A sensor-enhanced health information system to support automatically controlled exercise training of COPD patients

Concept and Prototype

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***Abstract*—For an improvement of the quality of life for patients suffering from chronic obstructive pulmonary disease (COPD) we developed a concept and prototype of a sensor-enhanced health information system. This system includes a component that is monitoring the rehabilitation training and automatically controls the target load for the exercise on the basis of his or her vital data. The system also detects potentially critical health states and communicates alarms to external users. The component interacts with a personal electronic health record (PHR) that provides additional health related information for the decision making process, as feedback to the user and as an opportunity for physicians to optimize the user's exercise plan. The PHR uses current medical informatics standards to store and transmit training data to health care professionals and to provide a maximum of interoperability with their information systems. We have integrated these components in a service oriented platform design that is located in the home environment of the user.**

***Index Terms*—smart homes, PHR, personal health record, decision support systems, distributed information systems, health care**

I. Background

The vision of pervasive healthcare demands a new breed of health information systems, not only because there will be a new quality and quantity of information gathered – e. g. by continuous sensor-based monitoring –, but also because of a changing orientation of healthcare provision towards personalized or person-centered care. These new systems are referred to as *sensor-enhanced health information systems* (seHIS) [4], stressing the requirement to cope with large amounts of sensor data. Most current institutional health information systems are not designed to store and interpret continuous data streams. Apart from this, seHIS will have to encompass not only a single institution, but all institutions of professional care that are in contact with a person, and – perhaps most challenging of all – non-professional caregivers and the person's environment [13]. This includes the person as well as her or his relatives as sources of information, which in turn raises severe concerns about data security and quality [15]. Furthermore, seHIS will have to rely heavily on the use of appropriate standards for medical information representation, e. g. the new *Personal Health Monitoring Report* (PHMR) draft standard [21], as well as for medical data interpretation logic, e. g. the HL7 *Arden Syntax for Medical Logic Modules* [17, 15].

A recent review has reported on progress in the design and deployment of seHIS [14], concluding that many systems are being developed and used (e. g. [23, 24] for cardiac patients), but that several of the demanding challenges given by Koch et al. [13] have not been met yet. This can be regarded as a 'normal' development, not only because demanding technical challenges have to be met, but also because of a fundamental shift in healthcare organization with an intense involvement of the individual is necessary. On the gradual way towards the implementation of seHIS, functional examples are needed in order to provide a means for learning from practice.

The aim of our research work for this paper – as part of the interdisciplinary Lower Saxony Research Network 'GAL' – is to present the model of a seHIS that supports autonomous exercise rehabilitation and disease management for one of the most important societal diseases of the future, *chronic obstructive pulmonary disease* (COPD) [16]. This system should make consistent use of standards for medical data representation and medical logic for data interpretation as well as implement a person-centered architecture.

A. Application scenario: COPD exercise training

COPD is a chronic disease that affects the pulmonary system in a way that, based on an inflammatory process, the bronchi are obstructed which in turn leads to a decreased capability for gas exchange. This slowly progressive disease finally leads to a gradual destruction of lung tissue.

The treatment consists of deleting the cause for inflammation, often smoking, and medication such as anti-inflammatory or dilating substances. One of the most important ways of treatment, however, is regular endurance exercise, which can improve physical capacity and quality of life in an

PERVASIVEHEALTH 2010, March 22-25, Munchen, Germany

DOI 10.4108/ICST.PERVASIVEHEALTH2010.8827

important range for daily life requirements. In an ambulatory rehabilitation setting, home ergometer training is often used in cardiac patients, but not in COPD.

A special challenge in this exercise rehabilitation for COPD patients, especially in advanced disease stages, lies in their extremely low functional capacity which is sometimes below 20 watts of power on average during a 20 minute endurance test [18]. Thus, the patients' exercise training has to be supervised, because unsupervised training often is either too low or too high in power, respectively causing dyspnoea. Therefore, considering home training, a close supervision of training parameters and a patient's individual physical reactions by a physician are necessary for an optimal long-term outcome. Our prototype gives an example of how monitoring of a patient's home ergometer training can be supported by a trans-institutional seHIS.

