Abstract

Objectives: Iris recognition is one of biometric identification methods adopted over worldwide. In this paper we intend to update the previous survey and cover the survey over the period of roughly 2010 to 2015. Methods: We focus on the paper that appeared in Springer, IEEE Xplore and International Conferences, National and International journals covering Image Processing, Signal Processing, Pattern recognition and Bioinformatics. This paper primarily focuses on the survey of Iris camera for Iris acquisition, Methods adopted for iris segmentation, feature extraction, matching and public Iris database. Iris segmentation and feature extraction are important steps in Iris recognition. As there are several publications on the segmentation and feature extraction separately in literature, we have selected and summarized only prominent work in our paper. Findings: We have compared the algorithm used by various researchers with the performance parameter obtained by other researchers. We have found that there is scope for improvement in algorithms and need to understand the Iris Code in detail. Application: This comparative analysis will help researcher to get view on present scenario related to Iris recognition system.

Keywords: Acquisition Segmentation, Database, Features, Iris, Matching

1. Introduction

In our daily lives, authentication of the person is necessary in order to verify their identity in various areas, for example ATM, secure entrance to building (residential and logical access control), iris patterns in lieu of passports and national biometric identification projects (ADHAR in India). Biometrics provides a valid authentication of humans by their peculiar characteristics and special knowledge of bodily working system i.e. physiological and behavioral type, so as to identify and recognize an individual, compared to traditional authentication mechanisms such as ID cards and passwords. The physiological characteristics are palmprint, iris, fingerprint and face, whereas voice, signature and gait recognition system falls under the behavioral recognition type system. A biometric system can be operated in two modes i.e. first is verification mode and other is Identification mode.

In the biometrics, using identification mode the goal is to identify the input biometric signal from the available biometric database signal by comparing the features of input signal with the stored features i.e. one-to many matching process. In biometrics using verification mode the input biometric signal is verified with the claimed identity i.e. one-to-one matching process is initiated. In recent past, iris recognition system has been given more
attention by the academic researcher due to number of advantages such as availability of hardware which gives high computation speed and accuracy of the result. Iris recognition system is also a one of pattern-recognition techniques which is based on the Iris images. The human iris is a circular part between the dark pupil and the white sclera, which has a peculiar pattern structure that provides many miniature characteristics such as stripes, freckles and coronas etc. Figure 1 shows typical human eye structure. These visible characteristics, which are called the texture of the iris, are unique. Iris has 256 unique spot compared to other biometric has 13 to 60 unique characteristics. Each eye is unique and remain stable for lifelong. Iris pattern are such that it does not matches with the left eye iris to right eye iris of same person and also it does not match with the iris of identical twins. No two irises in the universe are same.

The paper is organised as Section 2 discusses about the basic steps used in iris recognition system and different iris cameras used for iris acquisition. Section 3 explores the segmentation technique applied in Iris recognition and Comparative analysis is presented in tabular form. Section 4 explores the feature extraction and matching methods. Section 5 discusses the public available Iris data base.

2. Basic Iris Recognition System

The important steps involved in an iris recognition system are, (1) Acquisition of Iris Images (2) Accurate Segmentation (3) Normalization (4) Extraction of Iris features (5) Comparison of extracted features with database or claimed identity (6) Finding the Similarity values
2.1 Acquisition of Iris Images

Acquisition of Iris Images is done by using a standard Iris cameras operated in visible and infrared light band. Acquisition of Iris Image can be achieved by manual or automatic method. In the manual method, the person needs to adjust within six to twelve inches from the camera for correct focusing. In automatic image acquisition method set of cameras are used to locate the iris automatically. Pre-processing steps like histogram equalization, filtering and standard noise removal to remove the noise may be employed to enhance the image quality of image before applying to the next processing step. The various cameras to be selected for Iris acquisition are LG make Iris access 3000, LG 2200, LG 4000 camera with features such as auto focus, auto zoom, interface for voice. Panasonic make ET 3000 with features having dual eye camera, oblique illumination so that eye glasses may not be removed for acquiring iris image. Oki make Irispass M camera has facility to adjust height and position to find the tilted eye. Iris guard make H100 camera has lcd, usb interface along with autofocus and auto zoom facility. Securimeterics make PIER handheld camera is deployed in military and police. Iris Access iCam 7 Series is also best camera for iris acquisition, IrisKing IKEMB-100, Panas BM –ET100, Nikkon E5700, Cannon 5D; Sony DSC –F717, Sony Dxc-950p and Topcon TRC501A, are the other commercial camera adopted for iris acquisition.

