Developing a context-aware, multimodal Hospital Information System

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Abstract. The gradual merge of information systems and telecommunications with healthcare reflects one of the most recent trends in the today's scientific world landscape. Health sector with hospitals being the main representative, render an individual domain with great social interest, which is also convenient for deployment of any kind of modern technology. Regarding the design of Hospital Information Systems (HISs), much work has been done so far in order to introduce advanced computing technologies in hospitals, yet none of them has managed to wholly tackle the particularly complex and demanding hospital environment. As a result, the implementation of an advanced HIS integrated with functionality to support mobility, context-awareness, and multimodality seems to be compulsory for the effective fulfilment of the new requirements of composite hospital environments, and for the efficient management of their intense complexity, thus paving the way to qualitative, pervasively provided, healthcare. In this paper, an innovative HIS architecture, which incorporates the aforementioned operations, especially focusing on context-awareness and multimodality, is presented and analyzed. The functionality of this new architecture is demonstrated through a use case scenario.
Keywords: Hospital Information System (HIS), mobility, context-awareness, multimodality.

1. Introduction

A hospital environment has specific characteristics rendering it as one of the most complicated and demanding IT application domains. These characteristics include, among others: large amount of data to be processed, need for direct and convenient information access, urgency of service delivery, data security, considerable degree of mobility, need for harmonic collaboration and cooperation between all parties involved and intense working environment [1,2]. All of the abovementioned factors contribute to the common recognition that hospitals constitute an extensively complex environment which can greatly benefit from the incorporation into hospital information systems (HISs) of functionalities such as those supporting easy and adaptive access to information by authorized healthcare professionals irrespective of their location [3-5].

This paper presents an HIS architecture which incorporates context-awareness and multimodality to provide these services to healthcare professionals. The functionality of the proposed architecture is demonstrated through a use case scenario. The proposed architecture meant to complement and empower current HIS architectures by exchanging information with them, accessing data captured at multiple sources in real time and making them available to hospital staff at the point of care and integrating data in an overall user friendly and efficient HIS.

2. Requirements of a Modern Hospital Environment

In today's hospital environments, users' access to required information is being hampered by the fact that they have to resort to certain fixed access points, in order to acquire the desired data. It would be significantly more convenient, however, if information access was available at any place, instead of certain points. The mobility concept refers to the provision of ubiquitous mobile access to users at any time. This requirement is exceptionally important for a hospital environment, where physicians are constantly moving around different work settings and, information is needed at any time and from different locations. The mobility concept refers not only to physicians but to patients as well, giving the latter the ability to move unobtrusively around the hospital while their vital signs are constantly monitored [5].

Besides having access anywhere anytime, it would be quite useful if medical personnel had adaptive access to information, according to their location and identity, present time, etc. The term 'context' refers to user characteristics and experiences, while using the system (including the ambient conditions, the user's preferences and profile, and other related information), which can be exploited by a telecommunication system, in order to help it fulfil its goals [6]. As far as request of information is concerned, a physician, due to heavy workload and possible inexperience with computing devices, would really appreciate easy interaction in a user-friendly manner, with the handheld device. 'Multimodality' is the new trend for user interfaces, which combines all possible means (modes) of interaction, creating multi-modal applications, where one can use keyboard (when available), pointing device and voice simultaneously to control the application [7,8].

3. Architecture of an HIS using context-awareness and multimodality

The requirements specified in the previous section impose the modification of a typical HIS architecture and, specifically, the addition of new modules, each of which will carry out functions covering the requirements under consideration. Figure 1 illustrates the proposed HIS architecture. Mobility is fully supported by the new architecture. In order for this to be achieved, the following enhancements should be made to the Technological Platform of the HIS architecture: (a) use of wireless handheld devices and (b) WLAN setup. In the proposed architecture, the PDA is the basic tool for the automatic presentation and visualisation of the information needed by the user, at the specific moment, based on location, identity and role. Although this type of devices (e.g. PDAs) already exists in some of the current HISs, their functionality is limited to providing access to certain information, after an explicit user request. The establishment of a wireless network covering all hospital departments is a prerequisite for the use and operation of both PDAs and other artifacts. Although WLANs are already being used in certain HISs, no contextual information is transferred within them. Recently, WLAN technology has been enhanced by the provision of the new Wi-Fi Protected Access (WPA) security layer [9]. The utilisation of this layer is necessary in order to guarantee the security of sensitive medical data.

