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Soleprint Image Gabor Filtering, Extraction of Local Ridge Orientation, and Binarisation

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Abstract: Soleprint is an impression of the friction ridge of a part of the human plantar, a point on the sole of the foot adjacent to the big toe, at the flat space behind the toes, Lepers do have soleprint but mostly do not have fingerprint. The three (3) soleprint samples, a whorl, a loop and an arch were picked out of the 240 soleprint images collected from 120 lepers of 9 colonies in Nigeria, and compare withthree (3) fingerprint images, a loop, a whorl and an arch, drawn from a database created in 2010 during my PhD research. The fingerprint recognition algorithm was applied to the images for comparison, with interest in finding local ridges orientation, Gabor filtering and binarization. The orientation patterns revealed that fingerprint and soleprint images belonging to same class do have their line of orientation similar. The Binarized images were discovered to contain lots of false minutiae points because of dirt and little mutilation on the foot. The fact remains that 1/10 of a portion of the entire surface is sufficient enough to conduct a match. The image can also be enhancedusinga good technique for better results. The soleprint has identical features to that of the fingerprint that can produce minutiae points.

Keywords: Soleprint, Binarisation, Double Loop, Whorl, Arch, Fingerprint, Voting.

I.INTRODUCTION

A soleprint is an impression of the friction ridge of a part of the human plantar. This is a point on the sole of the foot adjacent to the big toe, at the flat space behind the toes, as depicted by Fig. 1. [1][2]. In accordance to the Henry's method, there are three (3) patterns in fingerprint, namely, arches, loops and whorls. There can be subdivided into six; arch, tented arch, left loop, right loop, double loop or twin loop and whorl [3]. The fingerprint pattern also contains other features that can be useful in classification of the patterns. These features, known as minutiae points or Galton point [3] are those small unique patterns on the fingerprint such as ridge endings and ridge bifurcations Studies has revealed in Obaje, (2010) [2] that the Soleprint also has patterns that are similar to those found on the fingerprint that can be studied. On the soleprint are loops and whorls, but the kind of arches found on the Soleprint are inverted [2]. Initially arch is an alphabet best described as inverted "U", that goes to say that the kind of arches found on the Soleprint are "U" in appearance. Should this impression henceforth be called "inverted arches", that is "inverted arch" and"inverted tented arch" respectively. The Soleprint is to be studied to see if it can replace the absence of fingerprint for some special set of people all over the world.

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The leprosy victims all over the world according to WHO (2017) stands at 1 out of 10,000 world population of 7.7 Billion as revealed by United Nations in Worldometer (2019). These huge populations of a group of stigmatized people known as lepers are not enjoying democracy at all [4][5]. These set of people are denied of their fundamental human right of voting and it is because of their inability to partake in voting. The basic mode for voting all over the world is through the use of fingerprint. And they lack the fingerprint and toeprint all together, they cannot vote for candidate of their choice. The lepers do have soleprint that can be used for voting if their finger or toe print is conspicuously absent.

Fig.1: Complete Palmar showing regions of Soleprint

The fingerprint image recognition system can also work for the Soleprint images. The main components of the image recognition system are sensing, feature extraction and matching.

Matching, the end point and the most crucial aspect of the recognition system, is to compare previously stored template of images against a candidates query image for authentication purposes.

The recognition system can be further summarised into stages like, image capturing, image enhancement, feature extraction, storage of extracted feature and matching.

After collection of image, the clarity of the image will suggest a choice of suitable algorithm to be employed, as a well enhanced image will produce high-quality feature extraction. Also, the result of matching with such good quality image is overwhelming. We can conclude to say that, a good image will yield fast and accurate matching result even with high threshold. In this experiment, special cognisance is given to three very crucial stages of the recognition system, these are; local ridge orientation, binarisation and thinning.

II.EXPERIMENTS

A comparable image recognition algorithm has been developed for both sun-print and finger-print tests (Jain et al., 1997; Chandan et al., 2005; Zhang, 1984; Hong, Wan and Jain, 1998; Maltoni et al., 2003)[6][8]. The images were selected such that, the three major classes, Loop (Double loop), Whorl and Arch are represented respectfully.

3.1 Local ridge orientation

The equation for calculating gradient is,

$$Vx(i,j) = \sum_{u=i-8}^{i+8} \sum_{v=j-8}^{j+8} 2gx(u,v)gy(u,v),$$

$$Vy(i,j) = \sum_{u=i-8}^{i+8} \sum_{v=j-8}^{j+8} gx^2(u,v) - gy^2(u,v),$$

$$\theta(i,j) = \frac{1}{2} archtan\left(\frac{Vy(i,j)}{Vx(i,j)}\right) \quad (1)$$

Where w is the size of the local window, 16 are the gradients in the x and y directions of gx, and gy.

