



# Biometric Technologies for Ambient Intelligence and Smart Living

**Vincenzo Piuri**  
University of Milan, Italy

2014 IEEE Vice President-elect for Technical Activities

# Summary

- Biometric Traits
- Biometrics for Ambient Intelligence and Smart Living
- Design Issues for Biometric Systems



# Biometric Traits



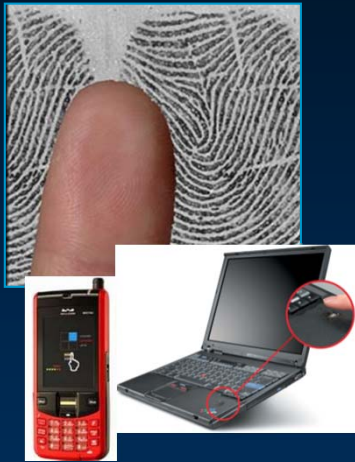
# Biometrics

*Automated methods of recognizing  
a person or a class of persons  
based on physiological or behavioral characteristics*



# Physiological Traits

## Fingerprint



## Face



## Iris



## Palmprint



## Palm geometry



## Ear shape



## Hand veins



# Behavioral Traits

Signature &  
Handwritten text



Gait



Emotion



Gesture



Keystroke



Age & Gender



# Properties of Biometric Traits (1)

- **Universality**: each person must have the considered trait
- **Distinctiveness (Uniqueness)**: the considered trait must allow for distinguishing any two persons
- **Permanence**: the considered trait must be time invariant
- **Collectability (Measurability)**: the considered trait must be easily measurable
- **Performance**: the identification accuracy, speed, and robustness must be appropriate and ensured without specific operating conditions
- **Acceptability**: percentage of persons who could accept the use of the considered biometric technology
- **Resistance to circumvention**: difficulty in circumventing the identification procedure



# Properties of Biometric Traits (2)

Biometrics	Universality	Uniqueness	Permanence	Collectability	Performance	Acceptability	Circumvention
Face	High	Low	Medium	High	Low	High	Low
Fingerprint	Medium	High	High	Medium	High	Medium	High
Hand Geometry	Medium	Medium	Medium	High	Medium	Medium	Medium
Keystrokes	Low	Low	Low	Medium	Low	Medium	Medium
Hand Vein	Medium	Medium	Medium	Medium	Medium	Medium	High
Iris	High	High	High	Medium	High	Low	High
Retinal Scan	High	High	Medium	Low	High	Low	High
Signature	Low	Low	Low	High	Low	High	Low
Voice Print	Medium	Low	Low	Medium	Low	High	Low
F. Thermograms	High	High	Low	High	Medium	high	High
Odor	High	High	High	Low	Low	Medium	Low
DNA	High	High	High	Low	High	Low	Low
Gait	Medium	Low	Low	High	Low	High	Medium
Ear	Medium	medium	High	medium	Medium	High	Medium





# Biometric Applications for Ambient Intelligence and Smart Living



# Adaptativity through Identification

## ■ *Person identification*

- for assigning known needs, preferences, and desires
- for recording new needs, preferences and desires for future use

## ■ *Person classification*

- for applying known characteristics of a class of persons for services and operations
- for refining the characteristic services and operations of the class of persons

