

Reconnaissance du visage

Jean-Luc DUGELAY
jld@eurecom.fr

Tutorial sur la biométrie
Section II

PaRISTIC
LaBRI
22 Novembre 2005

1

jld@eurecom.fr

Presentation overview

- **Basic recalls on face recognition from still image**
 - ✓ **Frontal**
 - ✓ **Specific acquisition (infra red, profile)**
 - ✓ **Specific parts (eyes: iris & retina, ears, dental)**

- **Novel Facial Biometrics: Video & 3D**
 - Temporal**
 - **Global: Pose & Head dynamics**
 - **Local: Facial expressions & mimics (Lips, Eyes, Mouth)**
 - 3-D**
 - **Diverse acquisitions**
 - **3D vs. 2D**

- **Concluding remarks**
 - **Evaluation: database?**
 - **Future?**

2

jld@eurecom.fr

Face

- **Frontal**
- **Specific acquisition (infra red, profile)**
- **Specific parts (eyes: iris & retina, ears, dental)**

3

jld@eurecom.fr

Face: frontal face recognition

Two successful classes of algorithms

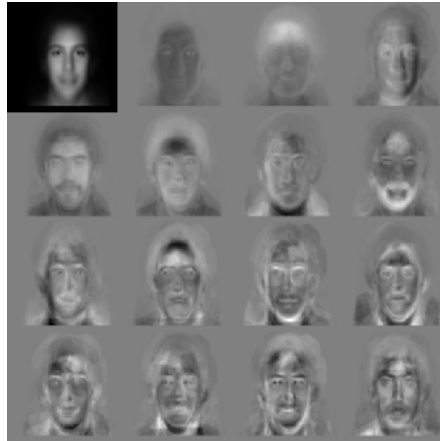
According to the last round of NIST evaluations, current best solutions are derived either from Eigenfaces or Elastic Graph Matching approaches.

- **Projection-based approaches: Eigenfaces**
- **Fisherfaces.**
- **Deformable models: Elastic Graph Matching (EGM)**
- **Elastic Bunch Graph Matching.**

4

jld@eurecom.fr

Eigenfaces



5

jld@eurecom.fr

Eigenfaces

(Originally designed for compression, not recognition)

Eigenspace can be built using the clients (higher performances but less flexible) or not

$I(x,y)$ can be considered as a two-dimensional $N \times N$ array of pixels (if $N=256$; can be seen as a point in a 65,536 dimensional space)

“face space”

The space of variation between photographs of human faces with the same orientation and scale lit in the same way can be described by a relatively low dimensional subspace.

Individual face image \approx linear combination of a small number of face components

$$I_i = E_0 + \sum_{k=1}^K \omega_k^i E_k + \varepsilon_k$$

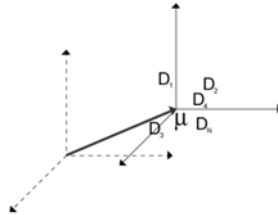
6

jld@eurecom.fr

Eigenfaces

$I_1, I_2 \dots I_N$: set of reference or training faces (eigenface 0) $E_0 = \mu = \frac{1}{N} \sum_{i=1}^N I_i$

Each face differs from the other faces by the vector $D_i = I_i - E_0$



7

Eigenfaces

Covariance matrix C: $C = \frac{1}{N} \sum_{i=1}^N D_i D_i^T$

Eigenvectors of C (variation between face images) → Eigenfaces E_k

Dimensionality Reduction Technique (DRT)

Principal Component Analysis (PCA)

→ **eigenvectors ordered by the magnitude of their contribution to the variation between the training images**

- > **Extract the R eigenvalues;**
 - > **Order them from largest to smallest, $\lambda_1, \lambda_2, \dots, \lambda_r$**
 - > **Order corresponding eigenvectors E_1, E_2, \dots, E_r**
- « **principal components** »

Weighted sums of a small collection of characteristic images $I_i = E_0 + \sum_{k=1}^K \omega_k^i E_k + \epsilon_k$

8

Using eigenfaces to detect faces

> There are 4 possibilities for an input image and its pattern vector :

1. Near face space

and near a face class

⇒ an individual is recognized and identified

2. Near face space

but no near a face class

⇒ an unknown individual is present

3. Distant from face space

and near a face class

⇒ is not a face image (*possibility of false positive?*)

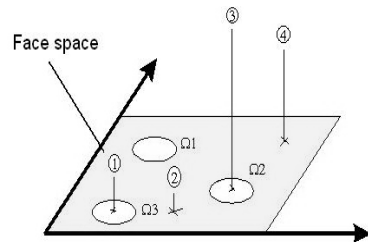
4. Distant from face space

and not near a known face class

⇒ is not a face image.



