SRI International (East)

Intelligent Physiology and Activity based Authentication System (IPAAS) for Mobile Devices

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Active Authentication PI Meeting

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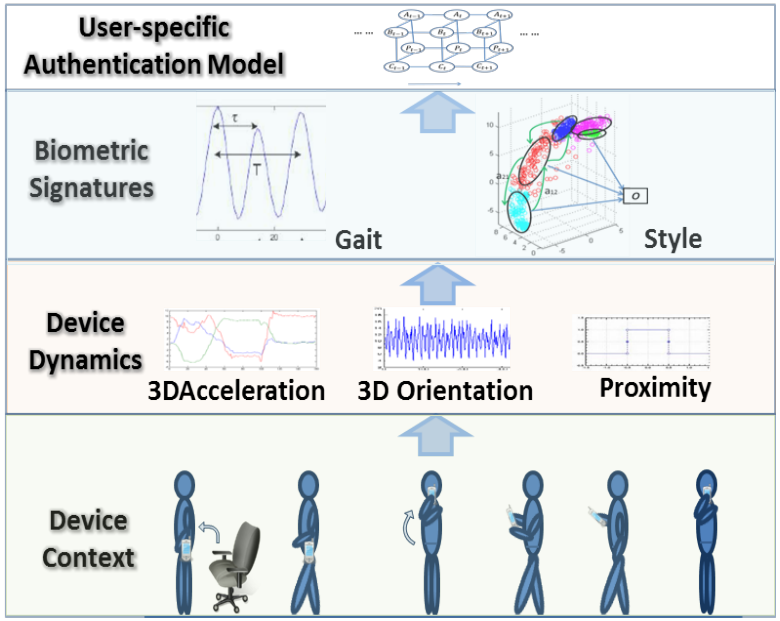
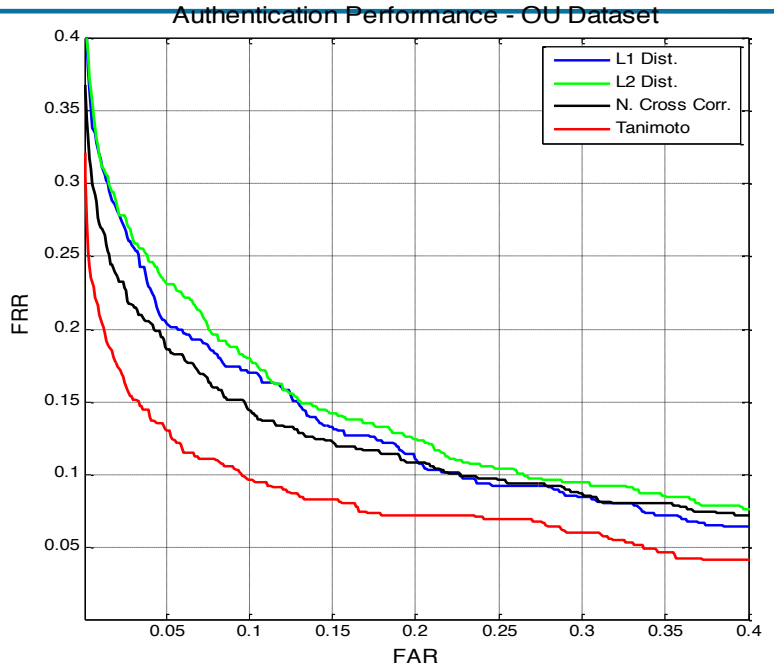
BIOMETRIC: Mobile device motion, where the motion is caused due to user's handling of the device or by user's movement while carrying device



Authentication from Device Dynamics



Activity based Authentication Results

Experiment:

- Authentication using activity dynamics, measured from a mobile device. Two data sets were used.
- Dataset 1: **744** subjects (389 males and 355 females) walking, with an IMUZ sensor attached to the back waist. This dataset is publically available
- Dataset 2: **101** subjects (63 male, 38 female), performing a variety of activities with mobile devices, including walking, picking up/ putting down devices and sending and receiving texts/calls in realistic situations

A novel mobile active authentication system using mobile intrinsic behavior biometrics of a user that is unobtrusive, and can work either in a standalone mode, or can use a network if available, and leaves user doing their regular mission.

Experiment Results using Equal Error Rate (EER) as a metric for walking activity while phone is placed in the pocket (*5 seconds*) achieves EER low 6.3% avg 6.8% high 7.6% and phone in the holster EER low 5.5% avg 6.7% high 7.5%. Both using Tanimoto Distance Measure.

Conclusions: Device dynamics can be exploited to reliably authenticate users when user is walking. Improved performance achieved when phone is not used compared with phone is used.

