Gait Recognition by Deformable Registration

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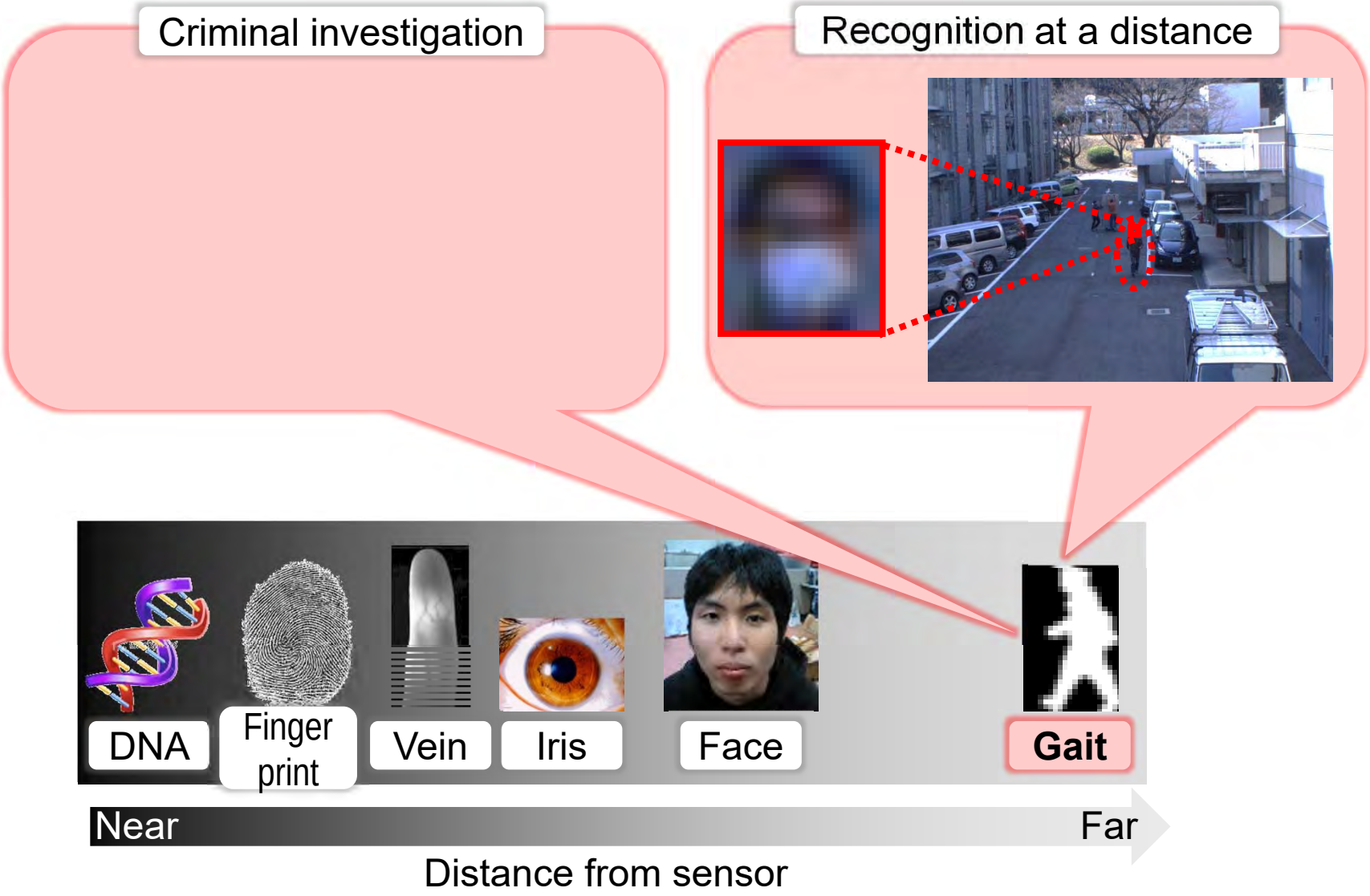
Gait recognition: Overview



Gait recognition: Use cases

Admitted as evidence in courts for the first time

- UK in 2008
- Japan in 2016

How biometrics could change security

Recent losses of personal data held on discs, laptops and USB keys by governments and companies have highlighted the need for better security. Here Dan Simmons looks to see if biometrics can help.

As the name implies biometrics is all about using a measurable biological characteristic, such as a fingerprint or iris pattern, to identify an individual.

And the field is not confined to gross physical characteristics such as facial features, more subtle measures - such as the way a person walks - can also be used to identify individuals.

Researchers at the University of Southampton have won funding from UK and US governments to establish this form of biometrics.

They claim their gait recognition system is 99% accurate when identifying people.

Outside labs

"From a picture, we take the human body silhouette, and we get a set of measurements which describe the subject's shape," said Prof Mark Nixon, head of the gait research group at Southampton.

"We also get a set of measurements which describe the movement, and together, those are used to recognise the person.

"The alternative to that is to use a model, and so we model the movement of parts of the body like the thorax and limbs. The motion of the model gives us the set of numbers that we then use to recognise you," he said.

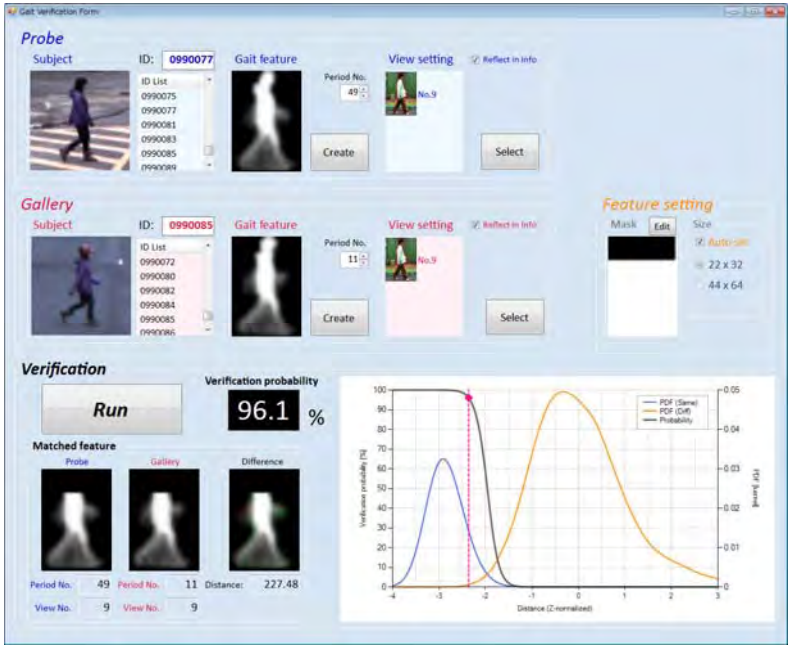
To collect data the team has designed a tunnel employing eight cameras that feeds data to sophisticated modelling software that collects data.

Through this work, researchers have been able to analyse variables in the real world, such as different surfaces and shoes and how these might affect the way people walk.

Prof Nixon's database currently stands at 100 students, but the technology is already being used outside the labs too.

Automatic gait recognition on public CCTV images has been admitted as evidence in UK courts for the first time.

