Iris Recognition Using Symmetric Graph Structure Based Pattern Matching

Aniruddh Kr. Shukla[1], Himanshu Aditya[1], Kundan Kr. Singh[1], Rinku Datta Rakshit[2], Deep Suman Dev[1](✉), and Dakshina Ranjan Kisku[3]

[1] Department of Computer Science and Engineering, Neotia Institute of Technology, Management and Science, Sarisa, South 24 PGS, Kolkata, West Bengal, India
deepsumandev@yahoo.co.in
[2] Department of Information Technology, Asansol Engineering College, Asansol, West Bengal, India
[3] Department of Computer Science and Engineering, National Institute of Technology, Durgapur, West Bengal, India
drkisku@cse.nitdgp.ac.in

Abstract. Automatic human identification using biometric information like Iris, leads on to the significant progress in the field of computer vision as it returns better authenticity and accuracy compared to other biometric recognition. This is because of its non-contact acquisition and user-friendly interface. But for unconstrained environment, it suffers when facial expression changes and light intensity differs. In this work, a novel approach for iris recognition called Multi Variant Symmetric Ternary Local Pattern (MVSTLP) is presented using the fundamental idea of pattern matching with the aim to find similarity between scene iris image and query iris pattern image by extracting distinctive features from them, where scene iris image is logically divided into number of query pattern size candidate windows. MVSTLP focuses on neighbour pixels selection in symmetric way within small image area and has unique ability to prioritize distinct feature extraction by establishing strong association between pixels. In effect of these, it can track very minute variations in image property and able to localize iris pattern within the scene iris image very accurately.

Keywords: Iris recognition · Local-feature descriptor · Symmetric patterns

1 Introduction

Historically, authentication conventions were based on things one possessed (a passport, a key, or identity credential), or things which are known (the answer of security question, a password, or a PIN). This information is mainly required to discourse privileges or confirm identity. However, these conventions could be conciliated as – possession of the requisite knowledge by the unauthenticated individual could lead to security breaches.

Biometrics is a mechanism that estimates distinctive physiological and behavioural characteristics of human being for authentication. These characteristics are proven to be more reliable than the traditional mechanisms for their uniqueness and accuracy. Iris,

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palm print, footprint, face, fingerprint are the physiological characteristics and keystroke, signature and voice are the behavioural characteristics of human being. Out of these characteristics, Iris recognition [1, 2] gained an exceptional acceptance in recent times for its distinctive features with intricate pattern, non-contact acquisition and user-friendly interactive interface. Recognition means whether in the iris image, iris features are present or not. Detection or localization means in which part of the iris image have feature similarity with the features of query pattern iris image. Moreover, Iris has discriminative phase information with span about 249 degrees of freedom [1]. These features make it reliable and help to do accurate biometric authentication.

Iris features become more distinctive by forming different complex and random structures for instance rings, ridges, furrows, freckles, crypts, corona. These features minimize the chances of having similarity between iris patterns of different individuals. Moreover, Iris features are very substantial and is imperceptive to environment and age. Iris recognition has been enforced widely in many large-scale identity authentication systems, such as UID project of India, border control system in docks, airports, hilly regions, access control in factories etc. and in some small-scale applications like, getting access in laboratories, mobile phones, workstations, Automatic Teller Machines (ATM), evidence rooms of police etc. due to its reliability and higher recognition rates.

Key features of Iris are:

- Reliability and Accuracy – Discriminative phase information with span about 249 degrees of freedom, makes Iris recognition very reliable and accurate compared to other biometric identification.
- Uniqueness – Iris of any human being is unique because of the iris pattern structures (instance rings, ridges, furrows, freckles, crypts, corona). No two human beings have same iris pattern structure and it does not also depend on heredity.

