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First application of behavoir recognition through the recording of ADL by radio modules in a home

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Abstract—**In this contribution the behavior of an elderly couple, recorded by a radio module system in their own home is analyzed. There is an increasing interest in giving elderly people the possibility to live at their own homes as long as possible. Since diseases like dementia are diagnosed through the change of behavior, especially the activities of daily living (ADL), there is a growing need of an objective instrument for measuring behavioral changes. Therefore the Eventlogger was developed and installed for 32 days in a home of an elderly couple. Throughout this paper the outcome of the data collection as well as first steps for analyzing it will be discussed. Furthermore we were able to observe different routines of the diseased and the healthy person. The diseased proband follows a very strict routine whereas the healthy proband routines are dependent on different factors.**

Keywords- interaction, ADL, radio module, recognition, behavior

Germany and other industrial developed countries are facing due to the demographic change, a huge future problem. The number of elderly people and therefore patients who suffer from dementia, is increasing dramatically. A significant quantity of these persons, live in special care units for elderly and demential patients. Those facilities are very expensive and cause rising costs for the health care system. Additionally to these facilities many patients, especially within the early stage of the disease, are cared for by their relatives, at home. This is a huge challenge and burden for the caregiver. Their physical and psychological stress and strains of caregiving are enormous and causing all kinds of diseases. So a relief of these strains is urgently needed. That's why besides the costs for the patients, the costs for the nurturing family members are also increasing. So there is an urgent need for an alternative way of living for dementia patients. One solution for these problems could be an interaction detecting system to help the patients manage their everyday life and to decrease the stress for their families. Therefore we developed the "Eventlogger" system.
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I. STATE OF THE ART

Systems for the recognition of interactions can be divided into passive and active systems. For using passive systems the user must not carry any device, whereas for active systems the wearing of a device is necessary.

One of the active interaction systems based on radio modules is called "Eventlogger" and was developed by [1]. This system enables to tag different objects by radio modules with different transmitting ranges, which are similar to an active RFID-system. This system and its application will be described in more detail later on. RFID based systems are used in particular, because of the batteryless transponder that obliterates the need for charging. Most RFID-systems are implemented in gloves or bracelets like the iBracelet [2]. Passive systems like video based systems are observing certain areas and extract the activities through different algorithms [3][4]. Other approaches have been implemented by measuring the sound for specific ADLs in the bathroom [5]. [6] are using PIR sensors (passive infrared sensors), a passive system to monitor the user. According to [7] it is also possible to monitor interactions by low-level sensors like switches.

Most of the systems were merely evaluated in laboratories or in special equipped living labs. Since they are developed for the everyday use they have to be evaluated in real home settings. Only this can provide the promised support. Most important for an acceptance by the user is comfort. Thus the system should not disturb the user when doing his daily activities. These facts should be observed when inventing such a system.

II. MATERIAL AND METHODS

The system used in this evaluation is called "Eventlogger" [1], [8]. It is based on radio modules with different transmission ranges. The device consists of a 2.4GHz radio module and is controlled by a microcontroller.

For storing data and time it comes with a SD-card and a real-time-clock. Every object or person with whom interaction should be measured is equipped with an Eventlogger. Each Eventlogger has a specific transmission range for transmitting its own ID, e.g. the basin with a very small range of about 40cm or the kitchen with a range of some meters. As soon as the user with his "personal" Eventlogger is entering the transmission area of another Eventlogger's range an event called sADL [8] is generated and saved on a SD-card. Over a base station these sADL can be read out and displayed on a device like a laptop.

The system Eventlogger has already been evaluated in a day hospital for old age psychiatry [9][10]. In this paper the results of the installation of the system in a domestic home is discussed. The data acquisition took place over a period of 32 days. Therefore one Eventlogger was worn in the pocket by each of the probands. As it is possible to wear the Eventlogger on the wrist as well as in the pocket it was an agreement since the wife feels a stigmatization by wearing the Eventlogger on the wrist and the men does not like to wear devices directly on the skin.

