Gait Image Analysis for Person Authentication

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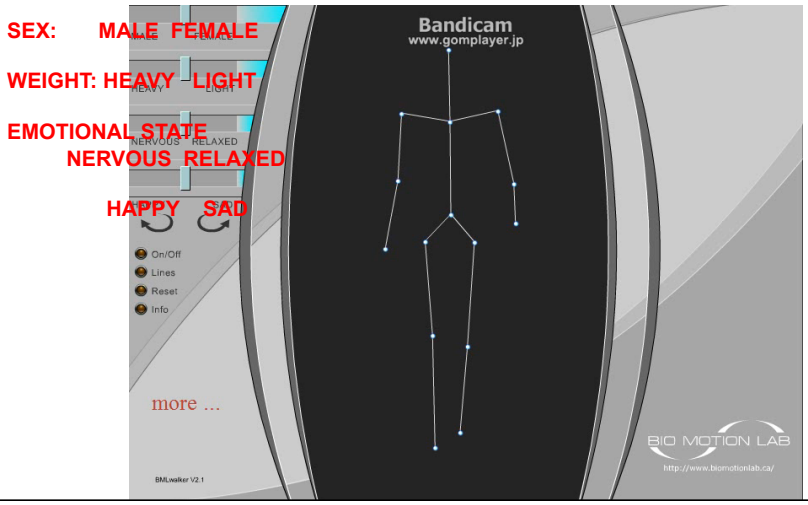
Human gait -Age-

- How old are they?

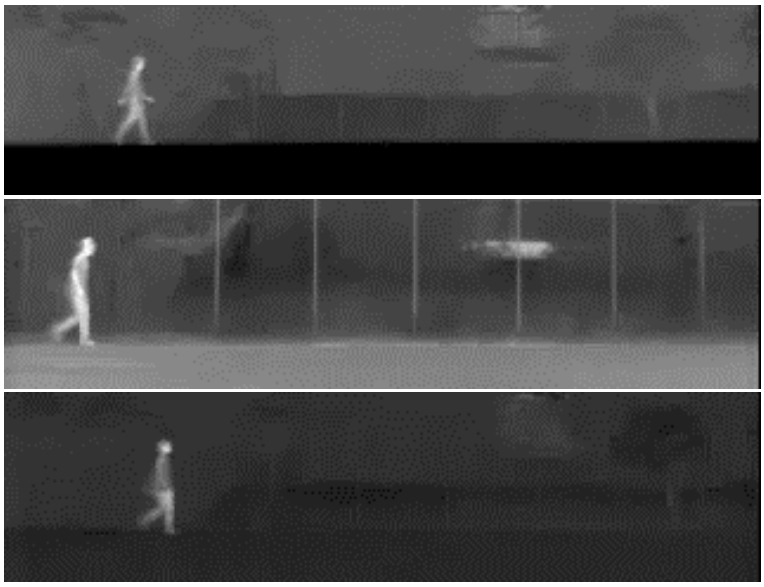
Subject	1	2	3
Gait			
Age	A. 4 years old B. 14 years old C. 24 years old	A. 62 years old B. 72 years old C. 82 years old	A. 34 years old B. 39 years old C. 44 years old

Human gait -Attribute-

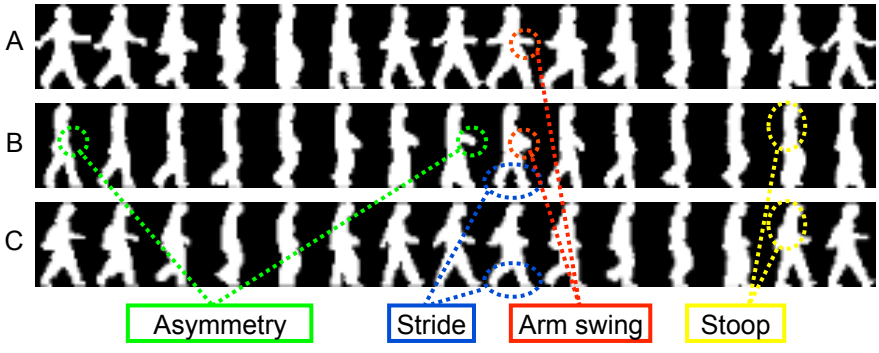
- Biological Motion Lab. Queen's University
  - http://www.biomotionlab.ca/Demos/BMLwalker.html



Human gait -Personality- Identity -



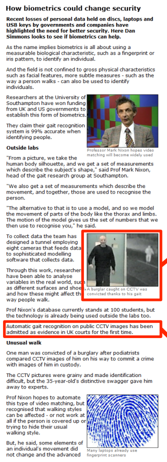
Human gait -Personality-



Gait recognition: Person authentication from gait personalities

Example of practical use (1)

- Gait recognition on burglar on CCTVs
  - Admitted as evidence in UK court[1]



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.

Professor Mark Nixon hopes video matching will become widely used

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.

A burglar caught on CCTV was convicted thanks to his gait

Through this work, researcher have been able to analyse variables in the real world, suc as different surfaces and shoe and how these might affect th 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.

Unusual walk

One man was convicted of a burglary after podiatrists compared CCTV images of him on his way to commit a crime with images of him in custody.

The CCTV pictures were grainy and made identification difficult, but the 35-year-old's distinctive swagger gave him away to experts.

Prof Nixon hopes to automate this type of video matching, but recognised that walking styles can be affected - or not work at all if the person is covered up or trying to hide their usual walking style.

Many laptops already use fingerprint scanners

But, he said, some elements of an individual's movement did not change and the advanced

A burglar caught on CCTV was convicted thanks to his gait

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

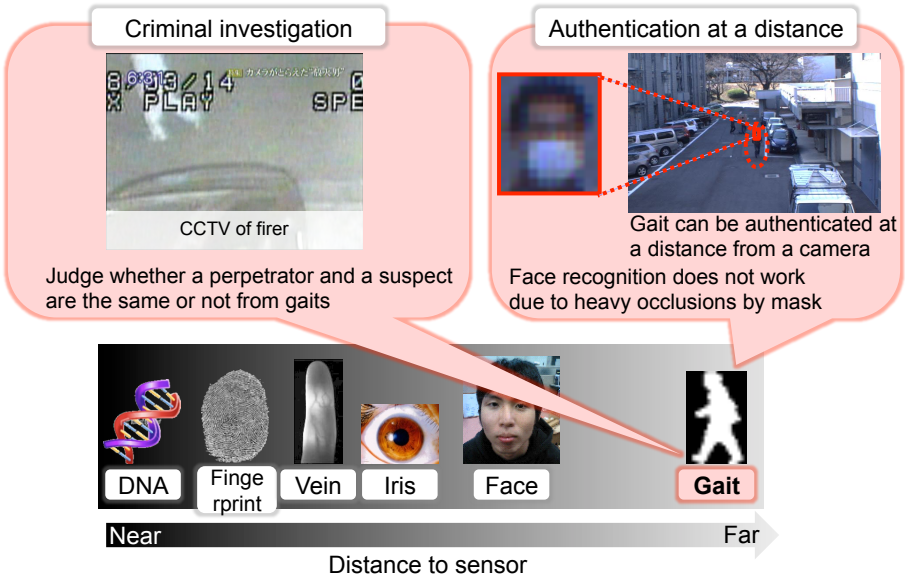
[1] http://news.bbc.co.uk/2/hi/programmes/click online/7702065.stm, "How biometrics could change security," BBC News, 31 Oct. 2008.