The level of consistency of the orientation field in the local block (i, j) was calculated with the formulae..

$$C(i,j) = \frac{1}{N}\sqrt{\sum_{(i',j')\epsilon D}|\theta(i',j') - \theta(i,j)|^2}, \quad (2)$$

$$|\theta' - \theta| = \begin{cases} d & if\ (d = (\theta^1 - \theta + 360)\ mod\ 360) < 180 \\ d - 180, & otherwise \end{cases} \quad (3)$$

3.2 Gabor Filtering

The Gabor filter design was based on the uniform real component of the original 2D Gabor filter that was also adopted in (Hong, 1998) [10] and (Jain andFarrokhnia1991) [11].

Thus,

$$g(x,y,T,\varphi) = exp\left(-\frac{1}{2}\left[\frac{x_\varphi^2}{\sigma_x^2}+\frac{y_\varphi^2}{\sigma_y^2}\right]\right) cos\left(\frac{2\pi x_\varphi}{T}\right) \quad (4)$$

$$x_\varphi = x \cos\varphi + y\, sin\, \varphi \quad (5)$$

$$y_\varphi = -x\, sin\, \varphi + y\, cos\, \varphi \quad (6)$$

φ is the orientation of the derived Gabor filter; and T is the period of the sinusoidal plane wave.

Decomposing the equation into two orthogonal parts, one parallel and the other perpendicular to the orientation φ, the following formula can be deduced.

$$g(x,y,T,\varphi) = h_x(x;T,\varphi)\ X\ h_y(y;\ \varphi)$$

$$= \left\{exp\left(-\frac{x_\varphi^2}{2\sigma_x^2}\right) cos\left(\frac{2\pi x_\varphi}{T}\right)\right\}.\left\{exp\left(-\frac{y_\varphi^2}{2\sigma_y^2}\right)\right\} \quad (7)$$

3.3 Binarization

Binarisation is to convert the gray scale image into binary image by fixing the threshold value. The algorithm made use of by, Jain, Hong, Pakanti and Bolle in [12] reported a ridge extraction or Binarisation algorithm whereby an image whose orientation is already known in a non-overlapping 16 x 16 neighbourhood is convolved with two masks. The two masks, $h_t(i,j;u,v)$ and $h_b(i,j;u,v)$, of size L x H (on average 11 x 7).

$$h_t(i,j;u,v) = \begin{cases} -\frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{u}{\sigma^2}}, if\ u=\left(v\cot(\theta(i,j)) - -\frac{H}{2\cos\theta(i,j)}\right),\ v \in \Omega \\ \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{u}{\sigma^2}}, if\ u=\left(v\cot(\theta(i,j))\right),\ v \in \Omega \\ 0, \quad otherwise \end{cases} \quad (8)$$

$$h_b(i,j;u,v) = \begin{cases} -\frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{u}{\sigma^2}}, if\ u=\left(v\cot(\theta(i,j)) + -\frac{H}{2\cos\theta(i,j)}\right),\ v \in \Omega \\ \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{u}{\sigma^2}}, if\ u=\left(v\cot(\theta(i,j))\right),\ v \in \Omega \\ 0, \quad otherwise \end{cases} \quad (9)$$

$$\Omega = \left[-\left|\frac{Lsin(\theta(i,j))}{2}\right|, \left|\frac{Lsin(\theta(i,j))}{2}\right|\right], \quad (10)$$

$\theta\ (i,j)$= pixel direction ; and σ = large constant.

III.RESULT AND DISCUSSION

The implementation environment used for the work is as follows: MATLAB R2015b on a Window 7 Operating System. The Sample set used for the experiment is three Soleprint images (a loop, a whorl and an arch) collected from 140 individual lepers of the 9 leprosarium in Nigeria. The opportunity for the data collection was given to me by the TETFund research grant offered me recently (2014). The Fingerprint image were also (a loop, a whorl and an arch), obtained from a previous work I did during my PhD work at University of Ilorin in 2010. All the images were collected through ink dab method.

Even though the image resolution was not exactly 256 × 256, the program demands to be adjusted to this.The experiment is aimed at subjecting the Soleprint to the same treatment with the fingerprint recognition algorithm and to see if a similar result will be obtained. Image quality and the algorithm performance evaluation is not the goal here, so the execution timeand effectiveness of algorithm was not taken into consideration.