2.2 Accurate Segmentation

Segmentation steps consist of localizing the pupil and inner sclera boundary in eye image. Eyelids and eyelash is located and removed. Iris segmentation method can be divided into two categories first is classification according to the region of starting point of segmentation and second classification is according to the operators used to describe the shapes. In the first category researchers starts the segmentation from darkest region of image i.e. pupil. Edge detection technique is used and it is followed by Hough transform to detect the shape of iris and pupil. In the second category, the process starts from the less saturated part of image i.e. sclera region. After determining the sclera region, the iris is detected using any one type of operators. The different types of operators used to detect

![Figure 2. Iris recognition steps.](image-url)
the edges are like daugman’s integro-differential operator, wildes and canny operator. Various method discussed in literature are gradient based hough transform, masek method, fuzzy clustering algorithm, pulling and pushing method, eight-neighbor connection based clustering, key local variations method, active contours.

2.3 Image Normalization

During the iris acquisition process, the size of image will change if there is variation in the location of person looking into camera. Size of the pupil is varying so to deal with this difficulty, the segmented iris part is converted in the Cartesian coordinate system to a fixed length from the polar coordinate system. Variation in illumination will also result in low contrast of iris texture which affects the accuracy of iris recognition process. To deal with all such difficulties image normalization and enhancement algorithms are used.

2.4 Extraction of Features and Template Creation

Extraction of features is a process in which features such as texture features, visual features and statistical features are extracted from normalized iris image. Then the most important features from the iris image which represent the most discriminating information related to iris image with dimensionality reduction is used for template creation i.e. unique representation or Iris code. Various feature extraction algorithm includes 2D Gaussian filter, wavelet encoding, multichannel Gabor filters, Log-Gabor filters, DWT Haar wavelet, Laplacian of Gaussian filters, principal component analysis, independent component analysis.

The comparison between the templates is done and a similarity or dissimilarity numeric value is obtained. Threshold is set, if the dissimilarity value is higher than a threshold value, the iris recognition system determines it as a non-recognise Iris, otherwise, the system determines a matched Iris, resulting in identification of the person. For this matching process bit to bit iris code is compared. Hamming distance and multi-block Binary pattern is used for matching and generating dissimilarity value.

3. Segmentation Techniques in Iris Recognition

Iris segmentation is an important step of the iris recognition which is directly affecting the feature extraction and coding step resulting on iris recognition accuracy. However, iris segmentation is a difficult problem due to the nonlinear deformations, different camera angles, pupil dilations, head rotations, motion blurs, reflections, non-uniform illumination and low image contrast present in the iris image. The iris segmentation algorithm segments the iris by regarding the iris as a ring between the pupil and sclera and finding the inner edge and outer edge of the iris. Typical steps involved in iris segmentation are depicted in Figure 3.

Various algorithms proposed in the literature for iris segmentation is discussed:

In proposed iris image segmentation method using watershed and region merging. Image is divided into structure part and texture part using total variation flow model. Light spots in pupil are removed by closing. In the proposed approach, watershed and region merging are both applied in structure part which is further divided.
into separate parts. An iris segmentation algorithm is presented in which is based on the local statistics of the texture region in the iris and is suited for segmenting poor quality iris images. The segmentation algorithm is inspired by the work on Active Contours without Edges for iris segmentation. Method proposed in includes pre-processing a gray-level input eye image in order to suppress abrupt gray variations. Later, a two-fold robust strategy based on CDA and gray statistics is adopted to localize coarse iris region reliably in pre-processed image along with pupillary boundary is localization. Finally, eyelids are localized using PDA and eyelashes and in addition to this reflection are also marked adaptively.

In researcher describes new iris segmentation scheme by using game theory to elicit iris/pupil boundaries from a non-ideal iris image. A parallel game-theoretic decision making procedure is applied by modifying algorithm, which include the region-based segmentation and gradient-based boundary computation. An iris segmentation method based on the Fourier spectral density is proposed by for noisy frontal view eye images captured with minimum cooperation from the subjects. The computational complexity of the method presented is lower than the methods based on Hough transform and active contour. A novel method is proposed to improve the reliability and accuracy of colour iris segmentation for both from static and mobile devices using a fusion strategy based on selection among the segmentation outcomes of various segmentation methods.

