AUTOMATIC CONTACTLESS MOBILE FINGERPRINTING SYSTEM

M. Baier, S. Foret, V. Oliyil Kunnil, M. Paradis, P. Bustos and S. Mil'shtein
Advanced Electronic Technology Center, Department of Electrical and Computer Engineering
University of Massachusetts Lowell, MA 01854, U.S.A.

Keywords: Fingerprinting, Electro-mechanics, Electro-optics, Mobile embedded system, Wireless.

Abstract: Increased security requirements relevant to the worldwide war against terrorism and cyber crime recently prompted the development of biometric systems for use in identifying individuals at commercial facilities, border crossings, airports, and government building access points. Fingerprinting is one of the oldest means of biometric identification; however, the current methods of fingerprint capture carry inherent limitations on image quality. The current study describes the development of a novel, mobile, and contactless fingerprinting system. This system combines the advantages of contactless fingerprinting with the ability to create a digital map of the blood vessels within a finger for use as a second data set for use in biometric identification. The distinguishing feature of the system is the use of line scanning technology which allows for the acquisition of nearly distortion-less 180^o or "nail-to-nail" fingerprints. The study describes a fully automatic system and assesses the technical aspects of this novel device. We describe the design of the subsystems: adaptive lighting, optical image formation, power management methods, wireless data transfer, and subsystem synchronization techniques. We will also discuss the system's embedded software, which synchronizes the operation of all subsystems and allows for fingerprint visualization on an onboard touch screen display.

1 INTRODUCTION

Fingerprint image acquisition is considered the most critical step of an automated fingerprint authentication system as it determines the final fingerprint image quality and therefore the rate of success of fingerprint recognition. Not long ago, the rolled-ink technique was widely used to obtain fingerprint images (Xia, 2003). This involves coating a finger in ink and then pressing the fingers surface against a piece of paper. This method has been slowly replaced by digital fingerprint readers which can be grouped into two major families: solid-state and optical (Xia, 2003). The basic idea behind each capture approach is to generate an image which will allow for the extraction of accurate fingerprint ridge data. When capturing a fingerprint using a solid-state reader, a finger must come in direct contact with the sensor; however, because the skin tissue which comprises a fingerprint is elastic, this "contact based" method can lead to fingerprint distortion. In (Mil'shtein, 2004) and (Parziale, 2006) it was demonstrated using contact based methods that under the pressure of a finger's own weight, fingerprint ridge spacing can be distorted by about 20% in the captured image. Forceful contact of the finger against the scanner produces even more distortion as can be seen in (Mil'shtein, 2004). The pressures magnitude and direction is directly correlated with the degree of distortion captured in the resulting image, causing an image of the same fingerprint to change every time it is printed. Because of this contact distortion, contactless techniques are the method of choice in any fingerprinting technology.

There are a number of contactless scanners on the market today. Most of these systems are comprised of a standard area-scan camera that takes a picture of a fingerprint from a known distance. This method is capable of imaging the flat portion of the finger without any distortion; however, close observation of the physical finger's edges will reveal that they are somewhat round in shape. These edge portions of the finger are not perpendicular to the camera's CCD, which causes their projection onto the flat surface of the sensing element to be a

Baier M., Foret S., Oliyil Kunnil V., Paradis M., Bustos P. and Mil'shtein S..
AUTOMATIC CONTACTLESS MOBILE FINGERPRINTING SYSTEM.
DOI: 10.5220/0003362004450450
In *Proceedings of the 1st International Conference on Pervasive and Embedded Computing and Communication Systems* (PECCS-2011), pages 445-450
ISBN: 978-989-8425-48-5

distorted representation of the actual finger (Parziale, 2006). As a result, current research has been directed to obtain rolled fingerprint equivalents in a contactless fashion. These fingerprints have been shown to be fully compatible with current law enforcement databases (Yi Chen1, 2006). Figure 1 displays an image of a test finger taken with a traditional CCD. The test finger has a pattern of dots arranged in a grid with regular spacing. As expected, it can be seen that the pattern appears to be compressed towards the edge of the image due the fact that the edges of the test finger are "falling away" from the CCD.

