First Steps towards a Recognition of ADLs with Radio Modules

Jakob Neuhaeuser, Axel Czabke, Tim C. Lueth
Department of Micro Technology and Medical Device Technology
Technical University Munich
Munich, Germany
jakob.neuhaeuser@tum.de

Abstract— The paper describes a system, designed for unsupervised detecting and recording the activities of daily living (ADL) of patients with mild cognitive impairment (MCI) without human observation. Many miniaturized, radio linked and mobile µC-based tags are used. Some are fixed to objects others are carried by the patients. All tags have a limited and adjustable communication range. Basic concept is to detect, to record and to analyze the combinations of µC-tags. This paper deals especially with a first user interface to evaluate the ADL of a patient as well as an evaluation of our system over several days for some activities with a sensitivity of 92%. This is the last step before entering a clinical environment.

I. Introduction

Most of the developed countries will face the same set of healthcare challenges in the upcoming years. The demographical, structural and social trends tend towards an increasing number of elderly people, while the number of the young and working people is decreasing. This will have a dramatic impact on society affecting both financial and organizational aspects [1].

Due to the desire of living as long as possible in the own home, there is a need of systems who can identify possible risks or first changes in behaviour. On the one side there are systems to monitor the vital parameters e.g. ECG [2]. On the other side it is common to monitor every day activities, to see if a person is still able to live autonomous. For that purpose, two specific sets of activities have been defined [3]. One describes the Activities of Daily Living (ADL) and focuses on the functional status of a person. The other one, the Instrumental Activities of Daily Living (IADL), describes interactions with the physical and social environment. An automated recognizing of ADLs would provide an objective tool to assess self maintenance abilities and to make even slight changes in behaviour visible and thus help to diagnose even slow degradation processes at an early stage. We suggest an approach that allows to detect the interaction with objects or persons and thus is capable to document the occurrence and accomplishment of some vital ADLs such as toileting or getting a drink. The idea is to interpret interaction with objects as the corresponding action. This is done by a scaleable local communication based on radio modules similar to the IR-modules in [4]. For example, “drinking coffee” can be inferred from a person’s interaction with “coffee machine” and “mug” which was already presented as a concept in [5]. The precondition for this approach is to have a tool or system that is capable of recognizing interaction in a reliable way without disturbing the user.

This work has received funding from the Bavarian Research Foundation (BFS) under contract number AZ-780-07. The views expressed here are those of the authors only. The BFS is not liable for any use that may be made of the information contained therein.
Jakob Neuhaeuser, Axel Czabke, and T. C. Lueth are with the Department of Micro Technology and Medical Device Technology, Technische Universitaet Muenchen, Boltzmannstr. 15, D-85748 Garching Germany (phone: +49 89 28915171; fax: +49 89 28915192; e-mail: jakob.neuhaeuser@tum.de)

II. State of the Art

A widely used ADL-scale is the Barthel Index (BI) [6]. Here data is collected by asking the nurse or if possible the patient questions about the ability to autonomously carry out daily routines, such as personal hygiene, using the toilet or bathing/showering. All these data finally amount to a score which then, transmitted to a scale, reveals the severity of ability dysfunctions.

The greatest disadvantage of these questionnaires is their subjectivity. [7] showed that the scores attained by doctors through interviewing the patients were insignificant. The Barthel Index scores surveyed by the patients` nursing staff therefore compared to the direct interviews of the doctors. There were significant differences found, probably due to the embarrassment of the patient on the one side and on the subjectivity on the other. Another study [8] was made to investigate whether different sources of data (patient, nursing staff, relatives, doctor) lead to the same score. It turned out that patients usually overestimate their functional activities whereas external observers mostly underestimate them. A further disadvantage of ADL-scales is that they are implemented when the person is already in care. Thus it is impossible to detect a slowly creeping degeneration of activities at an early stage. It is generally known however that early detection increases the chance of regeneration.

In research, there are various projects with the aim of developing a system, able to detect different ADLs

978-1-61284-696-5/11/$26.00 ©2011 IEEE

automatically. Quite a lot of research can be found based on RFID. [9], [10], and [11], for example, integrated RFID readers into bracelets or gloves. In [12], it was tried to get more information out of the system by adding an accelerometer. Infrared systems, based on PIR-Sensors (Presence Infrared Sensors) [13] and [14], oversee certain areas of interest and detect movements. Video based systems like [15] and [16] can monitor certain small areas. [17] and [18] for example combined a video system with an RFID-reader to detect eating activities. All in all, there are various approaches to the interaction recognition problem. Of course, they can and already have been combined with each other and/or smart home environments. Each technology has its own advantages and disadvantages.

