Investigation on Iris Recognition System Adopting Cryptographic Techniques

Shanmugam Selvamuthukumaran[1], Shanmugasundaram Hariharan[2] and Thirunavkarasu Ramkumar[1]
[1]Department of Computer Applications, A.V.C.College of Engineering, India
[2]Department of Computer Science and Engineering, TRP Engineering College, India

Abstract: *In a progressive digital society, the demand for secure identification has led to amplified development of biometric systems. The demand for such biometric system has increased dramatically due to the fact that such system recognizes unique features possessed by each individual. Iris recognition systems have widely adopted and accepted as one of the most effective ways to positively identify people, so as to provide a secure environment. Though there exists variety of approaches for iris recognition, this paper focus on to examine the matching phase of iris component using cryptographic technique. The performance of the matching phase is well analyzed and it is proved that proposed optimization technique namely, optimized iris matching using Cyclic Redundancy Check (CRC) would be more effective in nature as compared to other approaches. We have also proved that the proposed approach improves the overall iris recognition system performance by the improvement factor of 10 fold as well. The experimental investigations and the results presented reveals that there is a significant improvement in False Accept Rate (FAR) and False Rejection Rate (FRR).*

Keywords: *Iris recognition, security, optimization, biometric, cryptography, CRC.*

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1. Introduction

Over the years research on establishing the identity of a person has been so important, which includes knowledge based approaches by using secure passwords, token based approaches using identity cards, smart cards etc., [3, 4, 23]. However, these mechanisms surrogate representations where in the identity can easily be lost, shared, manipulated or stolen there by undermining the intended security. Biometric authentication deals with recognition the identity of individuals based on their unique physical or behavioural characteristics. Physical characteristics represented deals with as fingerprint, palm print, hand geometry, face, ear, voice, and iris patterns while behavioural attributes denotes gait, typing pattern and handwritten signature present information that is specific to the person and can be used in authentication applications [1, 22]. This paper intends to focus on the former approach and to be more specific, it deals on iris recognition systems.

The iris is so unique that no two irises are alike, even among identical twins or even between the left and right eye of the same person, in the entire human population. The iris is the externally visible, colorful, donut-shaped organ surrounding the pupil of the eye. The retina is the hemispherical organ behind the cornea, lens, iris, pupil and vitreous humour is not readily visible. The structure of a human eye with its unique features is illustrated in Figure 1. Research on iris recognition systems involves appearance based schemes [6], enhanced segmentation based schemes [10] and phase based, zero crossing representation method, Texture-analysis based method and approaches based on independent component analysis [20, 21]. Most iris recognition system involves identifying fast iterative algorithms which involves detection of pupil, iris and eyelids [13].

The iris texture has chaotic dimension because its details depend on initial conditions in embryonic genetic expression and the limitation of partial genetic nature, ensures that even identical twins have uncorrelated iris minutiae. Thus, the uniqueness of every iris, including the pair possessed by one individual, parallels the uniqueness of every fingerprint regardless of whether there is a common genome [7, 8]. The first step in iris recognition is capturing of an Image. During this process, irises are recorded by using an iris acquisition camera. The recorded image then goes through iris localization.

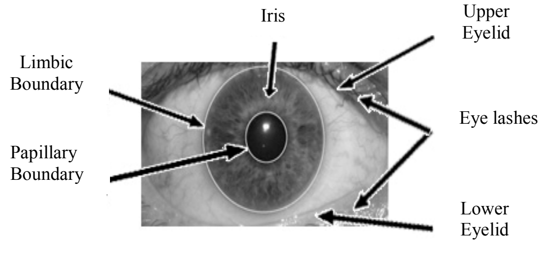


Figure 1. Structure of a human eye.

In this stage, system obtains the already stored recorded image and filters out everything except the iris. Then, the pictures are localized and stored in a binary format. The block diagram of general iris recognition system consists of several phases as shown below. In the matching stage, the localized iris picture is compared with the entities stored in the database for ensuring the matching [15].

