Robust Person Identification Based on DTW Distance of Multiple-Joint Gait Pattern

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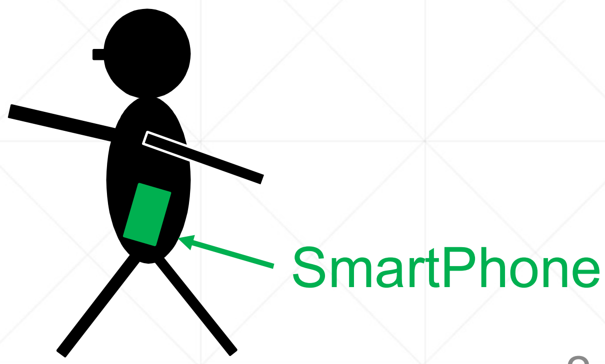
Background

- Gait information can be used to identify and track persons
  - It can be observed from outside
  - Multiple features can be aggregated
  - Target cooperation is unnecessary, etc.

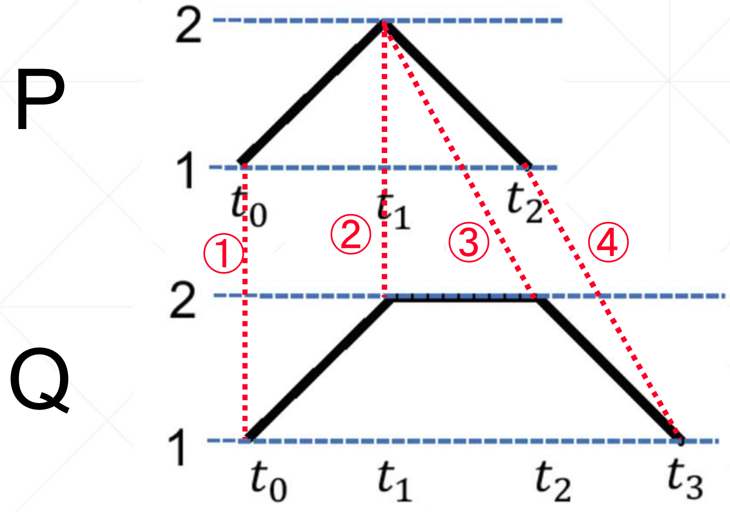
Related Works

- Statistics (Mori, 2018)
  - ❑Statistics don’t have enough resolution
  - ❑It changes even in the same person
  - ❑EER=0.25
- Wearable Sensors (Muaaz, 2017)
  - ❑Gait authentication using DTW algorithm to acceleration data of smartphone
    - » It can’t detect limbs movement
    - » It is not robust to obstacles of walking



What is the DTW algorithm?

- Dynamic Time Warping[10]
  - ❑ It is mostly used in speech recognition
- We can calculate distance of two time series data with this
  - ❑ Extend the time axis so as to minimize the distance
  - ❑ It can be applied even if the length of two data is different



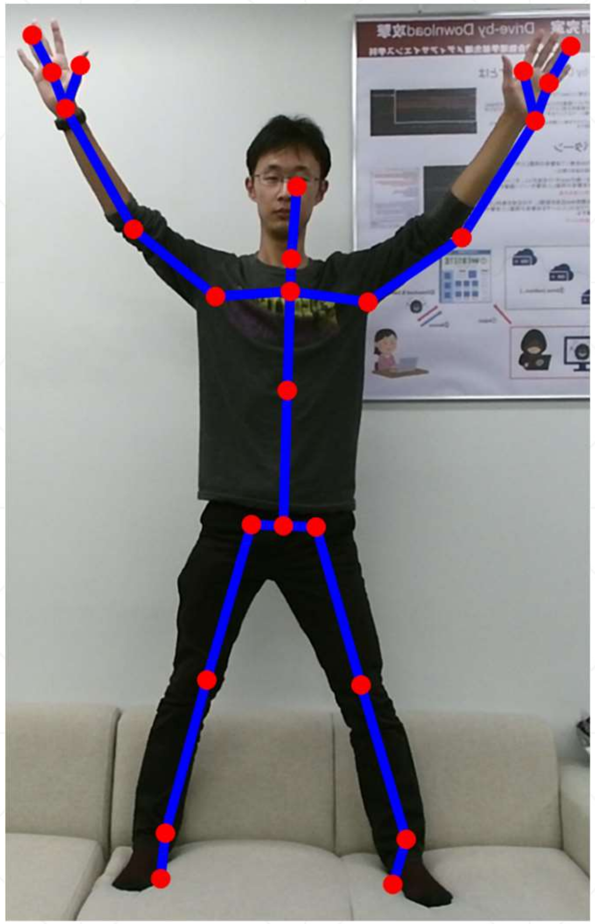
How do we address the drawbacks of the previous works?

