HTWG
KON

Hochschule Konstanz
Fakultät Informatik

Ubiquitous Computing
Laboratory

Tagung

Smart-Future- Living-Bodensee

**Freitag,
24.11.2017**

Die Veranstaltung wird gefördert durch die Internationale Bodenseehochschule (IBH), die HTWG Konstanz und die ZHAW.

Internationale
Bodensee
Hochschule

HTWG
KON
Fakultät Informatik

Zürcher Hochschule
für Angewandte Wissenschaften
zhaw

Smart-Future-Living-Bodensee

HTWG Konstanz
Alfred-Wachtel-Straße 8
78462 Konstanz
Germany

Edited by
Simone Orcioni, Massimo Conti, Eva Rodriguez de Trujillo

Proceedings of international workshop "Smart-Future-Living-Bodensee"

All the papers in this book correspond to works presented during the workshop "Smart-Future-Living-Bodensee", held in Konstanz, Germany, on November 24, 2017. The view and opinions expressed in the papers are the author's personal ones.

Copies cannot be reproduced for commercial profit.

Copyright © 2018. HTWG Konstanz

Printed in Germany, 2018

ISBN 978-3-00-058960-7

Contents

Preface	5
Workshop Organization	6
Smart Home in Baden-Württemberg <i>Christoph Rathfelder</i>	7
Technologietransfermanagement im Themenfeld Smart Home & Living im Schwarzwald-Baar-Kreis <i>Bastian Inthasane</i>	9
iCare-Do-It-Yourself Architektur ambienter Assistenzsysteme als ChatBots für Selbstbauer <i>Andreas Judt, Michael Bächle, Stephan Daurer, Tobias Mettler</i>	11
Innovative Smart Home & Living-Geschäftsmodelle für Kooperationen auf Augenhöhe (InGeKoop) <i>Jürgen Jarosch, Carsten Schmidt, Cathrin Braun, Dietmar Becker</i>	15
Ergänzende Technologien in der Home-Technik Vom stationären zum mobilen Sicherheitsdispositiv <i>Martin Rosenberg, Jack Loonen, Franca Denise Burkhardt</i>	19
Non-invasive sleep analysis with intelligent sensors <i>Maksym Gaiduk, Ralf Seepold, Simone Orcioni, Massimo Conti, Natividad Martínez Madrid</i>	23
Das Living Lab für assistives Wohnen der Hochschule Kempten <i>Petra Friedrich, Dominik Fuchs, Bernhard Wolf</i>	27
Intelligentes Monitoring als Basis für verbesserten Komfort und Energieeinsparung Erfahrungen aus dem EU-Projekt CETIEB <i>Jürgen Frick, Manuela Reichert, Ahmet Dogan Duran, Harald Garrecht</i>	29
Lehrstunden aus der Implementierung von Smart Home / AAL Lösungen <i>Tobias Werner, Isabella Hämmerle</i>	33
The Living Room as a Place for Therapy <i>Petra Friedrich, Dominik Fuchs, Kai Hinderer, Bernhard Wolf</i>	37
AALivingLab@home – Aufbau einer natürlichen Testumgebung für AAL-Innovationen in der Ostschweiz <i>Cora Pauli, Sabina Misoch, Stephanie Lehmann</i>	41
A review of health monitoring systems using sensors on beds or cushion <i>Simone Orcioni, Massimo Conti, Natividad Martínez Madrid, Maksym Gaiduk, Ralf Seepold</i>	45
Index of authors	49

A review of health monitoring systems using sensors on bed or cushion

Simone Orcioni, Massimo Conti
Department of Information
Engineering
Università Politecnica delle Marche
Ancona, Italy
{s.orcioni, m.conti}@univpm.it

Natividad Martínez Madrid
School of Informatics
Reutlingen University
Reutlingen (Germany)
natividad.martinez@reutlingen-
university.de

Maksym Gaiduk, Ralf Seepold
Ubiquitous Computing Lab
HTWG Konstanz
Konstanz, Germany
{m.gaiduk, r.seepold}@htwg-
konstanz.de

Abstract— How technology can answer the challenge that currently population ageing is facing to the healthcare system? In this work, systems and devices related to “smart bed” and cushion, that are commercially available or matter of research works, are reviewed.

