Biometrics and Fingerprint Authentication
Technical White Paper

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INTRODUCTION

Biometrics, the science of applying unique physical or behavioral characteristics to verify an individual's identity, is the basis for a variety of rapidly expanding applications for both data security and access control. Numerous biometrics approaches currently exist, including voice recognition, retina scanning, facial recognition, and others, but fingerprint recognition is increasingly being acknowledged as the most practical technology for low cost, convenient, and reliable security. Fidelica Microsystems' new and exclusive technology overcomes the limitations of previous systems and sets a new standard for compact, reliable, and low-cost fingerprint authentication.

THE BASIS OF FINGERPRINT AUTHENTICATION

Although fingerprints have been used as a means of identification since the middle of the 19th century, modern fingerprint authentication technology has little in common with the ink-and-roll procedure that most people associate with fingerprinting. In order to appreciate the distinction and understand modern fingerprint authentication technology, one needs to understand the basis of a fingerprint.

A fingerprint is composed of ridges, the elevated lines of flesh that make up the

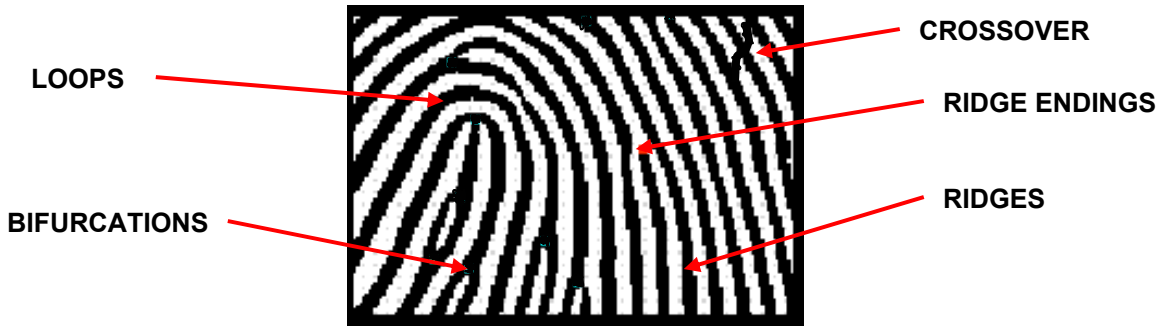


Figure 1

various patterns of the print, separated by valleys. Ridges form a variety of patterns that include loops, whorls, and arches. (Figure 1). Minutiae are discontinuities in ridges, and can take the form of ridge endings, bifurcations (forks), crossovers (intersections), and many others.

Fingerprint authentication is based on a subset of features selected from the overall fingerprint. Data from the overall fingerprint is reduced (using an algorithm application usually unique to each vendor) to extract a dataset based on spatial relationships. For example, the data might be processed to select a certain type of minutiae or a particular series of ridges.

The result is a data file that only contains the subset of data points – the full fingerprint is not stored, and cannot be reproduced from the data file. This is in contrast with ink-and-roll fingerprinting (or its modern optical equivalent) which is based on the entire fingerprint.

Modern forensic fingerprinting, with files on the order of 250kB per finger, is used in large scale, one-to-many searches with huge databases, and can require hours for verification. Fingerprint authentication, using files of less than 1000 bytes, is used for one-to-one verification and give results in a few seconds.

HOW FINGERPRINT AUTHENTICATION WORKS

In use, fingerprint authentication is very simple. First, a user enrolls in the system by providing a fingerprint sample. The sensor captures the fingerprint image. The sensor image is interpreted and the representative features extracted to a data file by algorithms either on a host computer or a local processor (in applications such as cellular handsets). This data file then serves as the users individual identification template. During the verification process, the sequence is repeated, generating an extracted feature data file. A pattern matching algorithm application compares the extracted feature data file to the identification template for that user, and the match is either verified or denied. State-of-the-art processor, algorithm and sensor systems can perform these steps in a second or two.

