# Robust fingerprint detection for access control


***Marco Gamassi, Vincenzo Piuri, Daniele Sana, Fabio Scotti***

University of Milan, Department of Information Technologies
Via Bramante 65, 26013 Crema (CR)
{gamassi, piuri, sana, scotti}@dti.unimi.it



**Abstract**

The paper presents a robust novel approach for access control based on the identification of the minutiae present in a fingerprint image based on the analysis of the local properties cards . The classical patterns of minutiae called *ridge termination* and *bifurcation* are identified by studying the intensity along squared paths in the image. The presented algorithm works both on grey-level image obtained directly scanning the fingerprint and binarized image and, despite its simplicity, it achieves good accuracy and can be a good candidate to be implemented in hardware or embedded on simple biometric hardware architectures or portable biometric applications such as cellular phones and smart cards.


## 1 Introduction

Biometric systems have been defined by the USA National Institute of Standards and Technology [1] as systems exploiting “automated methods of recognizing a person based on physiological or behavioral characteristics” (*biometric identifiers*, also called *features*). Physiological biometrics is based on data derived from direct measurement of a body part (i.e. fingerprints, face, retina, iris), while behavioral biometrics is based on measurements and data derived from a human action [2] (i.e. gait and signature).

Biometric systems are being used to verify identities and restrict access to buildings, computer networks, and other secure sites [3]. Recent global terrorism escalation is pushing the need for secure, fast and non-intrusive identification of people as a primary goal for homeland security. As commonly accepted, biometrics seems to be the first candidate to efficiently satisfy these needs. For example, by October 2004 USA planned to control the accesses to/from country borders by means of biometric passports [4, 5].

Personal identification has the form of token-based or knowledge-based methods, such as secret passwords and PINs (Personal Identification Numbers), ID cards, keys, passes *etc*. Biometric approach completely differs from traditional methods since the identification is based on personal and unique peculiarities of individuals, which cannot be easily misplaced, forged, or shared [6].

Because of unchangeability and uniqueness, fingerprints have been widely applied in several fields of personal identification such as criminal investigation, access control, and Internet authentication and provide efficient solutions to these modern identification and access problems.

A fingerprint as been defined by as a smoothly flowing pattern of alternating valleys and ridges [7]. Determining whether two representations of a finger extracted from its two impressions, possibly separated by a long duration of time, are indeed representing the same finger is an extremely difficult problem. It is necessary to capture some invariant representations (features) of the fingerprints: these features should continue to remain relatively unaltered even thought cuts and bruises, the orientation of the finger placement, occlusion of a small part of the finger, the sensors used to acquire the fingerprint from the finger, or the stretched distortion of the finger during the acquisition of the print.

Fingerprint representations can be widely categorized into two classes: *global* and *local* [8]. Global representation is an overall attribute of the finger and a single representation is valid for the entire fingerprint and is typically determined by an examination of the entire finger. A local representation consists of several components, each component typically derived from a spatially restricted region of the fingerprint. The most common representations of the local information in fingerprints are based on minute details called minutiae of the ridges (figure 1).

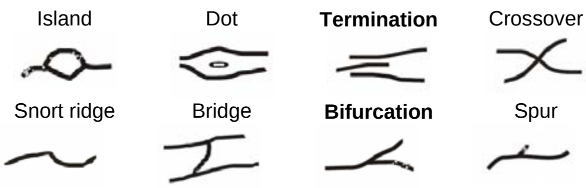


**Figure 1**: The most important minutiae types.

The localization of the minutiae in a fingerprint provide a valid and compact representation of the fingerprint. Therefore, in USA Federal Bureau of Investigation and in the most of the Automatic Fingerprint Identification Systems (AFIS), only the two most prominent types of minute details are used for their stability and robustness: *ridge ending* and *ridge bifurcation*.

Several approaches to local automatic minutiae extraction have been proposed in the literature. Although rather different from one other, most of these methods use classical approach transforming fingerprint images into binary images through an ad-hoc filtering algorithm. The images obtained are submitted to a thinning process which allows for the ridge line thickness in order to achieve a one pixel width. Finally, a simple image scan allows for locating the pixels that correspond to minutiae [7, 11]. In the following we refer to these methods as *classical* methods.