First of all, the RGB images were converted into gray scale images as found in the first table, Fig. 2(a) is the Grayscale Fingerprint and a double loop, Fig. 3(a) is the Grayscale Soleprint and is as well a double loop. Other Gray scale images are Fig. 4(a) Gray scale fingerprint – Whorl, Fig. 5(a) Gray scale soleprint – Whorl. Fig. 6(a) and Fig. 7(a) are the Gray scale images for finger and soleprint – Arch, respectively.

Before the orientation,preprocessing was purely done through normalization approach(results not shown).

Fig. 2(b) and Fig 3(b),shows the result of orientation for Double loop fingerprint and soleprint respectfully. Fig. 4(b) is the orientation result for Whorl fingerprint and Fig. 5(b) is that for Soleprint whorl. Orientation result for Arch fingerprint is as shown in Fig. 6(b) and that for soleprint is as shown in Fig 7(b).

It was observed that the orientation pattern formation is identical for images belonging to same class irrespective of whether it is a fingerprint or soleprint image. The double loop patterns are concentric at halfway on the plot. The whorls are concentrated at the centre, while the arches line of flow is from top to bottom of the plot.

It was observed that the images used for the experiment were of poor quality, especially on the soleprint and that could be due to dirtiness of the foot, which should be cleaned more properly if a better result is aimed at.

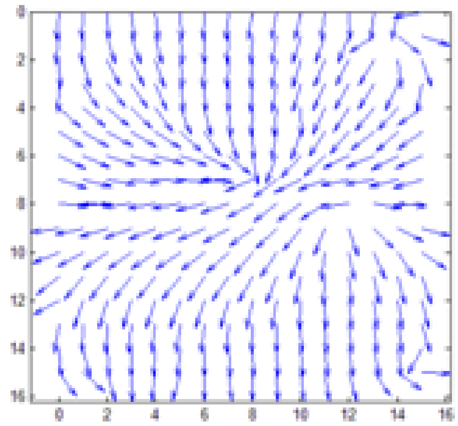
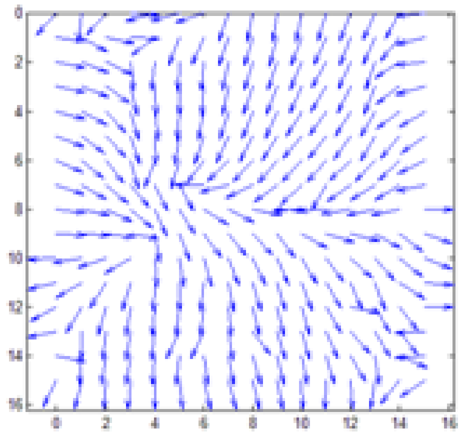
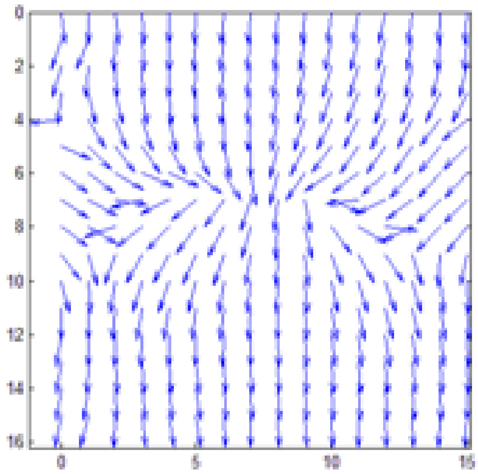
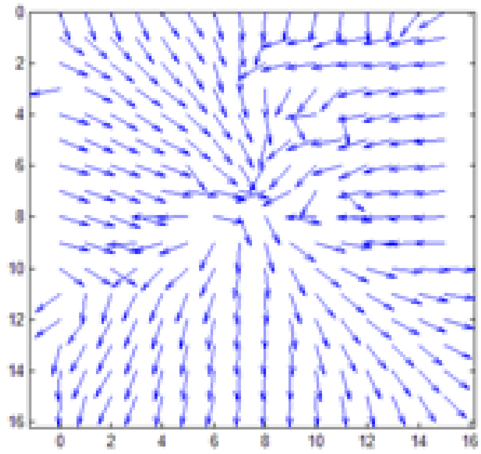
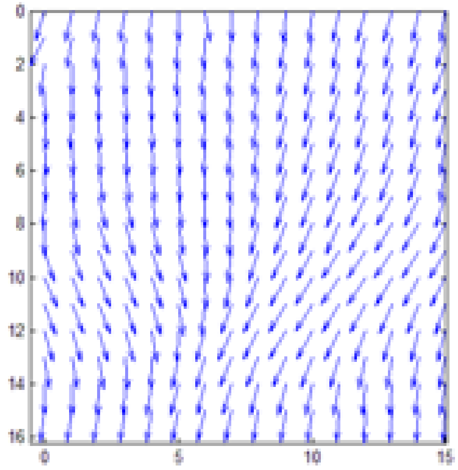
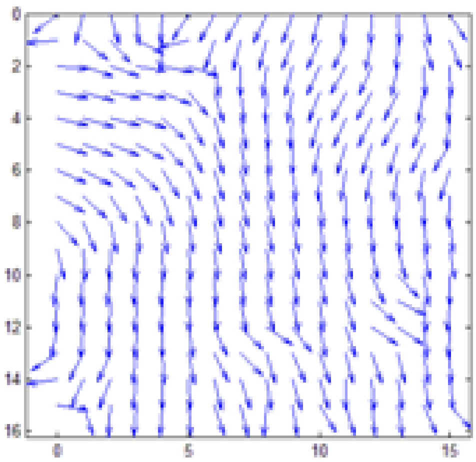
Due to the poor quality of the images, the Binarisation results revealed for both the fingerprint and the soleprint are not so good at all. As can be seen, this imageneeds to be properly enhanced before thinning, if not many false minutiae points would be created.

