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Towards Robust Gait Recognition

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  - Mr. Yusuke Fujihara
  - Ms. Betria Silvana Rossa
  - Mr. Ryo Kawai
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  - Mr. Ruochen Liao
  - Mr. Takuya Tanoue
  - Mr. Takuhiro Kimura
  - Mr. Jaemin Son

What is gait?

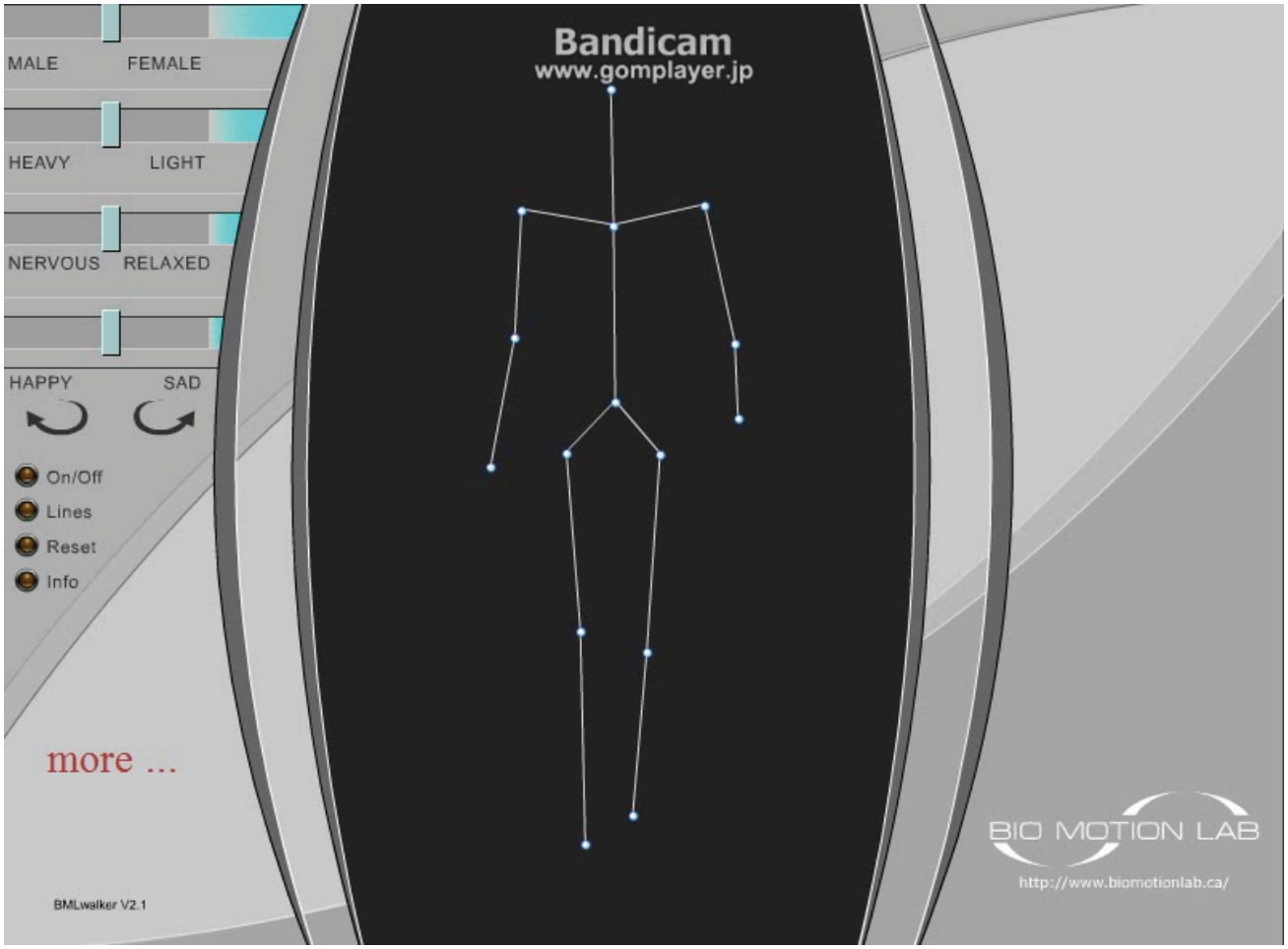
- Pattern of movement of the limbs of animals during locomotion over a solid substrate[1]

- Horse gait [2]

[1] Wikipedia. Gait — Wikipedia, the free encyclopedia, 2013.
[2] http://youtu.be/uG4NNaRttUE

Human gait -Biological motion-

- BMLwalker[3]

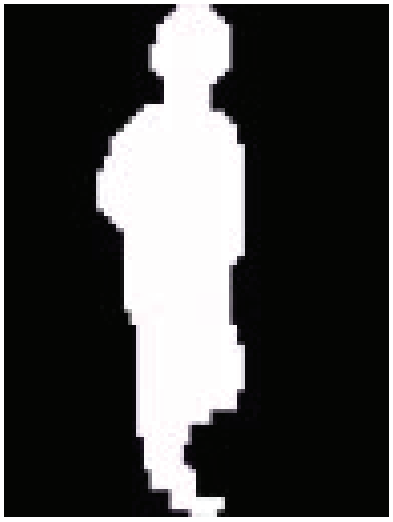
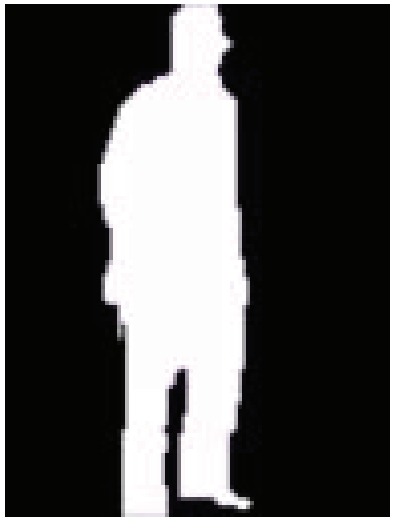
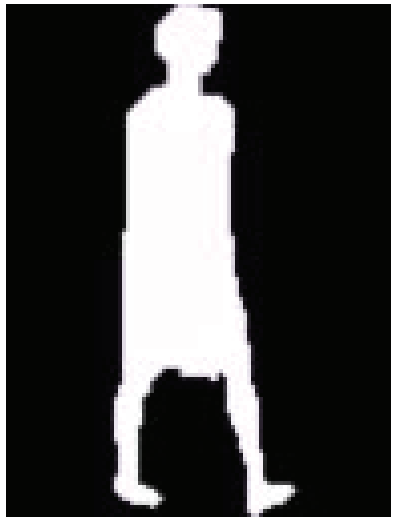


[3] BML walker, http://www.biomotionlab.ca/Demos/BMLwalker.html

Human gait -Age-

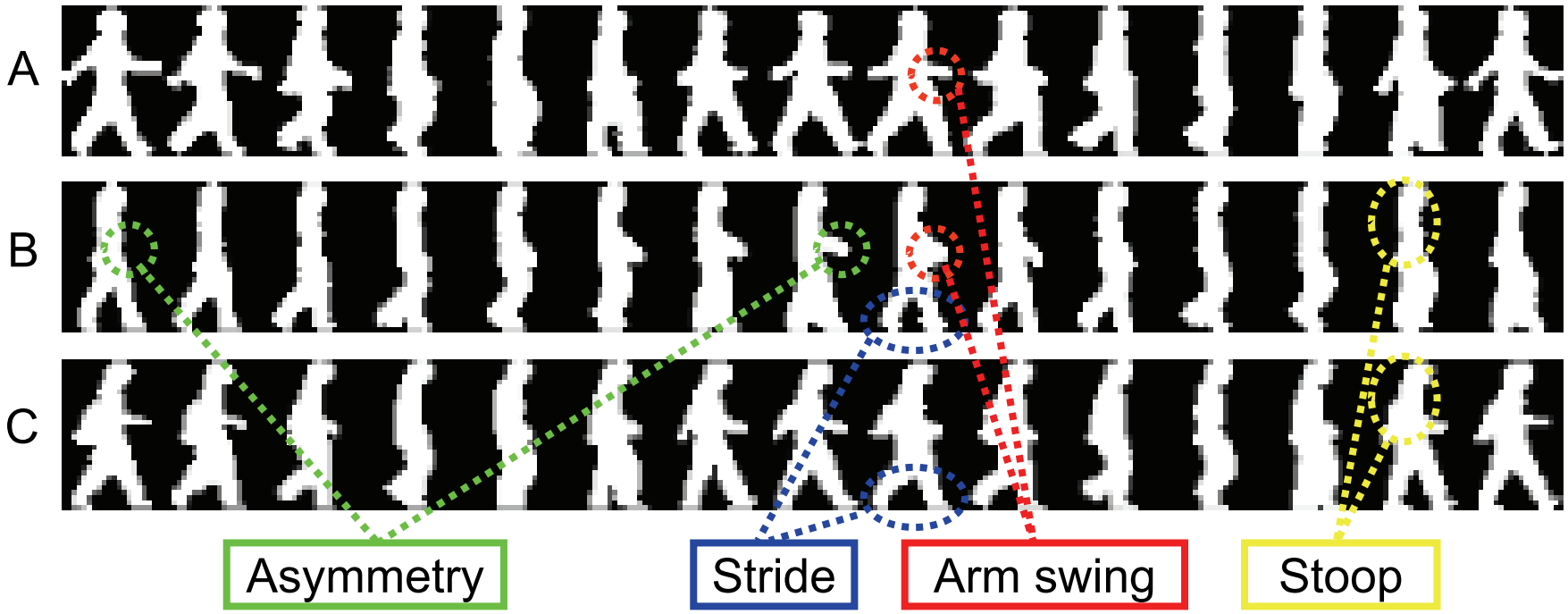
[Makihara et al. IJCB 2011]

- Quiz: How old are they?

Person	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. 24 years old B. 34 years old C. 44 years old

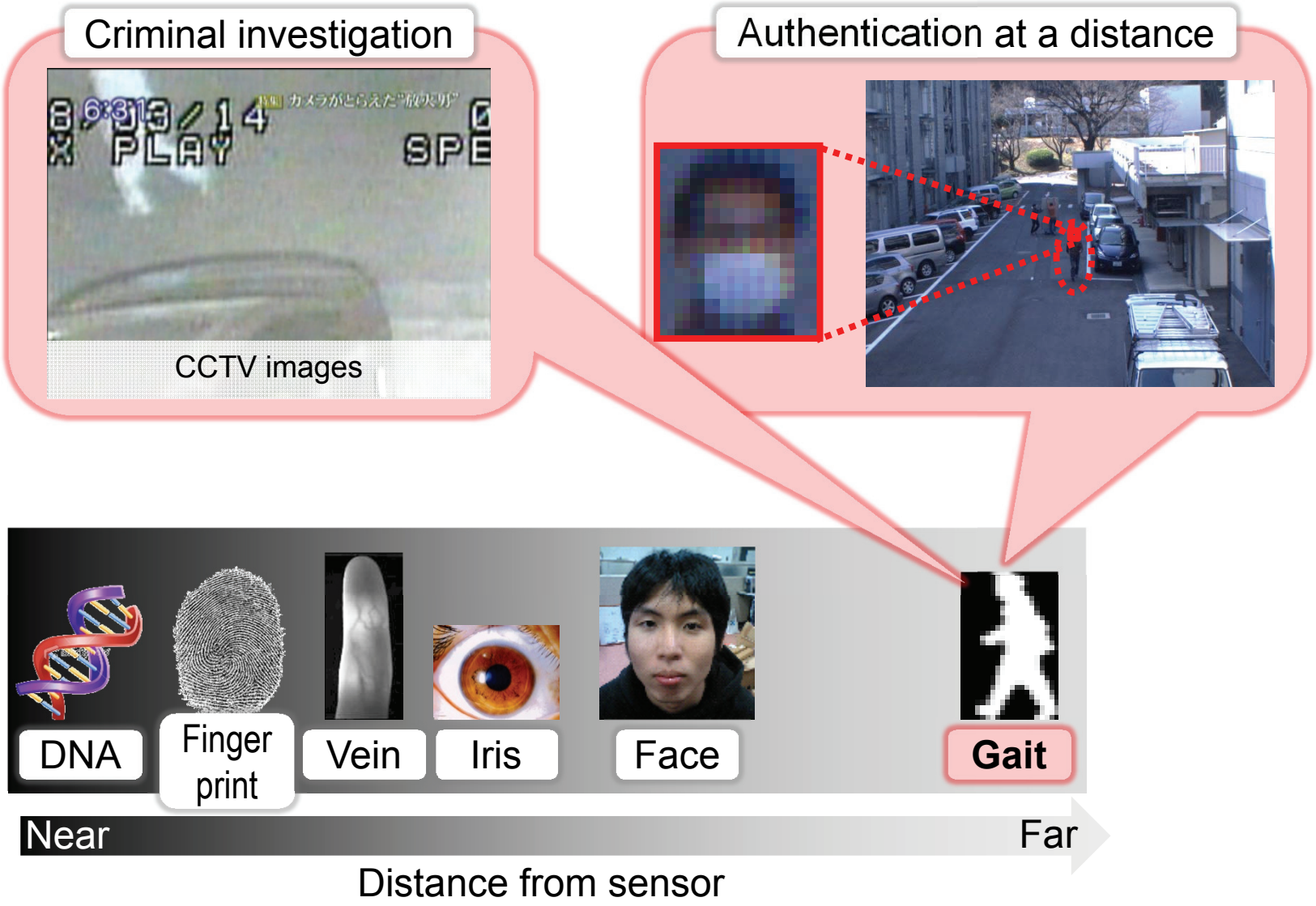
Human gait -Identity-

Human gait -Personality-



Gait recognition: Person authentication from gait

Why gait recognition?