- Image Acquisition.
- Localization.
- Segmentation.
- Noise Detection.
- Normalization.
- Feature Extraction.
- Matching.

After the successful completion of segmentation and normalization, an iris image is transformed into a unique representation by using various feature extraction schemes. As the output, the iris code is generated and stored in the database for future purposes. Matching is useful to test how well iris codes can be identified against a database of pre-registered iris codes. Hence, the iris code is necessary for the matching phase. The matching phase is the important phase in the iris recognition system. The number of false rejections and false acceptances are based on the matching only [18]. During the matching phase, the features of the scanned iris are compared to the stored template in the database. In order to, make the decision of acceptance or refusal, a distance is calculated to measure the closeness of match. Most of the systems are using hamming distance method for iris matching. In this paper, we are contributing the proposed method which would be used to improve the performance of the matching phase. Sometimes the process of matching is dependent on the previous phases, namely, segmentation, normalization and feature extraction. Noises which are not notified in such phases will be amplified. The amplified noises cause poor results in the matching phase.

The Hamming distance method provides a measure of how many bits are the same between two bit patterns. Using the Hamming distance of two bit patterns, a result can be made as to whether the two patterns were generated from different irises or from the same one [9, 15]. The hamming distance method is a widely accepted technique for handling the matching of the irises usually used in most of the existing iris recognition systems [25]. The Hamming distance determines the maximum number of bits in error that can be detected in a block.

The main disadvantage of Hamming codes is the fixed Hamming distance and the difficulty of implementing it for larger blocks. These types of conditions will tend to cause more frequent errors and produce ineffective matching results. The above reasons clearly indicate that matching is found for the irises even though for different persons falsely. This leads to a problem in the False Acceptance Rate (FAR) [24]. Similarly, in some cases, the matching result may be false although, for the irises of the same person, because of the functionality of the existing methods. This tends to a problem in the False Rejection Rate (FRR) [14]. The weighted Euclidean distance can be used to compare two templates composed of integer values. The weighting Euclidean distance gives a measure of how similar a collection of values are between two templates [24, 25]. Normalized correlation was able to account for local variations in image intensity that corrupts the standard correlation calculation [12, 14]. But, these methods are failed for iris images with more noise and eyelid and eyelash occlusion. Hence, optimization is required in matching phase. This can be achieved by the proposed method namely optimized iris matching using Cyclic Redundancy Check (CRC).

Though the process of normalization has been carried out well, it may happen that some flaws occur during segmenting the iris image, which in turn results in noises which are forwarded to the normalization phases also. This resultant noise may not be witnessed in the phase of normalization. This type of feed forwarding noise requires a good matching algorithm for an error free iris recognition system. The existing algorithms for matching phases could not perform well for the matching process.

The paper is organized as follows. Section 1 presents the overview of iris recognition and its importance in the biometric field. Section 2 discusses the past works carried out in iris recognition, while section 3 presents the proposed method with some basics on cryptographic algorithms and working mechanism of CRC and optimized iris matching techniques. The experimental work and investigations are briefed in section 4 and conclusion is presented in section 5.

2. Related Research

Radu *et al.* [19] have presented an iris recognition system to cope with noisy color iris images by employing score level fusion between different channels of the iris image. The robustness of the proposed approach was tested on three colour iris images datasets, ranging from images captured with professional cameras in both constrained environment and less cooperative scenario, and finally to iris images acquired with a mobile phone. The authors demonstrate to determine the channels from RGB and HSI colour spaces to reveal useful information from the iris texture by the means of an information theoretical analysis. During this process, score level fusion to combine information from the channels that were selected during the analysis.

McConnon *et al.* [16] presented some of the characteristics that can impact the performance of iris recognition in the UBIRIS.v2 dataset. The quality and characteristics of these images are surveyed by examining seven different channels of information extracted from them: Red, green, blue, intensity, value, lightness, and luminance. The authors present new quality metrics to assess the image characteristics with regard to focus, entropy, reflections, pupil constriction and pupillary boundary contrast. Experimental results clearly suggest the existence of different characteristics for these channels and could be exploited for use in the design and evaluation of iris recognition systems.