Example of practical use (2)

- Gait recognition on firer in Japan[2]

[2] 2009年2月20日 毎日放送 VOICE「指紋は不要？放火犯を追った驚きの科学捜査とは！-歩き方で捕まった放火男」
Mainichi Broadcast VOICE (2009/2/20)

Advantage of gait recognition



Today's topics

- Gait recognition
- What is the difficulty for applying gait recognition to wide-area surveillance ?
  - The difference of the observation direction
  - Low sampling rate
  - Occlusion in crowd scene
- Gait Analysis for Innovative Entertainment

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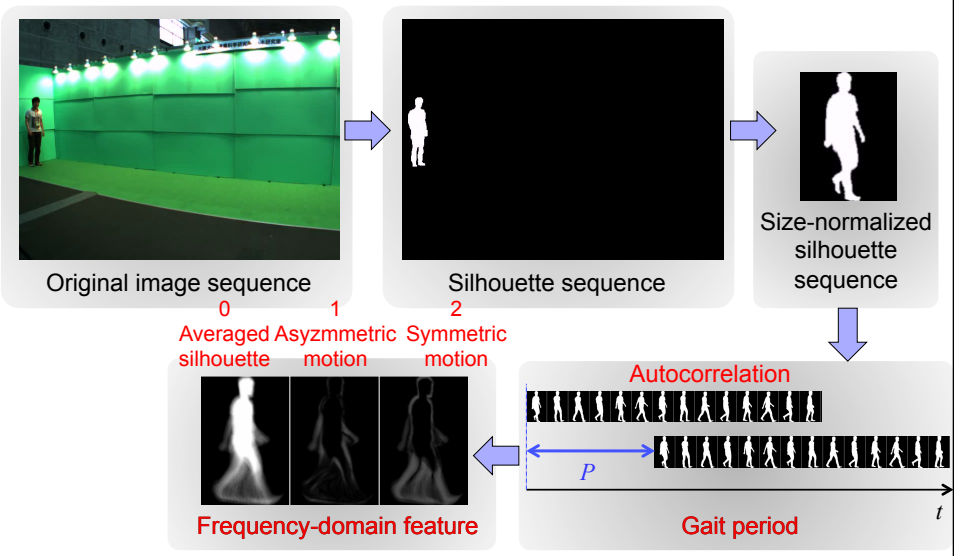
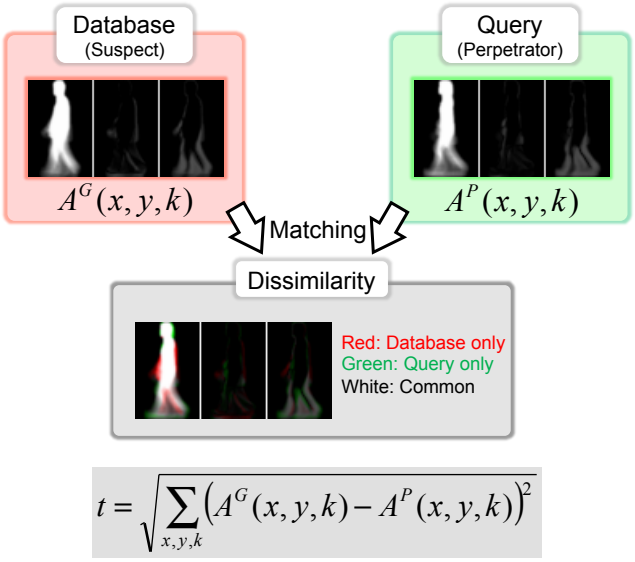
Gait identification & gait verification

Gait feature extraction



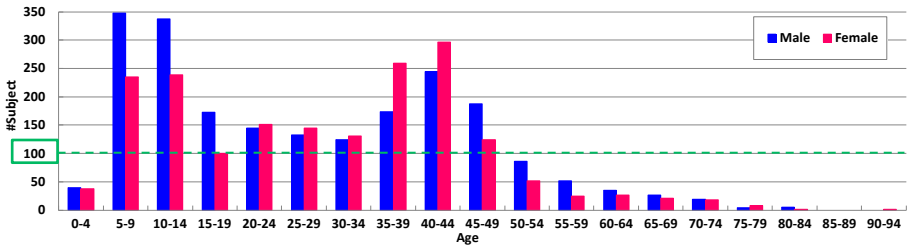
Y. Makihara, R. Sagawa, Y. Mukaigawa, T. Echigo, and Y. Yagi, ``Gait Recognition Using a View Transformation Model in the Frequency Domain,'' 9th European Conf. on Computer Vision, Vol. 3, pp. 151-163, 2006.

Dissimilarity: Single feature



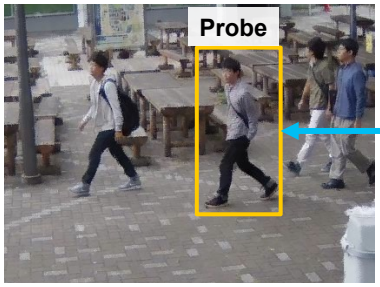
$$t = \sqrt{\sum_{x,y,k} \left(A^G(x,y,k) - A^P(x,y,k) \right)^2}$$

Database: OU-LP

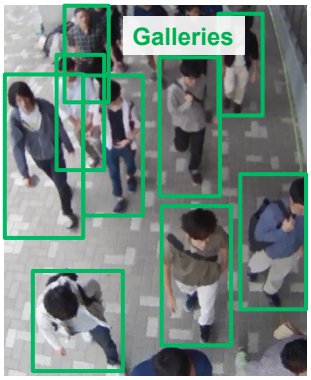


The world largest database with 4,007 subjects (Male: 2,135, Female: 1,872)

Identification (1:N matching)



Which one is the same



Applications

- Person re-identification
- ID-less access control

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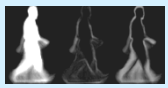
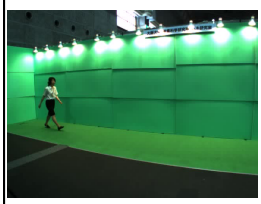
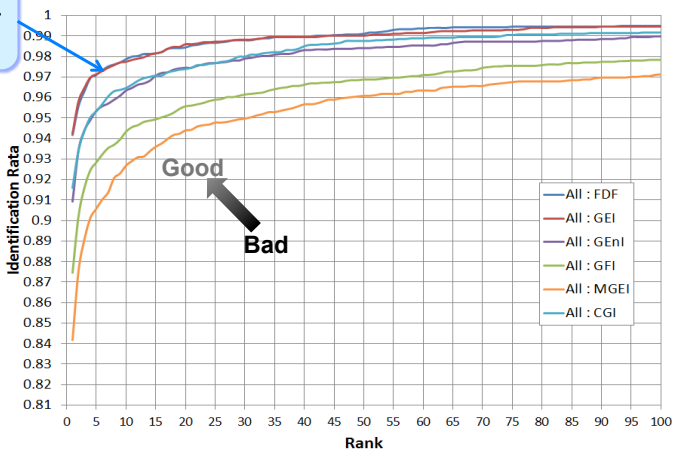
Performance evaluation: identification

[Iwama et al. IFS 2012]



FDF

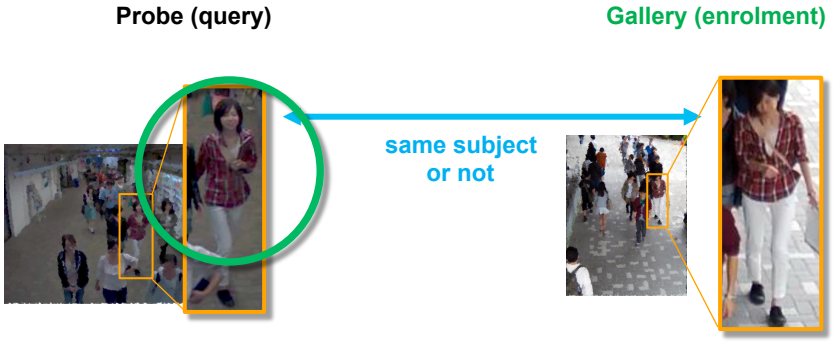




Cumulative matching characteristics (CMC) curve

94% rank-1 identification rate (N = 3,141)

Verification (1:1 matching)



Applications

- Matching a perpetrator and suspect for a criminal investigation.
- Detecting a specific person at border control.