The reason for the experiment is not to test the viability of any image recognition system but to show that a soleprint image is like the fingerprint image.

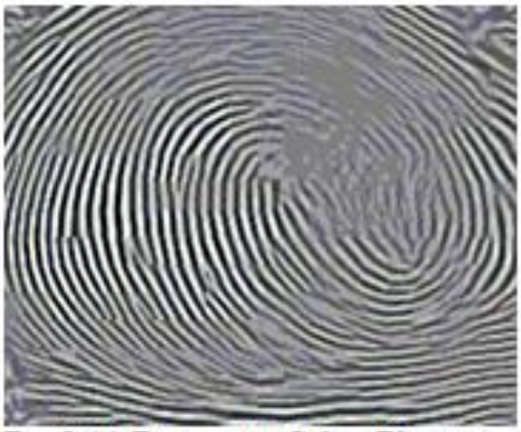
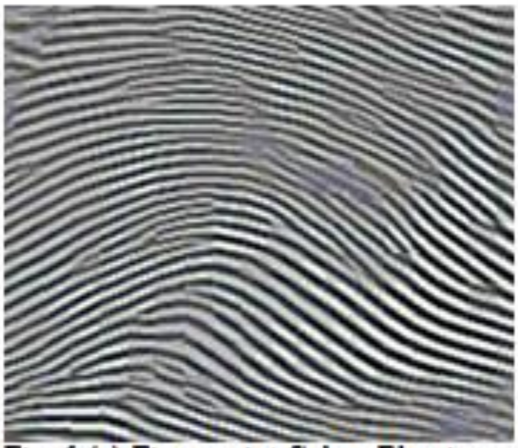
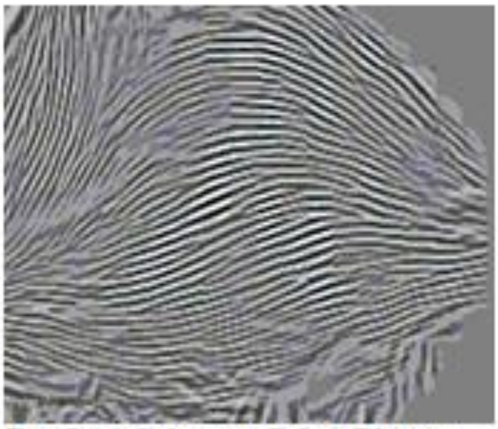
1. Result for Grayscale