Other approaches uses detect the minutiae directly by processing the gray scale image [8]. The basic idea of this method is to follow the ridge lines on the gray scale image, by "sailing" according to the fingerprint directional image. A set of starting points is determined by superimposing a square-meshed grid on the gray scale image. For each starting point, the algorithm keeps following the ridge lines until they terminate or intersect other ridge lines (minutiae detection). A labelling strategy is adopted to examine each ridge line only once and locate the intersections between ridge lines [8, 9]. In the following we refer to these methods as *direct gray scale* (DGS) methods.

Last group of local methods identifies the minutiae by analyzing the intensity patterns nearby a pixel with different techniques. For example, in [10] neural and neuro-fuzzy systems identify the presence of ridge ends and bifurcations using as input the pixels nearby the processed point sub-partitioned in 4 small quadrants.

In this paper we propose an algorithm belonging to the last group of algorithms. It solved the problem of local identification of *ridge ends* and *bifurcations* by analyzing the intensity patterns along squared paths centred on the processed pixel. The proposed method shows low computation complexity with respect to the methods presented in the literature [12], it requires small amount of memory, it performs a good accuracy of minutiae identification and it is suitable to parallel implementation. Nowadays, the attention on such a kind of issues is growing, aiming to host biometric systems onto cheap, small, portable and low-power hardware architectures [15]. Such architectures are characterized by low computing capabilities, limited memory and small biometric template size [15].

The paper is structured as follow: section 2 presents the proposed method and section 3 provides the accuracy indices necessary to correctly evaluate the accuracy of the system. Finally, section 4 describes the experimental results and the accuracy of the presented methods in terms of the presented quality indices.

## 2 The method of squares

In our paper the minutia point $M$ can be defined as a 4-uple, $M(x, y, t, \alpha)$ where, x and y are the coordinates of the minutia point in the image, $t$ is the type of the minutia (a *bifurcation* minutia or a *termination* minutia) and $\alpha$ corresponds to the orientation of the minutia point.

Our goal is to determine the elements of the 4-uple for each minutia present in the input image.

The analysis of squared paths around the point mean the base for the proposed algorithm.

The basic idea of the method of squares is sketched in figure 2.

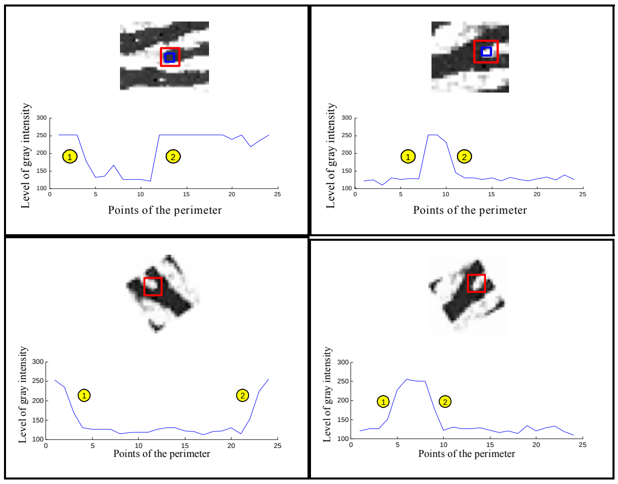


**Figure 2**: The pattern intensities along a square path around a ridge termination (left) and a bifurcation minutia (right). The bottom row shows the patterns of rotated sub-images.

Each pixel in the image has to be classified as bifurcation point, edge-termination point, or no-minutia point. The intensity pattern nearby the candidate pixel is studied along a squared path as shown in figure 2.a in the case of bifurcation and in the case of ridge termination (figure 2.b). The extracted intensities along the squared path have standard patterns when the candidate point is a *true* minutia. In particular, the number of pattern transitions between the mean dark and white levels is fixed. The presence of two transitions if the related to the presence of a minutia.

The choice of the square path as path of analysis is related just to implementative aspects: the *circular* path can be considered as an ideal path. On the other hand, processing an image along rows and columns can be faster than following different shaped scanning paths (i.e., circular).

Our intent is to demonstrate also that, even if the worst path shape is used (the squared path), the presented method still works, and it is rotational independent. The two plots on the bottom of figure 3 show the presence of the two transitions in the intensity pattern even in the rotated images.

