Chapter 2
Related Work

Abstract Compressive literature survey has been carried out and essence of it has been presented in this chapter. It reveals that in 1987, Flom and Safir proposed the first conceptual but unimplemented automated model of Iris recognition system. In 1992, Johnson analyzed Iris images and confirmed its high stability over a period of 15 years. Based on Flom and Safir model, Daugman in 1993 and Wildes in 1997 had proposed two complementary approaches of Iris recognition system and most of the research in this field is motivated and based on either of the two approaches. Related work carried out in iris segmentation, iris analysis, and feature extraction in last two decades has been presented and analyzed in this chapter. Either of the approaches, namely binary representation of Iris or real valued feature vector of Iris, has been explored very extensively by many researchers, mainly, either by using variants of Gabor filters or by using DWT for multi-resolution representation of Iris. Various iris image databases used by various research groups are also studied, and it is observed that CASIA database, which is less realistic has been explored more than realistic databases such as UBIRIS, UPOL.

Keywords Iris analysis and feature extraction • Daugman's approach • Wildes' approach • Flom and safir model • Gabor filters • Laplacian of Gaussian (LOG) filter • Iris code

2.1 Introduction

In 1987, Flom and Safir proposed the first conceptual but unimplemented automated model of Iris recognition system [1]. They suggested highly controlled and non-practical conditions to change the illumination so that pupil size in all images remains same for proper Iris segmentation. They outlined the major subsystems of Iris recognition system, namely image acquisition unit, preprocessing and Iris segmentation unit, Iris analysis and feature extraction unit, and matching unit along

R. M. Bodade and S. N. Talbar, *Iris Analysis for Biometric Recognition Systems*,
SpringerBriefs in Computational Intelligence, DOI: 10.1007/978-81-322-1853-1_2,

with suitable image processing and pattern recognition methods. This theoretical work on Iris recognition has proved as a foundation for all practical approaches of Iris recognition.

In 1992, before Daugman's work, Johnson [2] analyzed 650 Iris images in two sessions with a gap of 15 years and observed no change in the pattern of Irises. Thus, Iris is one of the highly suitable biometric traits for both person authentication and person identification due to its high stability.

Based on Flom and Safir model, Daugman in 1993 and Wildes in 1997 had proposed two complementary approaches of Iris recognition system, and most of the research in this field is motivated and based on either Daugman's approach or on Wildes' approach. The outline of these two main approaches has been stated below.

2.1.1 Daugman's Approach

In 1993 [3], John Daugman proposed most relevant system, forming the basis for all operational systems. His patent [4], in 1994, described the first functional Iris recognition system. His publications [5–7] stated the use of near infrared (NIR) illumination for image acquisition. NIR illumination not only remains nonintrusive to humans but helps to reveal the detailed structure of heavily pigmented Irises also.

For Iris segmentation, he assumed inner and outer boundaries of an eye as circles [3] which are characterized by radius, r, and coordinates of circle, x_0 and y_0. He introduced the integro-differential operator for detecting both inner and outer boundaries which is given by Eq. (2.1).

$$\max(r, x_0, y_0) \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r,x_0,y_0} \frac{I(x,y)}{2\pi r} ds \right| \tag{2.1}$$

where I(x,y) is the eye image and $G_\sigma(r)$ is Gaussian filter for smoothening.

This method tries to find a circle in the image with maximum gray level differences with its neighbors. Inner circle is determined first due to higher intensity gradient at inner boundary. Then, outer boundary is detected using same operator by searching the new parameter space. Then, the segmented Iris image is converted to dimensionless polar coordinate system for size normalization to compensate for the imaging inconsistencies.

Daugman used 2-D complex-valued Gabor filter to extract texture phase information of Iris, and each complex phase coefficient is quantized and encoded to obtain 256 byte binary 'Iris code' [3]. The compact and convincing representation of Iris with the help of binary code of 2-bit quantized phase information is the distinctive feature of Daugman method. Similarity between a pair of Iris code is measured by their normalized Hamming distance based on exclusive-OR operation.

2.1.2 Wildes' Approach

Wildes developed an Iris recognition system at Sarnoff Laboratory [8] with different approach as compared to Daugman's approach. He used a low-light-level camera along with a diffused source and polarization, for image acquisition.