The three main operational stages of iris recognition are: image pre-processing, feature extraction and pattern matching. To obtain informative iris region, image pre-processing is done in three steps: iris localization, iris normalization and image enhancement. Inner and outer borderlines are revealed by iris localization, preferably modelled in circular shape. Iris region covered by eyelashes and eyelids are identified and removed for better accuracy. Iris image is converted to Polar coordinates from Cartesian coordinates using iris normalization. The converted image seems to be a rectangular image with angular resolution. Factors like non-uniform illumination and low contrast due to position of light source are handled by image enhancement. Before the feature extraction and pattern matching, pre-processed iris scene image is logically divided into couple of candidate windows of iris query pattern image size following the need of pattern matching process. This entire methodology is based on the principle of pattern matching where candidate window formation is an integral phase. Because, feature matching cannot be initiated between two images with varying size. Followed by feature extraction from candidate windows of scene iris image and query iris image. To assess the similarity, features extracted from query iris image is compared with features extracted from each candidate windows of scene iris image. Iris image portion with the best similarity score will be localized. Generic iris recognition flow diagram is shown in Fig. 1.

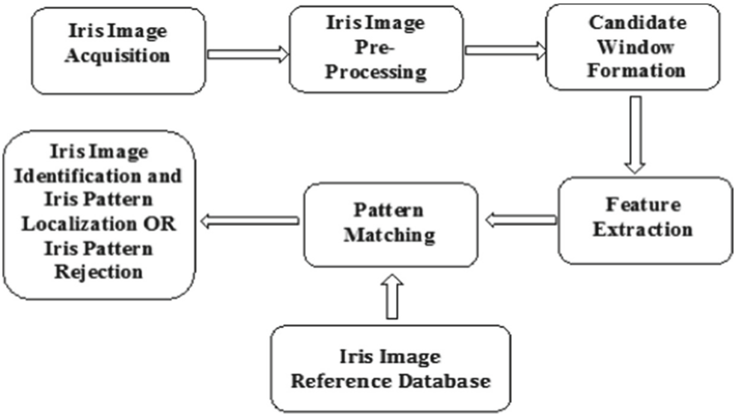

Fig. 1. Generic flow diagram of iris recognition

In Iris recognition, the most challenging factors are iris region partitioning and localization. Wrong partitioning and localization may raise the possibility to have poor outcomes and will degrade the efficacy of the iris recognition process. Image property variation such as, brightness, noise, contrast, blur, varying pigmentation levels, occlusion due to eyelashes, false rejection, false acceptance and environmental obstacles are putting the iris recognition process in challenge to achieve high degree of iris recognition accuracy.

Efficient feature extraction and accurate matching process help to achieve high degree of recognition accuracy. Intensity value of pixel in image, reflects image property. Image property will be changed if there is change in pixel intensity value. Feature extraction algorithm must be efficient to keep track of this change. To keep track of image property variations due to brightness, noise, contrast, blur, occlusion, false rejection, false acceptance and environmental obstacles, close correspondence between pixels in small image regions must be implemented. To implement this, graph structure based local descriptor is a very good candidate. Graph structure is nothing but the pixel orientation within an image area and the close coordination between pixels are implemented by forming pixel sequence path which looks like a graph structure. In image-based graph structure, graph is undirected. Pixel intensity value of an image represents "node" of the graph. Neighbour pixel of any pixel are connected through the line called "edge". Local descriptor identifies any node within a small image area as source or center pixel and refers the nearest neighbour pixels around that source or center pixel to extract distinct informative features. On the other hand, iris matching process can be done using the process of pattern matching. Pattern matching [3, 4] is one of the most advanced and improvised fields of research in terms of biometric and pattern recognition [5]. It has fascinating applications which include object tracking, image localization, image classification [6], shape matching, face tracking [7], face detection [8, 9], etc. Pattern matching process has the basic need of candidate window formation. Because, matching cannot be possible between two different size images. Large scene image is logically fragmented into small size image portions which are of query pattern image size and then comparison is done between candidate windows and query image. This process makes pattern matching very accurate while recognizing and localizing any pattern in large image.

Effective iris matching algorithm using pattern matching methodology with a high degree of matching accuracy and less dependency on computational resources under strict requirements of the matching process and various image complexities together is not achieved yet. Moreover, accurate localization of pattern, make the entire process more challenging.

While localizing an iris query pattern image, similarity measurement based on liner value proven to be inaccurate way to solve the problems because of not considering the measures of statistic like Sum of Squared Difference (SSD), Sum of Absolute Difference (SAD), Euclidian Distance, Mean Squared error (MSE) and Standard Deviation. Two matched patterns can have same MSE but may be different slightly in reality. So, all the factors of pattern must be considered for accurate localization.