Nithyanandam *et al.* [17] provided a walkthrough for image acquisition, segmentation, normalization, feature extraction and matching based on the Human iris imaging. To improve the security, the authors have used Reed-Solomon technique is employed directly to encrypt and decrypt the data. Experimental results show that our system is quite effective and provides encouraging performance.

Husam *et al.* [10] investigated some research on two fold segmentation methods of iris namely Daugman and Jin. Further, an enhanced method based on the techniques of the mentioned two methods is proposed, which could guarantee the accuracy of the iris identification system. The authors proposed method takes into account the elliptical shape of the pupil and iris. The next step is the eyelid detection which is been included in this study as a part of segmentation stage to localize the iris accurately and remove unwanted portions. The dataset included three subsets namely Interval, Lamp and Twin. The evaluation way of the proposed method is successful and gains a result of 98.5% which is a good result among existing methods.

Aydi *et al.* [2] analyzed the images of human iris containing specular highlights and reflective properties of the cornea. This corneal reflection is supposed to cause many errors not only in iris and pupil center estimation but also, to locate iris and pupil boundaries especially for methods that use active contour. The authors have addressed a novel reflection removal method and compared between several methods that were used for corneal reflection removal. From the experiments the authors have concluded that the proposed method is the fastest one and causes least harmless. Also, in terms of memory reservation, the proposed algorithm is deserved to have less memory than others.

3. Proposed Method

3.1. Optimized Iris Matching using Cyclic Redundancy Check

The CRC code is calculated using the generator polynomial. The selection of the generator polynomial is the most important part of implementing the CRC algorithm. CRC32 is a type of function that takes as input a data word of any length, and produces as output a value of a certain space, commonly a 32 bit integer.

CRC computation is a long division operation in which the quotient is discarded, and the remainder becomes the result with the significant difference that the arithmetic used is the carry-less arithmetic of a finite field. The length of the remainder is always less than or equal to the length of the divisor, which thus determines how long the result can be.

The CRC method calculates a fixed-length binary sequence, which is called the CRC code for the data code. Bits of the iris code are read and manipulated. It is applied on the input as well as the database object. If the new is not matched with the one in the database, then this method reports a mismatch.

The CRC method is based on the addition of a series of check bits to code words. It is a polynomial method, all the n-bit CRC's have n+1 bits. The CRC code is denoted by C and the CRC is represented by the polynomial as in Equation 1:

$$C(D) = C_{L-1}D^{L-1} + \dots + C_1 D + C_0 \tag{1}$$

Where D is the data bit and L is the length of the polynomial and it depends on the bits from the iris code.

In the iris code, all operations involve the binary value only, so in the CRC method, all the divisions and multiplications are defined as modulo 2. In additions, there is no carry, and in subtractions, there is no borrow. So, the addition and subtraction operations are equal in this arithmetic and both are the same as the XOR function over bits. In the polynomial form, for any, as given in Equation 2:

$$x^i + x^i = 0 \tag{2}$$

Because both 1+1=0 and 0+0=0 always. To multiply two iris code words, the corresponding polynomials are multiplied. If 100 and 011 are to be multiplied, then they can be represented in polynomial form as x^2 and $x+1$. The multiplication result is $x^3 + x^2$ and the corresponding code is 1100. Also, division is possible by the check sum. Binary division can generally be performed by a sequence of shifts and subtractions. The modulo 2 division makes addition and subtraction equal to bitwise XOR. Therefore, in modulo 2 arithmetic, binary division can be accomplished by shifts and bitwise XORs. The generator polynomial is the factor used to generate a CRC code. To make the original polynomial divisible by a factor, subtract the residual 'x' from it. Then, the polynomial is multiplied by a factor equal to the highest degree of the generator polynomial. It shifts the bits in the code word to the left. Then, the messages are divided by the generator polynomial, followed by subtraction of the residual.