- Drawbacks of previous works
  - ❑It can't detect limbs movement
  - ❑It isn't robust to obstacles of walking
- Approach of this work
  - ❑Using DTW algorithm for identification
  - ❑Using outside sensor to capture data

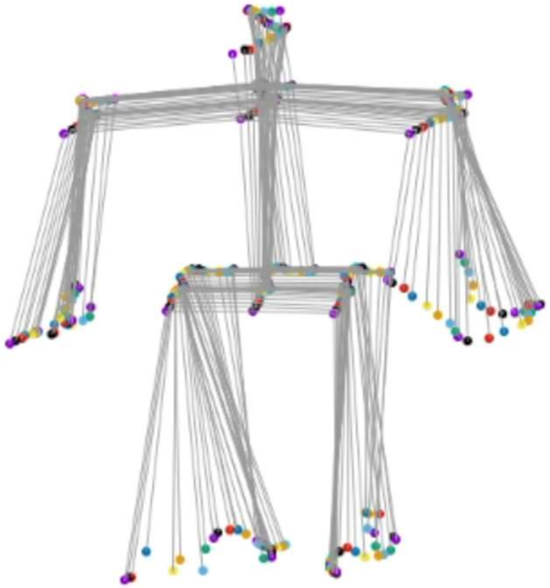
	Muaaz[7]	This work
No. of features	1	1-24
Sensor	inner	outside
Method	DTW algorithm	DTW algirhthm

Motion Capture Device

- Microsoft Kinect V2
- We capture three-dimensional coordinates of 25 joints called skeleton data



Sample of Skeleton Data

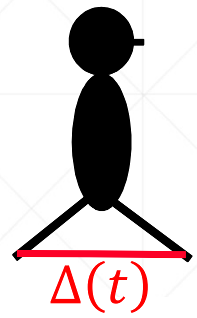


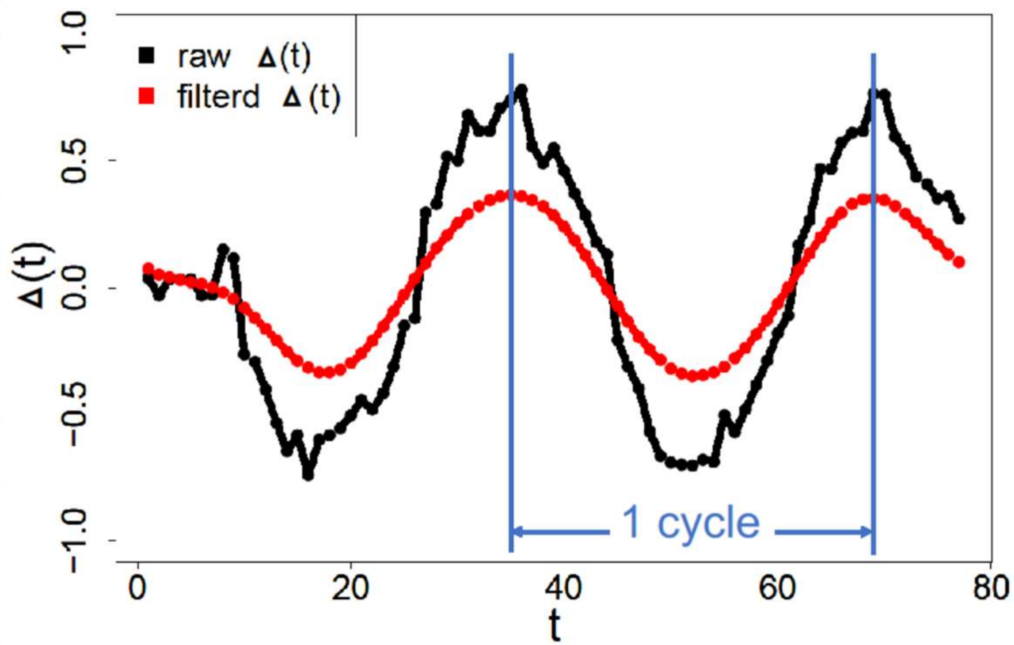
Proposed Method

- Steps
  1. Cycle extraction
  2. Calculation of relative coordinates
  3. Calculation of DTW distances
  4. Person identification

1. Cycle Extraction

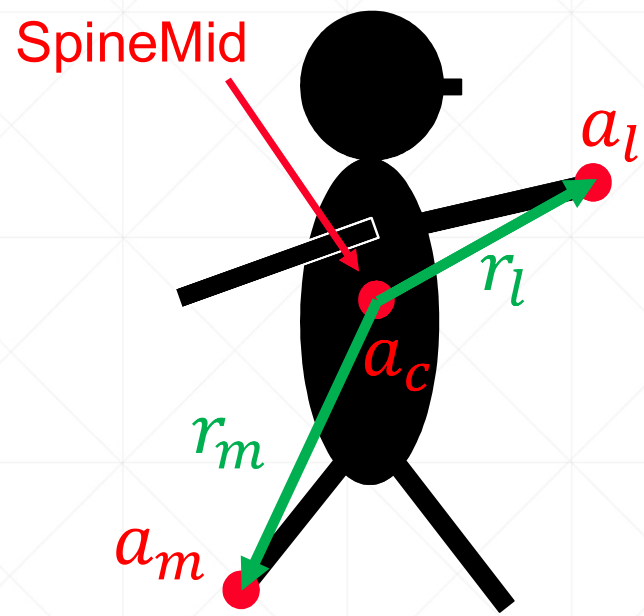
- Original coordinate: $a_l(t) = (x, y, z)$
- $\Delta(t) = \pm\|a_{RF}(t) - a_{LF}(t)\|$
- $^1/_{30}$ low pass filter is applied
- We extract between peaks