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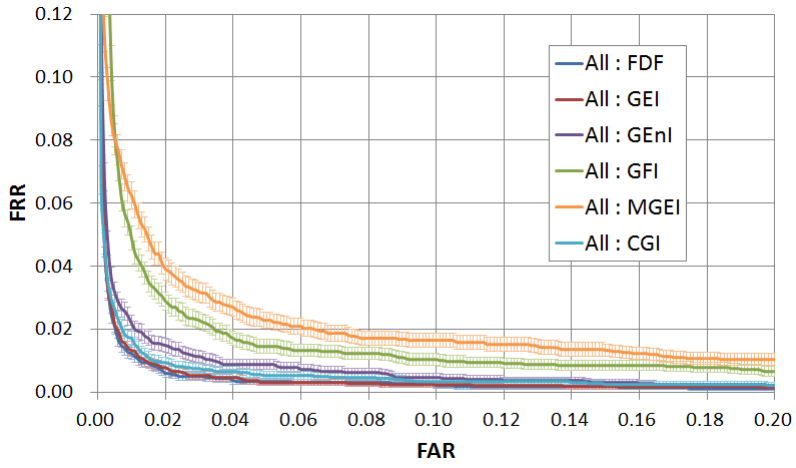
Performance evaluation: verification



EER: 1.15%

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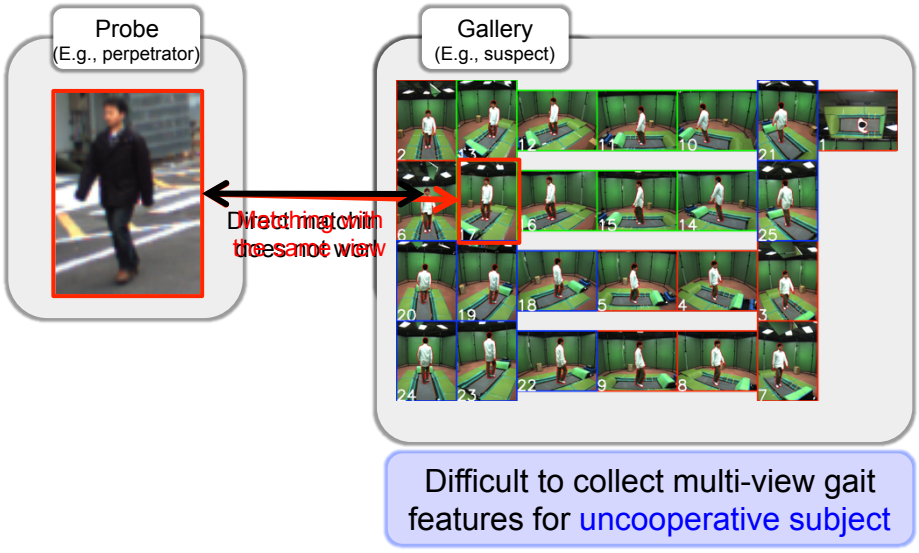
World first packaged gait verification system for criminal investigation

What is the difficulty for applying gait recognition to wide-area surveillance ?

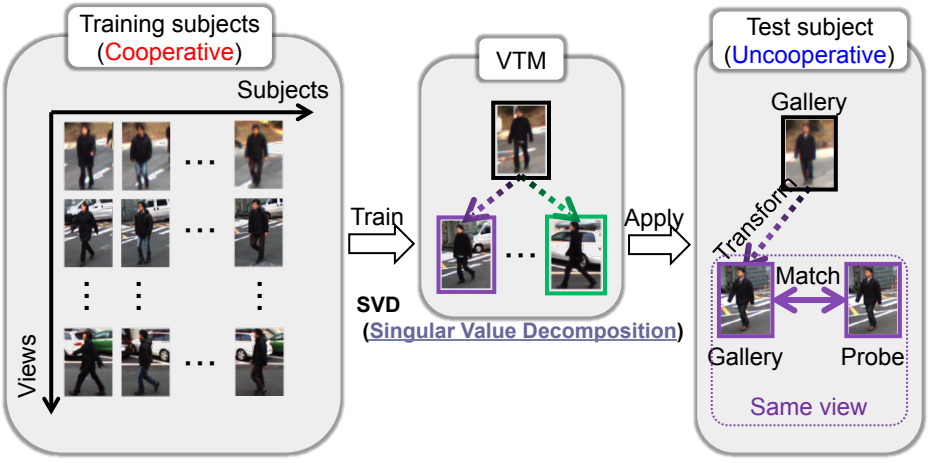
- The difference of the observation direction
  - ECCV2006
- Speed change CVPR2010
- The difference of clothes
  - Pattern Recognition 2010
- The difference of shoes
- Low sampling rate
  - ACCV2010, IJCB2011,
  - CVPR2012
- Occlusion in crowd scene

Challenge -View differences-



View transformation model (VTM)

[Makihara et al. ECCV 2006]



Formulation of VTM in frequency domain

- Decompose training data matrix of gait features into individuals and views by SVD

individual

view

$$\begin{bmatrix} \boldsymbol{a}_{\theta_1}^1 & \boldsymbol{a}_{\theta_1}^2 & \cdots & \boldsymbol{a}_{\theta_1}^M \\ \boldsymbol{a}_{\theta_2}^1 & \boldsymbol{a}_{\theta_2}^2 & \cdots & \boldsymbol{a}_{\theta_2}^M \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{a}_{\theta_K}^1 & \boldsymbol{a}_{\theta_K}^2 & \cdots & \boldsymbol{a}_{\theta_K}^M \end{bmatrix} = USV^T = \begin{bmatrix} P_{\theta_1} \\ P_{\theta_2} \\ \vdots \\ P_{\theta_K} \end{bmatrix} \begin{bmatrix} \boldsymbol{v}^1 & \boldsymbol{v}^2 & \cdots & \boldsymbol{v}^M \end{bmatrix}$$

Training data matrix

Transformation matrix to each view

View-independent individual vector

- Gait feature for mth subject from θ_i view

$$\boldsymbol{a}_{\theta_i}^m = P_{\theta_i} \boldsymbol{v}^m$$

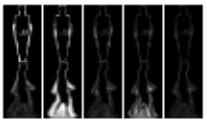
View transformation

- From a single reference θ_j to θ_i

$$\left.\begin{aligned} \boldsymbol{a}_{\theta_i}^m &= P_{\theta_i} \boldsymbol{v}^m \\ \boldsymbol{a}_{\theta_j}^m &= P_{\theta_j} \boldsymbol{v}^m \end{aligned}\right\} \Rightarrow \boldsymbol{a}_{\theta_i}^m = P_{\theta_i} P_{\theta_j}^{+} \boldsymbol{a}_{\theta_j}^m$$

