

New York Institute of Technology

Presenters: Kiran Balagani (PI), Gang Zhou (Co-PI), and Paolo Gasti (Co-PI)

Hand Movement, Orientation, and Grasp (H-MOG): A New Behavioral Modality for Active Authentication of Smartphone Users

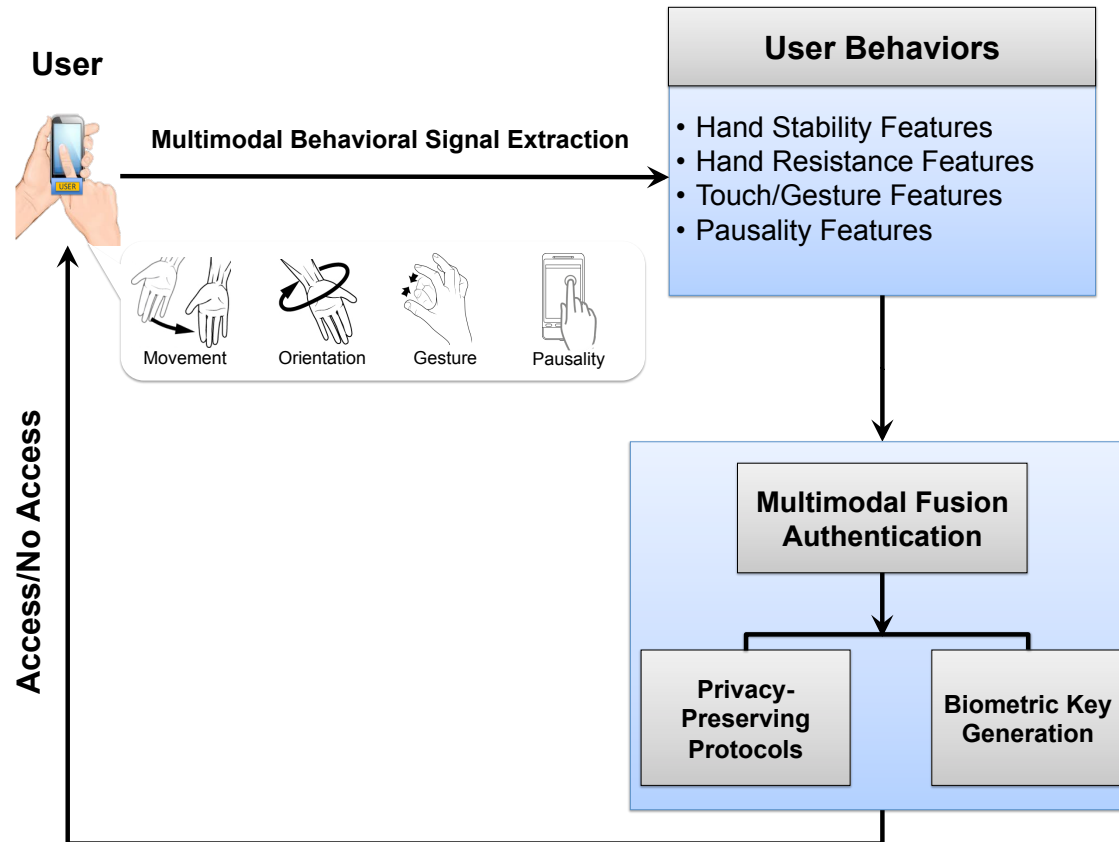


This research was developed with funding from the Defense Advanced Research Projects Agency (DARPA). The views, opinions, and/or findings contained in this article/presentation are those of the author(s)/presenter(s) and should not be interpreted as representing the official views or policies of the Department of Defense or the U.S. Government.



NEW YORK INSTITUTE OF TECHNOLOGY

BIOMETRIC: How a user moves and orients hands while interacting with the smartphone, during touch bursts and cognitive pauses



Experiment:

Number of volunteer participants: **100**

Volunteer participants performed typing, reading, and map navigation activities on Android based smartphones. Each volunteer participant interacted with the smartphone for 360 minutes, under two body motion conditions: 1) sitting and 2) walking.

Experiment Results:

- ✓ Equal Error Rate (True Positive Rate = False Positive Rate) = **7.23%** (Typing Task)
- ✓ Time before decision = **140 seconds**
- ✓ Implementation of privacy-preserving active authentication
- ✓ Biometric key generation code and results
- ✓ Code for extracting HMOG authentication features



HAND MOVEMENT AND ORIENTATION FEATURES

- **At least 100 multimodal features**

Measurement	Example Features	Sensors
Movement	• Aggregate acceleration in x, y, and z directions in time window T • Correlations between x, y, and z axes	Accelerometer, and gyroscope.
Orientation	• Aggregate angular velocity in x, y, and z directions in time window T • Correlations between x, y, and z axes	
Movement and orientation during gestures	• Zero-cross rate of angular velocities in x, y, and z directions during a touch-stroke starting at location "A" and ending at location "B" with mid-stroke contact area "C"	Touch and gesture event handler measures touch location, and contact area.
Movement and orientation during pauses	• Zero-cross rate of angular velocities in x, y, and z directions between two touch-strokes occurring within a pausality period of T seconds and starting at screen zone "A" and ending at screen zone "B" with mid-stroke pressure "C"	



GRASP QUALITY AND FREQUENCY DOMAIN FEATURES

- **Grasp Resistance Features (30)**

- The feature measures net displacements in the x , y , and z directions due to a touch-strokes and gestures.

