example IIT Delhi (IITD) database. The IIT Delhi (IITD) database is the first indian database consisting of a total of 1120 iris images from 224 subjects.

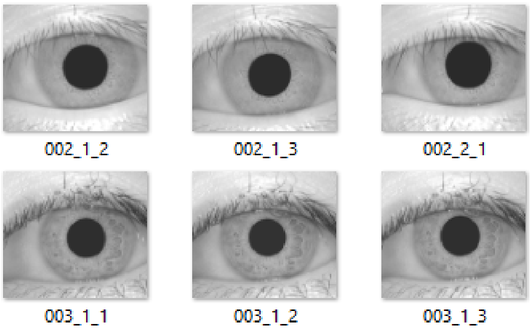


Fig. 5. CASIA database.

### B. *localization/segmentation*

The CASIA database eye image is used for the processing purpose. The first step is localization/segmentation, by this process the required region from the eye is obtained i.e the red concentric circle shown in fig.5. The eyelids, eyelashes, pupil and any light reflection in the image is considered as noise. The equation(1) is used to complete this process of localization.

Fig. 6. Iris localization.

### C. *Normalization*

After the localization of the image i.e selection of required area, normalization is done. Normalization uses the localized image and converts it from the polar form to Cartesian form (circular to rectangle) shown in fig.6. This is called as rubbersheet model of iris as proposed by J.Daugman. This model consists of unique features.The equation(2) is used to carry out the process of normalization.

### D. *Feature Extraction*

The rubbersheet model is used to extract features by using wavelet transform. By using proposed by the author [26].

### E. *Recognition*

The fig 9 shows the GUI for the recognition of the iris and the selection of images from the database is also shown.

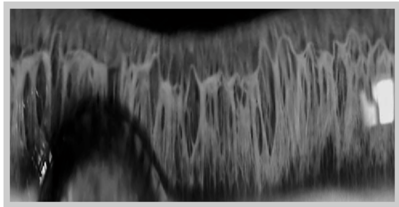

Fig. 7. Iris Rubbersheet model.

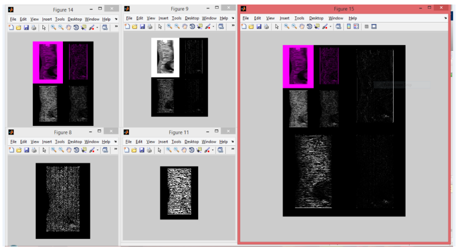

Fig. 8. Wavelet transform.

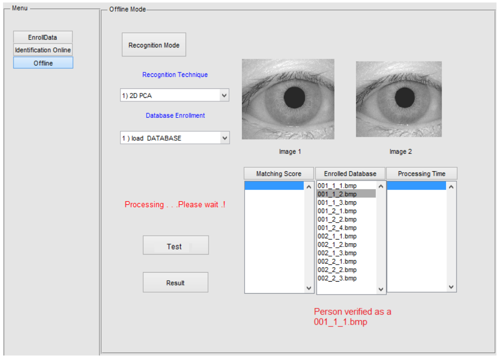


Fig. 9. GUI for iris recognition.

## V. CONCLUSION

In this paper we have used halfband filterbank which is designed using Euler Frobenius halfband polynomial (EFHP). We have extracted iris features with the help of discrete wavelet transform which assures better recognition rate. The above fig 9 shows the GUI for the recognition of the iris. The features ectracted from the iris images are shown in the fig 8.

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