2 Literature Survey

Iris features proven to be more unique and consistent compared to other biometric features of human being. It is also a proved fact that, no two persons can have the similar iris features as instance rings, ridges, furrows, freckles, crypts, corona properties vary from person to person.

Authors of [10] suggested that, various iris recognition methodologies can be fused and that can be utilized on non-perfect visible wavelength iris images taken in unimpeded environment. However, it suffers in terms of accuracy. In [11], an iris recognition strategy was proposed which uses different iris attributes present in iris images. But it is tested only on visible light iris images. It seems to be less efficient. By using Top hat filtering and Randon Transform, a flexible Iris recognition process is proposed in [12] and for feature extraction, DWT and DCT were used. It increases time complexity for real time applications. To escalate the recognition rate in noisy condition, a neural network structure was proposed in [13]. Computation time also became a factor here. Authors of [14] suggested a model for heterogeneous iris recognition, where weight map calculation is formulated depending on binary codes present in iris template. In [15], an iris encoding along with matching process was elaborated for noisy iris images. However, the multimodal procedure is not considered in this approach. Reflection and eyelash detection-based Iris segmentation is proposed in [16]. In [17], eyelid, eyelash and shadow localization are implemented as an integral part of iris recognition. Model presented in [18], based on Parabolic Hough model and Otsu's thresholding method, is used for eyelid and eyelash detection in normalized iris image. Gabor wavelet based genetic algorithm is used for iris feature extraction in [19]. A noise removal approach is introduced in [20] for non-cooperative iris recognition.

In [21] demonstrated a nonlinear mechanism which represents the local region consistency of iris bits. Also, this mechanism uses weight map to encode iris bits. This weighted calculation attains more informative elements of local iris features. An enhanced Daugman iris recognition algorithm is proposed in [22] by incorporating improvement needed for iris confinement and iris encoding. It has improved the speed of overall process to some extent. A center key point-based feature extraction process was delineated in [23] by doing productive fusion of SIFT features. It shows substantial improvement in recognition rate. So, it has been seen that feature, extracted on implementation of close correspondence between pixels in local region, gives a certain edge to the recognition algorithm and side-by-side helps to return higher matching accuracy.