2. Calculation of relative coordinates

- Features are translated to relative coordinate
- Absolute coordinate of joint l: $a_l(t)$, coordinate of center of body: $a_c(t)$
- Relative coordinate: $r_l(t) = a_l(t) - a_c(t)$

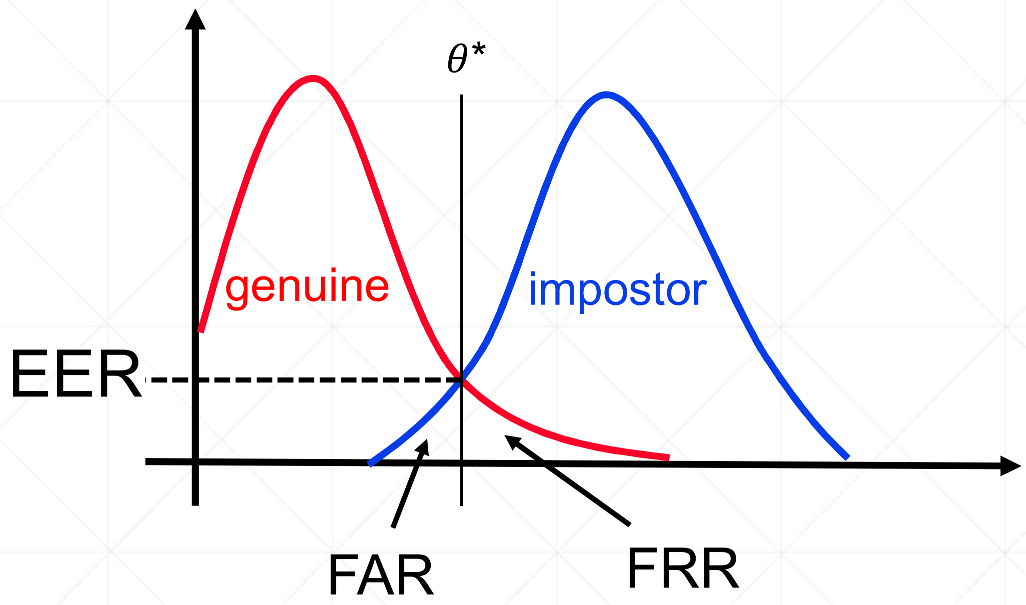


3. Calculation of DTW distances

- Distance of one pair of joints
  - $d(R_l, R_l')$: DTW distance of R_l and R_l'
    - » $R_l = \left(r_l(t_1), \dots, r_l(t_n)\right)$ and $R'_l = \left(r_l'(t_1), \dots, r_l'(t_n)\right)$
- Aggregated DTW (distance of joint l and m)
  - $D\left((R_l, R_m), (R_l', R_m')\right) = \sqrt{d(R_l, R_l')^2 + d(R_m, R_m')^2}$

4. Person Identification

- $if\ D\left(\boldsymbol{R}^{(u)}, \boldsymbol{R}^{(v)}\right) \leq \theta^*$,then $u = v$
- θ^* is determined by EER(Equal Error Rate)
  - EER: Point which FAR(False Acceptance Rate) equal to FRR(False Rejection Rate)



Experiment Purpose

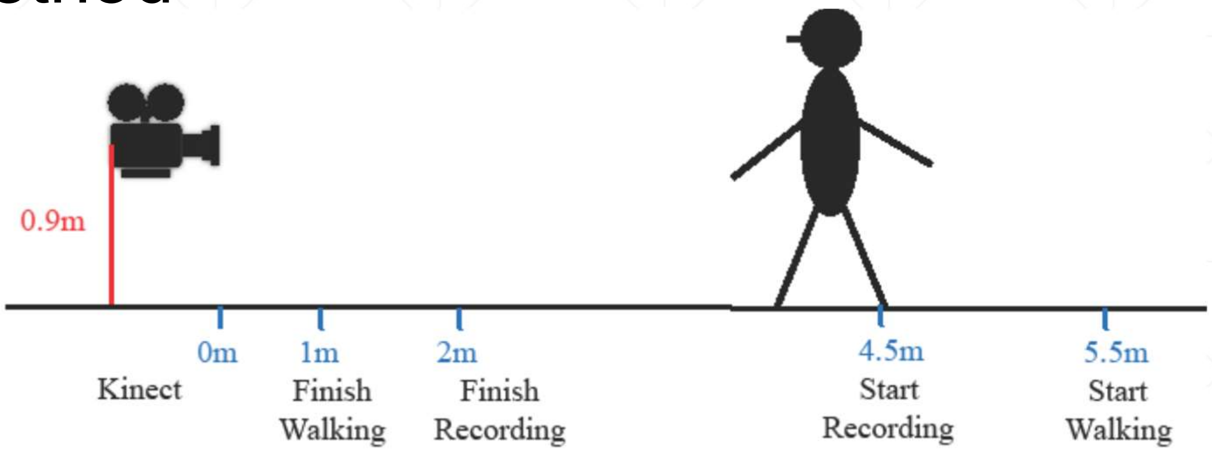
- Experiment 1
  - To identify the best parameters (choice of number of joints k and threshold θ^*) for the proposed gait identification method)
  - To estimate the fundermental accuracy of the proposed method
- Experiment 2
  - To evaluate the accuracy reduction with obstacles
  - To figure out the obstacle-robust joints