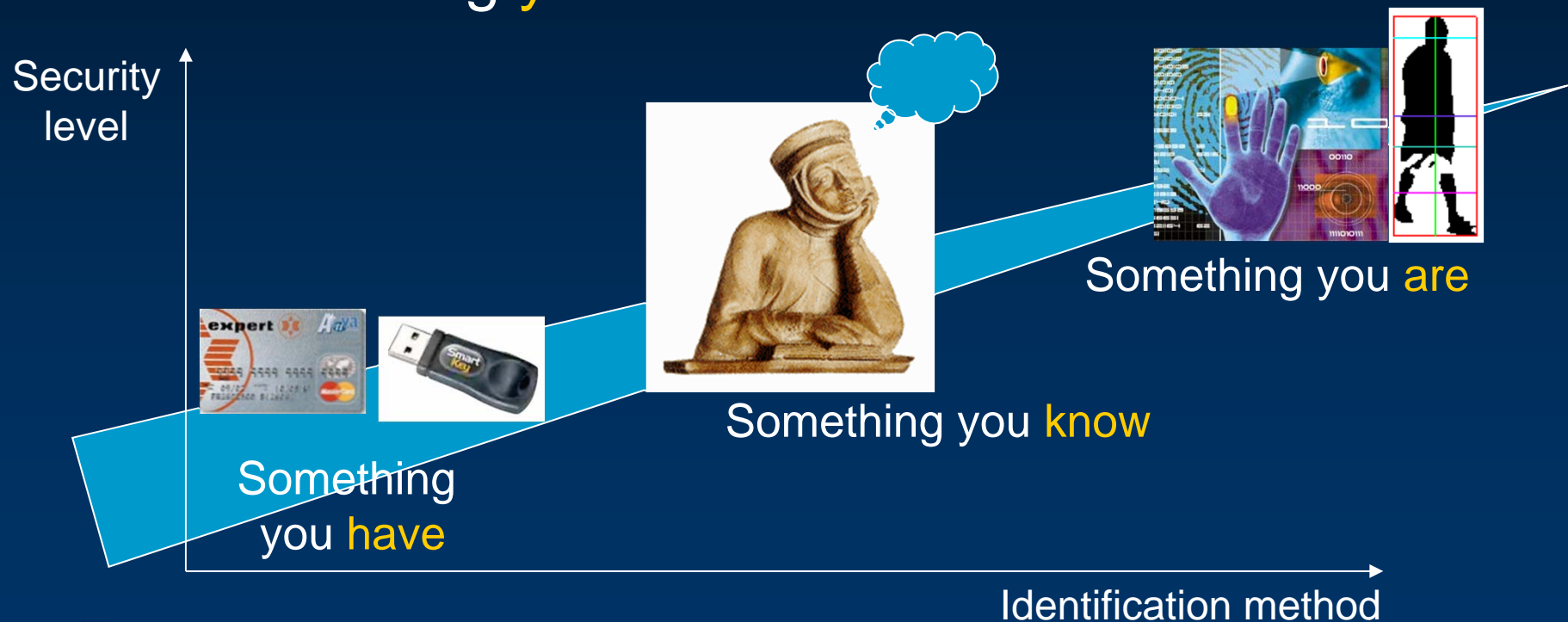
## ■ *Person action understanding*

- for applying services and operations to a human action



# Biometrics vs. Classical Identification

- From something **you have** (token, key) or something **you know** (password) to something **you are**



# Physical Access Control

- Critical areas
- Restricted areas
- Private areas
- Public buildings
- Sports arenas
- Bank caveau
- Transportations
- ...



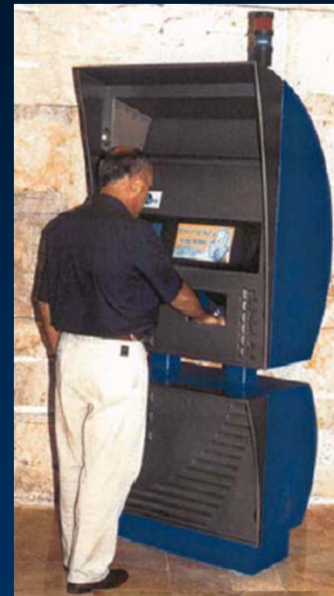
# Surveillance

- Buildings
- Public areas
- ...



# Logical Access Control to Services

- Home banking, ATM
- Supermarkets
- E-commerce
- Cellular phones
- Computers
- ...



```
* Type ID
* Swipe ID
* Select payment
  -OR-
* Pay cashier
Cred |Debit| EBT |
```



