Initial conceptual framework for Interactive system development with reflections on the ICT based public health information system (PHIS)

Shruti Sharma, Dr. Vishal Kumar

Abstract
Healthcare technology should be designed to support divergent uses in various contexts. This paper aimed at researching how a new research approach can be applied in the development of public health information system (PHIS) using ICT and its applications and how the research approach could be included in healthcare sector with ICT development. In this paper, it is revealed that the need for a new approach has been widely recognized in the field of health informatics; however, no research has been conducted to systematically and extensively support the proposed design of healthcare ICT applications. For these reasons, the development of new tools and services like SMS based services needs to be based on the needs of all stakeholders: healthcare professionals as well as patients, other citizens, and their supporting parties. Desired outcomes determine the goals for healthcare ICT design and thereby suggest that the healthcare contexts beneath the design are characterized with fairly distinct features. The user-centred design analysis described the components of context of use as presented in ISO 9241-11 standard.

Index Terms: PHIS, ICT, HTU, CTU, Development Tools, Interaction, Telemedicine

1 Introduction
The information may be used to increase the understanding of both the current practices, and the aspects of work procedures and technology applications which need to be redesigned. Without exception, an implementation of a new technology application requires changes in working practices. Therefore, it is important to realize that information about the existing context should guide the design and specification of an intended context and related changes. Today, technology has a key role in healthcare delivery and patient care. A wide variety of information systems are currently used in healthcare environments. Although currently healthcare workers are the primary users of healthcare information systems, the emerging ICT also has the capacity to empower the patients, enhance the collaboration between healthcare workers and patients, and enable the citizens them to become active participants in their healthcare. In the near future healthcare technologies are expected to reach patients’ and other citizens’ everyday lives. Regarding the changing role of healthcare ICT, there are at least two fundamental questions which need to be answered preparatory to new applications. These questions are: What are the reasons for developing and designing applications for healthcare purposes? What are the main goals these actions strive to accomplish? The previously presented analysis revealed that the healthcare context is characterized with various user groups, use environments, health-related activities and equipment’s. These findings indicate that from the design viewpoint, the healthcare context cannot be considered as a coherent entity. It seems that the differences and characteristics of various healthcare contexts have been left out of consideration in the...
health informatics literature. It is somewhat surprising that these specific characteristics of the healthcare domain, a wide variety of healthcare contexts and high degree of communication and cooperation among healthcare professionals, have generally gone unheeded, although within the past few decades’ significant effort has been paid to healthcare technology development. When designing healthcare systems and communication technologies, we at first need to understand the requirements for design deriving from the diverse contexts of use. It is essential to study these diverse contexts with regard to the related users, their tasks, equipment, and environments. Interaction and collaboration between healthcare professionals and patients play an important role in the care process as well as during single face-to-face appointments. The main reasons for conducting user-oriented studies in health informatics domain are:
a) to explore user acceptance and experiences,
b) to develop healthcare information systems and tools for healthcare professionals,
c) to research the usability of new technologies. As expected, most of the studies were conducted from healthcare workers’ viewpoint.
The currently used healthcare information systems are targeted mainly for healthcare professionals’ use. Therefore, these systems provide only limited support for collaborative actions between the patient and the healthcare professionals.

2 Background to the study
Healthcare is heading towards patient-centred actions in care delivery. The visions of patient-centred healthcare (Davis et al., 2004; Delbanco et al., 2001; Haux et al., 2002) share the idea of cooperative care, and information delivery and communication between healthcare workers, patients, and other involved parties. Today, the involvement of patients and other citizens in healthcare is a policy in many countries (Boote et al., 2002; Health Committee, 2007). Thereby, the adaptation of new healthcare information and communication technologies and applications are strongly supported. Several findings have indicated that patients and other citizens are willing to take an active role in their own health maintenance. Liederman and Morefield (2002) have found a high demand by patients to communicate electronically with their doctor. Patients have also expressed a clear need for more information about their personal health (Lähteenmäki et al., 2008). Several studies have investigated patient-physician communication and indicated positive findings: the experiences showed that both the patients and physicians found enhanced communication beneficial (Ilvonen et al., 2006; Lähteenmäki et al., 2008, Wiesenthal, 2009). Cutting-edge modern technology provides enormous possibilities for healthcare ICT development. If the patients could be given the rights to do part of the documentation themselves, self-documentation could reduce the workload of the healthcare professionals (Häyrinen et al., 2008) and provide them with rich information about the patients’ way of life and health-related habits. Because of their high rate of ownership and use, mobile phones show promise as a tool in healthcare communication technologies (Giménez-Pérez et al., 2002). Several aspects of the impact of mobile phones on personal health are self-evident: healthcare professionals and patients can reach each other more easily, discuss sensitive medical issues in privacy, and leave messages for one another (Patrick et al., 2008). In the same way, patients’ access to their own health information requires careful planning. Research about patients’ contribution to electronic medical summaries found the summaries in general practice inaccurate to a worrying extent (Ward & Innes, 2003).

