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
- Unobtrusive Access

Outline

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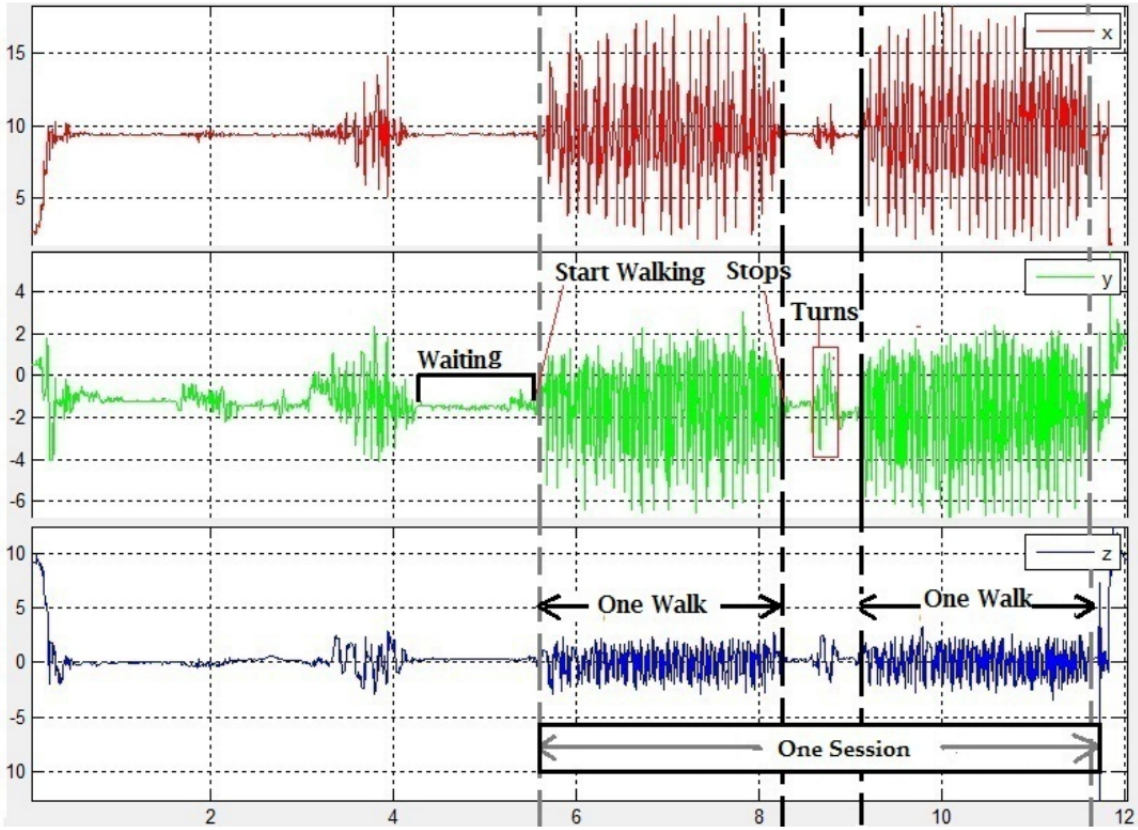
Biometrics