Towards practical use in UK [4][5]

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.

Professor Mark Nixon hopes video matching will become widely used

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.

A burglar caught on CCTV was convicted thanks to his gait

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.

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.

[4] I. Bouchrika et al., `` On Using Gait in Forensic Biometrics,'' J. of Forensic Sciences, 56(4), 882-889, 2011.
[5] http://news.bbc.co.uk/2/hi/programmes/click online/7702065.stm, "How biometrics could change security," BBC News, 31 Oct. 2008.

Towards practical use in Japan

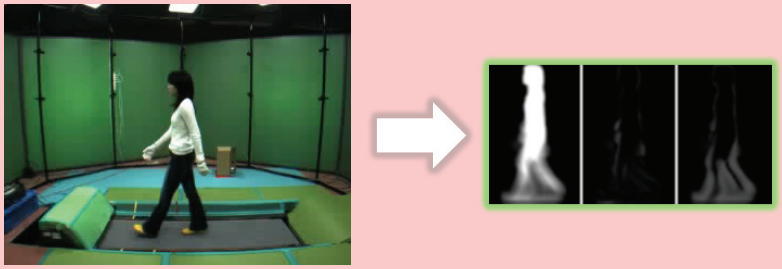
- First packaged gait verification system
  [Iwama et al. BTAS 2012, CVA 2013] [Muramatsu et al. ACPR 2013 Demo]

8 expert evidences requested by police

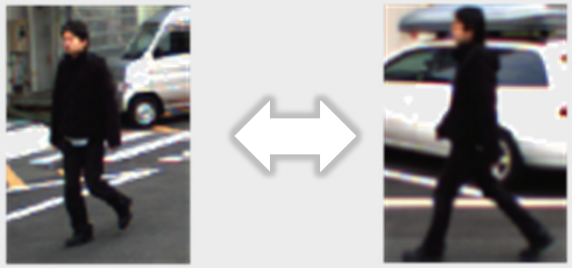
Basic approach
-Feature extraction and matching-

Contents

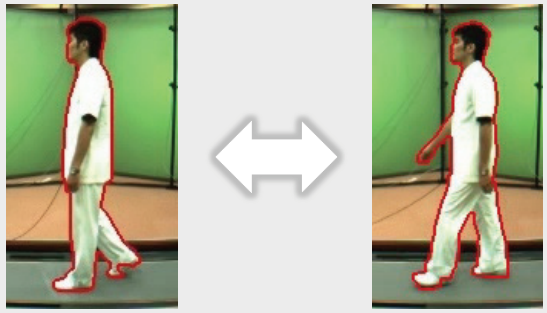
Basic approach



View invariance



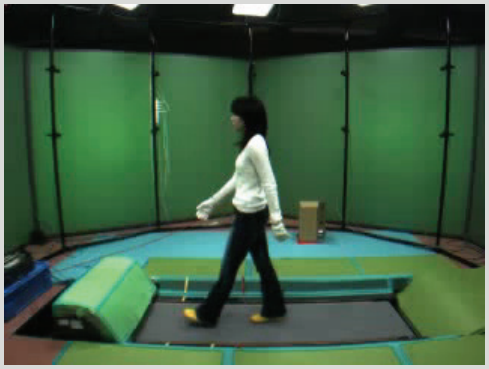
Speed invariance



Low frame-rate

Preprocess

Input



Background

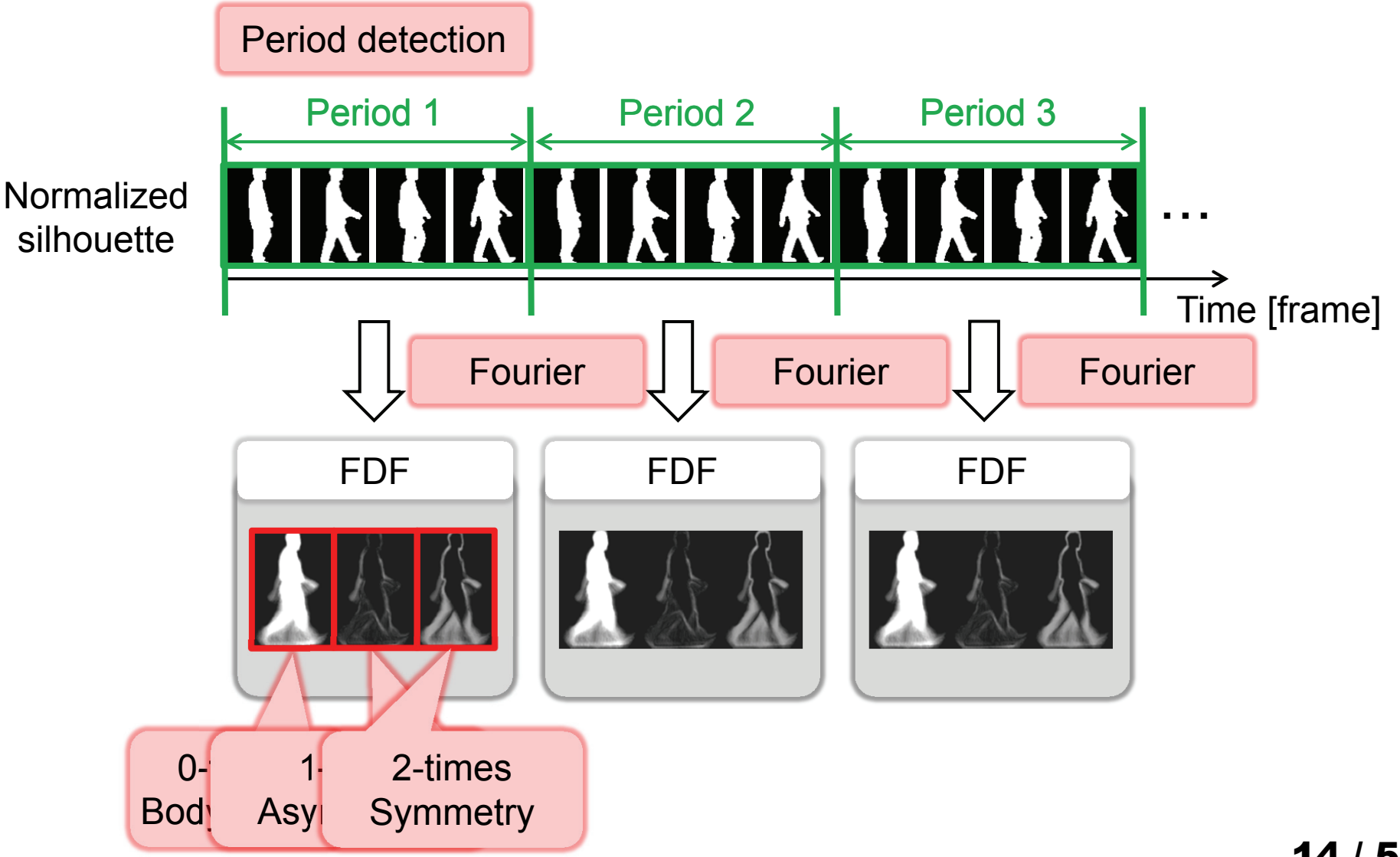
Silhouette

Background subtraction-based
graph-cut segmentation
[Makihara and Yagi 2008]

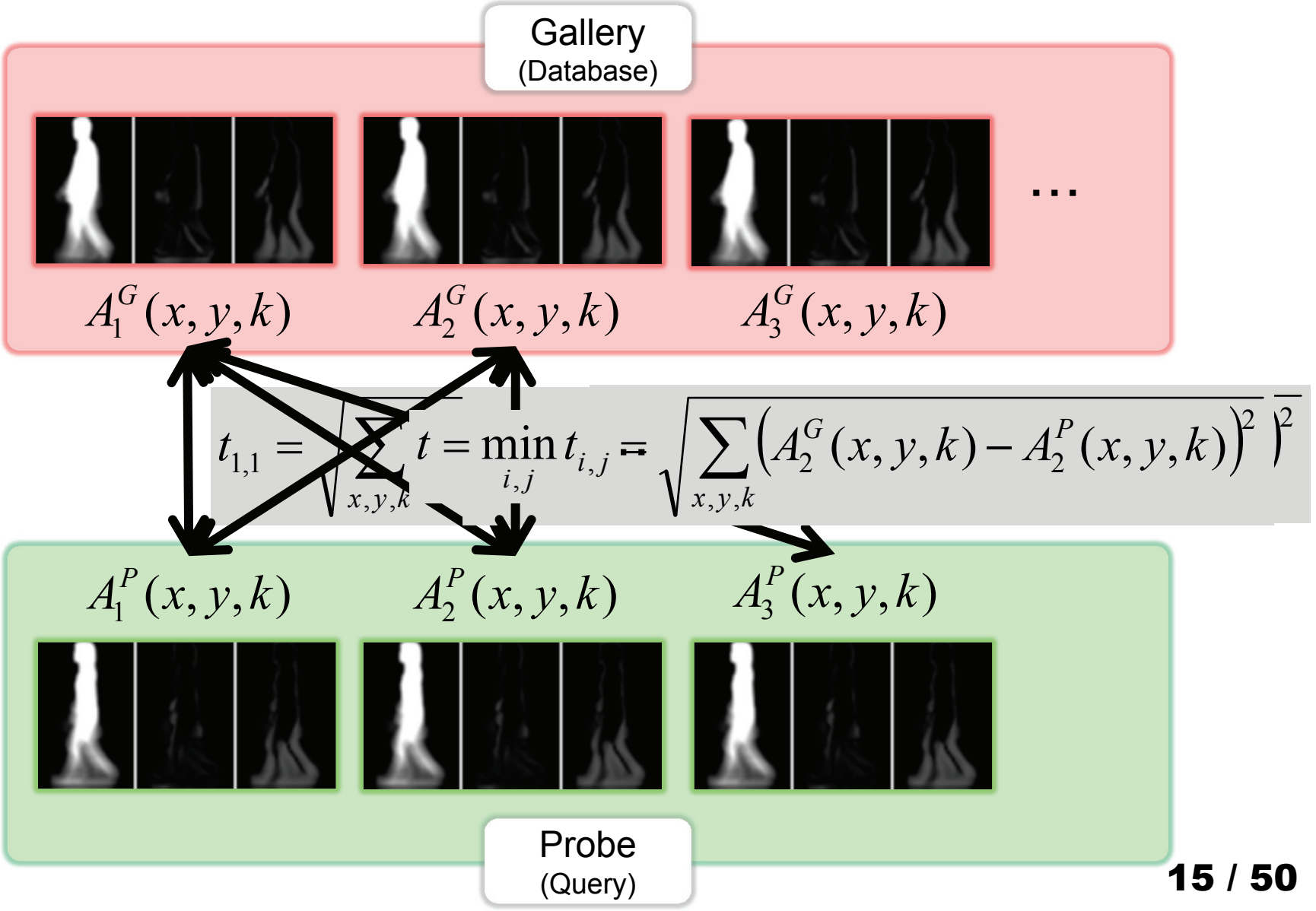
Normalized silhouette

Height normalization
Registration by gravity center

Frequency-domain feature (FDF)