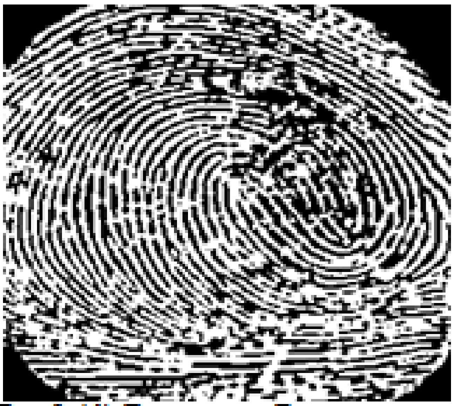
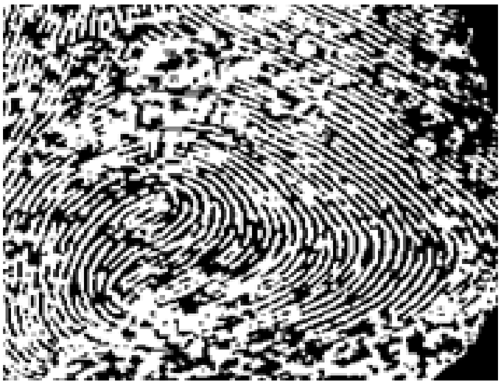
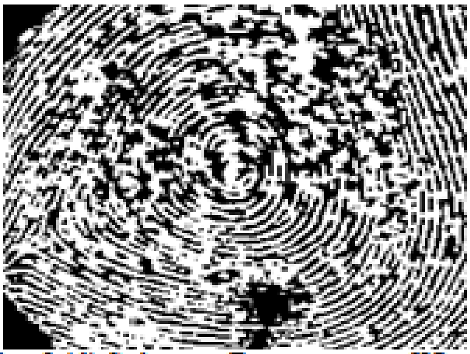
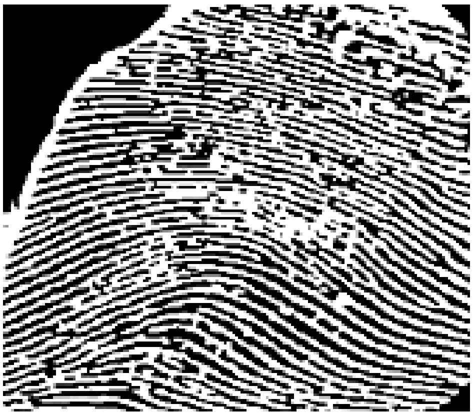
Class	Fingerprint	Soleprint
Loop	 Fig. 2 (a) Grayscale Fingerprint – Double loop	 Fig. 3 (a) Grayscale Soleprint - Double loop
Whorl	 Fig. 4 (a) Grayscale Fingerprint – Whorl	 Fig. 5 (a) Grayscale Soleprint – Whorl
Arch	 Fig. 6 (a) Grayscale Fingerprint – Arch	 Fig. 7 (a) Grayscale Soleprint – Arch (Inverted)

2. Orientation Result

Class	Fingerprint	Soleprint
Loop	 Fig. 2 (b) Fingerprint Orientation – Double loop	 Fig. 3 (b) Soleprint Orientation – Double loop
Whorl	 Fig. 4 (b) Fingerprint Orientation – Whorl	 Fig. 5 (b) Soleprint Orientation – Whorl
Arch	 Fig. 6 (b) Fingerprint Orientation – Arch	 Fig. 7 (b) Soleprint Orientation – Arch

3. Gabor Filter Result

Class	Fingerprint	Soleprint
Loop	 Fig. 2 (c) Fingerprint Gabor Blurring – Double loop	 Fig. 3 (c) Soleprint Gabor Blurring – Double loop
Whorl	 Fig. 4 (c) Fingerprint Gabor Blurring – Whorl	 Fig. 5 (c) Soleprint Gabor Blurring – Whorl
Arch	 Fig. 6 (c) Fingerprint Gabor Blurring – Arch	 Fig. 7 (c) Soleprint Gabor Blurring – Arch

4. Binarisation Result		
Class	**Fingerprint**	**Soleprint**
Loop	 Fig. 2 (d) Fingerprint Binarisation – Double loop	 Fig. 3 (d) Soleprint Binarisation – Double loop
Whorl	 Fig. 4 (d) Fingerprint Binarisation – Whorl	 Fig. 5 (d) Soleprint Binarisation – Whorl
Arch	 Fig. 6 (d) Fingerprint Binarisation – Arch	 Fig. 7 (d) Soleprint Binarisation – Arch

IV.CONCLUSION

The poor nature of the images as conspicuously visible on the results will introduce false minutiae points, loss of real minutiae points and also introduce large errors in minutiae direction or position. Image enhancement algorithm with more efficient performance and image handling capability should be employed if the image quality is a factor. The fact remains that 1/10 of a portion of the entire surface is sufficient enough to conduct a match. The experiment revealed that, the soleprint possess the basic characteristics of being unique to individuals, have features that can be extracted, and is characterized by presence of minutiae points. Hence, it can be used in place of fingerprint.. A leper or victim of accident that has no fingerprint can now make use of their soleprint. A new mode for personal identification known as the Soleprint capable of being used for voting by lepers and accident victims who have no fingerprint is hereby proposed.

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