

BIOMETRIC TECHNOLOGIES - PALM AND HAND

Chris Roberts
May 2006

Table of Contents

TABLE OF CONTENTS	2
Key Words	3
Abstract	3
Introduction	4
Palm Prints	4
Palmistry	5
Figure 1: Palmistry Diagram.....	5
Palm and Hand Print Recognition	6
Figure 2: Kuhl's Palm Prints.....	6
Palm Identification.....	6
Figure 3: Principal Lines and Wrinkles	7
Data Capture	7
Palm and Hand Print Readers	8
Reader Types.....	8
Reading Difficulties	8
Palm Recognition.....	8
Hand Geometry	9
Figure 4: Time Clock	9
Hand Geometry Readers	10
Hand Geometry advantages and disadvantages	10
Vein Patterns	11
Figure 5: Infrared Palm Image	11
Figure 6: ATM Palm Reader.....	12
Figure 7: Laptop Palm Reader	12
Figure 8: Vein scan access to bank safe.....	13
Figure 9: Back of Hand Scanner	13
Vein Pattern Advantages and Disadvantages.....	13
Hand and Hand Vein Thermograms	14
Standards	14
ENDNOTES	16

Key Words

Biometric, identification, security, hand, hand geometry, palm.

Abstract

This paper covers the biometric use of palm and hand prints and is the third in a series of papers on biometrics. A paper prepared in November 2005 provides an overview of biometrics, related standards, uses and concerns. This was followed by a paper in February 2006 describing fingerprint recognition, the biometric use of fingerprints, biometric standards and related security issues.

Introduction

Previous papers have covered a background to biometrics and the use of fingerprints as a biometric measure. Currently used for identity, authentication and forensic purposes, biometric technologies have been broadly grouped into four areas with several techniques in each:

1. Hands;
2. Heads and face;
3. Other physical characteristics; and
4. Behavioural characteristics.

While fingerprints are well accepted as a biometric measure, other techniques relating to hands are, perhaps, less well known or accepted. Perhaps the best understood is palm prints. Other techniques include hand geometry and vein patterns recognition.

Palm print recording and identification for law enforcement purposes has been in existence almost as long as fingerprint systems and palm prints are reported to comprise 30% of all crime scene marks¹. As much as another 20% are made up of the edge of the hand, fingers between the palm and fingertips and other parts of the hand. A key driver for law enforcement agencies to adopt full-hand scan technologies is the high incidence of hand related crime scene marks².

One of the earliest AFIS systems built to support palm prints is believed to have been developed in Hungary in the early 1990's. In 1997, the technology was bought by a US company. In recent years, most AFIS vendors have added palm print records capabilities to their systems.

Many law enforcement agencies are now making a significant investment in palmprint identification system, for example, the UK's Police IT Organisation (PITO) has signed a £122 million agreement with Northrop Grumman for palm and fingerprint identification technologies³.

Other law enforcement agencies have made similar investments and are reporting increased crime resolution rates⁴. In some cases, a palm print with an area of less than one square inch is sufficient to provide a positive match⁵.

Australia currently houses the largest repository of palm prints in the world. The Australian National Automated Fingerprint Identification System (NAFIS) stores over 4.8 million palm prints⁶.

Palm Prints

As with finger, palms of hands and soles of feet have epidermal ridges, thought to provide a friction surface to assist with gripping and object of surface. The biometric use of palm prints uses ridge patterns to identify an individual. Similar in many respects to fingerprint identification, palm print identification systems measure and compare ridges, lines and minutiae found on the palm.

Palm prints have a history perhaps equal to fingerprints, for example Joao de Barros, an early explorer and writer, wrote that the Chinese merchants distinguished young children from each other by recording palm prints and footprints on paper with ink.

