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Detection of Psychomotor Agitation Pattern from Motion Sensor Data in a Living Environment of a Patient with Dementia

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Abstract. Agitation is a symptom of many mental illnesses such as dementia. The aim of this work is to detect psychomotor agitation pattern in the living environment of a patient with dementia. To reach this goal, we built a smart home environment to collect the motion data of our patient. These data can be used to show the single movements of a person between different rooms in this apartment. The interpretation of these movements allows us to conclude if movements are normal or look like psychomotor agitation, in particular wandering around. This information might be useful for further analysis and interpretation. Additionally, it might be possible that the movement can give an indication of possible mood and behavioural changes in the patient. So it should be possible to create a long-term living environment that enables residents to live a long and independent life in their own home.

Keywords. Mental illnesses, dementia, behaviour monitoring and interpretation, ambient assisted living, health-enabling and ambient assisted technologies, home automation technology, smart home

1. Introduction

Agitation describes a neuropsychiatric symptom which is characterized by pathologically increased, unproductive motor activities and the feeling of being driven and agitated. [1] According to this definition, agitation manifests itself through excessive motor activities such as nesting, reaching around, constant undressing, trembling or pointless wandering. The basic characteristic of agitation is that the hyperactive movements are carried out hastily, erratically and aimlessly. In particular, this symptom can be found in mental illnesses such as dementia or depression. [1]

The review by Khan et al. [2] gives a brief overview of the existing studies that use sensors to detect agitation in patients with dementia. They conclude, "*that actigraphy shows some evidence of correlation with of agitation and […] multi-modal sensing has not been fully evaluated for this purpose"* [2]. Therefore, the research question of this paper is, if it is possible to detect *incidences* behaviours such as aimless wandering in the home with home automation technologies and health-enabling and ambient assistive technologies (HEAAT). This question is based on the work of Haux et al. and

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their conclusion that "*HEAAT remain an important field for future health care and for interdisciplinary research"* [3]. In addition, Mielke et al. describe in [4] the first example of an apartment as a diagnostic and therapeutic area. Following this example, it is possible to build up several modern apartments equipped with information and communication technology for medical care. They used home automation technologies and HEAAT to build this apartment, and as a result, they presented data from various types of sensors. Therefore, our goal is to build a Smart Home for medical care with the function to detect the psychomotor agitation pattern from motion sensor data in a living environment of a patient with dementia.

2. Method

In cooperation with Baugenossenschaft Wiederaufbau eG we equipped a housing unit in a building complex of assisted living with a home automation system, which can record and analyze selected data of the resident. Our first step to build this system was to develop a technical concept and a design on how to equip the apartment with sensors and smart home technologies. We decided to use the home automation system "provedo" with flat cables to minimize expenditure and cost for retrofitting. This home automation system was built by former company PROVEDO GmbH, and retrofitting was done by Baugenossenschaft Wiederaufbau eG. We equipped the apartment with a mini-computer and the necessary software to collect and analyze home automation data. In the following, we describe some details of this home automation system, the algorithm and the graphical user interface we developed for the detection of movement agitation patterns from motion sensor data in a living environment.

2.1. Details of the home automation system – sensors, data, resident

The apartment was equipped with different sensors. The installation includes motion sensors for activity detection, power sensors to collect the energy consumption, temperature and humidity sensors for automatic control of the heating system as well as contact sensors to detect the opening and closing of windows and doors. Therefore, the resident can experience several comfort functions like an automatic heating system, a chip-controlled door lock for keyless opening, a floor lighting as a night light, a stove and window control display and a stove monitoring. Additional to these comfort functions, the data collection runs autonomous and without any intervention of the resident. The sensors we used in the system are not intrusive and inconspicuous. PROVEDO offered a house bus system (see figure 1), which could easily be installed in existing apartments. Flat ribbon cables were used which could be placed under the wallpaper. The sensors and actuators are small devices that were mounted on the wall or ceiling like a light switch or smoke detector and thus could be integrated inconspicuously into the entire electrical installation of the home. Figure 1 shows the positions of the sensors in the apartment. The data recorded by the sensors are movement data within the apartment, the power consumption of the apartment, power consumption of the stove, room temperature and humidity, window status (open/closed) and access control. For the detection of psychomotor agitation, we used data recorded in the retrofitted apartment by a male subject aged 85+ and diagnosed with dementia between October 2016 and October 2018. The subject's guardian was

informed about the project details and a signed consent form for the collection and use of data is available.

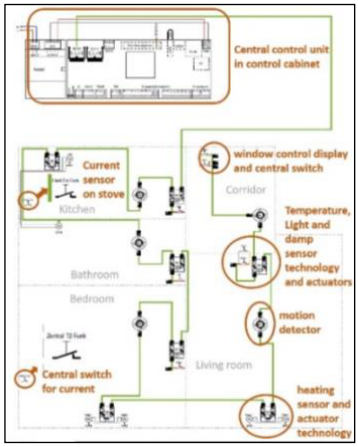

Figure 1. Schematic for the installation of sensors in the apartment with designation of individual components.

2.2. Algorithms for detection of movement agitation pattern

A relevant evaluation related to the behaviour of a person is the detection of inner restlessness and agitation. This evaluation is possible with the help of the analysis of all movement events over a certain period. In doing so, coherent movement sequences are identified, documented and evaluated. Connected motion sequences result from observation of individual motion events between rooms and their temporal distances. These movement sequences can be observed, recorded and evaluated by monitoring movements through individual rooms of the subject's home. In particular, the duration of an agitation phase and the frequency of room changes are of interest.