Experiment 1 Method

- Data capture

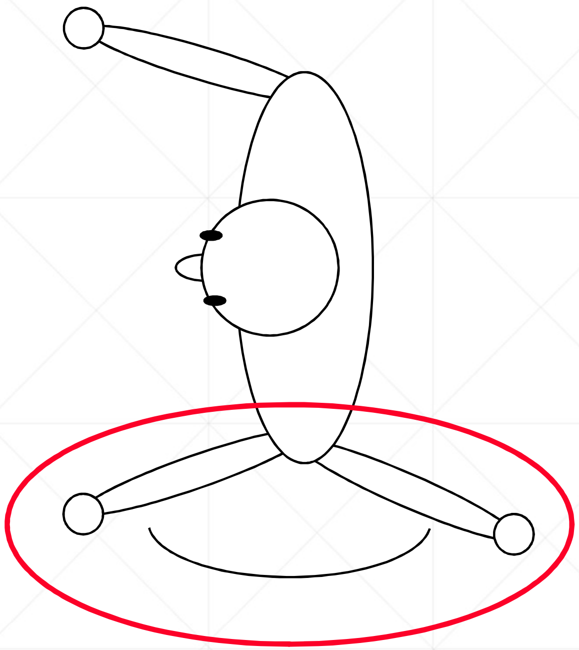
#Subjects	31 students and professor
Place	classroom of our university
Date	April 19, 2018

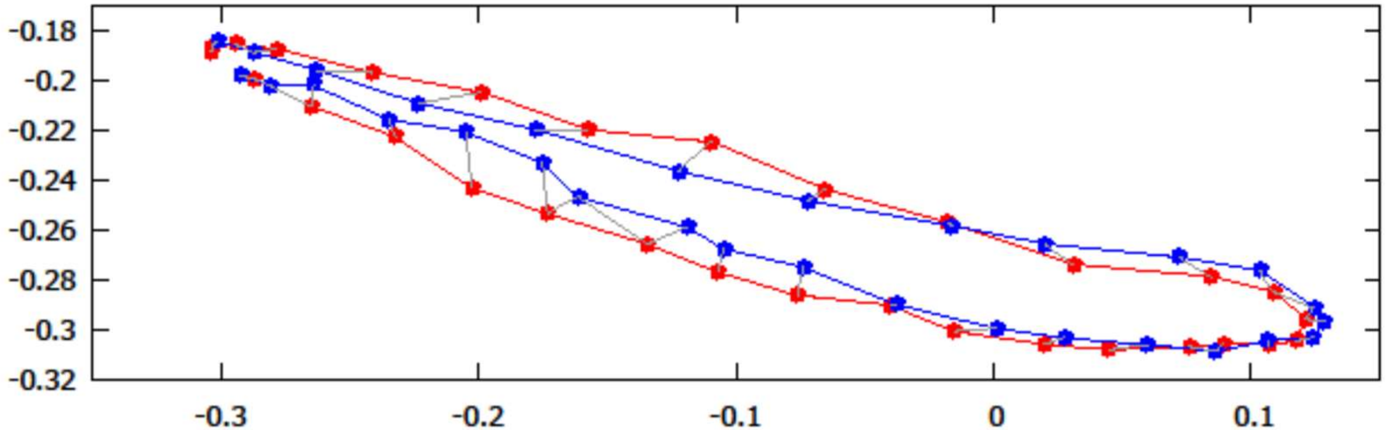
- Evaluate our proposed method
  - To determine the relation between combination num. k and EER



