MEDINFO 2010
C. Safran et al. (Eds.)
IOS Press, 2010

doi:10.3233/978-1-60750-588-4-48

A Home-centered ICT Architecture for Health-enabling Technologies

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Abstract

Population ageing needs health-enabling technologies for delivering pervasive health care. Home care plays an import role in pervasive health care. In this paper, we aim to construct a home-centered health information system architecture which can efficiently manage multi sensors, actuators and decision support systems. Open Services Gateway initiative (OSGI) was used for constructing the service oriented architecture. HL 7 Arden Syntax for medical logic module (MLM) was used to describe the medical knowledge; An Arden compiler was used to interpret the MLMs. The Arden compiler was packed in an OSGI bundle. All of the knowledge bases can share the compiler within the OSGI platform. System within the OSGI-based architecture can change their behaviors during runtime. The proposed prototype architecture was deployed in a case study.

Keywords:

Health-enabling technologies, Home care, Information system architecture, Decision support system.

Introduction

With the improvement of living standards and medical quality, people have rising life expectancy. A United Nations population division report shows the changes of the age structure [1]. The global potential support ratio (the number of people age 15-64 per one older person aged 65 or older) has decreased from 12 in 1950 to 9 for today and is estimated to 4 in 2050. The number of persons aged 80 or older is 1.6% of the population worldwide for today and is estimated to be 4.4% in 2050. Every country is facing or will face population ageing and the issues that come along with it. Older people have a significantly greater probability of having multiple chronic diseases than younger people [2]. An estimated 14% of the world's older persons live alone, who might need outside assistance in the case of illness or disability and are at greater risk of social isolation and poverty [3]. Population ageing is an unprecedented challenge for human societies.

With the development of information and communication technology (ICT), pervasive health care, which contributes for the independent life of ageing people, keeping up quality of life and self-sufficiency of ageing people, might be one solution for the ageing society. According to Jakob Bardram, one of the important pervasive health care aspects is home care [4, 5]. Many researchers try to develop home care system for monitoring of vital signs and for improving life quality. Rogers et al have developed a home-based monitoring system for measuring blood pressure [6]. Using of the home monitoring system, detection of essential hypertension has significantly improved. Angius et al have developed a home care system exploiting the DVB-T technology [7]. Using of the set-top box enables untrained or even elderly people can easily use the system. A low-cost base station for the acquisition of 1-lead ECG signal has been connected to the system. Jakkula et al have created a smart home which can perform automated health monitoring and detect anomalies [8]. Based on the context information of interactions with electronic devices, models of resident behavior in the smart home were analyzed.

Decision support system (DSS) is an effective method to improve the price-performance ratio of patient care and reduce medical error [9]. DSS has also been used in home care system for dealing with vital signs and for assisted living. Marschollek et al have developed a home care DSS which can merge smart home and vital signs [10]. Using data from different sauces enables individualized, more personal decision support. Song et al have developed a DSS for home-based rehabilitation of patients affected by chronic obstructive pulmonary disease [11]. This DSS can observe and control physical ergometer training sessions autonomously.

A home care information system contains some key elements: people especially old people, sensor for measuring data, DSS for processing data, and actuator for the implementation of the action. These four elements can form a loop (figure 1), this loop enables people have an assisted living. In order to fully care the elderly, multi sensors, DSSs, and actuators should be used in the home care information system. To efficiently manage the multi sensors, DSSs, and actuators, a high-quality information architecture is very important.

Objective

The aim of our research is to construct a home-centered health information system architecture which can efficiently manage multi sensors, actuators and DSSs.

Methods

Open Services Gateway initiative (OSGI)

OSGI is a service-oriented architecture and has been used in building automation [12]. We use OSGI framework to build up the home-centered health information system architecture. The so-called bundles within the OSGI framework are services. The bundles can be remotely installed, started, stopped, updated and uninstalled during runtime. This means, it is possible to connect or disconnect new services without having to reboot the system. We embedded the sensors, actuators and DSSs in the bundle so that they could work as service and could be controlled individually during run time.