Palmistry

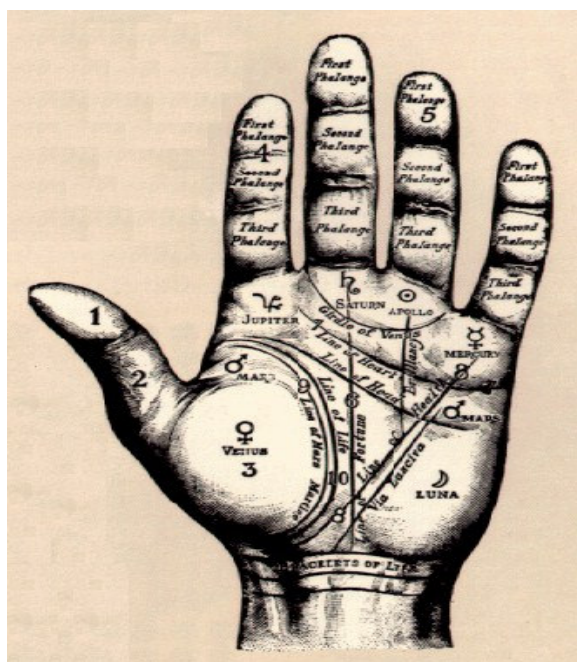
Palmistry, also known as chiromancy, is a study of the characteristics of the hands, including lines, markings, skin tone and fingernails in order to reveal the past, present and future. These characteristics can reportedly diagnose latent health problems, reveal character traits and guide future actions.

The hand has been ascribed a special significance from stone age time, illustrated by many cave paintings in Europe and other parts of the Western hemisphere and Bushman paintings in Africa. Hands made of stone, wood and ivory have been discovered in a number of archaeological excavations. Many ancient cultures including the Egyptians, Greeks and Romans used palmistry to foretell the future. History also records the use of palmistry in ancient India and China.

In the Middle Ages, in Europe, palmistry was condemned by the Church and branded as devil-worship. It is interesting to note, however, that there are many references to palm or hand reading in the Old Testament, Vedic scripts and early semitic writings⁷. One of the earliest texts on palmistry is understood to be *De Physiognomia* by Michael Scott published in 1477. This described the physiognomy of the human body and included a chapter on the human hand. Physiognomy is a pseudo-science with the premise that a person's appearance and visible characteristics reflect character and personality.

Today palmistry is found world-wide with many variations, both cultural and philosophical although many regard it as a pseudo-science with little or no support from substantive scientific evidence. It is certainly of little use for biometric and law enforcement or other evidential purposes.

Figure 1: Palmistry Diagram



Source: Palmistry Chiromancy⁸

Palm and Hand Print Recognition

One of the earliest uses of palm prints in a criminal case is the State of Nevada vs Kuhl (1918). This was the last horse-drawn mail stage robbery in the United States, and in which the driver was murdered. A palm print was found on a torn, bloodstained letter at the crime scene. This was later matched to Kuhl by two experts. Kuhl was sentenced to death, later commuted to life imprisonment⁹.

Figure 2: Kuhl's Palm Prints



Source: Howard Hickson's Histories. On the left is the palm print found at the scene. On the right is the a print taken from Kuhl on January 17, 1917. Photograph from the Nevada State Library, Archives, Carson City.

Another early case was the State of Ohio v. Betts (1917) and may be the first conviction based solely on palm print evidence. In 1917, Betts was arrested and charged with burglary based on the fact that his palm print was found on a windowpane at the crime scene¹⁰.

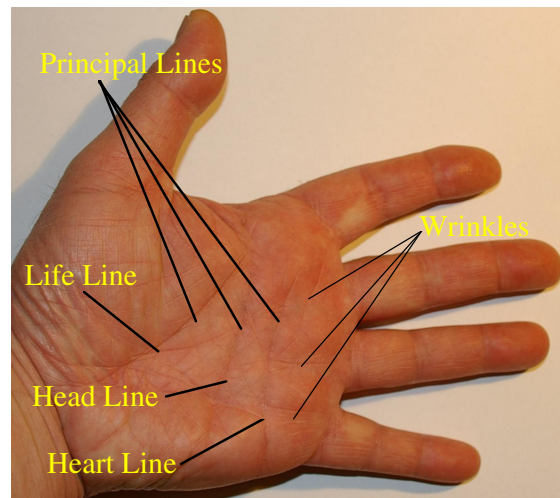
Palm Identification

There are three groups of marks which are used in palmprint identification¹¹:

- Geometric features, such as the width, length and area of the palm. Geometric features are a coarse measurement and are relatively easily duplicated. In themselves they are not sufficiently distinct;
- Line features, principal lines and wrinkles. Line features identify the length, position, depth and size of the various lines and wrinkles on a palm. While wrinkles are highly distinctive and are not easily duplicated, principal lines may not be sufficiently distinctive to be a reliable identifier in themselves; and
- Point features or minutiae. Point features or minutiae are similar to fingerprint minutiae and identify, amongst other features, ridges, ridge endings, bifurcation and dots.