The CRC considers a collection of data as the coefficients to a polynomial, and then divides it by a fixed, predetermined generator polynomial. The coefficients of the result of the division are taken as the redundant data bits. This modular arithmetic allows an efficient implementation of a form of division that is fast, easy to implement, and sufficient for the purposes of calculating the distance between the iris codes.

The selection of a generator polynomial is the most important part of implementing the CRC algorithm. The most important attribute of the polynomial is its length; i.e., the number of the highest nonzero coefficient, because of its direct influence on the length of the computed checksum. When creating a new polynomial, the general idea is to use an irreducible polynomial, which means that the polynomial cannot be divided by any polynomial with zero remainder except itself.

In the proposed method, a sequence of 'n' bits in the iris code can be interpreted as a polynomial of the maximum degree '*n-1*' as $\sum_{i=0}^{n-1} b_i x^i$ where each b_i takes the value of the bit in position '*i*' in the sequence, with bits numbered right to left.

In our proposed method, the CRC-32 is used as the polynomial generator, since it is the useful for the matching process. The CRC-32 process reads each iris image from the beginning to the end, and calculates a unique number from the file's contents. This number is used to compare this iris image with the database iris image to determine if they are identical. This method calculates a long integer from the file and is generally considered to be very accurate.

This procedure should be applied for both the database and acquired image if the difference between two irises is less than or equal to 0.5 then, a match is found otherwise, both images are not the same. Usually the difference should be zero if the two irises are same, but due to noise, the difference can be considered up to less than or equal to 0.5. Also, the CRC-32 is defined by an IEEE standards committee (IEEE-802), as in Equation 3:

$$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x + 1 \tag{3}$$

In order to, make the decision of acceptance or refusal of the input iris, a distance is calculated to measure the closeness of the irises. This can be done by computing the distance between the two iris codes by measuring their similarity. The proposed approach is based on the CRC which is used to measure the distance between the iris codes of the input image and the database image. The CRC is an error detection technique that is widely utilized in digital data communication and other fields such as data storage and data compression [11]. The CRC is based on polynomial manipulations using modulo arithmetic. There are many CRC algorithms, each of which has a predetermined generator polynomial, which is utilized to generate the CRC code. Table 1 shows some CRC types and their polynomial representation.

Table1. CRC types and their polynomial representation.

CRC Type	Polynomial
CRC-8	$x^8 + x^2 + x + 1$
CRC-10	$x^{10} + x^9 + x^5 + x^4 + x^2 + 1$
CRC-16	$x^{16} + x^{12} + x^5 + 1$
CRC-32	$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$

In our proposed method, CRC-32 is implemented for generating the CRC code, and then, the codes are processed for matching the iris images. The CRC is used to detect changes in the code of one iris image during its comparison with other iris images. The significance of such CRC mechanisms could be adopted to perform the match between the iris codes of the acquired iris and with the image that exists in the database. To determine whether two irises are from the same class, this method compared the similarity between their codes or by calculating the distance between them (discussed in detail in section 3.2). Both the irises can be accepted or rejected based on the similarity found in the iris codes by using the CRC. The block diagram of the proposed method is given in Figure 2.

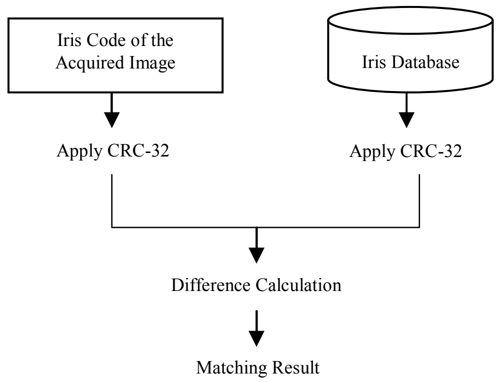


Figure 2. Block diagram of optimized iris matching using CRC.

