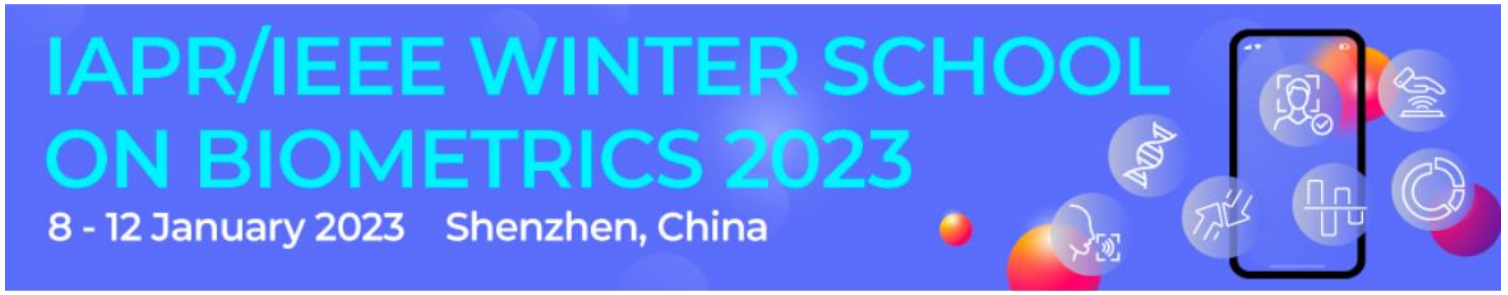

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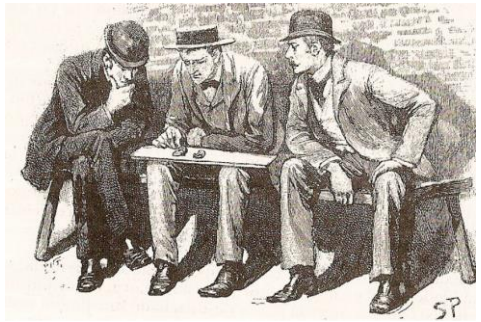


A Question of Evidence

Biometrics and forensics

Mark Nixon

University of Southampton UK

IEEE Biometrics Council Distinguished Lecturer

IEEE Biometrics Council

Where am I?

Southampton

Harbin

Shenzen

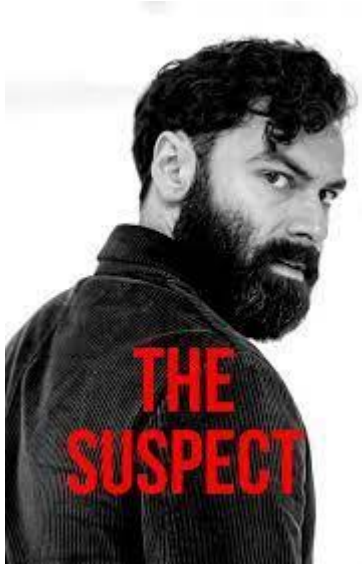
The question ….

You are a biometrics expert

… and are contacted by the police

… who have a suspect.

What do you do?



Identification - history

It's actually quite recent

1858 **Herschel**, palm print on contract (and fingerprint)

1880s **Bertillon**: anthropometry / identification, inc. iris, face, ear

1888 **Galton**: fingerprint

1899 **Henry**: fingerprint classification

1951 **Crick and Watson**: DNA

1964 **Iannarelli**: ear identification

1987 **Flom** and **Safir**: iris classification

1990 (ish) 'Biometrics'

KONAI's HANDPRINT
from the back of the contract
Bengal, India, 1858

Police involvement

What are forensics?

"scientific tests or techniques used in connection with the detection of crime"

So what is a crime?

"an action or omission which constitutes an offence and is punishable by law"

So forensics are

scientific tests used in connection with punishment by law

So in biometrics it's about producing evidence

Evidence and admissibility

- Many things are evidence, but not all are admissible
- Rules and procedures differ
- Daubert is for expert witnesses

(not much biometrics in forensics, so for a new technique)

1. *Whether the theory and methodology have been tested, peer-reviewed, or published:*

write a paper, apply it to something else

2. *The potential and known error rates for a particular technique:*

include error bars

3. *Any standards and controls applicable to the science.*
4. *The degree of acceptance in the scientific community:*

organise special session/ special edition/ competition,
edit book, get on television, podcast, tutorial

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Mr. Bean's evidence

No, it's not admissible
It fails Daubert, but it's great!

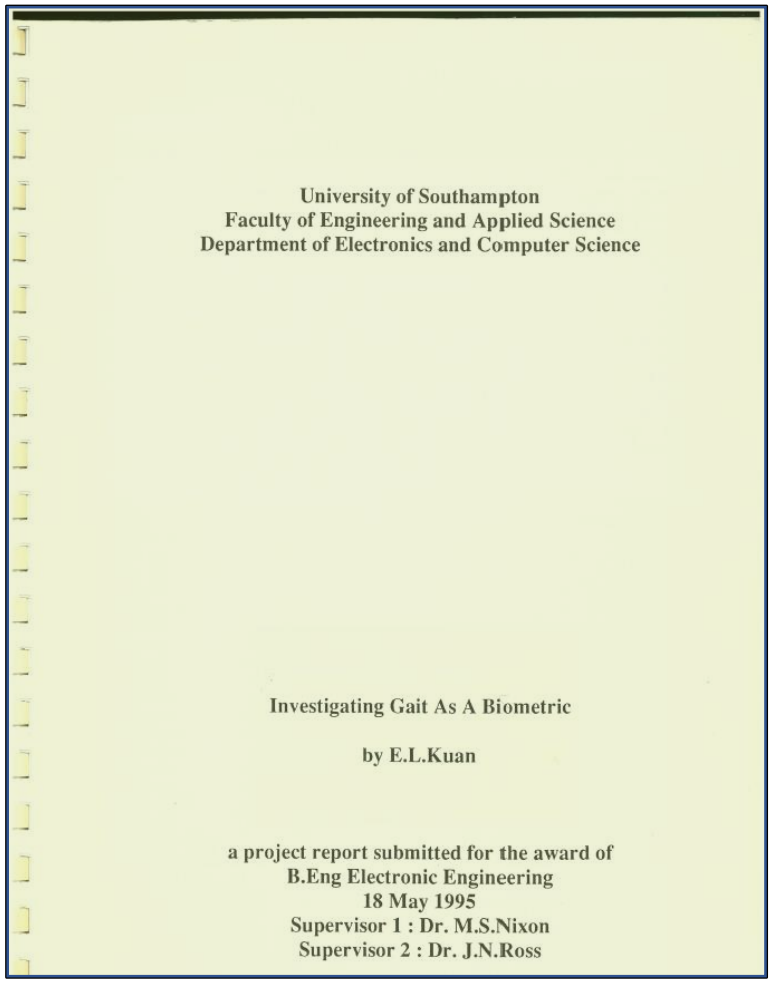
Judicial systems – presenting the evidence

Differing types of system

1. Adversarial – convince a jury
    A. Civic duty
    B. 'Random' composition
2. Inquisitorial – convince magistrates/ committees
3. Autocratic – hmm, better less said!!

You have to convince people who are not experts in biometrics

Identifying people by their gait



University of Southampton
Faculty of Engineering and Applied Science
Department of Electronics and Computer Science

Investigating Gait As A Biometric

by E.L.Kuan

a project report submitted for the award of
B.Eng Electronic Engineering
18 May 1995
Supervisor 1 : Dr. M.S.Nixon
Supervisor 2 : Dr. J.N.Ross

Gait recognition – the state of art

Technique: mainly deep

Data: Frontal-View Gait (FVG)
CASIA E

Applications: increasing use in crime scene analysis

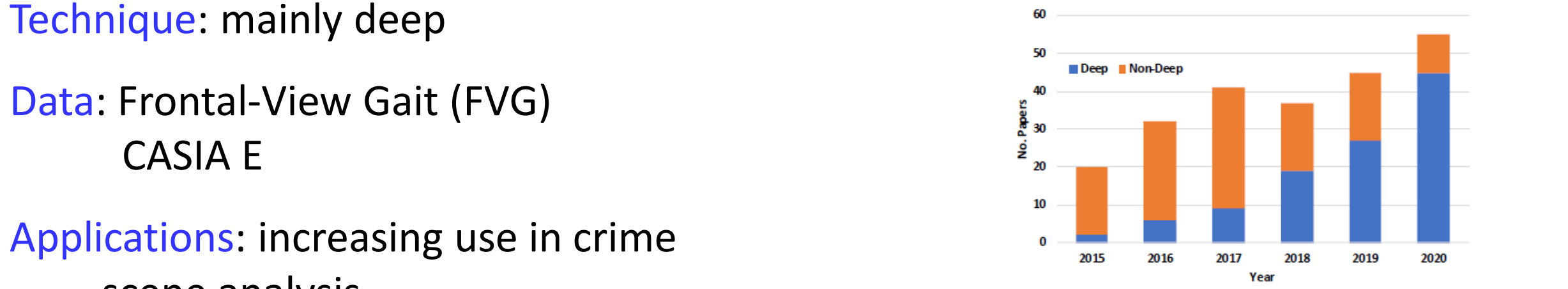
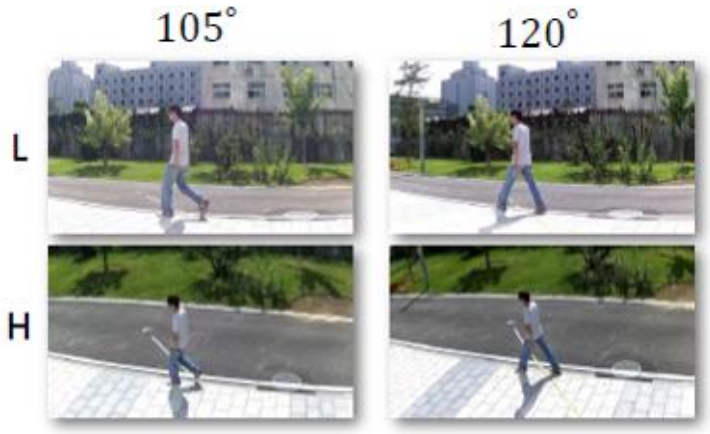


Fig. 1: The number of gait recognition papers published after 2015 using non-deep (orange) and deep (blue) gait recognition methods.

A Sepas-Moghaddam, *Deep Gait Recognition: A Survey*, 2022



HiD competition, ACCV 2020/ IJCB 2021/IJCB 2022

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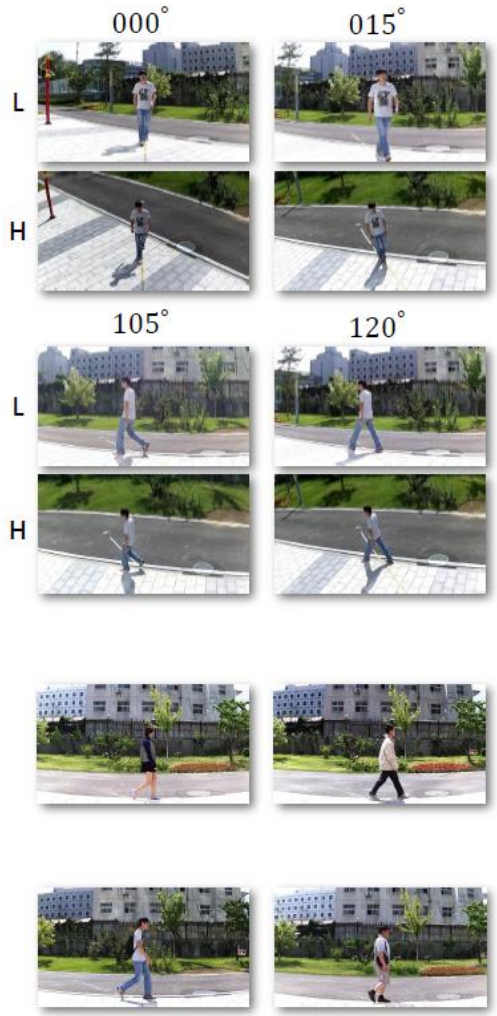
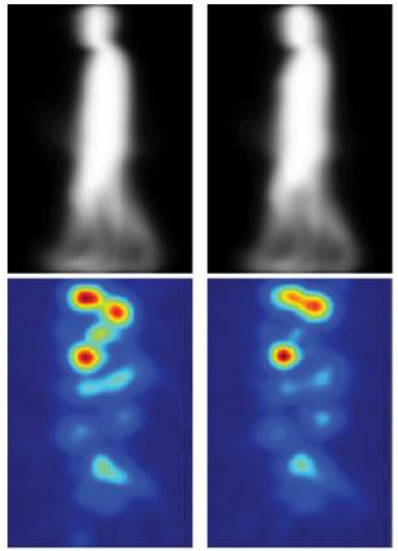
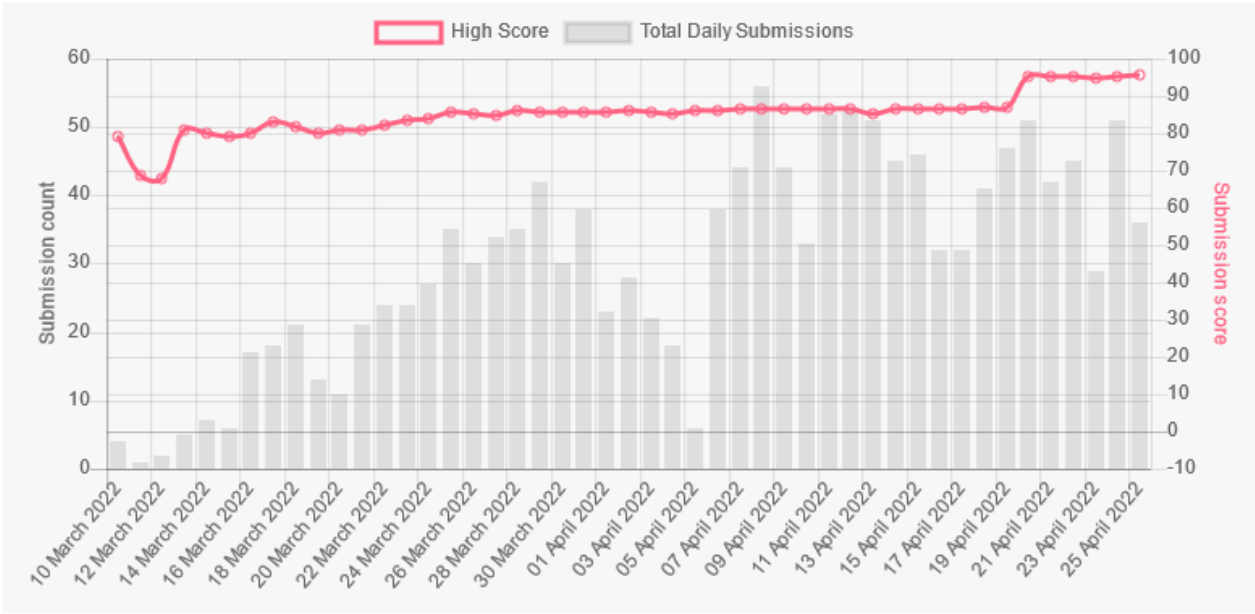