- Biometrics
- Gait Recognition
- Why Gait is Better

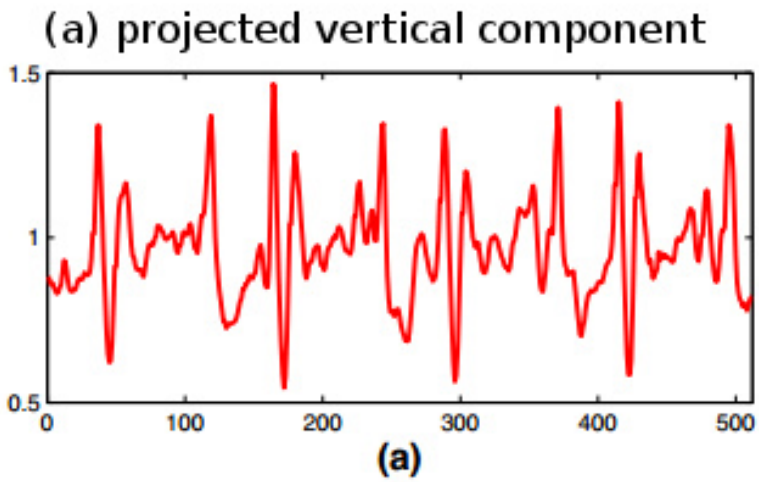
Fixed Method Approach

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



Unfixed Method Approach

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



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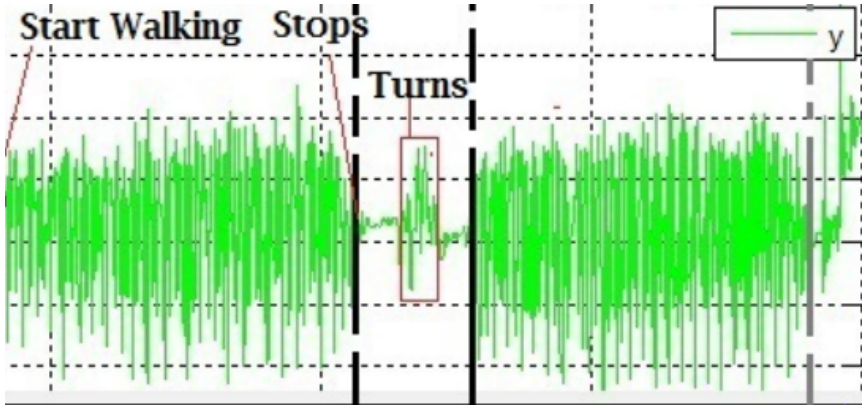
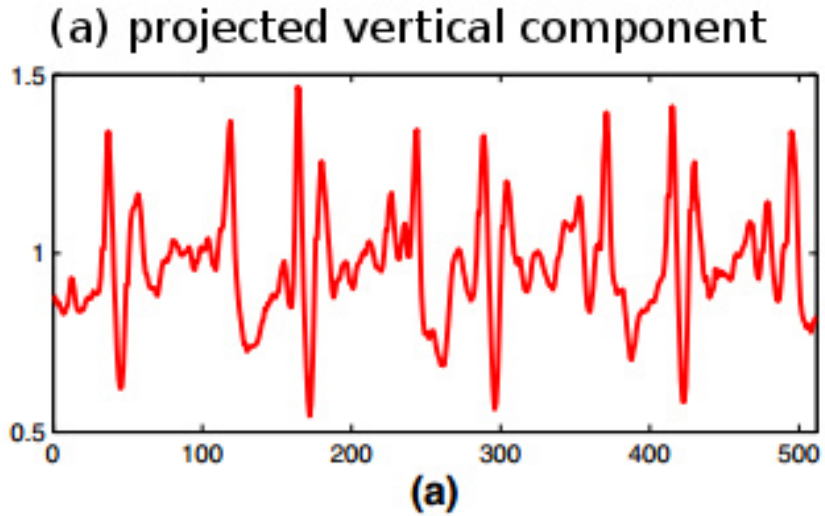
Preprocessing

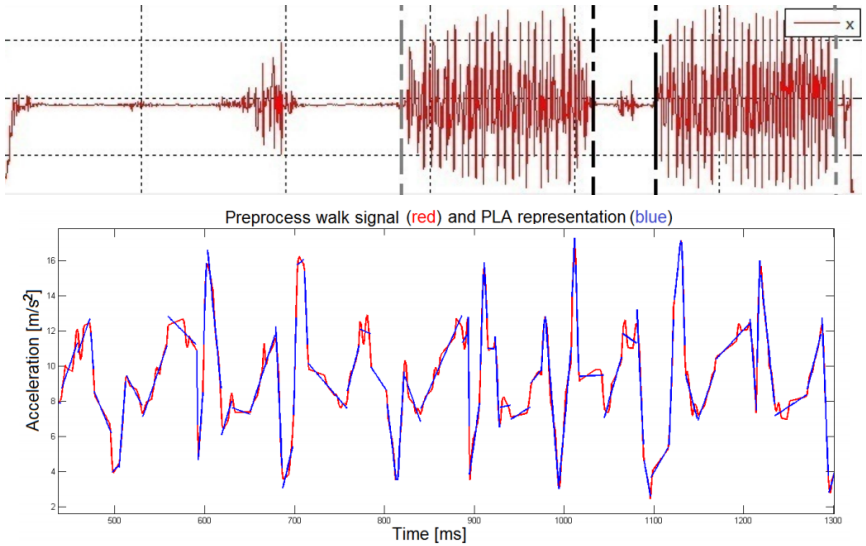
- Separates walking data from other noise
- Walks VS Frames