0 deg

90 deg

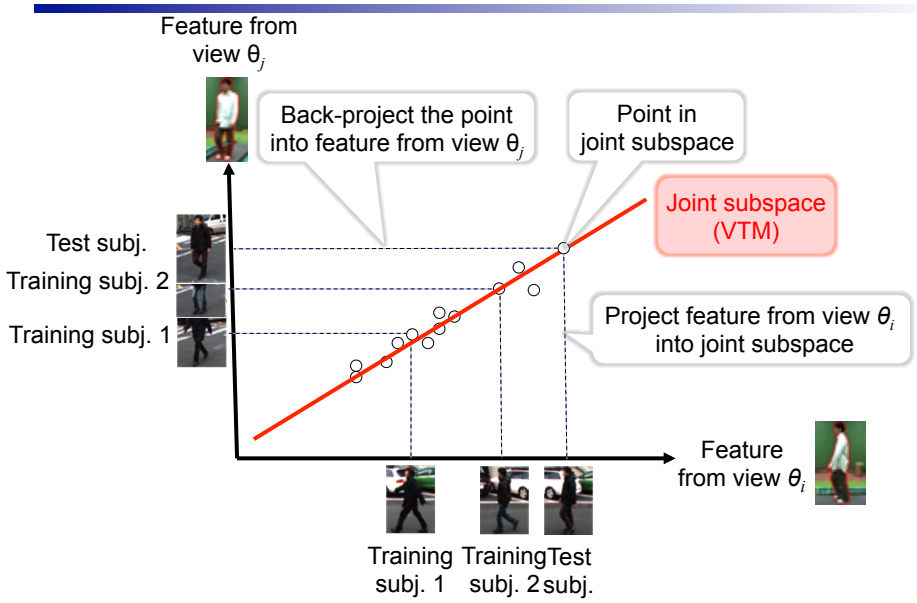


  - Orthogonal motion to reference θ_j is degenerated

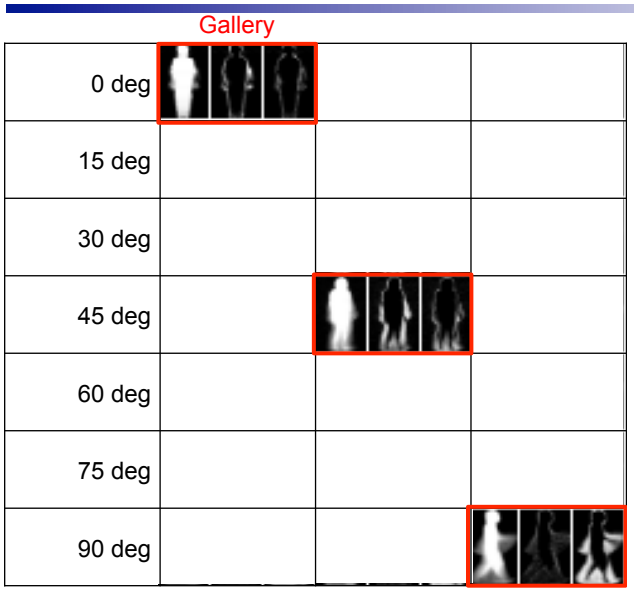
- From multiple references $\{\theta_j(1), \ldots, \theta_j(k)\}$ to θ_i

$$\left.\begin{aligned} \boldsymbol{a}_{\theta_i}^m &= P_{\theta_i} \boldsymbol{v}^m \\ \boldsymbol{a}_{\theta_j(1)}^m &= P_{\theta_j(1)} \boldsymbol{v}^m \\ &\vdots \\ \boldsymbol{a}_{\theta_j(k)}^m &= P_{\theta_j(k)} \boldsymbol{v}^m \end{aligned}\right\} \Rightarrow \boldsymbol{a}_{\theta_i}^m = P_{\theta_i} \begin{bmatrix} P_{\theta_j(1)} \\ \vdots \\ P_{\theta_j(k)} \end{bmatrix}^{+} \begin{bmatrix} \boldsymbol{a}_{\theta_j(1)}^m \\ \vdots \\ \boldsymbol{a}_{\theta_j(k)}^m \end{bmatrix}$$

How does it work?



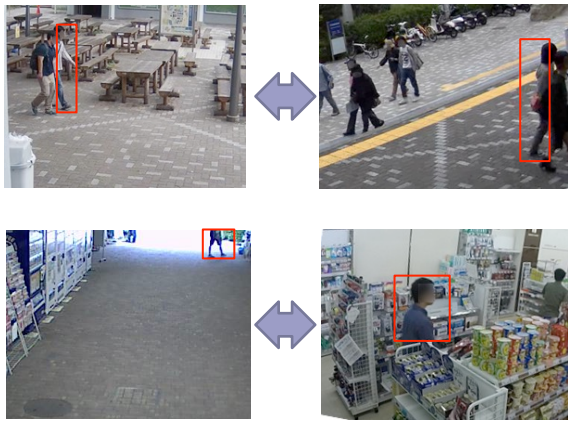
Transformation results



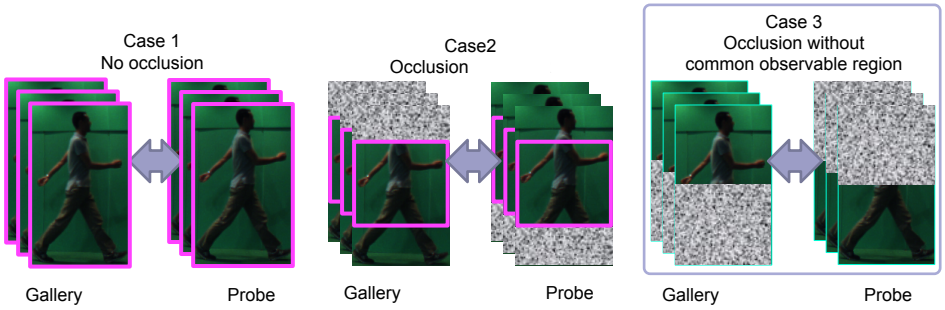
What is the difficulty for applying gait recognition to wide-area surveillance ?

- The difference of the observation direction
  - ECCV2006
- Speed change CVPR2010
- The difference of clothes
  - Pattern Recognition 2010
- Low sampling rate
  - ACCV2010, IJCB2011,
  - CVPR2012
- Occlusion in crowd scene
  - ICB2015

