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Research Article

Design and Implementation of a PC–Based Iris-Authentication System

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Abstract: This project is the design of a system grants or denies ingress through a door. The door is supposed to always be electrically shut. In a nutshell, once a digital image of one person's eyes to be verified is captured using a special camera – the CCD camera, the feature extracting processing is carried out and minutiae are extracted and stored as a template for future verification process. Users will then, at a subsequent time, need to be verified. This is achieved by the user making available the eye to the administrator for capturing who in turn triggers the software button (via the PC) so as to extract the minutiae from the captured image. Lastly, a matching algorithm is applied to match these minutiae with the previously stored template. A fusion mechanism that amalgamates both a Canny Edge Detection scheme and a Circular Hough Transform is used to detect the iris' boundaries in the eye's digital image. The Haar wavelet transform was applied in order to extract the deterministic patterns in a user's iris in the form of a feature vector. By comparing the quantized vectors using the Hamming Distance operator, we determine finally whether two irises are similar. The entire system works exactly as described. The system views and designs were implemented using Matlab for its ease in image manipulation.
Keywords: Bilinear Transformation, Biometrics, Canny Operator, Haar Wavelet, Hough Transform, Iris Recognition..

INTRODUCTION

The purpose of 'Iris Recognition', a biometrics based technology for personal identification and verification, is to recognize a person from his/her iris prints. In fact, iris patterns are characterized by high level of stability and distinctiveness. "Each individual has a unique iris; the difference even exists between identical twins and between the left and right eye of the same person"[1].

Biometric systems offer great benefits with respect to other authentication techniques. In particular, they are often more user friendly and can guarantee the physical presence of the user. "Iris recognition is one of the most reliable biometric technologies in terms of identification and verification performance"[2]. The first use of iris recognition can trace back to the Paris prison in eighteenth century, where police discriminated criminal by inspecting their irises color.

We implemented 'Iris Recognition' using Matlab for its ease in image manipulation and Wavelet applications. The first step of the project consists of image acquisition. Then, the image size and 'type' are manipulated in order to be able to subsequently process them. Once the preprocessing step is achieved, it is necessary to localize the iris and unwrap it. At this stage, we can extract the texture of the iris using Haar Wavelets. We compare the coded image with the already coded iris in order to find a match or detect an imposter. Finally, the user is granted or denied ingress through a door.

IMPLEMENTATION

Image acquisition

Image acquisition is considered the most critical step in our project since all subsequent stages depend highly on the image quality. In order to accomplish this, a CCD camera was used, the resolution set to 640x480 pixels, the 'type' of the image to 'jpeg', and the 'mode' to white and black for greater details. Furthermore, we took the eye images while trying to maintain appropriate settings such as lighting and distance to camera.

Image manipulation

In the preprocessing stage, we transformed the images from RGB to gray level and from eight-bit to double precision thus facilitating the manipulation of the images in subsequent steps.

Iris localization

Before performing iris pattern matching, the boundaries of the iris should be located. In other words, it is necessary to "detect the part of the image that extends from inside the limbus (the border between the sclera and the iris) to the outside of the pupil" [1]. This is done by determining the outer edge by first downsampling the images by a factor of 4, to enable a faster processing delay, using a Gaussian Pyramid. The Canny operator was applied with the default threshold value given by Matlab, to obtain the gradient image. Next, we apply a Circular summation which consists of summing the intensities over all circles, by using three nested loops to pass over all possible radii and center coordinates. The circle with the biggest radius and highest summation corresponds to the outer boundary. The center and radius of the iris in the original image are determined by rescaling the obtained results.

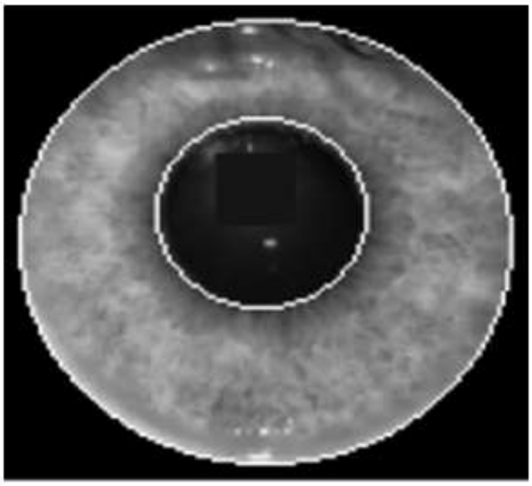

Fig-1: Localization of iris

After having located the outer edge, we next need to find the inner one which is difficult because it is not quite discernable by the Canny operator especially for dark-eyed people. Therefore, after detecting the outer boundary, we test the intensity of the pixels within the iris. Depending on this intensity, the threshold of the Canny is chosen. If the iris is dark, a low threshold is used to enable the Canny operator mark out the inner circle separating the iris from the pupil. If the iris is light colored, such as blue or green, then a higher threshold is utilized. "The pupil center is shifted by up to 15% from the center of the iris and its radius is not greater than 0.8 or lower than 0.1 of the radius of the iris"[3]. This means that processing time, dedicated to the search of the center of the pupil of this part is relatively small. Hence, instead of searching a downsample version of the iris, we searched the original one to gain maximum accuracy. Thus we have determined the boundaries of the iris as shown in Figure 1 and we can then manipulate this zone to characterize each eye.

