Abnormality Detection in Activities of Daily Living

Prof. Ahmad LOTFI

Medical Technologies and Systems Special Interest Group (SIG), 13 February 2018
Activities of Daily Living

• Activities of daily living (ADLs) are basic tasks that must be accomplished every day for an individual to thrive. These are tasks learned in childhood and are required for personal self-care and independent living throughout an individual’s lifetime.

• Basic ADL include: eating, climbing stairs, dressing, toileting, grooming, transferring, bathing and walking

• Some reasons for evaluating ADLs include:
  • Support for Independent living
  • Providing an overview of functional status
  • Determining physical/mental limitations
  • Evaluating and monitoring progress
  • Measuring and Facilitating the outcomes of rehabilitation

https://www.kindlycare.com/activities-of-daily-living/
Falls

• Falls are the largest cause of emergency hospital admissions for older people.
• 3996 people aged 65+ died from having a fall in 2014 (E&W, latest available data), equating to ten people every day. Of these 2130 were women and 1866 were men.
• Falls account for up to 40% of ambulance call-outs to homes for people aged 65+.
Dementia

• Dementia is one of the main causes of disability in later life, ahead of some cancers, cardiovascular disease and stroke and is the leading cause of death for women in the UK.
• 850,000 people are estimated to be living with dementia in the UK in 2014, of whom 773,502 were aged 65 years or over.
• By 2025, the number is expected to rise to 1.14 million. By 2051, it is projected to exceed 2 million.
• It affects 1 person in 6 over 80 and one in three over 95.
Loneliness and Isolation

- 3.5 million people aged 65+ live alone.
- Over 2 million, or nearly half (49%), of all people aged 75 and over live alone.
- 6% of older people (nearly 600,000) leave their house once a week or less.
- 31.4% or 3.6 million older people (65 and over) agree the television is their main form of company.
Older People as Carers

• Over a third of carers aged 65+ provide 50 or more hours of informal care each week. Nearly 12% provide 100 hours or more.

• Caring for another person also took its toll mentally, with 68.8% saying being a carer had damaged their psychological wellbeing, and 42.9% reporting that their mental health had worsened.
State of The Art Technologies

• Environmental sensor-based approach
  Pros: ambient assistant monitoring
  Cons: large installation

• Wearable sensor-based approach
  Pros: small, low cost, non-invasive
  Cons: customized, impractical, processing power

• Smartphone-based approach
  Pros: ubiquity, sensing and computing
  Cons: battery, insufficient accuracy
Independent Living

Many older adults prefer to stay in their own home rather than in an assisted living facility, even though they require long-term care.

Family care is the most accepted and preferred care setting for both long-term care patients and their relatives.

A significant increase in care responsibilities, which are typically performed by family and friends, appears and implies a need for innovative support approaches for the elderly and their carers.
Existing Telecare Solutions
This event was held as part of the INSTILS programme - a project part-funded by the European Regional Development Fund.
Tested Solutions

1. Fuzzy Entropy and Approximate Entropy (AppEn) in Abnormality Detection
2. Behaviour Evolution (Trend) in Activities of Daily Living
3. Video Based Fall Detection
Entropy Measure

- Quantify the amount of regularity and the unpredictability of fluctuations over time-series data.
- The presence of repetitive patterns of fluctuation in an ADL renders it more predictable than an ADL in which such patterns are absent. Entropy reflects the likelihood that similar patterns of observations will not be followed by additional similar observations.

Entropy Increases as Randomness Increases
From Sensor Data to Activities

This event was held as part of the INSTILS programme - a project part-funded by the European Regional Development Fund.

<table>
<thead>
<tr>
<th>Sensor Data</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table with columns</td>
<td>Table with columns</td>
</tr>
</tbody>
</table>

- From Sensor Data to Activities

14/02/2018
Ontology Representing Sensor Data
Activities - Sample Data

<table>
<thead>
<tr>
<th>ID</th>
<th>Timestamp</th>
<th>Activity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>66323</td>
<td>2016-07-28 07:15:37</td>
<td>Sleeping</td>
<td>Bedroom</td>
</tr>
<tr>
<td>66324</td>
<td>2016-07-28 07:16:35</td>
<td>LivingroomADL</td>
<td>Livingroom</td>
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<tr>
<td>66325</td>
<td>2016-07-28 07:32:23</td>
<td>Diet</td>
<td>Kitchen</td>
</tr>
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<td>66326</td>
<td>2016-07-28 07:32:47</td>
<td>LivingroomADL</td>
<td>Livingroom</td>
</tr>
<tr>
<td>66327</td>
<td>2016-07-28 07:33:04</td>
<td>Diet</td>
<td>Kitchen</td>
</tr>
<tr>
<td>66328</td>
<td>2016-07-28 07:33:51</td>
<td>LivingroomADL</td>
<td>Livingroom</td>
</tr>
<tr>
<td>66329</td>
<td>2016-07-28 07:34:09</td>
<td>UsingToilet</td>
<td>Bathroom</td>
</tr>
<tr>
<td>66330</td>
<td>2016-07-28 07:41:14</td>
<td>Diet</td>
<td>Kitchen</td>
</tr>
<tr>
<td>66331</td>
<td>2016-07-28 07:41:36</td>
<td>LivingroomADL</td>
<td>Livingroom</td>
</tr>
<tr>
<td>66332</td>
<td>2016-07-28 07:42:16</td>
<td>FrontDoorADL</td>
<td>Not specified</td>
</tr>
<tr>
<td>66333</td>
<td>2016-07-28 09:30:37</td>
<td>UsingToilet</td>
<td>Bathroom</td>
</tr>
</tbody>
</table>
Inferred activities - Example