In Out



9

Eigenfaces vs. Fisherfaces

• **Eigenfaces [Kirby & Sirovich, Turk & Pentland]:**

- no distinction between inter- and intra-class variabilities



Average face (eigenface 0) and first four eigenfaces

• **Fisherfaces [Belhumeur, Hespanha & Kriegman]:**

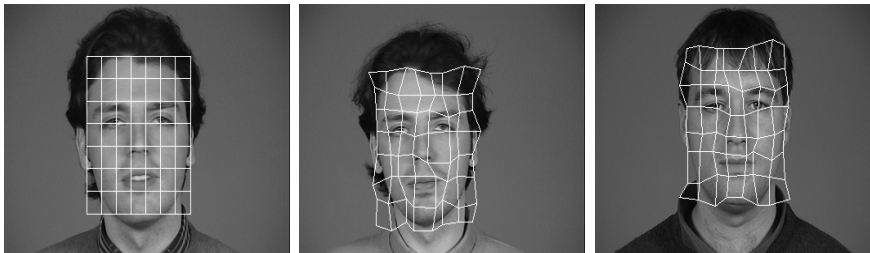
- discriminative approach: find a sub-space which maximizes the ratio of inter-class and intra-class variability
- same intra-class variability for all classes



Average face (Fisherface 0) and first four Fisherfaces

10

EGM Elastic Graph Matching



(a)

(b)

(c)

(a) Model grid for person A (1 feature vector / node)

(b) Best grid for test person A after elastic graph matching with the model grid.

(c) Best grid for test person B after elastic graph matching with the model grid for person A.

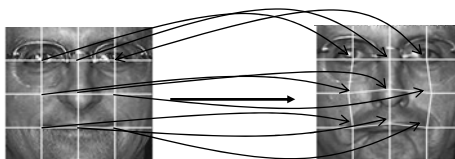
$$C_{\text{total}} = \lambda C_e + C_v$$

- Vertex labels (local mappings costs)
- Edge labels (local distortions costs)
- λ controls the rigidity of the image graph

11

jld@eurecom.fr

Eurecom's Framework



- **Goal: model the set of possible transformations between face images of the same person**
- **Approximation:**
 - **split global transformation into a set of local transformations**
 - **introduce neighborhood coherence constraints to avoid over-flexibility**
 - **embed the system within the probabilistic framework of a 2-D HMM**
- **Training a transformation model requires at least 2 images**
 \Rightarrow **use a shared transformation model (assume that the intra-class variability is the same for all classes)**

$$P(Fq | Ft, M)$$

12

jld@eurecom.fr

Face

- **Frontal**
- **Specific acquisition (infra red, profile)**
- **Specific parts (eyes: iris & retina, ears, dental)**

- Thermal pattern recognition systems faces security challenges head on
M. Lawlor, Signal Magazine Nov. 97
- Comparison of visible and infra-red imagery for face recognition
J. Wilder et al., Int. Conf. On Automatic Face and Gesture Recognition, Oct. 96

Facial Thermogram (IR imaging)

The facial heat emission patterns can be used to characterize a person

Patterns depend on 9 factors including:

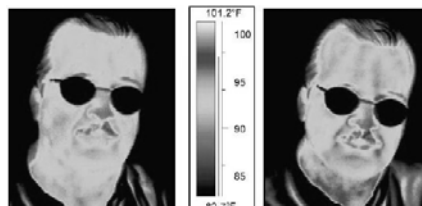
- **Location of major blood vessels**
- **Skeleton thickness**
- **Amount of tissue**
- **Muscle**
- **Fat**

Advantages:

- > **Unique (even for identical twins)**
- > **Stable over time**
- > **Cannot be altered through plastic surgery**
- > **Independent of the lighting conditions**

Disadvantages:

- > **IR imagery depend on the temperature**
- > **Opaque to glass**



Source: Other Biometric Techniques
Chapter 10, D. Bark and I. Kim

Profile

- **distance and angle between fiducial points**



Source:

15

jld@eurecom.fr

Face

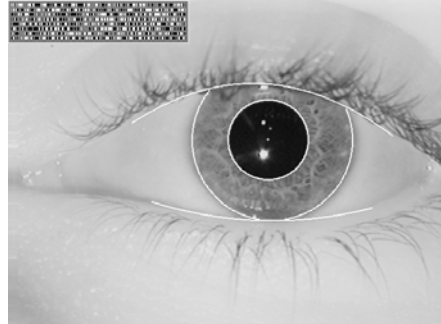
- **Frontal**
- **Specific acquisition (infra red, profile)**
- **Specific parts (eyes: iris & retina, ears, dental)**