Yu, Huang, Wang, Makihara + …,
Proc. IJCB, 2022

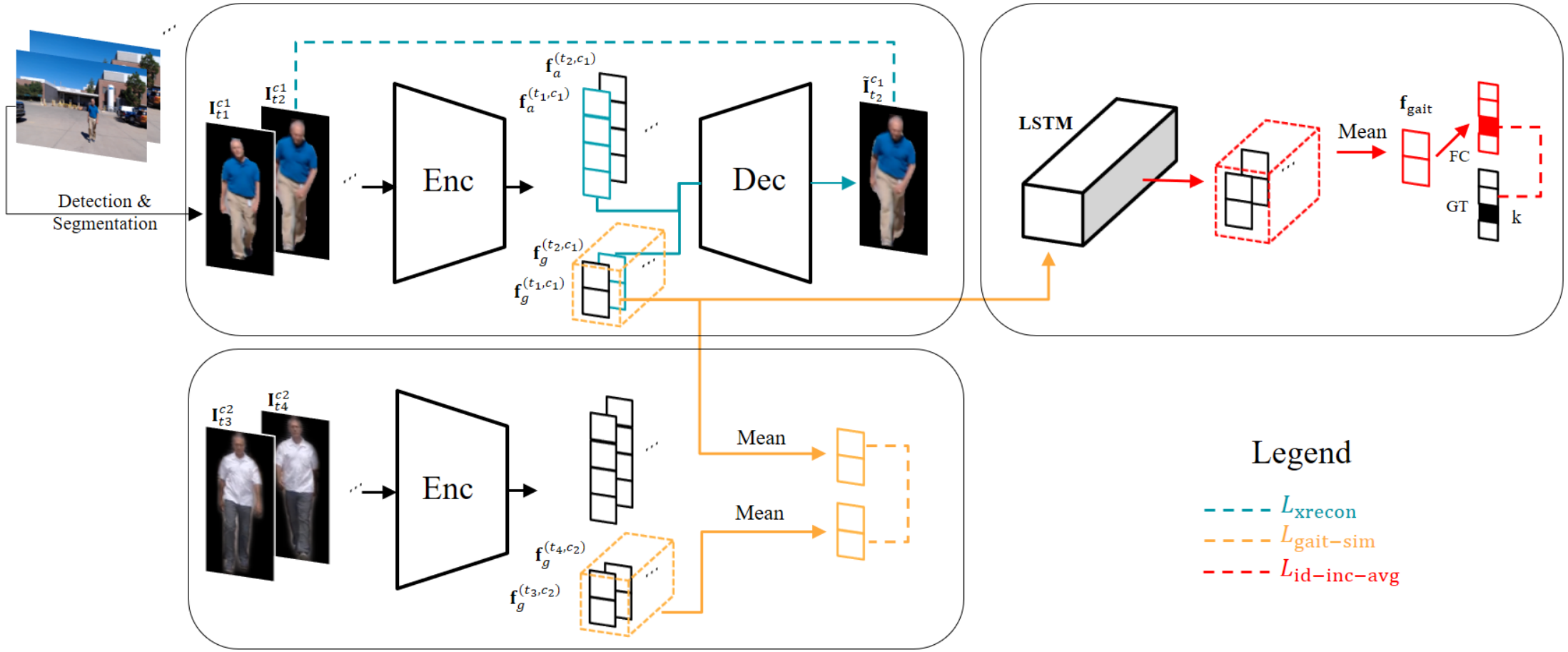
CASIA E GEIs



https://competitions.codalab.org/competitions/26085#learn_the_details

Gait recognition via disentangled representation learning

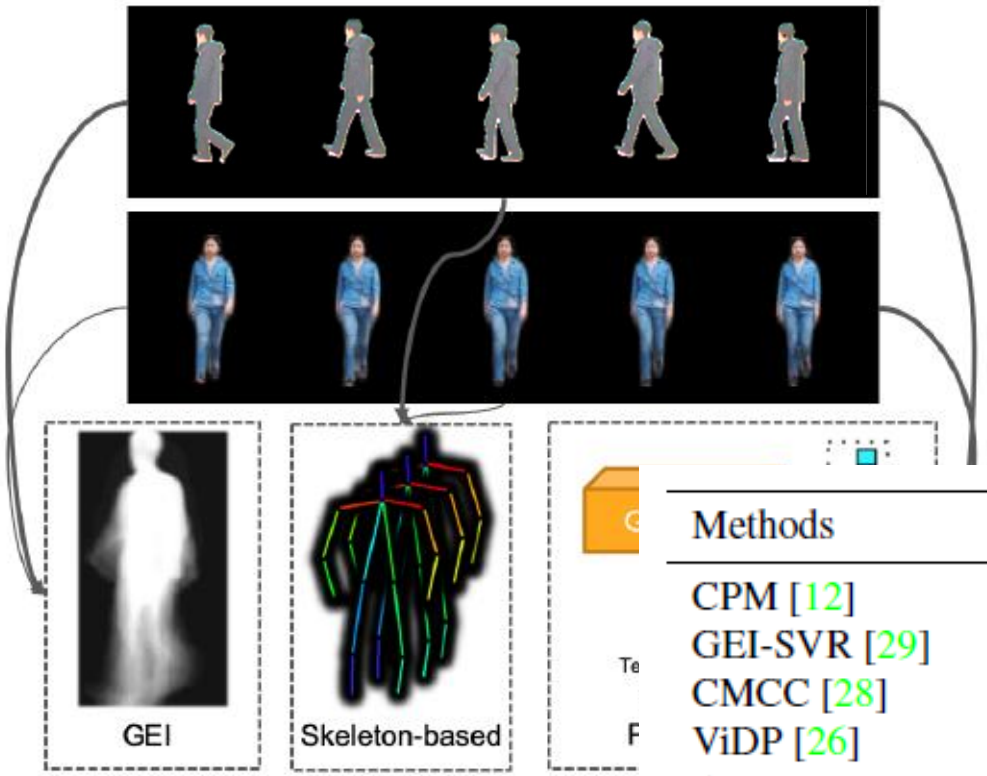
Ziyuan Zhang, Luan Tran, Xi Yin, Yousef Atoum, Xiaoming Liu (Michigan State University)



Zhang et al, *CVPR* 2019

See also: Li, Makihara, Xu, Yagi: Gait recognition via semi-supervised disentangled representation learning to identity and covariate features, CVPR 2020

Gait recognition via disentangled representation learning



Methods	0°	18°	36°	54°	72°	108°	126°	144°	162°	180°	Average
CPM [12]	13	14	17	27	62	65	22	20	15	10	24.1
GEI-SVR [29]	16	22	35	63	95	95	65	38	20	13	42.0
CMCC [28]	18	24	41	66	96	95	68	41	21	13	43.9
ViDP [26]	8	12	45	80	**100**	**100**	81	50	15	8	45.4
STIP+NN [30]	–	–	–	–	84.0	86.4	–	–	–	–	–
LB [46]	18	36	67.5	93	99.5	99.5	92	66	36	18	56.9
L-CRF [12]	38	**75**	68	93	98	99	**93**	67	76	39	67.8
GaitNet (ours)	**68**	74	**88**	**91**	99	98	84	**75**	**76**	**65**	**81.8**

Zhang et al, *CVPR* 2019

Generally, big(ger) numbers!!

Technology in 1994

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Electronics and Computer Science

Justifying gait as a biometric

- Shakespeare observed recognition:

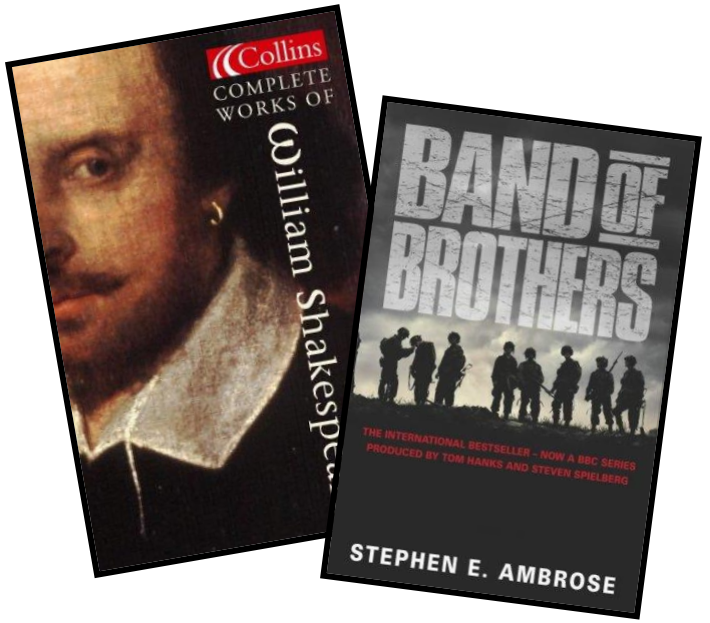
  "*High'st Queen of state; Great Juno comes; I know her by her gait*" [The Tempest]

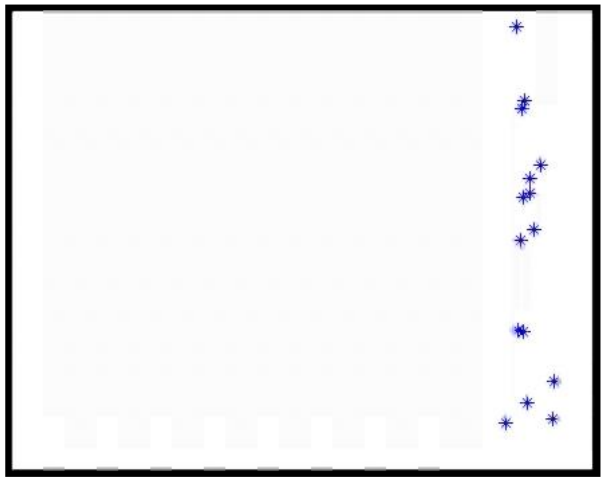
  "*For that John Mortimer….in face, in gait in speech he doth resemble*" [Henry IV/2]

- Psychology

  Johannson [73] MLDs recognised as humans

  Kozlowski [77] gender and effect of height





What is the state of knowledge

What affects the perception of gait?

Studied factors

Viewpoint

Illumination/ environment

Clothing/ footwear

Time

Luggage

Surface

Others

Mood
Diet
Health
….

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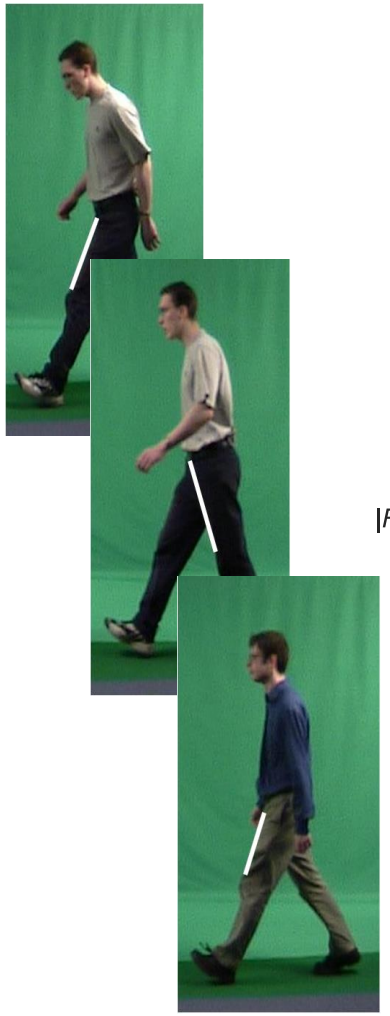
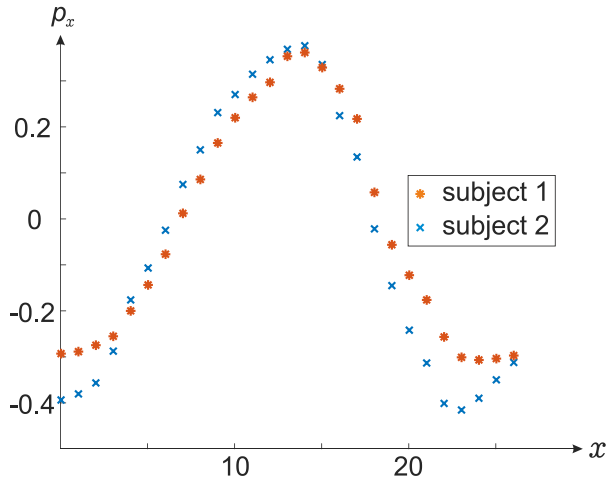
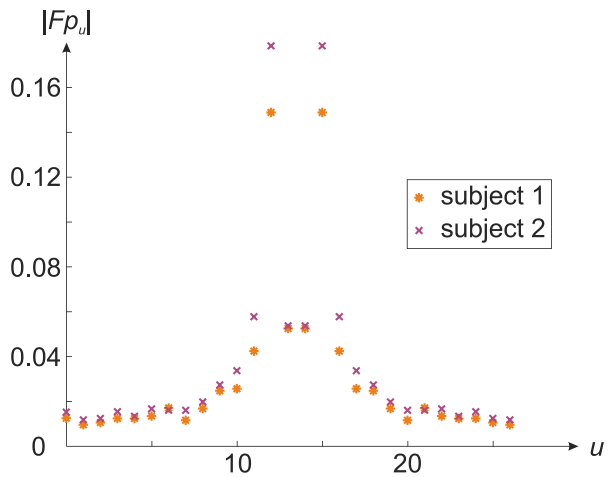
Model-based recognition