# Smart Home



# Personal Hygiene

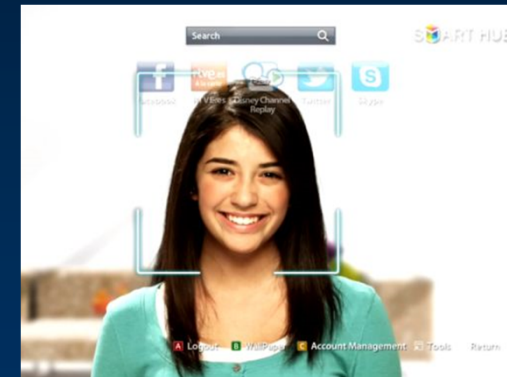




# Kitchen and Restaurants



# Smart Entertainment Systems



# Children Protection



# Smart Cars



# Smart Transportation Systems



# Intelligent Traffic Management



# Rental Services

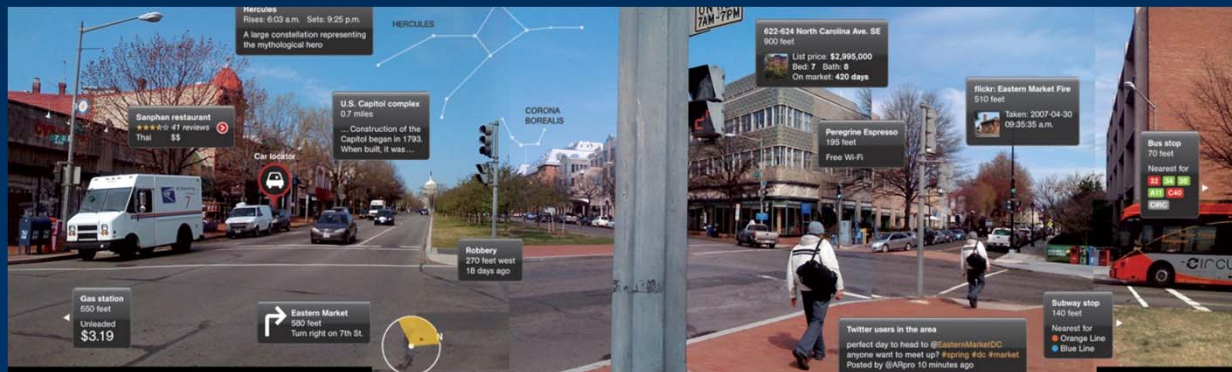


# Intelligent Shops





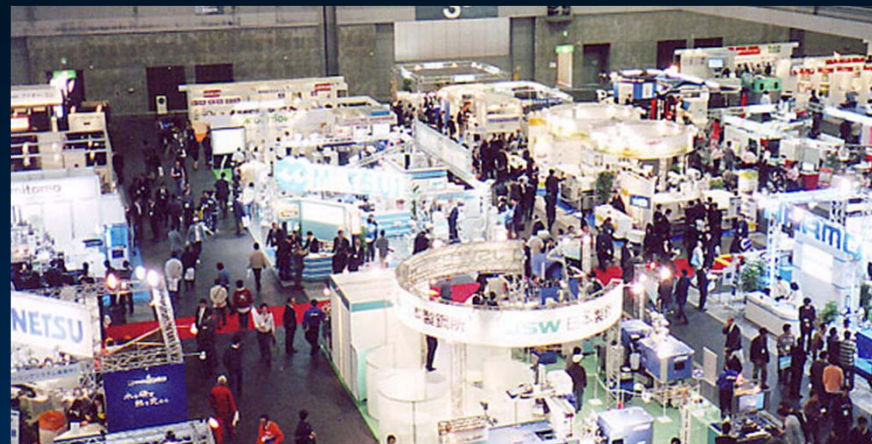
# Information Kiosks and Augmented Reality



# Ticket Offices and Entrance Gates



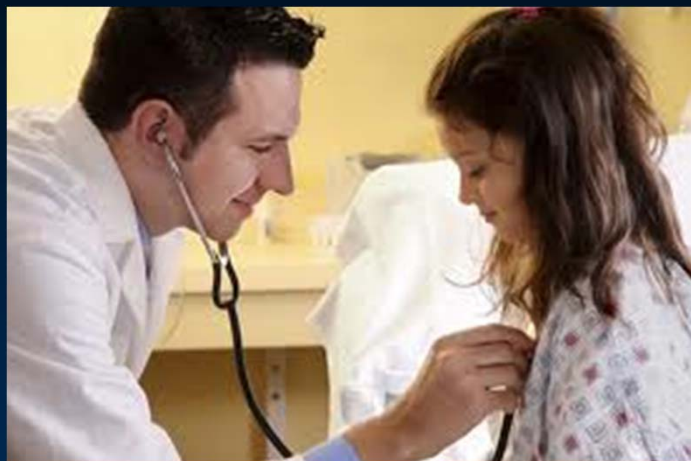
# Museums and Exhibitions



# Health Care and Hospitals



# Health Services

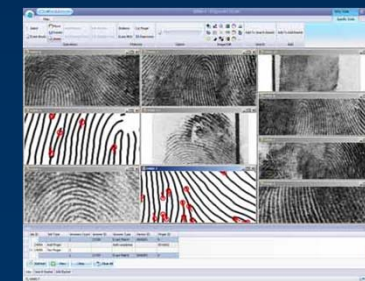
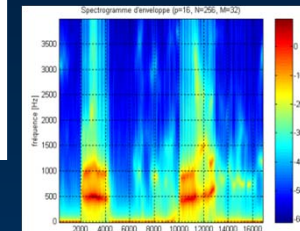
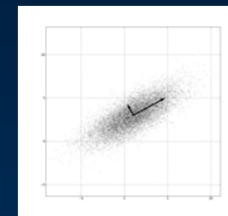


# Design Issues



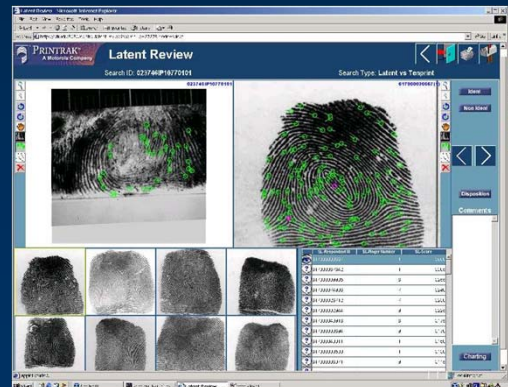
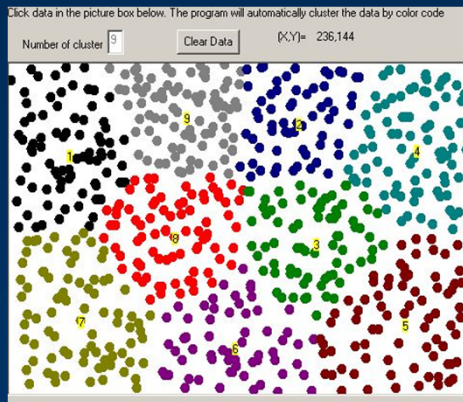
# Technologies for Biometric Systems (1)

- Sensors and measurement systems
  - Biometric sensors, liveness
- Signal processing
  - Feature extraction, liveness tests
- Image processing
  - Face, fingerprint, hand, iris, gait, ear, ...



# Technologies for Biometric Systems (2)

- Sensor data fusion
  - Matching module, multimodal biometric systems
- Classification and clustering
  - Characterization for template management and searching





# Technologies for Biometric Systems (3)

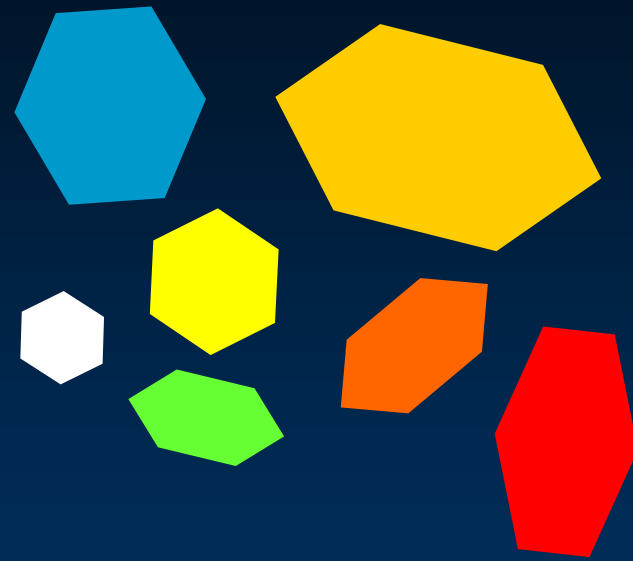
- Database management
  - Organization of very-large DB of biometric templates (national identification systems, large scale identification systems)
- Systems and database networking
  - Distributed biometric systems, communications, interoperability
- Security and privacy
  - Protection of biometric data