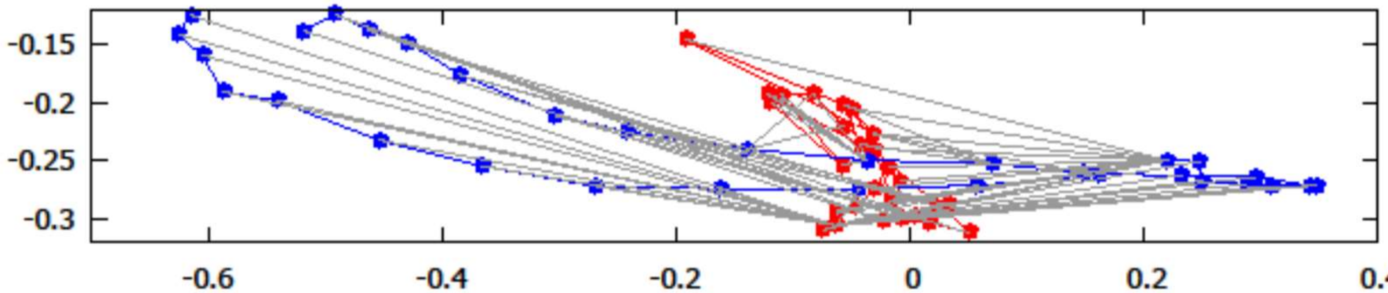
Environment

How the DTW algorithm works





With own data(distance=0.45m)



With other person’s data(distance=12m)

EERs of 24 joints

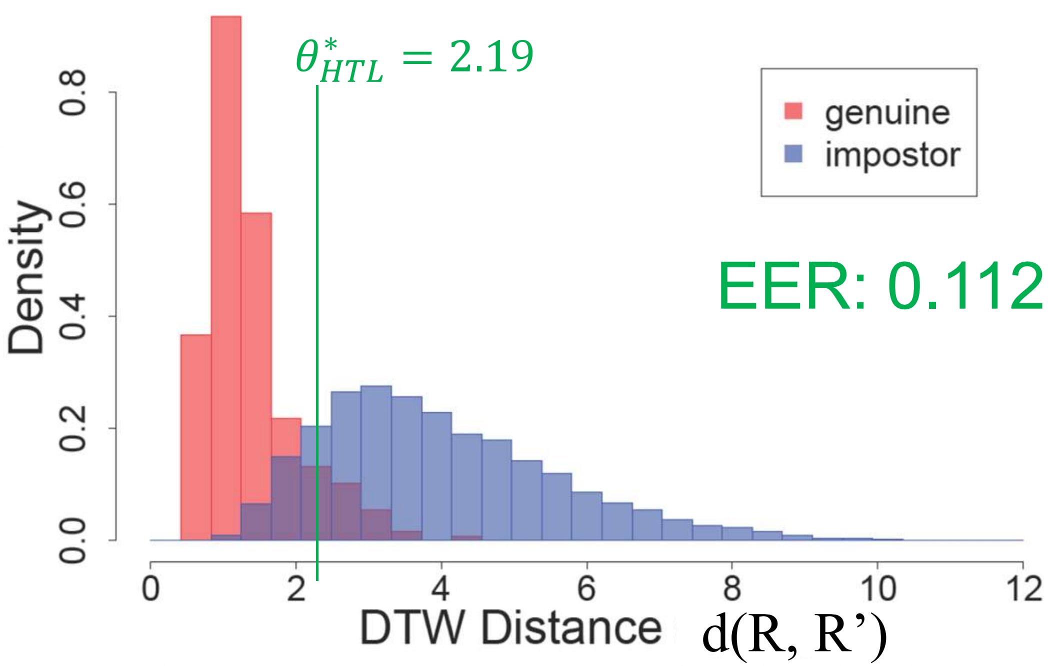
Rank	Joints	EER	Rank	Joints	EER
1	ElbowLeft	0.076	13	HandRight	0.124
2	ShoulderRight	0.081	14	HandLeft	0.127
3	ShoulderLeft	0.095	15	WristRight	0.133
4	Neck	0.100	16	HandTipRight	0.133
5	SpineShoulder	0.100	17	FootRight	0.144
6	WristLeft	0.107	18	KneeRight	0.145
7	HipRight	0.107	19	AnkleRight	0.148
8	HandLeft	0.108	20	KneeLeft	0.155
9	Head	0.110	21	ThumRight	0.177
10	HandTipLeft	0.112	22	ThumLeft	0.187
11	ElbowRight	0.113	23	AknleLeft	0.187
12	SpineBase	0.123	24	FootLeft	0.192