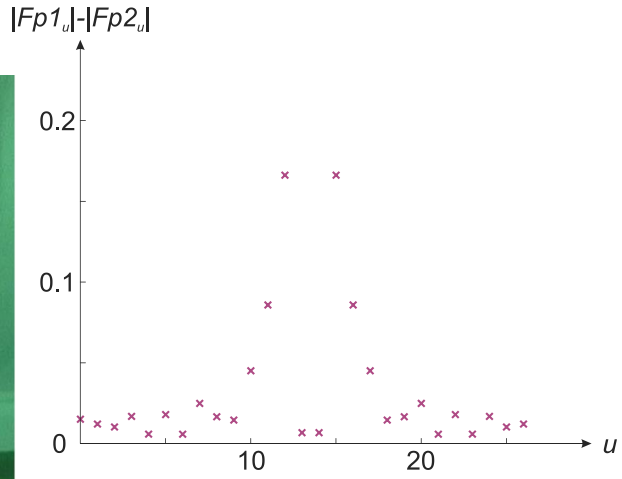




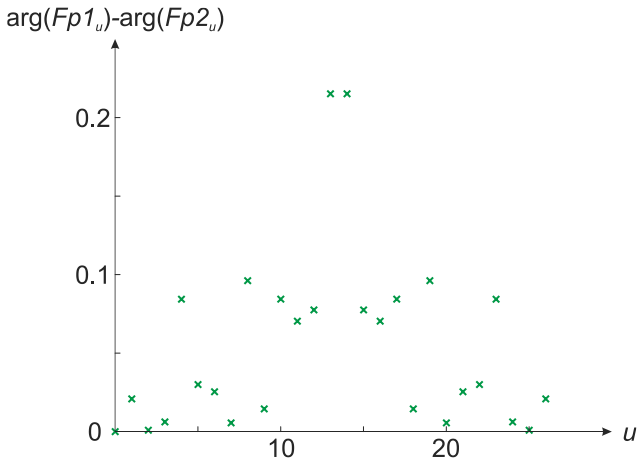
Inclination of thigh



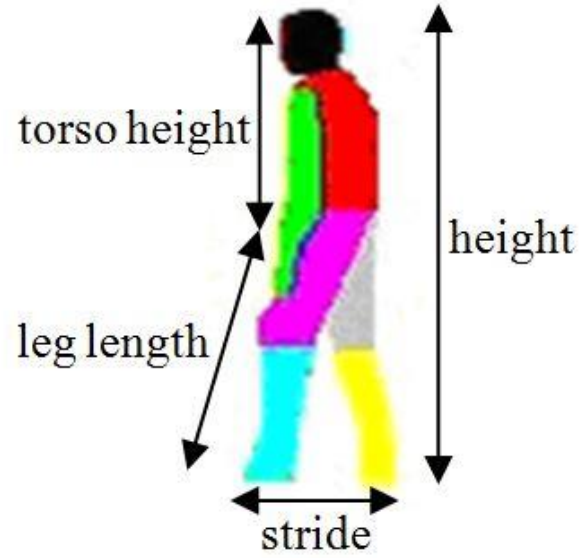
Magnitude of DFT



Difference between magnitude



Difference between phase



Other models are possible

D Cunado, MS Nixon, JN Carter, Proc. AVBPA, 1997

Gait as evidence – first use

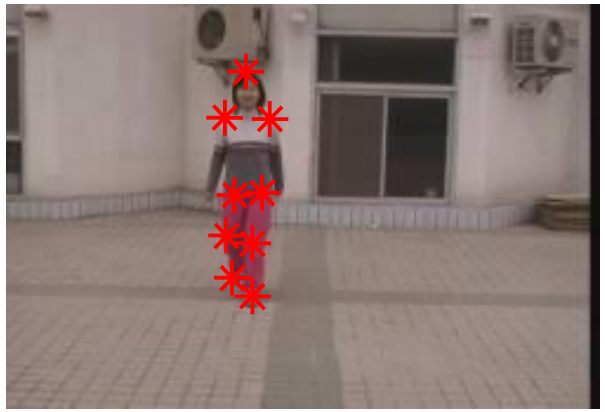
Bag snatcher, London 2008

Note controlled trajectory

Using gait as evidence -database

Use multiview gait data

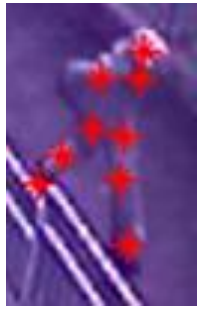
CASIA B at the time

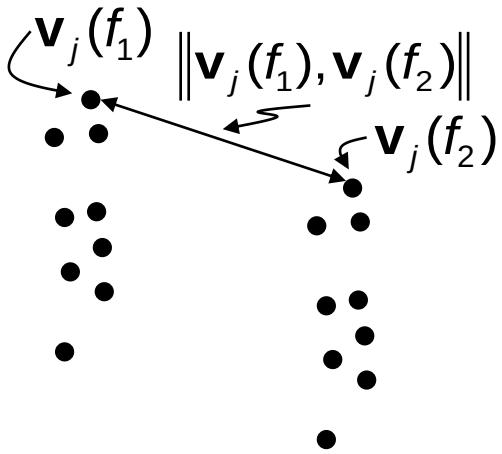


with automated labelling

Wang, Ning, Hu, Tan, *Proc. ICPR* 2002

Gait as evidence -approach





Match measure for subject, *N* vertices in *W* frames

$$d = \sum_{f_1,f_2 \in W | f_1 \neq f_2} \sum_{j,k \in N} \left\| \mathbf{v}_j(f_1), \mathbf{v}_j(f_2) \right\| \Big/ (N \times W)$$

Analysis from database, *S* subjects

Within class $$d_w = \left(\sum_{s \in database} \sum_{f_1,f_2 \in W | f_1 \neq f_2} \sum_{j,k \in N} \left\| \mathbf{v}_j(f_1,s), \mathbf{v}_j(f_2,s) \right\| \Big/ (N \times W) \right) \Big/ S$$

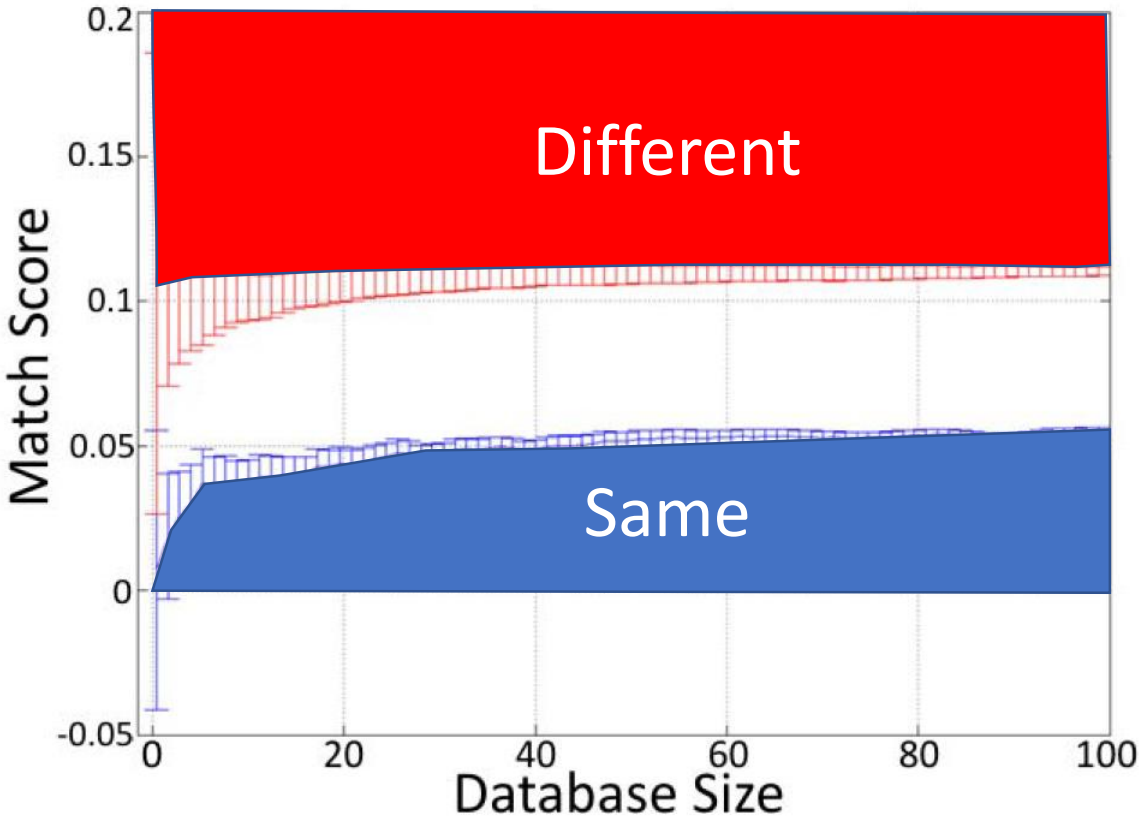
Between class $$d_b = \left(\sum_{s1,s2 \in database | s1 \neq s2} \sum_{f_1,f_2 \in W | f_1 \neq f_2} \sum_{j,k \in N} \left\| \mathbf{v}_j(f_1,s_1), \mathbf{v}_j(f_2,s_2) \right\| \Big/ (N \times W) \right) \Big/ S$$

Confidence = $$\Big(mean(d_b) + mean(d_w) \Big) \Big/ \Big(range(d_b) + range(d_w) \Big)$$

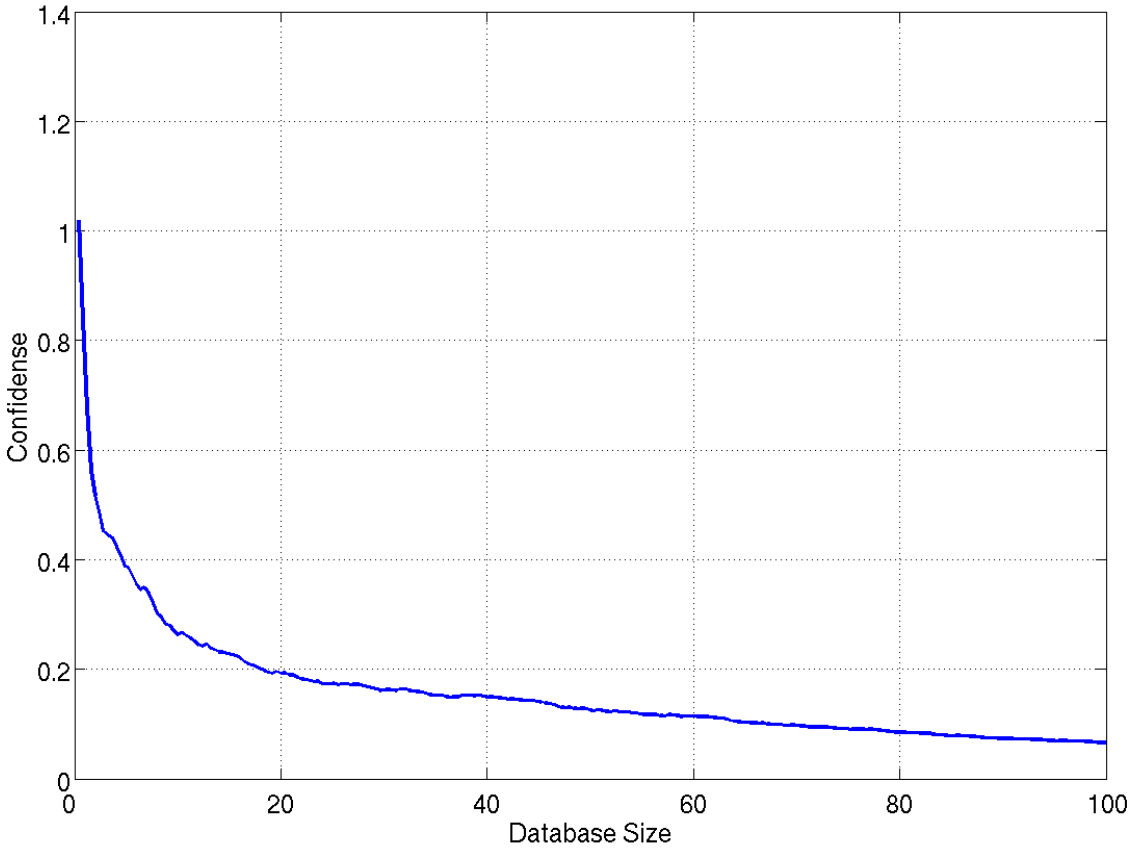
Match success = $$d \subset range(d_i)$$

Bouchrika, Nixon, Carter, *J. Forensic Science* 2011, and *Eusipco* 2010

Gait as evidence –analvsis on database



Distances



Confidence

Evidence

By computing the match based on the anthropometric distances, the aggregated difference in joints' position is lower than 3%. Currently, we consider that a match lower than 15% suggests a possible and that 3% indicates a very close match.

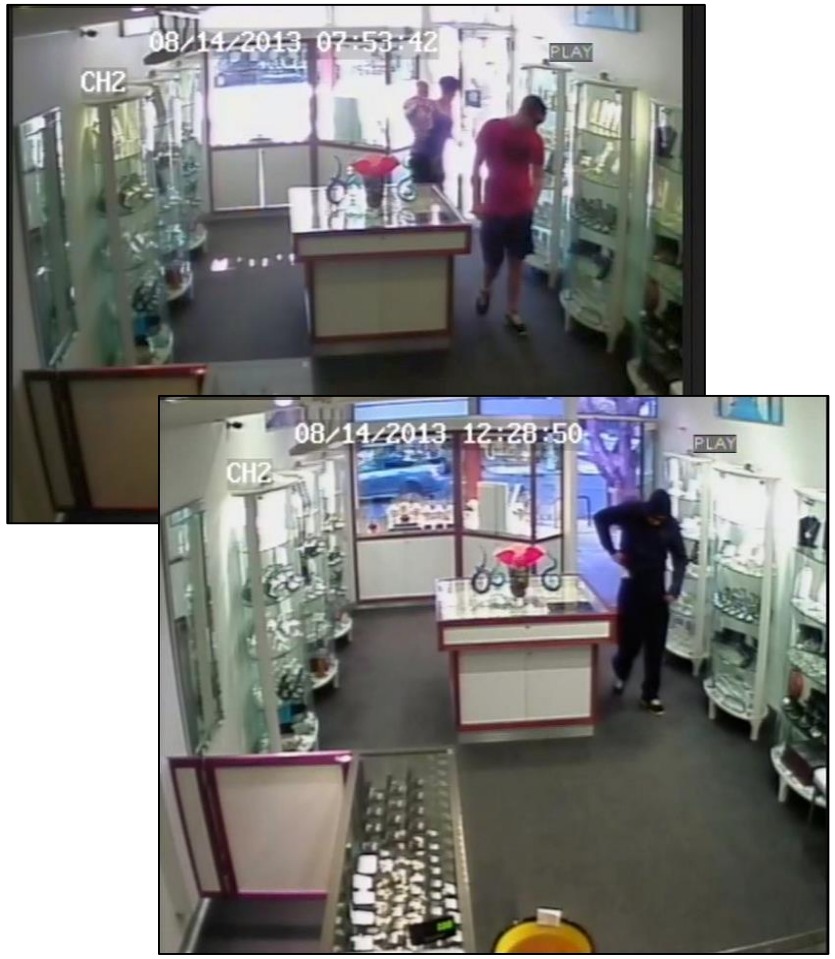
Accordingly, **I am very confident in my statement that there is a match between the male subject walking in Video A and the subject walking in Video B.**

I can provide the data used in our analysis should it be required. I can also provide images of the two subjects during ingress where the subject's posture and appearance appear to confirm this conclusion.

(Professor M. NIXON)
BSc PhD CEng FIET FIAPR

Plus:
Statement on self
Statement on gait
Description of data
Witness to signature

Australia case



https://www.youtube.com/watch?v=F1b_apXjjV0&feature=youtu.be

Likelihood ratio

- Introduces probabilistic reasoning to evidence
- Describes the degree of support of one proposition vs its alternative
- Prosecution proposition H_p: accused is same as perpetrator
- Defence proposition H_d: accused differs from perpetrator
- Likelihood ratio $LR = \frac{p(E|H_p)}{p(E|H_d)}$

  $LR > 1$ supports prosecution

  $LR < 1$ supports defence
- H_p is intra-class probability density; H_d is inter-class
- Needs score to LR calculation (logistic regression, kernel density, GMM)
- Needs calibration
- Needs standards

Ramos, Krish, Fierrez, Meuwly, *Handbook of Biometrics for Forensic Science*, 2017

Google Scholar

biometrics forensic

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[PDF] The role of speech technology in **biometrics**, **forensics** and man-machine interface.

S Singh - International Journal of Electrical & ..., 2019 - download.garuda.kemdikbud.go.id

... Fingerprint success in **forensic** science and law enforcement applications with growing ... of **biometric** systems is playing an important role in all areas of our society. **Biometric** applications ...

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[PDF] **Biometrics** in **forensic** identification: applications and challenges

M Saini, AK Kapoor - J **Forensic** Med, 2016 - academia.edu

... of **forensic biometrics** covers a wide range of applications for physical and cybercrime detection. **Forensic Biometrics** ... limitations of **biometric** science in the field of **forensic** identification. ...

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On using gait in **forensic biometrics**

I Bouchrika, M Goffredo, J Carter... - Journal of **forensic** ..., 2011 - Wiley Online Library

Given the continuing advances in gait **biometrics**, it appears prudent to investigate the translation of these techniques for **forensic** use. We address the question as to the confidence that ...

Save Cite Cited by 245 Related articles All 12 versions

Linkages between **biometrics** and **forensic** science

D Dessimoz, C Champod - Handbook of **biometrics**, 2008 - Springer

... In the following sections we will cover the main **forensic biometric** modalities and then show how an automatic approach has and will change the conduct of **forensic** examinations. ...

