Master's Thesis

Mobile Communication Technology for the Assessment of Postoperative Pain after Periodontal Surgery

By

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Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Wireless Communication

in the
Faculty of Engineering, LTH
Department of Electrical and Information Technology
Lund University, Sweden.

January, 2013

Abstract

Mobile communication systems have become one of the most important areas in the field of telecommunications and it is expected that within the next decade a considerable portion of our activities will become partially or completely wireless. The aim of this work is to develop a new approach to pain investigation in dental care field so that prompt solution can be offered to dental patients using mobile communication technology. A quite efficient and reliable mechanism can be developed to look for postoperative pain investigation vis-à-vis the previous and conventional paper based VAS-Visual Analogue Scale procedure that has been used in all these years. VAS is a reliable information acquiring technique but it is not often a prompt process and sometimes patients fail to follow it up carefully. Therefore, switching to mobile communication technology would be most appropriate and cost effective; it will help the dental professionals to evade formal paper based interviews with patients. Instead of traditional paper based Pain Investigation procedure, Mobile Phone communication system will be used and communication will be through SMS based application including to monitor the post dental healing of the patients. In this work I have suggested to use mobile telephony and SMS-Short Message Service technology to facilitate the management of pain investigations.

Once the patient is hospitalized and the surgery is performed, the patient can then be at home but connected with dental professionals by Mobile Phone with specific timetable and instructions to follow and thus, to remain connected at all times or whenever it is necessary. This mobile connectivity between the dental professionals in the hospital and the patient will save time, help the sick to get prompt support very efficiently and effectively.

Acknowledgement

First and foremost, I praise and thank the almighty, from the depth of our hearts, who has been an unfailing source of strength, comfort and inspiration in the completion of this work.

I express my respectful and sincere gratitude to my supervisor **Kaan Bür, PhD** for his invaluable guidance, encouragement, criticism and suggestion for each and every state to work with this thesis.

I also express sincere gratitude to **Jens A Andersson**, Lecturer, Dept. of Electrical Engineering, Lund University, Sweden and **Stefan Rüdiger,** Specialist Dental Care Centre, Public Dental Health Service, Malmö, Sweden, for their invaluable guidance.

Last but not least I pay sincere love and acknowledgement my family members, friends who have gifted their energy and efforts in making the thesis work successfully.

GOLAM KIBRIA SHAMIM

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List of the Acronyms

ADO	ActiveX Data Object
API	Application Programming Interface
BSC	Base Station Controllers
BSS	Base Station System
BTS	Base Transceiver Stations
CBS	Cell Broadcast Service
CDMA	Code Division Multiple Access
CLDC	Connected Limited Device Configuration
CLI	Common Language Infrastructure
CLR	Common Language Runtime
EDGE	Enhanced Data rates for GSM Evolution
GCF	Generic Connection Framework
GMSC	Gateway Mobile Switching Center
GSM	Global System for Mobile
GPRS	General packet radio service
HLR	Home Location Register
HSDPA	High Speed Downlink Packet Access
HSUPA	High Speed Uplink Packet Access
IDE	Integrated Development Environment
IL	Intermediate Language
IO	Input Output
IP	Internet Protocol
JVM	Java Virtual Machine
MIDP	Mobile Information Device Profile
MSC	Mobile Switching Center
OLEDB	Object Linking Embedded Data Base
PDA	Personal Digital Assistant
SMC	Short Message Center
SME	Short Message Entity
SMS	Short Message Service

SQL	Structure Query Language
TCP	Transport Control Protocol
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications System
VLR	Visitor Location Register
VAS	Visual Analog Scale
WAP	Wireless Application Protocol
WCDMA	Wideband Code Division Multiple Access
WMA	Wireless Messaging API

This thesis is dedicated to my parents and my wife.

Chapter 1

Introduction

The purpose of this thesis is to build a conceptual design of Mobile Communication system which provides a method for collecting patient's post-operative pain and discomfort data for a hospital database. We can divide this design task into two sub problems. The first problem is how will the system get the patient's pain and discomfort data. The next problem is how to store these data into database.

1.1 Background and purpose

Many ways have been adopted to communicate with the patient's post-surgery to get their feedback to know about their prevailing condition. These include paper based Visual Analogue Scale-VAS, telephonic interviews, emails etc. The paper based VAS is an established routine for evaluation of pain by ticking on a horizontal line. The left end of the line represents "no pain at all" and the right end represents "unbearable pain". It can be difficult for the patient to keep track of papers, schedule and timetable when the pain level is really high. My goal is instead of using classical ways of communicating with patients, to use a mobile communication technology, more specifically a SMS-Short Message Service System to assist investigations.

1.2 Participation

SMS application is using in Public Dental Health Service in Malmö, Sweden. Patients have periodontal disease and they are interested to undergo treatment. After the surgery, patient uses a cellular phone to provide feedback when he/she is being asked to provide his/her assessment of pain and discomfort at an individual timetable. We agree on the times of day that suits.

1.3 Method

After surgery, the computer program automatically sends text messages as notification to the patient's mobile phone according to the schedule in specific time point. Usually, SMS schedule is to set time point from first hour after surgery to every hour during first 12 postoperative hours then once at next 24 hours, 48 hours and 1st and 2nd week. The patient responds their pain and discomfort level by using a slider values between 0 and 100. Digit 0 stands is no pain and no discomfort at all while digit 100 stands for unbearable pain and substantial discomfort.

1.4 Data and privacy

Patient's answers regarding pain and discomfort value are considered confidential. Thus, we prevent an unauthorized access to data. Personal data is handled in accordance with the Data Protection Act. Collected data are handled and analyzed by the researcher who is responsible to take care of these data. Data cannot be traced by any unauthorized person. The traditional way of using the VAS values to get the feedback of the people getting surgery was rather more complicated and cumbersome and less reliable. There was no mechanism to if the patient actually filled out the scale at the designated time. That is why SMS based technology is used to get credible information about the patients.

1.5 Structure of the Thesis

Chapter 2 describes several related works using mobile communication system to collect healthcare data. There is a variety of proposals explaining how to build these systems.

Chapter 3 presents the problem description, our proposal solution and the evolution of proposed model. I briefly described on system architecture and procedure of sending and receiving SMS by the system.

Chapter 4 describes details on implementation and development environment and its core components of both mobile application and SMS server application. I have also described the user interface on mobile application and SMS server application.

Chapter 5 shows the test and result of statistical data on patient feedback.

Chapter 6 discusses conclusion and the future work of the thesis.

Chapter 2

Background and Related Works

I have studied several related works using mobile communication system to collect data. There is a variety of proposals in these works to describing how to build the systems. These proposals have different levels of implementation, performance and certain limitations. In this chapter, I have explained the related literature on mobile communication system that attempt to provide newer opportunities to health care organization.

2.1 Generic information system using SMS gateway

Saleem M. and Kyung-Goo Doh [1] have proposed a prototype of building an SMS application on Mobile Electronic Commerce. This prototype is used to frequently update information of billing system. In this method, user will send an SMS through mobile gateway to desktop application for requesting their necessary information. After collecting required information from a specific database, a prompt reply will be forwarded to the users.

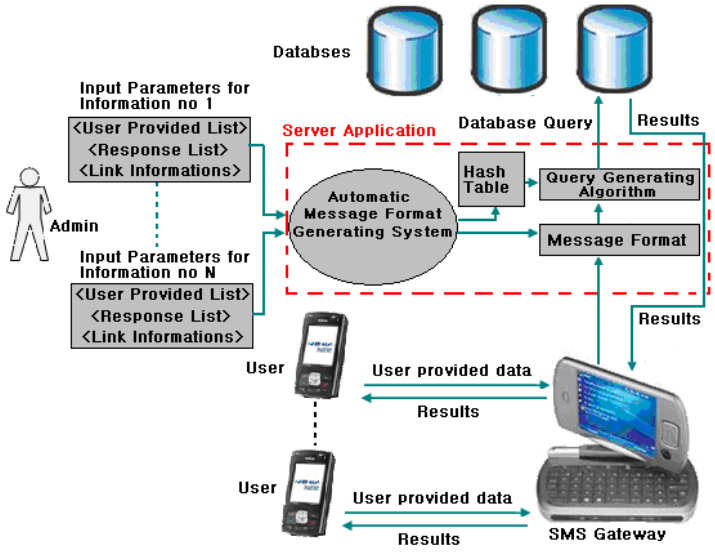


Figure 2.1: System model of generic information system using SMS gateway [1]

The communication system has various steps. First the user sends an SMS to the SMS gateway application with a specific identifier. Then the SMS gateway application forwards it to the server application with the corresponding user's phone number. Server application

then executes the query requested by the user and then generates a reply with information through SMS to mobile phone.

Limitation: It is a very simple and cost effective solution but security is the main issue to such a system. The message must be sent in a secure way between a user and a system.

2.2 An elderly health care system using wireless sensor networks at home

HongweiHuo, YouzhiXu, Hairong Yan, Mubeen S. and Hongke Zhang [2] have presented a prototype that integrates wireless sensor networks and public communication networks to build a healthcare system. The system supports large scale data interconnections, real time activity and health state reports to related persons (doctors or nurses, elderly person,

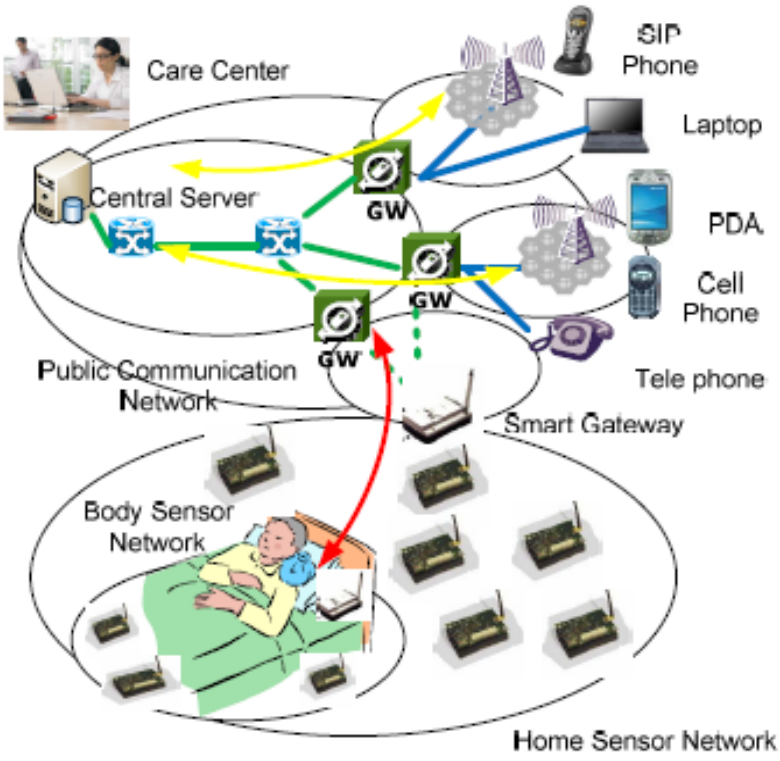


Figure 2.2: System architecture of health care system using wireless sensor networks [2]

or elder's relatives) through various communication media, such as automatic telephone call, SMS or email etc. There are four main system functions explained in this paper. The first part is the Body Sensor Network-BSN which can be defined as a collection of mobile sensor nodes worn on the elder's body. The mobile sensor nodes are usually equipped

with temperature sensors, pulse sensor, accelerometer and even ECG, EMG, EEG etc. BSN connects through the BSN gateway to the Home Sensor Network-HSN for indoor monitoring or to the public mobile communication network for outdoor monitoring. The second part is HSN consists of fixed-location sensors, including temperature, relative humidity, air pressure, light sensors and microphone at different locations of the patient's home. The third part is about access devices, which includes the BSN gateway and the HSN gateway. The BSN gateway plays the role of the access device if the elderly is outside. The HSN gateway is usually a base station of the home sensor network, which provides an interconnection between the home sensor networks and the server via public communication networks, such as GSM, 3G-WCDMA, Wi-Fi, x-DSL, Ethernet. The fourth part is the central server which makes data analyses, generates a regular report about the elder's activity and health states or generates alarm when a dangerous event occurs. This central server is able to send automatically SMS.

Limitation: The developers have claimed that the system has high reliability service but body sensor network may cause decision delay and disrupts the accuracy of collecting data but it can be fixed in future work.

2.3 Remote wireless health monitoring system

Priya, Rajendran, Bala and Gobbi R [3] have developed a remote wireless health monitoring system which is capable of sending SMS related to the health status of the patient. The main concept of this system is to implement a whole unit consisting of health

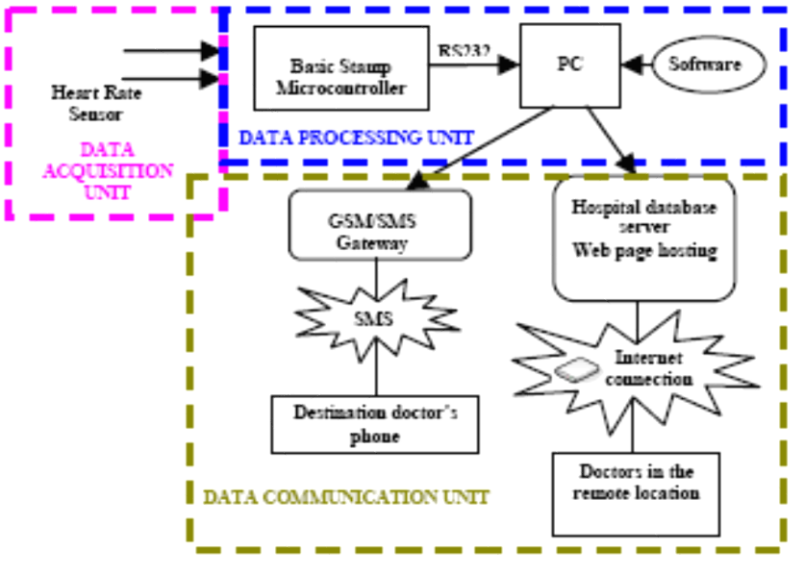


Figure 2.3: System block diagram of remote wireless health monitoring systems [3]

health monitoring sensors for measuring biological parameters like body temperature and pulse rate and passing the measured vital signs as input signals through signal conditioning circuit to the BS. The project is divided into three parts in data acquisition, data processing and communication. A data acquisition stage consists of biomedical sensors to monitor the temperature and pulse rate. The sensor outputs are converted to digital form and read by a Basic Stamp-BS microcontroller which does some processing and is sent through the serial port to the application software. The measured information is transmitted through serial port communication via RS232 from the BS to the local computer for the storing of patient data, including automatic processing and analysis. After successfully processing and analysis, decisions are made on sending an SMS from local computer to a specific doctor if patient's body temperature and pulse rates go above a certain threshold. Moreover, every hour or specific period, the central hospital database is updated automatically so that the doctor can keep track of the patient's health status.

Limitation: This prototype is to send SMS regarding the patient information to the doctors. The core limitation lies within the cost. Every patient has to be attached with such sensors which can be extremely expensive. Furthermore, developers have claimed about the accuracy of the biomedical sensors with which the sensors process data is not satisfactory but it can be fixed in future work.