Palm creases and ridges are often superimposed which can complicate feature extraction.

Figure 3: Principal Lines and Wrinkles



Some specialist terms describe the techniques used in palm, hands and feet recognition:

- Ridgeology is the study and identification of the friction ridges found on palms, fingers and feet;
- Edgescopy is the study of the detail and characteristics of ridge edges;
- Palmar Flexion Crease Identification studies creases on palms cause by flexing the hand.

As with fingerprint recognition, there are three principal palm matching techniques. These are:

- minutiae-based matching, the most widely used technique,
- correlation-based matching, and
- ridge-based matching.

Data Capture

There are three capture methods:

- Off-line, where palm prints are inked onto paper and later scanned into the palm print system;
- On-line, where palm prints are directly scanned; and
- Real-time, where palm prints are scanned and processed in real-time.

There is continuing research into the use of palm and hand prints for biometric identification using, for example, eigenspace techniques described as eigenpalm and eigenfinger. This technique uses features extracted from the fingers, thumb and palm which are mathematically transformed and consolidated to provide an overall matching score¹².

Other techniques being researched include cross one and two-dimensional ratios of the locations of finger creases¹³, quantized co-sinusoidal triplets, Gabor filters, Fourier Transforms, wavelets, Principal Component Analysis (PCA) and Independent Component Analysis (ICA)¹⁴. Some of these techniques are likely to be incorporated into new standards such as the ISO/IEC 19794-3 Biometric data interchange formats -- Part 3: Finger pattern spectral data. Other than for law enforcement purposes however, palm and hand print biometrics are not widely used.

Palm and Hand Print Readers

Palm and hand readers are, necessarily, larger than fingerprint readers. They are also more costly. Technology advances are reducing the size of palm and hand readers but there is a physical limit dictated by the size of the human hand. Technology is also allowing readers to be incorporated into a variety of devices, for example, a vehicle's gear shift so that only approved drivers are able to operate the vehicle¹⁵.

Reader Types

Palm readers are generally optical, although they may incorporate other reader technologies such as capacitive sensors also used in a "liveness" test. Other technologies include ultrasound, and thermal imaging. In this respect palm and hand readers are similar to fingerprint readers. Some palm readers have the capability of capturing 10-print fingerprints, as well as palm prints.

Low resolution readers (generally less than 100 dpi) can effectively only record principal lines and wrinkles. High resolution readers (generally greater than 400 dpi) are able to record point features and minutiae¹⁶.

Hand geometry, for example the points at which fingers are attached to the hand or the gaps between fingers, is used to establish the co-ordinates of the hand in relation to the reader for feature extraction and comparison purposes.

Reading Difficulties

Where users hands do not fully contact the palm readers, there made be some difficulty in obtaining a clear image. A complicating factor here is a change in scale caused by increasing or varying the distance between the reader and palm.

Another difficulty is in capturing a clear image of the hollow of the palm which may not fully contact the reader. This has been solved, to some extent, by providing curved readers that fully contact all parts of the palm.

Other difficulties have been caused by shifting position, closing fingers or placing the hand on different parts of the reader when registering. Again this has been largely solved by designing hollows for the palm and fingers to occupy or by providing pins to separate and locate the hand on the scanner.

Clearly a degree of user co-operation is required in registering palmprints or using biometric hand scanners. Because of the need to touch the hand reader, other concerns include hygiene and latent prints.

Palm Recognition

Some palm recognition systems scan the entire palm, while others allow the palm image to be segmented in order to improve performance and reliability. In general terms, reliability and accuracy is improved by searching smaller data sets. Palm systems categorise data based upon the location of a friction ridge area.