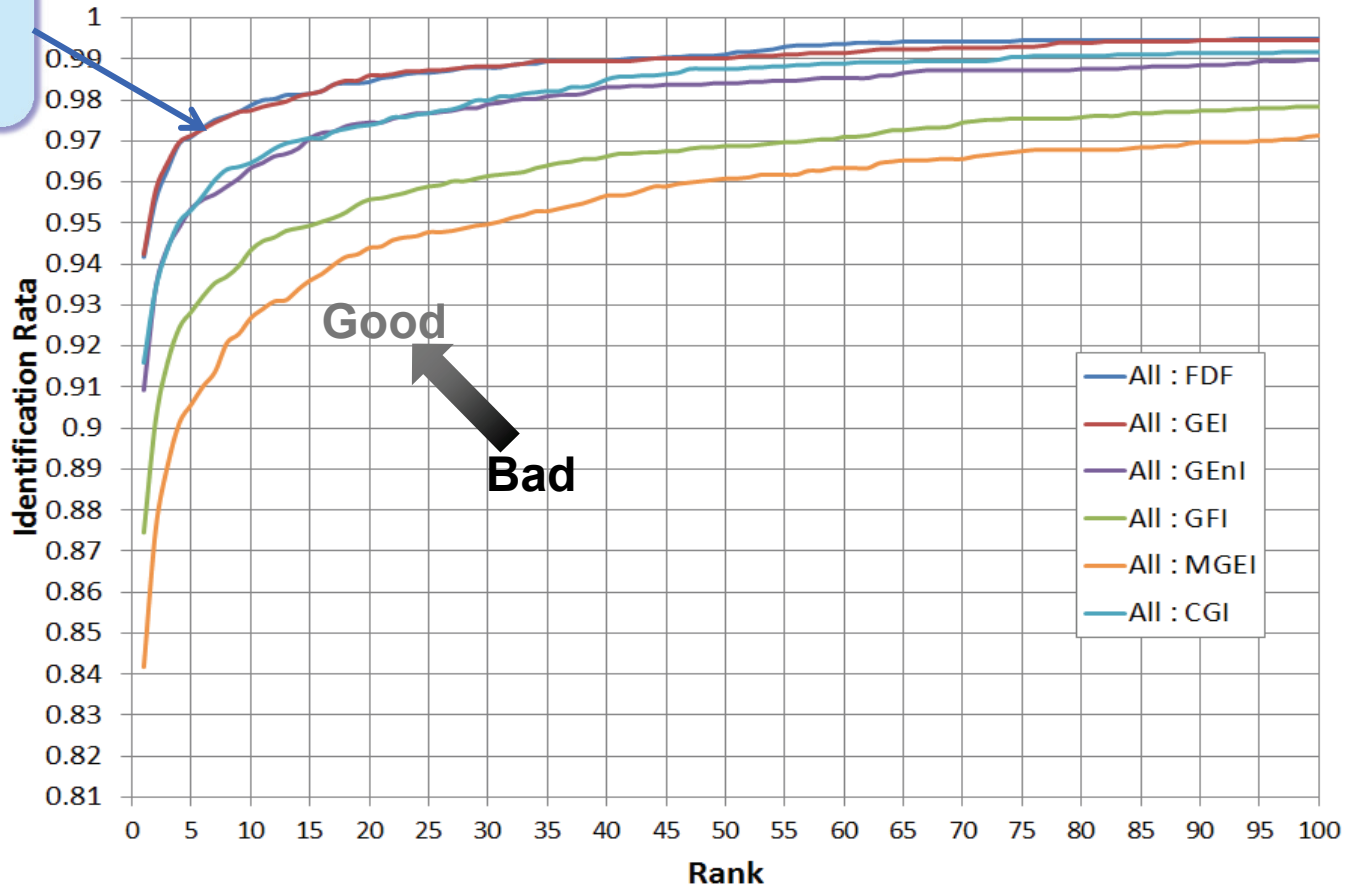
Matching -Dissimilarity measure-



Performance evaluation: Identification

[Iwama et al. IFS 2012]

FDF

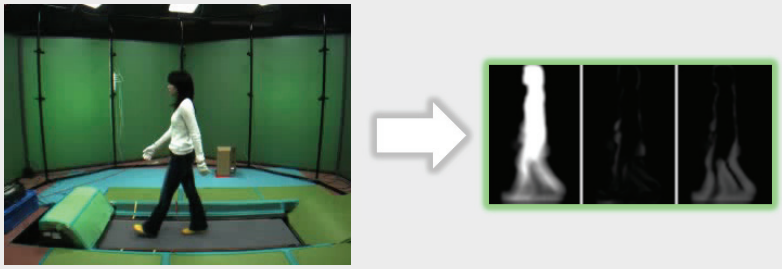


94% rank-1 identification rate (N = 3,141)