Keywords—*smart bed; smart cushion; population ageing; smart-care.*

I. INTRODUCTION

European people are living a longer and healthier life. The rapidly growing of the elderly population is also happening together a reduction in fertility rates that poses great challenge to the social protection systems in Europe [1].

Here we are most interest to the challenges that the population ageing is bringing up to the health care and long-term care programs in Europe. This is also a main focus of Horizon 2020 program, from the exact words of the Commissioner for Research, Innovation and Science, European Commission, Máire Geoghegan-Quinn: “Hundreds of millions of euros have been invested over recent years in health-related ageing research, neurodegenerative diseases, including Alzheimer’s, as well as in socioeconomic dimensions of ageing. The challenge-based approach of Horizon 2020 — the EU’s new programme for research and innovation — fits perfectly with the pressing need to address issues resulting from demographic change and ageing.” [1]. Then she concluded how it is important to “ensure the good quality of life and well-being of the elderly” [1].

While the prevision in [2] say that in 2015, in the whole Europe the over-60 population would be the 23.9% and will increase to 29.6% in 2030, from Fig. 1 we can see that in 2014 in Italy and Germany this percentage was just over the 30%.

Together to this world changing we witness the continuous progress of technology. Can these two facts combine to give some effective solutions for care? Does technology answer to the request for good quality of life and well-being of the elderly?

In this work, we will face these questions by making a review of commercial systems and components related to

“smart” bed and cushion. Then a review of recently research works on the same topic will follow.

Old-age dependency ratio, 2014 (%)
(%)

Fig. 1. Population ageing in Europe. SOURCE: [2].

II. COMMERCIAL DEVICES

A. Novel pliance-HS

The Novel pliance-HS system [3] provides a dynamic quantification of the sitting pressure points of patients in wheelchairs. The system helps in selecting the appropriate cushions and correct adjustments of the wheelchair to fit the individual patient. It functions with Bluetooth® wireless telemetry systems in a wide measurement range.

Connects up to 1024 sensors to a desktop, notebook or handheld Pocket PC. Collected data can be stored on the

internal flash memory or transmitted via Bluetooth® telemetry. Although its high spatial resolution and advanced characteristic it is not meant to be used for a daily use as an anti-decubitus system. Fig. 2 shows a picture of the sensors part of the system.

Fig. 2. Novel pliance-HS. SOURCE: [3].

B. EMFIT SafeBed

1) Emfit Safebed

The Emfit Safebed [4] is a bed occupancy monitoring system for fall and wandering prevention. It consists of a monitor device and an under-mattress bed sensor, operates as a fall or bed exit monitor and monitors the presence or absence of a person in bed by detecting all the person's movements and micro movements, such as those caused by a person's heart beating.

The bed sensor uses Emfit's patented, thinfilm ferro-electret technology (Electroactive Polymer) and it is installed under the mattress. The monitor has an audible notification with adjustable volume and a dry-contact output for connection to nurse call systems or personal emergency phones.

Fig. 3 shows the Emfit Safebed system.

Fig. 3. The Emfit Safebed. SOURCE: [4].

2) Safebed with sleep tracking.

Emfit Safebed QS [5] is a health and wellness tracker designed with seniors' additional safety needs in mind. It improves the safety of seniors and helps maintain their independence, enabling them to live on their own for a longer time. Like in Safebed, a highly durable sensor is simply installed underneath the mattress and paired with Wi-Fi. Safebed tracks sleep quality and quantity, heart and breathing

rates, and even heart rate variability. Changes in long-term trends can give very valuable information about health and wellbeing. It is provided in three different version, aimed respectively to improve the performances of sport amateurs or professionals, for assisted living & nursing homes, and as a clinical tool in sleep research studies. Fig. 4 shows an Emfit Safebed QS system.

Fig. 4. Emfit Safebed QS. SOURCE: [5].

C. Murata Contactless Bed Sensor SCA11H

It is a device aimed to patient monitoring and elderly care in hospitals, assisted living and even at homes. The signal processing of heart and respiration rate and beat-to-beat time enables patient monitoring from bed occupancy to condition quality analysis.