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3 An Initial Conceptual Framework for Design

An initial conceptual framework, presented in Table 1, encompasses the previously described three perspectives on healthcare ICT design, and thereby introduces several important starting points for application development. In addition to the starting points that are already known and established, the framework includes themes that are not yet well understood or discussed in research literature (these questions are marked with italic font). Most of the questions are related to the third design context "ICT support for cooperative care". These viewpoints are expressed as questions in the following table (Table 1) and are to be researched further in the near future. The starting points are to ground fundamentals for user-centred design of healthcare information and communication technologies. With the following aspects in mind, the healthcare ICT development could head towards a user-centred approach in an effort to improve the quality of care, support cooperative care, and provide pleasant e-Health services for citizens.

Table 1: Framework for PHIS design with ICT

<table>
<thead>
<tr>
<th>Context 1: Healthcare professionals as ICT users in healthcare environment</th>
<th>Context 2: New eHealth services for citizens' use</th>
<th>Context 3: ICT support for cooperative care between patients and healthcare professionals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Users</td>
<td>Various healthcare professionals with medical experience and knowledge</td>
<td>“Anyone”, broad population: citizens and their supportive stakeholders, (healthcare workers)</td>
</tr>
<tr>
<td>Context of use</td>
<td>Healthcare working environment</td>
<td>“Anywhere &amp; anytime” in leisure time, probably in collaboration with other users</td>
</tr>
<tr>
<td>Relationship between designers and users</td>
<td>Users as experts (medical knowledge and current working procedures) and cooperators</td>
<td>Citizens as informants, innovators, and designers</td>
</tr>
<tr>
<td>Overall design goals in context</td>
<td>Support communication, and improve quality of care and clinical documentation provided by healthcare workers</td>
<td>Empower the citizens by means of eHealth services</td>
</tr>
</tbody>
</table>
4 Proposed modules for PHIS

Our proposed PHIS model is an integrated software having some working modules like SPMS system that will comprise a monitoring system integrated with remote data transfer using SMS. The mobile application developed with Java ME, Remote synchronization functions were added to the mobile application like getting a patient record remotely from the server. Before the data transfer, the data will be compressed using the Java library with a parity-based compression algorithm to minimize the amount of SMS messages to be sent. Utilizing the designed reliability protocol, the data will be sent to the server. A server phone will be connected to the server with the help of SMS Library functions. This will receive the messages and a desktop application will process the messages from the phone. In return, it will send an appropriate response to the data sent back to the mobile phone, either to synchronize the record IDs or relay the patient data that was requested. Only ninety-five percent of the SMS sent reach the target phone. The other five percent are either delayed or lost. Since integrity is important in the data to be sent, there is a need to incorporate a layer that ensures that the SMS containing the queries reaches the server.

The protocol tries but does not guarantee 100% that the messages will reach the server. The messages are sent in batches called sessions. Each session contains an ID and at most 10 messages, each of which containing a sequence number. A stop-and-wait protocol would be implemented on the sessions, that is, the next session is not started until the current session completes.