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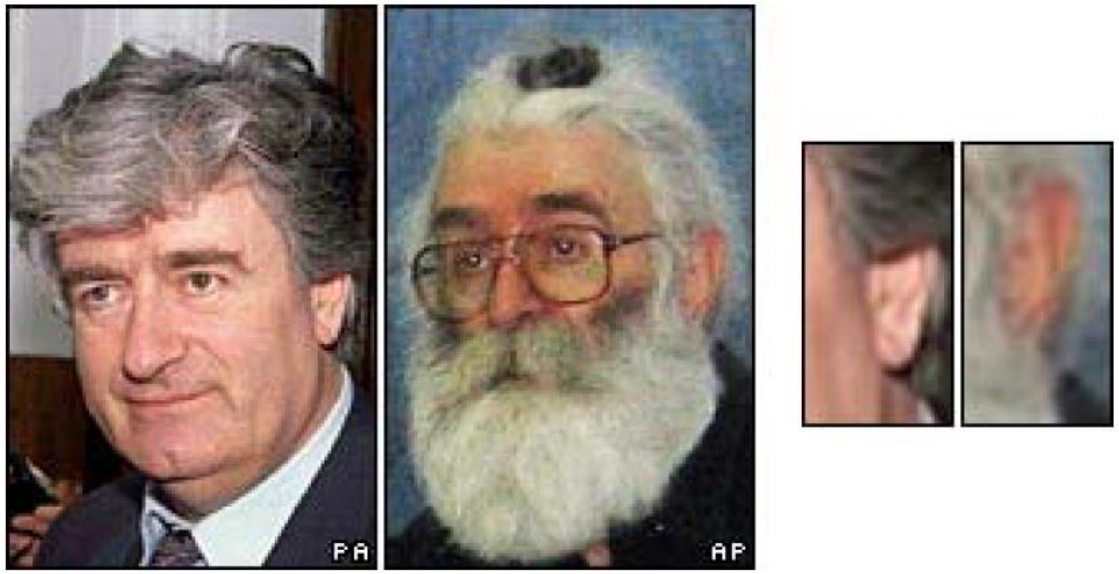
Search 7 Dec 2022

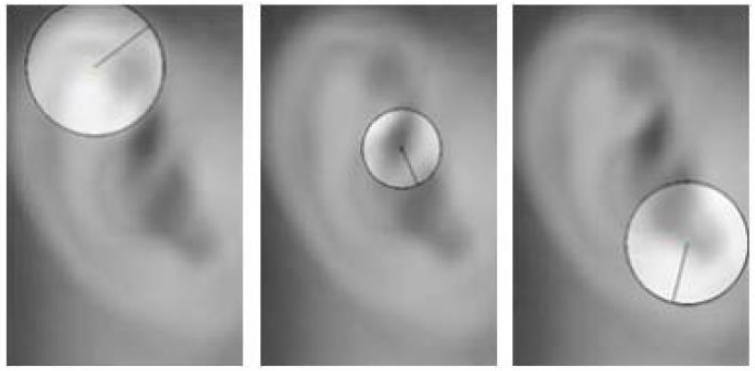
Ears by same procedure

Ears are unique and permanent, and rarely hidden (for ID)

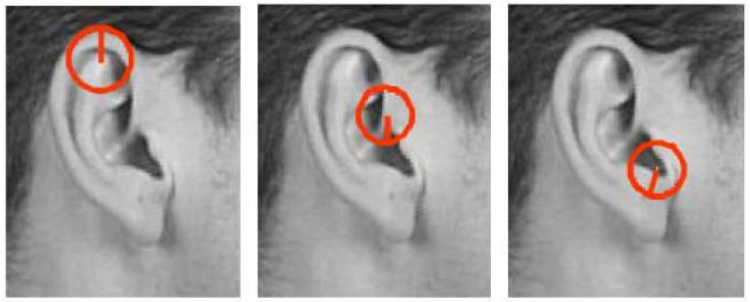


Nixon, Bouchrika, Arbab-Zavar, Carter, *Eusipco* 2010

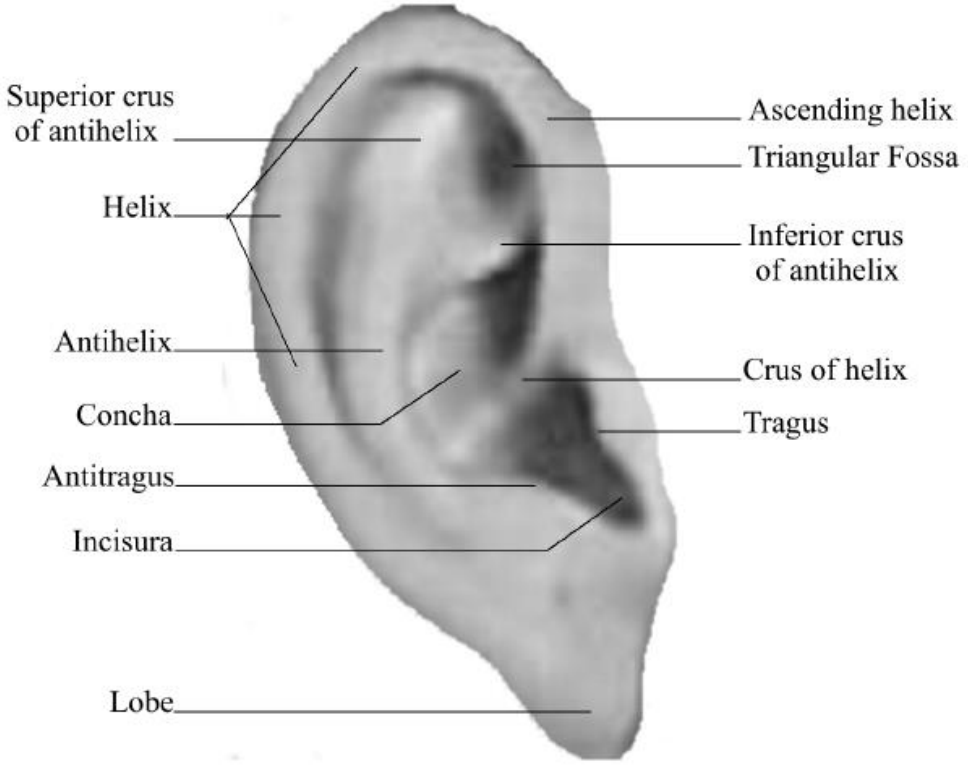
Ears have many interesting features



(a) Model parts

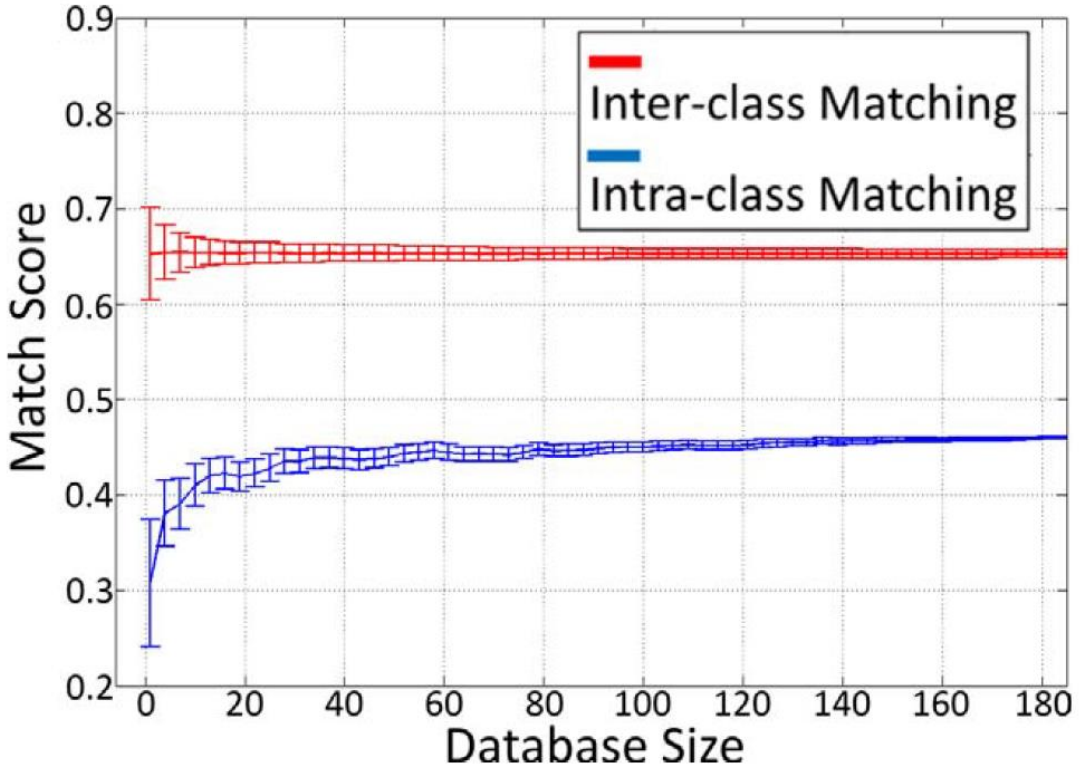


(b) Detected parts



Nixon, Bouchrika, Arbab-Zavar, Carter, *Eusipco* 2010

Matching on an ear database



Variance is much smaller

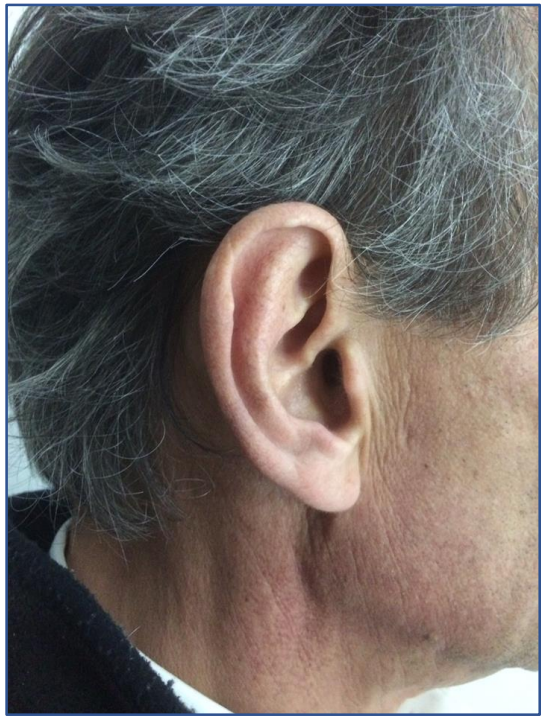
Nixon, Bouchrika, Arbab-Zavar, Carter, *Eusipco* 2010

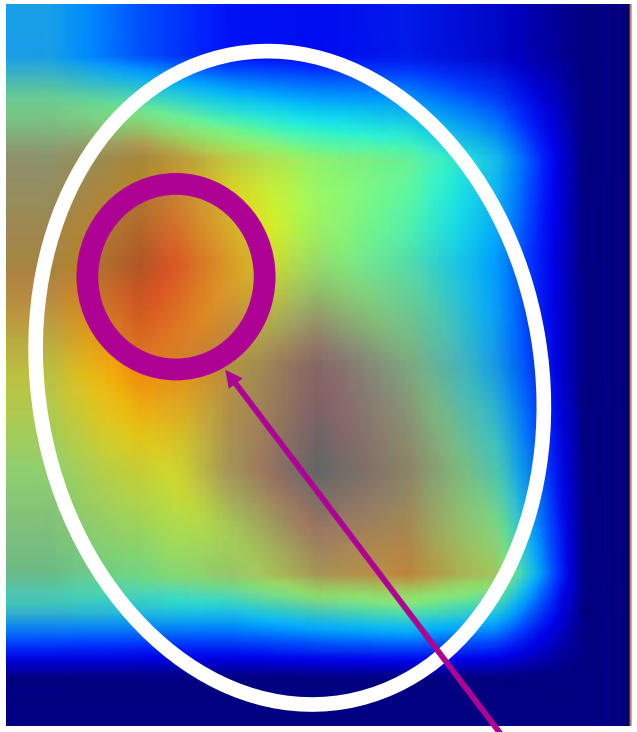
University of Southampton
Electronics and Computer Science

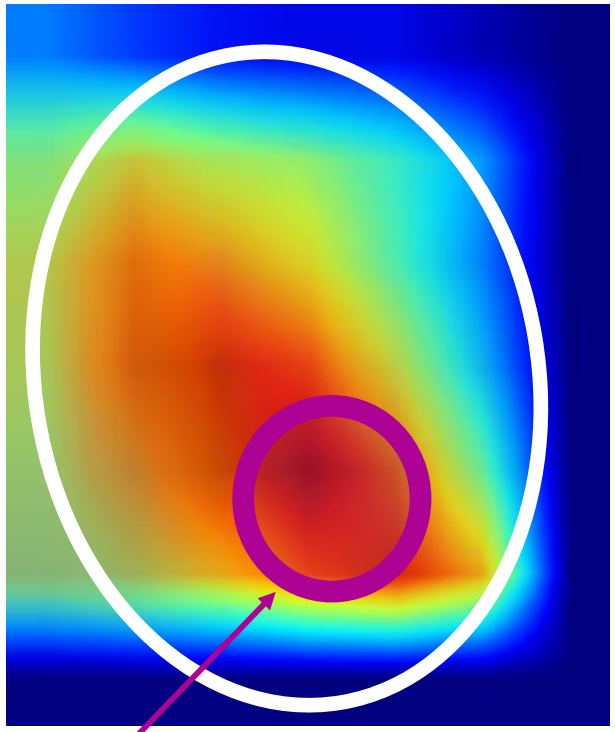
Identity science: where is gender in ears?

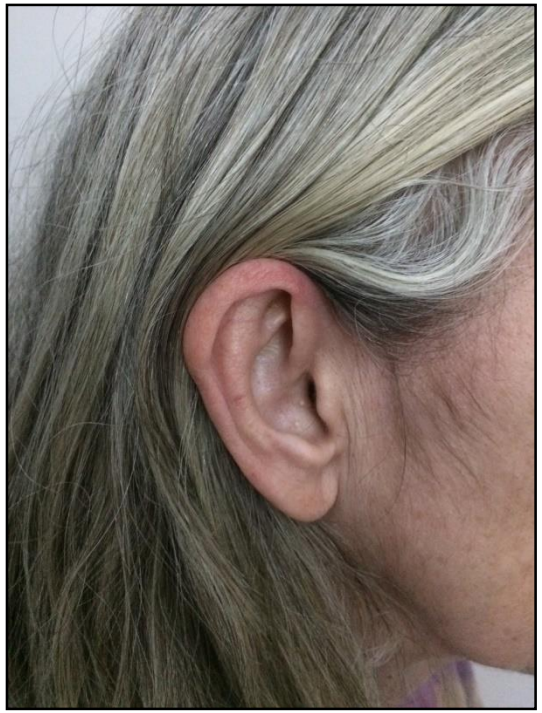
male

female









ROI

Meng, Nixon and Mahmoodi,
IEEE TBIOM, 2021

... and age, kinship, ...

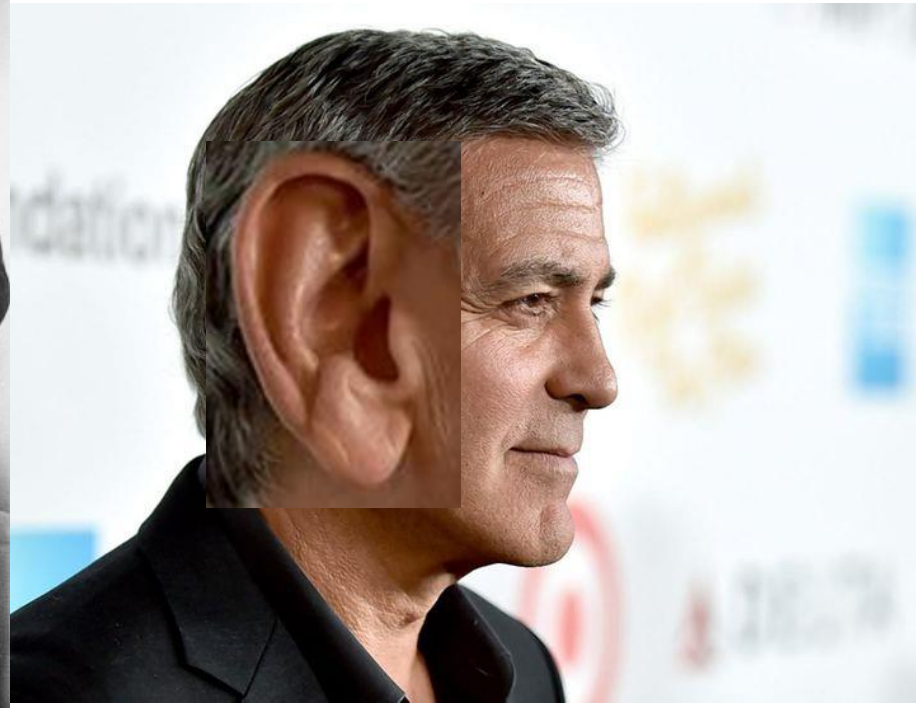
University of Southampton
Electronics and Computer Science

Can you determine gender by ear?