Outline/Progress Summary

- Introduction: Continuous Authentication via Device Dynamics
- IPAAS: System Overview
- Progress Summary
  - Data Collection
    - ***Finished data collection for 101 subjects***
    - **Data Labeling**
  - Activity Context Detection Improvements
    - ***Evaluated long-term movement***
    - **Conducted experiments for short-term activities (put down, pick up)**
  - Walking-based Authentication Algorithm Improvements (**Days Apart**)
    - ***Improvements OSU EER Using Normalization***
    - **Extensive Experimental Results using EER Low, EER Avg and EER High**
    - **Enhanced gait matching by filtering out noisy gait cycles**
      - **Self Dynamic Time Warping**
  - Physiological Signature Estimation
    - **Best gait cycle matching, Linear interpolation**
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    - ***Client-Server, Phone Stand Alone Implement Full Set of Activity Detection on Device***
    - **Combined Ctrace and Tracer into one App and System Robustification**
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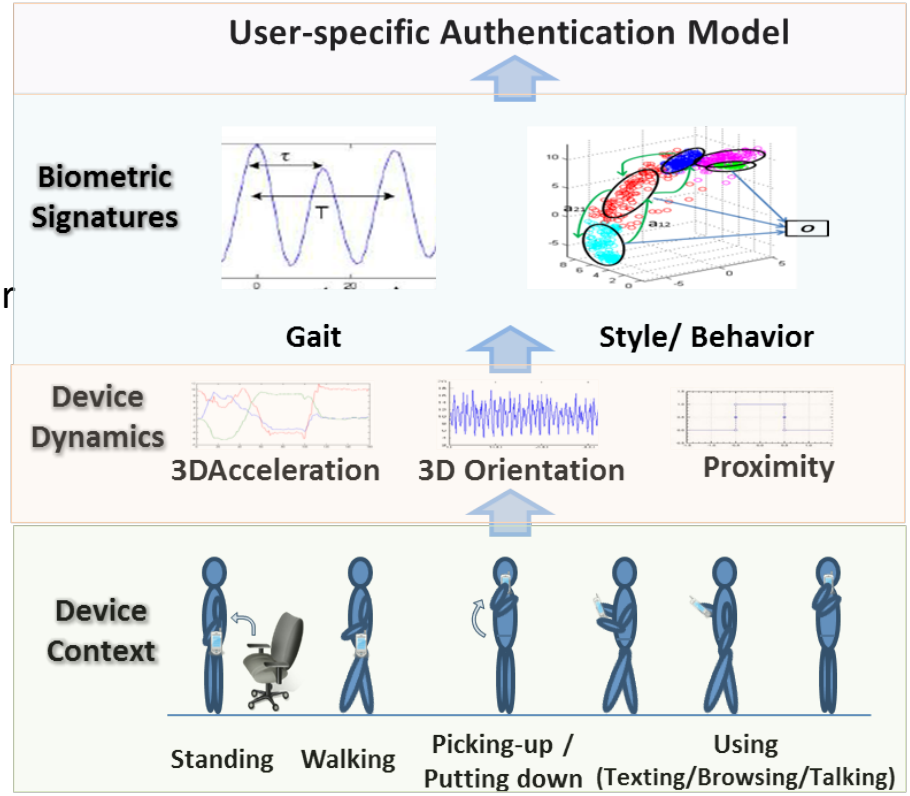
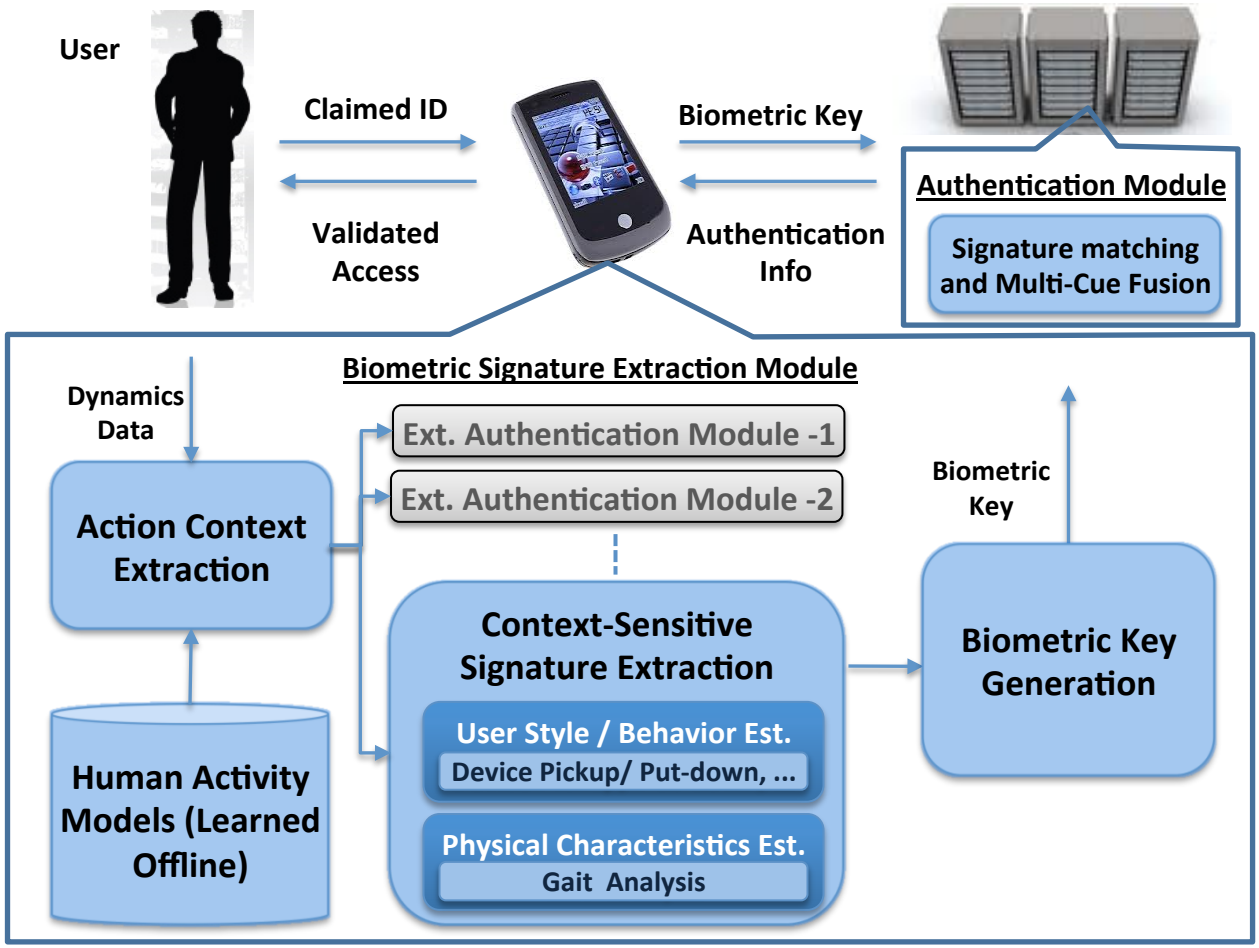
Introduction: Authentication via Device Dynamics

