Real-time Activity Recognition and Fall Detection System -RAREFall-

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EvAAL-AR 2013

• Our RAReFall system won the annual competition in activity recognition – EvAAL-AR 2013

• Our RAReFall system achieved the best performance including the results of the previous year’s (2012) competition
Outline

• Introduction
• EvAAL-AR Competition
• Our approach
  – System description
  – Methodology
• Results
• DEMO
• Improvements & Future work
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Aml and AAL

• What is Ambient Intelligence (Aml)?
  – Refers to electronic environments that are sensitive and responsive to the presence of people
  – Aml devices support people in carrying out their everyday life activities, in an easy, natural way using information and intelligence that is hidden in the devices’ network

• Ambient Assisted Living (AAL)
  – Application of the Aml tech. – to enable people with specific demands (handicapped, elderly) to live in their preferred environment longer
  – Elderly percentage: from 8% in 2013 to 16% in 2050
  – The ratio of the working-age population (15–64) to those aged 65+ is projected to decline from 4.3 to 2.3
AmI

Human Computer Interaction

Artificial Intelligence

Pervasive Ubiquitous Computing

Sensors

Networks

J. C. Augusto et al. (2007)
Activity Recognition

- Important task in AmI and AAL
  - Understanding the user’s situation
- Prerequisite for numerous applications
  - Health-care

Advantages:
- Non-intrusive

Disadvantages:
- Multiple users
- Complex computation
- User privacy (camera)

Environmental sensors

Body-worn sensors

Advantages:
- Person-specific
- More accurate for everyday activities
- Cheap
- Indoor/Outdoor

Disadvantages:
- Intrusive
- Wires
- Lots of sensors
Falls

• 30% of people over the age of 65 fall each year, and this proportion increases to 40% in those aged more than 70 years

• About 20% of all the fall accidents that involve an elderly person require medical attention

• Falls are particularly critical when the elderly person is injured and cannot call for help
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EvAAL-AR Competition

- **EvAAL** – **Evaluating AAL** Systems through Competitive Benchmarking

- universAAL project

- EvAAL tracks
  - **Activity Recognition** (2012, 2013)
  - Robot Companion (2013)
EvAAL-AR Competition

- Evaluation of AR systems intended to be used by elderly
- CIAml Living Lab in Valencia, Spain (90 m²)
EvAAL-AR Competition

- 2-phase evaluation
  - Extended abstract
  - Grand Finale – live demonstration

- No limitation to the number and type of devices

- Up to 1 hour for system installation and calibration

- Each competitor is evaluated individually

- TCP socket is used to retrieve the competitor's recognized activities

- NTP server is used for synchronization
EvAAL-AR Competition

• Test scenario (2 x 5min)
  – performed by a test person (actor)
  – not known in advance
  – identical for all competitors
  – includes actions of daily living
    • watching TV, working in the kitchen, bathroom activities, sleeping...

• Target activities: lying, sitting, standing, walking, bending, cycling and falling (4 announced, 1 performed)

• Elderly simulation kit

• Audio cues are played in order to get the same ground truth for all the competitors

• The ground truth is refined by an evaluator using an Android phone to mark the exact time-stamps of the activities

http://youtu.be/aychl7egrkc?t=18s
Evaluation criteria 2013

• (35%) Recognition accuracy
• (20%) Recognition delay
• (20%) Installation complexity
  – minutes of work per person needed to complete the installation
• (15%) User acceptance
• (10%) Interoperability with AAL systems
  – the use of open-source solutions
  – availability of libraries for development
  – integration with standard protocols
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Our Approach

• System Description

Calibration

**Input:**
Raw sensor data through serial COM Ports

**Performs:**
Data calibration

**Output:**
Calibrated data (m/s²)

AR & FD

**Input:**
Calibrated data

**Performs:**
Synchronization
Filtering
Data analysis
Fall detection
Activity recognition

**Output:**
Recognized activity or fall

EvAAL Evaluation Software
3D Accelerometer

- 3-axial acceleration vector projections

- Gravity
  - Low pass filter

- Inclination angles

\[ \phi_x = \arccos\left( \frac{a_x}{\sqrt{a_x^2 + a_y^2 + a_z^2}} \right). \]
System overview

- **Synchronization**
- **Data filtering**
- **Is fall pattern detected?**
  - yes
  - no
- **Body in horizontal position?**
  - yes
  - no
  - fall
  - activity

**Combine sensor measurements into snapshots**

**Low-pass filter**: removes dynamic motion

**Band-pass filter**: removes gravitational component
System overview

- **System overview**
  - Synchronization
  - Data filtering
  - Hybrid activity recognition
  - Is fall pattern detected?
    - yes: Body in horizontal position?
      - yes: Fall
      - no: Hybrid activity recognition
    - no: Hybrid activity recognition

- **Combined sensor measurements into snapshots**
  - **Low-pass filter**: removes dynamic motion
  - **Band-pass filter**: removes gravitational component

Diagram:
- Body in horizontal position?
  - yes: Fall
  - no: Hybrid activity recognition