Actual situation of observed gait in surveillance



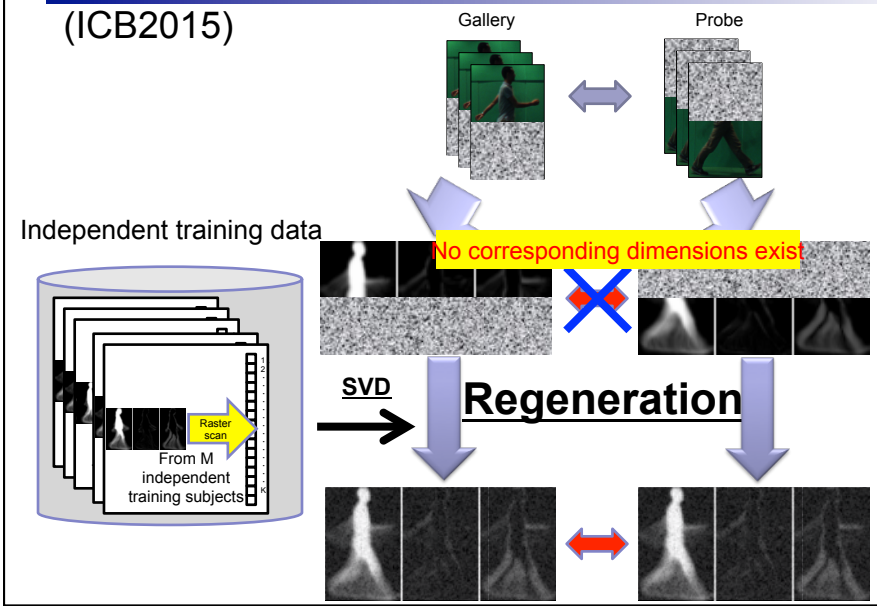
Challenge: Serious occlusion



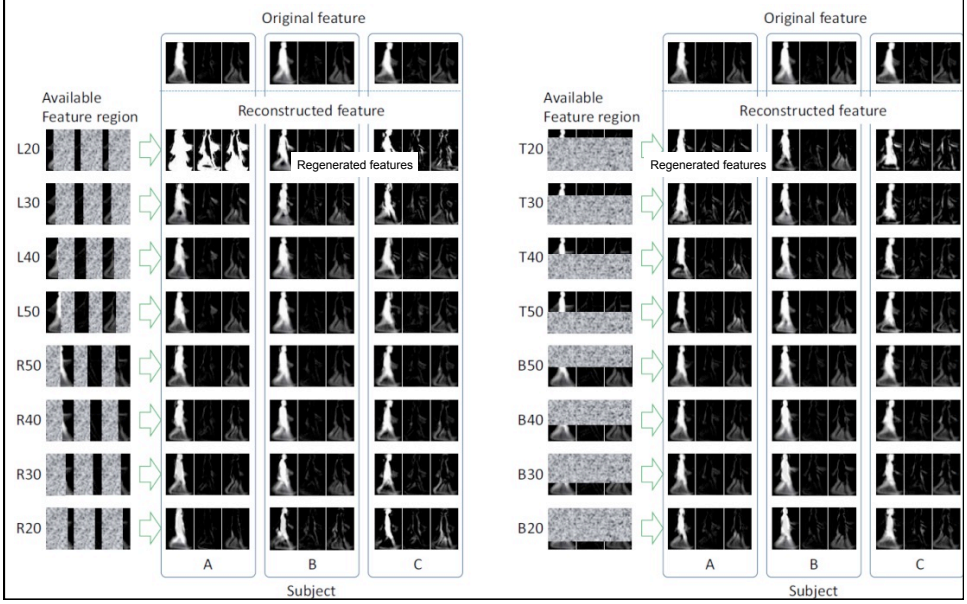
- Common observable regions (COR) are used for recognition
- Direct comparisons are impossible in case 3
  because any common region cannot be observed

Gait regeneration for recognition

(ICB2015)



Experiment : Regenerated gait



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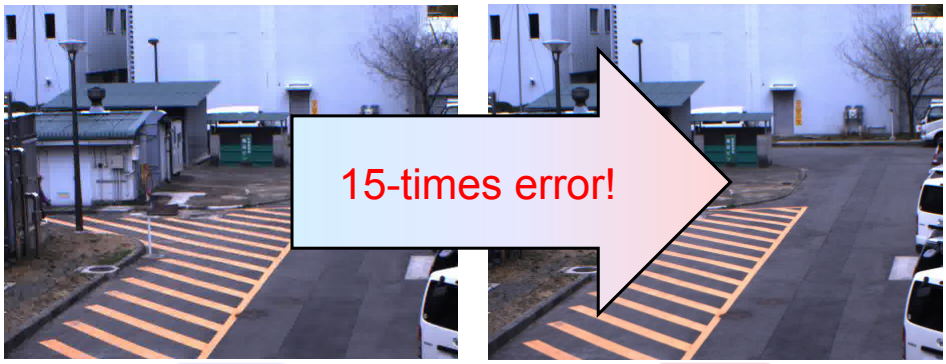
Challenge -Low frame-rate-



15 fps

1 fps

Solution

- Periodic Temporal Super Resolution (PTSR)

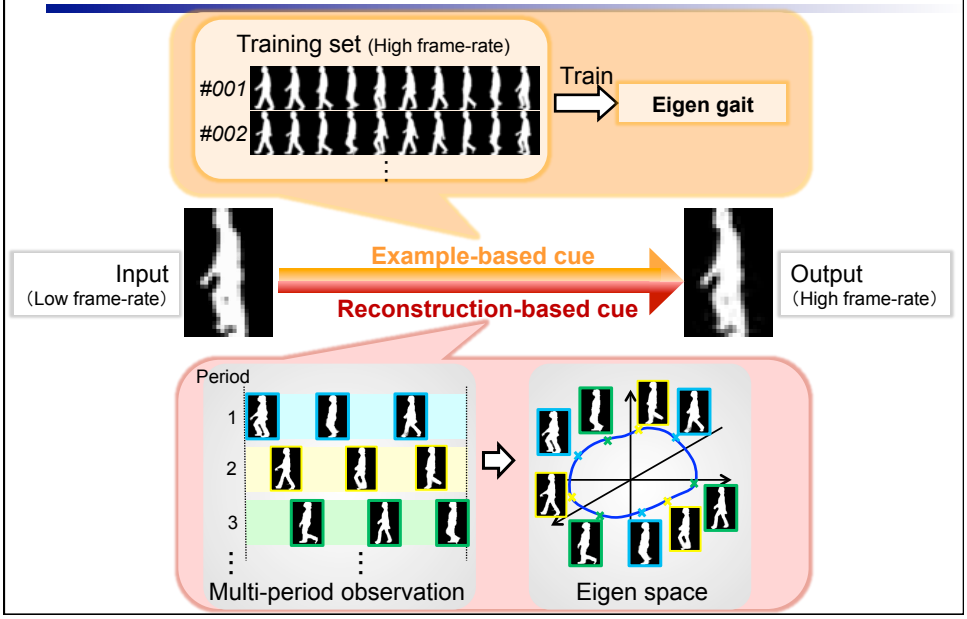
Low frame-rate video

PTSR

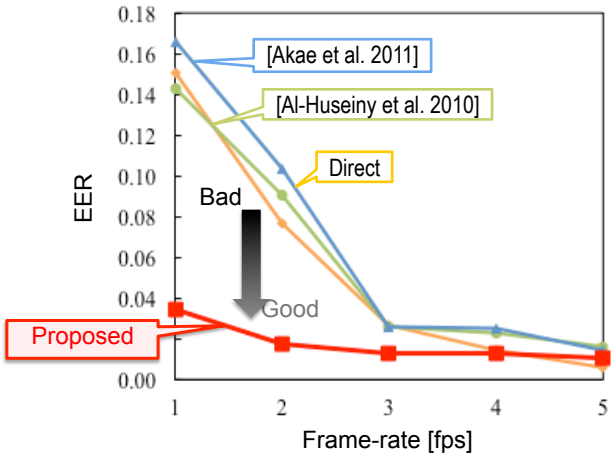
High frame-rate video

Improve accuracy

Unified approach to PTSR [Akae et al. CVPR 2012]

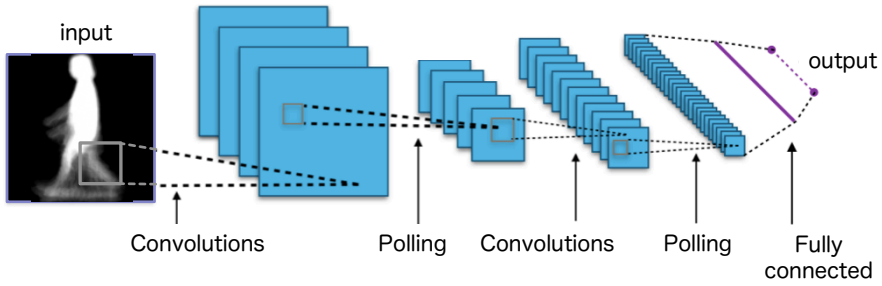


Performance evaluation: Verification



CNN-based discriminative approach

Convolutional Neural Network (CNN)-based gait recognition



- CNN-based methods have achieved state-of-the-art performance.
- Network architectures can be designed flexibly.