II. METHODS

To allow for a supervised endurance training of COPD patients at home, our system supports four use cases, namely *training control*, *emergency detection*, *real-time monitoring* and *disease management*. These use cases are supported by four application components:

(1) The *Decision Support System* (DSS) controls a patient's home ergometer training on the basis of her or his vital signs, detects adverse events and generates an alarm in the case of an emergency. The DSS has been described in detail in [18].

(2) Aggregated information about a patient's training results is forwarded to her or his *personal health record* (PHR), where it is stored in a database for personal disease management.

(3) To allow for an adaptation of the patient's training schedule, information about his latest training results is also forwarded to the application component *electronic medical record* (EMR), which is located at a medical practice.

(4) The physician of the medical practice is also provided with the ability to monitor the patients training in real-time, using the *training monitor*. This functionality is realized by the application component *training monitor*, also shown on the logical tool layer in Fig. 1. While the application components *DSS* and *personal health record* are located at the patients home on the "home box", the *training monitor* and *electronic medical record* are installed on a computer at the medical practice of the responsible physician.

A. Use Case Modeling with the Three-Layer Graph-Based Meta Model (3LGM²)

To create our prototype we first used a modeling tool named *Three-Layer Graph-Based Meta Model* (3LGM²) to design the architecture of the needed information system (cf. Fig. 2). The Three-Layer Graph-Based Meta Model is used for static modeling of health information systems [20]. It shows the architecture with all entities, functions and their relationships on three distinct layers: the *domain* layer containing enterprise tasks, the *logical tool* layer containing application systems and the *physical tool* layer showing all physical devices and network connections. The final model allows for an in-depth view of the system architecture (Fig. 1).

On the basis of the application scenario and the resulting 3LGM-model, we derived requirements for the required application components PHR and the DSS. We do not focus on the EMR, because most of the requirements for this component are not relevant in our scenario. However, the requirements that the EMR has to fulfill in our use cases are discussed in the next chapter.

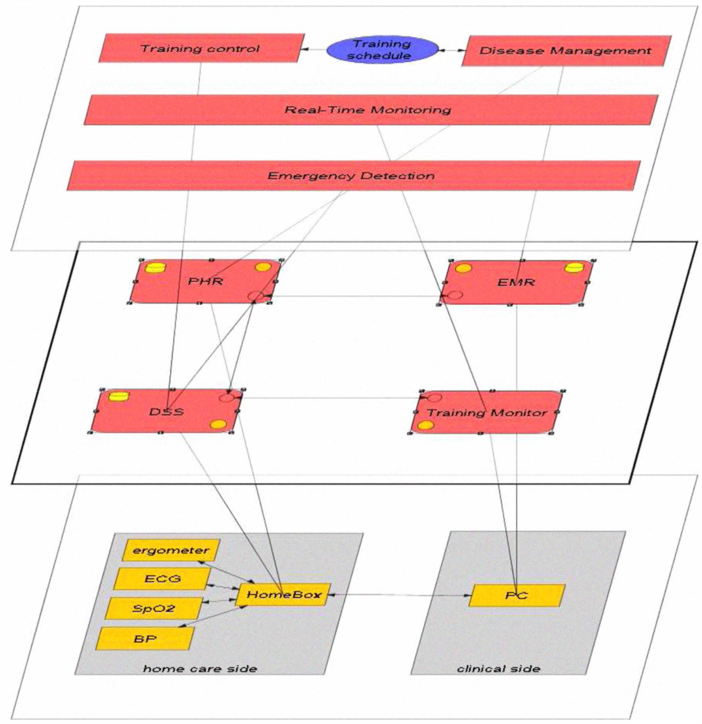

Figure 1. 3LGM²-model of our scenario

B. Requirements for the personal electronic health record

To ensure the best outcome for rehabilitation training, the PHR has to face different requirements. First, it needs to deliver all relevant information as input for the decision making process of the DSS-component. We divided this information into four categories:

- *Patient demographics*: family name, given name, date of birth, sex, height, weight, marital status
- *Medical core data*: list of current diagnoses, current medication
- *Training schedule*: creation date, expiration date, desired training units per week, training device type (e. g. exercise bike, stepper, rowing machine), target load (in Watt), target heart rate, target duration of the training)
- *Historical training data*: heart rate, oxygen saturation, breath rate (each of these parameters monitored over the time of one training session) and blood pressure.