- **Grasp Stability Features (20)**

- The feature measures how quickly a grasp restores angular velocity after a touch or gesture event.

- **Frequency Domain Features (70)**

- Principle frequency for acceleration in x , y , and z directions
- Spectral energy for acceleration in x , y , and z directions
- Magnitude of the first 5 components of FFT analysis for acceleration

Anomaly Detection Algorithms: Norm-based (e.g., L_1 and L_2), probabilistic (e.g., first-order) models, one-class support vector machines, and score-level fusion.

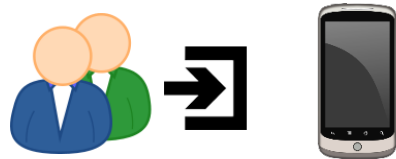


Data Collection



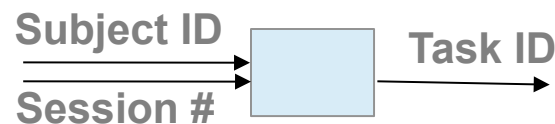
DATA COLLECTION PROCESS

1. Subject Login



Login ID is assigned to each subject

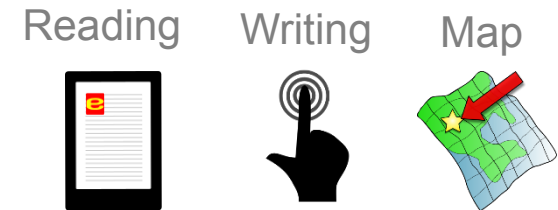
2. Task Allocation



Session # is retrieved from server

Task is determined by Subject ID and Session #

3. Task Execution



Two Scenario

Sitting



Walking



Real-time touch and sensor data is collected in background

- 100 volunteers (37 female and 53 male)
- 8 reading, 8 writing, and 8 map-navigation sessions
 - 12 sitting, and 12 walking



DATA COLLECTION TOOL UI

1. READING

My Name is Electra by Joanna Leyland

I am a very lucky girl and my family is the nicest in the world. Mummy and Daddy are important of course and when we're out we have to behave properly but when we're at home we play and laugh and have lots of fun. "You spoil them!" Mummy says, and she frowns and folds her arms in front of her but then she laughs and kisses him so I know she's not really serious. We have all sorts of games like the one where the hall is the world and the tables and chairs are different countries. Then Daddy tells us all about his travels, but he says the best thing was when he met Mummy and fell in love with her. "Now that's a happy ending," he says.

He's a wonderful Daddy and is always nice and funny. When Mummy sighs and says she's getting lots of white hairs he laughs and says, "I'll be getting them soon and then we'll be two little old people nodding off on the terrace together" then he hugs her till she cheers up. And he lets me ride on his back and gallops round the room making horse noises, then rolls on the floor. Or sometimes we play Hide and Seek or Blind Man's Buff, even if Daddy doesn't really like it. "I want to see everything all the time" he says. "Just look at my beautiful wife

Answer Questions

Like a *Web browser*.

Subjects could tap, scroll, or zoom in/out the text.

Q1: Is the girl talking about her garden?

- ☐ Yes
☒ No

Q2: Does anybody in the story make horse noises?

- ☒ Yes
☐ No

Q3: This story has a tragic ending?

- ☐ Yes
☒ No

Subjects need to answer several questions about the text.

Back to Text

Finish



DATA COLLECTION TOOL UI

2. WRITING

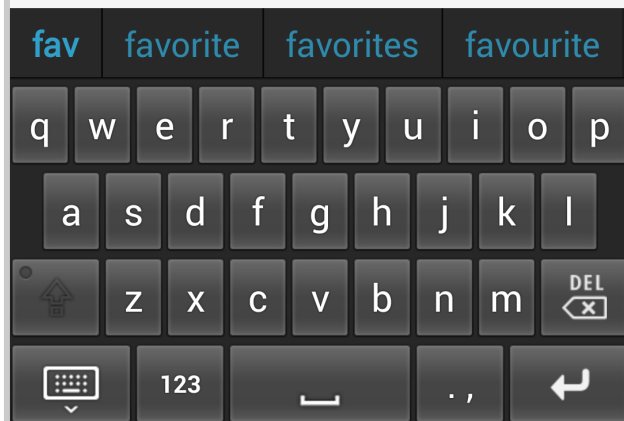
Write a summary (plot synopsis) of your favorite movie.

Submit

One of my fav

Like composing an E-mail or SMS.