In author proposed a method for the detection and segmentation of iris in frontal eye images. Coordinates of outer and inner iris borders and a decision that the image does not contain the iris of acceptable quality are obtained at the output. A knowledge-based approach is described to address the problem of locating and segmenting the iris in images showing close-up human eyes. The algorithm involves a succession of phases that deal with image pre-processing, pupil location, iris location, combination of pupil and iris, eyelids detection, and filtering of reflections. A novel algorithm is presented for iris segmentation in eye images taken under visible and near infrared light the proposed method consists of reflections localization, reflections filling in, iris boundaries localization and eyelids boundaries localization.

An approach for fast iris segmentation that relies on the closed nested structures of iris anatomy and on its polar symmetry is proposed by. The developed algorithm applies mathematical morphology for polar/ radial-invariant image filtering and for circular segmentation using shortest paths from generalized grey-level distances. In describes how to accurately extract the iris regions from, non-ideal quality iris images. The proposed method uses AdaBoost eye detection in order to compensate for the iris detection error caused by the two circular edge detection operations and it uses a colour segmentation technique for detecting obstructions by the ghosting effects of visible light. A fast iris segmentation algorithm is constructed by finding the rough position of the pupil centre using the circular Gabor filter. Later, the iris and pupil circles are localised using the Daugman’s integro-differential operator taken into account that the real centres of the iris and pupil are in the small area around the rough position of the pupil centre. Finally, the upper and lower eyelid boundaries are extracted using the live-wire technique.

In power of sparsity induced by L1-norm is used in overcoming the noise and degradations for color iris Images. The developed algorithm is divided into the different components, coarse iris localization, limbic boundary segmentation, pupillary boundary segmentation, eyelids fitting, reflection and shadow removal. The major boundaries are obtained by using canny edge Detector and Curvelet transform based feature extraction technique is explored for iris segmentation. Principal Component Analysis is then used to reduce the dimension of the features and finally SVM has been used as classifier. Effect Image degradations and how it can effect on the iris segmentation process is introduced by F Alonso and he evaluated the impact of 8 quality measures in the performance of iris segmentation. Adopted a method which distinguishes iris images exhibiting the red eye effect from those with a dark pupil. The detector starts with a 2D darkness map of the iris image, and generates a customized shape context descriptor from the estimated pupil region. The descriptor is then compared with the reference descriptor, generated from a number of training images with dark pupils.
### Table 1. Comparison of various iris segmentation algorithms

<table>
<thead>
<tr>
<th>Sr no</th>
<th>Paper Ref No</th>
<th>Authors</th>
<th>Feature extraction principle</th>
<th>Accuracy</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[5]</td>
<td>In⁵</td>
<td>Watershed and Region merging</td>
<td>--</td>
<td>2014</td>
</tr>
<tr>
<td>2</td>
<td>[6]</td>
<td>In⁶</td>
<td>Local texture statistics</td>
<td>90.3%</td>
<td>2011</td>
</tr>
<tr>
<td>3</td>
<td>[7]</td>
<td>In⁷</td>
<td>Circo differential accumulator (CDA) and gray statistics</td>
<td>99.42</td>
<td>2014</td>
</tr>
<tr>
<td>4</td>
<td>[8]</td>
<td>In⁸</td>
<td>A parallel game-theoretic decision making procedure by integrating the region-based segmentation and gradient-based boundary-finding</td>
<td>97.17</td>
<td>2012</td>
</tr>
<tr>
<td>5</td>
<td>[9]</td>
<td>In⁹</td>
<td>Fourier spectral density</td>
<td>98.49</td>
<td>2011</td>
</tr>
<tr>
<td>6</td>
<td>[10]</td>
<td>In¹⁰</td>
<td>Histogram of Oriented Gradients (HOG)</td>
<td>1.73 (Mean E1 Score)</td>
<td>2015</td>
</tr>
<tr>
<td>8</td>
<td>[12]</td>
<td>In¹²</td>
<td>Knowledge based</td>
<td>--</td>
<td>2010</td>
</tr>
<tr>
<td>9</td>
<td>[13]</td>
<td>In¹³</td>
<td>Edge map processing</td>
<td>93.24</td>
<td>2010</td>
</tr>
<tr>
<td>10</td>
<td>[14]</td>
<td>In¹⁴</td>
<td>Mathematical morphology for polar/radial-invariant image filtering grey-level distances</td>
<td>E = 0:022</td>
<td>2010</td>
</tr>
</tbody>
</table>
Table 1 Continued

