Gait Recognition in Mobile Security

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The Big Picture

What is Mobile Security?

- Information Storage
- Device Access

How is mobile security evolving?

- No More Passwords
- Something You Are

http://mobilebuzz.guru/wp-content/uploads/2014/06/Mobile-Security.png

Outline

Outline

Biometrics

- Biometrics
- Gait Recognition
- Why Gait is Better
- Unobtrusive Access

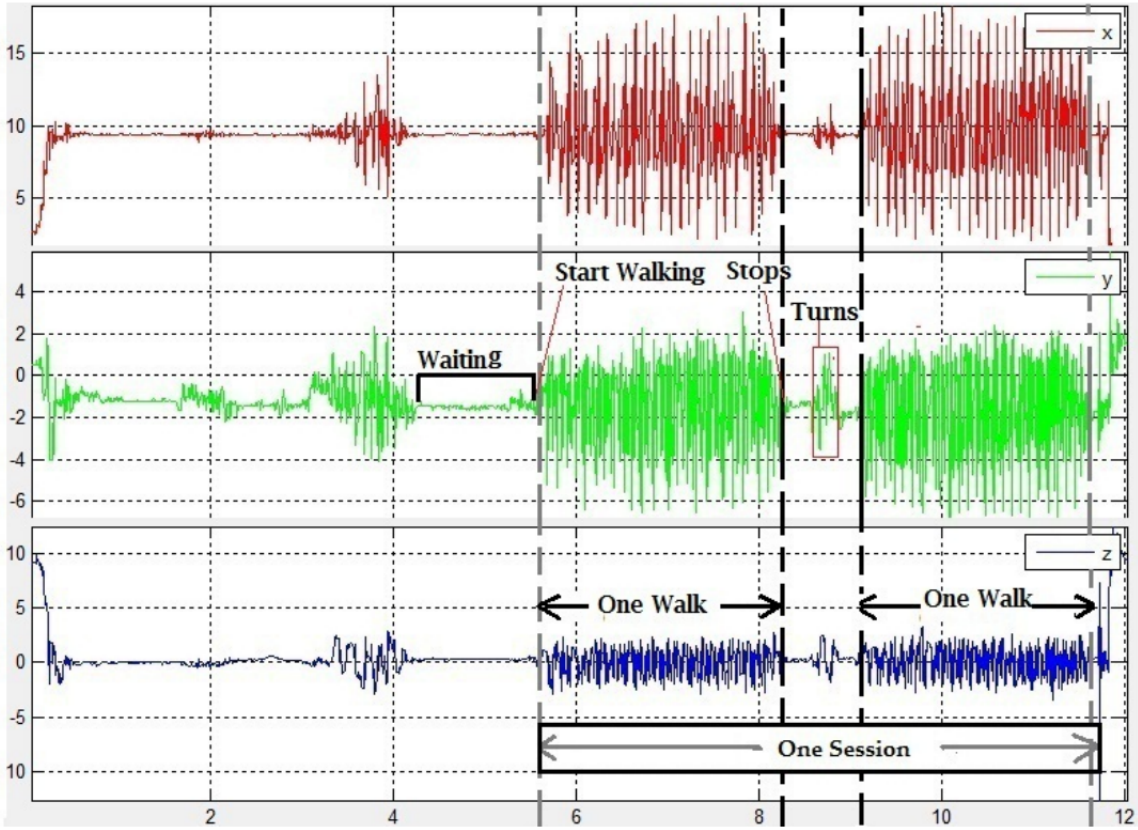
http://www.smc2012.org/images/jain3-1.jpg