- Man or woman?

Sophia Loren

George Clooney



Emma Watson

… and age, kinship, ….

Meng, Nixon and Mahmoodi,
IEEE TBIOM, 2021

Biometrics in the literature 1

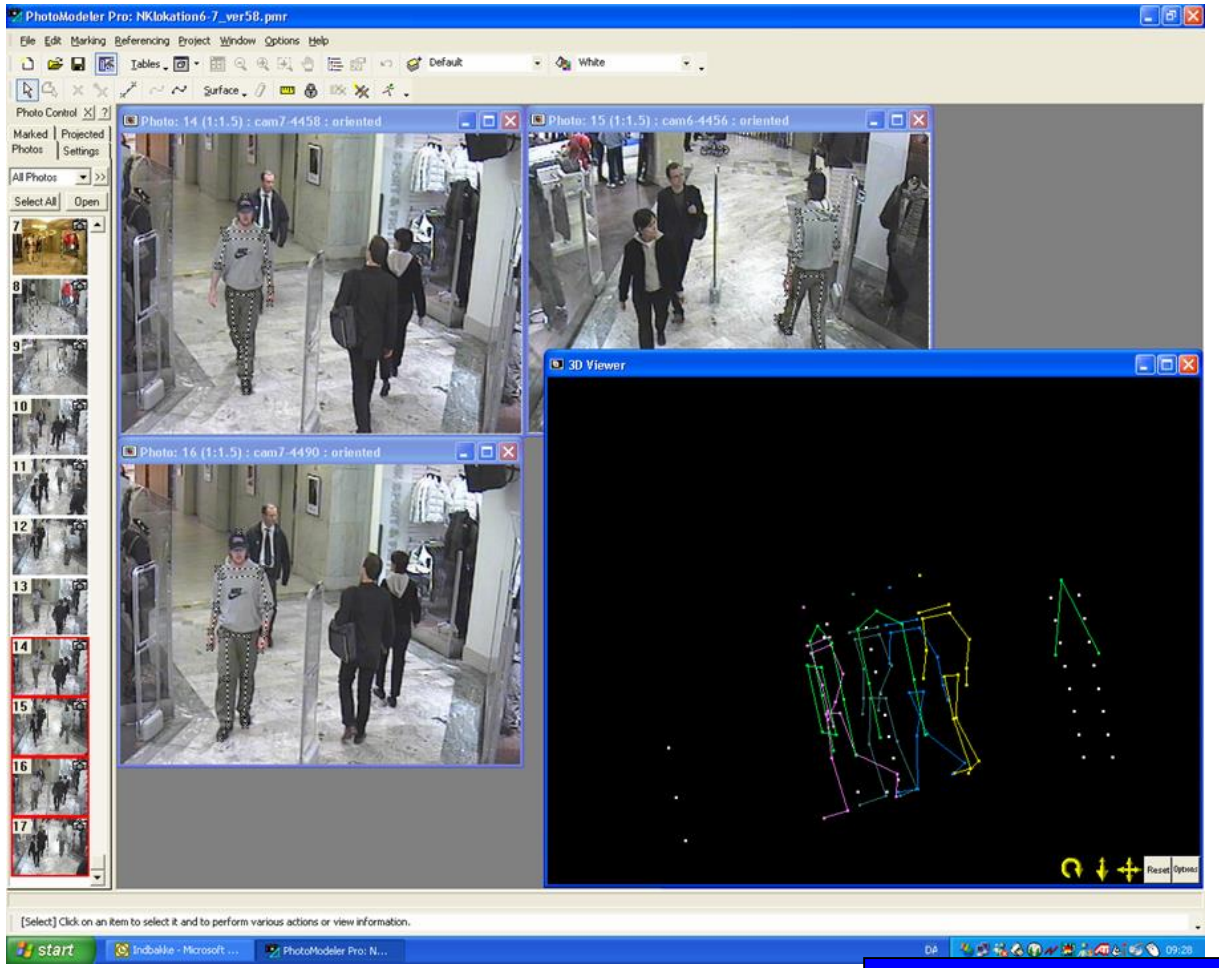
"…biometric systems in forensic science today aim at filtering potential candidates and putting forward candidates for further 1-to-1 verification by a forensic specialist.."

Dessimoz and Champod, *Biometrics Handbook*, Springer, 2007, Chap 21

Biometrics in the literature 2

Forensic anthropology

Murder of Swedish foreign secretary, Anna Lindh



N. Lynnerup and J. Vedel *J. Forensic Sci.*, 2005

Biometrics in the literature 3 Forensic podiatry

"Forensic gait analysis, the direct visual comparison of two or more video recordings to establish whether they are of the same individual … based on the gait pattern alone"

- "There is no published standardised approach for forensic gait analysis comparison"
- "There appears to be little consistency in the formal recording … for forensic gait analysis"
- "the strength of the conclusion … is often only a subjective estimate"
- "no credible database", "no published and verified error rates", "no published black-box studies"

And (!!)

- automated methods … differ from forensic gait analysis …make use of a much richer dataset

S Black, M Wall, R Abboud, R Baker, J Stebbins *Royal Society: Forensic gait analysis: A primer for courts,* 2017

End of forensic podiatry?

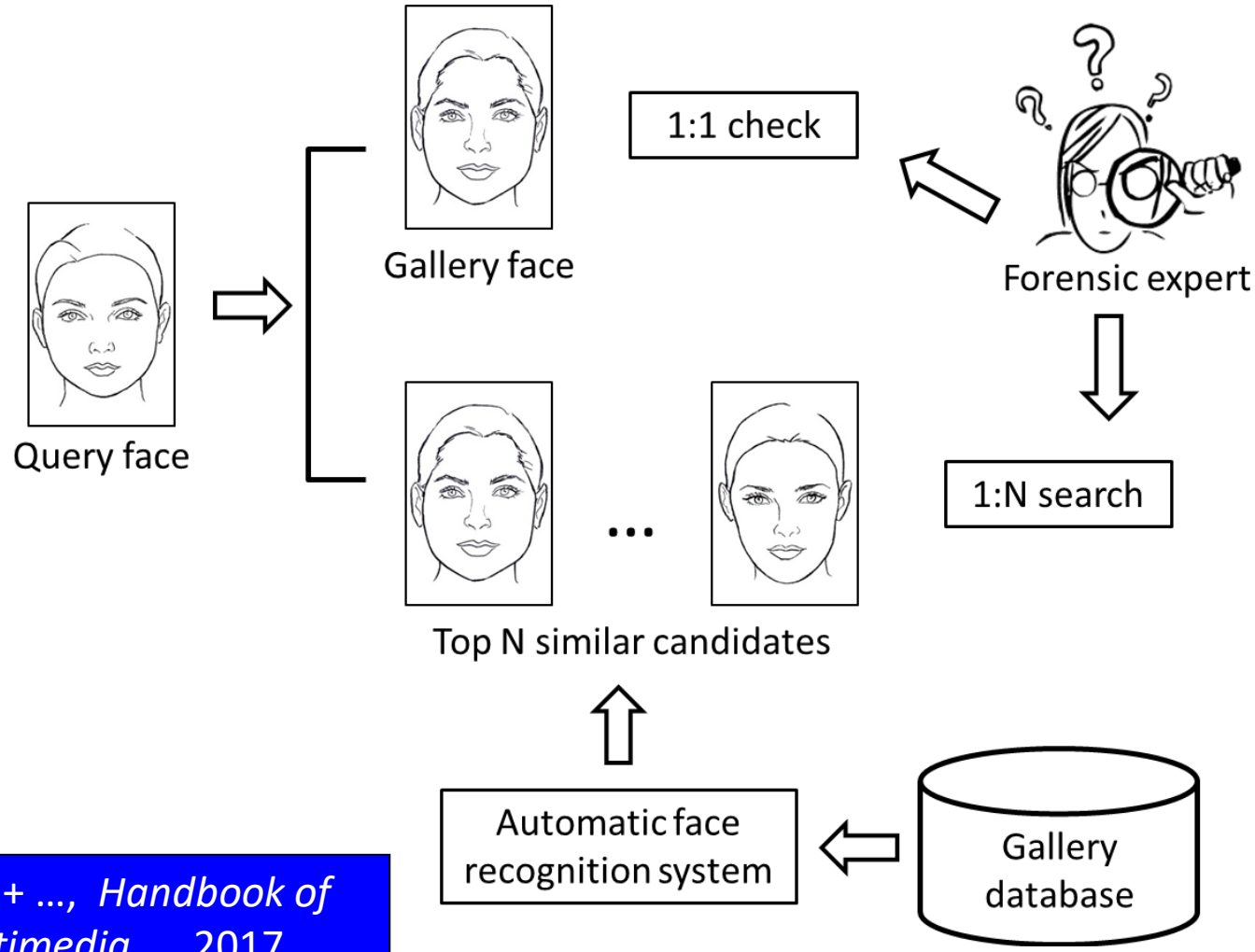
"The methods remain insufficiently robust, considering the recent paradigm shift witnessed in the forensic science community regarding quality of evidence."

"However, there is persistence in attempting to prove that as it stands, forensic gait analysis should not fall into disrepute in the forensic science community"

"Automated gait recognition has greatly surpassed forensic gait analysis"

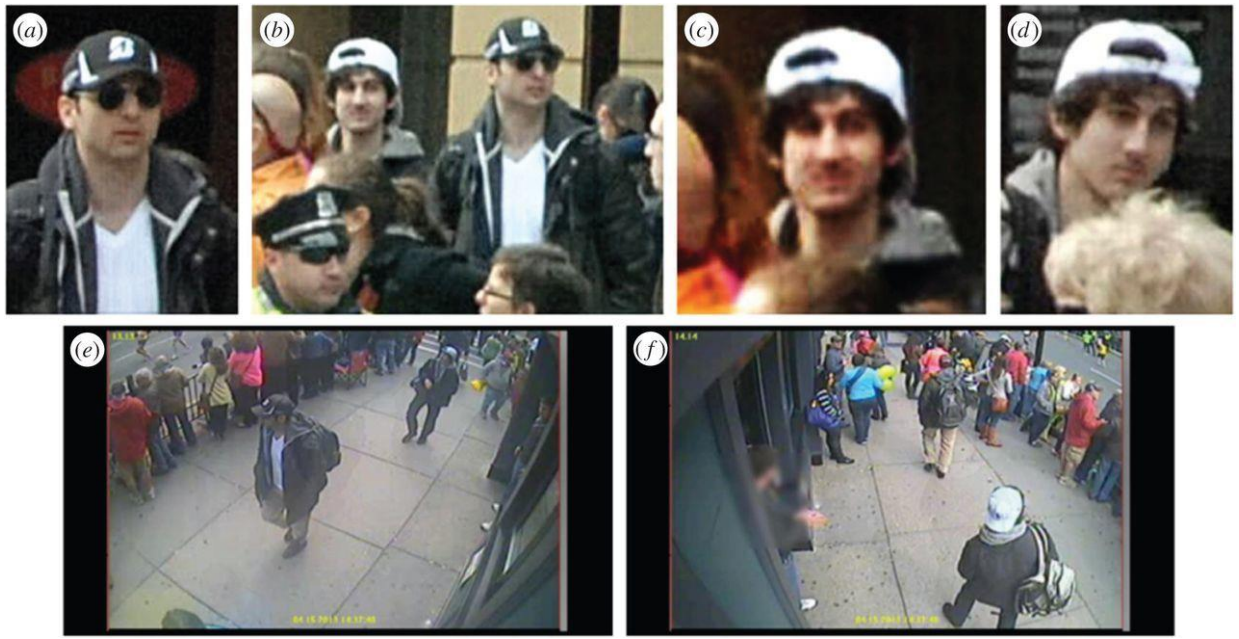
Macoveciuc, Rando +, Forensic gait analysis and recognition: standards of evidence admissibility, *J. Forensic Science* , 2019

Biometrics in the literature 4 - face

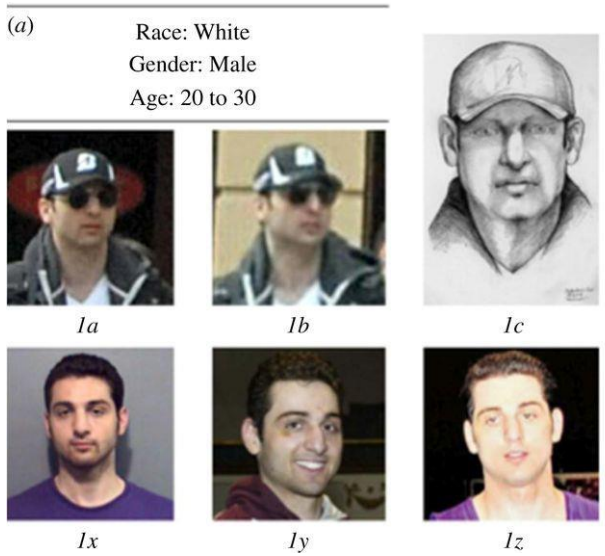


Arbab-Zavar, Wei, Bustard + …, *Handbook of Digital Forensics of Multimedia …*, 2017

Biometrics in the literature 3 Face recognition



Boston police video:
The public was asked to help identify these two individuals



(b) with demographic filtering (white male, 20–30)

	1a	1b	1c	mean
1x	5432	27 617	112	353
1y	518	25 780	1409	686
1z	3958	14 670	1142	1416
mean	424	5790	71	82

Biometrics:
composite-to-photo matching
Composite of Tamerlan Tsarnaev (*1c*) resulted in a better match with the gallery image (*1x*) than any of the probe images (*1a* and *1b*) released by the police

Jain, Ross, *Transactions of the Royal Society B*, 2015

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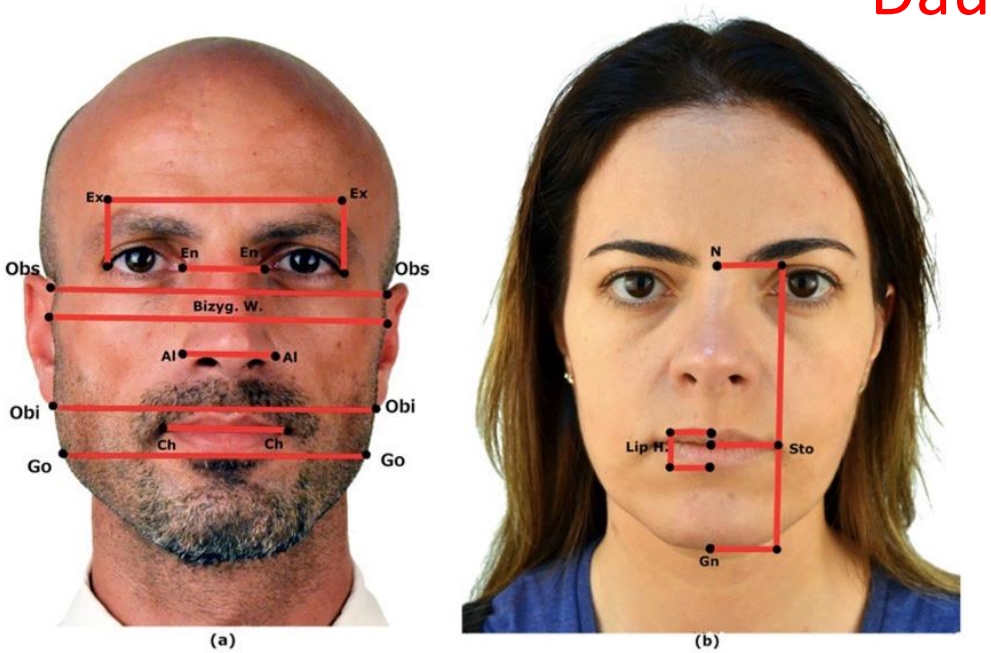
Sex estimation from biometric face photos for forensic purposes

Daubert

sex estimation could be made with an accuracy of 80.5%



(left), (right) Distances taken between landmarks (Obs: otobasion superior, Obi: otobasion inferior, Go: gonion, bizyg. W.: Bizygomatic width, En: endocanthion, Ex: exocanthion, Al: alare, Ch: chellion, N: nasion, Gn: gnathion, Sto: stomion).