Hand Geometry

Hand geometry is the most widely used of biometric technologies, has been commercially available for over 20 years. One of the first patents was registered in 1985 with the first commercial systems becoming available shortly after.

Typical applications using hand geometry include access control where dirt, grease, ink or other debris would reduce the reliability of fingerprint identification, for example, oil refineries or manufacturing plants. Hand geometry is also widely used to control access to nuclear plants.

San Francisco's international airport has used hand geometry systems for employee access control since 1993. Ben Gurion airport in Israel, uses hand geometry to allow trusted passengers to use express security control lanes.

The US INSPASS (Immigration and Naturalization Service Passenger Accelerated Service System) system was first implemented in 1993 and used hand geometry to identify pre-enrolled passengers, allowing them to bypass immigration queues at several US airports^{17,18}. Some 40,000 travellers were eventually enrolled in this programme which was later cancelled as being too expensive to maintain¹⁹, attributed largely to the complex and extended (30 minute) enrolment time.

It was superseded in 2004 by the DHS Registered Traveller Programme which requires fingerprints and iris scans. In trial at six US airports, it is planned to expand the trial to between 10 and 20 airports in 2006²⁰. The Canadian CANPASS programme, available at seven Canadian international airports also uses iris scans as the principal means of identification²¹.

Other examples of hand geometry usage is attendance recording²². A large number of US universities, colleges and day care centres use hand geometry scanning to control access to dormitories, classrooms, meal plans, libraries and so on. The U.S. Federal Bureau of Prisons uses hand geometry technology to monitor movements and control access for prisoners, staff and visitors²³.

Figure 4: Time Clock



Source: www.timeclockeshop.com

Security has become more integrated and has grown in importance with successive Olympic Games. From protecting athletes in the Olympic Village, it has expanded to cover venue and spectator protection and control. First seen in the 1984 Los Angeles games, hand geometry detectors have feature in access control for Olympic Games since then. The 1992 Barcelona Games marked the first time that biometric access control was expanded from the Olympic Village to the competitive venues. The 1996 Olympic Games used hand geometry scanning to control access to the Olympic Village, tracking 65,000 people. Further security overlays have been implemented to control access to national and press offices at the Olympics. For example, during the 2006 Turin Games biometric finger scanners were used to control access to Germany's Deutsches Haus facility used by athletes, coaches and media representatives²⁴.

Wells Fargo, Bank of America, Florida Credit Union and other US financial institutions have installed hand geometry readers for safety deposit box customers, allowing self-service and faster access without the need for a staff member to verify identity thorough a signature and then escort them to the deposit box storage area^{25, 26}.

Walt Disney World has been using finger geometry scans to identify holders of annual and seasonal passes since 1996. Scanning the index and middle fingers an algorithm extracts a numeric identifier for each pair. While not unique, the calculated value is considered to have sufficient statistical distinctiveness to identify pass holders.²⁷

Hand Geometry Readers

Readers measure fingers, combinations of fingers or the entire hand in either two or three dimensions using imaging technologies. Today these are usually CCD or CMOS imaging devices (described in the previous paper on fingerprints).

Characteristics typically recorded include length of fingers, curvature of fingers, thickness and width of fingers and palm, knuckle shape, distances between joints, hand surface area, bone structure and translucency. Approximately 90 measurements are taken and 31,000 points analysed in a full hand scan which ignores surface details such as scars, fingernails, fingerprints and dirt^{28, 29}.

Typical processing times are:

- Enrolment 30 to 60 seconds;
- Scan 5 seconds; and
- Identification 1 to 10 seconds.

Templates range from 9 to 20 bytes in size. This is significantly smaller than hand scans which record lines, wrinkles, creases and minutiae.

Hand Geometry advantages and disadvantages

Hand geometry has several advantages, including:

- Ease of use. The technology is simple to use and has been in widespread use for many years. It does not carry the negative perceptions of fingerprints and is perceived to be less intrusive than iris and retinal scans. Most users have sufficient dexterity to easily use the devices, thus reducing user error rates;
- Resistant to spoofing. The principal spoofing technique is a cast or latex model of a hand which is difficult to execute, particularly if simple physical security measures are in place.

