

Gait Recognition by Deformable Registration

Yasushi Makihara¹, Daisuke Adachi¹, Chi Xu^{2,1}, Yasushi Yagi¹

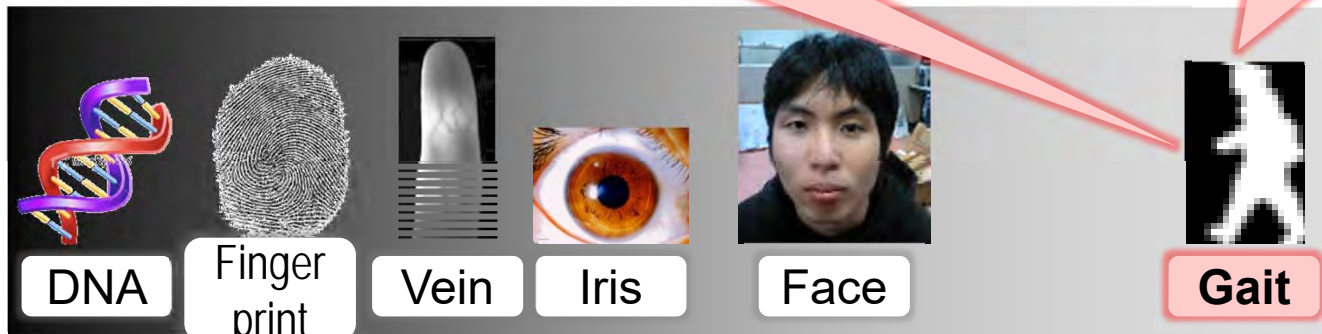
1: The Institute of Scientific and Industrial Research, Osaka Univ.

2: School of Computer Science and Technology, Nanjing University of Science and Technology

Gait recognition: Overview

Criminal investigation

Recognition at a distance



Near

Far

Distance from sensor

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.

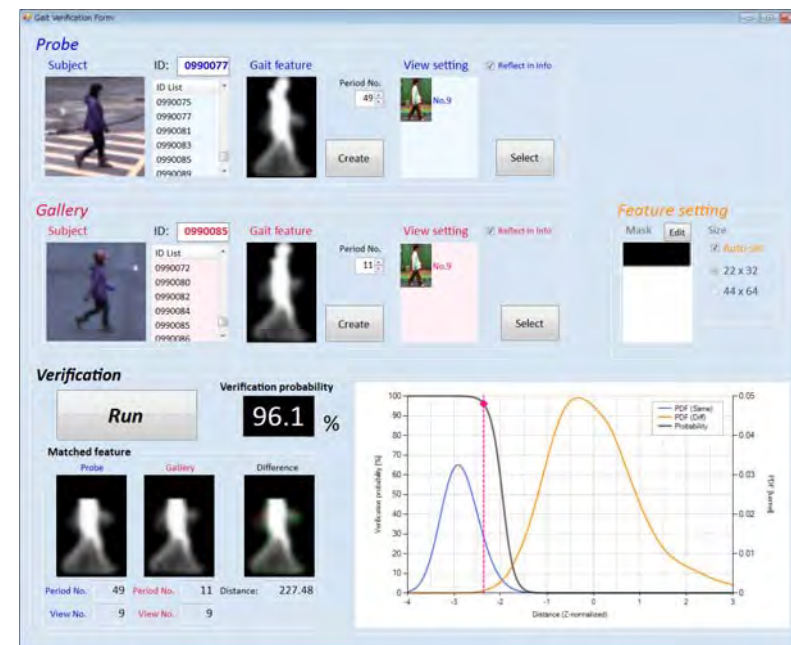
"The alternative to that is to use a model, and so we model the movement of parts of the body like the thorax and limbs. The motion of the model gives us the set of numbers that we then use to recognise you," he said.

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.



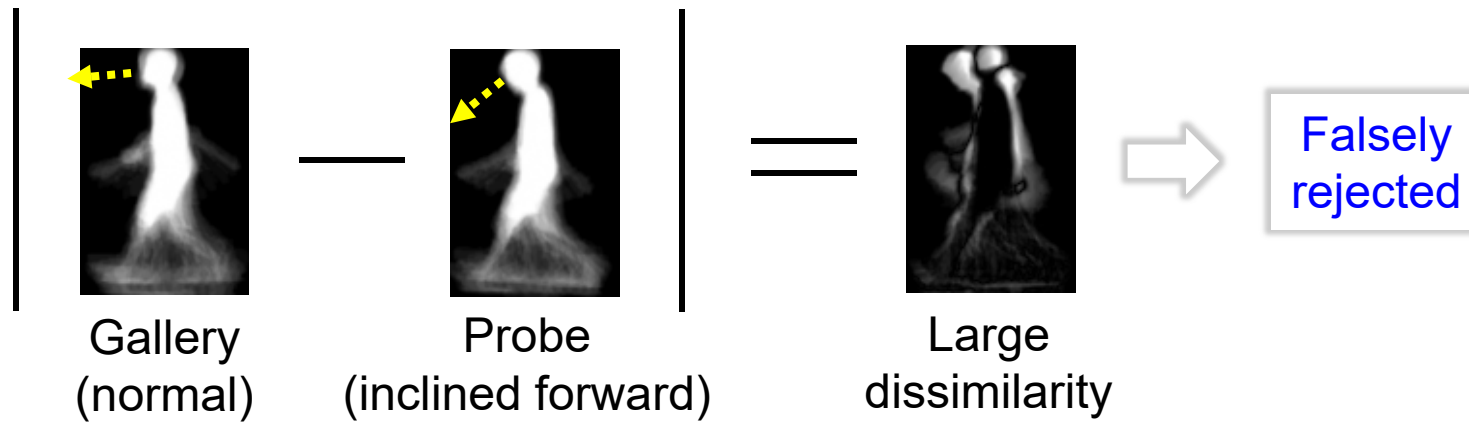
Gait verification system for criminal investigation [Iwama+ 2013]

[1] http://news.bbc.co.uk/2/hi/programmes/click_online/7702065.stm, "How biometrics could change security," BBC News, 31 Oct. 2008.3

Challenge of gait recognition



Distracted walking is often seen in the real world.