Two Methods

- Fixed Method
- Unfixed Method

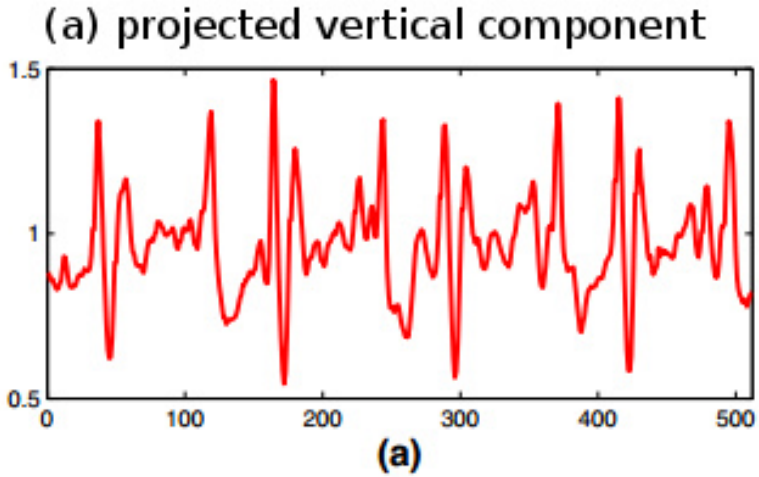
Fixed Method Approach

- 51 Subjects
- Phone Clipped to Waist
- Walked Down 18.5 Meter Hallway
- Separated into "Walks"



Unfixed Method Approach

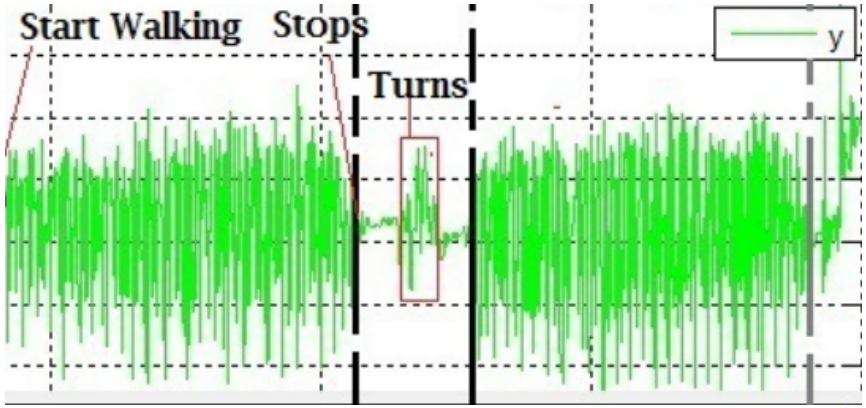
- 47 Subjects
- Phone in more natural location (pocket, handbag, backpack)
- Performed in Real-world Environments
- Separated Into Frames

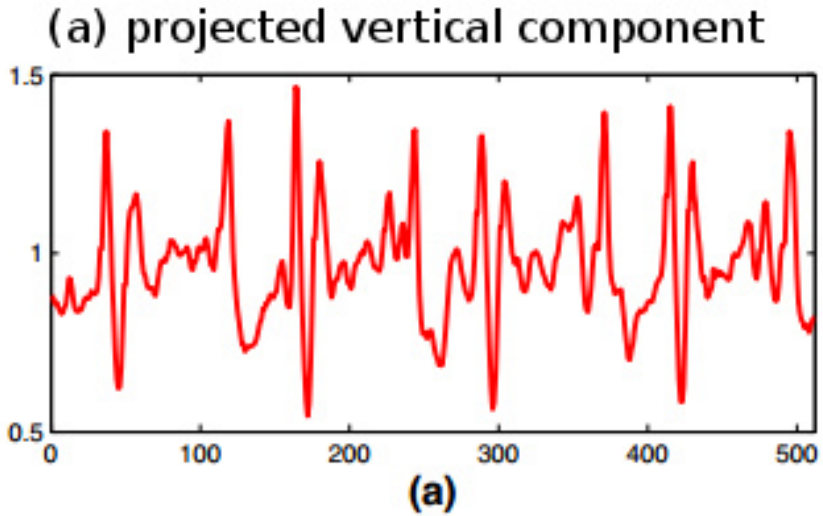


Outline

Preprocessing

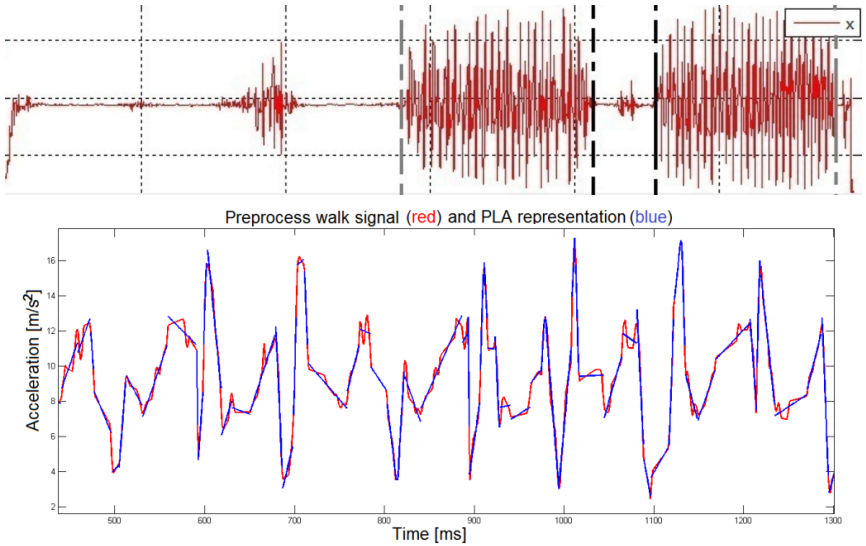
- Separates accelerometer data into sections
- Drops sections with little or no movement