Key press events on the virtual keyboard, along with other touch and sensor events, are recorded



Write a summary (plot synopsis) of your favorite movie.

Submit

One of my favorite movies is Frozen. It's a story about Elsa, who is princess of Arendelle and possesses the magical ability to create ice and snow. One night while playing, she accidentally hurt her younger sister, Anna. When Elsa comes out of age, the kingdom prepares for her coronation.

Each task requires at least 250 characters input, so that enough data are collected for later analysis.





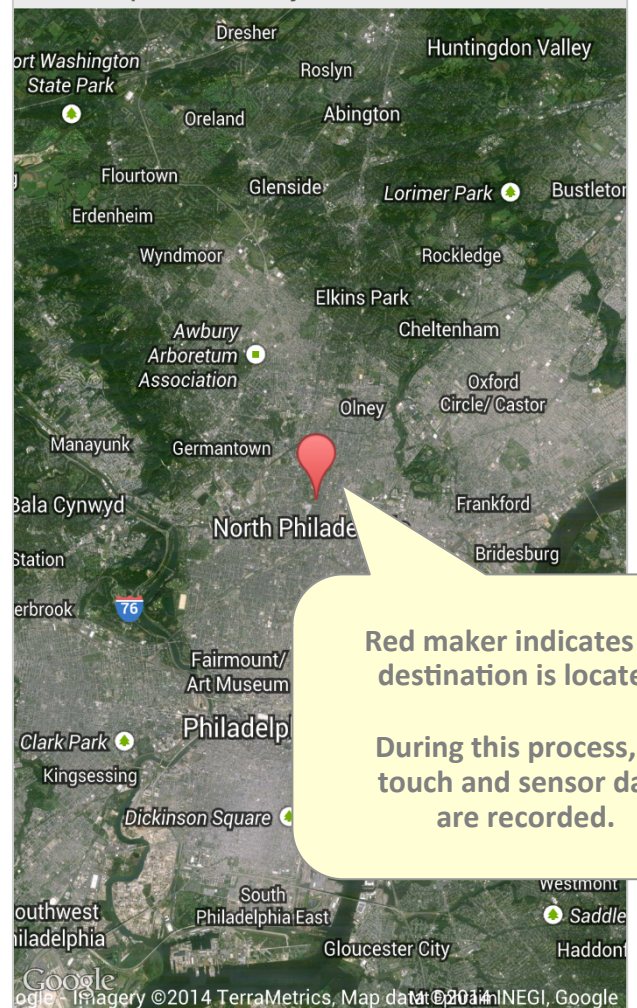
DATA COLLECTION TASK UI

3. MAP NAVIGATION

Destination: North Philadelphia, a section of Philadelphia, Pennsylvania



Destination: North Philadelphia, a section of Philadelphia, Pennsylvania



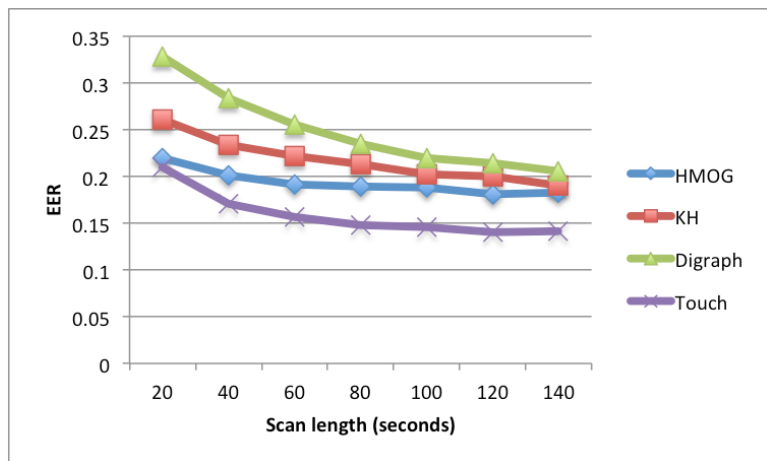


Authentication Results

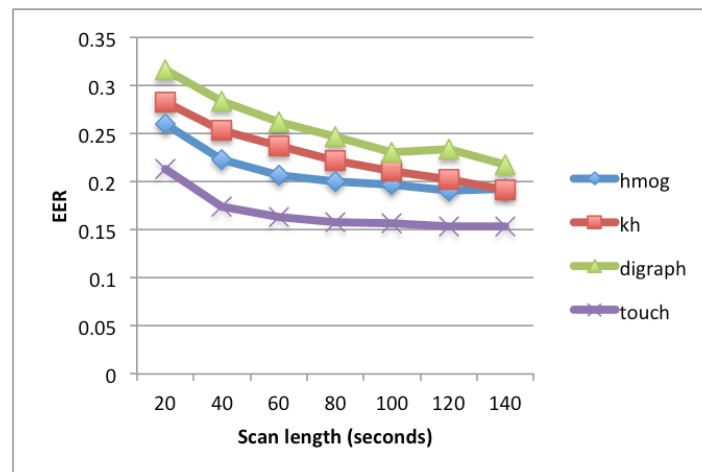


Comparison of H-MOG with State-of-the-art (Sitting)

