Appendix A

Biometric Technologies

1. Finger-Scan

Finger scan technology utilizes the distinctive features of the fingerprint to identify or verify the identity of individuals. Finger scan technology is the most commonly deployed biometric technology, used in a broad range of physical access and logical access applications. Dozens of finger-scan vendors compete in this marketplace, offering hardware devices, software packages, enterprise solutions, and standalone solutions.[Nan02] (see Figure 1.2)

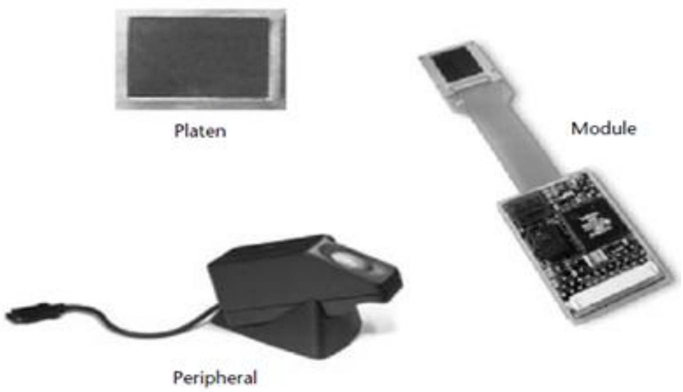

Figure (1) Finger scan devices. [Nan02]

2. Facial-Scan

Facial scan technology utilizes distinctive features of the human face in order to verify or identify individuals. Facial-scan currently plays a role in the biometric marketplace in 1:*N* identification applications. Used in conjunction with ID card systems, in booking stations, and for various types of surveillance operations, facial scan's most successful implementations take place in environments where cameras and imaging systems are already present. Facial-scan is also deployed in select environments as a 1:1 verification solution for physical and logical access, but has found only limited implementation in these areas.[Nan02]

3. Iris-Scan

Iris scan technology utilizes the distinctive features of the human iris in order to identify or verify the identity of individuals. Iris scan technology has the potential to play a large role in the biometric marketplace if real-world systems and solutions meet the technology's theoretical promise. Traditionally having been used in high security physical access applications, iris-scan technology has been successfully implemented in ATMs and kiosks for banking and travel applications and is being positioned for desktop usage. [Nan02]

Figure (2) iris scan devices. [Nan02]

Iris scan's strengths include the following:

- ➢ It has the potential for exceptionally high levels of accuracy.
- ➢ It is capable of reliable identification as well as verification.
- ➢ It maintains stability of characteristic over a lifetime. [Nan02]

Iris scan's weaknesses include the following:

- ➢ Acquisition of the image requires moderate training and attentiveness.
- ➢ It has a propensity for false rejection.
- ➢ A proprietary acquisition device is necessary for deployment.
- ➢ There is some user discomfort with eye-based technology. [Nan02]

Because the most fundamental argument on behalf of biometrics is increased security, a highly accurate technology such as iris scan has tremendous appeal. The challenge facing the technology is not to improve its resistance to false matching, but to ensure that its capabilities in real-world environments parallel its capabilities in a laboratory setting. [Nan02]

4. Voice-Scan

Voice scan technology utilizes the distinctive aspects of the voice to verify the identity of individuals. Voice-scan is occasionally confused with speech recognition, a technology that translates what a user is saying (a process unrelated to authentication). Voice-scan technology, by contrast, verifies the identity of the individual who is speaking. The two technologies are often bundled: Speech recognition is used to translate the spoken word into an account number, and voice-scan verifies the vocal characteristics against those associated with this account. [Nan02]

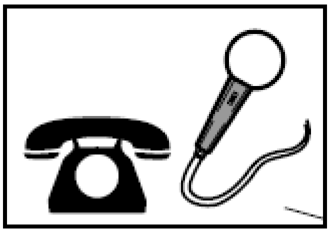

Figure (3) voice devices. [Nan02]

Voice-scan combines elements of behavioral and physiological biometrics: While the shape of the vocal tract determines to a large degree how a voice sounds, a user's behavior determines what is spoken and in what fashion. Voice-scan technology is text-dependent, meaning that a user must recite a particular phrase or word to be recognized the system cannot verify a speaker speaking random snippets of text. [Nan02]

5. Hand-Scan

Hand scan technology utilizes the distinctive aspects of the hand in particular, the height and width of the back of the hand and fingers to verify the identity of individuals. One of the most established biometric technologies, hand scan has been used for years in thousands of verification deployments. Hand scan is a more application-specific solution than most biometric technologies, used exclusively for physical access and time and attendance applications. [Nan02]

Figure (4) hand scan device. [Nan02]

6. Retina-Scan

Retina scan technology utilizes the distinctive characteristic of the retina the surface on the back of the eye that processes light entering through the pupil for identification and verification. Developed in the 1980s, retina-scan is one of the most well-known biometric technologies, but is also one of the least deployed. Retina-scan devices are used exclusively for physical access applications and are usually used in environments requiring exceptionally high degrees of security and accountability such as high-level government, military, and corrections applications. As of this writing, retina-scan is not a commercially available biometric technology: The original manufacturer is working on an updated device, and newer vendors have not officially released products. However, because of the technology's history and future potential, it is important for deployers to understand the good and bad of retina-scan technology. Retina scan and iris scan are often mistakenly confused with one another or grouped into a single category referred to as eye biometrics. Though they are both very accurate biometric technologies that use features of the eye for identification and verification, the similarities end there: The two technologies differ substantially. They measure different physiological features, the software and algorithm technology is very different, iris- and retina scan hardware and software are dissimilar, and the situations in which they can be successfully deployed differ. [Nan02]

Figure (5) Retina-scan device. [Nan02]

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة النهرين
كلية العلوم

تمييز قزحية العين بناءاً على الفهرسة الدلالية

رسالة

مقدمه الى كلية العلوم في جامعة النهرين كجزء من متطلبات نيل درجة الماجستير في علوم الحاسوب

مـــن قبـــل

انســـام احمـد علـوان
(بكلوريوس جامعة النهرين ٢٠٠٥)

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ربيع الاول 1432هـ
كانون الثاني 2011 م

Certification of the Examination Committee

We chairman and members of the examination committee certify that we have studies this thesis "***Iris Recognition Based on Semantic Indexing***" presented by the student ***Ansam Ahmed Alwan*** and examined her in its contents and that we have found it worthy to be accepted for the degree of Master of Science in Computer Science.

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List of Abbreviations

Abbreviation	***Meaning***
HBD	Horizontal Brightness Distribution
IR	Information Retrieval
IRS	Iris Recognition System
IRBSF	Iris Recognition Based on Semantic Features
LSI	Latent Semantic Indexing
LU	Lower and Upper triangular
Ri	Radius of iris
Rp	Radius of pupil
SVD	Singular Value Decomposition
U	Upper vector (eigen vector)
USA	United State America
1D	One dimension
2D	Two Dimension

Table of Algorithms

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IRIS RECOGNITION BASED ON SEMANTIC INDEXING

A Thesis Submitted to the College of Science of Al-Nahrain University as a Partial Fulfillment of the Requirements for the Degree of
Master of Science in Computer Science

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بِسْمِ اللهِ الرَحمن الرَحيم

اِقْرَأ وَرَبُكَ الْاَكْرَمُ 3 الَذِي عَلَمَ بِالْقَلَم 4 عَلَمَ

الإِنسَانَ مَالمْ يَعْلمْ 5

صدقَ اللهُ العظيمْ

سورة العلق

DEDICATED TO

My Husband ……
Daughters……
Parents……
Aunt and Uncle……
Sister and Brothers …

To everyone
Touch me a letter

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Abstract

The vast improvement of electronic commerce paved the way to the fear of terrorism since the traditional ways of personal identification like ID cards and passwords are no longer sufficient. Biometrics is the more secure option that uses parts of a body for authentication and thus is practically impossible to get lost, stolen or forgotten.

Biometric identification is an emerging technology that can solve security problem in our worked society. Biometric traits such as fingerprints, hand geometric, face and voice verification and iris recognition provide a reliable alternative for identify verification/identification and are gaining commercial and high user acceptability rate. The iris is one of the most useful traits for biometric recognition. This thesis presents proposed recognition system based on semantic indexing technique.

The generic structure of the proposed iris recognition system is presented in details, it is built depending on assuming that the good authentication system should be characterized by using features that are; (i) *Highly unique*; the chance of any two people having same characteristics will be minimal, and (ii) *Stable*; the feature does not change over time, and be easily captured in order to provide convenience to the user, and prevent misrepresentation of the feature.

The proposed system consists of two phases: the collection and recognition. The collection phase process of storing the characteristics of all models of iris images, while the recognition phase process on the characteristics of the iris compared to the input image with those stored in the database and issue a resolution of recognition depending on the results of

the comparison. Characteristics were used Singular Value Decomposition (SVD) and Upper Vector (U) has been found that they share the same amount of recognition in the decision making was therefore possible to use only one to give the same results of recognition.

The results of recognition by aggregating Results have been encouraging and it longer opportunity of development and this confirms the correctness of choice of technique used.

The recognition rate was more than 98%. The proposed system first find the iris localization by detect the center of pupil and pupil circle. Then find the iris detection by find the center of iris and iris circle. Then make mask image and compare it with eye image in order to separate the iris from eye image. Then convert the iris into binary code. Then make the decision making in order to either enrollment the iris into lookup table or make the recognition decision on it.

الخلاصة

إن تحسين التجارة عبر الانترنت مهد الطريق الى خوف الارهاب منذ الطرق التقليدية لاثبات الهوية الشخصية مثل بطاقة تعريف الهوية وكلمات السر لم تعودا كافية. استخدام القياسات الحيوية اصبحت الخيار الاكثر امانا الذي يستعمل اجزاء من الجسم للتحقق وهكذا من المستحيل ان تضيع، تسرق او تنسى.

المقياس الحيوي هي تقنية صاعدة التي يمكن ان تحل مشكلة الامن في مجتمعنا العامل. ميزات المقياس الحيوي مثل بصمات الاصابع، الايد الهندسية، اثبات الوجه والصوت و تمييز قزحية العين يمثل بديل موثوق يعرف التحقيق/ تعريف الهوية واعطي نسبة قبولية وتجارية عالية. القزحية هي واحدة من اكثر الميزات المفيدة في التمييز المقياس الحيوي. هذه الاطروحة اقترحت نظام تمييز مستند على تقنية فهرسة المعاني.

ان التركيب العام لنظام اعتراف السوسن المقترح مقدم في التفصيل. وهو مبني بافتراض اعتمادا على ان نظام التحقق الجيد يجب ان يميز باستعمال الميزات التالية (1) فريد جدا، فرصة اي شخصين سيكون لديهما نفس الخصائص يكون اقل مايمكن ، (2) ثابت، الميزة لاتبدل بمرور الوقت وتكون سهلة الحصول عليها لكي توفير الراحة للمستخدم، والحيولة دون تشويه هذة الميزة.

المنظومة المقترحة تتكون من مرحلتين: التجميع والتمييز. طور التجميع يقوم بخزن الصفات المميزة لجميع صور نماذج القزحية ، بينما يقوم طور التمييز على مقارنة الصفات القزحية للصورة المدخلة مع تللك المخزونة في قاعدة البيانات ويصدر قرار ا لتمييز اعتمادا على نتائج المقارنة . الصفات المميزة المستعملة كانت (SVD) و (U) وقد وجد انهما يتشاركان بنفس المقدار في صناعة قرار التمييز ولذلك كان من الممكن استخدام احدهما فقط ليعطي نفس نتائج التمييز.

ان نتائج التمييز بواسطة الأرشفة الدلالية كانت مشجعة وهي تعد بفرصة التطوير وهذا يؤكد صحة الاختيار للتقنية المستخدمة.

ان نسبة التمييز وصلت اكثر من 98%. النظام المقترح اولا يجد تحديد قزحية العين عن طريق ايجاد مركز البؤبؤ ودائرة البؤبؤ. وبعدها ايجاد مركز القزحية ودائرة القزحية. ثم يجد صورة التقنيع التي تقارن مع صورة العين لغرض عزل قزحية العين عن صورة العين . ثم تحول القزحية الى شفرة ثنائية. ثم يتخذ قرار التمييز اما يضيف القزحية الى جدول المقارنة او يتخذ قرار التمييز عليها.

Chapter five
Conclusion and Future Suggestion

5.1 Conclusion

According to the tests results presented in chapter four, the following conclusions have been derived:

1. The use of semantic features was successful in recognizing the iris images. The recognition result using just SVD is equivalent to the use of U only. Any one of SVD and U does not strength or weak the other.
2. The use of U is not necessary when using SVD for the recognition purposes.
3. Since the SVD values are fractions, the classes of different irises are found interfered with each other. Such that, the use of exponential feature as a function of SVD was found more descriptive than just SVD.

5.2 Future Suggestion

1. One can use the fractal geometry to recognize the random pattern of the iris texture; the fractal dimension can provides a useful measure for such textures.
2. The use of any clustering technique (such as K-means) may enhance the recognition results.
3. Applying the clustering on the resulted SVD values, such technique is modified under name K-SVD in.
4. Instead of adaptive exponential SVD, the use of fuzzy logic to make the recognition may enhance the recognition results, since there is interference appears in the SVD values belonging to different classes.
5. Evolutionary methods can be used to optimize the recognition process, which help to find the closest iris class to the query iris.

CHAPTER FOUR
RESULT AND ANALYSIS

4.1 Introduction

This chapter includes a presentation about how implement the algorithms mentioned in the previous chapter. Also, there is a detailed explanation related to the results achieved through implementing each stage in the proposed iris recognition system. The results of the recognition were presented in figures and tables including the final percentage of similarities between the used iris models. The results are analyzed quantitatively and qualitatively to evaluate the performance of the proposed iris recognition system. Moreover, a specific software called IRSBSF (Iris Recognition System Based Semantic Features) was designed and implemented to apply the proposed semantic technique on some chosen iris images. Such software is designed by Visual Basic version 0.6, and it is executing through the Windows operating system. The dedicated software has a pretty interface to show the query image and the results of each processing stage, the following sections show more details about the results and analysis of the employed technique.

4.2 IRBSF Software

This software is specified to identify the human iris image in comparison with other samples that previously stored in a database. The software includes an application to all suggested algorithms mentioned in the previous chapter, and shows their results in one specified interface. The presentation of the results in the interface was sequential according to the sequence of processing stages. The interface contains on two commands; the first is responsible on input, pre-processing, and coding the query iris image, while the second is responsible on recognize the query iris according to its semantic features or enrollment it in the codebook, depending on the selected options (Recognition task/Enrollment task). Figure (4.1) shows the interface of IRSBSF software, whereas Figure (4.2) shows the interface presenting the results of all the processing stages. In both phases: the recognition and enrollment, there is a massage appears at complementing the computations tell the user about successfulness of the enrollment or the successfulness of the recognition assigned with the recognition result. The recognition result is the serial (or name) of the iris sample that possesses greatest similarity percent in the codebook. This indicates that the proposed IRSBSF software is an iris identification system.

In case when all the resulted similarity percentages are weak (less than 98%), the system suggesting for the user to repeats the recognition process with another new query iris for the same sample (person). If the weak results are shown again, then the meant person is regarded as strange and does not have any information in the database (codebook), and the system suggest enrolling his iris sample in the codebook. To ensure the exception of the system against the query images, the query image should be chosen carefully. The following sections explain the conditions of the pass query images, also present and discuss the results of the proposed iris recognition system with details.