Mapping

After determining the limits of the iris in the previous phase, the iris should be isolated and stored in a separate image. The factors that we should watch out for are the possibility of the pupil dilating and appearing of different size in different images. For this purpose, we begin by changing our coordinate system by unwrapping the lower part of the iris (lower 180 degrees) and mapping all the points within the boundary of the iris into their polar equivalent (Figures 2 & 3). The size of the mapped image is fixed (100x402 pixels) which means that we are taking an equal amount of points at every angle. Therefore, if the pupil dilates the same points will be picked up and mapped again which makes our mapping process stretch invariant. When unwrapping the image, we make use of the bilinear transformation to obtain the intensities of the points in the new image. "The intensities at each pixel in the new image are the result of the interpolation of the grayscales in the old image"[4].

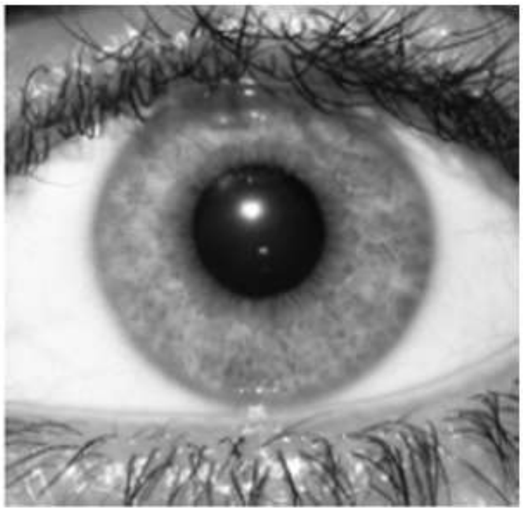

Fig- 2: Original image

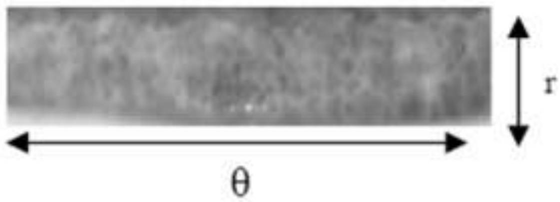

Figure 3: Iris isolated image

Feature extraction

"One of the most interesting aspects of the world is that it can be considered to be made up of patterns. A pattern is essentially an arrangement. It is characterized by the order of the elements of which it is made, rather than by the intrinsic nature of these elements"[4]. This definition summarizes our purpose in this part. In fact, this step is responsible of extracting the patterns of the iris taking into account the correlation between adjacent pixels. After performing lots of research and analysis about this topic, we decided to use wavelets transform, and more specifically the "Haar Transform". The Haar wavelet is illustrated in Figure 4.

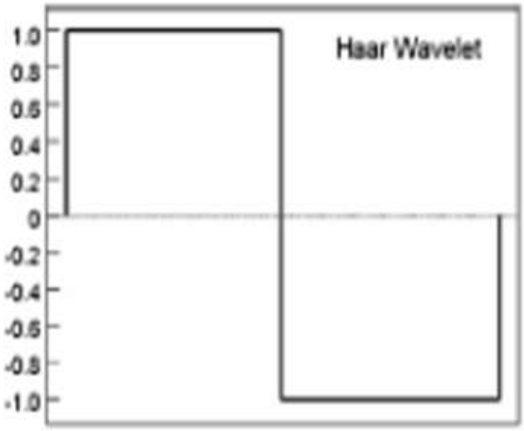

Fig-4: Haar Wavelet

Haar Wavelets

Most previous implementations have made use of Gabor wavelets to extract the iris patterns. But, since we are very keen on keeping our total computation time as low as possible, we decided that building a neural network especially for this task would be too time consuming and selecting another wavelet would be more appropriate.

A 5-level wavelet tree showing all detail and approximation coefficients of one mapped image is obtained from the mapping part. The mapped image is of size 100x402 pixels and can be decomposed using the Haar wavelet into a maximum of five levels. These levels are $cD1^h$ to $cD5^h$ (horizontal coefficients), $cD1^v$ to $cD1^v$ (vertical coefficients), $cD1^d$ to $cD1^d$ (diagonal coefficients).