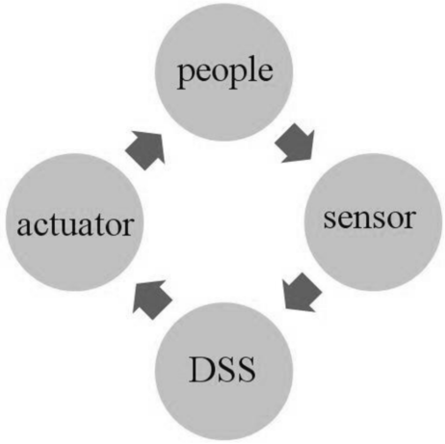

Figure 1- loop in home care information system (decision support system (DSS))

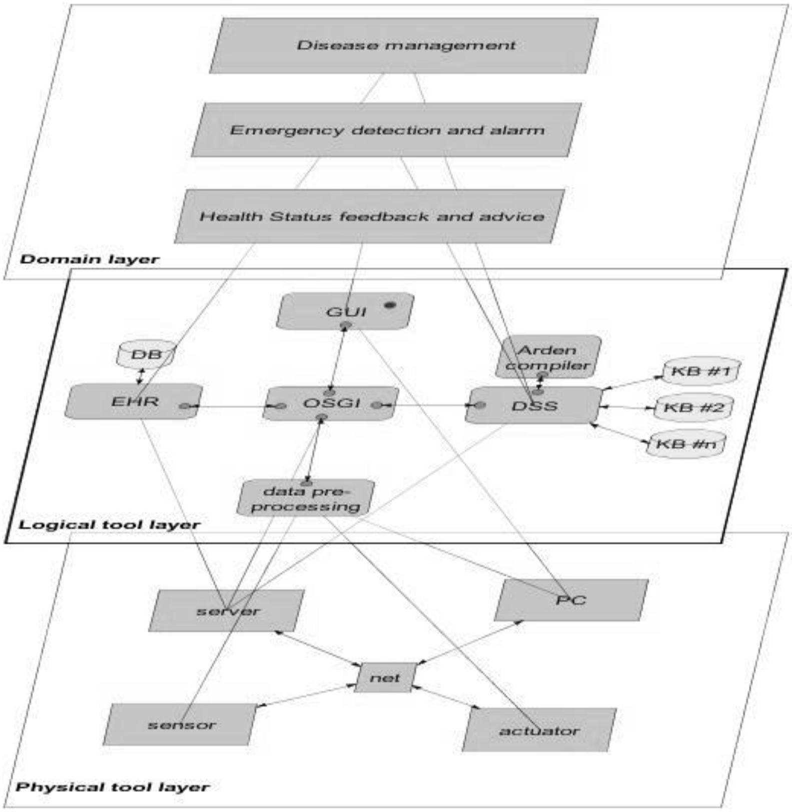

Figure 2- Three-layer Graph-based meta model (3LGM^2) of the proposed home-centered health information system architecture (electronic health record (EHR), graphic user interface (GUI), decision support system (DSS), knowledge base (KB), data base (DB), Open Services Gateway initiative (OSGI), personal computer (PC))

Arden Syntax for medical logical module (MLM)

Health level 7 (HL7) Arden Syntax for MLM is a language to encode medical knowledge for delivering decision support [13]. The medical knowledge is organized into MLM by Arden Syntax. We propose to use Arden Syntax for MLM in the home-centered health information system, because it facilitates knowledge sharing among health care providers. The knowledge base (KB) standardized by Arden Syntax for MLM can provide interoperability with other heath information system (e.g. hospital information system).

We utilized the commercial software “Medexter” [14] to interpret the Arden Syntax. “Medexter” contains an Arden compiler and an interface to connect to other host systems. The Arden compiler supports the Arden Syntax version 2.7.

Results

A service-oriented architecture

We use Three-layer Graph-based meta model (3LGM^2) [15] to describe the proposed home-centered health information system architecture (figure2). The three basic tasks of home care: disease management, emergency detection and alarm, as well as health status feedback and advice [16], proposed by Haux et al are shown at the domain layer. In the logical tool layer, OSGI framework is used to construct the service-oriented architecture, electronic health record (EHR), data pre-processing module, DSS and graphic user interface (GUI) are connected as bundles in the framework. The data pre-processing module is connected to sensors (or actuators) and used to provide preliminary data treatment. The meaningful data gathered from sensors are recorded into the EHR. The EHR is connected with DSSs which are used for emergency detection and alarm, disease management, as well as daily assistant. Delivering decision support for people especially old people in home environment contains many aspects, e.g.: fall detection, training controlling, appointment scheduling, etc. Each aspect should have a corresponding DSS. Managing of multi DSSs is a challenge in the architecture; the solution is reported in the next section. The GUI is used for the feedback of the health related information to people who live at home. In the physical tool layer, sensors, actuators and computers are connected by wireless or wired network. Sensors measure people’s vital parameters, actuators enable an assisted living.