- Mobile devices, by definition, are moved and manipulated by the user
- The motion induced on the mobile device due to activity of the user depends on
  - The physical traits of the user
  - The behavioral tendencies or style of the user
  - Location of the cell phone on the user
  - The activity being carried out by the user
- Most commonly available mobile devices have sensors to measure motion and orientation including accelerometer, gyroscope, magnetometer etc.
- Our goal is to extract the physical and behavioral traits of the user during common usage of the device and use these for continuous authentication



IPAAS: System Overview

- Real time processing of device sensor data for
  - Activity Context Extraction
  - Context Sensitive Signature Extraction
  - Biometric Key Generation
- User action context will be made available to all authentication services (touch, type, voice etc.)



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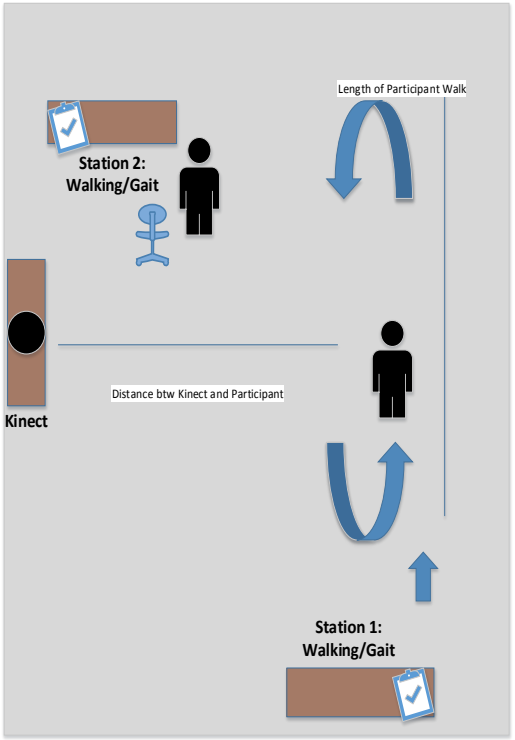
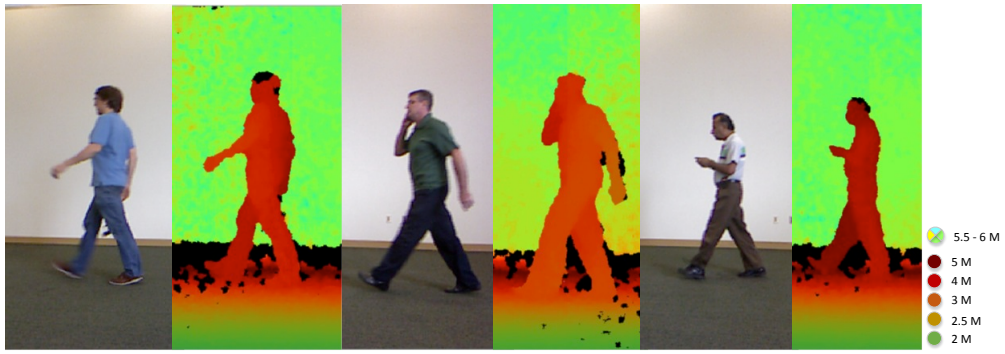
Data Collection

- In a single server approach, took approximately 40 minutes per person
  - A multi-stage approach adopted to run collection in parallel. Overall, each participant took an average of 24.51 minutes
- Arrive: Present IRB Form
  - Answer participant questions about study
  - Sign documents
- First station: Gait/Walking
  - Basic user training on how to use phone:
    - Skype application, Answer calls, Texting
- Second station: Stationary Activities
- Final Station:
  - Return phone
  - Verbal feedback on how collection went
  - Present gift card
  - Sign forms





Data Collection Statistics

Gender	
Female	38
Male	63
Age distribution (years)	
18 to 20	26
21 to 30	58
31 to 50	10
51 to 64	6
Unspecified	1
Height distribution (cm)	
110 – 120	1
151 – 160	16
161 – 170	33
171 – 180	34
181 – 200	17

Table 1. Data statistics

Time elapsed	# subjects
<= 1 week	20
> 1 week and <= 2 weeks	14
> 2 weeks and <= 3 weeks	14
> 3 weeks and <= 8 weeks	9

Table 2. Time between days apart collections

- Mobile Device Sensors Collected
  - Accelerometer
  - Orientation
  - Gyroscope
  - Proximity
  - Gravity
  - Magnetic Field
  - Linear Acceleration
  - Rotational Vector
- Other
  - Video
  - Depth Data

Data Labeling

Activity ID	Phone Home Location	Subject Action	Phone Action
01	Table	Sitting	Talk
02	Table	Sitting	Text
03	Table	Standing	Talk
04	Table	Standing	Text
05	Pocket	Sitting	Talk
06	Pocket	Sitting	Text
07	Pocket	Standing	Talk
08	Pocket	Standing	Text
09	Holster	Sitting	Talk
10	Holster	Sitting	Text
11	Holster	Standing	Talk
12	Holster	Standing	Text
13	Pocket	Walking	NONE
14	Pocket	Walking	Talk
15	Pocket	Walking	Text
16	Holster	Walking	NONE
17	Holster	Walking	Talk
18	Holster	Walking	Text

Data Scenarios

Column	Contents
ID	4 digit subject ID. Leading digit is 1, indicating this was the first data collection for the subject. Last 3 digits identify the subject uniquely.
Date	Date of data collection
Age	Self-reported age in years
Height	Measured height in inches
Weight	Self-reported weight in pounds (lbs)
Arm length	Measured arm length in inches
Leg length	Measured leg length in inches
Gender	Gender of subject (Male / Female)
Dominant hand	Hand naturally used for writing and similar activities
Video consent	Subjects consent for Kinect (video/depth) data collection during gait activities.