# How to Deal with Heterogeneous Aspects?

Nowadays:

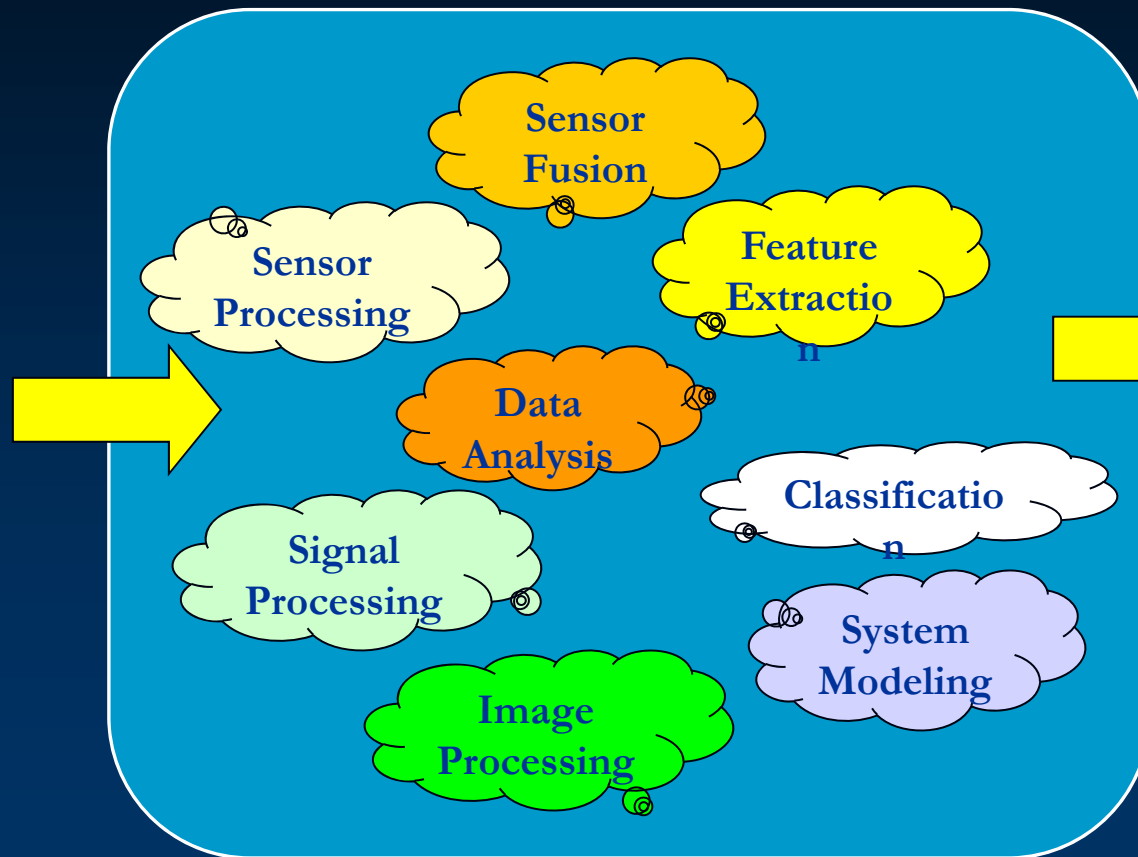
- Separate issues
- Module-oriented solutions
- Ad-hoc solutions



- Limited optimization
- Limited reusability
- Limited integrability
- Limited interoperability



