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Designing Ambient Assisted Living Applications: An Overview over State-of-the-Art Implementation Concepts

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Abstract. Research in the field of Ambient Assisted Living gained considerable momentum over the last decade and the diversity of existing applications is matched by a broad variety of implementation approaches. This paper takes a closer look at existing work in this field and provides a structured overview over state-of-the-art implementation concepts.

Keywords: Smart Medical Services, Ambient Assisted Living, E-Health, Intelligent Environments, Ubiquitous and Pervasive Computing

1. Introduction

Ambient Assisted Living (AAL) applications provide an immense potential for enhancing medical homecare, especially in the light of an increased importance of early detection and preventive care [31]. Remote patient monitoring does not only enable effective therapy support and the detection of abnormal conditions in an early state, it also proofed to contribute to a significant reduction of hospitalization and an increased success in long-term therapies [4][5][49]. The potential of technology-supported homecare was empirically confirmed for a variety of applications, including self-monitoring and dietary education of diabetic patients [46], remote patient monitoring and counseling [9], remote counseling for patients with congestive heart failures [16], or remote cardiac arrhythmia monitoring [50].

The diversity of Ambient Assisted Living applications is matched by a broad variety of implementation approaches. Looking at state-of-the-art prototypes shows that Ambient Assisted Living services can be successfully realized through a variety of different implementation approaches and device types. This paper takes a closer look at existing work in this field and provides a structured overview over selected applications and systems. Hence, this paper is not a research paper in the traditional sense. Instead, it has to be seen as scholarly article meant to provide a comprehensive overview over state-of-the-art implementation concepts in the field of Ambient Assisted Living. With respect to existing AAL prototypes and research demonstrators, it seems to be helpful to distinguish among the following five types of devices: mobile devices, smart artefacts, wearables, implants, and robots. Similar classification schemes are proposed by Orwat et al. [31] and Muras et al. [29]. The following sections provide a short description as well as exemplary systems for each device category.

2. Mobile Devices

Mobile devices are probably the simplest form of providing medical assistance for elderly users. They represent dedicated medical devices and, in most cases, can be easily recognized as such. Mobile medical appliances are designed for a variety of different illnesses and usually provide monitoring functions combined with patient-specific medical support. For example, the *SenseWear* armband is a wearable body monitor that was designed for both normal subjects and patients with chronic obstructive pulmonary disease and allows capturing body movement and energy expenditure [37]. A similar wrist-worn device called *HealthWear* is available from *BodyMedia*. The system captures temperature gradients from skin to environment, mechanical activity and bioimpedance of the skin [21]. Other applications are embedded into existing communication devices. For example, *Vitaphone* [47] is a mobile phone with integrated heart monitoring functions, and *Dr. Feelgood* [26] is a combination of a PDA and mobile phone, which measures various physiological functions. While these systems are usually designed to provide dedicated functionalities, Youngbum and Myoungho [51] developed a multi-functional system, which enable users to combine different modules. These modules include functionalities like fall detection, electrocardiograms, or non-invasive measurement of blood sugar and oxygen saturation [23].

3. Smart Artefacts

The notion of *Smart Artefacts* describes technology-enhanced everyday objects, which are equipped with sensors, memory and communication capabilities (see, e.g., [8] or [11]). Hence, they are able to capture information about their surrounding, communicate with each other and react according to previously defined rules [40]. Through their capability to interact with humans directly, they can help users to accomplish their tasks in new, intuitive ways [3]. In contrast to mobile medical devices, the additional medical functionalities of smart artefacts are usually not visible to outsiders. The *Smart Pillow*, for example, is an electronic monitoring devices in form of a traditional pillow, which checks the user's basic vital parameters, such as respiration, pulse and body temperature, and in the case of an emergency or illness immediately notifies medical personnel [35]. The *Smart Sofa* [20] is a sensor-enhanced couch that is able to identify individuals sitting on it and provides personalized services based on this information. *Smart Dishes* is a set of intelligent kitchen devices developed at the Massachusetts Institute of Technology [27], including, e.g., a smart pan that can determine whether it is too hot to be touched, a spoon that provides feedback about the temperature and viscosity of food, and a kettle that informs users how much longer they have to wait for their tea [6]. Other examples of smart household objects include, for example, interactive tablecloths [36] or smart coffee cups [10].

4. Wearables

Instead of an additional mobile device that has to be intentionally taken when users leave their stationary computer, the concept of *Wearable Computing* envisions computers to be an integral part of our everyday clothing. The goal is to have an always-on and networked computational artefact that assists mobile users in a wide range of everyday situations. With respect to wearable health technology, two main streams of research became prevalent over the last years: smart jewelry and smart clothes.