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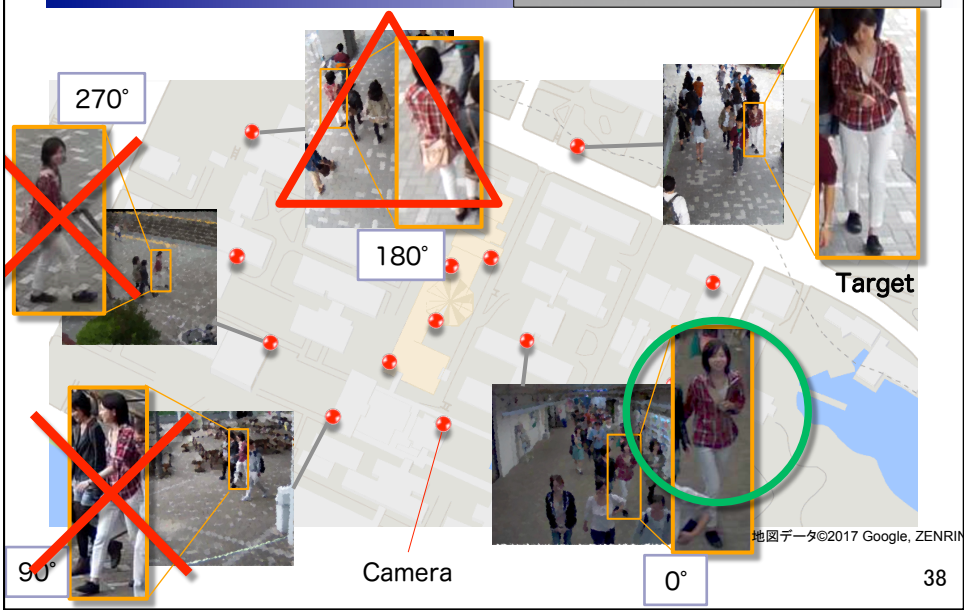
VTM based approach

・Walking direction is given
・Limitation of an angular difference of walking directions



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CNN based Cross View Approach

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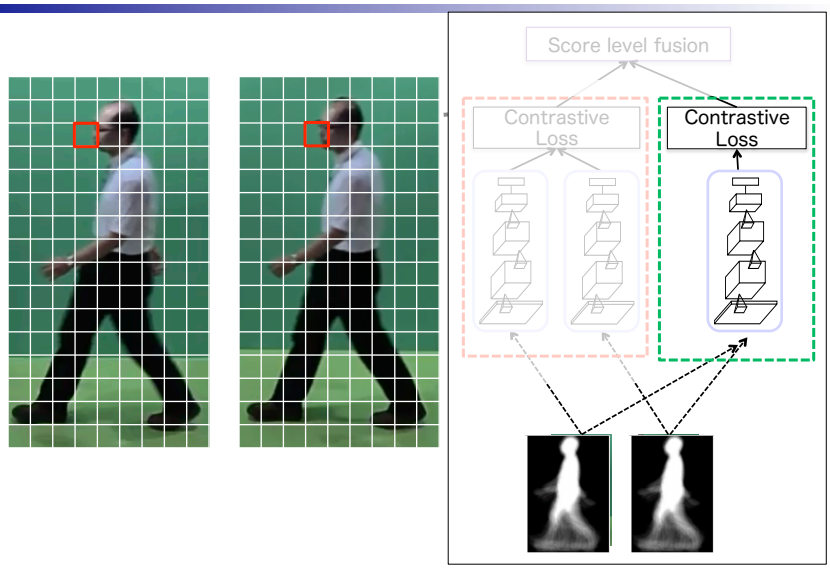
In case of small angular difference



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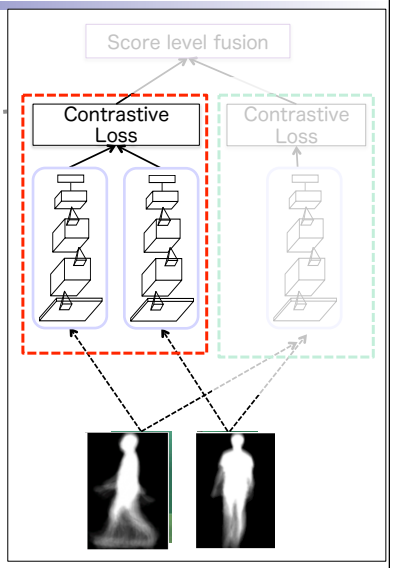
In case of large angular difference



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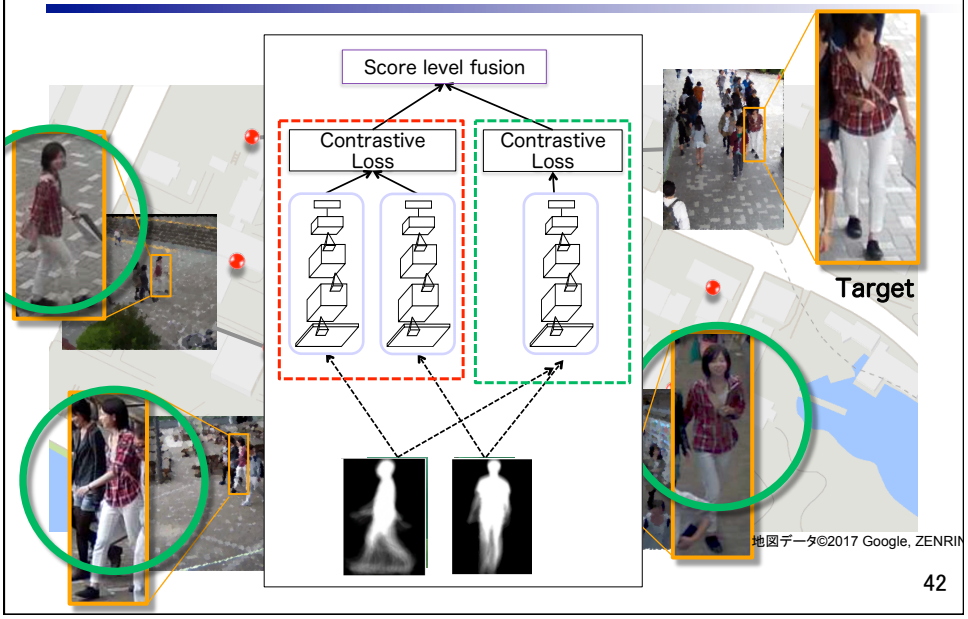
CNN based Cross View Approach



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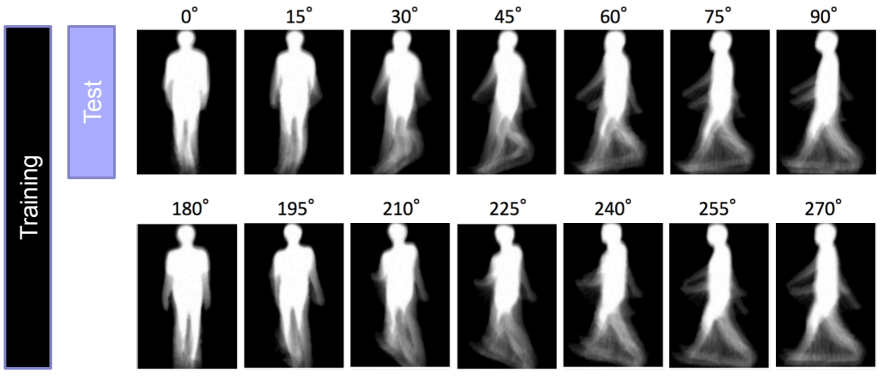
Gait database