Challenge: Intra-subject posture changes

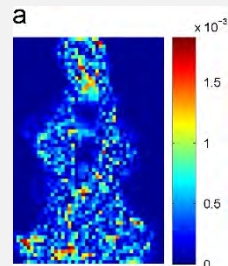
Related work

Robust gait recognition

Combination of appearance-based gait feature and metric learning



Gait energy image (GEI)
[Han+ TPAMI2006]

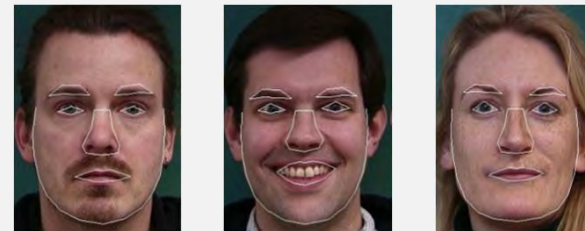


RankSVM
[Martin-Felez+ PR2014]

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]



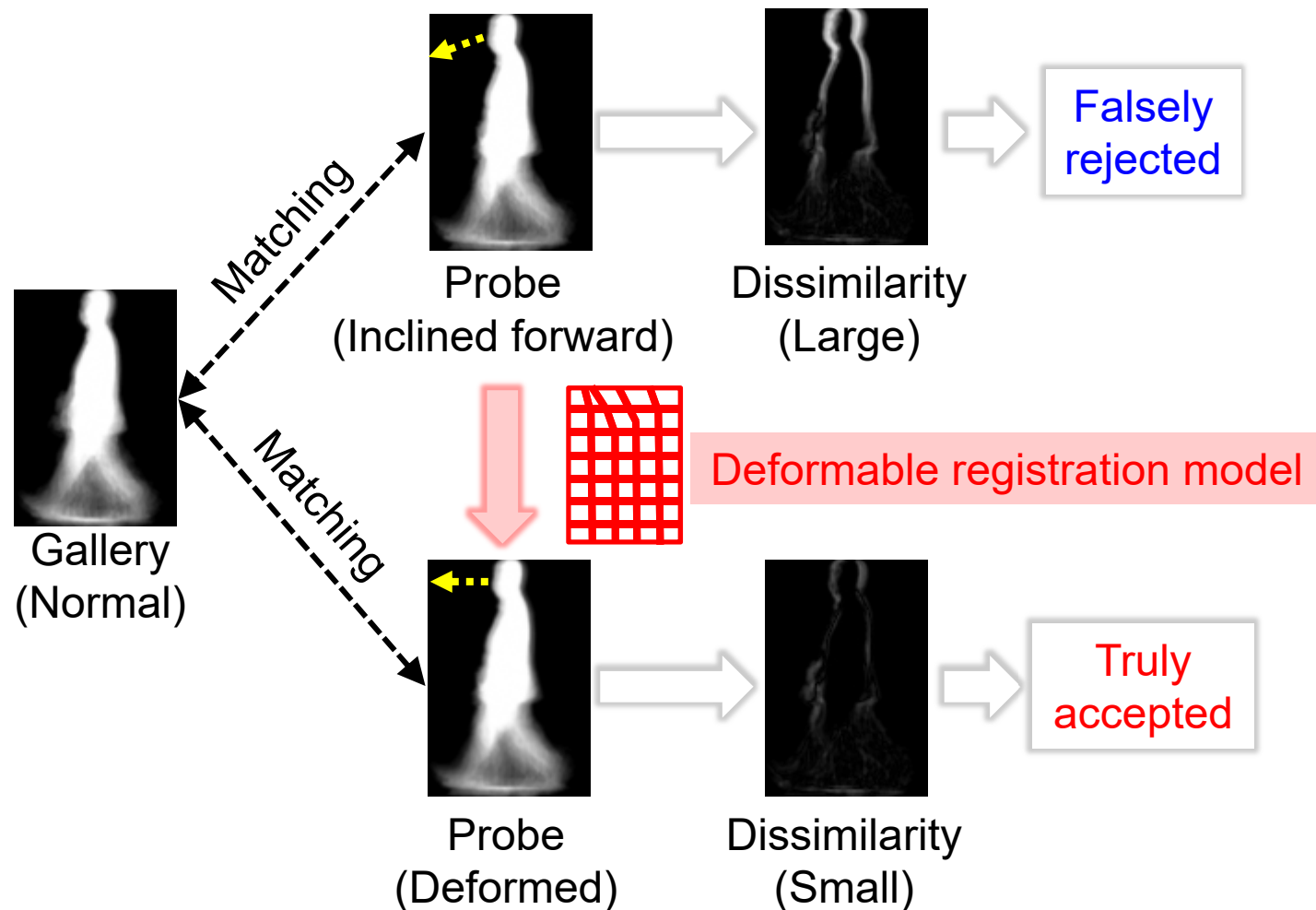
w/ robust constrained local models [Boddeti+ 2017]

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

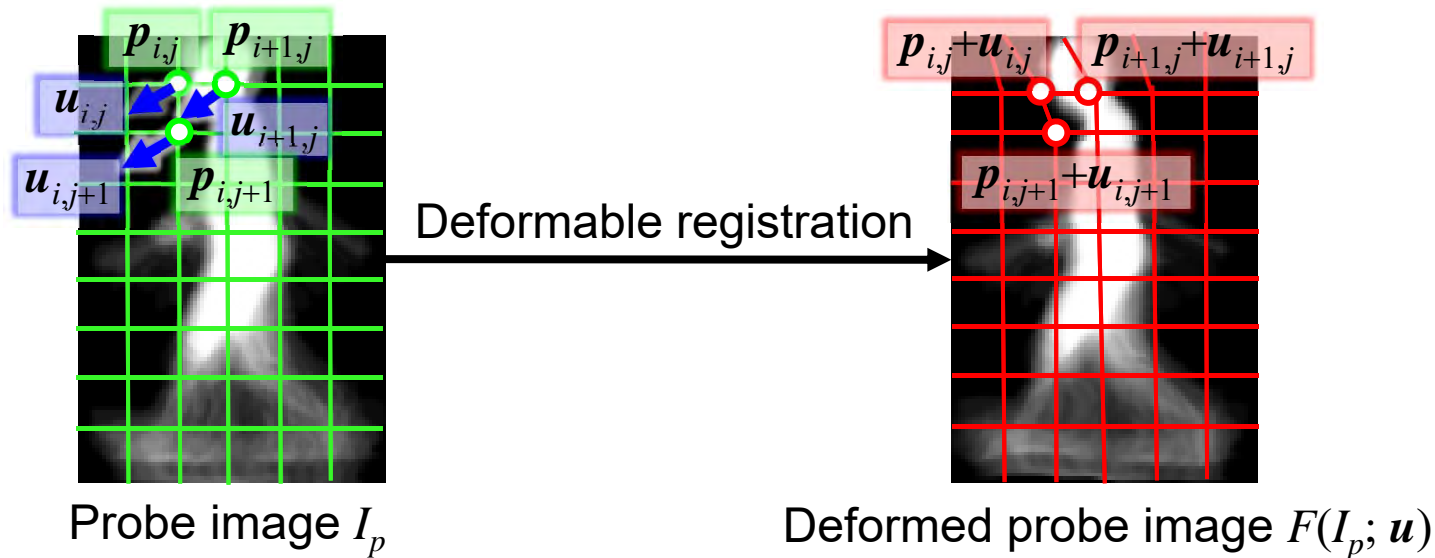
Deformable registration model for gait recognition is required.

