**Comparative Analysis of Fingerprint Preprocessing Algorithms for Electronic Voting Processes**

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**Abstract.** Fingerprints have been used for a long time as a very adequate method of distinguishing people. Matching fingerprints can be very difficult without a good algorithm for the scanners. Complexities especially during the verification phase can arise from problems with the algorithm scanners use. In elections and other forms of voting, security and proof of individuality remain some of the biggest obstacles to be surmounted. This project proposes an ideal algorithm which could solve these challenges. The Zhan-Suen Thinning Algorithm and the Guo–Hall Parallel Thinning Algorithm were compared using standard parameters from the perspective of fingerprint technology and electoral requirements to deduce the better algorithm. MATLAB® was used for the comparative performance analysis of the two algorithms. The time taken to complete iterations, quality of output produced and reliability were the parameters used to carry out the comparative performance analysis of the two algorithms. The better algorithm, Guo–Hall’s was recommended for implementation on e-voting systems. Guo-Hall’s algorithm is very effective and has the capacity to curb electoral fraud when adopted in e-voting process.

**Keywords:** Thinning, Authentication, Enrollment, Verification.

**1. Introduction**

Fingerprint enrollment is the sequences of steps taken to register a user’s fingerprint. The user’s fingerprint is extracted by a scanner, converted into a digital image, thinned and the minutia is extracted [3].The minutiae are used to distinguish one fingerprint from the other. The minutia is used to form a template that is stored along with the user’s demographic information in a database. Other important steps in authentication are verification and identification. Verification is the process where the biometric system compares a fingerprint to another which has been previously enrolled to determine if they are a match or got from the same finger (1:1 matching – as the system compares one query print to one enrolled print). Identification is when the biometric system compares a fingerprint of a user with the prints other enrolled users in the database to determine if that user is either known under a different name or a duplicate, false identity (1: N matching – N is the number of users which have been successfully enrolled) [1]. Most times, a prospective user’s inability to be enrolled or verified can be as a result of one or a combination of the following; age of the user, scarring and cuts on the finger, resolution and capture area of the sensor, biological, environmental and the nature of the user’s work.

Since the introduction of biometrics in Nigeria, there have been many cases where users who have been previously enrolled are reported to have problems with authentication. One of such cases occurred during the March 2015 general elections where the Independent National Electoral Commission reported that there was a 41% failure rate in the use of biometrics (fingerprints) [2]. In the report, INEC cited various possible reasons for failure in the use of biometrics, but one solid reason is the presence of flattened or worn out fingerprints in users. In Nigeria for example, there are different databases managed by different private or governmental organizations, each with their own unique way of capturing users’ fingerprint for data recognition. But an algorithm, selected through comparative analysis should form the foundation for developing uniform databases that make biometric enrollment and verification less cumbersome.

The aim of this paper is to compare with the aid of MATLAB® the efficiency of the Zhang–Suen thinning algorithm and the Guo–Hall parallel thinning algorithm, when implemented in an electronic voting machine that uses fingerprints scanner for enrolling voters. The Zhang–Suen thinning algorithm and the Guo–Hall parallel thinning algorithm were developed using Java. The efficiency each fingerprint algorithm and their comparative analysis were carried out using MATLAB®.

Fingerprints were acquired from a wide range of people from different walks of life. This was done to effectively prove that both algorithm works for different people. A fingerprint database that matches the fingerprints to each user’s demographic information was created

**2. Background and Literature Review**

 **2.1 Fingerprints in Electronic Voting**

Enrolling is the initial step in the use of any biometrics. The image of the fingerprint is got by a sensor and a digital form of the image is made. The most essential feature of the fingerprint that differentiate one user from the other is extracted from the digital image, used to make a template and stored in a database with the unique user’s information. To determine if the correct information was stored, a fresh sample template from the user is used to compare the stored sample for any match. Fingerprint samples got from an individual at different times are never exactly alike due to several factors among which are the way the user interacts with the biometric system and fingerprint changes due to injury and age. This is called Intra-class Variation. A threshold determines if two templates are a match. A score above the threshold is regarded as a match. In this work, a threshold of 0.40 which is the standard for iris recognition system was used. A detailed study of the intra-class and inter-class matching helps in determining False Rejection Rate and False Acceptance Rate.

When a template that is not stored in the database of the biometric recognition system is accepted, it is called False Acceptance and the frequency with which it occurs is called False Acceptance Rate. But when a template stored in the database of a biometric system is mistakenly rejected, it is called False Rejection and the frequency with which it occurs is called False Rejection Rate. These parameters are directly decided by the threshold value of the system. A high threshold value may lead to a higher false rejection rate while a low threshold value may lead to a higher false acceptance rate.

* 1. Zhang – Suen Fingerprint Thinning Algorithm

The Zhang–Suen algorithm is under a group of thinning algorithms which are known as iterative [3]. An iterative fingerprint algorithm is one which deletes pixels on the boundary of a pattern repeatedly until only a unit pixel-width thinned image remains. Thinning is done only on binarized images [4].

In the Zhang – Suen thinning algorithm, a digitized binary picture is defined by a matrix Z where each pixel Z $(i, j)$ is either 1 or 0. The pattern consists of those pixels that have value 1. Each stroke in the pattern is more than one element thick. Iterative transformations are applied to matrix Z point by point according to the values of a small set of neighboring points [3, 4]. In this algorithm, an 8–point connectivity matrix is used which makes the iteration possible.

