Remote Monitoring and Discrete Data Capture of Joint Pain and other Parameters via the NokiaN900 Device: Enhancing Patient/Physician Interaction

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Abstract

The new generation cellular phones have multi-functional capabilities such as imaging, video, audio recording and messaging in addition to providing internet access. In this paper we present an innovative application in the field of remote health monitoring using N900 Nokia tablet, which will serve as a communicating device between the patient and healthcare providers like doctors and nurses. Patients with arthritis require regular objective monitoring of their affected joints by healthcare providers requiring that patients report their subjective pain levels to their physicians. The application has a patient's module allowing the patient to select their pain level on a sliding scale from a graphical representation of various human joints and send this as an SMS to the doctor. The healthcare providers can review the pain level, save it to a database and make an informed decision about possible recommendations based on the data received via SMS. The doctor's module allows the doctor to capture all the attributes of an affected joint discretely using the graphical representation of the joints and associated dialog boxes. The complete Graphical User Interface (GUI) development and data base design are discussed and test cases are presented. We plan to evaluate the application in a real healthcare environment for usability, its role in improving patient satisfaction and health outcomes.

Index Terms: Human body joint pain, Remote Monitoring, Nokia N900, Health Outcomes.

I. Introduction

Cell phones have emerged as the most essential and favored tools for communication by humans all over the world. Though they were produced primarily to assist in communication between individuals who are geographically apart and on the move, in recent times they have become multifunctional devices. The rapid developments in the embedded designs, fast CPUs and newer operating systems have created immense opportunities for rapid application development besides audio communications. Today's mobile devices are able to perform imaging, video streaming, and messaging while accessing a wide variety of data and information over the Internet.

With such powerful computational power, modern cell phones are ready to take on applications that were never before thought of in challenging areas such as healthcare, agriculture and education. Particularly in healthcare, timely communication is critical and lack of it could mean pain and suffering or even life and death. Mobile devices have a specific role to play in healthcare and we can develop wide variety of applications which may augment patient's access to highly trained healthcare providers, save time, effort, commute and resources and thus impact morbidity and mortality. They may also influence healthcare affordability and more importantly modify patient's attitude and behavior towards chronic illnesses. and. Specifically, patients need to be empowered with better mobile applications that change the way the medical care is delivered to them. Towards this end, this work presents an innovative application that helps patients and doctors capture the status of pain and other parameters at specific joints and communicate remotely via SMS. There have been efforts in the past to utilize touch screen computers to manage chronic arthritides [1-4], but to the best of our knowledge, this is the first time a smartphone application has been developed to capture and communicate joint pain and other joint parameters. This paper presents the design methodology of GUI and database and application case studies on the NOKIA N900 device.

This paper is organized as follows; Section II presents design of GUI and workflow. In Section III we discuss architecture while Section IV present details on implementation. Testing and conclusion are given in Section V and VI respectively.

II. DESIGN

The specific aim of the design workflow is to facilitate interaction between patients with joint pain and the doctor (Rheumatologist). This is achieved by creating a graphical representation of the human joint system (Fig. 1) called "Homunculus" on a touch screen cell phone. The Homunculus is a term used, generally, in various fields of study to refer to any representation of a human being. Homunculus about joints is a pictorial depiction regularly used by rheumatologists to capture information about both axial and peripheral joints. The graphical description of the human joint system is developed using Qt for N900 devices. The joints Homunculus was downloaded from [5].

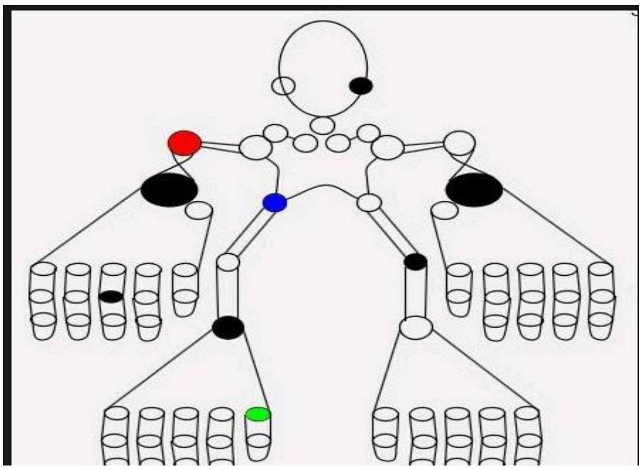

Fig. 1. Homunculus of the human joint system

In this section we present the processes involved in developing Homunculus on the N900 device. Each joint represented is a "hot spot" and is associated with parameters which depict subjective and objective assessments of pain, swelling, range of movement etc. As many variables are captured, there is a need to create a database to store the captured data. The design involves two modules:

