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Modular Approach in Integration of ICT Technologies into Mobile Heart-Work Monitoring System

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Abstract

Wide availability of modern information-communication technologies extends our potentials when building different and sophisticated healthcare systems. Using a modular approach, while integrating these technologies, makes resulted systems more flexible. With small changes on certain components these systems could provide slightly or completely different usage. This paper describes the usage of modular approach while integrating a few information-communication technologies into a system for heart work monitoring and analysis. Main characteristic of created electrocardiographic system is the possibility of patient's mobility which include possible dislocation with doctor. Mentioned modular approach, which is used in creation of heart monitoring system and in detail described in this paper, provides the possibility of transforming this system in completely different one. For example, replacing one or two main components could result in system with ability of blood pressure monitoring or insulin concentration monitoring.

Keywords: modular approach, plug-in based design, integrated system, heart work monitoring, ECG, telemedicine

1 Introduction

The everyday improvement of different information and communication technologies removes almost all obstacles and restraints we are faced with while developing new and sophisticated systems. This fact has enabled significant and rapid improvement in one field of medicine – telemedicine. Telemedicine can be defined as the use of electronic information and telecommunications technologies to share medical knowledge and provide health care over a distance (Grigsby and Sanders, 1998; Pattichis et al., 2002). Although telemedicine was introduced in the late 1960s and early 1970s (Bashshur, 2002), during the last few years this area became extremely interesting and popular. Fast development, low prices, better performance and minimalism in design make information and communication technologies easily reachable and suitable for different usages. This expands the possibilities of using these technologies while building wide range of healthcare systems with purpose of patients' life quality improvement, regardless if they need permanent medical care or not. For example, many of telemedicine systems are used to transfer electrocardiogram (ECG) and heart rate signs (e.g. Orlov et al., 2001; Tafa and Stojanović, 2006), some systems are developed to monitor patients' status (e.g. Tsang et al, 2001; Maglaveras et al., 2002), and several projects are used to transmit critical care medical information (e.g. Xiao et al., 2000; Kyriacou et al., 2003).

We have focused our research work on heart-work monitoring system (Vrček et al., 2006) which represents integration of several technologies into complex and sophisticated set-up whose main goals are the possibility of 24/7 heart-work monitoring and support for full patients' mobility. In addition, system has an ability of in time reaction if certain heart-work problems are detected. Doctor is immediately alarmed and ECG segment of critical heart work along with patients GPS position are sent to him. After a few seconds, dislocated doctor can perform additional analysis and professionally diagnose the problem in order to take additional steps if they are necessary.

This paper describes how the usage of modular approach while integrating different information and communication technologies can result in flexible system with the ability of transformation into slightly or completely different functionality if only a few modules or components are replaced. The implementation of client-server architecture along with modular and plug-in approach results in flexibility which is observed from two different levels. While observing just component layer we have described the possibility of gaining new usage of same component just by selecting different plug-in. At the other hand, while observing the system as a whole, the possibilities of transforming it into completely different one by replacing a few of its components are analysed and discussed.

2 Transformation Suitable Model

2.1 Overall System Architecture

One of the characteristics of previously introduced system is that it was created from already available commercial of the shelf components (COTS) which are connected through specifically developed software and also available communication technology (for glance look see Figure 1).

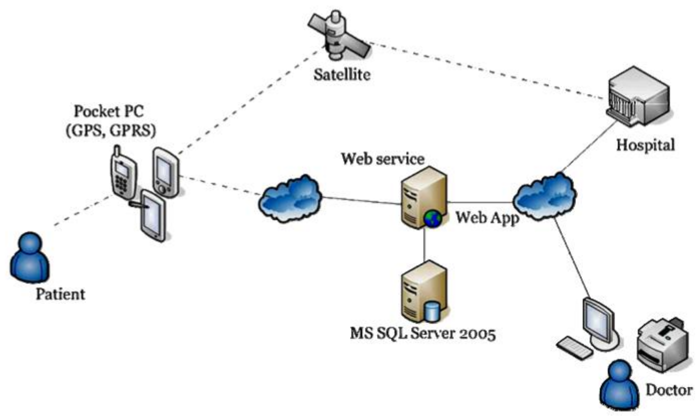

Figure 1: Overall system architecture (Vrček et al., 2006)