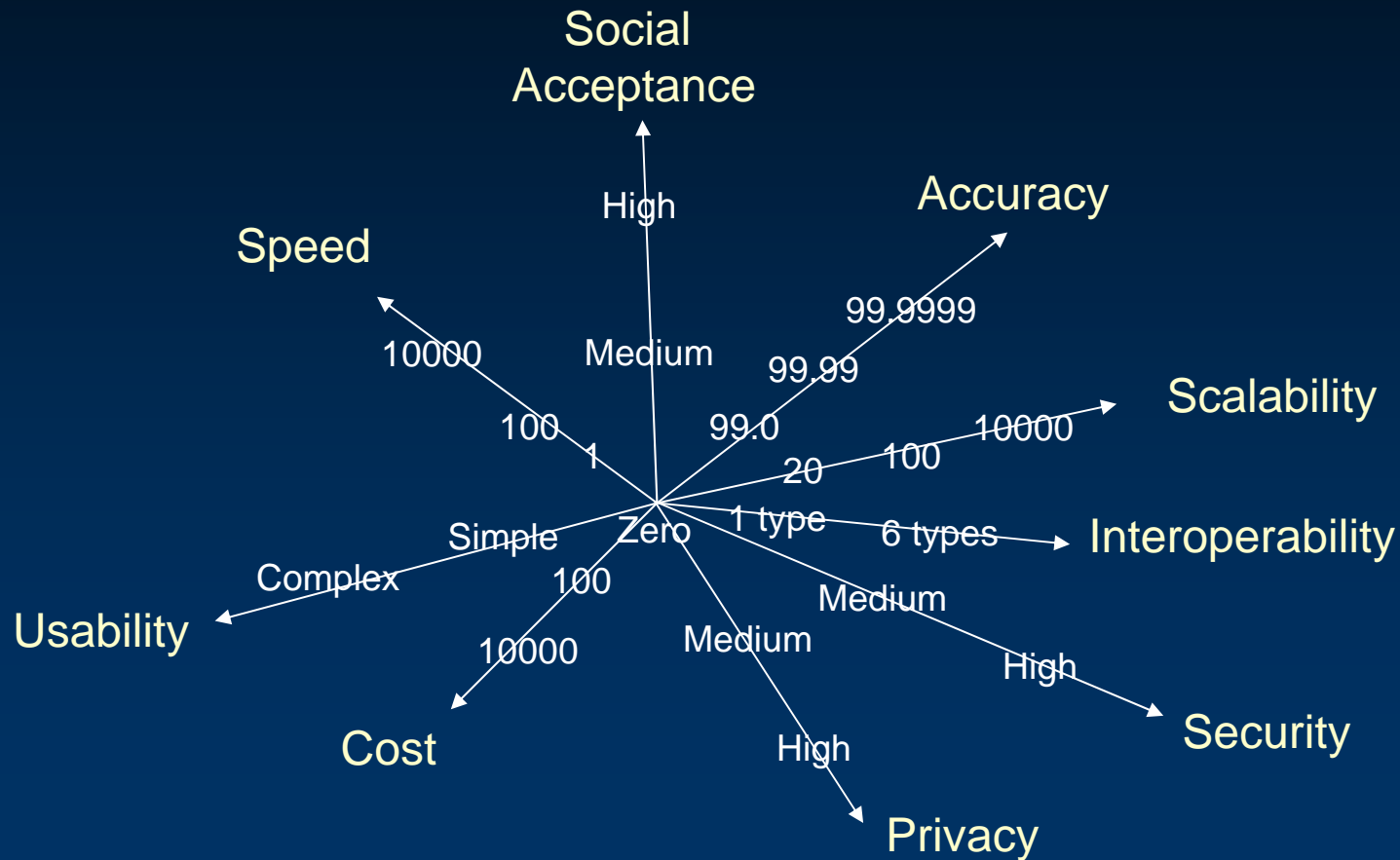
# A Comprehensive Design Methodology



Biometric System



# Biometric Systems Evaluation



# Biometrics

Opportunities for an effective, efficient,  
privacy-aware use of biometric traits  
to support adaptivity and intelligent solutions  
for Ambient Intelligence and Smart Living!



*Thanks!*

*Thanks!*

*Thanks!*



# References (1)

## ■ Introduction

- S. Z. Li, A. K. Jain, Encyclopedia of Biometrics, Springer Publishing Company, Incorporated, 2009.
- M.Tistarelli, S. Z. Li, R.Chellappa, *Handbook of Remote Biometrics: For Surveillance and Securit*, Springer Publishing Company, Incorporated, 2009.
- N. V. Boulgouris, K. N. Plataniotis, E. Micheli-Tzanakou, *Biometrics: Theory, Methods, and Applications*, IEEE Computer Society Press, 2009.
- A. K. Jain, P. Flynn, A. Ross, *Handbook of Biometrics*, Springer -Verlag New York, Incorporated, 2007.



# References (2)

## ■ Fingerprint

- D. Maltoni, D. Maio, A. K. Jain, S. Prabhakar, *Handbook of Fingerprint Recognition*, 2nd ed., Springer Publishing Company, Incorporated, 2009.
- D. Maltoni, "Fingerprint Recognition, Overview", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 510 – 513, 2009.
- V. Piuri, and F. Scotti, "Fingerprint Biometrics via Low-cost Sensors and Webcams", in *Biometrics: Theory, Applications and Systems, 2008. BTAS 2008. 2nd IEEE International Conference on*, pp. 1-6, October 2008.
- N. Yager, A. Amin, "Fingerprint verification based on minutiae features: a review", *Pattern Analysis & Applications*, Springer London, vol. 7, pp. 94-113, 2004.
- P. Komarinski, *Automated fingerprint identification systems (AFIS)*, Elsevier Academic, Amsterdam, 2005.
- N.K. Ratha, R.M.Bolle, *Automatic Fingerprint Recognition Systems*, Springer-Verlag, 2003.
- R. DonidaLabati, V. Piuri, and F. Scotti, "A neural-based minutiae pair identification method for touchlessfingerprint images", in *IEEE Symposium Series in Computational Intelligence 2011 (SSCI 2011)*, April 2011.
- R. Donida Labati, A. Genovese, V. Piuri, F. Scotti, "Touchless Fingerprint Biometrics: a Survey on 2D and 3D Technologies", in *Journal of Internet Technology*, 2014
- R. Donida Labati, A. Genovese, V. Piuri, F. Scotti, "Accurate 3D Fingerprint Virtual Environment for Biometric Technology Evaluations and Experiment Design", in *Proc. of the 2013 IEEE Int. Conf. on Computational Intelligence and Virtual Environments for Measurement Systems and Applications (CIVEMSA 2013)*, Milan, Italy, pp. 43 - 48, July 15 - 17, 2013
- R. Donida Labati, A. Genovese, V. Piuri, F. Scotti, "Contactless Fingerprint Recognition: a Neural Approach for Perspective and Rotation Effects Reduction", in *Proc. of the IEEE Workshop on Computational Intelligence in Biometrics and Identity Management (CIBIM)*, Singapore, Singapore, pp. 22 - 30, April 16 - 19, 2013
- R. DonidaLabati, V. Piuri, F. Scotti, "Measurement of the principal singular point in fingerprint images: a neural approach", in *2010 IEEE International Conference on Computational Intelligence for Measurement Systems and Applications (CIMSA)*, pp. 18 - 23, September 6-8, 2010.