3.2. Distance Calculation

In the proposed method the iris code is represented as in Equation 4:

$$i = \left[i_0, i_1, i_2 \ldots . i_{k-1} \right] \tag{4}$$

of '*k*' binary information digits i_j, $j=0,1,2\ldots.(k-1)$ blocks, where a block is represented as in Equation 5:

$$r = \left[r_0, r_1, \ldots . r_{p-1} \right] \tag{5}$$

of *'p'* parity bits r_j, $j=[0,1,\ldots.(p-1)]$ yielding a CRC code word, $c=[r,i]$ consisting of '$n=k+p$ binary digits.

The block *'r'* of parity bits is computed from *'i'*, using a Linear Feedback Shift Register (LFSR) in such a way that in Equation 6:

$$c(x) = (i(x) \bmod g(x)) \tag{6}$$

Where $i(x)$is given by Equation 7:

$$i(x) = i_0 + i_1 . x + \ldots + i_{k-1} . x^{k-1} \tag{7}$$

Interpreted as polynomials, and $g(x)$ is the generator polynomial of the code.

Matching of the irises is achieved by computing the parity bits from the database iris information block *'i'* and comparing these with the acquired iris's parity bits *'i'*. Any discrepancy between these two sets of parity bits then indicates the presence of mismatching. The distance of two irises can be defined as in Equation 8:

$$Dist = CodeX_{cal} \oplus CodeY_{cal} \tag{8}$$

Where, $CodeX_{cal}$ is the CRC value calculated in the input image X, and $CodeY_{cal}$ is the CRC value of the image Y in the database. $CodeX_{cal}$ is calculated by applying CRC-32 operation on the input iris image *'X'* and the polynomial generator and the result is stored in $CodeX_{cal}$. *'Dist'* is the result of *XOR* operation between $CodeX_{cal}$ and $CodeY_{cal}$. $CodeX_{cal}$ is defined as in Equation 9:

$$CodeX_{cal} = CRC(CodeX, g(x)) \tag{9}$$

Where, '*codeX'* is the input image iris code and *g(x)* is the generator polynomial. Similarly $CodeX_{cal}$ is defined as in Equation 10:

$$CodeY_{cal} = CRC(CodeY, g(x)) \tag{10}$$

Finally, the difference is calculated as given in Equation 11:

$$diff = \frac{1}{33}\sum_{1}^{33} dist_i \tag{11}$$

Optimized iris matching using the CRC is summarized in the following algorithm:

Step 1: *Read the bits as the maximum iris code from the input iris image which should be extended with n-1 zero bits appended to the end.*

Step 2: *Divide the bits of iris code by 33 bits generator polynomial g(x).*

Step 3: *The division is performed by XOR operation between the Input iris code and the 33 bit polynomial generator. If the input bit above the leftmost divisor bit is 0, move the divisor to the right by one bit. If the input bit above the leftmost divisor bit is 1, the divisor is XORed into the input. The divisor is then shifted one bit to the right and the process is repeated until the divisor reaches the right end of the input row.*

Step 4: *Find the remainder and add it to the end of the bits of the iris code as the CRC code of the Input iris image called* $CodeX_i$.

Step 5: *Do the same procedure for the database iris image Y also. The CRC code of the database image is stored in* $CodeY_i$.

Step 6: *Calculate the difference between the two images by performing the XOR operation between the two CRC values and the result should be divided by 33.*

Step 7: *If the value of difference is less than or equal to 0.5, matching is found otherwise the result is a mismatch.*

The steps are shown in the flowchart of Figure 3. Then, the well accepted metric FAR and FRR are to be computed. The FAR is the percentage of the iris images which are accepted as known from the unauthorized person. This value represents the error rate for the acceptance of unknown images. The FRR is the percentage of the iris images, which are rejected as unknown even though it is the iris of the same person. This value represents the error rate for the rejection of the known images. By using this model, the FAR and the FRR are improved. A summary of the results of this work and discussions are stated in the next section.