16

jld@eurecom.fr

Iris

- **Colored ring that surrounds the pupil;**
- **Unique in every eye, even on same person;**
- **Impossible to recreate;**
- **Contact lens and most trauma won't affect it.**



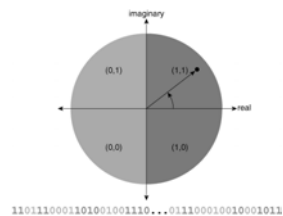
17

jld@eurecom.fr

Iris

4 steps

- 1. Acquisition (< 1 meter)**
 - 2. Find iris in the image (edge detection)**
 - 3. Features extraction:**
 - Local regions of an iris are projected onto quadrature 2D Gabor wavelets, generating complex-valued coefficients whose real and imaginary parts specify the coordinates of a phasor in the complex plane
 - The angle of each phasor is quantized to one of the four quadrants, setting two bits of phase information
 - This process is repeated all across the iris with many wavelet sizes, frequencies & orientations
 - 4. Verification**
- the Iris-Code (1024 phase bits are computed)



$$HD = \frac{\| (code A \otimes code B) \cap mask A \cap mask B \|}{\| mask A \cap mask B \|}$$

18

jld@eurecom.fr

Afghan girl (Sharbat Gula)



- **1984: in a refugee camp in Pakistan**
- **2002: (18 years later) in Afghanistan**

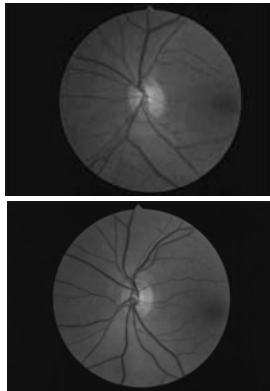
photographed twice by McCurry from National Geographic.

Source:

<http://www.cl.cam.ac.uk/users/jgd1000/afghan.html>

Courtesy of J. Leroux des Jardins

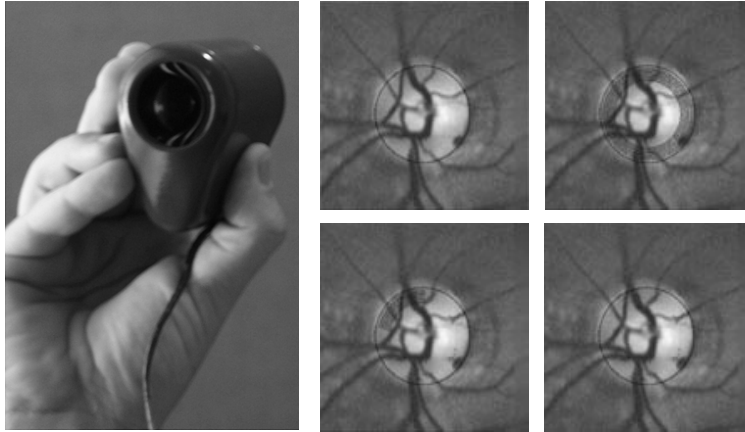
Retina



- **Unique**
 - ✓ **Number/Pattern of blood vessels, that emanate from the optic nerve and disperse throughout the retina**
 - ✓ **Relative angle w.r.t. optical nerve**
 - ✓ **Bifurcations**
 - ✓ **No two retinas are the same even in identical twins**
 - ✓ **Vascular pattern does not change over the course of life**
 - ✓ **Glasses, contact lenses, existing medical conditions (e.g. cataracts) do not interfere**
- At the moment, identification based on retina is used for animals (bovines)**
- **'Uncomfortable' acquisition**
 - ✓ **Eye has to fix a lighting point**
 - ✓ **Projected lighting source on the center of the optical nerve**
 - ✓ **Light is absorbed by red vessels but reflected by retina tissues**
 - ✓ **People would have to cooperate more than with the iris – normally used in high level security where comfort and cooperation aren't factors anyway.**

Retina

- **Extracting Intensity Profiles**
 - **Performing Scan**
- **Locating Blood Vessels**
 - **Generating Circular Bar Code**

