Reducing Process-Time for Fingerprint Identification System

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ABSTRACT

Fingerprints are the most widely used biometric feature for person identification and verification in the field of biometric identification. Fingerprints possess two main types of features that are used for automatic fingerprint identification and verification: (i) Ridge and furrow structure that forms a special pattern in the central region of the fingerprint and (ii) Minutiae details associated with the local ridge and furrow structure. In a traditional biometric recognition system, the biometric template is usually stored on a central server during enrollment. The candidate biometric template captured by the biometric device is sent to the server where the processing and matching steps are performed. This paper presents an approach to speed up the matching process by classifying the fingerprint pattern into different groups at the time of enrollment, and improves fingerprint matching while matching the input template with stored template. To solve the problem, we take several aspects into consideration like classification of fingerprint, singular points. The algorithm result indicates that this approach manages to speed up the matching effectively, and therefore prove to be suitable for large database like forensic divisions.

Keywords: Biometrics, identification, verification, minutiae points, singular points.

1. INTRODUCTION

Fingerprint is one of the most mature biometric traits and considered legitimate proof of evidence in courts of law all over worldwide. Fingerprints are, therefore, used in forensic divisions worldwide for criminal investigations. More recently, an increasing number of civilian and commercial applications are either using or actively considering using fingerprint-based identification because of a better understanding of fingerprints as well as demonstrated matching performance than any other existing biometric technology. Modern fingerprint matching techniques were initiated in the late 16th century [1]. Henry Fauld, in 1880, first scientifically suggested the individuality and uniqueness of fingerprints. At the same time, Herschel asserted that he had practiced fingerprint identification for about 20 years [2]. This discovery established the foundation of modern fingerprint identification. In the late 19th century, Sir Francis Galton conducted an extensive study of fingerprints [2]. He introduced the minutiae features for single fingerprint classification in 1888. The discovery of uniqueness of fingerprints caused an immediate decline in the prevalent use of anthropometric methods of identification and led to the adoption of fingerprints as a more efficient method of identification.

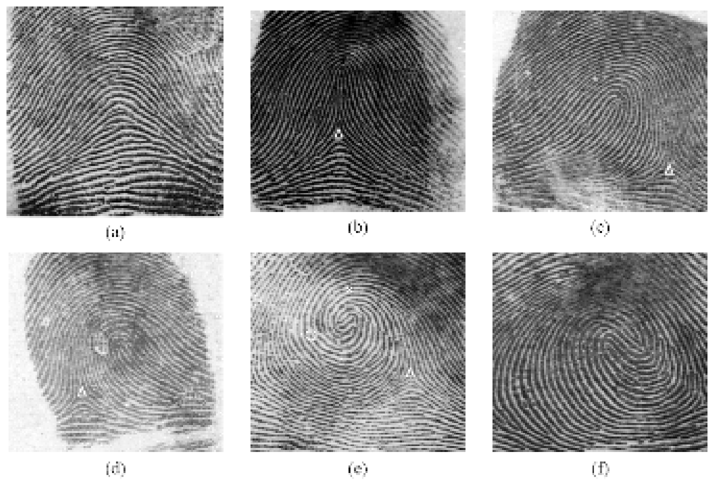


FIGURE 1: Fingerprints classification involving six categories: (a) arch, (b) tented arch, (c) right loop, (d) left loop, (e) whorl, and (f) twin loop. Critical points in a fingerprint, called core and delta, are marked as squares and triangles. Note that an arch does not have a delta or a core.

An important advance in fingerprint identification was made in 1899 by Edward Henry, who established the famous "Henry system" of fingerprint classification [1, 2]: an elaborate method of indexing fingerprints very much tuned to facilitating the human experts performing (manual) fingerprint identification. In the early 20th century, fingerprint identification was formally accepted as a valid personal identification method by law enforcement agencies and became a standard procedure in forensics [2]. Fingerprint identification agencies were setup worldwide and criminal fingerprint databases were established [2]. Loop, whorl, and twin loop.

1.1 Fingerprint Feature Extraction

The human fingerprint is comprised of various types of ridge patterns, traditionally classified according to the decades-old Henry system: left loop, right loop, arch, whorl, and tented arch.

