Literature Review on Assisted Living Technologies

Flávia Dias Casagrande
3rd March, 2017
Outline

• Quick review on Commercial ALTs

• Special Projects and Research Groups with Focus on MCI/D

• ALTs for the Elderly and for the Elderly with MCI/D
Commercial ALTs
Commercial ALTs

• Home automation (energy efficiency, comfort, safety, security)
• Complete home automation solution
• Medicine dispensers
• Fall detection (smart watches, help button, floor, depth sensor)
• Rehabilitation and exercising
• Behaviour pattern monitoring systems: QuietCare, Stack
• Simpler smart phones
• Object finders
• Wandering
Special Projects and Research Groups with Focus on MCI/D
COACH

Assistance for people with dementia in the hand washing activity.

Where/When: Canada and UK, 2001-2010

Functionalities:
Issue of cues to guide user through hand washing

Sensors:
Camera

Method:
ML for identification of activity steps

Trial/Status: (long-term care facility)
Simulation tests
Real tests with 7 persons with moderate-to-severe dementia, in 10-weeks trial
System can very well provide assistance
Still challenges: adaptability to user, improvement of algorithm

Hoey et al, 2010
COGKNOW Day Navigator

Address needs of people with mild dementia.

**Where/ When:** UK, 2007-2012

**Functionalities:**
- Reminders (clock, appointments, ...)
- Support social contact (picture dialing, ...)
- Support daily activities (radio/lamp control, music, ...)
- Enhance feeling of safety (contact/help icon, warnings, ...)

**Sensors:**
- Magnetic sensors, Power sensors
- Pressure sensors, GPS

**Trial/ Status:** *(real homes)*
- 42 persons with mild dementia in UK, Netherlands and Sweden
- Useful user friendly, easy to operate, simple to understand
- During the development, 15 persons with mild dementia gave feedback

Mulvenna et al, 2007
http://www.cogknow.eu/
COGKNOW Day Navigator

Mulvenna et al, 2007
http://www.cogknow.eu/
Elderly Day Navigator (EDN): COGKNOW

Early Detection System (EDS)
**Functionalities:** Records the pattern of behavior in daily living. Activity recognition for analysis of sleep-wake rhythm, mobility in- and outside the house, meal preparations, personal hygiene and the number of (emergency) alarms.

**Sensors:** PIRs, magnetic sensors, pressure sensors

**Method:** Rules and fuzzy logic

**Result:** 80% activity recognition

Unattended Autonomous Surveillance System (UAS)
**Functionalities:** Automatic fall detection, wandering detection and prevention, detection of smoke and fire, emergency response system, video observation and video telephony.

**Sensors:** PIRs, magnetic sensors, pressure sensors, wearable (emergency response), cameras (emergency situations)

**Method:** Qualitative research to investigate needs of users

**Result:** 18 persons (with different health problems, including person with dementia)
Rosetta

COGKNOW + Early Detection System + Unattended Autonomous Surveillance System

Rosetta

Where/When: Netherlands, Germany and Belgium, 2014

Method: Workshops and interviews with people with MCI/D, carers and experts to define final system.

Results:

Most relevant functionalities: help in case of emergencies, support with navigation outdoors, calendar function.

Least relevant: activity support and picture phone-dialling.

Trial/Status: (real homes)

Trials in Netherlands, Germany and Belgium.

Homes of 42 persons with MCI/D and 32 carers. Usage from half a month to eight months (avg 4 months).

Problems in the installation of EDS and UAS.

Rosetta proved to be useful, although not friendly device.

No significant impact in perceived autonomy, care needs, QoL, performance of daily activities, etc.
Where/ When: US, from 2007
(Trials: labs)

1. Behavioural analysis
Activity recognition (Chen et al., 2010)
Data: from volunteers living in the test bed for 5 months
Sensors: PIRs, temperature, water, burner, telephone, tags
Result: 90% accuracy with ML algorithms

2. Activity prediction
Forecast sleep patterns of people recovering from injuries and with disabilities (Williams and Cook, 2016)
Data: from 20 smart home test beds
Result: 99% accuracy with ML algorithms
3. Promoting systems

Automated prompting system (Holder and Cook, 2013)

Data: from 3 smart home test beds during 6 months

12 different ADLs: bathing, bed to toilet, cook, eat, enter home, housekeeping, personal hygiene, relax, sleep, take medicine, work

Result: needs improvement, many false positives - ML algorithms

4. Assessment of activities’ execution / Diagnosis tools

Detection of behavioural changes between healthy older adults, with Parkinson disease and with MCI when executing ADLs (Cook et al., 2015)

Sensors: PIRs, magnetic sensors, ambient lights, temperature, vibration sensors in objects, wearable inertial sensors

Data: 84 adults

Result: 97% accuracy with ML → possible health monitoring and detection of functional changes related to PD and MCI
DOMUS - Canada

Lab with studies in the field of cognitive assistance, medical monitoring and televigilance for people with cognitive disorders.