Same Day

Column	Contents
ID	4 digit subject ID. Leading digit is 2, indicating this was the second data collection after a few days for the subject. Last 3 digits identify the subject uniquely.
Date	Date of data collection
Age	Self-reported age in years
Height	Measured height in inches
Weight	Self-reported weight in pounds (lbs)
Arm length	Measured arm length in inches
Leg length	Measured leg length in inches
Gender	Gender of subject (Male / Female)
Dominant hand	Hand naturally used for writing and similar activities
Video consent	Subjects consent for Kinect (video/depth) data collection during gait activities.

Days Apart

Column name	Description
Subject ID	4 digit subject ID
Activity	Activity ID (01 – 18)
Phone ID	ID of phone used (1 – 4)
Seq #	Sequence # of data file
Pickup start	Row in csv file of start of phone pickup
Pickup end	Row in csv file of end of phone pickup
Action start	Row in csv file of start of action (Talk/Text)
Action end	Row in csv file of end of action (Talk/text)
Putdown start	Row in csv file of start of phone putdown
Putdown end	Row in csv file of end of phone putdown
Action	Action corresponding to activity (Talk/Text)

Actions

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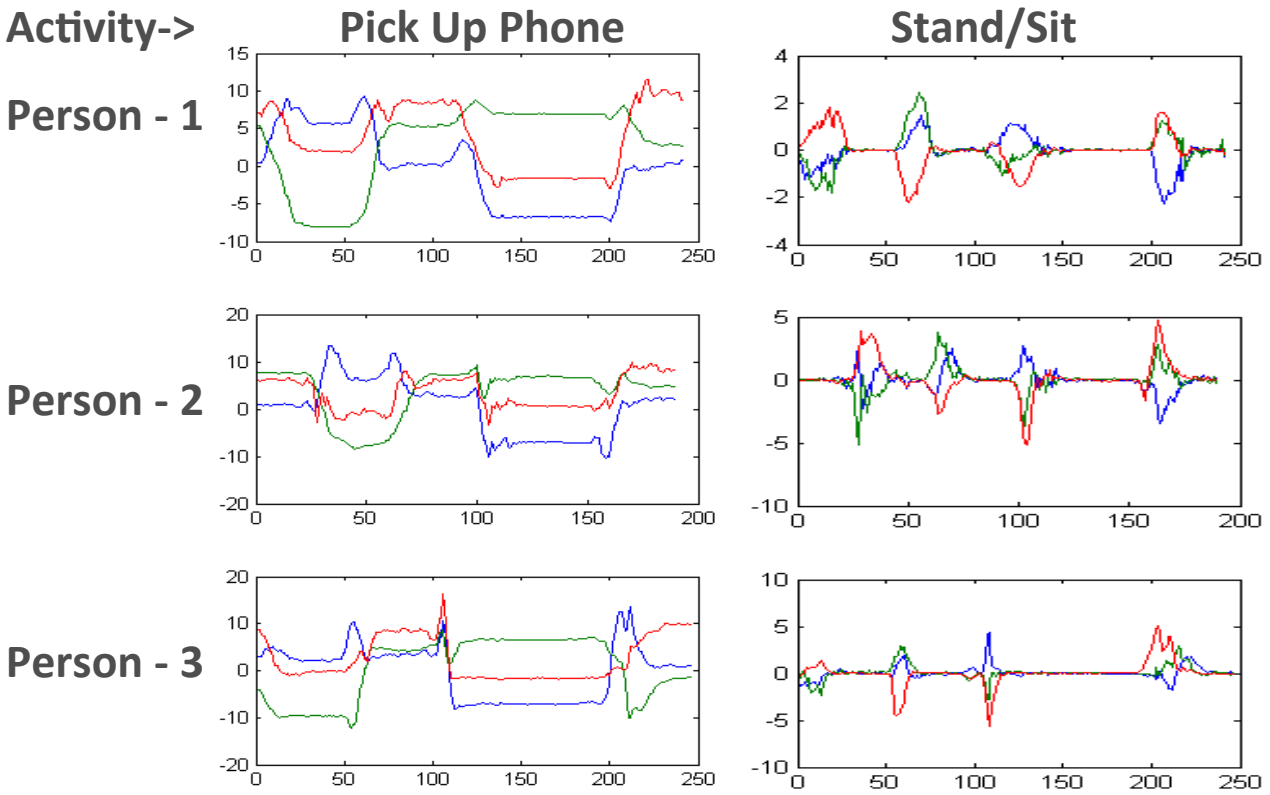
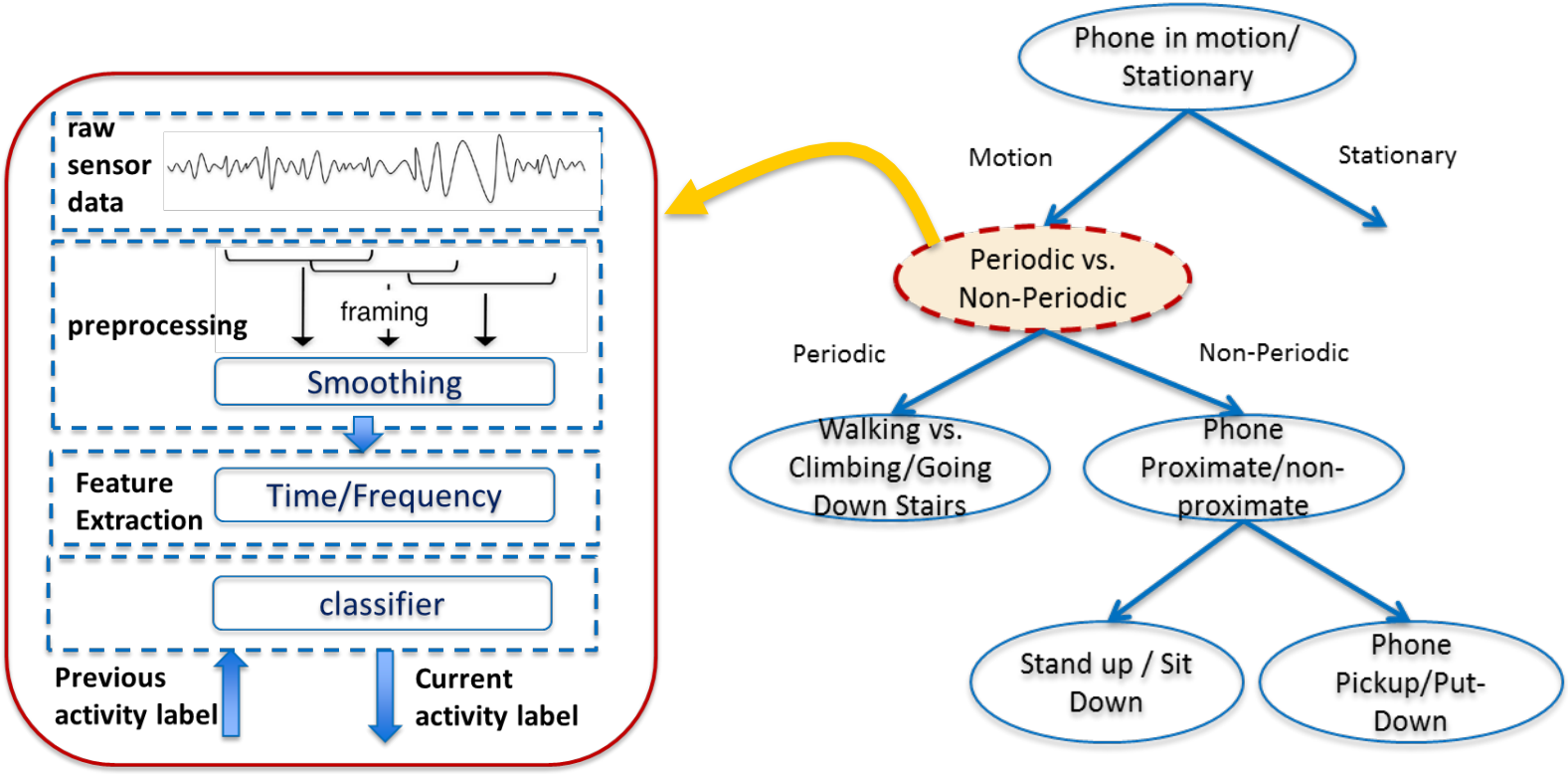
Activity Detection Progress

