KU LEUVEN

Continuous unobtrusive user authentication using gait for wearable devices

utilising machine learning algorithms

Faculty of Engineering Technology

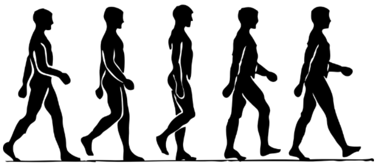
SenseID Wearable

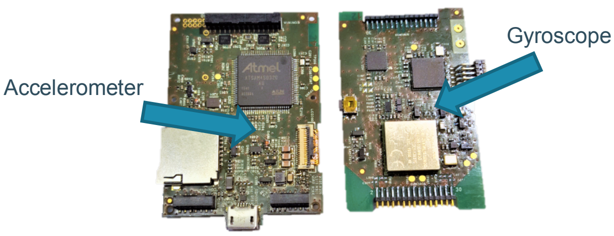
- Transparent and continuous authentication
- Wearable device packed with sensors
  - contextual data
  - biometric data

Can we develop a computationally inexpensive and accurate gait authentication model for mobile devices?

SenseID for Authentication

- Gait: “Locomotion achieved through the movement of human limbs.”
- Walking





Previous work

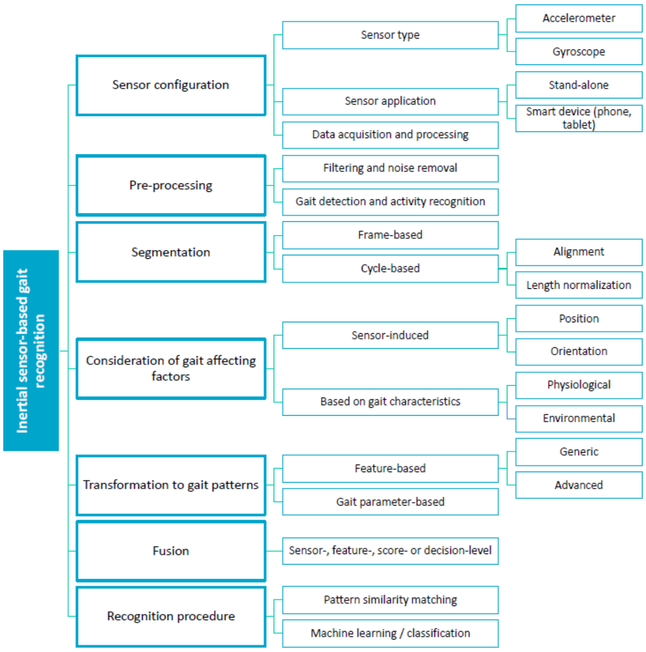
- Walk Detector

  gait **detection**
- Authentication

  gait **recognition**

State-of-the-art
gait **recognition**

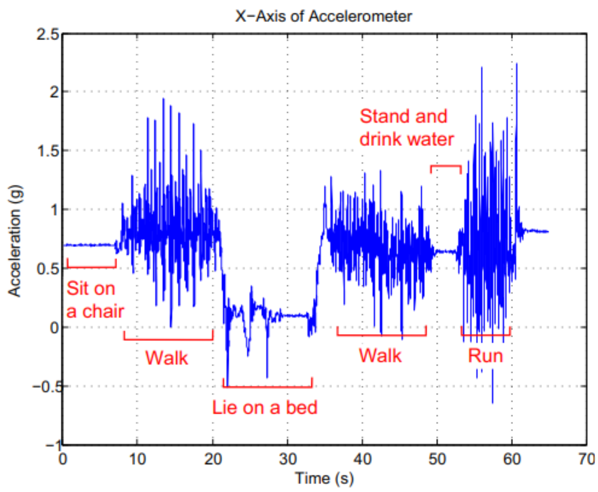
- Sensor configuration
- Pre-processing
- Segmentation
- Feature-based
- Fusion
- Machine learning