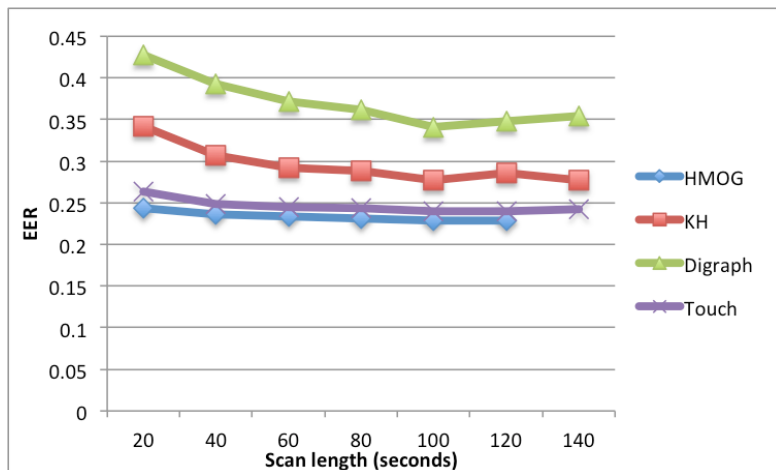
Scaled Manhattan



Scaled Euclidean



1-class SVM

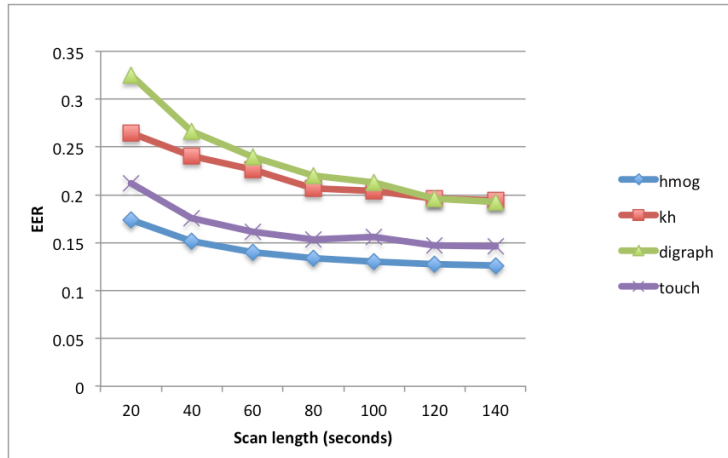


- EERs with touch features lower than H-MOG
- EERs with H-MOG lower than digraph and key hold features

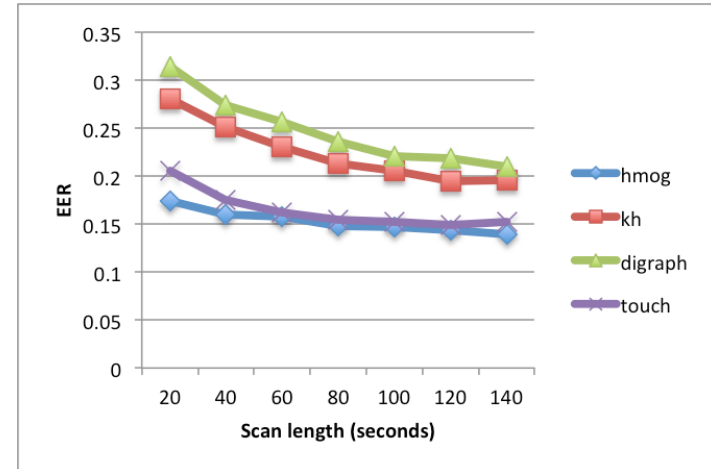


Comparison of H-MOG with State-of-the-art (Walking)