In the following of the paper we will consider binarized images as input, but the present method is suitable also with gray-scale image. Binary images represent the lowest quality image for a biometric fingerprint system since we have the maximum loss of information. Conversely, in the binary case, the identification of the transitions along the path is trivial. The binary case is reasonable considering small biometric system working with cheap sensors or with low computational hardware/low memory architecture (i.e a smart card or cellular phone).

The presented method is composed by the following steps for each pixel of the input image.

1. Create a 3x3 square mask around the $(x,y)$ pixel and compute the average of the pixels (0 and 1 in the binarized images). If the average is lesser than 0.25 the pixel is treated like a ridge end minutia, otherwise if the average is greater than 0.75 the pixel is treated like a bifurcation minutia.
2. Create a square perimeter $P$ around the $(x,y)$ pixel of size $W$x$W$, where $W$ is twice the mean ridge size in that point. There are many algorithms in the literature to estimate the mean ridge size [13].
3. Compute the number of the logic commutations present in the perimeter $P$ without considering isolated pixels as shows in figure 3 (blue pixel).

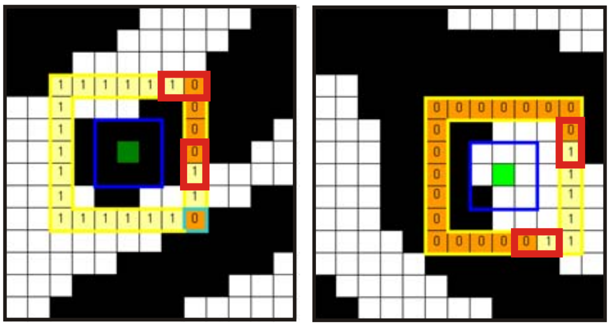

**Figure 3**: Processing the commutations.

4. If there are two logic commutation the algorithm go on, otherwise it jump to step 1 processing another pixel.
5. To avoid spurious minutiae as shows in figure 4, compute the average of the pixels in the perimeter P. If the pixel has been defined as a termination minutia in step 1, we check if the average is greater than 0.7. (in bifurcation minutia, the average must be lesser than 0.3) otherwise it jump to step 1 processing another pixel.

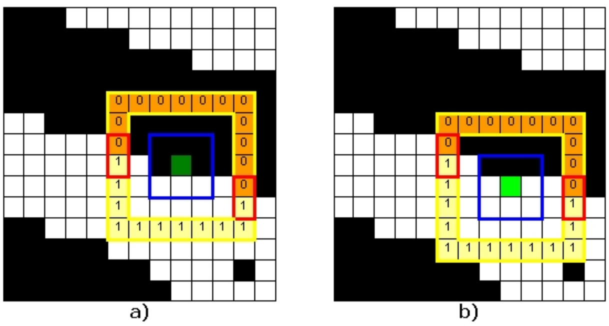


**Figure 4**: a) a spurious end ridge minutia b) a spurious bifurcation minutia.

6. Estimate the orientation angle $\alpha$ in the minutia point. The orientation angle estimation can simply obtained by a proportion between the position of the ridge mean point along the perimeter $P$ and the $2\pi$ angle. (figure 5, left) The mean point of the ridge is identified by considering the mean point of the segment along the perimeter P with zero/one values in the termination/ bifurcation case.
7. Spurious detection removal: create a square path $P_2$ twice larger than $P$. If $P_2$ intersects another ridge at $\alpha + \pi$ angle the minutia is rejected as spurious, otherwise is accepted as correct (figure 5, right).

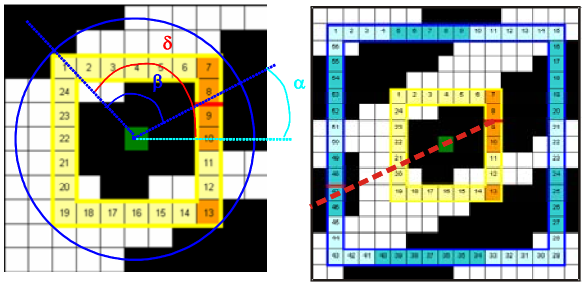


**Figure 5**: Estimating the orientation angle (left) and removing the false terminations detections (right).

8. The minutiae point are labeled directly on the image and the 4-uple values are stored in the minutiae array (figure 6).