The miniaturisation of the RFID-readers for mobile applications leads to a smaller reading range of up to 10cm. This range is mostly not wide enough to detect activities of people. The PIR-Sensors are cheap and easy to install, but they cannot distinguish between different users or between humans and pets. Video based systems have problems with occlusions, have complex data processing with high data amount and its acceptability is also in dispute.

III. Task and New Approach

The system "Eventlogger" is based on 2.4GHz radio modules [19] that are broadcasting their IDs (ID<#>) twice a second (f_T = 2Hz). The transmission power TP of the radio modules can be set by software to a value TP(ID<#>) from -33dBm to 0dBm. This equals to a communication range from 0.3 to 40 meters. Hence the distance within interaction is detected (interaction radius r_I) can be defined for different setups individually. This is a vital point in order to develop a system that does not affect the user when executing his/her activities. It opens up the possibility to provide the user with a device that unlike an RFID glove can be worn hidden in a pocket and yet has the power to detect interaction with marked objects. The duration for transmitting the ID d_T is 1 ms. Every mote can detect ID-Codes (IDC<#>) from other Motes at the specific time k, means detection: D(IDC<#>, k). This happens with a receiving frequency of f_R = 0.5Hz and a receiving duration d_R = 500ms. Figure 1 shows an example of two motes ID<1> and ID<2> in a varying distance. Depending on the affiliation of ID<1> and ID<2> the scenario can be described as following:

$$TP(ID<1>) > TP(ID<2>) \tag{1}$$

$$\begin{gathered} Distance(ID<1>,ID<2>) > TP(ID<1>), TP(ID<2>) \\ \Rightarrow ID<1>: D(IDC<2>,k) = 0; ID<2>: D(IDC<1>,k) = 0 \end{gathered} \tag{2}$$

$$\begin{gathered} TP(ID<1>) > Distance(ID<1>,ID<2>) > TP(ID<2>) \\ \Rightarrow ID<1>: D(IDC<2>,k) = 0; ID<2>: D(IDC<1>,k) = 1 \end{gathered} \tag{3}$$

$$\begin{gathered} Distance(ID<1>,ID<2>) < TP(ID<1>), TP(ID<2>) \\ \Rightarrow ID<1>: D(IDC<2>,k) = 1; ID<2>: D(IDC<1>,k) = 1 \end{gathered} \tag{4}$$

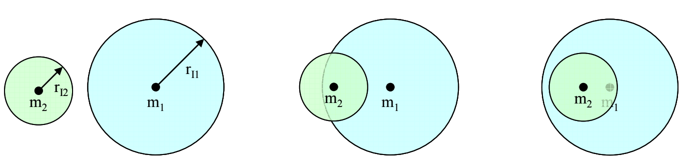

Figure 1. Two motes with different interaction radii r_I in varying distances.

The event (IDCE) saved after a detected contact, consists of the ID-Code, the start time and the duration. The events are saved in the mote ID<#> as described in the following:

$$\begin{gathered} (IDCE<\#>[k]_1; IDCE<\#>[k]_2; \ldots; IDCE<\#>[k]_n) \\ = \\ ([IDC<\#>_1, k_{on,1}, k_{off,1} - k_{on,1}]; [IDC<\#>_2, k_{on,2}, k_{off,2} - k_{on,2}]; \ldots \\ [IDC<\#>_n, k_{on,n}, k_{off,n} - k_{on,n}]) \end{gathered} \tag{5}$$

IV. System Design

A. Static system description

The data of an Eventlogger can be read out from a computer via a base station shown in Figure 2. The base station consists of the same hardware platform as the Eventlogger which was already presented in [19]. It is connected to the computer via a cable with USB-UART IC.