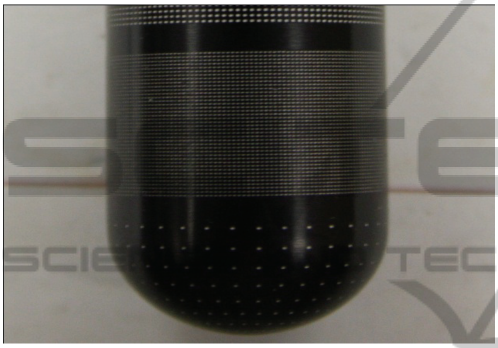

Figure 1: Image of the standard finger emulator with a traditional CCD. Distortion in the form of compression of the grid towards the left and right hands of the image can be seen.

In the current study, the advantages of contactless imaging techniques are combined with the very attractive attributes of line-scanning technology. A two dimensional image of a finger is recorded in one pixel-thick lines by scanning a line-scan camera around the finger, completing a 180^o arc. The image captured represents an uncoiled view of the finger equivalent to a "rolled ink" print. The line-scanner views each portion of the finger perpendicularly, therefore removing the projection errors inherent in conventional aerial-scanning techniques. Figure 2 displays an image of the same test finger shown in figure 1 taken using the line scanning technique. It can be seen that the irregularities present in figure 1 are nonexistent, and the regular spacing's of the grid pattern have been preserved.

In such a setup we are able to produce fingerprint images that are greater than 1000 ppi resolution and tests of the optical system suggest that the resulting image is virtually distortion free. Such high precision allows seeing fingerprint ridges and even pores in great detail. Figure 3 shows a sample image taken by our system.

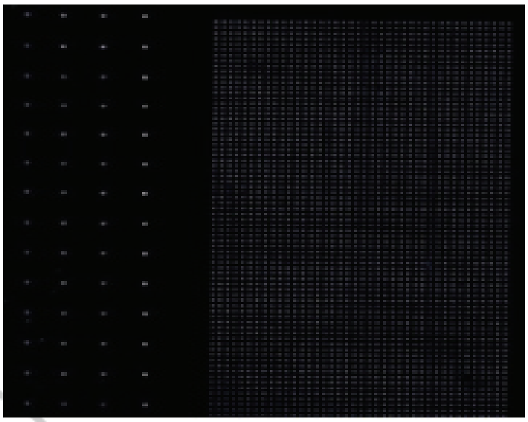

Figure 2: Image of the standard finger emulator taken with the rotational line scanning approach. Spacing between the lines is 0.44 mm.

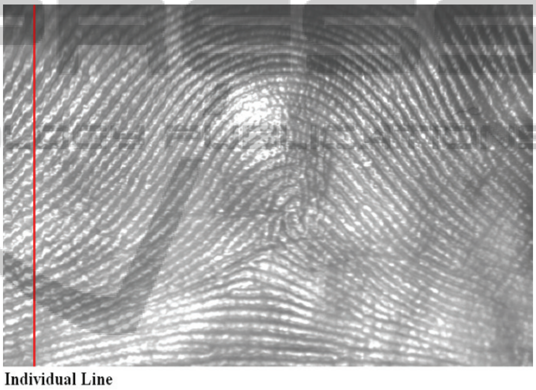

Figure 3: Fingerprint generated by line scan. The solid line denotes a single line taken by the line scanner.

2 DESCRIPTION OF MOBILE SYSTEM

2.1 Image Formation

The first step in a fingerprint authentication system is image capture. In the current study, a nail-to-nail fingerprint image is captured using the optical setup shown in figure 4.

The lens system used in this machine is designed with an overall object-to-image distance of 368mm. The working distance, which is the distance between the surface of the finger and the objective lens of the lens system, is established using the three first-surface mirrors as seen in Figure 4. First-surface mirrors are used instead of traditional secondary surface mirrors to minimize dimming and blurring of the image that occur as a direct result of light passing through the glass of a traditional mirror.