After a training session, the results have to be documented for further interpretation by physicians or automatic analysis. The stored data will also be used to generate direct feedback for the user, describing her or his training performance during

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http://dx.doi.org/10.4108/ICST.PERVASIVEHEALTH2010.8827

the completed session, and for the visualization of trends over a set of historical training sessions. These results should be stored in a clinical document with the following data items:

- ECG data
- Performance (in Watt), heart rate, blood pressure, oxygen saturation and breath rate over the training time
- Borg value to document the individual subjective effort of the patient [3]
- Patient's weight
- Free-text field for further comments (e. g. "training aborted by user after 5 minutes")

Beside these medical data, the PHR has to store administrative data for the management of more than one user. This also includes data for management of access rights, such as permissions granted to internal or external persons or organizations.

A PHR is not a value on its own; it gains its whole value through the interaction with other systems, in our example the DSS component, but also through data exchange with external applications like EMRs in clinical information systems or practice management systems. To be as interoperable as possible, a PHR should use standardized data storage and transfer concepts wherever possible. As the counter-part of the communication act, the EMR has to be compatible with the same communication method. If the DSS detects a critical situation during the training process, the PHR should also be able to communicate alarms to external users.

The main non-functional requirements for the PHR are a good performance, robustness and flexibility. The PHR should be available even if the DSS component or other health-related services running on the same platform are out of function or currently being updated.

C. *Requirements for the decision support system*

To support automatically controlled exercise rehabilitation training of COPD patients, the DSS has to fulfill requirements with regard to the following three aspects:

- Knowledge base
- Knowledge engine
- Interoperability

One important component of a DSS is the knowledge base, which in our application enables efficient and safe training of COPD patients. The knowledge in the knowledge base is required to be directly applied to the task of training control; which makes it "procedural knowledge". The common way to represent procedural knowledge is by production rules. The Arden Syntax, which has been adopted as an HL7 standard since 1999, is a language for representing medical rules in the form of *medical logic modules* (MLMs) [17]. A MLM contains maintenance information, library information, and the actual medical knowledge. The "meta information" of the medical knowledge is described in the maintenance and library category, whereas the medical logical is described in the knowledge category.

To compile a MLM into an executable form as part of a knowledge base, an Arden compiler is required. The HL7 specification only describes the Arden Syntax (thus the name of the specification), but does not describe how to actually implement it. There is some literature about projects implementing Arden compilers [12, 19, 5], however, most of these activities stopped after the prototype stage. An evaluation and an industrial application of the Arden compilers described in the available literature are rarely seen; however we consider "industrial strength" as an important criterion for selecting an Arden compiler for our application.

DSS in general are suffering from a communication problem that limits their interoperability [7]: The terminologies used in the medical logic of a DSS and the terminologies used in the external data sources from which the DSS draws the actual live values (such as vital parameters) on which decisions are based are often not the same, which makes it difficult to connect DSS and the information systems serving as data sources. This problem is known as the "curly braces" problem. There is no ultimate solution for this problem, because the ultimate solution would require all health IT systems to use a single, common standard terminology, which is very unlikely for the foreseeable future. The "curly braces" problem also affects our application as we link the MLM to the PHR. A specific software module that provides a mapping between different terminologies is, therefore, needed as an interface between the DSS and the PHR.

III. RESULTS

A. *Information model and interoperability*

One important decision in the data centric architecture of a PHR is the choice of the appropriate information model. So far, the existing standards in this field have seen only limited take-up in healthcare IT systems [6]. We have chosen the HL7 *Clinical Document Architecture* (CDA) for our system because this document format is highly interoperable with the HL7v3 standard, which in turn has the potential to be the successor of the HL7v2 standard that is frequently used to connect health IT systems in hospitals today. In addition, CDA was developed specifically for clinical documentation and, therefore, includes useful characteristics such as persistence, stewardship, authentication, context, wholeness, and human readability (for further information see [10]).

