Evaluation of Threshold-based Fall Detection on Android Smartphones

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Before we start ...
Outline

• Motivation
• Threshold-based fall detection
• Experiments and results
• Evaluation of fall detection applications in the Google Play Store
• Conclusion and future work
Motivation

Why is fall detection necessary?

• Elderly people have a high risk of falls
• 33% fall unintentionally each year [Mellone et al., 2012]
• Especially falls with loss of consciousness are dangerous → fast help is needed
Motivation

Why fall detection on smartphones?
• Easily accessible
• Cheap in contrast to dedicated hardware
• Future generations will have one by default
• Portability

Why no bracelets?
• Fall detection works bad if device is worn at the arm
• Device should be close to the center of the body
Alternatives

Smart Cameras for fall detection:
• Restricted to dedicated areas (garden?)
• Cost intensive
• Blind spots?
• Privacy?

Sensor mats:
• Restricted to dedicated areas (garden?)
• Cost intensive
• Stability?
• Hygiene?
Threshold-based fall detection

Fall characteristics:
Fall detection phases

- FreeFall Test Phase
  G-Value < LOWER_THRESHOLD for TIME1FREEFALL?

  - No & TIME2IMPACT expired
    - Impact Test Phase
      G-Value > UPPER_THRESHOLD?

      - No
        - Stable Test Phase
          rest position detected?

          - No
            - abort

          - Yes

      - Yes

  - Yes

- Orientation Test Phase
  orientation changed?

  - No
    - Fall Detected
      Start Alert

  - Yes
    - Alert Phase
      start timer

    - timeout or alert confirmed
      Emergency Call
Different implementations of the phases

<table>
<thead>
<tr>
<th></th>
<th>Karth FF*</th>
<th>Karth*</th>
<th>Mehner FF**</th>
<th>Mehner**</th>
<th>Gimpel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Fall</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Impact</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Stable A</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Stable B</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Orientation A</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orientation B</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Orientation C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*[Karth et al. 2012] (from our working group)

**[Mehner et al. 2013]*
Differences in the orientation phase

Orientation A (Karth)

- Moving average → last value before possible fall which is > 0.9g and < 1.1g → compute vector → angle between first vector after possible fall
- Angle > 45° → fall is assumed

Orientation B (Mehner)

- Mean value of the last 100 values for each axis before the possible fall vs. mean value of the 100 values for each axis after the possible fall
- Difference > 0.4g → fall is assumed

Orientation C (Gimpel)

- Mean value of the last 100 values for each axis before the fall vs. mean value of the 100 values for each axis after the presumed fall
- Values are used to compute the angle between the vectors
- Angle > 60° → fall is assumed
Evaluation

- HTC Desire 816 and Sony Xperia V
- Worn in a funny bag at the hip in front
- Front, left and right falls
- 3 probands

<table>
<thead>
<tr>
<th>Age</th>
<th>Front falls</th>
<th>Right falls</th>
<th>Left falls</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>Sony</td>
</tr>
<tr>
<td>29</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>Sony</td>
</tr>
<tr>
<td>55</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>HTC</td>
</tr>
</tbody>
</table>
Fall detection results of proband 23

The figure above illustrates the number of falls detected for proband 23, with data differentiated by various sources:

- **Karth FF**
- **Karth**
- **Mehner FF**
- **Mehner**
- **Gimpel**

The categories are:

- **Overall falls**
- **Left side**
- **Right side**
- **Straight ahead**

The data shows a significant number of overall falls compared to other categories.
Fall detection results of proband 55
Fall detection results of proband 29

The diagram shows the number of detected falls for different directions:
- Overall falls: Shows a significant number of detected falls.
- Ahead right, ahead left, left side, right side: Show relatively lower numbers of detected falls.

Legend:
- Number of falls
- Karth FF
- Karth
- Mehner FF
- Mehner
- Gimpel
Activities of daily life (ADL)

• Fall detection algorithms have to distinguish between ADLs and real falls
• 2 probands
• False positives:

<table>
<thead>
<tr>
<th>Age</th>
<th>Duration</th>
<th>Karth FF</th>
<th>Karth</th>
<th>Mehner FF</th>
<th>Mehner</th>
<th>Gimpel</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>286h</td>
<td>24</td>
<td>57</td>
<td>0</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>72</td>
<td>11h</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Conclusion on fall detection

• [Mehner et al. 2013] proposed to exclude the free fall phase

• Our ADL experiments show that the FF phase is vital for a low false positive rate

• Karth FF, Mehner FF, Gimpel
  • Mehner FF performed worse
    34.6% overall detection rate but 0 false positives
  • Karth FF and Gimple are comparable good
    94% / 84% overall detection rate
    24 / 2 false positives
Google Play Store fall detection apps

• September 2014
• 22 hits if searched for “fall detection”
• 13/22 are related to the topic
• 2/13 were commercial applications (4€ tested / 120€ not tested)
• 8/13 passed our exclusion reasons
Exclusion reasons

Following characteristics resulted in an exclusion for further tests:

• Failed/impossible installation
• No reaction of application after installation
• The need to register for a phone call in a foreign country
• The phone call destination is not obvious
Further tests

Specificity tests:
• Fixed set of ADL (walking around, climbing stairs, sitting down on chair)
• Done in varying speed in a 10 minutes window
• Smartphone was in a trousers pocket

Sensitivity tests
• 10 falls in forward direction (by proband 23 and proband 55)
<table>
<thead>
<tr>
<th>Name</th>
<th>FP</th>
<th>prob23</th>
<th>prob55</th>
<th>detection rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3LAB Fall Detector</td>
<td>no</td>
<td>1/5</td>
<td>3/5</td>
<td>40%</td>
</tr>
<tr>
<td>iCare Personal Emergency Alert</td>
<td>no</td>
<td>5/5</td>
<td>2/5</td>
<td>70%</td>
</tr>
<tr>
<td>Smart Fall Detection</td>
<td>no</td>
<td>0/5</td>
<td>0/5</td>
<td>0%</td>
</tr>
<tr>
<td>Emergency Fall Detector</td>
<td>no</td>
<td>0/5</td>
<td>0/5</td>
<td>0%</td>
</tr>
<tr>
<td>Fall Detector</td>
<td>yes</td>
<td>0/5</td>
<td>0/5</td>
<td>0%</td>
</tr>
<tr>
<td>Fade: fall detector</td>
<td>yes</td>
<td>3/5</td>
<td>3/5</td>
<td>60%</td>
</tr>
<tr>
<td>iFall: Fall Monitoring System</td>
<td>yes</td>
<td>0/5</td>
<td>2/5</td>
<td>20%</td>
</tr>
<tr>
<td>SecureMe Active (commercial)</td>
<td>yes</td>
<td>2/5</td>
<td>4/5</td>
<td>60%</td>
</tr>
</tbody>
</table>
Conclusion and Future Work

• Our algorithm (Gimpel) is a good compromise between low false positive rate (2 within 12,3d) and high fall detection rate (84%)

• Free fall phase is vital to distinguish between ADL and real fall

• Only one public available fall detection application with acceptable results (for Google)

• Testing of applications available in other stores and/or for other phones like iPhone (App Store)
Thank you for your attention!
Any questions?

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www.cs.uni-potsdam.de/bs/research/projectAl.html