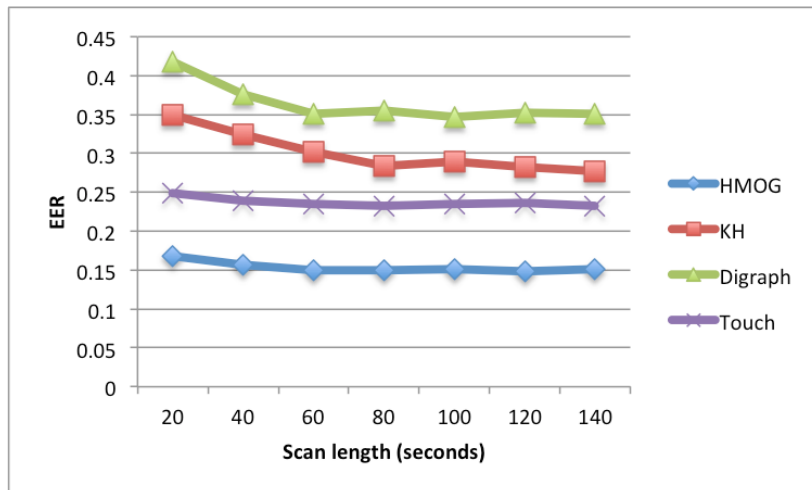
Scaled Manhattan



Scaled Euclidean



1-class SVM



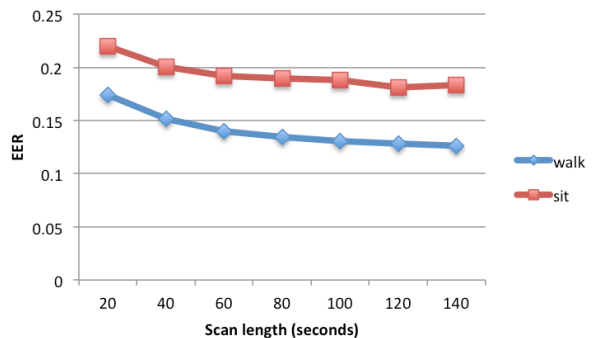
- EERs with H-MOG features lower than key hold and digraph.
- H-MOG performance better (or comparable) compared to touch features



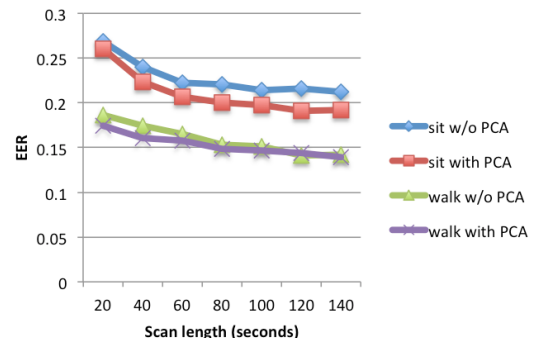
H-MOG Performance Improvement (Walking)

H-MOG:

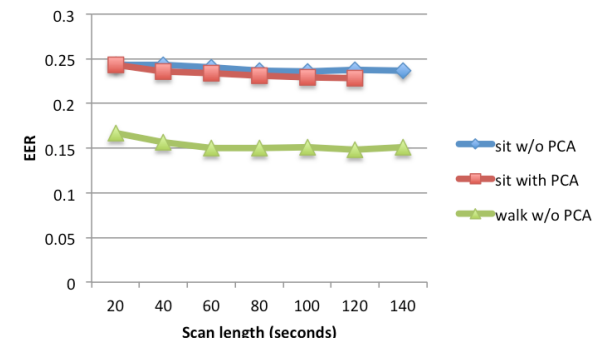
Scaled Manhattan



Scaled Euclidean

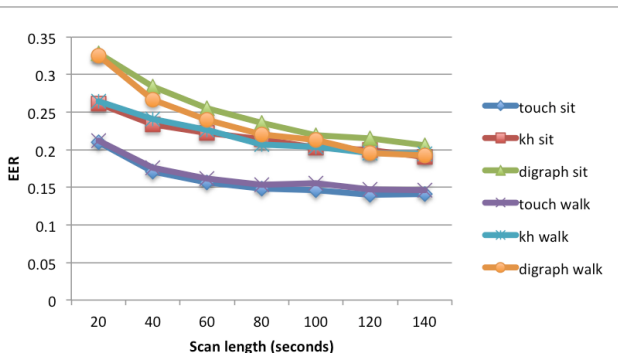


1-class SVM

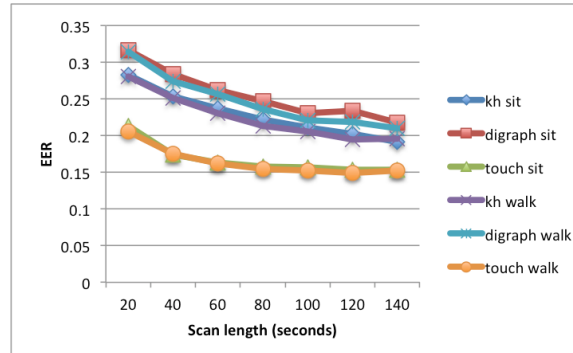


State-of-the-art:

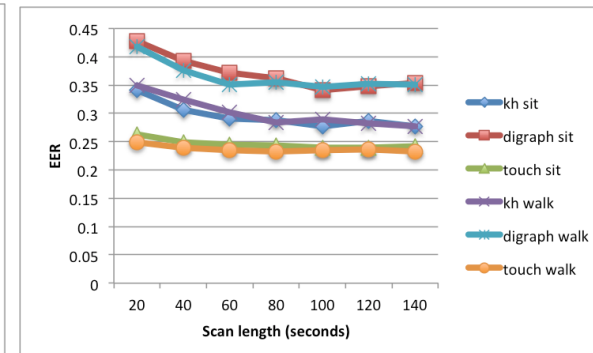
Scaled Manhattan



Scaled Euclidean



1-class SVM

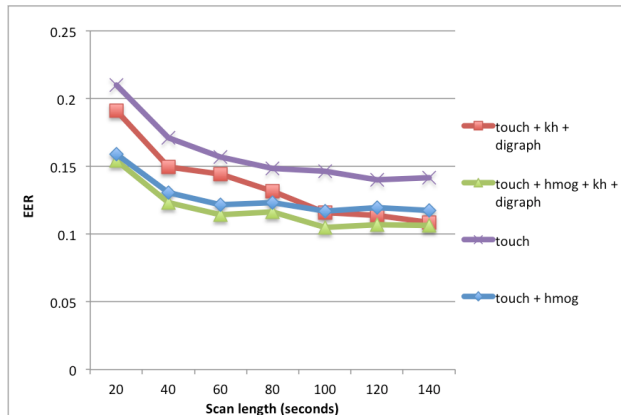




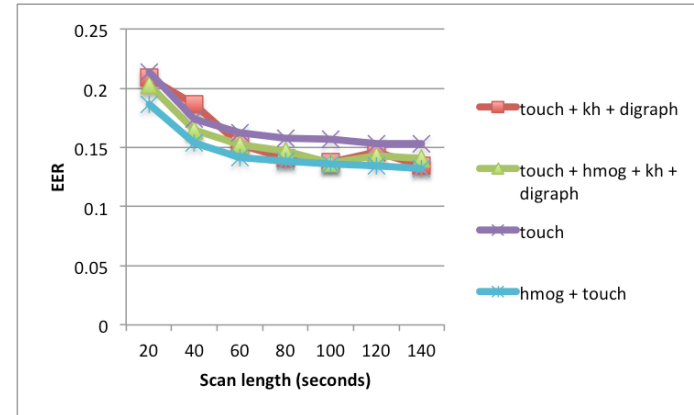
Fusion of Feature Sets

Sitting

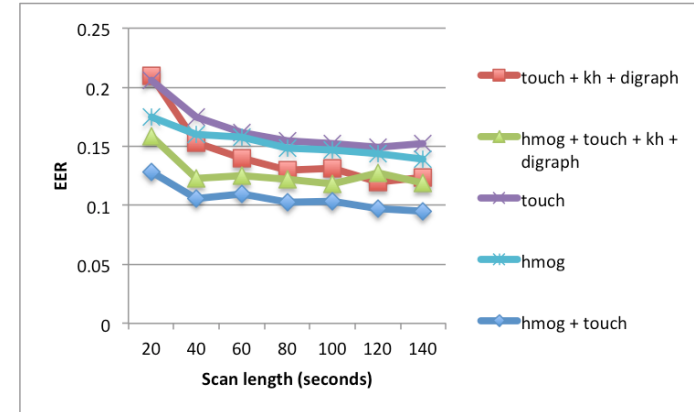
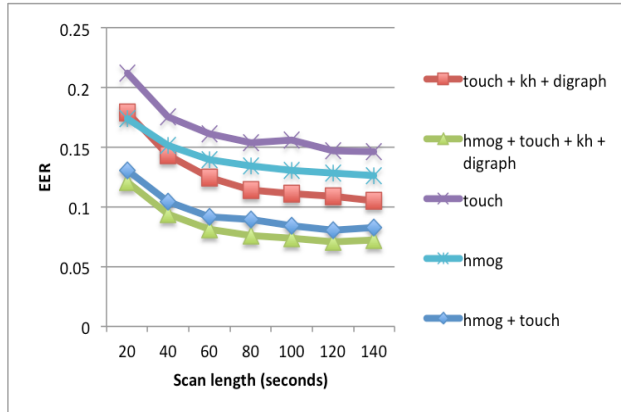
Scaled Manhattan



Scaled Euclidean



Walking



- **Sitting:** For shorter scans, combining with H-MOG yields lower EER than without H-MOG.
- **Walking:** Combining with H-MOG yields lower EER than combining without H-MOG.