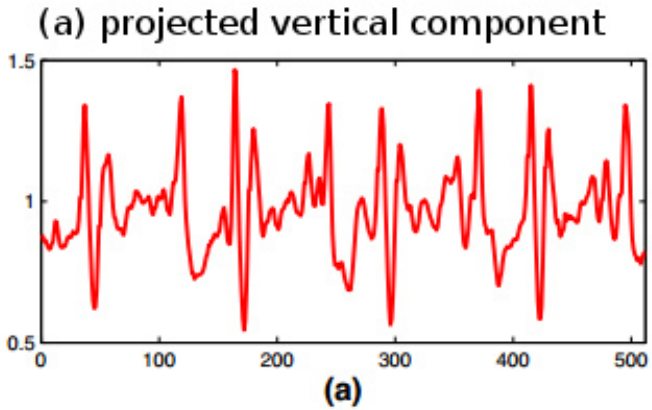
Linear Interpolation and Zero Normalization

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



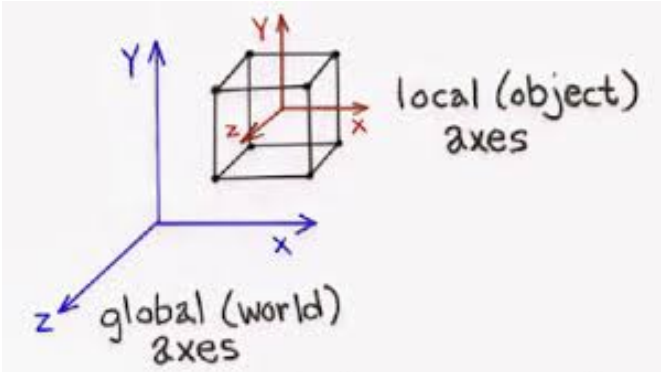
Framing

- 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.
- Each sample is split into two vectors:
  - Vertical (x)
  - Horizontal (y, z)
- Frame dropped if orientation is changed



Outline

What is Feature Extraction?

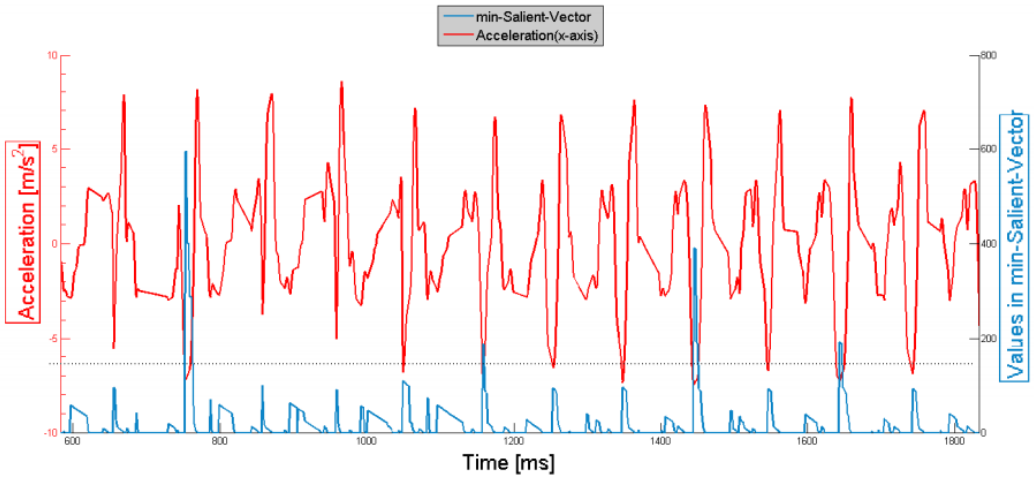
- Feature extraction separates "walking" cycles from "non-walking" cycles