Briefly, first component is wireless enabled mobile digital Holter ECG device with the assignment of heart-work recording. The recorded signal is then transmitted toward second component, PDA application, in order to be filtered, processed, analysed and stored. If some high-risk irregularities are detected, critical segment along with timestamp and patient's GPS location is sent after third component – web service. The critical transmission could be performed via any mobile wireless network, such as GPRS, EDGE, UMTS, HSDPA or other

(Sauter, 2006). Web service role is to receive the data, store it into a database and if instructed to, alarm the doctor. The mentioned database is fourth system component, and finally fifth component is from-scratch developed web application. Using the web application doctor can access the stored data and professionally diagnose heart-work problem. If necessary, additional steps should be taken, and for some heart related disorders like ventricular fibrillation, atrial fibrillation or sinus tachycardia in time reaction is important (Bergovec, 1997), so possibility of locating the patient via his GPS becomes crucial.

2.2 Multi-layer Architecture

One of the basic rules of modular approach while developing software products is the usage of multi-layer system architecture (Huang, 2000). The possibility to replace specific component with another one rises from the fact that component role is well defined with scope within single layer. Basically, observed system structurally could be divided into two separate subsystems (see Figure 2). Although each of those has its own functionality and specific usage, these two systems together form new and fulfilled application. First subsystem is composed of mobile Holter ECG device and PDA application, and components of the second one are web application along with doctor and hospital which are using it.
Each of two separated subsystems has a database as its fundament and PDA and web application recline on these databases (see Figure 2). Through different modules, PDA application performs simultaneous device-communication, data processing and analysing along with data presentation and storage. This application is fully automated and once the process is initialised all tasks are performed without user instructions. On the other side, web application has slightly different usage. Relying on main database, this application constantly communicates with user/s (doctor/s) in order to receive the instructions process them and/or to present requested data.

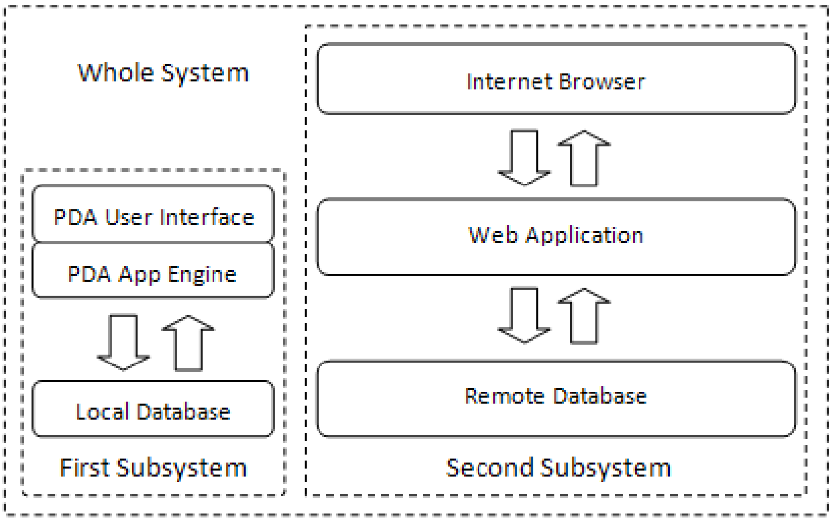

Figure 2: Multi-layer architecture of both subsystems

However, introduced subsystems are meant to work together. They are connected with already mentioned communication technologies and developed web service. According to this, architecture of system as a whole is also to be implemented as multi-layer architecture (see Figure 3).

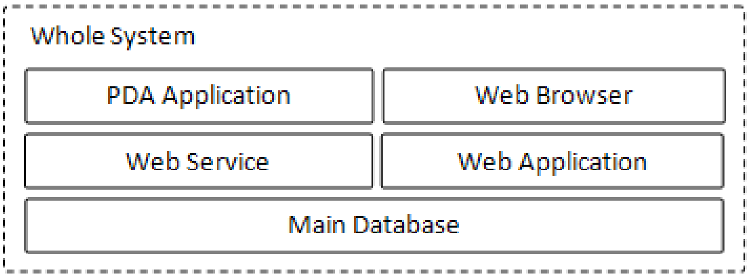

Figure 3: Overall multi-layer architecture

Web service and web application are directly connected with underlying database and they represent second layer. On the third, representation layer, we can find PDA application in order to represent data to patient, and web browser in order to represent data to doctor or other user. Within this multi-layer architecture, we can forget other previously mentioned roles of PDA application. Its main role in this architecture is reflected in heart-work data collection.