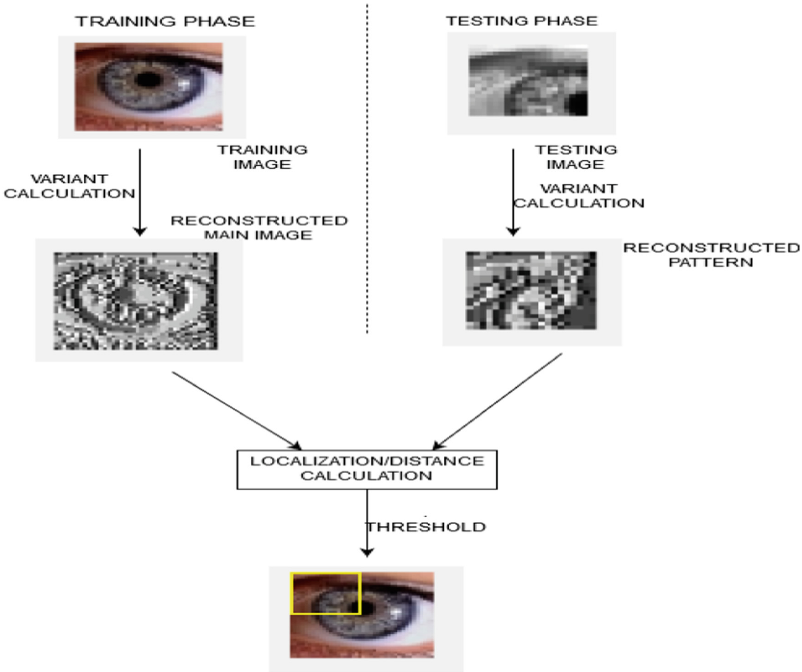

Fig. 2. Iris matching using MVSTLP based pattern matching process

Local Binary Pattern (LBP) [24], extracts local image information by comparing intensity value of the center pixel with intensity values of all its neighbours present in 3 × 3 small image area. Local graph structure (LGS) [25, 26] extract features from image using the concept of graph structure. It overrules the limitation present in LBP, by considering maximum feature in working grid area. LGS 3 × 4 structure refers neighbour pixels asymmetrically from left and right side of a source pixel. Illumination invariantness is one of the key properties of LGS. However, it struggles sometimes for its asymmetric graph structure and redundant relationship implementation between pixels. Improvement over LGS was done and reported as Symmetrical Local Graph Structure (SLGS) in [27]. It refers neighbour pixels of target pixel in a balanced symmetric way within a 3 × 5 small image area. SLGS reduces the number of redundant relationship implementations between pixels to maximum extent. A logical extension over LBP was proposed in [28] as Local Ternary Pattern (LTP) which also works in 3 × 3 small image area to extract features. These graph structure based local descriptors showed their proficiency in biometric application like face recognition with different image property variations. So, local graph structure-based descriptor can be a good candidate for iris recognition.

In this paper a novel approach, MVSTLP, has been proposed with a focus to maximize recognition rate compared to others by overcoming the limitations of existing methods. Variant formation for MVSTLP is done by comparing center pixel and its neighbour pixels within the small image area, followed by categorization of variants in different pixel groups. Similarity estimation is evaluated with Euclidean distance by comparing iris pattern with each candidate windows formed from individual iris image of the database. Candidate window with best similarity score will be considered as the best possible image area where presence of iris pattern image portion can be seen. Iris recognition using MVSTLP based pattern matching process is shown in Fig. 2. Here feature extraction and image reconstruction are the steps with great importance before the model being tested. Using local descriptor, local image features are extracted in terms of optimal weighted value of interest pixels. From these values image is reconstructed to have better image property clarity.

Iris recognition is done in this paper using graph structure based local descriptor. Local descriptor still has not been used for this purpose. Local descriptor basically works in small image area and extracts local image information by establishing close correspondence between pixels present within that area. To extract informative image information, pixel references surrounding an interest pixel should be symmetric (equal in count) in all direction. While fetching image information, different pixel orientation returns different image information. From that informative unique one will be selected. For these reason, multivariant symmetric approach is important.

Rest of the paper is delineated as follows. Novel MVSTLP based iris matching approach is presented in Sect. 3. Experimental evaluation is elaborated in Sect. 4. Concluding remarks is mentioned in the last section.

3 Proposed Iris Recognition Methodology Using Multi Variant Symmetric Ternary Local Pattern (MVSTLP)

3.1 Problem Formulation

The process of iris recognition with principle of pattern matching contains couple of sequential stages and they are iris image acquisition, iris image pre-processing, candidate window formation, feature extraction, matching and identification of iris pattern and iris pattern localization. In the iris image acquisition stage, iris images are acquired and stored in the database. Iris images are normalized and enhanced in the iris image pre-processing stage. Candidate windows of iris pattern image size are formed by logically dividing the input iris image for more accurate identification of iris pattern. Candidate windows of pattern image size are formed because matching cannot be formulated between different size if images. Suppose, input iris image size is $M_1 \times M_2$ pixels and query iris pattern image size is $Q_1 \times Q_2$ pixels where $Q_1 < M_1$ and $Q_2 < M_2$. MVSTLP works with 3×5 image area to extract the close association between the pixels present within that area. It calculates updated weighted decimal value for each interest pixel by forming variants with different orientation of neighbour pixels for that interest pixel. This helps to figure out distinctive feature points from both the iris image samples and iris pattern image. Then histogram is generated for both candidate windows and query iris pattern image and the histograms are compared to check for similarity. In the iris pattern localization stage, the matched portion in the iris image is localized with respect to query iris pattern image.

3.2 Proposed Methodology – Multi Variant Symmetric Ternary Local Pattern (MVSTLP)

The proposed MVSTLP algorithm which works on a fixed matrix size of 3 × 5 and updates the intensity value of the interest pixel based on the intensity values of the neighbour pixels. It covers the wide range of pixels within 3 × 5 image area. This algorithm gives a unique insight where it constructs a new image using feature extraction methodology. The variant calculation is the new add on to this algorithm. For example, pixel intensity values of the pixels present in an assumed 3 × 5 image area is shown in Table 1.