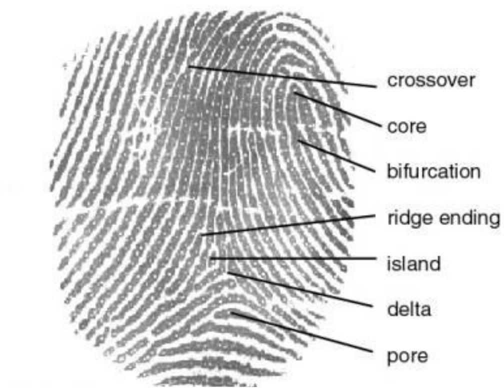


FIGURE 2: Minutiae- points on a fingerprint.

Loops make up nearly 2/3 of all fingerprints, whorls are nearly 1/3, and perhaps 5-10% are arches [3]. These classifications are relevant in many large-scale forensic applications, but are rarely used in biometric authentication. Many types of minutiae exist, including dots (very small ridges), islands (ridges slightly longer than dots, occupying a middle space between two temporarily divergent ridges), ponds or lakes (empty spaces between two temporarily divergent ridges), spurs (a notch protruding from a ridge), bridges (small ridges joining two longer adjacent ridges), and crossovers (two ridges which cross each other) [4].

1.2 Fingerprint-Matching Process

Fingerprint matching techniques can be placed into two categories: minutiae-based and correlation based. But the commonly used technique with minimum FAR and FRR is Minutiae-based techniques. In this process we, first find minutiae points and then map their relative placement on the finger. However, there are some difficulties when using this approach. It is difficult to extract the minutiae points accurately when the fingerprint is of low quality. Also this method does not take into account the global pattern of ridges and furrows [5]. Fingerprint Verification System is a system that determines the correspondence of an input fingerprint with a template fingerprint stored in data base. A typical block diagram of biometric matching systems is shown in Figure 3.

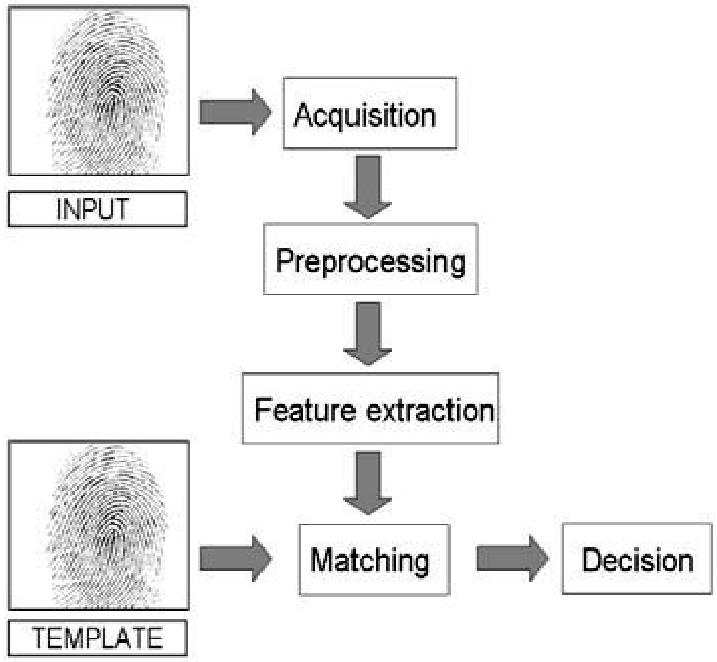


FIGURE 3: Block diagram of a typical Automatic Fingerprint Verification system.

In a verification fingerprint system, the template fingerprint image is obtained in the enrollment phase. After that verification process takes place by a inputting the sample of the user's fingerprint at sensor. Such input fingerprint must be processed, in the preprocessing step. The preprocessing includes image enhancement, gray level adjust, ridge thinning, etc. After the fingerprint image has been preprocessed, the feature extraction block extracts the relevant information that will be used for matching with the template fingerprint [6]. Finally a verification decision is made with the results or percentages of similarity obtained from the matching step. Section 2 describes the work in this field and the problems associated with this field. Section 3 describes the proposed work and the efficiency of proposed work based on experimental calculations.