KU LEUVEN

State-of the-art HAR (Human Activity Recognition)

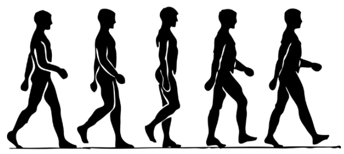
- gait **detection**
- Similar methods to gait recognition
- Machine learning



KU LEUVEN

Data Collection Procedure

- Accelerometer and Gyroscope data collected from Android LG Urbane Smartwatch
- Subjects were asked to do the following:
  - 10 minutes
  - Ordinary manner
  - Straight line
  - Repeated over few days

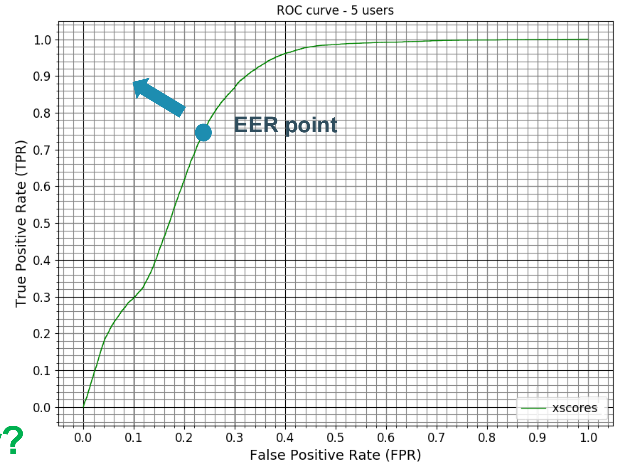


Initial Implementation (1)

- Wearable application (Android)
  - Capture Accelerometer
  + Gyroscope data
  - Save data to SD Card
- Server application (Python)
  - Processing
  - Train walk detector + authentication model
  - Inference models

Initial Implementation (2)

- Model for Walk Detection
- Model for Authentication
- Logistic Regression model



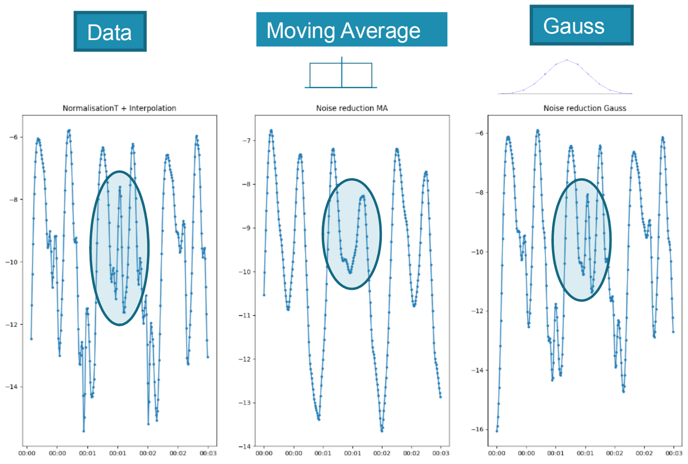
Can we improve further?

TPR: True Positive Rate
TNR: True Negative Rate
EER: Equal Error Rate

Machine Learning for Gait Authentication

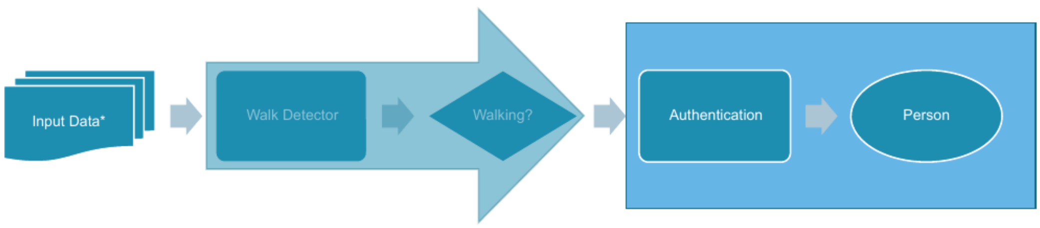
- Walk Detector (gait detection)
- Authentication Model (gait recognition)