Objective

- Gait recognition by deformable registration



Free-form deformation (FFD)



- Deformation vector on the control points (CPs)

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

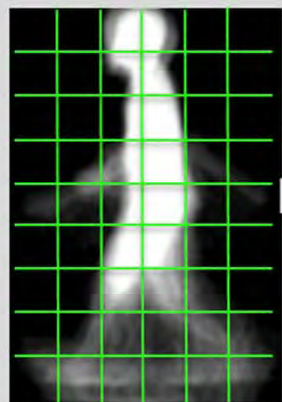
M_x : #CPs for horizontal direction
 M_y : #CPs for vertical direction

- Overall deformation field:
Bilinear interpolation from adjacent CPs

Computing FFD between two images

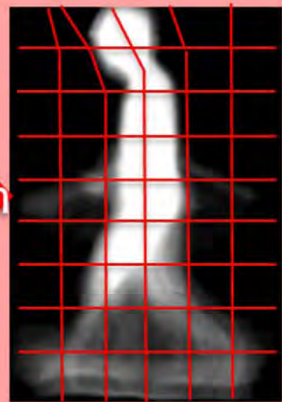
$$\mathbf{u}^* = \operatorname{argmin}_{\mathbf{u}} \|I_p \cdot F(\mathbf{u}) - I_g\|_1 + \lambda R(\mathbf{u})$$

Data term: Image difference



Probe I_p

Deform

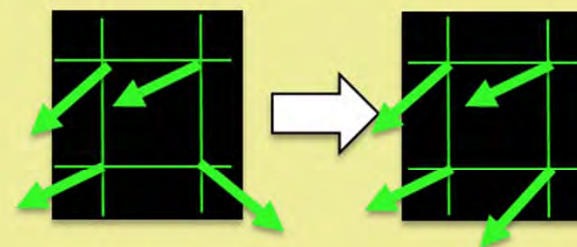


Deformed probe
 $F(I_p; \mathbf{u})$



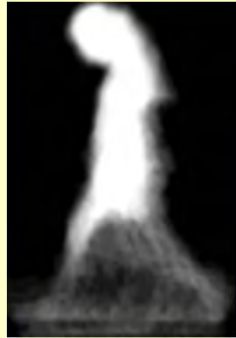
Gallery I_g

Smoothness term:
deformation difference between
adjacent control points

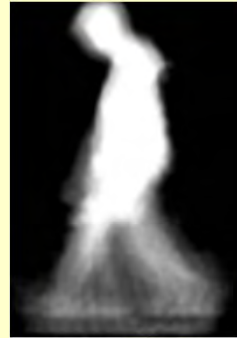


Intra-/inter-subject FFDs

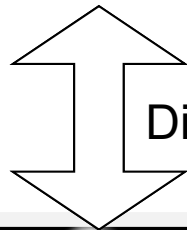
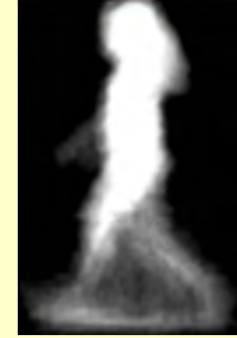
Intra-subject



Forward inclination



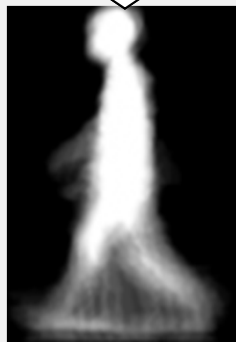
Translation



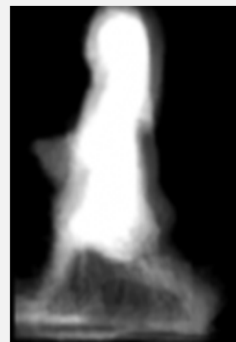
Different trend

Learn intra-subject deformation

Inter-subject



Body shape



Head-torso ratio



Arm swing

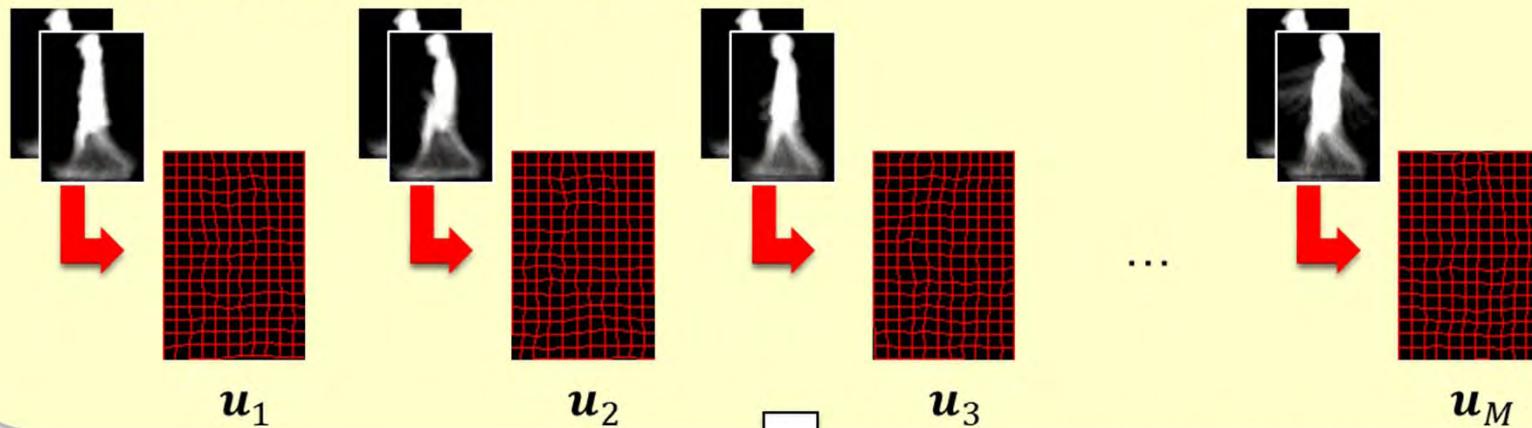


Stride

Deformation is represented by morphing.