# References (3)

## ■ Fingerprint (cont'd)

- R. DonidaLabati, V. Piuri, F. Scotti, "Neural-based Quality Measurement of Fingerprint Images in Contactless Biometric Systems", in *The 2010 International Joint Conference on Neural Networks (IJCNN)*, pp. 1 – 8, July 18-23, 2010.
- M . Gamassi, V. Piuri, and F. Scotti, "Fingerprint local analysis for high-performance minutiae extraction", in *IEEE International Conference on Image Processing, 2005 (ICIP 2005)*, pp. III - 265-8, September, 2005
- R. Donida Labati, A. Genovese, V. Piuri, and F. Scotti, "Two-view Contactless Fingerprint Acquisition Systems: a Case Study for Clay Artworks", in *2012 IEEE Workshop on Biometric Measurements and Systems for Security and Medical Applications, 2012*
- R. Donida Labati, A. Genovese, V. Piuri, and F. Scotti, "Virtual Environment for 3-D Synthetic Fingerprints", *2012 IEEE International Conference on Virtual Environments, Human-Computer Interfaces and Measurement Systems*, pp. 48 - 53, 2012
- R. Donida Labati, A. Genovese, V. Piuri, and F. Scotti, "Quality Measurement of Unwrapped Three-dimensional Fingerprints: a Neural Networks Approach", in *2012 International Joint Conference on Neural Networks (IJCNN 2012)*, pp. 1123 - 1130, 2012
- R. Donida Labati, A. Genovese, V. Piuri, and F. Scotti, "Fast 3-D Fingertip Reconstruction Using a Single Two-View Structured Light Acquisition", in *IEEE Workshop on Biometric Measurements and Systems for Security and Medical Applications*, pp. 1 - 8, 2011
- R. Donida Labati, V. Piuri, and F. Scotti, "A neural-based minutiae pair identification method for touchless fingerprint images", in *2011 IEEE Workshop on Computational Intelligence in Biometrics and Identity Management (CIBIM)*, pp. 96 -102, April, 2011
- R. Donida Labati, V. Piuri, and F. Scotti, "Neural-based Quality Measurement of Fingerprint Images in Contactless Biometric Systems", in *The 2010 International Joint Conference on Neural Networks (IJCNN)*, pp. 1 - 8, July 18-23, 2010
- R. Donida Labati, A. Genovese, V. Piuri, and F. Scotti, "Measurement of the Principal Singular Point in Contact and Contactless Fingerprint Images by using Computational Intelligence Techniques", in *2010 IEEE International Conference on Computational Intelligence for Measurement Systems and Applications (CIMSAS 2010)*, pp. 18 - 23, 2010



# References (4)

## ■ Iris

- R. Donida Labati, A. Genovese, V. Piuri, and F. Scotti, "Iris segmentation: state of the art and innovative methods", in *Cross Disciplinary Biometric Systems*, C. Liu, and V.K. Mago (eds.), Springer, pp. 151-182, 2012
- H. Proença, "Quality Assessment of Degraded Iris Images Acquired in the Visible Wavelength", *IEEE Transactions on Information Forensics and Security*, vol.6, no.1, pp.82-95, March 2011.
- Yung-hui Li, M. Savvides, "Iris Recognition, Overview", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 810 – 819, 2009.
- K.W. Bowyer, K. Hollingsworth and P.J. Flynn, Image understanding for iris biometrics: a survey, *Computer Vision and Image Understanding*, vol. 110, pp. 281-307, 2008.
- J. Daugman, "New Methods in Iris Recognition", *IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics*, vol.37, no.5, pp.1167-1175, October 2007.
- V. Piuri, and F. Scotti, "Adaptive Reflection Detection and Location in Iris Biometric Images by Using Computational Intelligence Techniques", in *IEEE Transactions of Instrumentation and Measurement*, pp.1825-1833, July 2010.
- R. Donida Labati, and F. Scotti, "Noisy iris segmentation with boundary regularization and reflections removal", in *Image and Vision Computing, Iris Images Segmentation Special Issue*, Elsevier, pp. 270-277, February 2010.
- R. Donida Labati, V. Piuri, and F. Scotti, "Neural-based Iterative Approach for Iris Detection in Iris recognition systems", in *IEEE Symposium on Computational Intelligence for Security and Defence Applications*, pp. 1-6, December 18, 2009.
- R. Donida Labati, V. Piuri, and F. Scotti, "Agent-Based Image Iris Segmentation and Multiple Views Boundary Refining", in *IEEE Third International Conference on Biometrics: Theory, Applications and Systems*, pp. 1-7, November 20, 2009.