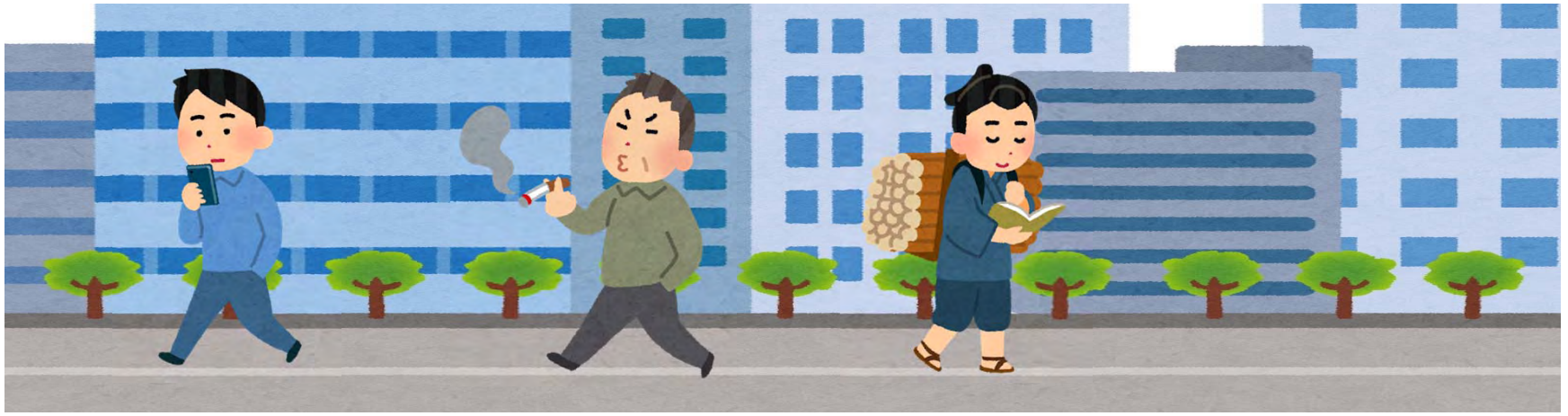
A burglar caught on CCTV was convicted thanks to his gait



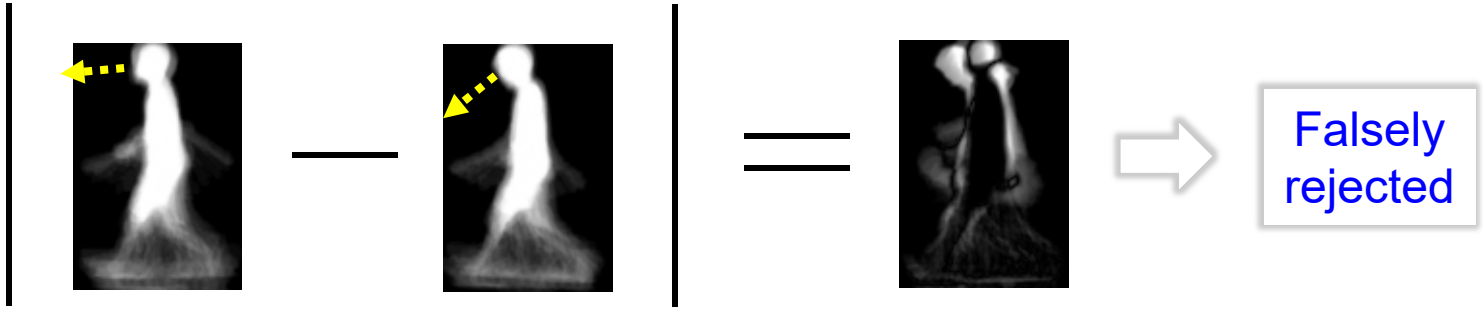
Gait verification system
for criminal investigation [Iwama+ 2013]

[1] http://news.bbc.co.uk/2/hi/programmes/click online/7702065.stm, "How biometrics could change security," BBC News, 31 Oct. 2008.

Challenge of gait recognition



Distracted walking is often seen in the real world.



Challenge: Intra-subject posture changes

Related work

Robust gait recognition

Combination of appearance-based gait feature and metric learning

Gait energy image (GEI)
[Han+ TPAMI2006]

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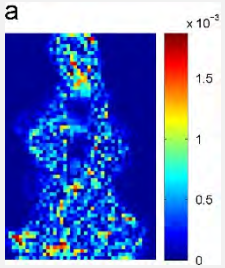


RankSVM
[Martin-Felez+ PR2014]

Not direct way to handle geometric deformation such as posture change

Registration model for face

Expression-invariant face recognition

w/ active shape model (ASM) [Thai+ IJBB2011]

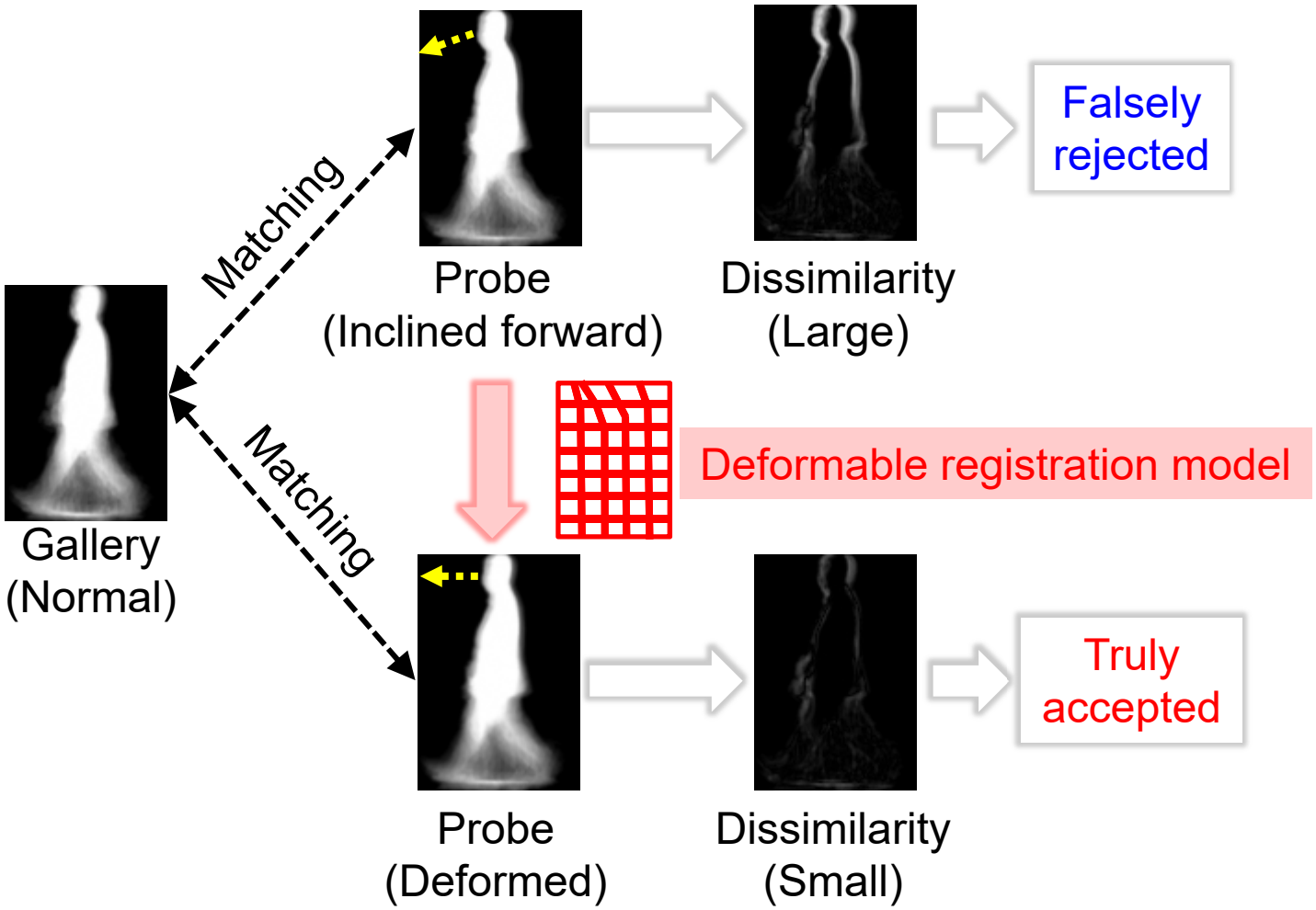
w/ robust constrained local models [Boddeti+ 2017]