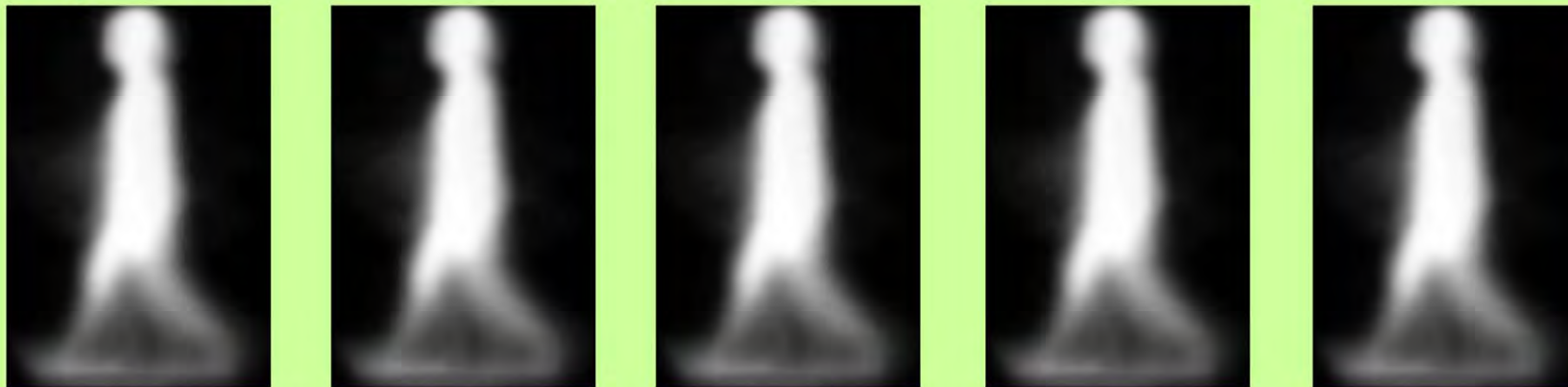
Eigen FFD

Training data for intra-subject FFDs



Principal component analysis (PCA)