Managing of multi DSSs

As expressed in the previous section, multi DSSs including KBs should be used in the home-centered health information system. We used Arden Syntax for MLM to standardize the knowledge and packed the Arden compiler into an independent OSGI bundle for sharing of the compiler. This compiler bundle exports all of the packages which are used by other bundles for interpreting MLMs. The MLMs in each KB were connected with the compiler bundle through an interface bundle. MLMs in the same KB can be linked directly according to the logic; MLMs in different KBs are not allowed to fire each other directly. The compiler bundle can be started or stopped. If the compiler bundle is stopped, the MLMs cannot be interpreted. This design is demonstrated in Figure 3.

Case study

We have built a smart home equipped with environment sensors and on body sensors to deploy our home-centered health information system architecture. This smart home is designed for old people who have multiple chronic diseases and live alone. OSGI-framework is used in the smart home to build up the architecture. Some sensors are embedded into OSGI bundles, so they could be controlled during run time. Figure 4 shows most of the sensors in the smart home.

We have constructed two DSSs which were embedded in the OSGI-framework. One DSS is used for rehabilitation training of patients suffering from COPD; the other is used for fall detection. The two DSSs shared one knowledge engine, but the two KBs in the two DSSs were stored and managed separately. MLMs which are stored in the same KB can call each other directly. The knowledge engine can find and fire the MLM through a unique routing.

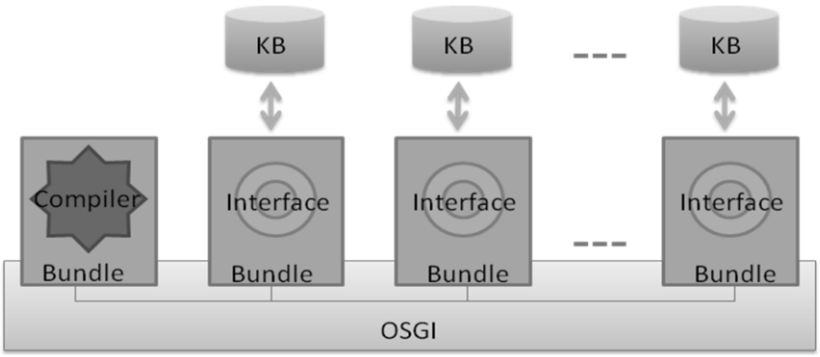

Figure 3- sharing of Arden compiler within Open Services Gateway initiative (OSGI) framework (knowledge base (KB))

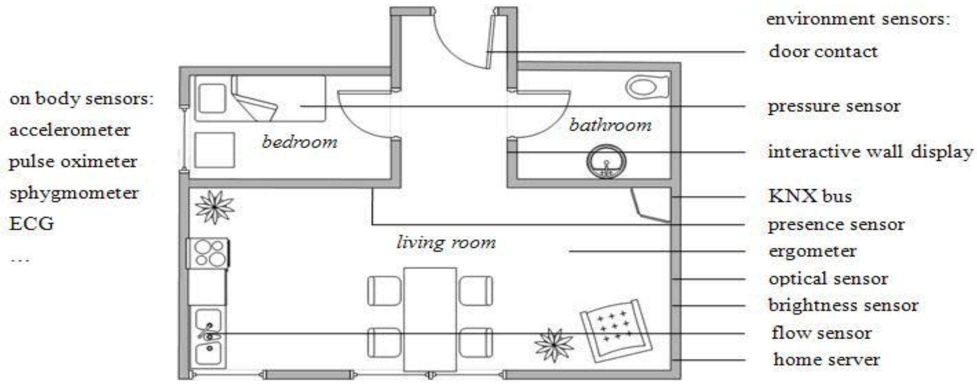

Figure 4- The smart home equipped by environment sensors and on body sensors (Electrocardiography (ECG))

The triaxial accelerometer is one of the on body sensors, it is used for activity detection (e.g.: fall, step, etc) [17]. We take the triaxial accelerometer as an example to follow a work flow of the smart home. An old person takes the triaxial accelerometer and lives in the smart home, once the DSS detects an emergency situation (e.g.: the person fell and cannot stand up alone), the DSS will automatically fire the rules and call for outside assistance. The related information about the fall gathered by the triaxial accelerometer and other sensors will be recorded into the EHR for further treatment and investment.

