COMPARATIVE INSIGHT IN TO WAVELET TRANSFORM AND CONTOURLET TRANSFORM FOR IRIS RECOGNITION SYSTEMS

Muhammad Umair Siddiqui
Department of Electrical Engineering, University of Engineering and Technology (UET), Lahore, Pakistan
umairbinsaadat@gmail.com
Amer Farhan Rafique
Center of Excellence in Intelligent Engineering Systems (CEIIES), Aeronautical Engineering Department,
King Abdulaziz University, Jeddah, Saudi Arabia
afrafique@kau.edu.sa

ABSTRACT*—Human iris recognition is one of the prominent type of biometric identification system. Iris recognition systems use texture modeling for the segmentation and classification of iris images. Texture modeling is an active research field and different techniques have been exhaustively studied for this purpose, including wavelet transform. However, due to the limited capability for capturing directional information of wavelet transform, it falls short of desired results for image analysis. More recently, contour transform is being studied to improve image analysis techniques for iris recognition systems. This paper provides an analytical insight in to why the contour transform is more suitable than wavelet transform for the purpose of iris recognition systems.*

Keywords—wavelet tranform; contourlet transform; iris recognition systems

1 INTRODUCTION

Iris recognition for biometric identification has been an active research area for almost two decades. Iris recognition offers more stability and anti-alteration features as compared to other biometric identification techniques such as finger or palm prints. The process to recognize an individual based on its unique iris basically consists of four main stages, namely segmentation, normalization, feature encoding and feature matching [1]. In the segmentation stage, the iris region in a digital image is separated out from the rest of the image. The quality of the digital image is an important factor in this stage as it affects the successful separation of the iris region. In the second stage, normalization, the dimensions of the iris region are properly marked. This is necessary to avoid dimensional inconsistencies and facilitate comparisons later on. In the third stage, feature extraction, the unique pattern information of a particular iris is extracted from the normalized iris region. That is the unique features of an iris are encoded so that they can be compared to others for a possible identification in the fourth stage, feature matching. All these four stages impact the reliability of the iris recognition system.

In this paper, we focus our attention on the techniques utilized for iris feature extraction stage. As mentioned earlier, the iris region is classified by extracting and encoding its most prominent and significant features. The encoding of the features is accomplished in such a manner that during the matching stage the comparisons can be done reliably without any false positive or false negatives. There are different techniques that can be used to encode the features of an iris, however we focus on the use of wavelet transform and contourlet transform for iris feature extraction and highlight their advantages and disadvantages in perspective of iris recognition. The rest of the paper is organized as follows. Section 2 provides an overview on the wavelet transform from the point of view of iris feature encoding. In section 3, we discuss the use of contourlet transform for extracting features of an iris. Section 4, we highlight the advantages and disadvantages of both techniques and finally, we conclude the paper in section 5.

2. OVERVIEW OF WAVELET TRANFORM

In the image processing arena, wavelet transforms act as an effective and powerful tool for signal representation. Instead of using sinusoids for the basis functions, as in Fourier transform, wavelet transforms are based on small waves, called wavelets. Wavelet transform allows having both the frequency and temporal information by using wavelets, unlike Fourier transform which only provided frequency information. Mathematically, a wavelet can be described as a function that decomposes a signal into different frequency elements. In terms of the iris recognition, the iris image data can be broken down using wavelets into multi-resolution components, i.e., into various elements that occur at various resolutions. For the case of representation of intermittent functions and precise deconstruction and reconstruction of definite, sporadic and non-static signals, the wavelet transform has advantages over the conventional Fourier transform. With the help of above mentioned basic attributes, the wavelet transform is able to create the necessary feature vector required for the iris recognition algorithm. The output of a wavelet filter for each resolution, where the corresponding wavelet is a calibrated adaptation of some basis function, is encoded to represent the iris region, concisely and determinately.

Boles and Boashash [2] presented a technique to encode iris features using 1-D wavelets. First, the iris region is normalized before using the dyadic wavelet transform which breaks down the 1-D signal at different resolution levels. The iris information is achieved by zero-crossing the dyadic wavelets transform. For more details, the reader can refer to [2].

Lim et al. [3] make use of 2-D wavelet transform for iris feature extraction. They use the Haar wavelet [4] as a basis function and apply the wavelet transform four times to obtain the feature vector for a particular fixed dimension iris image. In order to lessen the computational burden for handing the feature vector, the information in the feature vector is quantized to 0 and 1.

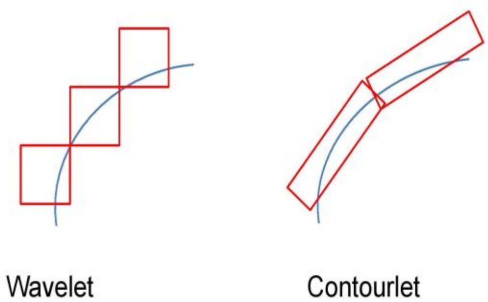

Fig. 1. Conceptual: Wavelet Transform vs Contourlet Transform (This figure is reproduced from [6]).