- Needs: same activities performed by different people have greater similarity in dynamics as compared to different activities performed by the same person. ***Dynamics based authentication only possible within the activity context***



Activity Detection Progress (*cont.*) – Classification Framework

- SRI proposes a flexible tree based classification framework for activity detection
  - Each node of the tree is a Support Vector Machine
- Semantically meaningful decomposition of the activity space
- Independent feature selection for each node



Activity Detection (*cont.*): features

- Features:

Signal Space	Feature Names
Time Domain	Mean, Variance, Mean Crossing Rate, Signal Derivatives at Multiple Temporal Scales ***(3)***
Frequency Domain	***Spectrum Peak, Sub-band Energy, (15)*** Sub-band Energy Difference, Spectral Entropy

- Approach Benefits:
  - Reduced computational complexity
    - Simpler classifiers applied early and reject majority of possibilities
    - Initially on linear acceleration used, additional sensors only used for a subset of possibilities
  - Flexibility in achieving targeted DR/FPR for specific activities

Activity Detection (*cont.*): existing performance

- Performance Evaluation from 100 Subjects

Activities	Magnitude	X,y,Z,magnitude
Walking	98%	99%
nonwalking	97%	98%

Activities	Magnitude	X,y,Z,magnitude
Pick Up	64%	89%
Put Down	73%	82%

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Authentication Experimental Results

Experiments

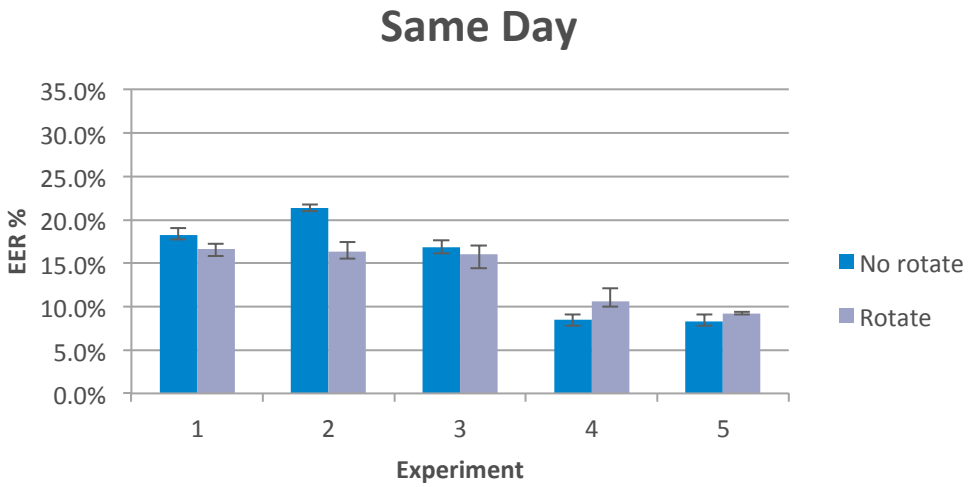
1. Gallery: activities 13 and 16
   Probes: activities 13 – 18