We must now pick up the coefficients that represent the core of the iris pattern. Therefore those that reveal redundant information should be eliminated. In fact, looking closely at Figure 5 it is obvious that the patterns in $cD1^h$, $cD2^h$, $cD3^h$, $cD4^h$ are almost the same and only one can be chosen to reduce redundancy.

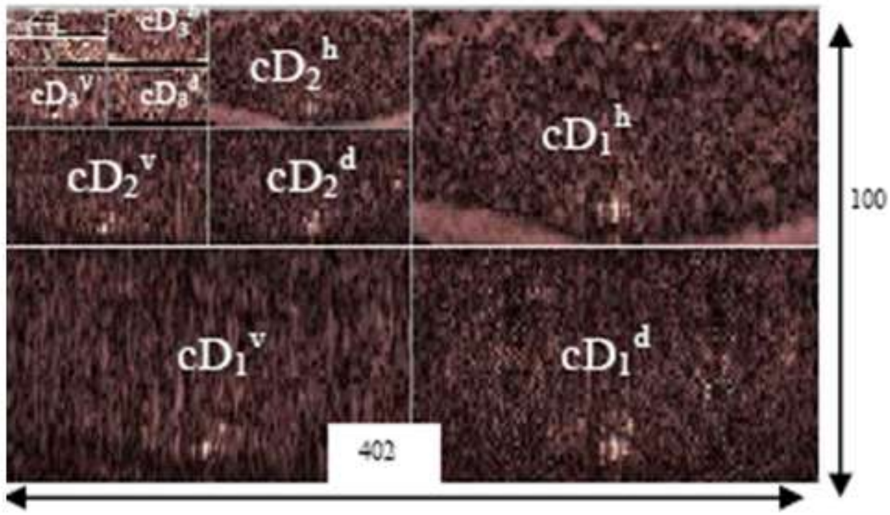

Figure 5: Diagram for organizing a feature vector

Since $cD4^h$ repeats the same patterns as the previous horizontal detail levels and it is the smallest in size, then we can take it as a representative of all the information the four levels carry. The fifth level does not contain the same textures and should be selected as a whole. In a similar fashion, only the fourth and fifth vertical and diagonal coefficients can be taken to express the characteristic patterns in the iris-mapped image. Thus we can represent each image applied to the Haar wavelet as the combination of six matrices:

- $_{cD}4^h$and $cD5^h$
- $_{cD}4^v$and $cD5^v$
- $_{cD}4^d$and cD_5^d

"All these matrices are combined to build one single vector characterizing the iris patterns. This vector is called the feature vector" [5]. Since all the mapped images have a fixed size of 100x402, then all images will have a fixed feature vector. In our case, this vector has a size of 702 elements. This means that it has been a success in reducing the feature vector of Daugman who uses a vector of 1024 elements [6]. This difference can be explained by the fact that he always maps the whole iris even if some part is occluded by the eyelashes, while we map only the lower part of the iris obtaining almost half his feature vector's size.

Binary Coding Scheme

It is very important to represent the obtained vector in a binary code because it is easier to find the difference between two binary code-words than between two number vectors. In fact, Boolean vectors are always easier to compare and to manipulate. In order to code the feature vector we first observed some of its characteristics. We found that all the vectors that we obtained have a maximum value that is greater than 0 and a minimum value that is less than 0. Moreover, the mean of all vectors varied slightly between -0.08 and -0.007 while the standard variation ranged between 0.35 and 0.5. If “Coef” is the feature vector of an image than the following quantization scheme converts it to its equivalent code-word:

$$\left.\begin{array}{l}\cdot \text{ If Coef(i) >= 0 then Coef(i) =1} \\ \cdot \text{ If Coef(i) < 0 then Coef(i) = 0}\end{array}\right\} \text{-------------------eq-1}$$

The next step is to compare two code-words to find out if they represent the same person or not.

Test of statistical independence

This test enables the comparison of two iris patterns. “This test is based on the idea that the greater the Hamming distance between two feature vectors, the greater the difference between them. Two irises are determined whether from the same class by comparing the similarity between their corresponding feature vectors”[3]. Inspired by the matching scheme of Daugman, the binary Hamming distance is used as metrics.

Similar irises will fail this test since the distance between them will be small. In fact, any two different irises are statistically “guaranteed” to pass this test as already proven. The Hamming distance (HD) between two Boolean vectors is defined as follows:

$$HD = \frac{1}{N}\sum_{j=1}^{N} C_A(j) \oplus C_B(j) \quad \text{----------eq-2}$$

“Where, $C_A$and C_B are the coefficients of two iris images and N is the size of the feature vector (in our case N = 702). The □ is the known Boolean operator that gives a binary ‘1’ if the bits at position j in C_A and C_B are different and ‘0’ if they are similar”[3].

