Biometric Systems are automated methods of verifying or recognizing the identity of a living person on the basis of some physiological characteristics, like a fingerprint or iris pattern, or some aspects of behavior, like handwriting or keystroke patterns.

Team

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Research Topics

- **Fingerprints**
  - Processing and Matching
  - Classification and Indexing
  - Synthetic Generation
  - Fake/Aliveness Detection
  - Scanner Quality

- **Face**
  - Localization
  - Recognition

- **Hand**
  - Geometry and Dermatoglyphics
  - Palmprint Recognition

- **Performance Evaluation**
  - Theoretical Models
  - Fingerprint Verification Competitions
The Handbook of Fingerprint Recognition

- The book includes results of BioLab research and provides an updated snapshot of the current state-of-the-art in fingerprint recognition

The first monographic book on automated approaches to fingerprint recognition (published by Springer in 2003)

Second edition (a major update) published in 2009
Fingerprints: minutiae detection

 Traditional approach

\[ \text{No!} \]
- A lot of information may be lost during the binarization process.
- Binarization and thinning are time-consuming.

The basic idea is to follow the ridge lines on the gray-scale image, by "sailing" according to the fingerprint directional image. A set of starting points is determined by superimposing a square-meshed grid on the gray-scale image. For each starting point, the algorithm keeps following the ridge lines until they terminate or intersect other ridge lines.

In 1997 BioLab published the first Direct Gray-scale detection approach.
Fingerprints: MCC representation

- **MCC** (Minutia Cylinder Code) is a novel minutiae representation and matching techniques
  - Fast and accurate
  - Bit-based, portable on light architectures
  - Suitable for template protection techniques

- Patent N. ITBO2009A000149

In 2010 BioLab published MCC approach
Fingerprints: classification

The five main fingerprint classes

- arch
- tented arch
- right loop
- left loop
- whorl

Approaches proposed:

- Inexact graph matching
- Dynamic masks
- MKL-based

In 2002 BioLab published the first fingerprint classification algorithm able to meet the FBI fingerprint classification requirements.
Fingerprints: indexing

• *Exclusive classification* is not a good indexing method for retrieval on large databases:
  – the number of classes is small
  – fingerprints are non-uniformly distributed
  – “ambiguous” fingerprints cannot be reliably assigned to a unique class

• *Continuous classification* associates a *multidimensional point* to each fingerprint and uses *spatial queries* for fingerprint retrieval by similarity.

In 1997 BioLab published the first fingerprint continuous classification approach
The idea behind the Locality-Sensitive Hashing (LSH) is that if two binary vectors are similar, then after a “projection” into a lower-dimensional subspace, they will remain similar.

\[ H_1 = \{23, 39, 56, 59, 103, 118, 137, 144, 146, 185, 200, 216, 218, 250, 278, 305\} \]
\[ H_2 = \{3, 8, 42, 45, 61, 94, 113, 123, 170, 175, 191, 207, 225, 281, 290, 292\} \]
\[ H_3 = \{4, 33, 52, 53, 86, 97, 109, 125, 134, 161, 203, 259, 268, 272, 294, 304\} \]

The set of indices defines a hash function that maps a cylinder to the natural number corresponding to its binary representation.

The similarity between two cylinders can be estimated by counting the number of collisions under many hash functions.

In 2011 BioLab published a novel indexing approach based on MCC.
Collecting large databases of fingerprint images is:

- **expensive** both in terms of money and time
- **boring** for both the people involved and for the volunteers, which are usually submitted to several acquisition sessions at different dates
- **problematic** due to the privacy legislation which protects such personal data

A method able to *artificially* generate realistic fingerprint images could be used in several contexts to *avoid collecting databases of real fingerprints*

In 2000, BioLab published the first approach able to generate realistic fingerprint images (SFinGe)
Fingerprints: fake detection

• One of the most recent challenges: fake finger detection

• Two novel approaches (to be published in 2006)
  – Distortion analysis (Patent IT #BO2005A000399)
    • The user is required to place a finger onto the scanner surface and to apply some pressure while rotating the finger

  • Odor analysis (Patent IT #BO2005A000398)
    • Using one or more odor sensors (electronic noses) to detect materials usually adopted to make fake fingers

