COMP 6211 Biometrics

Welcome!

Mark Nixon and Sasan Mahmoodi
Section 1: Introduction

COMP 6211 BIOMETRICS: RECOGNISING PEOPLE BY PERSONAL CHARACTERISTIC,

Mark Nixon and Sasan Ahmoodi

University of Southampton, UK
Course Objectives

✓ an overview of biometrics techniques, from basic to new biometrics
✓ an understanding of techniques from computer vision and image processing used in biometrics systems
✓ performance factors in biometric systems: how well do systems work, what are the limitations and advantages of these systems
✓ an appreciation of where current research is improving these new systems
Your skills mix (and biometrics)

- **Biometrics** knowledge? (face; finger; developer; sales)
- **Computer programming** skills (Matlab, C, Python)
- **Mathematics** (forgotten, discrete, continuous, statistics)
- **Hardware** (analogue, digital)
- **Computer vision** (yes, no)
- You could (probably) be recognised by your skills mix
More measures?

- Hair length
- Shirt colour
- Type of pen
- What did you have for dinner?
- Biometrics is about measuring unique and permanent personal identifiers
# Course Outline

<table>
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<th>Section 1</th>
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<th>Section 9</th>
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<tr>
<td><strong>Identification through the ages:</strong> history of biometrics and (forensic) identification.</td>
<td><strong>Iris</strong> recognition. Iris image acquisition and processing. Performance limits and evaluation.</td>
<td><strong>Demonstration.</strong> How do biometrics systems really work? Can we recognize people?</td>
<td><strong>New modalities and current research.</strong> Performance limits, how will they be resolved. Other info.</td>
<td><strong>Palm Biometrics Oldest</strong> biometric and how does it work.</td>
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</table>
UIAIA/ AADHAAR: the aim in India is to capture the biometrics of the entire India population to enable secure transactions for welfare, transport and banking (slides form Prabhakar at ICB)

- The Unique Identification Authority of India (UIDAI) was established in February 2009, attached to the Planning Commission. The purpose of the UIDAI is to issue a unique identification number (UID) to all Indian residents that is
  - robust enough to eliminate duplicate and fake identities, and
  - can be verified and authenticated in an easy, cost effective way

- UIDAI – created as a statutory body under a separate legislation to fulfill its objectives. The law will also stipulate rules, regulations, processes and protocols to be followed by different agencies partnering with the Authority in issuing and verifying unique identity numbers.
Giving Identity to 1.2B Souls

- A national registry to improve delivery of social services & for financial inclusion
- In democratic manner
  - Not mandatory
  - Inclusive: Residents
  - Pro-poor
  - Not Identity Card
- Right to Privacy
Who gets UID number?

- **UID number**
  - Only identity
  - No residency status
  - Removes ‘Cloak of anonymity’

All residents

- All, even infants
- Voluntary

---

Biometrics/ N
Section 1: Int
UID goals can be accelerated with urgency in implementation

- 12-18 months
- 1st UID issued
- + 4 years
- 600 mill. UIDs
- + ? years
- Complete coverage
- Faster enrolment
- Urgency in implementation
Second Phase of AADHAAR Enrolment has started

ENROL NOW!

A few good reasons to enrol for AADHAAR

- New Mobile Connection
- New LPG Connection
- Opening a Bank Account
- ID Proof for Rail Travel

Aadhaar enables you to avail these important services:

- Visit any Aadhaar enrolment centre and get enrolment done
- Use Aadhaar as POI and POA for new mobile connection
- Use Aadhaar as POI and POA for new LPG connection
- Aadhaar as ID Proof for Rail Travel