Currently there are mechanisms under development that should enable interoperability between the home care environment and clinical information systems. Two initiatives have to be mentioned here: *Integrating the Healthcare Enterprises* (IHE) is a non-profit organization with the aim "…to improve the way computer systems in healthcare share information." [11]. IHE defines a CDA-based integration profile to share information between a PHR on the home-care side and an EMR on the clinical side, named *Exchange of Personal Health Record Content* (XPHR). The other relevant organization is the Continua Health Alliance, a consortium of over 200 international health-related companies "…joining together in collaboration to improve the quality of personal healthcare" [1]. Continua currently defines a CDA-based document template named *Personal Health Monitoring Report* (PHMR), which allows for the storage and exchange of data

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http://dx.doi.org/10.4108/ICST.PERVASIVEHEALTH2010.8827

produced during a rehabilitation training [2]. Using CDA as the information model that is compatible with the PHMR document template for the content-storage and XPHR as an integration profile, we made our choices for a highly interoperable PHR. In our system's implementation, the information model is instantiated as a set of Java classes generated from the CDA model specification by the use of techniques from *Model Driven Development* (MDD). If the underlying CDA model changes, a new version of the Java classes could be generated and a switch to the new model would require only a minimal adaptation effort. Currently we are modelling a project specific CDA template based on PHMR to represent all of our training data in an interchangeable CDA based document format.

B. Exercise training control

In our system we are using the commercial Medexter software components (*medexter healthcare GmbH, Austria*) to write, compile, test, and execute MLMs. The software package contains three core components: an integrated development environment, an Arden compiler and an Arden engine. The integrated development environment facilitates the implementation of such MLMs. The Arden compiler can directly compile Arden source code to binaries and supports the Arden Syntax version 2.7. The Arden compiler is linked to our PHR, thus it can deliver medical recommendations based on the content in the PHR. The Arden engine is responsible for the "curly braces" problem; it has an interface which enables the manual mapping of different terminologies in MLM and PHR.

To control the training performance, the MLM needs to interact with the "wrapped" application controlling the rehabilitation training and with the PHR. Current sensor values are passed by the training application, whereas data such as the personal maximum heart rate is retrieved from the PHR. The sample MLM module shown in Fig. 2 demonstrates how training control and data communication are specified. The MLM checks the heart rate during the training session. If the rate drops to less than 65% of the personal maximum, the training performance is increased by 10%.

The Arden compiler is used to compile and execute the MLM. The meta information in the maintenance and library categories is irrelevant for the execution of the MLM. The operational "slots" (sections) are in the *knowledge* category: data, logic and action. The data slot is responsible for passing parameters, the logic slot controls the training performance based on the current heart rate and the personal maximal heart rate, and the action slot returns the most suitable training performance to the wrapped program, i. e. the application controlling the training session. A query from a CDA document located in the PHR is performed as the *read* statement in the data slot is executed. The query is implemented in the Arden engine, which can parse the CDA structure by calling a Java method of the PHR interface with an XPath expression as parameter and receiving the requested value in return.

A different training monitoring module has been implemented for physicians in a medical practice, where the exercise rehabilitation training of COPD patients can not only be supervised and controlled by the DSS, but also "manually" by physicians. The system checks these entries for invalid inputs which could lead to a critical state during the training session. This module is needed for example for patients with an abnormally large standard deviation of the heart rate – in such cases, it is important that the physician can directly intervene through the training monitoring module.

```
maintenance:
        title: MLM for test purposes;;
        mlmname: check pulse;;
        arden: Version 2.5;;
        version: 1.00;;
        institution: PLRI;;
        author: BS;;
        specialist: UT;;
        date: 2010-01-11;;
        validation: testing;;
library:
        purpose: test;;
        explanation: simple test MLM;;
        keywords: COPD, training;;
        citations:;;
        links:;;
knowledge:
        type: data_driven;;
        data: (current_pulse, performance) := argument;
        max_pulse := read
                {/ClinicalDocument/structuredBody/
                section/entry[@typeCode="DRIV"]/
                organizer[@classCode="CLUSTER"]/
                component/observation/
                value/@value};;;
        priority:;;
        evoke:;;
        logic:
        if current_pulse < 0.65 * max_pulse then
                performance := performance * 1.1;
                conclude true;
        endif;
        ;;
        action:
        return performance;
        ;;
        urgency:;;
end:
```

Figure 2. Arden Syntax MLM code example

C. Software component interaction and integration

The exchange of data from medical devices between the DSS and the PHR requires an efficient interface. To meet this requirement, we have constructed appropriate Java interfaces that are automatically wrapped as web services using Apache Axis 2. This enables us to provide the data delivery and access service to (trusted) external DSS components.