Outstanding landmarks such as eyes, nose, mouth, are unavailable for gait

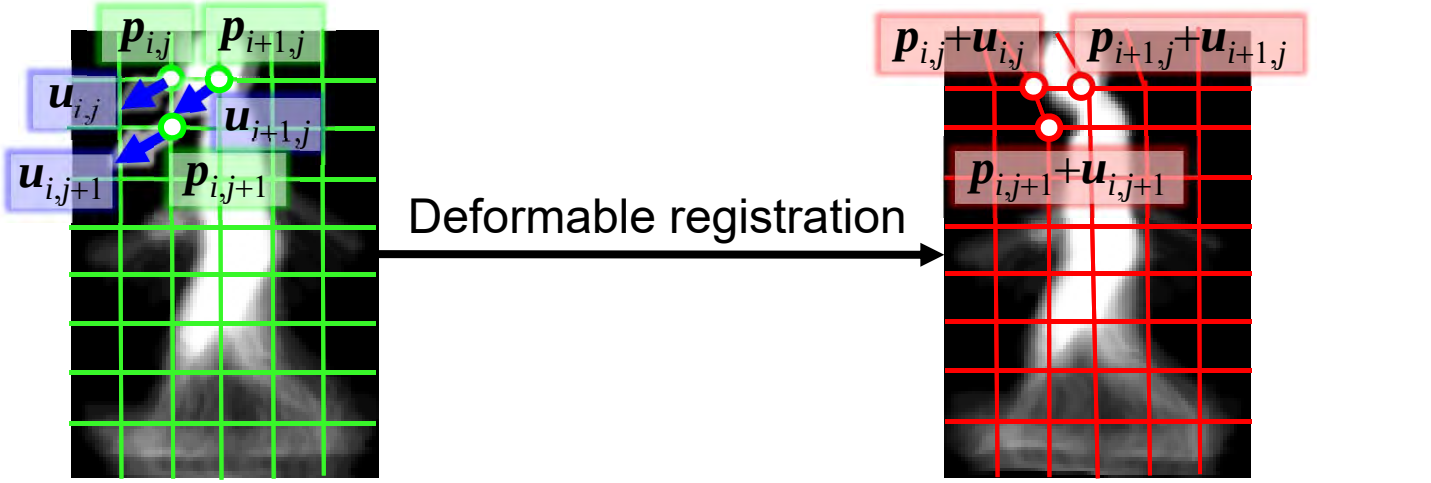
Deformable registration model for gait recognition is required.

Objective

- Gait recognition by deformable registration



Free-form deformation (FFD)



Probe image I_p

Deformed probe image $F(I_p; \boldsymbol{u})$

- Deformation vector on the control points (CPs)

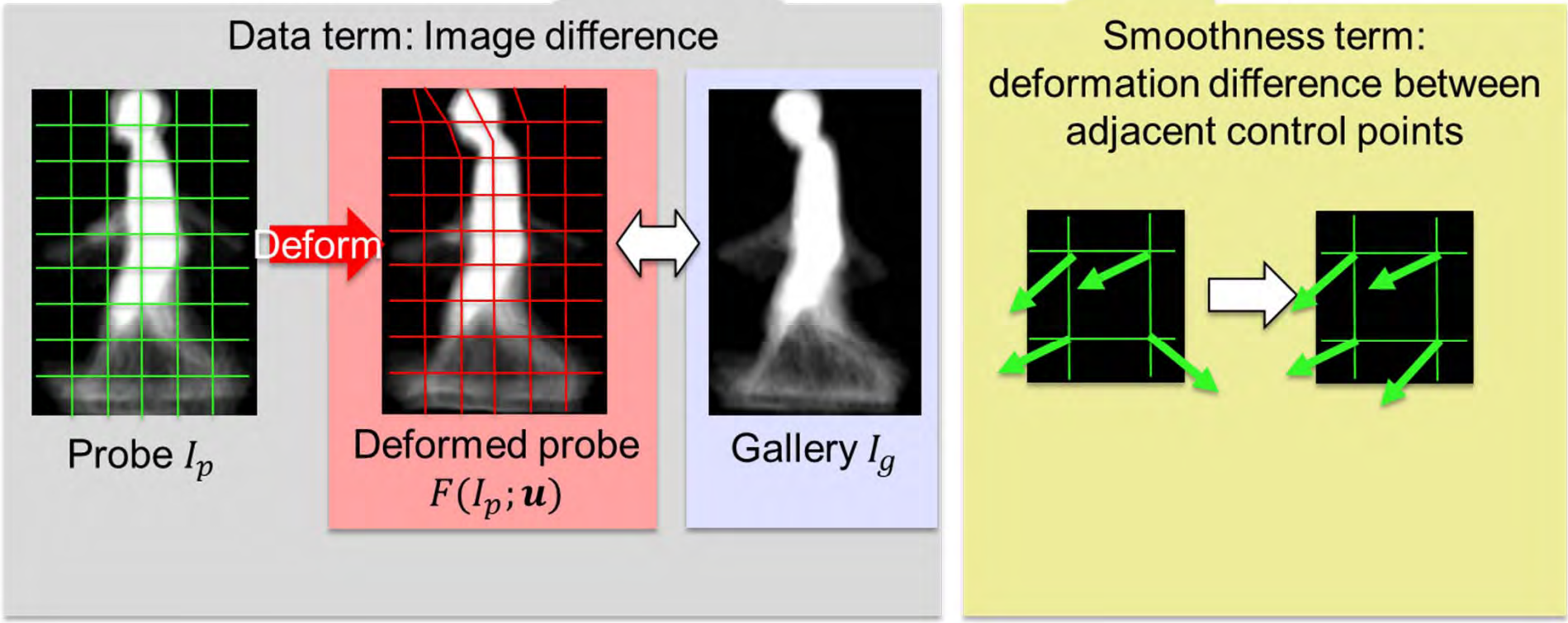
$$\boldsymbol{u} = [\boldsymbol{u}_{1,1}^T, \dots, \boldsymbol{u}_{1,M_y}^T, \dots, \boldsymbol{u}_{M_x,1}^T, \dots, \boldsymbol{u}_{M_x,M_y}^T]^T$$