1. Patient assessment module
2. Doctor's assessment module

A. Patient Assessment Module

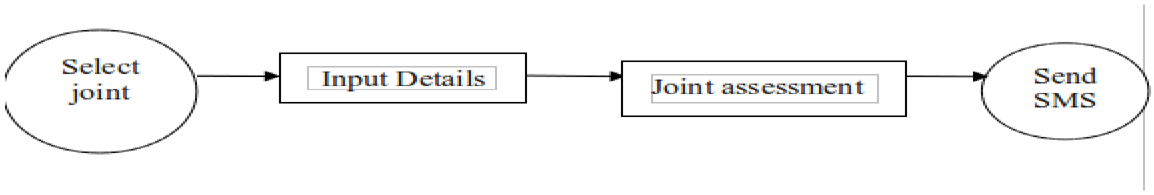

Fig. 2. Patient Assessment Module

Fig. 2 shows the process involved in generating a self-assessment of the patient's joint pain and then sending an SMS to doctor's phone number. The design should capture the

- Patient ID
- Patient Name
- Doctors Phone Number

The patient then provides assessment of respective joint pain by choosing the sliding bar which is provided on the GUI.

Sequence Diagram:

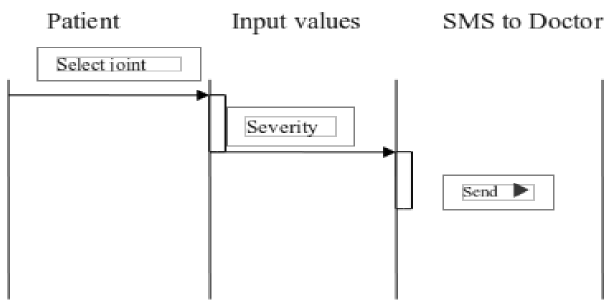

Fig. 3. Sequence diagram

Fig. 3 shows the sequence of steps followed in acquiring the data from patient module. Patient needs to select the joint and give the inputs likes severity and then sends SMS to doctor.

B. Doctor's Assessment Module

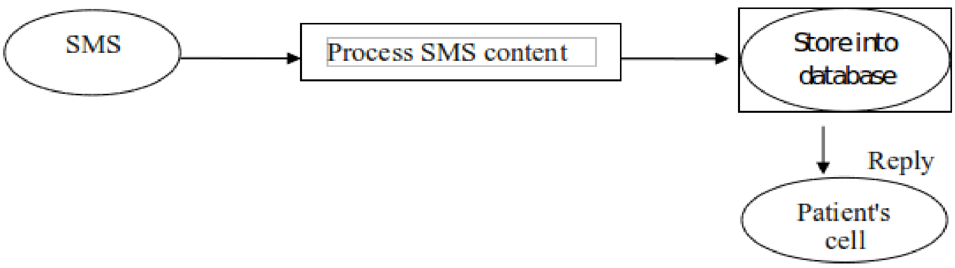

Fig. 4. SMS processing

Fig. 4 shows the process involved in receiving an SMS from the patient and capturing the patient's joint evaluation findings. He doctor can process the SMS if it is of standard format, save it to the database and suggest corrective actions in a return SMS to the patient. The second workflow involves evaluating the patient's affected joints and capturing and storing the attributes discretely.

