Future Generation Computer Systems 34 (2014) 161–175

Contents lists available at ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

Mobile and ubiquitous architecture for the medical control of chronic diseases through the use of intelligent devices: Using the architecture for patients with diabetes

Vladimir Villarreal [a,*], Jesus Fontecha [b,1], Ramon Hervas [b,1], Jose Bravo [b,1]

[a] Technological University of Panama, Lassonde, 6th West Avenue, David, CH, POB 6-2894, Panama

[b] Modelling Ambient Intelligence Research Lab, University of Castilla-La Mancha, Paseo de la Universidad, 13071, Ciudad Real, Spain

HIGHLIGHTS

- We define an application to allow the patient monitoring.
- We offer a solution that will help the improvement of life for patients.
- We design ontologies to enable obtaining the knowledge of the field of study.
- We define patterns for the generation of applications.
- Defining layers we facilitate the development and maintenance.

ARTICLE INFO

Article history:
Received 10 February 2013
Received in revised form
14 October 2013
Accepted 3 December 2013
Available online 16 December 2013

Keywords:
Design pattern
Layers-distribution devices
Parameterized mobile monitoring applications
Ambient assisted living
Ontology

ABSTRACT

This manuscript presents a mobile monitoring application to allow a patient to monitor a chronic disease using mobile devices. This application is developed according to three components that enable the semi-automatic development of software, independent of the target disease and adaptable to the particular user needs. First, we present ontologies that classify medical elements such as diseases, recommendations, preventions, foods, mobile devices and diet suggestions. The second element is the distribution of the devices in layers, allowing the generation of final applications distributed in a medical context. These layers are defined to develop and maintain the set of applications. The third and most important element is developing patterns known as MobiPatterns. A MobiPattern defines the schema of each control module that is a part of the final application. These elements include formal models that seek to uncover fundamental principles and essential features and algorithms, which need to be revisited in the context provided by mobility. Aspects of the application such as the functionality, user interface, and response time for a group of patients have been evaluated in a final application targeting patients with diabetes. The design focuses on simplicity, extensibility, scalability, heterogeneity, and application customization.

1. Introduction

The concept of Ambient Intelligence (AmI) has emerged to describe interactions between a multitude of network-enabled devices, services, and artifacts. The technology will be nearly invisible, embedded in all types of objects and everyday environments, such as the home, office, car, and train.

Advances in sensing, mobile, and embedded devices have made patient monitoring possible, and they have also provided medical treatments and other assistance in health care. Aging populations will benefit from reduced costs and improved health care through assisted living based on these technologies [1]. This concept denotes an intelligent environment customized for monitoring and assisting adults and elders with disabilities while they live alone at home.

This is a common situation for patients with chronic diseases: "*Liz is a woman diagnosed with diabetes. She uses a glucose meter to control the level of sugar in her blood. Every day, she maintains an adequate level of glucose through several measurements of the disease. As part of the process, she needs to make annotations in her notebook. Whenever a measurement is performed, she annotates the irregularities and changes presented during the day. If she has a problem, she has to call the doctor to consult about what has happened. Liz would like to obtain constant feedback about her measurements, obtaining recommendations and messages whenever the levels of glucose in her blood change. Additionally, she would like to manage all the incidents that she has presented in the last few days,*

* Corresponding author. Tel.: +507 7754563; fax: +507 7753012.
E-mail addresses: vladimir.villarreal@utp.ac.pa, vladvill22@gmail.com (V. Villarreal), jesus.fontecha@uclm.es (J. Fontecha), ramon.hlucas@uclm.es (R. Hervas), jose.bravo@uclm.es (J. Bravo).
1 Tel.: +34 926295300x96675.

0167-739X/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.future.2013.12.013

without the need to register them in her notebook. She wants to send these incidents to her doctor automatically. This would provide her with a better quality of life and a more constant monitoring of her disease".

This represents the ideal situation for a patient who suffers a chronic disease and needs constant monitoring. This is the main issue that these people face. We developed and implemented an application to facilitate continuous monitoring tasks allowing patients to lead normal lives without worrying about how to manage these medical tasks. This is a non-intrusive application with a low level of interaction. Once a vital sign has been measured, the application can process and visualize the results. This application is developed based on the patterns, layers and ontologies that are defined in our research. The objective of this application is to allow constant monitoring of patients with chronic diseases through the use of biometrics and mobile devices.

This application is remote and mobile, based on an adaptive system. The system can collect data while the patient is at home using a mobile phone and a biometric device. The remote application means that medical staff will be able to access all the collected data in a non-intrusive manner. This will facilitate a greater intimacy with patients. A mobile device, allowing continuous monitoring, can also receive this information.