This event was held as part of the INSTILS programme - a project part-funded by the European Regional Development Fund.
Results – ATypical Subject
Results – Subject was hospitalised on day 32, and day 31 shows slightly lower entropy.
Results – Subject claimed by carer to be hyperactive, and entropy levels much higher than for previous elders.
Data Complexity

3,522,673 Sensor Data Records
127,811 Activities + 60 Assessments
1,638 Problems Inferred

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2. Behaviour Evolution (Trend) in Activities of Daily Living

3. Video Based Fall Detection
Behaviour Evolution in Activities of Daily Living

How behavioural changes could be summarised to highlight the overall trends in Activities of Daily Living (ADL)?
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Sleeping Pattern Trend

Each peak represents the duration of sleeping in one day. This line shows the decreasing trend of sleeping pattern.
Measuring Behavioural Changes

• Simple Moving Average and different variations of the same technique are used commonly to identify trends in data sets.
• The same technique could be applied to identify trends in Activities of Daily Livings.
• Once the trend is measured, behavioural changes or abnormalities could be identified.
Trend of Sleeping Start Time using Simple Moving Average with 7 and 28 days of data points.
Moving Average Crossover

- Moving average crossover occurs when two moving averages are plotted and each of them has a different degree of smoothing.
- The crossover does not predict the future but it shows trend direction. The crossover between two (or more) moving averages is an indicator of trend direction.
The crossover happened many times in a small period of time which indicator of abnormal sleeping at that time are occurred.
Tested Solutions

1. Fuzzy Entropy and Approximate Entropy (AppEn) in Abnormality Detection

2. Behaviour Evolution (Trend) in Activities of Daily Living

3. Video Based Fall Detection with Enhanced Motion History Images
Motivation and Existing Solution

• Wireless cameras for home monitoring. Accessed by the carer through a mobile app.
  • It requires constant monitoring to identify any abnormal behaviour or fall.
• Pressure-sensitive mats
  • They may have unavoidable edges that can cause falls.
• Accelerometers and other wearable devices
  • May result in many false positives.
Proposed Solution

• Vision based automated system for monitoring activities in a home environment.

• Use of image processing algorithms
  • To detect human presence
  • To determine their motion
  • Determine if fall has occurred

• Strike a balance between privacy and coverage.
Processing Stages

- Identify the moving object with background subtraction algorithm.
- Estimate the velocity of the moving object (person) using the Timed-Motion History Image tMHI.
- Fit an ellipse if a person is identified in the scene.
- Analyse the changes in the ellipses’ properties.
- Infer from the properties if a fall has occurred.
Ellipse Fitting

• Approximated ellipse offers information in relation to the shape and orientation of the person in the image.

• The angle between the major axis of the person and the horizontal axis gives the orientation of the ellipse ($\theta$).

• The fitted ellipse shows any change in angle or eccentricity ($\rho$).
Ellipses Fitting

Standard deviation of orientation ($\sigma_\theta$) and standard deviation of ratio ($\sigma_p$) for different activities are calculated.

<table>
<thead>
<tr>
<th>Activity</th>
<th>$\sigma_\theta$</th>
<th>$\sigma_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>0.6831</td>
<td>0.4469</td>
</tr>
<tr>
<td>Sit down</td>
<td>0.9394</td>
<td>0.0716</td>
</tr>
<tr>
<td>Bend</td>
<td>0.07993</td>
<td>0.2631</td>
</tr>
<tr>
<td>Lie</td>
<td>0.3608</td>
<td>0.2006</td>
</tr>
<tr>
<td>Fall</td>
<td>0.7460</td>
<td>0.4375</td>
</tr>
</tbody>
</table>
Statistical Analysis

• Falls result in
  • High-velocity motion ($C_{\text{motion}}$) and
  • Large statistical variance in elliptical orientation/eccentricity

• In our experiments, there is a fall if all the following three conditions are true;
  • $C_{\text{motion}} > 65\%$,
  • Standard deviation of orientation $\sigma_\theta > 0.60$
  • Standard deviation of ratio $\sigma_\rho > 0.35$

<table>
<thead>
<tr>
<th>Activity</th>
<th>$C_{\text{motion}}$</th>
<th>$\sigma_\theta$</th>
<th>$\sigma_\rho$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>19.18</td>
<td>0.6831</td>
<td>0.4469</td>
</tr>
<tr>
<td>Sit</td>
<td>24.49</td>
<td>0.9394</td>
<td>0.0718</td>
</tr>
<tr>
<td>Bend</td>
<td>43.02</td>
<td>0.0799</td>
<td>0.02631</td>
</tr>
<tr>
<td>Lie</td>
<td>61.82</td>
<td>0.3608</td>
<td>0.2006</td>
</tr>
<tr>
<td>Fall</td>
<td>74.85</td>
<td>0.7460</td>
<td>0.4375</td>
</tr>
</tbody>
</table>
Concluding Remarks

• It is essential to build an environment which will be natural, informative and caring from human perspective.

• Incorporating Intelligence is still the most challenging aspect of independent assistive leaving research.
Thanks

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