He proposed the most common method of Iris segmentation through a gradient-based binary edge-map construction followed by circular Hough transform (CHT). Issues of eyelid noise and its removal also have been addressed in the method. This method is more stable to noise, but due to binary edge abstraction, it losses some data of Iris, which can be crucial in feature extraction.

Wildes used Laplacian of Gaussian filter at multiple scales to create a feature template. This template is a lesser compact representation of Iris because it incorporates finer distinctive data which is used to compute normalized special correlation as a similarity measure at matching stage. Wildes tested his method on several hundred Iris images. Wildes et al. [9] also filed patents for normalized spatial correlation for matching and user friendly image acquisition setup.

2.2 Segmentation of the Iris Region

This is one of the very important stages of Iris recognition system, and many researchers proposed various approaches. This stage consists of detection of pupillary (outer) and limbic (inner) boundaries, removal of pupil and sclera, detection, and removal of eyelids and eyelashes. As stated above, Daugman used integro-differential operator, whereas Wildes et al. used edge detection and CHT for Iris segmentation.

Ma et al. [10–12] has carried out the detailed analysis of Iris texture information and reported that Iris region closer to pupil provides the most useful texture information for recognition [10]. They approximated inner and outer boundary as circles and segmented the Iris using approach similar to Wildes' approach in two steps. After normalization, an image enhancement by subtracting an average of Iris from normalized Iris has been proposed in their work. Moreover, eyelashes and eyelids rarely occlude this region.

Most of the work in segmentation is based on Wildes et al. approach to improve one or the other aspect. Huang et al. [13] proposed variant of Wildes' method to reduce the computational complexity by finding the Iris boundaries in rescaled image in first step and then using that information to guide search on original image in next step. They also proposed the idea of making Iris rotation invariant for matching by making use of image of other eye as reference.

Similarly, use of Canny edge detector and Hough transform in a simplified manner is described by Liu et al. [14]. They proposed filtering of Iris normal region by using low-frequency filter. In addition to the detection of Iris boundaries, collarette boundary detection is proposed by Sung et al. [15] to increase the recognition rate. For finding the collarette boundary, histogram equalization and a high-pass filter, after using a one-dimensional DFT, are applied to the image. The collarette boundary is found using statistical information from the image.

Iris segmentation algorithm based on texture segmentation is proposed by Cui et al. [16] by using low frequency of wavelet transform of the Iris image for pupil segmentation and localize the Iris with a differential integral operator. The lower eyelid is localized using parabolic curve fitting based on gray value segmentation.

Kong and Zhang [17] used edge detector and CHT on nonlinearly enhanced eye image for Iris segmentation in first step, and in next step, eyelashes and eyelid interference has been removed from an Iris image. Lili and Mei [18] adopted edge point detection and curve fitting for Iris segmentation, and Iris image quality test has been conducted to discard poor quality Irises.

Teo and Ewe [19] utilized black hole search method to detect pupil because pupil is the darkest region in the image. This method is not suitable for eye image with dark Iris. Similar approach is proposed by Grabowski et al. [20].

He and Shi [21] carried out the binarization of image to detect the pupil, and then, with the help of edge detection and Hough transform, outer boundary is detected. Feng et al. [22] used a 'course-to-fine' approach to find the inner and outer boundaries of Iris by approximating them as circles. One of the important findings of their research is that use of the lower contour of the pupil in obtaining the inner boundary because it is stable even in the seriously occluded image. Tian et al. [23] proposed the method of searching a pixel of low intensity to detect an approximate pupil center and then use edge detection and Hough transform for boundary detection and Iris segmentation.

Prior pupil segmentation approach was proposed by Du et al. [24]. Further, they used polar coordinates and Sobel operator to detect the outer boundary by assuming concentric circles of Iris and pupil.

Camus and Wildes [25] proposed a method which was somewhat similar to Daugman's approach. This method was based on N^3 space search of three parameters: x, y, and r. The parameters were tuned to maximize the goodness-of-fit criteria to obtain accurate Iris segmentation. Roche et al. [26] also utilized N^3 space search for three circumference parameters (center (x, y) and radius r) where the difference between the average intensity of five successive circumferences is maximal. They made use of histogram stretching to maximize average intensity differences of the circumferences.

Most of the researchers used CASIA version 1 [27] image database for their research, but Phillips et al. [28] had reported that the pupil area in each image of this database had been replaced with the circular region of constant intensity (black) to mask out the specular reflections from the near infrared illumination source. This intestinally edited image database certainly reduces the challenges in Iris segmentation and calls into question any results obtained using it as it has made Iris segmentation artificially easy.