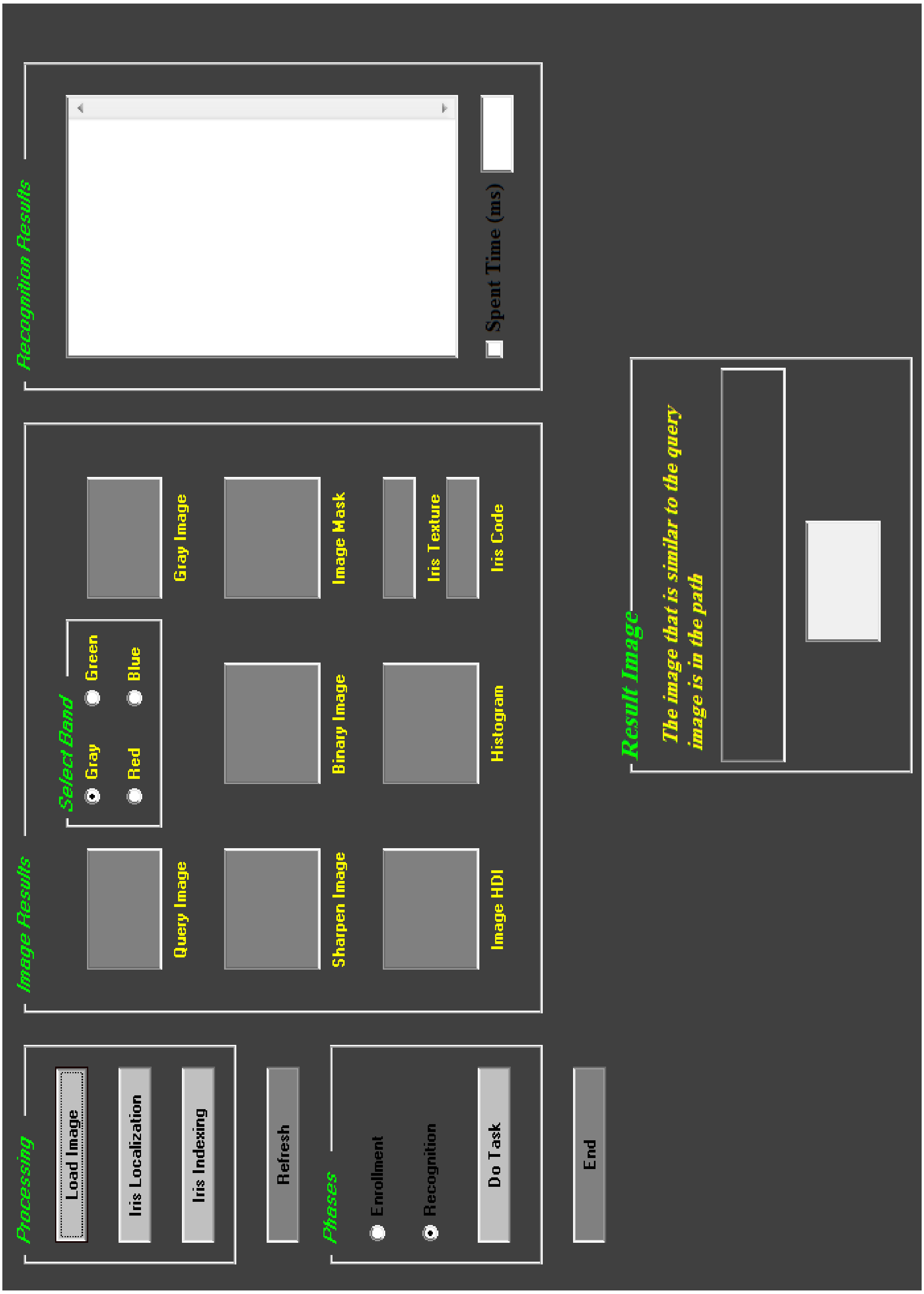


Figure (4.1) The interface of IRBSF software

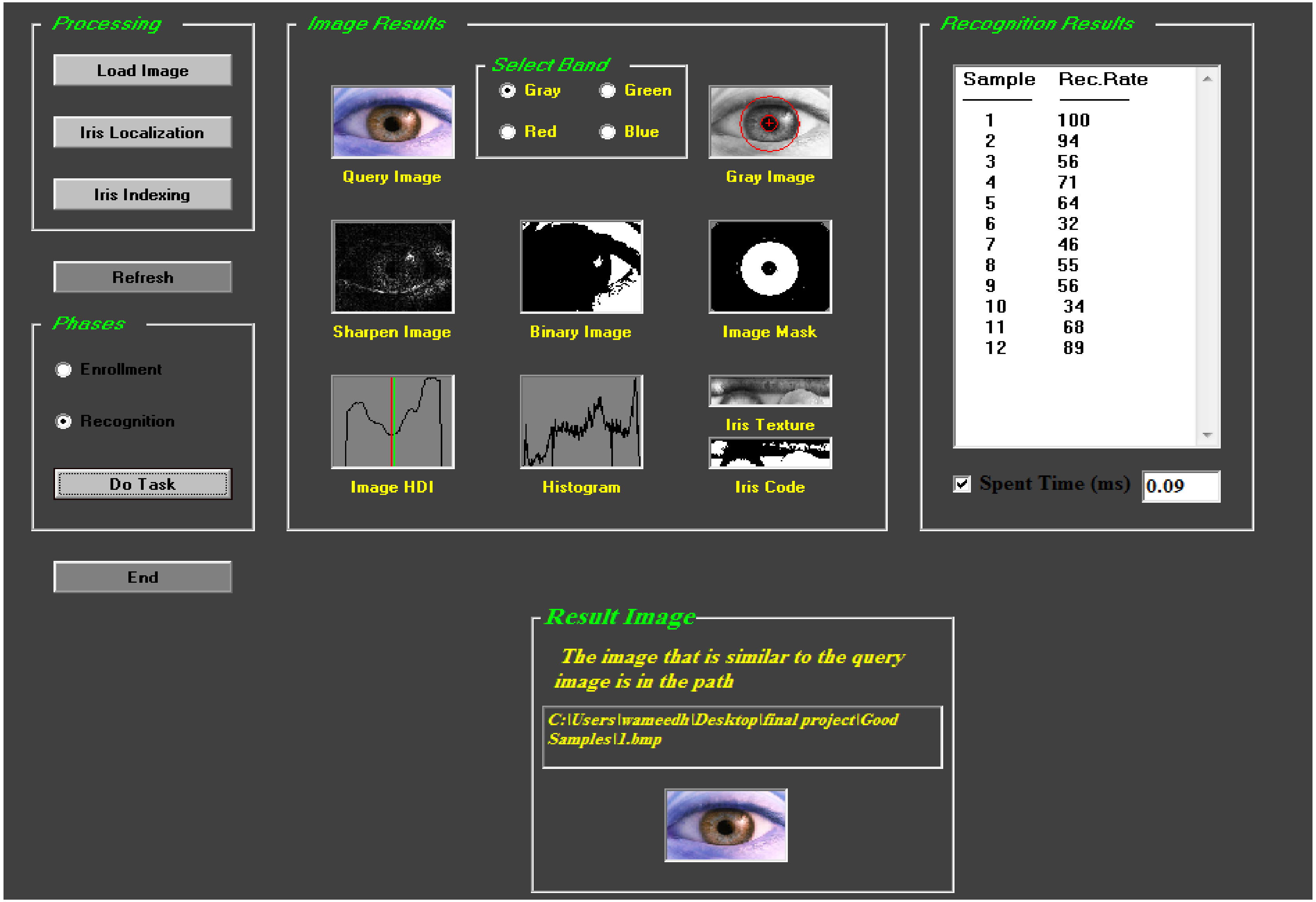


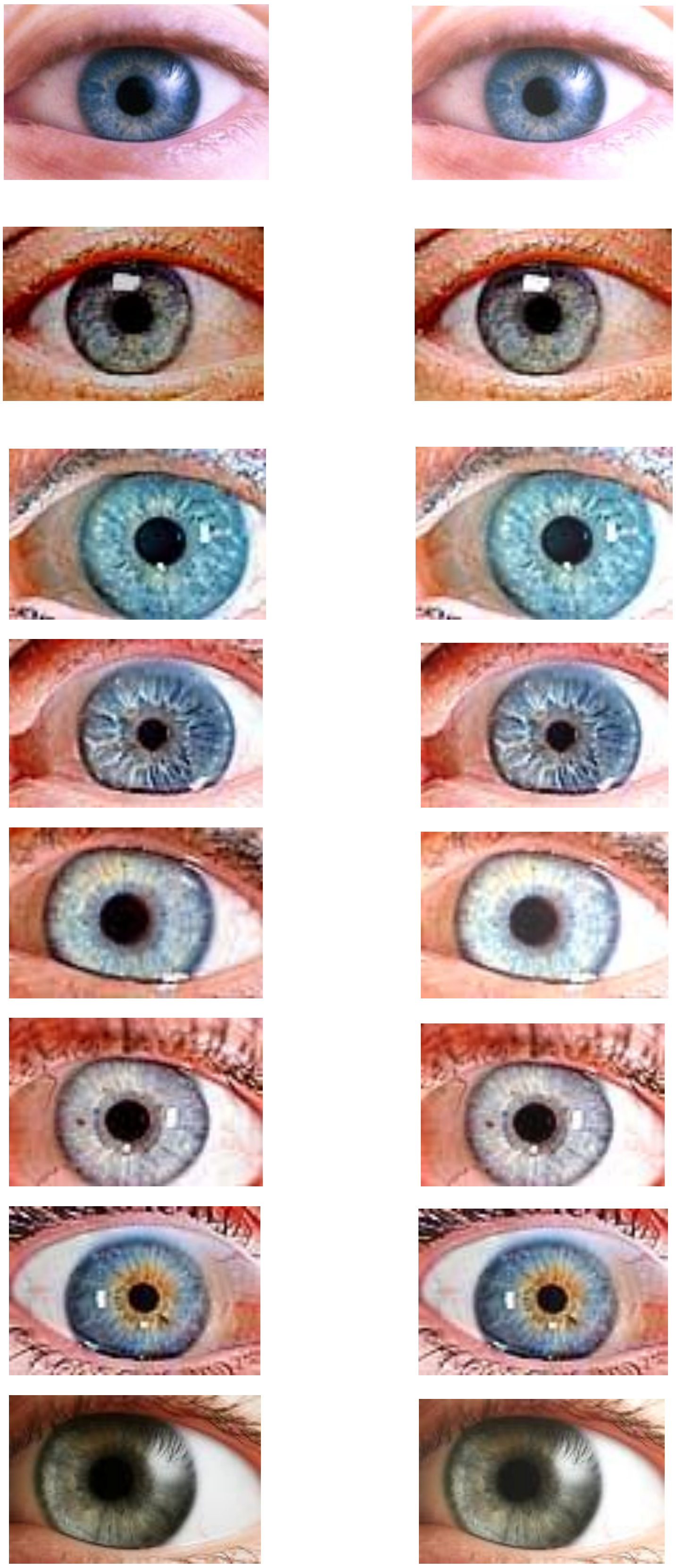
Figure (4.2) The interface the IRBSF presenting results of all the processing stages

4.3 Used Iris image

The iris images used in the present work were achieved by two Internet sites: *http://www.nlpr.ia.ac.cn/english/irds/irisdatabase.htm,* the institution CASIA, and http:// *www.istockimage/humaneye.html*. These Internet sites provide a lot of different samples of iris images specified for the recognition experiments. There was difficulty in achieving an iris images which are suitable for the proposed IRBSF, such images should not contain a specular reflections or some parts of eyelids or eyelashes that normally occlude the upper and lower parts of iris region since these mistakes will corrupting the iris pattern. Also, the appearance of the iris should be great and resolved to show more descriptive details. The color and size of the iris or pupil are careless.

Throughout the search, the achieved iris images shown in Figure (4.3) are suitable and identified the above mentioned conditions. These images are colored and high resolved, it is shown that the distinguished details in the test images are appeared sharply. This indicates that such images are taken by high quality camera specified for the iris imaging.

Figure (4.3) presents the model and the test of iris image, where (A) represent the image database that saved on the codebook and (B) represent the query iris image that compare it with the data on the codebook.



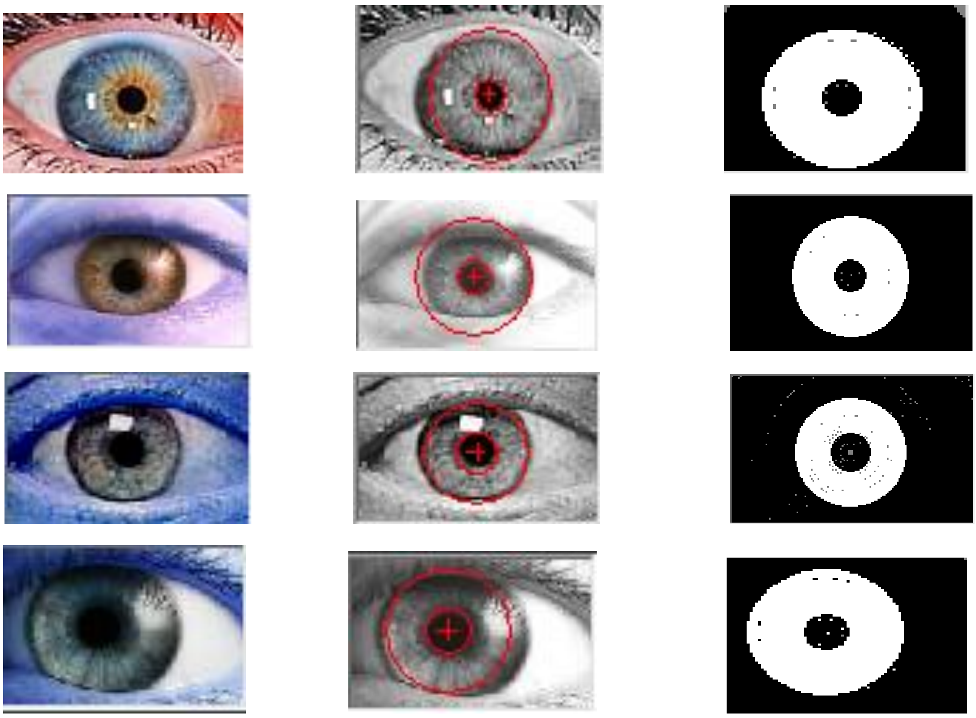
(A)Model image (B)Test image

Figure (4.3) Images of iris samples.

4.4 Iris Localization Results

To credit efficient performance for iris pattern matching, the boundaries of the iris should be located. Iris localization detected the inner and outer boundaries of the iris. Both the inner and outer iris boundaries were approximately modeled as circles. It was found that the center of iris does not necessarily concentric with the center of pupil.

Figure (4.4) shows the iris localization process, it is shown that the inner and outer boundaries of the iris are determined by white circles on a black background in Figure (4.4-b). it was found that the center of the iris does not necessarily concentric with the center of pupil. This reason may lightly decrease the iris information extracted from the image. Also, it was found that the outer boundary of the iris may be shifted to includes a small parts of eyelids or eyelashes, which may confuse the iris information extracted from the image.



(a) Colored images (b) Iris localization (c) Mask image

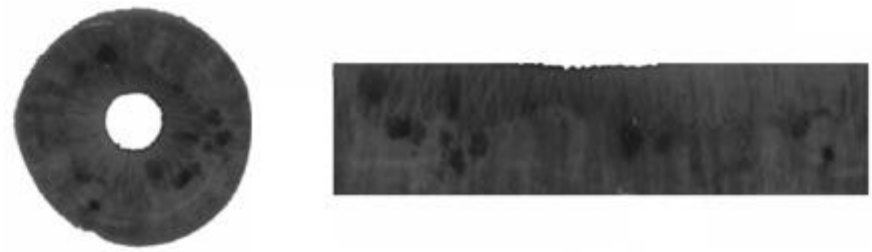
Figure (4.4) Iris localization and masking results.

Some investigation can be carried out to ensure the enough iris information extracted from the image, this is done by estimate the confused region due to shifting the outer boundary of the iris in comparison with the total region of the iris. The estimation shows that the confusion is insignificant and can be neglected. The images showed in Figure (4.4-c) presents the mask images corresponding to each iris sample. It is shows that the size of the mask is variable from sample to another since each mask was made depending on the values of radius of the iris and pupil (R_i and R_p).