Figure 1: Basic model of SMS based Patient Monitoring System
The overall platform has two main components: a central server for SMS receiving (Central Receiving Unit, CRU) and the remote sending data collection and transmitting units (Home Transmitting Unit, HTU). A general scheme of the platform is depicted in figure 1. The data collected remotely are transmitted by the HTU using a single SMS message, each day, to the CRU where are stored. The CRU, which is located in a clinical centre, acts also as a server for the database housing and for the users applications (data display, trend visualizations, and alarms). The platform is fully automated: no specific action is required to the patient for transmitting the data, nor from the clinicians for receiving and using them. To increase the robustness of the system, in this project, in case of lacked or uncorrected reception of the measures, the clinical centre may interact, directly or through the support of volunteers involved in the plan, with the patients in order to implement opportune corrective actions. The CRU consists of a laptop PC connected to a GSM modem (TC65, Siemens, Germany). The PC routinely interrogates the modem to look for new SMS messages sent from the HTUs. SMS messages are then downloaded, decoded and then cancelled from the modem memory. The communication between the PC and the GSM modem is implemented using the AT commands. A Java Sun Study 1.4.1 application decodes the messages and stores the data on the specific database, in a Microsoft Access database. The database consists of two tables: the first one concern the personal and medical data of the patient, and it is filled by the doctors during the registration procedure; in the second table the measures received through the messages are stored. The application also sends alerts and alarms in case of missing SMS or corrupted SMS content. The HTU is an embedded system able to retrieve data using the serial RS232 connection from up to 4 medical devices. This step counter is based on a wearable device with a force sensing resistor and a belt; it is affixed at the calf gastrocnemius level for the monitoring of the muscular expansion correlated to the gait. The GSM modem provides the wireless transmission of the data; it is also used as real time clock for the embedded system. The core of the embedded system is a microcontroller (18F8722, Microchips, USA) which manages the communication with the GSM modem, and retrieves the data from the meters of pressure, glycaemia and physical activity. A conditioning circuit is also necessary to multiplex and transceiver the serial data. Attention has been paid to the safety of the overall HTU. The power supply of the GSM modem and of the conditioning electronics has been obtained using a medical wall transformer compliant with the EN60601 harmonized standard; the blood pressure meter, the blood glucose meter and the physical activity monitor are battery operated. The microcontroller firmware was developed using the MPLAB IDE, in C. At the start-up (HTU connected to the mains), the system performs an initial check for the GSM signal quality as well as the local GSM service availability. A feedback led indicates that a valid connection to the operator has been established. The patients are instructed to place the HTU following this led indication. Then the HTU waits for either a connection to the blood glucose meter or to interrogate the GEMU and the blood pressure meter. In this module of PHIS a platform for the follow-up of post-acute event patients is described. This platform is based on the self-measurement and on the automatic transmission of blood glucose, blood pressure and physical activity, using the GSM network. The main peculiarity of the proposed platform relies on the choice of the SMS service to automatically transmit the medical data, without any action required to the patient. The choice of the SMS service through the GSM technology well fits the

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transmission of blood pressure, blood glucose and a daily activity parameter, since no particular bandwidth, transfer rate or memory amount are required.

**5 Framework of Telemedicine Module that integrates medical sensors to allow remote monitoring of patient**

People with special medical monitoring needs can, these days, be sent home and remotely monitored through the use of data logging medical sensors and a transmission base-station. While this can improve quality of life by allowing the patient to spend most of their time at home, most current technologies rely on hardwired landline technology or expensive mobile data transmissions to transmit data to a medical facility. The aim of this proposed module is to investigate and develop an approach to increase the freedom of a monitored patient and decrease costs by utilizing mobile technologies and SMS messaging to transmit data from patient to medical centres. To this end, we evaluated the capabilities of SMS and propose a generic communications protocol which can work within the constraints of the SMS format, but provide the necessary redundancy and robustness to be used for the transmission of non-critical medical telemetry from data logging medical sensors.

Figure 2: Interconnection of different modules

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The system supports both scheduled transmission and polled requests from a remote base station at the medical centre. Alternatively, a message may be triggered by an adverse event which the base station is configured to look for. As it is impossible for a controller at hospital or relatives to make any sense or analyse a constant flow of patient data, the data should be forwarded to the hospital to be analysed only in critical cases, for example when the data diverge from the patient’s history. It is important to note that, while the patient base station may send data regularly to the medical centre, the communication process is bi-directional. The medical centre may send a request to the patient’s local device, and the patient base station will respond to that request (a poll/response message pair). The protocol must therefore possess the capability of servicing a number of types of communication, including polls and responses, and scheduled communications. However, in addition to data messages, we should maintain the ability to control, configure and diagnose the remote system. The very concept of telemetry defines that we have remote devices measuring values. It may be necessary to turn on or off specific sensors, or change the frequency of data transmissions from the patient to the medical centre.