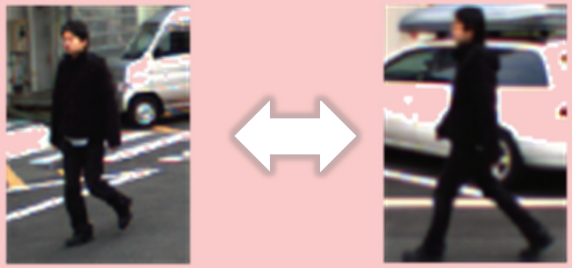
View-invariant Gait Recognition

Contents

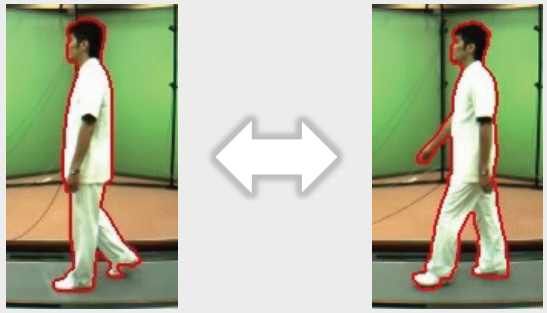
Basic approach



View invariance

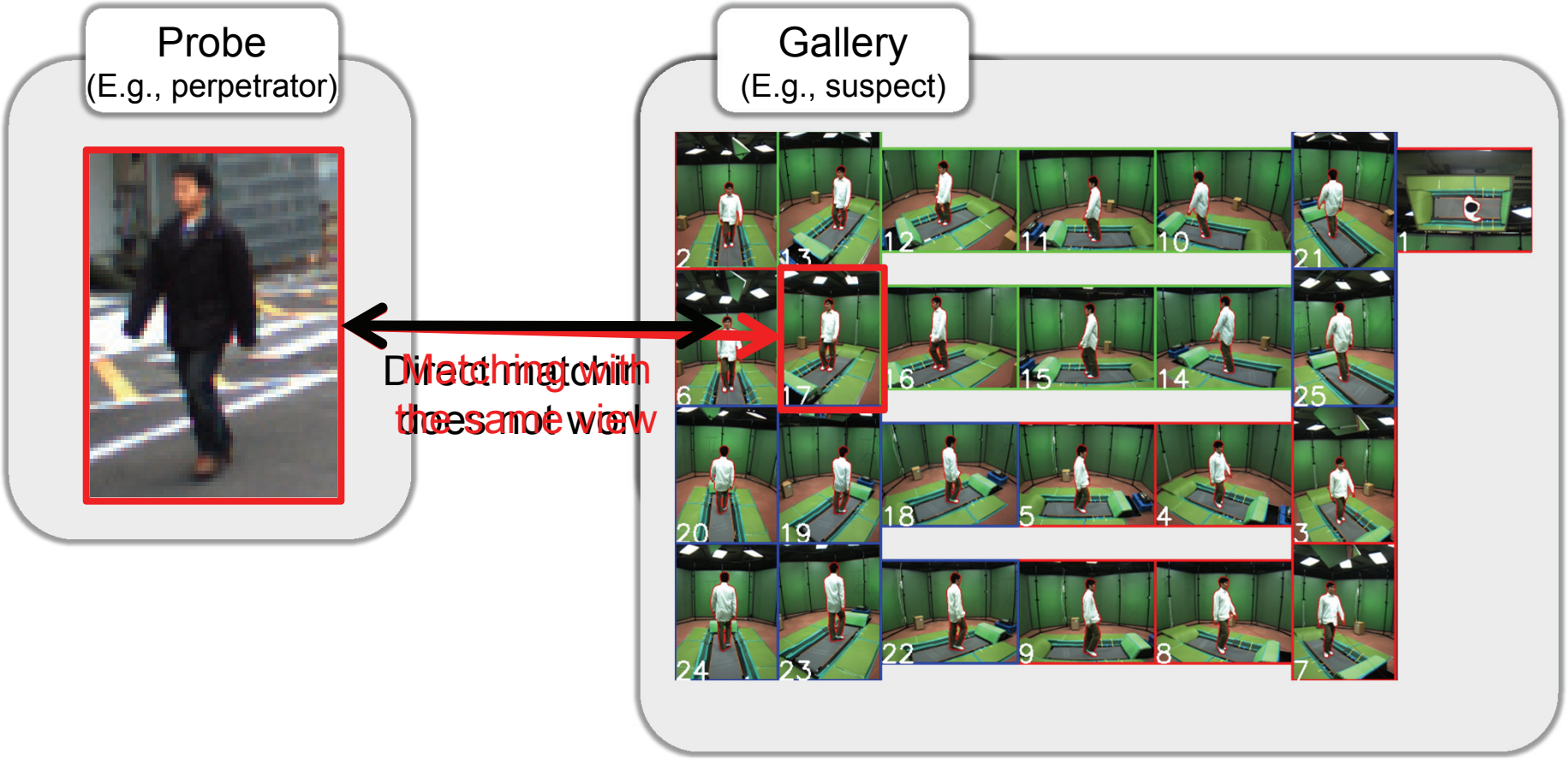


Speed invariance



Low frame-rate

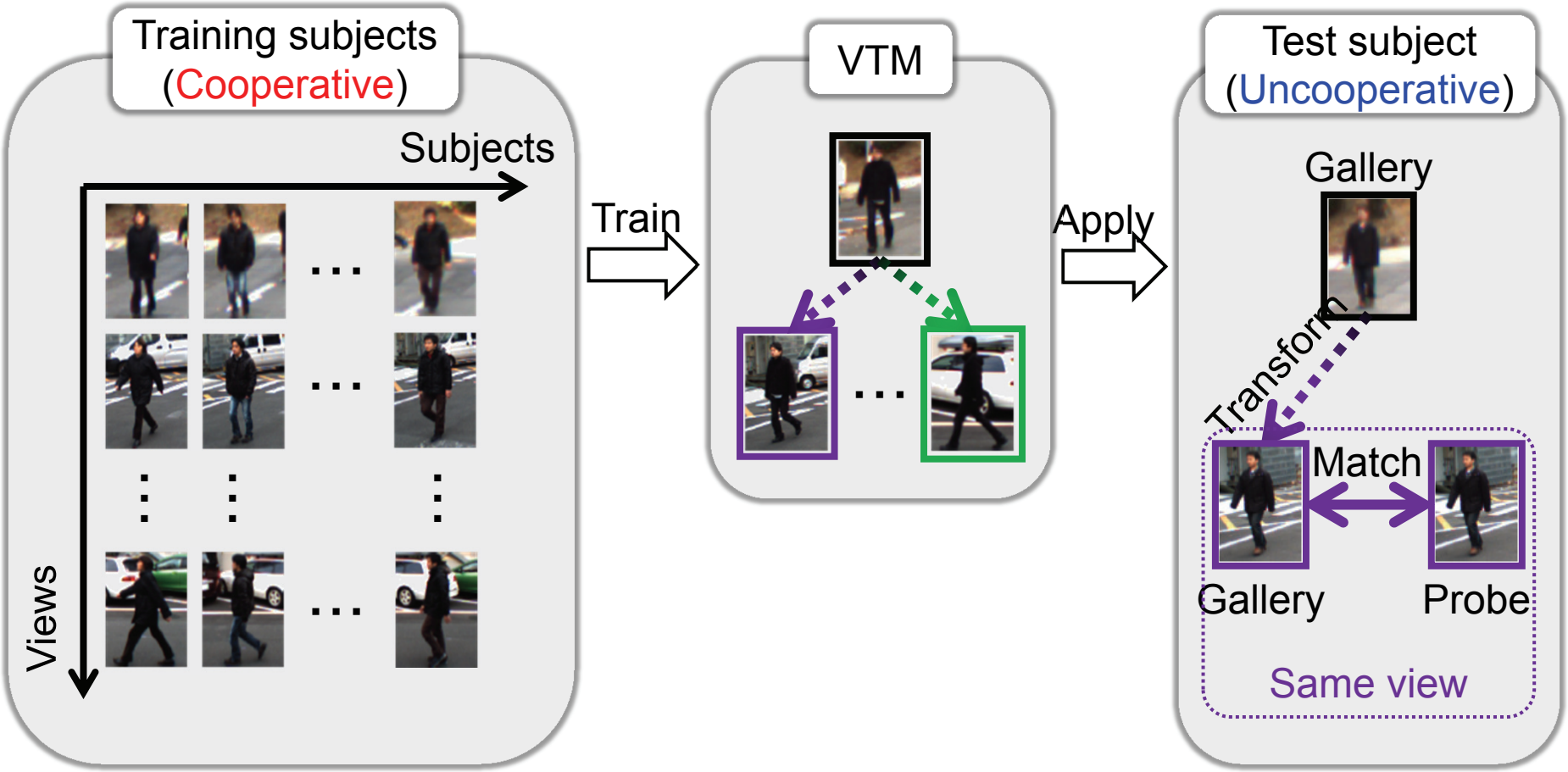
Challenge -View differences-



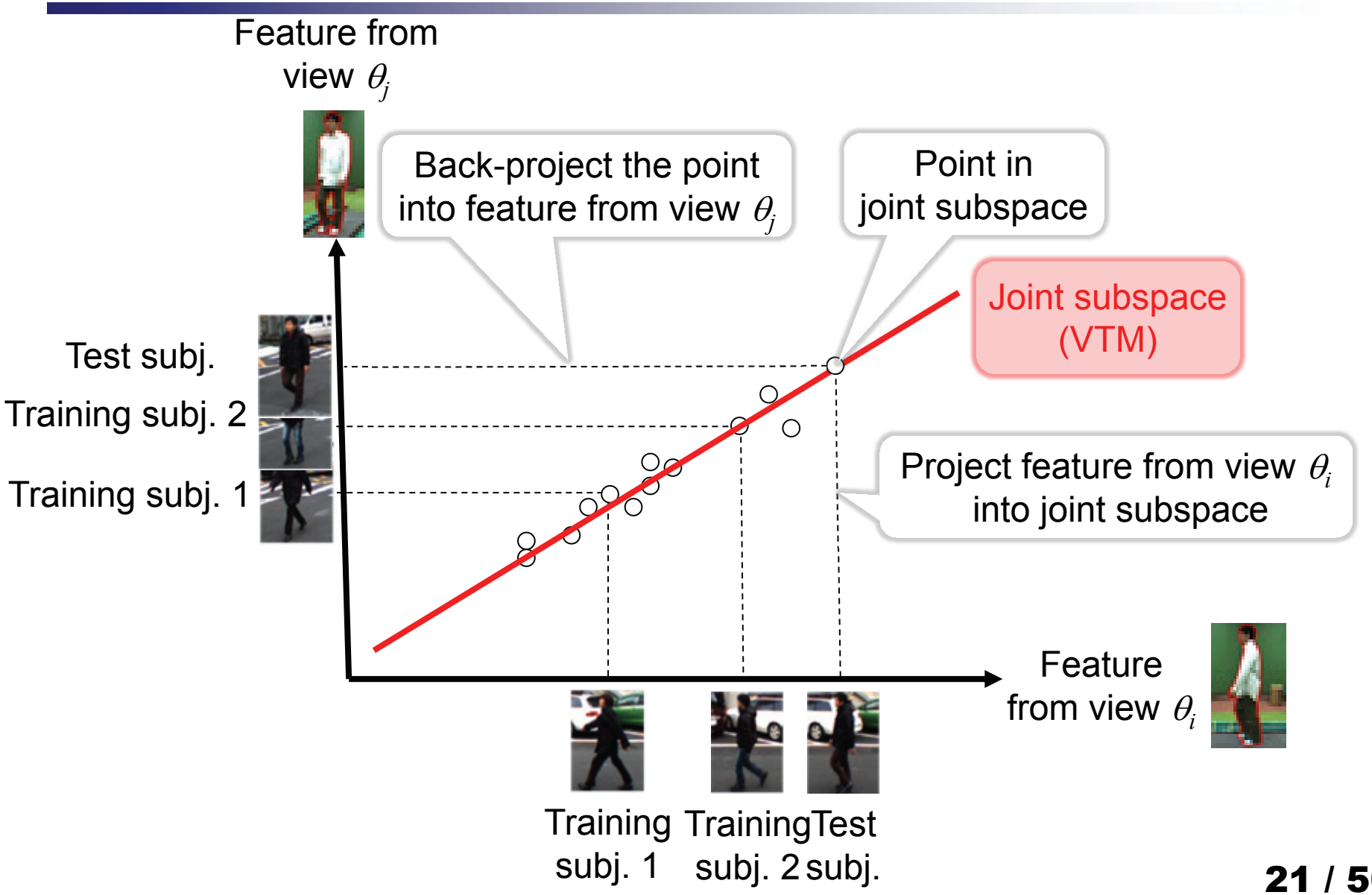
Difficult to collect multi-view gait features for uncooperative subject

View transformation model (VTM)

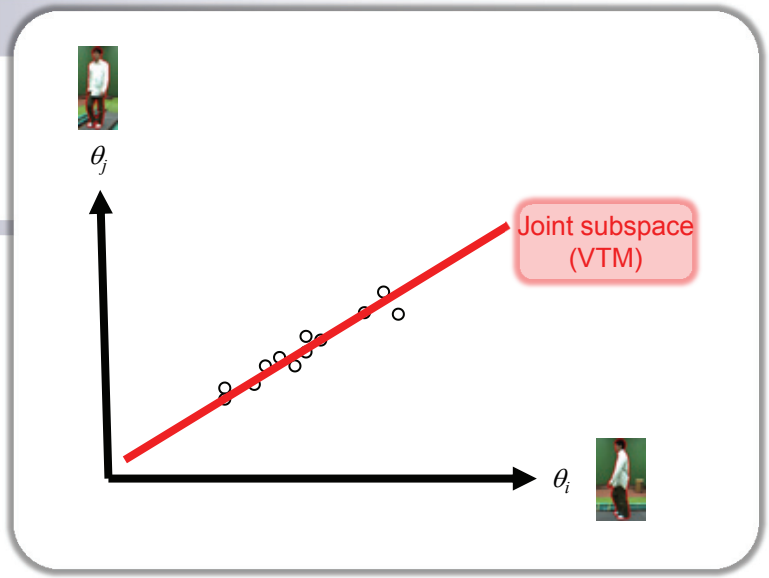
[Makihara et al. ECCV 2006]



How does it work?



Formulation
-Training VTM-



Individuals

Views

Training matrix

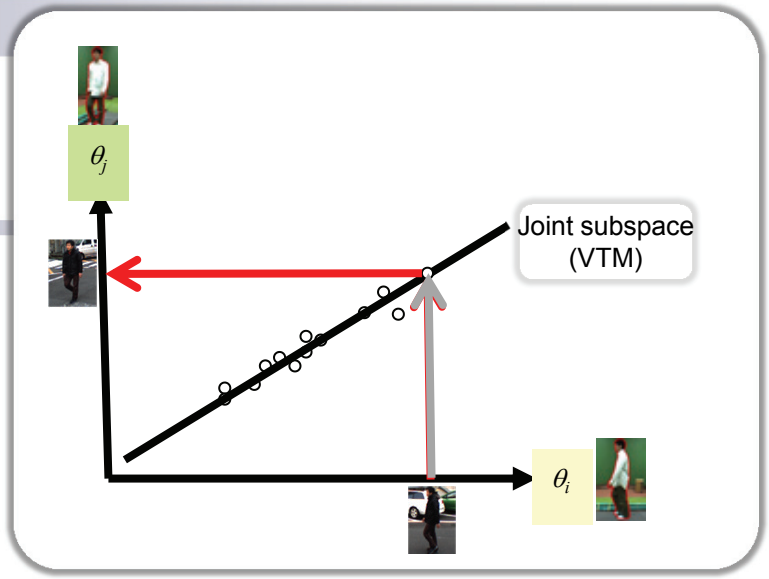
$$= \begin{bmatrix} P_{\theta_1} \\ P_{\theta_2} \\ \vdots \\ P_{\theta_K} \end{bmatrix} \begin{bmatrix} \boldsymbol{v}^1 & \boldsymbol{v}^2 & \cdots & \boldsymbol{v}^M \end{bmatrix}$$

Individual points in joint subspace

Joint subspace bases
(Projection matrix to each view feature)

Formulation

-Transformation from θ_i to θ_j -



- Project feature $\boldsymbol{a}_{\theta_i}$ to point $\boldsymbol{v}$ in joint subspace
  - Least square

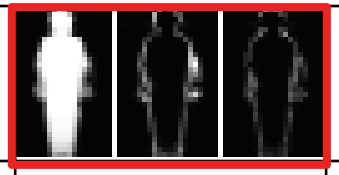
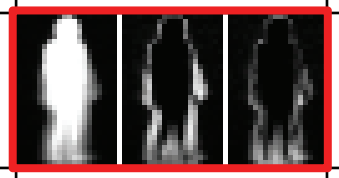
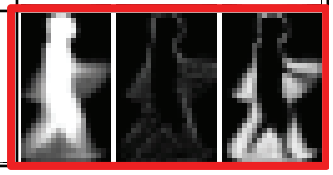
$$\hat{\boldsymbol{v}} = \arg\min_{\boldsymbol{v}} \left\| P_{\theta_i} \boldsymbol{v} - \boldsymbol{a}_{\theta_i} \right\| = P_{\theta_i}^{+} \boldsymbol{a}_{\theta_i}$$

- Back-project point $\hat{\boldsymbol{v}}$ in joint subspace into feature $\boldsymbol{a}_{\theta_j}$ from view θ_j

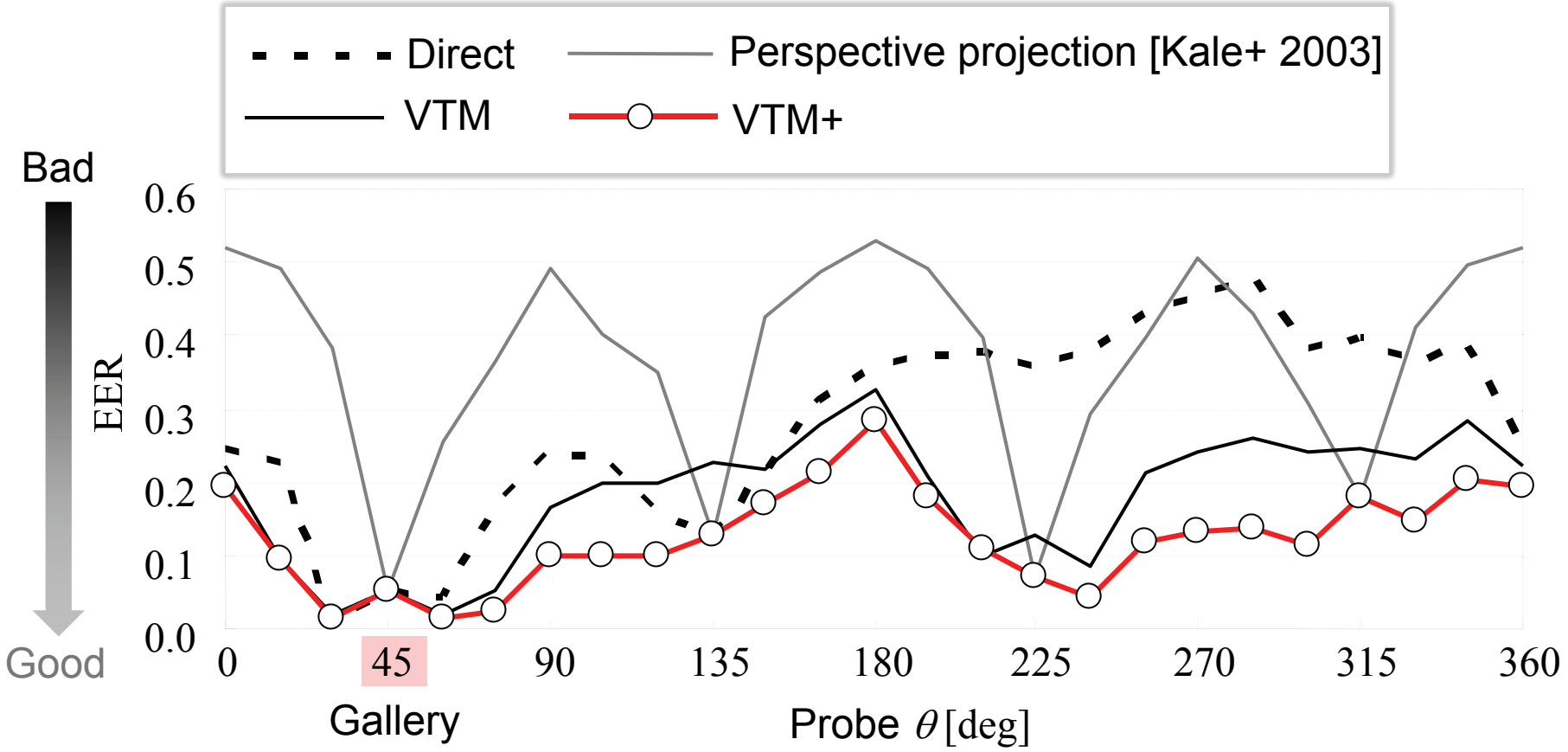
$$\hat{\boldsymbol{a}}_{\theta_j} = P_{\theta_j} \hat{\boldsymbol{v}} = P_{\theta_j} P_{\theta_i}^{+} \boldsymbol{a}_{\theta_i}$$