MODERN FINGERPRINT AUTHENTICATION TECHNOLOGY

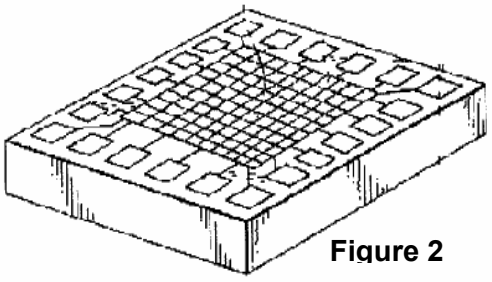


Figure 2

Fingerprint authentication can be based on optical, silicon, or ultrasound sensors. Optical technology is the oldest and most widely used, and is a demonstrated and proven technology, but has some important limitations. Optical sensors are bulky and costly, and can be subject to error due to contamination and environmental effects. Silicon technology, introduced in the late 1990's, offers some important advantages compared to optical sensors and is being increasingly applied. Ultrasound, utilizing acoustic waves, is still in its infancy and has not yet been widely used for authentication.

Silicon Sensor Technology

Silicon sensors are based on a two dimensional array of cells, as shown in Figure 2. The size and spacing of the cell is designed such that each cell is a

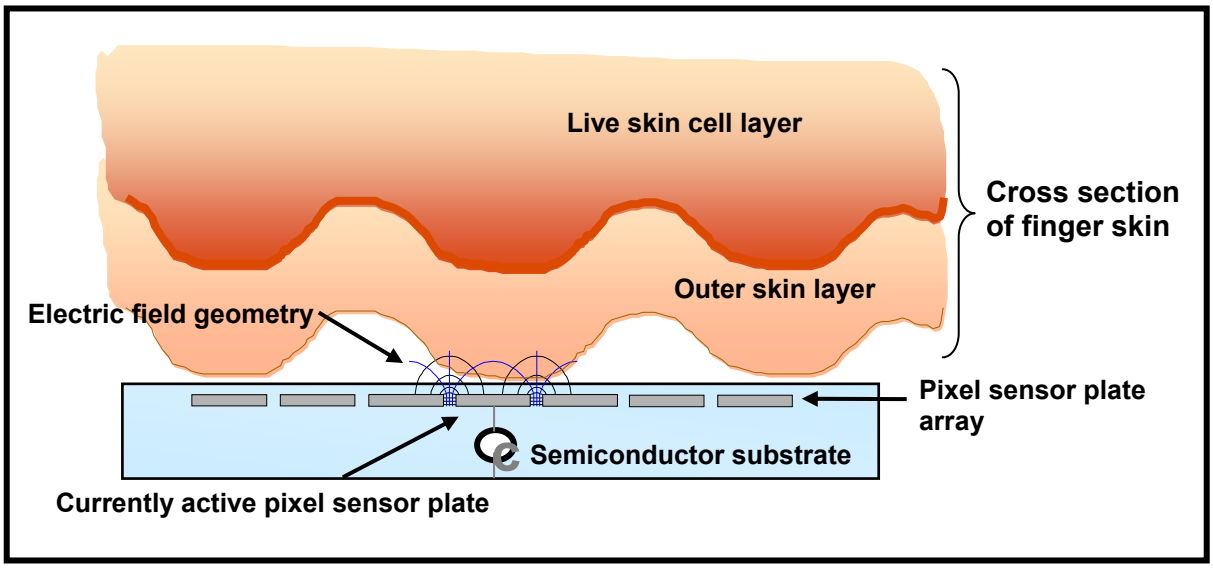


Figure 3

small fraction of the ridge spacing. Cell size and spacing are generally 50 microns, yielding a resolution of up to 500 dpi, the FBI's image standard. When a finger is placed on the sensor, the image is captured by activating transistors that underlay each individual cell. Each cell individually records a measurement from the point on the finger directly above the cell (Figure 3).

Though different vendors use different physical properties to make the measurement, the data is recorded as the distance, or spacing, between the sensor surface and that part of the finger directly above it as illustrated in Figure 4. However, distance measurement has some inherent weaknesses, which are overcome by Fidelica's novel technology, as described below.