John Daugman, the pioneer in iris recognition conducted his tests on a very large number of iris patterns (up to 3 million iris images) and deduced that “the maximum Hamming distance that exists between two irises belonging to the same person is 0.32”[3]. Thus, when comparing two iris images, their corresponding binary feature vectors are passed to a function responsible for calculating the Hamming distance between the two. The decision of whether these two images belong to the same person depends upon the following result:

· If HD <= 0.32 decide that it is same person
· If HD > 0.32 decide that it is different person
(or left and right eyes of the same person)

RESULTS AND PERFORMANCE

We tested our project on CASIA Iris Image Database, using a Pentium M processor, and we obtained an average of correct recognition of 93%. Table 1 gives the efficiency of each part of the system. The main reason for the failures we encountered is due to the quality of the images. Some of these problems are bad lighting, occlusion by eyelids, noises or inappropriate eye positioning.

Table-1:Efficiencies of the different parts

	Edge Detection	Mapping	Feature Extraction	Binary Code Generation
Efficiency %	73	70	73	75

SYSTEM HARDWARE IMPLEMENTATION

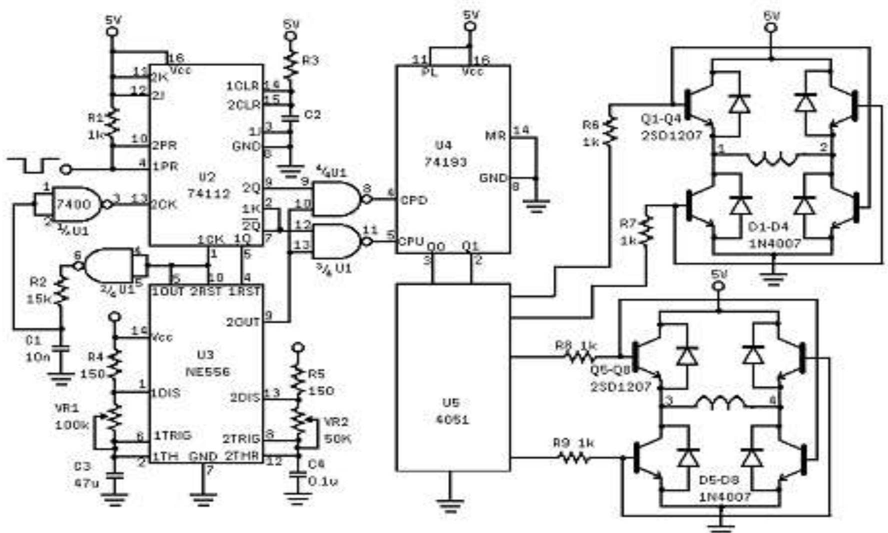

Fig-4 Circuit Diagram of Stepping Motor Controller

The system hardware circuit is shown in figure 4.

Door Control Unit

The door access control circuitry refers to the hardware components used for locking or unlocking of the door[7]. The door access control unit has two parts:

- The door lock circuit.
- The parallel port interface circuit

The interface circuit responds to the application software's request for lock/release. It generates an actuating signal which drives a stepper motor lock setup. The circuit could also be interfaced using a practical USB device interfacing system [8].

Door Lock Unit

Using basic standard logic, a stepper motor control circuitry was designed. The circuitry was designed to use the stepper motor to open a door, leave it open, and close it after three seconds have elapsed. In addition to this it takes the motor three seconds to open the door and another three seconds to close it.

CONCLUSION

Iris-based authentication is not an end in itself. It is usually incorporated into a broader system to affect security policies with respect to access control. Consequently, contemporary research in iris-based authentication can coarsely be divided into two categories. The first is the '**Iris Pattern Recognition'** – which studies and implements algorithm and more accurate extraction and matching of iris templates and the second being 'Iris Biometrics Integration ' – which makes inquest into possib;e areas of iris biometric applications by discovering and harnessing new ways of seamlessly integrating iris-based authentication into various usage environment.

At the very apex of these efforts is the desire to create viable solutions for the end user(s). In consonance with this prime and all encompassing objective, we set out with the design and implementation of a physical access control system, incorporating iris-based authentication. This work comprises iris image acquisition, iris processing algorithms, database storage and utility, authentication application development, and access control hardware actuation (the modules, interfaces, and alternatives). To achieve this, however, we had to embark on intense research for the sake of proficiency building.

From all indications, the future of authentication lies with biometrics. We therefore consider it an honour to have undertaken the department's and by and large, the University's first foray into this field.

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