Other spoofing techniques such as gloves or other devices are unreliable and more likely to be rejected;

- Small template size. Compared to other biometrics such as fingerprints, hand scan and iris scans, hand geometry is extremely small and can be accommodated on a variety of devices including magnetic stripe cards. The small template size allows fast processing, important where large volumes of users are processed;
- The readers are durable and able to process large volumes of users of several years without undue reader failure. They can also withstand wide temperature ranges and operate in hostile (such as high temperature and dusty) environments;
- The technology has been in use for many years and has proved reliable.

There are some disadvantages which include:

- Cost. Hand geometry scanners are relatively large and expensive and palm and hand scanners are equally or more costly. The size of the devices precludes use in portable applications or small devices such as a computer mouse;
- Hand changes and injuries. While the basic structure of the hand changes little over time, injuries, swelling or diseases such as arthritis can obscure this structure and cause recognition difficulties. It is interesting to note that students need re-enrolment once or twice in their scholastic lives to accommodate growth;
- Accuracy. Hand geometry is not sufficiently distinctive to allow 1-to-many searches and is generally limited to 1-to-1 authentication uses. Its use is therefore limited to identity verification rather than identification of an individual from a database. This is, however, considered an advantage by privacy advocates;
- Hygiene concerns, from multiple users touching the reader.

Vein Patterns

Vein pattern identification uses an infrared light source to scan for haemoglobin in the blood. De-oxygenated haemoglobin appears as a black pattern with the hand or finger showing as a lighter colour or white. The device then captures an image of vein patterns in wrist, palm, back of the hand, finger or face. This is similar to the technique used to capture retinal patterns. The backs of hands and palms have a more complex vascular patterns than fingers and provide more distinct features for pattern matching and authentication.

Figure 5: Infrared Palm Image



Source: Fujitsu

As with other biometric identification approaches, vein patterns are considered to be time-invariant and sufficiently distinct to clearly identify an individual. The difficulty is that veins move and flex as blood is pumped around the human body. However research appears to have overcome this challenge and an early demonstration device was built into a computer mouse by Fujitsu in a development of vein pattern identification by researcher Masaki Watanabe³⁰. This was used to control access to the computer system. More recently, Fujitsu demonstrated their Contactless Palm Vein Identification System at the annual CeBIT show in March 2005³¹. At least five vendors have been pursuing this technology including Fujitsu, Hitachi, Bionics Co., Identica and Techsphere³².

Japan's Bank of Tokyo-Mitsubishi made this technology available to customers on 5000 ATM's from October 2004³³. The biometric template is stored on a multi-purpose smart card that also functions as a credit and debit card and issued to customers. Other Japanese banks are also now introducing this technology.

Figure 6: ATM Palm Reader



Source: Fujitsu

EFTPOS terminals, incorporating palm vein technology are being developed for use in for use in retail stores.

While the size of earlier devices limited their use and added to cost, recent developments have reduced the size to make mobile and portable devices feasible. These use a 35mm² sensor which makes the device small enough to use with laptops and other mobile devices and other office equipment such as copiers³⁴.

Figure 7: Laptop Palm Reader



Source: Fujitsu

In other applications, Swiss and US banks have introduced access control to vaults and other key areas controlled by back of the hand vein scanners replacing key and code entry systems³⁵. Airports are also introducing this technology at customs, immigration and quarantine points.³⁶.

Figure 8: Vein scan access to bank safe



Source: LEGIC Identsystems Ltd

Figure 9: Back of Hand Scanner



Source: Jane's Airport Review

Vein Pattern Advantages and Disadvantages

Some advantages of vein pattern biometrics are:

- Vein pattern technology is perceived as secure as it incorporated “liveness” detection.
- Being contactless, it is also perceived as being hygienic and does not carry the stigma associated with fingerprints.
- The human vascular structure is individually distinct.
- Identical twins have different and distinct vascular patterns.
- Vein patterns are not easily spoofed, observed, damaged, obscured or changed.
- Vein pattern recognition requires simple low resolution imaging devices.
- The technology is reliable in that it shows little performance degradation in harsh environments, such as mines, manufacturing and construction sites as well as heavy traffic areas such as schools, military bases and dormitories.