Largest Biometric Database in the world
Section 1 Overview

• Your lecturers
• Biometrics
  – Modalities
  – Performance
  – Capability
• Human vision and computer vision
• Measurements
  – Difference
  – Uniqueness
• Glossary/ lexicon/ terminology

http://www.youtube.com/watch?v=acU9-6kI80w&feature=related
Your lecturers - Mark

- **Professor** of Electronics and Computer Science
- Southampton 1983-now
- PhD in stochastic filtering theory
- Head of VLC group and Leader of computer vision team in ECS
- FIET, FIAPR, CEng
- **Editorial board**: *IET Computer Vision, Image and Vision Computing, Advisory Editor* *Pattern Recognition Letters*
- **General Chair**: IEEE BTAS 10, IEEE ISBA 2015, IEEE IJCB 2017; **Program Chair**: Many conferences
- **President**: IEEE Biometrics Council
Your lecturers - Sasan

- **Lecturer** of Electronics and Computer Science
- Southampton 2005-now
Vision-based biometrics

Use computer vision and image processing to understand images
Headlines 29/1/18

Canada to Test Advancements in Biometrics and Blockchain to Welcome International Travellers
Market Watch 4 days ago
CNW Group Canada to Test Advancements in Biometrics and Blockchain to Welcome International Travellers Published: Jan 25, 2018 8:01 am ET -- The Government of Canada announced today it will pioneer the testing...

D-ID nabs $4M to protect images from being read by facial recognition algorithms
TechCrunch 7 days ago
As people become more aware of how their data is used — and abused — in our digital world; and regulations (like GDPR in Europe) are leading more organizations to implement better data protection ...

Samsung SDS, Spotinst to cooperate on cloud managed services
ZDNet 9 hours ago
Samsung SDS and Spotinst will collaborate on cloud managed service businesses, the companies have announced. Spotinst, founded in Israel in 201...

Republicans and Dreamers
The Wall Street Journal 5 days ago
“DACA,” incredibly, has become a household word, meaning that most people who vote have developed an informed opinion about the 800,000 or so...

Facebook acquires biometric ID verification startup Confirm.io
TechCrunch 6 days ago
Facebook has confirmed to TechCrunch that it’s acquired… Confirm.io. The startup offered an API that let other companies quickly verify someone’s g...

Hackers are con artists: The perils of social engineering
TNW 1 hour ago

Biometrics/ Nixon
Section 1: Introduction
Milestones in Southampton’s Biometrics

80’s face recognition
94 idea on gait
95 first PhDs on gait at ECS
    99 first book on biometrics
99 supported by DARPA
00’s started ear
    03 first conviction by gait
05 first book on gait
08 invented soft/ semantic biometrics
09 first broadcast demo (BBC1)
09 first UK conviction by gait
Using gait as an example

As a biometric, gait is available at a distance when other biometrics are obscured or at too low resolution
‘Lecture’ ‘style’

• Main points; wide coverage
• Not tied to any manufacturer or biometric
• Cover major biometrics and performance
• Some images missing from printed slides
• Paper selection by citations, fame or personal choice
  Indicates that book covers slide topic
Where you can find more info

Essential knowledge
What is a biometric?

- A biometric is a **unique** personal identifier
- It’s **something you have** as opposed to something you know or carry
- Biometrics will save you carrying keys and remembering numbers
- Biometrics are **here**, now
Biometric considerations

- **Vast range** of biometrics now available: face, hand, finger, eye, thermal
- **Basic considerations**: universality, acceptability, uniqueness, repeatability
- **Application potential**: contact, performance, circumvention, interaction
- **Business sectors**: immigration, security, airports, banking, forensic, ‘domestic’
Considerations

- **Universality**: do we all have that trait?
- **Acceptability**: are we prepared to reveal it, or happy for it to be measured?
- **Uniqueness**: is it unique to an individual?
- **Repeatability**: are the measurements the same at different times?

n.b. biometrics is 20 years old…..
What do we mean?

Subject A
Cheeks: wide
Nose length: short

Subject B
Face width: thin
Nose length: enormous

Face width

Audrey

4 samples of subject A

thin

short

Barbara

Nose length

4 samples of subject B

* * *
Have we got news for you?
What Biometrics are there?

Omron Corp; Tiresias.org; HR Industries; Fujitsu; Morpho
What is not a biometric?