Motion sensors on the ceiling of each room are the basis for movement detection. They generate an event every time they detect motion, which is stored as the number of events per second. We only attempt to detect movements when one person is present in the apartment. The first step is to create a list of the resident's location for every time of day. Because the detection radius of sensors in neighbouring rooms overlap, it is possible to detect one person as being present in two rooms simultaneously. When no sensor detects motion, the resident has either left the residence or is rather motionless in the current room. We assume the resident has left the apartment if no motion is detected for 30 minutes, and the last room was the corridor. The following list with the current timestamp and the corresponding room in the residence can be derived from the data.

```
[  [1498953600000, ["bathroom"]],
  [1498953955000, ["bathroom", "corridor"]],
  [1498954003000, ["corridor"]],
  [1498954037000, ["living room"]],
  [1498954044000, ["living room", "bedroom"]],
  [1498954091000, ["bedroom"]],
  ...]
```

The list of all movement sequences is composed of individual movements, which are aggregated to a complete sequence if on the last individual movement the occupant stays at the same place for at least three minutes. A sequence of movements is marked

as critical if it lasts more than three seconds and contains the same room more than three times none consecutively. It is also marked critical if it contains impossible room changes, i.e. a direct change between two non-neighbouring rooms because this could indicate that more than one person is present.

3. Results

The data analysis results in a list of movement sequences. Due to its type and quantity of information contained, this list is now the basis for assessment and evaluation of individual movement sequences with regard to inner restlessness and agitation. For the research apartment, figure 2 shows the general overview of the evaluation for the movement data. The schematic floor plan with the possible movement points for orientation and better visual comprehensibility of movement sequences in the apartment is shown. The selected period is also displayed as well as the general summary for all found motion sequences and the motion sequences that were marked as critical through the evaluation for inner restlessness. In addition, this illustration also shows a normal motion sequence from September 26, 2017, with a defined start and end of the motion and the list with single movement sequences detected in the selected period. The motion sequences of this list that are marked as critical in the sense of inner restlessness are shown in red. Figure 2 shows a passage to the bathroom with a duration of 1 minute and 16 seconds.

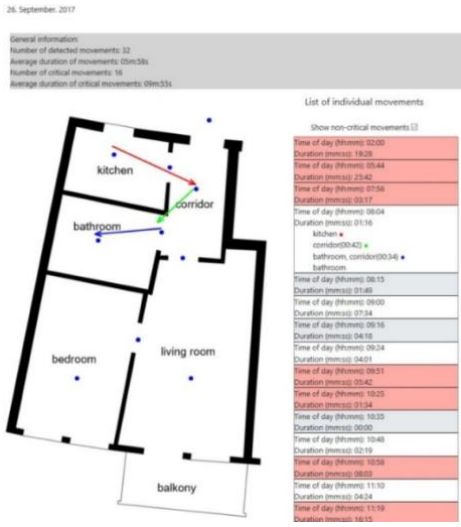

Figure 2. Controlled and targeted movement - a normal motion sequence with a defined start and end (Example from September 26, 2017, blue dots - motion points for single and neighbouring rooms, a motion is marked with an arrow in the floor plan and the same colour dot in the list of motions).

In contrast, figure 3 shows an accumulation of movement on the same day that has been evaluated as critical or conspicuous. This motion sequence is characterized as critical because each stay per room has lasted less than three minutes and contains the same room more than three times none consecutively.

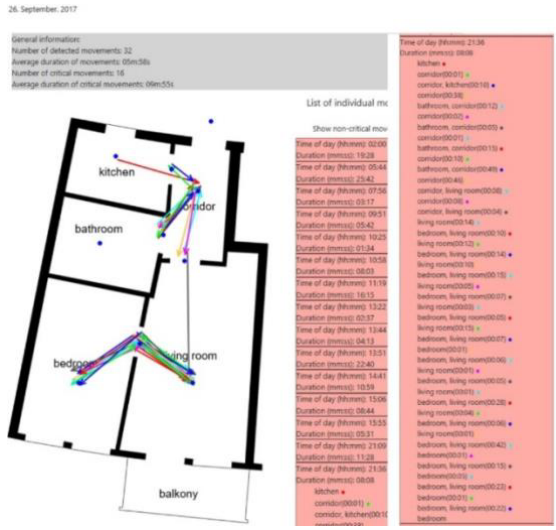

Figure 3. Agitation movement – movement sequence with many room changes about a duration of 8 minutes (Example from September 26, 2017, blue dots - motion points for single and neighbouring rooms, a motion is marked with an arrow in the floor plan and the same colour dot in the list of motions).

4. Discussion

The movement sequences marked as conspicuous or critical can give an indication of possible changes. The accumulation or temporal shift of such movement sequences could be indicators of a changing state of health in patients with dementia.

With the knowledge gained from this, we can develop systems that detect changes in lifestyle at an early stage. This enables relatives, caregivers or -providers, and doctors to intervene in a supportive manner in time. Thus, it should be possible to create a long-term living environment that enables residents to live a long and independent life in their own homes. In future work, we want to refine the algorithm, so that it is possible to improve the statements regarding agitations. Furthermore, we consider how a suitable study plan could look like in order to investigate to what extent agitation episodes can possibly be reduced with the help of the developed algorithm.

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