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<table>
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<tr>
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<tbody>
<tr>
<td>11</td>
<td>[15]</td>
<td>In</td>
<td>Adaboost</td>
<td>--</td>
<td>2010</td>
</tr>
<tr>
<td>12</td>
<td>[16]</td>
<td>In</td>
<td>Using circular Gabor filter</td>
<td>97.36</td>
<td>2012</td>
</tr>
<tr>
<td>13</td>
<td>[17]</td>
<td>In</td>
<td>Sparsity induced by ( \ell_1 )-norm</td>
<td>E=1.49</td>
<td>2014</td>
</tr>
<tr>
<td>14</td>
<td>[18]</td>
<td>In</td>
<td>Curve lets Transform</td>
<td>100</td>
<td>2013</td>
</tr>
<tr>
<td>15</td>
<td>[19]</td>
<td>In</td>
<td>8 quality measures</td>
<td>--</td>
<td>2013</td>
</tr>
<tr>
<td>16</td>
<td>[20]</td>
<td>In</td>
<td>A 2D darkness map generation and extraction of shape context descriptor</td>
<td>98.13</td>
<td>2013</td>
</tr>
<tr>
<td>17</td>
<td>[21]</td>
<td>In</td>
<td>Active contour and morphology</td>
<td>--</td>
<td>2014</td>
</tr>
<tr>
<td>18</td>
<td>[22]</td>
<td>In</td>
<td>Delogne–Kåsa Circle Fitting Based on Orientation Matching Transform</td>
<td>FPR=0.01</td>
<td>2014</td>
</tr>
<tr>
<td>19</td>
<td>[23]</td>
<td>In</td>
<td>Based on the active contours “Snake”.</td>
<td>E=0.77%</td>
<td>2012</td>
</tr>
<tr>
<td>20</td>
<td>[24]</td>
<td>In</td>
<td>Morphological maps</td>
<td>E=1.05</td>
<td>2014</td>
</tr>
<tr>
<td>21</td>
<td>[25]</td>
<td>In</td>
<td>Based on analysis of the curvature of isophotes, curves connecting pixels in the image with equal intensity.</td>
<td>86.5</td>
<td>2014</td>
</tr>
</tbody>
</table>
Fast and accurate algorithm for iris segmentation using a combination of morphological operations and Chan-Vese active contour model is developed by[21]. To determine a rough boundary of the iris region the morphological operations are used while the precise boundary is found by active contour.

In[22] uses the orientation matching transform based on edge map to find the rough outer and inner iris boundaries. Delogne–Kåsa Circle Fitting (DKCFS) is used to eliminate the outlier points of the rough outer and inner iris boundaries to extract a more precise iris area from an eye image. Pre-processing method using Bias-Corrected Fuzzy C-Mean (BCFCM) and iris segmentation based on the active contours “Snake” is presented[23]. Iris segmentation algorithm in which, approximate detection of eye center position is followed by approximate detection of inner and outer borders of iris region[24]. The method generates iris with precise borders.

In[25] used a method for iris segmentation that can be used in unconstrained environments, under non-ideal imaging conditions which does not require any interaction for adaptation to different operating conditions. Algorithm proposed in[25] takes an image as input and produces the circles along with their co-ordinate values. Finally, inner and outer circles which include eyelids and eyelashes are obtained resulting in iris segmentation.

Table 1 shows the summary of various iris segmentation algorithms proposed by different researchers. The work covers the period from 2010 to 2015.

4. Feature Extraction Techniques in Iris Recognition

Feature extraction is very important step in iris recognition. Visual features are such as colour, shape, colour histogram, Colour Moments (CM), Colour Coherence Vector (CCV) and colour correlogram. Shape feature extraction techniques can be broadly classified into two groups viz., contour based and region based methods. Texture features can be broadly classified into spatial texture feature extraction methods and spectral texture feature extraction methods based on the domain from which they are extracted. Texture features are getting extracted by computing the pixel statistics or by finding the local pixel structures in original image domain, whereas the second approach transforms an image into frequency domain and then calculates feature from the transformed image. Texture properties are coarseness, contrast, directionality, line likeness, regularity and roughness.