Where/ When: Canada, from 2007

Five ongoing projects.

1. COOK – culinary assistant (recent project): design a cognitive orthosis for meal preparation to help people with head trauma
2. Early detection of dementia: measurement of activities’ performance
3. Amelis Calendar: interactive calendar to display appointments, temporal orientation, help on maintaining interpersonal contacts and on memory of past events
4. AGE WELL: assist elderly people in specific ADLs
5. IPADL: indoor positioning through RFID antennas and passive tags

https://www.usherbrooke.ca/domus/en
Plan recognition algorithm which detects errors in the execution of activities and may issue cues for people in early stage of dementia.

**Where/ When:** Singapore, 2007-2010

**Functionalities:**
- Prompts when activities are being wrongly executed

**Sensors:**
- PIRs, ultrasound sensors, RFIDs and UWB tags
- Accelerometers, video and audio sensors
- Pressure sensors, magnetic sensors

**Method:**
- ML and reinforcement learning

**Trial/ Status:** (lab)
- Focus in the eating activity
Mainly designed for people with early dementia. Aim at orienting at night. System created with help of users.

**Where/ When:** Ireland, 2010-2014

**Functionalities:**
- Switch lights on/off automatically
- Attract users back to bed when wandering is detected
- Music to help user sleep
- Monitoring and analysis of sleep
- Identify level of cognitive impairment

**Sensors:**
- PIRs, bed movement sensors, magnetic and appliances (optional)

**Method:**
- Rules and thresholds

**Trial/ Status:** (real homes)
- 8 persons with dementia for 3 months
- Favourable reaction
- 12 healthy persons for feedback of functionalities

Augusto et al, 2011
### Full Sensor Recordings

<table>
<thead>
<tr>
<th>House_ID</th>
<th>Sensor_type</th>
<th>Location</th>
<th>Event_type</th>
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<td>on</td>
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<tr>
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<td>PIR</td>
<td>Bedroom</td>
<td>on</td>
<td>2011-07-04 13:05:19</td>
</tr>
<tr>
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<td>PIR</td>
<td>Bedroom</td>
<td>on</td>
<td>2011-07-04 13:05:29</td>
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<td>PIR</td>
<td>Bedroom</td>
<td>on</td>
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<td>on</td>
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<td>off</td>
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<td>on</td>
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<tr>
<td>House001</td>
<td>Bed-chair</td>
<td>Bedroom</td>
<td>on</td>
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<td>on</td>
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<td>on</td>
<td>2011-07-04 13:04:19</td>
</tr>
<tr>
<td>House001</td>
<td>PIR</td>
<td>Bedroom</td>
<td>on</td>
<td>2011-07-04 13:04:29</td>
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</tr>
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<td>PIR</td>
<td>Bedroom</td>
<td>on</td>
<td>2011-07-04 13:04:49</td>
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<td>House001</td>
<td>PIR</td>
<td>Bedroom</td>
<td>on</td>
<td>2011-07-04 13:05:09</td>
</tr>
<tr>
<td>House001</td>
<td>PIR</td>
<td>Bedroom</td>
<td>on</td>
<td>2011-07-04 13:05:19</td>
</tr>
<tr>
<td>House001</td>
<td>PIR</td>
<td>Bedroom</td>
<td>on</td>
<td>2011-07-04 13:05:24</td>
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<tr>
<td>House001</td>
<td>PIR</td>
<td>Bedroom</td>
<td>on</td>
<td>2011-07-04 13:05:27</td>
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<tr>
<td>House001</td>
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<td>Bedroom</td>
<td>on</td>
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<td>on</td>
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<tr>
<td>House001</td>
<td>PIR</td>
<td>Bedroom</td>
<td>on</td>
<td>2011-07-04 13:05:39</td>
</tr>
</tbody>
</table>

### Live Stream Output

- **New input from sensor:** a3
  - **Sensor type:** PIR
  - **Clients current location:** Livingroom
  - **The type of signal information received from the sensor is:** on

- **Wandering agent message:** New sensor location different from current location Warning: current wandering pattern is [Bedroom, Landing, Bedroom, Landing] Wandering agent message: entered a room previously visited Wandering agent message: these room lights need to be turned off: Livingroom Wandering agent message: updated current location to Landing Wandering agent message: added room to wandering pattern list