3.1 Intelligent Context Management Module (ICMM)

The ICMM is responsible for gathering all the necessary information from the environment (context parameters) and composing the user's context, in order to trigger the appropriate next action, by using an advanced reasoning engine. The ICMM consists of three sub-modules, namely the following ones:

- Contextual Information Collection Sub-module (or Perception Sub-module)
- Reasoning Sub-module
- Action Sub-module

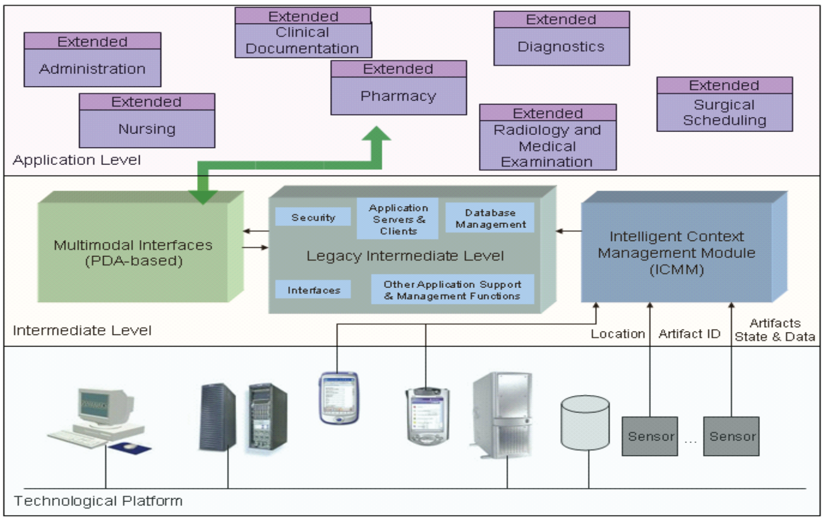

Figure 1: The proposed HIS architecture

The Contextual Information Collection Sub-module is able to accurately identify users and artifacts, as well as their locations, and at the same time collect vital patient data from various sensors, in order to transmit them to the Reasoning Sub-module. Therefore, it interacts with sensors and PDAs, within the hospital, in order to collect information about their locations, identities and states. Thus, this sub-module represents the "Perception Level" of the ICMM. The perception information that is gathered is then utilised by the ICMM's Reasoning Sub-module. Pertaining to location monitoring, the Perception Sub-module may incorporate four types of software, related to: (a) sensor fusion [10], (b) signal strength estimation [11], (c) RFID technology [12], and (d) face recognition software [13]. It is worth noting that, in the use case scenario described in last section, approach (b) has been adopted, although any of the alternative solutions could have been employed.

The Reasoning Sub-module is responsible for composing a more complex set of information, the context of use, on the basis of the information collected by the Perception Sub-module. Thus, this sub-module receives input from the Perception Sub-module and uses it to compose the current context of use, which is then exploited by the Action Sub-module.

The Action Sub-module is responsible for deciding the appropriate next action, based on the context composed by the Reasoning Sub-module. The term 'next action' implies the automatic provision to the user of the information needed at that time. Thus, the context composed by the "Reasoning Level" is exploited so as to trigger the adaptation of HIS services to the user's current needs.