2.3 Component-level flexibility

Plug-in concept in software development was introduced as a callback mechanism to extend an application (Birsan, 2005). Soon the benefits of using this approach while building software products were recognized and plug-in approach became usual concept used in many applications in order to solve the problem when flexible functionality is needed. While using plug-ins, it is possible to change or to extend the way software works through the user interface without the need of application to be compiled or deployed again. The mentioned plug-in approach was also used in design of in this paper presented PDA application. As it can be seen in Figure 5, different plug-ins were developed in order to extend data retrieval functionality.

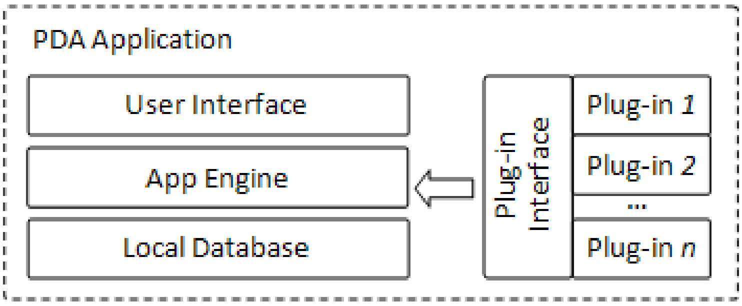

Figure 4: Implemented plug-in approach

Data retrieval and application flexibility mirrors itself through mentioned plug-ins. First plug-in can be used to retrieve data from Holter ECG device which performs real-time heart work data recording. Selecting the second plug-in, data acquisition is performed from local database and this functionality can be used to review and/or analyze recently saved signal. Finally, third plug-in is used in order to retrieve data from any specifically structured file. For example, this plug-in could be used to test application performance or critical segment detection algorithms using data which can be downloaded from publicly available online databases which store different segments representing problems in heart work (e.g. MIT-BIH online database (Physiobank, 2007)).

2.4 System-level flexibility

As a result of our research, we discovered a whole scale of health related problems which can be monitored and analyzed in a similar way as heart-work related problems. For example, there is reasonable need for 24/7 insulin concentration monitoring or real-time glucose monitoring at under aged children (for more information see Klonoff, 2005). Furthermore, there is also need for blood pressure monitoring system in order to give proper care for elderly people (see Hansen et al., 2006), or even a system which could recognize patients' psychological condition, epilepsy or maybe unreasonable fear attack (e.g. Casson et al., 2007).Design and implementation of these systems, with goal of monitoring mentioned or similar data, does not mean the necessity of performing all steps in software development life-cycle. Few changes on existing heart work monitoring system could result with completely new system with one of those specific functionalities.

Figure 5 represents the transformation of presented heart-work monitoring system into new system with role of insulin concentration monitoring.