Because the DSS component is monitoring the live training, it is also used to collect incoming data and deliver it to the PHR after the training session. Internally, the PHR instantiates an object and persists it as a CDA compliant XML file to the file system. To guarantee that every document is saved in the same manner and to avoid errors that could be caused by external document developers, we defined common store and load methods in the class from which every

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document in the PHR is derived. This design is good for the storage of documents but leads to performance problems when the DSS queries a big number of documents. In our scenario, this could be the case for queries such as "select the average heart rate during the last 50 training sessions". If the vital signs would be stored only in XML files that the PHR would have to open and parse to extract all the relevant data items for the aggregation, this could lead to a critical delay. To avoid this problem, we defined additional optional store and load methods that permit a document developer to define an optimized storage or retrieval methods specific to the data of a certain document type. For the above mentioned query, we chose a relational database for the storage of vital parameters to achieve the best performance for our queries.

The PHR and DSS components are executing as sets of Java classes inside so-called "bundles" on an OSGi-Platform in the home environment of the user. The OSGi immanent properties enable us to update or add bundles without stopping the whole framework. Our rehabilitation components use a set of other software components like the "Alarm Communication" bundle that is able to forward alarms that may be detected during rehabilitation training to external users. We have developed a service oriented platform architecture for the integration of such services named *Multi Service Home Platform* (MSHP), which is further discussed in [22]. The software components needed for the rehabilitation training are shown as parts of the overall architecture in Fig. 3.

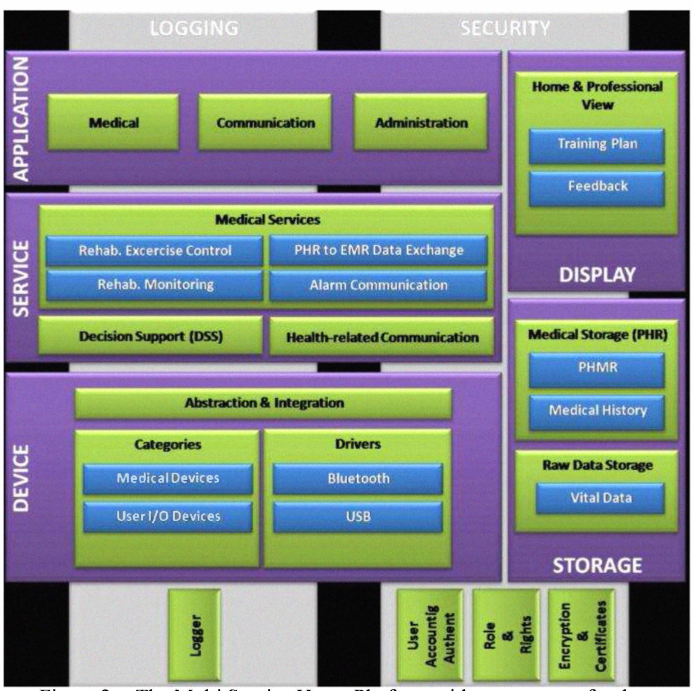

Figure 3. The Multi Service Home Platform with components for the rehabilitation training.

D. *Technical Evaluation*

Currently we are performing tests mainly on a component level. The PHR includes a mechanism to validate the generated documents using *XML schema* (XSD) specifications, which enables us to guarantee that only syntactically correct documents are saved in the PHR document repository. The graphical user interface of the PHR includes user feedback and enables physicians to create and edit training schedules. Testing and improvement of the user interface will be performed using an agile software development process. Initial results show that our concept for the interaction between PHR and DSS is able to deliver full interoperability between these two components. We have also successfully tested the 'alarm communication' component and evaluated it within an expert discussion.

The DSS has been evaluated with healthy volunteers and COPD patients. The proper functioning of the DSS has been confirmed in the evaluations. A detailed description about the evaluations can be found in [18].

IV. Discussion

This paper provides an example of a partial seHIS that meets some important challenges necessary to provide pervasive healthcare. The architecture may be best regarded as a home-centered architecture as defined by Haux et al. [9]. Nevertheless, the 'home box' may also be exchanged for a mobile smart device such as a PDA, leading to a 'person-centered' architecture. This would be the next step in COPD exercise rehabilitation, where a person is not confined to her or his home but may also conduct exercise at any other place.

