Connecting Health and Humans
K. Saranto et al. (Eds.)
IOS Press, 2009
© 2009 The authors and IOS Press. All rights reserved.
doi:10.3233/978-1-60750-024-7-483

Home Care Decision Support Using an Arden Engine – Merging Smart Home and Vital Signs Data

Michael MARSCHOLLEK[a], Oliver J. BOTT[b], Klaus-H. WOLF[a], Matthias GIETZELT[a], Maik PLISCHKE[a]; Moaaz MADIESH[a], Bianying SONG[a], and Reinhold HAUX[a]

[a] *Peter L. Reichertz Institute for Medical Informatics, University of Braunschweig - Institute of Technology and Hannover Medical School, Germany*
[b] *University of Applied Sciences and Arts, Hannover, Germany*

Abstract. The demographic change with a rising proportion of very old people and diminishing resources leads to an intensification of the use of telemedicine and home care concepts. To provide individualized decision support, data from different sources, e.g. vital signs sensors and home environmental sensors, need to be combined and analyzed together. Furthermore, a standardized decision support approach is necessary. *Objective*: The aim of our research work is to present a laboratory prototype home care architecture that integrates data from different sources and uses a decision support system based on the HL7 standard Arden Syntax for Medical Logical Modules. *Methods*: Data from environmental sensors connected to a home bus system are stored in a data base along with data from wireless medical sensors. All data are analyzed using an Arden engine with the medical knowledge represented in Medical Logic Modules. *Results*: Multi-modal data from four different sensors in the home environment are stored in a single data base and are analyzed using an HL7 standard conformant decision support system. *Conclusion*: Individualized home care decision support must be based on *all* data available, including context data from smart home systems and medical data from electronic health records. Our prototype implementation shows the feasibility of using an Arden engine for decision support in a home setting. Our future work will include the utilization of medical background knowledge for individualized decision support, as there is no one-size-fits-all knowledge base in medicine.

Keywords: tele home care, decision support, architecture, Arden Syntax, sensors

1. Introduction

It is well known that a demographic change will take place within the next decades, leading to an ageing society. There will be a marked rise in the elderly population, and especially in the group of persons aged 80 years and above [1, 2]. This shift in the society will have a significant impact on social as well as health care systems, because the financial foundation diminishes as the working population dwindles, and there will be a growing need for a workforce to care for the elderly.

Smart homes and telemedicine systems are deemed as a promising means to support health care processes and make up for diminishing resources by providing point-of-care support for caregivers, relatives and patients alike [3, 4]. Many projects have been conducted in this field of research, and e.g. sensor and communication technologies have reached a high degree of maturity.

Most of the projects that include decision support systems (DSS) have dealt with vital signs data for diseases and syndromes that are well-understood and easily interpretable, e.g. diabetes [5]. To provide individualized decision support, however, more data than just vital signs data need to be considered. Fig. 1 shows the different sources of data that need to be considered: vital signs data from 'classic' medical sensors (e.g. blood pressure or oxygen saturation), patient questionnaires and/or other information from the patient's surroundings, environmental or smart home data providing the context of a person and of the measurements taken, and – most importantly – medical data taken from the electronic health record (EHR). Without these data, decision support will lack the 'complete picture' and only be able to provide a 'one-size-fits-all' analysis.

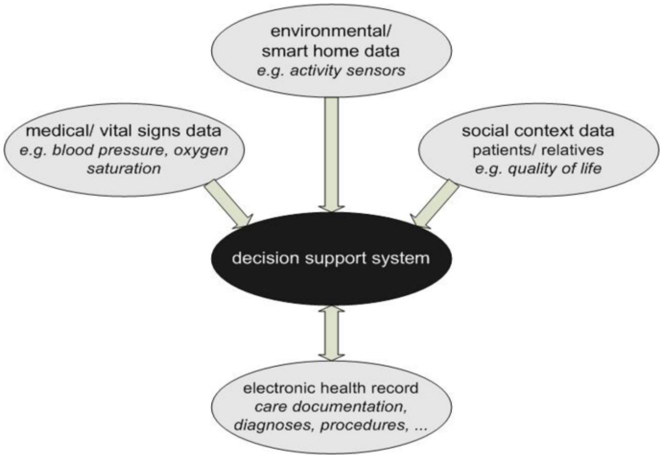

Figure 1: Data sources for home care decision support. The double arrow symbolizes the bidirectional data flow as the electronic health record is tapped for medical background information as well as complemented by home care information.