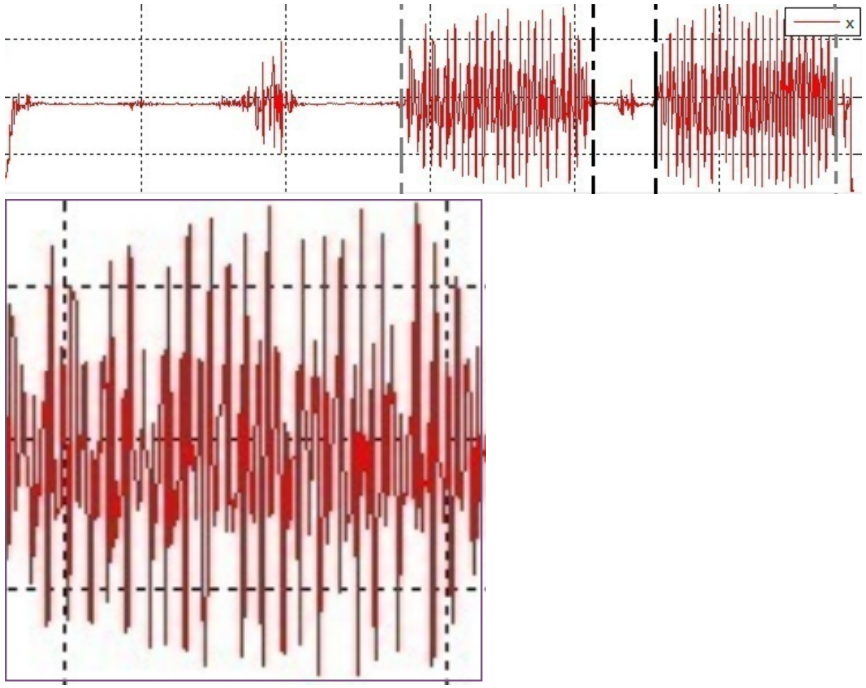
Fixed Method Preprocessing

- Walk Extraction
- Linear Interpolation (curve fitting)
- Zero Normalization



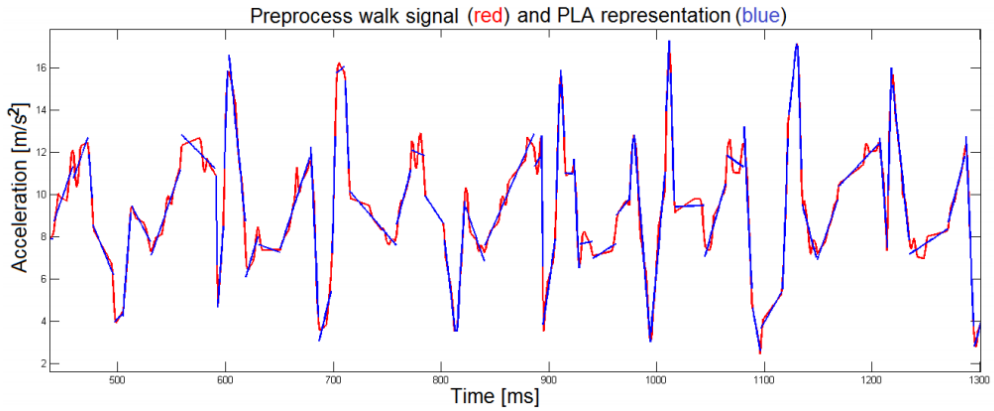
Walk Extraction

- Separates walking data from non-walking data



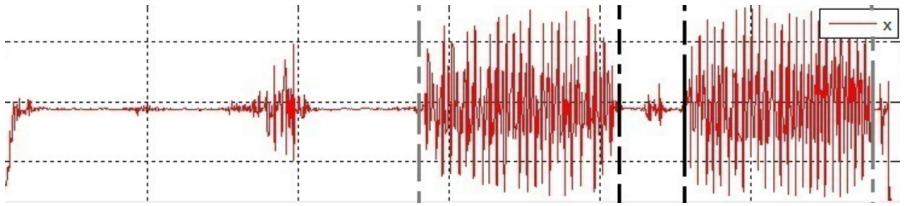
