Iris Recognition Using Semantic Indexing

Laith A. Al-Ani*[1], Mohammed Sahib Altaei[2], Ansam Ahmed Alwan[2]
[1]Department of Physics, College of Science, University of Al-Nahrain, Baghdad, Iraq
[2]Department of Computers, College of Science, University of Al-Nahrain, Baghdad, Iraq
mohamedaltaei@yahoo.com

Abstract

The iris of human eye is one of the most useful traits for biometric recognition. This paper presents an iris recognition system based on semantic indexing. The proposed system uses the concepts of latent semantic indexing (LSI) for iris recognition. One technique of LSI is the singular value decomposition (SVD). The SVD is an information retrieval uses numerical decomposition methods to compute one characteristic value (i.e. SVD) for each iris image to be used as a recognition feature. The proposed system consists of two phases: the training and recognition. The training phase is responsible on storing the iris models in the database, while the task of recognition phase is to compute the similarity measure between the SVD of the query iris image and SVDs of the iris images found in the database. The recognition decision is made according to the normalized similarities and appeared as a text message tells what the identity it is. The successful recognition rate was about 96%, which ensure the successful of the employed method and correct path of computations.

مطابقة هوية قزحية العين بأستخدام الفهرسة الدلالية

ليث عبد العزيز عباس العاني*[1]، محمد صاحب مهدي الطائي[2]، انسام أحمد علوان[2]
[1]جامعة النهرين، كلية العلوم، قسم الفيزياء، بغداد، العراق
[2]جامعة النهرين، كلية العلوم، قسم الحاسوب، بغداد، العراق
mohamedaltaei@yahoo.com

الخلاصة

القزحية هي واحدة من اكثر الميزات الحيوية المفيدة في التمييز. تم اقتراح نظام تمييزالقزحية في هذا البحث. المنظومة المقترحة تستخدم مفاهيم الفهرسة الكامنة الدلالية (LSI) لتمييز القزحية. ان تحليل القيمة المنفردة (SVD) هي احدى تقنيات LSI. وان SVD هي طريقة استعادة المعلومات التي تستخدم اساليب التحليل العددية لحساب قيمة مميزة واحدة (هي SVD) لكل صورة قزحية لاستخدامها كصفة تمييز. المنظومة المقترحة تتكون من طورين: التجميع والتمييز. طور التجميع يقوم بخزن نماذج القزحية في قاعدة البيانات, في حين ان مهمة طور التمييزهي حساب مقياس التشابه بين قيمة SVD لصورة القزحية المراد تمييزها مع قيم SVD لكل صور القزحية الموجودة في قاعدة البيانات. واعتمادا على مقادير التشابه المُعيرة يتم اتخاذ قرار التمييز، ويظهر قرار التمييز بشكل رسالة نصية تخبر عن هوية الشخص. كانت نسبة قرار التمييز الناجح حوالي 96% ، وهذا يؤكد نجاح اسلوب العمل وصحة مسار الحسابات.

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 [1]. 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 [2].
Dougman is pioneer how investigate the ability of the iris to verify the identity. He 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 sequence of multi-scale quadrature 2D Gabor wavelet coefficients, whose most-significant bits comprise a 256-byte "iris code" [3]. Daouk used 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 [4]. Masek presented an iris recognition method, the Log-Gabor filter 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 [5]. Dong suggested some restricting factors of iris image acquisition, which were analyzed and the optical formulas were derived. 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. [6]. Sudha presented that iris recognition is a potential tool in secure personal identification and authentication in view of properties such as uniqueness, a new approach based on the Hausdorff distance measure is proposed for iris recognition [7].
This paper presents newly proposed reliable method for iris recognition problem; such method uses the semantic indexing technique to establish person recognition system. Semantic features (SVD and U) were used to identify the enrolled irises, these feature were stored in the system to be used later in the recognition process. More details about the proposed method are explained in the following sections:

2. Proposed Iris Recognition Method

The used approach is a numerical method depends on finding set of solutions using set of input data; it input set of iris images. Each iris image pass through multi-stages, the first is iris localization stage aims at extracting just the iris segment from the image. This is carried out by newly suggested method, which determines the diameter and center of the iris. Next stage is iris documentation which includes encoding and then indexing the extracted iris. The generic structure of the proposed iris recognition method is shown in Figure (1). It is shown the proposed method is designed to be consisted of two phases: the training and recognition.