3.2 Multimodal Interfaces

The proposed Multimodal Interface consists of two parts: (a) the Graphical or Visual Interface and (b) the Voice or Speech Interface. The adoption of Multimodal Interfaces allows voice enabled commands within Wi-Fi networks (involving context-sensitive grammar creation, dynamic vocabularies and natural language voice selections) and continuous adaptation of the offered services to the user's context in terms of device capabilities. Speech interfaces deliver distinct usability advantages, especially in certain mobile situations characterised by a high cognitive load. Special attention should be given to the design of unobtrusive ways to introduce speech capabilities in the user interface, so that users in the medical domain can invoke these capabilities when they want to, but are not hampered in their free access to a more conventional graphical user interface when that is their preference.

4. Implementation issues

The use case scenario that follows simulates the functionality of the proposed HIS, in real hospital conditions, indicating the concrete advantages and the obvious facilities introduced by this system's operation. For the purposes of this paper, we consider a hospital setting, where 'X' represents a physician's initial location, 'A' and 'B' represent the location of two hospital patients, respectively, and 'Y' represent the location of a specific artifact, namely an external defibrillator (a device used in case of a heart attack; in this condition, the heart needs an external electrical charge to shock it back into normal rhythm). In this scenario, a physician enters the room of patient A, in order to carry out a routine medical examination. As soon as he approaches the patient's bed, his presence nearby A is detected and triggers the appearance of information related to patient A, such as the patient's current condition (vital signs), medical record and current medication treatment, at the physician's PDA-based portable device. The same set of information can also be displayed on a smart board conveniently placed behind or next to patient's A bed.

While the physician is in patient's A room, an urgent alarm notification is received by his portable device. Via the screen of his PDA, he is immediately informed about the location of the patient in danger. The patient in danger is patient B, and the physician hurries to his room. As patient's B condition is critical, he asks the nurse, who had also received the alarm notice and was entering the room, to bring a defibrillator, as soon as possible. The nurse does not want to waste any time searching for the device through the PDA's graphical interface, so a voice command is issued: "Find the defibrillator". The PDA recognises the command and provides the location of the nearest defibrillator on its screen (artifact Y). The nurse brings quickly the artifact and the patient is saved.

As shown in Figure 2, when a change in location occurs, the Perception Level realises it and sends new location information to the Reasoning Level. The latter composes the complete context of use and concludes that physician is near patient A. This piece of information is then utilised by the Action Level, in order to decide the most appropriate next action, which is the provision of patient's A medical record. Figure 3 illustrates all phases of patient's B case. In phase (a), vital signs data are collected by the Perception Level from patient's B sensor. The Reasoning Level evaluates the patient's condition and concludes that it is critical. Therefore, the Action Level triggers an alarm situation. In phase (b), the alarm notification is received by the physician’s handheld device. The device’s screen automatically presents the location where the alarm situation is occurring. Finally, in phase (c), the nurse needs to locate the nearest artifact of type Y (defibrillator) and issues a voice command.