Linear Interpolation

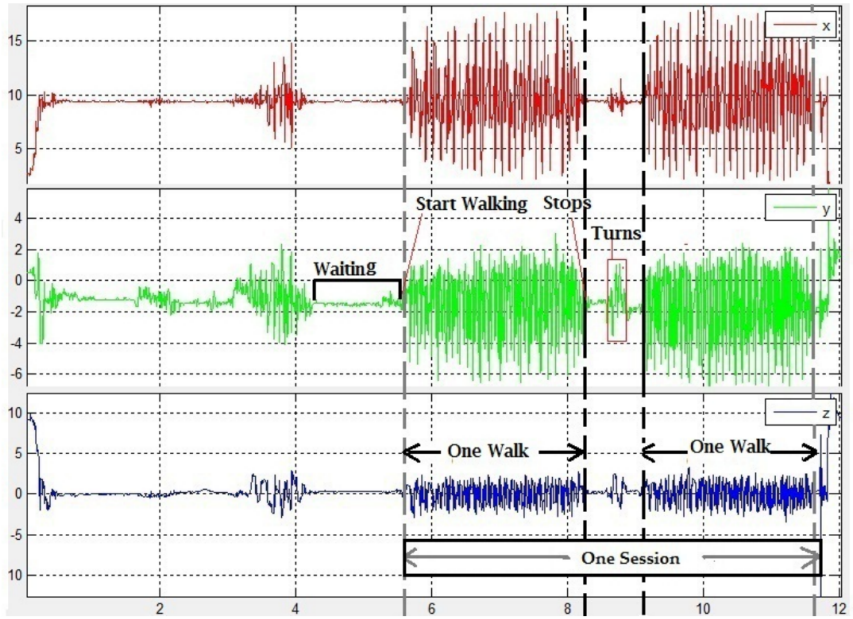
- Linear Interpolation (curve fitting)
- Organizes the data for future steps



Zero Normalization

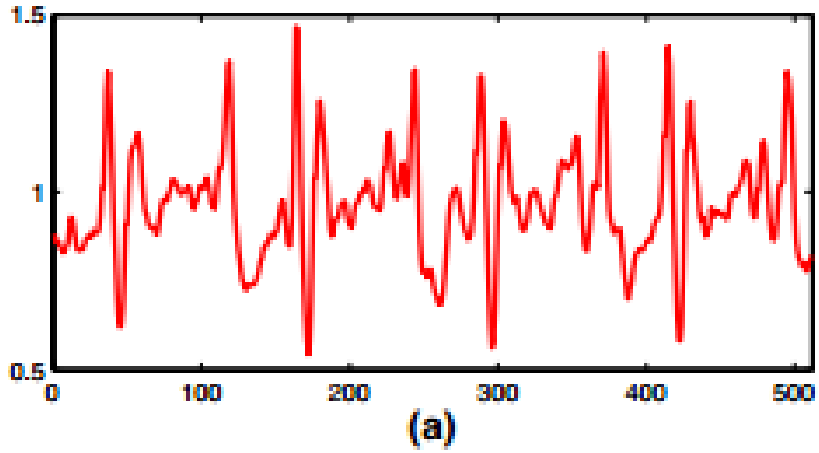
- Only need the axis influenced by gravity
- Acceleration along the other two axes must be zero