III. ARCHITECTURE OF THE PROPOSED SYSTEM

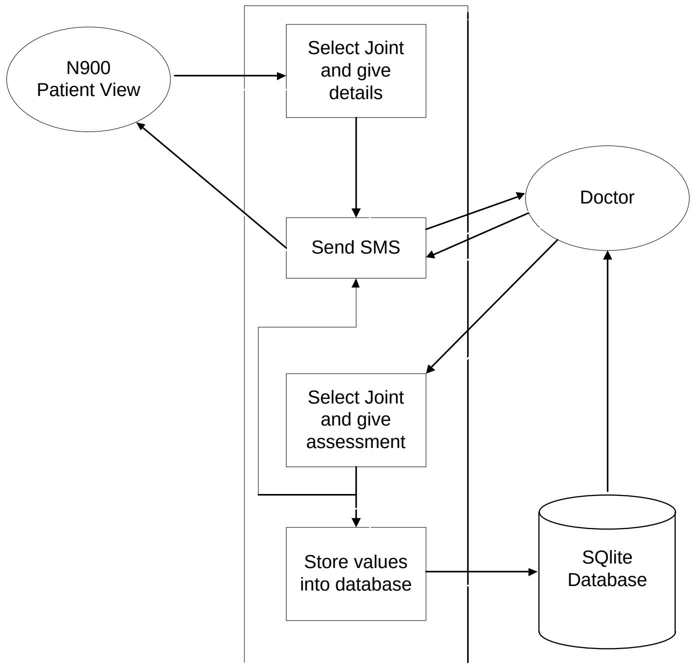

Fig. 5. Architecture of the proposed system

The Fig. 5 shows the overall architecture of the proposed system. It consists of the patient's view, doctor's view and database.

The SQlite database is used in the doctor's mobile phone to store patient's details for future reference.

The 'send SMS' module is used to send the SMSs from the patient to the doctor by selecting the appropriate joint and pain scores and then to send SMSs from the doctor to patient of any corrective measures.

IV. IMPLEMENTATION

The proposed system is implemented using Qt for front end GUI on mobile devices and SQlite for database storage and retrieval purposes [6-7]. The software development on Patient View and the structure of database tables for storing details of patient, user interface and SMS modules is presented in detail in the following section.

A. Doctors View

The doctor can accomplish two important workflows in doctor's view. He selects a joint and assesses the values passed by the patient and processes it. The processed values will be stored in the database.

The second important workflow is capturing attributes about affected joints after objective evaluation of the patient's joints. The doctor chooses the affected joints from the homunculus and a dialog box provides a form to capture all the variables about the joint. For example, for temperomandibular joint, he has to capture data about tenderness, deviation to the right or left and crepitus, whereas for a peripheral joint like the metacarpophalangeal joint, he has to capture data about tenderness, swelling and any Limited Range of Movement (LROM). Thus, the data variables can be different depending on the joints. For example, there is no “swelling” for hip joint as it is deep seated and cannot be assessed for swelling. Further, each variable will also have grading in the form of 1+, 2+, 3+ etc. The grading also depends on the joints and some are not graded. For example, there is no grading for deviation of temperomandibular joints. The advantage of grading is that the doctor can quantify the response to his treatment intervention over time, say from swelling of 4+ to 1+ over 3 months with treatment. This helps the doctor fine tune his management, help achieve the treatment goals and is anticipated to improve patient satisfaction and health outcomes.

The Doctor’s View consists of two tasks.

1 Input details

2 Database update

1) Input details:

This task includes getting input details like the patient’s id, name and phone number. As mentioned above, the doctor selects the joints, makes an assessment and the captured values are then stored into the database.

2) Database update:

This task includes updating the patient’s assessment values of a patient to the database. The stored values can be retrieved by the doctor for any future reference. Also, in anticipation of cell phone database growth with increased number of patients and interaction instances, plans are in place to download stored cell phone data into an external database.

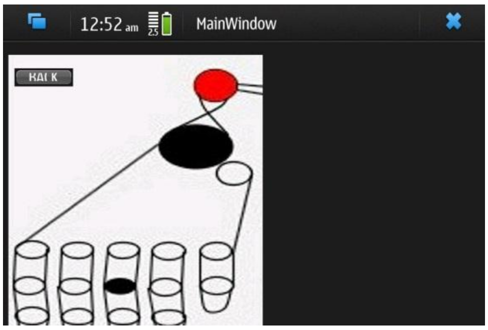

Fig. 6. Hand joints

Fig.6 shows how the user selects hand joints for assessment. After selecting a joint, the doctor can enter data values based on his objective assessment and also choose the severity using grading values.

Fig. 7 displays the various attributes about an affected joint. The doctor needs to select from the available options like swelling, tenderness, Limited Range of Movement etc. After selecting an attribute, depending on the joint, a dialog box appears and the doctor needs to choose from grading values like 1+, 2+ etc. or adjust the slider to give severity value. This process continues until attributes about all the affected joints are captured.