Therefore, Proenca et al. [29] evaluated clustering algorithms for preprocessing the images to enhance image contrast, and they tested not only their method on the

UBIRIS dataset [30] but also tested the methods of Daugman [3], Wildes [8], and other methods, which contains one session of high-quality images, and a second session of lower quality images. The comparative analysis found that the results of all methods other than Wildes method have underperformed compared to their original results.

Unlike many others, Bonney et al. [31] modeled inner and outer boundaries as ellipses instead of circles. They made use of least significant bit plane to detect pupil and then obtain the elliptical limbic boundary by computing the standard deviation in the horizontal and vertical directions.

Iris segmentation of off-angled images has been carried out by estimating the elliptical shape rather than circular shape by Li [32] and Abhyankar et al. [33]. Moreover, Abhyankar et al. [33] described that an elliptical shape boundaries of Iris can represent Iris more accurately than circular boundaries and in [34]; they used active shape models to detect the non-circular (elliptical) boundaries.

Detailed study of images of CASIA [27], UBIRIS [30], and UPOL [35] databases shows that change in the intensity (intensity gradient) at outer and inner boundary of Iris is maximum in CASIA database, moderate in UBIRIS database, and minimum in UPOL database.

2.3 Iris Analysis and Feature Extraction

As stated earlier, Daugman's approach is based on Gabor filters to produce a binary representation of Iris called as Iris code and Wildes' approach is based on Laplacian of Gaussian filters at multiple scales to represent Iris with a feature vector. These two main approaches in Iris recognition-motivated researchers to investigate various methods of feature extractions which are broadly categorized into three groups, namely filter-based methods, transform-based method, and texture-based statistical methods.

Modified Log-Gabor filters are used by Yao et al. [36] instead of Gabor filters for feature extraction because LOG-Gabor filters are strictly band-pass filters compared to Gabor filter. They state that Gabor filters could not represent high-frequency components in natural images properly. Hence, using the modified filters, EER is improved marginally. Zhang et al. [37] also used LOG-Gabor filter to find local and global texture feature because zero DC component can be obtained for any bandwidth by using a LOG-Gabor filter. They stated normal Iris code as local features and global features are considered to be invariant to Iris rotation and minor errors in Iris segmentation. They proposed a cascaded system, first based on global features and second on local features.

Sun et al. [38] proposed local ordinal encoding using of Gaussian filter with the gradient vector field of an Iris image. They also proposed a general framework of Iris recognition which is useful in Iris representation and is formulated in this paper. Sun et al. [39] also proposed a cascaded system of two stages, first stage is Daugman-like approach and second stage looks at global features, i.e., 'areas enclosed by zero-crossing boundaries.'

Park et al. [40] used directional filter bank for Iris decomposition and computed two feature vectors, one as binarized directional sub-band outputs and other as block-wise directional energy values. They use these feature vectors independently for recognition, and final result is declared after combination. Improvement has been reported due to combination.

Similar to Wildes approach, Chenhong et al. [41] used Laplacian of Gaussian filters to compute the discriminable textons from geometric and luminance attributes of texture elements. In this method, morphological operations with two threshold are also employed to segment Iris on the basis of local shape into small compact and thin elongated components. Chou et al. [42] used both derivative of Gaussian and Laplacian of Gaussian filters to find whether a pixel is on step edge or ridge edge. Major motivation for use these types of filters is that only three filter parameters are used for filter design, and hence, they can be easily determined.

Ma et al. [10] described the modification of elementary Gabor filter to circularly symmetric Gabor filters which are suitable to capture local details of Iris, and they used it at two scales to obtain the prominent information in many directions and more prominently in x and y directions. They stated that, 'the performance of their system reached very close to Daugman's system and all other methods [8, 43].' They concluded that phase information characterized by Daugman method provides local shape features of an Iris, whereas their method provides statistical information of the frequency information of a local region.

Boles et al. [43] converted concentric bands of extracted Iris into 1-D signals and operated wavelet transform on it to generate the zero-crossing presentation. Energy of zero-crossing representation is used as one feature, and dimensions of rectangular pulses of zero-crossing representations are used as other feature.

