Section 3: Face and Fingerprint

Face and Fingerprint Biometrics

University of Southampton, UK
Sources of information
Section 3 overview

- Automatic Fingerprint Recognition
  - History
  - Sensors
  - Acquisition
  - Recognition
- Automatic Face Recognition
  - Face detection
  - Face recognition
  - Problems
Fingerprint recognition

we need to automate it
Why fingerprints?

- Failure of Bertillionage
- Success of fingerprints
- Usage in history
- Individuality
- AFIS
Processes

Verification

Data → Processing → Features → Match → True/False

Recognition/Identification

Data → Processing → Features → Matching → Recognition
Fingerprint Data

Offline acquisition

Ink

Latent

Live Acquisition

Biometrics/ Nixon
Section 3: Face/ Fingerprint
Optical sensing

(a) passive

(b) active

Pixel Sensors
Optical fingerprint sensors

diffuser

light source

optics sensor
Capacitive fingerprint sensors

\[ Q = VC; \quad C = \varepsilon_0 \varepsilon_r \frac{A}{d} \]

Electrostatic discharge?
Fingerprint sensors

- M2 – Optical and RF swipe;
- Fidekica – pressure;
- Ultrascan – ultrasound;
- FlashScan 3D – structured light
Sagem unveils Finger on the Fly
03 Nov 2009
Sagem Sécurité (Safran group) has unveiled its Finger on the Fly technology, capable of reading fingerprints on a moving hand, at Biometrics 2009, the leading European trade show and exhibition dedicated to biometrics.
On sensor performance

Fingerprint pattern 1

- Fingerprint is a set of **ridges** (sweat bands)
- **Macro-singularities**, are **whorl**, **loop**, **arch**

arch

loop

whorl
Fingerprint pattern 2

- **Minutiae**, Galton’s characteristics, are the **terminations** (end points) or the **bifurcations** (splitting points)
Fingerprint pattern 3

- Depends on resolution

High – sweat pores

Medium – incipient ridges

Low – minutiae (and creases)
Other Terms

- Micro-singularities
- Delta (Henry)
- Short ridge
- Dot
- Pocket whorl
- Double loop
- Accidental
Basic enhancement – histogram equalisation
Basic filtering – median filtering

Original

Result
Basic feature extraction—thresholding

Original

Result
Enhancement 1

Input Image → Normalization → Orientation Image Estimation → Frequency Image Estimation → Region Mask Generation → Filtering → Enhanced Image
Enhancement 2

before

after
Recognition approaches

- **Minutiae** – choose maximum alignment of minutiae pairings (dominant technology)

- **Correlation** – maximise match between fingerprint images

- **Ridges** – maximise match of selected ridge features, such as local orientation, frequency, shape, and texture
Minutiae detection

- After ridge detection there is ridge tracking and
Comparison: manual vs automatic

Matching minutiae

- Needs feature vector, here from 2 nearest neighbours

\[ Fl_k = (d_{ki} \ d_{kj} \ \theta_{ki} \ \theta_{kj} \ n_{ki} \ n_{kj} \ t_k \ t_k \ t_j) \]

X. Jiang and W-Y Yau, ICPR 2000
Minutiae matching


Correlation

- Avoid “core” and minutiae detection
- Use pattern
- Holistic fingerprint recognition using Gabor filters

with core and four minutiae points  constant inter-ridge spacing  ridge dominant direction  fingerprint power spectrum pretuned to spacing

A. Ross and A. K. Jain, LNCS 2359, 2002
Gabor wavelets

- Allow sensitivity in space and in frequency

\[
gw2D(x, y) = \frac{1}{\sigma\sqrt{\pi}} e^{-\left(\frac{(x-x_0)^2+(y-y_0)^2}{2\sigma^2}\right)} e^{-j2\pi f_0 ((x-x_0)\cos(\theta)+(y-y_0)\sin(\theta))}
\]
Texture based matching

FingerCode approach (Jain et al. (2000))

Input image
Normalize each sector
Filtering

Locate the reference point
Divide image in sectors

Template FingerCode

Calculate Euclidean distance

Input FingerCode

Compute Average Absolute Deviation

Matching result

A. Ross and A. K. Jain, LNCS 2359, 2002
Challenges

- Pressure/ skin deformation - nonlinear change in appearance
- Image quality and forensic use
- Skin condition – effect of drugs
- Legal issues – is a fingerprint unique and permanent?
- Spoofing
The finger pressure against the sensor is not uniform, but decreases moving from the center towards the borders.