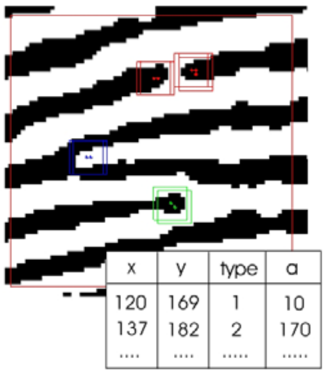


**Figure 6**: A portion of elaborated image. Blue square represent the bifurcations, green square represent the ridge ends and the red square the spurious minutiae. Figure represents also the minutiae list array.

## 3 Indexes of accuracy

In the following the indexes of evaluation used to compare automatic methods of minutiae's identification will be described. Unfortunately, the accuracy of a system that identifies minutiae in images has not yet standardized in the literature. The main problem is the reference: how it is possible to determine where exactly the minutiae are located in a fingerprint image? Nevertheless, this problem can be solved by assuming as correct the minutiae coordinates provided by a supervisor (i.e. an experienced operator) In our experiments the supervisor uses a graphical interface to identify the coordinates, the type and the orientation of each minutia present in a database of images.

A minutia extracted by an automatic method is *correct* if the supervisor identified a minutia of the same type in its neighbourhood [14]. Specifically, the **positional correctness** is the correctness of a minutia without considering the minutia's type (bifurcation or ridge). The **index of revelation minutiae** $I_{revealed}$ is the ratio between the minutiae *positionally correct* extracted by an automatic method ($N_{CorrectAuto}$) and the minutiae *positionally correct* extracted by the supervisor ($N_{Man}$). It is defined as follows:

$$I_{Revealed} = \frac{N_{CorrectAuto}}{N_{Man}} \quad (1)$$

The **index of positional correctness** $I_{PositionCorrect}$ is the ratio between the minutiae *positionally correct* extracted by an automatic method and the minutiae *correctly* extracted by the automatic method ($N_{Auto}$) and is defined as:

$$I_{PositionCorrect} = \frac{N_{CorrectAuto}}{N_{Auto}} \quad (2)$$

The **index of correctness** $I_{Correct}$ is the ratio of the minutiae *correctly* extracted by an automatic method. It is defined as follows:

$$I_{Correct} = \frac{N_{CorrectAuto} - N_{Exchanged}}{N_{Auto}} \quad (3)$$

where $N_{Exchanged}$ represents the number of minutiae whose type has been wrongly determined, i.e. a bifurcation has been extracted as a ridge and vice versa.

The index $I_{Correct}$ is the most valuable one among the other indexes: an automatic method which provides an index $I_{Correct}$ close to 1 but an index $I_{revealed}$ near to 0 is better than an automatic method characterized by a small value of index $I_{Correct}$ and an index $I_{revealed}$ close to 1. As such, it is most valuable that an automatic method of minutiae's identification extracts a large number of *correct* minutiae in respect to only a large number of minutiae, eventually exchanged.

## 4 Experimental results

The proposed method uses two threshold parameters: the first is the threshold hysteresys value to detect spurious transitions N described in section 2 and it has been empirically fixed to the value of 3 pixels in the case of 512x512 pixel input images. The threshold K required to classify the type of the located minutia has been empirically fixed to 70%.

The automated method of squares has been compared with the classical approach described in [7] and with the DSG method described in [8]. Figure 8 shows the minutiae selected by the supervisor, by the method of squares, by the classical methods and by the DSG method respectively. Table 1 shows the indexes of accuracy based on the sample image plotted in Figure 7.

The proposed algorithm has been also compared with respect to the neural and neuro-fuzzy system proposed in [9]. Since the original image is not available, we used as input of our method the original image scanned from the document. Results are given in Table 2.

As shown in Tables 1 and 2, the automated method of squares shows a good capability to correctly locate the minutiae without confusing the type: the most important index $I_{Correct}$ has the highest value in both tables.