Similar approach is also presented by Sanchez-Avila et al. [44] to compare the Gabor filter-based Daugman approach with dyadic wavelet transform-based zero-crossing approach and reported that Gabor filter approach achieves better performance than wavelet transform-based approach but wavelet transform-based approach showed better computational efficiency over Gabor filter-based approach. Krichen et al. [45] used wavelet packets for the feature extraction of images captured at visible light.

Thornton et al. [46] has considered seven different types of filters including Gabor wavelet for comparison and determined that Gabor wavelet gave the best recognition results among all. However, they brought out an interesting fact that the performance of Gabor wavelet is highly dependent upon parameters that define its form, and proper tuning of parameters is required for its optimum performance.

Kim et al. [47] used disk-shaped Iris image without normalization, and it is first convolved with a low-pass filter along the radial direction. Then, one-dimensional wavelet transform is operated on the smoothened Iris image to obtain angular directions of decomposed images which is approximated by an optimal piecewise linear curve connecting a small set of node points. The set of node points is used as a feature vector.

Tisse et al. [48] represented an Iris with the help of instantaneous phase. The *instantaneous* phase is obtained by constructing the *analytic signal*, which is the combination of the original signal and its *Hilbert* Transform. Miyazawa et al. [49]

has computed discrete Fourier transform (DFT) of Iris image and used phase information to create the feature vector for correlation.

Hosseini et al. [50] proposed a shape analysis approach for Iris recognition using FFT-based Tikhonov filter with the identity matrix as the regularization operator to represent shape of pigmented fibro-vascular tissue known as stroma which is extracted by operating adaptive filter.

Recently, in 2009, Azizi and Pourreza [51] have proposed contourlet transform-based method of feature extraction method for Iris recognition. Contourlet transform captures the intrinsic geometrical structures of Iris image to decompose the Iris image into a set of directional sub-bands with texture details captured in multiple orientations at multiple scales.

Statistical methods are also used for Iris analysis and feature extraction by limited researchers. As compared to Iris recognition, substantial research has been carried out in face recognition using PCA and ICA [52, 53]. Moreover, PCA and ICA have been found to be very successful methods of feature extraction for face recognition. Son et al. [54] used DWT, principal component analysis (PCA), linear discriminant analysis (LDA), and direct linear discriminant analysis (DLDA) for feature extraction, and experimented these features in combinations for Iris recognition. They concluded that DWT is best for feature extraction and DLDA is better to reduce the dimensionality of feature vector. Marian Stewart Bartlett et al. [55] used ICA with NN and presented results on frontal faces. Ekenel and Sankur [56] proposed the methodology of selection of number of independent components for feature selection and extraction using ICA.

In 2002, Huang et al. [13] experimented independent component analysis to extract the independent components of normalized Iris image using global approach. Similar approach of global processing using ICA has been presented by Dorairaj et al. [57]. However, Bae et al. [58] used ICA using local processing approach to extract the features of sub-images of Iris.

In 2008, Bowyer et al. [59] presented a systematic and detailed survey paper on Iris recognition which has covered existing research of all essential elements of Iris recognition system. This paper has been instrumental systematic study and provided comparison of various research work in Iris recognition which has greatly simplified our work of literature survey to proposed new methods of Iris segmentation and Iris feature extraction.

Selesnick et al. [60], Selesnick [61], and Nick Kingsbury [62] proposed the practical implementation of complex wavelet transform (CWT) using dual tree discrete wavelet transform (DT-DWT), in which one tree of DWT acts as real tree and other acts as imaginary tree. The low-pass and high-pass filters of both the trees are designed in such a way that second tree forms an approximate Hilbert transform of first tree. Oriented non-separable 2-D complex wavelet transform is derived by combining the sub-bands of two separable 2-D DWTs [60–62]. This transform is capable of providing orientations in six directions, phase information, and it is shift invariant too.

Kim and Udpa [63] designed new 2-D non-separable and oriented rotated discrete wavelet filter (RDWF) by rotating 2-D DWT filters by 45° for clear characterization of diagonally oriented texture. These filters clearly provide edges in the direction of 45° and −45° separately.

Kokare et al. [64] extended the work of Kim and Udpa [64] to derive the 2-D non-separable filters by rotating 2-D non-separable CWT filters, called as rotated complex wavelet filters (RCWF) to obtain the orientations in another six directions. They used these filters in combination with CWT for content-based image retrieval and reported the extremely good improvement in results as compared to DWT and CWT.