Fig. 5. Murata Contactless Bed Sensor. SOURCE: [6].

The balistocardiography (BCG) technology [6] allows to output vital signs and bed occupancy information such as: Heart rate, Respiration rate, Heart rate variability (correlates to stress level), Relative stroke volume (how much blood the heart pumps), Bed status indicator (is the bed empty, is patient in bed, is patient moving in bed).

The product is not meant for sale to the end user but is targeted for software solution- and service providers and OEM system integrators. Fig. 5 shows the Murata device.

D. Early sense

Early sense system [7] was designed with the aim to provide continuous patient monitoring by mean if the measurements of heart rate, respiratory rate and motion of a patient in bed. These data potentially allow the clinical team to manage fall prevention, patient health state and pressure ulcers prevention.

The system has been developed specifically for medical surgical, general care patients who are usually monitored by nurses once every four to six hours. Skilled nursing facilities are emerging as important centres of care and attention for elderly people. All data came from a sensing plate with an integrated piezo-electric sensor that is easily placed under the mattress. Utilizing a piezoelectric technology integrated into a membrane plate, the sensor detects mechanical vibrations of the heart cardio ballistic (motion) effect, respiratory and patient motion. The signal is sent to a bedside monitor.

The positioning of the sensing plate it is shown in Fig. 6, while Fig. 7 shows a detailed view of the sensing plate itself.

Table I summary the main features of the reviewed systems, highlighting the measured quantity and the type of sensor used for. In the last column are also summarized the main application topics of each device.

Fig. 6. Positioning of the Early sense sensing plate. SOURCE: [7].

Fig. 7. A Detail of the Early sense sensing plate. SOURCE: [7].

TABLE I. SUMMARY OF COMMERCIAL DEVICES.

Device	Quantity	Sensor	Application
Novel pliance-HS	pressure	capacitive transducer	Cushion selection; wheelchair personalization
Emfit safebed	pressure	quasi-piezoelectric thin film	Bed occupancy; sleep tracking
Murata bed sensor	Ballistocardiography (acceleration)	MEMS	HR, HRV, BR, RSV, measurements; bed occupancy
Early sense	Ballistocardiography (acceleration)	piezoelectric	HR, Motion; fall and pressure ulcers prevention

III. RESEARCH WORKS

The reviews papers are recent papers on smart bed and cushion published in international journal or conferences. They present sensors, systems and also methodology to improve system performances.

In Table II to each of the two research topics, smart bed or cushion, are assigned the corresponding references that are dealing with. We can see that there is an overwhelming presence of works about cushion among scientific literature, reflecting the fact that the commercial systems mainly are devoted to the smart bed.

Table III summarizes the results about the main aims of the research of each work. We can see that six works are devoted to sleep tracking, a topic still of interest especially regarding the correct matching between measurements and signal features extracted from measurements and the correct sleep phases. Always from Table III we can see that only one research work is devoted to bed fall detection, a topic currently covered by many commercial systems. Five works are devoted to the crucial problem for bedridden or wheelchair-bound people of pressure ulcers prevention. This is still an open and challenging topic. Six among the reviews papers are devoted to a topic that is gaining more and more attention that is the posture tracking. Finally, we can find five works generally devoted to the monitoring of vital signs.

TABLE II. SUMMARY OF DIFFERENT RESEARCH TOPICS OF RESEARCH WORKS LISTED IN REFERENCES.

Research topic	
Smart bed	Smart cushion
9, 11, 24, 27, 28, 29, 30, 31	8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24

TABLE III. MAIN AIMS OF RESEARCH WORKS LISTED IN REFERENCES.