Despite the well-established use of DSS in clinical care, e.g. in drug interaction checking [6], there are only few projects that propose decision support systems and their architectures in home care settings. Basilakis et. al. propose an architecture based on the JBoss process engine with two steps of data analysis: first statistic and/or signal analysis and then rule-based decision support on the aggregated data [7]. Garsden et al. suggest a similar architecture combining statistics and rules, and to use HL7 Clinical Document Architecture (CDA) files for home care data storage [8]. In our previous work, we have proposed a system architecture that not only uses HL7 CDA as document representation standard, but also a decision support system that employs an engine using the HL7 Arden Syntax for Medical Logical Systems [9, 10].
The aim of our research work is twofold:

- aim 1: to describe a laboratory prototype home care architecture that integrates data from different sources and facilitates decision support, and
- aim 2: to implement a decision support system that is based on the HL7 standard Arden Syntax for Medical Logical Modules.

Use case

As a use case scenario for our prototype, we chose a patient suffering from chronic obstructive pulmonary disease (COPD) who is regularly affected by exercise dyspnea while performing strenuous activities of daily living (ADL), but usually not at rest. Our system should be able to detect abnormal oxygen saturation dips that occur while resting in a chair or lying in bed, which may indicate an increase in the severity of the disease. Furthermore, the system should be able measure blood pressure and to verify if the measurements are performed when resting.

2. Material and Methods

Our three-room smart home laboratory is equipped with several unobtrusive environmental and context sensors that are connected to a standardized home bus system (*European Installation Bus/ EIB*). These include pressure switches, which are placed under a mattress or a chair to detect use of the appliance, and infra-red movement sensors (Fig. 2). Both of these sensors were used in our prototype system along with a wireless pulse oximeter (*Nonin 4100*) and a wireless blood pressure sensor (*Corscience 705IT BT*).

Figure 2: Wireless blood pressure sensor and pulse oximeter (left); infrared motion sensor (middle) and wireless pressure switch sensor that is placed under a chair cushion (right), both connected to a home bus.

A Linux home server system was installed in the lab and connected to the home bus system to read messages originating from the pressure and movement sensors. The two medical devices were connected to the server via Bluetooth. All sensor data are stored in a local SQL database (*PostgreSQL*) along with meta information on the sensor and a timestamp. A commercial Arden Engine (*Medexter Healthcare GmbH, Austria*) was installed on the server and connected to the database. Several prototype Medical Logic Modules (MLMs) were implemented to perform analyses of combined sensor values.

3. Results

3.1. Architectural model

Fig. 3 shows a block model [9] of the overall architecture implemented. Data from different modalities and sources (context sensors, on-body vital signs sensors, caregiver and patient questionnaires) are jointly stored in a personal database system ('pEHR') and analyzed using an Arden Engine. This decision support system serves as the central means of combined data analysis.

3.2. Decision support engine

The commercial Arden decision support engine was used for simple exemplary analyses of combined sensor data, e.g. a threshold-based oxygen saturation and heart rate check taking into account the current context situation (sitting on a chair, moving around in the flat, lying in bed) as derived from the environmental sensors connected to the home bus system. Thus, abnormal values, e.g. an oxygen saturation dip while resting in a chair, can be detected. In our prototype implementation the decision support engine is invoked in regular intervals.

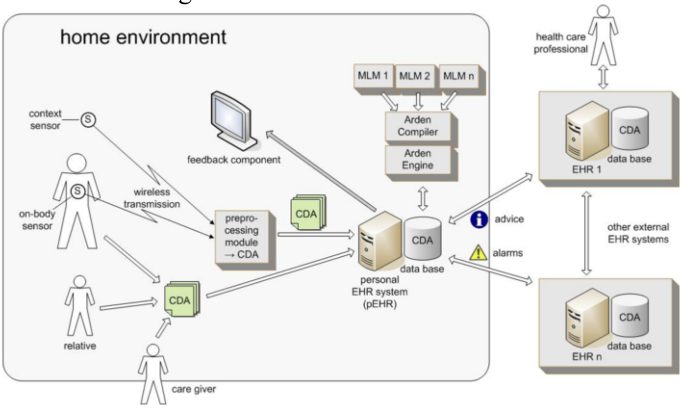

Figure 3: Component model of the proposed home care system architecture ([9]) and its connection to external application (EHR) systems. CDA = HL7 Clinical Document Architecture, EHR = electronic health record, MLM = Medical Logic Module

4. Discussion

For individualized decision support in a home care setting, it is of paramount importance to consider the current context situation of parameter measurements, e.g. of vital signs, as well as the medical background information about the person. Simple interpretations of data, e.g. heart rate data to detect arrhythmias, might be done with local, generic algorithms in real-time. Analyzing more complex data to give personalized advice, however, requires the interpretation of the data with regard to *all* available pieces of information. To provide an example, two patients with the same pulmonary condition might be monitored, treated and advised differently because of their co-morbidity profile, age, co-medications, social context or cognitive ability. Our prototype architecture addresses this requirement by combining data from two important sources (Fig. 1): vital signs data and home environmental data from a home bus system (aim 1). A standardized medical knowledge representation, Arden MLMs, are used to analyze these data and to identify pathologic patterns. To the authors' knowledge, this is the first implementation on an Arden engine in a home care setting (aim 2).

