

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

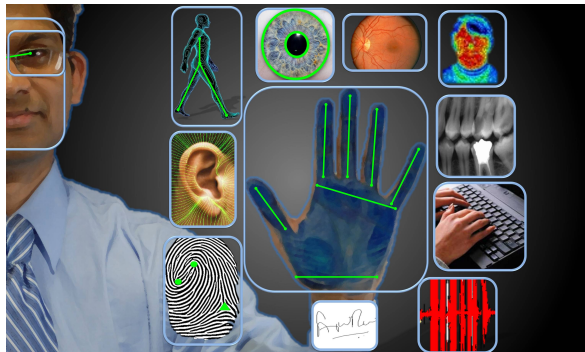
- 1 Background
- 2 Preprocessing The Data
- 3 Feature Extraction
- 4 Gait Classification
- 5 Results
- 6 Conclusion

Outline

- 1 Background
 - Biometrics
 - Two Methods
- 2 Preprocessing The Data
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Biometrics

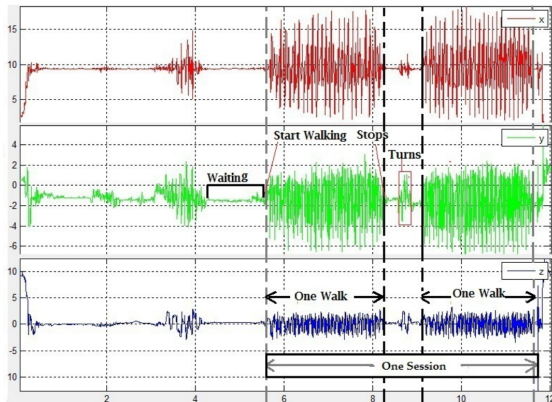
- Biometrics
- Gait Recognition
- Why Gait is Better
- Unobtrusive Access



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

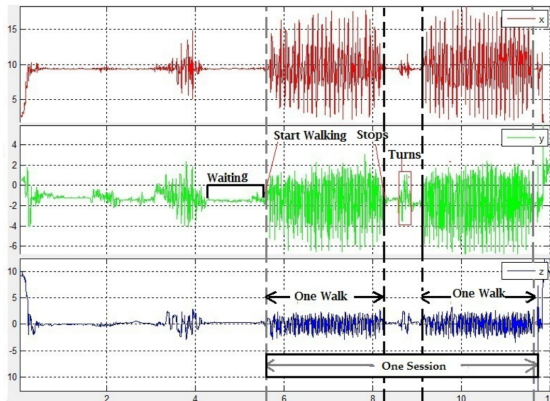
Two Methods

- Fixed Method
- Unfixed Method



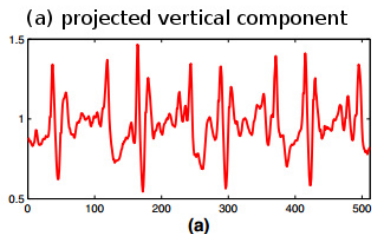
Fixed Method Approach

- 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

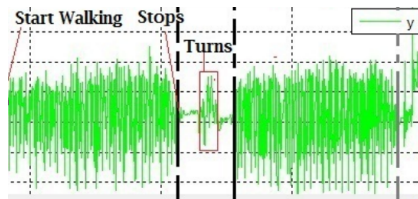


Outline

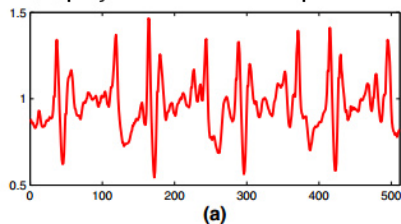
- 1 Background
- 2 Preprocessing The Data
 - What is Preprocessing?
 - Fixed Method Preprocessing
 - Unfixed Method Preprocessing
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Preprocessing

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

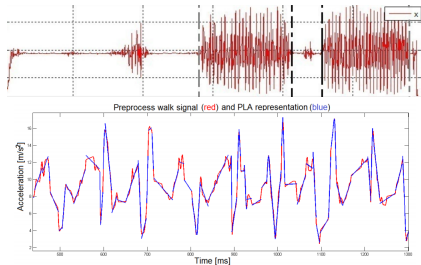


(a) projected vertical component



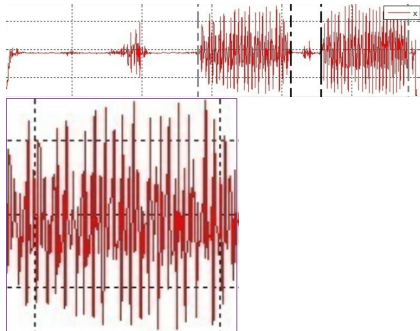
Fixed Method Preprocessing

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



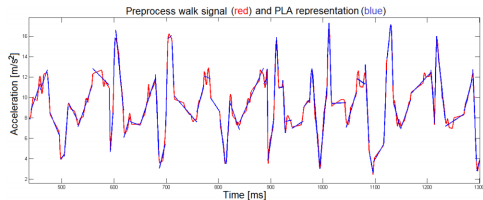
Walk Extraction

- Walk Extraction
- Separates walking data from non-walking data



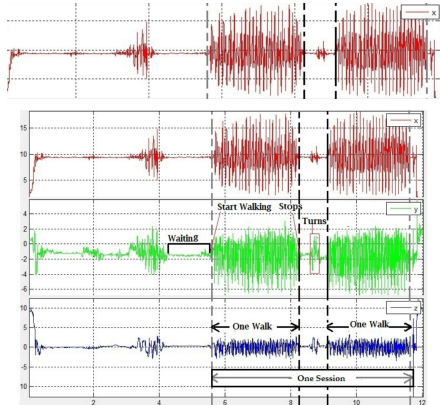
Linear Interpolation

- Linear Interpolation
(curve fitting)