2.4 Summary

An attempt has been made to highlight the important findings of different researchers in the area of Iris recognition over the last two decades with critical observations about merits and demerits of different techniques adopted. The outcomes of this literature survey has been analyzed to define the research goals, and these outcomes have been explored to devise new techniques of Iris segmentation and feature extraction in chapter three and four, respectively.

References

1. L. Flom, A. Safir, Iris recognition system, U.S. Patent 4,641,349, 1987
2. R. Johnston, Can iris patterns be used to identify people? *Los Alamos National Laboratory, Chemical and Laser Sciences Division Annual Report LA-12331-PR,* pp. 81–86 (1992)
3. J. Daugman, High confidence visual recognition of persons by a test of statistical independence. IEEE. Trans. Pattern. Anal. Mach. Intell. **15**(11), 1148–1161 (1993)
4. J. Daugman, Biometric personal identification system based on iris analysis. U.S. Patent No. 5,291,560, 1994
5. J. Daugman, High confidence visual recognition of persons by a test of statistical independence. IEEE Trans. Pattern Anal. Mach. Intell. **15**(11), 1148–1161 (1991)
6. J. Daugman, The importance of being random: statistical principles of iris recognition, Pattern Recogn. 279–291 (2003)
7. J. Daugman, How iris recognition works. IEEE Trans. Circ. Syst. Video Technol. **14**(1), 21–30 (2004)
8. R. Wildes, Iris recognition: an emerging biometric technology. Proc. IEEE **85**(9), 1348–1363 (1997)
9. R. Wildes, J. Asmuth, S. Hsu, R. Kolczynski, J. Matey, S. Mcbride, Automated noninvasive iris recognition system and method, United States Patent, no. 5572596, (1996)
10. L. Ma, T. Tan, Y. Wang, D. Zhang, Personal identification based on iris texture analysis. IEEE Trans. Pattern Anal. Mach. Intell. **25**(12), 1519–1533 (2003)
11. L. Ma, Y. Wang, T. Tan, Iris recognition using circular symmetric filters. in *Proceedings of the 25th International Conference on Pattern Recognition (ICPR02),* vol. *2,* pp 414–417 (2002)
12. L. Ma, Y. Wang, D. Zhang, Efficient iris recognition by characterizing key local variations. IEEE Trans. Image Process. **13**(6), 739–750 (2004)
13. Y. Huang, S. Luo, E. Chen, An efficient iris recognition system, in *Proceedings of International Conference on Machine Learning and Cybernetics,* vol. 1, pp. 450–454 (2002)