Table 1. Pixel intensity values in an assumed 3 × 5 image area

126	131	108	141	150
208	217	190	177	100
215	233	215	114	175

The pixel association with center pixel (CP) or interest pixel is shown in Fig. 3 following MVSTLP. The numbers marked from 0–5 denote the index of the pixels. MVSTLP generates local ternary patterns by referring neighbour pixels symmetrically in three-pixel groups using Eq. 1.

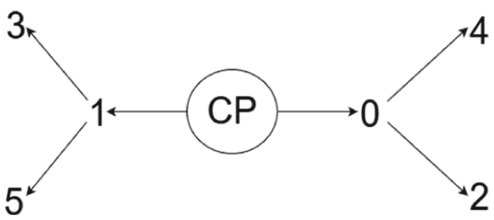

Fig. 3. Position wise neighbour pixels for center pixel (CP)

$$\sum_{i=0}^{N/3}[S(n_{2i} - n_{2i+1})3^i] \quad (1)$$

where N is the number of reference neighbour pixels and for MVSTLP, N = 6. Following Eq. 1, the loop will move from i = 0 to i = 2. Three groups will be formed and, in each group, there will be 2 pixels. For first group (PG 1), where i = 0, neighbourhood reference pixels at positions 0 and 1 are selected with respect to center pixel (CP). For second group (PG 2), where i = 1, neighbourhood reference pixels at positions 2 and 3 are selected with respect to center pixel (CP). For third group (PG 3), where i = 2, neighbourhood reference pixels at positions 4 and 5 are selected with respect to center pixel (CP). With respect to the reference neighbourhood pixel selection different pixel association can be formed with different orientation, which are known as 'variants'. Pixel group and variant formation are shown in Table 2.

Table 2. Pixel group and different variants of MVSTLP with respect to center pixel (CP)

Pixel group	Candidate pixels (index)	Variants		Updated decimal values
PG 1	0^{th} and 1^{st}	V1	(CP-0)(CP-1)(CP-2)(CP-3)(CP-4)(CP-5)(2-3)(4-5)	186
		V2	(CP-0)(CP-1)(CP-2)(CP-3)(5-4)(3-2)(5-CP)(4-CP)	186
		V3	(CP-4)(CP-5)(2-3)(5-4)(CP-0)(CP-1)(CP-2)(CP-3)	187
		V4	(5-4)(3-2)(5-CP)(4-CP)(CP-0)(CP-1)(CP-2)(CP-3)	171
PG 2	2^{nd} and 3^{rd}	V5	(CP-0)(CP-1)(CP-2)(CP-3)(CP-4)(CP-5)(0-1)(4-5)	184
		V6	(CP-0)(CP-1)(CP-2)(CP-3)(5-4)(1-0)(5-CP)(4-CP)	190
		V7	(CP-4)(CP-5)(0-1)(4-5)(CP-0)(CP-1)(CP-2)(CP-3)	139
		V8	(5-4)(1-0)(5-CP)(4-CP)(CP-0)(CP-1)(CP-2)(CP-3)	235
PG 3	4^{th} and 5^{th}	V9	(CP-0)(CP-1)(CP-2)(CP-3)(CP-4)(CP-5)(0-1)(2-3)	185
		V10	(CP-0)(CP-1)(CP-2)(CP-3)(3-2)(1-0)(5-CP)(4-CP)	182
		V11	(CP-4)(CP-5)(0-1)(2-3)(CP-0)(CP-1)(CP-2)(CP-3)	155
		V12	(3-2)(1-0)(5-CP)(4-CP)(CP-0)(CP-1)(CP-2)(CP-3)	107

Optimal updated intensity value of center pixel is calculated using Eq. 2.

$$\left(avg \sum_{PG=1}^{3} (avg \sum_{V=1}^{4} set \ V) \right) \tag{2}$$

where PG = Pixel Group and V = variant number. Average of 4 variants is taken for each pixel group, so total 3 average values from 3 pixel groups are obtained. After that, again average value from those 3 average values is calculated, which is the optimal updated intensity value of the corresponding center pixel.