Static joints

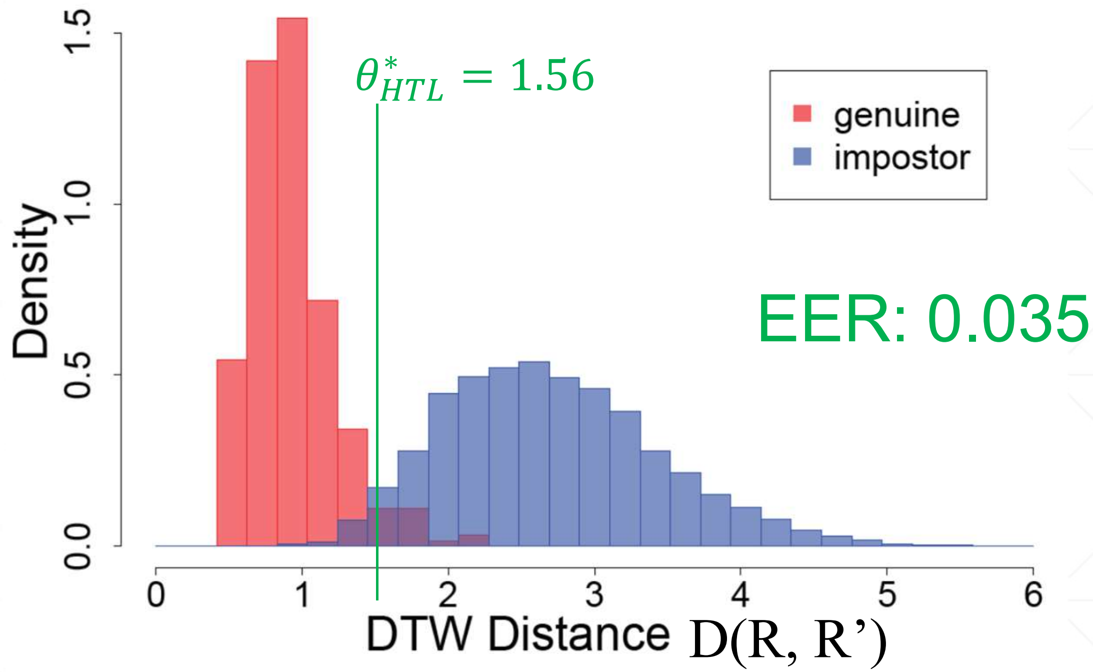
Joints in hands
Left > Right

Joints of Feet

Distributions of Single and Aggregated DTW Distances

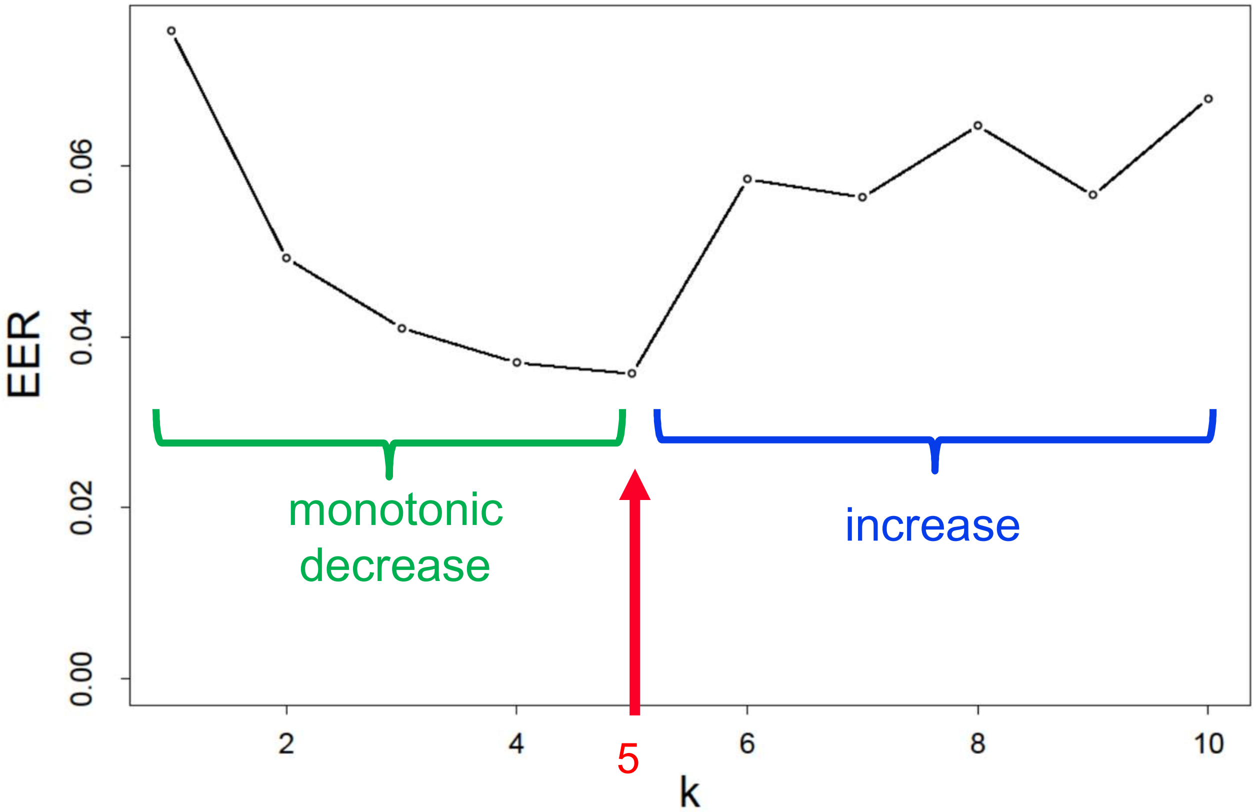


Histogram of DTW distances using single features (HandTipLeft)