4.5 Image Indexing Results

Image indexing includes image segmentation and image coding. Image segmentation is transforming just the iris image from the circular shape into the rectangular one as shown in Figure (4.5). It is noticeable that the accurate determination of iris boundaries through the iris localization stage gave a uniform distribution for the image pixels as shown in Figure (4.5). Whereas, when the iris boundaries were lightly shifting, then there are a positioning fluctuations appear in the distribution of the pixels of the rectangular images, especially at the lower part that corresponding to the outer boundary of the iris in the circular image as shown in Figure (4.6). This ensure that the pupil detection method was more accurate, while the iris detection method was not perfect, which may affect the iris description and may degraded the recognition score.

Also, it is shown that the rectangular image seems to be high descriptive texture of the iris constituting features. Figure (4.7) shows the results of the coding stage, in which the rectangular colored image is converted into binary one. The choice of the suitable threshold value leads to make best representation for the iris code. Many tests were showed that the use of the average of the pixel values to be a threshold in the binarization process gave best code for the image of the iris sample.



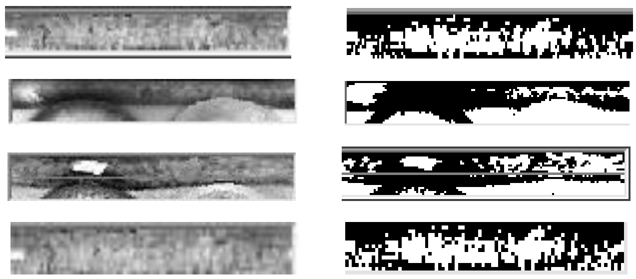
(a) Circular iris image. (b) Rectangular iris image.

Fig (4.5) Iris segmentation result (1).

(a) Circular iris image. (b) Rectangular iris image.

Fig (4.6) Iris segmentation result (2).

(1)
(2)
(3)
(4)



(a) Iris texture. (b) Iris code.

Figure (4.7) Iris coding result.

4.6 The Recognition Result

The results of the proposed IRBSF was good issues. The similarities between the query iris sample and those found in the codebook were computed as percent measure. The recognition decision was made referring to the iris sample in the codebook that possesses higher similarity percent. Table (4-1) shows the values of IRBSF for the iris samples of the codebook, while Figure (4.8) shows the behaviors of the U associated to each SVD in Table (4-1). Because the SVD values are fractions of small differences in between, and also the behaviors of the U are appearing monotonic, the recognition strength of the employed technique should be investigated. Table (4-2) shows the identification results between all available query irises with that of the codebook, these results save the chance to make quantitative and qualitative analysis to evaluate the performance of the proposed IRBSF.

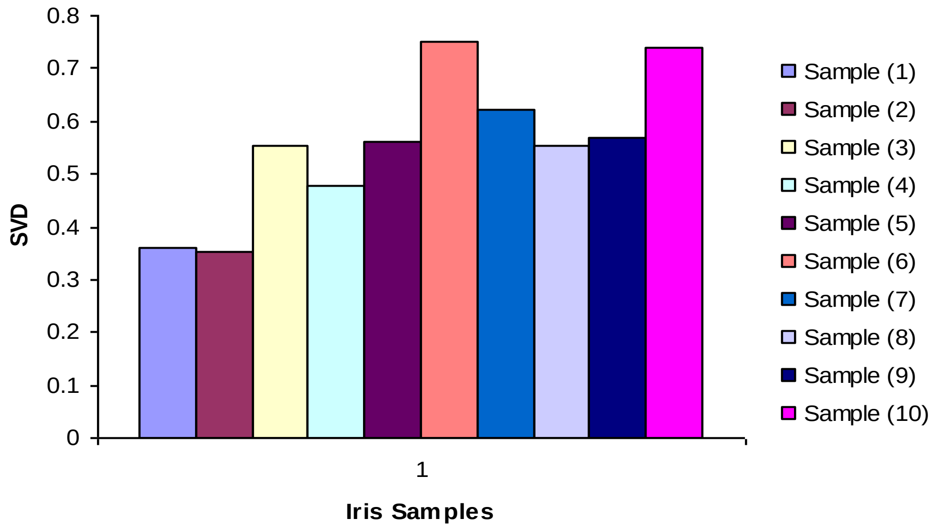


Fig (4.8) The SVD results of the ten codebook iris samples.

Table (4.1) The SVD results values.

Samples	SVD
S1	0.3421188
S2	0.357347
S3	0.5748055
S4	0.4961721
S5	0.5179465
S6	0.7385736
S7	0.6347926
S8	0.584887
S9	0.5552828
S10	0.7780603

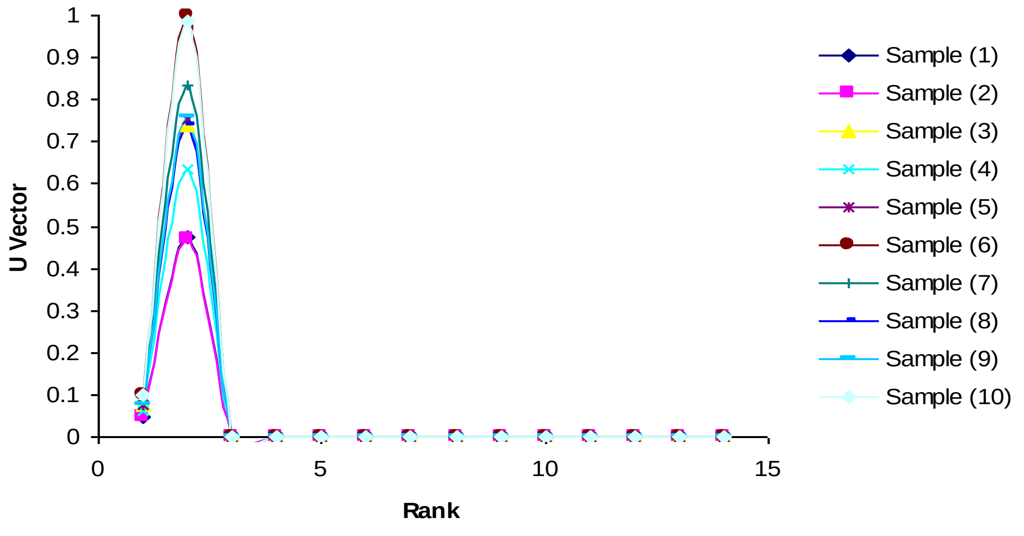


Fig (4.9) The U behaviors results of the ten codebook iris samples.

Table (4.2) Recognition results between the ten iris queries and the ten codebook samples.

Q / C_B	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}
C_1	100	94	56	71	64	32	46	55	56	34
C_2	94	99	57	70	65	34	47	56	58	35
C_3	56	57	100	78	84	85	99	93	92	86
C_4	71	70	78	100	97	73	86	94	96	74
C_5	64	65	84	97	99	71	84	94	93	72
C_6	32	34	85	73	71	99	85	74	76	97
C_7	46	47	99	86	84	85	98	89	89	91
C_8	55	56	93	94	94	74	89	98	93	84
C_9	56	58	92	96	93	76	89	93	99	83
C_{10}	34	35	86	74	72	97	91	84	83	99

4.7 Result Analysis

By noting the SVD values in Table (4-1), it is found that the SVD values are fractions in between 0-1. Some of them may differs from each other at (or after) the second decimal order, which indicates the ability of the SVD to recognize the iris images. In correspondence, the U curves showed monotonic behaviors for the different iris samples in the codebook. It is clearly appeared that the U curves are approachly identified at all their points except the second one. This means the differences between U curves that computed according to eq. (3.7) are greatly depending on the second point in each U curve, i.e. the difference is computed by one point not curve (set of points).

Throughout the analysis, an additional experiment to re-compute the recognition scores twice: ones by using just the SVD (i.e. the first term of eq.3.7), and the second by using the U only (i.e. the second term of eq.3.7). The recognition results of such experiment are shown in table (4-3), it is shown that the results are nearly identified in both cases, which refers to the behavioral weakness of the U in the purpose of recognition. Therefore, the recognition result using just SVD is equivalent to the use of U only. Any one of SVD and U does not strength or weak the other. Such that, it can neglect the U in the recognition computations by dropping the second term in eq.(3.7).

Furthermore, the analytical consideration of SVD values in Table (4.1) shows that the differences between the SVD values were not equal which greatly affect the recognition results. Since the SVD became the unique responsible parameter on the recognition, the results should be improved by making the centroides of the SVD that belonging to the iris samples in the codebook which are more distinguished. The results improvement is a new SVD formation, i.e. instead of SVD, new feature based on SVD exponential fitting can be adopted. The adopted recognizable feature will be 100^{SVD} rather than SVD. This adaptation in the recognition feature will make the centroides to move away from each other and support the recognition results. Table (4-3) shows the values of the adapted recognition feature in comparison with the last one, the recognition results became more distinguished.

Table (4-3) The adaptive recognition feature values in comparison with SVD.

Samples	SVD	100^{SVD}
S1	0.3421188	4.833232
S2	0.357347	5.184346
S3	0.5748055	14.112729
S4	0.4961721	9.825263
S5	0.5179465	10.86158
S6	0.7385736	30.001792
S7	0.6347926	18.603095
S8	0.584887	14.783389
S9	0.5552828	12.899284
S10	0.7780603	35.984925

4.8 Further Analyses

The further analyses are related to the evaluation of some proposed stages to find the optimal operation of IRBSF software. Since the proposed method uses one color band (red, green, blue; or even gray), one can find the best representation of the three bands that gives best results, this is achieved by analyzing the variation of the recognition results due to the variation of the color bands. Also, one can analyze the variation of the recognition results corresponding to different quantization results through the stage of iris coding. Furthermore, the spent time during implementing the IRBSF software can be evaluated, and estimates the ability of IRBSF to be operated with huge database. The implementation and analyses of above mentioned subjects are given in the following sections.

4.8.1 Color Bands Analysis

The used iris images are true colored, in which each pixel is saved in 24 bits; each 8 bits belong to one band (red, green, or blue). Therefore, it is able to separate each band accurately. In order to analyze the performance of IRBSF with the variation of color bands, the normalized recognition results (*NR*) of the kth band (B_k) belong to ith iris sample are given in the following relation:

$$NR_{ik} = \frac{B_{ik}}{\sum_{b=1}^{3} B_k} \tag{4.1}$$

Where B_i is same NS_i given in equation (3.8), k is pointer refers to the color band. The results of equation (4.1) are pictured in Figure (4.10). It is noticeable that the average percentage of IRBSF performance using green band (*G*) was the greatest for all iris samples about 54%. The red (*R*) band gave an average performance percentage of about 27%. Then, the blue band (*B*) occupies the latest place with average performance percentage of about 19%. Actually, these percentages indicate the amount of information found in each color band. Such that, one can regard the resulted percentages as a contribution share for each color band to create one optimal band (B_o) used in the recognition phase.

$$B_o = 0.27R + 0.54G + 0.19B \quad \ldots (4.2)$$

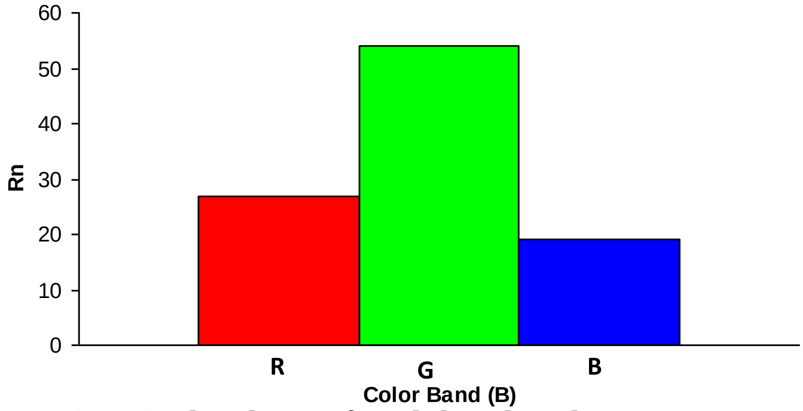


Fig (4.10) The share of each band in the recognition process.

Figure (4.11) describes the recognition results of the three color bands R, G, and B besides gray (B_g) and optimal band (B_o). It is important to note that the B_o showing more stability in the recognition results along all iris test samples, which ensure that the suggested optimal band is the best since it carried most of the image information that describe in the three bands.

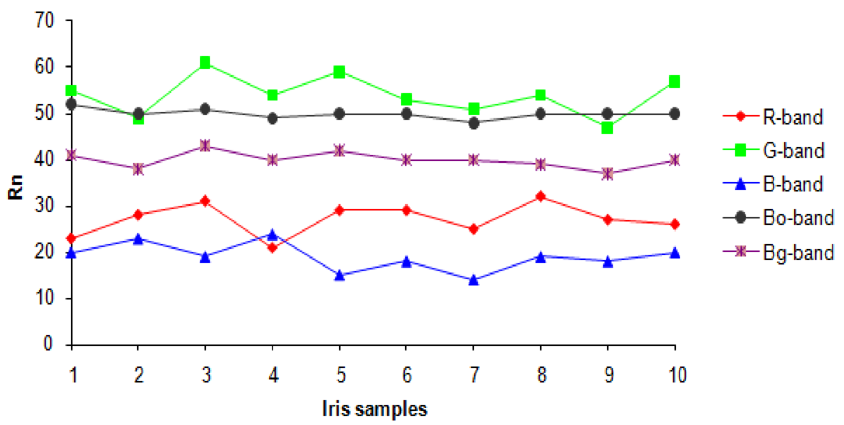


Fig (4.11) The behavior of R_n versus iris sample for the considered color bands.

4.8.2 Quantization Test

Throughout iris coding stage, the binarization process can be replaced by a quantization one. Thus, the code of the iris becomes consists of predefined number (N_q) of quantization levels.

To apply such test, one can choose N_q=2, 4, 8, 16, and 32. Figure (4.12) shows the recognition results versus N_q. It is noticeable that the increase in N_q leads to decrease the recognition score and also decrease the stability of the recognition results. The behavior of the recognition of lower N_q appears less fluctuation, i.e. more stability. Such that, one may deduce that the binary code was showed best situation for IRBSF software.

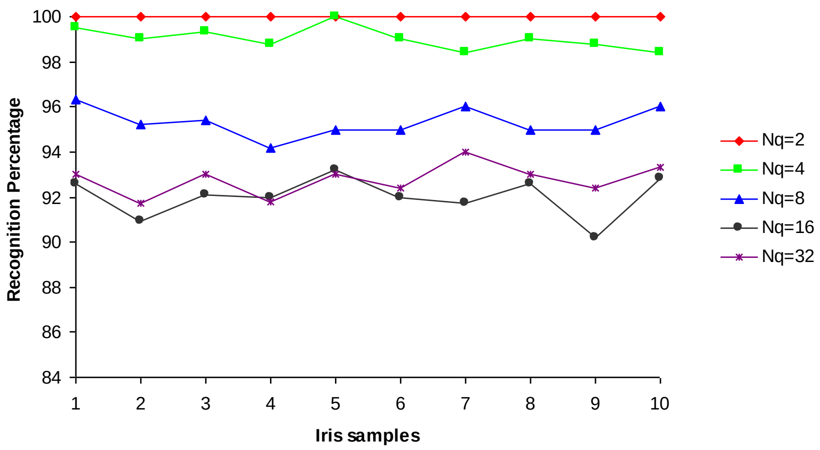


Fig (4.12) The behavior of recognition score versus iris sample for different quantized levels.

4.8.3 Spent Time Test

To test the validity of IRBSF to be work with huge database, the time rate of implementing the IRBSF are computed for different database sizes. The computed time is the time elapsed to implement just the indexing and recognition not iris localization, that due to two reasons: (1) the iris localization depends on the image resolution, it spent different time intervals for different images resolutions, (2) The localization is not included in the indexing technique.