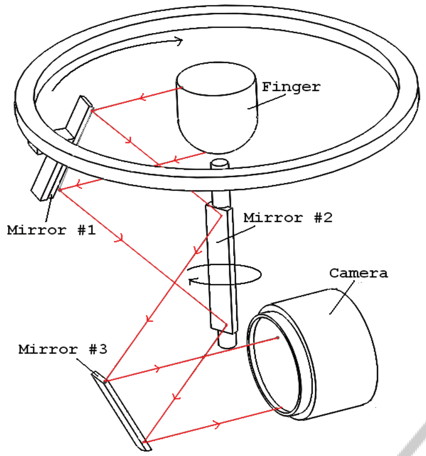

Figure 4: Optical system - arrangement of the mirrors, camera and finger.

These mirrors direct the image onto the stationery line-scan camera. Mirror #1 as shown in figure 4 is mounted onto a rotating turntable. This turntable allows the mirror to revolve 180° concentrically around the finger being imaged. While rotating, this Mirror (#1) directs the light rays which are reflected from the fingers surface onto Mirror #2. Mirror #2 is located directly below and on axis with the center of the finger. During a scan, Mirror #2 rotates through a 90° sweep within the same time Mirror #1 completes a 180° sweep, allowing light rays reflected from the finger to always be focused onto the stationery Mirror #3 which then directs these rays into the camera lens. The entire scanning procedure takes approximately ¾ of a second. This mirror system greatly reduces the overall size of the unit to 6”x7”x10” and minimizes the number of moving parts needed.

The lens system consist of two major parts, the first is a series of lenses with an effective focal length of 80mm and the second is a focusing mount which allows for fine focusing adjustments to the lens system. This system allows high-resolution imaging of the fingerprint at resolutions greater than 1000ppi.

The optics, mechanical drive train, and other components within the scanner are rigidly mounted within a 6061-T6 aluminum superstructure. The scanner chassis has been optimized to reduce the overall weight of the machine, as well as the size of its construction.

2.2 Lighting Systems

In a typical fingerprint lighting system, illuminators are aimed at the fingerprint at the start of the scan and then shut off once a scan is complete (Palma, 2006). This method offers no feedback from the camera on whether the lighting conditions are optimal. This can result in washed-out or over saturated images and the loss of useable information. For this reason, this scanner utilizes a novel lighting servo system.

This servo system uses real-time feedback from the line-scan camera to adjust the lighting intensity over three separate zones in the fingerprint: top, middle, and bottom. Every time the scanner’s processor receives a new line from the line-scan camera (this happens approximately 1300 times for a scan at 1000ppi resolution) the line is broken into three segments: top, middle and bottom. The average value of the light intensity within each of the three sections is then computed (pixels in each segment (numbering N) are summed and the resulting number is divided by N) and the lighting zone associated with each of the respective segments (top, middle, and bottom) is adjusted up or down as needed. This process is continued until all of the lines which comprise the fingerprint image have been taken. This method allows for 3900 different lighting intensities to be implemented throughout one scan of 1300 lines, and is visually described below in figure 5.

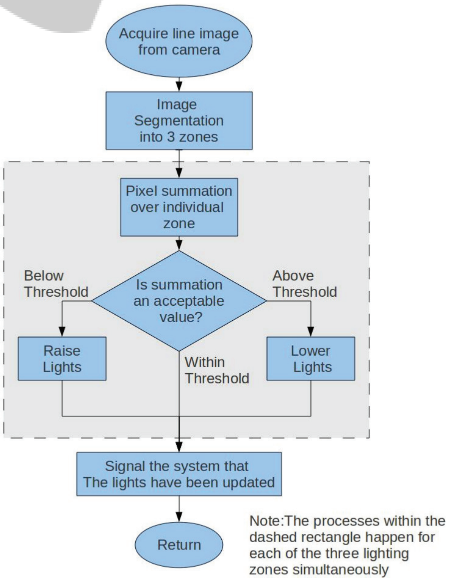

Figure 5: Logical flow chart of the contactless fingerprinter’s lighting servo system. This process is repeated every time the system receives a new line from the camera.

2.3 Blood Vessel Mapping

There are well known systems made by Mitsubishi and Hitachi that use blood vessel mapping as a primary method of finger identification (Mitsubishi, 2006). In contrast, our system uses blood vessel mapping as a secondary finger recognition method, as well as to check the "liveliness" of a finger, or whether there is blood actively being circulated within the fingers veins.

