Smartphones + X: Applications of Mobile Sensing

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What is biometric recognition? “biometrics”
What is biometric recognition? “biometrics smartphone”
Definition: Biometrics

• A biometric system is a pattern recognition system that operates by acquiring biometric data from an individual, extracting a feature set from the data, and comparing this set against the template set in the database.

• Two modes of operation: verification and identification
  • Verification – Are you who you claim to be?
  • Identification – Who are you?
Sensors Everywhere
The average smartphone has at least 10 sensors. Here are the most common.

- **Camera**
  - What would you do without your selfies?

- **Proximity Sensor**
  - This is what keeps you from accidentally pressing buttons with your cheek during calls!

- **Pedometer**
  - More and more phones are including a fitness element. Experts recommend 10,000 steps a day.

- **Camera**
  - What would you do without your selfies?

- **Proximity Sensor**
  - This is what keeps you from accidentally pressing buttons with your cheek during calls!

- **Light Sensor**
  - Have you ever turned your phone on in the dark and had it been too bright? Your light sensor may have been malfunctioning.

- **Magnetometer**
  - The magnetometer measures the strength of the magnetic field around the device to determine what direction it is moving.

- **Accelerometer**
  - Have you ever wondered how your phone knows which way you are holding it to display vertically vs. horizontally? The accelerometer is the answer!

- **Thermometer**
  - If you’ve ever left your phone out in the sun you’ve most likely seen it turn off due to heat. The thermometer is useful to monitor internal operating temperature.

- **Gyroscope**
  - If you like taking non-blurry photos you have the gyroscope to thank. It helps to correct for camera shake.

- **Fingerprint Sensor**
  - The new fingerprint sensor adds an extra layer of security to your phone.

- **Microphone**
  - The oldest sensor on any phone. Microphones make it possible for others to hear what you are saying.

Image source: https://www.corneralliance.com/blog(phone-internet-of-things)
Why mobile biometrics?

Three main ways to verify a person’s identity:

1. **Knowledge-based**
   Does this person know the correct information?

2. **Token-based**
   Does this person have the correct item?

3. **Biometrics-based**
   Does this person’s physical or behavioral data match?
Knowledge-based?

Ten most common passwords:
• 123456
• 123456789
• qwerty
• password
• 111111
• 12345678
• abc123
• 1234567
• password1
• 12345.

Token-based
Requires additional hardware

Biometrics-Based

• Reduced memory load
• Convenience – 25 to 75 app sessions per day
• One-to-one correspondence
• Continuous and passive
How it works

Training Data → Preprocessing → Feature Extraction → Model Learning

Test Data → Preprocessing → Feature Extraction → Classification → Decision

Gait Recognition

Terminal Stance  Pre Swing  Initial Swing  Mid Swing  Tern
What is gait?

• A person’s walking style
• This is a **behavioral** biometric modality
• Three main approaches in the academic literature:
  1. Video recording
  2. Floor sensors
  3. Wearable sensors

By chipotng [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons
Video Recordings

(https://www.youtube.com/watch?v=bhCR0UbW13Y)
Floor Sensors

(https://www.youtube.com/watch?v=fYKPU-qXa9k)
Wearable Sensors

• Benefits
  – No explicit interaction from the user
  – Continuous and passive authentication
  – No additional hardware – accelerometers are typically standard sensors
Data Collection

• Attach a motion sensing device such as a smartphone to a person
  – Pants pocket
  – Belt clip
  – Ankle
• 100 samples per second is common
• Subjects are asked to walk several times on a controlled surface
  – E.g., hallway
• Record the accelerometer data to obtain the raw data
Cycle Detection

- One cycle = 2 steps
- Can you see the cycles?
Keystroke Dynamics and Touch Gestures

https://www.youtube.com/watch?v=mC2ZuW172rY
Keystroke Dynamics: **Features**

- **Key press/down**, or the time of a key press event.
- **Key release/up**, or the time of a key release event.
- **Latency**, or the time from press-to-press, release-to-release, or release-to-press events.
- **Hold time**, or the duration of a key press event.
- **Pressure**, or the measurement of the finger’s pressure on the screen.
- **Size**, or the area of the screen pressed by the finger.
- **Error rate**, or the number of times the user presses a backspace or delete key due to erroneous input.
Detect common gestures

A “touch gesture” occurs when a user places one or more fingers on the touch screen, and your application interprets that pattern of touches as a particular gesture. There are correspondingly two phases to gesture detection:

1. Gather data about touch events.
2. Interpret the data to see if it meets the criteria for any of the gestures your app supports.

Refer to the following related resources:

- Input Events API Guide
- Sensors Overview
- Making the View Interactive

Support library classes

The examples in this lesson use the GestureDetectorCompat and MotionEventCompat classes. These classes are in the Support Library. You should use Support Library classes where possible to provide compatibility with devices running Android 1.6 and higher. Note that MotionEventCompat is not a replacement for the MotionEvent class. Rather, it provides static utility methods to which you pass your MotionEvent object in order to receive the desired action associated with that event.