	Age groups					
	20–39 ($n = 143$)			40–59 ($n = 130$)		
Measurements	*N*	Mean	SD	*N*	Mean	SD
Obs-Obs	143	73.177	4.221	130	74.199	4.238
Obi-Obi	143	67.638	4.855	130	69.390	4.624
Go-Go	143	63.507	4.822	130	65.131	5.103
Bizyg W.	143	51.292	5.307	130	51.605	5.206
En-En	143	16.773	1.588	130	17.006	1.747
Ex-Ex	143	48.035	3.121	130	47.330	3.620
Al-Al	143	18.579	2.329	130	19.653	2.152
Ch-Ch	143	27.813	2.435	130	28.465	2.621
Lip H.	143	7.908	1.576	130	6.653	1.797
N-Gn	143	60.952	4.058	130	62.029	4.368
N-Sto	143	39.590	3.010	130	40.249	3.073

Obs: otobasion superior; Obi: otobasion inferior; Go: gonion; Bizyg. W.: Bizygomatic width; N: nasion; Gn: gnathion; Sto: stomion; LipH: Lip High; Bizyg W: Bizygomatic width.
* $P < 0.05$.

N Sezgin, B Karadayi, *Medicine, Science and the Law* , 2019

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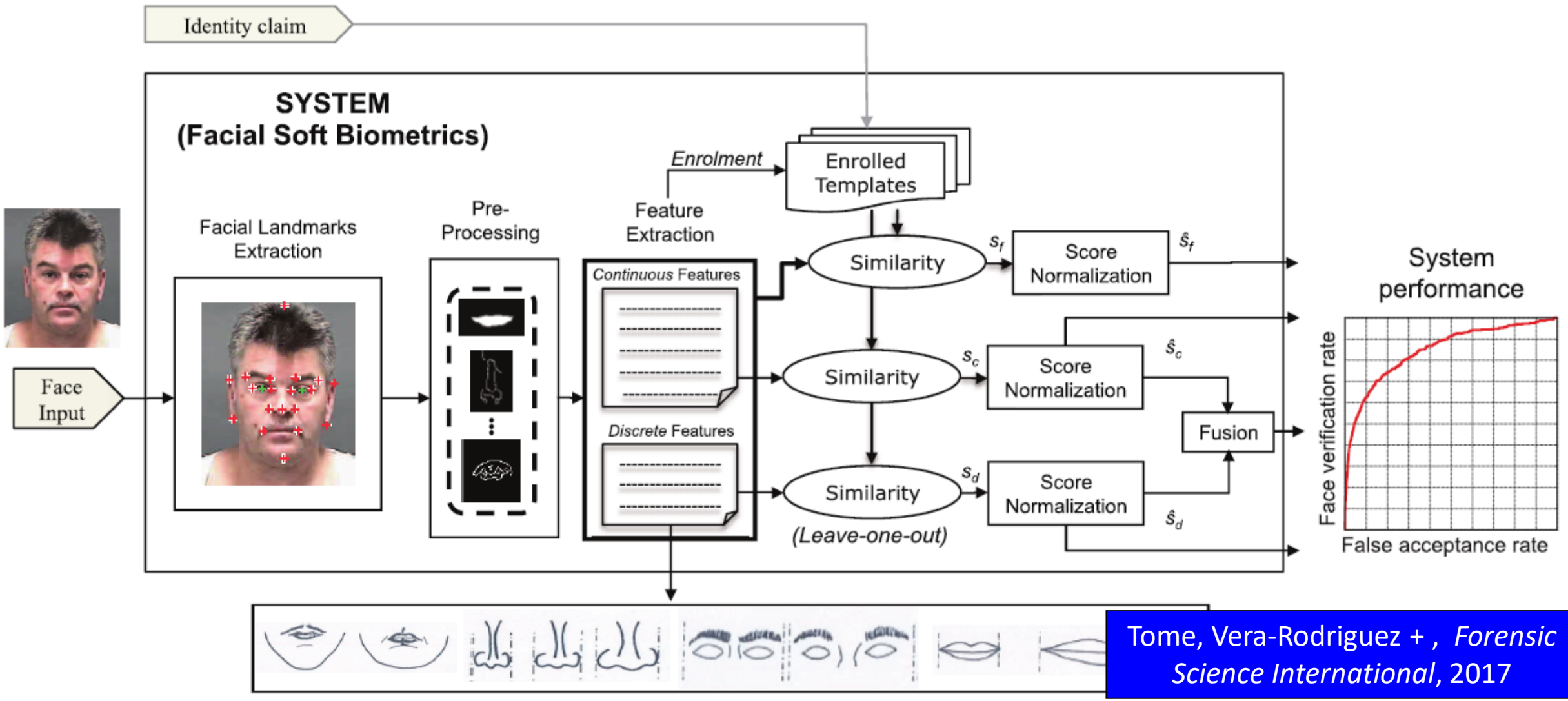
Facial Soft Biometric Features for Forensic Face Recognition



Tome, Vera-Rodriguez + , *Forensic Science International*, 2017

Advantages of biometrics in forensics

1. Large databases – representative of large modern populations

   (vs databases of criminals; lineups/ identity parades)

2. Large databases – reduce cognitive bias

   (vs. subjective reality of criminal data)

3. Automated processing

   fast and reproducible results

   chain of reasoning

   error bars

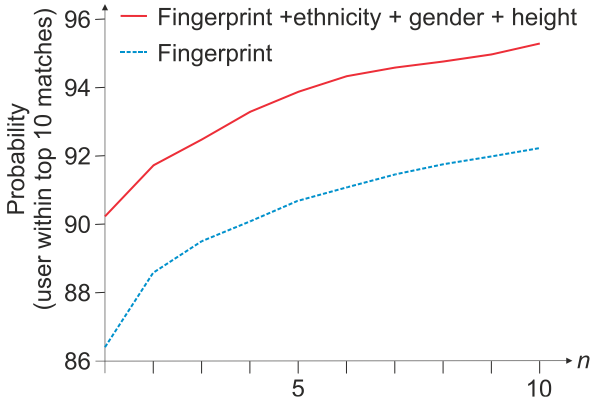
Future work

- Law
- Methodology
- Evidence
- Identity science
- Use human vision?

Soft Biometrics

Bertillonage 1890
(body, face, iris, ear, nose…)

Nandakumar and Jain 2004
(augmenting traditional biometrics)



Face Soft
Attribute
Kumar, Klare, Zhang, Gonzalez-Sosa
Relative Attribute
[Graumann], Reid, Almudhahka,

Body Soft
Categorical Samangooei
Comparative
Reid, Martinho-Corbishley
Forensic
Lucas

Other Soft
Tattoos Lee
Clothing Jaha
Makeup Dantcheva
Eyes & glasses
Mohammed
Hair Proenca

Applications: Performance, identification, marketing, fashion …..

Dantcheva, Elia, and Ross: What Else Does Your Biometric Data Reveal? *IEEE TIFS* , 2016

Nixon, Correia, Nasrollahi, Moeslund, Hadid, and Tistarelli: On soft biometrics? *Patt Recog Lett*, 2015

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Descriptions and attributes for identification

Eyewitness statement

"24 year old male average height wearing shirt"

Image of crime

Generate description

Subject	Gender	Age	Height	Nose W	Top
?	M	24	171	2.4	Shirt

Database of images

Generate descriptions

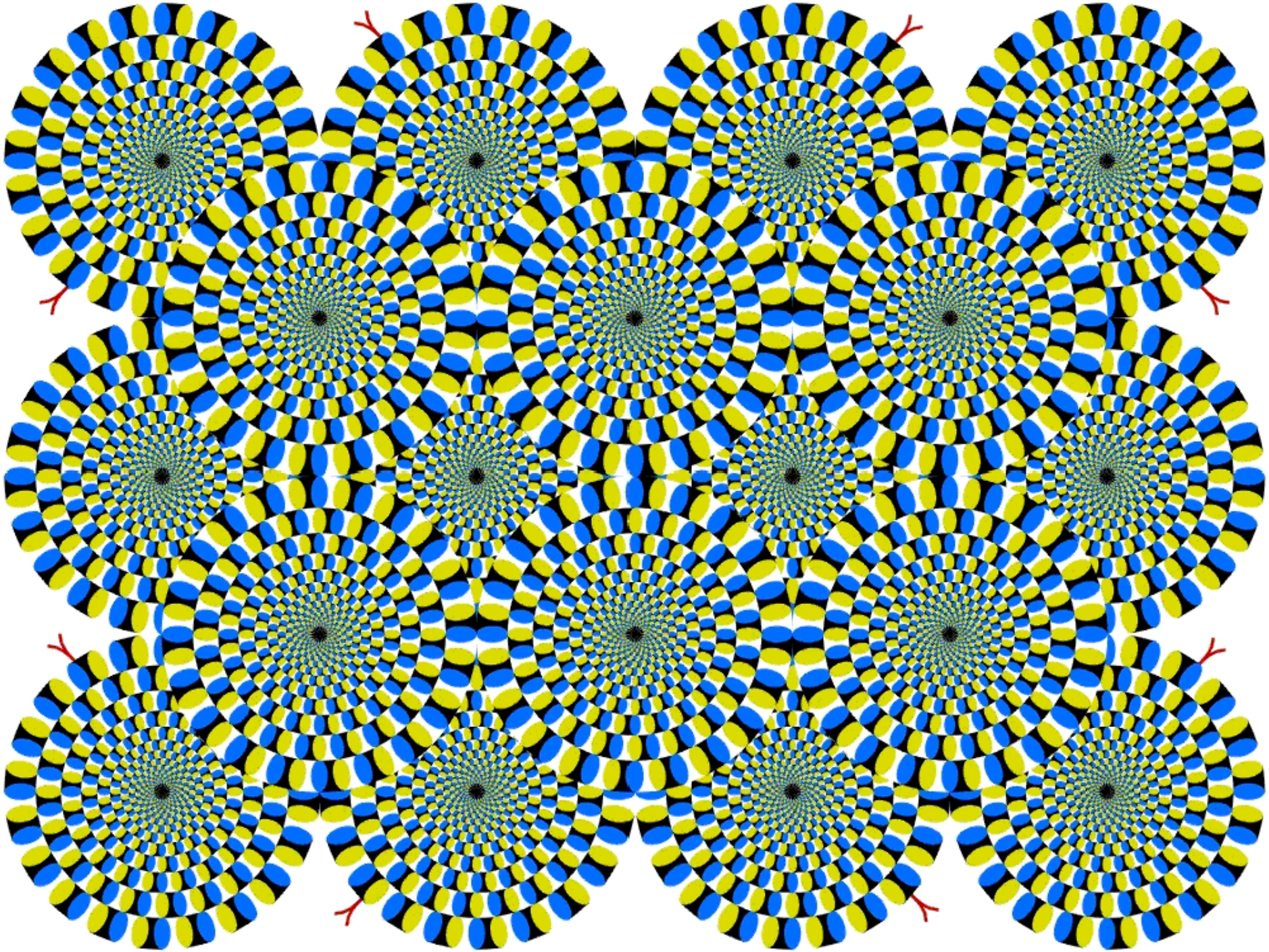
Subject	Gender	Age	Height	Nose W	Top
123456	M	25	172	2.3	Shirt
123457	F	36	156	2.2	Blouse
123458	M	58	182	1.2	T shirt

Database of descriptions

Images: more than meets the eye?

Computer Vision and Human Vision have different abilities

Van Dyck 1635; Trafalgar Square



Describing people: traits and terms

Global Features

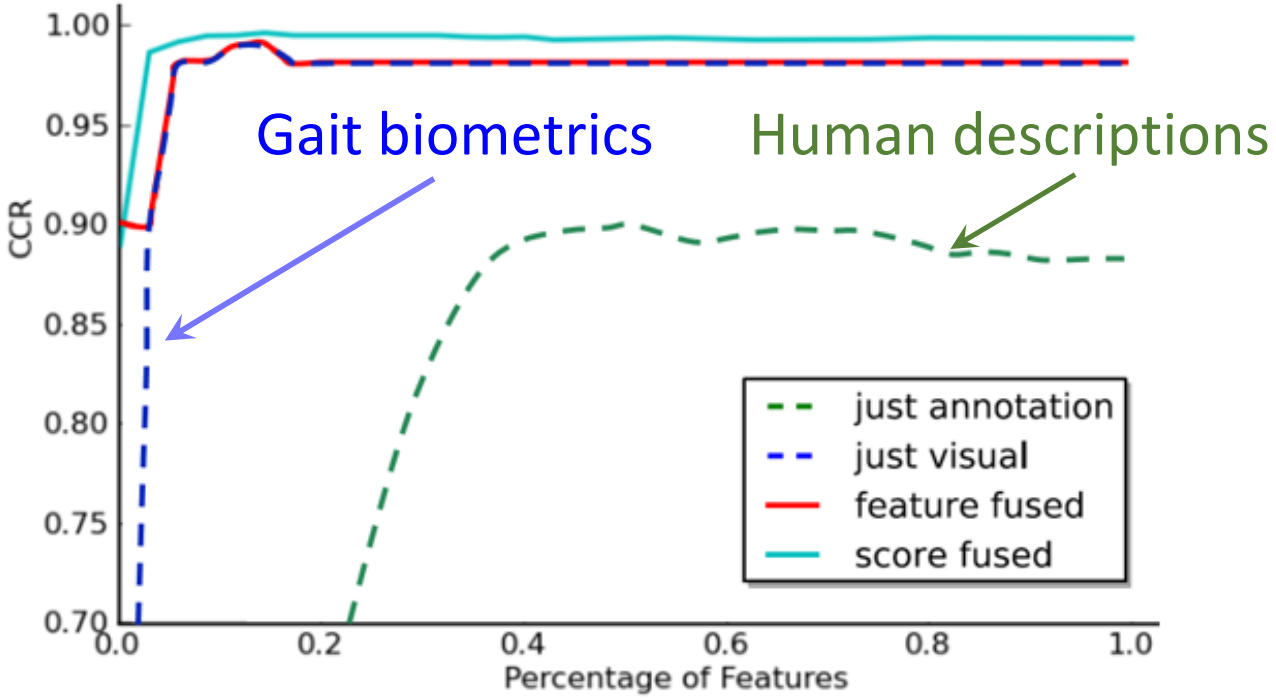
- Features mentioned most often in witness statements
- Sex and age quite simple
- Ethnicity
  - Notoriously unstable
  - There could be anywhere between 3 and 100 ethnic groups
  - 3 “main” subgroups plus 2 extra to match UK Police force groupings