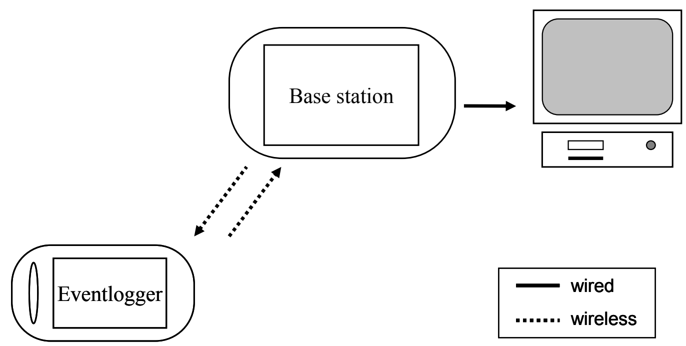

Figure 2. Automated transmission of data from the Eventlogger through the base station to the computer

As soon as an Eventlogger is nearby the base station and it has collected new data the base station is able to "catch" the Eventlogger and read out its data. Therefore the base station sends out a request with a communication range of 0.3 meter (TP(base)) = -33dBm.

B. Dynamic system description

When an Eventlogger is in range of the base station the transmission power TP is set to maximum while transferring the data to get a stable communication. After transmitting the ID and the name of the Eventlogger, the amount of events, as well as the IDs with their corresponding Eventloggernames are sent. This is done to save storage on the microcontroller, because now the events (IDCE) only need the ID. On the computer the ID and the name can be reunited. The amount of saved events is needed for a transmission failure check. In the next step the events (IDCE) are transmitted one after another. After transmitting all events correctly, and the sum is checked with the number of saved Eventlogger, the base station sends out an acknowledgement and the Eventlogger erases the data on the SD-card.

The Data is saved on the computer in a SQL-Database. For first steps of using the system in a geriatric environment we suggest two different visualization modes. The first is the sum over the complete day of each detected mote:

$$\sum_{i=0}^{N} k_{off,i} - k_{on,i}\left(IDC < x >_i\right) \tag{6}$$

With N:= number of contacts of the detected mote x. An example of how it would look like is shown in figure 3.

Figure 3. Visualization mode 1: Sum of each mote over one day

For detailed information we suggest the second visualization, which is based on the depiction of appointments in a common used calendar. Every contact is marked with a start and a finishing point. The exposition is shown in figure 4.

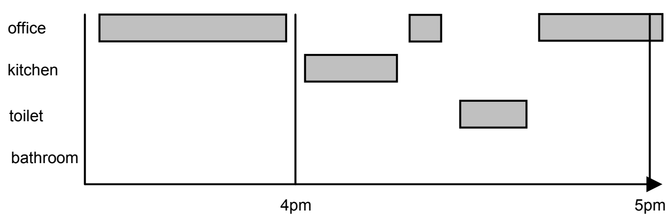

Figure 4. Visualization mode 1: Events shown like a calendar with appointments

These visualizations are only two out of several possible ones. Surely there will be further development needed when working together with the clinicians. From the point of an engineer and to fulfill the current conditions the used visualization is an adequate one.

V. Experiment

In [19] we proved already the functionality of the system over a short period of time (15 minutes). We showed up that the setting of interaction radii, the recognition of a certain number of motes as well as the overlapping of interaction is working. In this paper we will prove that the system, in particularly the automated read out as well as the two different ways of visualizing the data, are working. For evaluating the functionality of the system it was evaluated during a period of several days. Additionally the sensitivity of the system was calculated by the number of interactions measured by a mote ID<1> divided through the number of interactions written down:

$$\frac{\sum \text{IDCE<1>}}{\sum \text{minute IDCE<1>}} = sensitvity \tag{10}$$

A. Experiment Setup

To carry out the experiment we marked objects and rooms at the department of Micro Technology and Medical Device Technology with motes and set their transmitting ranges using the initializing device. The objects/ rooms were: the kitchen and the coffee machine in the kitchen, the office and the printer within the office. Besides these objects, the toilet and the coffee mugs were endued with mote. A test person carried around the mote for four days and recorded the beginning of every interaction with the object/room.

B. Results

After the examination the Eventlogger was brought to the base station where the data was transmitted to the computer. The data correctly was displayed correctly in both visualization modes. The objects marked with a mote and their corresponding colors are shown in table 1.

TABLE I. Motes and their corresponding number and color

Mote	Number	Color
Kitchen	P31	Blue
Coffee machine	A05	Grey
Office	P32	Green
Printer	P34	Yellow
Toilet	P33	Orange
Mug	A11	Black

Figure 5 shows the total time of each contact over one day. It is easy to see that the subject was most of the time in the office.