3.3 Steps of MVSTLP Based Iris Recognition Process

Step 1: Read query iris image and stored iris images.

Step 2: Divide each stored iris images into candidate windows (shown in Fig. 4) of query iris pattern image size.

Step 3: Apply local feature descriptor "Multi Variant Symmetric Ternary Local Pattern (MVSTLP)," on query iris pattern image and on all candidate windows formed from stored iris images to extract features.

Step 4: MVSTLP works on 3 × 5 reference image area (keeping interest pixel at center of 3 × 5 image area). For each 3 × 5 image area of query iris image and of each candidate window, extract features by calculating binary value and corresponding decimal value using MVSTLP.

Step 5: Generate histogram for each 3 × 5 block with the updated weighted value (applicable for query iris pattern image and each candidate window).

Step 6: Marge all histograms to get one histogram (applicable for query iris pattern image and each candidate window).

Step 7: Distance is calculated between each candidate window histogram with the query iris pattern image histogram using Euclidian Distance metrics.

Step 8: Comparison (distance calculation) gives recognition accuracy.

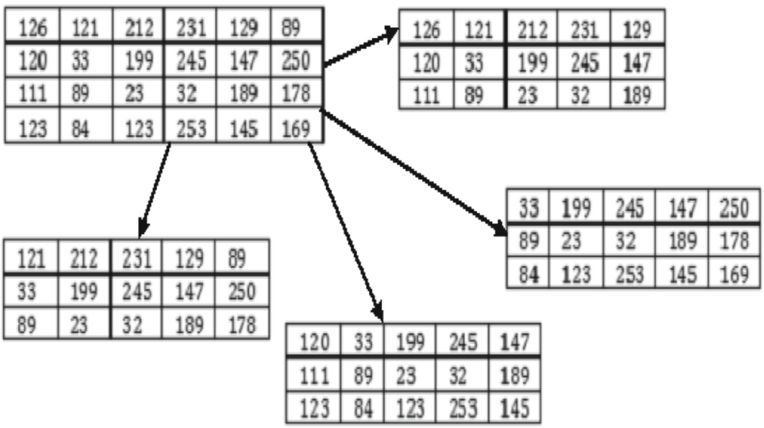

Fig. 4. Sliding candidate window formation

Dividing the stored image at every time means forming the candidate windows of iris pattern image size, is a basic structural need of any recognition using pattern matching concept.

4 Experimental Evaluation

Initially, iris database images are logically divided into number of candidate windows of iris pattern image size. Followed by calculation of optimal weighted value for the center pixel within each 3 × 5 area using MVSTLP. Similarity proximity is calculated with Euclidean distance by comparing iris pattern histogram with each candidate histograms formed from individual iris image of the database. Candidate window with best similarity score will be treated as the most possible image area where iris pattern image portion is present.

The proposed iris recognition process is evaluated on 400 iris images chosen from CASIA-Iris V.3-Interval database. The format of iris images is 8-bit gray level JPEG and the images are captured under near infra-red (NIR) illumination about 700–900 nm. A sample iris image is shown in Fig. 5.

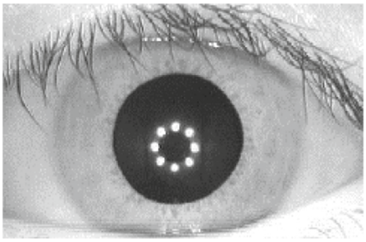

Fig. 5. A sample image from CASIA-Iris V.3-Interval database

Sample iris image, iris pattern image, reconstructed iris and iris pattern image using MVSTLP are shown in Fig. 6. Iris pattern localization using MVSTLP based iris recognition process is shown in Fig. 7.