A notable example for smart jewelry is a series of *Smart Ring* devices developed by Asada et al. [1]. The rings are wearable like traditional jewelry and equipped with saturation sensors, an energy supply and an RF link [21]. With the *Gesture Pendant*, Starner et al. [44] developed a wearable control device, which recognizes pre-defined gestures and corresponding control tasks. A variety of other examples for smart jewelry were created by different designers like, e.g., Kikin-Gil [18], who developed smart jewelry for supporting non-verbal communication within small teenage groups.

Another popular approach is to integrate medical monitoring devices into watches. Some devices are already commercially available, like, e.g., the *Actiwatch* from *Cambridge Neurotechnology*. The *Actiwatch* device is equipped with a miniature accelerometer that measures the general activity of its wearer. In combination with additional sensors the functionality of the watch could be extended to monitoring insomnia, mood, energy expenditure or the detection of periodic limb movement during sleep [21]. There are several other examples of wristwatches offering additional medical functionalities, including cystic fibrosis testing [25], glucose measurement [45], blood oxygen monitoring [48], or emergency calls [52].

One of the first examples of smart clothes was the *Smart Shirt* developed at the Georgia Institute of Technology [12]. Different types of sensors are integrated into the design of the *Smart Shirt*, which allow monitoring a variety of vital parameters, including heart rate, electrocardiogram (ECG), respiration, temperature, or vital functions [7][13]. A further example for a wearable physiological monitoring system is the *Smart Vest* [32]. The system allows monitoring multiple physiological parameters such as ECG, heart rate, blood pressure, or body temperature, and transmits the captured physiological data along with the geo-location of its wearer to remote monitoring stations [33]. Some systems are already available as commercial products, like the *LifeShirt* from *Vivometrics*, which includes a respiratory inductive plethysmography system to monitor various cardiorespiratory parameters [14]. But medical technology is also integrated into other pieces of clothing. The *Actibelt*, for example, functions like a traditional textile belt, but has a three-dimensional accelerometer integrated in its buckle [39]. The sensor captures the type and intensity of movement and allows monitoring the wearer's physical activity outside institutional settings over an extended period of time. Other examples of smart clothes include active hip protectors [42], smart shoes [15], intelligent knee sleeves [28] or smart baby bodies [22].

5. Implants

Dental implants are probably the most widely accepted form of medical implants. In most cases, sensor and telemetry systems are integrated into an artificial tooth or crown invisibly located inside the patient's mouth. One of the first systems was developed within the European project *Saliwell* and aimed at patients with insufficient saliva production. The prototype of a dental implant is based on an electronic saliva-stimulating device, which constantly monitors oral parameters and automatically restores salivation without additional medication [41]. Other EU-funded research projects working on related topics are the *NanoTIMER* project, which develops nano technology for mechanical-electrical resonators, or the *HEALTHY AIMS* project, which aims at the development of nano-scale materials, sensors and microsystems for medical implants. A further example for a dental implant is the *IntelliDrug* system, an automated medication device implemented in a denture [41].

6. Robots

The use of robotic systems for elderly care seems to be debatable and appears to be driven by a strong cultural component. While there are numerous companies and research institutes working on care robots in Asia, especially Japan and Korea, the research activities in this field in Europe and the United States are almost non-existent. In general, medical robot systems are used for two types of applications. First, for compensating a handicap of a user (see, e.g., [19], [24] or [38]) and second, for supporting users in carrying out daily activities and tasks (see, e.g., [17] or [43]). One of the first robot systems offering medical home care was *KARES I* [43], a wheelchair-based rehabilitation robot. The system offered four basic services for supporting severely handicapped patients in home environments. The functionality of *KARES I* was extended in the second version (*KARES II*), which now supports twelve predefined tasks [2]. *DO-U-MI* [34] is another nursing robot system especially designed for elderly and disabled people, which assists users in moving independently in indoor environments. The system provides an easy-to-use interface and is able to detect and localize human faces and sound sources in order to position itself for services. Jung et al. [17] developed an intelligent bed robot system that actively helps disabled patients to move within their beds by monitoring their postures and motions and supporting the body movement with a robotic manipulator.