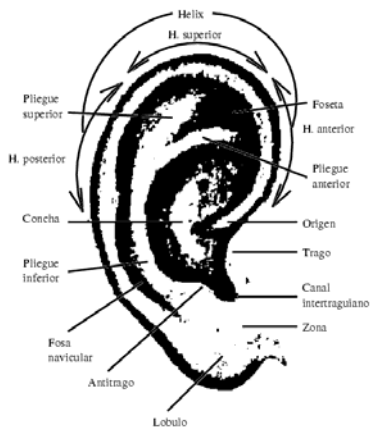


21

Sources

- On the use of Outer Ear Images for Personal Identification in Security Applications
B. Moreno et al., IEEE 1999.
- <http://www.dcs.shef.ac.uk/~miguel/papers/msc-thesis.html>
- Ear Biometrics for Machine Vision M. Burge and W. Burger

Ear



- **Advantages of ears over faces**
 - **Uniform distribution of colors**
 - **Reduced surface**
 - **Less variability vs. pose/expressions,**
 - **Shape and appearance fixes.**
- **Passive identification (≠ fingerprints)**
- **Algo.**
 - **Eigenears**
 - **Feature points**

22

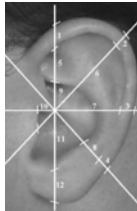
Iannarelli's Ear Biometrics

> **Iannarelli System (1949) is based on 12 measurements.**

(External anatomy)

- 1 Helix Rim,**
- 2 Lobule,**
- 3 Antihelix,**
- 4 Concha,**
- 5 Tragus,**
- 6 Antitragus**
- 7 Crus of Helix**
- 8 Triangular Fossa**
- 9 Incisure Intertragica**

Distance between each of the numbered areas



- > **Segmented outer ear**
- > **Segmented inner ear**

Sources:

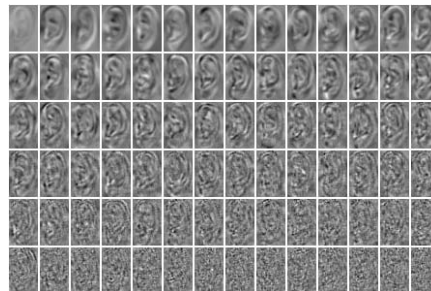
- On the use of Outer Ear Images

For Personal Identification in Security Applications

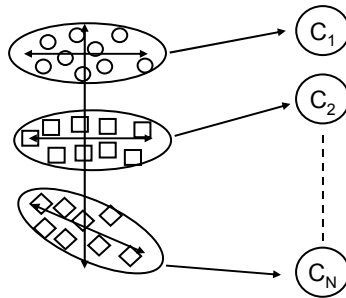
B. Moreno et al., IEEE 1999.

- <http://www.dcs.shef.ac.uk/~miguel/papers/msc-thesis.html>

Eigenears



Pattern classification



- **Given:**
 - a set of observations
 - a set of classes
- ⇒ assign each observation to one class
- **Main challenge of pattern classification: distinguish between**
 - intra-class variability
 - inter-class variability

- **Face recognition is very challenging due to variations in:**
 - facial expression
 - pose
 - illumination conditions
 - presence / absence of eyeglasses and facial hair
 - aging, etc.

25

jld@eurecom.fr

Face: frontal face recognition

- **Face detection - *Is there a face?***
- **Face segmentation - *Where?***
- **Face tracking (if video)**
- **Face size and position.** In practice, it is very difficult to control the position of the subject with respect to the camera
 - **“Normalize” inter-ocular distance...**
- **Changes in illumination.** If a spotlight is not used, lighting variations occur. For example, close to a window, the lighting depends strongly on the time of the day and the weather
 - **“Normalize” gray-scale histogram...**
- **Facial expressions.** In practice, it is almost impossible to control the mood of the subject. The smile causes probably the largest variation of facial expressions
- **Others.** Glasses, Hats, Facial hair, etc.