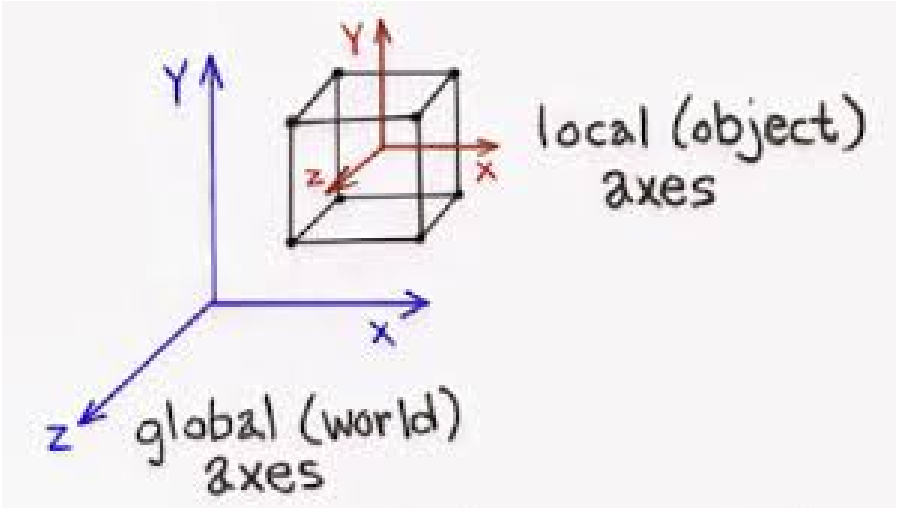




Unfixed Method Preprocessing

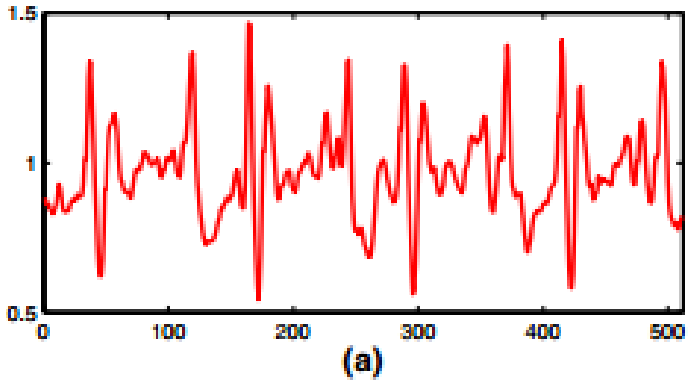
- Framing
- Projection





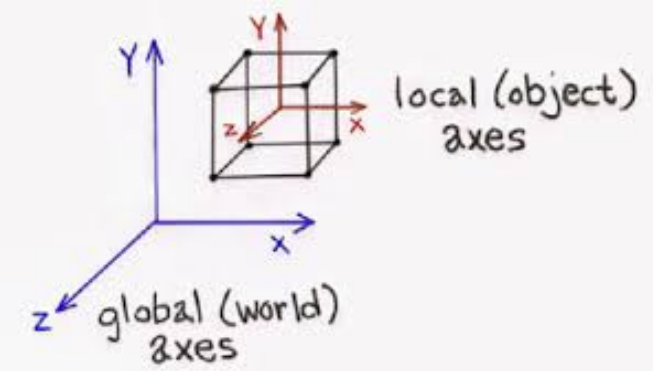
Framing

- Separating Data into Equal Sections
- Frame Length: 5.12 seconds
- Each Frame contains 512 Samples
- Stationary frames are dropped



Projection

- Each sample is projected onto a global coordinate system (sample = x, y, and z)
- Estimating direction of gravity with changes in x, y, and z.
- Frame dropped if orientation is changed



Outline

What is Feature Extraction?

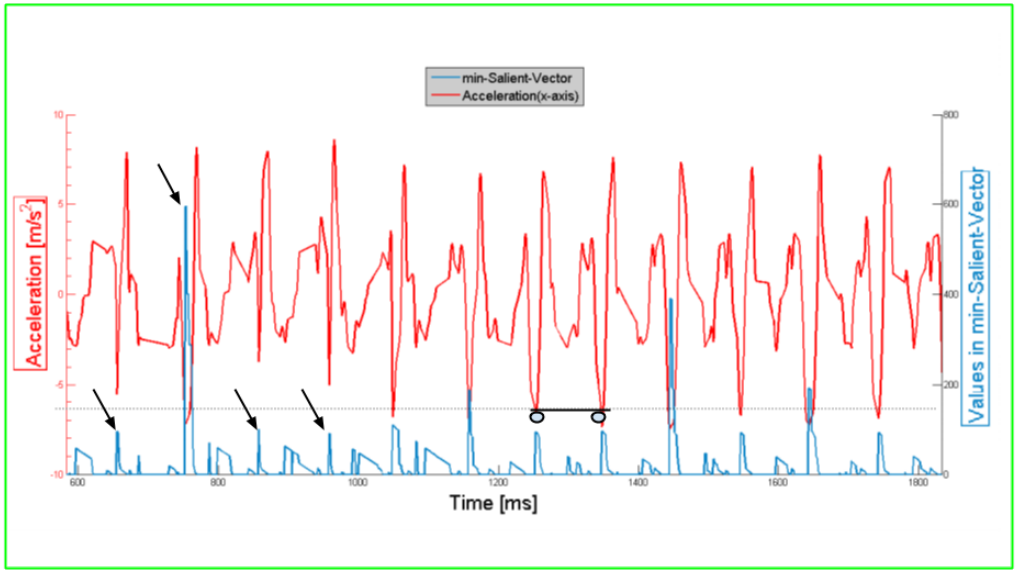
- Feature extraction separates "walking" cycles from "non-walking" cycles