Transformation matrix

Transformation results

	Gallery		
0 deg			
15 deg			
30 deg			
45 deg			
60 deg			
75 deg			
90 deg			

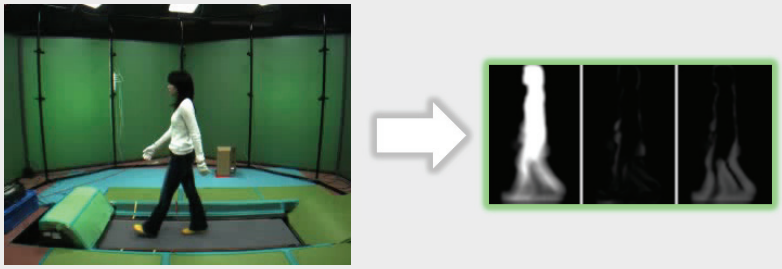
Performance evaluation: Verification



Speed-invariant Gait Recognition

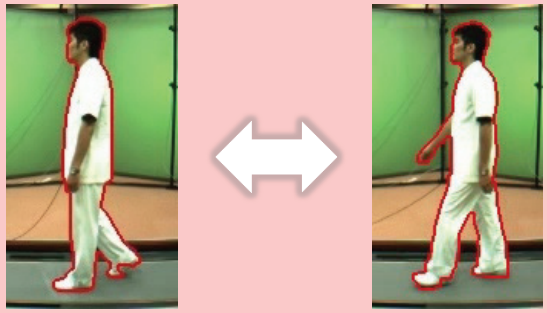
Contents

Basic approach



View invariance

Speed invariance

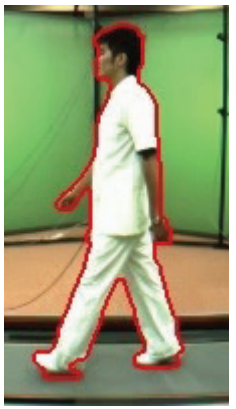


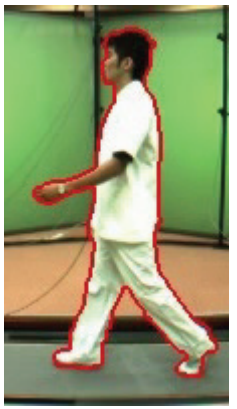
Low frame-rate

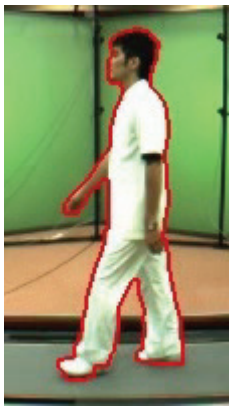
Challenge -Speed difference-


2 km/h


3 km/h


4 km/h


5 km/h


6 km/h


7 km/h

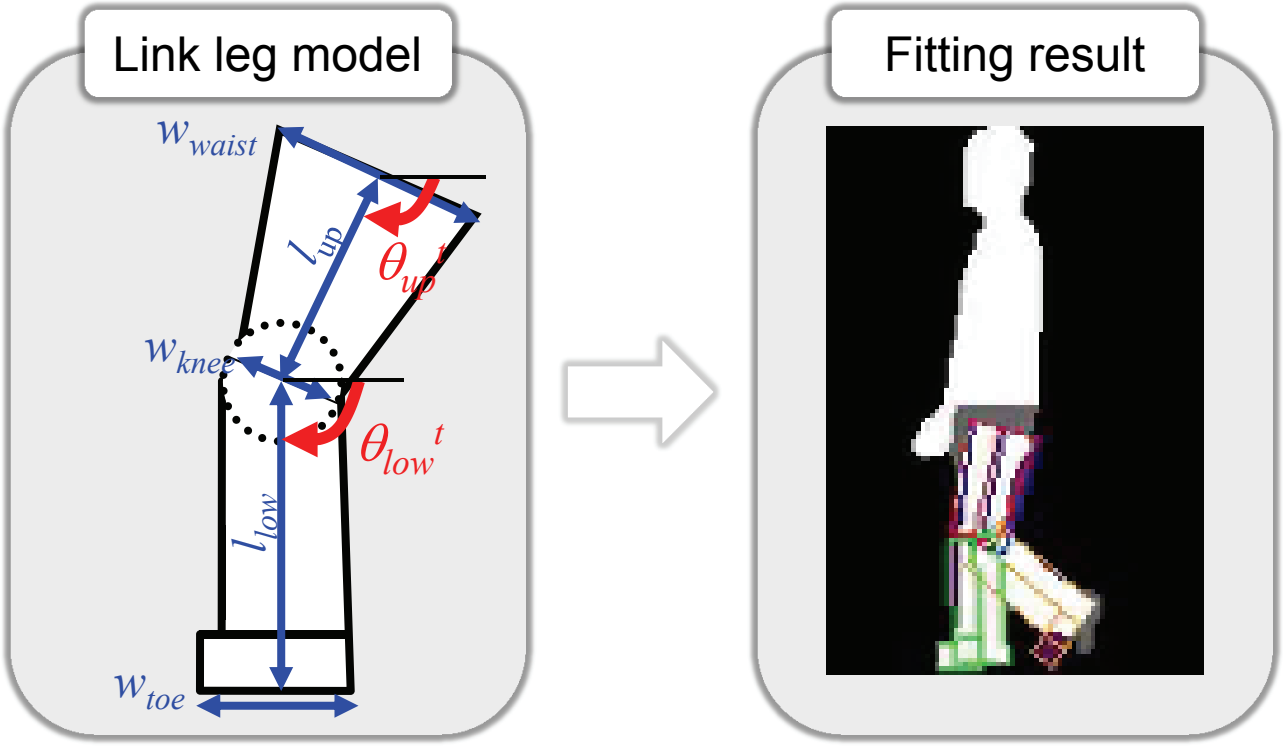

8 km/h


9 km/h


10 km/h

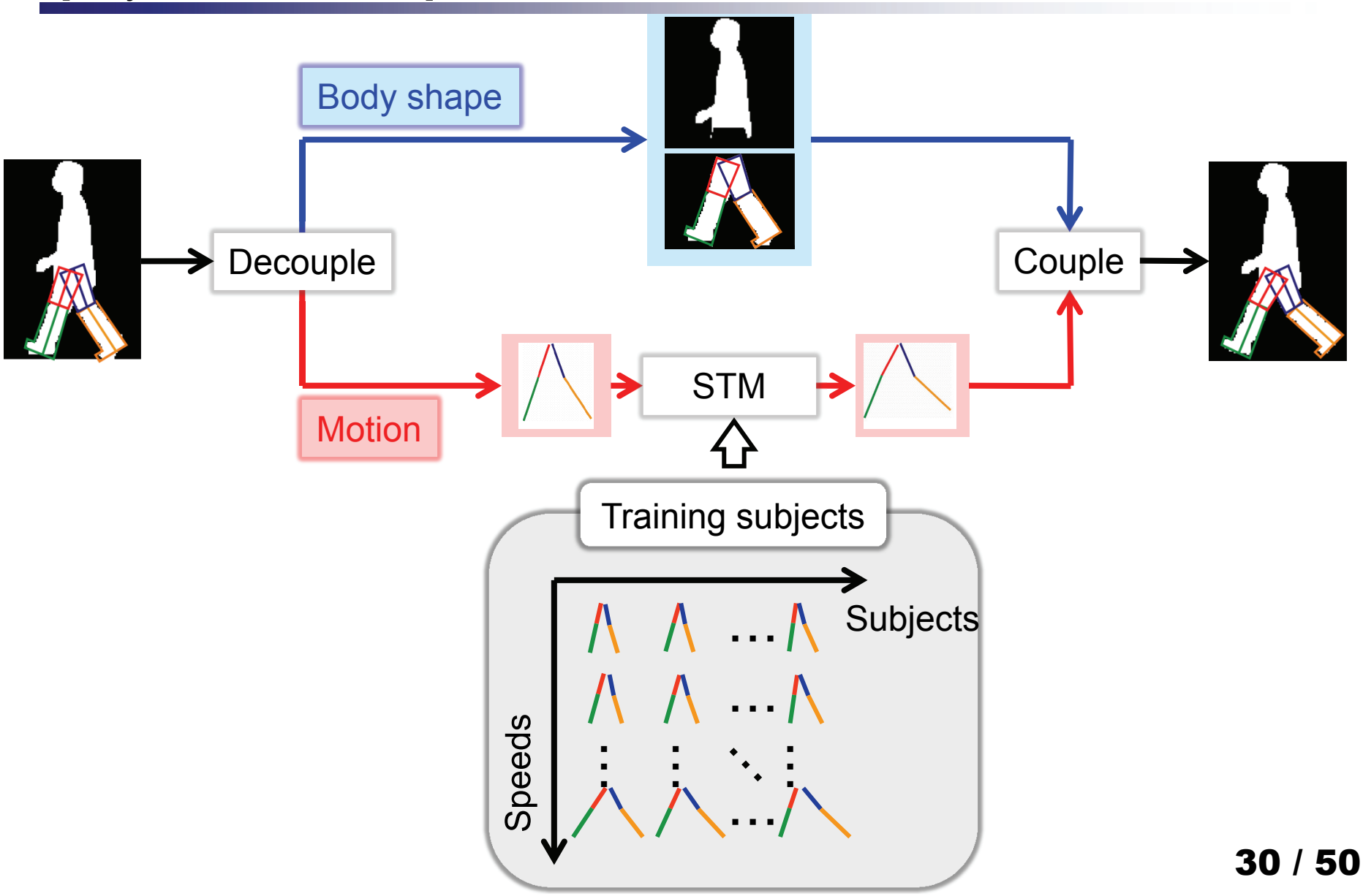
Human model fitting

- Energy minimization
  - Data term: Penalize diff. between model and silhouette
  - Smoothness term: Penalize abrupt joint angle changes

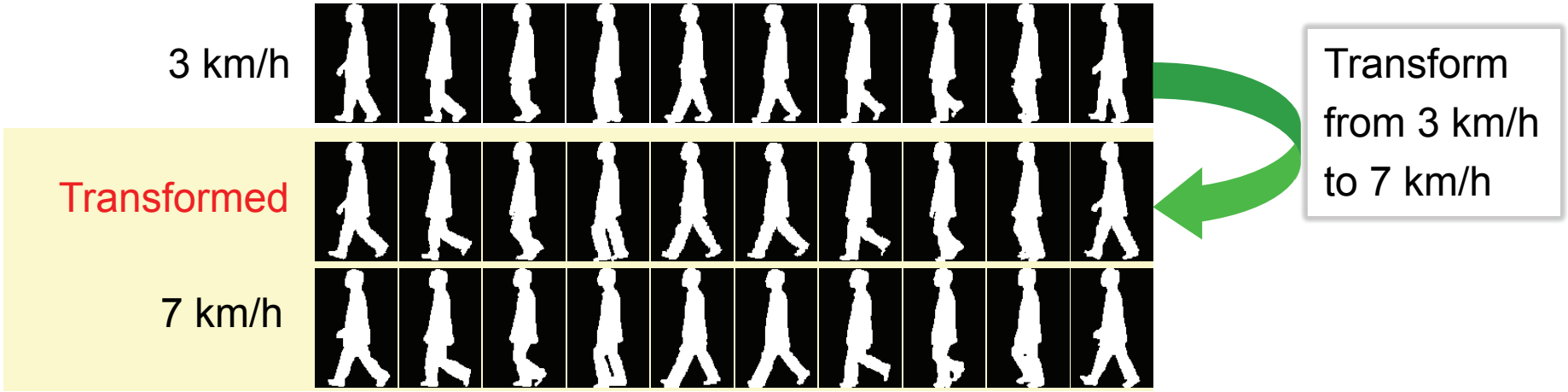


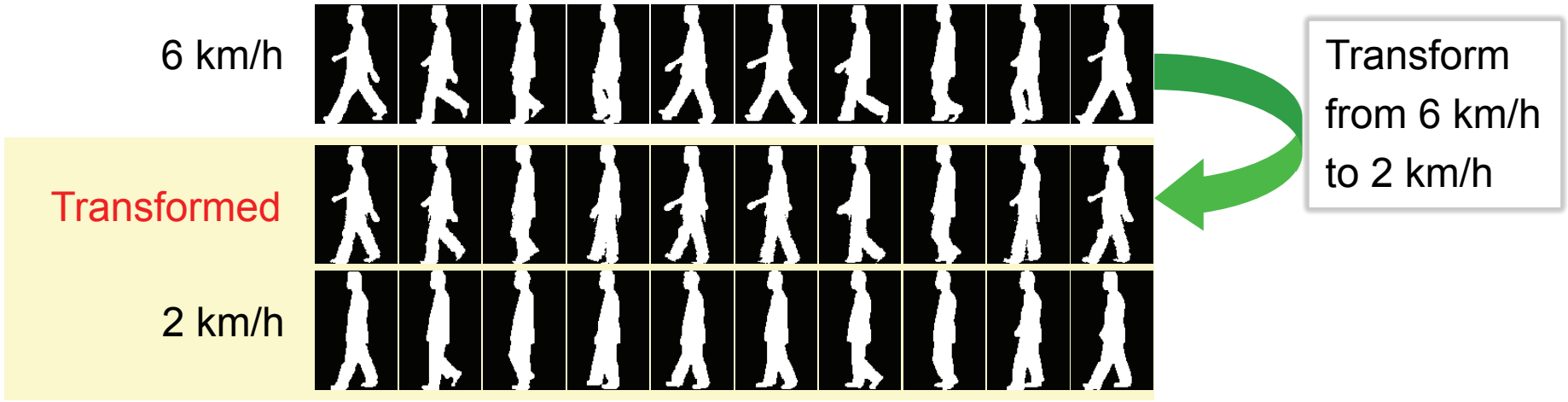
Speed transformation model (STM)

[Tsuji et al. CVPR 2010]



