Fingerprint and Iris Identification Method Based on the Hough Transform[1]

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Abstract. This paper presents an application of the Hough Transform to fingerprint and iris identification within computer vision systems. The presented method is based on the Hough Transform for irregular objects, with a parameter space defined by translation, rotation and scaling operations. The technique may be used in an identification system or for image analysis, directly on grey-level or colour images.

1. Introduction to the problem

At present around the world identification signatures: face image, fingerprint, voice print or iris pattern, and other physical characteristics are commonly used. These characteristics are measured with sophisticated equipment using sensors, then digitised and stored in computer databases for reference. The person's identity may be later verified by digitally measuring the selected biological factor and comparing it to the reference template. This technique is called biometrics [14].

Biometrics identification is commonly in use for example at banks, airports, and government agencies. Face recognition uses video cameras to match a person's face with a stored image. The image of the face is digitised, analysed and compared to a picture taken previously and stored in the database or an ID card. Present day techniques of fingerprint or iris analysis require less than second [31],[32]. The new biometric technologies can be stealthy so that people will not even know it is happening.

This paper presents a fingerprint and iris identification method based on the Hough Transform with a parameter space defined by translation and rotation operations for irregular

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objects. The problem of complex pattern detection in an image is converted into one that searches for local maximum in a parameter space. A fundamental element of this method is the generalised Hough Transform for grey-level and colour images.

In a computer vision system the identification of fingerprints and irises takes part using previously learned patterns. In the proposed method the process of pattern learning is executed in a way that may be presented in the form of an algorithm. The task to identify a pattern M in an image B may be regarded as determining parameters (w, k, α), which uniquely describes its location (w, k) and orientation α in the given image.

The Hough Transform has many positive virtues, which other methods used for image segmentation do not have. Each point of the image is considered independently. Therefore, the method may be executed using simultaneous calculations on multi-processor systems. This is why the Hough Transform is appropriate for real time systems. Partly deformed objects are also detectable. This results from the fact that the value of a given accumulator unit is determined by a number of image points consistent with the pattern. The method is insensitive to image interference. This turns out to be useful for segmentation of low quality images, which is possibly the single most important feature of the Hough Transform. It is also possible to detect many segments (within the same pattern class) in one image since each of them generates separate local maximum or a group of them in the accumulator.

2. Basic definitions

Let us define binary **digital images**, i.e. images, which are formed with sets of points, which by convention are either black or white. Such binary images may be represented with the following function [20]:

$$B : D \to \{0,1\}, \quad \text{where} \qquad D = [1,...,W] \times [1,...,K] \subset N^2. \tag{1}$$

Hence, we may consider a digital image as a matrix with row and column indices identifying a point in the image.

Given an image B, we can define an **object** $b(B)$ as follows:

$$b(B) = \{(x, y) \in D : B(x, y) = 1\}. \tag{2}$$

An **image with 256 grey levels** means a set of points, which have a value or "shade" from the set $\{0,...,255\}$. Such an image may be presented as:

$$B_G : D \rightarrow \{0,...,255\}, \quad \text{where:} \quad D = [1,...,W] \times [1,...,K] \subset N^2. \tag{3}$$

Object $b(B_G)$ in image B_G means any fragment of that image which may be recorded in terms of

$$Q_G : D_Q \rightarrow \{0,\ldots,255\}, \quad \text{where:} \quad D_Q \subset D = [1,...,W] \times [1,...,K] \subset N^2. \tag{4}$$

Pattern M_W defines an image (square matrix) of size $N_W \times N_W$ which is

$$M_W : D_W \rightarrow \{0,...,255\}, \quad \text{where:} \quad D_W = [1,..., N_W] \times [1,..., N_W] \subset N^2. \tag{5}$$

3. Introduction to the Hough Transform

The Hough Transform is based on a representation of the image B into the accumulator array A, which is defined as follows:

$$A : P \rightarrow N, \quad \text{where} \quad P = P_1 \times P_2 \times \cdots \times P_p. \tag{6}$$

The symbol $P_i \subset N$ determines the range of i-parameters of a p-dimensional space P. Determining array A is conducted through the calculation of partial values for points of an object $b(B)$ and adding them to the previous ones, which constitutes a process of accumulation.