2. Related Work

Figure3 above shows the process of matching for fingerprint. It is obvious that if fingerprint templates are stored in a particular manner then it will quite increase the efficiency of biometrics device. We have visited Madhuban Forensic Laboratory, Karnal to know which methods are used there as there are lots of templates in database. There we see the matching process of fingerprint identification among apx. 150000 database templates. The software being used there is FACTS (Finger Analysis Criminal Tracing System) developed by CMC and based on the theory of Dr. Henry Faulds. This approach involves the print of all the fingers of both hands and assign weights to each of fingers print pattern [7].

2.1 Explanation of the Henry Classification System

The Henry Classification System allows for logical categorization of ten-print fingerprint records into primary groupings based on fingerprint pattern types. This system reduces the effort necessary to search large numbers of fingerprint records by classifying fingerprint records according to gross physiological characteristics.

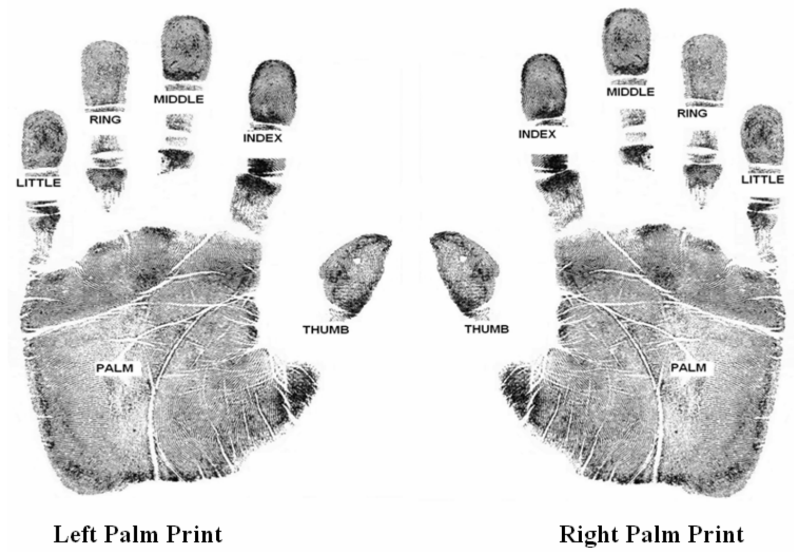


FIGURE 4: Both palm print of a single person.

Subsequent searches (manual or automated) utilizing granular characteristics such as minutiae are greatly simplified. Henry Classification System assigns each finger a number according to the order in which is it located in the hand, beginning with the right thumb as number 1 and ending with the left pinky/little as number 10. The system also assigns a numerical value to fingers that contain a whorl pattern; fingers 1 and 2 each have a value of 16, fingers 3 and 4 have a value of 8, and so on, with the final two fingers having a value of 1. Fingers with a non-whorl pattern, such as an arch or loop pattern, have a value of zero. Images of various fingerprint patterns are shown already in figure1. In accordance to the Henry Classification System, finger numbers and finger values are assigned as following: The fingerprint record's primary grouping is determined by calculating the ratio of one plus the sum of the values of the whorl-patterned, even-numbered fingers; divided by one plus the sum of the values of the whorl-patterned, odd-numbered fingers (Harling 1996). This formula is represented below [8]:

Henry Classification System Formula:

Primary Grouping Ratio (PGR) =

$$\frac{1+ \text{(Sum of whorled, EVEN finger value)}}{1+ \text{(Sum of whorled, ODD finger value)}}$$

	L Pinky	L Ring	L Middle	L Index	L Thumb	R Thumb	R Index	R Middle	R Ring	R Pinky
Finger Number	10	9	8	7	6	1	2	3	4	5
Value (if Whorl)	1	1	2	2	4	16	16	8	8	4

If, for example, an individual has a fingerprint record with a LWAALALWLA pattern series (the series begins with Finger 1, the right thumb and ending with Finger 10, the left pinky), the corresponding classification ratio would be 19:1. This example is calculated below [8] :

	L Pinky	L Ring	L Middle	L Index	L Thumb	R Thumb	R Index	R Middle	R Ring	R Pinky
Finger Number	10	9	8	7	6	1	2	3	4	5
Value (if Whorl)	1	1	2	2	4	16	16	8	8	4
Pattern Type	**Arch**	**Loop**	***Whorl***	**Loop**	**Arch**	**Loop**	***Whorl***	**Arch**	**Arch**	**Loop**
Finger Value	**0**	**0**	***2***	**0**	**0**	**0**	**16**	**0**	**0**	**0**