(identity theft?)
## Properties

<table>
<thead>
<tr>
<th>Biometric</th>
<th>Universality</th>
<th>Uniqueness</th>
<th>Permanence</th>
<th>Collectability</th>
<th>Performance</th>
<th>Acceptability</th>
<th>Circumvention</th>
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</thead>
<tbody>
<tr>
<td>Face</td>
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<td>Fingerprint</td>
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<td>Hand Geometry</td>
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<td>Thermogram</td>
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<td>DNA</td>
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<td>Gait</td>
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</tbody>
</table>

Note: not included in Handbook of Biometrics
Biometrics/ Nixon
Section 1: Introduction

Processes

Enrolment

Data → Processing → Features → Database

Verification
Recognition/ Identification

Data → Processing → Features → Matching

Verification: accept
Recognition: identity
Biometric Measurements

- E.g. 5 measurements each of 5 attributes

\[
\begin{bmatrix}
52 & 8.75 & 1.5 & 0.4 \\
51.9 & 8.8 & 1.5 & 0.39 \\
52.2 & 8.75 & 1.49 & 0.41 \\
52 & 8.76 & 1.51 & 0.32 \\
51.5 & 8.82 & 1.46 & 0.4 \\
\end{bmatrix} \\
\]

\[
\begin{bmatrix}
81 & 22.14 & 1.0 & 0.37 \\
80.5 & 22.28 & 1.1 & 0.39 \\
81.5 & 22.16 & 1.05 & 0.41 \\
80.9 & 22.18 & 1.11 & 0.32 \\
81 & 22.12 & 1.16 & 0.4 \\
\end{bmatrix} \\
\]

\[
\begin{bmatrix}
89 & 32.14 & 1.0 & 0.37 \\
70.5 & 32.28 & 1.1 & 0.39 \\
101.5 & 32.16 & 1.05 & 0.41 \\
180.9 & 32.18 & 1.11 & 0.32 \\
161 & 32.12 & 1.16 & 0.4 \\
\end{bmatrix} \\
\]

\[
\begin{bmatrix}
89 & 42.14 & 1.0 & 0.37 \\
70.5 & 42.28 & 1.1 & 0.39 \\
101.5 & 42.16 & 1.05 & 0.41 \\
180.9 & 42.18 & 1.11 & 0.32 \\
161 & 42.12 & 1.16 & 0.4 \\
\end{bmatrix} \\
\]

\[
\begin{bmatrix}
89 & 52.13 & 1.0 & 0.37 \\
70.5 & 52.28 & 1.1 & 0.39 \\
101.5 & 52.16 & 1.05 & 0.41 \\
180.9 & 52.18 & 1.11 & 0.32 \\
161 & 52.12 & 1.16 & 0.4 \\
\end{bmatrix} \\
\]

Column 1 identical

Columns 3 and 4 identical
Basis

i) we measure distance $d$:

$$d(A, B) = \sqrt{\sum_{i=1}^{N} (x_{iA} - x_{iB})^2}$$

$N = \# \text{ measurements}; i \in 1, 3; A, B = \text{ subjects}$

ii) we want (variance within subject) $<<$ (variance between subjects)

$$i = 1$$

$$i = 2$$

$$i = 3$$
Distance Measures - Basic

- Manhattan
- Euclidean

\[ d_M = |p_1_x| - \]

\[ d_E = \sqrt{(p_1_x)} \]
Distance Measures - Advanced

- **Mahalanobis**
  
  \[ d_{MAH} = \sqrt{(p - \mu)^T \Sigma^{-1} (p - \mu)} \]

- **Cosine**
  
  \[ d_C = \cos(\theta) = \frac{p_1 \cdot p_2}{|p_1||p_2|} \]
Performance measures

- **Verification**
  - Confirmation of identity
  - Is the subject in the database (as they claim to be)
  - Inter- and intra-class variation (of distance)
  - True and False accept rate; True and False reject rate
  - True and False positives