14. Y. Liu, S. Yuan, X. Zhu, Q. Cui, A practical iris acquisition system and a fast edges locating algorithm in iris recognition, in *Proceedings of IEEE Conference on Instrumentation and Measurement Technology,* pp. 166–168 (2003)
15. H. Sung, J. Lim, J. Park, Y. Lee, Iris recognition using collarette boundary localization, in *Proceedings of International Conference on Pattern Recognition,* pp. 857–860 (2004)
16. J. Cui, Y. Wang, T. Tan, L. Ma, Z. Sun. A fast and robust iris localization method based on texture segmentation, in *Proceedings of the SPIE Defense and Security Symposium,* Vol. 5404, pp. 401–408 (2004)
17. W. Kong, D. Zhang, Accurate iris segmentation method based on novel reflection and eyelash detection model. in Proceedings of International Symposium on Intelligent Multimedia, Video and Speech Processing, pp. 263–266 (2001)
18. P. Lili, X. Mei, The algorithm of iris image processing, in *Proceedings of 4th IEEE Workshop on Automatic Identification Technologies,* pp. 134–138 (2005)
19. C. Teo, H. Ewe, An efficient one-dimensional fractal analysis for iris recognition, *Proceedings of 13th WSCG International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision,* pp. 157–160 (2005)
20. K. Grabowski, W. Sankowski, M. Zubert, M. Napieralska, Reliable iris localization method with application to iris recognition in near infrared light, *MIXDES (*2006*)*
21. X. He, P. Shi, A novel iris segmentation method for hand-held capture device, in *Springer LNCS 3832: International Conference on Biometrics,* pp. 479–485 (2006)
22. X. Feng, C. Fang, Z. Ding, Y. Wu, Iris localization with dual coarse-to-fine strategy, in *Proceedings of International Conference on Pattern Recognition,* pp. 553–556.(2006)
23. Q. Tian, Q. Pan, Y. Cheng, Q. Gao, Fast algorithm and application of hough transform in iris segmentation, in *Proceedings of International Conference on Machine Learning and Cybernetics,* vol. 7, pp. 3977–3980 (2004)
24. Y. Du, R. Ives, D. Etter, T. Welch, C. Chang, A new approach to iris pattern recognition. in *Proceedings of the SPIE European Symposium on Optics/Photonics in Defence and Security,* Vol. 5612, pp. 104–116 (2004)
25. T. Camus, R. Wildes, Reliable and fast eye finding in close-up images, in *Proceedings of International Conference on Pattern Recognition,* pp. 389–394 (2002)
26. D. Martin-Roche, C. Sanchez-Avila, R. Sanchez-Reillo, Iris recognition for biometric identification using dyadic wavelet transform zero-crossing. IEEE Aerosp. Electron. Syst. Mag. Mag. **17**(10), 3–6 (2002)
27. Chinese Academy of Sciences Institute of Automation, *Database of 756 Greyscale Eye Images*, http://www.sinobiometrics.com
28. P. Phillips, K. Bowyer, P. Flynn, Comments on the CASIA version 1.0 iris dataset, *IEEE Trans. Pattern Anal. Mach. Intell.***29**(10), 1869–1870 (2007)
29. H. Proenca, L. Alexandre. Iris segmentation methodology for non-cooperative recognition, in *Proceedings of IEE Conference on Vision, Image and Signal Processing,* Vol. 153, pp 199–205 (2006)
30. H. Proenc¸ and L. Alexandre, UBIRIS: Iris image database, (2004), http://iris.di.ubi.pt
31. B. Bonney, R. Ives, D. Etter, Y. Du, Iris pattern extraction using bit planes and standard deviations, in *Proceedings of 38th Asilomar Conference on Signals, Systems, and Computers,* Vol. 1, pp. 582–586 (2004)
32. X. Li, Modeling intra-class variation for non-ideal iris recognition, *In Springer LNCS 3832: International Conference on Biometrics,* pp 419–427 (2006)
33. A. Abhyankar, L. Hornak, S. Schuckers, Offangle iris recognition using bi-orthogonal wavelet network system, in *Proceedings of 4th IEEE Workshop on Automatic Identification Technologies,* pp. 239–244 (2005)
34. A. Abhyankar, S. Schuckers, Active shape models for effective iris segmentation, *In SPIE 6202: Biometric Technology for Human Identification III,* pp. H1–H10 (2006)
35. High contrast iris image database downloaded from: http://phoenix.inf.upol.cz/iris/download/
36. P. Yao, J. Li, X. Ye, Z. Zhuang, B. Li, Iris recognition algorithm using modified log-gabor filters, in *Proceedings of International Conference on Pattern Recognition,* pp. 461–464 (2006)