Aim of the research	
sleep tracking	11, 27, 28, 29, 30, 31
fall detection	10
ulcers prevention	12, 14, 15, 18, 20
posture tracking	8, 13, 16, 19, 21, 23
monitoring vital signals	10, 21, 22, 27, 28

REFERENCES

- [1] European Commission, Population ageing in Europe, Facts, implications and policies, Luxembourg: Publications Office of the European Union, 2014, doi:10.2777/60452.
- [2] European Union (EU). People in the EU – population projections. June 2015, <http://ec.europa.eu/eurostat/statistics-explained/>.
- [3] Novell, <http://www.novel.de/novelcontent/pliance/wheelchair>.
- [4] Emfit, <http://www.safetysystemsdistribution.co.uk/bed-exit-alarms/>
- [5] Emfit, <https://www.emfits.com/>
- [6] Murata, <https://www.murata.com/>
- [7] EarlySense, <https://www.earlysense.com/>
- [8] Wenyao Xu; Ming-Chun Huang; Navid Amini; Lei He; Majid Sarrafzadeh , eCushion: A Textile Pressure Sensor Array Design and Calibration for Sitting Posture Analysis, IEEE Sensors Journal , Year: 2013, Volume: 13, Issue: 10 . Pages: 3926 - 3934, DOI: 10.1109/JSEN.2013.2259589.
- [9] Lin Shu; Xiaoming Tao; David Dagan Feng , A New Approach for Readout of Resistive Sensor Arrays for Wearable Electronic Applications, IEEE Sensors Journal, Year: 2015, Volume: 15, Issue: 1, Pages: 442 - 452, DOI: 10.1109/JSEN.2014.2333518.
- [10] Lin Yang; Yanhong Ge; Wenfeng Li; Wenbi Rao; Weiming Shen , A home mobile healthcare system for wheelchair users , Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design (CSCWD), Pages: 609 - 614, DOI: 10.1109/CSCWD.2014.6846914.
- [11] Yosuke Kurihara; Kajiyo Watanabe, Suppression of Artifacts in Biomeasurement System by Pneumatic Filtering, IEEE Sensors Journal , Year: 2012, Volume: 12, Issue: 3 , Pages: 416 - 422, DOI: 10.1109/JSEN.2010.2073700.
- [12] Sandra Arias; Eladio Cardiel; Laura Garay; Blanca Tovar; Michele Pla; Pablo Rogeli , A pressure distribution measurement system for supporting areas of wheelchair users , 2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Pages: 4751 - 4754, DOI: 10.1109/EMBC.2013.6610609.
- [13] Lishuang Xu; Gang Chen; Jiajun Wang; Ruimin Shen; Shen Zhao . A sensing cushion using simple pressure distribution sensors, 2012 IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems (MFI), Pages: 451 - 456, DOI: 10.1109/MFI.2012.6343048.
- [14] Daisuke Chugo; Kazuya Fujita; Yuki Sakaida; Sho Yokota; Hiroshi Hashimoto, A Depressurization Motion Assistance for a Seated Wheelchair User Using Pressure Distribution Estimation, 2012 5th International Conference on Human System Interactions, Pages: 75 - 80, DOI: 10.1109/HSI.2012.21.
- [15] Rui Dai; Sharon Eve Sonenblum; Stephen Sprigle, A robust wheelchair pressure relief monitoring system , 2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Pages: 6107 - 6110, DOI: 10.1109/EMBC.2012.6347387.
- [16] Guanqing Liang; Jiannong Cao; Xuefeng Liu, Smart cushion: A practical system for fine-grained sitting posture recognition , 2017 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops) , Pages: 419 - 424, DOI: 10.1109/PERCOMW.2017.7917599.
- [17] Luke Russell; Rafik Goubran; Felix Kwamena, Posture sensing using a low-cost temperature sensor array, 2017 IEEE International Symposium on Medical Measurements and Applications (MeMeA), Pages: 443 - 447, DOI: 10.1109/MeMeA.2017.7985917.
- [18] Arshia A. Khan; Michael Reuter; Nam Phung; Syed S. Hafeez , Wireless solution to prevent decubitus ulcers: Preventive weight shifting guide, monitor, and tracker app for wheel chair users with spinal cord injuries (phase II), 2016 IEEE 18th International Conference on e-Health Networking, Applications and Services (Healthcom), Pages: 1 - 6, DOI: 10.1109/HealthCom.2016.7749500.