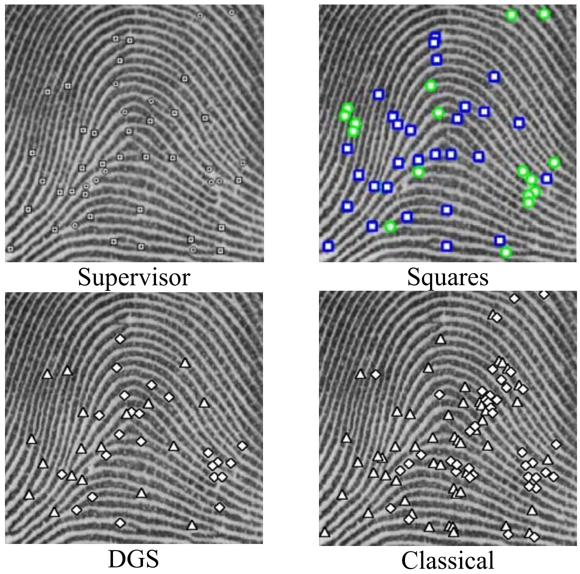


**Figure 7**: Example of identified minutiae for a sample image with the *method of squares*, *DSG* and *classical* algorithms.

**Table 1.** Results for the *method of squares*, *DSG* and *classical* algorithms

| Method | $N_{man}$ | $N_{auto}$ | $N_{corr.Auto}$ | $N_{exch.}$ | $I_{Rilevated}$ | $I_{Position\ Correct}$ | $I_{Correct}$ |
|---|---|---|---|---|---|---|---|
| Classic | 47 | 95 | 45 | 2 | **96%** | 47% | 45% |
| DSG | 47 | 41 | 37 | 10 | 79% | **90%** | 66% |
| Square | 47 | 47 | 38 | 1 | 81% | 81% | **79%** |

**Table 2.** Results with respect to the neural and neuro-fuzzy classification systems

| Method | $N_{man}$ | $N_{auto}$ | $N_{corr.Auto}$ | $N_{exch.}$ | $I_{Rilevated}$ | $I_{Position\ Correct}$ | $I_{Correct}$ |
|---|---|---|---|---|---|---|---|
| Fuzzy | 19 | 47 | 6 | N.A. | 32% | 13% | Max 13% |
| NeuroF. | 19 | 41 | 8 | N.A. | 42% | 20% | Max 20% |
| Square | 19 | 65 | 19 | 0 | **100%** | **29%** | **29%** |

## 5 Conclusions

This paper presented a robust method for biometric access control based on the minutiae identification present in a fingerprint image exploiting the analysis of the local properties. The typical patterns of minutiae called ridge termination and bifurcation are identified by studying the intensity along squared paths in the image. Results indicate that the analysis of minutiae based on presented methods is achievable and it offers remarkable identification accuracy. The presented method can be considered as good candidate to be implemented in hardware (i.e. FPGA co-designed systems) and biometric systems hosted on simple processor board cellular phones and smart cards. Further studies will be focused in order to validate the algorithm on larger datasets and to make the method fully adaptive with respect to all the threshold parameters.

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Fingerprints Biometrics access control, Low cost fingerprint time attendance recorder, low cost robust access controller, simple fingerprint reader, standalone fingerprint reader, Door Access Control, access control india, door locks, access control, Fingerprints access control, biometric door lock, security door control, access control, fingerprint door locks. iScan v100. Compact Low-cost Access Control.Â  Just Press Grey key and place you Finger for instant advanced 1:N Identification matching. Within seconds your fingerprint is identified and access granted. IScan can be attached to standard Electric Strike or Electromagnetic locks. iScan can register upto 100 fingerprints. Security with advanced fingerprint minutiae matching. 4 Fingerprint Access Controller for Residential Applications. The most important feature of the fingerprint recognition access controller for residen-tial applications is to realize a good product for ordinary people, especially for senior citizens or housewives who tends to have poor quality fingerprints and frequently at rough conditions.Â  Because the algorithm is robust to those who have poor quality fingerprint, and the application products can be simple and cost-effective by using the ASIC, the resultant fingerprint recognition access controller can be ideal for residential applications. It is noticeable that the POC based algorithms, including the one described in this paper, are less dependent on the structure of target images, and therefore they are good for other biometrics. Fingerprint recognition for automated border control and other high-security applications needs robust integrated anti-spoofing capability. Facing the thre.Â  Conferences > 2016 IEEE Symposium on Techno Robust and interoperable fingerprint spoof detection via convolutional neural networks. Publisher: IEEE. 3. Author(s). Emanuela Marasco ; Peter Wild ; Bojan Cukic. View All Authors. Sign In or Purchase.