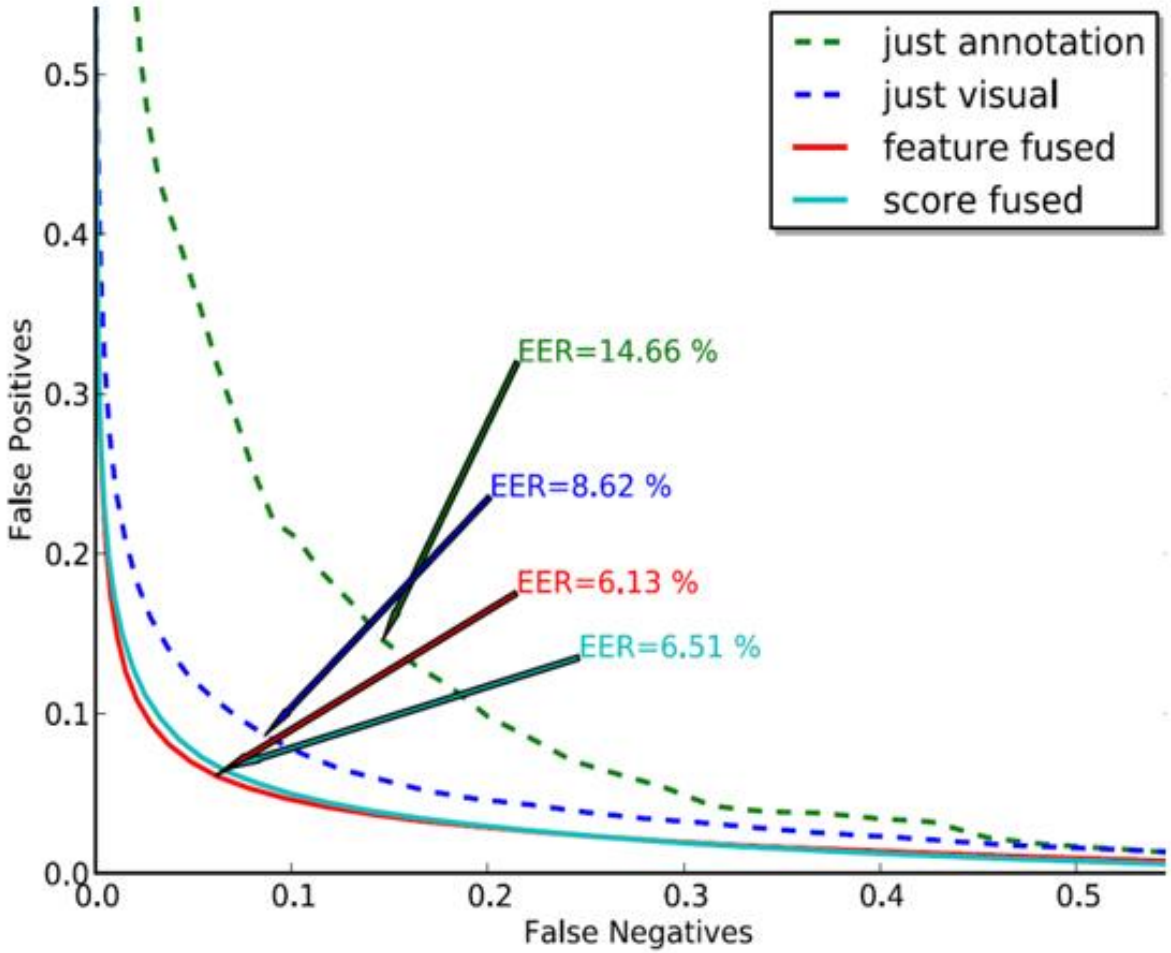
So we thought!!

Samangooei, Guo and Nixon, *IEEE BTAS* 2008

- Global
  - Sex
  - Ethnicity
  - Skin Colour
  - Age
- Body Shape
  - Figure
  - Weight
  - Muscle Build
  - Height
  - Proportions
  - Shoulder Shape
  - Chest Size
  - Hip size
  - Leg/Arm Length
  - Leg/Arm Thickness
- Head
  - Hair Colour
  - Hair Length
  - Facial Hair Colour/Length
  - Neck Length/Thickness

Human descriptions: recognition capability



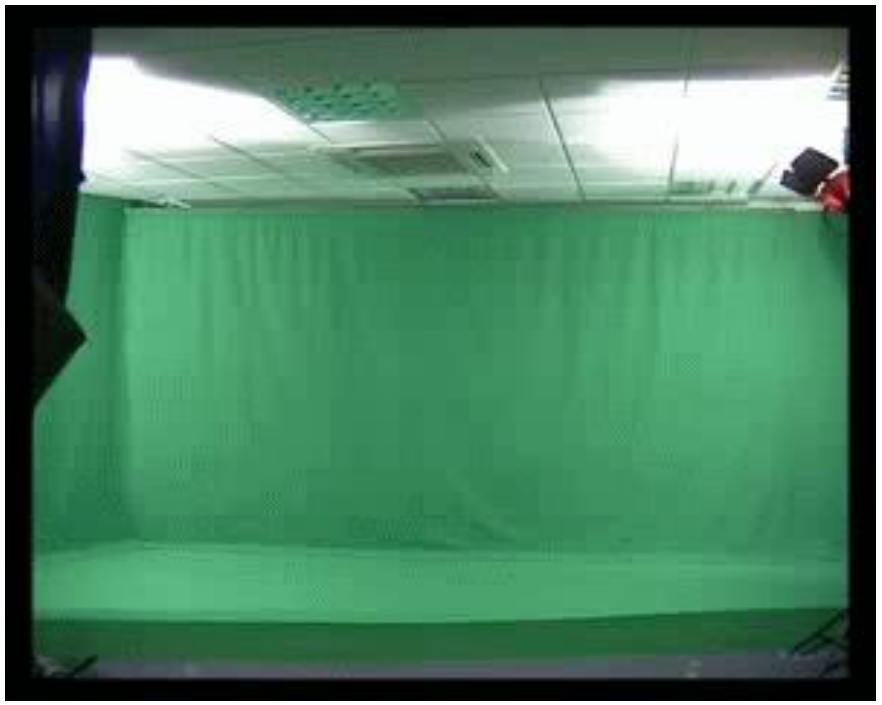


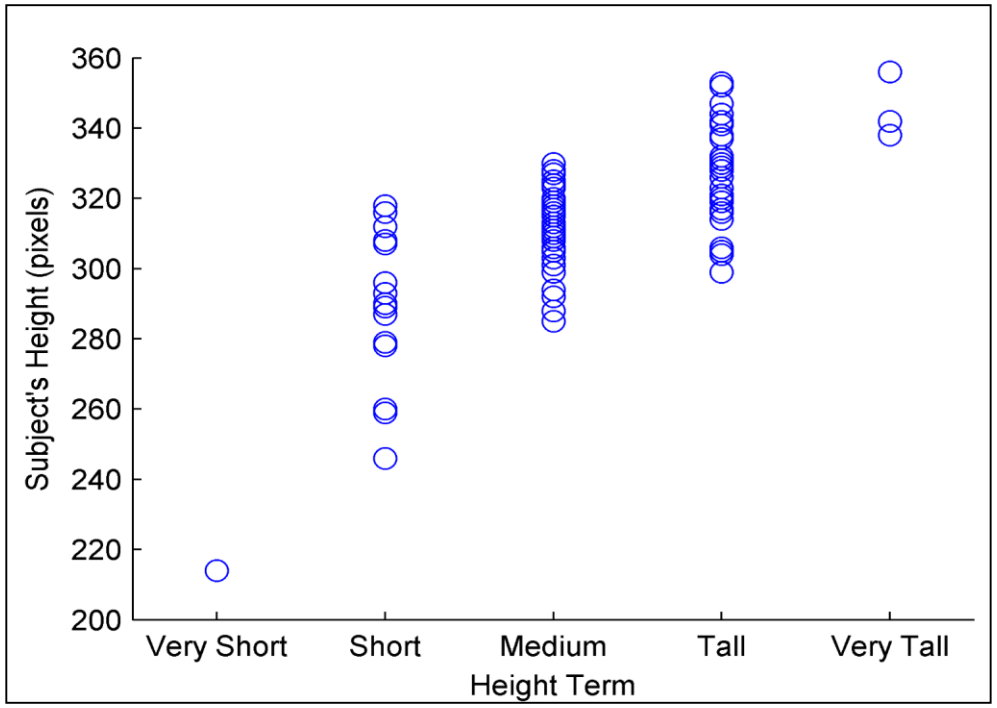
First result

Samangooei and Nixon, *IEEE BTAS* 2008

Problems with absolute/ categorical descriptors

Subjective = unreliable; Categorical = lacks detail

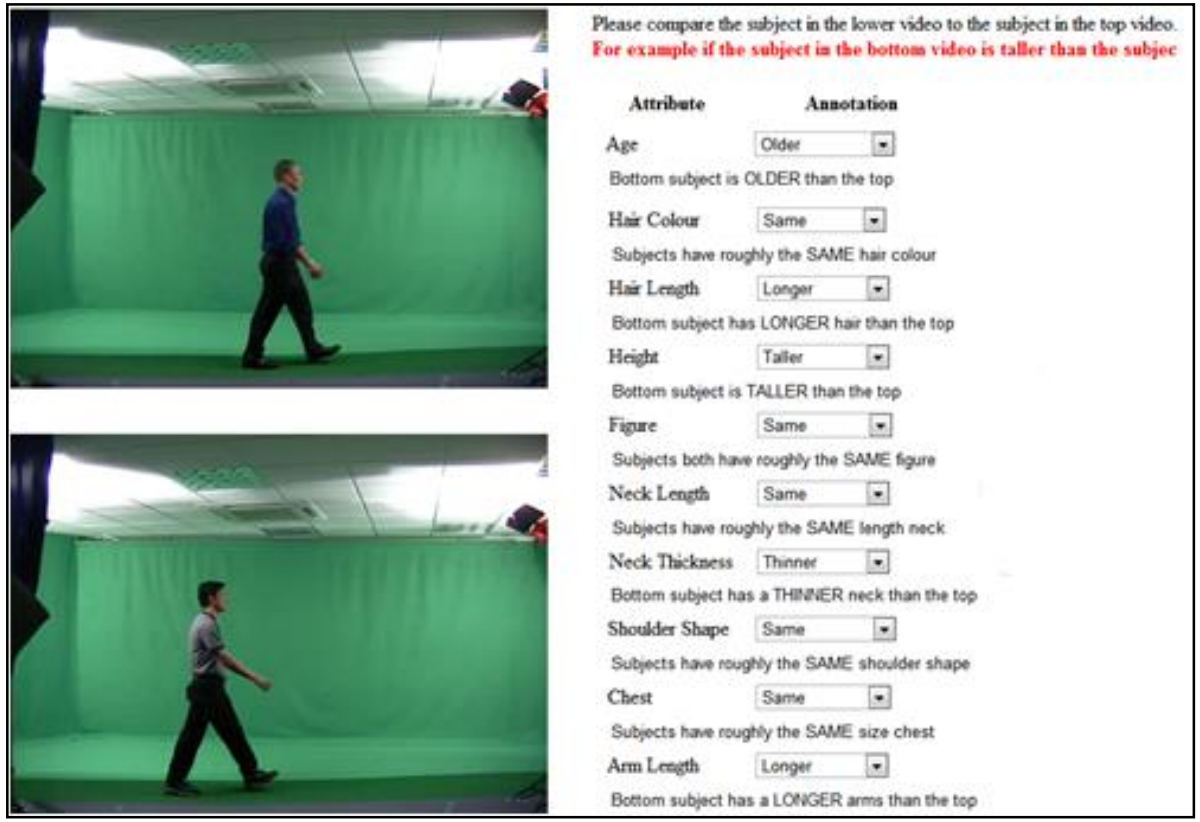




Reid and Nixon, *IEEE IJCB 2011; TPAMI* 2015

Comparative human descriptions

- Compare one subject's attribute with another's
- Infer continuous relative measurements



Reid and Nixon, *IEEE IJCB 2011*

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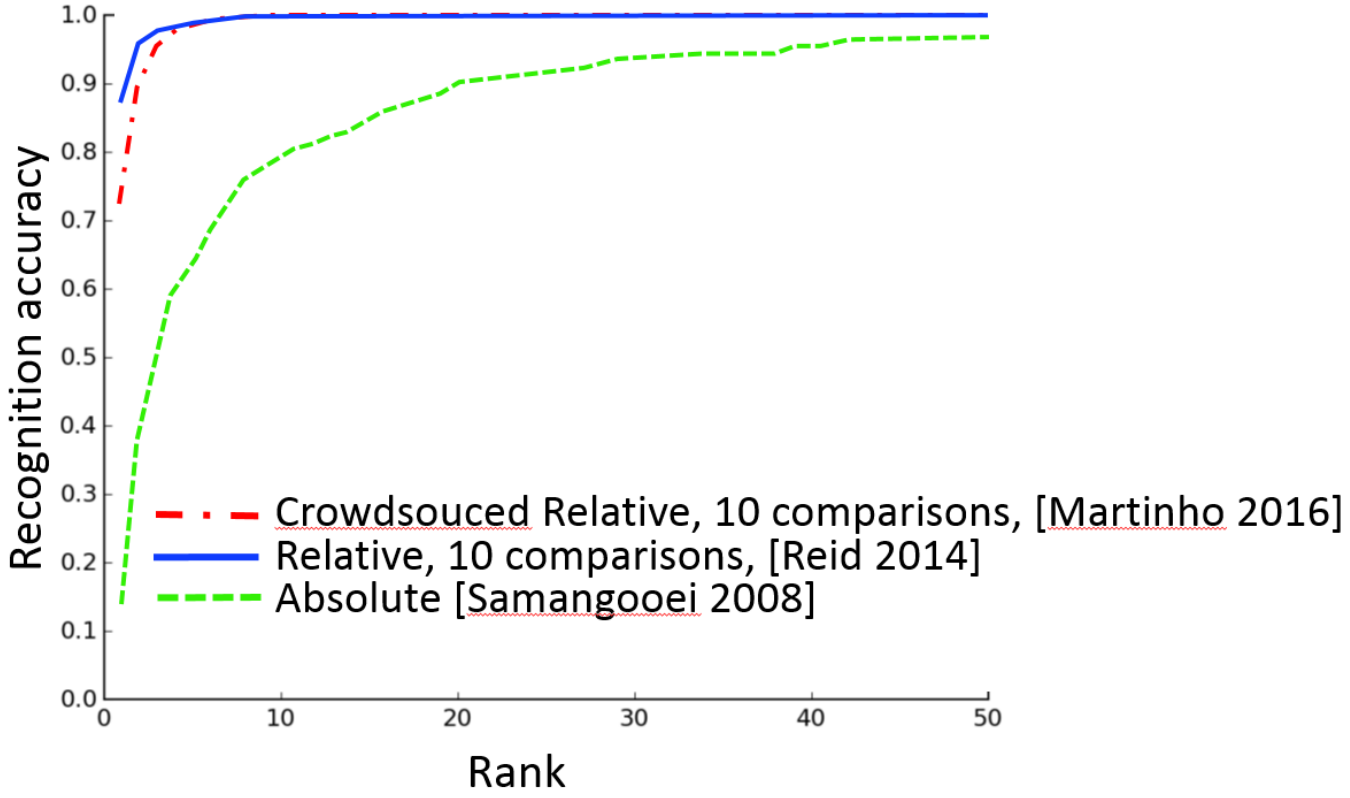
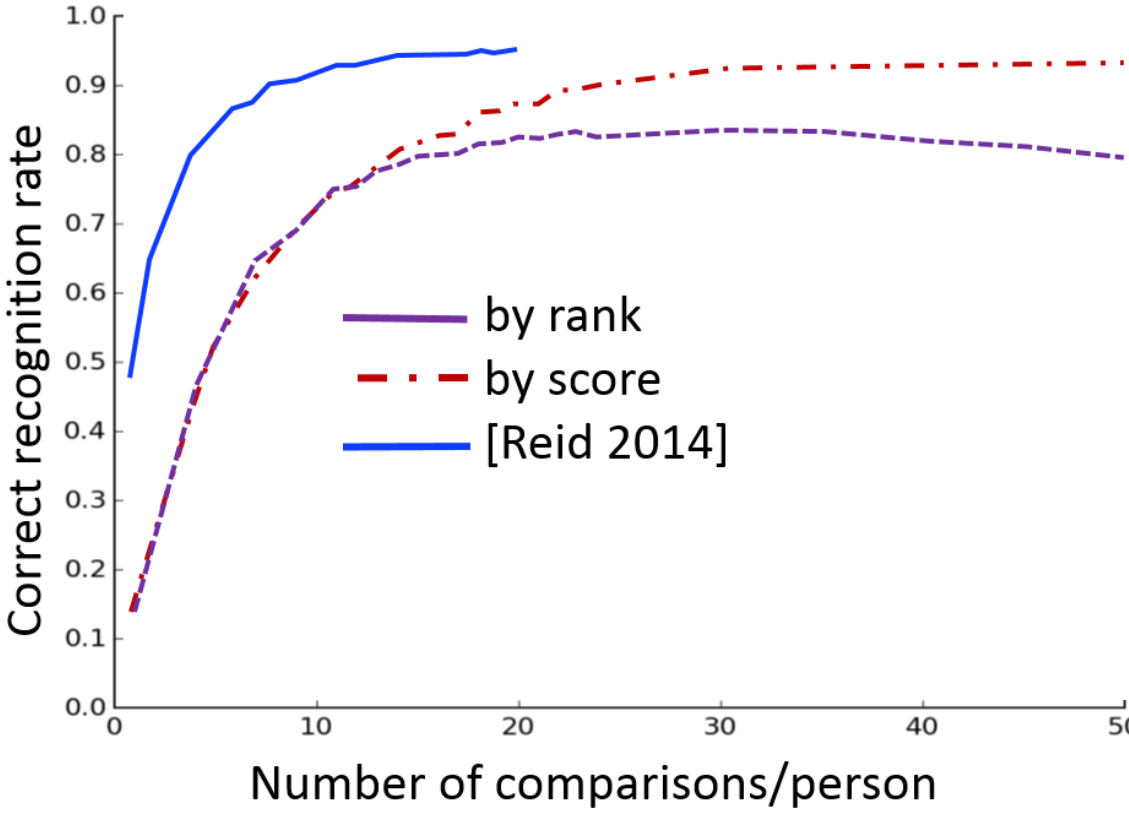
Recognition by crowdsourced body labels