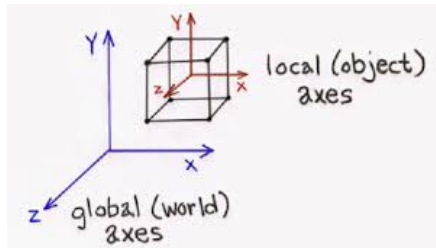
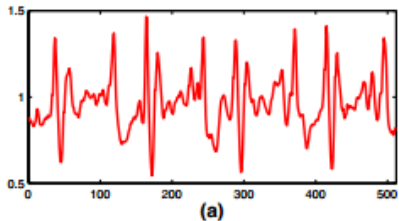
Zero Normalization

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



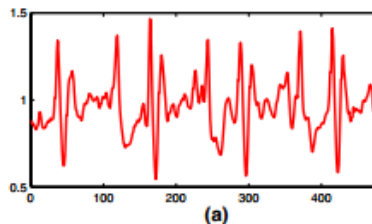
Unfixed Method Preprocessing

- Framing
- Projection



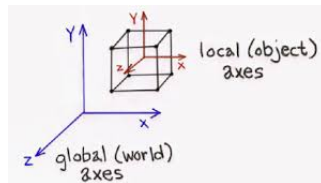
Framing

- 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



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 - What is Feature Extraction?
 - Fixed Method Feature Extraction
 - Unfixed Feature Extraction
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What is Feature Extraction?

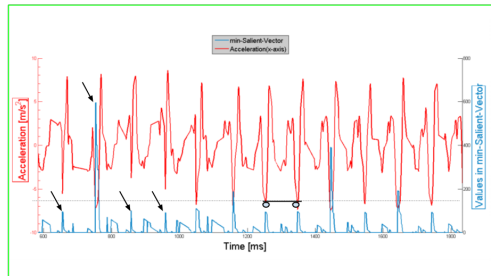
- Feature extraction separates "walking" cycles from "non-walking" cycles

Fixed Method Feature Extraction

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

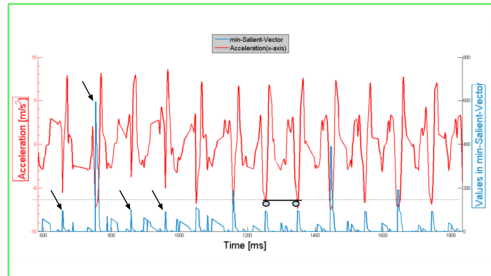
Cycle Length Estimation

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



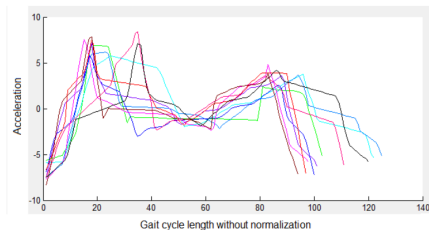
Cycle Detection

- 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



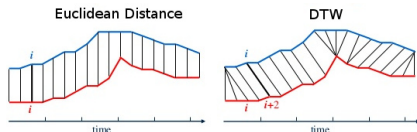
Cycle Length Normalization

- 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

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

Walking Detection

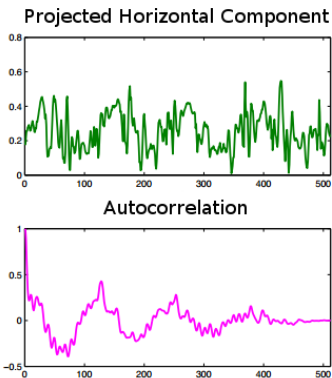
- Three classifications:
 - Walking: 1-2Hz
 - Non-Walking: $>3\text{Hz}$ (running, biking, in moving vehicle)
 - Random Movements: $>0\text{Hz}$ (transitional movements, short spikes)
- Cycles labeled as walking move onto the next step

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 a cycle
- Example: Phone inside a pocket
- Segmentation methods, like minimum salience vectors, cannot be used
- Autocorrelation can reveal features even with noise



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 - Overview
 - Fixed Method Gait Classification
 - Unfixed Method Gait Classification
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What is Gait Classification?

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

Fixed Method Gait Classification

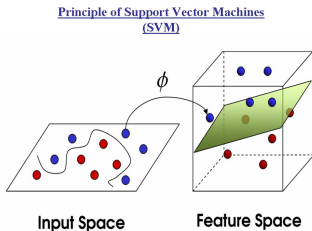
- Template-based
- Machine Learning

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

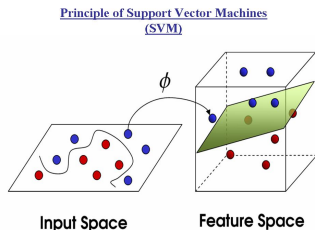
Machine Learning

- 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

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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

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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