26

jld@eurecom.fr

Pose



27

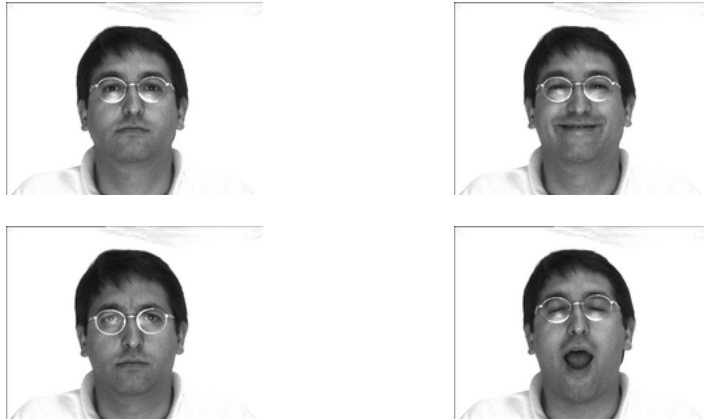
jld@eurecom.fr

Illumination



jld@eurecom.fr

Facial expressions



29

jld@eurecom.fr

Dynamic Video Biometrics

Higher potential of video w.r.t. still images

- **More clues (Abundant data)**
- **Face / Facial feature tracking**

New opportunities

- **Visual speech data**
 - **correlation between speech and lip motion**
 - **Dynamic facial Expression**
 - **behavior (not physical only)**

From Physical to Behavioural biometric?

- **Shape/Structure from motion**

Useful for covert surveillance (but non-cooperative with low resolution)

30

jld@eurecom.fr

Video strategies

- > **Frame by frame approach**
combining tracking and recognition
Chellappa et al.
- > **Exploiting facial motion**
Chen et al.
- > **Exploiting global motion and pose**
- > **Others**
e.g. Video used in order to access to 3-D.

31

jld@eurecom.fr

Background...

Coupling pose & expressions



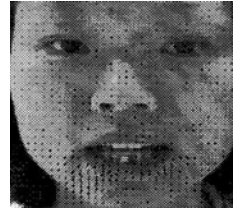
32

jld@eurecom.fr

Person Identification using Facial Motion

L.-F. Chen et al. (Taiwan)

- **Images are aligned in order to compensate head motion;**
- **Only lower half of a flow field is used;**
- **Motion field are concatenated (motion rhythm) in order to form high-dimensional feature vector;**
- **PCA**
- **Robustness against varying illumination conditions (i.e. better results than the ones obtained when using gray level information)**
- **Perspective: to combine information extracted from both facial appearance and motion data.**



33

jld@eurecom.fr

Behavioural approaches

- **Recognition using behaviour:**
 - ✓ **Human gait**
 - **Surprising results**
- **Question: head displacements**
 - ✓ **Can be a biometry?**



34

jld@eurecom.fr

Overview of our system

- **Our person recognition system**
 - ✓ **Displacement signals**
 - Automatically extracted from videos
 - Work on image plane
 - ✓ **Tracking of some head features**
 - Eyes, nose, mouth
 - Displacements: $d(t)$

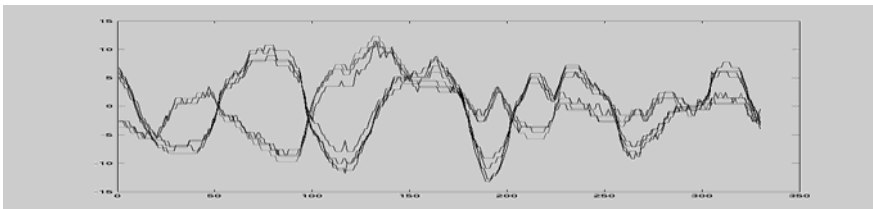


35

jld@eurecom.fr

Experimental set-up

- **Horizontal & vertical displacements**
 - ✓ Eyes, nose, mouth
 - ✓ 8 signals
 - ✓ Normalization: centered
- **8-dimensional Gaussian classifier**

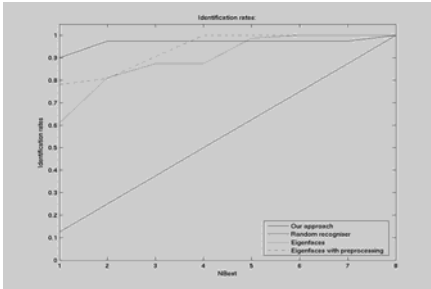


36

jld@eurecom.fr

Identification scores

- **Identification scores**
 - ✓ **90.0% & 97.5%**
 - ✓ **Better than eigenfaces**
 - **61.0% & 87.5%**
 - **78.1% & 90.6%**

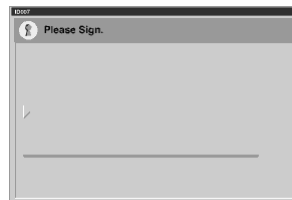


37

jld@eurecom.fr

Perspectives

- **Recognition using behaviour:**
 - ✓ **Signatures**
 - **Shape**
 - **Pressure, inclination**
 - ✓ **Face**
 - **Appearance**
 - **Head Motion**