2.4 Recording of Time-Varying back pain data: A wireless solution

Tacha Serif and Gheorghita Ghinea [4] have developed a real time prototype on patient monitoring systems and context-aware hospitals that use Wireless Application Protocol-WAP enabled devices with mobile access. In this paper, authors present a concept to

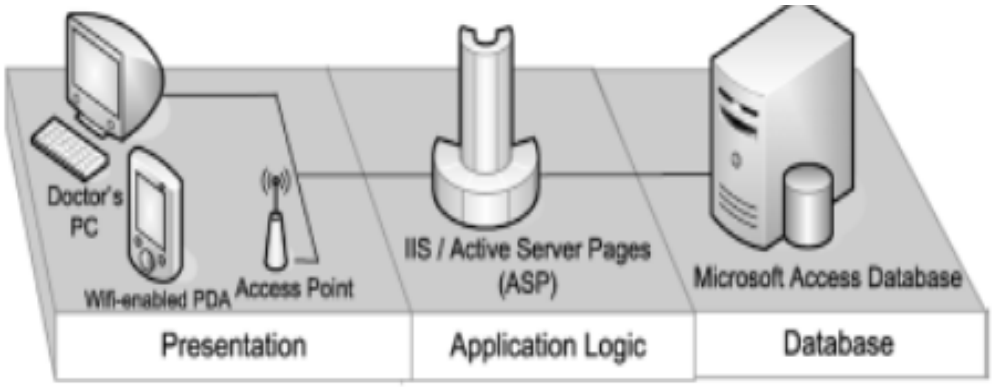


Figure 2.4: System model of recording of Time-Varying back pain data [4]

implement a wireless enabled monitoring system for back pain of patients. The motivation behind their work lies that there is a relatively small number of tools for the collection and digitization of back pain data. Using this system, authorized users, hospital personnel, and patients' relatives can access patient's physiological data stored in the hospital's database. A context-aware hospital mobile prescription system can identify according to the location of tagged items i.e. Personal Digital Assistant- PDA, patient's bed, and hospital trolleys. It is possible to prescribe the correct medication to patients based on their bed identification. The developed system is conceptually made up of two user groups, patients and doctors/clinicians. Figure: 2.4 has shown system model, consists of wireless-enabled PDA, a doctor's computer and database server.

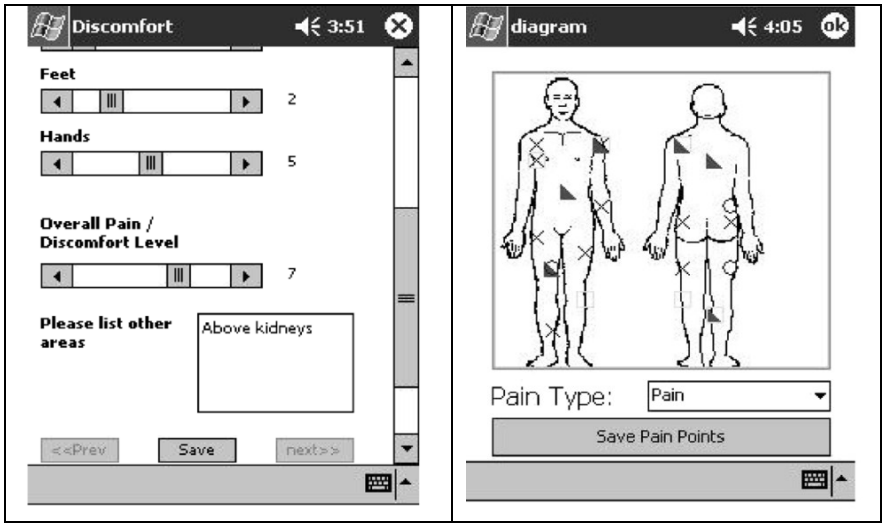


Figure 2.5: Pain and discomfort level, drawing with pain points [4]

The initial interaction takes place between the doctor and the wireless enabled PDA device, where the doctor creates a user account for the patient. Following this phase, the patient enters pain data to the device. The device responds to pain data by creating a graphical representation for every pain point added to the body diagram, shown in figure: 2.5. At the end, the pain data are saved whenever a wireless connection is available through an access point, the user can request data transmission to the hospital server. The server can then receive the data that is sent by the PDA and save it to the hospital database.

Limitation: The study has exposed certain limitations with current technologies, especially when these are handled by different individuals. The conceptual study has not addressed issues such as scalability and security. It need to be updated in line with future developments. However, the paper has shown an adequate work on patient's physiological

data collection technics for hospital. In many cases, data collection cannot take place unless medical personnel are present at the patient's home. This situation occurs frequently and is both unrealistic and impractical.

2.5 Body temperature and electro cardiogram monitoring using SMS based telemedicine system

Tahat and Ashraf A [5] have proposed SMS based mobile telemedicine (monitoring) system which locates the patient (client) and the health care professional (server) anywhere with GSM (cellular) network coverage. The patient's ECG, body temperature

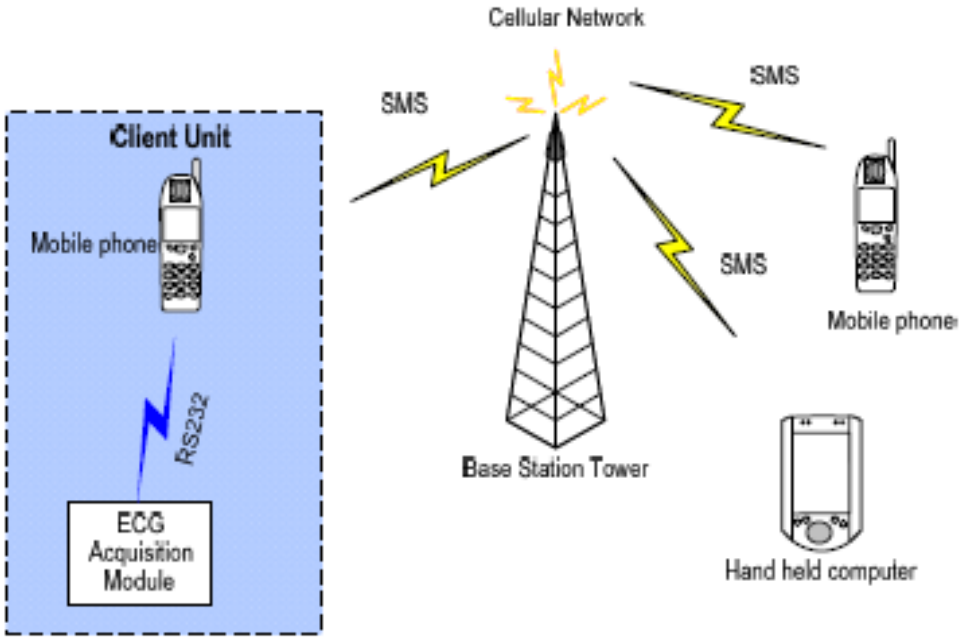


Figure 2.6: Mobile monitoring, measurement using SMS based telemedicine system [5]

and other clinical data can be acquired by the patient himself or the patient can be assisted by a family member or a health care professional under follow up scenario. An Infrared temperature sensor was integrated with a three lead ECG monitor (client unit) to a mobile phone which can be considered as a real time transmission mode. The paper suggests that signal acquisition process is to be performed by attaching ECG electrodes and the temperature sensor to the patient's body at designated places as is normally done in a typical setup. The client part (ECG Module) communicates with the mobile phone via an RS232 connection, which can be established through a serial cable, or a Bluetooth

transceiver. The mobile phone sends a SMS that contains the clinical data. Application software is required on the mobile device to decode the bio-signal to SMS messages and plot the ECG and display the body temperature. If the SMS reach their mobile phone or PDA, they are either transferred by application software running on PC, or it can be imported by a mobile application running on the mobile phone or PDA.

Limitation: The proposed work can be found to fulfil its objectives, but the cost effectiveness still remains an issue because such monitoring is only possible through expensive smart phones for decoding.

2.6 GSM based ECG Tele-Alert system

Sukanesh R, Rajan S.P, Vijayprasath S, Prabhu S.J and Subathra P [6] have proposed ECG Tele-Alert system which consists of an ECG bio amplifier that picks up the bio signal and then converts into electrical signal followed by a low pass filter. Output is digitized by an A/D converter, and then programmed in AT89C52 Micro controller followed by the GSM MODEM. The patient and the health care professional can be located anywhere with cellular network coverage. The primary purpose is to monitor patient's cardiac activity if there is a chance that patient has cardiac problems such as an irregular heartbeat or arrhythmia that require close monitoring. Particularly, the proposed system is designed for detection of cardiac disorder of the patients who are located in the remote areas or in travel and are not in a position to report to the doctor for immediate treatment. System will send SMS as an alert message to the doctor.

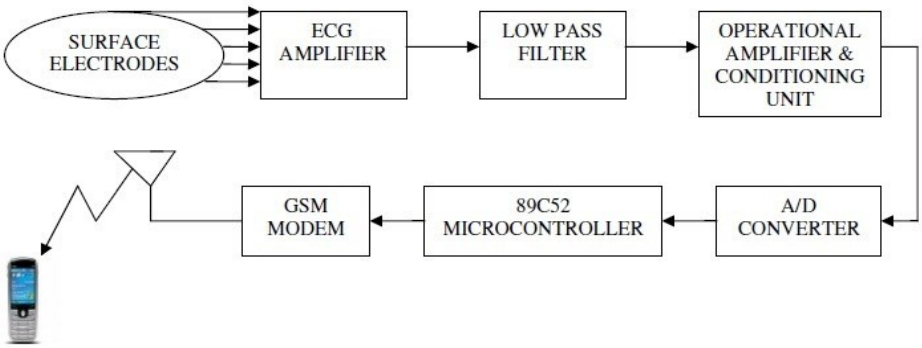


Figure 2.7: Block diagram of ECG Tele-Alert system [6]

Limitation: Though the prototype of this system is satisfactory and does provide a model for the mobility of patients, it is a limitation that the patient has a duty to carry a bio signal acquisition unit.

2.7 Health status monitor based on embedded photo plethysmography and smart phone

Postolache O, Girao P. S, Sinha P, Anand A and Postolache G [7] have given a concept to build Wireless Personal Area Network-WPAN as well as two Bluetooth enabled measuring nodes that deliver information about physiological parameters extracted from plethysmography signals and provide information of indoor air temperature and relative humidity. Authors have proposed to design an application software for detection and identification, data reading, data storage and automatic alarm generation. The system sends an automatic SMS while a patient is in critical health state. The work focused to join embedded hardware technology and software technology in order to obtain a mobile system that performs acquisition of the information from physiological measuring nodes as well as from indoor air quality measuring nodes to correlate the patient's health status and indoor air conditions such as temperature and humidity. A physiological measuring node consists of a microchip, microcontroller and RS232 Bluetooth bridge. Additional measurement tasks such as heart rate estimation, oxygen saturation measurement are obtained through the microcontroller. An important part of this proposed system is that mobile application runs on smart phone in order to assure primary data processing, alarm signal generation according to the patient's health status and therefore automatic SMS generation for critical health conditions.

Limitation: The system is very applicable but it requires expensive devices like biomedical smart sensor.

2.8 A Mobile phone based intelligent scoring approach for assessment of critical illness

Fahim Sufi, Qiang Fang and Cosic I [8] have proposed a system to collect patient's various physiological signals, as well as subjective parameters. Physiological signals include ECG, EEG, temperature and continuous blood pressure. Subjective parameters are the level of pain, alertness, awareness, behavioural responses etc. After accumulation of these data, a scoring system is operated for early detection of critical illnesses. In many cases, the scoring system is performed manually. The medical practitioner ticks on to a scoring board. In some cases, the information from scoring board is transferred to a PC by specific application program used to calculate these scoring data. Authors have proposed a new approach of using mobile phone to calculate the scoring. The system integrates four major parts. The existing medical scoring criteria, mobile phone programming techniques, hospital servers and the communication protocols. The mobile application is integrated with SMS, MMS and HTTP connectivity. In this system, the medical practitioner enters the parameters into mobile phone application and collects data from score. At the end,

specialists (doctors) are contacted automatically by SMS. The results of the scoring are transmitted to the hospital server.

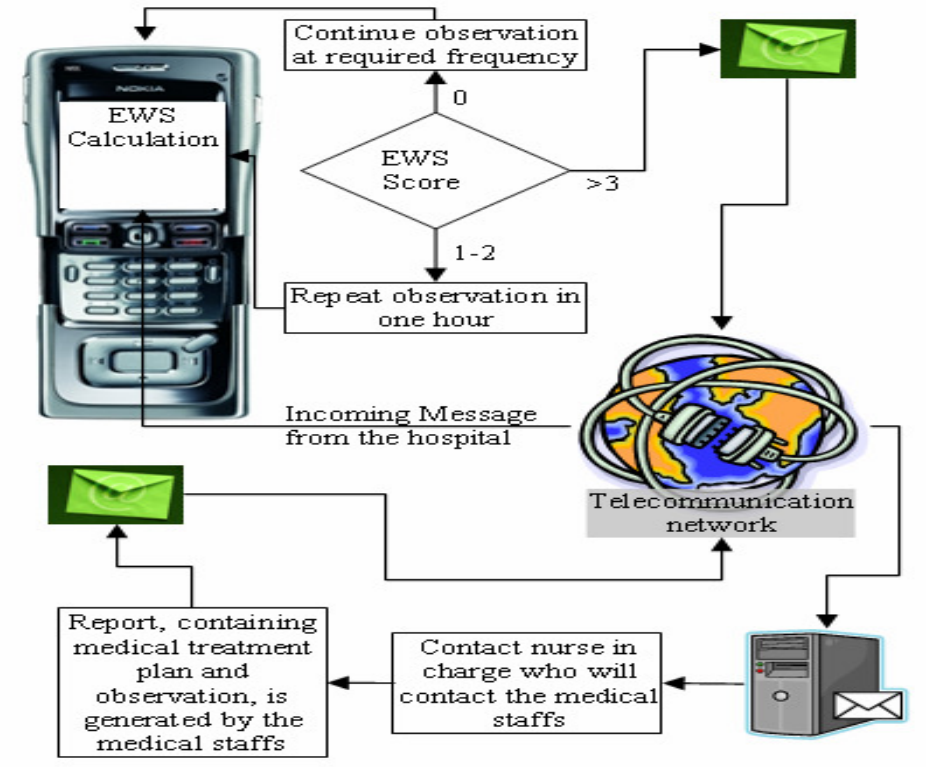


Figure 2.8: System Architecture of the mobile phone based scoring mechanism [8]

Limitation: This proposed system is not fully automatic and during any catastrophic event, it is required to have medical professionals for patient monitoring.

2.9 Conclusion

The above works have presented several specifications of software and hardware systems to build SMS applications and exposed certain limitations with current technologies. Some of proposed system emphasizes to concentrate on cost effective solution and suggested that data transmit must be sent in a secure way between user and system. According to the section 2.1 and 2.3, I have design SMS server application which would be connected to low cost GSM MODEM instead of GSM gateway. Our proposed system for pain assessment is capable of collecting patient's post-operative pain and discomfort data

through SMS without any expensive data acquisition unit as the related works proposed in 2.2, 2.6 and 2.7 section. Furthermore, Automatic SMS send method is applied to send as notification to patient mobile phone which ensures to get patient feedback timely and securely. I have described details on problem description and solution in next chapter.