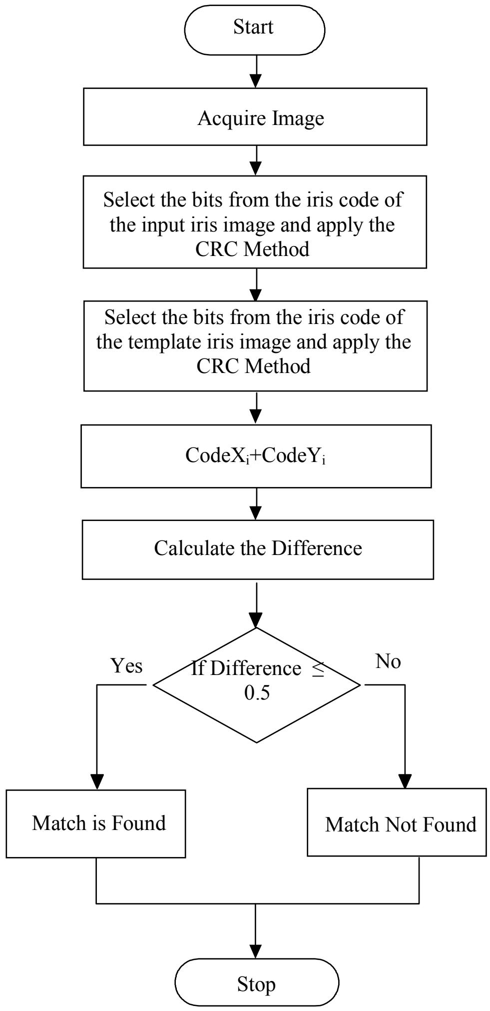


Figure 3. Flow chart of optimized CRC method for iris matching.

4. Experiment, Results and discussion

4.1. Database Used

The proposed method, results and further discussions were presented in this section. For experiments iris image database CASIA Database Version 3.0 (CASIA-IrisV3) released by the Center for Biometrics and Security Research.

Table 2. FAR and FRR.

Matching Methods	Successrate (%)
Optimized Iris Matching using CRC	99
Hamming Distance Method	89
Normalized Correlation	85
Weighted Euclidean Distance	79

The National Laboratory of Pattern Recognition, the Institute of Automation and the Chinese Academy of Sciences has been used [5]. The database is most widely used iris image database publicly available to iris recognition researchers for testing and experimentation, containing three subsets of databases, namely, the CASIA-IrisV3-Interval, the CASIA-IrisV3-Lamp and the CASIA-IrisV3-Twins. The

CASIA-IrisV3 contains a total of 22,035 iris images from more than 700 subjects. All the iris images are 8 bit grey-level JPEG files, collected under near infrared illumination. The CASIA-IrisV3-Interval consists of 249 subjects, 395 classes and 2655 images with the resolution of 320*280 taken in an indoor environment.

The CASIA-IrisV3-Lamp contains 411 subjects, 819 classes, 16213 images with the resolution of 640*480 taken in an indoor environment with lamp on/off. The CASIA-IrisV3-Twins contains 200 subjects, 400 classes, 3183 images with the resolution of 640*480 taken in an outdoor environment. For our test, images with regions partially occluded by eyelashes have been selected from CASIA database. The images from the database which consists of noisy images were also chosen for experiments and further verification of the proposed approach, when needed.

4.2. Results and Discussion

The experimental data consisting of 900 iris images in 30 classes were chosen and the corresponding iris code is generated and stored in the database. The input image's code is compared with all the other iris codes that are stored in the database earlier (based on the chart given in Figure 3). The performance of our system by optimized iris matching after applying CRC-32 is illustrated. Figure 6 illustrates the difference of iris image (S124R01) as shown in Figure 5.