The adopted database sizes are D_s=10, 20, 30, 40, and 50 samples. The results of the spent time test showed that there is an exponential relationship between the spent time and the size of the database as shown in Figure (4.13). These time results are computed for same iris sample that put in different database size at each time test, in which the processor of the used computer was 2*GHz* and 1*GB* RAM.

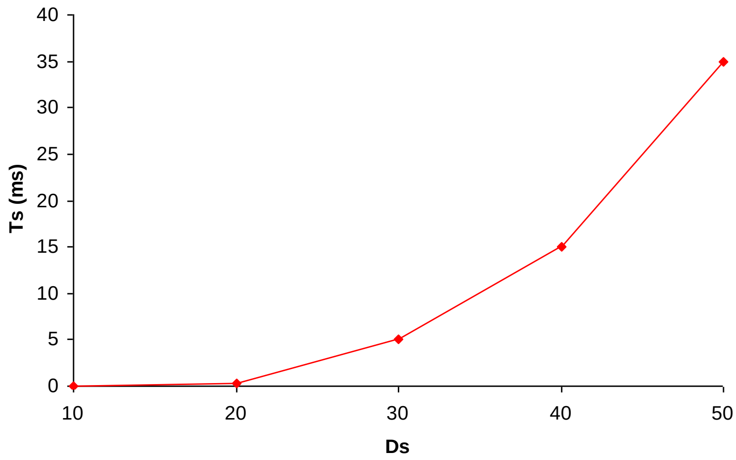


Fig (4.13) The behavior of spent time versus database size.

It is shown that the increase in the time is approachly uniform due to equally increasing in the size of the database. This behavior of spent time saves the chance to predict the time needed to complete the recognition process at any D_s value. For example; it is expected that the time of IRBSF implementation to be 65 *ms* when the database size is 100 samples. The following exponential fit is prepared to compute the spent time (T_s) at different database size (D_s).

$$T_s = 3e^{-7D_s} \tag{4.3}$$

Equation (4.3) gives an acceptable result refers to the fastness of IRBSF implementation, which encouraging to the ability of building iris recognition systems based on semantic indexing technique.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introduction

Human authentication has a great importance in modern days. Instead of passwords or magnetic cards, a biometric authentication based on physical or behavioral characteristics of humans are used [Sud09]. A wide variety of biometric signatures has been considered over the years in support the challenge of authentication problem. Viable signatures include those based on fingerprints, facial features, hand shape, voice, automated recognition of retinal vasculature, and the iris. The iris is an overt body that is available for remote assessment. The variability of features of any one iris is well enough constrained to make possible a fully automated recognition system based upon machine vision. For example, even identical twins have distinct iris features [Rob03].

Iris recognition is especially attractive due to the high degree of entropy per unit area of the iris, as well as the stability of the iris patterns with age and health conditions. John Daugman is the pioneer scientist who invented iris recognition, he proposed the first successful algorithm used in the majority of today's commercial iris recognition systems [Jai09]. Later, a number of groups have explored iris recognition algorithms and some systems have already been implemented and put into commercial practice by companies such as Iridian Technologies, whose system is based on the use of Daugman's algorithm. Recently, iris recognition is used in government programs, border or restricted areas access control. The United Arab Emirates (UAE) in 2009 are conducting a great border control program in which they report that three billion comparisons per day are performed [Jai09].

1.2 Biometric Technology

Biometrics is the science of measuring physical or anatomical characteristics of individuals. Biometric technology is employed in different applications with increasing demands in automated personal authentication. There are various biometric technologies contain a computer-based biometric scans for person recognition founded (see appendix A). Security applications use devices to capture and computer based processing the biometric characteristics in order to confirm or determine the identity of an individual as Figure (1.1), [Cor06], [Big05].

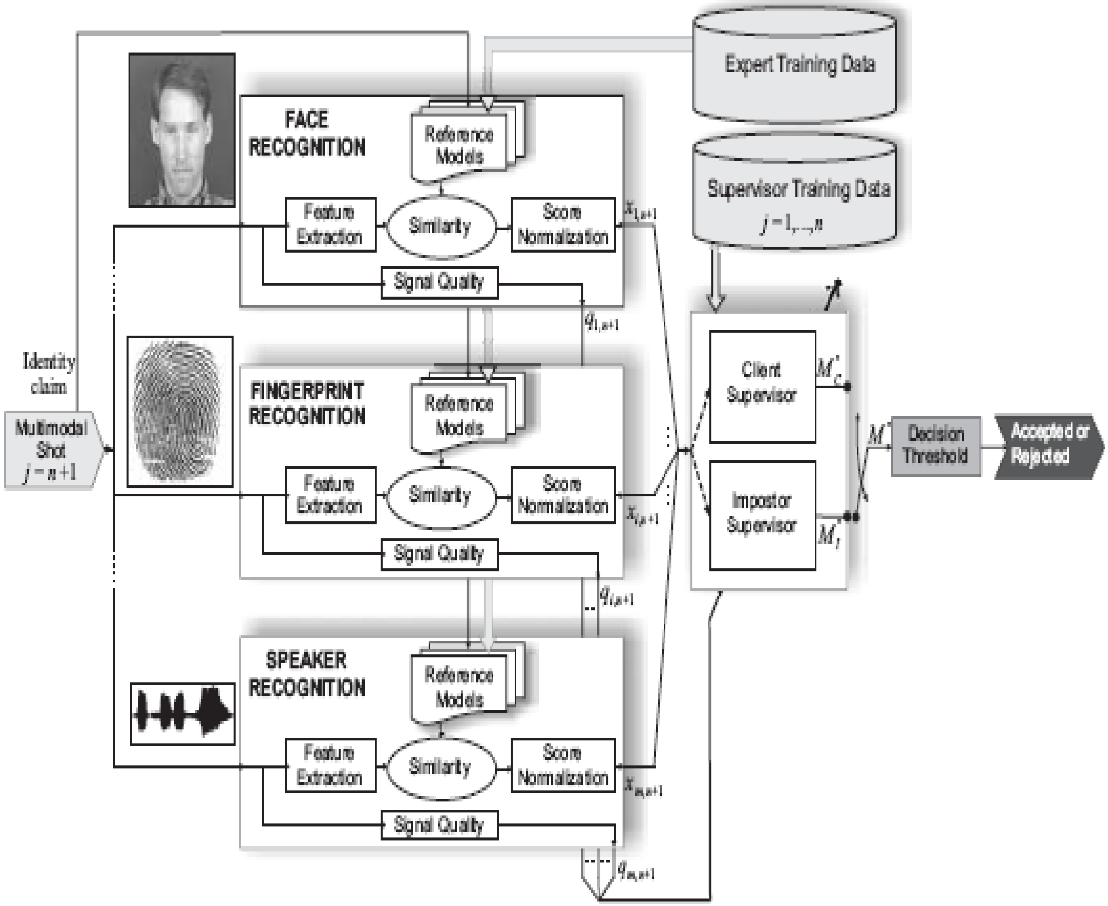


Figure (1.1) Biometric Technology

Biometric technology becomes an essential component of effective person identification solutions because biometric identifiers cannot be shared or misplaced, and they intrinsically represent the individual's bodily identity. Consequently, recognition of persons by their body, then linking that body to an externally established “identity” forms a powerful tool with tremendous potential results [Jan04].

The benefit of using biometric features in authentication systems may be increased security, increased convenience, reduced fraud, or delivery of enhanced services. In addition to reliable performance, the biometric system is more secure option that uses parts of a body for authentication and thus are practically impossible to get lost, stolen or forgotten. Users need not worry about someone using their token or PIN code without their knowledge. Also, it saves the time since the problems of handling forgotten PINs/passwords and lost/stolen keys or access cards are eliminated [Rho04].

Iris recognition is one of the biometric technologies which utilize iris patterns as a method of gathering unique information about an individual. Iris of human eye is characterized by the fact that it is considered unique to an individual; its epigenetic pattern remains stable through life. The pattern variability is enormous among different persons make iris very attractive for use as biometric feature for authentication purposes [Big05].

1.3 Iris of Human Eye

Iris is the colored portion between the pupil and the white sclera in the eye; it is approximately 11*mm* (0.433 *inches*) in diameter and contains a several layers and distinct features such as furrows, ridges, coronas, crypts, rings which controls the amount of light that enters into the eye [Dou04]. The iris consists of a number of layers, the lowest is the epithelium layer, which contains dense pigmentation cells. The stromal layer lies above the epithelium layer, and contains blood vessels, pigment cells and the two iris muscles. The density of stromal pigmentation determines the color of the iris. The externally visible surface of the multi-layered iris contains two zones, which often differ in color. An outer ciliary zone and an inner pupillary zone, and these two zones are divided by the collarette, which appears as a zigzag pattern as Figure (1.2) shows. Consequently, iris is consisting a rich texture based on interlacing features, which is well known to provide a signature that is unique to each subject [Mas03].

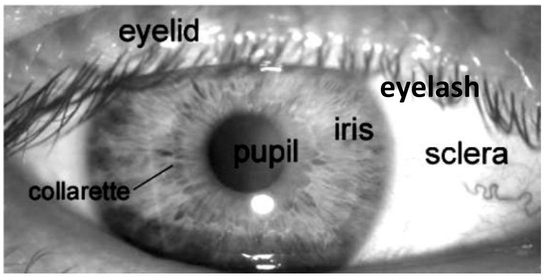


Figure (1.2) Iris of human eye [Mas03].

Formation of the iris begins during the third month of embryonic life. The unique pattern on the surface of the iris is formed during the first year of life, and pigmentation of the stroma takes place for the first few years. Formation of the unique patterns of the iris is random and not related to any genetic factors. The only characteristic that is dependent on genetics is the pigmentation of the iris, which determines its color. Due to the epigenetic nature of iris patterns, the two eyes of an individual contain completely independent iris patterns, and identical twins possess uncorrelated iris patterns [Mas03].

Varying in shades of brown, blue and green, no two irises are alike, not even within the same individual or identical twins. Glasses and contact lenses, even colored ones, do not interfere with the process. In addition, recent medical advances such as refractive surgery; cataract surgery and cornea transplants do not change the iris characteristics. In fact, it is impossible to modify the iris without risking blindness. And even a blind person can participate. As long as a sightless eye has an iris, that eye can be identified by iris recognition [Dau04].

1.4 Aim of Thesis

This thesis aims at proposing a reliable and fast system design for iris recognition problem based on semantic indexing technique to establish a person recognition system. Semantic features are used to identify the enrolled irises, these feature should be stored in the system to be used later in the recognition process in identifying unknown person who should be previously enrolled by the established system.

1.5 Literature Survey

1. Dougman presented a method for rapid visual recognition of personal identity based on the failure of statistical test of independence. The visible texture of person's iris in a real-time video image is encoded into a compact sequence of multi-scale quadrature 2D Gabor wavelet coefficients, whose most-significant bits comprise a 256-byte "iris code". Statistical decision theory generates identification decision from exclusive-OR comparisons of complete iris codes at the rate of 4000 per second, including calculation of decision confidence levels. The distributions observed empirically in such comparisons imply a theoretical "cross-over" error rate of one in 131000 when a decision criterion is adopted that would equalize the false accept and false reject error rate. In the typical recognition case, give the mean observed degree of iris code agreement, the decision confidence levels correspond

formally to a conditional false accept probability of one in about 10^{31} [Dou93].

2. Daouk described the novel techniques that they developed to create an iris recognition system, in addition to an analysis of their results. They used a fusion mechanism that amalgamates both, a Canny edge detection scheme and a circular Hough transform to detect the iris boundaries in the eye's digital image. They then applied the Haar wavelet in order to extract the deterministic patterns in a person's iris in the form of a feature vector. By comparing the quantized vectors using the Hamming distance operator, they determined finally whether two irises are similar. Their results showed that their system is quite effective [Dao02].
3. Masek presented a biometric system provides automatic identification of an individual based on a unique feature or characteristic possessed by the individual. The work presented in the thesis involved developing an 'open-source' iris recognition system in order to verify both the uniqueness of the human iris and also its performance as a biometric. For determining the recognition performance of the system two databases of digitized grayscale eye images were used. The iris recognition system consists of an automatic segmentation system that is based on the Hough transform, and is able to localize the circular iris and pupil region, occluding eyelids and eyelashes, and reflections. The extracted iris region was then normalized into a rectangular block with constant dimensions to account for imaging inconsistencies. Finally, the phase data from 1D Log-Gabor filters was extracted and quantized to four levels to encode the unique pattern of the iris into a bit-wise biometric template. The Hamming distance was employed for classification of iris templates, and two templates were found to match if a test of statistical independence was failed. The system performed with perfect recognition on a set of 624 images resulted in false accept and false reject rates of 0.005% and

0.238% respectively. Therefore, iris recognition is shown to be a reliable and accurate biometric technology [Mas03].

4. Daugman described algorithms developed for recognizing persons by their iris patterns have now been tested in many field and laboratory trials, producing no false matches in several million comparison tests. John Daugman has proposed a method for iris recognition, which is divided into four steps: segmentation, normalization, feature extraction and matching. The recognition principle is the failure of a test of statistical independence on iris phase structure encoded by multi-scale quadrature wavelets. The combinatorial complexity of this phase information across different persons spans about 249 degrees of freedom and generates a discrimination entropy of about 3.2 b/mm2 over the iris, enabling real-time decisions about personal identity with extremely high confidence. This paper explains the iris recognition algorithms and presents results of 9.1 million comparisons among eye images from trials in Britain, the USA, Japan, and Korea [Dau04].
5. Praks presented a method for an automatic verification of persons by iris recognition. A raster image of the human iris is represented as a sequence of pixels. Information retrieval is conducted by the latent semantic indexing (LSI) method. The partial symmetric eigenproblem is computed effectively using a Lanczos-based iterative method. Numerical experiments on a real data-collection indicates feasibility of the here presented approach as a tool for automated image recognition without any image preprocessing [Pra04].
6. Basit described an efficient method for personal identification based on the pattern of human iris. It is composed of image acquisition, image preprocessing to make a flat iris then it is converted into eigeniris and decision is carried out using only reduction of iris in one dimension. By

comparing the eigenirises it is determined whether two irises are similar. The results show that proposed method is quite effective [Bas05].

7. Hegazzy described the biometric person identification technique based on the pattern of the human iris is a very costly top secure application. This work describes a robust personal identification system based on the human iris imaging through providing a set of algorithms that describes image acquisition, image segmentation, feature extraction, and pattern forming. For image acquisition, a proposed image enhancement algorithm is presented to get more accurate image feature results. In addition, a proposed boundary localization algorithm is proposed to find the pupil boundary. Three algorithms that analyze local variations of the iris are used to construct feature selection vector (s) that can be used to extract features of any iris image size. Extensive experimental results using Pearson's correlation coefficient to verify one’s identity on CASIA iris images database shows that the proposed system is effective and encouraging [Heg06].
8. Otero-Mateo presented that image preprocessing stage (i.e. iris segmentation) is the first step of the iris recognition process and determines its accuracy. They proposed a method for iris segmentation. In order to get a robust method they combine several well-know techniques to achieve final result. As some of these techniques are based on intensive searching, therefore slow, they apply their knowledge of the problem (iris image features and iris morphology) to speed up the algorithms by reducing search spaces and discarding information. A fast and robust iris segmentation method that successfully works on CASIA 1.0 data set is presented [Ote07].
9. Dong presented that iris recognition is regarded as the most reliable biometrics and has been widely applied in both public and personal security areas. However users have to highly cooperate with the iris

cameras to make his iris images well captured. They aim at discussing whether and how can make iris recognition easier. Firstly the restricting factors of iris image acquisition are analyzed and the optical formulas are derived. Then the solutions of state-of-the-art iris recognition systems are reviewed and summarized. Finally, they proposed two novel iris recognition systems with good human-computer-interface but with two different strategies which respectively meet the requirements of low-end and high-end market [Don08].