III. VALIDATION

The questions analyzed are:

- **Recognition of ADLs** like toileting, cooking, breakfasting or TV watching
- **Recurring daily routines of a person**, which are based on different ADLs as well as other events

  These are for example personal hygiene (at least once a day, mostly in the morning, often also in the evening), food intake (very individual, at least 2 times a day, but also outside the flat possible), sleeping (very individual, about 6-8 hours), drinking, repeated toileting (frequency and duration individual) and social contacts. Additionally there are activities like shopping, sport, job-related activities and other duties like cleaning the flat.
- **Changes** of the "normal" daily routines

  Changes of "normal" daily routines can have different possible causes. They are very individual e.g. occupation, weather, mobility, family position, age, lifestyle (sport, recreational activities,..), season, weekday, , illness, social environment, housing situation and a lot more .
- **Differences between daily routines** of a healthy and a diseased proband (dementia)

Therefore the system was installed in a home of an elderly couple. The wife is 64 years old and healthy; the man is 73 years old and suffering from a starting vascular dementia since an apoplectic stroke six years ago. The husband is able to do most of the activities on his own, but sometimes has to be reminded to fulfill a task. Due to his medication he is not able to stay awake the whole day.

The installation of the Eventlogger is shown in fig. 1. For the personal hygiene the bathroom is equipped with an Eventlogger, detecting all the activities in the bathroom. Additionally the basin in the bathroom is equipped with another short range Eventlogger to detect hand washing. The toilet is also tagged with an Eventlogger, only the basin in the toilet room is not observed because it is not used for hand washing. In the kitchen three Eventlogger are installed to detect a) the whole kitchen b) the work area and c) the table where the meals are eaten. The sleeping room has one Eventlogger for detecting the bed and a second one for the whole room, to detect dressing and undressing. In the living room one Eventlogger covers the sitting area, another one (with a short range) nearby the TV detects when it is switched on and off. Further Eventloggers are installed in the washing room as well as in the workroom.

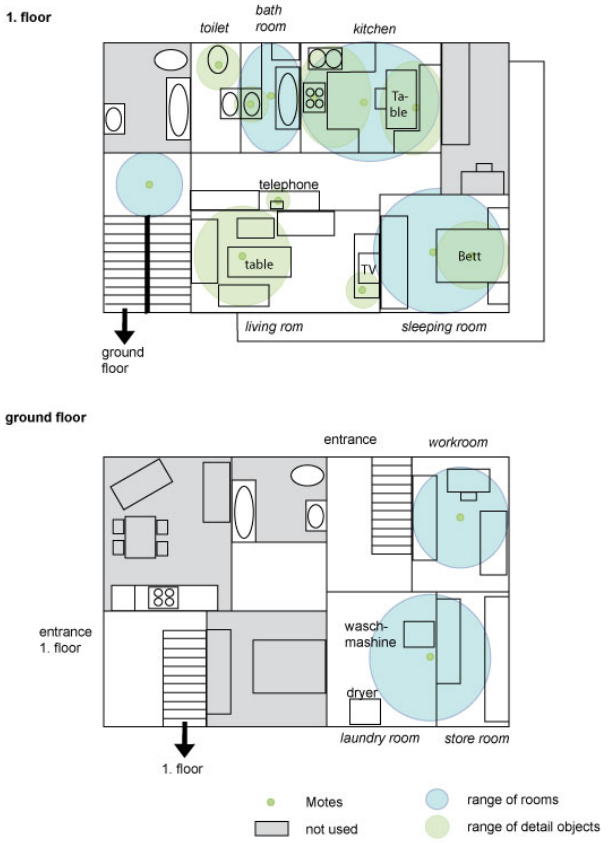

Figure 1. Installation of the Eventlogger in the house of the probands with the different transmission ranges.

IV. RESULTS

The probands made handwritten recordings about special events. The data of the 32days were analyzed, and afterwards discussed with the probands to get straight , if the estimated daily routines are .accurate

Recognition of ADLs

For better intelligibility Interactions with the toilet and the mostly ensuing interaction with the basin are assumed as

toileting (figure 2) - although there is a risk to misinterpret the cleaning of the toilet as using it.