- A vein pattern technologies have a high degree of usability with some research showing 99.98 percent usability.
- It is convenient, fast and requires little user training.

As with hand geometry technology, cost and hand changes and injuries are the main disadvantages. In common with most technologies, however, costs are reducing as technology improves and usage increases.

Hand and Hand Vein Thermograms

Heat patterns of the human body is characteristic of an individual and can be used as a biometric. Thermograms are non-contact and non-invasive, they can be unreliable in uncontrolled environments, for example, large numbers of people, central heating, localised heat sources such as radiators, machinery and even vehicle engines and exhausts.

While some research has been undertaken with thermograms, much of this has been in relation to facial thermograms. There is little information available yet on hand thermogram research.

Standards

Standards relating directly to palm and hand biometrics include:

- ISO/IEC FDIS 19794-3 - Finger Pattern Spectral Data. This proposed standard is in its Final Draft International Standard (FDIS) stage.
- ISO/IEC 19794-4:2005 Information technology - Biometric data interchange formats - Part 4: Finger Image Data. This includes some reference to palm image data;
- ISO/IEC FCD 19794-8: Biometric Data Interchange Format Part 8 - Finger Pattern Skeletal Data. This is a proposed standard in Final Committee Draft (FCD);
- ISO/IEC FCD 19794-9, Biometric Data Interchange Format – Part 9, Vascular Image Data. Also a proposed standard in Final Committee Draft³⁷;
- ANSI INCITS 396-2005 Hand Geometry Interchange Format defines the data interchange format for storing, recording, and transmitting hand geometry information. It defines both content and format of the data for exchange as well as the units used for the measurement of the hand geometry data. This US standard corresponds to the proposed ISO/IEC FCD (Final Committee Draft) 19794-10 Biometric Data Interchange Formats – Part 10, Hand Geometry Silhouette Data international standard³⁸.
- FBI IQS IAFIS Image Quality Specification Appendix F. The FBI tests a variety of fingerprint and hand scanners, card scanners, printers and related devices and provides a list of approved products. This list does not rate the technologies of each device, providing only confirmation that the tested device meets the FBI's Integrated Automated Fingerprint Identification System (IAFIS) Image Quality Specifications (IQS)³⁹.
- ANSI NIST ITL-2000 standard defines sixteen record types in ASCII, binary, or a combination of the two. It was originally intended for use by law enforcement agencies and specifies formats for the exchange of descriptive text, fingerprint, face, scar, mark, and tattoo information used in identification of a subject. An ANSI/NIST file can contain other information such as personal descriptive data, criminal history, palm and facial data. This standard is currently under revision⁴⁰. The ANSI NIST ITL-2000 Type-15 record standard is used for palm print data. Most AFIS systems currently available comply with this standard.

There are a number of other standards in common with other biometric technologies. These have been discussed in an earlier paper and include:

- Common Biometric Exchange Formats Framework (CBEFF) published as NISTIR 6529 by the (US) National Institute of Standards and Technology (NIST). CBEFF describes data elements for the support of biometric technologies independently of applications and the usage;
- Federal Information Processing Standard (FIPS) 201 - Personal Identity Verification of Federal Employees and Contractors;
- XML Common Biometric Format (XCBF);
- ANSX9.84 Biometric Information Management and Security;
- ANSI BioAPI Specification Version 1.1 (formerly ANSI INCITS 358-2002). Defines the Application Programming Interface and Service Provider Interface for a standard biometric technology interface.
- ITU X.509
- ISO 10918 series including ISO 10918-1:1999 Information Technology - Digital compression and coding of continuous tone still images;
- FIPS 190: Guideline for the Use of Advanced Authentication Technology Alternatives; and
- INCITS 377, 378, 379, 381, 385 approved data interchange formats.