Our system makes consistent use of the HL7 standards CDA and Arden Syntax for Medical Logic Modules, thus providing key prerequisites for interoperability between different application systems within the seHIS. The use of the CDA PHMR draft standard allows us to exchange document-based information with several current institutional health record systems. While the use of Arden MLMs for this application may seem cumbersome when compared to e. g. a Java class or a JBoss rule class, an important advantage of course is their standardized representation and exchangeability. Furthermore, the system presented provides an exercise feedback module not only for the treating physician, but also for the patient, thus addressing the issue of 'patient empowerment' or 'new ways of living' as defined in [4].

Gomez et al. describe a closed-loop insulin-pump control system for diabetics [8], also making use of HL7 CDA for information representation, but with a proprietary interpretation module. Dabiri et al. stress the use of standards such as HL7 CDA and ISO/IEEE 11073 to achieve semantic interoperability, but focus on a hierarchical on-body sensor network.

Limitations and future work

Our system focuses on the use of a personal health record based on HL7 CDA and a decision support module using the HL7 Arden Syntax. Referring to the challenges mentioned by Bott et al. [4], within our research network we have addressed middleware architectures and have used a service-oriented approach (OSGi). Furthermore, we have developed a solution for 'Alarm Communication'. Both of the above mentioned solutions are not described here in detail. We are currently working on a CDA Level 3 conforming document that fulfills all of our needs to store training data. We have not yet addressed data security and transmission rate service guarantees in our system, but will work on that in the future.

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Furthermore, we will work on a full integration of our system into routine care at Hannover Medical School and will conduct a controlled clinical trial in order to study the long-term rehabilitation effects of our approach. Our components will also be used within our research network to support a second medical application scenario – fall detection and prediction.

V. Conclusion and Outlook

People suffering from COPD benefit from periodic supervised exercise training. We have addressed a scenario that covers the whole process from the creation of a training schedule to a safe and automatically controlled training session up to the documentation of the results.

For this purpose we have modeled a sensor-enhanced health information system that reflects this scenario and takes it to the level of interoperable software components. We have developed a prototype for a DSS and a PHR component and have addressed problems that will come up during the implementation and integration of components for similar scenarios as well as for ours.

The concept and our early prototype show requirements and solutions for the design and integration of these components that have to work together to produce a real benefit for the patients' health and quality in life.

Acknowledgment

The work has been performed as part of the German Lower Saxony Research Network "Design of Environments for Ageing" (www.altersgerechte-lebenswelten.de), which is supported by the Lower Saxony Ministry of Science and Culture through the "Niedersächsisches Vorab" grant programme (VWZN 2420).

References

[1] Continua Health Alliance. http://www.continuaalliance.org/. Website, January 2010. Last visit 2010.01.27.

[2] Liora Alschuler, Calvin Beebe, Keith W. Boone, and Robert H. Dolin. Implementation Guide for CDA Release 2.0 Personal Healthcare Monitoring Report (PHMR). Technical report, Health Level Seven, Inc., 2008.

[3] G Borg. Perceived Exertion as an indicator of somatic stress. *Scandinavian journal of Rehabilitation Medicine*, 2(2):92–98, 1970.

[4] OJ Bott, M Marschollek, KH Wolf, and R Haux. Towards new scopes: sensor-enhanced regional health information systems - part 1: architectural challenges. *Methods Inf Med*, 46(4):476–83, 2007.

[5] egadss. Evidence-based guidelines and decision support system, 2010. Accessed Feb. 2nd.

[6] M. Eichelberg, T. Aden, J. Riesmeier, A. Dogac, and G. B. Laleci. A survey and analysis of Electronic Healthcare Record standards. *ACM Comput. Surv.*, 37(4):277–315, 2005.

[7] E German, A Leibowitz, and Y Shahar. An architecture for linking medical decision-support applications to clinical databases and its evaluation. *J Biomed Inform.*, 42(2):203–18, 2009.

[8] EJ Gomez, ME Hernando Perez, T Vering, M Rigla Cros, O Bott, and G et al Garcia-Saez. The INCA system: a further step towards a telemedical artificial pancreas. *IEEE Trans Inf Technol Biomed*, 12(4):470–9, 2008.