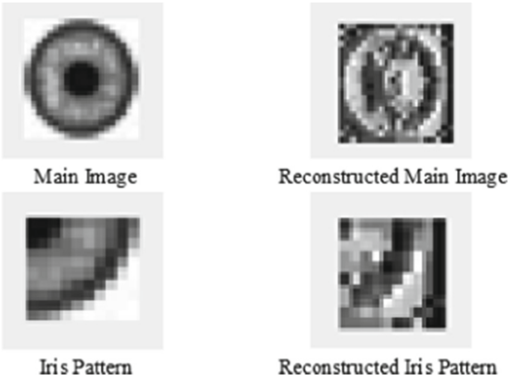

Fig. 6. Sample main and Iris pattern image with initial and reconstructed view using MVSTLP

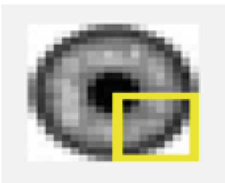

Fig. 7. Iris pattern localization using MVSTLP

To show the efficiency of the proposed MVSTLP based iris recognition process, it was tested along with existing iris recognition processes [16–20] and few local descriptors-based processes by determining essential parameters such as False Rejection Rate (FRR) with assuming False Acceptance Rate (FAR) = 0.001%, Equal Error Rate (ERR) and Correct Recognition Rate (CRR). In candidate windows, it has been seen that pattern appearance may match in more than one candidate windows. However, it is not possible to take all. The more likely candidate window will be selected. So, how much methods are able to discriminate these negligible candidate windows, that is the matter of concern. For that, FAR is assumed to be fixed with 0.001% and FRR is calculated. Comparative study is conducted on normal image and noisy converted image types of the above mentioned database.

4.1 Results on Iris Images (Normal Type)

For any recognition, feature study is the main step. Extracted feature will include not only image property, but also image property deviation due to noise, blur etc. For this reason, along with other recent state-of-the-art methods, methods delineated in [16–19] and [20] are tested because of their motivation towards iris recognition.

The comparative study between the other processes and proposed MVSTLP based iris recognition process on normal type images is shown in Table 3 and Fig. 8. By keeping FAR = 0.001%, it has been seen that FRR of the process in [20] is less than of the method in [18], but they have shown their competitiveness with similar CRR. Proposed MVSTLP has appeared better than other methods with less FRR and good CRR. Though LGS, SLGS and LTP are tested on face recognition previously, but they have also shown their effectiveness in iris recognition.

Table 3. Recognition accuracies on Iris images (normal type)

Author name/Approach name	FRR (%) @ FAR = 0.001%	ERR (%)	CRR (%)
Kong and Zhang [16]	2.57	0.59	99.14
He et al. [17]	1.90	0.46	99.28
Min and Park [18]	2.37	0.53	99.34
Hamed Ghodrati et al. [19]	3.16	0.93	98.42
Hamed Ghodrati et al. [20]	1.51	0.40	99.34
LGS [26] based approach	3.05	0.86	98.56
SLGS [27] based approach	2.81	0.64	98.87
LTP [28] based approach	2.72	0.61	99.02
MVSTLP based approach	1.46	0.38	99.43

4.2 Results on Iris Images (Noisy Type)

Performance of the algorithms are also tested on noisy converted images of the CASIA-Iris V.3-Interval database. Iid zero-mean Gaussian noise with noise level 100 is applied on the images to make them noisy.

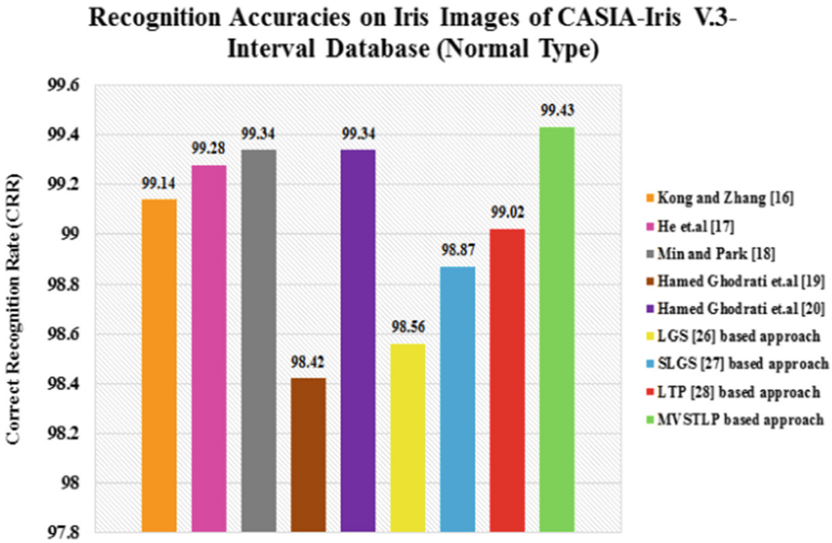

Fig. 8. Comparative accuracy measurement on Iris images (normal type)

