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A Dual System Capture Biometric Fingerprint Scanner.

Oduah, Uzoma Ifeanyi (Dr.), Yang Wu

Physics Department, Faculty of Science, University of Lagos

Email: *uoduah@unilag.edu.ng; uzoma_i_oduah@yahoo.com*

Phone Number: 08033421101

Optik Design, Technische Universitaet Ilmenau, Germany

Email: *yang.wu@tuilmenau.de*

Abstract –

In this research a dual system capture method is applied in the development of a biometric fingerprint scanner with enhanced sensitivity and resolution. The device utilizes a combination of the optical imaging and capacitive imaging to capture the biometric features of the fingerprint. The system therefore shuffles between the optical mode and capacitive mode while scanning. Designed software compares and matches the fingerprint using Fourier series. By capturing and matching the minutia features and fingerprint patterns, this scanner can be used for cryptography to authenticate a user.

Keywords: Fingerprint, Scanner, Imaging, Biometrics, Cryptography

I. Introduction

In 1892, Sir Francis Galton found that the typical fingerprint has 35-50 identification points ("minutiae") and the odds of two being alike are 1 in 64 billion. With a 2006 world population of 6.5 billion individuals (and thus 65 billion fingertips), it would be impossible for all of them to be different. In practice, however, identifications are commonly made from as 8 to 12 minutiae. Using only a fifth of the minutiae would reduce the potential number of different fingerprints. Ordinary fingerprints made of sweat, sebum, dirt, and skin contaminants are called latent fingerprints, to distinguish them from the comparison imprints deliberately taken with inked fingers on "fingerprint cards" [1]. Smartphones, laptops and payment systems are among the technologies that can be unlocked by fingerprints instead of typed passcodes. But these security systems can be fooled by dirt and grease. The image capturing technique is very important in determining the effectiveness of biometric fingerprint scanner in authentication. Ink and paper are the tried-and-true way to take fingerprints, but technology has found ways to eliminate smudges and ink stains. The oldest live-scan readers use frustrated refraction over a glass prism (when the skin touches the glass, the light is not reflected but absorbed). The finger is illuminated from one side with Light Emitting Diode while the other side transmits the image through a lens to a camera. This is referred to as frustrated total internal reflection. It is also possible to directly read the light transmitted by the finger. A CMOS camera about the size of the finger can be used with a fiber optic in between, the light is coming from the edges. In July 2005, Nanoldent unveils a flexible fingerprint sensor using polymer/organic photo-detector. During the period, the Thin Film Transistor Liquid Crystal Technology (TFT-LCD) was introduced [2]. A variant of TFT devices is the use of capacitance in information instead of reflected light. Several solutions, depending on the material have been proposed such as Conductive membrane on a CMOS silicon; Conductive membrane on TFT; Micro-electromechanical switches on silicon chip.

The objective of the fingerprint scanner is to provide an identification of a person based on the acquisition and recognition of those unique patterns and ridges in fingerprint. The fingerprint is made up of a pattern of ridges and valleys (loop pattern, whorl pattern, and arch pattern) as well as characteristics that occur at the minutiae points classified as Ridge bifurcation, Short ridge or dot, and Ridge ending. The optical scanner captures the image of the fingerprint targeted on identifying the ridges and the valleys on the pattern of the finger placed on a glass plate using a Charged Couple Device (CCD) camera. The capacitance scanner generates an image of the ridges and valleys of the finger using the active capacitive pixel sensing technology. Each sensor cell contains an active capacitive feedback circuit whose effective feedback capacitance is modulated by the presence of a live skin placed on the surface sensor[3 -5].

Historically, there are various optical fingerprint recognition systems such as system based on Joint Transform Correlator and Volume Holographic Correlator, Fourier Plane Binary and Output Peak Intensity normalization technique. Other fingerprint recognition system include Multi-channel matched correlators using photorefractive material that can output multiple correlation results with single input. Watanabe *et al* proposed an ultrahigh speed compact optical correlation system using volume holographic disc that can be used for fingerprint recognition [6-10].