The basic application of the Hough Transform concerns detecting straight lines [29]. The following equation of a straight line must be considered:

$$\rho = x\cos(\alpha) + y\sin(\alpha). \tag{7}$$

This task of detecting a straight line is reduced to setting a pair of parameters (ρ, α), which uniquely describes the line on the plane.

Thus, the space of parameters P is defined in the following way ($\rightarrow$ 6):

$$P = P_1 \times P_2, \tag{8}$$

where:

$$P_1 = [-v, v], \quad P_2 = [0, l), \quad (\rho \in P_1, \alpha \in P_2). \tag{9}$$

The symbols v and l denote the range of permissible values of parameters ρ and α ($l = 180$ is often assumed). Value v results from the dimensions X, Y of the examined image, value l and equation (7).

Figure 1 shows an example of image B that includes a number of points. It shows array A corresponding to this image which is the result of applying the Hough Transform.

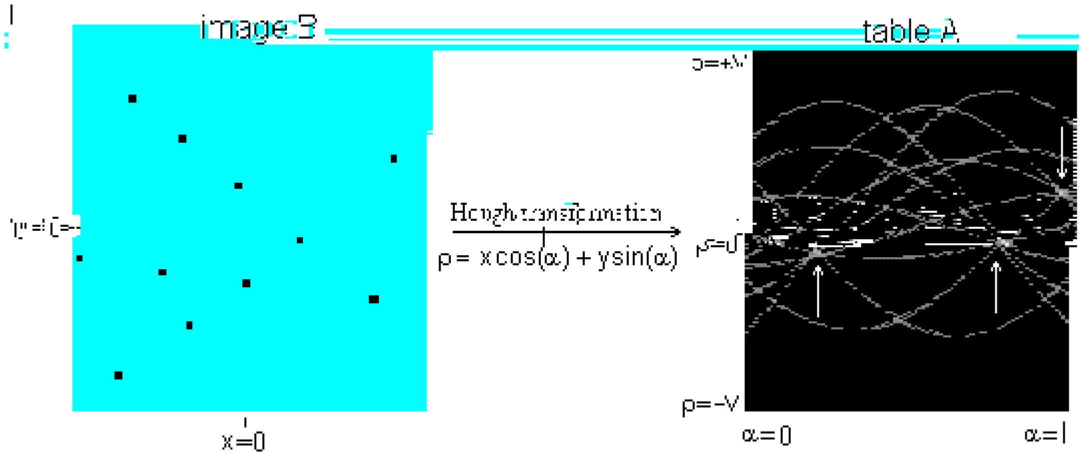

Figure 1. Image B and accumulator array A obtained from computing the Hough Transform

There are characteristic sinusoidal curves ($\rho = \frac{y}{\cos(\gamma)}\sin(\alpha+\gamma)$, where $tg(\gamma) = \frac{x}{y}$), in array A generated by object points in image B. The equivalent of any curved line within the parameter space is a number of straight lines end in a point (x, y) of object $b(B)$ in image B.

The value of any element $A(\rho, \alpha)$ in the obtained array represents a number of pixels of image B lying along a straight line defined by parameters (ρ, α). Three characteristic elements (local maxima), which correspond to three straight lines from points in image B, are indicated (by arrows) in array A. The straight lines obtained represent the searched segments of image B.

Initially, this method was quoted in the literature (for the first time by Rosenfeld [33]) and used to detect straight lines. However, in 1972 Duda and Hart [9] made the first step towards its application to analytic curves. The Hough Transform was then introduced to solve many new problems, as numerical methods became feasible, and has found wide applications in many aspects of Computer Vision [21].

The Hough Transform currently has a variety of methods that have evolved. They are: the Fast Hough Transform [23], the Probabilistic Hough Transform [19], the Randomised Hough Transform [34], the Hierarchical Hough Transform [24], the Fuzzy Hough Transform [10] and the Multiresolution Hough Transform [2].

The most common theoretical problems are detection of straight lines [25],[36], curves [28], arcs [18],[30], polygons [7], circles [35],[37] and ellipses [22]. It is also possible to apply the Hough Transform to three-dimensional images.