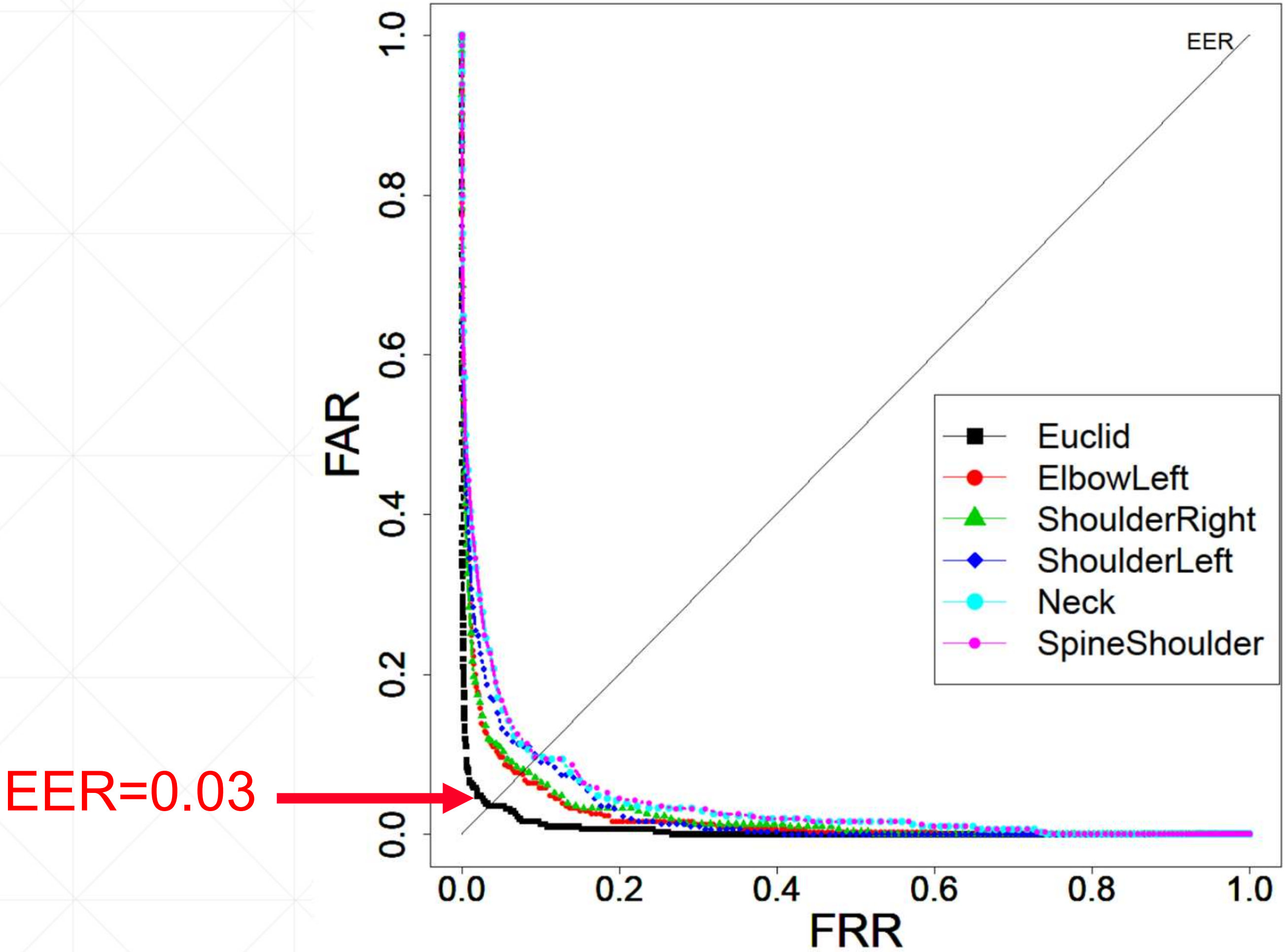
Histogram of integrated DTW distance when $k = 5$

How many features are to be used to have the best accuracy?