OU-MVLP（OU-ISIR Multi-View Large Population）

- Gait feature: GEI (Gait energy image)
- #Subjects：about 10,000 (training : testing = 1 : 1)
- View variation：14 views（0-90°, 180-270°, 15°-intervals）



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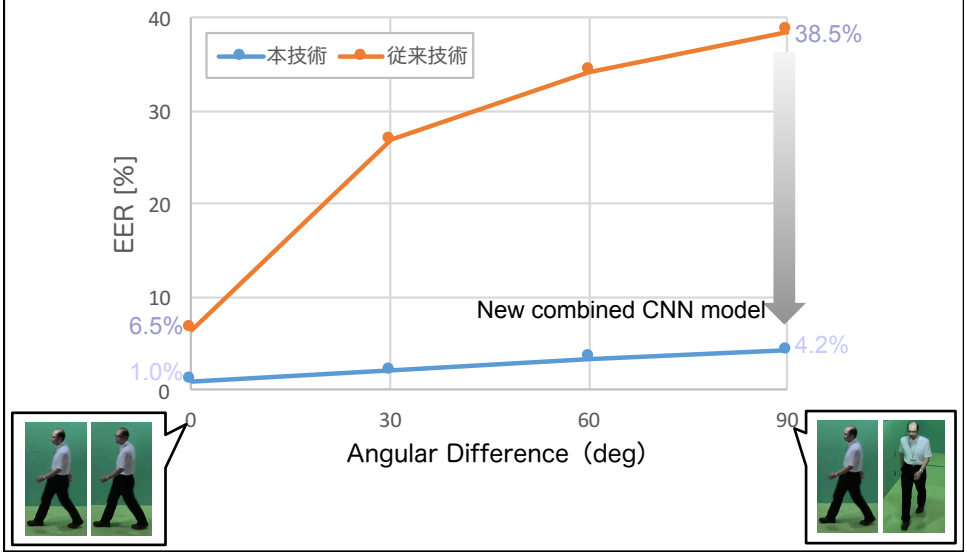
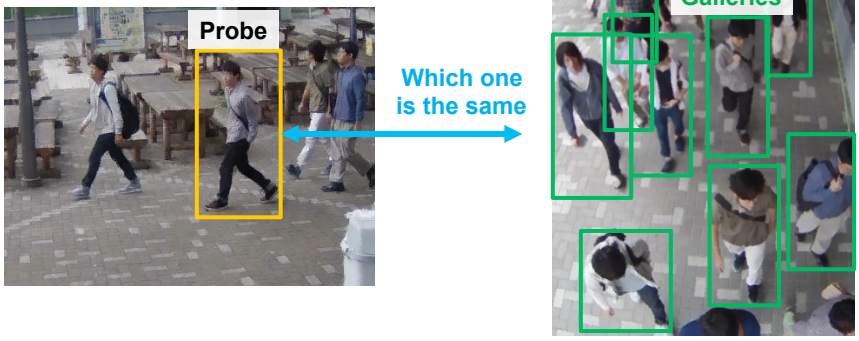
Equal Error Rate of new combined CNN model



Identification (1:N matching)



Applications

- Person re-identification
- ID-less access control

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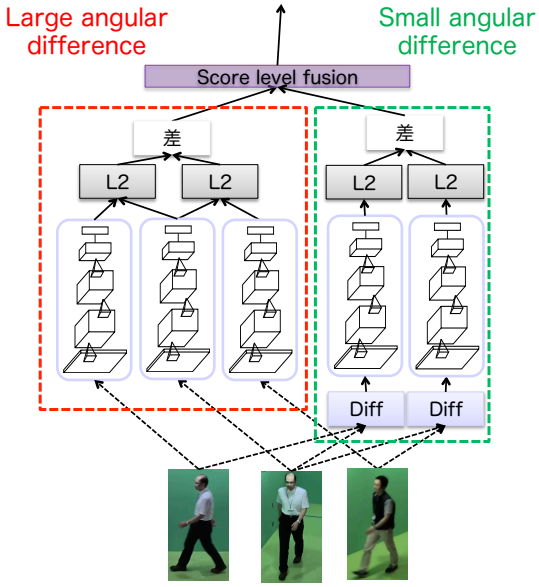
CNN based gait identification



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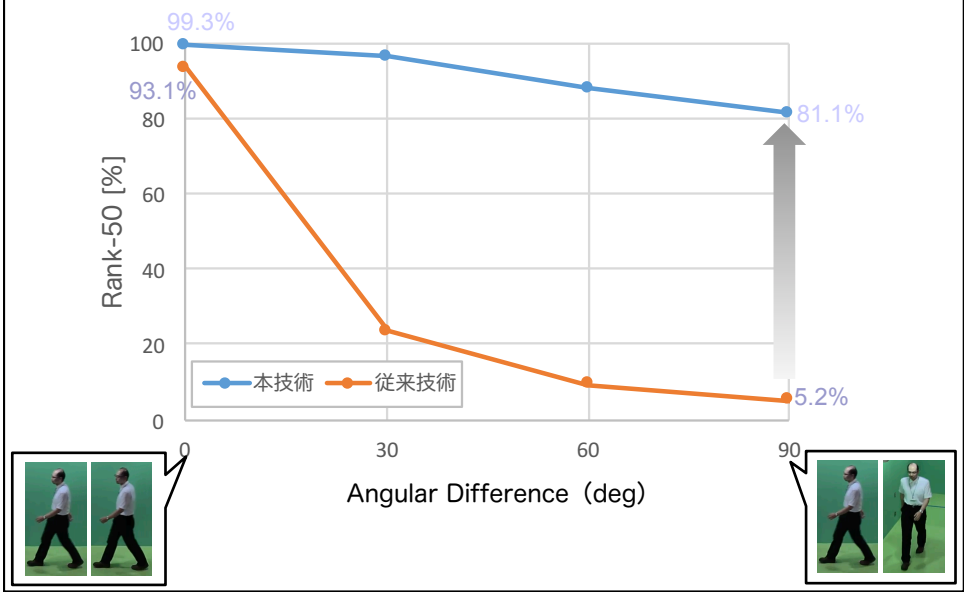
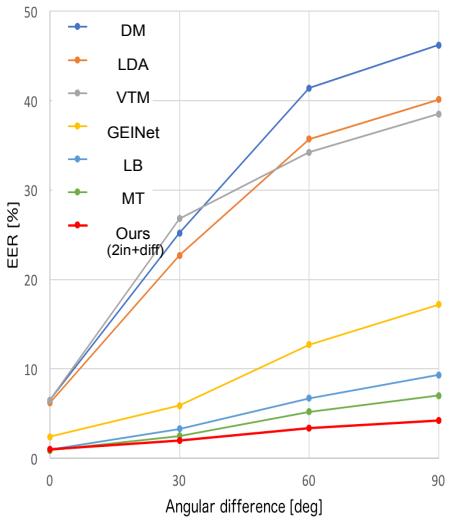
Rank-N identification rate（Subject about 5,000）