Chapter 3

Problem Description and Solution

Generally it is not easy to know about patients' pain and discomfort experience after periodontal surgery. Patients usually go home after a surgical mediation and may not be examined about their temporary pain frequently. A common practice is that patients are given paper based VAS form to fill out at home after surgery. Another possibility is to conduct telephone interviews. Both options have to be followed in a very short time. Respect for patient's privacy after a dental treatment is weighted up against scientific analysis of data collection. On the other hand, patients may have developed psychological and emotional problems to deal with the pain. Because of these problems, patients cannot tell directly about their pain, which can lead to complications and delay treatment. A middle way might be to ask patients retrospectively to evaluate the postoperative experience. It is necessary to test this approach and identify the level of pain and discomfort after periodontal surgery. It helps the medical staff not only to know about how much pain he/she feels, but also to identify patient's state of discomfort during treatment. In this work, the pain investigation system access patients' surveillance outside of hospital especially at home. The focus of my work is to implement the patient monitoring systems and context-aware hospital system. M. A. Munoz [9] has addressed on a context-aware messaging system that can investigate patient's current pain level and react by patient's mobile phone in certain time period, which can store the appropriate medical data into a hospital database. Using this system, authorized users and hospital personnel can access a patient's physiological data for further use.

Current technological advances have enabled the introduction of a broad range of mobile phone applications, such as SMS based remote-patient monitoring [10]–[11], and health-care management. The integrated application of mobile telecommunication and information technology can be used in hospital to arrange and storing patient's pain information [12]. Once information is received and recorded into database that can easily be traced when required.

3.1 Implementation

Newer cellular access technologies, such as 3G, UMTS provides much higher data transmission speeds (rates) than basic second generation (2G) GSM cellular system. As J. Grimsonet [13] has claimed based on an interview with several mobile phone users, the majority of users are still using 2G based GSM phone and they have no experience of using internet over mobile telephone. In our case study (interview with several patients), I

have found that the majority of patients are using low cost second generation GSM based mobile phone. It can be good solution to collect patient's pain data through GSM gateway or MODEM over GSM network.

3.1.1 SMS Architecture

It is important to discuss SMS concepts and the function of numerous system entities to see how the different components of SMS system architecture work together. Author Jeff Brown, Bill Shipman, and Ron Vetter [14] have described the Short Message Service as a method of delivery of short messages over the GSM network (figure 3.1).

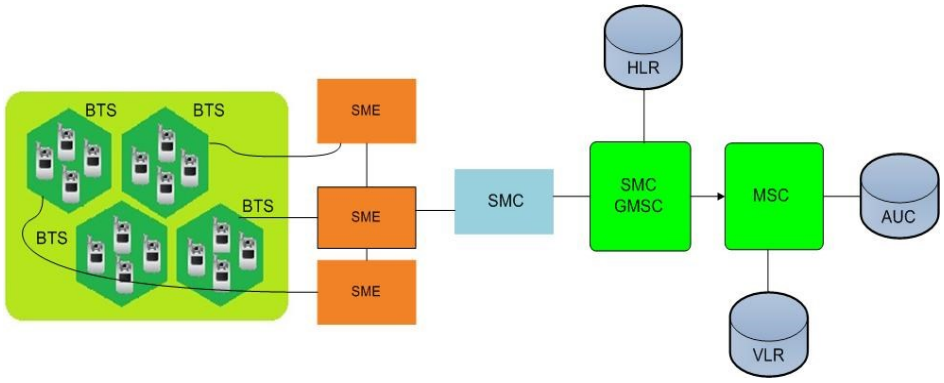


Figure 3.1: Architecture and process of SMS system [14]

The message from the sending mobile phone is stored into a Short Message Centre-SMC which forwards it to destination mobile phone. Home Location Register-HLR is a main database used for permanent storage and management of subscriptions and service profiles while Visitor Location Register-VLR communicates to each MSC and contains temporary information about the mobile phone information like identification and the cell where the mobile phone is currently situated.

3.1.2 GSM MODEM

A GSM MODEM consists of a SIM card and function over a subscription to a mobile operator. From the mobile operator viewpoint, a GSM MODEM seems just like a mobile phone. It can be used as a device through a serial, USB or Bluetooth connection. GSM MODEM is used as a common term to refer to any MODEM that supports one or more protocols in the GSM family, as well as the 2.5G technologies like GPRS and EDGE and 3G technologies WCDMA, UMTS, HSDPA and HSUPA [15]. It exposes an interface with

an application that is able to send and receive messages over the MODEM interface. GSM MODEM is efficient way to get started with SMS, because a special subscription to an SMS service provider is not required. Though the mobile operator charges for this message sending and receiving, GSM MODEM is a cost effective solution for sending or receiving SMS. I choose GSM MODEM over SMS gateway because of the following benefits:

- Easy to use and there is no deal with Network operator (i.e. fixed monthly fees).
- GSM MODEM is cheap and SMS delivers lower cost.
- SMS messages are quick to send and convenient to receive.
- It is very low powered device.

3.2 Proposed System Design

System design is a solution about how to approach of creation a new system. The figure: 3.2 has presented the workflow which is the core of the system. My proposed system consists of two parts. The first part is SMS server application which is installed in Hospital PC and connected to GSM MODEM. Database is used to store patient's incoming and outgoing messages for further evaluation. Main job of SMS server application is to monitor current pain or discomfort state of patients in this system. Second part is mobile application installed on patient's mobile phone. Using mobile application, patients will send current pain and discomfort value through SMS at different time point.

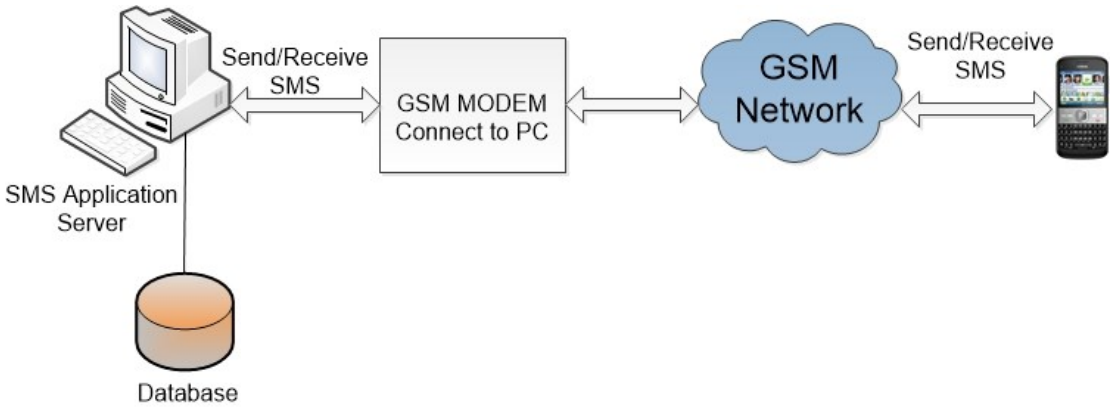


Figure 3.2: Proposed System Architecture

3.2.1 Generic Work Flow of Proposed System

After periodontal surgery of a patient, user needs to set SMS schedule for sending automatic SMS notification to patient mobile phone. Send SMS module handles automatic notification to patients for requesting patient's feedback. However, it could be stored reminder in mobile application to send pain and discomfort values in specific time point.

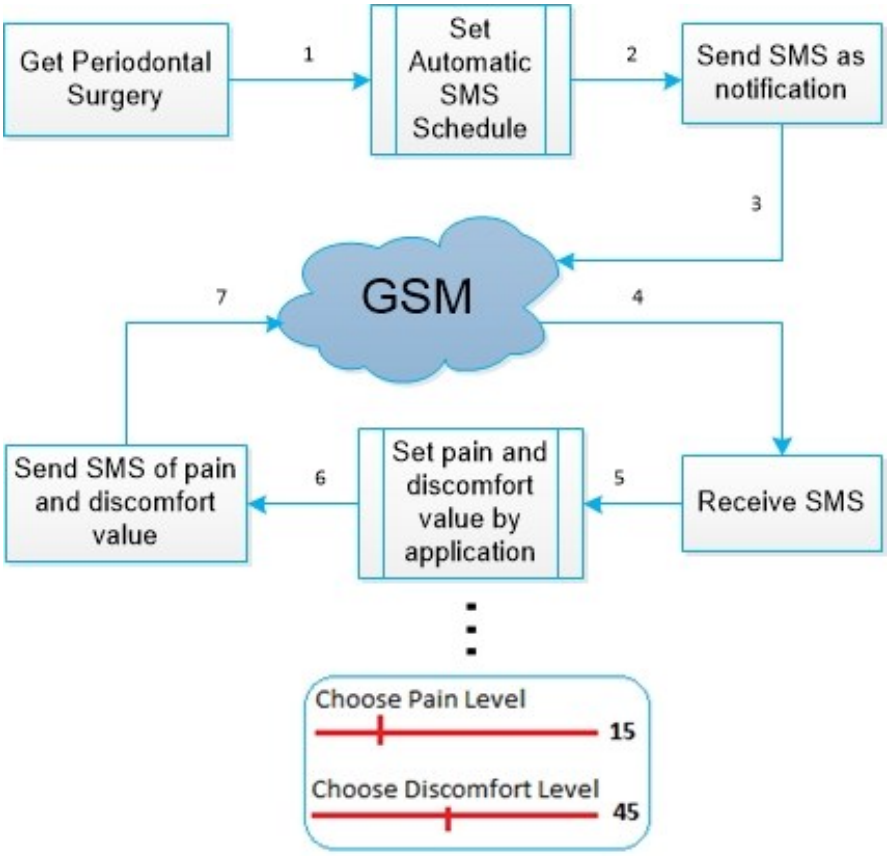


Figure 3.3: Generic Work flow of System

But for the simplicity, the SMS server application sends text messages as notification to the patient's mobile phone according to the schedule in specific time point. Figure: 3.3 shows a generic work flow of proposed system how the system maintains SMS activities and eventually get patient's feedback. This phase provides an understanding and procedural details of implementing a system. I have developed two methods to ensure sending automatic SMS and authenticate procedure of receiving SMS which are described in next section.

3.2.2 Automatic SMS sending procedure

The first step of this procedure is to select patient who is undergoing treatment. User will set start date and time after patient's surgery to generate automatic SMS schedule. Once setting date and time, SMS schedule would be created for corresponding patient and store

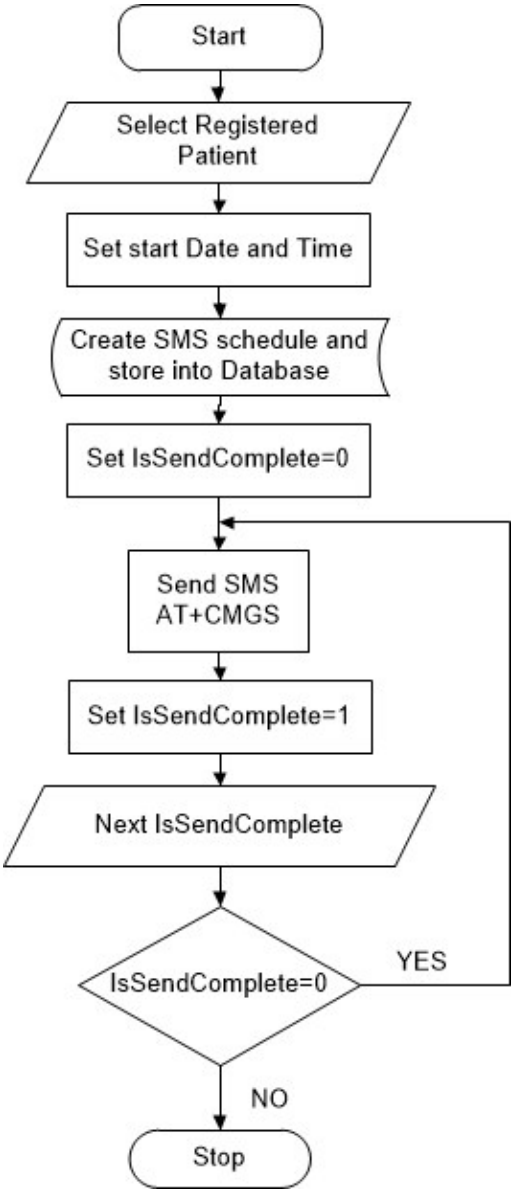


Figure 3.4: Work flow diagram of Automatic SMS Schedule

into database. A Boolean field IsSendComplete is included to verify for sent or unsent SMS. After sending an SMS, IsSendComplete filed would be true and updated database as sent SMS. A timer will check next time point of unsent SMS from database to send SMS as notification to patient's mobile phone. This process will continue until end of the time point of SMS schedule.

3.2.3 Authentication procedure of receiving and storing SMS

Authentication procedures involve inspecting recognized information i.e. pain and discomfort values provided by the participant (patient). For this case, database query is to check the active Patient ID and phone no. Server application will recognize only active

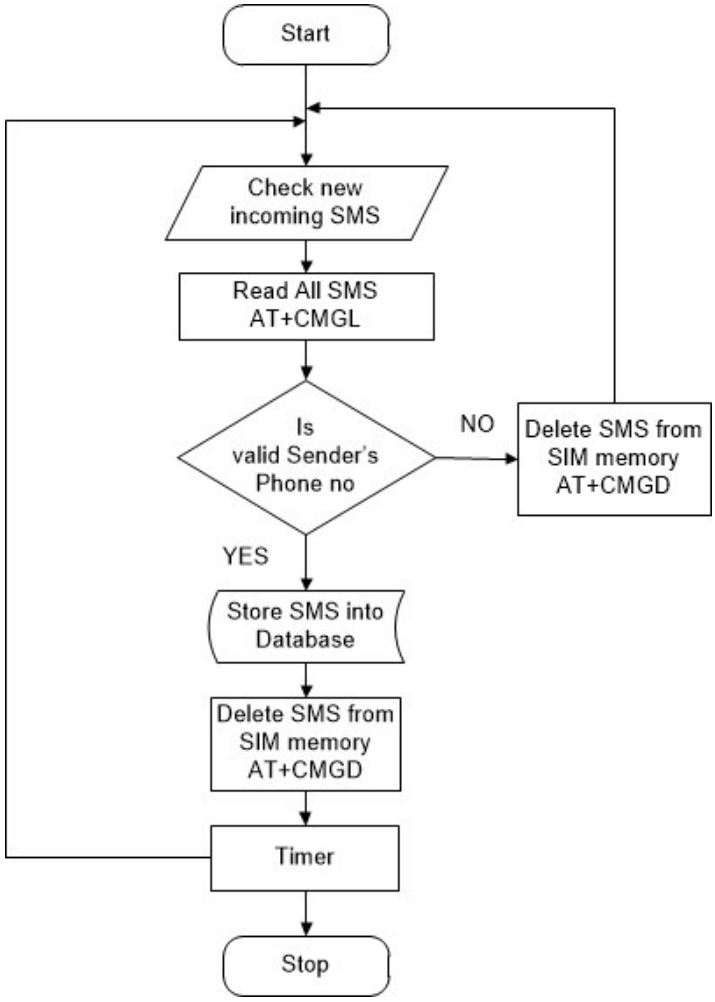


Figure 3.5: Work flow diagram of Receiving SMS by server application

patient who are undertaking treatment as an authenticate user to accept his/her SMS. Figure 3.5 gives the control flow of SMS validity. A timer is included to check new incoming SMS frequently. If new SMS arrives, the application reads all SMS from SIM memory through connected MODEM. Before storing SMS into database, an SQL statement will compare sender's phone no of new SMS with patient phone no. Patients' pain and discomfort value are set as a valid SMS format. The system is designed to accept only valid SMS. For this case, SMS server application is able to ignore different type of invalid SMS, i.e. SMS send by operator or incomplete messages and delete from SIM memory each time. If all above criteria is satisfied, SMS would be stored into database and immediately deletes from SIM memory. This process would be continuing as long as the MODEM connection state is open.