# References (5)

## ■ Face

- Yun Fu, GuodongGuo, T. S. Huang, "Age Synthesis and Estimation via Faces: A Survey", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol.32, no.11, pp.1955-1976, November 2010.
- A. M. Martinez, "Face Recognition, Overview", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 555 – 559, 2009.
- S. Romdhani, J. Ho, T. Vetter, D. J. Kriegman, "Face Recognition Using 3-D Models: Pose and Illumination", *Proceedings of the IEEE*, vol.94, no.11, pp.1977-1999, November 2006.
- Z. Li, A. K. Jain, *Handbook of Face Recognition*, Springer-Verlag, 2005.
- W. Zhao, R. Chellappa, A. Rosenfeld, P. J. Phillips, "Face Recognition: A Literature Survey", *ACM Computing Surveys*, pp. 399-458S, 2003.
- S. S. Rakover & B. Cahlon, *Face recognition: cognitive and computational processes*, John Benjamins Publishing Co., Amsterdam, The Netherlands, 2001.

## ■ Ear shape

- M. Choras, "Ear Biometrics", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 233 – 240, 2009.
- B. Bhanu, H. Chen, *Human Ear Recognition by Computer (Advances in Pattern Recognition)*, Springer Publishing Company, Incorporated, 2008.
- D. J. Hurley, B. Arbab-Zavar, M. S. Nixon, "The Ear as a Biometric", in: *Handbook of Biometrics*, pp. 131-150. A. K. Jain, P. Flynn, A. Ross, Springer-Verlag New York, Incorporated, 2007.
- S. M. S. Islam, M. Bennamoun, R. A. Owens, R. Davies, "Biometric Approaches of 2D-3D Ear and Face: A Survey", in *Advances in Computer and Information Sciences and Engineering*. Springer Netherlands, pp. 509-514, 2007.



# References (6)

## ■ Hand geometry

- N. Duta, "A survey of biometric technology based on hand shape", *Pattern Recognition*, vol. 42, n. 11, pp. 2797-2806, November 2009.
- N. Duta, "Hand Shape", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 682 – 687, 2009.
- R. Sanchez-Reillo, C. Sanchez-Avila, A. Gonzalez-Marcos, "Biometric identification through hand geometry measurements," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol.22, no.10, pp. 1168- 1171, October 2000.

## ■ Palmprint & Palmvein

- D. Zhang, Z.Guo, G. Lu, L. Zhang, Y. Liu, W.Zuo, "Online joint palmprint and palmvein verification", *Expert Systems with Applications*, vol. 38, no. 3, pp. 2621-2631, March 2011.
- A. Kong, D. Zhang, M. Kamel, "A Survey of Palmprint Recognition", *Pattern Recognition*, vol. 42, no. 7, pp. 1408-1418, July 2009.
- M. Watanabe, " Palm Vein", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 1028 – 1033, 2009.
- D. Zhang, V. Kanhangad, " Palmprint, 3D", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 1037 – 1042, 2009.



# References (7)

## ■ DNA

- J.M. Butler, *Fundamentals of Forensic DNA Typing*, Elsevier Academic Press, San Diego, 2010.
- R. AH van Oorschot, K. N. Ballantyne, R. J. Mitchell, "Forensic trace DNA: a review", *Investigative Genetics*, pp. 1 – 14, 2010.
- T. Hicks, R. Coquoz, " Forensic DNA Evidence", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 573 – 579, 2009.
- P. M. Vallone, C. R. Hill, J. M. Butler, "Demonstration of rapid multiplex PCR amplification involving 16 genetic loci", *Forensic Science International: Genetics*, vol. 3, no. 1, pp. 42-45, December 2008.



# References (8)

## ■ Voice

- H. Beigi, *Fundamentals of Speaker Recognition*, Springer-Verlag New York Inc., January 2011.
- J. Markowitz, "Speaker Recognition, Standardization", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 1270 – 1277, 2009.
- J. Benesty, M. MohanSondhi, Y Huang, *Springer Handbook of Speech Processing*, Springer-Verlag, January 2008.
- R. D. Peacocke, D. H. Graf, "An introduction to speech and speaker recognition", *Computer* , vol.23, no.8, pp.26-33, August 1990.

## ■ Gait

- M. Goffredo, I.Bouchrika, J. N. Carter, M. S. Nixon, "Self-Calibrating View-Invariant Gait Biometrics", *IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics*, vol.40, no.4, pp.997-1008, August 2010.
- R.Chellappa, A.Veeraraghavan, N.Ramanathan, "Gait Biometrics, Overview", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 628 – 633, 2009.
- M.S.Nixon, J. N. Carter, "Automatic Recognition by Gait," *Proceedings of the IEEE* , vol.94, no.11, pp.2013-2024, November 2006.
- N.V. Boulgouris, D. Hatzinakos, K.N. Plataniotis, "Gait recognition: a challenging signal processing technology for biometric identification", *IEEE Signal Processing Magazine*, vol.22, no.6, pp. 78- 90, November 2005.