IR LEDs are positioned directly behind the finger and opposite the first imaging mirror. These provide light that is transmitted through the finger then recorded via the same line-scan camera used in fingerprinting. This feature allows for a second basis of comparison for an individual, and increases the overall reliability of identification (Nixon, 2005). Figure 6 presents an example of an unprocessed view of blood vessels in a finger.

Figure 6: Image of blood vessels produced by IR light transmitted through the finger. The image was recorded by a line-scan camera.

2.4 Processor

The current system uses an OMAP35X processor running Linux kernel version 2.6.31. This processor is ideally suited for handheld, high level computing applications. It has a DSP core and an ARM cortex A8 core, which enables the device to interface with advanced peripherals such as WiFi modules, a touch screen, and a large image sensor. This processor runs at 600 MHz, and is accompanied by 256MB of DDR RAM and 256Mb of flash memory.

Stepper motor control pulses are driven by PIC microcontroller which communicates with the OMAP35X processor via a serial connection.

2.5 Software Architecture

Figure 7 describes the different relevant software components running on the OMAP35X. The software is roughly split into three components namely, the Linux Kernel, Middleware, and Graphical User Interface.

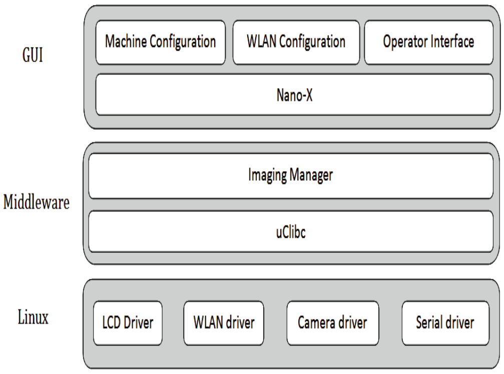

Figure 7: Software Architecture of the mobile unit.

The uppermost software layer consists of the user interface applications that interact with the end user, allowing for configuration of the machine's parameters, network configurations, and control. These applications are based on a windowing API provided by Nano-X.

The processor runs Linux kernel 2.6.31, along with device drivers for the LCD and touch screen, WLAN, Serial port, and camera. The middleware is a user-mode application called Imaging Manager. The Imaging Manager controls the camera, and coalesces the line-scan pixel-thick images into a single image. It is also responsible for calculating the lighting values for the adaptive lighting system. These values are used as feedback by the adaptive lighting system to moderate incident ambient light on the finger. The imaging manager also securely transfers fingerprints to any remote image database over a WLAN connection.

A PC-based image database application receives the images read by the fingerprinting device. This facilitates registration of new images to a local database as well as comparison of fingerprint images. This application may also be used to connect to any larger or remote database to store the fingerprint image or for fingerprint image via an internet connection. This connection can be provided by LAN, WLAN, or 3G/4G cellular networks. This feature allows for the full system to be fully utilized and remain in communication with existing fingerprint databases anywhere there is available cellular service. The flow of image data can be seen in Figure 8.

2.6 Battery and Power Management Systems

The unit's power management system is designed to supply power to all of the onboard electrical systems. It is supplied by three Li-ion polymer cells.

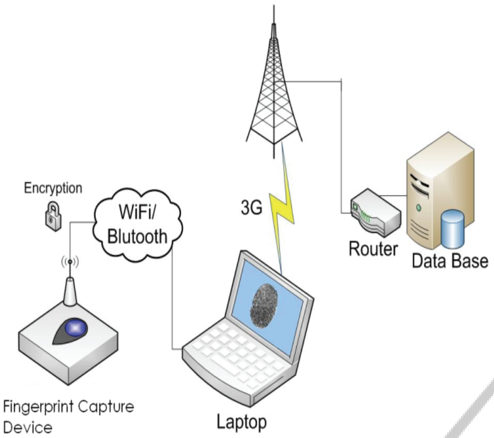

Figure 8: System diagram displaying the flow of data from the mobile unit to a nearby supporting PC and then to a remote database via a 3G cellular connection.