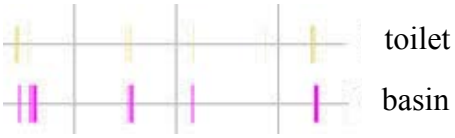

Figure 2. Example for the toileting of the wife

Since the breakfast is eaten at the table in the kitchen, interactions between the user and the kitchen, the work area and the table are expected. This assumption is approved as shown in figure 3.

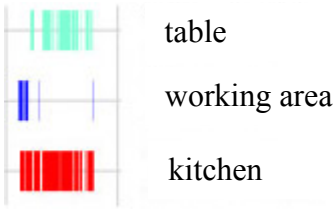

Figure 3. Example for the breakfast of the wife

These interactions can also be observed during different times around noon and in the evening. This can be interpreted as lunch anddinner.

Since the husband uses the living room merely for watching TV, the interaction with the living room can be interpreted as watching TV. Additionally the Eventlogger "TV" has a very short interaction radius to detect the on- and off switching. Considering the wife it is not possible to make a unique statement. Sometimes she is just walking around the living room, listens to music or switches the TV in standby mode.

Recurring daily routines of a person

The daily routine of the husband is shown in table 1. This table also shows the percentage of the days detected. As already mentioned the husband sometimes forgot to put the Eventlogger in the pocket of his "new" trouser after changing his cloth. Therefore the detection of his behavior can be grouped in the recordings of all days and the recordings where the Eventlogger was worn for sure.

TABLE I. REGULARITIES OF THE DAILY ROUTINE OF THE HUSBAND OVER 32 DAYS

Time of Day		regularity	Interactions	detectet on percentage of days	detectet on percentage of days with datarecording
6am -9am	morning	between 7am and 9am	kitchen/table	97%	100%
		at least once in the morning	toilet - bathroom/basin	81%	81%
		between 8am and 11am mostly before personal hygien	sleeping room	94%	94%
9am-12pm	late morning	second long stay between 8am and 10am	kitchen/working area /table	76%	76%
		between 8am and 11am for about 1 hour	bathroom/basin	88%	88%
		short activities in the home between 10am and noon	kitchen/working area	91%	91%
		longer stay in the living room between 10am and noon	living room	91%	91%
		personal hygine before lunch	bathroom/basin	41%	41%
12pm - 6pm	afternoon	lunch between noon and 1pm	kitchen/table	94%	100%
		personal hygine after lunch	Bathroom/basin	81%	87%
		long stay in the bedroom, sleeping	bed/sleeping	69%	not evaluabe
		Food in the kitchen between 2pm and 4pm	kitchen/working area/table	47%	65%*
		Watching TV in the living room	living room	34%	69%*
		at least 1 time toilet and hygiene	toilet - bathroom/basin	97%	not evaluabe
		Food in the evening between 5pm and 7pm	kitchen/working area/table	66%	100%*
6pm - 9pm	evening	when stood up again, once again sleeping	bed/sleeping	50%	84%*
		staying in bed is interrupted only by occasional toilet, kitchen and bathroom visits	toilet - bathroom/basin	22%	37%*
			kitchen/working area/table		
9pm-6am	night	no regularities out of the data since the mote is worn very rarely at this time. Most of the stay is registred in the bed/sleeping room	bed/sleeping	41%	87%*

* computation

The daily routines of the husband are in contrast to the wife very continuous. It usually starts with a stay in the kitchen, where he is cleaning the dishes and prepares the breakfast. In the course of the morning he spends about one hour for personal hygiene. Due to the recordings it is not possible to interpret exactly what he is doing in the bathroom. The only housework the elderly men is doing during the morning is making the beds. This can be seen by the recordings of the bed. Thereafter the husband watches TV until noon. Lunchtime is normally between noon and 12:30 pm. After the lunch the male proband is taking a nap which sometimes lasts until dinner. Through fewer contacts with the Eventlogger, it is obvious that the husband has a very small cruising radius and spends most of the time in the house.

The daily routine of the wife is shown in table 2.