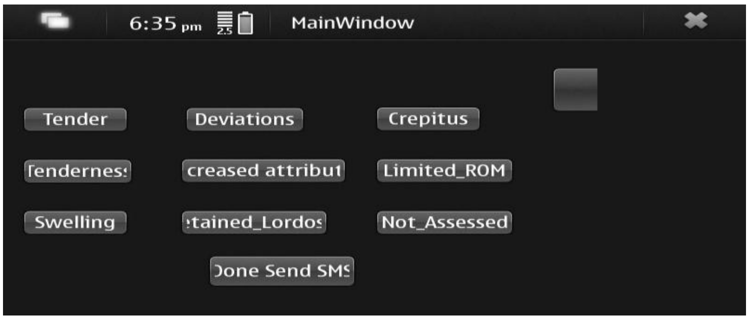

Fig. 7. Option for selection

Fig. 8. Captured data received as SMS

Fig. 8 represents the values captured for the right metacarpophalangeal joint for pain, swelling, tenderness and LROM attributes and their grading levels. After the above process the doctor selects the Send button to store the values in to the database.

B. Patient View

In this module, the patient selects the painful joints on the homunculus, provided as GUI on cell phone touch screen, uses the sliding scale to represent the pain level and sends SMS to the doctor. The data also gets stored in the local database. The process involves three stages such as

1. Input details
2. SMS module
3. Database update

1) Input details:

This task includes getting input details like patient id, name, and doctor's phone number. Patient selects the joint and then pain severity level on a sliding scale.

2) SMS module:

The task of SMS module is to get the information given by patient and send it to the doctor in the form of an SMS. Since the SMSs need to follow a standard format, the data generated by the patient is structured into a standard format and an SMS will be sent to the doctor.

3) Database Update:

The SMS sent by the patient is received by the doctor's cell phone. The doctor assesses the data, can store the values into the database and also send any therapeutic suggestions as an SMS reply to the concerned patient. A set of such stored pain data values can be used to trend pain levels over time.

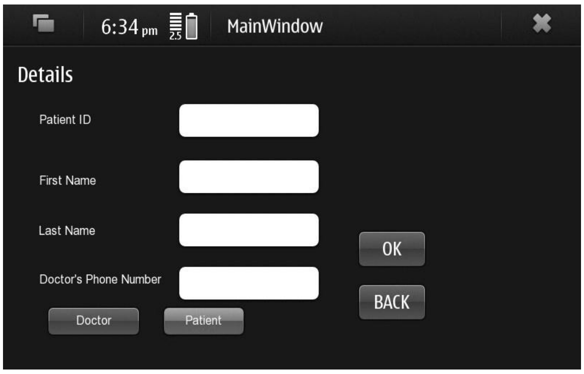

Fig. 9. Patient data screen

Fig. 9 shows the data the patient needs to enter. Some of the patient's details like name and phone number are mandatory and a dialog message highlights the missing details. Once all the required details are entered, the patient presses the OK button to store the data.

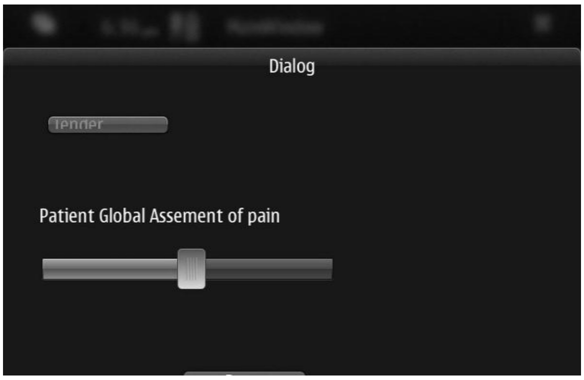

Fig. 10. Pain assesing slide bar

Fig. 10 displays the sliding scale for pain levels to be selected by patient. After choosing a level, an SMS is sent to the doctor about the patient's global assessment of pain.

C. SMS module

The SMS module contains the cell phone number and the message text. In the patient's view window on the cell phone, the message text contains the severity values which have been selected by the patient on the chosen joint and sent an SMS.

V. TESTING

The application was tested with potential users to demonstrate how it enables the doctor to assess and provide feedback to the patient. Table 1 indicates the typical values of severity of specific joints of different patients. This shows that the values generated from the GUI of the homunculus are translated into measurable data and are stored in the database server. This database grows with the inclusion of more patients and repeated interactions between the doctor and patient. Table 2 indicates the data progression of one specific patient. This is useful in assessing the disease progression. Table 3 shows sample patient data.