Eigen FFD



1st PC

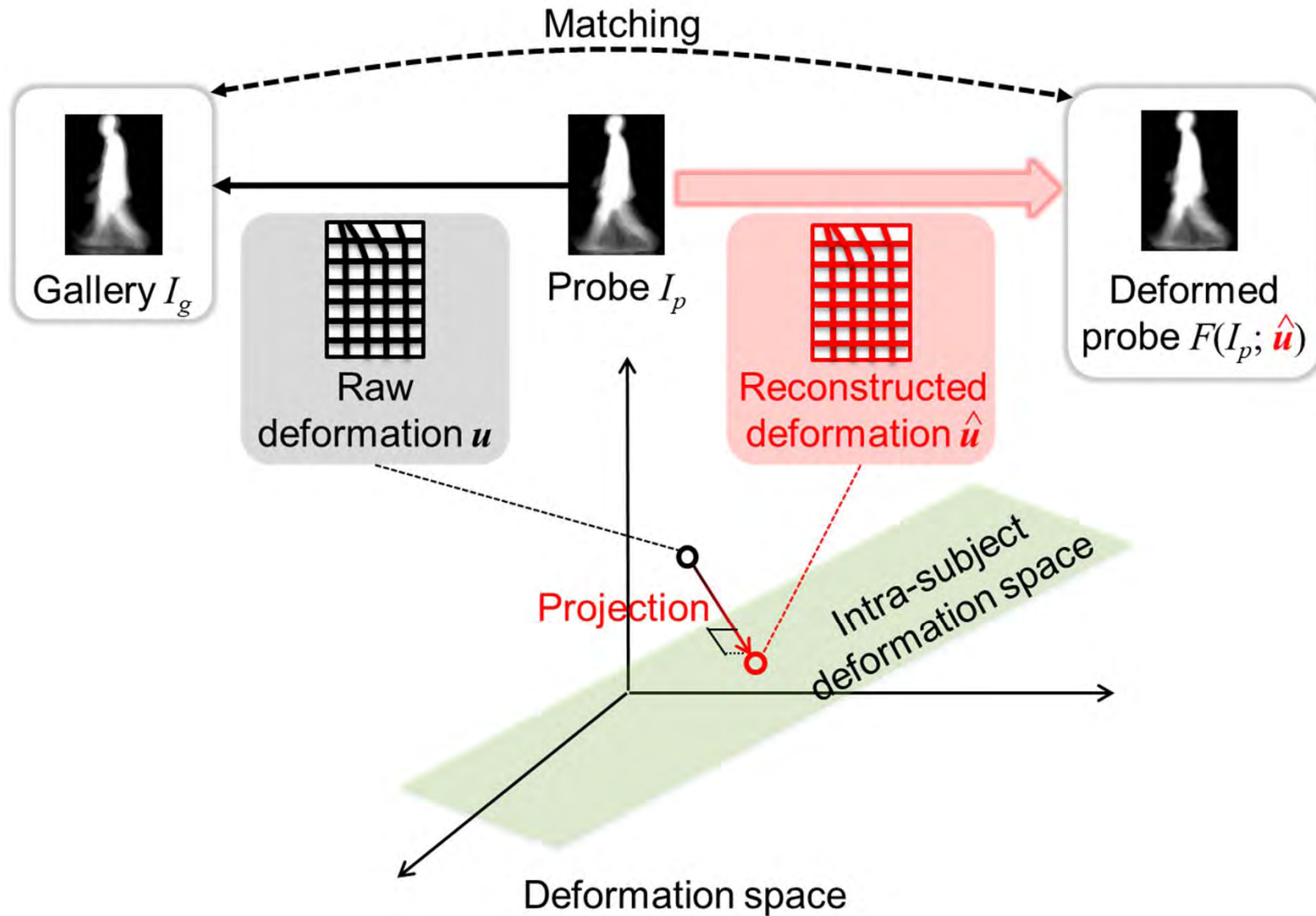
2nd PC

3rd PC

4th PC

5th PC

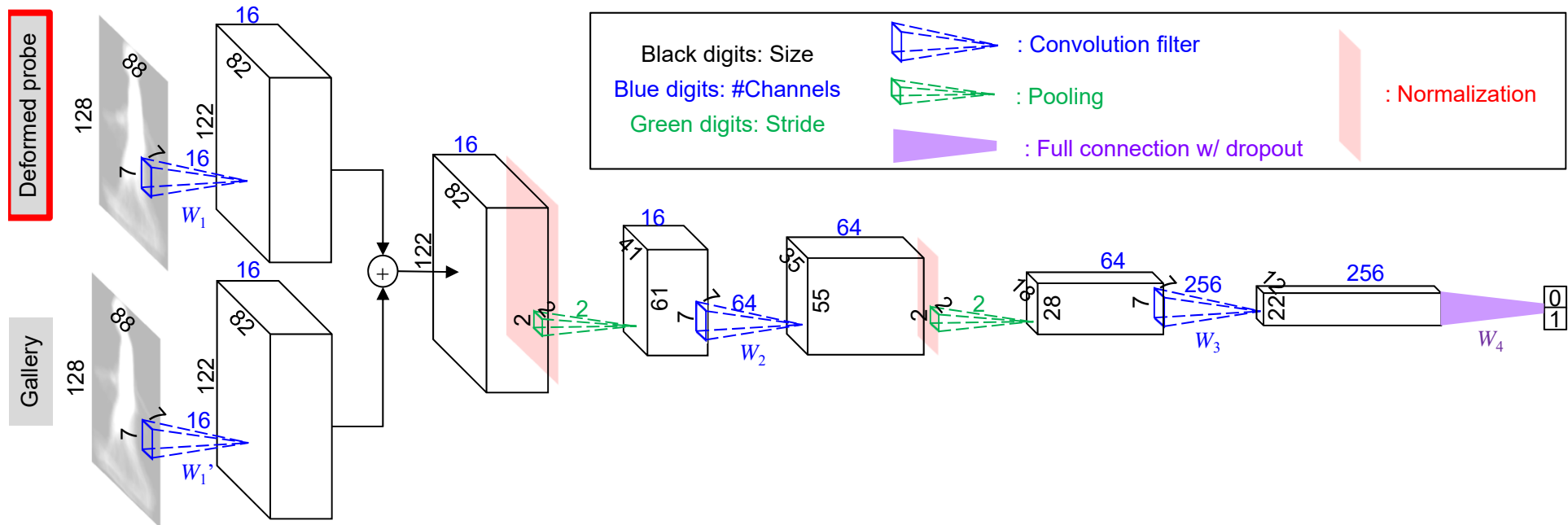
Matching by eigen FFD



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 $\lambda=100$

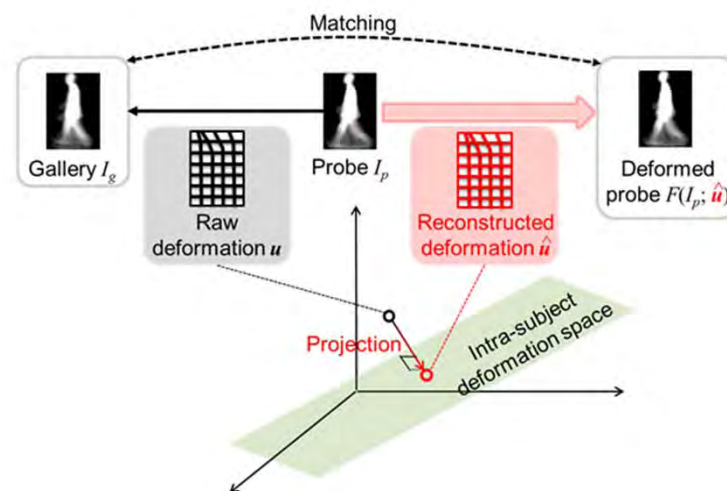
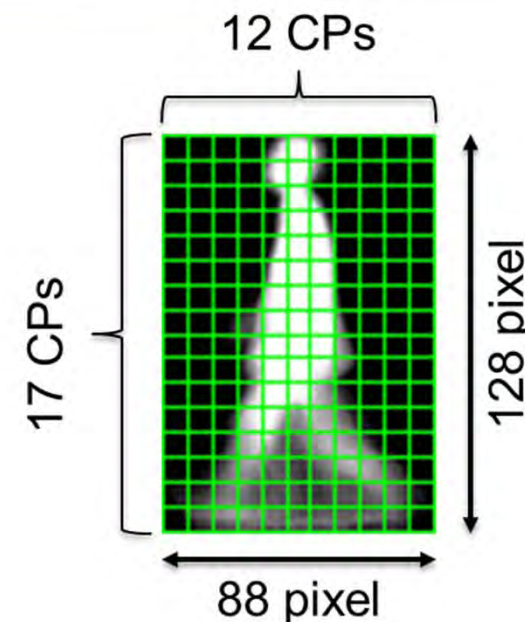
- #Dimensions of eigenFFD: 5

- Benchmarks

- Direct matching

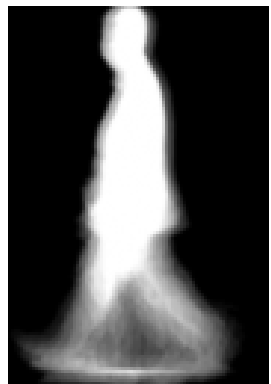
- Raw FFD u

- Eigen FFD \hat{u} (proposed)