3.3 Conclusion

In this chapter, I find out the initial requirement to design our system. In proposed system design section, I have explained procedural details of implementing a system. Generic work flow presents how the system will maintain SMS activities by creating automatic SMS schedule and collecting data from received SMS. In the end, I have evaluated certain benefits and limitations of our proposed system. System is able to ignore unspecified and invalid incoming SMS and storing patient's data (pain and discomfort value) from low cost MODEM. But MODEM should be connected to PC all time and two-way SMS system means extra cost. We will describe on development environment, database design and user interface in next chapter.

Chapter 4

Implementation and Development Environment

The quality of information system depends on design, development and implementation. In this chapter, I have described on implementation. The user interfaces have been described briefly in end of the chapter.

4.1 Development environment of mobile application

Mobile application has been developed using NetBeans Integrated Development Environment-IDE. NetBeans is a free open source IDE for Java ME with an integrated mobile toolkit emulator [16]. Java ME or micro edition is core of Java mobile platform, a set of technologies that let developers develop applications and services for mobile devices.

Figure 4.1: Mobile application runs on NetBeans Emulator

Figure 4.1 shows a mobile application MIDlet runs on the Java ME emulator. Java ME emulators is used to test applications without actual hardware. The java application programming interface provides gauge control that return numeric values of 0 to 100. I have included two gauge components are intended to let patient easily select numeric value to choose their pain and discomfort level. There are two commands “send” and “exit” included in this screen.

4.1.1 Wireless Message Connection

Connected Limited Device Configuration-CLDC provides Application Programming Interface-API and a virtual machine that runs on mobile devices with limited memory [17]. CLDC provides abstract class javax.microedition to enable the mobile phone system software to create an instance of MIDlet. MIDlet is Java ME applications that run on the Mobile Information Device Profile-MIDP and act as java applet, which is enabling established GSM connections in this application [18]. I have defined javax.microedition.io class for establishing the Generic Connection Framework-GCF [19]. The figure 4.2 shows

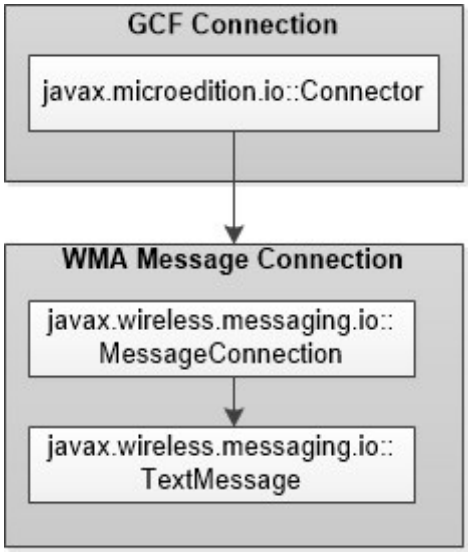


Figure 4.2: Relationship between GCF and Message Connection.

relationship between GCF and Message Connection. The Connector class is used to create new connection object. Wireless Messaging API provides a common interface to enable an application environment MIDP to send and receive SMS. The figure 4.3 shows code example of establishing Message Connection and SMS send. WMA message

connections are established by MessageConnection interface which defines several methods for sending or receiving messages. It has two modes: client connection and server connection. A client connection can only send messages, while server connections can both send and receive messages [20]. TextMessage interface is used to form a message with a text payload, for example an SMS based text message.

```
MessageConnection cn = (MessageConnection) Connector.open();
      (MessageConnection)Connector.open("sms:// +46123456789");
        TextMessage MSG =
          (TextMessage)cn.newMessage(MessageConnection.TEXT_MESSAGE);
             MSG.setPayloadText(“ MY Pain value is 30 and Discomfort value is 40”);
                cn.send(MSG);
```

Figure 4.3: Code example of Message Connection and send SMS

4.2 Mobile application

Initially, mobile application is installed on patient’s mobile phone. The figure 4.4 shows application running on mobile phone. Patients choose their pain and discomfort value by scrolling gauges value. The left end start from 0 represents "no pain at all" and the right

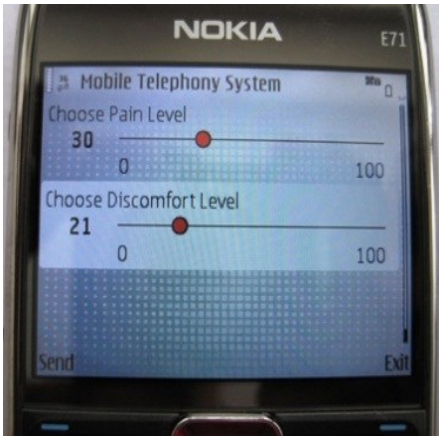


Figure 4.4: Application running on Mobile Phone

end of the "Unbearable pain" which range up to 100. After selecting pain and discomfort value, patient will press send button to send these data as SMS to specific mobile number that connects to Hospital PC through GSM MODEM.

4.3 Development Environment

SMS server application is developed by Visual C# Express Edition 2008. I have chosen C# to develop SMS server application because it has integrated debugger, an advanced code editor, an easy user interface for designers and it is easier to connect any database. Usually C# syntax is similar to C++ or java and build process is more flexible. .NET has built in virtual execution system known as Common Language Runtime-CLR and an integrated set of class libraries. CLR is implemented by Common Language Infrastructure-CLI for creating execution and development environments where languages and libraries work together seamlessly [21].

4.3.1 Work Flow of SMS server application

In this section, I explain the workflow of server application (figure 4.5). User must enter username and password through a login form to enter into this system. After successfully

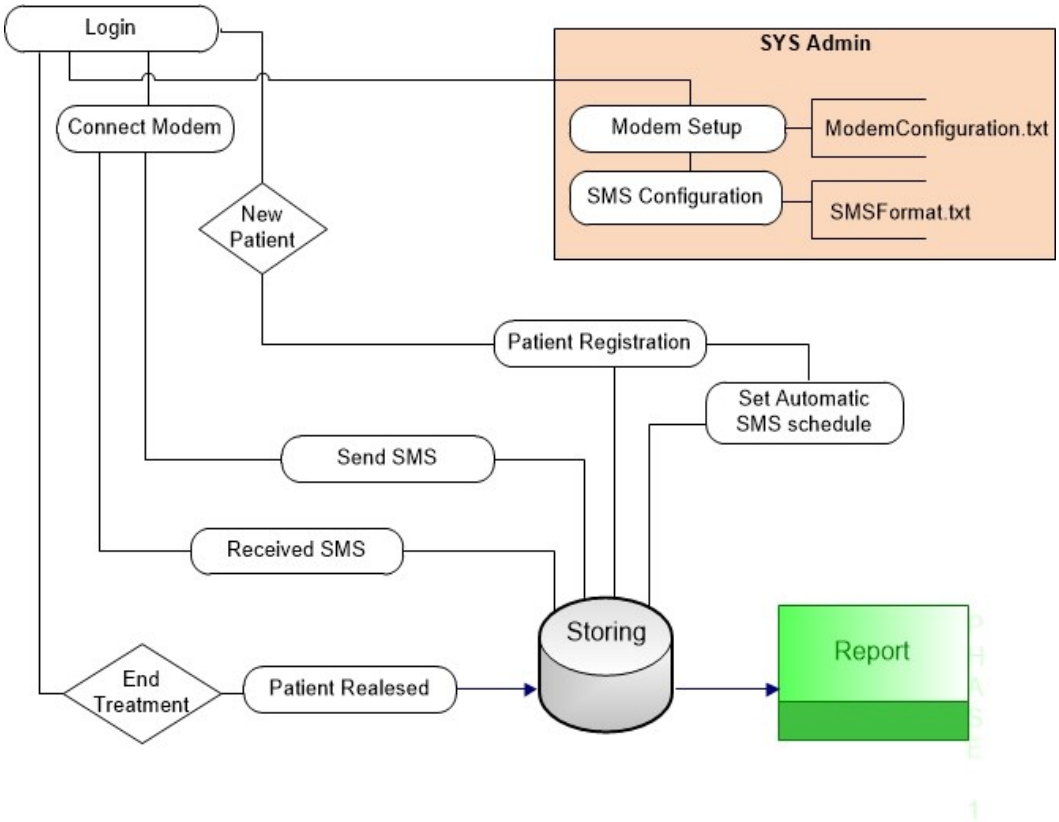


Figure 4.5: Work flow of SMS Server Application

login, main window will appear. The main window consists of several menus and toolbar. To receive and send SMS through this system, it requires connecting MODEM to PC. If MODEM connects successfully, the left panel of main window will provide message or notification of current status of connection status, port no etc. I have included MODEM setup module, which used to configure MODEM connection. To connect MODEM through serial port, it requires different baud rates, data bits, parity, timeout depends on its hardware requirement and finally is to set the port no. The configuration information writes into MODEMConfigaration.ini file. So it is very convenient and useful that user may not configure each time when the application is run. SMSFormat.ini file contains predefined notification message. Patient Registration module is responsible to register a new patient. After successfully registering a patient, user needs to set SMS schedule for sending automatic SMS notification to patient mobile phone. Send SMS module handles automatic notification to patients for requesting patient's feedback. Receiving SMS is the main objective of this system to collect patient's pain and discomfort data. Patient Released module sets patient as inactive and stopping all SMS activity after end of the treatment. Finally, application incorporates real time report facilities to print or export to appreciate documents as user's requirement.

4.3.2 Class Diagram of SMS server application

The class diagram is static structure of system showing functions, events of different classes and their relationship (figure 4.6). DataHandler class is used to declare database connection and define functions to execute SQL command. Other classes are associated with this class for established database connection and close. Setting class has included ReadSMSFormat() function to read predefined text from text file to send as SMS notification. WriteSMSFormat () function is used to append text if user desires to modify automatic SMS draft. Write() function will response to append current MODEM connection parameter in text file. While Read() function will take connection parameter values from text file to establish connection. SMS class is used to open and close connection port of MODEM. SMS class is also responsible for read, write and delete SMS from SIM memory. Patient Registration class stores new patient's information into database. While Patient Released class ends all SMS activities of corresponding patient by setting patient as inactive. The main class associates with SMS and DataHandler class to invoke functions and does the key role of this application. There are several menu factions are included in Main class. It sends and checks new incoming SMS and executes SQL commands to store into database. It accepts valid SMS as patient's pain and discomfort value. SMS schedule class is used to create new SMS schedule and stores into database. Whereas RecivedSMS and SendSMS class connect database and execute SQL command to display incoming and outgoing SMS information.

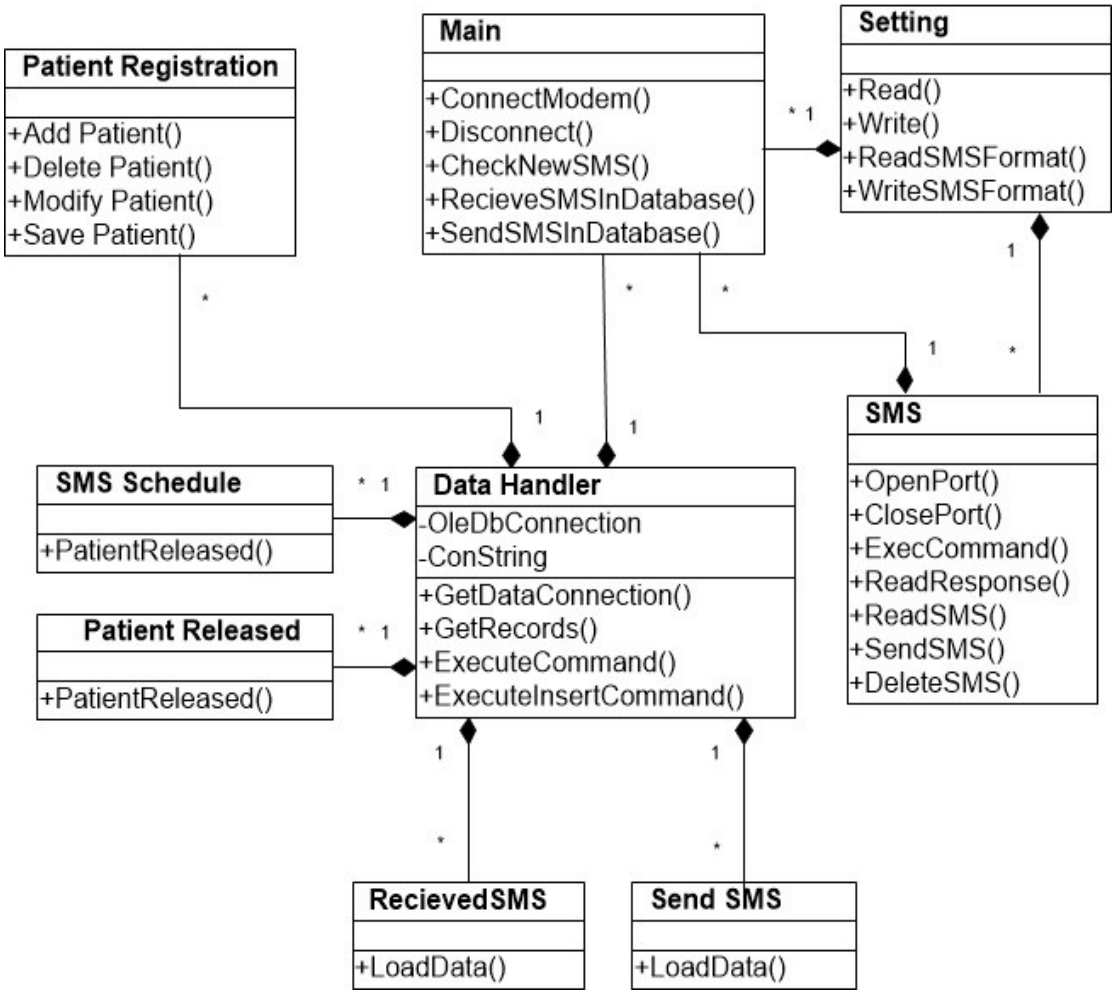


Figure 4.6: Class diagram of SMS Server Application

4.4 Database Design

Database is developed using normalization technique which ensures efficiently manipulate database. Normalization is the process of simplifying the relationship between data elements in a record. Normalized data structures are considered as simpler, more stable and easier to maintain. By choosing primary key in a table that is used to uniquely identify each row and reduce of repetition of data. An example might be Patient ID. My main goal

is to design a relational database in which normalization process would satisfy the following criteria:

- To structure the data that there is no repetition of data to help in saving space.
- To simplify maintenance of the data through insertion, update and deletion.
- To permit simple retrieval of data in response to query and report application.
- To reduce the need for restructuring or reorganizing data when new application requirement arise.