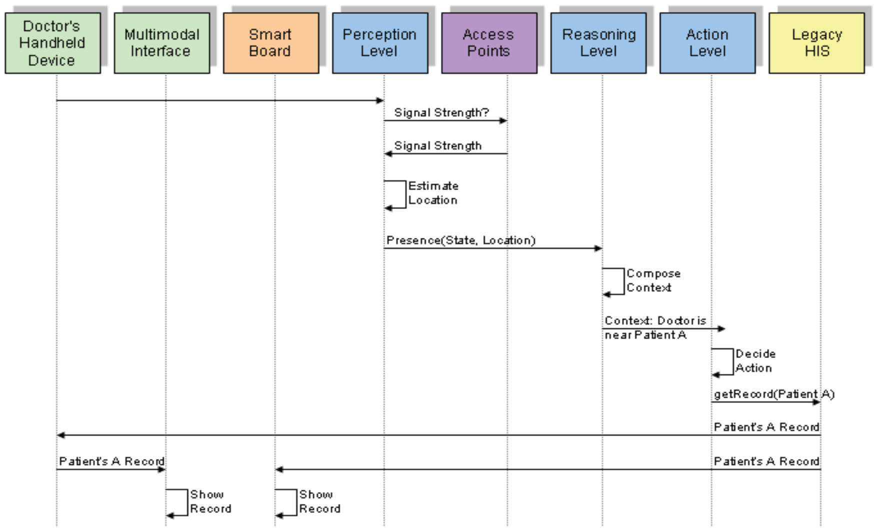

Figure 2: Message Sequence Chart for Patient’s A Case

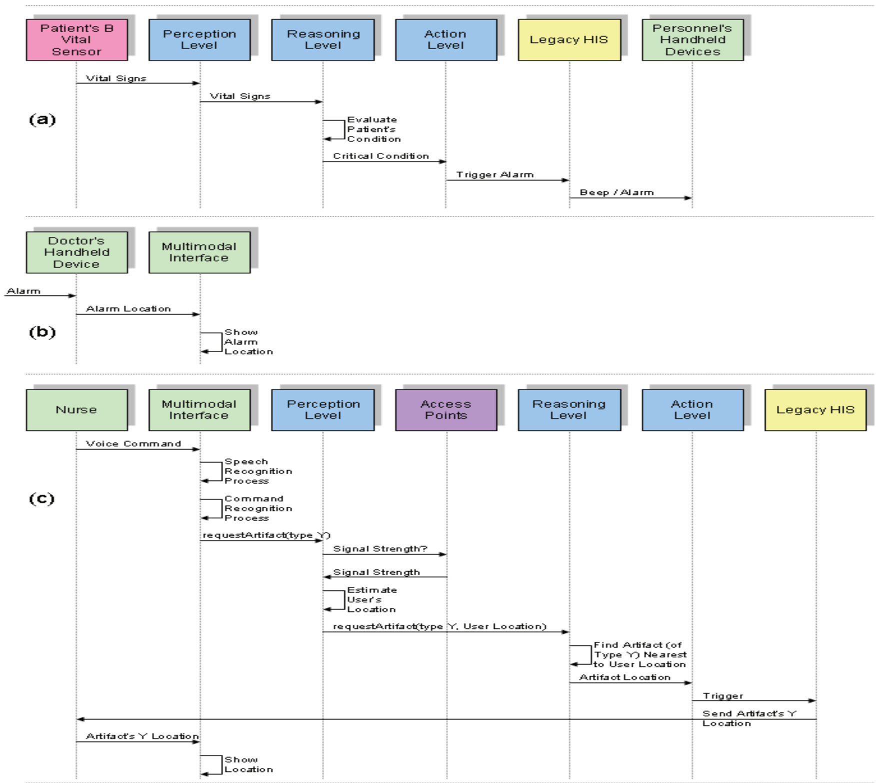

Figure 3: Message Sequence Chart for Patient's B Case – (a), (b) and (c)

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The Multimodal Interface successfully recognises this command, and an appropriate request is sent to the Reasoning Level, together with the nurse's current location. The nearest requested artifact is then located and its location is shown on the screen of the nurse's handheld device

5. Conclusions

The HIS architecture discussed in this paper incorporates additional modules and functionality, aiming at the satisfaction of the new – constantly increasing – requirements of a hospital environment. These requirements include the integration of mobility, context-awareness and multimodality to existing HISs. In particular, the context-awareness ability has the potential to give a major boost to the healthcare sector, by improving provided HIS services and adjusting them to current user needs, while multimodality is invoked to facilitate human-machine interaction. Specific challenges that have to be met in the near future include the following two issues: Firstly, it is important to find ways of persuading people for the actual benefits of the proposed advances, by overcoming their prejudice against technological breakthroughs and newly developed techniques. Secondly, the impact of electromagnetic radiation (EMR) needs to be taken into account in any relevant research effort.

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