- Is fall pattern detected?
  - yes: Combine sensor measurements into snapshots
  - no: Hybrid activity recognition
Fall Detection

- Acceleration Fall Pattern

  \[
  \text{IF } (((\text{Max} - \text{Min}) > \text{Threshold}) \quad \text{AND} \quad (\text{Max appeared after Min})) \quad \text{Then} \quad \text{Check\_Body\_Orientation()}
  \]

- Upper Body Orientation

  \[
  \text{IF Horizontal} \quad \text{Then FALL} \quad \text{ELSE No\_FALL}
  \]

\[
\varphi_x = \arccos\left(\frac{a_x}{\sqrt{a_x^2 + a_y^2 + a_z^2}}\right).
\]
System overview

- Synchronization
- Data filtering
- Is fall pattern detected?
- Body in horizontal position?
- Hybrid activity recognition

- Yes: Is fall pattern detected?
- No: Hybrid activity recognition

- Yes: Body in horizontal position?
- No: Hybrid activity recognition

- Yes: fall
- No: activity

- Combine sensor measurements into snapshots
- Low-pass filter: removes dynamic motion
- Band-pass filter: removes gravitational component
Hybrid activity recognition

Feature Vector -64-

Random Forest → Other activities → R-BAR → Activities in upright posture → Random Forest

- Cycling
- Lying
- Sitting
- Bending

- Walking
- Standing

Activity classifier

Recognized activity

Group of activities
R-BAR

R-BAR is used to differentiate between body postures

- Orientation is computed for each axis for both accelerometers
- Computed orientation is compared to a reference orientation (for each posture)
- Difference between the orientations is transformed into error
- Posture with lowest error is returned

Example of a rule for sitting: \( O_{\text{sitting}} = (90^\circ, 180^\circ, 90^\circ ; 180^\circ, 90^\circ, 90^\circ) \)
Pre-competition evaluation

• 90 minutes pre-defined activity scenario
  • Recorded by 10 people
  • Leave-one-person out

• Activity Recognition
  - Precision: 98.85%
  - Recall: 99.22%
  - F-measure: 99.04%

• Fall Detection

<table>
<thead>
<tr>
<th>Events</th>
<th>Detected/All</th>
<th>Recall</th>
<th>Precision</th>
<th>F-measure</th>
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<tbody>
<tr>
<td>Tripping</td>
<td>15/15</td>
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<td></td>
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<tr>
<td>Fainting</td>
<td>13/15</td>
<td>93.33%</td>
<td>66.67%</td>
<td>77.78%</td>
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<td>Quickly lying</td>
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<td></td>
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<tr>
<td>Quickly sitting</td>
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<tr>
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Point by point approach

• Evaluation Criteria
  – (35%) Recognition accuracy → More than 99%
  – (20%) Recognition delay → Up to 2 seconds
  – (20%) Installation complexity → 1-2 mins.
  – (15%) User acceptance → Tradeoff between the no. and placement of sensors and the performance
  – (10%) Interoperability with AAL systems
    • the use of open-source solutions
      Java, WEKA
    • availability of libraries for development
      Java docs, Free available under GNU GPL
    • integration with standard protocols
      TCP/IP, Bluetooth

http://dis.ijs.si/chiron/evaal/
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EvAAL-AR Results

<table>
<thead>
<tr>
<th>Location</th>
<th>2012</th>
<th>2013</th>
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<tr>
<td>Dublin (Ireland)</td>
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<td>Chiba'13 (Japan)</td>
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<td>CNR (Italy)</td>
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<td>Seville'12 (Spain)</td>
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<td>JSI (Slovenia)</td>
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<td>8.36</td>
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</table>
EvAAL-AR Detailed Results

Score from 0 to 10

<table>
<thead>
<tr>
<th>Team</th>
<th>Accuracy</th>
<th>Delay</th>
<th>Installation complexity</th>
<th>User Acceptance</th>
<th>Interoperability</th>
<th>Score</th>
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<td>2.67</td>
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</tbody>
</table>
Other Competitors

CHIBA
Japan

CNR
Italy

Spain
Summary

- Efficient system
- Easy installation
- User acceptable
- Interoperable
- Accurate?? (6.9 out of 10)
  - “Pre vs. At” the competition results

Pre-competition
Accuracy: 99.2%

At the competition
Accuracy: 75.6%
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Future Work

• System improvements
  – Smaller sensors with lower power consumption
  – Transferring system to a smartphone
  – Additional sensors: Location, ECG, GSR, Temperature sensors...

• Extending functionality
  – Energy Expenditure Estimation
  – High-level activities (cooking, watching TV, working on a PC)
  – Detecting health problems/anomalies
Health monitoring device

- Prototype health monitoring system developed together with the Department of Communication Systems at the Jozef Stefan Institute
Media Recognition

• The victory attracted media attention:
  – 2 minute clip on Dnevnik:  
    [http://youtu.be/Ma3H8-DYWVQ](http://youtu.be/Ma3H8-DYWVQ)
  – Several appearances in radio shows
  – Several articles in newspapers

• Interest by people to further develop the prototype and release it into practical use