4. The Hough Transform for irregular objects

The Hough Transform may be successfully applied to detect irregular objects [3], [13]. In the generalised Hough Transform, an object is represented by a pattern, which is a list of boundary points $\{(x_i, y_i): i = 1,...,n\}$ (without a concrete analytical description), and the parameter space is defined for translation $[x_T, y_T]$, rotation α and (alternatively) scale s of the pattern in the image.

The Hough Transform $H(x_T, y_T, \alpha)$ for a grey-level image $B_G(x, y)$ (equation 3) in the process of identification of pattern M_W (equation 5) is given by

$$H(x_T, y_T, \alpha) = \sum_{(x_i, y_i) \in M_W} h(x_i, y_i, x_T, y_T, \alpha), \tag{10}$$

where

$$h(x_i, y_i, x_T, y_T, \alpha) = 255 - \left| B_G(x_i', y_i') - M_W(x_i, y_i) \right|, \tag{11}$$

provided that values x_i', y_j' are calculated with the following formulas:

$$\begin{cases} x_i' = x_r + (x_i - x_r)\cos(\alpha) - (y_i - y_r)\sin(\alpha) + x_T \\ y_i' = y_r + (x_i - x_r)\sin(\alpha) + (y_i - y_r)\cos(\alpha) + y_T \end{cases}. \tag{12}$$

The above formulas reflect the situation illustrated in Figure 2.

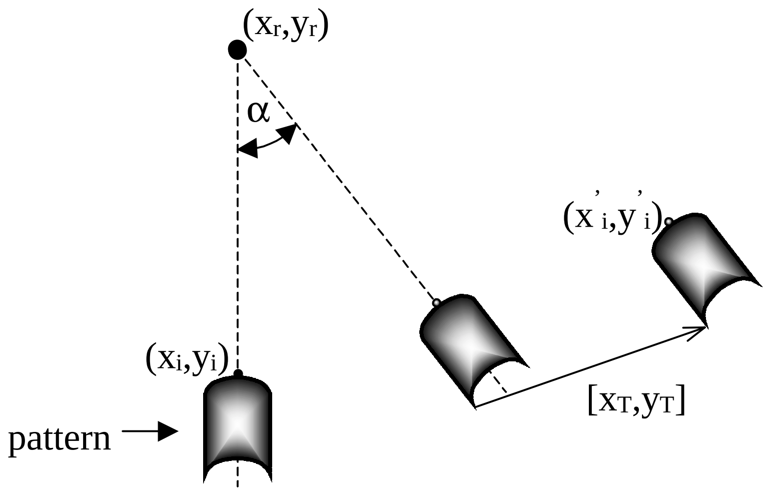

Figure 2. Rotation and translation of the pattern in relation to an arbitrary point (x_r, y_r)

As the above formulas show, the implementation of this definition of the Hough Transform enables us to apply the method directly to grey-level images. This process is illustrated in Figure 3.

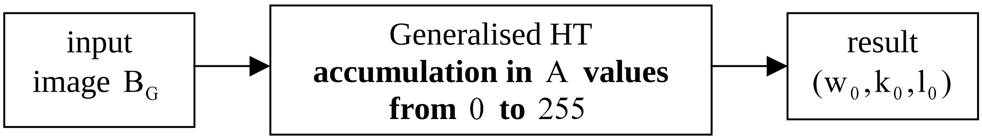

Figure 3. The Hough Transform for grey-level images

Figure 4 shows the initial image, identified patterns and content of accumulator (for the best angle of pattern rotation) and the effect of the identification (denoted by a circle in the initial image).