Discussion

Health-enabling technologies have the potential to significantly improve quality of life and efficiency of health care in aging societies [18, 19]. Sensor-enhanced information system plays an important role in Health-enabling technologies for delivering pervasive health [20]. Haux et al identified four major paradigms of ICT architectures for health-enabling technologies: [16]

- person-centered ICT architectures,
- home-centered ICT architectures,
- telehealth service-centered ICT architectures,
- health care institution-centered ICT architectures.

In this paper, we propose a service-oriented home-centered ICT architecture. This architecture contains sensors, actuators, data pre-processing module, DSSs, EHR, GUI, etc. Our architecture is based on the OSGI framework and can thus change system behavior on the fly. Using health-enabling technologies in home environment for improving life quality of older people has not only technical issues but also social issues. Sensors might not be accepted for various reasons [21], privacy can be a barrier for people's adoption [22]. E.g.: although a camera can detect an unexpected fall, people don't want to install a camera in their own bathroom. The OSGI framework based architecture enables people choice services on demand during run time.

There are also some other related works about using OSGI in home care information system. The SAPHIRE project tries to develop an intelligent healthcare monitoring and DSS on a platform integrating medical sensor data [23]. OSGI was used to build up the multi-services home care platform which communicates between clinic and the patient's home. In addition, this platform manages the execution of the individualized guideline which is modeled by Guideline Interchange Format (GLIF). The Gator Tech Smart House project aims to create assistive home environments that can sense themselves and resident and enables the communication with outside services [24]. To create the Gator Tech Smart House, a generic reference architecture which contains five layers (physical, sensor platform, service, knowledge, context management, and application layers) was built up. In the service layer, OSGI was used to maintain leases of activated services. In the knowledge layer, ontology was connected to the system.

Comparing with architectures in the SAPHIRE project and the Gator Tech Smart House project, our architecture has not only similarity but also difference. The similarity is that all of the three architecture use OSGI framework. The difference is that we use Arden Syntax for MLM to represent the knowledge in the DSSs (SAPHIRE uses GLIF, Gator uses ontology). Knowledge could also be represented in other formats, e.g.: Drools. We use Arden Syntax for MLM because it has been standardized by HL 7 since 1999 and it facilitates knowledge sharing among health care providers. To the authors' knowledge, this is the first integration of Arden Syntax for MLM into OSGI framework.

To deliver decision support for people especially old people in home environment, multi DSSs including multi KBs should be used. Ng et al have developed an architecture for managing multi DSSs [25]. In this architecture, each DSS has its own KB and knowledge inference engine. We think that sharing the knowledge inference engine among the multi KBs could improve its reusability and reduce the system redundancy. The precondition of sharing knowledge inference is that the knowledge in different KBs should have a unified representation form. The KBs which are standardized by Arden Syntax for MLM in our proposed architecture fulfill the precondition. We packed the knowledge inference engine (Arden compiler) into an independent OSGI bundle. This Arden compiler bundle is responsible for interpreting MLMs in all of the KBs. We evaluated this design with two KBs in a prototype-like laboratory implementation; a formal evaluation with multi DSSs will be done in the further.

Conclusion

In this paper we have introduced a home-centered ICT architecture for delivering pervasive health care. Systems in this OSGI framework based architecture can change their behaviors on the fly. To deliver decision support, HL 7 Arden Syntax for MLM was integrated into the architecture. This architecture could be used in a home environment for improving life quality of people especially old people.

Acknowledgements

This work has been done in the Lower Saxony research network "Design of Environments for Ageing" (www.altersgerechte-lebenswelten.de). It has been partially funded by the Lower Saxony Ministry of Science and Culture through the "Niedersächsisches Vorab" grant program.

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