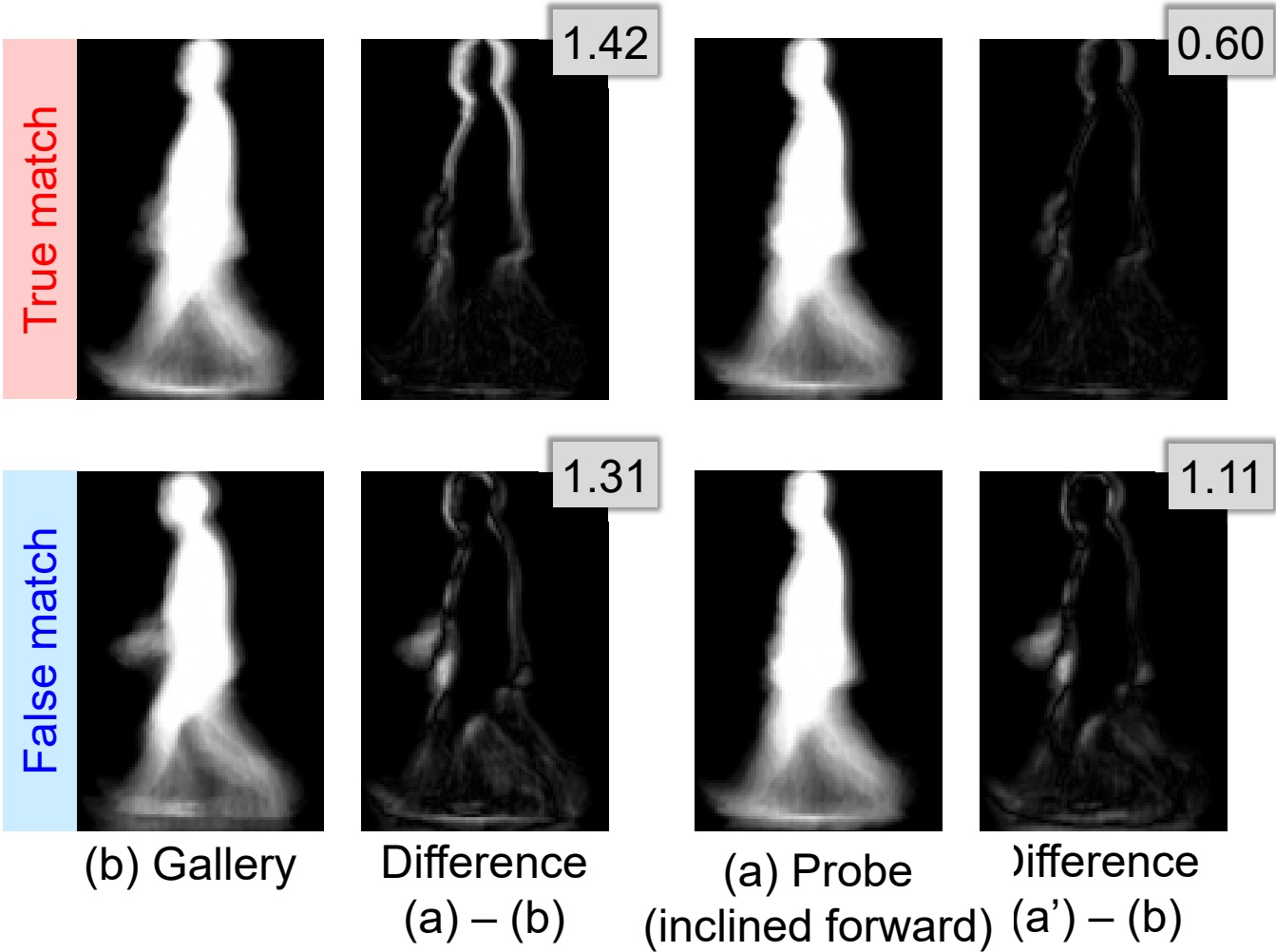


Matching example

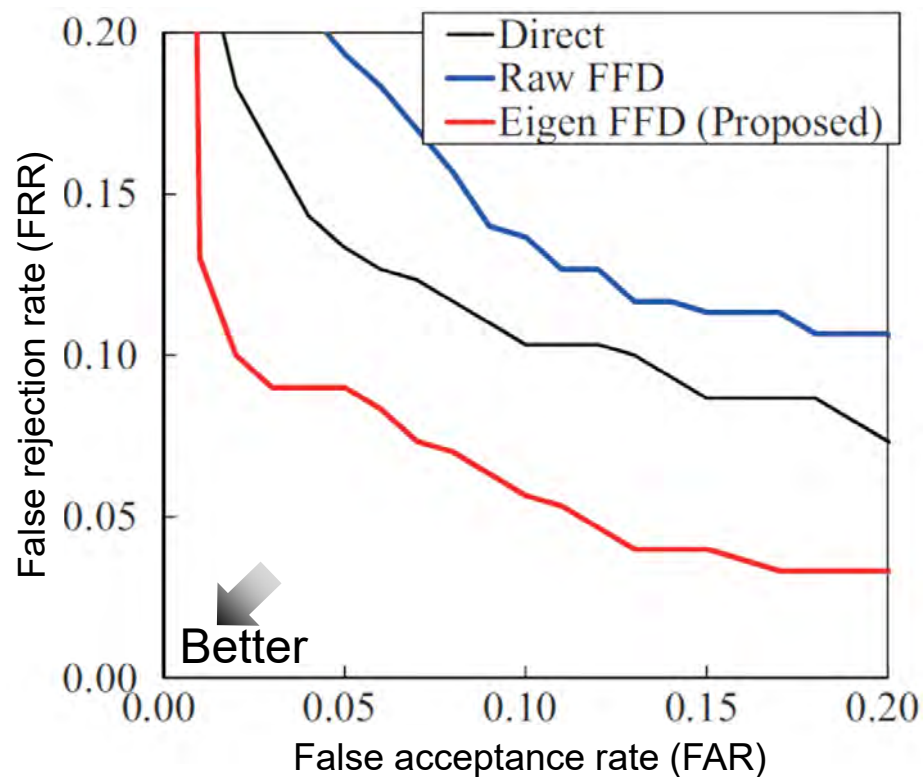
Dissimilarity score



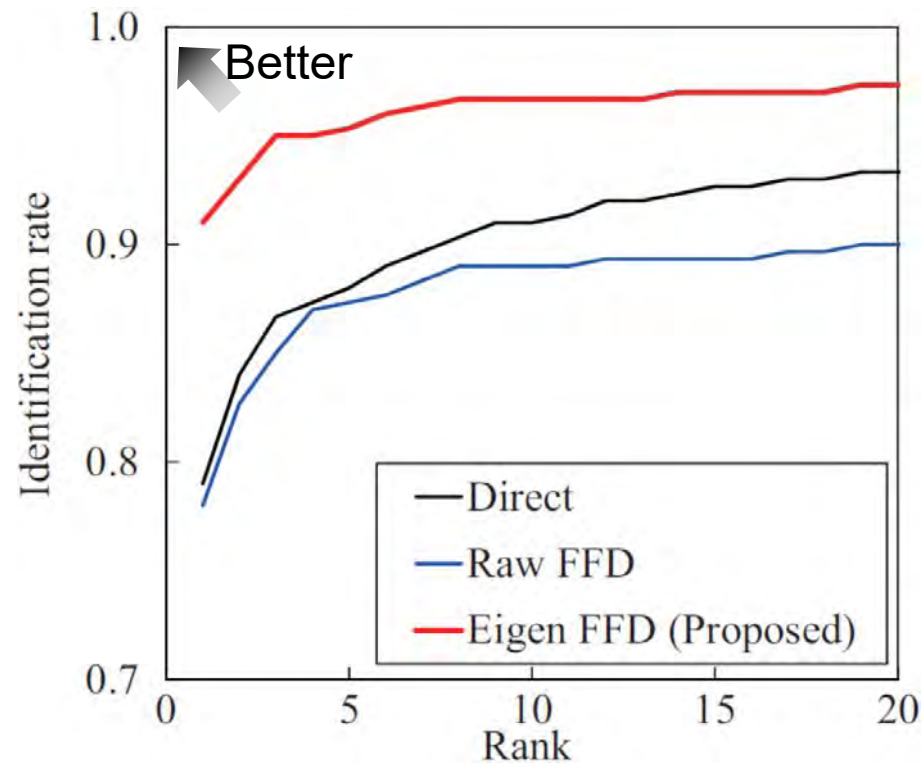
(a) Probe
(inclined forward)