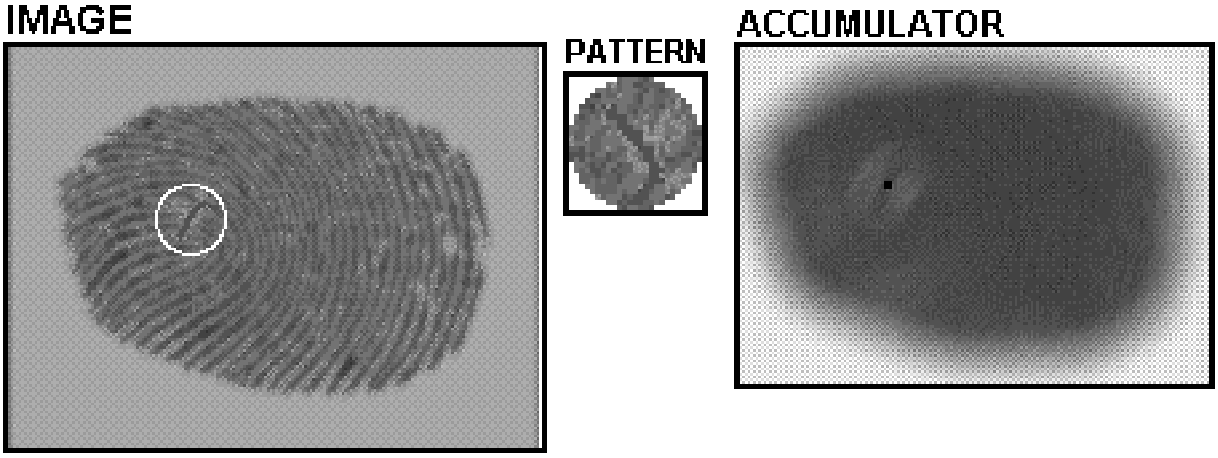

Figure 4. Identification of part of a fingerprint

Application of the histogram function

The histogram function is an obvious characteristic of the pattern that is invariant under rotation. The histogram study is introduced into the previous scheme (Figure 3) as shown in Figure 5. The histogram of pattern M_W is determined once only and compared with the histograms of fragments of image B_G, determined at all possible locations of the pattern M_W.

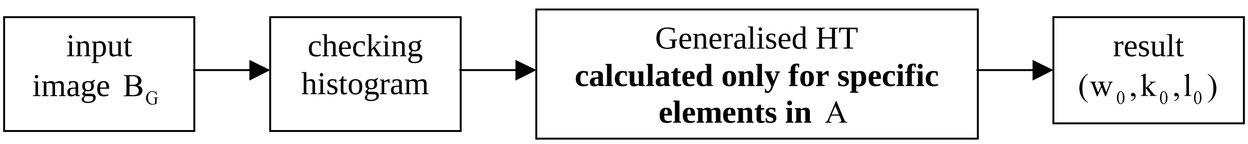

Figure 5. Pattern localisation process taking into consideration a histogram study

In the computer implementation we calculate the histogram for the pattern and then compare it with the histograms of fragments and “mark” (write down the value of -1 or 0) it in the accumulator (e.g. value -1 means there is no need to calculate the transform for this unit).

This simple method reduces the complexity in terms of the calculation performed for the whole process. The example below shows the gains made in this way. White areas are not calculated (more than 50%).

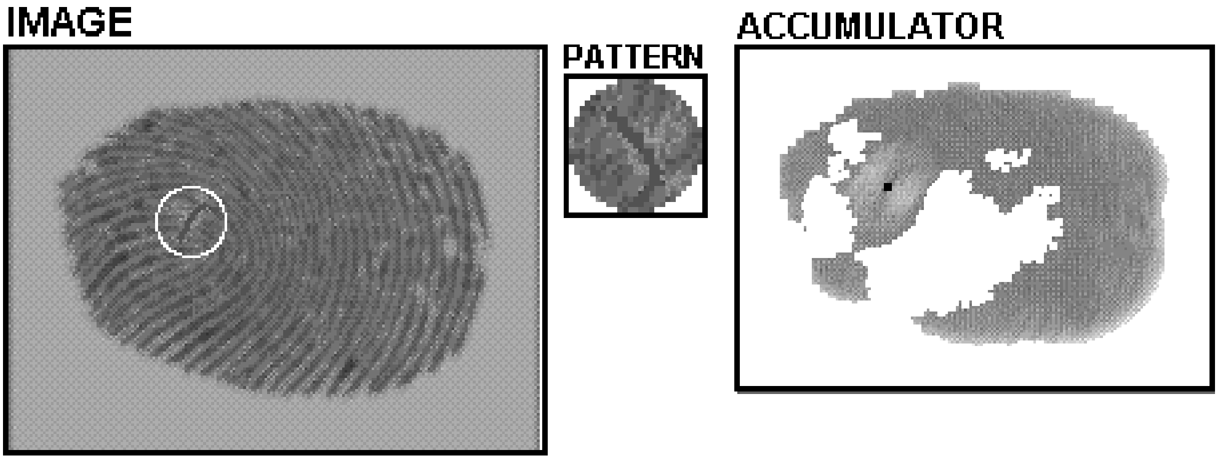

Figure 6. Identification of a fingerprint fragment (→ Figure 4)