The performance of the different recognition processes on noisy type images is shown in Table 4 and Fig. 9. Methods of [17, 18, 20] are good in performance and also competitive to SLGS and LTP based recognition process. Though MVSTLP based recognition process come with little bit higher FRR than method of [20] but surpasses all other methods with very high CRR.

Table 4. Recognition accuracies on Iris images (noisy type)

Author name/Approach name	FRR (%) @ FAR = 0.001%	ERR (%)	CRR (%)
Kong and Zhang [16]	3.17	0.71	98.59
He et al. [17]	2.35	0.58	99.02
Min and Park [18]	2.84	0.62	99.16
Hamed Ghodrati et al. [19]	3.44	0.96	98.77
Hamed Ghodrati et al. [20]	1.78	0.51	99.21
LGS [26] based approach	3.61	0.97	98.02
SLGS [27] based approach	2.68	0.67	99.07
LTP [28] based approach	2.34	0.59	99.18
MVSTLP based approach	1.79	0.38	99.29

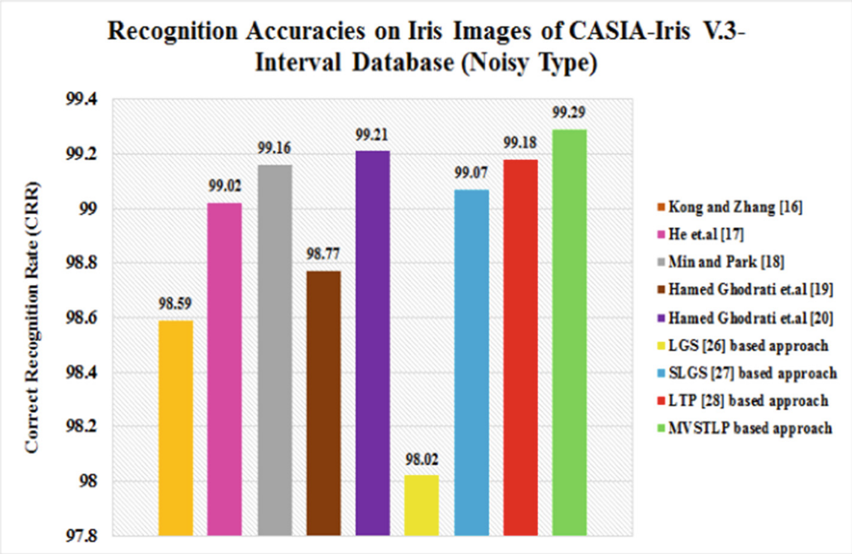

Fig. 9. Comparative accuracy measurement on Iris images (noisy type)

5 Conclusion

This paper has presented an effective local descriptor (MVSTLP) based iris recognition methodology. It has minimized the limitations of other local descriptors such as LGS, SLGS and LTP. For its dominant feature extraction structure and pattern matching procedure in the process of iris identification and localization, it tries to overcome the challenges of other iris recognition processes and increases the matching accuracy also. Another point for any biometric authentication method is that, the captured images not always be without any image property variations, there may be some variations due to image property change. MVSTLP extracts the features in more symmetric way from 3×5 small image area by referring unique neighbour pixels. Different variants are formed to extract informative and distinct features. As, MVSTLP works in small image area to extract distinct features, it can identify each image property variations accurately. In addition to this, the distinct feature extraction process of MVSTLP helps to prove its efficacy not only on normal images but also on noisy images. As it is very effective on normal and noisy images, it can also be very effective on blurred, contrast enhanced and noisy (with Gaussian, Brownian, Periodic, Impulse Valued, Quantization noises) images. MVSTLP based matching process can also be used in other biometric identifications like, face, palm print, fingerprint, footprint etc.

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