The set of data from all cells in the sensor is integrated to form a raw, gray scale fingerprint image as shown in Figure 5. Fingerprint imaging using a continuum of

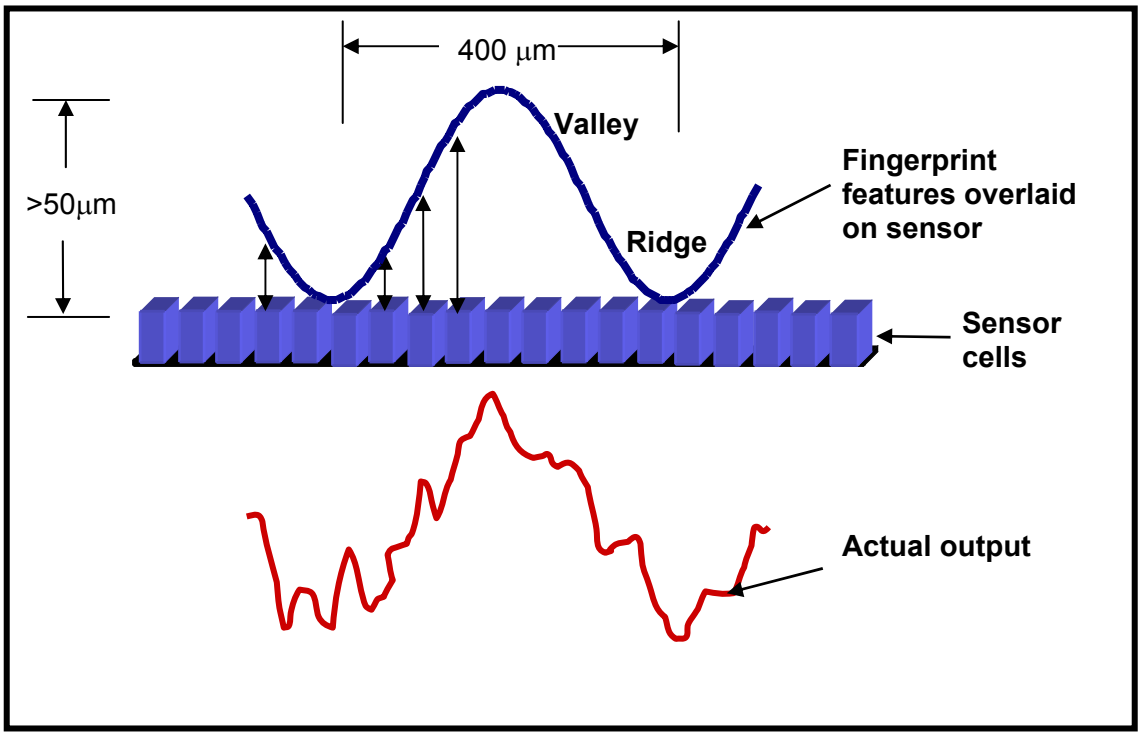


Figure 4

distance measurements results in an 8-bit gray scale image, with each bit corresponding to a specific cell in the two-dimensional array of sensors. The extreme black and white sections of the image correspond to low and high points on the fingerprint. Only the high points on the fingerprint are of interest, since they correspond to the ridges on the fingerprint that are used to uniquely identify individuals. Therefore another algorithm that must be used to deconvolute the 8-bit gray scale image into a binary, or bitonal, image. This process is a common source of error, since there could be many false high points or low points due to dirt, grease, etc., each of which could result in a false minutia extraction, and hence, introduce additional error in the matching process.

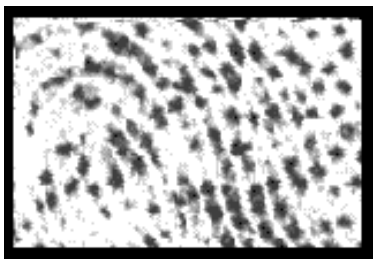


Figure 5

A feature extraction algorithm is then applied to the fingerprint to extract the specific features that make up the individual's unique data file. This data file serves as the user's individual identification template, which is stored on the appropriate device. During verification, the imaging and feature extraction process is repeated, and the resulting data file compared with the users identification template by pattern matching software to verify or deny the match.

One of the principal differences between Fidelica's sensing technology and competing methods is that Fidelica's sensor directly generates a binary image. While there is more information in a gray-scale image, much of it is extraneous and must be filtered out. Both image types contain the same essential information content necessary for identification, specifically the minutiae and ridges.