5. Fingerprint identification method based on the Hough Transform

The biometric technologies require that a computer has a record of a face, fingerprint, iris or voice. Fingerprint scans translate the finger's unique ridge patterns to a digital code. The question arises - what actually makes a fingerprint unique? The distinct pattern of any fingerprint consists of ridges (raised part of skin) and furrows (lower part of skin). Most unique and individual for a given fingerprint is the set of features or characteristics called 'minutiae'. This set of small details carries information about terminations or bifurcations of the fingerprint ridges for example. Also the manner in which the ridges flow is very distinctive. The graphical representation of the most important characteristics is shown in Figure 7.

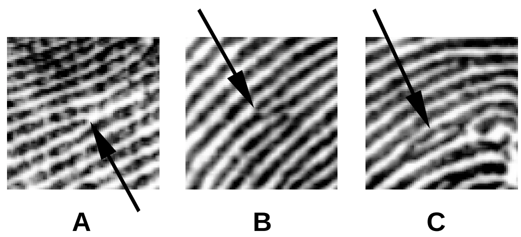

Figure 7. Minutiae examples (A – Ridge Ending, B – Bifurcation, C – Enclosure)

All fingerprints can be additionally classified into categories based on their major central patterns [16]. These patterns include the arch, tented arch, loop (left or right), twin loop, and whorl, which are shown in Figure 8.

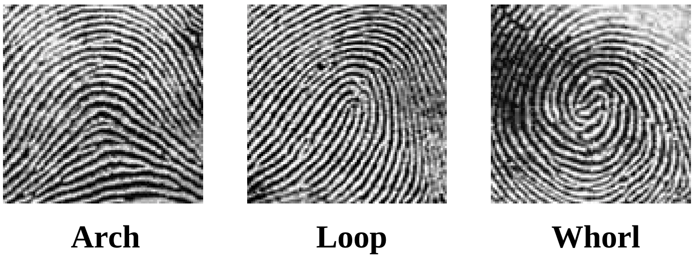

Figure 8. Three essential fingerprint classifiers [5]

The task of fingerprint identification is made difficult by obstacles, for example unknown rotation angle, missing areas, image defects or displacement. Also a slight scaling problem may occur if the fingerprint pattern was recorded at a young age. The proposed fingerprint identification method is based on the Hough Transform and it enables us to identify a fingerprint even if the scanned image is of poor quality or information about rotation angle is unknown.

The assumption of this method is that there is information stored in the database about three different characteristic regions of a fingerprint (3 patterns) and their distances (3 numbers). The identification result is positive if all three patterns and their distances are matched in respect to required threshold.

The method has been tested on several images and patterns. Some results are shown below. The figures 9 and 10 show scanned initial images, identified three patterns, contents of accumulators obtained for patterns (for the best angle of the pattern rotation), and the effect of the identification (pointed by circles in the scanned image). It is necessary to remark that information about angle rotation for the patterns was not given.

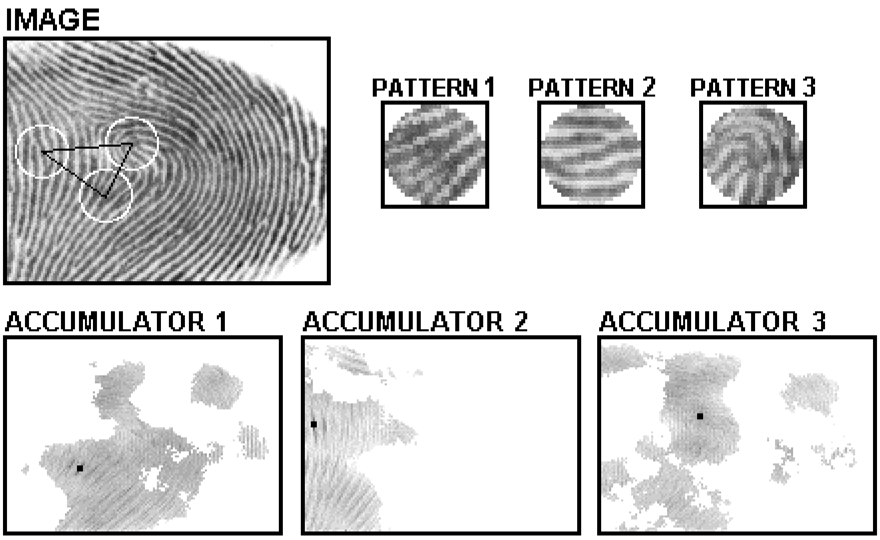

Figure 9. Fingerprint identification results (the gains made by histogram checking is notable)