Endnotes

- ¹ Cross Match Technologies Introduces Innovative Full Hand Print Live Scan System, Find Biometrics.com, 11 May 2004, <http://findbiometrics.com/viewnews.php?id=1124>, accessed 5 March 2006
- ² Law Enforcement Technology, June 2004, Royce Taylor and Michael Knapp, <http://www.identix.com/industries/law/LET.pdf>, accessed 10 March 2006
- ³ UK Police upgrade biometric identification tech, Sylvia Carr, silicon.com, 15 December 2004, <http://news.zdnet.co.uk/hardware/emergingtech/0,39020357,39181344,00.htm>, accessed 26 February 2006
- ⁴ Motorola Fingerprint and Palmprint Technology Helping to Solve More Crimes in Palm Beach County, Florida, Motorola Corporation, 27 June 2005, <http://www.motorola.com>, accessed 5 March 2006.
- ⁵ Let Me Read Your Palm, Jaypeetex.com, <http://www.jaypeetex.com/products/Law%20Enforcement/AFIS/Palm.htm>, accessed 26 February 2006
- ⁶ Palm Print Recognition, National Science and Technology Council, 27 March 2006, <http://www.biometriccatalog.org/NSTCSubcommittee/Documents/Palm%20Print%20Recognition.pdf>, accessed 5 May 2006
- ⁷ Palmistry History, <http://www.paralumun.com/palmhistory.htm>, accessed 5 March 2006
- ⁸ Palmistry Chiromancy, <http://www.crystalinks.com/palmistry.html>, accessed 5 March 2006
- ⁹ Case Number 606 Makes History, Howard Hickson's Histories, www.outbacknevada.us/howh/606.html, accessed 26 February 2006
- ¹⁰ Michele Triplett's Fingerprint Terms, <http://www.fprints.nwlean.net/s2.htm>, accessed 5 May 2006
- ¹¹ Palmprint Verification: An implementation of Biometric Technology, Wei Shu and David Zhang, <http://ccrma.stanford.edu/~jhw/bioauth/palm/00711120.pdf>, accessed 26 February 2006
- ¹² A Biometric Identification System Based on Eigenpalm and Eigenfinger Features, Slobodan Ribaric and Ivan Fratric, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol 27, No. 11 November 2005, <http://www.cse.unr.edu/~bebis/CS790Q/PaperPresentations/PalmFinger.pdf>, accessed 02 March 2006
- ¹³ Personal Identification by Cross Ratios of Finger Features, Zheng *et al*, University of Colorado, <http://vast.uccs.edu/~tboult/cs601/NOTES/hnad-biometric.pdf>, accessed 02 March 2006
- ¹⁴ Palmprint Recognition with PCA and ICA, Connie *et al*, Multimedia University, Malaysia, November 2003, http://sprg.massey.ac.nz/ivcnz/Proceedings/IVCNZ_41.pdf, accessed 02 March 2006
- ¹⁵ Biometrics - Great Hope for World Security or Triumph for Big Brother?, Guardian Newspapers, 6/17/2004, <http://www.buzzle.com/editorials/6-17-2004-55585.asp>, accessed 12 March 2006
- ¹⁶ Online Palmprint Identification, David Zhang, Wai-Kin Kong, Jane You, and Michael Wong, Ieee Transactions On Pattern Analysis And Machine Intelligence, Vol. 25, No. 9, September 2003, <http://appsrv.cse.cuhk.edu.hk/~jschen/files/online%20palmprint%20identification.pdf>, accessed 02 March 2006
- ¹⁷ The emerging use of biometrics, The Economist, 08 Dec 2003, http://www.ebusinessforum.com/index.asp?layout=rich_story&doc_id=6878, accessed 21 April 2006
- ¹⁸ The Myth of Airport Biometrics, Robert McMillan, 09 August 2002, <http://www.wired.com/news/conflict/0,2100,54418,00.html>, accessed 23 April 2006
- ¹⁹ Florida airport sells biometric security pass for \$80/year, 01 August 2005, http://www.boingboing.net/2005/08/01/florida_airport_sell.html, accessed 23 April 2006
- ²⁰ TSA Announces Next Steps for Registered Traveler Program, April 20, 2006, <http://www.tsa.gov/public/display?theme=44&content=09000519801cdf0d>, accessed 23 April 2006
- ²¹ Fact Sheet - CANPASS Air, Government of Canada, July 2005, <http://www.cbsa-asfc.gc.ca/newsroom/factsheets/2005/0419-e.pdf>, accessed 23 April 2006
- ²² Biometric time clocks, <http://www.timeclockshop.com/>, accessed 21 April 2006
- ²³ Biometrics: The future of security, CBC News Online, 14 December 2004, <http://www.cbc.ca/news/background/airportsecurity/biometrics.html>, accessed 20 April 2006