Evaluation w/o metric learning

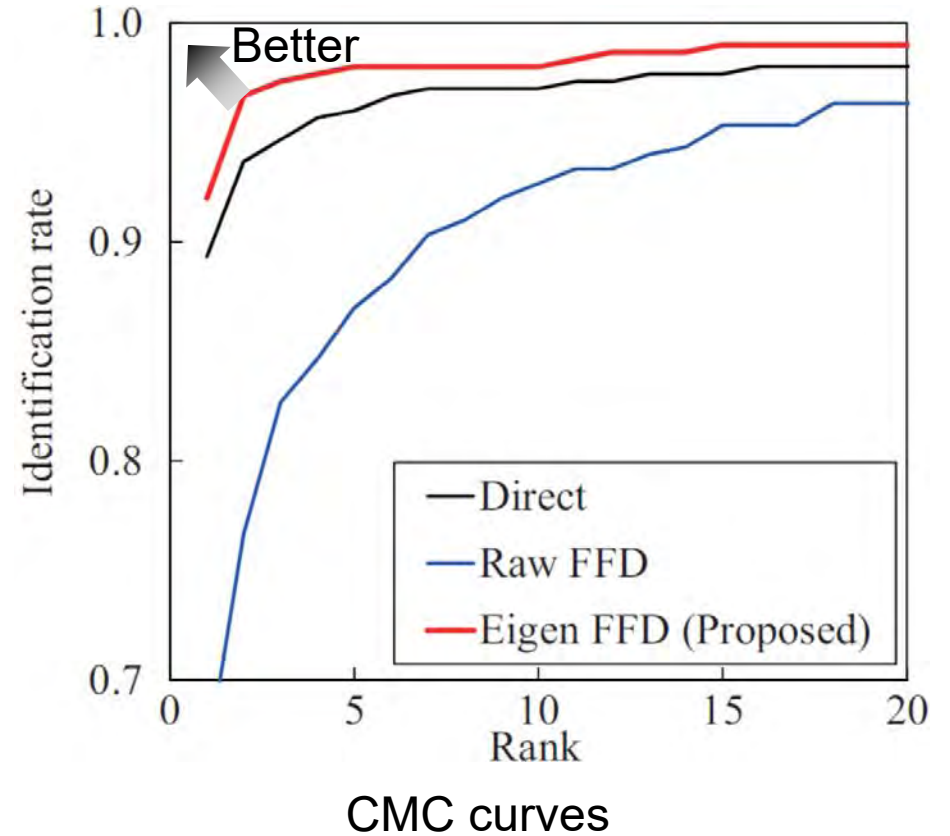
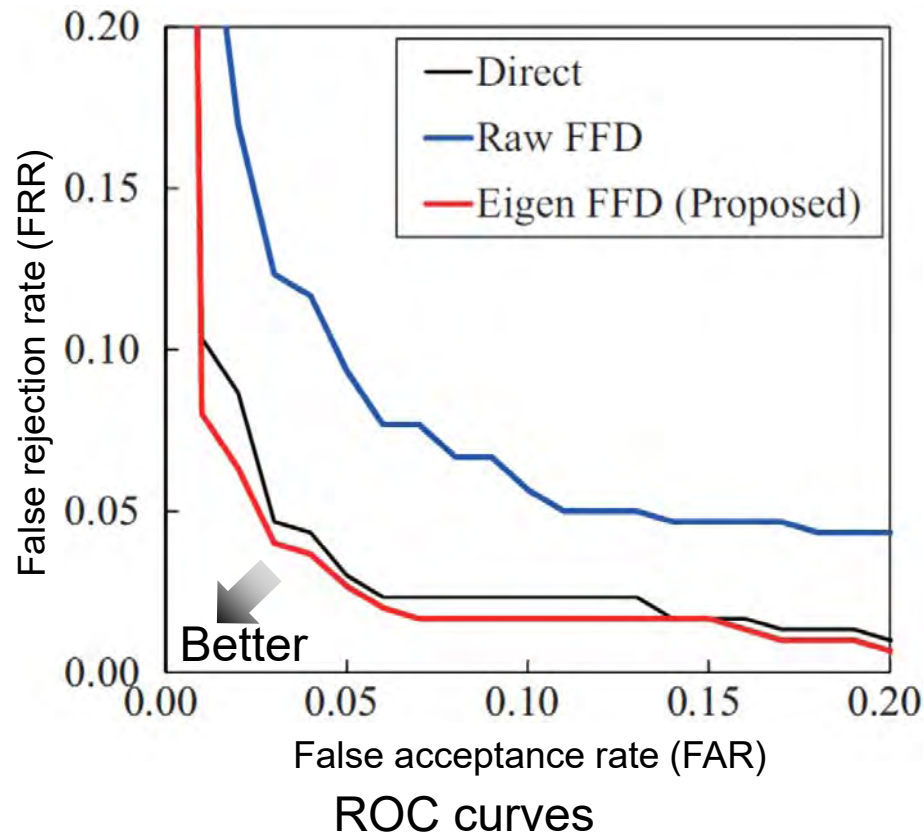


Receiver operating characteristics (ROC) curves



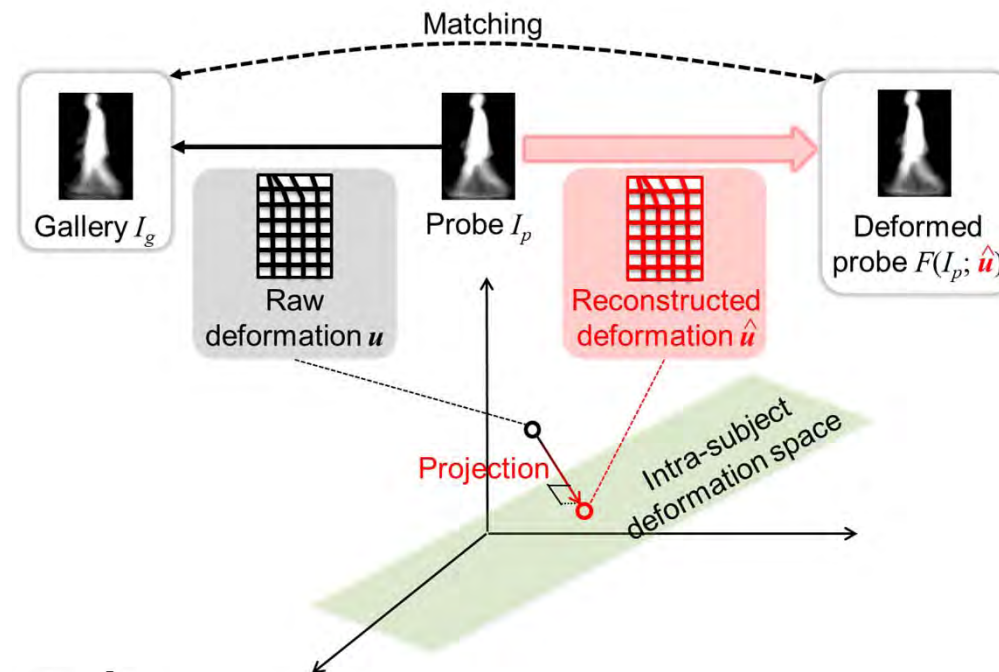
Cumulative matching characteristics (CMC) curves