This research focuses on the capture of the fingerprint in 3-dimensional oriented ridge – valley pattern using a combination of capacitive sensor, optical sensor, and holography technology. Usually in fingerprint analysis, there are two kinds of singular points of key interest namely the cores and the deltas. In practice, the singular points detection and analysis is used for topographical feature of the fingerprint types. Most times the Point care index is used for singular points detection. This is defined as the sum of the orientation change along a close circle and around the points. However, due to the noise in the real images, this feature is not ideal for detection. A further development led to the discovery of multi-resolution approach[11 – 13]. Other methods include the partitioning method and heuristic rules for detection. But all these works are only based on local characteristics of singular points. Consequently, the fingerprint analysis results are always affected by creases, scars, smudges, damped prints and other spurious detections [14 – 16]. An improvement of these methods is the application of orientation diffusion which uses the global constraint of the oriented texture during the dynamic diffusion process as proposed by Perona.

In this research, the combinational manifolds of dimensions 3(3D manifold) is used to deduce the relationship between the cores and deltas in the captured fingerprint. This process therefore implements an algorithm for both the local feature and the global information.

The application of Volume Holographic Imaging is very important in designing efficient application specific computational imaging systems where the hologram act as a front-end processor for the optical field, and the post-processing algorithms, such as point multiplication and the pseudo-inverse, increase the information extracted from the raw image data.

The photorefractive effects of Lithium Niobate (LiNb03) crystals which are characterized by a change in its refractive index that results from an optically induced separation of electrons and the linear electroptic effect have been used in various optical devices. The ability to record holograms makes LiNb03 crystals attractive for many applications such as holographic data storage, optical information processing, phase conjugation, and wavelength filters [17 – 21].

The fingerprint scanner technology involves three processes namely the capturing of the fingerprint image, the storage of the captured image, and the sampling of the stored image for matching and retrieval. These processes must be properly implemented as any defect or imperfections will generally affect the efficiency and accuracy of the fingerprint scanner. A poorly captured image will introduce errors during sampling and retrieval of stored image. Also a bad storage device can lead to introduction of noise or even the loss of data. A faulty sampling and retrieval process will render inaccurate results with very poor sensitivity. It is therefore very important that all the steps are considered critically to achieve the desired efficiency.

A. *The Capturing of Fingerprint Image*

This research combines the capacitive method and the optical method to capture the fingerprint. A shutter controls the Laser beam which takes the image of the target first and shuts off before the capacitive sensor is enabled. The system shuffles between the capacitive mode and optical mode. During the optical mode, the main unit of the optical scanner is Charge Coupled Device (CCD). A CCD refers to an array of light sensitive diodes called photosites, which generate an electrical signal in response to light photons. So, the photosites record the pixels which are tiny dots representing the Laser beam that hit the finger being captured. A combination of the light and dark pixels constructs the image of the fingerprint as shown in figures 1. A system of analogue to digital converter processes the analogue electrical signal to generate a digital representation which is then matched with the signal transmitted from the capacitive method.