Transformation results





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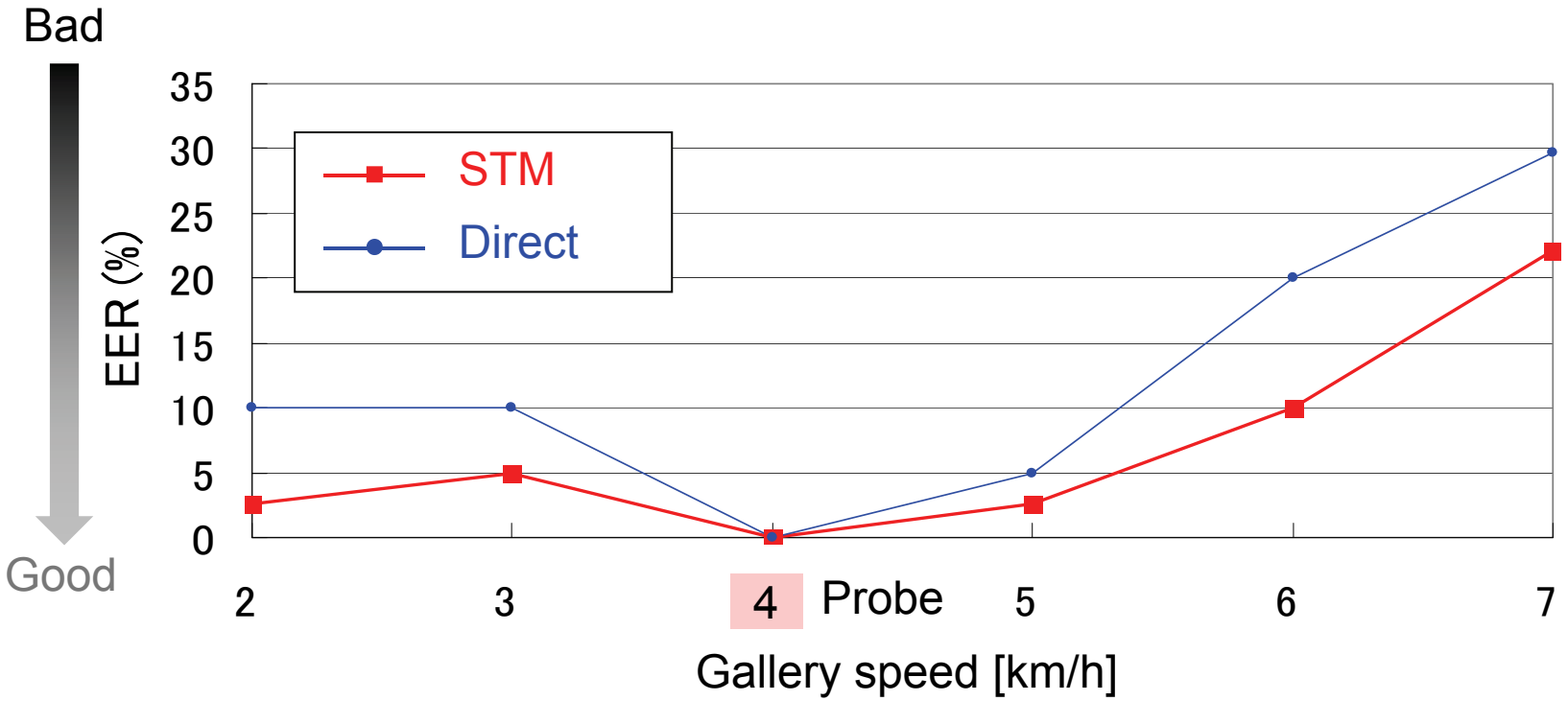
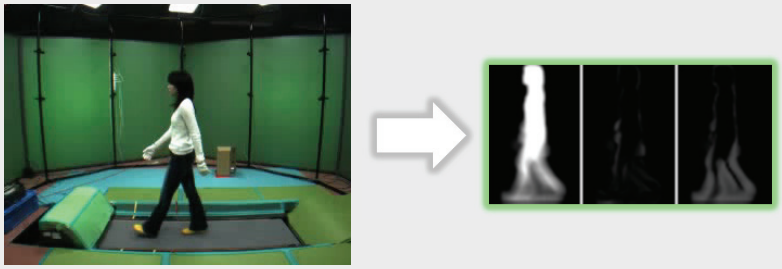


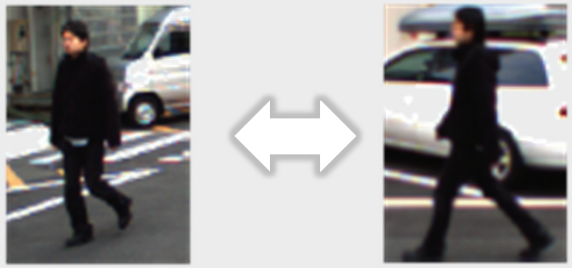
Gait Recognition from Low Frame-rate

Contents

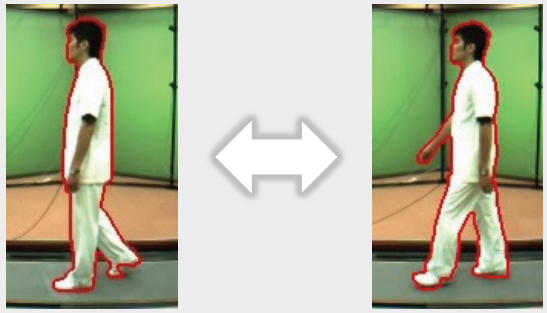
Basic approach



View invariance



Speed invariance



Low frame-rate

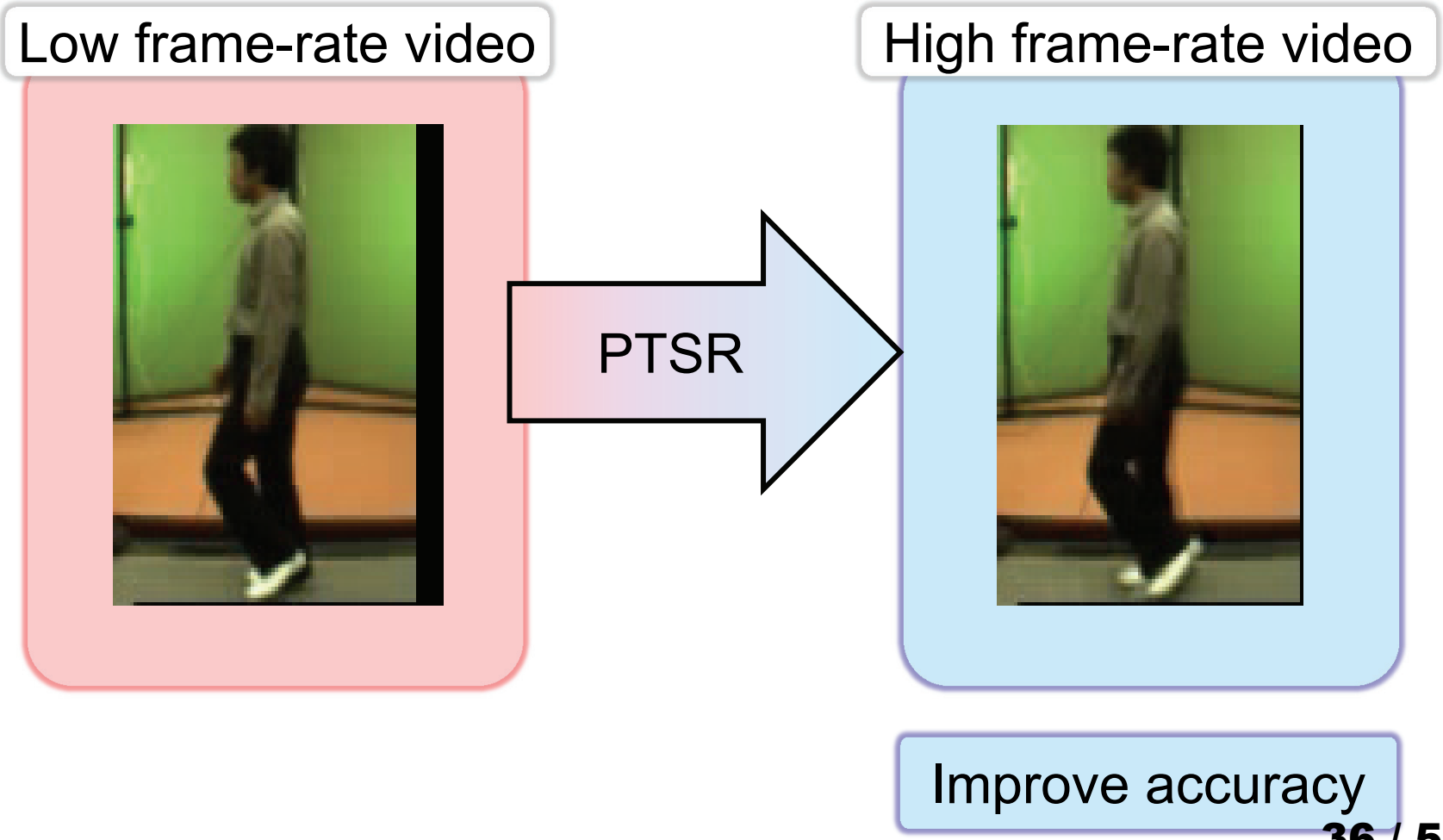
Challenge -Low frame-rate-

15 fps

1 fps

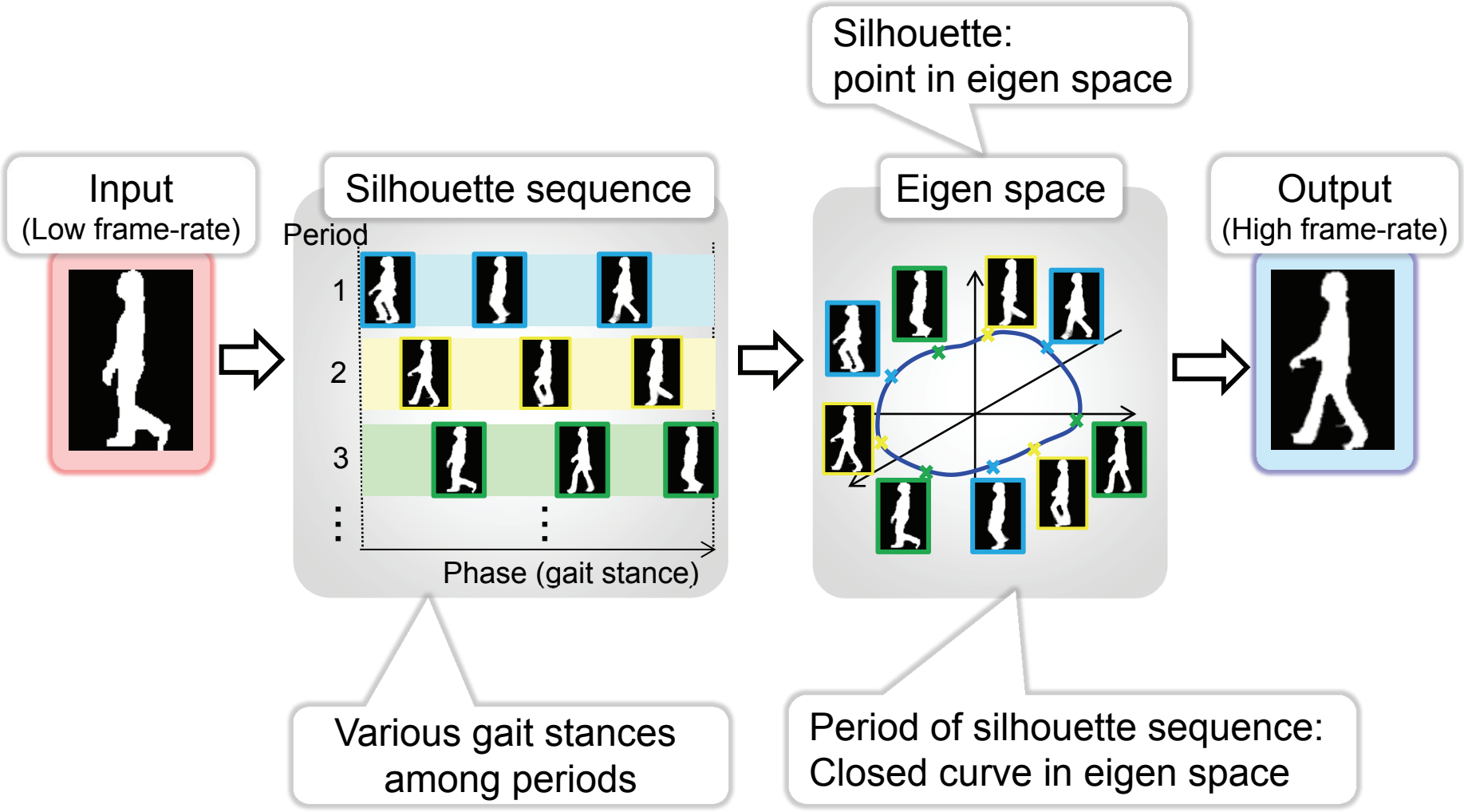
Solution

- Periodic Temporal Super Resolution (PTSR)



Reconstruction-based PTSR

-Overview- [Makihara et al. ACCV 2010]



Reconstruction-based PTSR

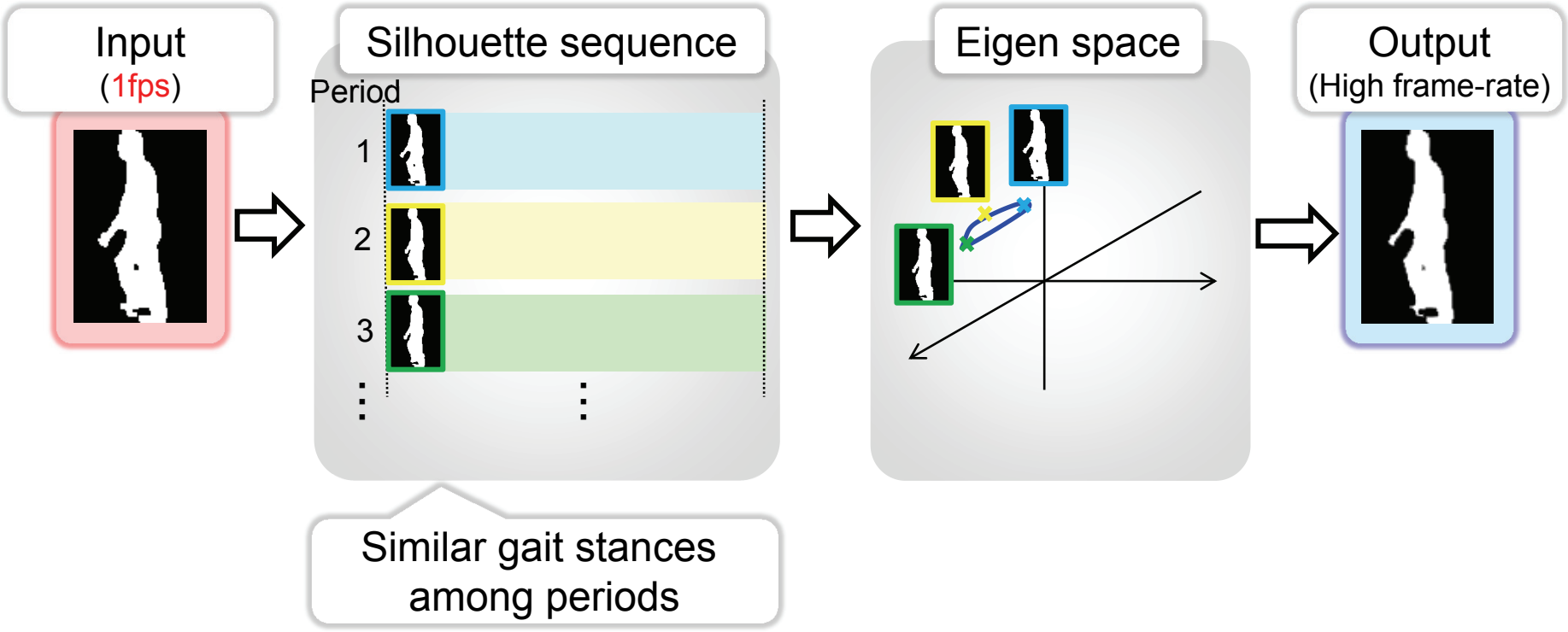
-Stroboscopic effect-

Sampling interval = period

It looks as if it is static!