37. P. Zhang, D. Li, Q. Wang, A novel iris recognition method based on feature fusion, in *Proceedings of International Conference on Machine Learning and Cybernetics,* pp. 3661–3665 (2004)
38. Z. Sun, T. Tan, Y. Wang, Robust encoding of local ordinal measures: A general framework of iris recognition, in Proceedings of BioAW Workshop, pp. 270–282 (2004)
39. Z. Sun, Y. Wang, T. Tan, J. Cui, Cascading statistical and structural classifiers for iris recognition, in *Proceedings of International Conference on Image Processing,* pp 1261–1262 (2004)
40. C. Park, J. Lee, Extracting and combining multimodal directional iris features, *In Springer LNCS 3832: International Conference on Biometrics,* pp. 389–396 (2006)
41. L. Chenhong, L. Zhaoyang, Efficient iris recognition by computing discriminable textons, in *Proceedings of International Conference on Neural Networks and Brain,* Vol. 2, pp. 1164–1167 (2005)
42. C. Chou, S. Shih, W. Chen, V. Cheng, Iris recognition with multi-scale edge-type matching, in *Proceedings of International Conference on Pattern Recognition,* pp. 545–548 (2006)
43. W. Boles, B. Boashash, A human identification technique using images of the iris and wavelet transform. IEEE Trans. Signal Process. **46**(4), 1185–1188 (1998)
44. C. Sanchez-Avila, R. Sanchez-Reillo, Multiscale analysis for iris biometrics, in *Proceedings of IEEE International Carnahan Conference on Security Technology,* pp. 35–38 (2002)
45. E. Krichen, M. Mellakh, S. Garcia-Salicetti, B. Dorizzi, Iris identification using wavelet packets, in *Proceedings of International Conference on Pattern Recognition,* pp. 335–338 (2004)
46. J. Thornton, M. Savvides, B. Vijaya-Kumar, An evaluation of iris pattern representations, *In Biometrics: Theory, Applications, and Systems* (2007)
47. J. Kim, S. Cho, J. Choi, R. Marks, Iris recognition using wavelet features. J. VLSI Signal Process Syst. **38**(2), 147–156 (2004)
48. C. Tisse, L. Torres, M. Robert, Person Identification based on iris patterns, in *Proceedings of the 15th International Conference on Vision interface* (2002)
49. K. Miyazawa, K. Ito, T. Aoki, K. Kobayashi, H. Nakajima, An efficient iris recognition algorithm using phase-based image matching, in *Proceedings of International Conference on Image Processing,* pp. 49–52 (2005)
50. S. Hosseini, B. Araabi, H. Zadeh, Shape analysis of stroma for iris recognition, in *Springer LNCS 4642 International Conference on Biometrics,* pp. 790–799 (2007)
51. A. Azizi, H. Pourreza, A novel method using contourlet to extract features for iris recognition system, In Springer LNCS 5754, *International Conference on Emerging Intelligent Computing Technology and Applications,* pp. 544–554 (2009)
52. P. Hoyer, A. Hyvarinen, Independent component analysis applied to feature extraction from colour and stereo images. Netw. Comput. Neural Syst. **11**, 191–210 (2000)
53. P. Yuen, J. Lai, Face representation using independent component analysis, *Pattern Recogn.***35**(6), 1247–1257 (2002)
54. B. Son, H. Won, G. Kee, Y. Lee, Discriminant iris feature and support vector machines for iris recognition, in *Proceedings of International Conference on Image Processing,* vol. 2, pp. 865–868, (2004)
55. M. Bartlett, J. Movellan, T. Sejnowski, Face recognition by independent component analysis, *IEEE Trans. Neural Netw.***13(**6), 450–461 (2002)
56. H. Ekenel, B. Sankur, Feature selection in the independent component subspace for face recognition. *Pattern Recogn. Lett.* **25**(12), 1377–1388 (2004)
57. V. Dorairaj, N. Schmid, G. Fahmy, Performance evaluation of non-ideal Iris based recognition system implementing global ICA technique, in *Proceedings of ICIP*, vol. 3, pp. 11–14, (2004)
58. K. Bae, S. Noh, J. Kim, Iris feature extraction using independent component analysis, in *Proceedings. of 4th International Conference. Audio-and Video-Based Biometric Person Authentication*, Guildford, UK, vol. 2688, pp. 1059–1060 (2003)
59. K. Bowyer, K. Hollingsworth, P. Flynn, Image understanding for iris biometrics: a survey. *Comp. Vis. Image Understand., Acadamic Press,* **110**(2), 281–307 (2008)

60. I. Selesnick, R. Baraniuk, and N. Kingsbury, The dual tree complex wavelet transform: a coherent framework for multiscale signal and image processing, IEEE Signal Process. Mag. **22**(6), 123–151 (2005)
61. I. Selesnick, The design of approximate hilbert transform pairs of wavelet bases. IEEE Trans. Sig. Process. **50**(5), 1144–1152 (2002)
62. N. Kingsbury, The dual-tree complex wavelet transform: a new technique for shift invariance and directional filters, in *Proceedings of 8th IEEE DSP Workshop, Utah,* p. 86.20 (1998)
63. N. Kim, S. Udpa, Texture classification using rotated wavelet filters. IEEE Trans. Syst. Man Cybern. Part A Syst. Hum. **30**(6), 847–852 (2000)
64. M. Kokare, P. Biswas, B. Chatterji, Rotation invariant texture features using rotated complex wavelet for content based image retrieval, in *Proceedings* of *IEEE International. Conference on Image Processing, Singapore,* Vol. 1, pp. 393–396 (2003)

http://www.springer.com/978-81-322-1852-4

Iris Analysis for Biometric Recognition Systems
Bodade, R.M.; Talbar, S.
2014, XIX, 109 p. 63 illus., Softcover
ISBN: 978-81-322-1852-4