$k(1 \leq k \leq 10)$ features are combined in descending order of EER

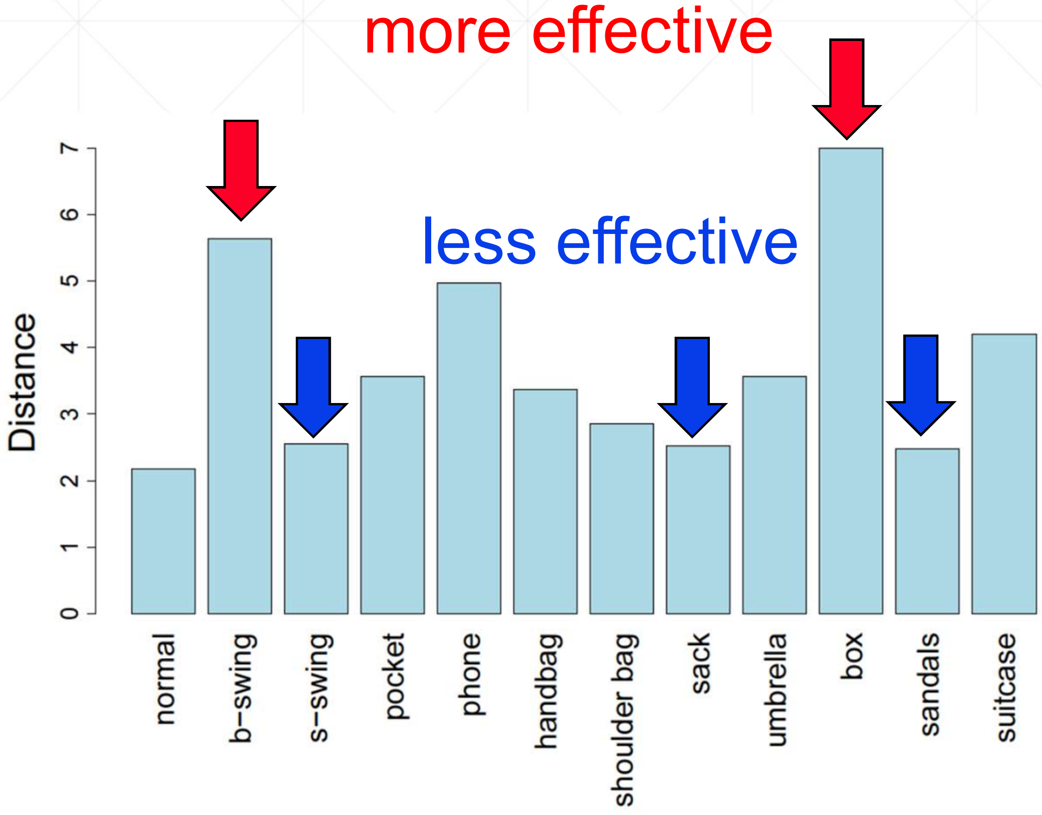
ROC Curves of Top 5 features and that of combined them



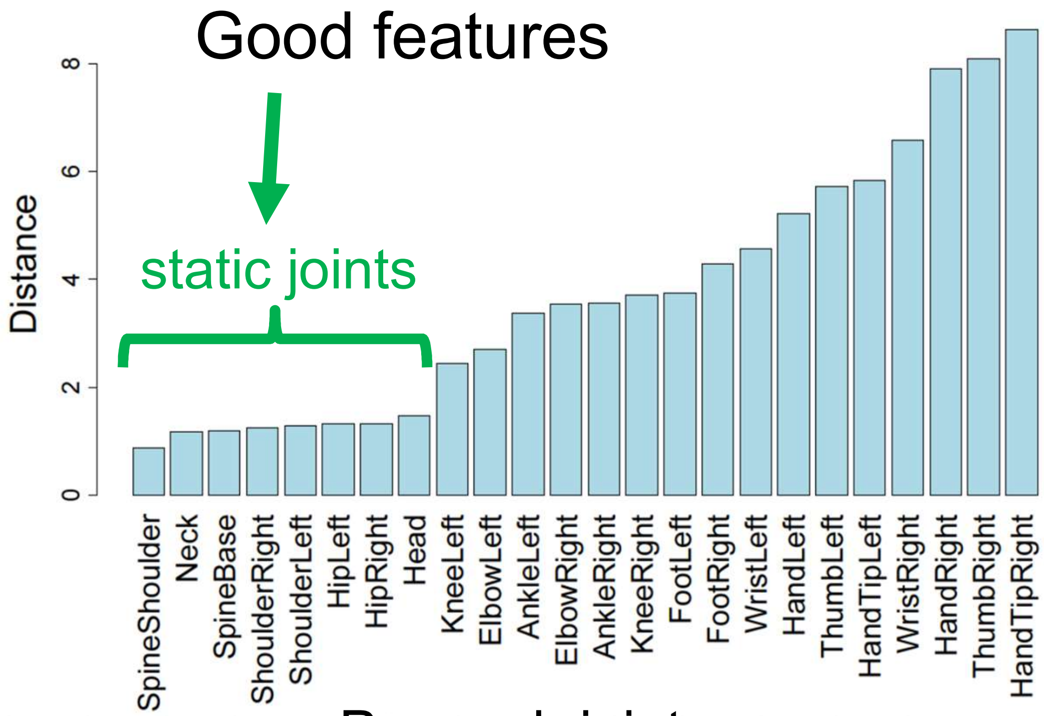
Experiment 2 Method (Obstacles)

- Data Capture
  - ❑Subjects: five students
    - » Each walks two times
  - ❑Place: our laboratory
  - ❑Date: March 26, 2018
- We calculate each DTW distances
- Evaluate effects

Average of DTW distances



Per each obstacles



Per each joints
(including obstacles)

Conclusions

- Static joints are good features
  - EER=0.03 using the best combination
- Best value of k is five
  - FRR increases in $k < 5$ because it has too many dimensions
- We evaluated proposed method against obstacles
  - Static joints are good features