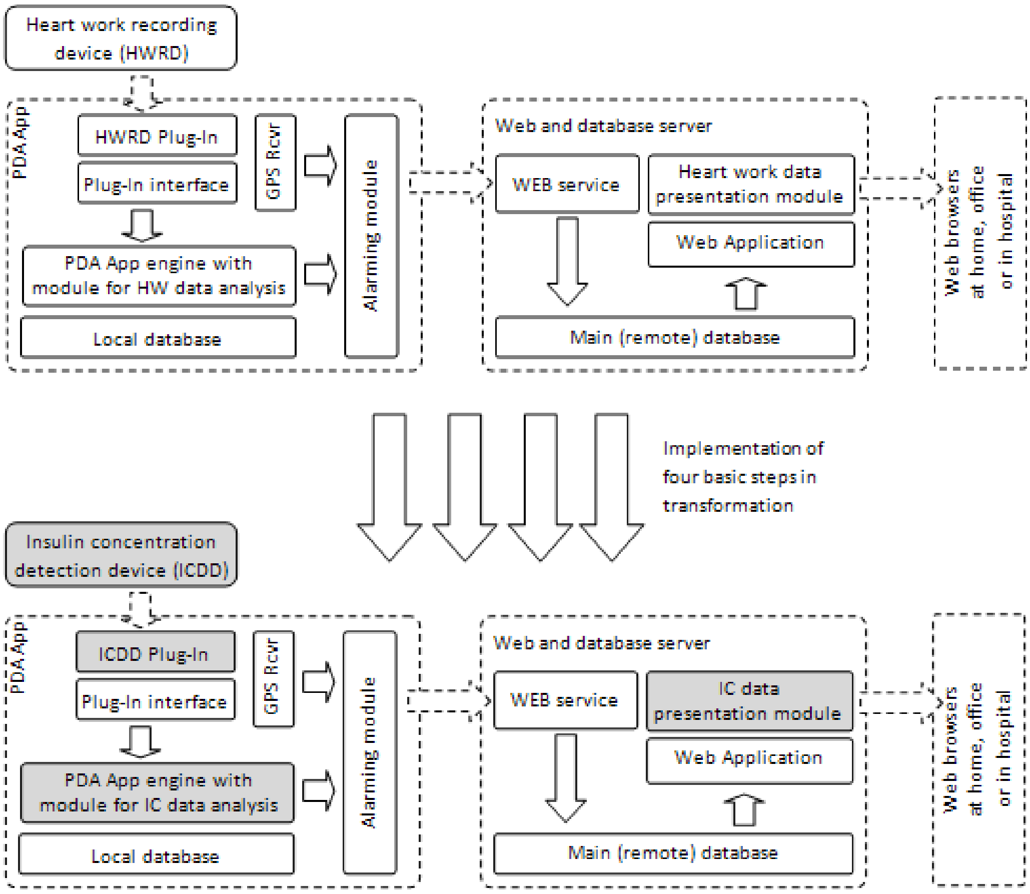

Figure 5: Complete system transformation

The transformation towards this or any other mentioned system could be performed in just four recommended:

1. First step is data recording device acquisition. Specific data monitoring means specific device to record it. Either the device is commercially available or built from scratch, its function should be simple and targeted towards the specific need (body temperature recording, blood pressure recording, insulin/glucose/adrenaline concentration monitoring) with the ability of on demand wireless data transmission.

2. Second step should be specific plug-in development. Specific device means specific plug-in to communicate with it. For the purposes of testing or data review already developed plug-ins could be used. In these cases data could be retrieved from files or existing databases.
3. Third step should be new analysis-module development. The basic difference between these modules would be specific parameters they use, concerning the type of real-time analysis performed. Unchanged method, needed in all these modules would probably be the alarming one, whose role is to initiate the transmission of critical segment of data after some irregularity is detected.
4. Finally, the web application should be updated with new module for data representation. Specific health-related problems have specific characteristics which should be taken into consideration.

After implementation of four listed steps, that included creation of new modules and plug-ins, system benefited in completely new functionality. It is important to notice that none of connections between components or modules were altered. As it can be seen in above figure, the overall system architecture remained untouched. Transformation process involved only components which have data-specific roles, as specific data recording, specific analysis or data representation. All other components that compose basic architecture and infrastructure as well as components that provide real-time reaction on detected health-related problems and patients' mobility also remain unchanged.

3 Conclusion

Although information and communication technologies are becoming widely available, demands that need to be fulfilled by systems composed of these technologies are becoming bigger and more complex. This fact results in growing number of failed projects in software development domain. In this paper we have presented that design of complex system can be guided by principles of modular approach and development in order to create its functional flexibility. The use of modular design and approach enables us to relatively easily transform created system into partly or completely different one. We have shown that an important change of functionality can be accomplished on two levels. On the component level, we can gain new and different functionality just by utilizing plug-ins, even without recompilation or redeployment of the application. On the other side, if entire system functionality needs to be changed, development of the new system does not have to encompass all the phases. The four recommended transformation steps should be enough.

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