Touch Gestures Data Collection
Touch Gestures: Features

- **Contact size** – Surface area of the finger
- **Direction** – Up-to-down, left-to-right, vice versa
- **Pressure** – Force of the finger
- **Location** – Coordinates of the finger
- **Speed** – Velocity of the gesture
- **Length** – How “long” the gesture is
- **Curvature** – Slope of the gesture
- **Click Gap** – Latency between two clicks
- **Context** – “where/when” the gesture occurs
WHAT ABOUT SOFT BIOMETRICS?
Gender Classification

- 100 male and 89 female subjects
- A subject’s frequency to the top 1,000 events
- Chi-square tests are applied for selecting 25%, 50%, and 75% of the most discriminating features.
- Kernel Support Vector Machines, Random Forests, Multilayer Perceptron, and multinomial Naive Bayes are trained on a random selection of 70% of the samples (i.e., 132 samples) and tested on the remaining 30% (i.e., 57 samples).

## Gender Classification Results

### Table 1: Best classification results using a single modality.

<table>
<thead>
<tr>
<th>Modality</th>
<th>$\chi^2$</th>
<th>Acc</th>
<th>Pr</th>
<th>Re</th>
<th>$F_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>75%</td>
<td>0.637</td>
<td>0.673</td>
<td>0.637</td>
<td>0.633</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>75%</td>
<td>0.889</td>
<td>0.890</td>
<td>0.887</td>
<td>0.887</td>
</tr>
<tr>
<td>Wi-Fi</td>
<td>75%</td>
<td>0.713</td>
<td>0.723</td>
<td>0.713</td>
<td>0.710</td>
</tr>
</tbody>
</table>

### Table 2: Best classification results using a multimodal approach.

<table>
<thead>
<tr>
<th>Modality, Bluetooth</th>
<th>$\chi^2$</th>
<th>Acc</th>
<th>Pr</th>
<th>Re</th>
<th>$F_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application, Bluetooth</td>
<td>100%</td>
<td>0.801</td>
<td>0.803</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Application, Wi-Fi</td>
<td>75%</td>
<td>0.696</td>
<td>0.713</td>
<td>0.697</td>
<td>0.7</td>
</tr>
<tr>
<td>Bluetooth, Wi-Fi</td>
<td>75%</td>
<td>0.918</td>
<td>0.923</td>
<td>0.917</td>
<td>0.917</td>
</tr>
</tbody>
</table>
Gender Classification Results

![Graph showing hourly device usage per gender. The x-axis represents time of day, and the y-axis represents the average number of records. The graph includes lines for male activity, male standard deviation, female activity, and female standard deviation.]
Gender Classification Results

Differences in Within-Session Transitions

media
browser
tools
communication
gaming
personalization
navigation
news
camera
networking
settings
social
sports
weather
system
core
food
drink
education
health
events
home
productivity
miscellaneous

media
browser
tools
communication
gaming
personalization
navigation
news
camera
networking
settings
social
sports
weather
system
core
food
drink
education
health
events
home
productivity
miscellaneous
Few More Tidbits on Soft Biometric Classification

From **call** logs, the **duration** of the call (minutes), **familiarity** of the telephone number, and the **type** of call

The **familiarity** and **type** (i.e., incoming or outgoing) of **SMS** messages

The **application** name
Older subjects have more applications related to planning, organization, and health, while younger subjects are more security-aware and have a preference for media-related services.

Subjects with a bachelor’s degree may enjoy social networking and communicating with others.

Female subjects appear to use their devices for file management more so than their male counterparts.
Ongoing Work

Mobile sensors for mHealth

Culturally-relevant emotion recognition

Selective posting
# Mood and Emotion Sensing

<table>
<thead>
<tr>
<th>Data</th>
<th>Data Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call Logs</td>
<td>Elhai et al found a positive correlation between non-social smartphone use and anxiety.</td>
</tr>
<tr>
<td>SMS Logs</td>
<td></td>
</tr>
<tr>
<td>Screen Status Light Sensor</td>
<td>These readings may correlate with sleeping patterns, which may be an indication of stress.</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>Bluetooth sightings (log of visible devices surrounding the user) offer a “coarse estimate of human density around the user. ...We refer to Bluetooth density as a rough proxy for social context (being alone or in a small or large group).”</td>
</tr>
<tr>
<td>Location</td>
<td>Brusilovskiy et al. utilized GPS technology to study mobility patterns and participation of those recruited from a community mental health center, showing that data regarding destinations is an indicator of participation.</td>
</tr>
<tr>
<td>Accelerometer Gyroscope</td>
<td>Accelerometers and gyroscopes detect acceleration and angular speed and are useful for activity recognition.</td>
</tr>
<tr>
<td>Application Logs</td>
<td>Statistics on app usage may provide information regarding the participant’s daily activities.</td>
</tr>
</tbody>
</table>
Wrap-Up

- Mobile sensors allow for ubiquitous sensing and behavior/activity recognition
- Applications in IoT, healthcare, education, etc.
- Applied machine learning makes a lot of this possible
- Much of my work has been in the space of biometrics, but we’re moving towards applications of smartphone sensing
  - mHealth interventions
  - Drug abuse interventions
  - Scene recognition / reconstruction
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