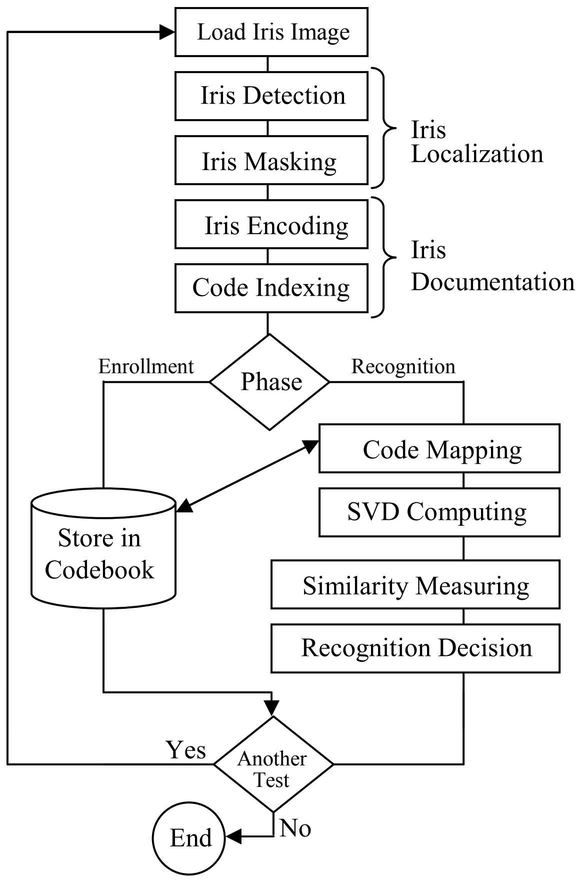

Figure 1- Block Diagram Shows The Proposed Iris Recognition Method.

The training is an offline phase in which the test irises are stored in a database file. Whereas the recognition is an online phase includes: iris mapping which attempt to estimate the semantic features SVD and U for all test images (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.

2.1 Iris Localization

It is a preprocessing stage, in which the iris is extracted from the eye image. The proposed method requires passing through three steps: Iris determination, pupil determination, and iris masking.

A- Iris Determination

The sclera appears at relatively more expanded bright region than other cues in the eye; it is shown as great as close the iris. The horizontal brightness distribution (HBD) of the eye image can be computed, HBD is a vector has a long 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.

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

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) shows.

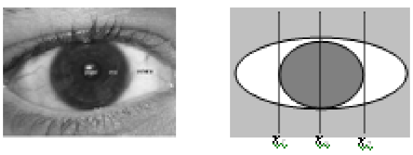

Figure 2- Human Eye Design.

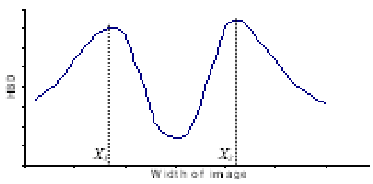

Figure 3- The HBD Behavior.

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 hori... he iris (x_o) as follows:

$$D = x_2 - x_1 \qquad \dots (2)$$

$$x_o = \frac{x_1 + x_2}{2} \qquad \dots (3)$$

One can use a vertical search with circular window of diameter D along the vertical line of the position xo 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.

B- 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 [8]. 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 3 pixels and centers are shifted by 1 pixel up and down the center of the central circle are computed as shown in Figure (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 4- The Four Circles Around The Central One Of The Pupil Detection.

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 any assumed color value that belong to the iris not pupil.

C- 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 2-D 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:

$$M(x,y)=\begin{cases}1 & \text{if } \sqrt{(x-x_o)^2+(y-y_o)^2} \le D/2 \\ 0 & \text{Otherwise}\end{cases} \quad \dots (4)$$

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

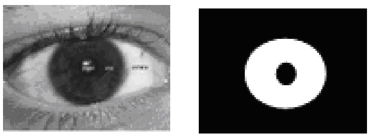

Figure 5- The Iris Mask.

2.2 Iris Documentation

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 as follows:

A- Iris Transformation

The Cartesian to polar reference transform should be authorized to be equivalent rectangular representation of the zone of interest as shown Figure (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.

Figure 6- Iris Rectangular Representation.

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:

$$x(\rho,\theta)=(1-\rho)x_p(\theta)+\rho\times x_i(\theta)$$
$$y(\rho,\theta)=(1-\rho)y_p(\theta)+\rho\times y_i(\theta) \quad \dots (5)$$

and,

$$x_p(\theta)=x_o(\theta)+R_p\cos(\theta)$$
$$y_p(\theta)=y_o(\theta)+R_p\sin(\theta) \quad \dots (6)$$

$$x_i(\theta)=x_o(\theta)+R_i\cos(\theta)$$
$$y_i(\theta)=y_o(\theta)+R_i\sin(\theta) \quad \dots (7)$$

Where Rp and Ri 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.

B- Iris Encoding

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 (7).

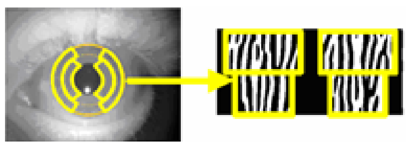

Figure 7- Iris Encoding.

C- Iris Code Indexing

The procedure of the indexing is carried out by arranging the iris codes as a sequence of samples, see Figure (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×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 ith term in the j^{th} sample document.

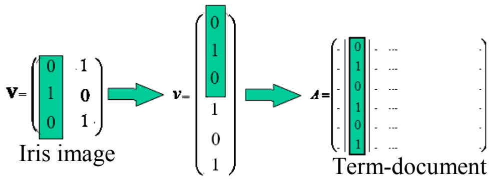

Figure 8- Iris Indexing.

The interest point in such arrangement is 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).