Fixed Method Feature Extraction

- Four Steps:
  - Cycle Length Estimation
  - Cycle Detection
  - Cycle length normalization
  - Omitting Unusual Cycles

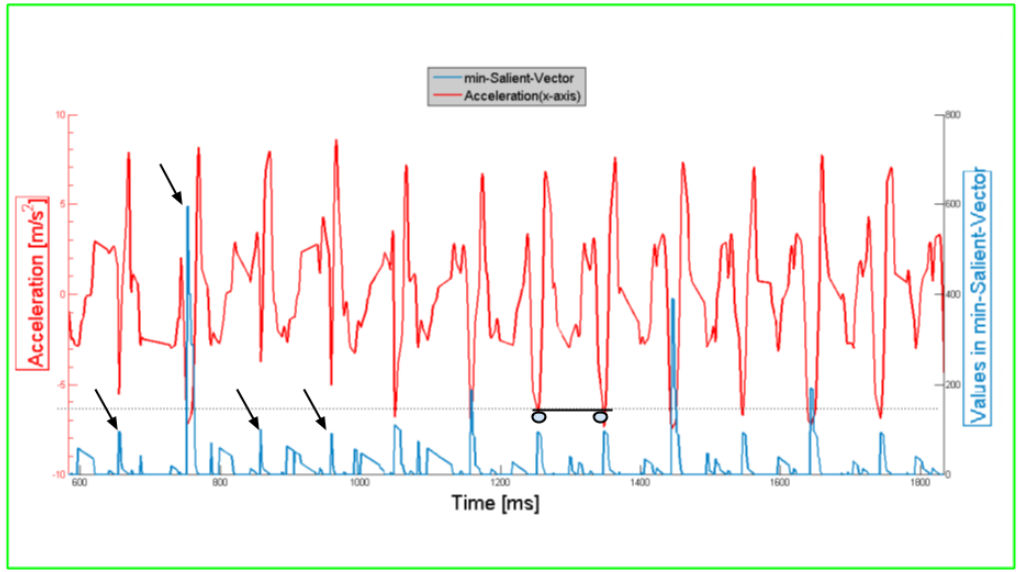
Cycle Length Estimation

- Computes the Minimum Salience Vector of each cycle
- Minimum Salience Vector
  - Contains one entry for each data point
  - Each entry is the count of data values between the current value and following smaller value



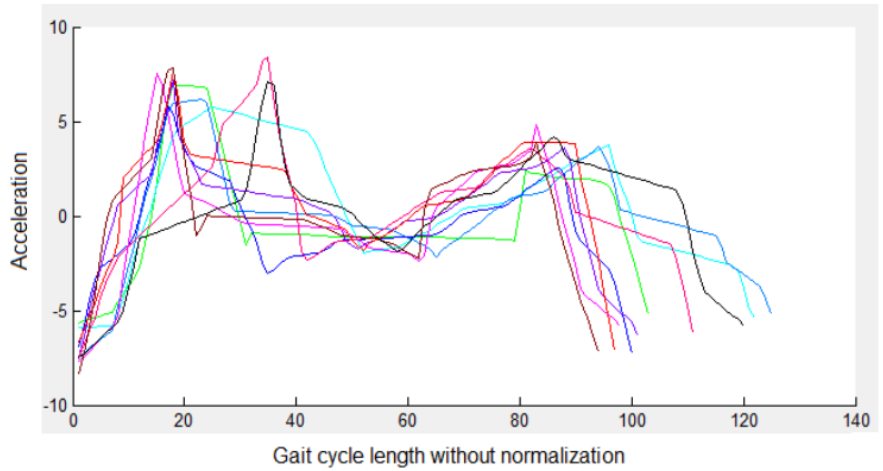
Cycle Detection

- Detecting Individual Cycles
- Start of each cycle is located using the entry with the greatest value
- Spikes show the length of each cycle
- Long cycles are split again using the same method