Evaluation w/ metric learning



Summary

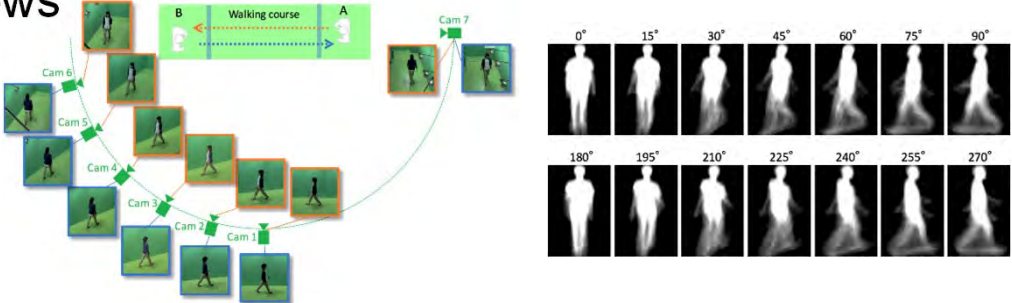
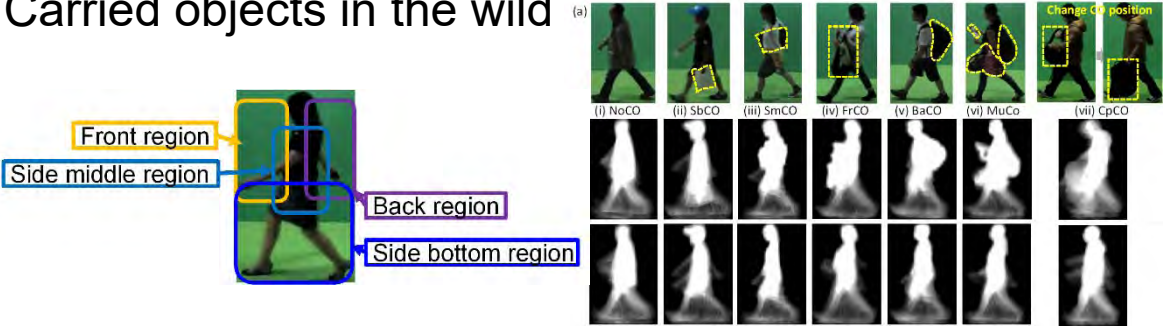
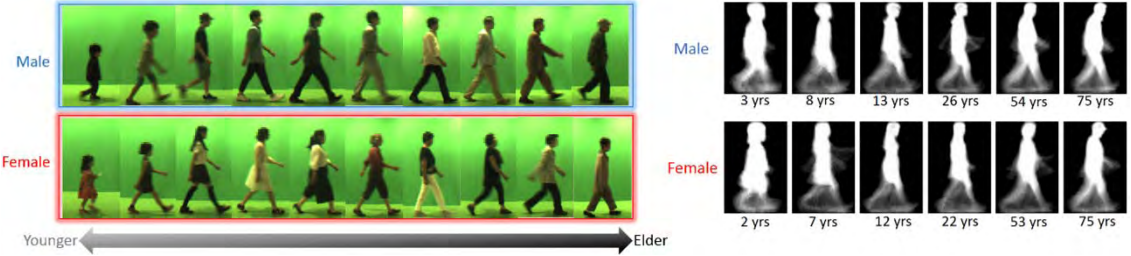
- Gait recognition by deformable registration robust against intra-subject posture change



- 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	<p>14 views</p> 
OULP-Bag [Uddin + 2018]	62,528	<p>Carried objects in the wild</p> 
OULP-Age [Xu+ 2018]	63,846	<p>Wide age range</p> 

World's largest gait database



- Available at

<http://www.am.sanken.osaka-u.ac.jp/BiometricDB/index.html>

The screenshot shows a web browser window displaying the "OU-ISIR Gait Database, Multi-View Large Population Dataset" page. The browser's address bar shows the URL www.am.sanken.osaka-u.ac.jp/BiometricDB/GaitMVLPhtml. The page features a navigation menu on the left with options like "Index", "Gait Database Treadmill Dataset", "Gait Database Large Population Dataset", "Gait Database Speed Transition Dataset", "Gait Database Large Population Dataset with Bag", "Gait Database Large Population Dataset with Age", and "Gait Database Inertial Sensor Dataset". The main content area has a title "OU-ISIR Gait Database, Multi-View Large Population Dataset" and an "Introduction" section. The introduction text states: "The OU-ISIR Gait Database, Multi-View Large Population Dataset (OU-MVLP) is meant to aid research efforts in the general area of developing, testing and evaluating algorithms for cross-view gait recognition. The Institute of Scientific and Industrial Research (ISIR), Osaka University (OU) has copyright in the collection of gait video and associated data and serves as a distributor of the OU-ISIR Gait Database. The data was collected in conjunction with an experience-based long-run exhibition of video-based gait analysis at a science museum. The approved informed consent was obtained from all the subjects in this dataset. The dataset consists of 10,307 subjects (5,114 males and 5,193 females with various ages, ranging from 2 to 87 years) from 14 view angles, ranging 0°-90°, 180°-270°. Gait images of 1,280 x 980 pixels at 25 fps are captured by seven network cameras (Cam1-7) placed at intervals of 15-deg azimuth angles along a quarter of a circle whose center coincides with the center of the walking course. Its radius is approximately 8 m and height is approximately 5 m." Below the text is a diagram illustrating the camera setup. It shows a "Walking course" with points A and B, and seven cameras (Cam 1 to Cam 7) arranged in a semi-circle around the course. Each camera is shown with a small inset image of a person walking from its perspective.