7. Conclusion and Outlook

Research activities in the field of Ambient Assisted Living increased considerably in the last 5 to 10 years. Recent developments in the area of information and communication technologies lay the groundwork for new patient-centered homecare solutions. While the majority of computer-supported healthcare tools designed in the past focused mainly on supporting care-givers and medical personnel, this trend recently changed with the introduction of assistive technology for providing supportive and adaptive services to ill or disabled individuals at home. A variety of authors even expect the next generation of healthcare systems to be mainly based on the homecare idea, thereby extending healthcare from the traditional clinic or hospital setting to the patient's home. This development raises new challenges for the conceptualization and design of future health technologies. While many medical and technical problems encountered in early prototype systems have been solved by now, there is very little knowledge about the needs and wants of potential end users if the next generation of electronic health technologies should be actually integrated into the patients' homes.

8. References

[1] Asada, H. H., Shaltis, P., Reisner, A., Rhee, S., Hutchinson, R.C. (2003). Mobile Monitoring with Wearable Photoplethysmographic Sensors. In: *IEEE Engineering in Medicine and Biology Magazine*, 22(3), pp. 28-40.

[2] Bien, Z. Z., Park, K.-H., Kim, D.-J., Jung, J.-W. (2004). Welfare-Oriented Service Robotic Systems: Intelligent Sweet Home & KARES II. In: Z. Z. Bien, D. H. Stefanov (Eds.): *Advances in Rehabilitation Robotics: Human-Friendly Technologies on Movement Assistance and Restoration for People with Disabilities*, Lecture Notes in Control and Information Sciences, Springer, Berlin, Germany, pp. 57-94.

[3] Bohn, J., Coroama, V., Langheinrich, M., Mattern, F., Rohs, M. (2004). Living in a World of Smart Everyday Objects – Social, Economic, and Ethical Implications. In: *Journal of Human and Ecological Risk Assessment*, 10(5), pp. 763-786.

[4] Braun, G., Nelles, S., Rumm, P. (2009). Telemonitoring von Gesundheits- und Vitaldaten – Ökonomischer und qualitativer Nutzen bei chronischen Erkrankungen. In: *Proceedings of AAL'09*. VDE, Berlin, Germany. CD-ROM.

[5] British Department of Health (2001). *National Service Framework for Older People*. Department of Health, London, UK, Crown Copyright. Brown and Adams.

[6] Cook, D. J., Das, S. K. (2007). How Smart are Our Environments? An Updated Look at the State of the Art. In: *Journal of Pervasive and Mobile Computing*, 3(2), pp. 53-73.

[7] Demiris, G., Tan, J. (2005). Rejuvenating Home Health Care and Tele-Home Care. In: J. Tan (Ed.): *E-Health Care Information Systems: An Introduction for Students and Professionals.* Jossey-Bass, San Francisco, pp. 267-290.

[8] Ferguson, G. T. (2003). Have Your Objects Call My Objects. In: *Harvard Business Review*, 80(6), pp. 138-143.

[9] Friedman, R. Kazis, L., Jette, A. (1996). A Telecommunication System for Monitoring and Counseling Patients with Hypertension: Impact on Medication Adherence and Blood Pressure Control. In: *American Journal of Hypertension*, 9, pp. 285-292.

[10] Gellersen, H.-W., Beigl, M., Krull, H. (1999). The MediaCup: Awareness Technology Embedded in an Everyday Object. In: *Proc. of Intern. Symp. on Handheld and Ubiquitous Computing*, Springer, Heidelberg, pp. 308-310.

[11] Gellersen, H.-W., Schmidt, A., Beigl, H.-W. (2000). Adding Some Smartness to Devices and Everyday Things. *IEEE Workshop on Mobile Computing Systems and Applications*, December 7 - 8, Monterrey, USA.

[12] Georgia Institute of Technology (2004). From Research to Market: Smart Shirt Moves. Georgia Institute of Technology, GA, USA.

[13] Gopalsamy, C., Park, S., Rajamanickam, R., Jayaraman, S. (1999). The Wearable Motherboard: The First Generation of Adaptive and Responsive Textile Structures (ARTS) for Medical Applications. In: *Virtual Reality,* 4, pp. 152-168.

[14] Halin, N., Junnila, M., Loula, P., Aarnio, P. (2005). The LifeShirt System for Wireless Patient Monitoring in the Operating Room. In*: Journal of Telemedicine and Telecare*, 11, pp. 41-43.

[15] Jagos, H., Oberzaucher, J., Zagler, W. L. (2007). *Erste Schritte bei der Entwicklung instrumentierter Schuhe zur Sturzvorbeugung alter Menschen*. IKTForum.

[16] Jerant, A. F., Azari, R., Nesbitt, T. S. (2001). Reducing the Cost of Frequent Hospital Admissions for Congestive Heart Failure: A randomized Trial of a Home Telecare Intervention. In: *Medical Care*, 39(1), pp. 1234-1245.