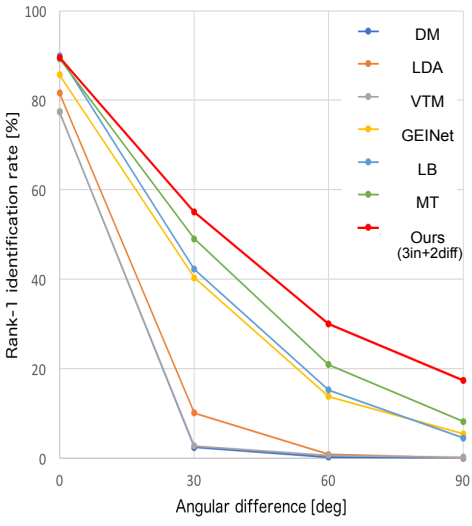


Comparison with benchmarks

Verification



Identification

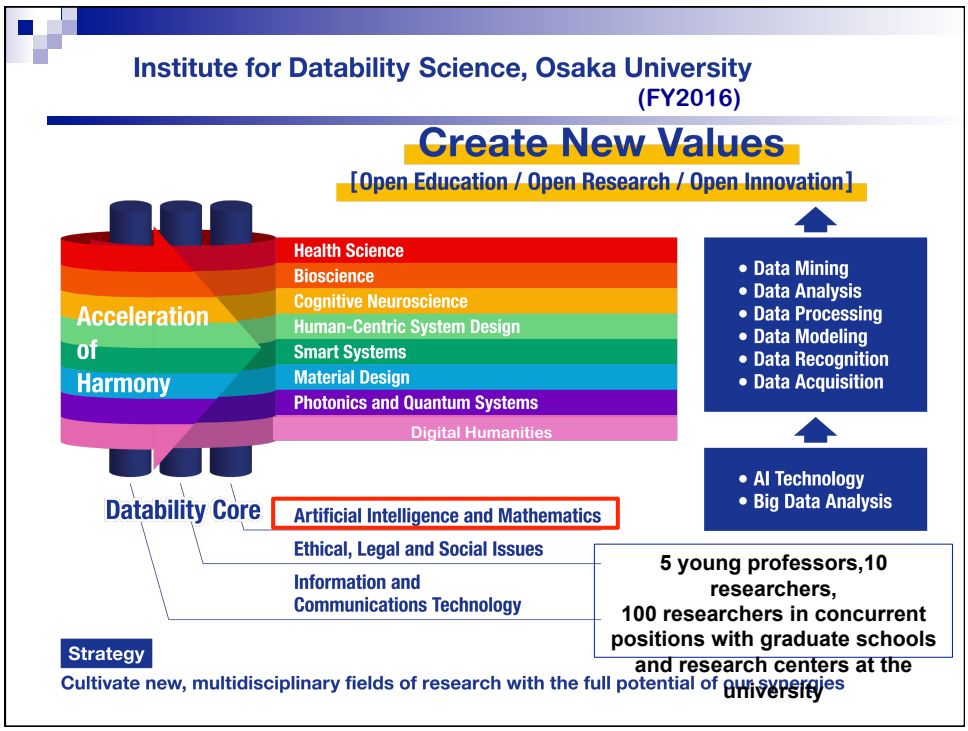


OU-ISIR Biometric Database

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

- *The OU-ISIR Gait Database*
  - *Treadmill Dataset*
    - **dataset A -Speed variation-**
    - **dataset B -Clothes variation-**
    - **dataset C -view variation-**
    - **dataset D -Gait fluctuation-**
  - *Speed Transition Dataset*
  - *Large Population Dataset (4,016 subjects)*
  - *Large Population Dataset with Bag* (1,034 subjects)
  - *Large Population Dataset with Age* (63,846 subjects)
  - *Multi-view Large Population Dataset (10,307 subjects)*
  - *Inertial Sensor Dataset*
  - *Similar Actions Inertial Dataset*
- *The OU-ISIR Biometric Score Database*

Please note that each corresponding signed release agreement is required to get the access to each dataset, i.e., required release agreements are different among datasets.



Missions of Institute for Datability Science

1 Data-driven research

- Matchmaking among researchers in different fields for collaboration
- Designing research plans with research field-specific know-hows

2 Databases ready for secondary uses and standardization

- Collecting data by opt-in anonymization in the circumstance of university's publicness

Databases of 1000 extras' behavior data and voluntary university staffs' life-log data, deeming the campus as Super Smart City

Linked databases of biological/medical data and clinical data

3 Practice-oriented human resource cultivation

- Task-oriented education program in OJT
- Wide coverage from basics to advanced (lectures and OJT)
- "Pick-as-you-want" style education program

Osaka University Hospital's Network

- Create a clinical research network to carry out joint research in response to social needs
- Gather useful evidence in clinics and develop advanced diagnostic and preventive methods
- Develop revolutionary methods of medical treatment and new drugs that lead to clinical application

1. Osaka University Hospital's technological base

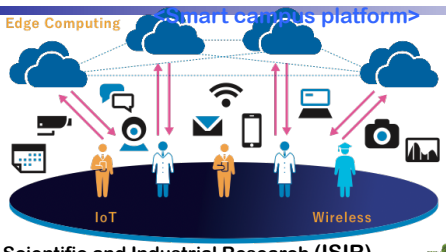
- Develop new methods of prevention care, individualized medicine, and innovative treatment of serious illnesses by strengthening research through big data analysis

2. A network involving relevant hospitals

- As the Core Clinical Research Hospital, Osaka University Hospital is launching a 10,000-bed network

By investing funds obtained through the practical application of research results into R&D and human resource development, the university will continuously contribute to cutting-edge medical development and clinical care.

Overall Plan of Super Smart Campus Project



<2016-2017>
- The Institute of Scientific and Industrial Research (ISIR)
  - 40 Cameras

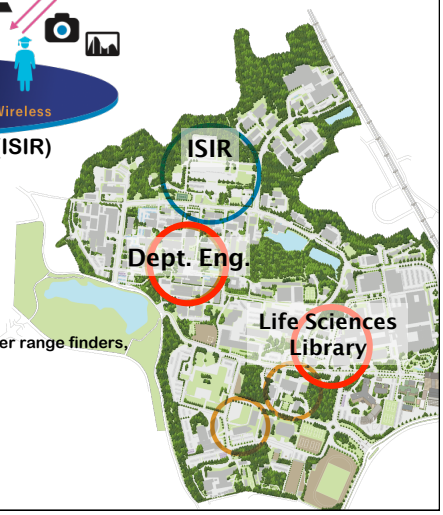
<2017-2018>
- Graduate School of Engineering

  Cafeteria
  - Cameras, WIFI access points, laser range finders, WIFI packet sensors, etc.

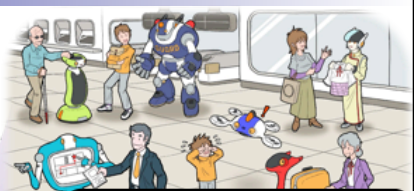
  Peripheral
  - Cameras, WIFI mesh network, WIFI access points, laser range finders, WIFI packet sensors, etc.
- Life Sciences Library

<2017-2019>
- Sports Ground at Toyonaka Campus

<2021->
- New Minoh Campus



Development of Human-Robot Symbiotic Society



Human and intelligent system symbiotic society

- Making elderly people stay active, by using assist by information and robot technology.
- Maintaining and raising QOL in the depopulating society.
- Building a sustainable and functional society by collaboration with local community.

Joint research for practical applications with companies

Archiving and distributing social data

Experimental environment on Minoh campus of Osaka Univ., where people from 70 countries make cultural exchange assisted by advanced IT

Minoh

Suita

Toyonaka

Experimental environments at Osaka University

Osaka City

Experimental environment in the Second Development Zone of the Northern (Umekita) Area of Osaka station (handling 2.4 million people per day)

2017 2022 2027 2050

THANKS FOR YOUR ATTENTION

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