Li-ion polymer cells were chosen due to their high energy density and low internal resistance. A robust set of features protect and maintain these battery cells. These include the use of high efficiency switching regulators, selective power delivery, and clock frequency switching on all onboard processors. Individual battery cells are different due to variances in manufacturing processes. In a multi-cell battery pack each cell may have minor differences in their discharge and charge profiles resulting in each cell charging to slightly different voltages. Cell balancing is used to keep the cells in the battery system balanced and to maximize battery longevity and capacity. This is done in the current system in real-time and is controlled through software on the PIC microcontroller. This system also features low voltage, over voltage, over discharge, and over charge protection. Idle power consumption has been minimized to obtain longer battery life. When in idol mode, both of the systems processors clock frequencies are reduced in an effort to minimize unnecessary power consumption. Selective power management techniques, which intelligently deliver power to each module in the system as needed, are also utilized. In the current design, each subsystem is severed from its power source programmatically when it is not needed. For instance, when the unit is idle, all of the circuitry controlling the adaptive lighting, the motor, and the camera systems are disconnected from system power. This eliminates most of the idle power consumed by devices while not in use. Through the use of selective power delivery, the current system is able to achieve over 150 hours of standby operation, or over 1000 scans per charge.

3 CONCLUSIONS

The line-scan contactless fingerprinting system described is compatible with AFIS and APIS. This novel fingerprinting technology meets the requirements of federal law enforcement regulations. Our study has shown that a line-scan technique is a suitable and high-resolution technique for contactless and low-distortion acquisition of fingerprints. In contrast to the contactless system that uses six separate area cameras as described in (Parziale, 2006), line-scanning allows for the creation of high-resolution fingerprint capture systems that are cheap, small, and portable (Mil'shtein, 2008). The system described is expected to be used in police patrol cars, border patrols, access control environments, and in fingerprint data processing centers. For mobile applications, the system is equipped with a battery system that allows for over 150 hours of standby operation, or over 1000 scans per charge. The system also contains a WIFI module to facilitate wireless connectivity and fingerprint transfers between the fingerprint reader and a host computer. This system also acquires a blood vessel map for use as a second method for biometric identification. The automatic operation of our fingerprint capture system is supported by embedded software released under GPL, which will allow any potential customer to purchase the system without a need to license any external software package. In the near future, we will be testing the novel system with the police departments and the police officers.

REFERENCES

Xia X., O'Gorman L., 2003. "Innovations in Fingerprint Capture Devices" Pattern Recognition, 36, 2, pp: 361-369.

Mil'shtein S., Doshi U., 2004. "Scanning of the pressure-induced distortion of fingerprints" Scanning, 26, 4, pp: 323-327.

Palma J., Liessner C., and Mil'shtein S., 2006. "Contactless Optical Scanning of Fingerprints with 180º View", Scanning, 28, 2, 90.

Parziale G. and Diaz-Santana E., 2006. "The Surround Imager: A Multi-Camera Touchless Device to Acquire 3D Rolled-Equivalent Fingerprints," Prec. of Conf. Int'l Conf. Biometrics, pp. 244-250.

S. Mil'shtein, J. Palma, C. Liessner, M. Baier, A. Pillai, and A.Shendye, 2008. "Line Scanner for Biometric Applications" IEEE Intern. Conf. on Technologies for Homeland Security, ISBN 978-1-4244-1978-4 P 205-208.

S. Mil'shtein, M. Baier, C. Granz and P.Bustos, 2009. "Mobile System for Fingerprinting and Mapping of Blood -Vessels across a Finger", ISBN 978-1-4244-4179-2, p.30-34.

Parziale G., Diaz-Santana E., 2006 "3D Touchless Fingerprints: Compatibility with Legacy Rolled Images" Proc. Int'l Conf. Biometrics, pp: 244-250.

Yi Chen, Geppy Parziale, Eva Diaz-Santana, and Anil K. Jain, 2006. '3D Touchless Fingerprints: Compatibility with Legacy Rolled Images' 1 Michigan State University, Department of Computer Science and Engineering, East Lansing, Michigan, 48824, 2 TBS Holding AG, Schindellegistrasse 19 CH-8808, Pfaeffikon, Switzerland

Nixon K. A., Rowe R. K., 2005. "Multispectral Fingerprint Imaging for Spoof Detection," Proc. SPIE Conf. Biometric Technology for Human Identification, pp: 214-225.

Mitsubishi, 2006. "Mitsubishi Touchless Fingerprint Sensor," http://global.mitsubishielectric.com.