- **New input from sensor:** a3
  - **Sensor type:** PIR
  - **Clients current location:** Livingroom

### Agent Results

<table>
<thead>
<tr>
<th>House_ID</th>
<th>Activity</th>
<th>Result</th>
<th>Time_and_date</th>
</tr>
</thead>
<tbody>
<tr>
<td>House001</td>
<td>Actuation</td>
<td>[Bedroom and Bathroom light on]</td>
<td>2011-07-04 15:04:10</td>
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<tr>
<td>House001</td>
<td>Wandering</td>
<td>[The client has started wandering]</td>
<td>2011-07-04 15:05:02</td>
</tr>
<tr>
<td>House001</td>
<td>Wandering</td>
<td>[Entered the Landing]</td>
<td>2011-07-04 15:05:24</td>
</tr>
<tr>
<td>House001</td>
<td>Actuation</td>
<td>[Landing light on]</td>
<td>2011-07-04 15:05:02</td>
</tr>
<tr>
<td>House001</td>
<td>Wandering</td>
<td>[Entered the Livingroom]</td>
<td>2011-07-04 15:05:09</td>
</tr>
<tr>
<td>House001</td>
<td>Actuation</td>
<td>[Livingroom light on]</td>
<td>2011-07-04 15:05:09</td>
</tr>
<tr>
<td>House001</td>
<td>Wandering</td>
<td>[Entered the Landing]</td>
<td>2011-07-04 15:05:09</td>
</tr>
<tr>
<td>House001</td>
<td>Wandering</td>
<td>[Entered the Bedroom]</td>
<td>2011-07-04 15:05:27</td>
</tr>
<tr>
<td>House001</td>
<td>Bed Occupancy</td>
<td>[The Client has returned to bed]</td>
<td>2011-07-04 15:05:32</td>
</tr>
<tr>
<td>House001</td>
<td>Actuation</td>
<td>[Echo command to turn all lights off]</td>
<td>2011-07-04 15:05:32</td>
</tr>
</tbody>
</table>
Dem@Care: Dementia Ambient Care

Sensor-based techniques to support people with dementia. Three environments.

**Where/When:** France, Greece, Ireland and Sweden, 2012-2015

1. **Hospital labs** – France and Greece: *early dementia diagnosis* (e.g. König et al, 2015)
   **Functionalities:**
   - Diagnosis of dementia and assessment of autonomy in executing ADLs
   **Sensors:**
   - Kinect color and depth camera
   **Method:**
   - People detection, tracking, gait analysis and event recognition
   **Trial/Status: (lab)**
   - Tests with 14 healthy people, 23 with MCI, 12 with Alzheimer
   - They were asked to perform certain ADLs
   - Results suggest that it is possible to quantitatively assess ADLs execution

2. **Nursing homes** – Sweden: *monitoring daily life*
Dem@Care: Dementia Ambient Care

3. Homes – Ireland and Greece: support of cognitive functions (e.g. Karakostas et al, 2015)

Functionalities:

- Support cognitive abilities of people with Alzheimer and dementia
- Monitoring of results for clinicians

Sensors:

- Color and depth camera, PIRs, wristwatch (physical activity measurement)
- Power sensors, pressure sensors, microphones

Method:

- Semantic integration and semantic web technologies

Trial/ Status: (real home)

- 1 trial with person with MCI during 3-months pilot
- Results show person has improved in some habits
- System installed in 4 homes and proceeding with data collection
Dem@Care: Dementia Ambient Care

Comparison of activities
Karakostas et al, 2015
Dem@Care: Dementia Ambient Care

Frequency pattern of devices’ usage
Karakostas et al, 2015
Research on ALTs for the Elderly and Elderly with MCI/D
Detection of Falls

- Kinect (depth sensor)
  - Tracking methods
  - Geometrical analysis

Depth sensor: information related to distance the surfaces are «seen» from the point of view of the sensor.

Yang et al, 2016
Detection of Falls

• Accelerometers

Bagalà et al, 2012

• Floor-vibration sensor

Alwan et al, 2006
Detection of Falls

• Drawbacks:

  Althought results reach 100% fall recognition, there is also many false alarms!