Indeed, for the first half century that fingerprints were used by law enforcement a bitonal ink image or photograph was the standard. The switch to gray-scale images is largely an artifact of the output of the optical sensors, the prevailing technology available when the transition was made to a digital database. The FBI fingerprint standard[1] reflects this history: for purposes of commonality, a gray-scale fingerprint sensor is required when new templates are added to the database; however, the fingerprint sensor used to compare an individual with the database is not specified and binary images are commonly used for the comparison.

FIDELICA'S TECHNOLOGY

A. PRESSURE SENSING SCIENCE

Fidelica's sensor technology is unique among commercially available fingerprint authentication systems. Fidelica uses a thin film-based sensor array that measures pressure to differentiate ridges from valleys on a fingerprint. This is in contrast to distance measurement, which is the basis of all other commercially available sensors, whether optical or silicon-based.

Fidelica's sensor is architecturally and physically similar to other silicon sensors in terms of cell size and spacing, and therefore offers similar resolution. However, when a finger in placed over the sensor, only the ridges come in contact with the individual pressure sensing cells in the two-dimensional array, whereas no other part of the finger contacts the sensors. As a result, only those sensors that experience the pressure from the ridges undergo a property change. To record the image, the array is scanned using proprietary electronic circuits. With an appropriate threshold setting, a distinction can be made between those sensors that experience pressure and those that do not.

The Fidelica technology employs a resistive sensor network at each cell location. Each cell incorporates a structure similar to those employed in the Micro-Electro-Mechanical System (MEMS) industry. Upon the application of a fingerprint, the structures under the ridges of the fingerprint experience a deflection, and a change in resistance results. This change in resistance is an indication of the

[1] Derived from the Criminal Justice Information Services, CJIS-RS-0010 (V4), IAFIS Image Quality Specifications for Scanners

presence of a ridge above the cell being addressed. In principle, although the resistance value is an analog value, the difference between the resistance in the pressed and unpressed states is large enough that, with an appropriate threshold setting, one can easily distinguish between the presence or absence of a ridge with high resolution and accuracy.

Pressure measurement offers some inherently powerful performance advantages over the measurement of spacing. The first is improved accuracy of ridge and valley detection. Because the Fidelica sensor detects pressure rather than distance, it readily differentiates between ridges and valleys. A valley exerts no pressure at all on the sensor underneath it (as shown in Fig. 6), whereas all the sensors underneath a ridge would record a pressure. With the appropriate threshold setting, this results in a "digital" response: the sensor either records a ridge or a valley. In contrast, the spacing measurement technique used by competing methods generates a continuum of measurements or a gray scale, which must be corrected for noise reduction, gray scale adjustment, gain and sensitivity adjustment.