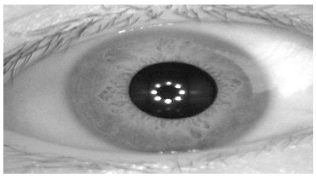


Figure 5. iris image-S1249R01.

In this method, after finding the CRC code for the input and database iris images, the XOR operation is performed. The difference is 0.42, the difference is less than or equal to 0.5. Hence, the matching is found. The following are some of the iris images of the same person with less noise and are closer to the above database image and matching is found. The irises with noises are matched with the database image S1249R01 are given in Figure 6. The corresponding CRC code and its differences are given along with their matching percentage is given in Table 2. The system performed with perfect recognition on a set of 180 eye images. But, tests on another set of 687 images resulted significant change in FAR and FRR. Various experimental studies have been performed, and the results are obtained. Table 2 gives the FAR and FRR and the difference for the various thresholds. The verification test shows that the optimum threshold for the proposed algorithm is 0.098 where the FAR rate and the FRR are equal.

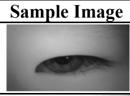
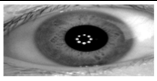
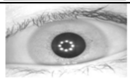
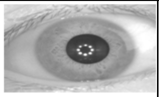
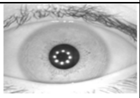
Sample Image	Difference	Sample Image	Difference
	0.39		0.97
	0.33		0.89
	0.42		0.92

Figure 6. Difference as compared to S1249R01 image.

Table 3. Success rate of the matching methods.

Threshold	FAR	FRR	FAR-FRR
0.1	0.495	0.302	0.193
0.2	0.368	0.201	0.167
0.3	0.256	0.167	0.089
0.4	0.172	0.101	0.071
0.5	0.098	0.098	0.000

From the above table, it is clear that by using the optimized iris matching using CRC method, the FAR and FRR are improved. The success rate of the proposed method as compared with those of the previous methods Hamming Distance Normalized correlation and Weighted Euclidean distance. Table 3 shows the success rate of the different matching methods.

Table 3 shows the strength of the proposed method which works better than the existing methods since 99% of accuracy for the irises, which is the value much.

Higher while comparing the respective results obtained using the existing methods. Our proposed method is showed that significant improvement in recognition accuracy on these datasets over the existing methods. It has been observed that the proposed system achieves a higher recognition rate and faster computation than the conventional iris matching methods. Therefore, this method is shown to be a reliable and accurate method.

5. Conclusions

In this paper an approach for optimization in the Iris Matching phase using CRC was achieved and illustrated with CASIA database. An overall rank of 91.24% is achieved, which is much higher than the reported accuracies for iris recognition which have been studied in the literature. The proposed method worked well especially for the low quality iris images.

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Shanmugam Selvamuthukumaran received his PhD in computer science in the year 2011. He is currently working as Director of Computer Applications Department at A.V.C College of Engineering, Mayiladuthurai, India. His area of interest includes computer vision and database technologies. Presently, he is guiding research scholars in the field of computer vision and big data managements. He is a senior fellow member of IEEE and ISTE.

Shanmugasundaram Hariharan is an associate professor at the Department of Computer Science and Engineering Collage, TRP Engineering Collage, India. He received his BEs degree in computer science and engineering from Madurai Kammaraj University in 2002, ME degree in computer science and engineering in 2004 and the PhD in the area of information retrieval from Anna University. He is a member of IAENG, IACSIT, ISTE and CSTA, he has 9 years experience in teaching. His research interests include information retrieval, data mining, opinion mining, web mining. He has to his credit several papers in referred journals and conferences. He also serves as editorial board member and as program committee member for several international journals and conferences.

Thirunavkarasu Ramkumar is a professor in the Department of Computer Applications, A.V.C Collage of Engineering, India. He received his MCA degree in computer Applications from Bharathidasan University, India in 1998, and PhD in computer science from Anna University, India in 2010. His area of specialization includes knowledge discovery from multiple databases and object computing. He is the fellow member of ISTE. He also serves as editorial board member and as program committee member for several international journals and conferences.