Example: $\dfrac{1+\text{(Sum of Even finger value)}}{1+\text{(Sum of Odd finger value)}} = \dfrac{1+(16+2)}{1+(0)} = \boxed{\dfrac{19}{1}}$

Therefore, this individual belongs to the 19:1 primary group. If, for example, an individual does not have any whorl-patterned fingerprints, his or her classification ratio, or primary group, would be 1:1. If an individual has all ten fingerprints containing a whorl pattern, his or her classification ratio would be 31:31. The Henry Classification System allows for up to 1,024 primary groupings.

2.2 Problems associated with Existing System

Above method work very efficiently when we have palm prints of all fingers of both hands. We assign weights to the person prints and calculate PGR. On the basis on PGR factor the search goes to particular domain and identified the proper match. But if we have only one finger print as input print, then there will be problem as in this case we can't find PGR factor. Further the problem can also arise if the criminal is made some trick while giving its input prints to the system. He can change the order of his fingerprint while giving input print, if this happen then his print can't be matched anywhere in the system.

3. PROPOSED WORK

Proposed work is based on the theory of fingerprint classification, we store only single finger print of person in the database. This single print can be thumb print or print of index finger. One obvious advantage of this approach is that it will considerably reduce the amount of memory required to store the fingerprint template as only one print is stored instead of 10 prints for an individual. Now let us see how the proposed system will work. First let us talk about the enrollment process; in conventional system the database contains the fingerprint templates in an ordinary manner. But here in our proposed system the database contains the different set of templates according to classification. During the enrollment process, sensor senses the fingerprint, then next step is feature extraction, here minutiae points are extracted. After this step we put a classifier to check the classification of input template that whether it is left-loop, right-loop, arch or whorl. The detail function of classifier is shown in figure 6. After classification the input template will be stored in particular domain. A domain in the database contains the templates of same classification. Normally the fingerprints are classified as Whorl, arch and loop. Loops make up nearly 65% of all fingerprints, whorls are nearly 30%, and perhaps 5% are arches [3]. These classifications are relevant in many large-scale forensic applications, but are rarely used in biometric authentication. Since the loops are 65%, we further divide this domain into two parts i.e. left loop 32% apx. and right loop 33% apx . So we have four different domains i) Left-Loop ii) Right-Loop iii) Arch and iv) Whorl as shown in figure5. Now let us come to the verification process, here the finger or finger print is placed at sensor and then its features are extracted and a final template is generated for matching. Now this template will not matched with every templates in the database rather it extracts its classified domain out of 4-domain and will perform match from this extracted domain. This process, no doubt will be fast and more efficient especially when the stored database is very large that is more than 1, 00000 templates. Let D and T be the representation of the Database Template and Stored Template respectively. Each minutia may be described by a number of attributes, including its location in the fingerprint image, orientation, type etc. Most common minutiae matching algorithms consider each minutiae as a triplet m= $\{x,y,\theta\}$that indicates the minutiae location coordinates and the minutiae angle θ.

$D = \{m_1, m_2, \ldots\ldots m_n\}$ $\quad m_i = \{x_i, y_i, \theta_i\}$ i= 1….m

$T = \{ m'1, m'2, \ldots\ldots m'n \}$ $\quad mj = \{x'j, y'j, \theta'j\}$ j= 1….n

Where m and n denotes the number of minutiae in D and T respectively.
Database Template and Stored Template and stored template will be matched, If we calculate Spatial Distance (SD) and direction difference (DD) that will not be below than specified value r0 and θ0 or we can write as [9].

$$SD (m'1, m1) = sqrt [(x'i - xi)2 + (y'i - yi)2] >= r0 \qquad \text{----------------(1)}$$