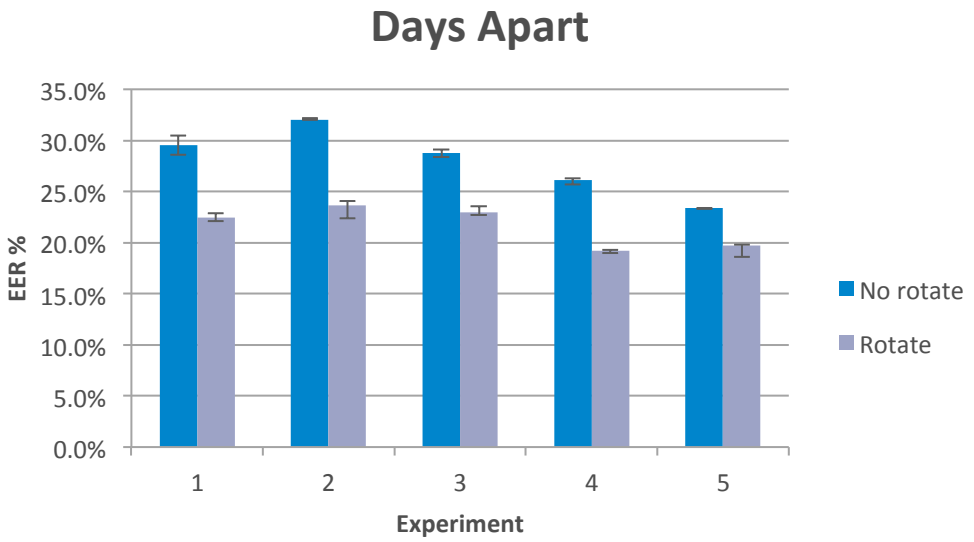
2. Gallery: activities 13
   Probes: activities 13 – 15

3. Gallery: activities 16
   Probes: activities 16 – 18

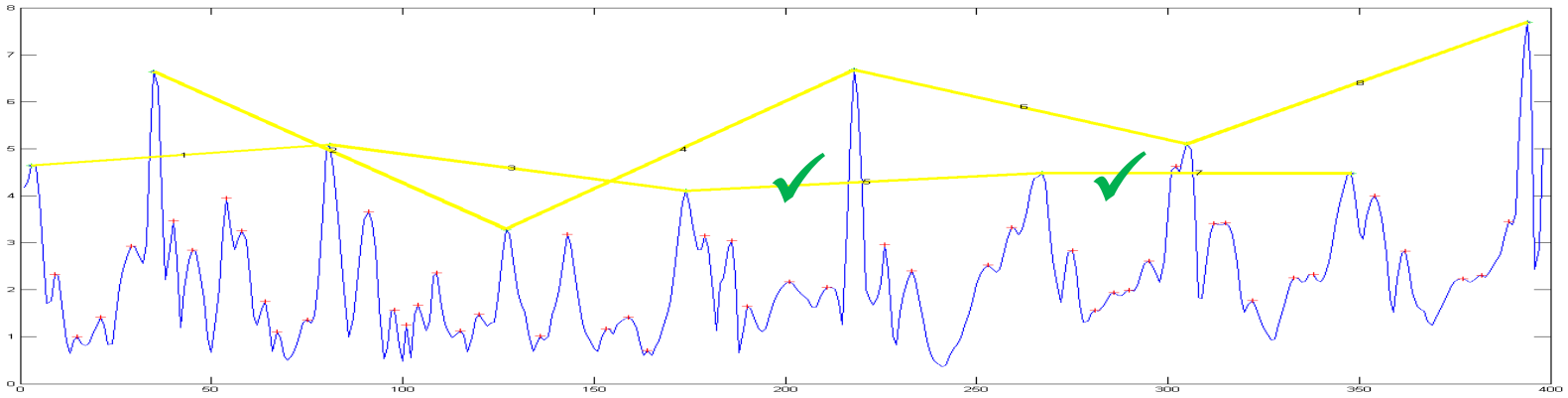
4. Gallery: activities 13
   Probes: activities 13