- **Recognition**
  - Can the subject’s identity be determined
  - Correct Classification Rate (CCR)
  - Rank
Inter- and Intra-class Variation

Distance between same subjects

Distance between different subjects

Confusion region
Good Recognition Capability

Distance between same subjects is small

Distance between different subjects is large
Poor Recognition Capability

Confusion region is large
Performance

Is (the code of) a person the same as one in the database?
Are two people similar or different?
Can be summarised as performance measures

<table>
<thead>
<tr>
<th></th>
<th>True</th>
<th>False</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accept</td>
<td>True accept</td>
<td>False accept FAR</td>
</tr>
<tr>
<td></td>
<td>True positive</td>
<td></td>
</tr>
<tr>
<td>Reject</td>
<td>True reject</td>
<td>False reject FRR</td>
</tr>
<tr>
<td></td>
<td>True negative</td>
<td></td>
</tr>
</tbody>
</table>

- at an FAR of one in 10,000, 70 false matches are expected in a database of 300 subjects and 750,000 nonmatch comparisons
Correct Recognition Rate (CCR) =
\[ \frac{\sum(\text{subjects correctly recognised})}{\sum(\text{subjects})} \]

**Rank** = ordered list of subject recognition

- closest = rank 1; furthest = rank \( N \)

Correct recognition rate (CCR) =
\[ \frac{\sum(\text{correct subjects at rank 1})}{\sum(\text{subjects})} \]
Verification - choosing a threshold

Threshold value determines nature of system performance.
Thresholding

Threshold

client

imposter
Thresholding

Thresholding is a process used in biometric systems to determine the threshold for classification between client and imposter. The graph shows the distribution of intra-class and inter-class variations, with the threshold set to separate true positives from false negatives and true negatives from false positives.

- True positive: True accept
- True negative: True reject
- False positive: False accept
- False negative: False reject

The graph illustrates the Euclidean distance between client and imposter samples, with the threshold set to achieve optimal classification performance.
Verification - choosing a threshold

True positive

Low false positive

Threshold
Verification - choosing a threshold

![Histogram and curve diagram showing true positive and false positive regions.]

- True positive
- False positive
- Threshold

**Intra/Inter-class variation**

**Euclidean distance**

**Probability density**

**Medium**
Verification - choosing a threshold

![Verification Diagram]

- True positive
- False positive
- High false positive

Intra/Inter-class variation

Threshold
Receiver Operator Characteristic (1)

Trend of increasing performance

Random rate

Area under ROC curve
Verification - choosing a threshold

Threshold value determines nature of system performance
Verification - choosing a threshold

![Graph showing intra-inter class variation with threshold and FAR, FRR indicated]

Low false accept
Verification - choosing a threshold

Equal error

threshold
Verification - choosing a threshold

Threshold

Low false reject
Receiver Operator Characteristic (2)

Area under curve is a better descriptor?

Equal error rate

Trend of increasing performance
Thresholding

Thresholding

True positive
True accept

False positive
False accept

True negative
True reject

False negative
False reject

client

imposter
Verification - choosing a threshold

Diagram showing the relationship between False Rejection Rate (FRR) and False Acceptance Rate (FAR) with respect to security and banking. The graph illustrates the intra-class and inter-class variations in Euclidean distance.
Other performance measures

• **(Daugman’s) Decidability** \(d’\) measures means’ separation in terms of standard deviation

\[
d’ = \frac{\sqrt{2} |\mu_{\text{genuine}} - \mu_{\text{imposter}}|}{\sqrt{\sigma_{\text{genuine}}^2 + \sigma_{\text{imposter}}^2}}
\]

• **\(F\_ratio\)** also measures means’ separation in terms of standard deviation

\[
F\_ratio = \frac{\mu_{\text{genuine}} - \mu_{\text{imposter}}}{\sigma_{\text{genuine}} + \sigma_{\text{imposter}}}
\]

• If distributions are **Gaussian**

\[
EER = \frac{1}{2} - \frac{1}{2} \text{erf} \left( \frac{F\_ratio}{\sqrt{2}} \right) \quad \text{where} \quad \text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt
\]
Correct classification rate (CCR)

Trend of increasing performance

Identification rate

Rank
Other terms

• Detection Error Tradeoff DET (False Non Match vs False Match)
• Precision
• Recall
• Failure to enrol (acquire)
• A match is a hit, accept, true positive, success
Classification

- Simplest is $k$-Nearest Neighbour ($k$-NN)

- Many advanced, e.g.