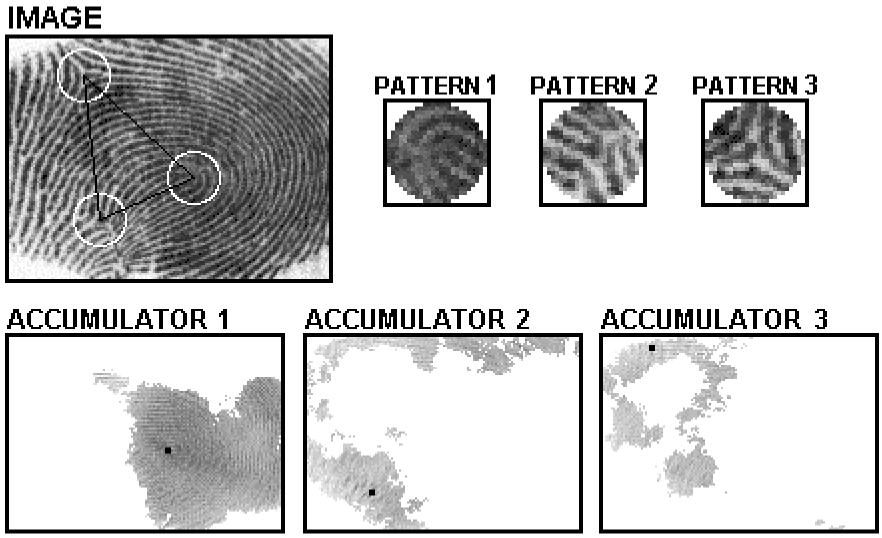

Figure 10. Fingerprint identification results (image has been scanned with 20% normal noise)

6. Iris identification method based on the Hough Transform

Using an analogy to the method for fingerprint identification it is possible to use Hough's technique in the case of iris identification (even though the structure of iris pattern is more unique than structure of fingerprint). To obtain this aim we need to make a similar assumption that there is information stored in the database for three different characteristic regions of an iris (3 patterns) and their distances (3 numbers). Additional assumption relates to scanning process. It is strongly recommended to scan irises with the same environment conditions, otherwise patterns may not match to irises due to eye reactions from light. The identification decision is based on the same rule as previously described (patterns are matched in respect to required threshold and their distances).

Some results for this elaborated method are shown below. Figures 11 and 12 show scanned irises, three identified patterns, contents of accumulators obtained for patterns (for the best angle of the pattern rotation), and the effect of the identification (indicated by circles in the scanned image).

It is necessary to remark that the problem of iris image rotation is less intensive than in the case of fingerprint identification (the reason is obvious). Colours of irises make additional advantage. It is possible to use this property in the purpose of preliminary classification. The modification of the Hough Transform in this way allows this technique to be used directly on colour images. It can be calculated the modifying Equation (11).