M_x: #CPs for horizontal direction
M_y: #CPs for vertical direction

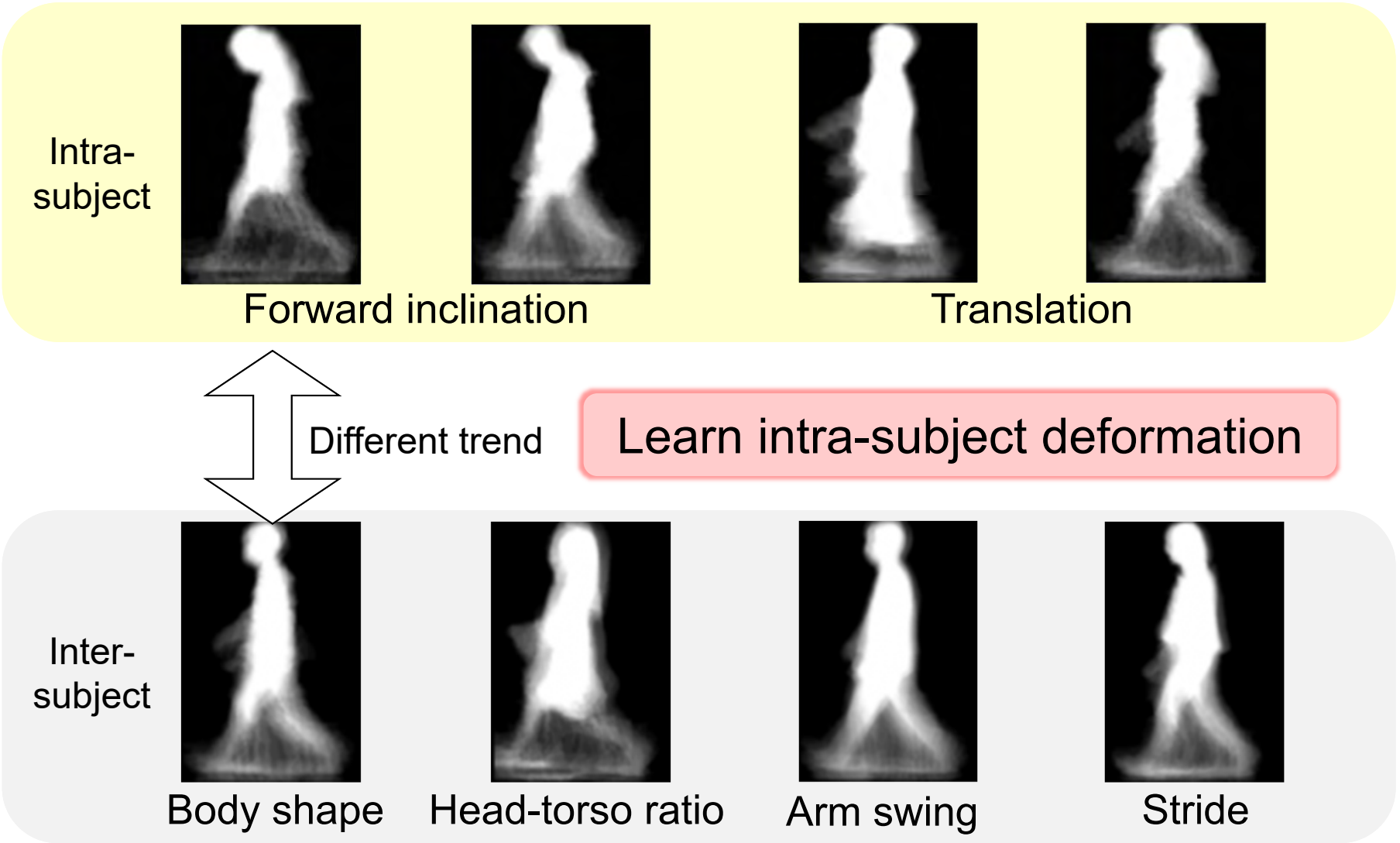
- Overall deformation field:
  Bilinear interpolation from adjacent CPs

Computing FFD between two images

$$\boldsymbol{u}^* = \underset{\boldsymbol{u}}{\operatorname{argmin}} \left\| I_p \cdot F(\boldsymbol{u}) - I_g \right\|_1 + \lambda R(\boldsymbol{u})$$