Support Vector Machine
Other terms

- Detection
- Liveness
- Spoofing
- Goats
- Response time/throughput
- Covariates
- Doppelganger...
Allied Subjects

- (Computer Vision and Image Processing)
- Anthropometry (proper ‘Biometrics’!)
- Psychology
- Machine Learning/ Artificial Intelligence
- Statistics
- Legal Issues
- Standards and standardisation
- Forensics
Human vision vs. computer vision

- Human vision is *conceptually similar* to computer vision
  - Sensor, storage and processing
- Differences in *sensing*
- Differences in *measurement*
- Differences in *processing*
- Differences in *training*

- Is human vision a *good paradigm* for computer vision?
Images: more than meets the eye?

Computer Vision and Human Vision have different abilities

Van Dyck 1635; Trafalgar Square
Stare at the + in the centre
Other factors of human vision

- Other race effect
- Prosopagnosia
- Prosopamnesia
- Familiar (face) recognition
- Confirmation bias
- Training
- Concentration
- Resolution
- Colour
For non-contact (non-invasive) biometrics

Sensor is not necessarily a (conventional) camera, but data is 2D
Approaches

Model based measures e.g. features, points

Image based measures e.g. transforms, mappings

Recognition

Image
Biometrics which use Computer Vision
Where are we now and quo vadis?

- Biometrics work
- Biometrics systems have major deployments
- There is still concern about performance
- Research continues:
  - Recognition
  - Performance
  - Capability
  - Extension
  - Applications
Analysis of Submissions to IAPR ICB 2009

Biometric technologies

- Face
- Fingerprint
- Iris/retina
- Iris/hadwriting
- Gait/body
- Speaker
- Palm/hand
- Skin
- Eeg/ecg
- Lip
- Ear
- Keystroke
- Novel

Performance factors

- Performance
- Security
- Covariate
- Quality
- Aging
- Fusion
- System

Alghero 2009
Analysis of Submissions to IEEE BTAS 2010

Biometric technologies

- Face
- Fingerprint
- Iris/retina
- Sig/hadwriting
- Gait/body
- Speaker
- Palm/hand
- Skin
- Eeg/ecg
- Lip
- Ear
- Keystroke
- Soft
- Novel

Performance factors

- Performance
- Security
- Covariate
- Quality
- Aging
- Fusion
- System
- Resolution
- Distance

Biometrics/ Nixon
Section 1: Introduction

Washington D.C. 27-29 Sep 2010
Commercial
More projections

1. Revenues for biometrics industry will more than double between 2007 and 2012 (a). A range of technology modalities will be involved, with the largest share going to conventional and automated and live-scan Fingerprinting (b). (courtesy of the International Biometric Group “Biometrics Market and Industry Report 2007-2012”)
Applications

Where do you need measures of identity?

- Immigration
- Surveillance
- People Counting
- Retail
- Social Networking
- Security
- Hospital
Working systems

Haj travel

Phones
Laptops

Disneyworld

Japanese banking
UK immigration
Sources of more information
Conference and journals (and abbreviations)

- Computer vision and biometrics journals: *Computer Vision and Image Understanding (CVIU)*, *Pattern Recognition*, *International Journal Computer Vision (IJCV)*, *IEEE Transactions on* (PAMI, TIFS, SMC etc)
- Computer vision conferences: *IEEE Computer Vision Pattern Recognition (CVPR)*, *British Machine Vision Conference (BMVC)*, ISVC + many
- Biometrics conferences: *International Conference on Biometrics (ICB)*, (AVBPA), *IEEE Biometrics Theory Applications and Systems (BTAS)* + fewer
From the early days, when security was the driving force behind biometric research, today's challenges go far beyond security. Machine learning, Image understanding, Signal analysis, Neuroscience, Forensic science, Digital forensics and other disciplines, converged in a truly multidisciplinary effort to devise and build advanced systems to facilitate the interpretation of signals recorded from individuals acting in a given environment. This is what we simply call today "Biometrics".