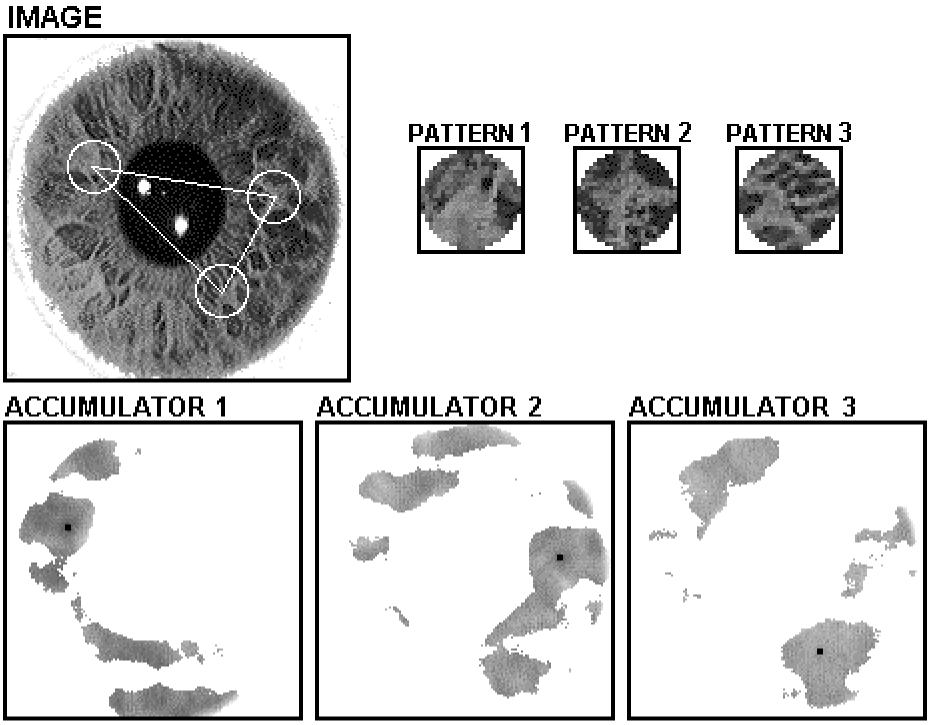

Figure 11. Iris identification results (input image without noise)

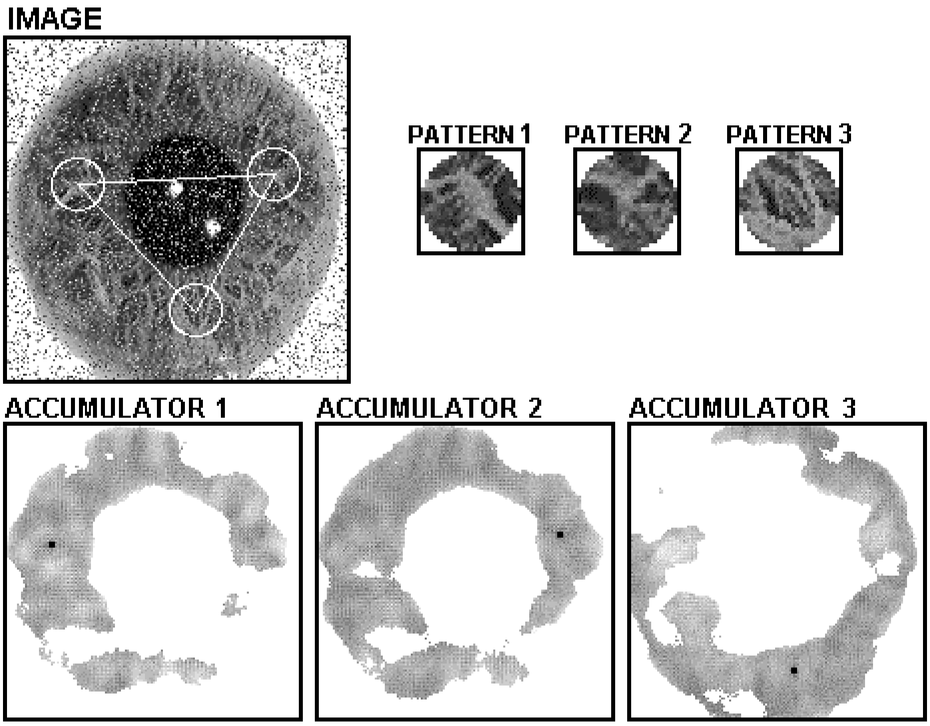

Figure 12. Iris identification results (image has been scanned with 20% speckle noise)

7. Conclusion

Automated fingerprinting allows identifying people quicker and more precisely than other traditional methods. With some of the more subtle technologies it may not be know if you have been scanned. It is early to predict if these near future biometric identification methods will have large influence on our daily business and others aspects of life.

In this paper the proposition of using the Hough Transform in a biometric system has been presented. Fingerprint and iris scans translate their unique patterns to a digital (binary) code. The elaborated method allows the system to work directly on grey-level images without the necessity of binarisation. The most important feature of this method is the insensitivity to image interference found in low quality images. For improvement the presented method may be able to use ideas from the Fast or Randomised Hough Transform.

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