Data Filtering for Noise Removal

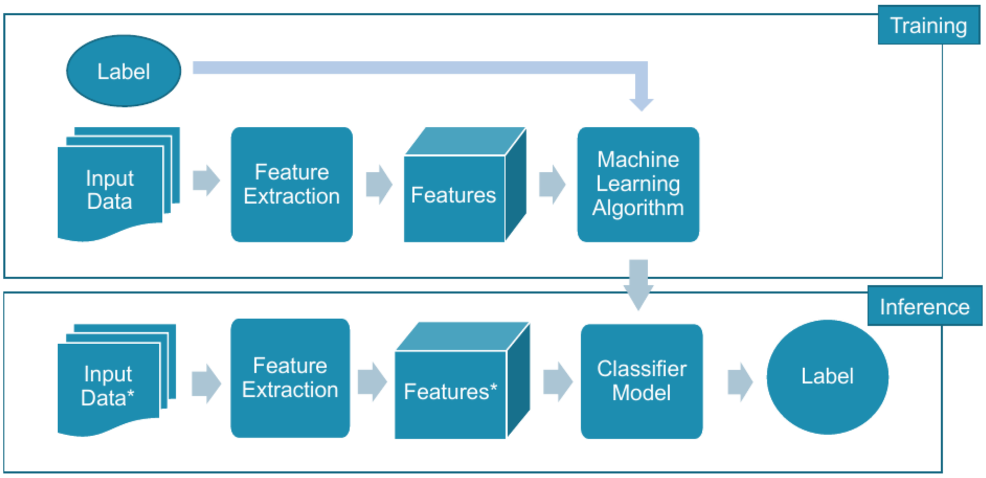


Machine Learning for Gait Authentication

- Walk Detector (gait detection)
- Authentication Model (gait recognition)

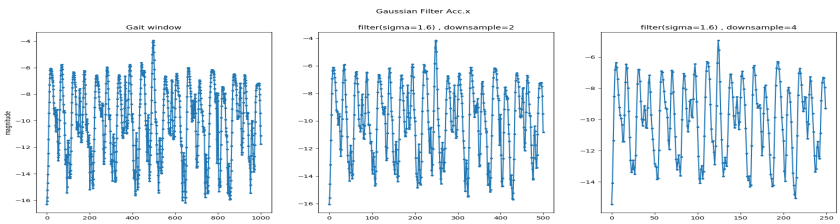


Machine Learning components



KU LEUVEN

New Feature: Derivatives



Full resolution **Half resolution** **Quarter resolution**

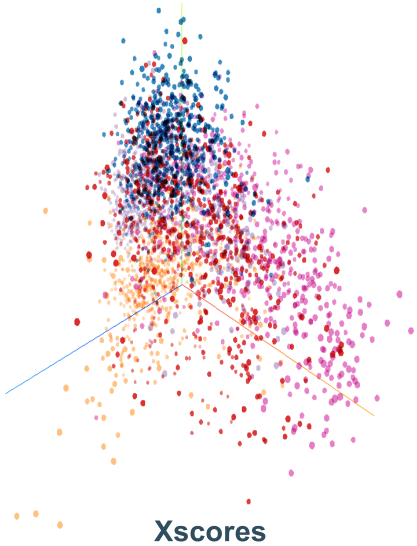
Data

derivative filter [-1 0 1]