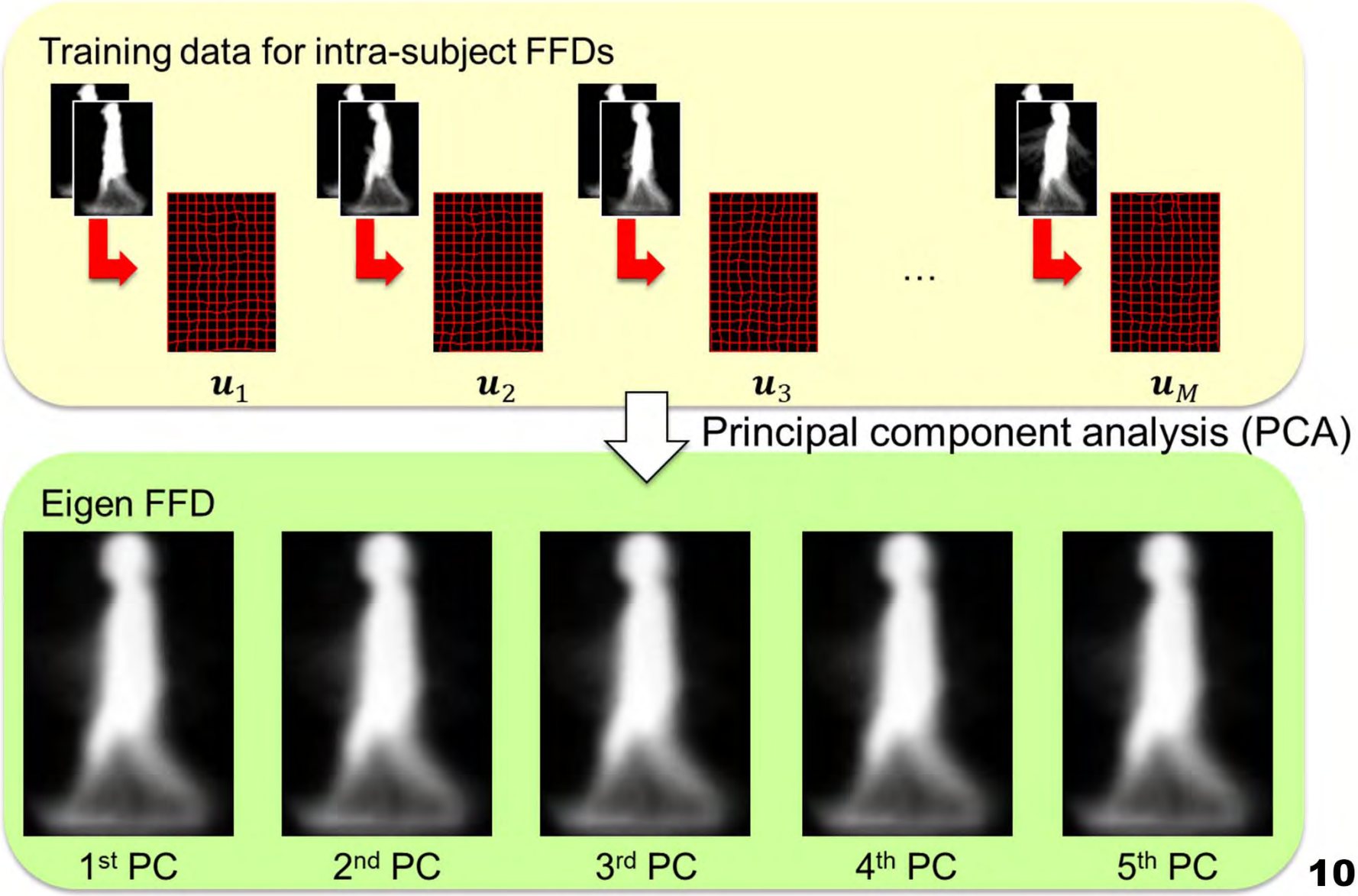


Intra-/inter-subject FFDs

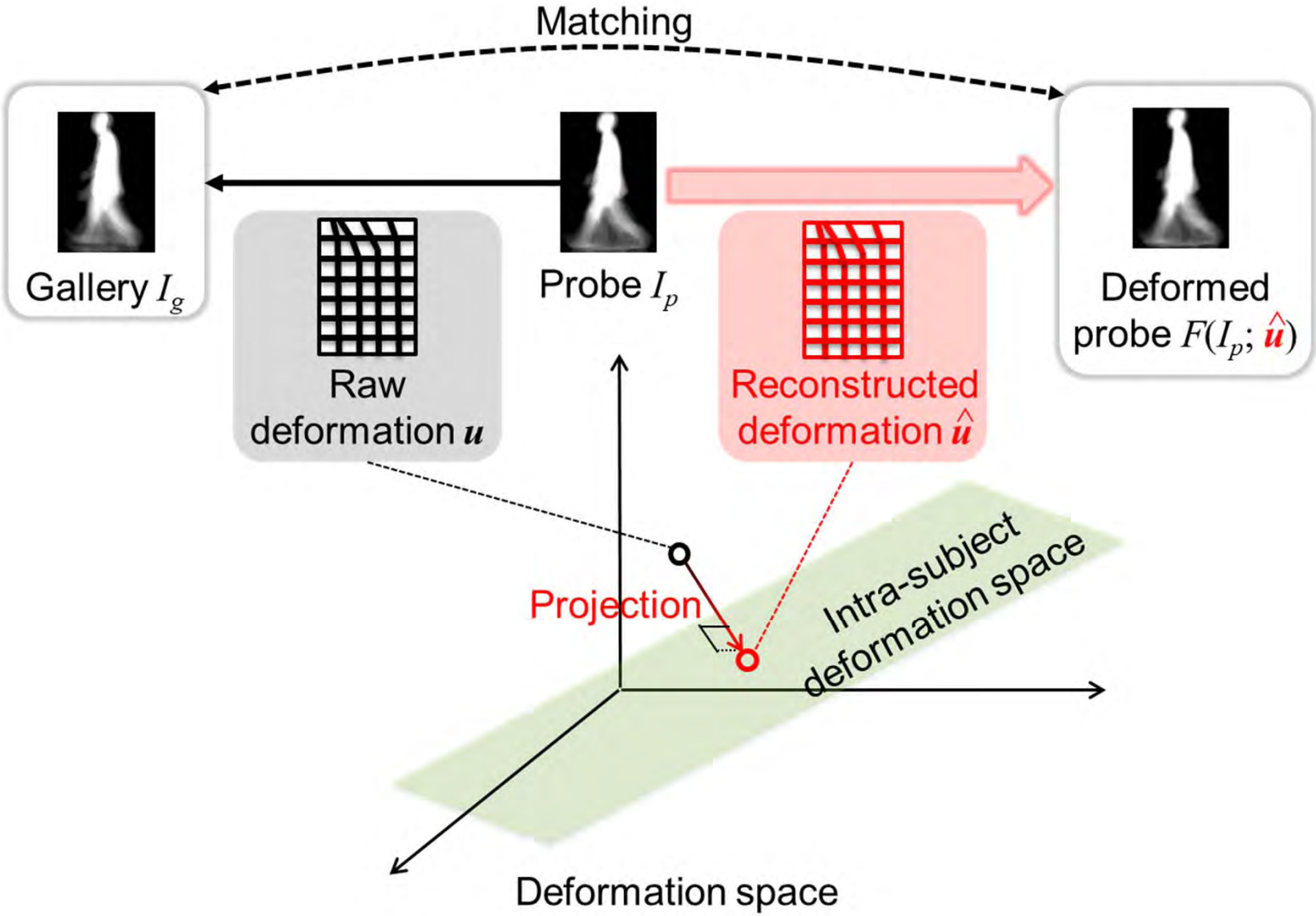


Deformation is represented by morphing.

Eigen FFD


Training data for intra-subject FFDs
u_1
u_2
u_3
...
u_M
Principal component analysis (PCA)
Eigen FFD
1st PC
2nd PC
3rd PC
4th PC
5th PC

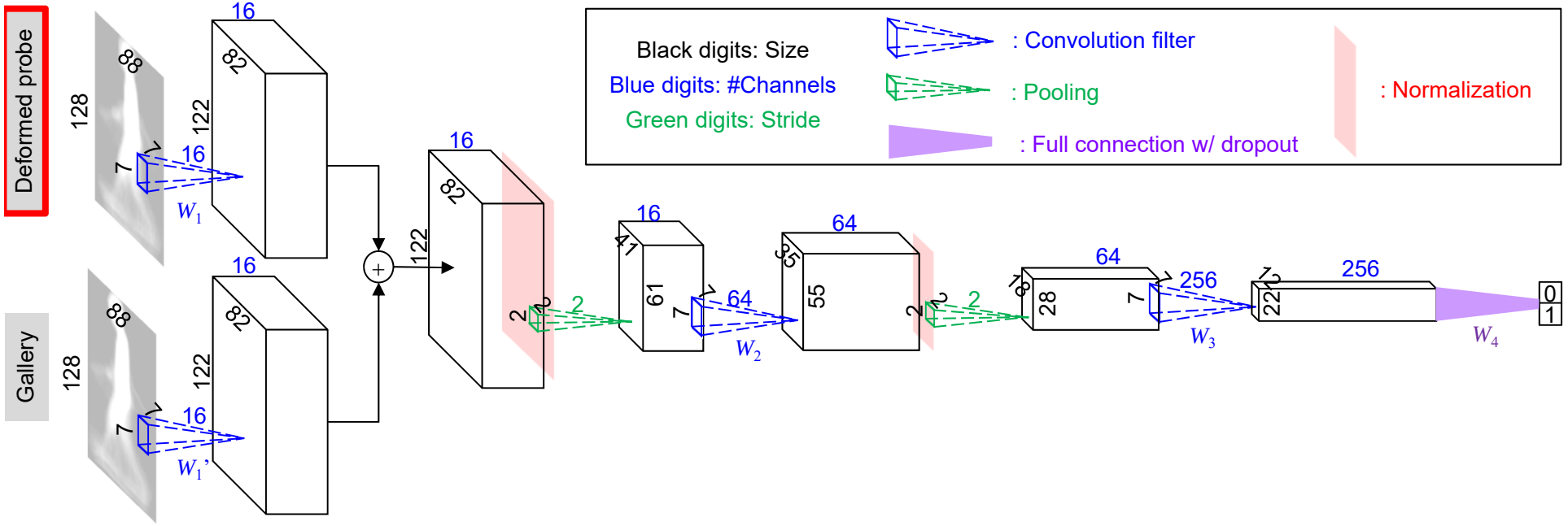
Matching by eigen FFD



Metric learning

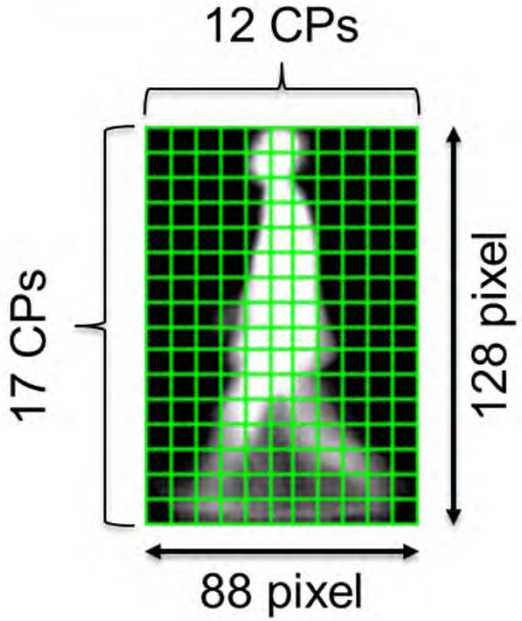
Convolutional neural network:

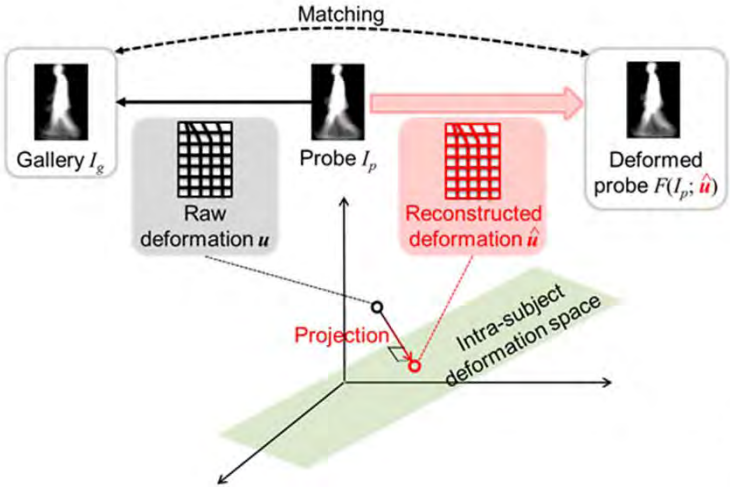
Matching local features at the bottom layer [Wu+ TPAMI 2016]



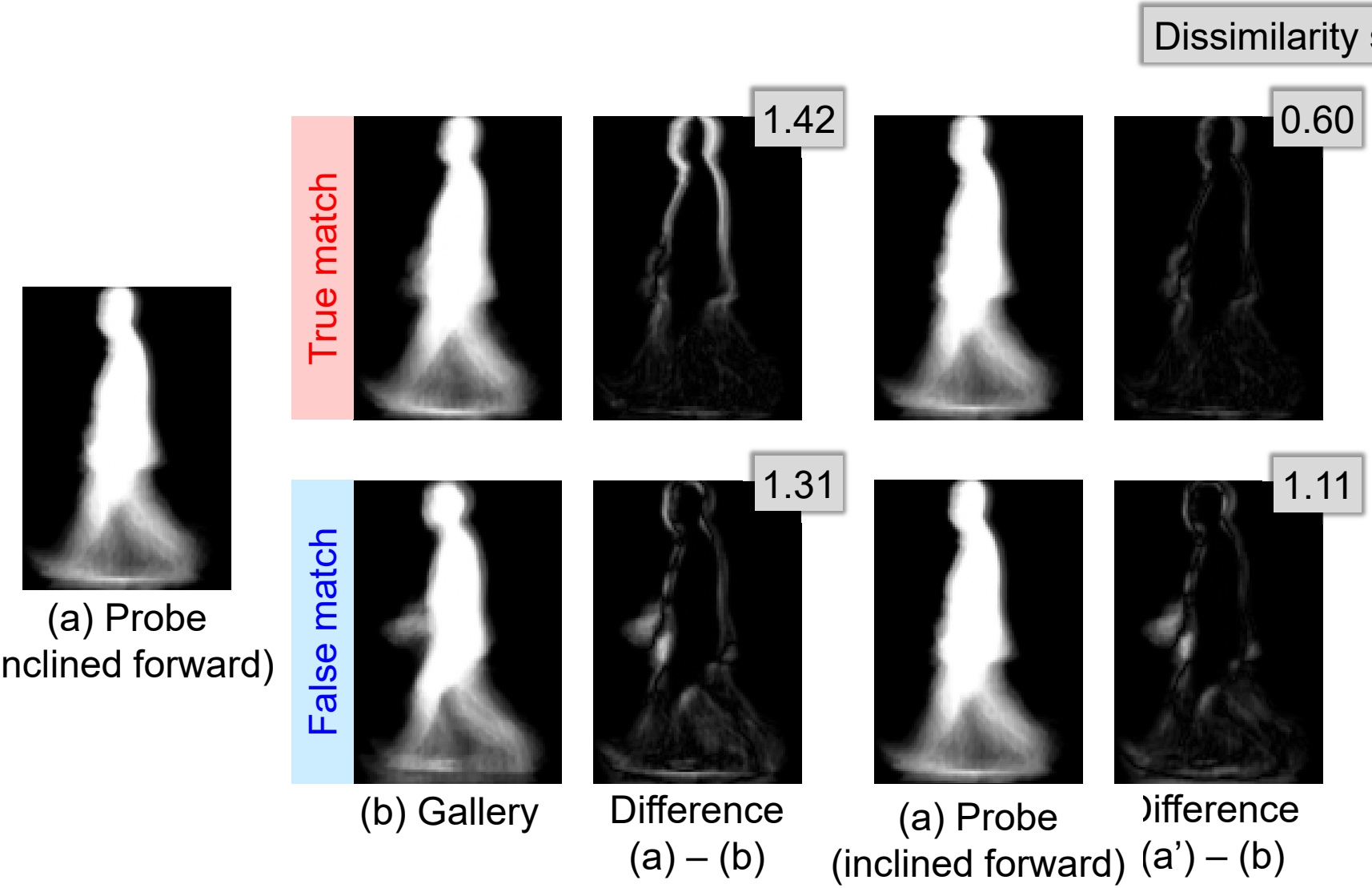
Experimental setup

- Data set: OULP-Bag-β (partial)
  - #Training subjects: 1,034
  - #Test subjects: 300
- Gait feature: GEI [Han+ TPAMI2006]
- Hyper-parameter setting
  - Smoothness coefficient λ=100
  - #Dimensions of eigenFFD: 5
- Benchmarks
  - Direct matching
  - Raw FFD $\boldsymbol{u}$
  - Eigen FFD $\hat{\boldsymbol{u}}$ (proposed)