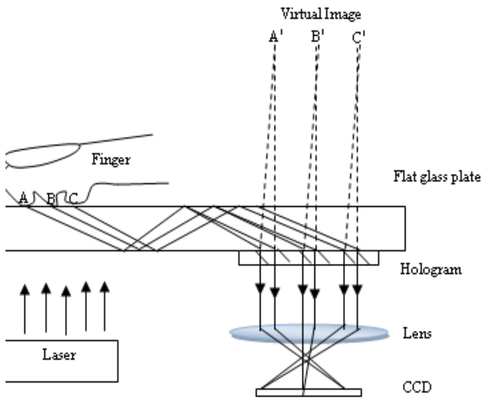

Fig. 1. Optical Scanner

In the capacitive mode, the surface of each pixel is composed of two adjacent metal plates which are separated from the skin and the environment by an ultra hard protective coating. These sensor plates create a fringing capacitance between them whose field lines extend beyond the surface of the silicon as shown in figures 2 and 3. When the finger is placed close to the sensor plates, the fingerprint valley and ridge interferes with the field lines between the two plates and reduces the effective capacitance between them. The feedback capacitance is minimized at the fingerprint ridge while the feedback capacitance is maximized at the fingerprint valley. The action of the sensor cell is in two phases namely the reset phase and the set phase. During the reset phase, the input and the output of the inverter are shorted together through a reset switch, causing the charge integrator output to settle to the logical threshold of the inverter. In the set phase, the reset switch is opened and a calibrated charge is input into the input plate of the sensor cell, causing the charge integrator output to change by an amount proportional to the feedback capacitance between the two sensor cells. As the feedback capacitance of a fingerprint ridge is smaller than that of a fingerprint valley, consequently the output swing of a sensor cell under a ridge will be greater than the output swing of a sensor cell underneath a fingerprint valley. A two dimensional array of sensor cells is used to capture the entire fingerprint image which is addressed in a random access mode through row and column decoders. Now, using advanced functions of windowing and sub-sampling, the output of the sensor array is passed through an analogue-signal conditioning block providing the capability to adjust sensor gain and offset before the signal is converted through on-chip Analogue-Digital Converter into an 8-bit digital signal for output off chip.

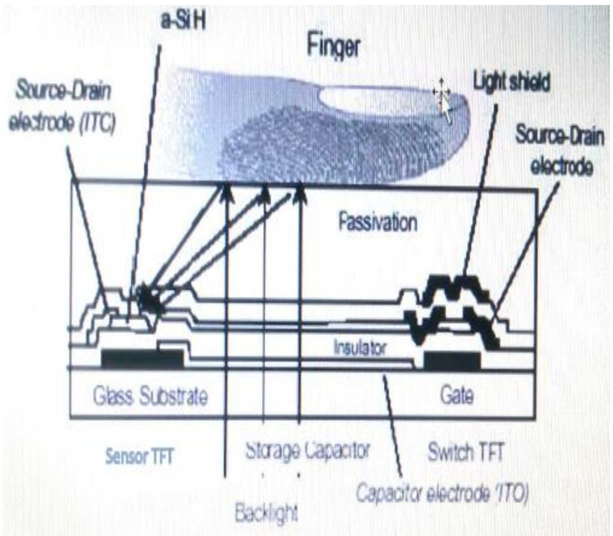

Fig. 2. The Capacitive Sensor

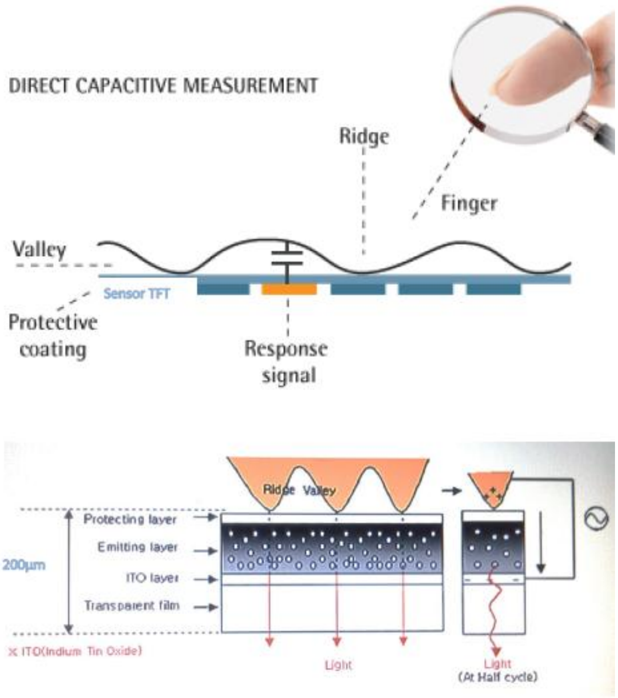

Fig. 3. Demonstration of Capacitive Scanning

The template data page construction was done with Minutiae Cylinder-Code (MCC). This fingerprint encoding method is named as multi-page local structure coding with all the parameters described in figure 4. A fingerprint image is assigned Nm minutiae template data pages with Nm equals to the total number of minutiae of that fingerprint [22][23].