It can be seen from the tables that the software modules developed for the N900 cell phone have the capability to capture joint pain data, sending them as SMS to the doctor and the doctor in turn is able to advise the patient as appropriate via SMS. Further, the data stored is available for generating graphs and trending disease progression.

Table I shows the parameter values of patients generated from sliding bar for a typical joint problem.

Table II shows accumulated data of a patient on a specific joint problem.

Typical patient entry data is shown in Table III.

TABLE I
PATIENT'S DATA

Patient id	Joint id	Tender	Dt right	Dt Left	Crepitus	Tenderness	Dec_ exten	Dec_ Flex
101	12	5	7	7	8	7	8	7
102	9	8	8	7	6	8	7	8
103	7	8	7	8	8	6	7	7
104	6	7	7	6	6	7	6	6
105	8	8	7	8	8	7	7	9
Dlf Right	Dlf left	Dlr right	Dlr left		Dec_all_ranges	Lim_range_ move	Retained_ Lordosis	Swelling
7	8	6	5		4	7	4	6
6	7	5	7		5	8	7	6
8	6	7	7		8	7	6	5
6	7	8	7		5	4	3	3
7	8	7	8		8	8	7	6
Tess_1+	Tness_2+	Tness_3+	Tness_4+		S_1+	S_2+	S_3+	S_4+
7	0	0	0		0	0	7	0
0	8	0	0		0	7	0	0
0	0	8	0		6	0	0	0
6	0	0	0		0	8	0	0
9	0	0	0		0	0	0	7
Limited_ROM _1plus		Limited_ROM _1plus			Limited_ROM _1plus	Limited_ROM _1plus	Not_Assessed	
8		0			0	0	1	
7		0			0	0	3	
0		6			0	0	1	
0		0			0	8	2	
0		7			0	0	2	

VI. CONCLUSION AND FUTURE WORK

We have presented an innovative application that highlights the Nokia N900 cell phone’s ability to capture the patient's subjective assessment of severity of joint pain and the doctor's objective evaluation of the patient’s affected joints. Further, they both can communicate the data using SMS and store the values in a database. It was evaluated using few test cases and results provided in tables. This pilot study clearly showcases the usefulness of mobile devices in managing health problems remotely and over time. We continue to add functions and features to the application and conduct usability testing. We are researching further to develop robust software plug-ins for effective management and incorporating controlled vocabulary to improve interoperability. Future plans are to conduct studies in a real healthcare environment and to evaluate the application's role in transforming healthcare delivery and improving outcomes.

TABLE II
PATIENT'S DATA STORED IN DATABASE

Patient id	Joint id	Date	Ten der	Dt right	Dt left	Crepitus	Tender ness	Dec_ exten	Dec_ Flex
101	12	12-02-	5	7	7	8	7	8	7
101	12	13-02-	5	8	8	7	7	8	6
101	12	14-02-	4	7	6	6	6	5	4
101	12	15-02-	3	4	3	3	2	1	2
101	12	16-02-	2	2	2	2	1	1	1

Dlf Right	Dlf left	Dlr Right	Dlr left	Dec_all_ranges	Lim_range_ move	Retained_ Lordosis	Swelling
7	8	6	5	4	7	4	6
6	8	6	4	4	7	3	5
5	6	4	4	4	5	4	4
4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3

Tess_1+	Tness_2+	Tness_3+	Tness_4+	S_1+	S_2+	S_3+	S_4+
7	0	0	0	0	0	7	0
6	0	0	0	0	0	7	0
6	0	0	0	0	0	6	0
6	0	0	0	0	0	6	0
4	0	0	0	0	0	5	0

L_ROM	L_ROM	L_ROM	L_ROM	Not_Assessed	Dev_to_the_	Dev_to_the
8	0	0	0	1	6	6
7	0	0	0	1	5	5
6	0	0	0	1	5	5
5	0	0	0	1	6	6
5	0	0	0	1	6	5

TABLE III
PATIENT'S DETAILS STORED IN DATABASE

Patient id (primary key)	First name	Last name	Phone number
101	shiv	Prakash	9945099450
102	prakash	SP	9009009101
103	Prashanth	Bhat	9738553865
104	Anurag	B	9343297599
105	Charan	Pai	9480104627

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