Fixed Method Feature Extraction

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

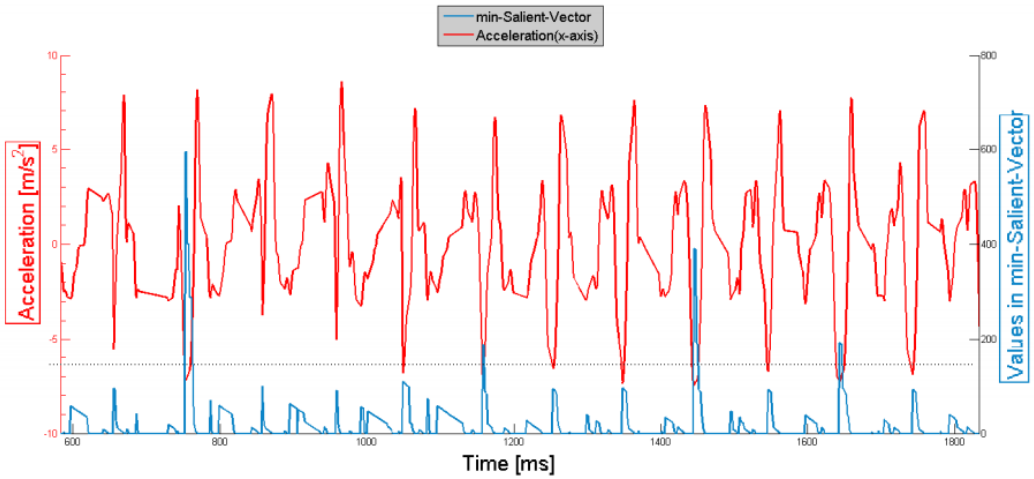
Cycle Length Estimation

- Estimate cycle lengths by computing Minimum Salience Vectors
- 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



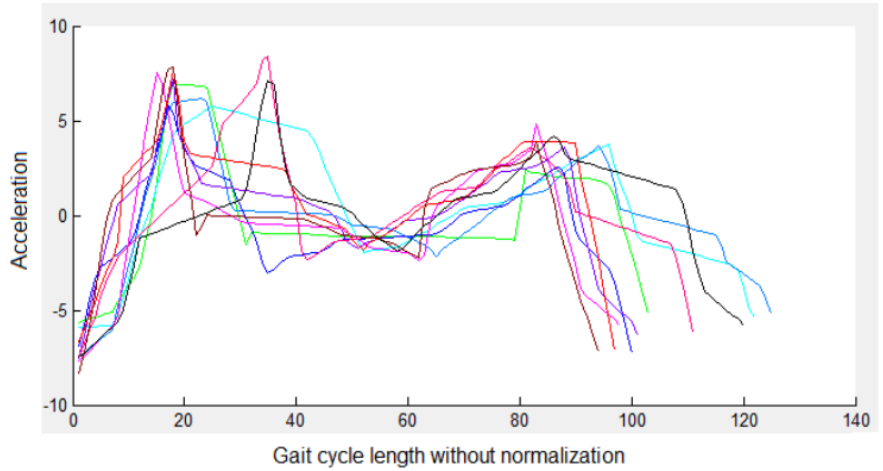
Cycle Detection

- Detecting Individual Cycles
- Start of each cycle is located using the entry with the greatest value
- Spike around points 750, 1150, 1450, 1650
- Long cycles are split again using the same method