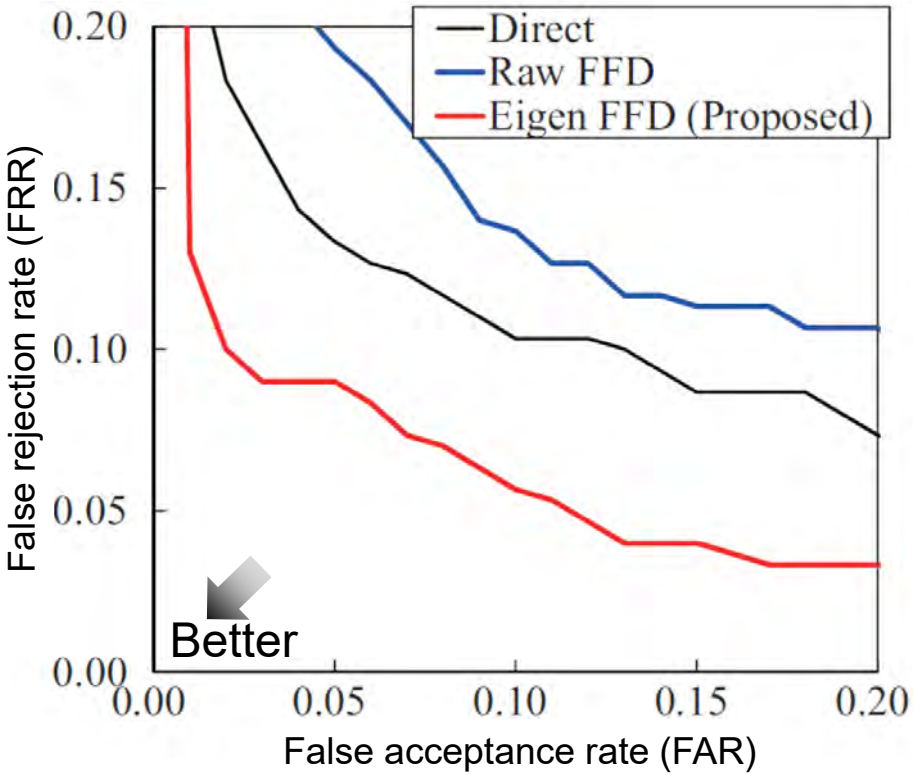




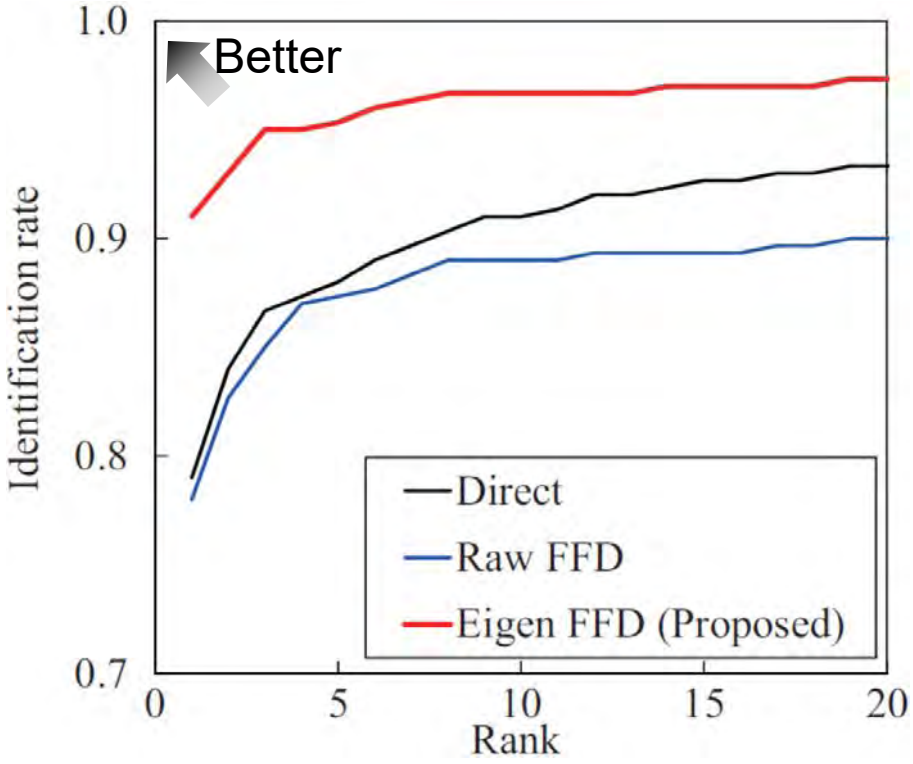
Matching example



Evaluation w/o metric learning

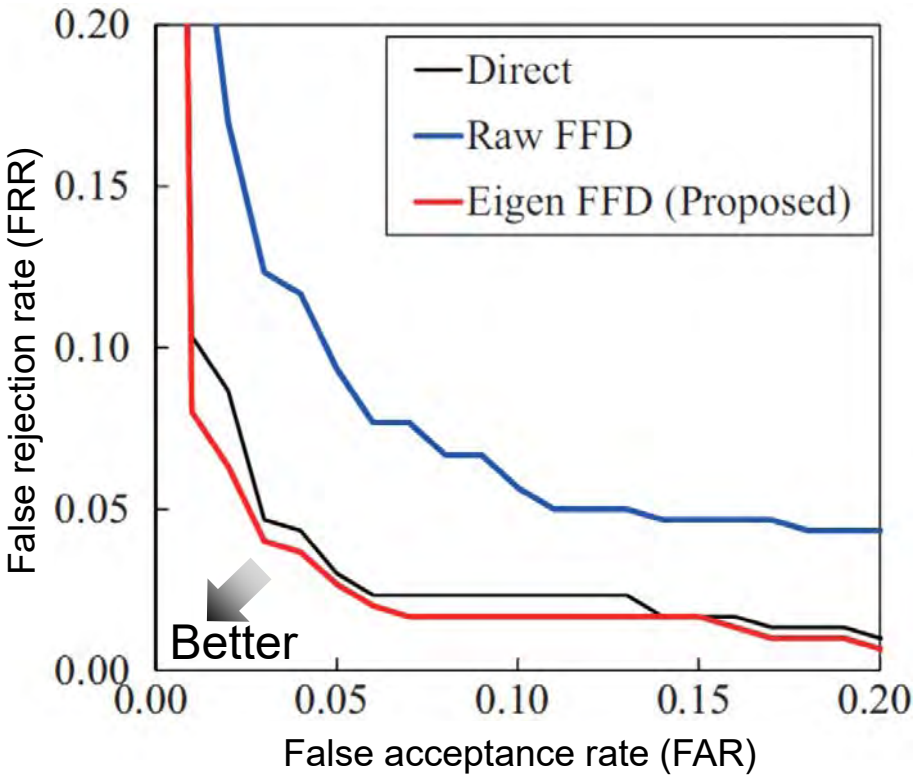


Receiver operating characteristics (ROC) curves

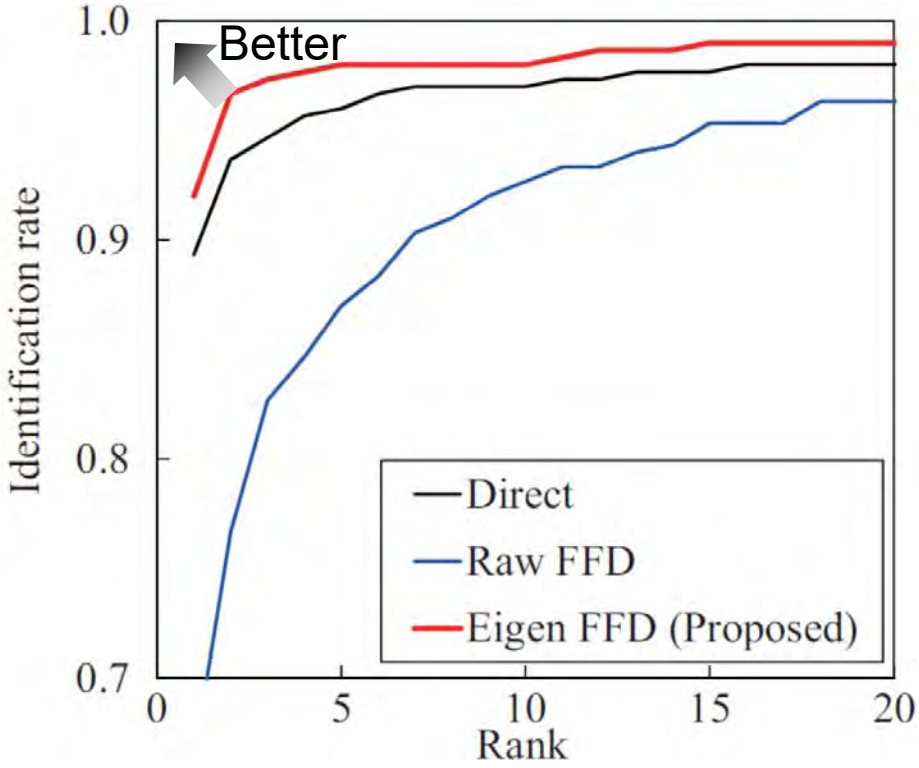


Cumulative matching characteristics (CMC) curves

Evaluation w/ metric learning



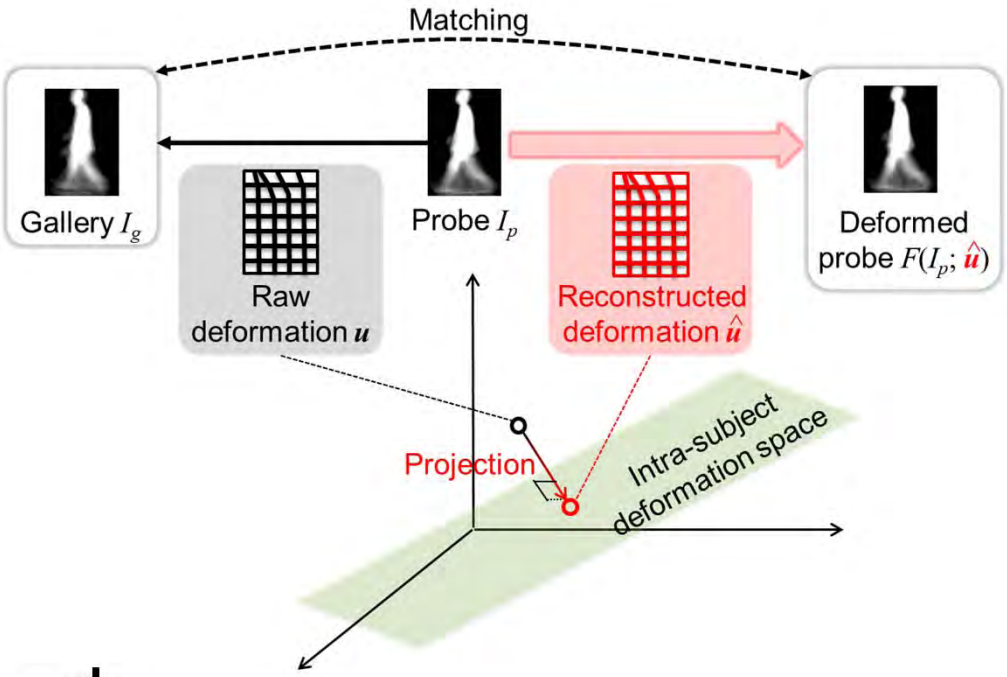
ROC curves



CMC curves

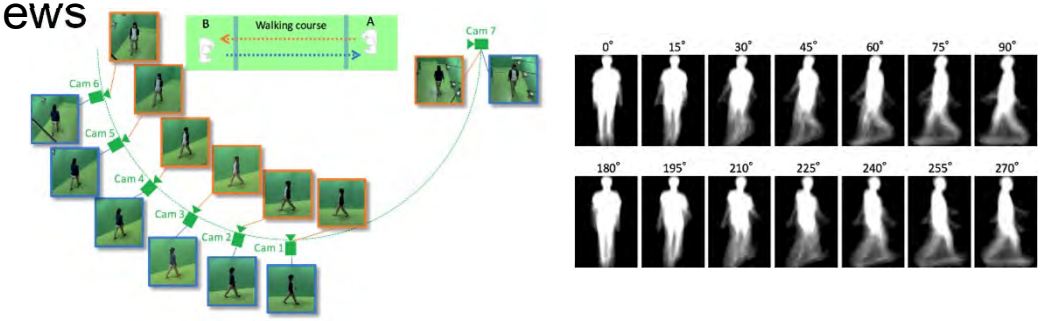
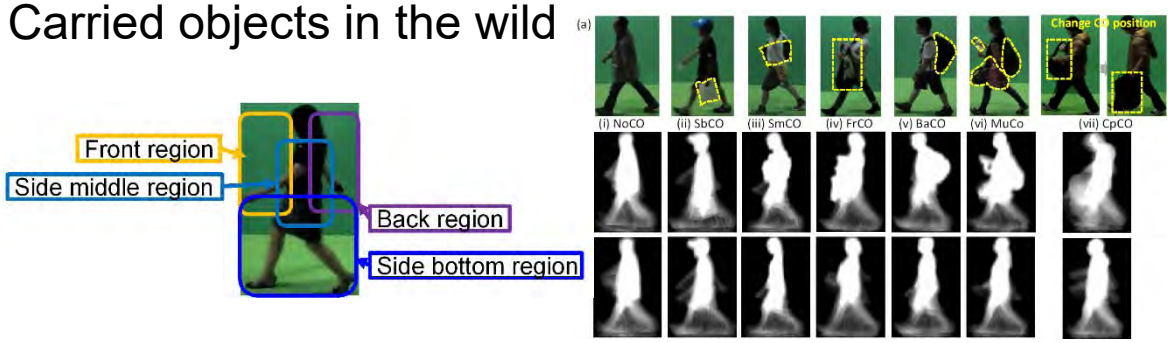
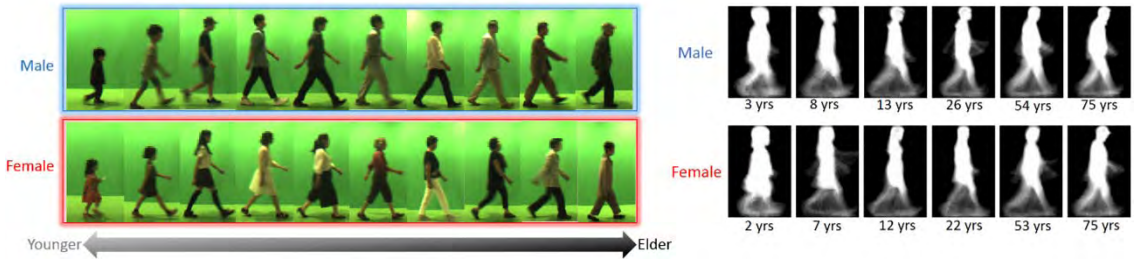
Summary

- Gait recognition by deformable registration robust against intra-subject posture change



- Future work
  - Handle more posture changes (e.g., climbing up stairs)
  - Jointly optimize deformable registration and metric learning

World's largest gait database

Data set	#Subjects	Covariates
OUMVLP [Takemura+ 2017]	10,307	14 views 
OULP-Bag [Uddin + 2018]	62,528	Carried objects in the wild 
OULP-Age [Xu+ 2018]	63,846	Wide age range 

World's largest gait database

- Available at
  http://www.am.sanken.osaka-u.ac.jp/BiometricDB/index.html