Similarly

$$DD (m'1, m1) >= \theta 0 \qquad \text{----------------(2)}$$

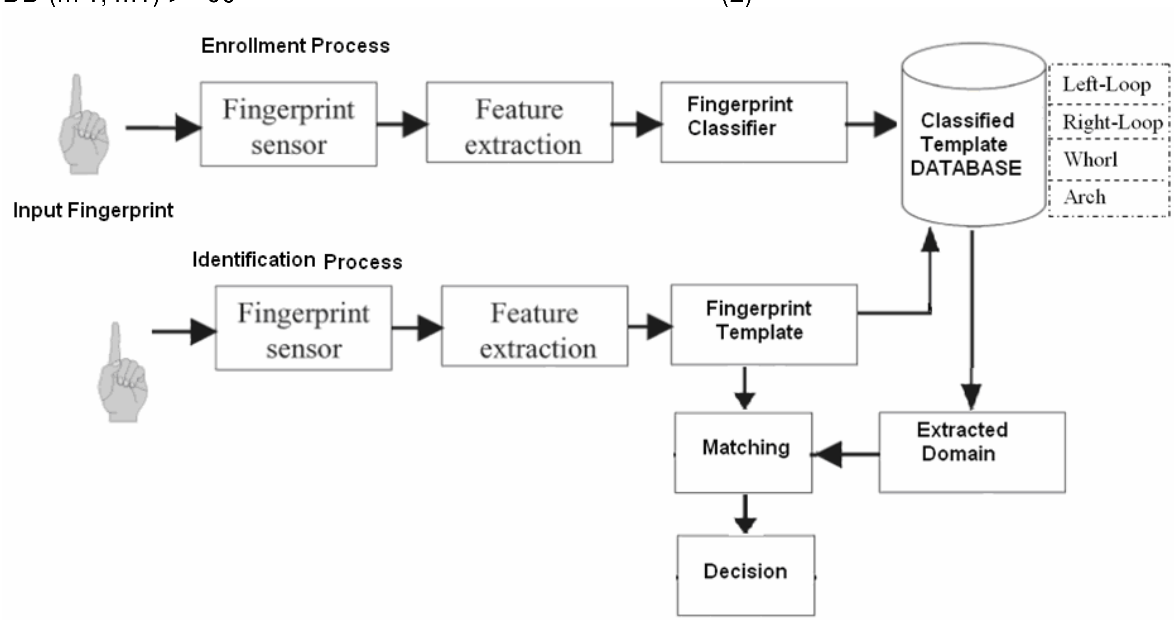
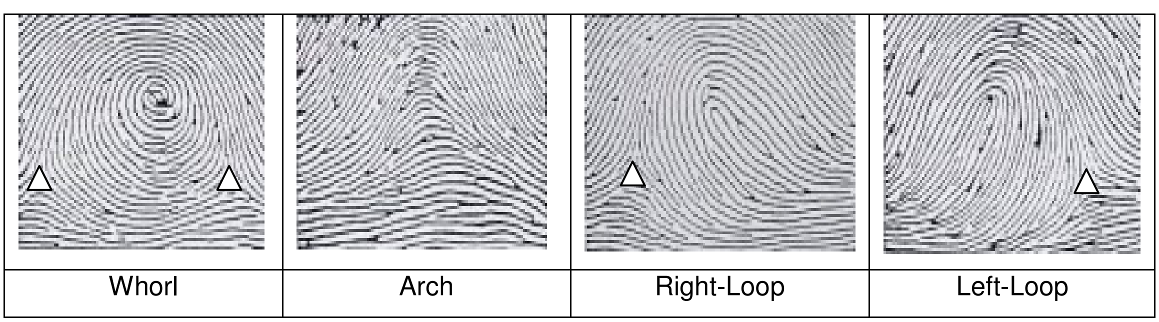


FIGURE 5: Proposed scheme for Fingerprint Identification

3.1 Fingerprint Classifier

Fingerprint classifiers classify the input fingerprint into four major categories namely Left-Loop, Right-Loop, Whorl and Arch. The proposed classifiers works on the basis of singular point (Delta) extracted. If there are two deltas then it will be counted as whorl or twin loop. If there is no delta then it will be counted at arch. If only one delta is there then it will be either left loop or right loop.



Figures 6. Position and numbers of deltas in different finger prints.

We further find the category of loop by measuring Relative position (R). If relative position, R of delta with respect to symmetry axis is R = 1 means the delta is on the right side of symmetry axis then it will be left loop otherwise it will be right loop [10]. On the basis of above idea, a flowchart (figure 6) for algorithm is designed to find the fingerprint classification.