-
- ²⁴ Biometrics used to protect Germany's Olympic athletes, Linda Rosencrance, Computerworld, 22 February 2006, <http://www.computerworld.com/printthis/2006/0,4814,108902,00.html>, accessed 30 April 2006
- ²⁵ The Identity Business, Betty Joyce Nash, International Biometric Group, http://www.biometricgroup.com/in_the_news/03_21_05.html, accessed 12 March 2006
- ²⁶ Thinking outside the safe deposit box: Florida Credit Union members use biometric HandReaders, SecureID News, 3 March 2005, <http://www.secureidnews.com/news/2005/03/03/thinking-outside-the-safe-deposit-box-florida-credit-union-members-use-biometric-handreaders/>, accessed 30 April 2006
- ²⁷ Ticket Tag Finger Scans For Passes, <http://allearsnet.com/pl/fingerscan.htm>, accessed 21 April 2006
- ²⁸ Hand Geometry, Bioenable Technologies (Pvt) Ltd, <http://www.bioenabletech.com/biometrics/>, accessed 21 April 2006
- ²⁹ Hand Geometry, National Science and Technology Council, 27 March 2006, <http://www.biometriccatalog.org/NSTCSubcommittee/Documents/Hand%20Geometry.pdf>, accessed 5 May 2006
- ³⁰ Fujitsu develops palm reading mouse, technology, ITworld.com, 27 September 2002, <http://www.itworld.com/Comp/2838/020927fujitsumouse/pfindex.html>, accessed 10 March 2006
- ³¹ Fujitsu's biometric scanner reads palms, Dan Ilett, ZDnet UK News, 11 March 2005, <http://news.zdnet.co.uk/hardware/emergingtech/0,39020357,39190994,00.htm>, accessed 21 April 2006
- ³² New Biometric Technologies Get Beneath The Surface, CardTechnology ID Newswire, 14 October 2005, <http://www.cardtechnology.com/article.html?id=20051026CTDMQSN1>, accessed 10 March 2006
- ³³ Place Your Hand On The Scanner, Trends in Japan, 10 May 2005, <http://web-japan.org/trends/science/sci050510.html#>, accessed 10 March 2006
- ³⁴ Fujitsu launches new compact, high-performance palm vein biometric authentication device, Fujitsu Press Release, Sydney 9 March 2006, <http://www.fujitsu.com/au/news/pr/archives/2006/20060308-02.html>, accessed 5 May 2006
- ³⁵ Renown Swiss Bank uses high-security biometric control with LEGIC, Press Release, Legic Identsystems Ltd, March 2006, accessed 5 May 2006
- ³⁶ Security Get an Upper Hand, Janues Airpoirt review, September 2005, <http://www.biometricsandsecurity.com/images/Jane-Sept.pdf>, accessed 5 May 2006
- ³⁷ List of Technical Committees - JTC 1/SC 37 Biometrics, International Organisation for Standardisation, <http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?COMMID=5537&scopelist=PROGRAMME>, accessed 7 May 2006
- ³⁸ ISO/IEC FCD 19794-10, International Organisation for Standardisation, <http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=43638&scopelist=PROGRAMME>, accessed 7 May 2006
- ³⁹ Products Certified For Compliance With The FBI's Integrated Automated Fingerprint Identification System Image Quality Specifications, <http://www.fbi.gov/hq/cjisd/iafis/cert.htm>, accessed 10 March 2006
- ⁴⁰ Summary of April 2005 ANSI/NIST Fingerprint Standard Update Workshop, McCabe and Garris, NIST, July 2005, <http://fingerprint.nist.gov/standard/workshop1/ir7242.pdf>, accessed 7 May 2006