  System is based on thresholds → many adjustments (different homes, people, etc...)
    • Solution: Machine Learning
Detection of Falls

- Kinect (depth sensor)

Stone and Skubic, 2014
Detection of Falls

- Accelerometers

Özdemir and Barshan, 2014

- Radar + motion sensors
  Doppler radar
  Network of sensors (reduce false alarms)

Zhang et al, 2014
Detection of Falls

• Drawbacks:

  Accuracy results vary from 70% to 100%

  Still false alarms (less than without ML)

  Lack of real falls datasets
Management and Fall Risk Assessment

• FARSEEING project

Where/ When: Italy, 2012-2015

Smart phones, smart shoes, smart home interface, wearable, telemedical service, fall risk assessment tool (probability of falling over a year)

Mellone et al, 2012

Nawaz et al, 2014

Nawaz et al, 2014
## Diagnosis Tools

Some examples of diagnosing tools for MCI/D

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Hayes et al., 2008</th>
<th>Oswald et al., 2010</th>
<th>Riboni et al., 2015</th>
<th>Ashraf and Taati, 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>How</strong></td>
<td>In-home monitoring</td>
<td>Outdoor mobility</td>
<td>Detection of abnormal behaviour when executing ADLs</td>
<td>Analysis of hand washing activity</td>
</tr>
<tr>
<td><strong>Sensors</strong></td>
<td>PIRs and magnetic sensors</td>
<td>GPS</td>
<td>PIRs, magnetic, temperature, pressure, RFID</td>
<td>Color video</td>
</tr>
<tr>
<td><strong>Method</strong></td>
<td>Computation of walking speed and total movement</td>
<td>Observational study</td>
<td>Activity/anomaly recognition with ML</td>
<td>Statistics of occupancy of the regions of the sink and motion trajectory of hands - ML</td>
</tr>
<tr>
<td><strong>Participants</strong></td>
<td>7 healthy and 7 MCI</td>
<td>7 healthy, 6 MCI, 6 dementia</td>
<td>21 actors (lab), 1 elderly MCI (home)</td>
<td>27 older adults</td>
</tr>
<tr>
<td><strong>Period (days)</strong></td>
<td>418</td>
<td>360</td>
<td>21 (lab), 90 (home)</td>
<td>90 days (trials)</td>
</tr>
<tr>
<td><strong>Conclusions</strong></td>
<td>Walking patterns suggest early transition to MCI</td>
<td>Healthy participants have higher levels of well-being and smaller network</td>
<td>99% accuracy in detecting abnormal behaviour</td>
<td>Potential in hand washing to indicate dementia</td>
</tr>
</tbody>
</table>
Memory-Aid: Autominder + Pearl

Cognitive orthotic system to provide personalized reminders.

**Where/ When:** US, 2002-2004

**Functionalities:**
- Reminders
- Modelling of user’s activities
- Navigation assistance
- Speech and face recognition

**Sensors:**
- Differential drive system, laser range finders, sonar sensors
- Microphones and speakers, stereo camera systems

**Method:**
- Reinforcement learning for adaptation over time

**Trial/ Status:** *(long-term care facility)*
- System deployed on Pearl
- Trials for 5 days – general public and 6 specific elderly users
- Detection of flaws (robot’s velocity and speech recognition)

Pollack et al, 2003
Montemerlo et al, 2002
Smart Homes

Acoustic Bathroom Activity Monitoring System (Singapore, 2005): generation of reports for carers on personal hygiene behaviour of people with dementia.

Casattenta (Italy, 2010): smart home for elderly people containing sensors to identify dangerous situations. System included in European project ALFA.

ALFA (Italy, 2012): integration of three solutions for people with dementia at early stage and stimulate cognitive functions: agenda and fall detector, monitoring of activities and motion and gait analysis.

Easyline+ project - AmI Kitchen (Spain, 2013-14): aim at easing the use of household appliances. 63 real users and 31 carers (older people and young with disabilities).

Sweet-home project (France, from 2013): smart home based on audio technology and environment sensors.

SenseCare (Germany and Ireland, from 2016): new project. Aim at identifying emotions of people with dementia.

Farella et al, 2010 - Casattenta

http://www.t3lab.it/en/progetti/alfa/

Easyline+  

Blasco et al, 2013 and Bono-Nuez et al, 2014
Summary and Conclusions

• Commercial ALTs: lots of standalone devices → complete smart home system
• More restricted and less evolved commercial ALT for elderly and elderly with MCI/D
• Even some commercial ALT are still on research field, e.g. falls’ detection
• Much research on smart homes for elderly and elderly with MCI/D
  - Behaviour monitoring
  - Indoor mobility
  - Indoor safety
• A lot of research on diagnosis tools
• Technical development of ALTs: machine learning very visible in research; clear benefits
• A lot of research activity on activity recognition. Not direct value, but necessary for future functionalities.
• Limited number of research projects have real homes to test and validate their algorithms and technologies.