Higher recognition accuracy via comparative

Lower recognition accuracy via crowdsourcing (expected)

More labels and comparisons increase accuracy (expected)

Reid and Nixon, *IEEE TPAMI 2013*

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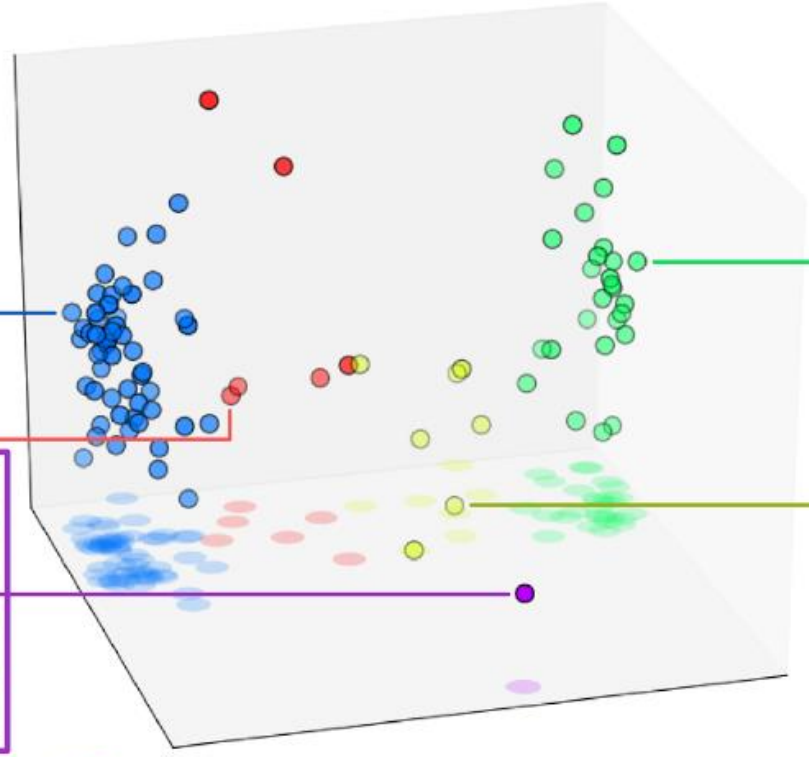
Analysing gender on PETA

Group 0 - "male"
54 subjects
6.8% uncertainty
(98.1% labelled male)

Group 1 - "female"
27 subjects
6.8% uncertainty
(0.0% labelled male)



Group 2 - "possibly male"
6 subjects
25.8% uncertainty
(66.7% labelled male)

Group 3 - "neutral"
1 subject
3.2% uncertainty
(0.0% labelled male)

Overall
95 subjects
9.7% uncertainty
(61.1% labelled male)

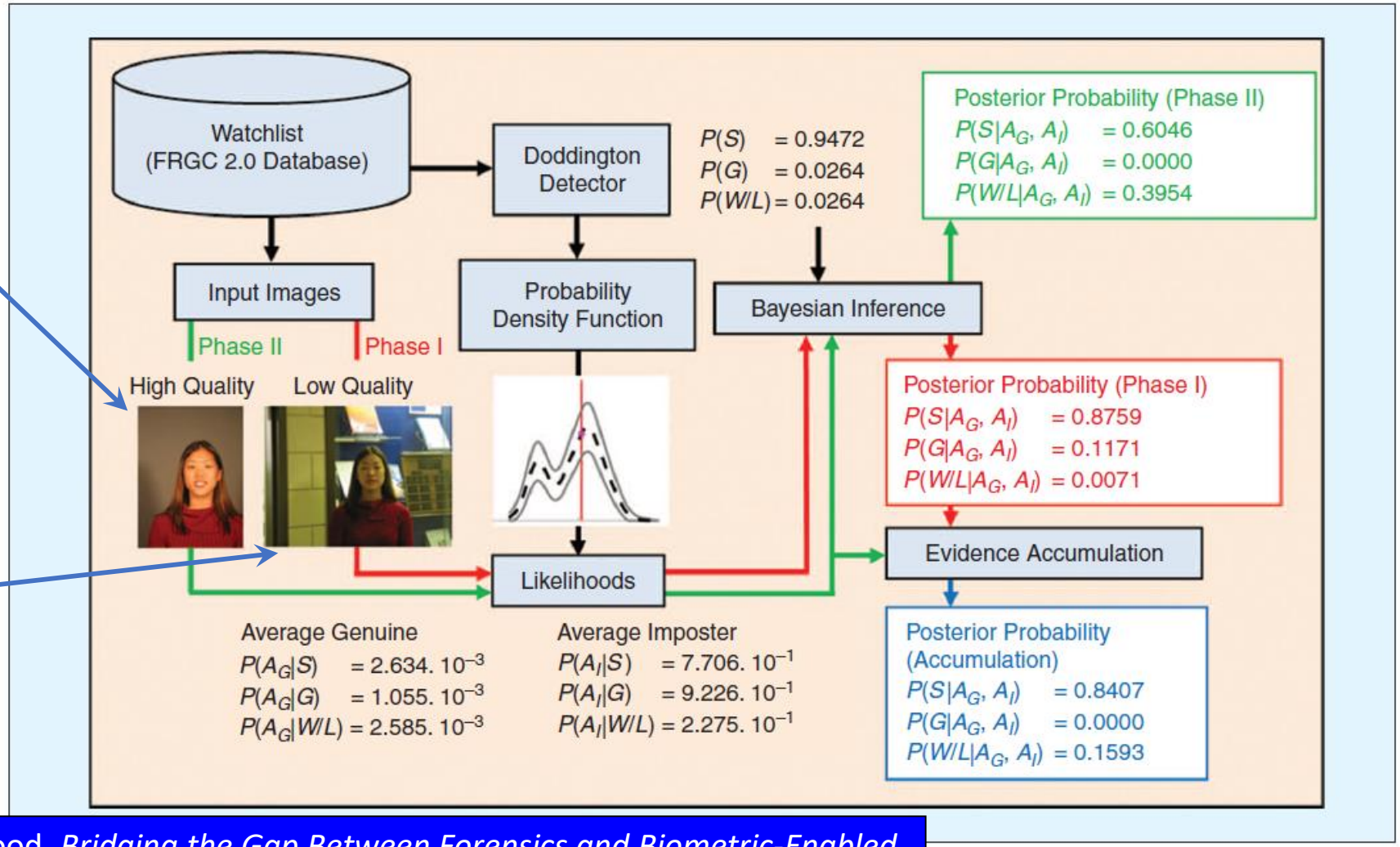
Group 4 - "possibly female"
7 subjects
31.5% uncertainty
(14.3% labelled male)

Martinho-Corbishley, Nixon and Carter, *BTAS* 2016,*TPAMI* 2019

Biometrics in watchlists

Subject in database

Subject in passport queue

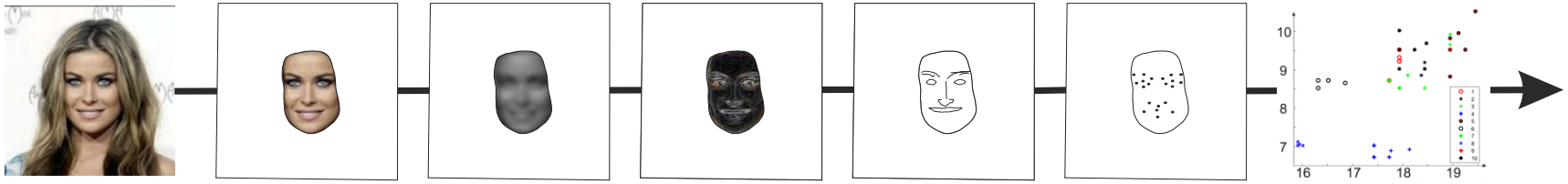


Lai; Yanushkevich; Shmerko; Eastwood, *Bridging the Gap Between Forensics and Biometric-Enabled Watchlists for e-Borders, IEEE Computational Intelligence,* 2017

Approaches to recognition

processing

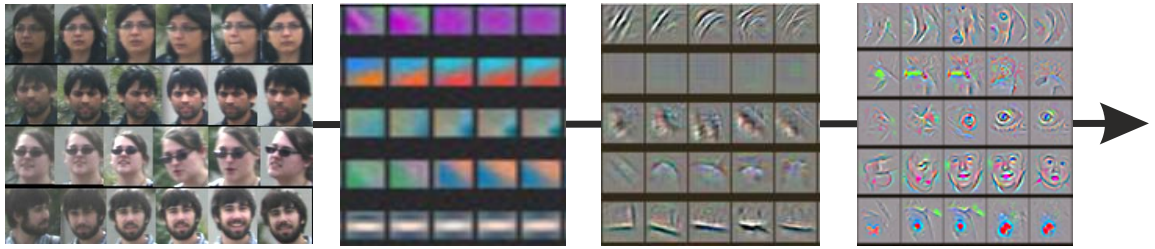
Handcrafted



data face intensity edges shapes points analysis

processing

Deep learning



data colour regions edges

If deep learning learns it

Clearly, the performance is fantastic, and we can do new things

…. do we need to know what it learns?

….. is colour any use (or does it just look good) ?

….. what about causality ?

….. where is it going?

Problems

There are many advantages to using biometrics in forensics…

But the coverage/ usage is lower

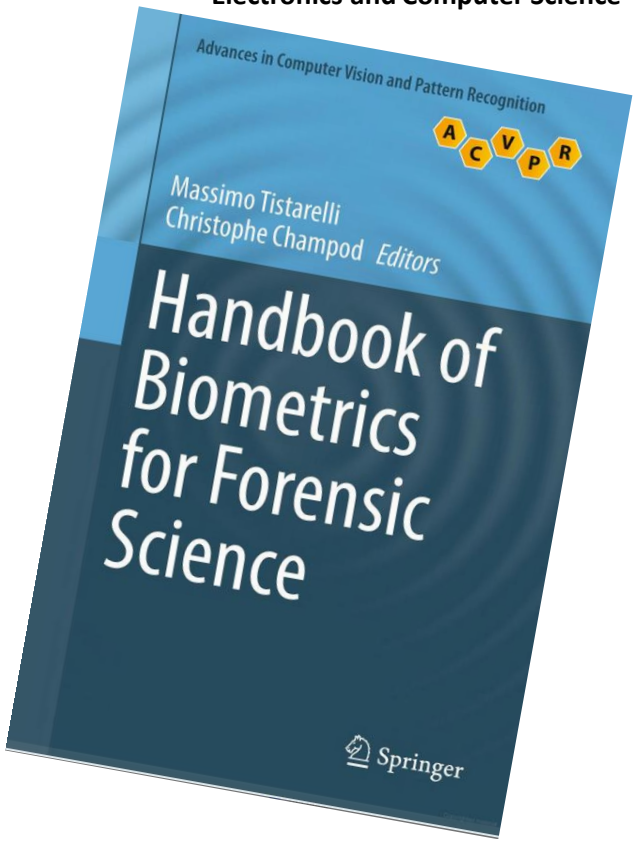
We need:

1. To engage the constituents
2. Prepare appropriate modes of evidence
3. Justify our technology in means other than usual in our science

Suggestions for generating biometric evidence

1. Write a paper, apply it to something else
2. Include error bars
3. Generate likelihood ratio
4. Use biometric standards
5. Organise workshop/ special session/ tutorial/ special edition/ competition
6. Edit book, write news article/ get on television
7. Get advice on writing statement

Conclusions



- In biometrics, forensics is the production of evidence
- Biometrics have many advantages
    1. Automation
    2. Size of data and repeatability
    3. Scientific justification
- We followed the suggestions given here
- Likelihood ratio is a strong contender

There is a need to engage more with justice both in the production and in the dissemination of evidence

Further reading

1. **Linkages between biometrics and forensic science**, D Dessimoz, C Champod - **Handbook** of **biometrics**, 2008
2. **Handbook of biometrics for forensic science**, M Tistarelli, C Champod – 2017
3. **From biometric scores to forensic likelihood ratios**, D **Ramos**, RP **Krish**, J **Fierrez**, D **Meuwly** - In 2
4. **On using gait in forensic biometrics**, I Bouchrika, M Goffredo, J Carter… - Journal of **forensic** …, 2011
5. **Bridging the gap: from biometrics to forensics**, AK Jain, A Ross - … Transactions of the Royal Society B …, 2015
6. **On forensic use of biometrics**, B Arbab-Zavar, X Wei, JD Bustard… - … of digital **forensics** of …, 2015
7. **Forensic gait analysis and recognition: standards of evidence admissibility**, I Macoveciuc, CJ Rando… - Journal of forensic …, 2019