38

jld@eurecom.fr

Facial expressions



> **The Silesian University of Technology, Institute of Computer Science, proposes to recognize persons using the eye movement when following a target on a computer screen. Special glasses are required, using infrared light, to measure the eye moves.**



> **The Stony Brook university system relies on probing the characteristic pattern of muscles beneath the skin of the face. Guan takes two snaps of a person in quick succession, asking subjects to smile for the camera. He then uses a computer to analyse how the skin around the subject's mouth moves between the two images. The software does this by tracking changes in the position of tiny wrinkles in the skin, each just a fraction of a millimetre wide. The data is used to produce an image of the face overlaid with tiny arrows that indicate how different areas of skin move during a smile. This movement is controlled by the pattern of muscles under the skin, and is not affected by the presence of make-up or the size of the subject's smile. The system is sensitive enough to produce such a map from muscle twitches even when people are trying to keep their expression unchanged. Note: tested on 4 subjects (!).**

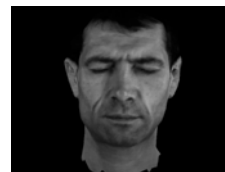
jld@eurecom.fr

- Face Recognition using range images B. Acherermann et al., VSMM 97.
- Face Identification by Fitting a 3D Morphable Model using Linear Shape and Texture Error Functions, S. Romdhani et al., ECCV 2002
- Face Recognition based on depth maps and surface curvature G. Gordon, SPIE Proc., vol. 1570, 1991.

3-D Faces, range data

Advantages:

- > **Access to the depth information (i.e. shape)**
- > **Pose and light conditions may be compensated**
- > **Higher robustness**
(e.g. the system cannot be trapped by an impostor using a 2D picture of someone else)



Disadvantages:

- > **Acquisition process is slow and highly expensive, e.g. 3-D Scanner, 2 calibrated video cameras**
- Cooperation of the users is required**

Little literature available on the topic (novel facial biometrics)

Some published works...

- ✓ **Extension of existing algorithms from 2-D to 3-D (e.g. eigenfaces)**
- ✓ **Adaptation of a generic 3-D Deformable Model to 2-D images of users to provide a set of parameters associated with a person**
- ✓ **Segmentation of range data into 4 surface regions; Normalization based on the location of eyes, nose and mouth; Distance computed from the volume between surfaces**
- ✓ ...

Acquisition of 3-D Models



Source:
Three-Dimensional Facial Adaptation for MPEG-4 Talking Heads
N. Grammalidis, N. Sarris, F. Deligianni and M. G. Strintzis
EURASIP JASP, October 2002

41

jld@eurecom.fr

Acquisition 3D

> **Scanner Geometrix™**



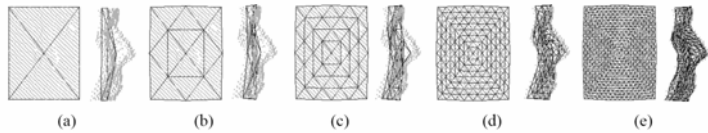
42

jld@eurecom.fr

3D Reco.

> 3D Eigenfaces

A depth map is generated from the 3D mesh of the face and the Eigenfaces technique is applied to classify subjects.



43

jld@eurecom.fr

« Eigenfaces 3D »



Picture (texture)



Depth Map (shape)

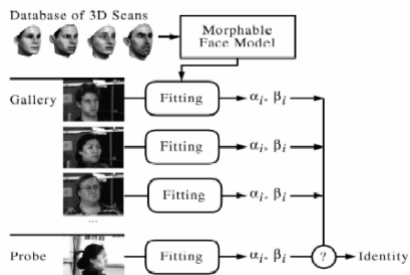
44

jld@eurecom.fr

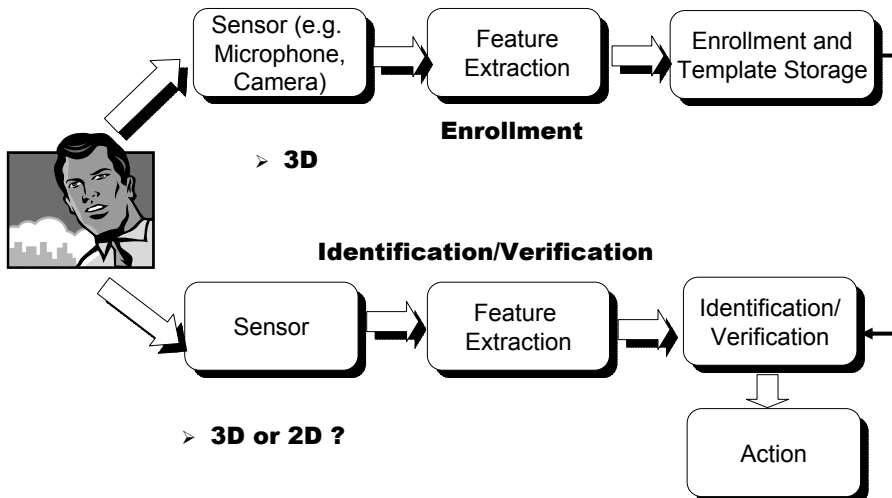
3D Reco.