5.1 System Component
This component diagram of Telemedicine module represents the components of the Telemedicine module applications. Doctor’s component represents the doctor’s activities of application. This component also contact with the external email server for receiving emails. The method read_emails() request the email from the email pop3 server and give it back to doctors component where the doctor’s component receive all emails and separate patient’s images and text descriptions and save it into databases. This component also need patients records so that the doctors can be able to treat their patients.
patients after viewing and analysing their previous history records, fetch_record() will fetch the records from database to the doctors components by using web services.

![Flow chart of the microcontroller operations](image)

**Figure 4: Flow chart of the microcontroller operations**

5.2 SMS-Based Telemetry Data Transmission Protocol

While the protocol defined in this section is ostensibly generic, the chosen application for our communications protocol is to send medical telemetry from a patient to the healthcare providers. For our protocol to have a purpose there must be an appropriate implementation of a telemetry system and

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any such system should contain the following components integrated to address the following requirements:

- Allow the gathering of data from patient-based sensors.
- Provide a mechanism for the collection and formatting of the data into appropriate protocol messages.
- Allow for the transmission of the data to a remote monitoring site.
- Allow for the receipt and appropriate processing of the data at some remote point.

Moreover, we must consider overall capacity, the robustness and reliability of the medium, the availability of the carrier mechanism, and the tolerance of the system for faults and corruption. Ultimately, all of these factors must be considered in any system aiming to use SMS for the purposes of data transmission.

5.3 Structure of Protocol

The SMS communications protocol fits within the confines of a single SMS message by using a structured header and an extensible user data payload. The user data payload may spread across the capacity of a concatenated SMS. The protocol is comprised of three main components.

The first element in the protocol is the SMS packet itself. Each SMS message is encapsulated in a packet called a PDU. The protocol is implemented in field 12 of the PDU, the user data segment. While we must be aware of the PDU’s structure and data, the PDU is pre-defined and is outside the scope of the protocol design, other than as a data source. Our protocol is not responsible for implementing the PDU packet, as this is done by the mobile device.

The second and third elements of the protocol can be considered to be the true protocol, and these sections are encoded in the PDU’s user data segment as the “SMS message” that we are sending. The second element is the protocol header. The protocol header contains consistent, structured information for any protocol message. This information is used for administration and control purposes (for example, identifying the message type, specifying the sender device ID, destination device ID, and so on). The header is a fixed length component of the protocol message, and is always located in the first SMS message of any protocol transmission (whether single SMS or concatenated SMS).

The third component of the protocol is the user data payload. This is a variable length field, containing application specific information based on the current use of the message. The data segment is used in an application specific way. For example, in medical telemetry, the user data segment may contain 100 heart rate samples for a patient, or an aggregated set of values from multiple sensors, or sensor readings for different patients all monitored at the same site.

<table>
<thead>
<tr>
<th>Table 2: Three main components of protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PDU FIELDS (1-11)</strong></td>
</tr>
<tr>
<td><strong>PROTOCOL HEADER</strong> (Fixed Length)</td>
</tr>
</tbody>
</table>

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Table 3: Information Contain by the Protocol Header

<table>
<thead>
<tr>
<th>Information Contain by the Protocol Header</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronization Marker</td>
<td>Start of protocol message</td>
</tr>
<tr>
<td>Message Format and Protocol ID</td>
<td></td>
</tr>
<tr>
<td>Message Structure</td>
<td>Multipart or Single Message</td>
</tr>
<tr>
<td>Application ID</td>
<td>Protocol user information</td>
</tr>
<tr>
<td>Sender Device ID</td>
<td>Unique application ID of the sender</td>
</tr>
<tr>
<td>Recipient Device ID</td>
<td>Unique application ID of the recipient</td>
</tr>
<tr>
<td>Message ID</td>
<td>Sequential ID of this message</td>
</tr>
<tr>
<td>Generation Timestamp</td>
<td>When was the message sent by the remote device</td>
</tr>
<tr>
<td>Validity Period</td>
<td>How long should the message remain valid for</td>
</tr>
<tr>
<td>Receipt Required Flags</td>
<td>Is a receipt required, and if so, what type of receipt?</td>
</tr>
<tr>
<td>Control Octets</td>
<td>Containing control messages for the remote device</td>
</tr>
<tr>
<td>User Data Segment Length</td>
<td>How many octets of user data to follow</td>
</tr>
<tr>
<td>User Data Segment Encryption ID</td>
<td>Is the user data encrypted, and by what mechanism</td>
</tr>
<tr>
<td>Validity Period</td>
<td>How long should the message remain valid for</td>
</tr>
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<td>Is the user data encrypted, and by what mechanism</td>
</tr>
<tr>
<td>Header Checksum</td>
<td>Checksum for header data only</td>
</tr>
<tr>
<td>Message Checksum</td>
<td>Checksum for entire message, including the other checksums</td>
</tr>
<tr>
<td>User Data Segment Checksum</td>
<td>Checksum for user data only</td>
</tr>
</tbody>
</table>