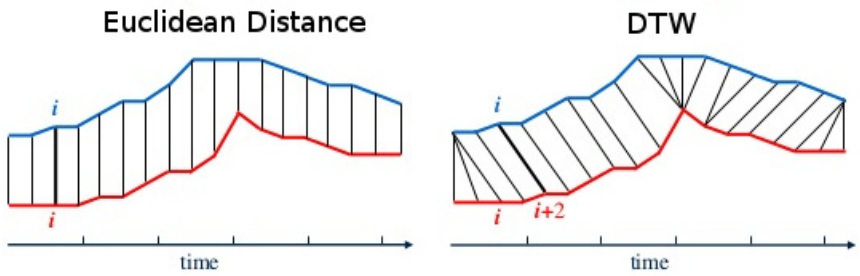
Cycle Length Normalization

- 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



Omitting Unusual Cycles

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



Unfixed Method Feature Extraction

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

Feature Extraction I

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

Walking Detection

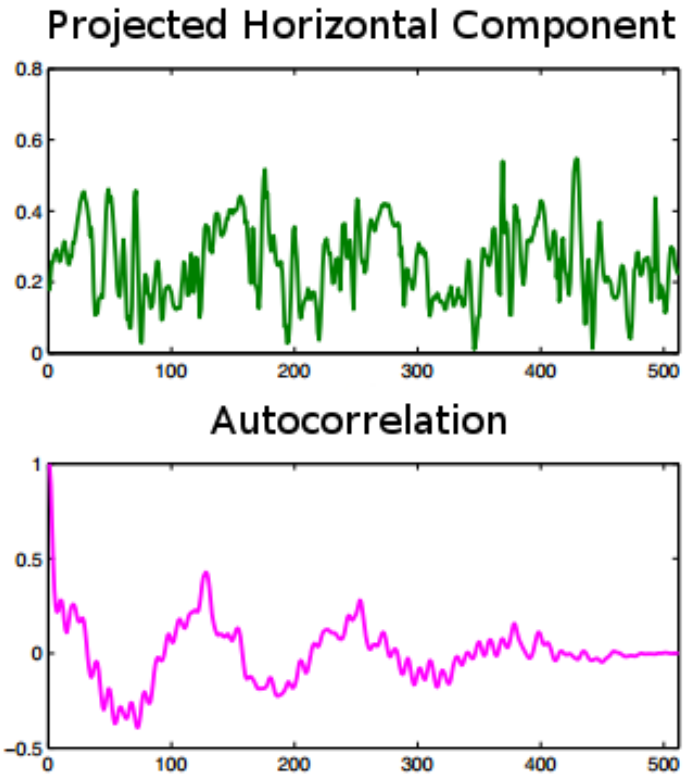
- Three classifications using a decision tree:
  - Walking: 1-2Hz
  - Non-Walking: >3Hz (running, biking, in moving vehicle)
  - Random Movements: >0Hz (transitional movements, short spikes)
- Cycles labeled as walking move onto the next step

Feature Extraction II

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

Autocorrelation

- Useful to find periodicity and cadence of the gait
- Collecting data from a phone inside a pocket
- Jostling of the phone can create spikes
- Segmentation, 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
- Unfixed Method Gait Classification
  - Gausian Mixture Model-Universal Background Model

Template-based

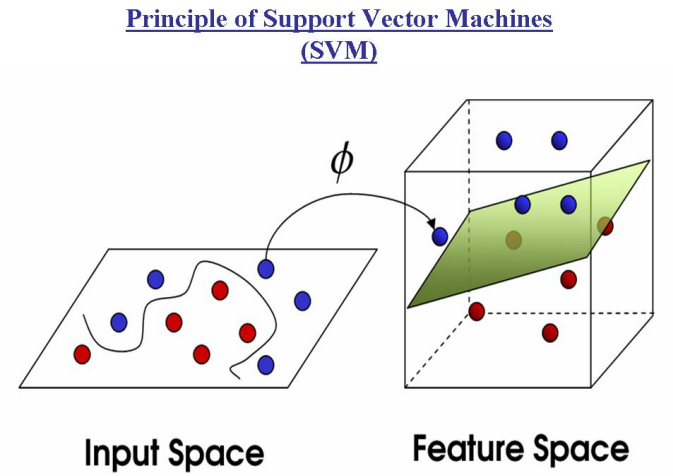
- Feature Cycle (the cycle with the lowest DTW distance)
- Probe Cycles (the remaining cycles)
- After computing probe and reference cycles for all walks two classes are made:
  - Genuine
  - Impostor
- Genuine and Impostor are made by comparing the DTW distance of all the reference and probe cycles
- 50% of the Probe cycles must vote 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. Again, the class with the maximum votes wins.



Unfixed Method

- The use of more than one training model is used to help classify gait cycles
- Universal Background Model (UBM) is used to train a large source of data
- User's gait model is generated relating the odds of one event to the odds of another
- Maximum-a-Posteriori (MAP) is used to adjust Gaussian components and mixture weight to personalize the UBM model
- The current user's gait cycle is compared to the personalized UBM model and either accepts or rejects.
- MAP is also used by recording false negatives

Outline

Conclusions

- The unfixed method is developed more and is better for real-life situations
- Given time, the fixed method can perform just as well as the unfixed method

References