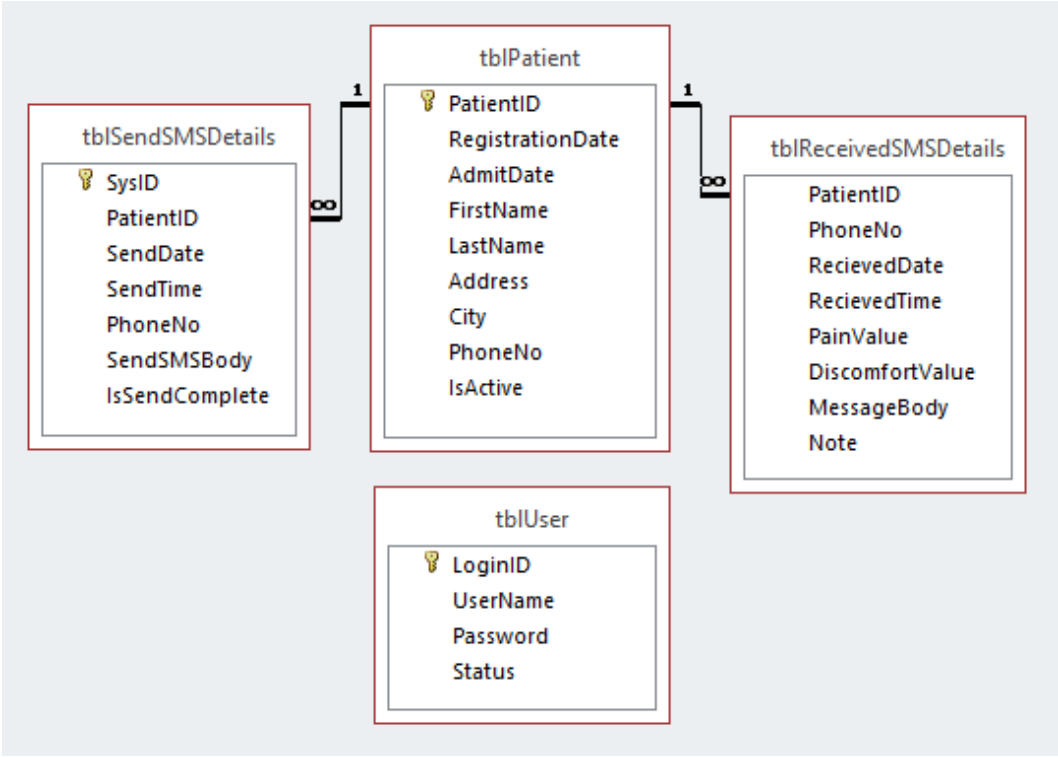


Figure 4.7: Relationship of Database Tables

Figure 4.7 shows relationship of database table using in this application. TblPatient contains Patient's necessary information while tblSendSMSDetails stores automatic SMS schedule and tblRecievedSMSdetails contains Patient's pain and discomfort value as well. Patient ID is defined as secondary key in tblRecieveSMS and tblSendSMS to form one to many relationship in this database.

Table 4.1 shows the constraints and data types of data tables.

Table Name	Field Name	Data Types and Constraints	Description
tblPatient	PatientID	**Primary Key**	Patient's identity number
	RegistretionDate	Date	Date of Registration
	AdmitDate	Date	Date of Admission (Surgery)
	FirstName	Short Text	Patient's First Name
	LastName	Short Text	Patient's Last Name
	Address	Short Text	Address of Patient
	City	Short Text	City of Patient
	PhoneNo	Short Text	Patient's mobile phone number
	IsActive	Boolean	Active or Inactive status
tblReceiveSMS	PatientID	**Secondary Key**	Patient's identity number
	PhoneNo	Short Text	Patient's mobile phone number
	RecieveDate	Date	Date of Receiving SMS
	RecieveTime	Date	Time of Receiving SMS
	PainValue	Number	Patient's pain value
	DiscomfortValue	Number	Patient's discomfort value
	SendSMSBody	Text	Message body
tblSendSMS	SysID	**Primary Key**	Auto generated Send SMS ID
	PatientID	**Secondary Key**	Patient's identity number
	SendDate	Date	Date of sending SMS as notification to Patient
	SendTime	Date	Time of sending SMS as notification to Patient
	PhoneNo	Short Text	Patient's mobile phone number
	SendSMSBody	Text	Message body
	IsSendComplete	Boolean	Sending SMS status
tblUser	LoginID	**Primary Key**	User Login ID
	Password	Short Text	User Password
	Status	Boolean	Active or Inactive user status

Table 4.1: Data Dictionary

4.4.1 Database Connectivity through ADO. NET

ActiveX Data Object-ADO .NET has been designated to connect front-end tool C# to back end database engine. It is developed by Microsoft to simplify the development of the application that may have to target a variety of databases. ADO .NET connects data sources and retrieve, manipulate, and update data [22]. It provides reliable access to data sources such as Microsoft Access to expose through Object Linking Embedded Data Base-OLEDB. There are several fundamental components of ADO. NET used in this application that are Data Set, and the data provider such as Connection, Command, Data Table, Data Reader, and Data Adapter objects [23]. The figure 4.8 shows code example of declaring Connection object which makes database connectivity from data source.

```
public OleDbConnection oleConnection=new OleDbConnection();
public string conString;
conString = @"Provider=Microsoft.Jet.OLEDB.4.0;Data Source=..\\DB\\pain.mdb";
```

Figure 4.8: Code examples of declaring Database Connection

Data Table is core component of ADO .NET. Usually, Data Table initializes Recordsets into Data table. The figure 4.9 shows that Data Adapter establishes bridge between the Data Tablet object and the data source. The different user controls can be initialized data from Data Table adequately. While the OleDbCommand object allows access to SQL commands to insert, modify, delete data and as well as run query or retrieve information.

```
DataTable dataTable = new DataTable();
oleConnection.Open();
string sqlQueryString = "SELECT * FROM tblPatient";
OleDbDataAdapter dataAdapter = new OleDbDataAdapter(SQLQueryString,
oleConnection);
      dataAdapter.Fill(dataTable);
           oleConnection.Close();
              return dataTable;
                  txtPatientID.Text = dataTable.Rows[0]["PatientID"].ToString();
                              .
                              .
```

Figure 4.9: Code example to fill data into DataTable Data Adapter

The Data Reader is used to retrieve data from a database. It uses Command objects to execute SQL command at the data source to load data. For example, the figure 4.10 shows code example execution of SQL query in which the database records of tblPatient (all Patient ID who are considered active in undergoing treatment) read by Data Reader object.

```
OleDbCommand cmd = new OleDbCommand("SELECT PatientID from tblPatient
where IsActive='1' AND [MobileNo]='" + msg.Sender + "'", datahandler.oleConnection);
datahandler.oleConnection.Open();
   OleDbDataReader dtReader = cmd.ExecuteReader();
      string a = "";
         while (dtReader.Read())
            {
               a = dtReader[0].ToString();
                  }
                     dtReader.Close();
```

Figure 4.10: Code example to execute Data Reader by OLEDB Command

4.5 User Interface

This section gives a detailed explanation of every aspect of SMS server application from a user's perspective.

4.5.1 SMS Server Application

A simple application has been developed in order to receive patient's pain and discomfort values by SMS. The incoming SMS should be stored into database. The application performs automatic notification to send patient's mobile phone in specific time for requesting sends his/her current pain or discomfort values. The user interface will give a feel for how we approach the task of creating an environment that will not only store and manage data but also enable effectively and easily interact with patient's data.

4.5.2 Main Window

The Main Window consists of several menus, status bar and notification windows. The left notification windows show the status about MODEM connection. There are several menus

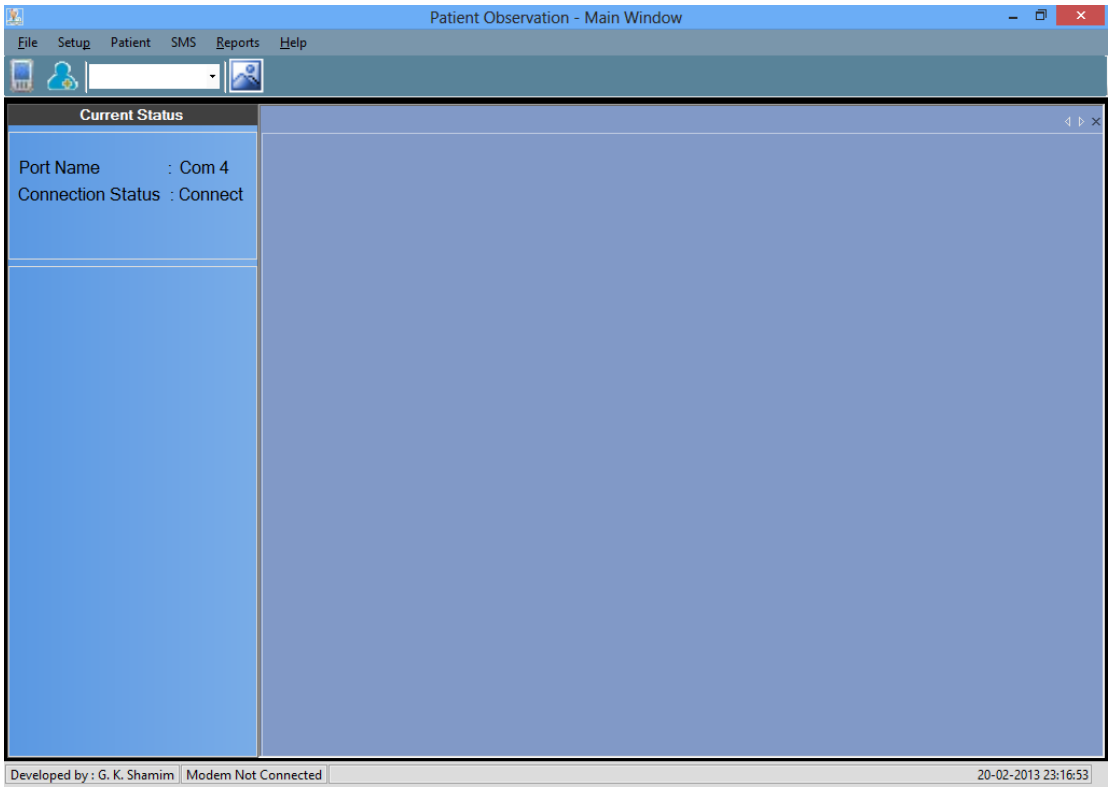


Figure 4.11: Main Window

in application interface. These are File, Setup, SMS, Reports, and Help. The menu listings and their function are described below:

Menu Name		Description
File	Organization Info	Splash Screen appears to display Organization information.
	User Information	Splash Screen appears to display User information.
	Exit	Terminate the application.
Setup	MODEM Connection Test	Appear MODEM Connection Form.
	Send SMS Configuration	To defined SMS notification.
	Connect MODEM	Connecting MODEM if it is disconnected.
	Disconnect MODEM	To disconnect MODEM.
	Backup and Restore	Appear Backup and Restore Form.
Patient	Patient Registration	Appear Patient Registration Form.
	Automatic SMS Schedule	Appear Automatic SMS Schedule Form.
	Patient Released	Appear Patient Released Form.
SMS	Received SMS Details	To display received SMS.
	Send SMS Details	To display SMS schedule by corresponding Patient.
	Send SMS Manually	Send SMS by Manually to Patient.
Reports	List of Patient	Report generates of all Patient's Information.
	All Patient SMS information	Report generates of all Patient's pain, discomfort value.
Help	Index	Help index of user manual.
	About	Screen to display current version or developer Info.

Table 4.2: Menu and its function

4.5.3 Connection Setup Form

The Connection Setup form used to connect MODEM to PC. There are several parameters such as communication port, baud rate, data bits, parity, stop bits and time out are used to established connection of MODEM through serial port (figure 4.12). To connect MODEM, user will select communication port and different parameters. By clicking Set button, the configuration information writes into MODEMConfigaration.ini file. This method is applied so the user who need not configure MODEM each time the application starts System will read port configuration from file. User can also test MODEM connection status in run time.

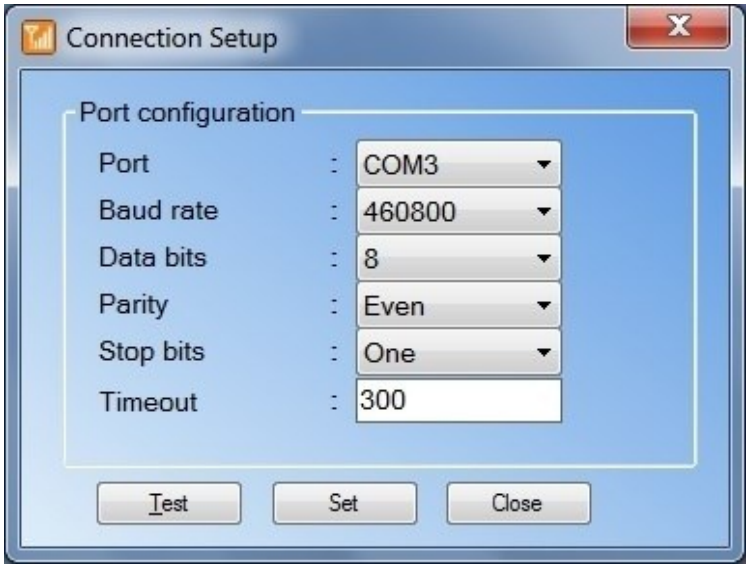


Figure 4.12: Connection Setup Form

4.5.4 Automatic SMS Configuration Form

An automatic SMS acts as a reminder by requesting patient to provide assessment of pain and discomfort. In this form (figure 4.13), user sets a text message to send patient's mobile phone as notification. User can modify text in run time and it will save to SMSFormat.ini file.

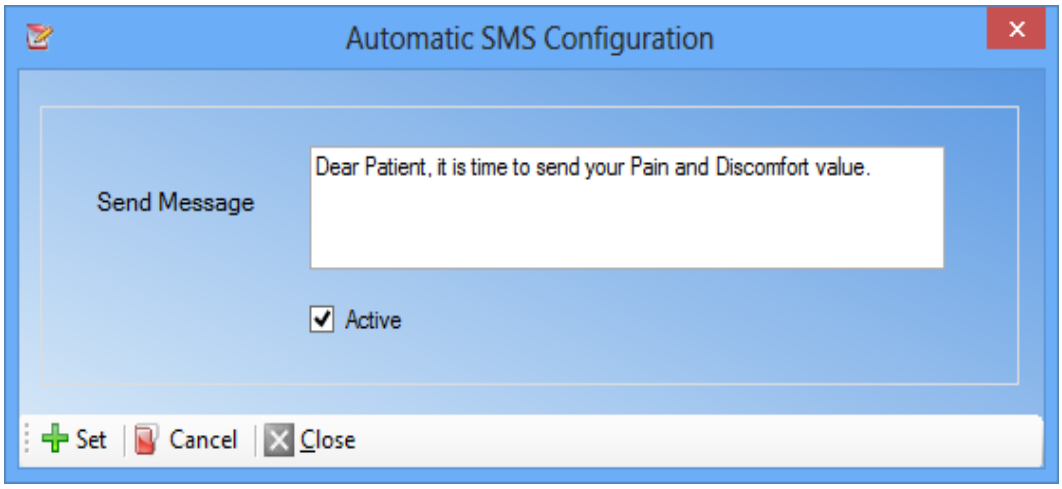


Figure 4.13: Automatic SMS Configuration Form

4.5.5 Patient Registration Form

This form will take as input new patient's personal information and store it into database. There are several input controls like text boxes and checkbox are included for accepting patient's necessary information (figure 4.14). A data grid control used to display all patient's information. The patient ID will auto generate while user need to register a new patient. Several command buttons have specific event to insert, edit and save data.