Reconstruction-based PTSR

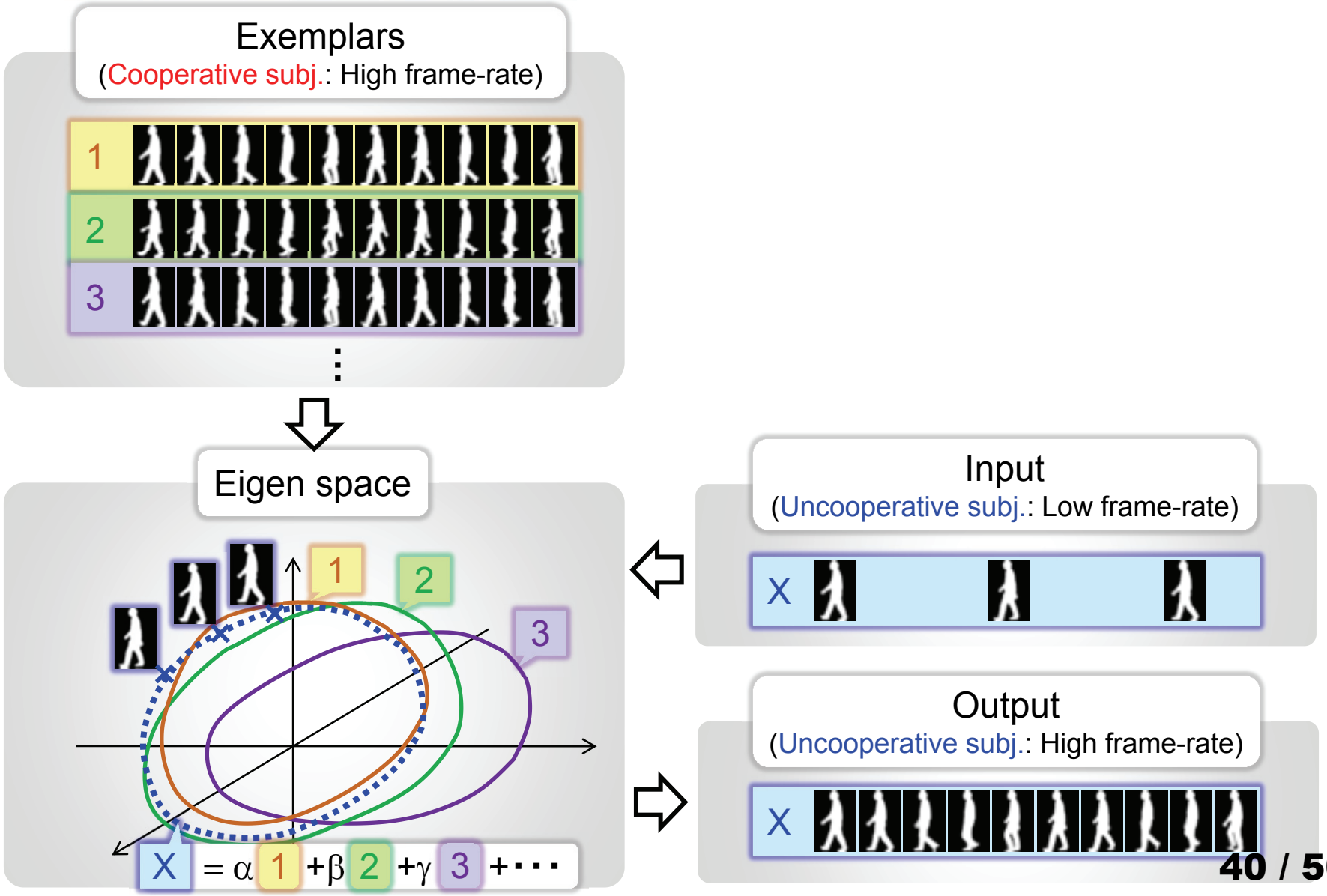
-Failure mode-



Fail under stroboscopic effect

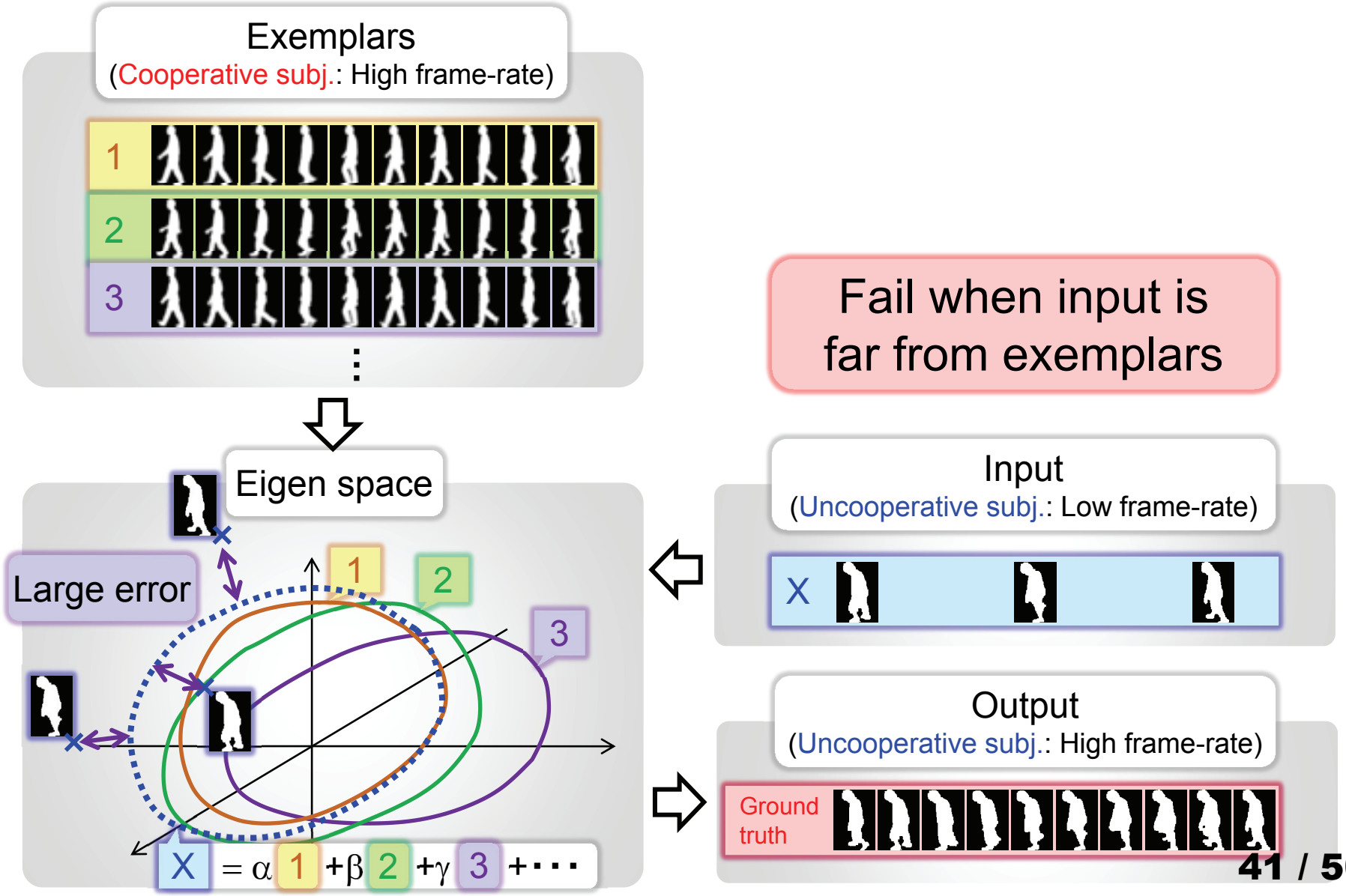
Example-based PTSR

-Overview-



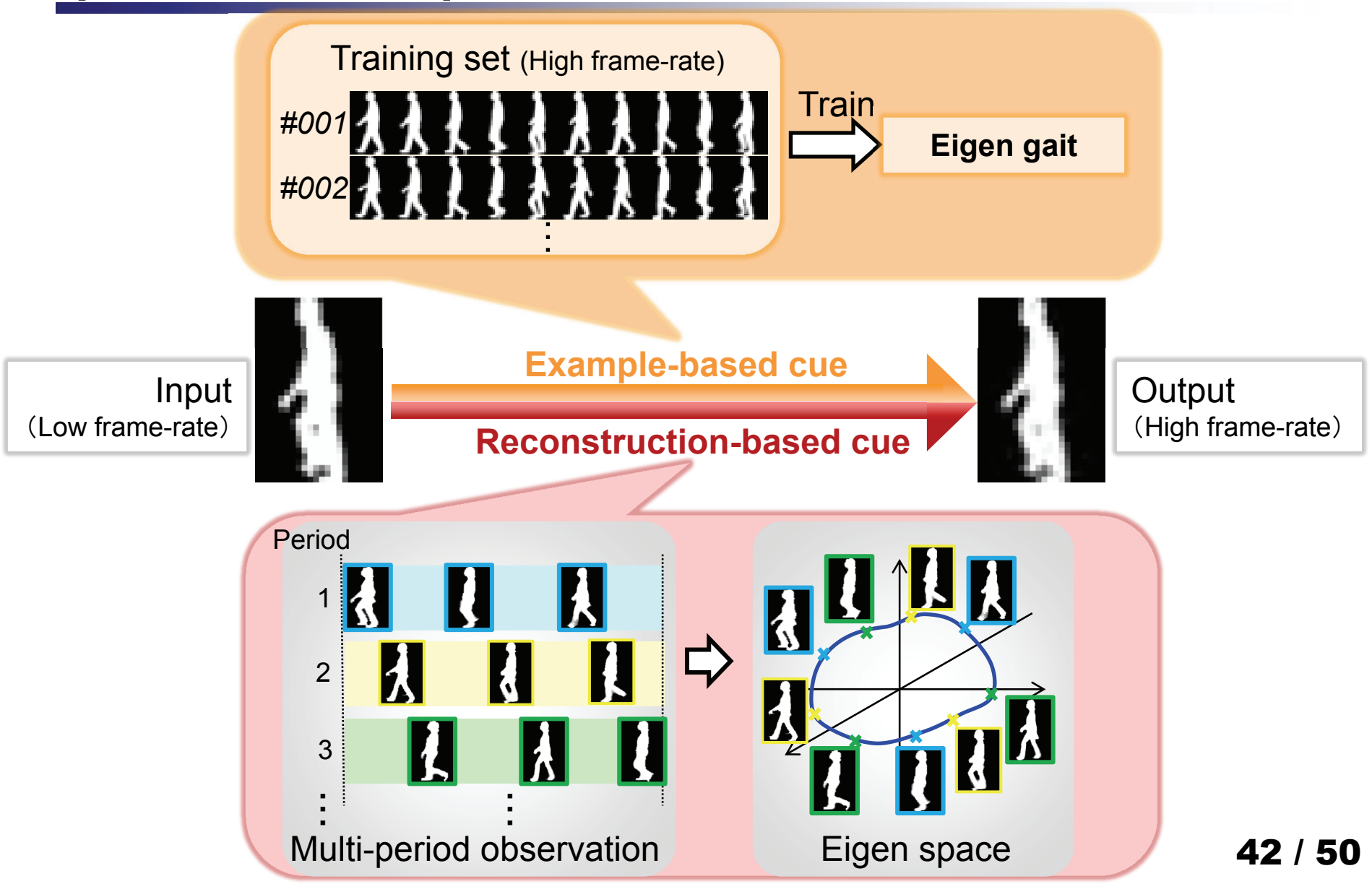
Example-based PTSR

-Failure mode-

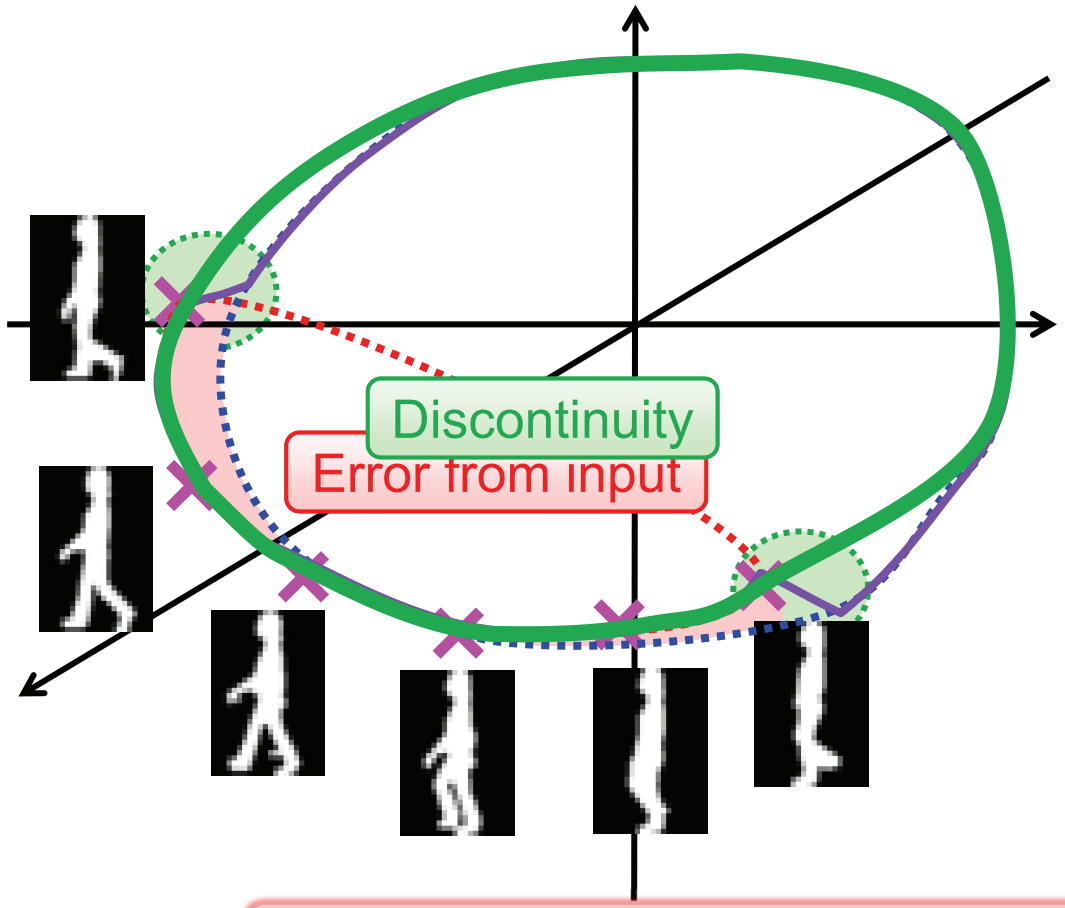


Unified approach to PTSR

[Akae et al. CVPR 2012]



How does it work?



Reconstruction-based

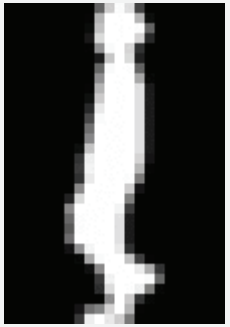
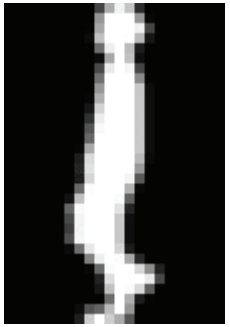
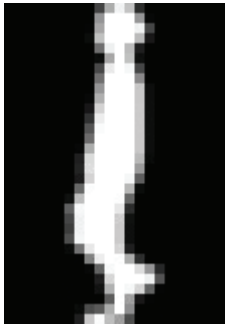
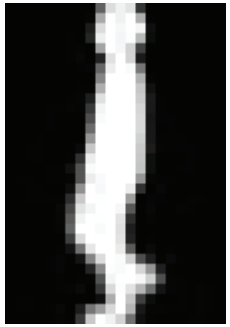
Example-based

Reconstruction
+ Example

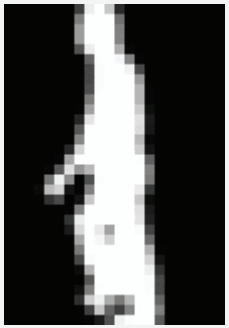
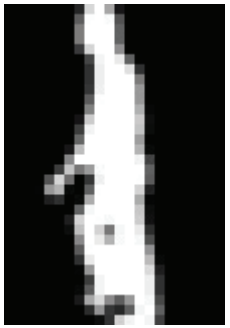
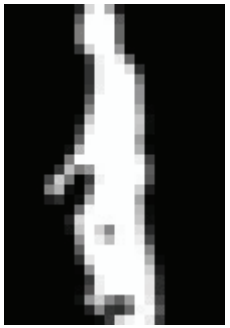
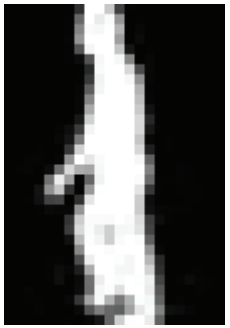
Reconstruction
+ Example
+ Prior (smoothness)

Solve by energy minimization framework

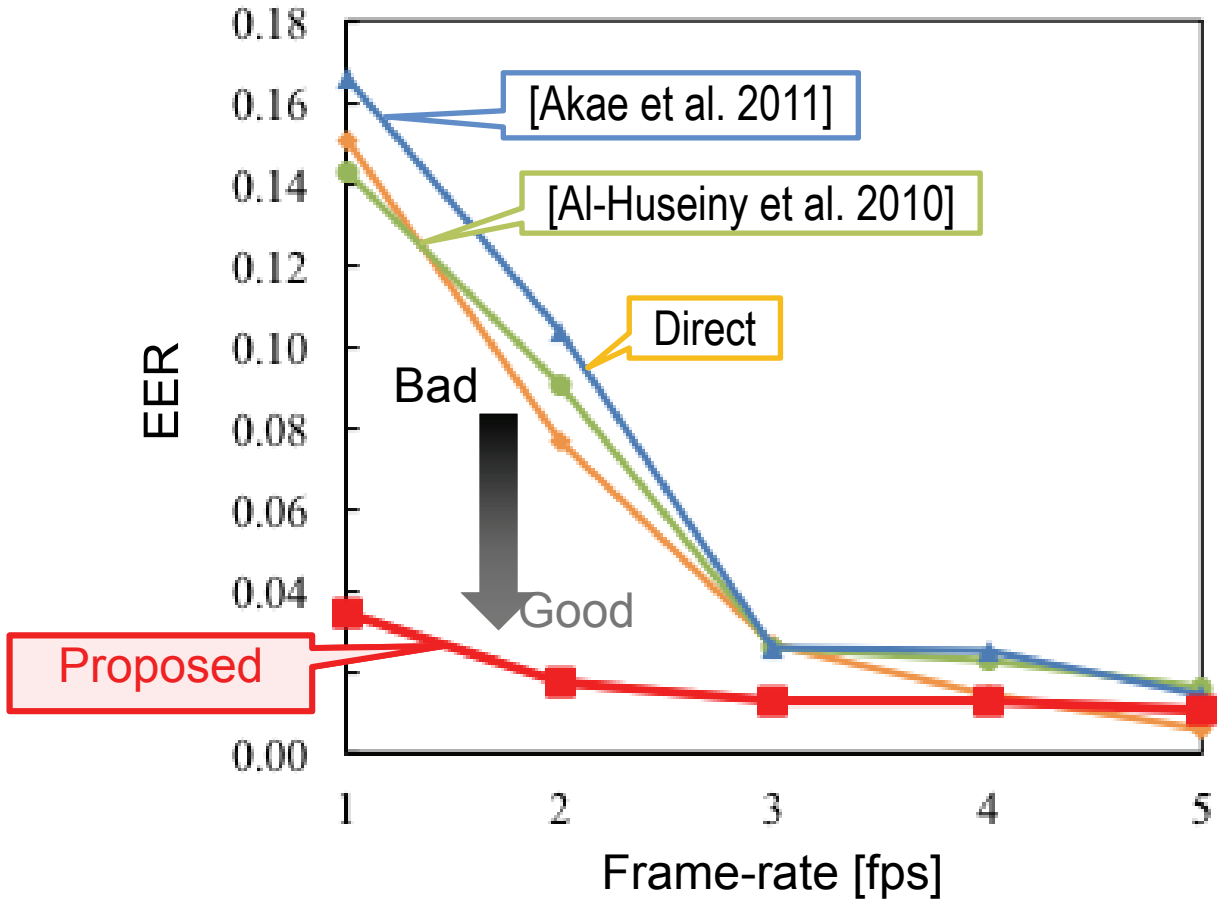
PTSR results -2 fps-