> **3D Morphable Model**

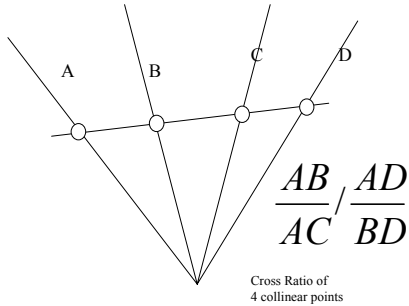
Given a 2D image of the subject, a large set of parameters used to morph a general 3D face model to the given face is stored both in training that in testing. Faces are matched comparing the corresponding vectors of parameters.



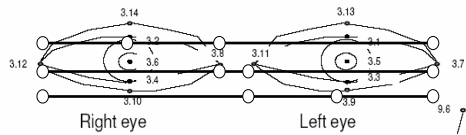
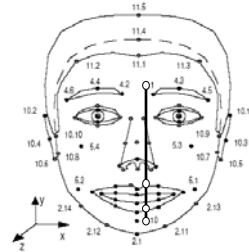
A Generic Biometric System



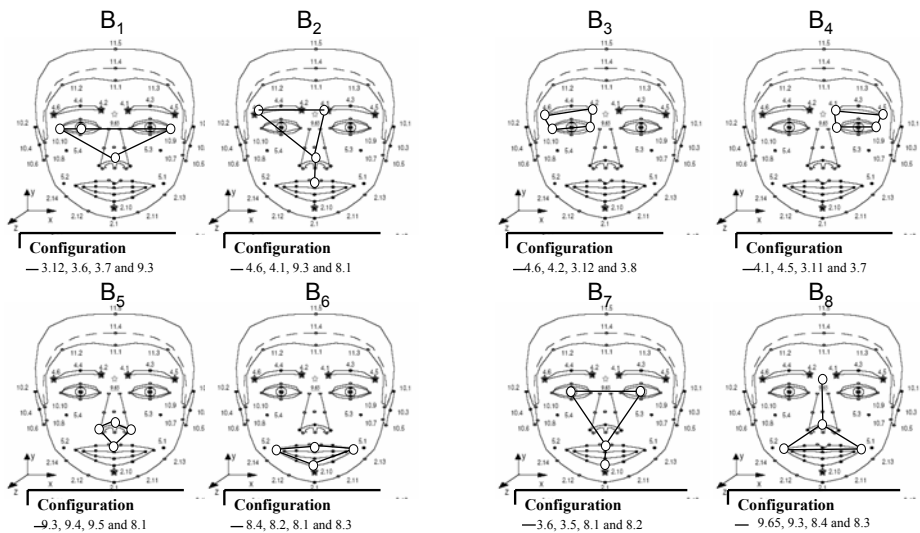
Using Projective Invariants in 3D Face Recognition *Ratio*



(a)



47



48

Concluding remarks

- **Promising results
but how to perform evaluation?
*database?***
- **Existing companies on 3-D Face Reco.,
e.g. Geometrix
But possibly potential in video is higher.**
- **Multimodal**

49

jld@eurecom.fr

- **If time permits...**

50

jld@eurecom.fr

A. Bertillon

Bertillon, Louis Adolphe

[Paris, 1821 – Neuilly 1883]

French statistician and demographer; doctor; and cofounder of the school of Anthropology of Paris.

Alphonse Bertillon

[Paris, 1853 – id., 1914]

**French anthropologist and criminologist
(Chief of criminal identification for the Paris Police)
who devised the Bertillon system (1880)**

A system formerly used for identifying persons by means of a detailed record of body measurements, physical description, and photographs (called metric frames and stereo metric photography).



**[Also, A. Bertillon, as a forensic expert, and using a geometrical process and probability calculations, wrongly concluded that a handwritten document had been produced by A. Dreyfus...Rennes Trial Feb. 1899
<http://www.law-forensic.com/forerunners.htm>]**

Bertillonage

- Abolition of the marking of prisoners in France (1832)
- Problem to identify habitual offenders.
- First scientific method of criminal identification.