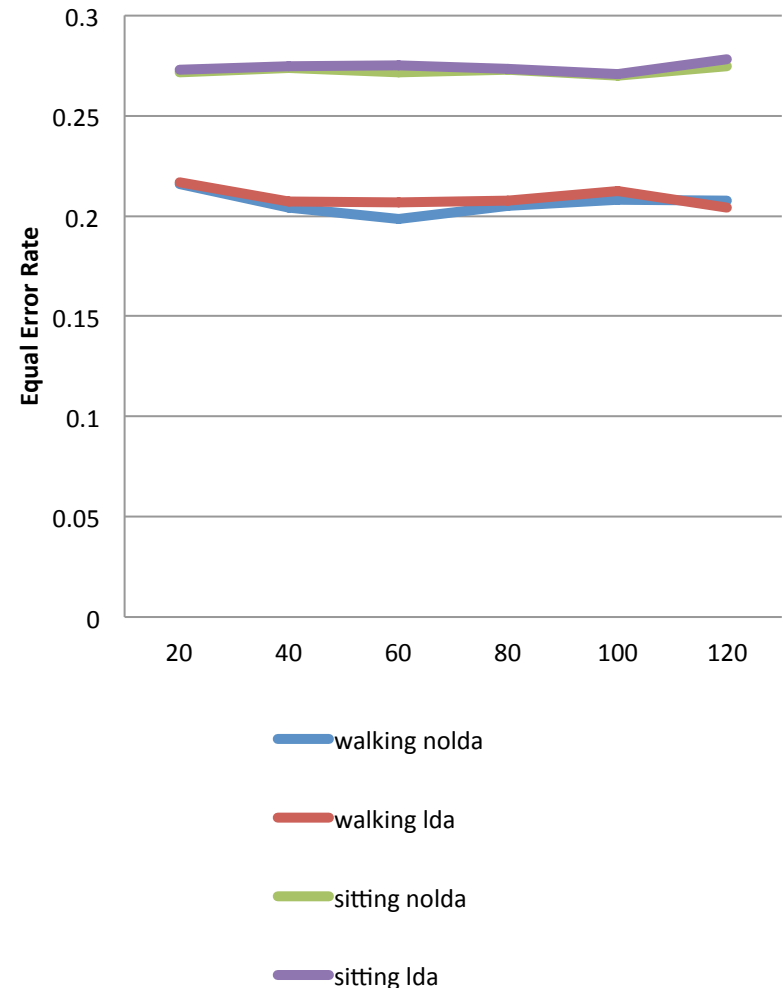
Biometric Key Generation Results



H-MOG Features

- Top 31 features
- Accuracy is better in walking scenario
- Scan windows longer than 60 seconds do not increase accuracy