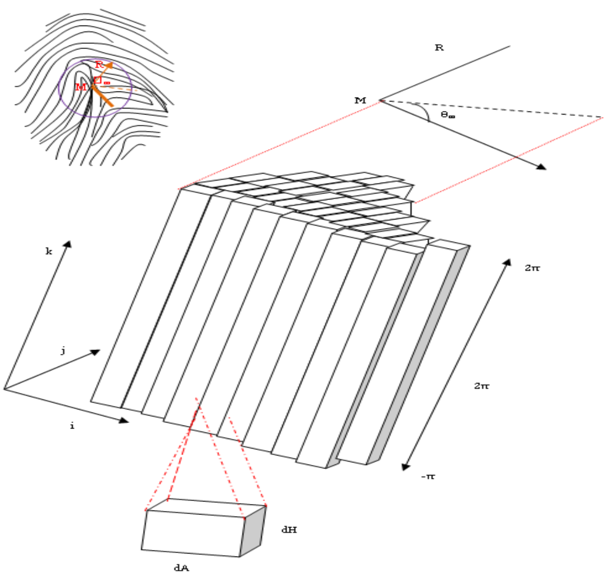

Fig. 4. Describing the system for Minutiae Cylinder Code (MCC)

The accumulating contribution of neighboring minutiae around the cell (mt Є Npij) is defined as:

$$V(i,j,k) = \sum m_t \in \ N_{pij} \ (C_M^S\left(m_t, p_{i,j}\right). C_M^D(m_t, \emptyset_k))$$

------- equation 1

Where C_M^S (mt, pi,j) and C_M^D(mt,∅k) are the distance and angle contribution minutia mt gives to cell (i,j,k)

B. Storage of Fingerprint Templates

There are four major locations for storing of a template as follows: In a token or smartcard; In a central database on a server; On a workstation; Or directly on the sensing device. Each of the locations offers its unique applications with advantages and disadvantages. Fingerprint stored on a portable token such as smartcards can be used for identity card purposes. It enables the user to carry the information from one point to another. It requires the encryption of the fingerprint code on a chip which can be decoded by a reader device. Large storage templates can be done on a central repository on a server. This allows multiple-access and with sufficient memory size can contain fingerprint templates for numbers above trillions. It is very suitable for national census data collection and other public data centre. Individual workstation is a middle ground between central database and storage on a sensing device. With workstation the user cannot authenticate from multiple locations.

C. The Fingerprint Image Sampling and Retrieval Technique

The Volume Holographic Optical Correlator System was used for the recognition system.

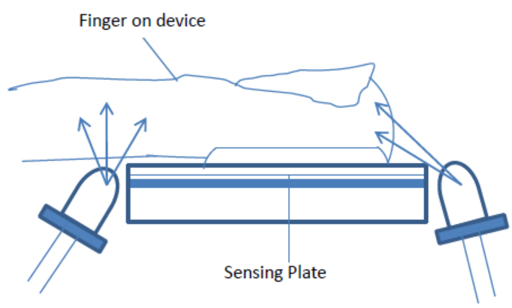

Fig. 5. A dual System Capture Biometric System Scanner

First step: The minutiae of each fingerprint extracted by the optical and capacitive method are constructed into Minutiae Cylinder Code. Secondly, the encoded data pages of the database are sequentially stored into Fe:LiNbO3 crystal applying angular multiplexing.

Third Step: Search arguments are created by uploading all the query fingerprints to the Spatial Light Modulator (SLM). Finally, the fingerprint matching scores are calculated based on similarities in the minutiae samples[24 – 25].