Bertillon's anthropometrical system of personal identification was divided into three integrated parts:

- (1) the bodily measurements that required measurements, conducted with the utmost precision and under carefully prescribed conditions, a series of the most characteristic dimensions of bony parts of the human anatomy;**
- (2) the morphological description of the appearance and shape of the body and its measured parts as they related to movements "and even the most characteristic mental and moral qualities";**
- (3) a description of peculiar marks observed on the "surface of the body, resulting from disease, accident, deformity or artificial disfigurement, such as moles, warts, scars, tattooing, etc."**

Bertillonage (Cont.)

| Characteristics Point at which | Acceptable error (+- mm) non-identity | Divergence (+- mm). serious errors appear. | Errors or difference establishing (+- mm) |
|-----------------------------------|---|---|---|
| Height | 7 | 15 | 30 |
| Outstretched arms | 10 | 20 | 40 |
| Trunk | 7 | 15 | 30 |
| Length of the head | 0.5 | 1 | 2 |
| Width of the head | 0.5 | 1 | 2 |
| Right ear | 1 | 2 | 4 |
| Left foot | 1.5 | 3 | 5 |
| Left middle finger | 0.5 | 1 | 2 |
| Left small finger | 0.75 | 2 | 3 |
| Left fore-arm | 1.5 | 3 | 6 |

7 measurements in 1886; 11 later.

(Fingerprint, added later as a supplementary measure)

Bertillon had calculated that the probability of 2 people having precisely the same 11 measurements was one in four million.



Figure 12. Bertillon's system of body measurements, with all anthropometric, as well as characteristic photographs (Courtesy: S&P)

53

jld@eurecom.fr

Bertillonage (Cont.)

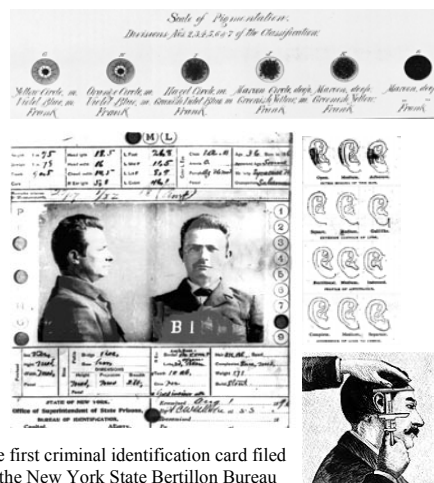
By dividing each of the measurements into small, medium and large groupings,

Bertillon could place the dimensions of any single person into one the 243 distinct categories.

Further subdivisions by eye (7) and hair color provide 1,701 separate groupings.

For example, in a file a 5,000 records, each of the primary categories would hold about 20 cards.

Therefore, it was not difficult to compare the new record to each of the other cards in the same category.



The first criminal identification card filed by the New York State Bertillon Bureau

54

jld@eurecom.fr

Origins of the New York State Bureau of Identification

- > **Bertillonage was officially adopted in France in 1882 and soon after in some other countries.**
- > **Anthropometry was first introduced in the United States by Major McClaughry, the translator of Bertillon's book (*Spoken portrait*), in 1887 when he was the warden of the Illinois State Penitentiary at Joliet.**
 - ✓ **1896: Establishment of the National Bureau of Identification; forerunner of the FBI (Federal Bureau of Investigation), Chicago, 1897.**
 - ✓ **After 1 year: 16,000 Bertillon cards; and 24,000 after 2 years;**
 - ... **and 131 criminals received at State Prisons as « first offenders » were found to have prior records.**
 - ✓ **1900: A law allows the Prison Department to accept Bertillon cards.**



The NY State Bertillon Bureau in 1902

The case of Will West

In 1903,

- **Will West as a new prisoner;**
- **Will West's Bertillon measurements and photography done;**
- **Will West denied ever being incarcerated in the facility;**
- **Using Bertillon measurements, the system retrieves the Bertillon card for a William West;**
- **Will West continued to deny that the William West card was his;**
- **Subsequent investigation disclosed that William West was already incarcerated in the facility in 1901, and still a prisoner...**

Will West's Bertillon Measurements

178.5; 187.0; 91.2; 19.7; 15.8; 14.8; 6.6; 28.2; 12.3; 9.7



William West's Bertillon Measurements

177.5; 188.0; 91.3; 19.8; 15.9; 14.8; 6.5; 27.5; 12.2; 9.6; 50.3