BIOSIGNALS 2017

COMPARING MACHINE LEARNING APPROACHES FOR FALL RISK ASSESSMENT

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Technological solution for fall risk screening and falls prevention

Consortium

sensingfuture
a greater step

Fraunhofer
PORTUGAL

Partner Institutions
1. Falls in the elderly population

- 30% of 65+ and 50% of 80+ community-dwelling people fall each year.

- Falls are one of the most common health related problems in the elderly population, representing more than 50% of the hospitalizations due to injuries.

- Direct costs of falls are 25 billion EUR\(^1\) in EU and $31 billion\(^2\) in USA per year.

- Falls are also considered one of the main causes for institutionalization and loss of independence.

\(^1\)Hartholt, K, Falls and drugs in older population: medical and societal consequences, Erasmus University Rotterdam, 2011.

1. Falls in the elderly population

- Falls have a multifactorial origin
- Fall risk factors are amendable by improving strength and balance
- Even though, fall risk screenings and the implementation of preventive exercise programs are rarely part of the elder’s routine.
2. FallSensing Technology

- Fall risk evaluations
- Risk of fall assessment
- Preventive exercise
- Visual feedback
- Enhance capacity
- Promote participation
3. Data collection

Data were collected by two health professionals in different settings.
Total of **296 subjects**

The mean age: **70.2 years**

- 68% are women
- 25% live alone
- 51% only have primary education
- 11.5% use an assistive device
- 47% are afraid of falling
- 30.7% have fallen

### Health Conditions

- Diabetes: 15%
- Osteoarthritis: 10%
- Osteoporosis: 7%
- Other: 2%

### Falls

- Outdoor falls: 20%
- Indoor falls: 15%
- Medical attention: 10%
- Wrist fracture: 5%
4. Proposed protocol

<table>
<thead>
<tr>
<th>Fall Risk Test</th>
<th>Traditional Metric</th>
<th>Normative Value</th>
<th>References</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sensitivity 71%</td>
</tr>
<tr>
<td></td>
<td>repetitions</td>
<td></td>
<td></td>
<td>Specificity 84%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Specificity 94%</td>
</tr>
</tbody>
</table>

**Questionnaires:**
Personal information & Medical conditions
Falls history questionnaire
5. Signal Acquisition & Processing

Instrumentation:
- **Accelerometer & Gyroscope** from wearable sensor (Fraunhofer)
- Lower back placement
- 50Hz sampling rate
- **Pressure distribution** from Physiosensing Platform
- 50Hz sampling rate
- 1600 pressure sensors (10mm²)

**TUG test segmentation** into 5 phases (stand, walk, turn, walk back, sit)

**STS phases identification** (stand-to-sit and sit-to-stand)

**4-stage balance test**: center of pressure coordinates for each of the 7 postures
6. Feature Extraction & Selection

**Accelerometer:**
- Magnitude signal:
  - Statistical features (mean, max, min, stdev, IQR, median, energy, entropy)
  - Frequency-domain (fundamental harmonic of FFT spectrum and amplitude)
- Number of steps
- Time to stand
- Power of STS

**Center of Pressure (CoP):**
- ML and AP positions:
  - Statistical features: mean, stdev, RMS, max, min
  - Velocity
  - 95% confidence ellipse area
- Sway (amplitude of CoP oscillations):
  - Path length, stedv, max and min

ML: medio-lateral; AP: antero-posterior
IQR: interquartile range; RMS: root mean square
8. FallSensing Technology

- Inertial Sensors
- Pressure Platform
8. FallSensing Technology
9. Fall Level

High and low fall risk groups were defined based on history of falls needing medical attention and use of walking aid.

Low risk group: 83%
High risk group: 17%
## 10. Statistical Analysis

**Fisher Exact Test**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Personal Metrics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feminine Gender</td>
<td>1.04</td>
<td>1.00</td>
</tr>
<tr>
<td>Age &gt; 65</td>
<td>2.86</td>
<td>0.01</td>
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<tr>
<td>BMI &lt; 13.7 or BMI &gt; 29.7</td>
<td>1.58</td>
<td>0.18</td>
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<tr>
<td>More than 4 Medicines</td>
<td>1.96</td>
<td>0.05</td>
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<tr>
<td>More than 2 Health Conditions</td>
<td>1.56</td>
<td>0.38</td>
</tr>
<tr>
<td>Has Fear of Fall</td>
<td>3.35</td>
<td>0.00</td>
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<tr>
<td><strong>Functional tests scores</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TUG Duration &gt; 10 s</td>
<td>6.51</td>
<td>0.00</td>
</tr>
<tr>
<td>STS Cycles &lt; 15</td>
<td>11.25</td>
<td>0.00</td>
</tr>
<tr>
<td>Not completed 10s Tandem Stance (eyes open)</td>
<td>3.59</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Null hypothesis**: there are no non-random associations with fall level
11. Machine Learning

F-Score = 
\[
\frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}
\]

<table>
<thead>
<tr>
<th></th>
<th>Naïve Bayes</th>
<th>Random Forest</th>
<th>Decision Tree</th>
<th>Neural Network</th>
<th>Linear Regression</th>
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</thead>
<tbody>
<tr>
<td>Personal metrics +</td>
<td>72.9</td>
<td>56.0</td>
<td>64.1</td>
<td>67.9</td>
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<td>Functional tests scores</td>
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</tr>
<tr>
<td>Personal metrics +</td>
<td>92.6</td>
<td>92.9</td>
<td>93.1</td>
<td>92.7</td>
<td>92.1</td>
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<tr>
<td>Features extracted from</td>
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<tr>
<td>sensors during</td>
<td></td>
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<tr>
<td>functional tests</td>
<td></td>
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</tbody>
</table>

Forward feature selection 10-fold cross validation
12. Conclusions & Next Steps

- Preliminary results suggest there are advantages in using sensors for fall risk screening.

- **Ongoing**: follow-up study to register falls in the period of 6 months after screening.

- **Future**: understanding which of the tests and metrics from the screening are most relevant.

- **Future**: Fall risk screening protocol validation.
Thank you

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fallsensing.com