- **external region:** skin moved
- **transitional region:** skin distorted
- **close-contact region:** skin not moved

a) close-contact region, where the high pressure and the surface friction does not allow any skin slippage
b) transitional region where an elastic distortion is produced to smoothly combine regions a and c
c) external region, where the low pressure allows the skin to be dragged by the finger movement
Pressure correction 2

- Can then correct for skin distortion
3D fingerprint scanning

- Uses structured light
3D results

• Less ridge distortion and no overall distortion – no pressure correction either
Performance evaluation

- **FVC2006**: the Fourth International Fingerprint Verification Competition
- [http://bias.csr.unibo.it/fvc2006/](http://bias.csr.unibo.it/fvc2006/)
  - tracks recent advances in fingerprint verification, and benchmarks state-of-the-art
- # Four new **databases** (three real and one synthetic)
- # Two **categories** (Open Category and Light Category)
- # 53 **participants** (27 industrial, 13 academic, and 13 independent developers)
- # 70 **algorithms** submitted (44 in the Open Category and 26 in the Light Category)
FVC 2006 categories

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FVC 2006 scanners/technologies

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<th>Image</th>
<th>Resolution</th>
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<td>Electric Field Sensor (AuthenTec)</td>
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<td>DB4</td>
<td>Synthetic Generator (SFinGe v3.0)</td>
<td>288×384</td>
<td>About 500 dpi</td>
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FVC 2006 fingerprints

- A fingerprint image from each database, at the same scale factor.
FVC 2006 average results over all databases – top 5

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<th>Avg EER</th>
<th>Avg FMR 100</th>
<th>Avg FMR 1000</th>
<th>Avg Zero FMR</th>
<th>Avg REJ\text{ENRO}</th>
<th>Avg REJ\text{MATC}</th>
<th>Avg Enroll Time</th>
<th>Avg Match Time</th>
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<td>0.00%</td>
<td>0.00%</td>
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<td>0.798 s</td>
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For comparison, FVC 2000: slower, less accurate (different data)
Further work

- Latent fingerprints
- Forensics
- It’s possible to determine gender from fingerprints (Ross 2014)
- 50% of Japanese ATMs use fingervein recognition - fuse with fingerprint?
Face recognition

We need to automate it

http://www.youtube.com/watch?v=H2a0KYtG97E
Approaches

Automatic Face Recognition (side or front)

Holistic
- Image as a whole

Model Based
- Recognition by parts
Eigenface overview

1. Calculate a set of weights based on the input image and the $M$ eigenfaces by projecting the input image onto each of the eigenfaces.
2. Determine if the image is a face at all (whether known or unknown) by checking to see if the image is sufficiently close to “face space.”
3. If it is a face, classify the weight pattern as either a known person or as unknown.
4. (Optional) Update the eigenfaces and/or weight patterns.
5. (Optional) If the same unknown face is seen several times, calculate its characteristic weight pattern and incorporate into the known faces.

See also http://www.pages.drexel.edu/~sis26/Eigenface%20Tutorial.htm

http://www.youtube.com/watch?feature=player_detailpage&v=Rlxq_R3VmR0
Principal Components Analysis PCA

- Original Data
- Eigenvectors
- Transformed Data

using Singlular Value Decomposition (SVD)
Using PCA

classification via PCA

compression via PCA
Eigenface data

[Image: 15 grayscale images of a person's face in different poses]

Eigenface approach

1. Collect image dataset (multiple samples with variation in expression and lighting. (Say four images of ten people, so $M = 40$.)