Limitations

Arden engines work on documents, e.g. HL7 CDA conformant documents. Sensors often produce data continuously, so that these have to be aggregated and fused into documents before the Arden engine is invoked in regular intervals. We currently use a direct data base connection to retrieve the sensor data for decision support, but the necessity for on-the-fly conversion of sensor data into XML documents and handling of these might hamper online performance of the DSS as outlined in our architecture. A data stream management approach might provide better performance in this aspect [11]. Nevertheless, standard conformant data representation is necessary to provide for semantic interoperability, e.g. with information from an EHR.

So far we have not implemented a connection to the EHR system, but only use data from two home sources. As part of a trans-institutional health information system [12], all links need to be established to reach full functionality. Additionally, more data from other environmental sensors need to be considered to evaluate the context.

5. Conclusion

Our prototype implementation demonstrates the feasibility of using data from different sources for individualized, more personal decision support. The use of a standardized representation of the knowledge base, the Arden Syntax, facilitates interoperability and thus the incorporation of medical data from EHRs and other information sources within a trans-institutional health information system. Our future work will include the use of these sources for data interpretation against the background of individual needs.

6. Acknowledgement

We thank the *Medexter Healthcare GmbH* (Vienna), and especially Professor Dr. Klaus-Peter Adlassnig, for lending us their *medexter-Arden* software package for our research work.

7. References

[1] Federal Statistical Office of Germany, "11. Koordinierte Bevölkerungsvorausberechnung - Annahmen und Ergebnisse," vol. 2007. Wiesbaden: Press office, 2006.
[2] United Nations, "World Population Ageing: 1950-2050 - Executive Summary," 2001.
[3] S. Koch, "Meeting the challenges--the role of medical informatics in an ageing society," Stud Health Technol Inform, vol. 124, pp. 25-31, 2006.
[4] O. J. Bott, E. Ammenwerth, B. Brigl, P. Knaup, E. Lang, R. Pilgram, B. Pfeifer, F. Ruderich, A. C. Wolff, R. Haux, and C. Kulikowski, "The challenge of ubiquitous computing in health care: technology, concepts and solutions. Findings from the IMIA Yearbook of Medical Informatics 2005," Methods Inf Med, vol. 44, pp. 473-9, 2005.
[5] S. Montani, P. Magni, R. Bellazzi, C. Larizza, A. V. Roudsari, and E. R. Carson, "Integrating model-based decision support in a multi-modal reasoning system for managing type 1 diabetic patients," Artif Intell Med, vol. 29, pp. 131-51, 2003.
[6] T. Falas, G. Papadopoulos, and A. Stafylopatis, "A review of decision support systems in telecare," J Med Syst, vol. 27, pp. 347-56, 2003.
[7] J. Basilakis, N. H. Lovell, and B. G. Celler, "A decision support architecture for telecare patient management of chronic and complex disease," Conf Proc IEEE Eng Med Biol Soc, vol. 2007, pp. 4335-8, 2007.
[8] H. Garsden, J. Basilakis, B. G. Celler, K. Huynh, and N. H. Lovell, "A home health monitoring system including intelligent reporting and alerts," Conf Proc IEEE Eng Med Biol Soc, vol. 5, pp. 3151-4, 2004.
[9] M. Marschollek, K. H. Wolf, O. J. Bott, M. Geisler, M. Plischke, W. Ludwig, A. Hornberger, and R. Haux, "Sustainable ubiquitous home health care--architectural considerations and first practical experiences," Medinfo, vol. 12, pp. 8-12, 2007.
[10] Health Level Seven (HL7), "Health Level Seven Arden Syntax," 2002.
[11] C. Sirish, C. Owen, D. Amol, J. F. Michael, M. H. Joseph, H. Wei, K. Sailesh, R. M. Samuel, R. Fred, and A. S. Mehul, "TelegraphCQ: continuous dataflow processing," in Proceedings of the 2003 ACM SIGMOD international conference on Management of data. San Diego, California: ACM, 2003.
[12] R. Haux, "Individualization, globalization and health - about sustainable information technologies and the aim of medical informatics," Int J Med Inform, vol. 75, pp. 795-808, 2006.

Email address for correspondence: Michael.Marschollek@PLRI.de