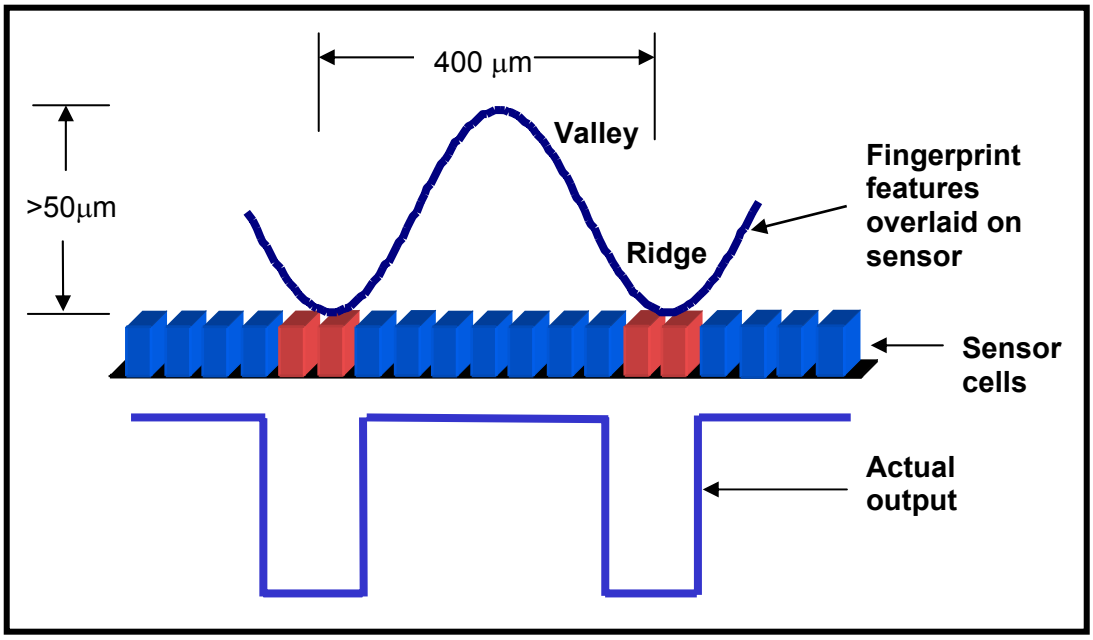
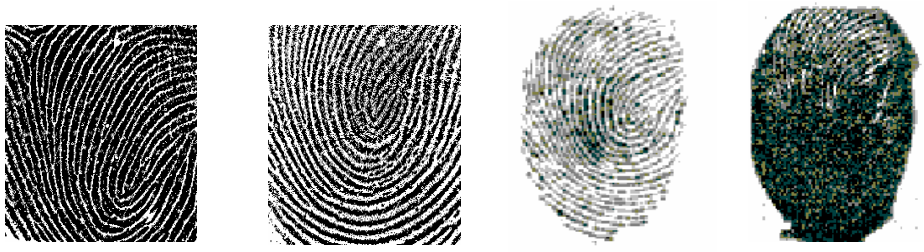


Figure 6

As a result of employing pressure rather spacing to image the fingerprint, the Fidelica sensor is considerably less sensitive to interference from dirt and grease on the finger or the sensor, wet or dry fingers, and other effects. In the presence of moisture, sweat, grease or other oils which are usually present as thin layers on the surface of the skin, there is usually no effect on a pressure-based sensor, whereas with a distance-based measurement, these thin layers cause significant distortion in the resulting image output. An example of a fingerprint image under

wet and dry conditions for a Fidelica sensor versus a competitive sensor is shown in Figure 7.



Dry fingerprint image from a pressure sensor

Wet fingerprint image from a pressure sensor

Dry fingerprint image from a silicon sensor

Wet fingerprint image from a silicon sensor

Figure 7

B. ARRAY ADDRESSING SCHEME

In addition to the force sensing technology described above, Fidelica has developed a complementary technology for addressing a large two-dimensional array of cells using entirely passive means.

Today, all competing silicon-based technologies must scan each cell of the array individually and then compile the data from all of the cells. To perform the scan, active switching devices such as diodes or transistors are built into each cell so that the addressing electronics can sequentially turn on the diode or transistor in each cell, acquire the data from that cell and then move on to the next cell.

Fidelica's technology allows addressing of an array with entirely passive means within the array. As a result all the electronic circuitry is built and physically integrated into the array, but is not a part of the array. This allows Fidelica to use manufacturing technologies that are far less expensive than silicon-based manufacturing methods.

A significant limitation of competing technologies is that the active devices (diodes or transistors) are built using complementary metal-oxide semiconductor (CMOS) technology, which dictates that the entire sensor be built on a silicon substrate. However, considering that the fingerprint array is rather large in dimensions (typically 16mm X 18mm), one can only fit about 20 – 25 of these devices on a typical 6- to 8-inch silicon wafer. Since the cost of processing a silicon wafer is typically in the range of $500 - $600, the cost of a device to the sensor manufacturer is unlikely to fall below $20. Clearly, this limits the ability to deploy this device in mass-market applications such as computing, PDAs and cellphones and smart card readers.

Fidelica's sensor is manufactured using thin film technology, which offers several significant advantages compared to silicon wafer semiconductor methods. Thin film technology is substantially cheaper than conventional semiconductor manufacturing methods. Thin film methods produce devices on large panels rather than 6- or 8-inch diameter single crystal silicon wafers at far lower costs. Fidelica can typically fit 1000 devices onto a single panel as opposed to 25 devices on a silicon wafer, which lowers the fully assembled manufacturing cost to $2, an improvement of an order of magnitude over the competition.