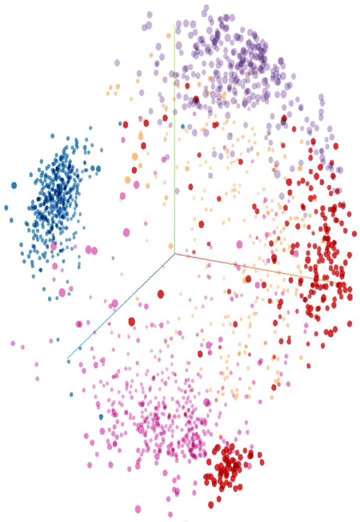
Feature 72

KU LEUVEN

Feature visualization with PCA: three principle components

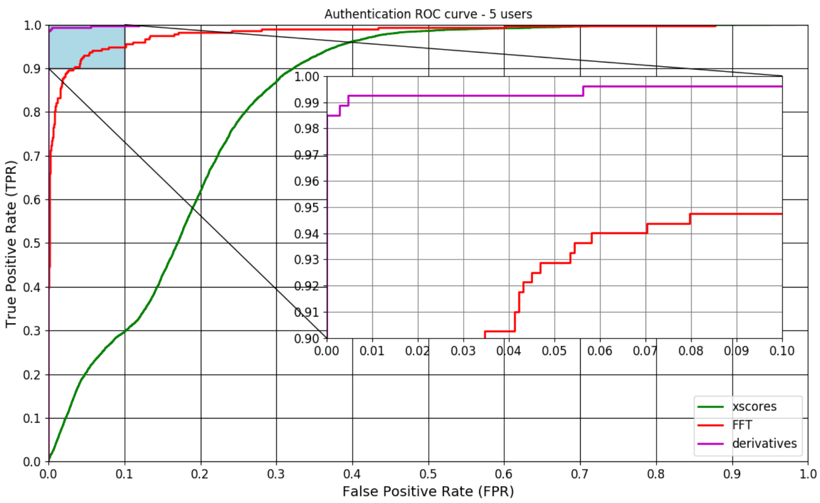


Xscores



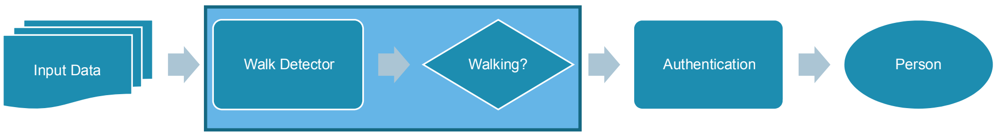
derivatives (new)

ROC Graph Authentication Results



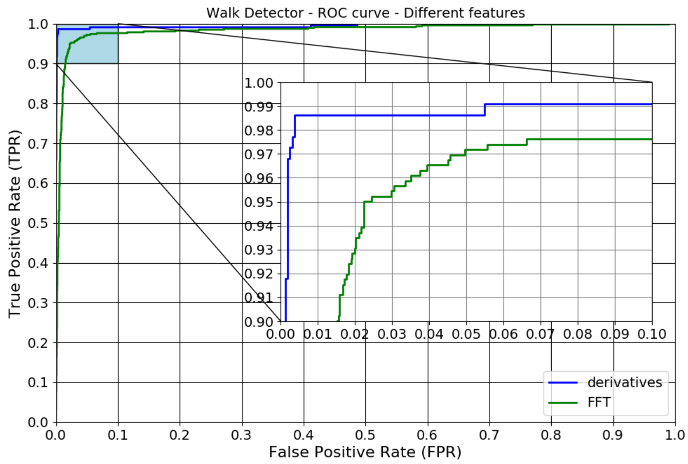
Machine Learning for Gait Authentication

- Walk Detector (gait detection)
- Authentication Model (gait recognition)



KU LEUVEN

ROC Graph Walk Detector



KU LEUVEN

Feature Computation time

Feature	Preprocessing (ms)	Feature Computation WD+Auth (ms)	Predict WD+Auth (ms)	Total (ms)
Xscores	13.5	724	0.4	817.9
derivative (current)	11	26	0.4	37.4