2. Calculate the $(40 \times 40)$ matrix $L$, find its eigenvectors and eigenvalues, and choose the $M'$ eigenvectors with the highest associated eigenvalues. (Let $M' = 10$ in this example.)

3. Combine the normalized training set of images according to Eq. (6) to produce the $(M' = 10)$ eigenfaces

4. For each known individual, calculate the class vector by averaging the eigenface pattern vectors per subject. Choose thresholds for face class, and face space.

5. For new face image calculate pattern vector and distances to classes, to face space. If the minimum distances < threshold, face class identified

6. If the new image is known, this image may be added to the original set of familiar face images, and the eigenfaces may be recalculated
Average face and eigenfaces

Images and face space

Results

1. Each graph shows **averaged performance** as lighting conditions, head size, and head orientation vary.
2. The *y axis* depicts number of correct classifications (out of 16).
3. The **peak** (16/16 correct) in each graph results from recognizing the particular training set perfectly.
4. The **other two** graph points reveal the decline in performance as the following parameters are varied: *(a)* lighting, *(b)* head size (scale), *(c)* orientation, *(d)* orientation and lighting, *(e)* orientation and size (#1), *(f)* orientation and size (#2), *(g)* size and lighting, *(h)* size and lighting (#2).
Face detection – Haar wavelets

and then Adaboost = classification + feature set selection. These says largely obsolete and techniques use more advanced algorithms (e.g. LBP).
Finding faces

M. Viola and M.J. Jones, *IJCV*, 2004
Face databases - FERET

fb, has different facial expression. The fc images recorded with a different camera and under different lighting. Duplicate images recorded later, 0 and 1031 (duplicate I) or 540 to 1031 (duplicate II) days later.

Additional set of pose images from the FERET database: right and left profile (labeled pr and pl), right and left quarter profile (qr, ql), and right and left half profile (hr, hl).
More face databases; more challenge

University of Texas Video Database.
Example images for the different recording conditions of the database. First row: Facial speech. Second row: Laughter. Third row: Disgust

Notre Dame HumanID database. Example images of the “unstructured” lighting condition recorded in the hallway outside of the laboratory.
Enhanced Local Texture Feature Sets for Face Recognition Under Difficult Lighting Conditions

X. Tan and B. Triggs, IEEE TIP, 2010
Method

Raw images → Illumination Normalization → Robust Feature Extraction → Subspace Representation → Output

Input → Gamma Correction → DoG filtering → Masking (optional) → Equalization of Variation → Output

Biometrics/ Nixon
Section 3: Face/ Fingerprint

X. Tan and B. Triggs, IEEE TIP, 2010
Data

- (Top) two images of the same subject from the FRGC-204 dataset.
- (Bottom) the LBP histograms of the marked image regions,
- (left) without preprocessing,
- (right) after preprocessing. Note the degree to which preprocessing reduces the variability of the histograms of these relatively featureless but differently illuminated facial regions.

Preprocessing comparison

- Examples of the effects of the different preprocessing methods. Rows 1–5, respectively, show images of one subject from subsets 1–5 of the Yale-B data set, and rows 6–8 show images of different subjects from the CAS-PEAL data set, with from left to right: (None) no preprocessing; (HE) Histogram Equalization; (MSR) Multiscale Retinex; (GB) Gross and Brajovic method; (LTV) Logarithmic Total Variation; (TT)

Local Binary Patterns

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Threshold

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Binary code: 11000011
Multiple features

Raw Image → Preprocessed Image → Robust Preprocessing

- Training Dataset

Robust Feature Sets

- Gabor Features
- LBP Features
- Other Features

Score Calculation

- Kernel Subspace

Normalization

- Z-score
- Z-score
- Z-score

Score Fusion

Fused Scores

X. Tan and B. Triggs, IEEE TIP, 2010
Face recognition in changing illumination

- Evaluated on Yale B, CAS Pearl R1 and on FRGC

Challenges in face recognition

- Lighting/ illumination
- Viewpoint
- Occlusion
- Resolution
- Facial expression
- Ageing
- Make-up/ cosmetics
Biometrics/ Nixon
Section 3: Face/ Fingerprint