10. Ahmed A. present the iris recognition technique for personal identification using Gabor filters, this technique utilized several image processing methods; e.g. edge detection, contour following, chain coding, Gabor filter, image normalization, feature extraction, etc., JPEG images of size 256×256 pixels are converted into grayscale form by average their Red, Green and Blue bands. The producing grayscale image then traced into edges and boundaries using Marr-Hildreth edge technique with an appropriate Gaussian standard deviation value (i.e. σ =3). Iris region is detected by performing a suggested contour following method which is based on the chain coding algorithm. The result of using Gabor filter alone has been found as to be copying better than utilizing the gradient Sobel filter with Gabor filter; i.e. the Gabor result alone yield higher variance values between different persons. The classification accuracy = 100% using Gabor filter alone, while the classification accuracy =80% using Sobel filter with Gabor filter [Ahm08].

11. Sudha presented that iris recognition is a potential tool in secure personal identification and authentication in view of properties such as uniqueness, non- invasiveness and stability of human iris patterns. A new approach based on the Hausdorff distance measure is proposed for iris recognition. In contrast to existing approaches that consider grey or color images, the new approach considers the binary edge maps of irises. Edge maps have

advantages in terms of low storage space, fast transmission, fast processing and hardware compatibility. A new measure, called local partial Hausdorff distance, is computed between the binary edge maps of normalized iris images. The proposed dissimilarity measure has been tested on the high-quality UPOL iris images captured in a constrained environment. The recognition performance of the proposed method has been studied for different values of parameters such as block size and partialness. An appropriate choice of these parameters achieves a recognition rate of more than 98%. The results emonstrate the significance of linear features in the iris edge maps in discriminating different irises [Sud09].

1.6 Thesis Layout

The thesis consists of five chapters; chapter one is a general introduction to the basic concepts related to the field of interest, whereas the other four chapters deal with the proposed iris recognition technique and discuss some measures and tools that determine the efficiency of the recognition process. The following is a brief description about each one:

Chapter Two, Entitled: Semantic Indexing Based Iris Recognition

This chapter presents the pattern recognition system and how latent semantic indexing used for recognition of human iris using singular value decomposition.

Chapter Three, Entitled: Proposed Iris Recognition Method

This chapter presents the design and implementation steps of the system are presented.

Chapter Four, Entitled: Result and Discussion

This chapter show the test results and presented and discussed to evaluate the performance of the establish system.

Chapter Five, Entitled: Conclusions and Suggestions for Future Work

This chapter contains some derived conclusions are listed and a list suggestions for the future work are given.

CHAPTER THREE

PROPOSED IRIS RECOGNITION METHOD

3.1 Introduction

The originally random constitution of human iris help the specialists to continually search on more reliable and efficient iris authentication systems to be employed in the high secured applications. To credit the efficient performance of such authentication systems, the supplement devices (such as camera, or processor) should be chosen at high quality, which ensures greater appearance for the constituting features that should be processed during short time. The industrial improvement offers many models of supplement devices through intended attributes to be used in such systems. Also, the technical improvement produces an established authentication systems are made by some respect companies, but these companies monopolized the knowledge related to the employed approach and structure of their production.

This chapter concerned with explanation how using the semantic features as effective approach to establish an iris recognition method. Each stage in the proposed method is discussed and explained by editing its algorithm that based on the relationships mentioned in the previous chapter.

3.2 Proposed Iris Recognition Method

The concept of multi-stage query processing and code indexing has been used to model the proposed approach. It is claimed that these stages can beneficially be combined and that, through the combination, a significant fast and efficient iris recognition system can be achieved.

The generic structure of the proposed iris recognition method is shown in Figure (3.1), it is noticeable that the proposed method do not need high processing on the iris images, that due to the test materials are high quality images taken by high resolution camera. This is useful in reducing the computation time of the recognition process. Since the used approach is a numerical method depends on finding a set of solutions, the proposed method need to input a set of iris images. Each iris image pass through multi-stages, the first is a preparing stage aims at extracting the image segment of interest (i.e. iris) from the overall image. This is carried out by newly suggested method, which determines the diameter and center of the iris. Next stage concerned with encoding and then indexing the detected iris.

The proposed method is designed to be consisted of two phases: the enrollment and recognition. The enrollment is an offline phase in which the test irises are indexed in a database file. Whereas the recognition is an online phase includes the following stages: iris mapping which attempt to estimate the semantic features (i.e. *SVD* and *U*) of all the images under test (i.e. query and those encoded in the database). Last stage is a comparison based on semantic features between the query iris and that found in the database, the result of the comparison will determine the similarity measure between the considered irises and then help to make the recognition decision. In the following more explanation about each stage are given in details.

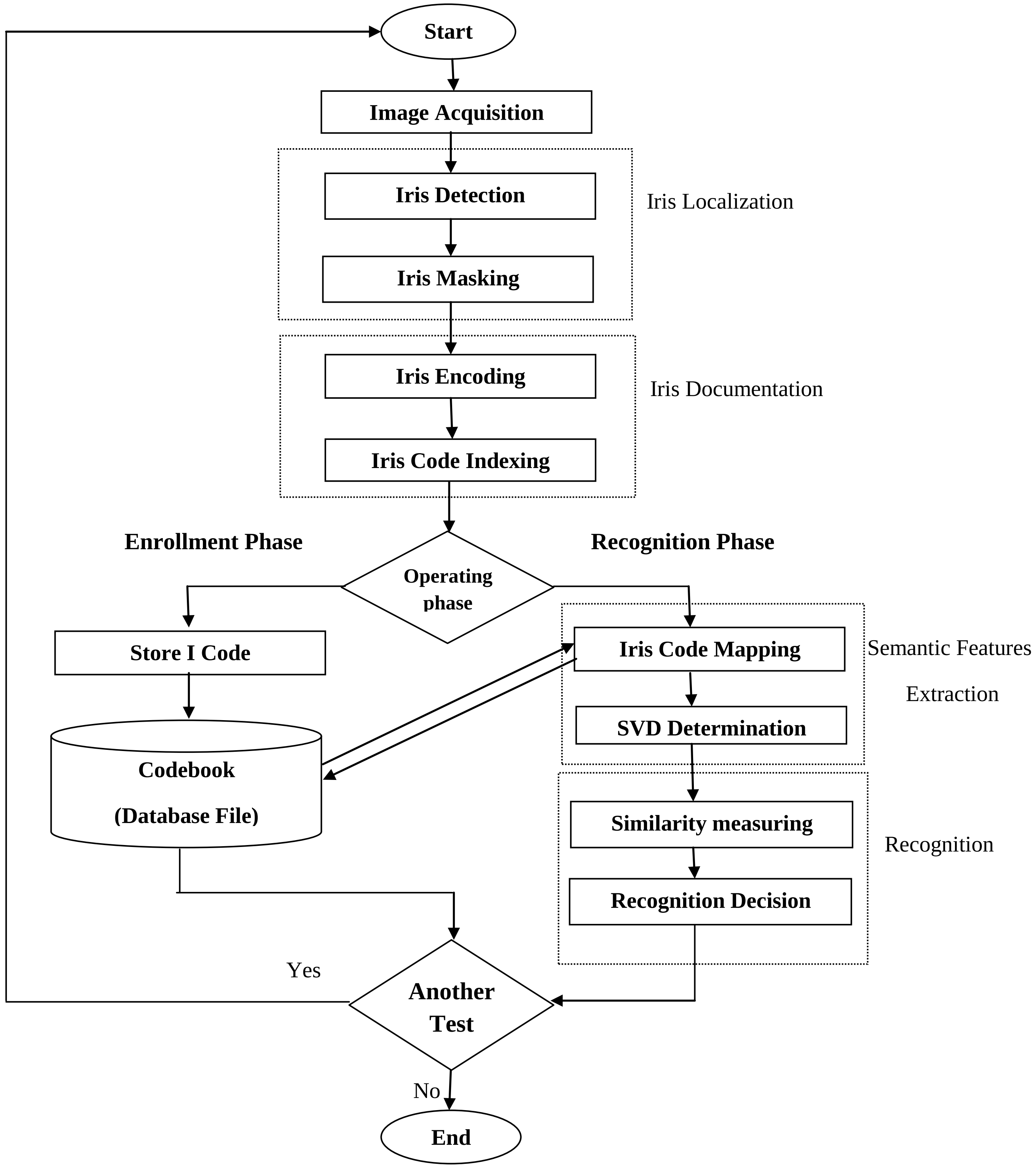


Figure (3.1) Block diagram shows the proposed iris recognition method.

3.3 Iris Localization

It is a priory stage aims to prepare the iris image for the recognition process. In such stage, the iris is extracted from the eye image. The proposed method requires passing through two steps: (i) Iris detection, which determines the region of the iris segment and estimate the diameter of its circular shape and the position of its center. (ii) Iris masking, which produce a binary circular mask takes the same size and center position of the iris to isolate all the pixels around the iris when compared with eye image, i.e. extracting the iris. More details about each step are given in the following:

3.3.1 Iris Detection

The suggested method of iris detection is depending on the natural design of the eye, where the eye takes an elliptical shape with a white sclera within the eyelash and encloses a dark iris as shown in Figure (3.2). The sclera appears at relatively more expanded bright region than other cues of the eye; it is shown as great as close the iris. This point is useful to determine the size and location of the iris. The adopted method includes two operations within: the first determines the diameter and the central position of the iris on the horizontal coordinate, whereas the latter determines just the vertical position of the iris center. More explanations about them are given in the following:

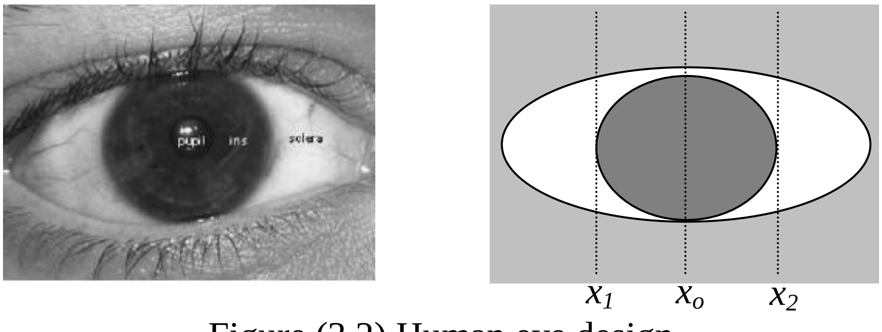


Figure (3.2) Human eye design.

First operation

The horizontal brightness distribution (HBD) of the eye image can be computed and analyzed: HBD is a vector has size equal to the width of the image, each value in such vector represent the sum of all the pixel values that belonging to its corresponding column in the image.

$$HBD_x = \sum_{y=0}^{h-1} f_{xy} \qquad \dots (3.1)$$

Where, f is the pixel values of the image, x and y are indices referring to the position of the current pixel.The behavior of HBD is found contains two greater characteristic peaks restricting lower valley in between as Figure (3.3) shows. The two characteristic peaks refer to the expanded bright regions of sclera on the both sides of iris, while the valley refers to the dark region of the iris in the image. By smoothing the behavior of the HBD and searching the location (x_1 and x_2) of the greatest two peaks enclose the lowest valley, one can determine the diameter (D) and central horizontal position of the iris (x_o) as follows:

$$D = x_2 - x_1 \qquad \dots (3.2)$$

$$x_o = \frac{x_1 + x_2}{2} \qquad \dots (3.3)$$

Algorithm (3.1) presented the finding of the diameter and the horizontal position of iris in order to localized the iris from eye image.

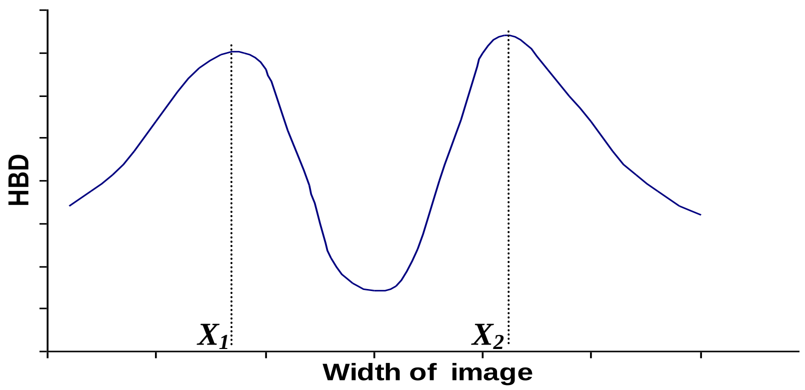


Figure (3.3) HBD behavior.

Algorithm (3.1) Iris diameter (D) and position (X_0) determination.

Input:

W \\ Width of the image.

H \\ Height of the image.

Img \\ 2D array represent the iris image.

Output:

D \\ Diameter of the iris.

X_0 \\ Horizontal position of the iris.

Procedure:

Loop X = 0 ***to*** W-1

Loop Y = 0 ***to*** H-1

Set HBD(X) ⟵ HBD(X) + Img(X, Y) / H

End loop

End loop

\\ To make smoothing for HBD (N times)

Loop K = 1 ***to*** N

Loop X = 1 ***to*** W-2

Set HBD(X) ⟵ (HBD(X - 1) + HBD(X) + HBD(X + 1)) / 3

End loop

End loop

\\ To find the position (X_1 and X_2) of the two peaks and iris diameter (D)

Set M ⟵ 0

```
Loop X = 1 to W-1
    If HBD(X-1) < HBD(X) And HBD(X+1) < HBD(X) Then
        Set M ⟵ M+1
        Set P(M) ⟵ X
    End If
End loop
Set X1 ⟵ P(1)
Set X2 ⟵ P(2)
Set D ⟵ X2 - X1
Set X0 ⟵ (X2 - X1) / 2
```

Second operation

The second operation requires a vertical search with circular window of diameter D along the vertical line of the position x_o to find darkest region (less average) enclosed by the window. The determined darkest circular window is the detected iris region, and the position of the center of the determined window is the position (y_o) of the center of the iris on the vertical coordinate.

Algorithm (3.2) presented the determination of the vertical position of iris in order to localized the iris and separated it from eye image.

Algorithm (3.2) Iris position (Y_0) determination.

Input:

W \\ Width of the image.

H \\ Height of the image.

X_o \\ Position of the iris center on the horizontal coordinate.

Output:

Y_o \\ Position of the iris center on the vertical coordinate.

Procedure:

```
Set R ⟵ 3
Set K ⟵ 0
Loop Y = R to H-1-R
    Loop J = Y-R to Y+R
        Loop I = X0-R to X0+R
            Set K ⟵ K+1
            Set W(K) ⟵ Img(I, J) / (R*R)
        End loop
    End loop
End loop
Set Min ⟵ W(1)
Set Yo ⟵ 1
Loop For C = 2 to K
    If W(C) < Min Then
        Set Min⟵ W(C)
        Set Yo ⟵ C
    End If
End loop
```

3.3.2 Pupil Detection

The pupil detection aims to determine just the region of the pupil inside the iris, the adopted method depends on the theory of the optimal search. By assuming the initial search point is the center of the iris (x_o,y_o), one can determine the average of all pixel values included in a circle centered at (x_o,y_o) with initial radius of R_p=2 to be the central circle. Also, the averages (A_{up},A_{down}, A_{left}, *and* A_{right}) of all pixel values belonging to the four circles of radius equal to 3 *pixels* and centers are shifted by 1 *pixel* up and down the center of the central circle are computed as shown in Figure (3.4). It is noticed that the four terminal circles are interfered with the central one, since they ling on the circumference of the central circle.