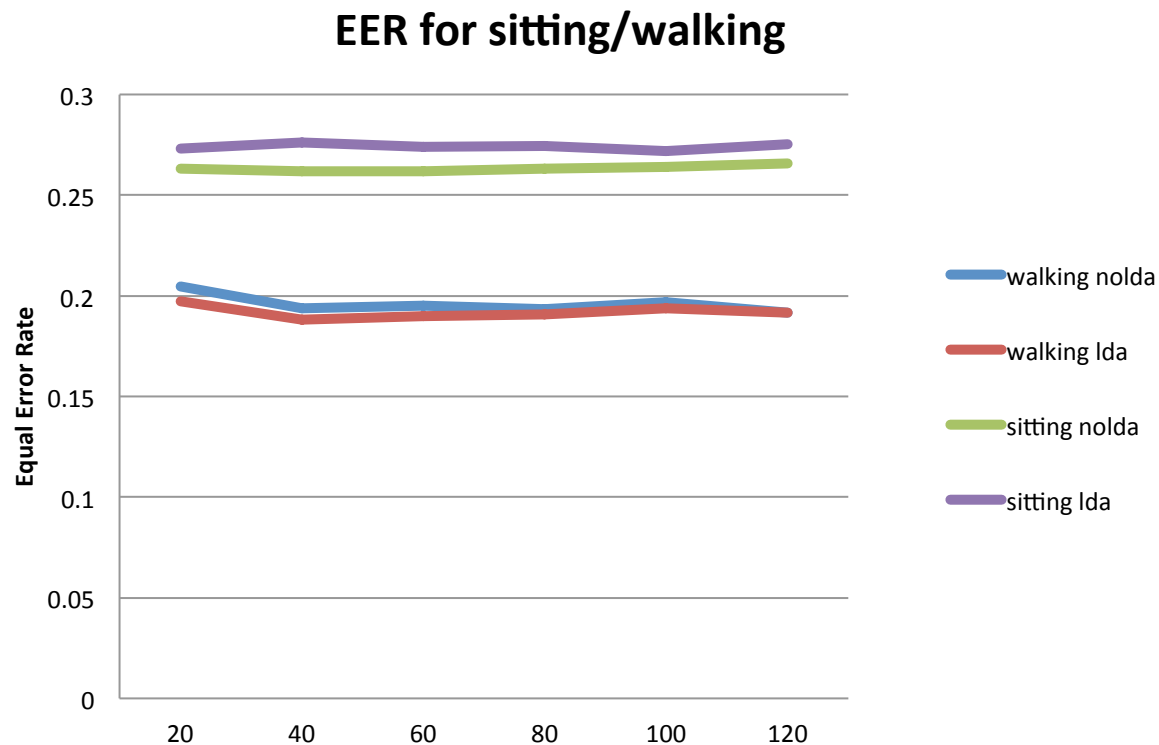
EER for sitting/walking





H-MOG Combined with Touch Features

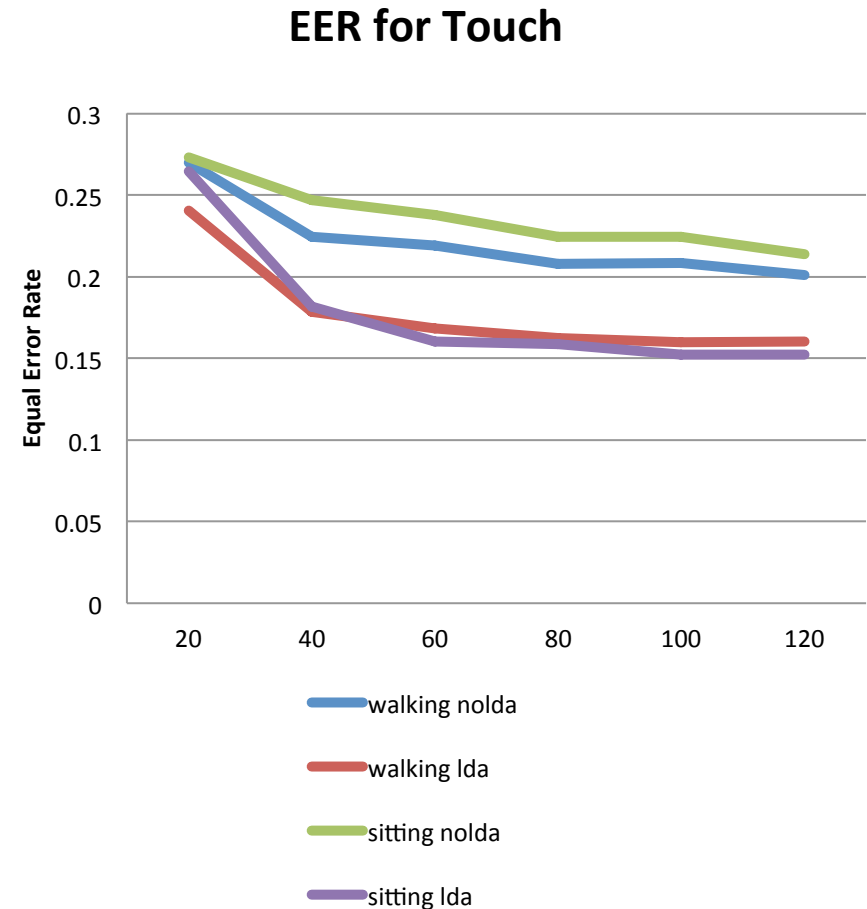
- Top 3 touch + 31 H-MOG features
- Accuracy: 18.8% (EER, walking)





Touch Features

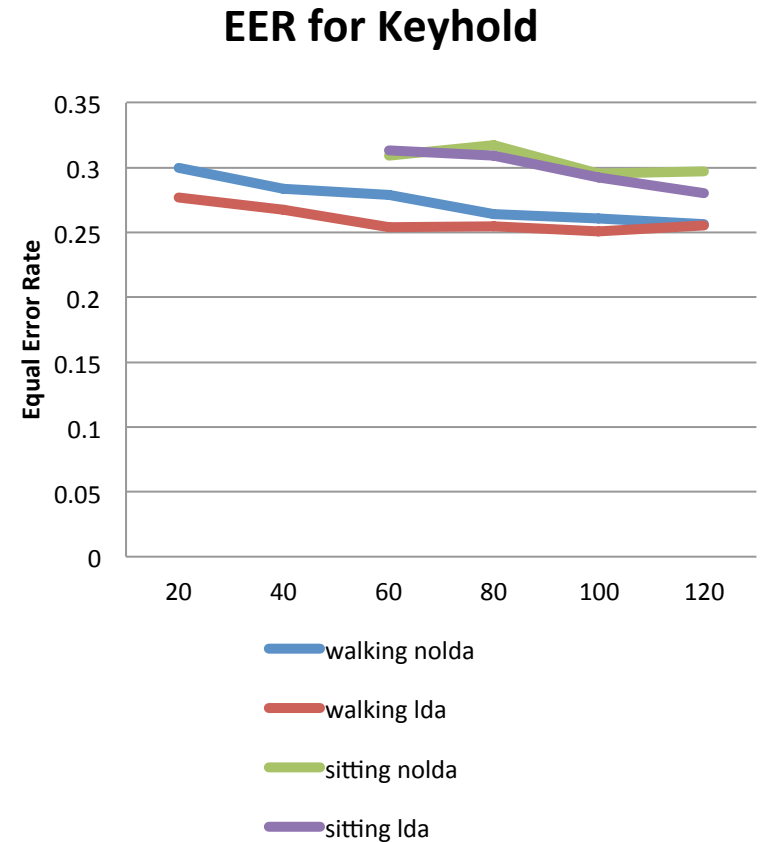
- LDA reduces EER to 15%
- Scan windows longer than 60 seconds improve accuracy
- Touch features achieve best EER





Keyhold Features

- BKG cannot handle missing values
- We used:
 - 8 features for walking
 - 13 features for sitting
 - no digraphs
- EER is over 25%





- Authentication
 - H-MOG performs best during walking
 - H-MOG performs better than keystroke dynamics
 - Lowest EER with fusion of H-MOG and touch features
- Biometric Key Generation
 - H-MOG performs well when combined with touch features – well suited for short scans
 - Touch features alone perform better than H-MOG, but only for long scans
 - Keyhold signals not suitable for BKG due to frequent missing values