TABLE II. REGULARITIES OF DAILY ROUTINE OF THE WIFE OVER 32 DAYS

Time of Day		regularity	Interactions	detectet on percentage of days	detectet on percentage of days with datarecording
6am -9am	morning	at least one time every morning	toilet - bathroom/basin	50%	63%
		between 8am and 9am personal hygiene in the bathroom	bathroom/basin	83%	100%
		between 8:30am and 10am longer stay at kitchentable: breakfast (15-30 min)	kitchen/table	77%	96%
9am-12pm	late morning	additonal personal hygiene (bathroom): brushing teeth, make up, aso.	bathroom/basin	77%	96%
		longer stay: getting goods from larder, dispose waste	laundry	80%	100%
		use of toilet without regularity, several times a day	toilet - bathroom/basin	66%	71%
		leaving the flat, approximately every second day	laundry or storage room	50%	65%
		before luch time: shopping, things to take care of			
		doing laundry once a week	laundry	13%	every Monday
		shopping by car	laundry	13%	every Thursday
		cleaning the flat, changing rooms frequently	livingroom-bathroom-kitchen	40%	52%
		preparations for lunch	kitchen/working area /table	83%	100%
12pm - 6pm	afternoon	lunch between noon and 1pm	kitchen/working area /table	83%	100%
		seperate interaction with the table can be identified as a rest	kitchen/table	40%	50%
		Tidying up and cleaning in the home (mainly during the week)	livingroom-bathroom - kitchen	37%	not evaluable
		Stay away from home	laundry or vestibule	63%	100%
		Also in the afternoon interacting with toilet and basin	toilet - bathroom/basin	63%	83%*
		Stay at the kitchen table with coffee, cake (3pm)	kitchen/cooker/table	43%	65%*
		walk through the house between 5:30pm and 7:00pm	livingroom-bedroom-kitchen-bathroom	60%	not evaluable
6pm - 9pm	evening	toilet and washing hands before dinner	toilet - bathroom/basin	60%	78%*
		dinner between 7:30pm and 9:30pm	kitchen/table	90%	96%
		a repeated stay in the garden / walk	laundry	37%	50%*
9pm - 6am	night	Stay in toilet and bath	toilet - bathroom/basin	53%	73%*
		Leisure in the kitchen (read) or in the living room (television or listening to music) for about 1 hour	kitchen livingroom	60%	86%
		going to bed sequence, stay in the kitchen and personal hygiene	kitchen bathroom/basin	60%	100%
		sleeping very continuous form 12am to 8am	bed/sleeping room	43%	72%

* computation

After getting up the wife spends some time in the bathroom for personal hygiene. This is only interrupted by the breakfast at the kitchen table. Afterwards there is a periodic activity in the laundry room/storeroom. This is interpreted as arrangements for the day. In the course of the morning there are changing activities in- and outdoors depending on the weather. The indoor activities in this time sequence which takes place in different rooms can be interpreted as cleaning or venting. Shortly before noon the activities in the kitchen nearby the work area start, interpreted as cooking. The meal is taken between noon and 1pm most of the time together with the husband at the kitchen table. In the afternoon the activities are once again in- and outdoors. The data frequently shows a stay at the kitchen table for drinking coffee at 3pm. Between 5 and 7pm there is a walk through the house which is recorded by interactions in nearly every room as well as with the husband. In the evening, the couple has dinner at the kitchen table. Before going to bed there is a special sequence observable. First there is an interaction with the TV (shutting it off), then a short sequence in the kitchen nearby the table, followed by a few minutes in the sleeping room the bathroom and at the toilet. This can be interpreted as preparations of going to sleep. Finally the bed is recorded as last detection of the day.

There are also weekly periodic activities which affect on the daily routine of the wife. Based on the recordings she leaves the house twice on Thursdays, first in the morning for about three hours and then again in the afternoon for two to four hours. This is confirmed by the short interaction of the Eventlogger in the laundry room, which is the connecting passage to the garage.

Another weekly periodic activity on Mondays is a long interaction in the laundry room (see fig. 4). The duration as well as the frequency differs from other activities and is interpreted as “washing clothes”. This was confirmed by the wife.