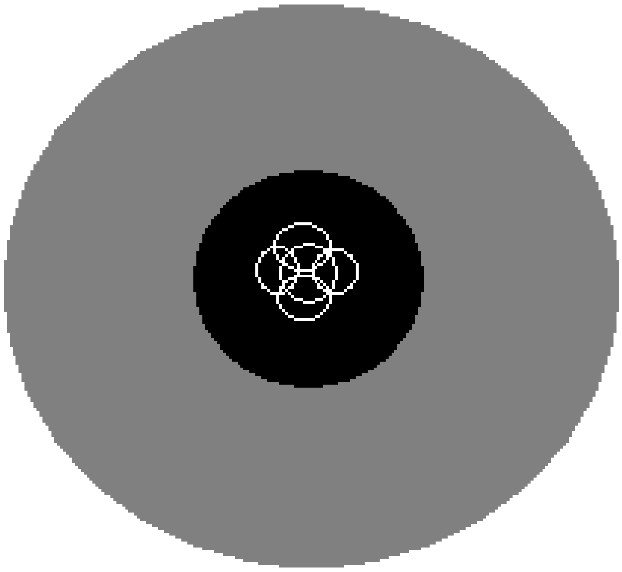


Figure (3.4) The four circles around the central one of the pupil detection method.

By comparing A_{up} with A_{down}, the central circle is shifted toward the circle of the less average by a vertical amount is 1 *pixel*. Also by the same manner, the comparison between A_{left} *and* A_{right} determines the direction of the next horizontal shift. In case of equaling each two averages on the corresponding terminals, the radius of the central circle is increased by one and then the comparison of the new four circles is repeated. The comparison and the expansion of the central circle are continued until reaching a termination condition, which necessitate existing at least three averages are greater than a specific threshold (*T*). In such case the central circle is fitting the size of the pupil appears in the iris image. The threshold value may equal to any assumed color value that belong to the iris not pupil, such as 100. Algorithm (3.3) presents the pseudo code of applying the pupil detection method in order to separate the pupil from the iris. Algorithm (3.4) presents the working of image weight function that returns the average of the pixel value those ties inside the pupil. The value of (Thr) represents the difference between the average of pupil circle from iris circle that equal to (20) because the differences between the outer circle of the iris and the pupil circle is not equal more than 20,the number 20 was obtained from experiences.

Algorithm (3.3) Pseudo code of pupil detection and iris detection.

<u>Input:</u>

W \\ Width of image.

H \\ Height of image.

Thr\\Threshold represents the color difference between the pupil and iris

X_o \\ Pre-position of the iris on the horizontal coordinate.

Y_o \\ Pre-position of the iris on the vertical coordinate.

<u>Output:</u>

Xc \\ Fitted position of the iris on the horizontal coordinate.

Yc \\ Fitted position of the iris on the vertical coordinate.

D \\ the diameter of the iris.

<u>Procedure:</u>

Loop X = 0 ***to*** W-1

Loop Y = 0 ***to*** H-1

End loop

End loop

Set R_o ⟵ 3

Set Rp ⟵ D/2

Set PuplAv ⟵ Av_Img(X_o, Y_o, R_o)

Loop

Set Ap ⟵ Img_Av (X_0, Y_0, Rp)

Set Intrfrnc ⟵ 1

Set AUp⟵ Img_Av (X_o, Y_o-Intrfrnc * Rp, R_o)

Set ADn⟵ Img_Av (X_o, Y_o+Intrfrnc * Rp, R_o)

Set ALf ⟵ Img_Av (X_o-Intrfrnc * Rp, Y_o, R_o)

Set ARt ⟵ Img_Av (X_o+Intrfrnc * Rp, Y_o, R_o)

Set ChgX⟵ False

Set ChgY ⟵ False

Set VstX ⟵ False

Set VstY False

If Abs (ALf-Ap) > Abs (ARt-Ap) ***And*** Vist(X_o,Y_o) = False ***Then***

Set X_o ⟵ X_o + 1

Set ChgX⟵ True

Set VstX ⟵ True

ElseIf Abs (ARt-Ap)>Abs (ALf-Ap) ***And*** Vist(X_o,Y_o)=False ***Then***

Set X_o ⟵ X_o-1

Set ChgX ⟵ True

Set VstX ⟵ True

End If

If Abs(AUp -Ap)>Abs(ADn -Ap)***And***Vist(X_o,Y_o) = False ***Then***

Set Y_o ← Y_o+1

Set ChgY ← True

Set VstY ← True

ElseIf Abs(ADn -Ap)>Abs(AUp-Ap)***And***Vist(X_o,Y_o)=False ***Then***

Set Y_o ←Y_o-1

Set ChgY ← True

Set VstY ← True

End If

If Abs (Ap - PuplAv) > Thr ***Then*** GoTo 6

If VstX = True Or VstY = True ***Then*** Set Vist(X_o, Y_o) ← True

If ChgX = True Or ChgY = True ***Then***

Set Countr ← Countr + 1

End If

If ChgX = False And ChgY = False ***Then***

If Rp < 4 * R_o ***Then***

Set Rp ← Rp + 1

Set Vist(X_o, Y_o) ← False

Else

6 Set Xc ← X_o

Set Yc ← Y_o

Exit loop

End If

End loop

Algorithm (3.4) Img_Av image weight function returns the average of the pixel value those ties inside the pupil.

Input:

W \\ Width of image.

H \\ Height of image.

X_o \\ Position of the iris center on the horizontal coordinate.

Y_o \\ Position of the iris center on the vertical coordinate.

R_o \\ Radius of the pupil.

Img \\ 2D array represent gray image.

Output:

ImgAv \\average of the pixel values that lies inside a circle of center (X_o, Y_o) and radius Rp.

Procedure:

Set S ⟵ 0

Set C ⟵ 0

Loop X = 0 ***to*** W-1

Loop Y = 0 ***to*** H-1

Set R ⟵ Sqr $((X - X_o)^2 + (Y - Y_o)^2)$

If R <= R_o ***Then***

Set S ⟵ S + Img(X, Y)

Set C ⟵ C + 1

End If

End loop

End loop

Set mg ⟵ S / C

3.3.4 Iris Masking

In the iris masking step, the pre-determined diameter and position of the center of iris in the image are employed to construct a mask *M*; which is a 2D array takes the same size of the eye image i.e. *M*(*w*,*h*). The mask *M* has binary values: it takes 1 at the region belonging to the iris, otherwise it takes a zero values according to the following condition:

$$M(x,y)=\begin{cases}1 & \text{if } \sqrt{(x-x_o)^2+(y-y_o)^2}\le D/2 \\ 0 & \text{Otherwise}\end{cases} \qquad \ldots (3.4)$$

In order to extract just the iris from the eye image, one can check if the mask value *M*(*x*,*y*) corresponding to the position of the current pixel *f*(*x*,*y*) is 1 or 0. According to the check result, the current pixel is accepted as iris or not as follows:

if M(x,y) = 1 then f(x,y) is a pixel belong to the iris
Otherwise leave the current pixel

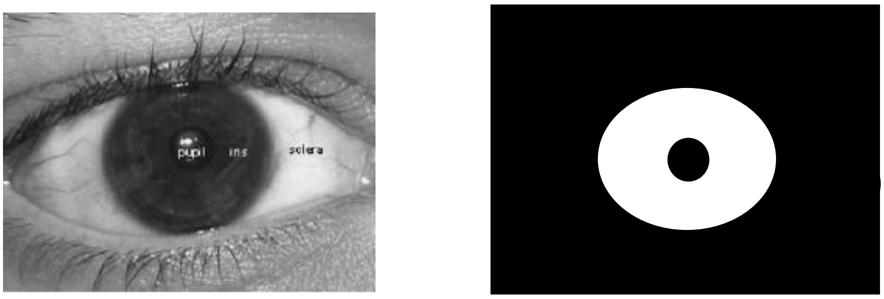


Figure (3.5) Iris mask.

Algorithm (3.5) presents the making of masking image in order to separate the iris and the pupil from eye image

Algorithm (3.5) Image masking.

Input:

H \\ Height of image.

W \\ Width of image.

Xc \\ Position of the iris center on the horizontal coordinate.

Yc \\ Position of the iris center on the vertical coordinate.

D \\ Diameter of the iris.

Rp \\ Radius of pupil of the iris.

Output:

Mask \\ Binary two dimensional array.

Procedure:

```
Set Ri ⟵ D/2
Loop Y = 0 to H-1
    Loop X = 0 to W-1
        Set R ⟵ Sqr ((X - Xc)^2 + (Y – Yc)^2)
        If R < Ri And R > Rp Then
            Set Mask(X, Y) ⟵ 1
        Else
            Set Mask(X, Y) ⟵ 0
        End If
    End loop
End loop
```

3.4 Iris Documentation

A new client submitted to the iris recognition system passing through an initial documentation stage. This stage involves encoding of the iris image though presentation of trustworthy document of iris code to corroborate the identity of a trusted individual in the enrollment or recognition stage. During the documentation, a number of iris samples are encoded and then indexed. The quality of the encoding operation is of paramount importance in assuring the optimal performance of the recognition process. A quality threshold is set for the query image to enforce a repeat documentation when the processing fails to provide a sufficiently good sample. An explanation about the documentation details related to the iris encoding and indexing is given in the following subsections:

3.4.1 Iris Encoding

The quality test of iris sample documentation is carried out; each iris code is checked by using newly suggested resolution measure, which go to estimate the weight of edges corresponding to overall iris image size, if this weight is greater than 10% of iris image size then this image is accepted for recognition else it should be replaced by capturing new iris image. Locating iris in the image delineates the circular iris zone of analysis by its own inner and outer boundaries. The Cartesian to polar reference transform should be authorized to be equivalent rectangular representation of the zone of interest as shown Figure (3.6). In this way, the stretching of the iris texture is compensated as the pupil changes in size, the frequency information contained in the circular texture is unfolded in order to facilitate next features extraction. Moreover this new representation of the iris breaks the eccentricity of the iris and the pupil. The h parameter and dimensionless q parameter describe the polar coordinate system. Thus the following equations implement the transformation of the image $f(x(r,q), y(r,q))$ from the Cartesian to polar coordinates:

$$\left.\begin{aligned} x(\rho,\theta) &= (1-\rho)x_p(\theta) + \rho \times x_i(\theta) \\ y(\rho,\theta) &= (1-\rho)y_p(\theta) + \rho \times y_i(\theta) \end{aligned}\right\} \qquad \ldots\ldots (3.5)$$

And

$$\left.\begin{aligned} x_p(\theta) &= x_o(\theta) + R_p \cos(\theta) \\ y_p(\theta) &= y_o(\theta) + R_p \sin(\theta) \end{aligned}\right\} \qquad \ldots\ldots (3.6\text{-a})$$

$$\left.\begin{aligned} x_i(\theta) &= x_o(\theta) + R_i \cos(\theta) \\ y_i(\theta) &= y_o(\theta) + R_i \sin(\theta) \end{aligned}\right\} \qquad \ldots\ldots (3.6\text{-b})$$

Where R_p and R_i are respectively the radius of the pupil and the iris, while $(x_p(h),y_p(h))$ and $(x_i(h),y_i(h))$ are the coordinates of the pupillary and limbic boundaries in the direction h. The frontier zones (iris/pupil and iris/sclera) are truncated to avoid noising the iris rectangular representation by other patterns not included in the iris texture. It is noticed that (i) the pupil is not perfectly circular, and (ii) the outer iris boundary detection is often not well defined due to the positioning of contact lens bound.

Figure (3.6) Iris rectangular representation.

To encode the iris image, the texture of the rectangular representation of the iris is binarized using a dynamic threshold driven from the histogram of the iris image. The distribution of the histogram is normal similar to bell shape, i.e. Gaussian distribution. The threshold takes the color corresponding to the maximum value found in the histogram. The result will be a binary texture look like the bar code as shown in Figure (3.7). Algorithm (3.6) presents the way of encoding the iris image.

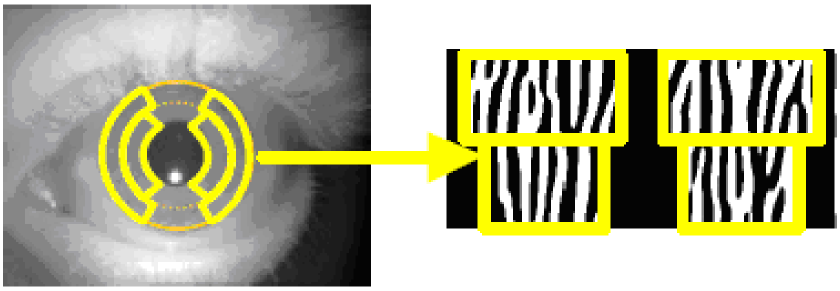


Figure (3.7) The encoded iris image.

Algorithm (3.6) Encoding the iris image.

Input:

Xc \\ Position of iris center on the horizontal coordinate.

Yc \\ Position of iris center on the vertical coordinate.

W \\ Width of iris image.

H \\ Height of iris image.

Ri \\ Radius of the iris.

Img \\ 2D array represent image.

Mask \\ Pointer array refers to the pixels belonging to the iris region.

Rp \\ radius of pupil iris.

Output:

SIris \\ 2D array represent the rectangular iris representation.

Procedure:

Set Dth ⟵ 360

Set dx1 ⟵ Xc

Set dx2 ⟵ W-Xc

Set dy1 ⟵ Yc

Set dy2 ⟵ H-Yc

Set Dx ⟵ min (dx1, dx2)

Set Dy ⟵ min (dy1, dy2)

Set Dr ⟵ min (Dx, Dy)

Set Ri ⟵ max (Dr, Ri)

Set Rr ⟵ -1

Loop R = Rp+1 ***to*** Ri-1

  Set Rr ⟵ Rr + 1

  Loop Th = 0 ***to*** Dth-1

    Set X ⟵ CInt(R * Cos ((22 / 7) * Th / 180)

    Set Y ⟵ CInt(R * Sin ((22 / 7) * Th / 180)

    Set X ⟵ Xc + X

    Set Y ⟵ Yc + Y

    Set SIris(Rr, Th) ⟵ Img(X, Y)

  End loop

End loop

Set Dr ⟵ Rr

Loop R=0 ***to*** Dr

  Loop Th=0 ***to*** Dth-1

    Set His(SIris(R, Th)) ⟵ His(SIris(R,th))+1

  End loop

End loop

Set Max ⟵ His(0)

Set S ⟵ 0

```
Loop c=0 to 255
    If His(c) > Max Then
        Set Max ⟵ His(c)
        Set S ⟵ c
    End if
End loop
Set C ⟵ 0
Loop R=0 to Dr
    Loop Th=0 to Dth-1
        If SIris(R, Th) > S Then
            Set BIris(R,Th) ⟵ 1
            Set C ⟵ C+1
        Else
            Set BIris(R,Th) ⟵ 0
        End if
    End loop
End loop
```

3.4.2 Iris Code Indexing

The procedure of the indexing is carried out by arranging the iris codes as a sequence of samples, see Figure (3.8). Then, the coded iris can be understood as a vector of an *m*-dimensional space, where *m* denotes the number of pixels (attributes) found in the iris image. Let the symbol *A* denotes $m \times n$ term-document matrix related to *m* terms (iris codes) in *n* documents (image samples). So that, the term-document matrix *A* is representing a sequence of coded images, in which the element (i,j) represent the pixel value of i^{th} term in the j^{th} sample document. Algorithm

(3.7) presents the pseudo code of iris indexing. The interest point in such arrangement in the document matrix. The term-document matrix is capable to be updated each time when new iris code is indexed. An additional two arrays are made to save the number of documents (NoDoc) and number of terms at each document (NoTrm).