Conversely, silicon wafer semiconductor manufacturing, using single crystal silicon wafers, is optimized for maximizing transistor density by minimizing the size of individual transistors. The economies of scale that have made silicon wafer processing the technology of choice for many semiconductor applications do not apply to fingerprint sensors. Modern memory chips, for example, contain on the order of a billion transistors on a 2x2cm chip. Fingerprint sensors require only 100,000 cells on a similar sized device. Silicon wafer semiconductor facilities are designed to manufacture high-density integrated circuits (IC), and costs are about the same per wafer to produce a low circuit density fingerprint sensor as it costs to produce a memory or processor chip. Furthermore, thin film methods are not restricted to single crystal silicon substrates. Sensors can be produced on glass, ceramics, plastics, and other substrates. Alternative substrates also reduce cost, and allow greater flexibility for integration with all types of devices.

In addition to the enormous cost benefits that are allowed by the elimination of active switching devices in the array, the Fidelica technology also allows greatly enhanced Electrostatic Discharge (ESD) reliability. ESD damage is common on CMOS-based circuits until they are packaged and sealed before incorporation into different products. However, in a fingerprint sensor, the CMOS device is directly exposed to the user for multiple uses in widely varying environments, which significantly increases the risk of ESD damage. Conversely, the elimination of CMOS-based active circuitry on the Fidelica device drastically reduces the susceptibility to ESD damage.

The Fidelica sensor technology is also self-calibrating. A reference measurement is always made prior to or immediately following the actual fingerprint capture. This not only allows the sensor to automatically correct for effects such as environmental temperature or humidity, but also reduces the need for post image gain or sensitivity adjustments based on ambient temperature. Other sensors depend on the presence of a finger to perform a measurement, and therefore it is impractical to determine a bad sensor from an invalid finger.

SUMMARY

Fidelica's sensor solves the size, cost, and reliability problems that have limited the widespread application of fingerprint authentication. These are the most important criteria to any authentication system, and Fidelica directly addresses each:

- Size - Fidelica's sensor chip is small - about the size of a postage stamp – and can be integrated into practically any device – cell phone, keyboard, mouse, and door lock, nearly any security application imaginable.

- Cost – Fidelica's sensor chip is thin film-based, rather than silicon, and can be manufactured on plastic, glass, and many other substrates. Thin film manufacturing is substantially less expensive than other methods. Fidelica's sensor chips can be produced and distributed for less than $5 in quantity.

- Reliability and Sensitivity – Fidelica's thin film technology, combined with unique control circuitry, yields a more durable and reliable sensor. Fidelica's unique pressure sensor technology is 10x more sensitive that other methods, resulting in more reliable identification that is less affected by dirt and moisture. Fidelica's sensor eliminates semiconductor cell addressing circuitry, which improves reliability and reduces the potential of ESD damage.

- Fidelica Microsystems has conducted extensive comparisons of the performance, such as False Acceptance Rate (FAR) and False Rejection Rate (FRR), of bitonality and gray-scale fingerprint images using several commercial pattern matching and verification algorithms. The bitonal fingerprint image from force-based sensor resulted in performance that equaled or exceeded that offered by other sensors that produced a gray-scale image.

Fidelica's innovative technology is changing the way people think about fingerprint authentication, and opening up a whole new world of simple and inexpensive security. With Fidelica's sensor, fingerprint authentication systems could soon be as common as the computer mouse.

About Fidelica Microsystems
Fidelica Microsystems is a developer of Biometrics technology for electronic security and access control. Fidelica's proprietary, state-of-the-art pressure sensing technology is ideally suited for widespread, mainstream adoption of highly reliable, cost-effective fingerprint identification and authentication solutions. Accuracy, simplicity and ease-of-use make Fidelica the best choice from the time a firm first thinks about an authentication solution all the way through design-in and fulfillment, for dramatically reduced manufacturing costs and maximum profitability. For more information about Fidelica, visit www.fidelica.com.