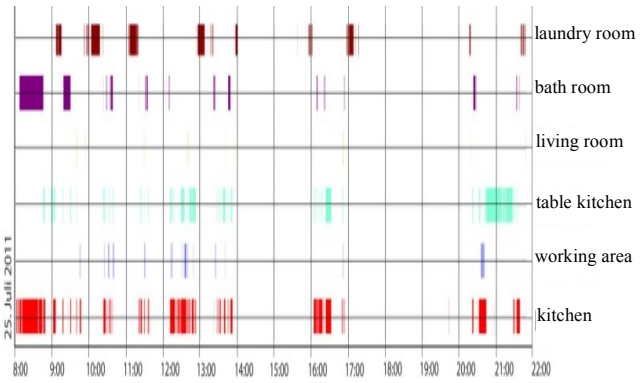

Figure 4. Recorded interactions on a Monday from the wife

Changes of the “normal” daily routines can be detected.

Considering the findings of the wife’s activities changes of the usual daily routine can be detected. The activities of the wife are dependent on the weather conditions. That’s why during nice weather she spends a lot of time outside, while she does a lot of work in the house on rainy days. But since the comparatively short evaluation period over one month the daily routine of the wife has not changed distinctly. The man’s routine changed only once when he went back to bed at 9:30 am, because of an illness. Whereas sudden changes in the daily routines could be detected easily, slight changes were missed.

V. DISCUSSION

Recognition of ADLs

The system is able to detect interactions that can be interpreted as activities considering a certain context. However the performance of an activity cannot be perceived directly by the system. Up to date there were no hints, within our recent studies, that provide a need of such detailed information. Considering the data collected in this study it has to be clarified if in a household with more than one person, the activities could be mixed up. For example in this case the husband was making the breakfast for his wife. So there were no interactions between the wife and the working area in the kitchen before breakfast. This could be misinterpreted as “forgetting the breakfast”. Therefore it will be necessary to include the data of other persons in the same household to get the full dataset and to prevent misinterpretations.

Recurring daily routines of a person

Recurring daily routines can be detected by the Eventlogger system. Through the analysis of the data it can be concluded that the daily routine is dependent on three different events.

- daily periodic events.
- events with large continuous interval

- appointments or influencing factors from outside.

Daily periodic events are for example lunch or personal hygiene. Events with larger continuous interval are weekly events like shopping. This includes also the difference between a work day and the weekend. The third type of events are appointments (e.g. consulting the doctor), the weather conditions and the influences of third persons.

Changes of the "normal" daily routines

As the system is able to detect recurring daily routines it is also possible to detect changes of them - although the reason for the change is not necessarily perceptible.

Differences of daily routines of a healthy and a diseased proband (dementia)

This question cannot be answered in general as we merely collected samples of two probands. Considering the presented case the diseased proband had in sum fewer interactions with objects. Whereas the duration of each interaction lasted longer compared to the healthy wife. The strict routine of the diseased is clearly recognizable. Although both probands are retired, the daily routines of the husband do not differ between workdays and the weekend. In contrast the wife sleeps longer at least one day during the weekend and spends more time in the kitchen. Furthermore the activities in the house are significantly reduced during the weekend.

VI. CONCLUSION

To put in a nutshell the application of the Eventlogger system in the house of an elderly couple led to useful findings. To begin with: within these 32 days of running the system in the household a huge number of new datasets were collected. That information can be further analyzed and used in future settings of the Eventlogger system. Furthermore useful feedback for the hardware was given by the elderly couple. They criticized for example, that the charging of the system over a connector is not suitable for elderly people, since it is to filigree. Therefore it is projected to develop an inductive charging station. Above all the elderly couple recommended, that the Eventlogger system is not disturbing their normal daily activities. One of the advantages of the System that is used in this study is the easy handling, since you can wear it on the wrist or in a pocket of a cloth. Unfortunately sometimes the subjects forgot the device when changing their clothes. Therefore a reliable solution like some kind of reminder should be evaluated in the near future. Up to date it is not examined how to include the date of additional individuals (like a visiting doctor or a nurse for example) within the dataset. That will be the topic of further studies. In addition to these findings the creation of an algorithm that enables to detect the behavior automatically is intended in the nearer future. For this the collected datasets are elementary.

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