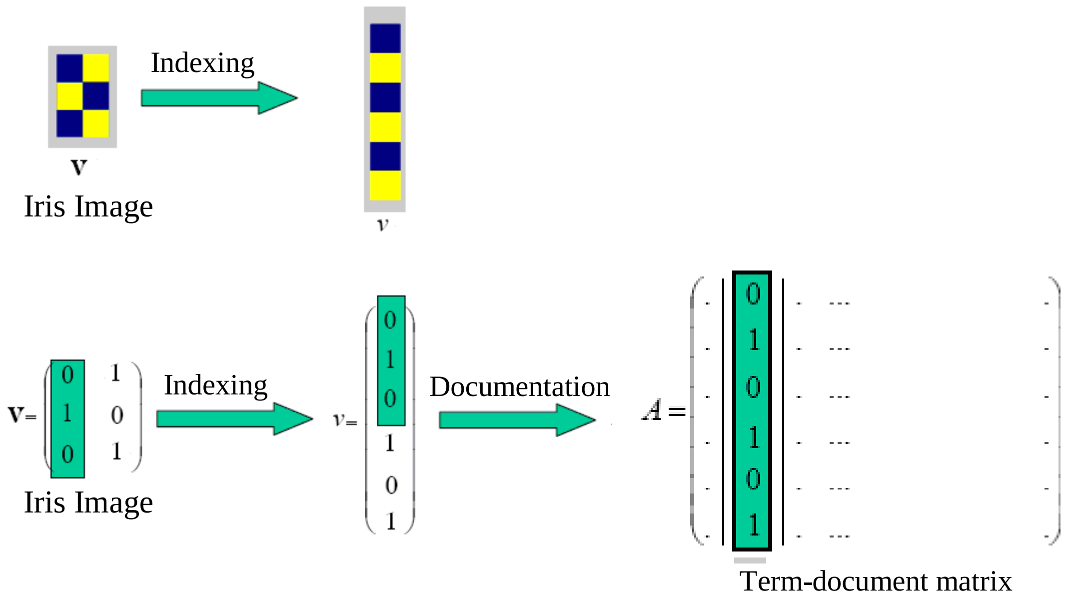


Figure (3.8) Indexing of the iris images.

Algorithm (3.7) Indexing of the Iris Code.

Input:

BIris \\ Binary array of the iris code.

Dth \\ Width of the binary iris code.

Dr \\ Height of the binary iris code.

NoDoc \\ Number of documents found in the term-document matrix.

Output:

A \\ 2D array represent the term-document matrix.

```
    NoDoc   \\ Number of document found in the term-document matrix.
    NoTrm   \\ Number of term found in each document.
Procedure:
    Set NoDoc ⟵ NoDoc+1
    Set C1 ⟵ 0
    Loop R=0 to Dr
        Loop Th=0 to Dth-1
            Set C1⟵ C1+1
            Set A(C1,NoDoc) ⟵ BIris(R, Th)
        End loop
    End loop
    Set NoTrm(NoDoc) ⟵ C1
```

3.5 Enrollment and Recognition

The enrollment and recognition phases are two operating modes designed for the proposed iris recognition to be work within. The enrollment includes the first stages: iris localization and iris documentation. The additional distinct stage in the enrollment phase is saving the term-documents matrix in a database append file called codebook. Because the adopted approach is numerical method, it needs several samples of iris images to be work. Such that, the database file should be includes the previously encoded samples of the irises belong to different persons. In addition, an independent two files are made; the first is employed to store the number of documents, and the later is appended one used to store the numbers of terms sequentially in each document. Algorithm (3.8) shows the pseudo code of the term-document stage. Whereas, the recognition phase works only when the database file is contains enough number of iris samples through the enrollment. (i.e. greater than 1 iris). The query image of the iris to be recognized are input to the proposed iris recognition system that work through the recognition mode. The query iris with database irises is collected to implement the recognition task. Also, the recognition phase is composed of two distinct stages in addition to the first one. The distinct stages are specified for making the recognition decision; these distinct stages of the recognition phase are explained in the following subsections:

Algorithm (3.8) Enrollment stage of iris code.

Input:

A \\ 2D array represent the term-document matrix.

NoDoc \\ Number of documents in A.

NoTrm \\ 1D array represent the number of terms in each document found in A.

Codebook file \\ Text file to store the components of A.

NoDoc file \\ Text file to store the number of documents in A.

NoTr file \\ Text file to store the number of terms in each documents found in A.

Output:

Codebook file \\ Text file to store the components of A.

NoDoc file \\ Text file to store the number of documents in A.

NoTr file \\ Text file to store the number of terms in each documents found in A.

Procedure:

Open "Codebook" for Append as #1

Open "NoDoc" for Append as #2

Open "NoTrm" for Append as #3

Set Nt ⟵ min(NoTrm)

```
Loop n =1 to NoDoc
    Loop m =1 to Nt
        Set #1 ⟵ A(n, m)
    End loop
    Set #3 ⟵ NoTrm(n)
End loop
Set #2 ⟵ NoDoc
```

3.5.1 Iris Code Mapping

Eigen problem is employed as a tool to map the iris code into latent semantic features in order to solve the iris recognition problem. The eigenproblem uses the numerical linear algebra as a basis for information retrieval. Many numerical methods are used in this purpose, power method is adopted in the present work to estimate the eigenvalue and eigenvector since it regarded as the most common and training one.

The eigenproblem based features mapping involves eigenvalue and eigenvector of *A*, which is still very memory and time consuming operation. The use of just the iris binary code instead of the whole image in the indexing leads to reduce the computation time and memory size, such that the operation being faster even at large data collection. The mapping of the non-square matrix *A* by the eigenproblem of A^TA (where *T* refers to the transpose superscript) using power method can be obtained very effectively. The features of the indexed iris code in the *A* are mapped into new semantic ones are: the *SVD* which is the square root of the eigenvalue, and the upper vector *U* associated to the meant *SVD* that equal to the eigenvector corresponding to the same eigenvalue. Both the *SVD* and *U* are computed for each document in A and stored in a lookup table as Figure (3.9) shows.

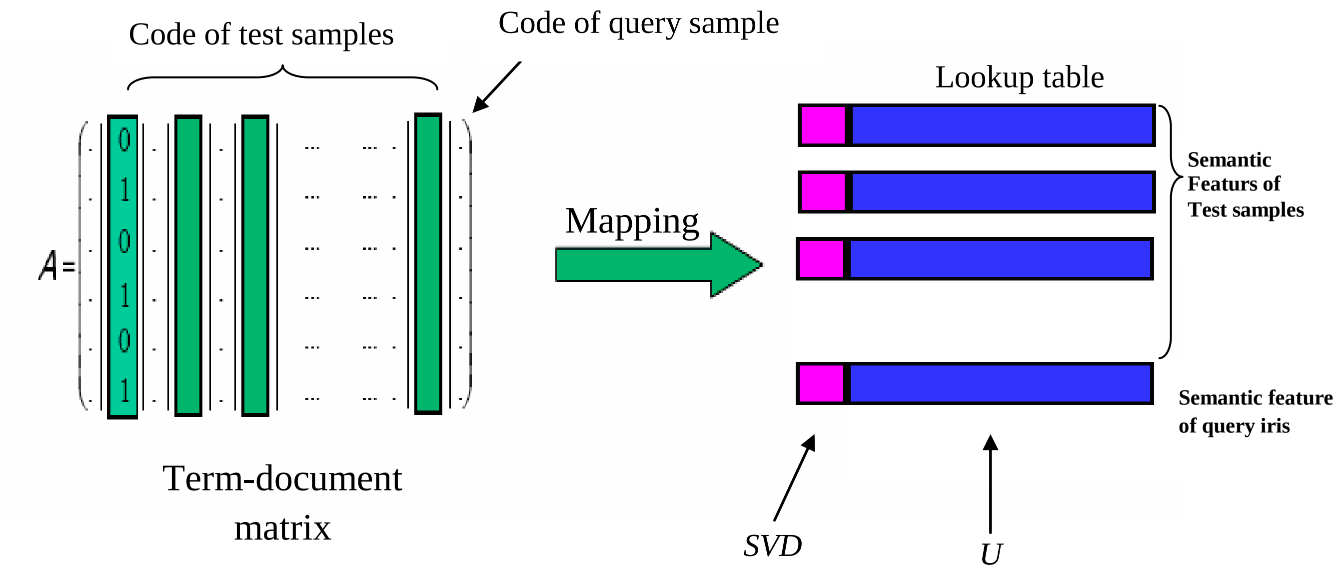


Figure (3.9) Mapping the term-document matrix (*A*) into semantic features (*SVD* and *U*).

The semantic features; *SVD* and *U* are computed for the codes of query iris code and all test samples (iris codes) found in the codebook. The document in A are regarded as a comparable encoded classes. The computed semantic features (*SVD* and *U*) are sequentially arranged in lookup table. The lookup table contains the *SVD*s of all iris samples found in the first column followed by *U* for each sample. Lookup table is effectively simplified the recognition score computation. The *SVD* is a single numerical feature that can provide a quantitative assignment for the query iris to the numerically closest class. While the *U* is a set of points (curve) can pictures the behavior of each iris sample, and also it provides a qualitative indication about the closest class may be found in the codebook. Algorithm (3.9) presents the way of mapping the iris codes into semantic features (*SVD* and *U*), i.e. shows how compute them by the numerical power method.

Algorithm (3.9) Semantic Features (AVD and U) estimation.

Input:

Codebook file \\ Text file stores the code documents of each iris sample.

NoDoc file \\ Text file stores the number of documents in the codebook.

NoTrm file \\ Text file stores the number of terms in each document.

QTmg \\ 1D array represent the binary code of the query image.

Output:

Lookup Table \\ Structural 1-D array composed of two items: SVD which is a single value and U which is a vector f length NoDoc.

Procedure:

Set A ⟵ Get_Codebook \\ A is term-document matrix.

Set A ⟵to continue the query document in an additional (last) column.

Set M ⟵ NoDoc

Set N ⟵ NoTrmM

Set A_{mean} ⟵ vector of length M, each element equal to the mean of each column.

Set A_{Dif} ⟵ 2D array of the difference between A and A_{mean}; each element in A is subtracted from its corresponding mean in A_{mean}.

Set A^T ⟵ Transpose of A_{Dif}

Set B ⟵ $A^T * A_{Dif}$

Set Allwd_Err ⟵ 0.0001

Set Old_Lampda ⟵ 0

Loop k= 1 ***to*** M

Set V ⟵ Unity vector of length M

Set B Err ⟵ 0

```
        Loop Err >= Allwd_Err
            Set L ←— B* V   \\ vector of length M
            Set Lampda ←—  Max(L)
            Set Ln  ←— L/Lampda    \\ vector of length M
        End loop
        Set Lookup_Table(k).SVD ←—  Square Root(Lampda)
        Set Lookup_Table(k).U  ←— Ln
        Set Um ←— V*V
        Set B ←—  B-Um
        Set Err ←— Abslute value (Lampda – Old_Lampda)
        Set Old_Lampda ←—  Lampda
    End loop
```

3.5.2 Recognition Decision Making

The recognition decision is computed depending on quantitative and qualitative comparisons between the semantic features of the query iris image and that encoded ones found in the codebook. The results of the comparisons indicate how the query iris is similar (close) to the iris samples. It is expected that there is at least one similar sample when the query iris is predefined in the codebook, and there is a high recognition score. Otherwise the recognition scores that come from the estimated similarities are dispersed between other samples, and there is no highly score attended. There is two interested operations may be adopted to make accurate recognition decision; the first aims to estimate the percent similarities between the query iris and the samples in the codebook, and the latter aims to normalize the similarities to make unique recognition decision, both are given with details in the following:

First Operation

The similarity measure between any two samples is made to be percent value related to the amount of the mean squared difference of the semantic features belong to the query iris and the database of the encoded samples, as given in the following relationship:

$$S_i = 1 - \left[w_1 \frac{\left(SVD_i - SVD_q\right)^2}{\sum_{k=1}^{N_S}\left(SVD_k - SVD_q\right)^2} + w_2 \frac{\sum_{j=1}^{N_S}\left(U_{ij} - U_q\right)^2}{\sum_{k=1}^{N_S}\sum_{j=1}^{N_S}\left(U_{kj} - U_q\right)^2} \right] \quad \ldots (3.7)$$

Where, i is pointer refers to the current sample in the codebook, k is pointer refers to each sample in the codebook, j is pointer refers to the serial of current value of the U, while N_S is the number of values in the vector U, N_S is the number of iris samples found in the database, while w_1 and w_2 are the contribution weights of the SVD and U respectively in making the recognition decision, the default values of them are 0.5 for each. These weights can be varied through out the analysis, especially for studying their effect on the recognition score. Figure (3.10) shows the procedure of computing the similarity percentages schematically according to the comparison between the semantic features of the query iris and those found in the database.

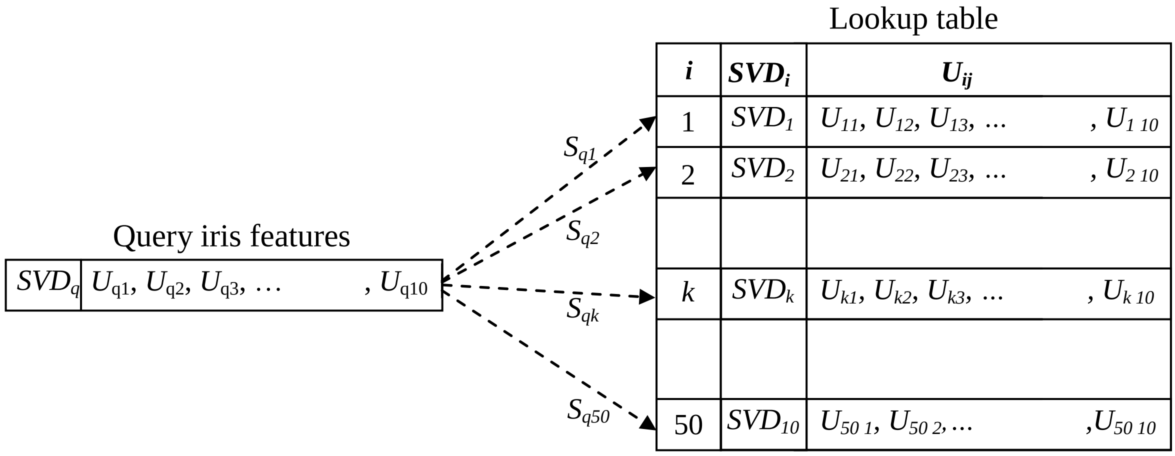


Figure (3.10) Similarity measuring between the query and fifty Lookup table.

Second Operation

This operation aims to normalize the similarities (S_i) resulting from the comparison. The normalization is curried out by dividing each S_i by the summation of all the similarities as follows:

$$NS_i = \frac{S_i}{\sum_{i=1}^{N_S} S_i} \qquad \dots (3.8)$$

Using such way, all the similarities will share to unify the recognition decision, i.e. the sum of all the similarities will be 100%. This is useful in recognizing high similarity among others, since it surely will takes successful score above 50%. Also, it excluded the weak similarities (even that greater than 50% by small amount) by making its score less than 50%. Moreover, this operation useful to analyze the false/true of the rejection/acceptance rate, which is very important analysis in designing most of the authentication systems. The recognition decision is then made to be a text message (R) tells the serial number (or name) of closest iris sample found in the Lookup table, as follows:

R= Message ("the closest sample found in the database is of serial number), K, where K is the serial number of the iris sample that has greater NS. Algorithm (3.10) shows the pseudo code of recognition decision making.

Algorithm (3.10) Recognition Decision making.

```
Input:
    NoDoc   \\ number of documents.
    Lookup table   \\ 1-D structure array of two items; SVD and U.
Output:
    S   \\ 1-D array of the similarities between the query and iris samples.
    R   \\ Text message shows which (who) the iris (person) that the query
     iris belong to.
```

Procedure:

Set $S_1 \longleftarrow 0$

Set $w_1 \longleftarrow 0.5$

Set $w_2 \longleftarrow 0.5$

Set $S_3 \longleftarrow 0$

Loop i= 1 ***to*** NoDoc

Set $D_1(i) \longleftarrow$(Lookup_Table(i).SVD – Lookup_Table(NoDoc+1).SVD)^2

Set $S_1 \longleftarrow S_1+D_1(i)$

Set $S_2 \longleftarrow 0$

Loop for j= 1 ***to*** NoDoc

Set $D_2(i) \longleftarrow$ [Lookup_Table(i).U(j) – Lookup_Table((NoDoc+1) .U(j)]^2

Set S2 ⟵ S2+D2(i)

End loop

Set S(i) ⟵ 1-[(w1*D1(i) / S1) + (w2*D2(i) / S2)]

Set S3 ⟵ S3+S(i)

End loop

Set NS ⟵ S/S3

Set P ⟵ 1

Set Mx ⟵ NS(P)

Loop i= 2 ***to*** NoDoc

If NS(i) > Mx ***then***

Set Mx ⟵ NS(i)

Set P ⟵ i

End if

End loop

Set R ⟵ Message (The closest iris sample in the database to the query iris is of serial), P

CHAPTER TWO

SEMANTIC INDEXING BASED IRIS RECOGNITION

2.1 Introduction

Iris scan has been developing a recognition system capable of positively identifying and verifying the identity of individuals without physical contact or human intervention, such technology shows promise of overcoming previous shortcomings [Jam05].