Frame-rate of input	Input	[Al-Huseiny et al. 2010]	[Akae et al. 2011]	Proposed
2 fps				

PTSR results -1 fps-

Frame-rate of input	Input	[Al-Huseiny et al. 2010]	[Akae et al. 2011]	Proposed
1 fps				

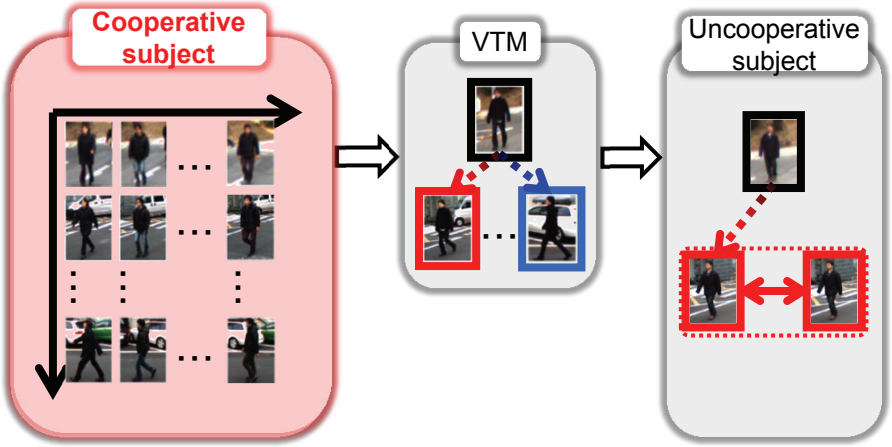
Performance evaluation: Verification

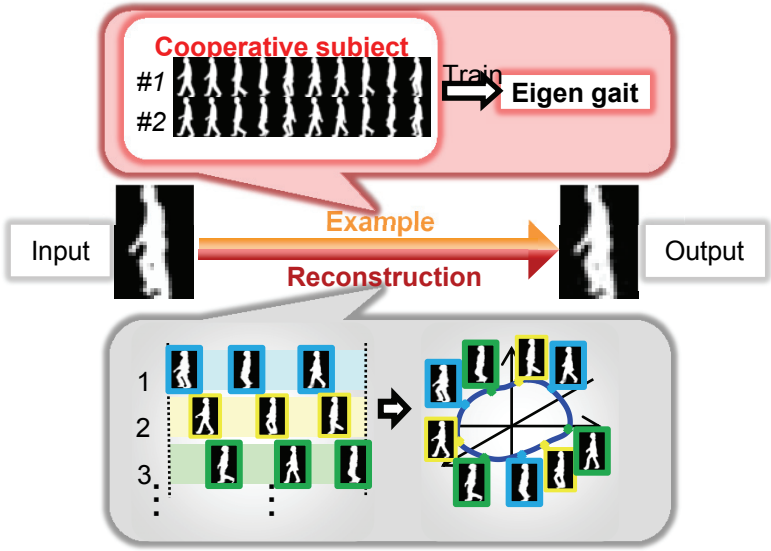


Conclusion and future direction

Conclusion

- Towards robust gait recognition





Key idea

Make the most of cooperative training subjects' variations to cope with uncooperative test subject's variations

Gap between practice and definition

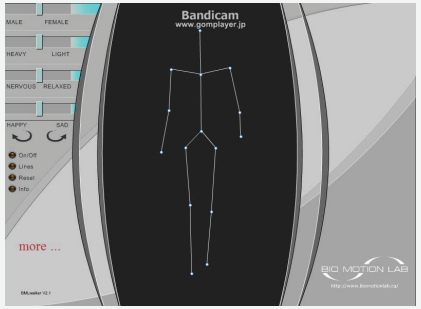
Mainstream of gait recognition

Silhouette-based
(Movement + body shape)

Gap!

Definition of gait

Pattern of movement
of the limbs of animals …



Human model fitting?

High computational cost
Error-prone

Trailer

- S. Lombardi, K. Nishino (Drexel Univ.), Y. Makihara, Y. Yagi (Osaka Univ.), ``Two-Point Gait: Decoupling Gait from Body Shape,'' ICCV 2013.