 Zhang-Suen thining algorithm matrix:

$$\left[\begin{matrix}P9, (i-1, j-1)&P2, (i-1, j)&3, (i-1, j+1)\\P8, (i, j-1)&P1, (i, j)&P4, \left(i, j+1\right)\\P7, \left(i+1, j-1\right)&P6, (i+1, j)&P5, (i+1, j+1)\end{matrix}\right]$$

* 1. Guo–Hall Fingerprint Algorithm

This algorithm makes use of an 8-point connectivity matrix. Its iteration process is longer and takes more time to implement. The flowchart for the implementation Guo-Hall algorithm is shown in Figure 1.



Fig. 1. Flow chart for Guo – Hall algorithm..

**3. Methodology and Proposed framework data flow**

The comparative analysis was carried out using MATLAB®. The criteria used for comparison are:

1. Time taken to complete iterations (time taken to complete thinning process).
2. Quality of output produced (how close the fingerprint template is to the voter’s fingerprint and the image’s clarity).
3. Reliability (the algorithm’s performance and behaviour over a defined period of time).

The FVC – 2000 data set provides the database from which thirty (30) fingerprints were randomly selected and used to carry out the comparative analysis.

**4. Result and discussion**

1. *Time taken to complete iterations:* the number of fingerprints used to carry out this test was increased in batches starting with just one fingerprint. The fingerprints on which each algorithm performed the thinning process were the same and in the same order. The time taken for both algorithms to complete the thinning process is tabulated below.

 Table I: Fingerprint thinning time for each algorithm.

|  |  |  |  |
| --- | --- | --- | --- |
| **Batch** | **Prints number** | **Zhang – Suen** | **Guo – Hall** |
| 1 | 1 | 3.77s | 4.38s |
| 2 | 2 | 7.50s | 8.8s |
| 3 | 3 | 11.4s | 13.3s |
| 4 | 4 | 15.2s | 17.4s |
| 5 | 5 | 19.0s | 22.0s |
| 6 | 10 | 38.0s | 44.3s |
| 7 | 15 | 57.3s | 65.3s |
| 8 | 20 | 77.4s | 88.1s |
| 9 | 25 | 95.3s | 110.3s |
| 10 | 30 | 115.1s | 132.7s |

From the table above, it can be seen clearly that in comparison to Guo-Hall algorithm, Zhang-Suen algorithm performs its iterations (fingerprint thinning process) in a shorter time.

The graphical representation of the two algorithms’ thinning time for each batch of fingerprint is shown in Figure 2.

Fig 2. Graphical representation of the time to complete iteration (thinning time) for both algorithms

This graphical representation also shows that Zhang-Suen fingerprint algorithm’s time to complete iteration is shorter.

1. *Quality of output produced*: the Guo-Hall parallel thinning algorithm produced a better output for twenty-eight out of thirty outputs, whereas the Zhang-Suen thinning algorithm produced only three comparatively better outputs for the same process. This is due to the fact that Zhang-Suen algorithm does not preserve the eight–point connectivity principle that is used to group and view images as one. Guo-Hall algorithm preserves this eight–point connectivity principle and thus produces a better output. A sample fingerprint input is shown in Figure 3.



Fig. 3. Sample Fingerprint input.

 The iteration results (fingerprint templates showing their respective minutiae details) of the Zhang-Suen and Guo-Hall thinning algorithms details are on the sample fingerprint shown in Figure 4.





Fig. 4. Fingerprint template output of Zhang-Suen and Guo-Hall thinning algorithms respectively.

From the above images, it can be clearly seen that the Guo–Hall algorithm provides an output with better thinned lines than that of Zhang–Suen. Intricate lines like ridges, bifurcations and other form of measurable minutia are visible on the two outputs but they are less pronounced on the Zhang–Suen algorithm output.

1. Reliability: the number of useful outputs each algorithm produced for each batch of fingerprints is summarized in the table below:

TABLE II: Comparison of useful outputs produced by each algorithm.

|  |  |  |  |
| --- | --- | --- | --- |
| **Batch** | **Prints number** | **Useful Outputs****(Zhang-Suen)** | **Useful Outputs****(Guo-Hall)** |
| 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 2 |
| 3 | 3 | 3 | 3 |
| 4 | 4 | 3 | 4 |
| 5 | 5 | 5 | 4 |
| 6 | 10 | 8 | 9 |
| 7 | 15 | 12 | 14 |
| 8 | 20 | 17 | 19 |
| 9 | 25 | 22 | 20 |
| 10 | 30 | 26 | 26 |

From the table above it was discovered that the number of useful fingerprint templates was quite consistent. The two algorithms showed an average non-useful output of 13%. The number of non-useful fingerprint template output climbed to its peak as the number of fingerprints in each batch to be thinned increased. The overall reliability test showed that the Guo-Hall thinning algorithm was more reliable especially as the number of fingerprints to be thinned increased.

The graphical representation of the table above is in Figure 5:

Fig. 5. Graph showing useful outputs for both Zhang-Suen and Guo-Hall algoritms

This graph shows that the Guo-Hall algorithm performs better in terms of reliability as it consistently produces more useful outputs as the number of fingerprints to be thinned increases.

**Conclusion**

The following can be deduced from the results of this comparative analysis:

1. The Zhang-Suen algorithm can be implemented in fingerprint enrollment and verification processes where timing is a serious concern.
2. The Guo-Hall algorithm should be implemented when the accuracy and reliability of fingerprints templates (output) are a major concern.
3. In all, despite the slower time for iteration shown by the Guo-Hall algorithm, it is superior to the Zhan-Suen algorithm in terms of output quality and reliability.

**Future work**

The development of an hybrid algorithm that would incorporate the strengths of the Zhang-Suen and Guo-Hall algorithms.

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