We have indicated that the application will be mobile because the solution is based on the integrated or embedded hardware of portable and wireless devices; the patient does not have to carry heavy devices. Additionally, the system is adaptive, and the development will provide not only information about biometric values but also control activities for each of the patients. Therefore, medical staff will obtain their patients' biometric values and several notifications when patients may be at risk.

The hypothesis of our research is as follows: "*Is it possible to develop a mobile application that offers services that allow patients to use biometric devices to provide data and information to mobile devices (e.g., mobile phone, PDA, Internet tablet, or small computer) that collect information, evaluate trends, provide advice on health and diet or suggest ways to evaluate symptoms of a disease using a transparent and redundant data link between the patient and the personal mobile device?*".

The results of this hypothesis define our contribution in the area of ambient assisted living and mobile computing as well as provide an application to help people based on software engineering techniques related to the definition of interfaces, communication technologies, and medical knowledge.

This application can be adapted to some diseases, such as diabetes, high blood pressure, and fever, through biometric devices such as glucometers, tensiometers, and thermometers. When the application is running on the mobile device, the patient can add a new disease. The application development is evaluated in a medical context for patients with diabetes and blood pressure issues, always with the recommendation of a doctor.

This paper is organized into seven sections. After this introduction, Section 2 introduces the related work and compares it with our proposal. Section 3 presents a general proposal for generating mobile monitoring applications that link information to the patient's profile, contain medical modules and generate alerts. Section 4 describes the application of our architecture for patients with diabetes. We describe the evaluation of our application in Section 5, and in Section 6, we include a discussion of our proposal. Finally, Section 7 presents the paper's conclusions.

2. Research background

Some research has been developed for use in both indoor and outdoor environments. Most of the monitoring systems are focused on a single task, such as simple vital sign monitoring, fall detection, environment customization, or locating a person. Some devices may have a limited effectiveness because during a heart attack or a stroke, a patient may not be able to push the panic button. Other systems are based on a public or mobile phone or a pager-like device. This research proposes the development of software elements implemented in medical situations.

2.1. Researchers' contributions

Nirmalya [2] offers the idea of an architecture that supports a mix of efficient context-aware information for healthcare applications with an ambiguous context. It provides a systematic approximation to derive fragments of the context and to handle the probability of ambiguity in this context. This framework has been evaluated to monitor elderly people in small home environments. This design has been developed and labeled using Dynamic Bayesian Networks (DBNs) and a rule-based model. In our case, we do not have ambiguity in the data. To achieve this, we defined an individual profile for each patient, and the functionality of this architecture lies in the profile.

Mei [3] proposes the development of a framework for representing patients' vital signs. This framework facilitates the representation of the different notations for vital signs [4–6]. He proposes an XML schema to design the representation of the vital signs framework, specifying the existing standards of representation. Additionally, he proposes the creation of data sheets that contain the representations of vital signs that result from the mobility of the (patient) users in heterogeneous environments. Our proposal is not based on the representation of vital signs but rather on their control and interpretation.

Kebler [7] discusses how to use the context information to improve the analysis of similarity. He talks about three uses measurements of similarity in the geospatial domain and investigates which aspects of Dey and Abowd's definition of context (e.g., identity, activity, location or time) play a crucial role in defining the similarity in each of them. This alignment makes it possible to relate the structure of a shared vocabulary in the base of knowledge and the context information. The context parameters examined by the study are used to influence the results of the similarity analysis. The fundamental key that permits the care handling modules is the behavioral record in the patient's profile.

Preuveneers [8] investigates how the mobile phone platform can help individuals diagnosed with diabetes handle their blood glucose levels without resorting to additional systems (beyond the equipment they currently use) or without adding any additional activity sensors, such as pedometers, accelerometers, or heartbeat monitors. Participants in this study were patients with Type-1 diabetes. Our proposal focuses on patient monitoring; it is not necessary to know the location of the patient, but it is crucial to know the activities the patient was carrying out at a specific moment. This allows our system to learn for future situations. Our study is not only for diabetes; we can monitor many different chronic diseases using biometric devices to obtain the measurement.

Mamykina [9] presents MAHI (Mobile Access to Health Information), an application that monitors patients diagnosed with diabetes. This application is capable of acquiring reflexive thought skills for social interaction with diabetes educators. In our proposal, only the endocrinologists become involved because they are the only ones who know the patients' specific profiles. Managing the reflexive analysis of past experiences is one of the most essential skills in managing diabetes.

Bravo [10] proposes a patient tele-monitoring process. He proposes using a monitoring device that a person (patient or assistant) could activate by touching an NFC (Near-Field Communication) tag with the phone to launch the mobile phone application. As a result, the monitoring device should be active, and the measurements are