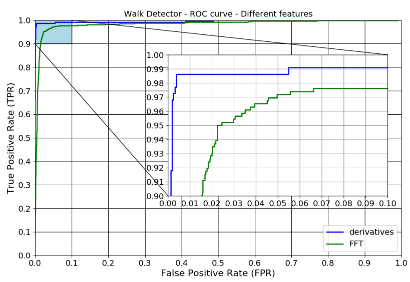
KU LEUVEN

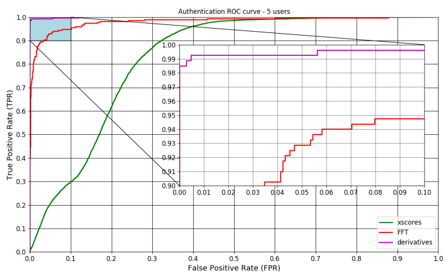
Intermediate Conclusion

- Accuracy improvement (TPR: 83.0%, TNR: 90.1%) to EER<1%
- Speed improvement: 540ms to 13ms

Representative?

Accurate?





KU LEUVEN

Validation on public datasets

- Walk Detector (gait **detection**)

  HAR (Human Activity Recognition)

- Authentication Model (gait **recognition**)

  Representative dataset: **51 users**

	Gait detection	**Gait recognition**
Size	>=5	>=50
Sensors	accelerometer and/or gyroscope	
Hardware	smartwatch, smartphone	
Position	wrist, front pocket, hip	
Duration	1 minute per activity	5 minutes
Activity	sitting, lying, standing, walking	walking

KU LEUVEN

Datasets

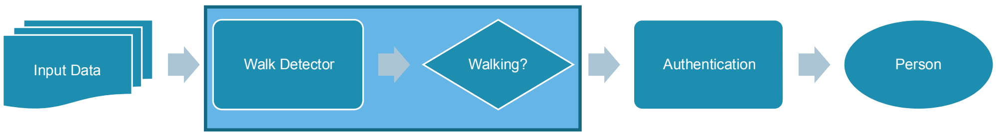
- Gait detection: PAMAP2, USC-HAD
- Gait recognition: IDNet

Dataset	**IDNet [1]**	**Z-JU [29]**	**PAMAP2 [3]**	**G. Wu [30]**	**USC-HAD [2]**
Sensors	both	only accelerometer	both	both	both
Position	front pocket	wrist+others	wrist+others	fingertip	hip
Duration	>5 minutes	1 minute	5 minutes	>5 minutes	>5 minutes
Activity	walking	walking	multiple	multiple	multiple
Conditions	some outside	inside	some outside	inside	inside
Subjects	50	175	9	40	14

KU LEUVEN

Validation

- Walk Detector (gait detection)
- Authentication Model (gait recognition)