- [19] Byeong-Gu Ahn; Tae-young Kim; Mangal Sain; Do-Un Jeong, Implemented of posture discriminate system through the seat weight distribution, 2015 IEEE Conference on Wireless Sensors (ICWiSe), Pages: 24 - 27, DOI: 10.1109/ICWiSe.2015.7380348.
- [20] Edward Sazonov; Robert Abele; Ashley Gerrity; Patrick May; Kenneth Spradling; Travis Kennamore; Yu-ying, Chen; Philip Klebine, Development of wheelchair cushion pressure monitoring system, 2014 IEEE International Symposium on Medical Measurements and Applications (MeMeA), Pages: 1 - 5, DOI: 10.1109/MeMeA.2014.6860066.
- [21] Ying-Xun Lai; Hung-Yu Chang; Wei-Yi Lin; Wen-Chang Tsai; Yueh-Min Huang , Multifunctional pressure and oxygen sensing health monitor system for long-term computer users, 2013 1st International Conference on Orange Technologies (ICOT), Pages: 314 - 317, DOI: 10.1109/ICOT.2013.6521221.
- [22] Junrong Bao; Xiaoyun Shou; Hua Wang; Haiyan Yang , Study on Heartbeat Information Acquired from Pressure Cushion Based on Body Sensor Network , 2013 IEEE International Conference on Green Computing and Communications and IEEE Internet of Things and IEEE Cyber, Physical and Social Computing, Pages: 1103 - 1108, DOI: 10.1109/GreenCom-iThings-CPSCoM.2013.190.
- [23] Masakazu Takahashi; Reiji Nanba, An analysis of elderly person's arising action from chair using cushion-type support tool, 2012 Proceedings of SICE Annual Conference (SICE), Pages: 623 - 628.
- [24] Hong Liua, Yuan-Fei Zhanga, Yi-Wei Liua, Ming-He Jin, Measurement errors in the scanning of resistive sensor arrays, Sensors and Actuators A, 163 (2010) 198–204.
- [25] Jaehong Lee , Hyukho Kwon , Jungmok Seo , Sera Shin , Ja Hoon Koo , Changhyun Pang , Seunghae Son , Jae Hyung Kim , Yong Hoon Jang , Dae Eun Kim , and Taeyoon Lee, Conductive Fiber-Based Ultrasensitive Textile Pressure Sensor for Wearable Electronics, Advanced Materials 2015, 27, 2433–2439.
- [26] Matteo Stoppa and Alessandro Chiolerio, Wearable Electronics and Smart Textiles: A Critical Review, Sensors 2014, 14, 11957-11992; doi:10.3390/s140711957.
- [27] Kajiyo Watanabe, Takashi Watanabe, Harumi Watanabe, Hisanori Ando, Takayuki Ishikawa, and Keita Kobayashi, Noninvasive Measurement of Heartbeat, Respiration, Snoring and Body Movements of a Subject in Bed via a Pneumatic Method, IEEE Transaction on Biomedical Engineering, vol. 52, no. 12, December 2005.
- [28] N. Bu, N. Ueno, and O. Fukuda, "Monitoring of respiration and heart-beat during sleep using a flexible piezoelectric film sensor and empirical mode decomposition," in Proc. IEEE Eng. Med. Biol. Soc. , 2007, pp. 1362–1366.
- [29] S. Tanaka, Y. Matsumoto, and K. Wakimoto, "Unconstrained and non-invasive measurement of heart-beat and respiration periods using a phonocardiographic sensor," Med. Biomed. Eng. Comput., vol. 40, no. 2, pp. 246–252, 2002.
- [30] Gaiduk M., Kuhn I., Seepold R., Ortega J.A., Madrid N.M. (2017) A Sensor Grid for Pressure and Movement Detection Supporting Sleep Phase Analysis. In: Rojas I., Ortuño F. (eds) Bioinformatics and Biomedical Engineering. IWBBIO 2017. Lecture Notes in Computer Science, vol 10209. Springer, Cham.
- [31] Baran Pouyan, M., Nourani, M., Pompeo, M.: Sleep state classification using pressure sensor mats. In: 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), pp. 1207–1210, 26 August 2015. ISSN 1094-687X.