Real finger   Fake finger
Fingerprints: reconstruction from templates

• Can minutiae templates be reverse-engineered?
  – The template extraction procedure has been traditionally considered similar to a one-way function, since many researchers and practitioners in the biometric field postulated that a template does not include enough information to reconstruct a fingerprint image

• A reconstruction approach based on three steps:
  – Fingerprint area estimation
  – Orientation field estimation
  – Ridge-line pattern generation

In 2007, BioLab published the first effective reconstruction approach from standard minutiae templates
Fingerprint scanners: operational quality

- How to evaluate the impact of each quality parameter (e.g. acquisition area, resolution accuracy, MTF) on the matching performance?
- Operational fingerprint scanner quality
  - The ability of acquiring images that maximize the accuracy of automated fingerprint recognition systems
- A large experimentation to understand the effects of the various quality parameters has been carried out

In 2008, BioLab introduced a new operational definition of fingerprint scanner quality
The fast face location algorithm was published by BioLab in 1998.
Face: recognition

Enrollment

Face location and normalization → Feature extraction → MKL subspace learning → Distances from MKL subspaces → Classification → Template → Recognition/Verification

MKL-based face recognition: published by BioLab in 2002
Performance evaluations: FVC

- FVC is a technology evaluation of algorithms
  - Not complete systems, but only algorithms
  - Not a performance evaluation in a real application
- Main aims
  - Track the state-of-the-art in fingerprint recognition
  - Provide updated benchmarks and a testing protocol for fair and unambiguous evaluation of fingerprint verification algorithms

FVC2000 was the first international competition for fingerprint verification algorithms
Performance evaluations: FVC-onGoing

Web-based automatic evaluation of fingerprint recognition algorithms

- Participants can be: companies, academic research groups, or independent developers
- Algorithms are tested on sequestered datasets and results are reported using well-known performance indicators and metrics
- Fully automated:
  1. The system automatically tests the algorithm submitted by a participant
  2. The participant sees the results in its “private area”
  3. Then the participant may decide to publish the results in the public section of the FVC-onGoing web site

http://biolab.csr.unibo.it/FVConGoing
### FVC-onGoing: Participants and Algorithms

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<th>Registered Participants</th>
<th>Jun 2010</th>
<th>Jun 2011</th>
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<td>Academic Research Groups</td>
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<td>Fingerprint ISO Template Matching</td>
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<td>Fingerprint ISO Template Matching</td>
<td>13</td>
<td>26</td>
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*From July 2009 to June 2011*
Main collaborations in EU projects

FIDELITY
Fast and trustworthy Identity Delivery and check with ePassports leveraging Traveller privacy

http://www.fidelity-project.eu/

INGRESS
Innovative Technology for Fingerprint Live Scanners

http://www.biosecure.info
Collaboration with the Italian government

- BioLab scientifically supports the Italian National Centre for Information Technology in the Public Administration (CNIPA) within the established “Task Force on Biometrics” to:
  - Provide guidelines and support to the PA, and in particular to: Istituto Poligrafico e Zecca dello Stato, Min. Giustizia, Min. Interni, Min. Esteri, Esercito, ...
  - Test and certify biometric solutions

- BioLab members are coauthors of the following “Quaderni CNIPA”:
  - N.9: Linee guida per l’impiego delle tecnologie biometriche nelle pubbliche amministrazioni
  - N.17: Linee guida per l’impiego delle tecnologie biometriche nelle pubbliche amministrazioni. Indicazioni operative
Other collaborations

• Academic
  – Michigan State University (Prof. Anil Jain)
  – San Jose State University (Prof. Jim Wayman)
  – Hong Kong Polytechnic University (Prof. David Zhang)
  – Universidad Autonoma de Madrid (Prof. Javier Ortega Garcia)
  – Tsinghua University (Prof. Jie Zhou and Dr. Jianjiang Feng)

• Industrial
  – Development of sensors and algorithms (Atmel – France, Biometrika – Italy, Siemens – Germany, STMicroelectronics – USA)
  – Support for the evaluation and certification of biometric systems (G&D – Germany and other companies)
  – Licensing of the SFInGe synthetic generator (more than 60 organizations, including Accenture, Nokia, Infineon, Cross Match, Mitsubishi, NEC, and some US government departments)
References

• Books

• Journal papers