Image processing techniques can be employed to extract the unique iris pattern from a digitized image of the eye, and encode it into a biometric template, which can be stored in a database. This biometric template contains an objective mathematical representation of the unique information stored in the iris, and allows comparisons to be made between templates [Mas03].

This chapter includes iris recognition system that can be used one of the two modes Identification and Verification, iris recognition approach, information retrieval, latent semantic indexing (LSI) and singular value decomposition (SVD).

2.2 Iris Recognition Systems

Iris recognition systems are essentially pattern recognition systems. They vary in complexity, capabilities, and performance, but all share several elements: they use acquisition devices such as cameras and scanning devices as shown in Figure (2.1) to capture images, and computer hardware and software to extract, encode, store, and compare the characteristics of acquired iris image. Because the process is automated, a decision-making is generally very fast, in most cases taking only a few seconds in real time [Enc09], [Jam05].

Figure (2.1) Iris Scanner [Jam05].

Iris recognition system is considered to be one of the most reliable systems with some of the lowest false rejection and false acceptance rates and so it is less intrusive [Azi09]. In fact, the operating probability of false identification by the Daugman algorithm can be of the order of 1 in 1010 compared with other biometric signatures. Such that, the iris is generally considered more stable and reliable for person authentication, which leads to attracted a lot of attention in the researches because of its uniqueness, stability and noninvasiveness that can provide a promising solution to security in the near future [Enc09].

Depending on the application, recognition systems can be used in one of two modes: ***verification*** or ***identification***. Verification is used to verify a person's identity, i.e. the goal is to accept or reject the given identity claim. Identification is used to establish a person's identity, i.e. to determine who a person is. Although biometric technologies measure different characteristics in substantially different ways, all biometric systems start with an enrollment stage followed by a matching stage that can use either verification or identification as Fig (2.2) shows [Rho04], [Way04]. In the following a brief description about each of the two modes:

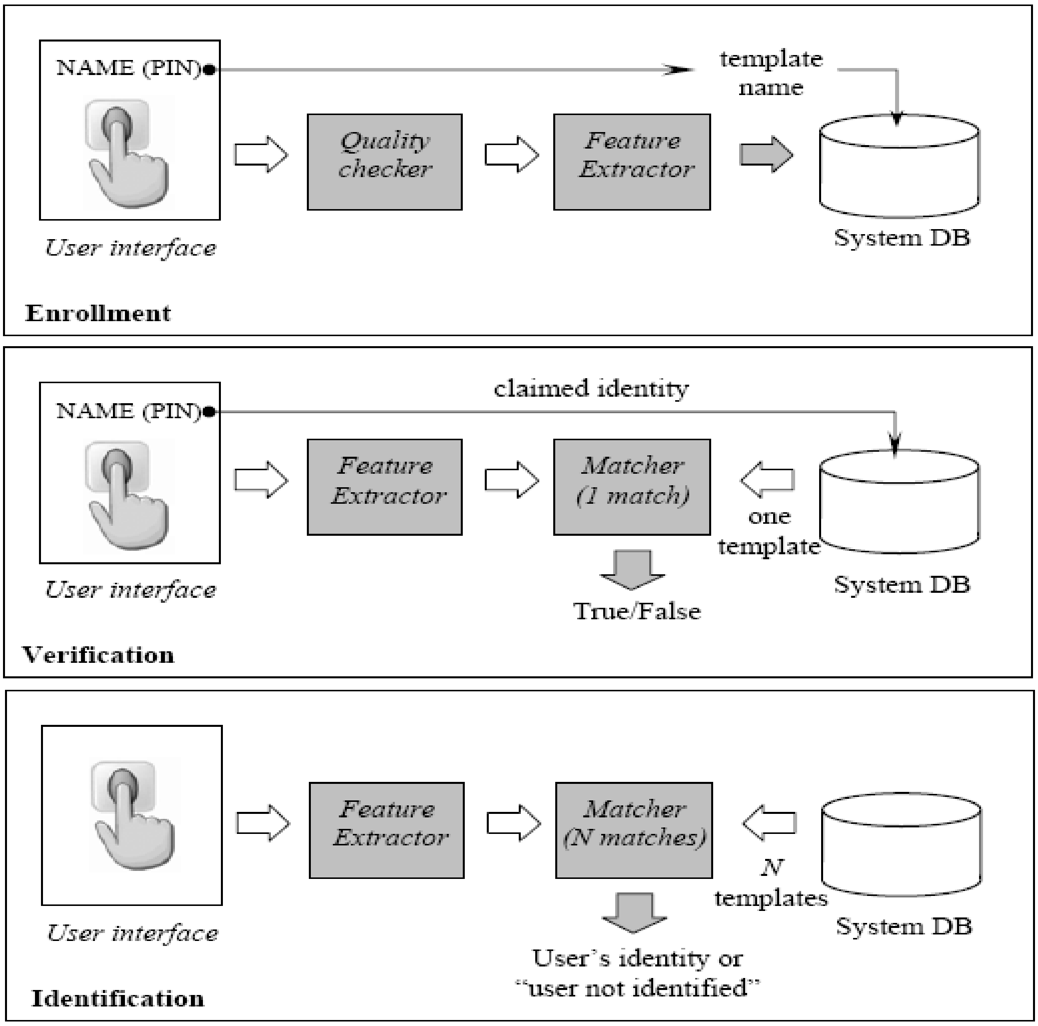


Figure (2.2) Generic recognition system [Way04].

2.2.1 Verification System

The verification is also called authentication, since the verification system requires employees to authenticate their claimed identities before granting them access to secure buildings or to computers. Such system captures the biometric material (e.g. iris) and generates a trial template that is based on the vendor's algorithm. Then, the system compares the trial biometric template with the reference one that stored in the system during enrollment to determine whether the person's trial and stored template are matched. The verification is often referred to as 1:1 (one-to-one) matching. Verification systems can contain databases ranging from dozens to millions of enrolled templates but are always predicated on matching an individual's presented biometric against his/her reference template. Nearly all verification systems can render a match/no-match decision in less than a second [Rho04].

2.2.2 Identification System

The identification system is used to identify who the person is. In such system a trail templates are previously estimated and stored in the database of the system. To find a match, the trial template is compared against the stored reference templates of all individuals enrolled in the system. Identification systems are referred to as 1:N (one-to-many) matching because an individual's biometric is compared against multiple biometric templates in the system's database [Rho04]. Identification systems require more computational power than verification systems, because more comparisons take place before a match occurs in some cases, millions of matches. In addition, there are more opportunities for an identification system to error, because many more matches must be conducted. Whereas, the verification systems are generally faster and more accurate than identification systems, since they need only match a person's data against his/her existing data. This requires less computing power and decreases the likelihood that the system will match an unauthorized user [Nan02].

2.3 Iris Recognition Approaches

A major approach for iris recognition is to generate feature vectors corresponding to individual iris image and to perform iris matching based on some distance metrics. Most of the commercial iris recognition systems implement a famous algorithm using iris codes proposed by Daugman [Jai09]. One of the difficult problems in feature-based iris recognition is that the matching performance is significantly influenced by many parameters in feature extraction process, which may vary depending on environmental factors of iris image acquisition. Given a set of test iris images, extensive parameter optimization is required to achieve higher recognition rate [Zha05].

Recent years have witnessed a phenomenal growth in image databases and retrieval systems. Information retrieval is a field of multimedia research that aims at extracting meaningful (semantic) media information directly from the pixel level. Features are usually represented as high-dimensional data vectors. Dissimilarity of media objects is measured as distance between feature vectors. The fundamental database problem of information retrieval is to establish the efficient storage of feature vectors in order to enable fast and flexible retrieval [Eid04]. Such systems use computationally cheap algorithms, enabling real time iris recognition, and allow adding knowledge of the real world to the recognition and retrieval engines [Isr04].

In general, various approaches of iris recognition are challenging because of the following reasons: The size and the quality of the iris images vary depending on the camera to-eye distance and the lighting condition. Moreover, the image of the entire iris is normally not available because of occlusion by the eyelid. Other noise factors such as eyelash and specular reflection are also introduced. Appropriate preprocessing techniques are necessary to localize and normalize the iris and to enhance the iris image. Suitable feature extraction and matching techniques are necessary to achieve high performance in a reliable iris recognition system [Sud09].

2.4 Information Retrieval

Information retrieval (IR) is important application, where the extracted information contributes to a more refined representation of documents and query. Information retrieval is concerned with making the information as accurately as possible, it is typically involves the querying of unstructured information such as images, which referring to well-defined metadata that are attached to the documents at the time of drafting [Fra06].

Information retrieval systems are based, either directly or indirectly, on models of the retrieval process. These retrieval models specify how representations of the documents and information needs should be compared in order to estimate the likelihood that a document will be judged relevant. The estimates of the relevance of documents to a given query are the basis for the document rankings that are now a familiar part of IR systems, [Amh02]. Within information retrieval research, information are usually indexed, retrieved, and organized on the basis of their concepts, a query searches for information that are "match" a concept, or information might be grouped by the concepts they cover. The research takes a different view, focusing on the semantic features that are described by the iris image rather than the broader concept it covers, [Amh02].

The numerical linear algebra is used as a basis for information retrieval in the retrieval strategy called latent semantic indexing (LSI) was used as an efficient tool for semantic analysis of large amount of text documents. The main reason is that more conventional retrieval strategies (such as vector space, probabilistic and extended Boolean) are not very efficient for real data, because they retrieve information solely on the basis of keywords and polysemy (words having multiple meanings) and synonymy (multiple words having the same meaning) are not well effectively matched. LSI can be viewed as a variant of the vector space model with a low-rank approximation of the original data matrix via numerical methods. Numerical experiments pointed out, that some kind of dimension reduction, which is applied to the original data brings to the information retrieval. The following two main advantages: automatic noise filtering, and naturally clustering of data with "similar" semantic. Such that, LSI can be successfully used for biometric identification via the iris recognition, as a tool for gene expression data analysis in the biology [Pra05].

2.5 Latent Semantic Indexing

Latent Semantic Indexing (LSI) is an advanced information retrieval (IR) technology that was developed by research scientists at Telcordia Technologies over ten years ago. LSI is a variant of the vector retrieval method that exploits dependencies or "semantic similarity" between terms. It is assumed that there exists some underlying or "latent" structure in the pattern of word usage across documents, and that this structure can be discovered statistically. One significant benefit of this approach is that, once a suitable reduced vector space is computed for a collection of documents, a query can retrieve documents similar in meaning or context, concepts but which share no words with it [Bas03].

Latent Semantic Indexing (LSI) is an information retrieval method that organizes information into a semantic structure that takes advantage of some of the implicit higher-order associations of words with text objects. The resulting structure reflects the major associative patterns in the data while ignoring some of the smaller variations that may be due to idiosyncrasies in the word usage of individual documents. This permits retrieval based on the "latent" semantic content of the documents rather than just on keyword matches [Fol90].

Latent Semantic Indexing takes advantage of the implicit higher-order structure of the association of terms with articles to create a multi-dimensional semantic structure of the information. Through the pattern of co-occurrences of words, LSI is able to infer the structure of relationships between articles and words. Singular-value decomposition (SVD) of the term by article association matrix is computed producing a reduced dimensionality matrix containing the best K orthogonal factors to approximate the original matrix as the model of "semantic" space for the collection. This semantic space reflects the major associative patterns in the data while ignoring some of smaller variations that may be due to idiosyncrasies in the word usage of individual documents. In this way, LSI produces a representation of the underlying "latent" semantic structure of the information. Retrieving information in LSI overcomes some of the problems of keyword matching by retrieval based on the higher level semantic structure rather than just the surface level word choice. Research on LSI shows that retrieval of relevant documents is significantly improved over keyword matching. [Fol90].

2.6 Singular Value Decomposition [Pre07]

There exists a very powerful set of techniques for dealing with sets of equations or matrices that are either singular or else numerically very close to singular. In many cases where Gaussian elimination and LU decomposition fail to give satisfactory results, this set of techniques, known as *singular value decomposition* (*SVD)*, will diagnose for you precisely what the problem is. In some cases, SVD will not only diagnose the problem, it will also solve it, in the sense of giving you a useful numerical answer, although, as we shall see, not necessarily "the" answer that you thought you should get. SVD is also the method of choice for solving most *linear least-squares* problems.

SVD methods are based on the following heorem of linear algebra, whose proof is beyond our scope: Any M×N matrix A can be written as the product of an M×N column-orthogonal matrix U, an N × N diagonal matrix W with positive or zero elements (the *singular values*), and the transpose of an N × N orthogonal matrix V. The various shapes of these matrices are clearer when shown as tableaus. If M >N (which corresponds to the over determined situation of more equations than unknowns), the decomposition looks like this:

$$\begin{pmatrix} \\ & \mathbf{A} & \\ \\ \end{pmatrix} = \begin{pmatrix} \\ & \mathbf{U} & \\ \\ \end{pmatrix} \cdot \begin{pmatrix} w_0 & & & \\ & w_1 & & \\ & & \cdots & \\ & & \cdots & \\ & & & w_{N-1} \end{pmatrix} \cdot \begin{pmatrix} & \mathbf{V}^T & \end{pmatrix} \quad \ldots..(2.1)$$

If M <N (the *undetermined* situation of fewer equations than unknowns), it looks like this:

$$\left(\quad A \quad \right) = \left(\quad U \quad \right) \cdot \begin{pmatrix} w_0 & & & \\ & w_1 & & \\ & & \cdots & \\ & & \cdots & \\ & & & w_{N-1} \end{pmatrix} \cdot \left(\quad V^T \quad \right) \quad \text{.....(2.2)}$$

The matrix V is orthogonal in the sense that its columns are orthonormal,

$$\sum_{j=0}^{N-1} V_{jk} V_{jn} = \delta_{kn} \qquad \begin{matrix} 0 \le k \le N-1 \\ 0 \le n \le N-1 \end{matrix} \qquad \text{.....(2.3)}$$

That is, $V^T.V = 1$. Since V is square, it is also row-orthonormal, $V. V^T = 1$. When M ×N, the matrix U is also column-orthogonal,

$$\sum_{i=0}^{M-1} U_{ik} U_{in} = \delta_{kn} \qquad \begin{matrix} 0 \le k \le N-1 \\ 0 \le n \le N-1 \end{matrix} \qquad \text{.....(2.4)}$$

That is, $U^T.U = 1$. In the case $M < N$, however, two things happen:

(i) The singular values wj for j =M,…, N -1 are all zero, and

(ii) The corresponding columns of U are also zero. then holds only for k, n ≤ M-1.

The decomposition (2.1) or (2.2) can always be done, no matter how singular the matrix is, and it is "almost" unique. That is to say, it is unique up to (i) making the same permutation of the columns of U, elements of W, and columns of V (or rows of V^T); or (ii) performing an orthogonal rotation on any set of columns of U and V whose corresponding elements of W happen to be exactly equal. (A special case is multiplying any column of U and the corresponding column of V by -1.) A consequence of the permutation freedom is that for the case M <N, a numerical algorithm for the decomposition need not return zero wj in the canonical positions j = M,…,N-1; the N - M zero singular values can be scattered among all positions j =0,1,…, N-1, and one needs to perform

a sort to get the canonical order. In any case, it is conventional to sort all the singular values into descending order.