In[26] proposes a novel method for recognition of iris patterns by using a support vector machine and Hamming distance. iris features are extracted using the zigzag collarette area of the iris. An adopted Gabor filter for feature extraction was used to evaluate half iris for recognition and with Support Vector Machine as classifier[27]. The proposed techniques could be used to overcome occlusion due to eyelids and eyelashes during segmentation. Improved iris recognition algorithm is developed using DWT and DCT based feature extraction and binary particle swarm optimization for feature selection by[28]. In addition to this, Radon transform is employed for lines detection presented in iris texture and Top hat filtering is used for image enhancement.

Empirical Mode Decomposition (EMD) which is an adaptive multi-resolution decomposition technique is used for iris recognition[29]. It was shown that, ignoring the boundary effect still can indicate eminent performance for iris recognition in the paper. A novel method based on a multi-scale Taylor expansion for feature extraction was developed[30]. They are: (1) a phase-based representation that is based on binarized first and second order multi-scale Taylor coefficient, (2) based on the most significant local extremum points of the first two Taylor expansion coefficients and (3) combination of the first two representations. An iris recognition method was proposed based on dynamic partition of the noise-free iris into disjoint regions from which MPEG-7 color and shape descriptors are extracted[31].

In[32] first segmented iris image and projected onto 1-D signals by the vertical projection and then the 1-D signal features are extracted by the 1-D wavelet transform. Finally, a PSO algorithm is adopted to train the PNN and optimizes the structure of PNN. In[33] uses data partitioning approach. Feed forward artificial neural network classifier is employed for the classification purpose. In[34]
used DauBechies Wavelet Transform (DBWT) to extract the textural features and Genetic Algorithms (GAs) were deployed to select the subset of informative features by combining the multiple feature selection criteria. Finally, a combined approach called the Adaptive Asymmetrical Support Vector Machines (AASVMs) was used for detection.

In\(^3\) proposed a novel method to perform iris encoding using bi-orthogonal wavelets and directional bi-orthogonal filters is discussed. Firstly, all the iris images are enhanced using the wavelet domain in-band de-noising method. In addition to this, a framework to assess the iris image quality based on occlusion, contrast, focus and angular deformation is developed. When iris images are captured under unconstrained conditions then quality can be highly degraded by poor focus, off-angle view, motion blur, Specular Reflection (SR), and other artifacts. To overcome these issues, an iris recognition algorithm for noisy images is proposed in\(^3\). Feature extraction is done using the 1-D Gabor filter is applied to the red, green, and gray image channels to get sets of iris codes from iris textures. Another iris recognition algorithm for unconstrained conditions is proposed by\(^3\), using reverse bi-orthogonal wavelet transform.

In\(^4\) applied a Weighted Co-occurrence Phase Histogram (WCPH) for representing the local characteristics of texture pattern. The weighting function used in the algorithm avoids the quantization problem typical of the traditional histogram. The WCPH models the joint probability distribution of both the phase angle and spatial layout which is capable of capturing richer information in texture pattern. In\(^4\) applied Daubechies Wavelet Transform (DWT) for feature extraction and the Modified Contribution-Selection Algorithm (MCSA) for iris feature ranking based on the Multi-Perturbation Shapley Analysis (MSA), a framework which relies on cooperative game theory to estimate the effectiveness of the features iteratively and select them using either forward selection or backward. An approach to construct two-dimensional (2-D) non-separable, non-redundant, multiscale Combined Directional Wavelet FilterBank (CDWFB) for iris feature-extraction is proposed in\(^4\). The CDWFB is obtained by the combination of Directional Wavelet FilterBank (DWF) and Rotated Directional Wavelet FilterBank (RDWF). Also, the dissimilarity measure of each region is fused at the decision level by exploring 1-out-of-\(n\): post-classifier in order to reduce the false rejection rate.

An algorithm proposed in\(^5\) for iris recognition with a low lighting or low contrast ratio between the iris and pupil iris images using Iso-contrast limited adaptive histogram equalization approach. Two functions are used for implementing the algorithm: (1) a local intensity histogram and (2) cumulative distribution function. In\(^5\) presented a machine learning technique to mitigate the cross-sensor performance degradation by adapting the iris samples from one sensor to another. The study was performed in order to evaluate cross-sensor matching, where the test samples were verified using data enrolled with a different sensor, often led to reduced performance.