Facial expressions

- Mental States
  - Felt Emotions
  - Conviction
  - Cognition
- Non-Verbal Communication
  - Unfelt Emotions
  - Emblems
  - Social Winks
- Facial Expressions
- Physiological Activities
  - Manipulators
  - Pain
  - Tiredness
- Verbal Communication
  - Illustrators
  - Listener Responses
  - Regulators

Face ageing analysis

Gabor wavelet facial expression analysis

Component facial expression analysis

\[ \text{Difference} = | \text{action face} - \text{neutral} | \]

Active shape models

- Label face points in training data
- Compress data using PCA
- Evaluate eigenvectors
- Acquire face image
- Iterate model to find face features
- Determine feature vector
- Active appearance models include texture

Cootes, T. F., Taylor, C. J. et al, CVIU, 1995
Active appearance models

Face ageing

23

25

34

40  50  60  70
Face de-ageing
Age estimation

K. Luu, K. Ricanek et al., *IEEE BTAS* 2009
Age estimation

![Graph showing cumulative score against error level (years) for different age estimation methods. The methods include RPK, AGES, BM, WAS, AAM + SVR, and AAM. The graph plots cumulative score percentage on the y-axis and error level (years) on the x-axis.](image-url)
3D recognition

- Gives viewpoint invariant recognition

[Link to video: http://www.youtube.com/watch?v=nice6NYb_WA]

V. Blanz and T. Vetter, Siggraphh ‘99
Improving the fit

J. Bustard and M. S. Nixon, CVPR 2010
Registered head models
Face Recognition Vendor Test FRVT 2006

- Standard evaluation organised by NIST
- Started as FERET
- FRVT 2006 has front-face and 3D
- Continues to show advance in performance
- Progressed to face expression, illumination, 3D and background – no ageing
Evolution

1993

17 Years
8 Evaluations
5 Challenge Problems (Technology Development)
3 Biometrics
150,000+ Facial and Iris Images

2000

FERET

2002

FACE RECOGNITION VENDOR TEST 2002

2003

GAIT

2005

2006

MBGC

2009

MBGC

2010

P. J. Phillips Biometrics Summer School 2010
Progress

- 1993: Turk & Pentland (Partially Automatic) - FRR at FAR = 0.79
- 1997: FERET 1996 (Fully Automatic) - FRR at FAR = 0.54
- 2002: FRVT 2002 (Fully Automatic) - FRR at FAR = 0.20
- 2006: FRVT 2006 (Fully Automatic) - FRR at FAR = 0.01

References:
FRVT face data

Controlled lighting and expression

Uncontrolled lighting and ‘expression’

3D
## Participants

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Reporting results
Still face recognition

Comparison with human performance

3D face recognition

Future work

• Influence of deep neural networks
• Labelled Faces in the Wild (LFW) database
• Better ageing datasets
• Performance evaluation
• 3D unlikely
• Immigration systems?
• and attributes (using human descriptions)
Face Attributes/ Semantics

Facial Annotations

Face
- Shorter
- Subjects have a SIMILAR head length
- Narrower
- Wider
- Bottom subject has a NARROWER face than the top
- More bony
- More Fleshy
- Bottom subject has a MORE BONEY face than the top

Skin
- Lighter
- Darker
- Bottom subject has LIGHTER skin than the top
- Smoother
- More Wrinkles
- Subjects have SIMILAR skin complexion
- Clearer
- More Pimples
- Subjects have SIMILAR skin complexion

Hair
- Shorter
- Longer
- Bottom subject has SHORTER hair than the top
## What labels did we use?

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• Plenty of room for improvement
How many labels did we get?

- Lots, some comparative and some categorical

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Did it work?

Few comparisons needed, achieving high accuracy
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