5. Gallery: activities 16
   Probes: activities 16



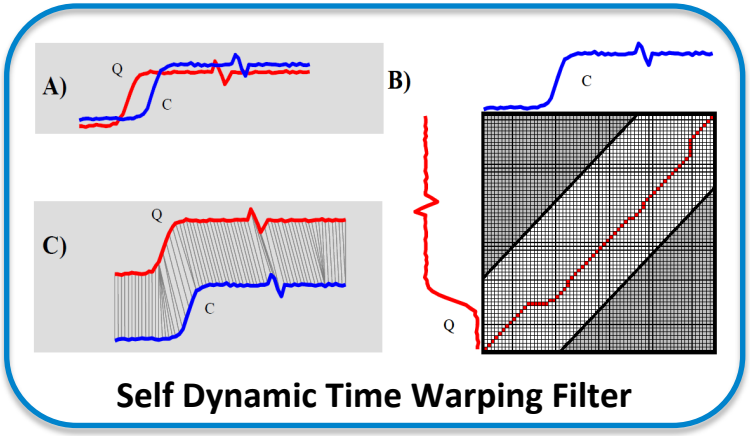


Enhanced Gait Cycle Extraction



Detected walking cycles

Gait Cycle filters



Self Dynamic Time Warping Filter

Magnitude Normalization

Peak Change Detection

Peak Balance Filter

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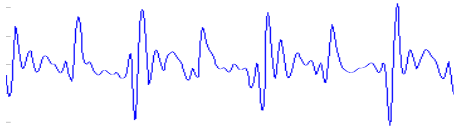
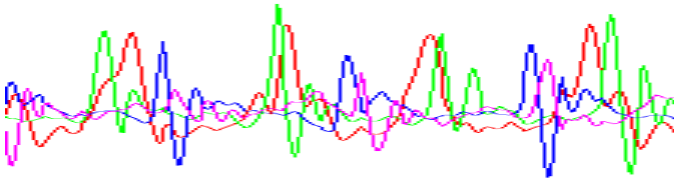
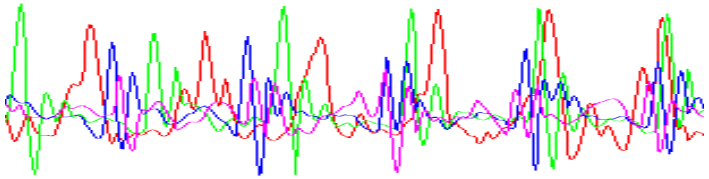
Physiology Signature Estimation Idea



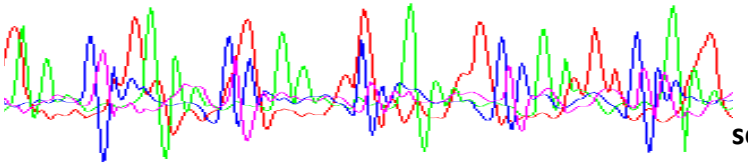
query walking gait
…
query pick up activity
query put down activity



Subject 1: Physiology Signatures



Subject 2: Physiology Signatures



Subject k: Physiology Signatures

score

score

score

Linear Combined
Physiology Signatures

Physiology Signature Estimation

	Age year	Height Inches	Weight Lbs	ArmLen Inches	LegLen Inches
Labels and standard deviation	***18-64*** +-10.1	***47-78*** +-4.5	***94-280*** +-39.9	***18-34*** +-3.8	***34-46*** +-2.5
Averaged L1 error using all matches and standard deviation	**6.8 (24%)** +-7.8(15%)	**3.5(5%)** +-3.1(6%)	**28.9(19%)** +-26.2(16%)	**3.1(14%)** +-**2.1(8%)**	**1.9(5%)** +-**1.6(4%)**
Averaged L1 error using top matches and standard deviation	**7.4(25%)** +-8.5(21%)	**3.7(6%)** +-4.2(7%)	**27.2(18%)** +-24.5(16%)	**3.3(14%)** +-**2.0(9%)**	**2.0(5%)** +-**1.6(4%)**