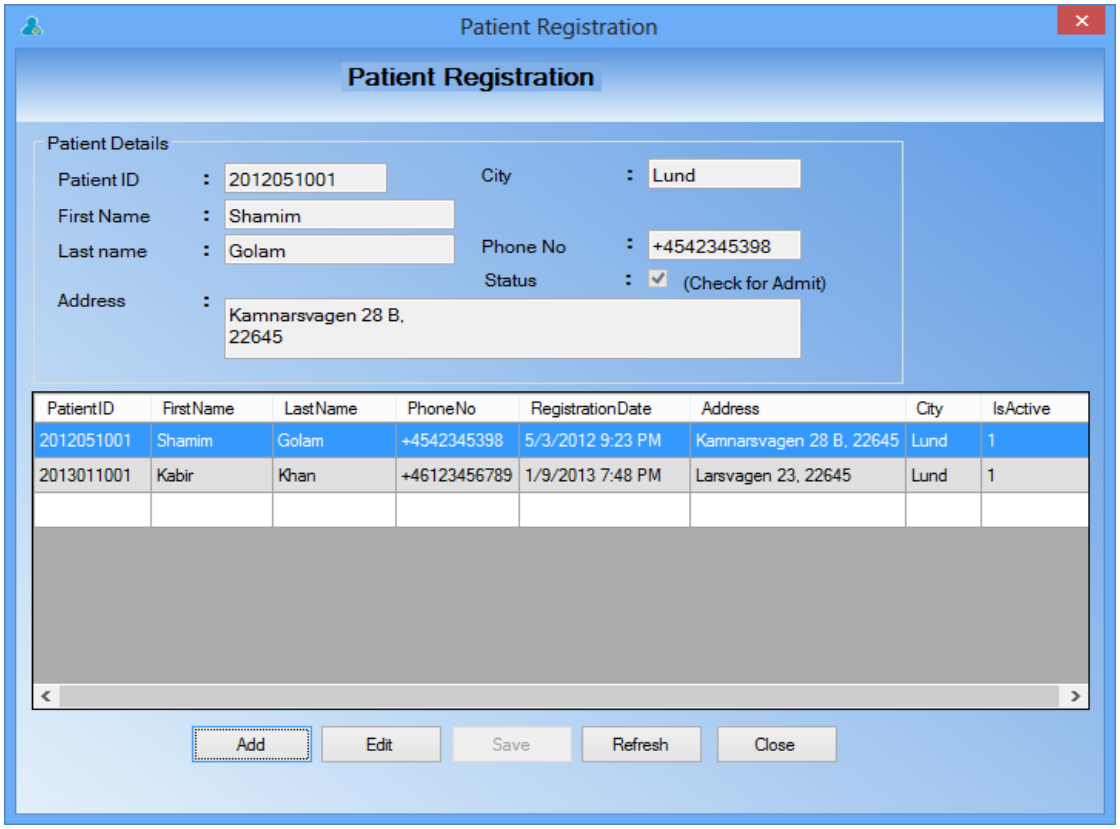


Figure 4.14: Patient Registration Form

4.5.6 Patient Release Form

Patient Release form provides functionality of patient's end of the treatment (figure 4.15). User should input Patient ID and click Search Button, SQL query will execute to select record from patient table and display patient information like Patient Name, Admission Date and Phone No. By clicking Released button, IsActive field of Patient table is to be updated to "0". It means that patients are released from ongoing treatment and the server will stop all SMS activity of corresponding Patient.

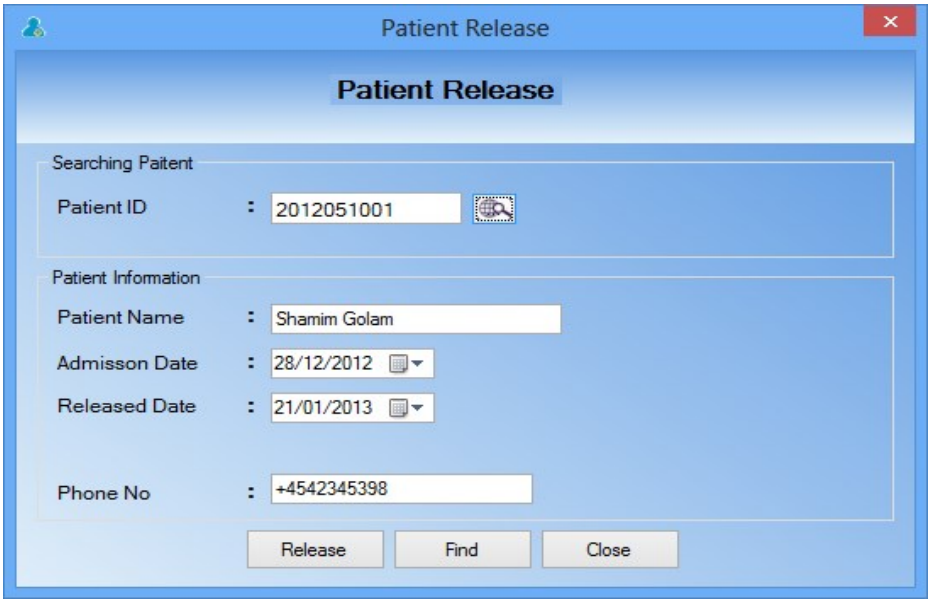


Figure 4.15: Patient Released Form

4.5.7 Automatic SMS Schedule Form

Automatic SMS schedule form is used to create automatic SMS schedule when a registered patient is undergoing treatment (figure 4.16). User can set specific date and time

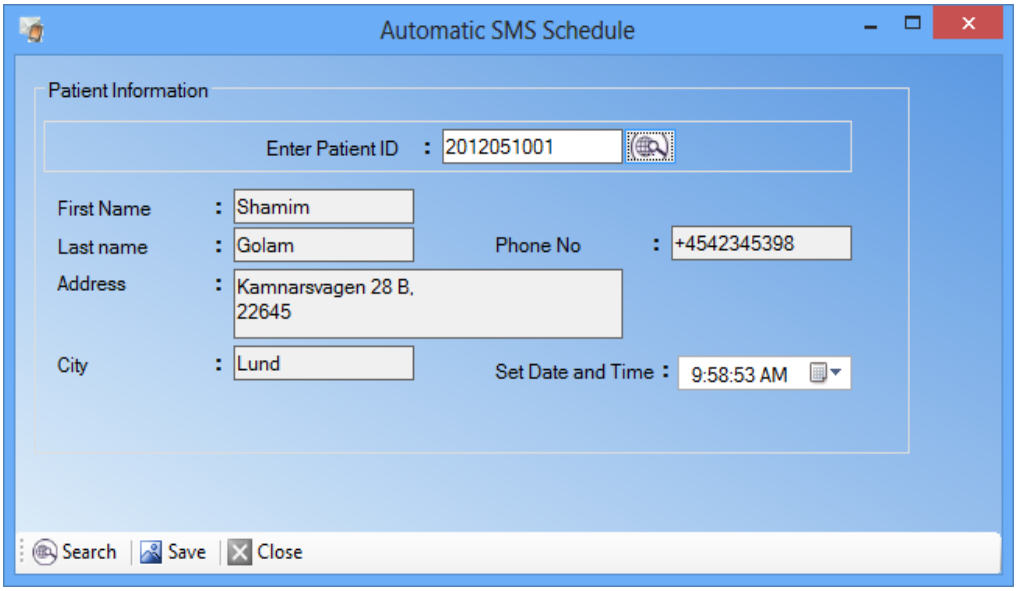
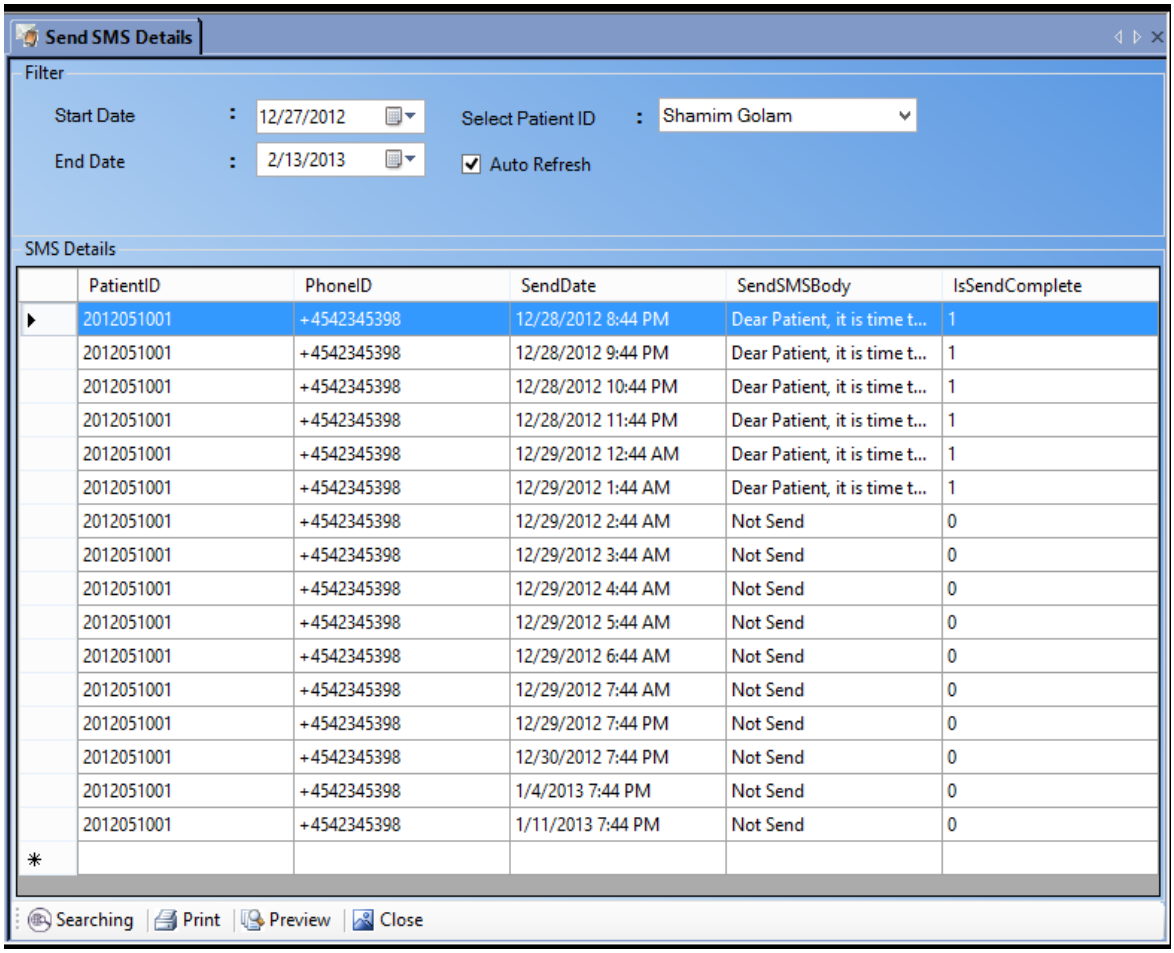


Figure 4.16: Automatic SMS Schedule Form

to generate SMS schedule. Search button is used to find specific registered patient. SMS schedule is stored into database and sends SMS automatically to corresponding patient's mobile phone based on time point.

4.5.8 Send SMS details Form

This form displays SMS schedule from database (figure 4.17). User will select Patient ID, Start Date and End Date to see sent and unsent SMS notification of corresponding patient. If Auto Refresh check box is checked, a timer checks frequently on new outgoing SMS. A Boolean field IsSendComplete is included to verify for sent or unsent SMS. After sending an SMS, IsSend filed itself to true and database is updated as sent SMS.



PatientID	PhoneID	SendDate	SendSMSBody	IsSendComplete
2012051001	+4542345398	12/28/2012 8:44 PM	Dear Patient, it is time t...	1
2012051001	+4542345398	12/28/2012 9:44 PM	Dear Patient, it is time t...	1
2012051001	+4542345398	12/28/2012 10:44 PM	Dear Patient, it is time t...	1
2012051001	+4542345398	12/28/2012 11:44 PM	Dear Patient, it is time t...	1
2012051001	+4542345398	12/29/2012 12:44 AM	Dear Patient, it is time t...	1
2012051001	+4542345398	12/29/2012 1:44 AM	Dear Patient, it is time t...	1
2012051001	+4542345398	12/29/2012 2:44 AM	Not Send	0
2012051001	+4542345398	12/29/2012 3:44 AM	Not Send	0
2012051001	+4542345398	12/29/2012 4:44 AM	Not Send	0
2012051001	+4542345398	12/29/2012 5:44 AM	Not Send	0
2012051001	+4542345398	12/29/2012 6:44 AM	Not Send	0
2012051001	+4542345398	12/29/2012 7:44 AM	Not Send	0
2012051001	+4542345398	12/29/2012 7:44 PM	Not Send	0
2012051001	+4542345398	12/30/2012 7:44 PM	Not Send	0
2012051001	+4542345398	1/4/2013 7:44 PM	Not Send	0
2012051001	+4542345398	1/11/2013 7:44 PM	Not Send	0

Figure 4.17: Send SMS details Form

4.5.9 Received SMS Form

Received SMS form displays patient's pain and discomfort value (figure 4.18). When a user select Patient ID along with starting date and ending date, data grid displays a list of patient's pain and discomfort values between these two dates. Auto Refresh check box is included to set a timer to check new incoming SMS and load from database. Preview button is included to see report of corresponding patient's pain and discomfort data.