In\(^6\) proposes an accurate iris recognition from the distantly acquired face or eye images under less constrained environments. A set of coordinate-pairs, which is referred to as geometric key which uniquely defines the way how the iris features are encoded from the localized iris region pixels is randomly generated and exclusively assigned to each subject enrolled into the system. The presence of a textured cosmetic contact lens which poses a challenge to iris recognition with contact lens is discussed by\(^6\). In\(^7\) also proposes bag of words method for contact lens detection using IIIT-D Iris Contact Lens.

In\(^8\) proposes, a Zernike moment based phase encoding for iris features. Zernike moments-based phase features are computed from the partially overlapping regions to more effectively accommodate local pixel region variations in the normalized iris images. Experimental results presented using UBIRIS.v2, FRGC, and CASIA.v4 iris image database.

Iris code is a binary code that summarizes the features of iris. In\(^9\) author attempted to understand the iris code by looking for stable bit in iris code using log Gabor filter. In iris code all the bits are not equally useful; some bits are more consistent than other bits. The bits toward the pupil and limbic boundary are more fragile and investigated the
### Table 2. Table of comparison of feature extraction and matching method

<table>
<thead>
<tr>
<th>Sr</th>
<th>Paper Ref No</th>
<th>Feature Extraction principle</th>
<th>Database used</th>
<th>Matching Process</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[27]</td>
<td>Zigzag Collarette area of the iris.</td>
<td>CASIA</td>
<td>SVM</td>
<td>99.91% and 99.88%</td>
</tr>
<tr>
<td>2</td>
<td>[28]</td>
<td>Gabor features</td>
<td>CASIA</td>
<td>SVM</td>
<td>FAR and FRR of 0.21%</td>
</tr>
<tr>
<td>3</td>
<td>[29]</td>
<td>DWT and DCT</td>
<td>Phoenix and IITD</td>
<td>Euclidean distance classifier</td>
<td>88.56</td>
</tr>
<tr>
<td>4</td>
<td>[30]</td>
<td>EMD</td>
<td>CASIA</td>
<td>Hamming Distance</td>
<td>98.7</td>
</tr>
<tr>
<td>5</td>
<td>[31]</td>
<td>Multi-scale Taylor expansion of the iris texture.</td>
<td>Casia 2.0 ICE-1 and MBGC-3l</td>
<td>Elastic similarity metric</td>
<td>EER=0.026 (CASIA 2.0)</td>
</tr>
<tr>
<td>6</td>
<td>[32]</td>
<td>MPEG.7 color and shape descriptors</td>
<td>NICE:II</td>
<td>Similarity metric</td>
<td>FAR = 0.01</td>
</tr>
<tr>
<td>7</td>
<td>[33]</td>
<td>1-D wavelet transform</td>
<td>CASIA</td>
<td>PNN</td>
<td>99.1</td>
</tr>
<tr>
<td>8</td>
<td>[34]</td>
<td>Horizontal, vertical and block partitioning method</td>
<td>CHUK</td>
<td>FANN</td>
<td>93.33%</td>
</tr>
</tbody>
</table>
Table 2 Continued

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Bi-orthogonal wavelets and directional bi-orthogonal filters</th>
<th>CASIA, Bath, WVU and Clarkson</th>
<th>Hamming Distance</th>
<th>EER= 0.07%, 0.15%, 0.81% and 1.29</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>[36]</td>
<td>Feature extraction using 1-D Gabor filter applied to the red, green, and gray image channels</td>
<td>NICE.II</td>
<td>hamming distance</td>
<td>EER = 16.942</td>
</tr>
<tr>
<td>11</td>
<td>[37]</td>
<td>Reverse biorthogonal wavelet transform</td>
<td>UBIRIS &amp; NICE I</td>
<td>Hamming Distance</td>
<td>EER= 12.03%</td>
</tr>
<tr>
<td>12</td>
<td>[38]</td>
<td>weighted co-occurrence phase histogram (WCPH)</td>
<td>UBIRIS.v2</td>
<td>Bhattacharyya distance</td>
<td>EER= 0.2278</td>
</tr>
<tr>
<td>13</td>
<td>[39]</td>
<td>Daubechies Wavelet Transform (DWT)</td>
<td>ICE 2005, UBIRIS</td>
<td>Hausdorff distance (HD)</td>
<td>98.3, 97.49,</td>
</tr>
<tr>
<td>14</td>
<td>[40]</td>
<td>multiscale combined directional wavelet filterbank (CDWFB)</td>
<td>UBIRIS &amp; MMUI</td>
<td>Canberra distance (CD)</td>
<td>99 &amp; 98.16</td>
</tr>
<tr>
<td>15</td>
<td>[41]</td>
<td>Iso-contrast limited adaptive histogram equalization</td>
<td>UBIRIS.v2</td>
<td>Hamming Distance</td>
<td>95.5</td>
</tr>
<tr>
<td>16</td>
<td>[42]</td>
<td>1D Log-Gabor filter.</td>
<td>LG2200 and LG4000</td>
<td>squared euclidean distance</td>
<td>95.73</td>
</tr>
</tbody>
</table>
In[49] author investigated using non zero DC Gabor filter. Iris code is still very incomplete because limited work is devoted to its theory.