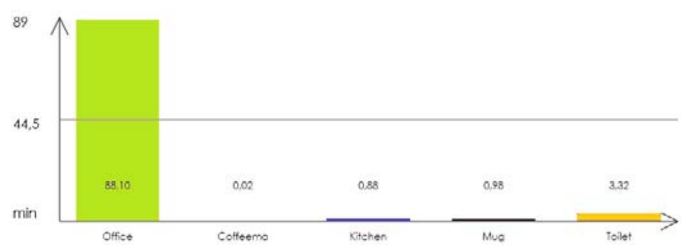

Figure 5. Total time of each contact over one day

Figure 6 shows a cut out of the calendar like visualization for 30 minutes. The x-axis is equivalent to the time. Within this time the office (green) was left at the beginning and the toilet (orange) was attended. Afterwards a paper was printed in the office and fetched at the printer (yellow). Later on the subject went to the kitchen (blue) with the mug (black) and made a coffee at the coffee machine (grey).

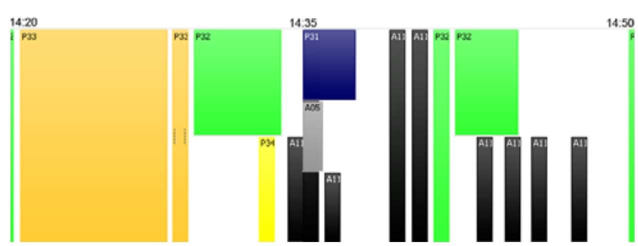

Figure 6. Cut out of the display for 30 minutes, where the contacts are representet by events in a calendar

Overall the test person logged 71 interactions. Out of them 65 (92%) were detected correctly. Six detections were wrong and only two were not recognised by the system. The detailed detections are shown in table 2:

TABLE II. NUMBER OF DETECTED EVENTS, NUMBER OF THE EVENTS RECORDED BY THE SYSTEM AND THE NUMBER OF WRONG DETECTIONS (DETECTION ALTHOUGH NO INTERACTION)

Mote	Interactions (Log)	Detected by Eventlogger	Not detected by Eventlogger	Wrong detection by Eventlogger
Kitchen	8	8	0	1
Coffeema	5	1	4	0
Office	40	39	1	0
Printer	2	2	0	1
Toilet	11	11	0	0
Mug	5	4	1	0
Complete	71	65	6	2

The coffee machine had the biggest error rate. A reason for this may be the communication range of 50cm, which could be too small, because the person does not have to stand close to the machine while making the coffee. The false positive detection of the kitchen was while the test person was walking along the corridor close to the kitchen. But it could also be that the person threw something into the garbage bin in the kitchen, which the test person was not able to remember whether he had done this or not.

C. Discussion

The Results of the experiment prove that the system is working. Now can be used from non developers. The detection of interactions is working rather well, but with the exact measuring of interaction time has sometimes short dropouts. Therefore a way of post processing must be found to eliminate such small dropouts.

VI. CONCLUSION

In this article the automatic read out of the system Eventlogger for the detection of interaction with objects was presented. The system was already evaluated [19]. The evaluation has shown the advantages of setting individual communications ranges as well as an easy installation set up. Within this paper we proved, with a sensitivity of 92%, that the system is detecting interactions with objects correctly over some days. Above all two different visualization modes with an automatic read out were presented, so that by now the system can be used from third persons like clinicians. This is exceedingly important to use the system in a nursing home, which is the nest planed step. The system will be used by elderly people, as well as installed and operated by a doctor. With the data gained out of the experiment in the nursing home we would like to find first possibilities for an algorithm to detect automatic behaviour, as well as develop the visualization modes further. Currently 50 motes are build up for the experiments in a nursing home.

REFERENCES

[1] Federal Statistical Office, *Germany's Population by 2060 – Results of the 12th Coordinated Population Projection*, Wiesbaden: Federal Statistical Office, 2009.

[2] L.T. D'Angelo, E. Tarita, T.K. Zywietz, and T.C. Lueth, "A system for intelligent home care ECG upload and priorisation," *Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE*, vol. 2010, 2010, pp. 2188-2191.