KU LEUVEN

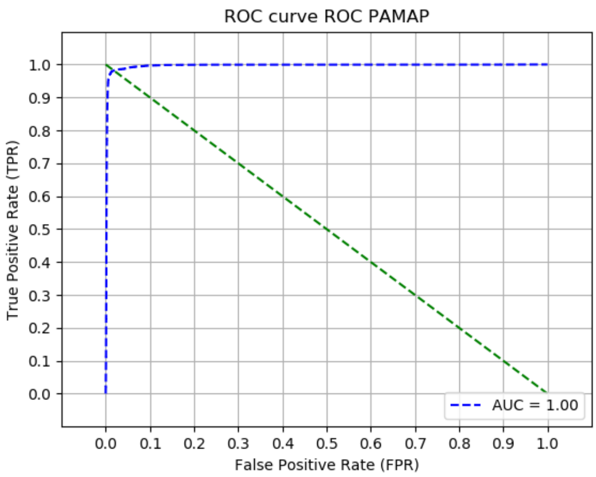
Gait detection PAMAP2

Train | Test

	subject101	subject102	subject103	subject104	subject105	subject106	subject107	subject108	subject109	Sum	Nr. of subjects
1 – lying	271.86	234.29	220.43	230.46	236.98	233.39	256.1	241.64	0	1925.15	8
2 – sitting	234.79	223.44	287.6	254.91	268.63	230.4	122.81	229.22	0	1851.8	8
3 – standing	217.16	255.75	205.32	247.05	221.31	243.55	257.5	251.59	0	1899.23	8
4 – walking	222.52	325.32	290.35	319.31	320.32	257.2	337.19	315.32	0	2387.53	8
5 – running	212.64	92.37	0	0	246.45	228.24	36.91	165.31	0	981.92	6
6 – cycling	235.74	251.07	0	226.98	245.76	204.85	226.79	254.74	0	1645.93	7
7 – Nordic walking	202.64	297.38	0	275.32	262.7	266.85	287.24	288.87	0	1881	7
9 – watching TV	836.45	0	0	0	0	0	0	0	0	836.45	1
10 – computer work	0	0	0	0	1108.82	617.76	0	687.24	685.49	3099.31	4
11 – car driving	545.18	0	0	0	0	0	0	0	0	545.18	1
12 – ascending stairs	158.88	173.4	103.87	166.92	142.79	132.89	176.44	116.81	0	1172	8
13 – descending stairs	148.97	152.11	152.72	142.83	127.25	112.7	116.16	96.53	0	1049.27	8
16 – vacuum cleaning	229.4	206.82	203.24	200.36	244.44	210.77	215.51	242.91	0	1753.45	8
17 – ironing	235.72	288.79	279.74	249.94	330.33	377.43	294.98	329.89	0	2386.82	8
18 – folding laundry	271.13	0	0	0	0	217.85	0	236.49	273.27	998.74	4
19 – house cleaning	540.88	0	0	0	284.87	287.13	0	416.9	342.05	1871.83	5
20 – playing soccer	0	0	0	0	0	0	0	181.24	287.88	469.12	2
24 – rope jumping	129.11	132.61	0	0	77.32	2.55	0	88.05	63.9	493.54	6
Labeled total	4693.07	2633.35	1743.27	2314.08	4117.97	3623.56	2327.63	4142.75	1652.59	27248.27	
Total	6957.67	4469.99	2528.32	3295.75	5295.54	4917.78	3135.98	5884.41	2019.47	38504.91	

KU LEUVEN

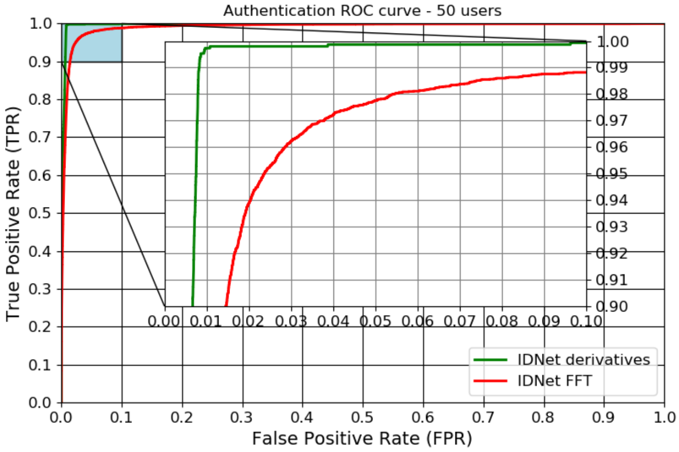
Results on PAMAP2 dataset



Gait recognition IDNet

- 50 subjects
- period of six months
- Android smartphones in front pocket
- Several sessions of five minutes were performed for each subject
- variable conditions, mimic real world scenarios

Results on IDNet



KU LEUVEN

Conclusion and Future Work

- **Can we develop a computationally inexpensive and accurate gait authentication model for mobile devices?**

- SenseID wearable
  - Multiple devices
  - Realistic

KU LEUVEN