[9] R Haux, J Howe, M Marschollek, M Plischke, and Wolf KH. Health-enabling technologies for pervasive health care: on services and ICT architecture paradigms. *Inform Health Soc Care*, 33(2):77–89, Inform Health Soc Care.

[10] HL7. HL7 Implementation Guide: CDA Release 2 – Continuity of Care Document (CCD). Technical report, HL7, 2007.

[11] IHE International. www.ihe.net. Website, January 2010. Last visit 2010.01.27.

[12] HC Karadimas, C Chailloleau, F Hemery, J Simonnet, and E. Lepage. Arden/J: an architecture for MLM execution on the Java platform. *J Am Med Inform Assoc.*, 9(4):359–68, 2002.

[13] S Koch, M Marschollek, KH Wolf, M Plischke, and R. Haux. On health-enabling and ambient-assistive technologies. What has been achieved and where do we have to go? *Methods Inf Med*, 48(1):29–37, 2009.

[14] M Marschollek. Recent progress in sensor-enhanced health information systems - slowly but sustainably. *Inform Health Soc Care*, 34(4):225–230, 2009.

[15] M Marschollek, OJ Bott, KH Wolf, M Gietzelt, M Plischke, and M et al. Madiesh. Home care decision support using an Arden engine - merging smart home and vital signs data. *Stud Health Technol Inform*, 146:483–7, 2009.

[16] M Marschollek, KH Wolf, OJ Bott, J Howe, and R Haux. Predictions for epidemiologic indicators of age-related diseases and implications for the development of health-enabling technologies. In M FA Mühlhäuser and Aitenbichler E, editors, *Constructing Ambient Intelligence: AmI-07 Workshops Proceedings*, Darmstadt, 2008. Springer.

[17] Health Level Seven. Arden Syntax, Version 2.5 (revision of ANSI/HL7 Arden V2.1-2002). Technical report, ANSI/HL7 Arden V2.5-2005, 2005.

[18] B Song, KH Wolf, M Gietzelt, O Al Scharaa, U Tegtbur, R Haux, and M Marschollek. Decision support for teletraining of COPD patients. *Methods Inf Med.*, 49(1):96–102, 2010.

[19] A Tatsukawa, Y Mitshuishi, Y Toda, T Endo, Y Kawazoe, T Noguti, K Miyo, and K Ohoe. An implementation of a Web server with an Arden Syntax interpreter. *28th Joint Conference on Medical Informatics*, 2008.

[20] A Winter, B Brigl, and T Wendt. Modeling hospital information systems. Part 1: The revised three-layer graph-based meta model 3LGM2. *Methods Inf Med*, 42(5):544–51, 2003.

[21] KH Wolf, S Schirmer, M Marschollek, and R Haux. Representing sensor data using the HL7 CDA personal healthcare monitoring report draft. *Stud Health Technol Inform*, 150:480–4, 2009.

[22] A Hein, M Eichelberg, O Nee, A Schulz, A Helmer, and M Lipprandt: A Service Oriented Platform for Health Services and Ambient Assisted Living. *Proceedings AINA Workshops/Symposia 2009, IEEE 23rd International Conference on Advanced Information Networking and Applications, Bradford, United Kingdom, 26-29 May 2009, pp. 531-537, IEEE Computer Society, 2009.*

[23] C Busch, C Baumbach, D Willemsen, O Nee, T Gorath, A Hein, and T Scheffold: Supervised training with wireless monitoring of ECG, blood pressure and oxygen-saturation in cardiac patients. *J Telemed Telecare 2009;15:112-114*

[24] M Lipprandt, M Eichelberg, W Thronicke, J Krüger, I Drueke, D Willemsen, C Busch, C Fiehe, E Zeeb, F Golatowski, and A Hein: OSAMI-D: An Open Service Platform for Healthcare Monitoring Applications. *Proceedings 2nd International Conference on Human System Interaction (HSI'09), 21-23 May 2009, Catania, Italy, pp. 139-145*

Digital Object Identifier: 10.4108/ICST.PERVASIVEHEALTH2010.8827
http://dx.doi.org/10.4108/ICST.PERVASIVEHEALTH2010.8827