3. Training 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 of; 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 two store the number of documents, and the later is append one used to store the numbers of terms sequentially in each document. 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 wants 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 ones. The distinct stages are specified for making the recognition decision; these distinct stages of the recognition phase are explained in the following:

3.1 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 (9) shows.

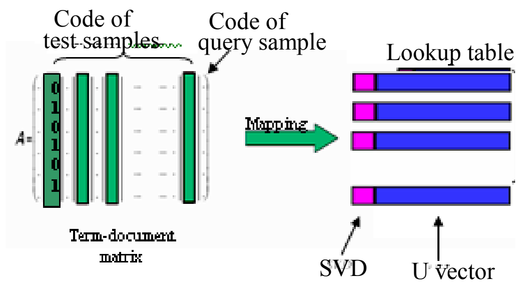

Figure 9- Mapping The Term-Document Matrix Into Semantic Features.

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 SVDs 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.

3.2 Recognition Decision Making

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:

$$S_i = 1 - \left[w_1 \frac{(SVD_i - SVD_q)^2}{\sum_{k=1}^{N_S} (SVD_k - SVD_q)^2} + w_2 \frac{\sum_{j=1}^{N_S} (U_{ij} - U_q)^2}{\sum_{k=1}^{N_S} \sum_{j=1}^{N_S} (U_{kj} - U_q)^2} \right] \quad \dots (7, \qquad (8)$$

here, 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, N_v 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 (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.

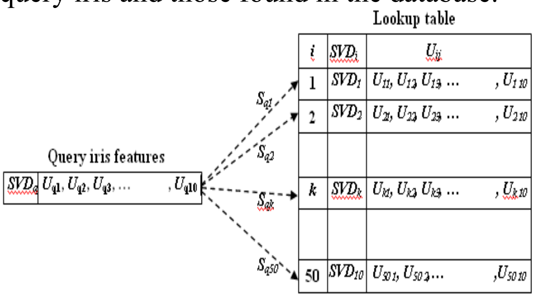

Figure 10- Similarity Matching Between The Query And Ten Lookup Table Irises.

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:

$$NS_i = \frac{S_i}{\sum_{j=1}^{N_S} S_j} \quad \dots (9)$$

4. Recognition Results

The results of the proposed iris recognition based on semantic features were 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. Figures (11 and 12) show the SVD values and U vector behaviors of iris samples in the codebook, while Figure (13) shows the recognition 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 iris recognition based on semantic features.

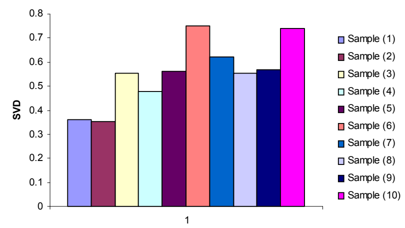

Figure 11- Resulted SVD Values.

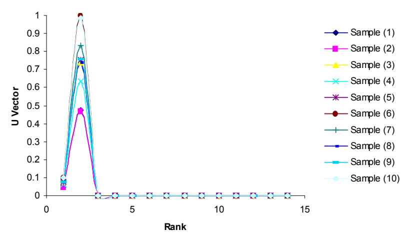

Figure 12- Resulted U vectors.

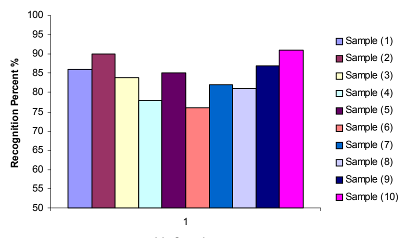

Figure 13- Recognition Results.

5. Results And Discussion

By noting the SVD values in Figure (11), 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.(8) are greatly depending on the second point in each U curve, i.e. the difference is computed by just one point not all points of the curve. Through out 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.8), and the second by using the U only (i.e. the second term of eq.8). The recognition results of such experiment were nearly identified in both cases, which refers to the behavioral weakness of the U for iris 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.(8).

The analytical consideration of SVD values in Figure (11) 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 models in the codebook to be more distinguished. The results improvement is a new modified SVD feature, i.e. instead of SVD, new feature based on SVD exponential fitting can be adopted. This feature is 100^{SVD} rather than SVD. This feature modification made the centroides to move away from each other and support the recognition results. Figure (14) shows the recognition results using the modified feature, it is shown that the average recognition percent became 96%, whereas it was 84% by using SVD. This enhancement in the recognition ensures the embedding ability of the SVD in the recognizing tasks.

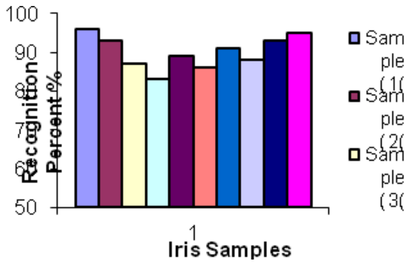

Figure 14- Recognition Results Using The Modified Method.

6. Conclusions

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 or U does not strength or weak the another. The use of U is not necessary when using SVD for the recognition purposes. Since the SVD values are fractions, the classes of different irises are found interfered slightly with each other. Such that, the use of the modified exponential feature as a function of SVD was found more descriptive than just SVD.

7. References

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