# References (9)

## ■ Signature & hand writing

- V. A. Bharadi, H. B. Kekre, "Off-Line Signature Recognition Systems", *International Journal of Computer Applications* vol. 1, no. 27, pp. 48–56, February 2010.
- O. Henniger, D. Muramatsu, T. Matsumoto, I. Yoshimura, M. Yoshimura, "Signature Recognition", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 1196 – 1205, 2009.
- D. Impedovo, G. Pirlo, "Automatic Signature Verification: The State of the Art", *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews*, vol.38, no.5, pp.609-635, September 2008.

## ■ Keystroke

- N. Bartlow, "Keystroke Recognition", in *Encyclopedia of Biometrics*. S. Z. Li and A. K. Jain, Springer Publishing Company, Incorporated, pp. 877 – 882, 2009.
- D. Shanmugapriya, "A survey of biometric keystroke dynamics: approaches, security and challenges", *International Journal of Computer Science and Information Security*, vol. 5, pp. 115 – 119, September 2009.
- Enzhe Yu, Sungzoon Cho, "Keystroke dynamics identity verification - its problems and practical solutions", *Computers & Security*, vol. 23, no. 5, pp. 428-440, July 2004.

## ■ Weight

- R. Donida Labati, A. Genovese, V. Piuri, and F. Scotti, "Weight Estimation from Frame Sequences Using Computational Intelligence Techniques", *2012 IEEE International Conference on Computational Intelligence for Measurement Systems and Applications (CIMSA 2012)*, pp. 29 - 34, 2012



# References (10)

## ■ Biometric Privacy

- M. Upmanyu, A. Namboodiri, K. Srinathan, and C. Jawahar, "Blind authentication: A secure crypto-biometric verification protocol", *Information Forensics and Security, IEEE Transactions on*, vol. 5, no. 2, pp. 255–268, June 2010.
- J. Golic, M. Baltatu, "Entropy analysis and new constructions of biometric key generation systems," *IEEE Transactions on Information Theory*, vol. 54, no. 5, pp. 2026–2040, 2008.
- A. K. Jain, K. Nandakumar, A. Nagar, "Biometric template security", *EURASIP Journal on Advances Signal Processing*, vol. 2008, pp. 1-17, 2008.
- Y. Dodis, R. Ostrovsky, L. Reyzin, and A. Smith, "Fuzzy extractors: How to generate strong keys from biometrics and other noisy data", *SIAM Journal on Computing*, vol. 38, no. 1, pp. 97–139, 2008.
- N. K. Ratha, S. Chikkerur, J. H. Connell, and R. M. Bolle, "Generating cancelable fingerprint templates", *IEEE Transaction on Pattern Analysis and Machine Intelligence*, vol. 29, no. 4, pp. 561–572, 2007.
- A. Teoh, A. Goh, and D. Ngo, "Random multispace quantization as an analytic mechanism for bihashing of biometric and random identity inputs", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 28, no. 12, pp. 1892–1901, December 2006.
- M. Barni, T. Bianchi, D. Catalano, M. Di Raimondo, R. DonidaLabati, P. Failla, D. Fiore, R. Lazzeretti, V. Piuri, F. Scotti, and A. Piva, "A Privacy-compliant Fingerprint Recognition System Based on Homomorphic Encryption and Fingercodes Templates", in *2010 Fourth IEEE International Conference on Biometrics: Theory Applications and Systems (BTAS)*, pp. 1-7, September 27-29, 2010.





# References (11)

## ■ Biometric Privacy (cont's)

- M. Barni, T. Bianchi, D. Catalano, M. Di Raimondo, R. DonidaLabati, P. Failla, D. Fiore, R. Lazzeretti, V. Piuri, F. Scotti, and A. Piva, "Privacy-Preserving Fingercod Authentication", in *Proceedings of the 12th ACM workshop on Multimedia and security*, ACM, New York, NY, USA, pp. 231 - 240, September 9-10, 2010.
- T. Bianchi, R. Donida Labati, V. Piuri, A. Piva, F. Scotti, S. Turchi, "Implementing FingerCode-Based Identity Matching in the Encrypted Domain", in *2010 IEEE Workshop on Biometric Measurements and Systems for Security and Medical Applications (BIOMS)*, pp. 15 - 21, September 9, 2010.
- S. Cimoto, M. Gamassi, V. Piuri, R. Sassi, and F. Scotti, "Privacy in Biometrics", in *Biometrics: Theory, Methods, and Applications*, Wiley-IEEE Press, 2008.
- S. Cimoto, M. Gamassi, V. Piuri, R. Sassi, and F. Scotti, "Privacy-Aware Biometrics: Design and Implementation of a Multimodal Verification System", in *Annual Computer Security Applications Conference, 2008. ACSAC 2008*, pp. 130-139, December, 2008
- S. Cimoto, M. Gamassi, V. Piuri, R. Sassi, and F. Scotti, "A Multi-Biometric Verification System for the Privacy Protection of Iris Templates", in *International Workshop on Computational Intelligence in Security for Information Systems*, October 23-24, 2008
- S. Cimoto, M. Gamassi, V. Piuri, R. Sassi, F. Cimoto, and F. Scotti, "A Biometric Verification System Addressing Privacy Concerns", in *Computational Intelligence and Security, 2007 International Conference on*, pp. 594-598, December 2007.
- S. Cimoto, M. Gamassi, V. Piuri, D. Sana, R. Sassi, and F. Scotti, "Personal identification and verification using multimodal biometric data", in *Proceedings of the 2006 IEEE International Conference on Computational Intelligence for Homeland Security and Personal Safety*, pp. 41-45, October, 2006