The Table 2 shows the summary of feature extraction and matching methods proposed by various researchers. The work included is covering the period 2010 to 2015.

### 5. Public Datasets for Iris Images

Various iris image databases are available publically. We reviewed few of the important iris image databases in this section including CASIA, ICE, UBIRIS, WVU, BATH and MMU. database[50].

#### 5.1 CASIA Iris Database

Casia iris image dataset of (version 1.0) consist of 108 different classes and total 756 images[51]. Two sessions were employed to capture 7 images, first session collected three samples and second session collected four. The casia Version 3 consist of 2655 images and 249 persons were used and dataset has 396 classes. Images were acquired in two sessions with a gap of one month. Images are of size 320 X 280 with 8-bit gray intensity levels.

#### 5.2 ICE Database

The Iris Challenge Evaluation (ICE) dataset consist of 244 class and total 2954 images which is divided into 1528 images of left eye iris and 1425 of right eye iris[52]. Few iris ICE database contains images with poorly focused and iris covered by eyelids and eyelash. Also, there are some rotated iris images and partially captured images. Size of iris image is 640 X 480 with 8-bit intensity level.

#### 5.3 UBIRIS Database

It is an iris dataset for biometric purposes. The ubiris Version 1 database consist of total 2,410 iris images captured in visible wavelength. Two sessions were employed to capture iris image. Noisy images are also provided in database so that robustness and accuracy of algorithm can be checked[53].

### Table 2 Continued

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<tbody>
<tr>
<td>18</td>
<td>[44]</td>
<td>Randomly generated set of coordinate-pairs, which is referred to as geometric key</td>
<td>UBIRIS.v2, FRGC and CASIA.v4</td>
<td>Hamming distance</td>
<td>EER= 0.1667, 0.1987, 0.0356</td>
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<tr>
<td>19</td>
<td>[45]</td>
<td>Textured effect of Contact Lenses.</td>
<td>IIT-D Iris Contact Lens database and the ND-Contact Lens</td>
<td>Weka classifier</td>
<td>80.94 &amp; 80.04</td>
</tr>
<tr>
<td>20</td>
<td>[47]</td>
<td>Zernike moment based phase encoding</td>
<td>UBIRIS.v2, FRGC, and CASIA.v4</td>
<td>modified Hamming distance</td>
<td>0.1196, 0.1986, 0.0290</td>
</tr>
</tbody>
</table>
5.4 WVU Database
The West Virginia University (WVU) dataset consist of total 800 images captured in poor illumination condition and with 200 classes. Each class is consisting of four images collected at three different angles. The size of iris images 640X480 with 8-bit intensity level.

5.5 Bath Database
The University of Bath (BATH) iris image database presently consist more than 16000 images, 400 subjects were considered for 800 eyes. The student and staff of bath university were main subjects for this dataset and very high quality camera was employed.

5.6 MMU Database
The Multimedia University (MMU) has a small data set consisting of only 450 iris images. The iris image database consists of 100 subjects with five iris images per subject with different ages and nationalities.

Other useful dataset is released by Dam University ND IRIS -0405, IIT Delhi and UPOL.

6. Conclusion
This study is effective in understanding various algorithms used for iris segmentation, extracting features of iris, and matching of iris code which are main steps in iris recognition system. This work identified that most of the algorithm techniques used provide good results, yet there is scope to improve the results. This paper will be useful for researcher who wish to view a larger picture of current state of Iris recognition system, as this paper covers right from the type of camera to be used for image acquisition to list of public database of iris available for research.

7. References
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