[3] S. Katz, "Assessing self-maintenance: activities of daily living, mobility, and instrumental activities of daily living," *Journal of the American Geriatrics Society*, vol. 31, Dec. 1983, pp. 721-727.

[4] T.C. Lueth, R. Grasman, T. Laengle, and J. Wnag, "Cooperation Among Distributed Controlled Robots by Local Interaction Protocols," *Invited paper at ISRAM Int'l. Symp. on Robotics and Manufacturing*, Montpellier, France: ASME Press, 1996, pp. 405-410.

[5] L.T. D'Angelo, A. Czabke, I. Somlai, K. Niazmand, and T.C. Lueth, "ART - a new concept for an activity recorder and transceiver," *Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE*, 2010, pp. 2132-2135.

[6] K.P.Y. Liu, C.C.H. Chan, M.M.L. Chu, T.Y.L. Ng, L.W. Chu, F.S.L. Hui, H.K. Yuen, and A.G. Fisher, "Activities of daily living performance in dementia," *Acta Neurologica Scandinavica*, vol. 116, Aug. 2007, pp. 91-95.

[7] A.H. Ranhoff and K. Laake, "The Barthel ADL index: scoring by the physician from patient interview is not reliable," *Age and Ageing*, vol. 22, May. 1993, pp. 171-174.

[8] L.Z. Rubenstein, C. Schairer, G.D. Wieland, and R. Kane, "Systematic biases in functional status assessment of elderly adults: effects of different data sources," *Journal of Gerontology*, vol. 39, Nov. 1984, pp. 686-691.

[9] M. Philipose, K.P. Fishkin, M. Perkowitz, D.J. Patterson, D. Fox, H. Kautz, and D. Hahnel, "Inferring activities from interactions with objects," *Pervasive Computing, IEEE*, vol. 3, 2004, pp. 50-57.

[10] D. Wyatt, M. Philipose, and T. Choudhury, "Unsupervised activity recognition using automatically mined common sense," *Proceedings of the National Conference on Artificial Intelligence*, 2005, pp. 21-27.

[11] T.C. Lueth, L.T. D'Angelo, and A. Czabke, "TUM-AgeTech – A New Framework for Pervasive Medical Devices," *Pervasive and Smart Technologies for Healthcare*, A. Coronato and G. De Pietro, Eds., IGI Global, 2010, pp. 295-321.

[12] M. Stikic, T. Huynh, K. Van Laerhoven, and B. Schiele, "ADL recognition based on the combination of RFID and accelerometer sensing," *Pervasive Computing Technologies for Healthcare, 2008. PervasiveHealth 2008. Second International Conference on*, 2008, pp. 258-263.

[13] G. LeBellego, N. Noury, G. Virone, M. Mousseau, and J. Demongeot, "A model for the measurement of patient activity in a hospital suite," *Information Technology in Biomedicine, IEEE Transactions on*, vol. 10, 2006, pp. 92-99.

[14] D.H. Wilson and C. Atkeson, "Simultaneous tracking and activity recognition (STAR) using many anonymous, binary sensors," *Pervasive computing*, 2005, p. 62–79.

[15] Z. Uhrikova, C.D. Nugent, and V. Hlavac, "The use of computer vision techniques to augment home based sensorised environments," *Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE*, 2008, pp. 2550-2553.

[16] Zhongna Zhou, Xi Chen, Yu-Chia Chung, Zhihai He, T.X. Han, and J.M. Keller, "Activity Analysis, Summarization, and Visualization for Indoor Human Activity Monitoring," *Circuits and Systems for Video Technology, IEEE Transactions on*, vol. 18, 2008, pp. 1489-1498.

[17] A. Tolstikov, J. Biswas, Chen-Khong Tham, and P. Yap, "Eating activity primitives detection - a step towards ADL recognition," *e-health Networking, Applications and Services, 2008. HealthCom 2008. 10th International Conference on*, 2008, pp. 35-41.

[18] Sangho Park and H. Kautz, "Hierarchical recognition of activities of daily living using multi-scale, multi-perspective vision and RFID," *Intelligent Environments, 2008 IET 4th International Conference on*, 2008, pp. 1-4.

[19] A. Czabke, J. Neuhauser, and T.C. Lueth, "Recognition of interactions with objects based on radio modules," *Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2010 4th International Conference on*, 2010, pp. 1-8.