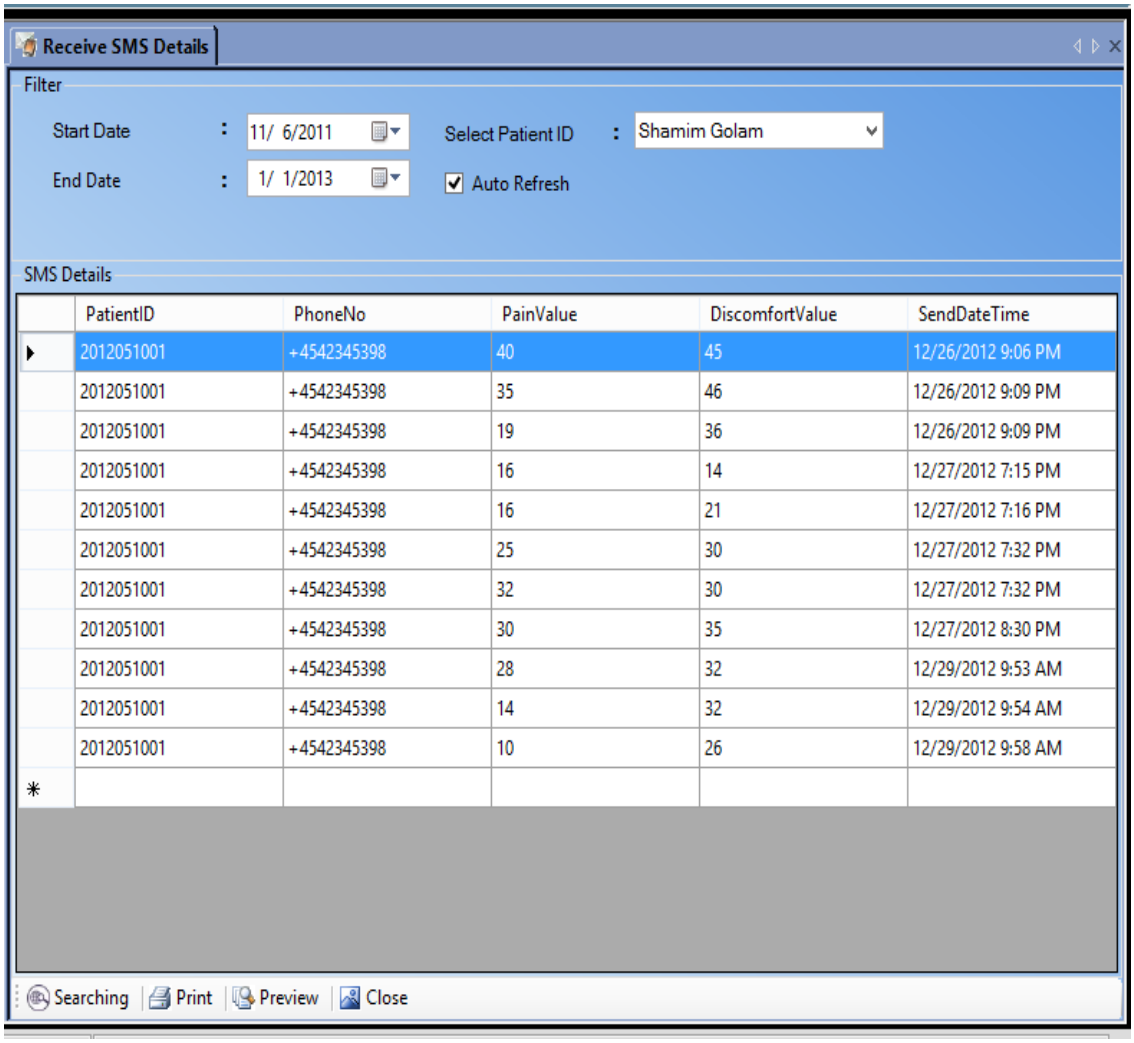


Figure 4.18: Received SMS Details Form

4.5.10 Backup and Restore

Backup and Restore feature is included in the application to create data backup. This module provides easy user interface to protect from data loss. Data loss can happen consequently of hardware failure, user errors, software faults, or disaster. A common hardware failure is disk drive failure. User errors take account of the unintentional deletion of important data. Software errors cause of a software bug. User needs to select location and choose file name where database is to save. Restore is same process to choose source of database and save into destination database project folder.

Figure 4.19: Backup and Restore Form

4.6 Conclusion

In this chapter, I have described development environment and its core components. The User interface of both applications are easy and simple. Several user controls are defined in different forms, which provide proper input validation. A necessary utility is also included in server application i.e. MODEM test in run time or data backup and restore facilities seem like real time application environment. Furthermore, an efficient SQL query is used to access database and generates real time reports that describe in next chapter.

Test and Result

Testing is a sequence of different tests whose principal purpose is to fully exercise the software before it use. Each test has a different purpose, all work should verify and ensure all system components have been properly integrated and performed as it allocated functions. The system has been tested in the location of the developer and Hospital.

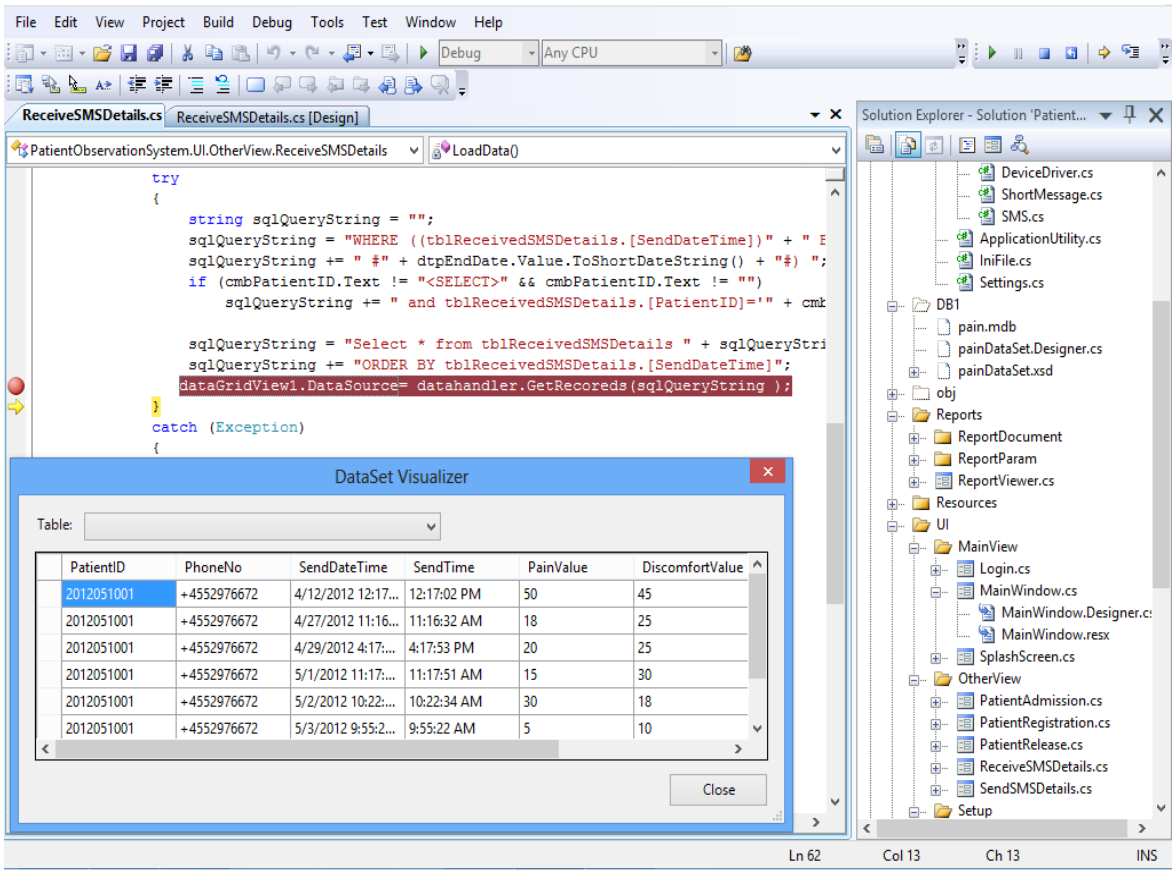


Figure 5.1: SQL test by Microsoft Visual C# debugger

Testing has been conducted on the smaller unit of server application design module. The figure 5.1 shows SQL test by built in Microsoft Visual C# debugger. I have tested to uncover errors within the boundary of the several classes and procedures by integrated debugger. The relative complexity of tests and the errors detected as a result is limited by the

constrained scope established for testing. To prevent error, the text fields of several forms in this application are designed to accept only numeric or alphanumeric characters.

5.2 Reports

This system gives the real time report facilities, which developed by Crystal Report Evaluation version, facilities to print patient's information and SMS data when user needs.

Public Dental Health Care

Spårvägsgatan 12, 214 27 Malmö, Sweden. Telefon:040-623 06 10.

Patient SMS 1/13/2013

PatientID	Patient Name	Phone No	Send Date	Time	Pain Value	Discomfort Value
2012051001	Shamim Golam	+4542345398	26-Dec-2012	9:06:51 PM	40	45
2012051001	Shamim Golam	+4542345398	26-Dec-2012	9:09:37 PM	35	46
2012051001	Shamim Golam	+4542345398	26-Dec-2012	9:09:44 PM	19	36
2012051001	Shamim Golam	+4542345398	27-Dec-2012	7:15:17 PM	16	14
2012051001	Shamim Golam	+4542345398	27-Dec-2012	7:16:59 PM	16	21
2012051001	Shamim Golam	+4542345398	27-Dec-2012	7:32:13 PM	25	30
2012051001	Shamim Golam	+4542345398	27-Dec-2012	7:32:48 PM	32	30
2012051001	Shamim Golam	+4542345398	27-Dec-2012	8:30:32 PM	30	35
2012051001	Shamim Golam	+4542345398	29-Dec-2012	9:53:52 AM	28	32
2012051001	Shamim Golam	+4542345398	29-Dec-2012	9:54:48 AM	14	32
2012051001	Shamim Golam	+4542345398	29-Dec-2012	9:58:31 AM	10	26

Pain and Discomfort history

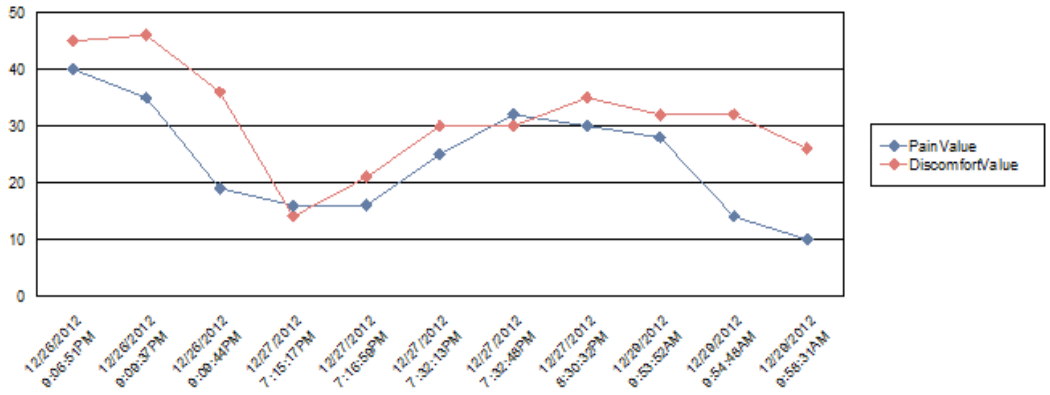


Figure 5.2: Test report generates by SMS Server Application

The Report also allows importing various files type like Microsoft word, Acrobat Reader or Microsoft Excel. The figure 5.2 shows patient's pain and discomfort history that generates by report viewer.

5.3 Patient's experience of using Mobile Application

The clinical application started in June 2011. Patients were addressed immediately after completion of a surgical procedure if they would be interested in participation. The primary selection of the patient was based on the therapist's subjective judgment on the patient's probable ability to participate in the study. In the study period June 2011 to December 2012, 60 patients were asked to participate, whereas 10 patients denied. The mobile application was well accepted by the patients who agreed to take part in the study and send VAS values according to the instructions. None of the patients commented on the technical handling. The real time values reported through SMS were generally lower than the values given by the patients at the time point of suture removal in retrospect. The finding may support the notion that reporting pain captured in real time by SMS alleviates managing pain.

5.4 Clinical Result

Results of the first 11 patients (as of October 2011) were analysed and presented as poster on www.europerio7.com in Vienna in June 2012 [24]. The trial is still on-going. After successfully using mobile application, we get result shown in bellow table 5.1 and figure: 5.3. The VAS values given during the hours directly post-surgery were significantly ($p<0.05$) higher than those given on the following two days and the rest of the week. Scatter plot of all VAS values over time showed that a peak was reached from three to six hours post-surgery. Patients kept to the given schedule by a deviation of 7 min (median; quartiles -39 to 57 min), which was negatively correlated to the response rate ($r= –0.9$; $p<0.01$).

	Hours directly Post-surgery	The following Two days	Rest of the Week	Total
Compliance	0 to 1[b] 0.83[c] 0.25 to 1[d]	0.25 to 1 0.75 0.75 to 1	0 to 1 0.7; 0 to 1	0.14 to 1 0.88 0.57 to 0.93
Mean values	0.8[e] 0 to 68.2[b] 28.3[c*] 9.9 to 46.3[d]	0.72 0 to 25 8.3; 0 to 12	0.6; 0 to 18.8 4.4; 0 to 8.8	0.71 0 to 32.4 11[c]; 1 to 18.9[d]
[a]Ratio number of responses to number of schedule assessments. [b]Range; [c]Median; [d]Qualities; [e]Prevalence% (VAS>0); *p<0.05 for VAS values directly post-surgery vs the first two post-surgical days and the rest of the post-surgical week.				

Table 5.1: Compliance and VAS values during three investigation periods (n=11).

The figure: 5.3 shows scatter plot of the patient's VAS values from 1st hour to 24th hours after their surgery.

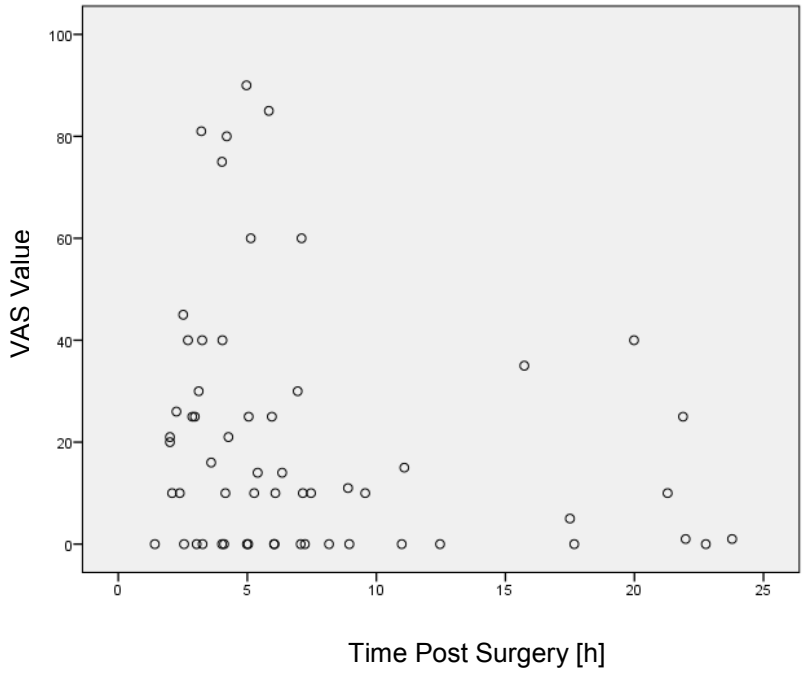


Figure 5.3 Scatter plot of all VAS values during the first hours post-surgery [24]

Chapter 6

Conclusion and Future Works

Traditional Pain Investigation procedure was paper based Visual Analogue Scale-VAS system. This process is time consuming and not collateral to collect data regularly. It is also inconvenient for elder patients to submit their VAS value by travelling to hospital frequently. To solve these problem, I have developed mobile application for pain assessment on a continuous VAS system. This system is capable of performing ubiquitous electronic monitoring of pain and discomfort by mobile application through SMS. Mobile application interface is very simple but more robust and prompt. Notably, the patient successfully operates mobile application since June 2011. Still now we didn't find any patients compliant. Server application provides better screen and the necessary reports are generated in a neat format with required details. Automatic SMS sending method is applied to transmit notification to patient's mobile phone that makes sure to get patient feedback timely. Server application provides MODEM configuration interface to connect, disconnect or test connection during running application and configuration information save into file so that users do not need to configure MODEM each time. To protect data loss, it also included real time database backup and restore feature. Although it is virtually difficult to develop software that can be fully error free, attention has been taken to prevent the occurrences of errors by using methods and techniques that include error detection and error tolerance.