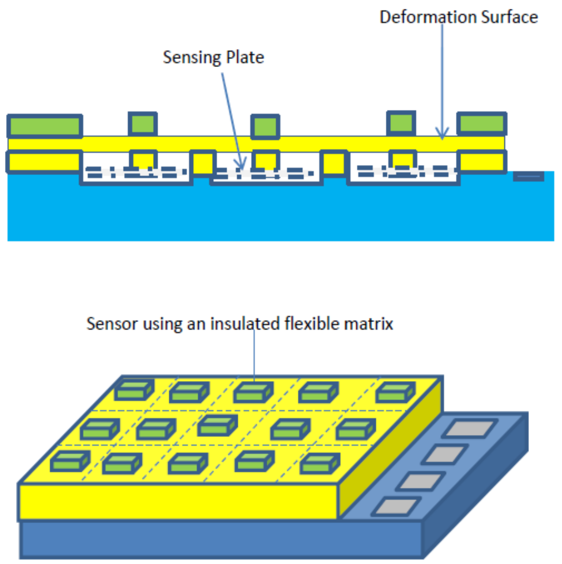

Fig. 6. Describing the sensor plate

II. RESULTS

This research produced a biometric fingerprint scanner with improved sensitivity and resolution as shown in figure 5. The device was put to test in large scale database to discriminate the genuine fingerprint from its similar fake fingerprints. In this work, it is tested on a database of 2,290 scanned fingerprints collected from the drivers licensing office in Lagos, Nigeria, using this device. The testing protocol is as follows: A sample fingerprint is randomly chosen from the database to be the query fingerprint. The similarities between it and all the fingerprints in the database are digitally calculated. The 50 fingerprints with the highest matching scores are selected as the sub-database to represent the whole database in the study. The sub-database represents the fingerprints which are the most difficult ones to discriminate from the query fingerprint in the whole database. Then the sub-database (their minutiae templates) are encoded and stored in the crystal as filter bank and the query fingerprint is retrieved. The experiments show that the recognition accuracy of the device improved by 80% following the dual system of fingerprint capture system applied.

A Biometric fingerprint scanner that shuffles between the optical mode and capacitive mode has been developed. The developed fingerprint scanner was subjected to robustness test and sensitivity test. The developed fingerprint scanner was found to detect gummy fingers and artificial fingers made with silicon or gelatine. Figure 6 describes the sensor plate.

III. CONCLUSION

Fingerprint recognition has been around for quite a while and is used for many different reasons, but security and identity confirmation is the technology's main purpose. Using biometric systems especially fingerprint readers can greatly increase the security of the electronic devices, including the personal computer, company computers, and the priceless data on the devices. Laptops often come with built-in fingerprint readers so that users can make their data more secure, but not all of them. When considering the security of the computer, a fingerprint reader may provide the secure, convenient protection needed.

The development of a fingerprint scanner requires an image capturing technique that is devoid of trapezoid distortions and all forms of imperfections experienced in conventional fingerprint sensors. The performance of the developed fingerprint scanner showed improved functionalities such as high sensitivity, image resolution, speed of operation, dimensions, weight, portability, memory capacity, cost, and ease of operation. The overall performance efficiency of this fingerprint device improved by 80% compared to the conventional device that uses one capturing technique.

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Uzoma I. Oduah was born in Ogwashi-Uku, Nigeria, in October 31, 1971.

He holds both a Doctorate Degree (Ph.D.) in Physics Electronics (2009) and a Master of Technology Degree (M.Tech.) in Physics Electronics (2000) from Nnamdi Azikiwe University, Awka, Anambra State, Nigeria. Furthermore, he specializes in Nanotechnology, Semiconductor Bandgap Engineering, Photonics and Advanced Micro-electronics.

He is a lecturer in Physics Department of University of Lagos, Faculty of Sciences, Akoka Campus, Lagos, Nigeria where he is involved in teaching some of the departmental courses in Optoelectronics, Advanced Digital Electronics, Photonics, and Laboratory Practical Demonstrations. He has over 10years research experience garnered from various world class institutions. His previous work experience includes a Business Development Manager, in Telecommunication Group of Spring Bank Plc, 143 Ahmadu Bello way, Victoria Island, Lagos, Nigeria in 2010 where he rendered Professional Advisory Services to telecommunication multinational companies. His current research work is on carrier mobility enhancement in semiconductor Complementary Heterostructure Metal oxide Semiconductor Field Effect Transistors (CHMOSFET).

Dr. Oduah is a Senior Member of International Association of Computer Science and Information Technology (IACSIT). Also, he is a member of Biometric Research Professionals and a Member of Institute of Physics (IOPs) International.