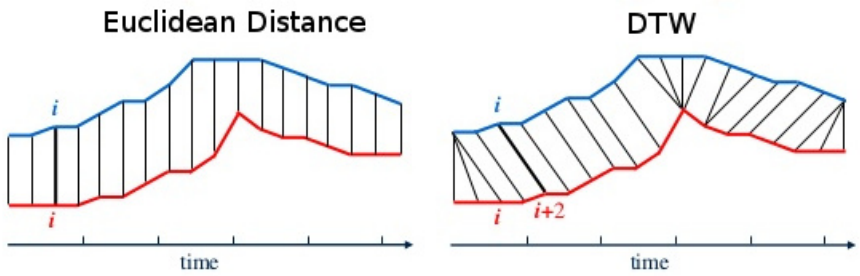
Cycle Length Normalization

- The distance of each cycle is measured from the start of one cycle to the start of the following.
- Cycles need to be of a set length for later Gait Analysis
- Linear Interpolation helps to normalize the data



Omitting Unusual Cycles

- Deleting Unusual Gait Cycles
- Dynamic Time Warping (DTW): An algorithm used to measure similarity between two sequences
- Euclidean VS DTW
- Cycles with half the distance of the average cycle are dropped



Unfixed Method Feature Extraction

- Three Steps:
  - Feature Extraction I
  - Walking Detection
  - Feature Extraction II

Feature Extraction I

- Determines differences between "walking" and "non-walking"
- Walking 1-2Hz vs Running >3Hz
- These features are used in Walking Detection

Walking Detection

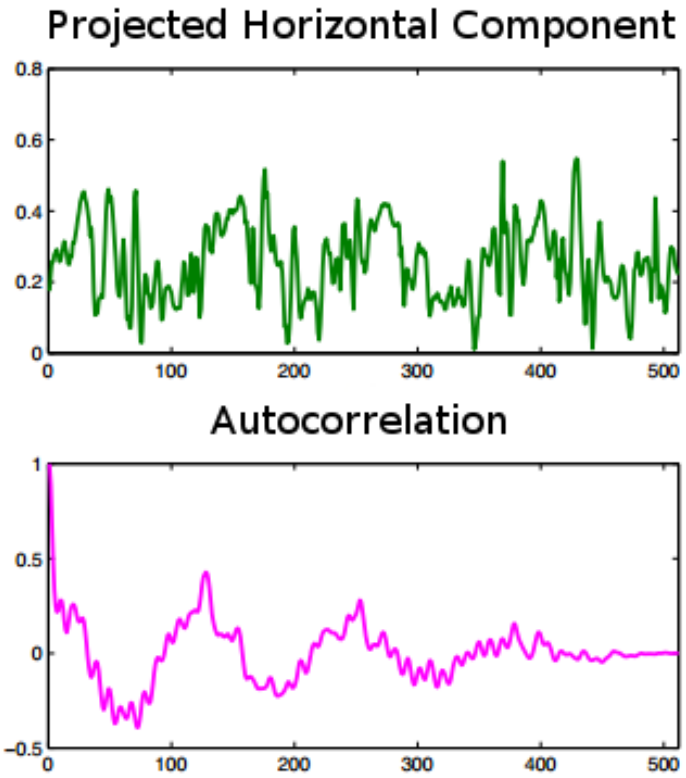
- Three classifications:
  - Walking: 1-2Hz
  - Non-Walking: >3Hz (running, biking, in moving vehicle)
  - Random Movements: >0Hz (transitional movements, short spikes)
- Cycles labeled as walking move onto the next step

Feature Extraction II

- Once Walking Detection confirms that the frame contains walking data, more relevant features are extracted
- Some features are extracted using Autocorrelation

Autocorrelation

- Useful to find periodicity and cadence of a cycle
- Example: Phone inside a pocket
- Segmentation methods, like minimum salience vectors, cannot be used
- Autocorrelation can reveal features even with noise



Outline

What is Gait Classification?