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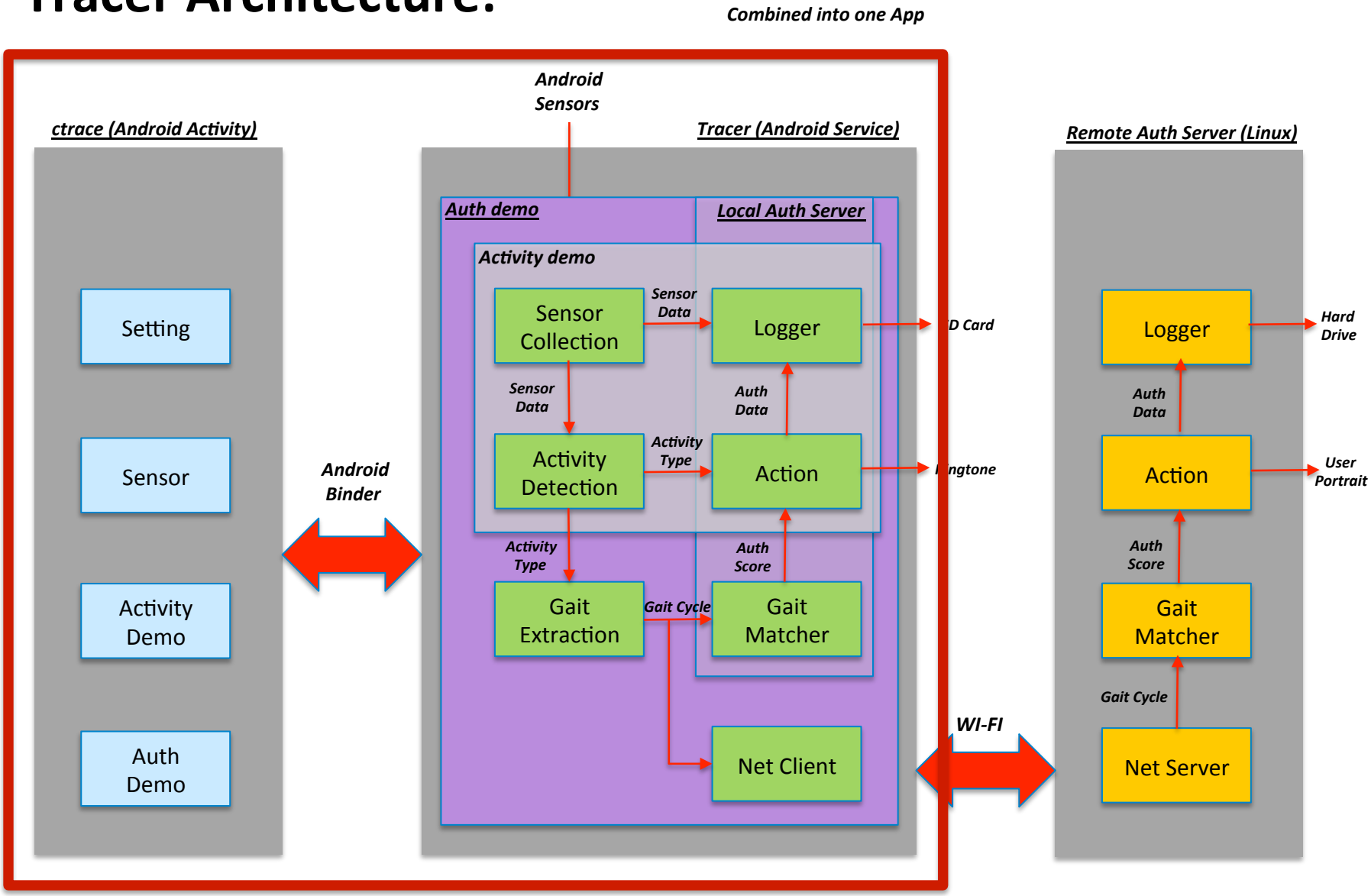
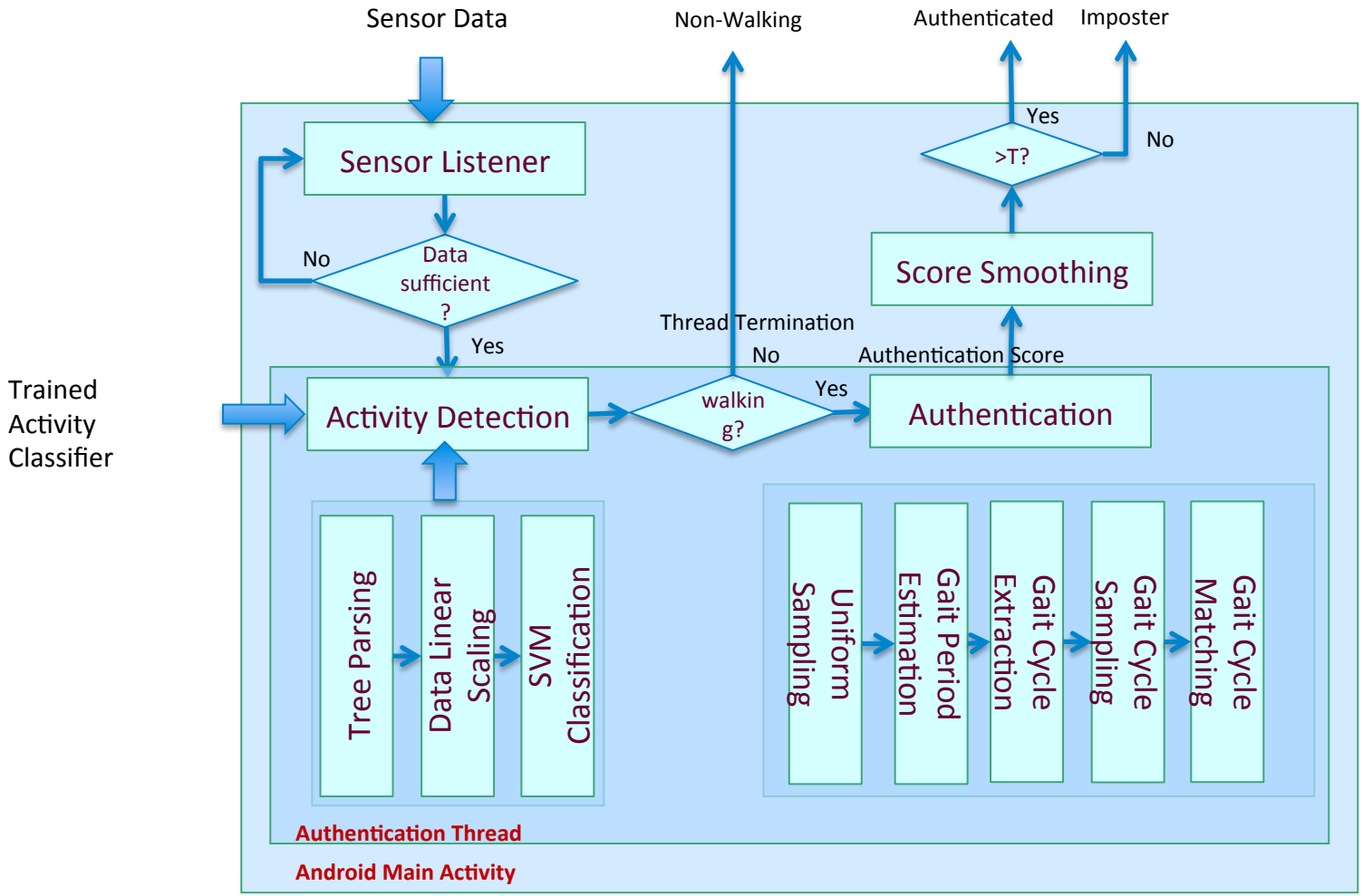
System and Software Details

- SRI Active Authentication software includes two mobile applications
  - ***Tracer***
    - An Android service that continuously extracts user's unique context of usage for authentication
    - Extract signatures and transmits to authentication server
    - Average CPU usage 7%
    - Average MEMORY usage: 56% of allocated 25MBytes
  - ***CTrace***
    - an Android activity providing a GUI front end to manage tracer
    - Average CPU usage 14%
    - Average MEMORY usage: 59% of allocated 25MBytes
  - Combined power consumption ~50mW (per *PowerTutor2*)
- Dependent 3rd party software
  - OpenCV Manager 2.4.8
  - JeroMQ 0.3.0
  - Android 4.1.3 (API 16)

Tracer Architecture:



System data flow (walking example)



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IPAAS: System Demonstration (If Time Allows)