In [5], Daugman uses 2-D Gabor wavelets for encoding iris pattern data. A Gabor filter is constructed by modulating a sine/cosine wave with a Gaussian. Gabor filters are able to provide optimum conjoint representation of a signal in space and spatial frequency. The encoding process includes patch-wise phase quantization of the iris region [5].

A comparison between Gabor wavelet transform and Haar wavelet transform is provided by Lim et al. [3]. Their results claim that the Haar wavelet transform performs a little better than the Gabor wavelet transform in terms of recognition rates.

3. Overview of Contourlet Tranforms

The contourlet transform is a new two-dimensional extension of the wavelet transform proposed by Do and Vetterli [6]. The basic functions of contourlet transform are multi-scale and multi-dimensional, thus allowing it have multi-resolution, localization, directionality, critical sampling and anisotropy (*more on these properties in next section*). With these properties in hand, the curves in images can be adequately captured with the use of few coefficients.

The structure of contourlet transform is similar to that of curvelet transform which enables to apprehend the curve of the images with precision by using different shapes in different directions. However, curvelet transform was conceived in continuous domain and contourlet transform was developed as the discrete domain version initially.

In order to capture the necessary information related to the smooth curves in an image, the contourlet transform uses two types of filter banks. Firstly, the point discontinuities are extracted using the Laplacian pyramid (LP) [7]. Then these point discontinuities are transformed in to a linear structure with the help of Directional Filter Bank (DFB) [8]. This ingenious combination of DFB and LP allows complementing each other's short comings. For example, the LP facilitates in removing the low frequency components, since DFB performs inadequately for low frequency content of an image. This combination of the LP and DFB constitutes a double filter bank arrangement known as pyramid directional filter bank (PDFB) [6]. Furthermore, if perfect reconstruction filters are used, then contourlet transform is able to provide perfect reconstruction of the original image.

4. Comparison With Respect to Iris Recognition

Wavelets are a linear transform. They allow presenting the signals at different resolutions according to the time or space and at the required frequency. For one dimensional (1-D) wavelet transform, wavelets are used for signal processing as they require fewer coefficients to capture more frequency information. As a consequence the reconstruction of the signal, in the 1-D case, is restricted by the available coefficients. As discussed in Section II, the 2-D wavelets are an extension of the 1-D wavelets, as done by Lim et al. [3]. However, a normal 2-D wavelet transform has inadequate directional data available in its coefficients. As a consequence, a 2-D wavelet transform maps the edges conveniently but without the directional information of the edge which is all more important for images containing curves. Thus, it requires more coefficients to do an appropriate reconstruction of the edges, especially if the image consists of curves [6].

In summary, for processing a signal, a two-dimensional wavelet transform enables:

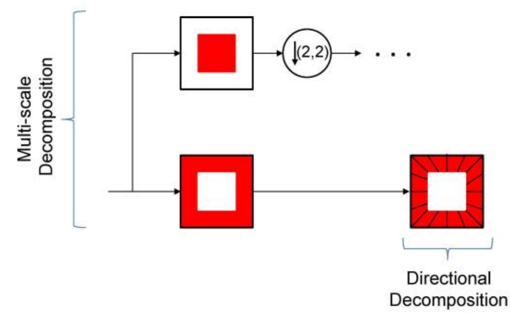

Fig. 2. Pyramid Directional Filter Bank (PDFB) (*This figure is reproduced from [6]*).

- to envision the transform at different resolutions, i.e., multi-resolution.
- to map the basic components in the spatial as well as frequency domain, i.e., localization.
- repetition and verbosity for the basic components, i.e., critical sampling.

On the other hand, normal 2D wavelet transform are ineffective in the provisioning of directionality and anisotropy, which provide essential information very much needed for images containing curves. The directionality and anisotropy can be defined as follows:

- Directionality: It is the ability to define the basic components in different directions [6]
- Anisotropy: It is the ability to define the basic components in different aspect ratios and froms. [6]

As discussed in Section III, the contourlet transform is the extended discrete domain adaptation of the curvelet transform. The main goal of contourlet transform is to encompass curves instead of points, in order to provide for directionality and anisotropy. However, there are several directional advancements on the regular 2-D wavelet transform that could be used to achieve the goal of directionality and anisotropy.

The contourlets achieve the directionality and anisotropy information by using the filter bank. The filter banks disintegrate the multi-scale and the directional information components. The conceptual depiction of this disintegration using the filter banks is shown in Figure 2, as proposed by Do and Vetterli [6]. We observe that, first; a multi-scale disintegration is achieved through a Laplacian pyramid. Secondly, the directional filter banks accomplish the directional disintegration. With this extra information in its arsenal, the contour transform is more suitable for iris feature extraction stage, as the iris region involves high curve content.

4 CONCLUSION

In this paper, we briefly touched upon the wavelet transform and contourlet transform in the perspective of iris feature extraction. We observed that although the 2-D wavelet transform is capable of providing multi-resolution, localization, and critical sampling for a signal, however it falls short of providing directionality and anisotropy information, which are very vital for images containing curves, such as the iris images. We also highlighted that the contourlet transform, with the help of its double filter banks consisting of LP and DFB, is able to cater not only for multi-resolution, localization, and critical sampling but also for directionality and anisotropy, hence making it more appropriate transform to be used for iris feature extraction as compared to the wavelet transform.

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