[17] Jung, J. W., Lee, C. Y., Lee, J. J., Bien, Z. Z. (2003). User Intention Recognition for Intelligent Bed Robot System. In: *Proceedings of the Eighth International Conference on Rehabilitation Robotics* (ICORR'03), pp 100-103.

[18] Kikin-Gil, R. (2005). Buddybeads: Techno-Jewelry for Non-Verbal Communication within Teenager Girls Groups. In: *Personal and Ubiquitous Computing*, 10(2-3), pp. 106-109.

[19] Krebs, H. I., Hogan, N., Volpe, B. T., Aisen, M. L., Edelstein, L., Diels, C. (1999). Robot-Aided Neuro-Rehabilitation in Stroke: Three-Year Follow-Up. In: *Proceedings of the Sixth International Conference on Rehabilitation Robotics* (ICORR'99), pp. 34-41.

[20] Legon, J. (2003). *'Smart Sofa' Aimed at Couch Potatoes*. CNN, September 23, 2003.

[21] Leonhardt, S. (2006). Personal Healthcare Devices. In: S. Mukherjee et al. (Eds.): *AmIware: Hardware Technology Drivers of Ambient Intelligence*, Springer, Dordrecht, pp. 349-370.

[22] Linti, C., Horter, H., Österreicher, P., Planck, H. (2006). Sensory Baby Vest for the Monitoring of Infants. *International Workshop on Wearable and Implantable Body Sensor Networks*, April 3-5, MIT, Cambridge, MA.

[23] Lüder, M., Salomon, R., Bieber, G. (2009). StairMaster: Ein neues Gerät zur online Erkennung von Stürzen. In: *Proceedings of the Second German Congress on Ambient Assisted Living*. VDE, Berlin, Germany. CD-ROM.

[24] Lum, P. S., Burgar, C. G., Shor, P. C., Majmundar, M., Van der Loos, H. F. M. (2002). Robot-Assisted Movement Training Compared with Conventional Therapy Techniques for the Rehabilitation of Upper Limb Motor Function After Stroke. In: *Archives of Physical Medicine and Rehabilitation*, 83, pp. 952-959.

[25] Lynch, A. (2000). Point-of-Need Diagnosis of Cystic Fibrosis Using a Potentiometric Ion-Selective Electrode Array. In: *Analyst*, 125(12), pp. 2264-2267.

[26] Marey, A., Buchner, M., Noehte, S. (2001). Mobiles Monitoring – Eine neue Chance für die Diagnostik. In: *Proceedings of the Workshop "Mobiles Computing in der Medizin".* April 2, Cologne, Germany, pp. 158 - 165.

[27] MIT (2006). *Things That Think*. Massachusetts Institute of Technology, Cambridge, MA, USA.

[28] Munro, B. J., Steele, J. R., Campbell, T. E., Wallace, G. G. (2004). Wearable Textile Biofeedback Systems: Are They Too Intelligent for the Wearer? In: *Wearable eHealth Systems for Personalised Health Management: State of the Art and Future Challenges*. IOS Press, Amsterdam, pp. 271-277.

[29] Muras, J. A., Cahill, V., Stokes, E. K. (2006). A Taxonomy of Pervasive Healthcare Systems. In: *Proceedings of the Pervasive Health Conference and Workshops*, Innsbruck, Austria, pp. 1-10.

[30] Orwat, C., Graefe, A., Faulwasser, T. (2008). Towards Pervasive Computing in Health Care - A literature Review. In: *BMC Medical Informatics and Decision Making*, 8(1), pp. 1-18.

[31] Orwat, C., Rashid, A., Wölk, M., Holtmann, C., Scheermesser, M., Kosow, H. (2008). Pervasive Computing in der medizinischen Versorgung. In: *Technikfolgenabschätzung - Theorie und Praxis*, 17(1), pp. 5 - 12.

[32] Pandian, P. S., Mohanavelu, K., Safeer, K. P., Kotresh, T. M., Shakunthala, D. T., Gopal, P., Padaki, V. C. (2007). Smart Vest: Wearable Multi-Parameter Remote Physiological Monitoring System. In: *Medical Engineering and Physics*, 30(4), pp. 466-477.

[33] Pandian, P. S., Safeer, K. P., Gupta, P., Shakunthala, D. T., Sundersheshu, B. S., Padaki, V. C. (2008). Wireless Sensor Network for Wearable Physiological Monitoring. In: *Journal of Networks*, 3(5), pp. 21-29.