6 Interoperability through Web Services
We used different web services in Telemedicine application, these web services are allowing to communicate and interchange the data between similar or dissimilar telemedicine systems. Simple Object Access Protocol (SOAP) has been used as an XML based message binding protocol, the

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primary protocols of SOAP are HTTP and HTTPS, and POP3 is used for communicating with email server. Here SOAP defines how messages can be well ordered and processed by system that facilitates cross platform independency in different programming language or platform, and thus interoperability between applications written in different programming languages and running on different operating systems can be achieved.

Interoperability, that is ultimately required now a days can be achieved in our system by adopting the services oriented architecture. Interoperability is one of the important achievements that are gained from implementing those web services according to the services oriented interoperability. It is difficult to integrate two or more dissimilar system, but a web services layer between application and client can significantly remove these difficu
ties. Figure 4 shows applications communicate through XML based SOAP message over HTTP and they communicate by interpreting WSDL, through this service, dissimilar Tele-WoundTM application can communicate through SOAP based architecture by using web services. All above services are the part of Tele-Wound TM in order to support all other telemedicine applications that are wonder to be connected to different telemedicine application.

Figure 4: Telewound applications in different User

The communication between the services can involve data interchange. Now, the technology of Web services built on existing and emerging standards such as HTTP, Extensible Markup Language (XML), Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL) and Universal Description, Discovery and Integration (UDDI). Designing an effective architecture especially for the problems seems like a promising solution.

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7 Analysis & Findings

- The initial conceptual framework for user-centered design of healthcare ICT summons up the author’s knowledge and understanding of user-centered design theories and practices, and the analysis and findings of user-oriented research in the health informatics domain. The user-centered framework for healthcare ICT development aims at increasing the understanding of how a user-centered design approach can be applied to address the current challenges of ICT development.

- The framework describes the three distinct contexts of healthcare ICT design and discusses the design fundamentals, and thereby is to provide background and starting points for user-centered healthcare ICT design.

- It seems that the available user-centered design (UCD) methods and earlier experiences in system development in other industries can be utilized to support the design in the first and in the second context (Healthcare professionals as ICT users in healthcare environment and e-Health and m-Health services for citizens’ use). However, the third one (ICT support for cooperative care) challenges the currently applied UCD methods and research approaches.

- The presented framework preliminary and therefore needs to be evaluated and developed further. In the near future the framework will be applied in case studies that will be conducted in the field of healthcare ICT development. The practical studies are expected to provide us with a better understanding of the special characteristics of the development domain.

- The intent is to gather experiences and findings of the UCD approach and with the help of those evaluate and develop the described framework further. The following tasks are to serve as a guide through the further framework analysis and the planning of practical research cases.

- However, within the health informatics domain, conventional UCD methods have been criticized as being insufficient for safety-critical system design. It seems that the traditional methods of UCD, characterized with face-to-face communication and intensive data capturing sessions, might as such be challenging to apply in the healthcare research field. The dictation case study and open interaction methodology approach have already provided some important experiences on applying UCD methods in the health informatics field.

8 Conclusions

The development of healthcare ICT applications seems to follow the traditions of system-centered design. In the healthcare domain, information technology has been adapted in an effort to increase the effectiveness of care and processes. The relatively small group of recently conducted studies indicates that the area of user-centered healthcare ICT research is beginning to gain importance in both healthcare ICT development and in the usability research field. The selected articles illustrated a variety of qualitative and quantitative research approaches on healthcare ICT use and development.
and hence I did find the selected group representative enough for the purposes of the descriptive review. The relevance of the presented research In conclusion, I found my work about a user-centered design approach on healthcare ICT development valuable for several reasons. First, the need for considering user perspectives in healthcare ICT development has been established both in academic research forums and in public discussions. Therefore, the research area seems to have a high practical relevance. Second, the academic research on the health informatics field is lacking commonly established models, theoretical approaches, and practical procedures for user-oriented research.

8 References