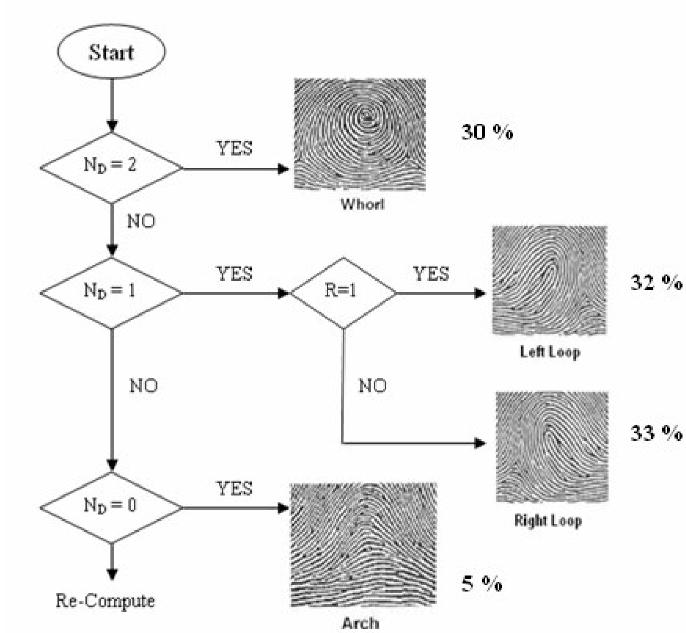


FIGURE 6: Proposed working of Fingerprint classifier.

3.3 Performance Estimation of Proposed Scheme

Let us take the example of Madhuban forensic laboratory, Karnal where database of more than 1, 50000 templates are stored. We had performed an experiment at Madhubhan by inputting a single template at the sensor and started to identify it from their database. The process takes 25-30 minutes to identify and also gives 34 matched templates (equations 1, 2 satisfy for 34 templates) [7]. These 34 templates again have to match manually and consume around 5-6 hours i.e. it's a quite time consuming and complex task. First let us see why the system takes so much time.
Let's assume that time taken to perform a single match = 1 ms (1 milli seconds)

Performance of Existing System

For Best case i.e. the template is First match, Time required = 1 X 1 = 1 ms
For worst case i.e. the template is last match, Time required = 1 X 1, 50000 = 150 sec. = 25 min.
For an Average case, Time required= apx 10-20 min.

Performance of Proposed System

For Best case i.e. the template is First match, Time required = 1 X 1 = 1 ms
Now let us calculate for worst case
We have assumed 1, 50000 templates, According to classification there will be
45000 whorls (30%) + 48000 Left Loop (32%) + 49500 Right Loop (33%) + 7500 Arch (5%)
At First stage we get the template classification and accordingly particular domain will be extracted. Now we calculate the time taken for each classification

For Whorl = 1ms X 45000 = 45 sec.
For LL = 1ms X 48000 = 48 sec.
For RL = 1ms X 49500= 49.5 sec
For Arch = 1msX 7500= 7.5 sec.

Average time = 150/4= 37.4 sec.
For an Average case, Time required= apx 20-24 sec.

$$\text{Performance Factor} = \frac{\text{Time take in worst case of existing system}}{\text{Time take in worst case of proposed system}} = \frac{25\ \text{min}}{37.4\ \text{Sec}} = 40.1$$

i.e. the new approach is apx 40 time better than the existing one.

4. CONCLUSION AND FUTURE SCOPE

An approach has been presented for fingerprint matching in an effective way to reduce time. The proposed scheme has been calculated as 40 times efficient as compared with an existing system. We have taken four major classifications of fingerprint, whorl, arch, left-loop and right-loop. But still there is some problem in existing system that is in our proposed system our pre-request is concern about our database. Our database should contain only one print of every individual not both palm prints. Proposed system will not work if we try to match fingerprint of middle finger or little finger. For that purpose we have to store all the fingerprints of a person but the turnaround time can be reduced by study further in this direction as 20-25 minutes are quite lengthy time to wait and moreover there is not single match in the result rather there are 35-50 templates matched.

5. REFERENCE:

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