[34] Park, H. K., Hong, H. S., Kwon, H. J., Chung, M. J. (2002). A Nursing Robot System for The Elderly and The Disabled. In: *Proc. of the International Workshop on Human-Friendly Welfare Robotic Systems*, Daejeon, Korea.

[35] Park, S. H., Won, S. H., Lee, J. B., Kim, S. W. (2003). Smart Home - Digitally Engineered Domestic Life. In: *Personal Ubiquitous Computing*, 7(3+4), pp. 189-196.

[36] Philips (2006). *Vision of the Future*. Philips Corporate Design, Eindhoven, The Netherlands.

[37] Pitta, F., Troosters, T., Probst, V. S., Spruit, M. A., Decramer, M., Gosselink, R. (2006). Quantifying Physical Activity in Daily Life with Questionnaires and Motion Sensors in COPD. In: *European Respiratory Journal*, 27(5), pp. 1040-1055.

[38] Rao, R., Agrawal, S. K., Scholz, J. P. (2000). A Robot Test-Bed for Assistance and Assessment in Physical Therapy. In: *Advanced Robotics*, 14(7), pp. 565-578.

[39] Scheermesser, M. (2009). Akzeptanz des Bewegungsmonitorings bei chronischen Patienten. In: *Proceedings of the Second German Congress on Ambient Assisted Living*. VDE, Berlin, Germany. CD-ROM.

[40] Schoch, T., Strassner, M. (2003). Wie smarte Dinge Prozesse unterstützen. In: *HMD*, 229, Feb. 2003, pp. 23-32.

[41] Scholz, O., Velten, T. (2009). Integration von AAL-relevanter Sensorik in zahntechnische Vorrichtungen. In: *Proceedings of the Second German Congress on Ambient Assisted Living*. VDE, Berlin, Germany. CD-ROM.

[42] Schwabe, D., Heide, M., Neudeck, A., Mehring, U. (2008). Aktive Hüftprotektoren mit Telemonitoringfunktion. In: *Proceedings of the German Congress on Ambient Assisted Living*. VDE, Berlin, Germany. CD-ROM.

[43] Song, W. K., Lee, H., Bien, Z. Z. (1999). KARES: Intelligent Wheelchair-Mounted Robotic Arm System Using Vision and Force Sensor. In: *Robotics and Autonomous Systems*, 28(1), pp. 83-94.

[44] Starner, T., Auxier, J., Ashbrook, D., Gandy, M. (2000). The Gesture Pendant: A Self-Illuminating, Wearable, Infared Computer Vision System for Home Automation Control and Medical Monitoring. In: *Proceedings of the IEEE International Symposium on Wearable Computing*, IEEE Press, pp. 87-94.

[45] Tamada, J. A., Lesho, M., Tierney, M. J. (2002). Keeping Watch on Glucose: New Monitors Help Fight the Long-Term Complications of Diabetes. In: *IEEE Spectrum*, 39(4), pp. 52-57.

[46] Turnin, M. C., Bolzonella-Pene, C., Dumoulin, S., Cerf, I., Charpentier, G., Sandre-Banon, D., Valensi, P., Grenier, J. L., Cathelineau, G., Mattei, C. (1995). Multicenter Evaluation of the Nutri-Expert Telematic System in Diabetic Patients. In: *Diabetes and Metabolism*, 21(1), pp. 36-33.

[47] Vitaphone (2008) *Telemedizin aktuell.* Ausgabe 2, 2008, Medizin - Service, Institut für Strategisches Marketing & Kommunikation, Wesel, Germany.

[48] Wahr, J., Tremper, K. (1995). Non-Invasive Oxygen Monitoring Techniques. In: *Critical Care Clinics*, 11(1), pp. 199-217.

[49] Wannamethee, S. G., Shaper, A. G., Walker, M., Ebrahim, S. (1998). Lifestyle and 15 Survival Free of Heart Attack, Stroke and Diabetes in Middle-Aged British Men. In: *Archives of Internal Medicine*, 158, pp. 2433-2440.

[50] Wu, J., Kessler, D., Chakko, S., Kessler, K. (1995). A Cost-Effectiveness Strategy for Transtelephonic Arrhythmia Monitoring. In: *American Journal of Cardiology*, 75, pp. 184-185.

[51] Youngbum, L., Myoungho, L. (2008). Accelerometer Sensor Module and Fall Detection Monitoring System Based on Wireless Sensor Network for e-Health Applications. In: *Telemedicine and e-Healt*h, 14(6), pp. 587-592.

[52] Zahneisen, A. (2009). SOPHIA- Best Practice. In: *Proceedings of the Second German Congress on Ambient Assisted Living*. VDE, Berlin, Germany. CD-ROM.