Future Work

Currently, mobile application implemented by Java program and run on MIDP supported low cost mobile phone. I have also tested Windows Phone emulator for this system and it works without error. Mobile application can be further developed for Windows, IOS or Android supported high end smart phone for future work. Server application can be design better user interface and included more user controls if it requires for future works. It is common issue can be raised that how would be redesigned server application, if it is going to be deployed in other Dental Hospitals of whole Skåne, Sweden. In this case, the HTTP connectivity would enables to connect directly SMSC over the IP network to send or receive a large number of SMS. It is an alternative solution of using a GSM MODEM connected to a PC. For database design, I would suggest to replace Microsoft Access to server side database like MySQL or SQL Server because these databases provide large scale data storage capacity, more powerful built in data backup and recovery, security and robust SQL features. The existing Access database can be migrated easily to MySQL or SQL Server in future application development.

Figure 6.1: A prototype of future application runs in Windows Phone Emulator

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Appendix A

I have used Nokia E-5 smartphone to test mobile application and Huawei E-1750, 3G/GPRS MODEM, to test for experiment. The hardware specifications for the devices are listed in bellow. I have chosen this phone because it has most of the features that can be expected to be found in future mobile devices. The Operating System used is the Symbian with a rich Application Programming Interface (API) support for application developers.

	OS		Symbian OS v9.3, Series 60 rel. 3.2
	CPU		600 MHz processor
	Display	Size	320 x 240 pixels, 2.36 inches, QWERTY keyboard
	Communications	Network	GSM 850 / 900 / 1800 / 1900, HSDPA 900 / 1900 / 2100
	Data	3G	HSDPA 10.2 Mbps; HSUPA 2.0 Mbps
		WLAN	Wi-Fi 802.11 b/g
	Java		MIDP 2.0
	Data	3G	HSUPA / HSDPA / UMTS 2100MHz
	Transfer Rate		Down: 7.2 Mbps Up: 5.76 Mbps
	Connection		USB

Hardware Requirements:

The hardware requirements recommended for running this system and the minimum requirements for running these systems are as follows.

- 1 GHz processor (minimum)
- 1 GB RAM (minimum) or 2 GB RAM (recommended)
- 20 GB Hard Disk Driver or More.

Software Requirements

The application is a standalone application and it needs one intranet network to work with the database. The application is developed in the following OS environment and requires the same environment for execution.

- Windows XP, or Windows 7
- .Net Framework 3.5 or later.

Mobile Application Download

- The application size is relative small (3 KB) and is downloaded in less than a minute via Bluetooth.

Appendix B

Setup and Deployment

Here, I have described general instruction to install Pain Observation application and how to configure.

After successfully developed Pain Observation Application, I have created setup and deployment of this application for installing different computer. The setup folder consists of some prerequisite like .Net Framework 3.5 and Crystal Report, Setup.EXE.

Step 1: Open Setup Folder.

Step 2: Click on Setup.exe, then the setup splash screen would appear.

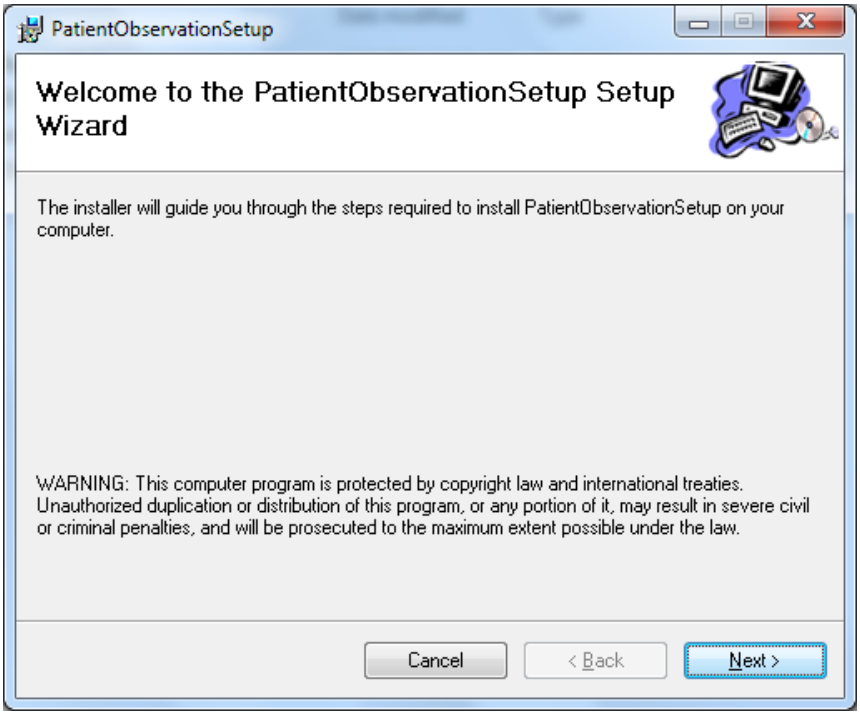

Figure: Starting installation

Step 3: In this dialog box, select next to install the program. The next dialog box informs that the Pain Investigation Application is being installed. Before installing PatientObservationSetup, the Installation Wizard will install .Net Frame work 3.5 and Crystal Report application, which is prerequisite of Application, that are already included in Setup Folder.

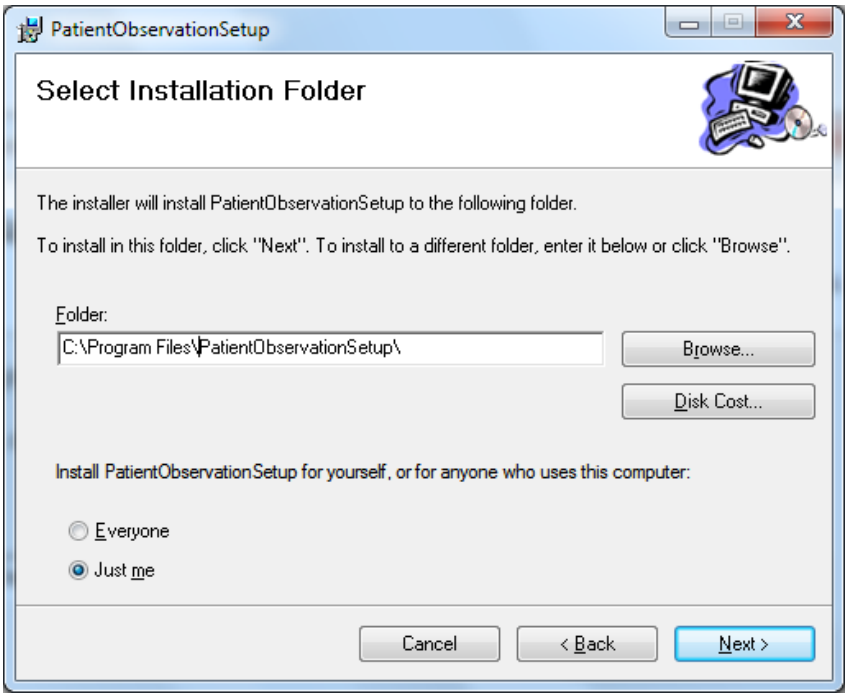

Figure: Choose Installation Folder

Step 4: Select Install folder where all necessary files and database folder should be stored. By default setting of installation folder is:

[c:\program Files\PatientsObservationSetup\ ]

By clicking Next button the bellow window will appear which indicate the installation process and tell User to wait while Setup is continuing.

The following table 8.1 shows Files and Folder will store after installing application into Installation Folder: [c:\program Files\PatientsObservationSetup\ ].

Folder	Files	Comments
\DB	Pain.mdb	Access Database File
\Patient Observation	PatientObservationSystem.exe	Execution File
	MODEMConfiguration.ini	MODEM Configuration File
	SMSFormat.ini	SMS Configuration File

Table: Folder and Files list of Installation Folder

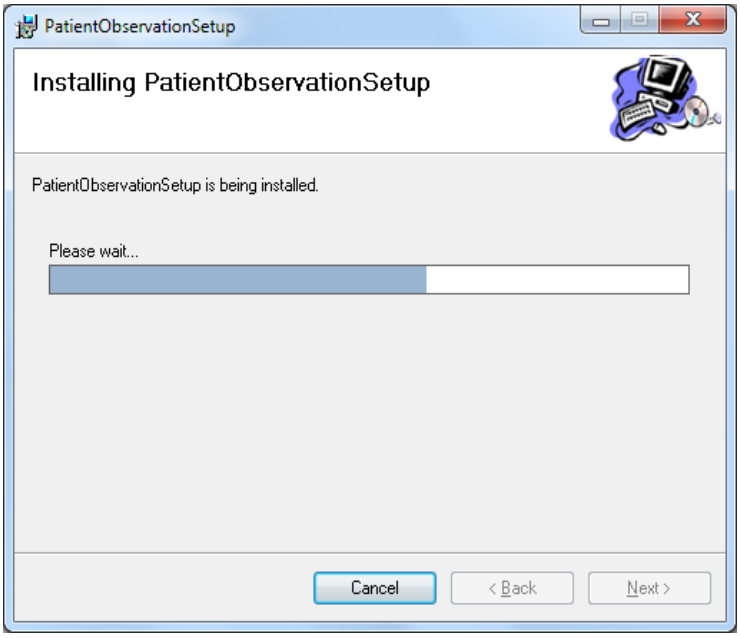

Figure: Installation progress

After successfully install program the below window will appear.

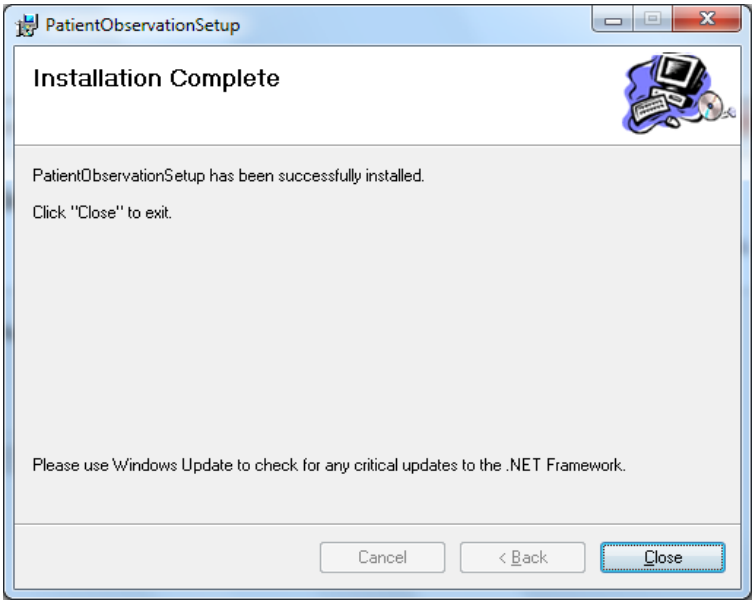

Figure: Complete Installation

Step 6: click on close button to complete the installation.

Appendix C

The abstract and poster published on an international conference on gum diseases, Europerio7, Vienna, Austria 6-9 June, 2012. http://www.europerio7.com

Mobile communication technology for the assessment of postoperative pain after periodontal surgery

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Background

Self documented pain assessments in outpatients may need to be interpreted with caution. Written evaluations at home may be made at other time points than was agreed on.

The aim of this study was to develop a more reliable approach using the mobile communication technology.

Method

Subjects & treatment

- 11 periodontitis patients (aged 36 to 81 years, 7M/4F) in need for surgical treatment.
- Exclusion criteria: extreme dental anxiety or need of comprehensive pre-medication or pre-operative care.

Mobile communication technology

- Mobile Phone Application for pain assessment on a continuous visual analogue scale (VAS).
- Cellular phones (Nokia E5) were equipped with the application .
- On evaluating pain and discomfort value, the VAS value is immediately sent to Hospital Database application through a GSM/GPRS Modem by SMS.

Evaluation of pain

- Directly post surgery, patients were informed and instructed how to use the SMS application.
- Patients were asked to evaluate postoperative pain (from "no pain at all" to "unbearable pain")
  - hourly on the day of the surgery
  - twice daily on the following two days
  - once daily for the rest of the week.
- VAS values, time points and dates were recorded.

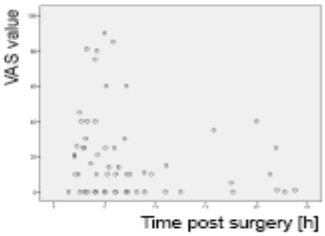
Data analysis

- Mean values of the three pain investigation periods (day of surgery, the two following days, rest of the week) were used.
- Analytical statistics was performed using non-parametric tests.

Results

- The SMS application was well accepted by the patients who agreed to take the part in the study (Table 1).
- The VAS values given during the hours directly post surgery were significantly ($p<0.05$) higher than those given on the following two days and the rest of the week.
- Scatter plot of all VAS values over time showed that a peak was reached from three to six hours post surgery (Figure 1.)
- Patients kept to the given schedule by a deviation of 7 min (median; quartiles -39 to 57 min) which was negatively correlated to the response rate ($r= -0.9$; $p<0.01$).

Figure 1. Scatter plot of all VAS values during the first hours post surgery



Conclusions

The results of this study indicate that mobile communication technology can reliably be used in outpatients for the assessment of postoperative pain over time.

Acknowledgements

This study was supported by the Research and Development Fond o the Region of Skåne (FoU Nr. 696).

Table 1. Compliance[a] and VAS values during the three investigation periods (n=11)

	hours directly post surgery	the following two days	rest of the week	total
Compliance	0 to 1[b] 0.83 [c] 0.25 to 1[d]	0.25 to 1 0.75 0.75 to 1	0 to 1 0.7; 0 to 1	0.14 to 1 0.88 0.57 to 0.93
Mean VAS value	0.8[e] 0 to 68.2[b] 28.3[c,*] 9.9 to 46.3[d]	0.72 0 to 25 8.3; 0 to 12	0.6; 0 to 18.8 4.4; 0 to 8.8	0.71 0 to 32.4 11[c]; 1 to 18,9[d]

[a]ratio number of responses to number of scheduled assessments
[b]range ; [c]median; [d]quartiles; [e]prevalence% (VAS>0);
*p<0.05 for VAS values directly post surgery vs the first two post surgical days and the rest of the post surgical week

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