For the last fifteen years, the International Summer School on Biometrics has been closely following the developments in science and technology to offer a cutting edge, intensive training course, always up to date with the current state-of-the-art.

What are the most up-to-date core biometric technologies developed in the field? What is the potential impact of biometrics in forensic investigation and crime prevention? How to detect impersonation attacks and disguise? What can we learn from human perception? What is a biometric recognition system?

This school follows the successful track of the International Summer Schools on Biometrics held since 2003. In this 15th edition, the courses will mainly focus on new and emerging issues:

1. How Biometrics can deal with impersonation and disguise;
2. How to exploit new biometric technologies in forensic and security applications;
3. Standardization, evaluation and assessment of biometric and forensic applications;
4. Biometric and Forensic identification and advanced research: What is next?
Morning Schedule

June 12-16 2017

COURSE SCHEDULE

Chair: Massimo Tistarelli

Monday June 12

Massimo Tistarelli
Opening

Arun Ross
(Michigan State University, USA)
Introduction to Biometrics and Multibiometrics

Alessandro Verri
(University of Genova, Italy)
Machine Learning and Deep Networks in Biometrics

Massimo Tistarelli
(University of Sassari, Italy)
Face Recognition

Davide Maltoni
(University of Bologna, Italy)
Fingerprint Recognition

Welcome cocktail

Chair: Arun Ross

Chair: Davide Maltoni

Tuesday June 13

Arun Ross
(Michigan State University, USA)
Iris and Periocular Features for Recognition

Mark Nixon
(University of Southampton, UK)
Soft Biometrics

Thirimachos Bourlai
(West Virginia University, USA)
Practical Biometric Systems and Project Session 1

Peter Claes
(University of Leuven, Belgium)
Predicting Faces from DNA

Student presentations

Chair: Alice O'Toole

Wednesday June 14

Jonathon Phillips
(NIST, USA)
Challenges in Face Recognition and Visual Biometrics

Vishal Patel
(Rutgers University, USA)
Continuous Authentication in the Mobile World

Alice J. O'Toole
(University of Texas, USA)
Biological Recognition of Human Faces & Bodies

Ida Gobbini
(University of Bologna, Italy)
Mechanisms for Recognition of Familiar Faces

James Haxby
(Dartmouth College, USA)
Commonality of the fine-grained structure of neural representations across brains

Visit to Alghero and Gala dinner

BUS LEAVES AT 18:45
## Section 1 Glossary

<table>
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<th>Acceptability</th>
<th>Detection Error Tradeoff</th>
<th>Human Vision</th>
<th>Recall</th>
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<tbody>
<tr>
<td>Biometric Classification</td>
<td>Distance</td>
<td>Image processing</td>
<td>Recognition</td>
</tr>
<tr>
<td>Collectability</td>
<td>Enrolment</td>
<td>k-NN classification</td>
<td>Repeatability</td>
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<td>Computer vision</td>
<td>Equal Error Rate</td>
<td>Liveness</td>
<td>Sensor</td>
</tr>
<tr>
<td>Correct Classification Rate (CCR)</td>
<td>EER</td>
<td>Measurements</td>
<td>Spoofing</td>
</tr>
<tr>
<td>Cumulative Match Characteristic (CMC)</td>
<td>Euclidean distance</td>
<td>Other race effect</td>
<td>Support Vector Machine SVM</td>
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<td>Decidability</td>
<td>Failure to enrol</td>
<td>Performance</td>
<td>Threshold</td>
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<td>Features</td>
<td>Precision</td>
<td>Throughput</td>
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