- Gait Classification determines if the user is "genuine" or an "impostor"

Fixed Method Gait Classification

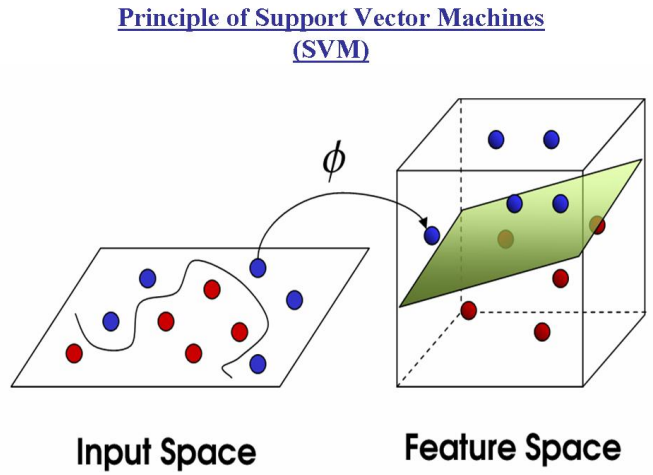
- Template-based
- Machine Learning

Template-based

- Feature Cycle: The cycle with the lowest DTW distance
- Probe Cycles: The remaining cycles
- After computing probe and reference cycles for all walks two classes are made:
  - Genuine
  - Impostor
- Genuine and Impostor are made by comparing the DTW distance of all the reference and probe cycles
- 50% of the Probe cycles must be classified as genuine

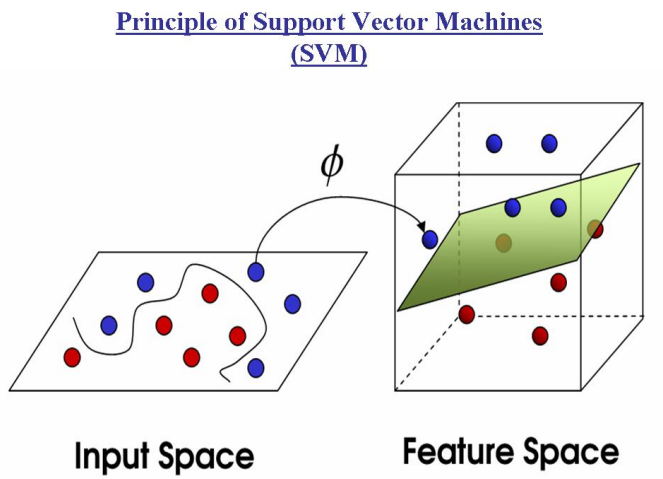
Machine Learning

- Data is split into two groups:
  - Training (80%)
  - Testing (20%)
- Support Vector Machines (SVMs) are used for biometric classification
- A SVM finds a hyperplane that linearly separates data into two classes: genuine and impostor



Machine Learning

- The data is not usually linearly separable. Therefore, a kernel function is used.
- A kernel function maps non linearly separable data to a high dimension space
- These data points are now compared to the Testing data set and labelled as genuine or imposter
- Classification: Class with the most data points



Unixed Method Gait Classification

- Universal Background Model:
  - Data Pooled from a group of subjects
  - Represents various gait patterns

Unfixed Method

- The UBM is trained with a user's data
- The current user's gait model is generated from the extracted features
- The current user's model is compared to the personalized Universal Background Model and either accepts or rejects.
- Further training of the UBM is done by recording false negatives

Outline

Conclusions

- Accuracy calculated by Equal Error Rate (EER):
  - False acceptance rate and false rejection rate are equal.
  - The Lower the EER the more accurate the method
- EER:
  - Fixed: EER 22.49%
  - Unfixed: EER 14%
- RunTime:
  - Fixed: 2-3 minutes
  - Unfixed: 30 milliseconds

Outline

Conclusions

- The unfixed method:
  - Uses a real-world approach
  - More accurate
  - Faster

References

Questions?

1) H. Lu, J. Huang, T. Saha, and L. Nachman, Unobtrusive gait verification for mobile phones, 2014

2) M. Muaaz and R. Mayrhofer, An analysis of different approaches to gait recognition using cellphone based accelerometers, 2013